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Phase 1 report

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Foreword

ETSI Technical Reports (ETRs) are informative documents resulting from ETSI studies which are not appropriate for European Telecommunication Standard (ETS) or Interim European Telecommunication Standard (I-ETS) status.

An ETR may be used to publish material which is either of an informative nature, relating to the use or application of an ETS or I-ETS, or which is immature and not yet suitable for formal adoption as an ETS or I-ETS.

This ETR has been produced under the responsibility of an ad-hoc committee, dealing with satellite personal communications, of ETSI's Technical Committee Satellite Earth Stations (SES); the ETR has been approved by TC-SES.

This ETR has been developed following the receipt by ETSI of a Mandate from the European Commission. The allocated resources were divided by ETSI into two phases; this ETR is the outcome of phase 1, the decision to proceed with phase 2 has yet to be made formally.

Introduction

General introduction to the work

Following growing technical and commercial interest in the establishment of Personal Communications Networks (PCNs) for the provision of telecommunications services direct to users through small hand-portable equipment, much work has been undertaken world-wide to develop standards, systems and technologies capable of supporting such networks. Satellite links will form a natural part of most, if not all, PCNs and in addition Satellite Personal Communications Networks (S-PCNs) are able to provide PCN services either as a separate overlay network or as an integral part of the terrestrial network.

Because of this increasing interest in S-PCNs, the "World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum" (WARC-92) made a number of new frequency allocations to the Mobile Satellite Service (MSS) in bands around 140 MHz, 310 MHz, 400 MHz, 1,5/1,6 GHz and 2,0/2,5 GHz (and also in the 20/30 GHz area).

Some of these bands are restricted to MSS from Low-Earth Orbits (LEOs) or from other Non-Geostationary Orbits (NGSOs), whilst others are available for use from Geostationary Satellite Orbit (GSO) or NGSO. The WARC adopted a resolution (COM5/8) establishing interim procedures for the co-ordination and notification of frequency assignments for NGSO networks, although these only apply to certain space services and certain bands. These provisions generally apply, however, to the new frequency allocations for the MSS listed above, when the frequencies are operated from NGSO.

Because of concerns at the WARC, inter alia, that the first global LEO system to be implemented by one country, organisation or company might result in de facto standards being imposed on the rest of the World, a further resolution was passed by the WARC. This resolution (COM5/11) calls for the establishment of standards for the operation of low-orbit satellite systems and in particular resolved to invite:

> "...the organs of the ITU ... to carry out, as a matter of priority, technical, regulatory and operational studies to permit the establishment of standards governing the operation of low-orbit satellite systems so as to ensure equitable and standard conditions of access for all countries and to guarantee proper world-wide protection for existing services and systems in the telecommunication network."(see Final Acts - WARC 92 [1])

The WARC further resolved to invite:

> "...administrations interested in, or affected by, the introduction and operation of low-orbit satellite systems to participate in such work as the organs of the ITU may undertake in that connection."

Following this invitation, the Commission of the European Communities (CEC) has developed a proposal for a "Council Resolution on Satellite Personal Communications" and has:

> "...provided ETSI with a mandate to prepare a technical report in which the standardisation aspects [of satellite personal communications] are investigated in some depth and details [are] provided on the desirability and required availability of standards within the strategic context of the implementation of the service." (see (CEC), COM(93)171 Final [2])

ETSI has assigned responsibility for this work to its Technical Committee on Satellite Earth Stations (TC-SES) which has established an ad-hoc group, the TC-SES/Ad-Hoc. Committee on Satellite Personal Communications (TC-SES/Ad-Hoc. SPC), to undertake the work. An ETSI Voluntary Project Team (PT 37V) has been recruited to undertake the drafting of this initial text, which has resulted in the production of this ETR.

Structure and contents of this ETR

The technical standards issues relevant to S-PCN are wide and complex. There are many countries, organisations and companies making proposals for networks (13 are identified in this ETR); the configurations of their proposed networks are widely different as are the technologies they propose to use. In addition, all of these organisations make different proposals for the numbers of satellites and the orbit constellations required to support their system.

When trying to analyse these many and different proposals to determine the standardisation requirements, it is necessary to build this analysis on a common and solid platform which has to be separated from the variety of the different system proposals.

It is not sufficient to make a survey of the different schemes proposed by the various organisations; what is necessary is a sound analysis of the underlying general concepts, setting a boundary on what is possible for the provision of S-PCN services both from GSO and NGSO. If these general concepts are taken into account when identifying the need or otherwise for standardisation then it is likely that the resulting standards will be generally relevant, rather than concentrating specifically on the proposed systems that are currently being considered. Only after this general analysis does it make sense to consider the details of the specific proposed S-PCN systems.

Thus, this ETR is structured so as to meet the above requirements, giving first general descriptions before looking at the specific proposals and ending with a review of the options for standardisation.

The main areas of the report are thus:

- a detailed description of the technologies applicable to the provision of S-PCNs;
- an overview of NGSO concepts relevant to S-PCNs;
- a descriptive review of the S-PCN networks currently proposed internationally, and finally;
- an initial examination of the possible areas and levels of standardisation that might be considered for satellite personal communications networks in Europe.

The ETR is intended to serve as a basis for further discussions within ETSI and the CEC particularly regarding the standardisation of certain areas of such networks.

Guidance for the reader

Readers with differing interests may find it of use to concentrate on specific elements of this ETR:

- for a general review of the technical concepts of satellite personal communications .... Clause 2
- for a general review of the concepts of non-geostationary orbits and their use for the provision of S-PCN services .... Clause 3
- for a comprehensive description of each of the proposed S-PCN systems being made world-wide .... Clause 5
- for an analysis of the areas of S-PCN that are candidates for possible European standardisation .... Clause 6

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1 Scope

This ETR aims to provide a comprehensive review of the possible areas and levels of standardisation that might be applied to satellite personal communications networks in Europe. The ETR is intended to serve as a basis for further discussions within ETSI and the European Commission regarding the standardisation of such networks.

2 References

[1] Final Acts of the World Administrative Radio Conference for Dealing with Frequency Allocations in Certain Parts of the Spectrum (WARC-92), Malaga-Torremolinos, Spain, 1992.

[2] "Communication from the Commission and Proposal for a Council Resolution on Satellite Personal Communications", Commission of the European Communities, Brussels, COM(93)171 Final, 27 April 1993.

[3] "Framework for Satellite Integration Within the Universal Mobile Telecommunications System", ETSI Technical Report, D-ETR/SMG-51201, Version 0.1.0, 29 September 1992.

[4] "Radio Regulations, Part A, Article 1, RR10", Edition of 1990.

[5] "Direct Broadcast Satellite - Radio: Portable and Mobile Reception Trade-offs", Golshan N., Proceedings of the Workshop on Advanced Network And Technology Concepts for Mobile, Micro and Personal Communications, Jet Propulsion Labs, Pasadena, May 1991.

[6] "Integration of Terrestrial and Satellite Land Mobile Systems", CCIR Report 1177, 1990.

[7] "Draft Interim ERO Contribution: Mobile Satellite Services (1 - 3 GHz)", European Radiocommunications Office, Copenhagen, April 1993.

[8] "Intellectual Property Rights Policy and Undertaking", ETSI General Assembly, 18 March 1993.

[9] "Crosslink Architectures for a Multiple Satellite System", Binder R. et al, Proceedings of the IEEE, Vol. 75, No. 1, January 1987.

[10] "PEGASUS dedicated and multiple launch capabilities for low earth orbit communications satellite constellations", Mosier M., American Institute of Aeronautics and Astronautics Conference, 1992.

[11] "Analytic Design of Satellite Constellations for Zonal Earth Coverage Using Inclined Circular Orbits", Rider L., Journal of the Astronautical Sciences, Vol. 34, No. 1, pp. 31 - 64, January - March 1986.

[12] "Circular Polar Constellations Providing Single or Multiple Coverage Above a Specified Latitude", Adams W. and Rider L., Journal of the Astronautical Sciences, Vol. 35, No. 2, pp. 155 - 192, April - June 1987.

[13] "Satellite Networks for Continuous Zonal Coverage", Lüders R., American Rocket Society Journal, Vol. 31, pp. 179 - 184, February 1961.

[14] "Rosette Constellations of Earth Satellites", Ballard A., IEEE Transactions on Aerospace and Electronic Systems, Vol. AES-16, No. 5, pp. 656 - 673, September 1980.

[15] "Continuous Whole-Earth Coverage by Circular-Orbit Satellite Patterns", Walker J., Technical Report 77044 (UDC 629. 195: 527), Royal Aircraft Establishment (UK), March 24, 1977.

[16] "Design of Satellite Constellations of Optimal Continuous Coverage", Beste D., IEEE Transactions on Aerospace and Electronic Systems, Vol. AES-14, No. 3, pp. 466 - 473, May 1978.2.

[17] CCIR Recommendation 818: "Satellite operation within Future Public Land Mobile Telecommunication Systems (FPLMTS)".

[18] CCITT Recommendation E.163: "Numbering plan for the international telephone service".

[19] CCITT Recommendation E.168: "Application of Recommendation E.164 numbering plan for universal personal telecommunications".

[20] CCITT Recommendation E.212: "Identification plan for land mobile stations".

[21] GSM 03.03: "Numdbering, addressing and identification".

[22] CCITT Recommendation E.213: "Telephone and ISDN numbering plan for land mobile stations in public land mobile networks (PLMN)".

[23] CCITT Recommendation E.164: "Numbering plan for ISDN era".

[24] CCITT Recommendation X.121: "International numbering plan for public data networks".

3 Abbreviations

For the purposes of this ETR the following abbreviations apply.

ACD	Average Call Distance
AMAP	Adaptive Mobile Access Protocol
ANSI	American National Standards Institute
AOM	Administration, Operation and Maintenance
ASN	Abstract Syntax Notation
BAPT	Bundesamt für Post und Telekommunikation (Federal Ministry for Post and Telecommunications - Germany)
BER	Bit Error Rate
BFSK	Binary Frequency Shift Keying
BPSK	Binary Phase Shift Keying
BSC	Base Station Controller
BSS	Broadcast Satellite Service
BT	Base Transceiver
BTS	Base Transceiver Station
CCIR	Comité Consultatif International des Radiocommunications (International Radio Consultative Committee) 1)
CCITT	Comité Consultatif International des Telegraf et Telecommunications (International Telegraph and Telecommunications Consultative Committee) 2)
CDMA	Code Division Multiple Access
CEC	Commission of the European Communities
CELP	Code Excitation Linear Prediction
CENELEC	European Committee for Electrotechnical Standardisation (acronym of the French name)

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1) As part of the recent ITU restructuring process the CCIR has been renamed the Radiocommunications Sector but because no internationally accepted acronym has yet been adopted and because the new name will not be familiar to all readers the term "CCIR" has been used throughout this ETR.

2) Similarly the CCITT has been renamed the Telecommunications Standardisation Sector but the term "CCITT" has been used throughout this ETR.

CEPT	Conférence Européenne des Postes et Télécommunications (European Conference of Post and Telecommunications)
CIS	Commonwealth of Independent States
CIRF	Co-channel Interference Reduction Factor
CS	Cell Selection
CTR	Common Technical Regulation
D-AMPS	Digital Advanced Mobile Phone System
DAB	Digital Audio Broadcasting
DCS	Digital Cellular System
DECT	Digital European Cordless Telecommunications
DS-SSMA	Direct Sequence Spread Spectrum Multiple Access
EA	Early Assignment
EC	European Community
EIR	Equipment Identity Register
EIRP	Effective Isotropic Radiated Power
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Field
ERC	European Radiocommunications Committee
ERO	European Radiocommunications Office (of the ERC)
ESA	European Space Agency
ETSI	European Telecommunications Standards Institute
FAC	Final Assembly Code
FCC	Federal Communications Commission
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FES	Fixed Earth Station
FM	Frequency Modulation
FMS	Fleet Management Service
FPLMTS	Future Public Land Mobile Telecommunications System
FS	Fixed Service
FSS	Fixed Satellite Service
GA	General Assembly (of ETSI)
GC	Global Coverage
GCS	Ground Control Station
GPS	Global Positioning System
GSM	Global System for Mobile Communications
GSO	Geostationary Satellite Orbit
GW	Gateway
HEO	Highly Elliptical Orbit
HIO	Highly Inclined Orbit
HLR	Home Location Register
HPA	High Power Amplifier
HPT	Hand-held Personal Telephone
I-ETS	Interim-ETS
ICO	Intermediate Circular Orbit
IEEE	Institute of Electrical and Electronic Engineers
IFRB	International Frequency Registration Board
IMSI	International Mobile Subscriber Identity
IN	Intelligent Network
INIRIC	International Non-Ionising Radiation Committee
IPR	Intellectual Property Rights
ISC	International Switching Centre
ISL	Intersatellite Link
ISM	Industrial, Scientific and Medical
ISS	Inter-Satellite Service
ISU	Iridium Subscriber Unit
ITU	International Telecommunications Union
JIWP	Joint Interim Working Party (of the CCIR)
LA	Location Area
LEO	Low-Earth Orbit
LMSS	Land Mobile Satellite System
LOOPUS	Geostationary Loops in Orbit Occupied Permanently by Unstationary Satellites

LR	Location Register
LU	Location Updating
LVD	Low Voltage Directive
MAP	Mobile Application Part
MEO	Medium Earth Orbit
MES	Mobile Earth Station
MS	Mobile Station
MSC	Mobile Switching Centre
MSS	Mobile Satellite Service
MTP	Message Transfer Part
NGSO	Non-Geostationary Satellite Orbit
NS/CC	Network Service/Control Centre
OACSU	Off-Air Call Set-Up
OBP	On-Board Processing
ONP	Open Network Provision
OSI	Open Systems Interconnection
PC	Personal Computer
PCN	Personal Communications Network
PFD	Power Flux Density
PLMN	Public Land Mobile Network
PN	Personal Number
PSTN	Public Switched Telecommunications Network
PTO	Public Telecommunications Operator
QPSK	Quadrature Phase Shift Keying
RAS	Radioastronomy Service
RDS	Radio Data System
RDSS	Radiodetermination Satellite Service
RF	Radio Frequency
RFHMA	Random Frequency Hopping Multiple Access
RGS	Route Guidance Service
RMA	Random Multiple Access
RNCC	Regional Network Control Centre
RR	Radio Regulation
S-PCN	Satellite Personal Communications Network
SCCP	Signalling Connection Control Part
SCP	Service Control Point
SCPC	Single Channel Per Carrier
SG	Study Group
SIM	Subscriber Identity Module
SMG	Special Mobile Group
SNR	Serial Number
SPFD	Spectral Power Flux Density
SS7	Signalling System Number 7
SSP	Signalling Switching Point
SU	Subscriber Unit
TAC	Type Approval Code
TBR	Technical Basis for a Regulation
TCAP	Transaction Capabilities Application Part
TDM	Time Division Multiplex
TDMA	Time Division Multiple Access
TIS	Traffic Information Service
TT&C	Telemetry, Tracking and Command
TTC&M	Telemetry, Telecommand, Control and Monitoring
UHF	Ultra High Frequency
UMTS	Universal Mobile Telecommunications System
UPT	Universal Personal Telecommunications
VHF	Very High Frequency
VLR	Visitor Location Register
VSELP	Vector Sum Excitation Linear Prediction
WARC	World Administrative Radio Conference
WHO	World Health Organisation
WRC	World Radiocommunications Conference

4 Satellite personal communications concepts

4.1 Personal communication (the evolution towards Personal Communications Network (PCN))

The evolution of communications networks has been driven in the last few years by technical and commercial interests towards personal services. The fast growing radio voice communications network demonstrates the demand for communications mobility and is commonly considered the most evident consequence of this process, even if mobile communications are still developing towards PCNs.

A PCN is a network that provides personal communications services to users. A personal communications service is characterised, generally speaking, by its capacity to respond universally to a wide range of communications needs. This leads to a user oriented approach adopted in developing the PCN concept in contrast to the network oriented approach adopted in the development of the communications network so far.

The essence of personal communications is that it is provided to an entity to which it is not possible to assign a fixed known geographic location and that the entity has control in some detail of its service profile and parameters. In a personal communications network each call is treated according to the personal service profile defined and independently of the location of the two or more entities involved. The latter requirement is the "ubiquitous service" definition, the former is often addressed as a form of customer control. The "ubiquitous service" identifies entities by a personal identity number and allows mobility of the entity across several networks using different terminals, adding therefore a further dimension to mobility. In PCNs mobility becomes an attribute of the entity, not only of the terminal. It is possible to derive some basic features from those outlined above. Personal communications services are characterised by:

- mobility (the service is independent on the location of the terminal and the user);
- location (the location addressed is a coarse estimate of the actual user position);
- tailoring (the service parameters are under the user control);
- affordability and capacity (both essential because of the wide diffusion);
- security (the personal service should have the same or enhanced security provisions compared to the fixed service).

The distinction between the terminal and the user is fundamental in order to allow mobility of the user across several networks. The user makes use of its Subscriber Identity Module (SIM) to access the personal service from any terminal (cellular, satellite mobile). The PCN functionalities cover the:

- mobility management (registration, authentication, location management, number recognition and translation, terminal access assignment);
- universal service availability (access across multiple networks with wired or wireless terminals);
- call management (caller identity, service type, messaging, speech to text conversion and vice versa);
- charge management (split charging, customised billing);
- customer control (service profile management, customised terminal configuration);
- security (authentication and privacy of the communication independent on the terminal used).

The role of the satellite in the development and deployment of PCNs has been identified both for fixed and mobile services in the general frame of Universal Personal Telecommunications (UPT). The integration of satellite components in the third generation of mobile telecommunication systems in Europe, called Universal Mobile Telecommunication System (UMTS) has been decided by the Special Mobile Group (SMG) of ETSI and the report is in progress of approval. The UMTS standard may comply with the world wide standard for Future Public Land Mobile Telecommunications Systems (FPLMTS) developed by the International Telecommunication Union (ITU).

In the ITU, Task Group 8/1 (TG 8/1) of Study Group 8 (SG 8) of CCIR has discussed the role of the satellite in FPLMTS. TG 8/1 is developing a series of Recommendations on specific aspects of FPLMTS. A set of radio interfaces has been identified (R1 - R7) to provide different mobile services ranging from paging to high bit rate video phone. Some radio interfaces are specified for satellite networks, namely interfaces R3 and R6, interface R4 is specified for paging service in both terrestrial and mobile satellite networks. The minimum service to be provided by R3 is two way data and voice communications between a portable terminal and a fixed network such as the Public Switched Telephone Network (PSTN). The service provided by R6 is high bit rate data communications between a vehicle mounted base station (mobile base station) and a fixed network. As radio interfaces are specified differently for the terrestrial and satellite mobile part, the terminal to be used in FPLMTS may have two radio interface functions. The access to the satellite network is possible directly or indirectly through a combination of radio interfaces. The mobile satellite terminal may have the capability to access the terrestrial part of FPLMTS but is characterised by a direct access to the satellite resources. The mobile terminal communicating with a fixed or mobile earth station may also have access to the satellite indirectly via the base station. In this way it is considered possible to provide UPT services, provided that mobility management, and in particular location identification, is irrespective of the radio interface established for the communication.

4.2 Personal communications via satellite

The public direct access to the satellite from portable or pocket size terminals is the new and distinguishing feature of PCN via satellite. The concept of mobile personal communications applied to satellite systems leads to Satellite Personal Communications Networks (S-PCNs).

The S-PCN differs from PCN in the services provided and, mainly, in making these services available via a single network through a very wide region that can be the whole world.

For the purposes of this report S-PCN is defined as covering cases only where the user corresponds directly from a hand-held (or other portable/mobile) terminal to a satellite. PCNs may also integrate satellites at a deeper level (e.g. a mobile Digital European Cordless Telecommunications (DECT) "base station" (fixed part) on a train may be interconnected to the public network via a satellite link so that users correspond from their handsets to the base station and not the satellite) but this report does not regard such applications as S-PCN.

Unlike other satellite systems, S-PCNs design is driven mainly by the requirements of the user segment (Subscriber's Unit, (SU)), any other part of the system is mainly tailored in such a way to fulfil the service requirements, given the constraints imposed by the SU characterisation. Therefore it is important at this stage to give a general outline of the SU requirements in order to consider it a part of an S-PCN.

The S-PCN SU is mainly limited in power and size, it is a portable unit and its size is similar to that of a cellular SU. Power constraints are related to safety from radiation effects of transmitted microwave Power Flux Density (PFD) for the user and to the capability of providing operation (busy in communication) and standby intervals with power sources comparable to those typical of a portable cellular unit. It is still to be investigated in detail the characterisation in terms of availability of the subscriber link in an S-PCN, this parameter depends on the particular system considered and the environment in which the service is provided. In S-PCN systems it is difficult to find analogies with cellular engineering, it is not possible to tune locally many coverage parameters because coverage is the result of a complex trade off to the extent that it could be considered as a given parameter. It is possible that the SU will include a coverage quality meter in order to ease its use in particular environments. The operating bands affect mainly the antenna subsystem and the Radio Frequency (RF) part of the terminal. An antenna tracking subsystem is not generally suitable for S-PCN as it could add complexity to a mobile terminal; the benefits of such a subsystem are limited if the L-band is employed, as the antenna is limited in size, but at other bands such as Ku-band, phased array antennas (e.g. patch) could be used.

S-PCNs coverage area will comprise several terrestrial based PCNs. S-PCNs in a mobile integrated environment could not only complement the existing and developing terrestrial mobile network but, most important, could establish a standard de facto whose main advantage for the user would be a true global roaming capability. The global roaming capability is the first requirement for a PCN and therefore S-PCNs could realise the first stage of PCNs. Integration with the existing PSTN is essential for S-PCN and could be considered the starting point for the investigation on standardisation issues of S-PCNs.

Mobility management issues are important and not dependent on the particular access considered so that S-PCNs mobility management could be based on procedures developed for a general PCN.

ETSI has already recognised by that there will be a satellite component in UMTS. Consequently ETSI is developing the "Framework for satellite integration within the Universal Mobile Telecommunications System (UMTS)" - SMG-51201 [3]. One of the priorities of UMTS in Europe is global roaming:

"A regional satellite solution for UMTS should (therefore be) avoided, and European requirements should be satisfactory covered in a global solution" (see D-ETR/SMG-51201 [4]).

UMTS may be based on or identical to the ITU standard for FPLMTS. The frequency bands intended to be used for the satellite component of FPLMTS are assumed to be used for UMTS entirely. Operating scenarios for the satellite component of FPLMTS apply also to UMTS, and are defined in CCIR Recommendation 818 [17]. The relationship between UMTS and S-PCN needs to be further addressed, particularly relating to the service definition as will be clear from the following parts of this ETR.

4.3 Type of services

In a PCN perspective the service features are under control of the subscriber by direct access to network service management functions parameters. Here the S-PCN main service is considered to be the voice service, other services will be addressed with reference to their differences with respect to services offered by a generic terrestrial based system.

4.3.1 Mobile voice service

Voice is commonly the prime S-PCN service. It is the capability to deliver and process a voice call (real time two way bearer connection) within a defined region (coverage service area), with a certain service availability and a certain overall service quality. The definition of the service quality should group together different parameters. Link margins may not allow the coverage area for this service to be defined in certain environmental situations such as inside buildings, therefore a suitable definition of service area has to be investigated.

The voice service is characterised by the voice coding technique employed and the related achievable quality. Here it is assumed that the S-PCN service is characterised by a voice coding that guarantees a quality sufficient to provide a public telephone service. The minimum requirement for this service being the recognition of the speaker. This is important particularly when considering the interconnection with the fixed network. The voice quality has been addressed here for it should not constitute an inhomogeneity in the PCN, although it should not be considered the ruling parameter for the determination of the quality of service.

The voice quality should be balanced against the capability of the system to provide a wireless voice channel on a very wide area (ultimately the entire World) and so a direct comparison with a terrestrial based system is unfair under this point of view. This stresses the importance of a global voice service quality parameter.

4.3.2 Mobile real time data service

The capability to establish a data channel for real time data services other than voice is characterised by the maximum rate achievable, the maximum transmission delay and probably the minimum rate guaranteed and the same parameters of service as the voice service. The real time data service could be provided globally or only locally (i.e. within the coverage area of one satellite and, for NGSO satellites, to a single user during the time of a single satellite pass).

4.3.3 Mobile store and forward data service

This service is the capability to establish a simplex or half duplex data channel for delayed communications with a store and forward technique. One way of working this service is as follows:

- the data to be transmitted on either side of the link are kept in the terminal until the data channel is available and then transmitted to a relay that can be either the satellite or a base earth station, not necessarily the terminating station;

- the message is then forwarded with the same method toward the destination terminal or station where it is kept until retrieved with a retrieve command.

For this service to work it is not necessary for the S-PCN coverage to be time or space continuous. Even with a discontinuous coverage it is possible to forward the message, for example employing different passes of the satellite over contiguous regions. The service is characterised by the minimum and maximum delivery time and by the capability of the system to confirm the delivery to the destination, either another S-PCN terminal or a fixed or a terrestrial mobile terminal of the PCN that integrates the S-PCN.

Data can be general textual messages, electronic mail messages, voice mail (digitised voice messages), images monitoring data for data collection or any kind of storable data.

A service with the characteristics of a mobile data service is that commonly offered by NGSO systems operating in the hundred MHz band allocations.

4.3.4 Paging/messaging

This service is the capability to deliver a short data message (or longer messages) with no acknowledge from the receiving terminal with a specified correct reception probability and within a specified delivery time. It can also be used to contact a terminal when insufficient link margin exists to establish a normal call. It can be considered a particular type of mobile data service but with no confirm of reception. Various strategies can be employed to make the service reliable (retransmissions, powerful error protection) but it can not be compared with the mobile data service because of the different requirements to the mobile terminal.

4.3.5 Paging with acknowledgement

This service has the capability to deliver a short data message with automatic confirmation of reception. The pager will provide an acknowledgement that the page has been received and indicate that is has been received correctly.

4.3.6 Positioning (radiodetermination)

Positioning is part of the Radiodetermination Satellite Service (RDSS) and is the capability to determine:

- "the position, velocity and/or other characteristics of an object or the obtaining of information relating to these parameters, by means of the propagation proprieties of the radio waves" (Radio Regulations definition RR10 [4]).

The positioning data are related to the S-PCN terminal "object" in RDSS and are characterised mainly by their accuracy and acquisition time.

The positioning information acquisition can be sampled at fixed known intervals to derive other physical parameters such as velocity profiles and profiles of other physical parameters of the object (terminal) that can be stored in the terminal. These services will not be here distinguished from the basic positioning information as they are all derived from the same set of services by the terminal and so are not to be considered as a feature of the S-PCN services.

Methods employed to obtain RDSS data at the S-PCN terminal side are various. They can be based on the acquisition and observation of emissions of one or several satellites or on the observation of the same emission repeated by two or more satellites.

4.3.7 Position reporting and related services

These services are essentially a mobile on line data access. The particular service depends on the kind of data derived from the transmission of RDSS data obtained at the terminal side. A remote gateway obtaining RDSS data transmits them to a Service Centre (SC) for processing to supply services such as Fleet Management Service (FMS), Route Guidance Service (RGS) or Traffic Information Service (TIS). FMS includes tracking of the vehicle, vehicle monitoring, load monitoring, route guidance and facilities to re-route vehicles to optimise their efficiency in transportation. RGS provides the mobile terminal with navigation information which is basically the position of the terminal with respect to a determined route. TIS provides the terminal with information comparable to those offered for example by today's traffic information services of the Radio Data Service (RDS) system operating in the radio broadcast FM band in Europe, one of the features of TIS is automated radio tuning (and possibly switching on from standby).

Among other services to be included in the present category there is remote data sensing; data are collected from remote sensors and sent from an automated device in a specified format together with the positioning data of the device to the SC in charge of their processing. The latter service employs a mobile data service described above.

4.4 Additional services (non S-PCN)

Some system proposers intend to offer additional services which whilst technically similar to S-PCN (the service could be provided to an S-PCN terminal with techniques like those of S-PCN) fall within a different regulatory framework. These are mentioned here for completeness but should not form part of the consideration of possible standardisation of S-PCN.

These additional services would not generally be provided in the MSS bands used for S-PCN but would use their own allocated bands.

Digital Audio Broadcasting (DAB) as a Broadcasting Satellite Service (BSS) is a direct sound distribution service from NGSO or GSO satellites. The present allocations have enough bandwidth to accommodate a DAB service from NGSO as well as GSO satellites. In some S-PCN proposals an explicit reference is made to this possibility due to the interest in providing high quality sound services to relatively simple receiving-only mobile or fixed satellite terminals. Powerful coding algorithms for audio compression are being investigated to be used in DAB to save bandwidth. Some grades of audio quality, related to coded bit rate, have been identified for DAB applications (see Direct Broadcast Satellite Radio [5]) that allow high quality audio (high quality audio is often assumed to have a band of about 20 kHz) to be coded down to 192 to 256 kbit/sec. Some studies (European Space Agency (ESA), for example, employing High Elliptical Orbits (HEO)) have already pointed out that a satellite DAB, both for mobile and fixed services, could justify by itself a dedicated multi-satellite system. Single GSO systems are under study (USA initiatives in ITU Region 3 and AfriSat in ITU Region 1) for regional service. Taking advantage of the unique features of the satellite several local, regional, continental radio stations could share the same space segment.

Sharing and co-ordinations procedures for DAB (need especially if NGSO systems will operate in the same band of GSO systems) are still to be defined but again do not form part of the analysis of S-PCN.

4.5 Frequency availability for S-PCNs

Because of the increasing interest in S-PCNs, the World Administrative Radio Conference (WARC) held in 1992 (a Conference held under the auspices of the ITU) has made available a number of new frequency allocations to the Mobile Satellite Service (MSS) in bands around 140 MHz, 400 MHz, 1,5/1,6 MHz and 2,0/2,5 GHz (also around 20/30 GHz). Whilst these bands are intended for general MSS use, it seems likely that their newly allocated status will make them attractive to S-PCN system proposers since the sharing problems with other MSS services will be minimised.

Annex A summarises the present status of frequency allocations for MSS.

4.5.1 Frequency sharing

An S-PCN network operating in the bands allocated to the MSS will have to co-exist with other S-PCN networks and other MSS networks. There will also be a need to share with non-MSS services which have allocations in the frequency bands.

S-PCN feeder links in FSS bands will have to share with FSS networks and other non-FSS services allocated to those bands. Sharing will be necessary in the case of NGSO with NGSO networks and for NGSO with GSO networks.

Sharing is a difficult problem, made more difficult by the NGSO nature of most S-PCN proposals.

The International Radio Consultative Committee (CCIR) is currently studying the problem of frequency sharing with a view to establishing suitable recommendations

Annex A, Clause A.4, presents a brief review of some of the problems involved in sharing frequencies between S-PCNs and other systems.

4.5.2 Frequency re-use in S-PCN

One of the characterisations of a general PCN, and therefore of an S-PCN, is its communications capacity, essential to support a large user base (subscribers). In S-PCN this requirement turns out to be mainly a requirement of spectral efficiency. It is not possible to satisfy the capacity requirement if a frequency re-use method is not employed, because of the shortage of spectral resource available to the development of S-PCNs. The problem is similar to that posed by terrestrial mobile systems where the allocated spectrum is narrow. The network and transmission techniques proposed therefore are a mixture of those used in satellite communications and typical concepts of cellular systems architectures. The cellular frequency re-use technique is extended on a regional or global basis with the adoption of macro cell coverages that are the footprint of satellite spots. The satellite coverage can make use of hundreds of such macro-cells, depending on the orbital parameters.

The frequency re-use factor is one of the parameters that leads to the actual channel re-use in the system, its importance depends on the combination of access/modulation and system configuration parameters. It is important to relate the frequency re-use to the complexity that it involves. It is possible to observe that the frequency re-use issues are mostly different from those presented by cellular network where the coverage is "static". In S-PCNs, if implemented by NGSO systems, the coverage may require dynamic re-configuration not necessarily related to traffic, depending on the system design.

5 General NGSO concepts

This ETR is expected to have a wide circulation; it is likely to be used in a number of roles and by a broad readership. It is, therefore, felt to be beneficial to present a short clause summarising the key concepts relating to the use of NGSOs, especially for the provision of personal communications services, so that a common base of understanding is established for the following clauses.

5.1 Non-geostationary orbits and constellations

To undertake a full analysis of the proposed S-PCN systems set out in Clause 5 and the options for European standardisation set out in Clause 6 it is necessary to have a good understanding of the principles defining the configuration of a satellite orbit and a constellation of satellites so that any analysis made can be based on a common understanding of the significance of the choice of various parameters made by the different system proponents.

Annex F presents a detailed tutorial review of the main terminology and parameters defining orbits and constellations and then goes on to review and contrast the different classes of orbit which might be used to provide S-PCN services.

ETSI has developed a number of reference charts showing how key parameters, such as orbit period, lower bound on the number of satellites required for a global coverage, the period of visibility of a single satellite at a single location on the Earth, etc. vary as a function of orbit altitude. This information is presented in Annex G, but it is not possible there to explain and assess all the varying parameters and all the pertinent design points for all possible systems.

5.2 Satellite personal communications with NGSO satellites

In this subclause the use of NGSO networks to provide S-PCN services is discussed; in particular the specific features and problems due to the use of NGSOs to provide personal communications services is presented.

An S-PCN system is composed of a user segment, a ground segment and a space segment. In this subclause the characteristics of what makes a NGSO S-PCN different from one employing GSO is presented. The main differences are identified in terms of coverage, service, integration capability, access, network access, mobility (handover in particular) and general features of small NGSO satellites intended to be deployed in constellation.

The user segment is the user terminal, different terminals are to be foreseen depending on the functions they provide. The typical terminal considered here will be the voice communications terminal.

The ground segment comprises all the satellite control and monitoring facilities needed to control the space segment operation, traffic ground stations and access gateways and the network associated.

The space segment is composed in general of multiple NGSO satellites distributed in a system of orbits that constitutes the system constellation. It has been considered useful to address some issues that help in identifying the specific features of a NGSO satellites.

5.2.1 S-PCNs via multiple NGSO satellites

This section addresses those aspects of S-PCN related to the multi-satellite space segment.

This ETR defines the coverage of NGSO S-PCNs as one of four classes:

- regional [3] coverage;
- multi-regional coverage;
- world-wide latitude bounded coverage; or
- Global Coverage (GC).

A regional coverage is achieved by a system that ensures continuous coverage of a defined portion of a continental region of the globe bounded in latitude and longitude, such as Europe. A multi-regional coverage is achieved by a system that ensures continuous coverage to several regions at the same time, such as a system covering Europe, North America and the far East. A world-wide latitude bounded coverage is achieved by a system that ensures continuous coverage of a latitude bounded portion of the globe, such as a system covering the globe excluding both polar regions. A GC is achieved by a system that ensures continuous coverage of the globe with no limitations in either latitude or longitude.

An S-PCN system is composed of a user segment, a ground segment and a space segment. The space and ground segments can be shared at different levels. The space segment can be shared among different networks, as in several satellite systems, but what characterises the NGSO sharing is the capability to be shared in time and space. Time sharing refers to the capability to share the satellite capacity among different networks located within a common region. Sharing in space refers to the capability to share satellite capacity among different networks located in different regions. Sharing does not necessarily involve continuity in coverage, a non-continuous NGSO coverage constellation provides sharing in space while time sharing in the same area. Sharing in different regions needs only a loose co-ordination procedure (or even none) while the co-ordination procedure needed to implement time sharing has to be efficient.

The ground segment may be able to be shared by different networks already sharing satellite capacity. The traffic earth stations, network gateways, and other network entities (database nodes) are all shareable, the S-PCN can also be integrated with other terrestrial or satellite mobile networks. Some terrestrial based monitoring and control facilities can also be shared.

The multi-satellite space segment can be designed to be deployed in several stages providing modular coverage and capacity. It is possible to plan mission launches accordingly, adding flexibility to the project for cost-effective solutions. Multiple satellite S-PCN mission launches are, in general, multiple launches and a launch vector is employed to carry and distribute into orbit several small satellites at a time. Some of the issues related to launch vehicle requirements are discussed in Annex E, Clause E.2.

5.2.2 Global systems

An S-PCN has to take as a reference the GC, this will be described here as the reference global system, other coverage options can be derived from the GC.

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[3] Note that in this context regional is not used in the sense of "ITU Regions" but as a way of defining a large service area which would cover more than a single nation. Throughout this ETR where ITU Regions are meant, this is stated explicitly.

5.2.2.1 Global radio coverage

A GC has been defined simply as continuous coverage of the globe with no limitations in either latitude or longitude values of the covered area. This definition is loose if it is taken into account that any practical satellite coverage is defined with at least a specified minimum elevation angle, a specified set of power density flux values inside the coverage or, equivalently, a set of link margin values for the operation of the service, given some values of terminal parameters. For a multi-satellite mobile application such as that of S-PCN this standard set of parameters is inadequate because of the dynamic coverage.

Other coverage parameters are needed to characterise the global NGSO multi-satellite coverage. A basic assumption here is that the elevation angle of the communication satellite is the main parameter of the radio channel and that its best value corresponds to the highest available.

The coverage area of a system has to be specified to satisfy certain requirements including geometrically covered area (with a guaranteed minimum elevation angle) and flux density values, but also possibly the number of satellites simultaneously available to the terminal, depending on the communication subsystem characteristics. A detailed investigation of the possible definition of coverage area is here identified as suitable for further work and should identify the exact list and ranges of parameters associated to a geographical location in order to consider it part of an actual covered area of a given system. It must be underlined that the coverage area is an information specifically related to a system and that the above mentioned analysis could at least define the broad category into which the coverage of a system falls.

The number of satellites visible above the minimum specified elevation angle characterises the higher instantaneous elevation angle theoretically available at any location. This is purely a geometric parameter. The requirement for a GC is for this figure to be always equal to or greater than one.

It is important to make clear the relationship between a global system and a GC. A global system is not necessarily characterised by a GC, but provides a communications channel to all locations globally for some but not necessarily all times.

Other non-geometric parameters (e.g. coverage availability) will be identified in the following sections.

Annex B provides the detailed definition of radio coverage as used in this ETR for both cases (i.e. GC and global system).

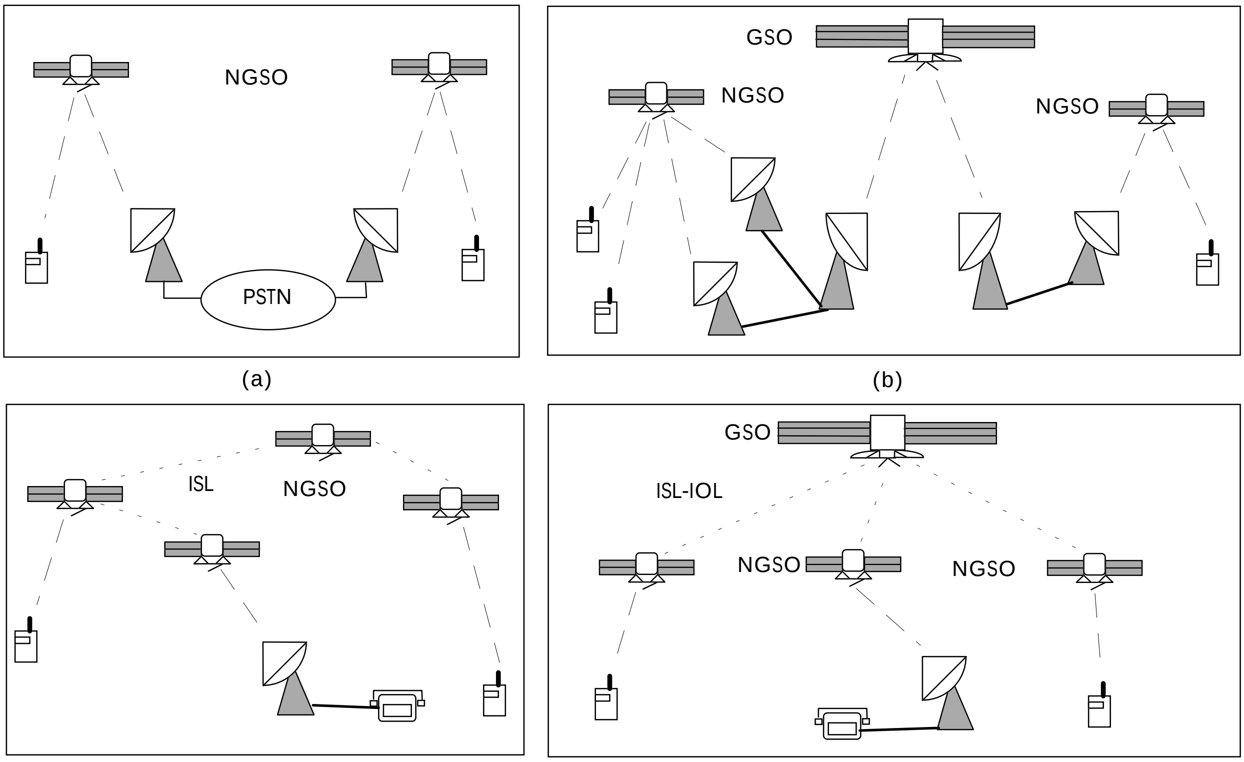
5.2.2.2 Network architectures

The network associated to a GC is global, it provides connectivity to any location continuously in time. The global mobile satellite network will provide the user with full international roaming, in the sense that there will not be any technical limitation to roaming. Some new applications will become feasible using additional satellite global services such as position determination and reporting. The global network architecture depends on the assumptions made regarding the space segment. The possible options are those of a transparent transponder, a payload with On-Board Processing (OBP) capabilities, the adoption of Inter-Satellite Links (ISLs) within the constellation or with other data relay satellites. A set of some possible link architectures is given in figure 1. The first option, figure 1(a), refers to an S-PCN relying upon the terrestrial network, no ISLs are present and the mobile to mobile call is delayed by at least two NGSO hop delays. The second option, figure 1(b), refers to an S-PCN using a GSO satellite to provide connectivity among earth stations, a mobile to mobile call is at least delayed by two NGSO hops plus a GSO hop. The third option, figure 1(c), refers to an S-PCN using ISLs among satellites of the constellation, each satellite may have to establish several ISLs with others at the same time, the network may still rely upon the terrestrial network for some functions, the mobile to mobile call may have different delays depending on the routing adopted on the ISL backbone. The fourth option, figure 1(d), refers to an S-PCN with direct interconnection of NGSO using ISL inter-orbit links by a data relay geostationary satellite, the mobile to mobile call is delayed by at least two half-NGSO hops plus one NGSO to GSO hop. In this configuration the GSO satellite is directly accessed by NGSO, in principle three GSO data relay satellite would be needed to obtain full interconnection GC.

For some communications technologies single satellite coverage may not be sufficient and more than one satellite may need to be in view of a user to effectively communicate.

The first architecture is applicable to areas of the world where the ground network is developed and able to support the S-PCN operation. The other architectures, i.e. interconnection with a GSO data relay satellite, either directly or indirectly, and inter-constellation ISL interconnection, can be adopted independently of the development of the ground network and its capability to support the operation of S-PCN. A global network may in principle employ any applicable combination of such links. Employing only one kind may simplify the network management from several points of view.

The interconnection of S-PCN with PSTN/PLMN raises the problem of the resulting possible end to end overall delay. If the global network internally employs GSO hops neither a fixed terminated nor originatedcall would be compatible with a further GSO hop inside the PSTN, also different call setup delays are foreseen for different S-PCN architectures.



(a) (b)

(c) (d)

Figure 1: Some possible global network architectures for S-PCN

5.2.3 Service availability

The service here considered is the voice service, similar considerations hold for other services such as paging and data transmission. In S-PCN some services could be available all the time while other services could be available non-continuously. Availability in S-PCN is distributed as it is defined by several factors. If a call is either fixed originated or terminated the availability parameters taken into account should be only those of the entities inside the S-PCN in order to separate them from availability effects due to other networks.

Parameters relevant to the availability of the service can be found by breaking down the entities involved in the call route. Annex C contains a detailed description of service availability within the scope of this ETR.

One of the observable effects of the availability of the service is the mean time needed before a usable channel becomes available, either at any location within the coverage at any time or at a specific location within the coverage at any time.

5.2.4 Service quality

The service quality is related to parameters that include the following:

- service availability;
- end to end link quality (including effects due to other networks);

- voice coding quality (balanced with the service ubiquitous availability);

- service access and integration.

The end-to-end link quality includes effects of delay, call setup delay and channel quality, often measured in Bit Error Ratio (BER) for digital systems (measures exist to minimise delay effects, using for example echo suppressers).

Service access includes all those features that ease service access and provision. Many of these features are an essential part of the concept of personal communications and include service customisation parameters. The capability of the S-PCN to be integrated at different levels with other system also adds quality to the service provided.

Several points need to be further addressed:

- detailed analysis of access and transmission delay in real time and non-real time data communications over S-PCNs for various constellation options and network topologies;

- CCITT/CCIR Recommendations relevant to service quality in S-PCNs.

5.2.5 Integration

Integration of S-PCN has to be considered in the general frame of interest of integration of satellite networks with terrestrial mobile networks. The role of the satellite network depends mainly on the development of other networks inside the satellite service area. Where both cellular and mobile satellite services are available, various resource assignment strategies are possible taking into account parameters such as the cost of a satellite circuit and its value as a shareable resource.

It has been pointed out already that the S-PCN plays an important role in making the mobile radio service ubiquitous, providing telecommunication services irrespective of the user position, and possibly of the terminal position. Integration between S-PCN and PSTN/PLMN would therefore greatly improve service from the user's point of view. The S-PCN would be ultimately a component of the general PCN. Here integration levels are briefly identified for S-PCN together with their requirements.

There are some possible relationships (see CCIR Report 1177, [6]) between a terrestrial and a satellite mobile system:

- compatibility;

- commonality;

- integration.

Compatibility is a scenario where two different systems can be accessed with the same mobile unit, with no difference at all (the user would not be even conscious of what system was being accessed during a call). As S-PCN design parameters are quite different from those of cellular system this perspective is to be considered as an ideal reference. Commonality is the relationship between all those features that can be placed in common between the two systems, particularly when they are operated at close frequencies and power flux densities levels. The main impact of a commonality relationship is expected to be on cost savings. Integration is a higher level relationship that allows some form of co-operation between the two systems giving not only cost saving but also service benefits.

Integration is not truly a single relation, since It is possible to identify at least four integration "levels" that have different system requirements and outcomes.

Figure 2 shows how the levels are related so that each higher level includes the features of the lower levels, the system level being the highest level of integration.

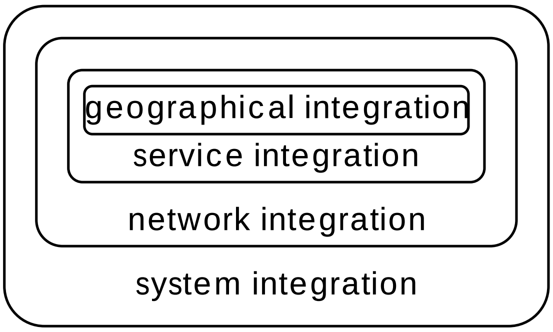


Figure 2: Levels of integration

Geographical integration is obtained when the terrestrial and satellite part are characterised by a complementary radio coverage and separated in all other components (physical entities). They are actually two different systems with independent networks, numbering schemes, type of services, terminals. The mobile originated call has to follow two different procedures depending on which mobile system is employed. The difference will appear at all levels including user interface. The fixed originated call is routed to the system selected by the dialled number, no provisions are made to select automatically the system where (in which coverage) the terminating terminal is located. The advantage of a geographic integration is the extension of mobile radio service coverage. For this geographically integrated case, a mobile to mobile call between PLMN and the mobile satellite network is not possible in general.

At service integration level the two systems are able to provide common services. The two networks are not different from those of the previous level but their design parameters are chosen in order to support at least a common set of services. Fixed and mobile originated calls are placed following the same procedures given above but they can offer the same set of services. It becomes possible to make a mobile to mobile call between a PLMN and a mobile satellite terminal.

Network integration is characterised by the sharing of network infrastructures and functionalities that allow the capability to transparently handle the call routing due to roaming of the mobile unit between the two networks. The fixed originated call is routed to the mobile destination with no call routing selection by the fixed user as the mobile user has a unique calling number associated. Once a link is established and associated to a call it is treated separately inside each system. No handover of live calls is therefore possible between the two networks. A mobile to mobile call between a PLMN and a mobile satellite terminal is possible using a single numbering scheme. The common network infrastructures, such as switching centres and mobility databases, are supposed to result in cost savings in design and network deployment.

System integration is the maximum conceivable level of the integration relationship between the two mobile networks. Integration at this level makes in all senses the mobile satellite network a component of the mobile part of the PCN. The mobile satellite coverage is seen by the network as an homogeneous part of the cellular coverage, providing the same set of services with the same mobility management functionalities. The satellite to cellular handover (and vice versa) has no procedural difference from a cellular handover, not even being apparent at the user interface level. The two networks share all components except the radio link control parts that are assumed here to operate in different bands. This distinction seems necessary because of the different link control requirements for the two components.

Geographical integration is of little interest for an S-PCN. It represents a level of integration not quite sufficient to satisfy the basic personal communications requirements. Integration at system level can be taken as a reference while considering features of service and network integration levels as possible standardisation areas.

Implications on the network design need to be further addressed.

5.2.5.1 Mobility and roaming

Mobility management is the key feature of mobile networks, it includes location updating, paging and handover procedures. In a global system mobility management will have to be performed on a global basis, new problems arise that have to be addressed in order to arrange for the mobility management efficiently. In S-PCN employing NGSO multi-spot satellites handover procedures due to mobility are activated mainly by the mobility of the constellation.

Mobility is allowed by a suitable network architecture and protocol. A mobile network is composed in general by a switching part connecting coverage areas and a control part, necessary to account for the mobility of the terminals and satellites in an NGSO S-PCN scenario. Commonly, covered region areas are assigned to network control entities and databases according to a signalling reduction principle and layering of subscriber data. Information transfer between mobility management entities is supported by a suitable protocol that has functional provisions to support mobility management, personal addressing, multiple and supplementary services and security.

Mobility management allows roaming of a mobile communications terminal in the coverage area and across PLMN boundaries, providing the subscriber with location independent services. Personal addressing is designed to identify the subscriber and not the equipment being used. Multiple and supplementary services support using one identity (personal addressing) involves the capability of the network to retrieve all the information (parameters) necessary to setup the services the customer has subscribed to (such as call forwarding, closed user group, barring of outgoing/incoming calls). Security aspects include access authentication and communication privacy as well as masking of subscriber identity to prevent tracking.

Multi-layering of databases is intended to keep "local" some data relevant to access and services, these data are "moved" through the network following the user migration. A protocol designed to meet these requirements will make migration possible and transparent to the subscriber.

Some useful general definitions for mobility and mobility management are the following:

- **Location Register (LR)**: is the database where location and service information is stored to route any mobile terminated call to the actual location area. The entity is logically unique. When layered in two layers the two entities work in a master-slave configuration to achieve consistency of information throughout the network. A Home Location Register (HLR) serves as master and addresses the proper Visitor Location Register (VLR). Any variation in mobile terminal location information is first brought back to HLR level to be updated.

- **Location Area (LA)**: is the physical area in which a mobile station may move freely without updating the Location Register. A LA may consist of one or more cells. The LA represents the spatial resolution adopted by the network to track the mobile.

- **Mobile Switching Centre (MSC) area**: is the part of the network in charge of a single MSC. An MSC area may consist of several LAs.

- **Cell Selection (CS)**: is the procedure used by the mobile terminal to select the serving coverage cell.

- **Location Updating (LU)**: is updating of LR for position location purposes. LU is performed when the mobile terminal enters a new LA.

- **Paging**: is a broadcast in an addressed LA containing the mobile station identity (translation of the subscriber's address).

- **Handover**: is the procedure of dynamic real time channel reassignment to a call. It is mainly intended to maintain a live call when the mobile terminal moves with respect to coverage entities but can also be performed for other reasons such as traffic management commands. A traffic management command could, for example, force all S-PCN calls approaching a certain area or inside that area to be allocated to a pre-determined portion of the available frequency band.

5.2.5.2 NGSO multiple access

Efficient modulation and multiple access techniques are necessary to share the small amount of spectrum available to S-PCNs and to cope with mobile unit (and satellite) power and size constraints.

Annex D contains references to access and modulation methods applicable to S-PCN.

5.2.5.3 Handover and routing

As discussed above, handover is mainly intended to maintain a live call when the mobile terminal moves with respect to coverage entities but can also be performed for other reasons such as traffic management commands. In S-PCN employing NGSO multi-spot satellites handover procedures due to mobility are activated mainly by the mobility of the constellation. In cellular systems handover has the effect of a radio channel reassignment between adjacent cells, with or without call interruption. On this basis the first characterisation of handover is based on the way in which it occurs:

- make before break handover, involving a new traffic channel assignment and occupation before the original channel is released;

- break before make handover, involving a new traffic channel assignment that is occupied (shortly) after the release of the original channel.

Both types of handover can occur between different entities. Referring to an S-PCN integrated at system level with a cellular system, four handover events are here identified:

- intra-satellite handover, between spot beams of the same satellite;

- adjacent satellite handover, between spot beams of adjacent satellites;

- satellite to cellular handover, between a satellite spot beam and a terrestrial cell;

- cellular to satellite handover, between a terrestrial cell and a satellite spot beam.

The first two are strictly related to terminal relative mobility and spot beam size while the last two are more related to traffic and link quality. Spot beam cells can be several hundred km wide, a part of a several thousand km footprint. For a GSO multi-spot satellite, handover is justified when the mobile terminal speed makes the Average Call Distance (ACD, the mean linear distance covered during a call) comparable with the signal degradation distance.

In NGSO LEO systems beam spots move fast so that the mobile terminal speed becomes negligible and the ACD parameter is not meaningful, the average call duration becomes itself the critical parameter instead. In this case it is more adequate to evaluate the average satellite visibility (either the geometric visibility time or the time during which a satellite of the constellation provides a channel with a quality over a decided value) and compare it to the average call duration. In Annex G, Clause G.3 the transit time (geometric visibility time) for an assumed stationary Earth is given as a function of orbital altitude and in Annex G, Clause G.4 the transit time error due to the stationary Earth assumption is shown. The need (and average number of) inter- and intra-satellite handovers depends on the transit time and the average call duration.

Another characterisation of handover is its randomness. For fixed spots the handover statistical properties merely depend on the mobile unit. When spot speed becomes very high, handovers become almost predictable so that they tend to be a deterministic process. In this case the handover procedures may be simplified.

Satellite to cellular and cellular to satellite handovers belong to a system integration scenario that optimises resource assignment. All handover procedures apply with no changes to the cellular or satellite part of the network. Cellular to satellite handover may be used, for example, to increase network service quality by switching cellular overflow traffic to the overlapping spot beam while satellite to cellular handover may be used to drop traffic channel from the satellite when the quality of the link becomes poor. Applying these algorithms to a fast moving cell pattern requires, in principle, an accurate knowledge of the network state derived from terrestrial as well as satellite network nodes. No further reference will be made here to these handover categories, rather, it is important to observe that the satellite to cellular handover procedure has network and call handling processing requirements that go far beyond those of the cellular to satellite handover procedure.

5.2.5.3.1 Handover in LEO systems

Inter-satellite handover procedure for LEO NGSO systems includes, for all handover modes, the following procedures:

- spot beam assignment procedure;
- radio channel reassignment procedure;
- differential Doppler shift compensation procedure (refer to Annex G, Clause G.8, where worst case Doppler shift is given).

There are some simplifications in the handover procedure compared to the cellular due to the structure of LEO dynamic coverage. As the mobile terminal can be considered as fixed with respect to the earth by definition (as shown in the previous section), as LAs are associated to MSCs with a two way correspondence and as the LA is not associated with the radio coverage but is only a geographical concept it is impossible that a handover event involves more than one MSC. The cellular handover procedure instead has to account for call re-routing through several different MSCs as an inter-LA handover is just as probable as an ordinary inter-cell handover. Therefore it is possible to logically separate LAs in a LEO system.

Call routing may involve other handover procedures if Inter-Satellite Links (ISLs) (either inter-constellation or inter-orbit) are employed. ISL establishing in a LEO system involves the possibility to dynamically rearrange ISLs, due to inter-satellite relative dynamics.

5.2.5.3.2 Handover in HIO/HEO systems

In HIO/HEO systems the inter-satellite handover procedure is related to the inter-satellite relative movement rather than to the relative satellite movement with respect to the mobile terminal. The handover event closes the apparent loop ensuring coverage continuity. HIO/HEO inter-satellite handover procedure is in principle synchronous and applied to all calls at the same time. Between inter-satellite handover events the intra-satellite handover procedure is hardly applicable.

5.2.5.3.3 Routing

Routing in NGSO systems has several aspects to be outlined. Here are addressed some aspects relating to first/second choice routing and ISL routing algorithms.

In regions such as Europe, it is possible that a large percentage of the region will be covered by both terrestrial and satellite PCN systems due to the level of penetration of mobile communications. An S-PCN mobile terminal is therefore likely to integrate a cellular mobile terminal. The mobile dual mode terminal may either:

- select the system automatically, on the basis of a selection algorithm (e.g. first/second choice); or
- select the system on command;

provided that both systems are available and support the service requested.

Call routing for the voice service depends on the S-PCN architecture. If no ISLs are employed the call is handled by the S-PCN earth station associated with the LA where the call originates and then routed through MSCs either to the S-PCN earth station associated to the mobile terminating terminal or to a gateway between the S-PCN and PSTN/PLMN. The gateway selection procedure takes into account:

- the location of the PSTN end terminal; and
- the network access point of the PLMN end mobile terminal.

Once the route is selected, possibly through several MSC and fixed switching centres, it should be possible to setup the call without the need for real time re-routing procedures, as observed in subclause 5.2.5.3.1.

ISL multi-satellite routing algorithms for data and voice services have been analysed in the past with particular reference to military applications where the ISL adaptive routing is mainly intended to enhance the network survivability against satellite failures and local conditions at the satellite such as jamming. Each satellite may either handle local up/down link traffic, crosslink to crosslink traffic or, in general, a mix of both. ISL routing algorithms rely upon routing tables stored on board, if satellites are given a mark depending on their position with respect to the earth and to their orbit plane three schemes can be considered:

- flooding;

- orbit-independent routing;

- orbit-dependent routing.

The flooded network does no deterministic routing. A message entering the network is transmitted over each available ISL with a simple algorithm ensuring network stability, that is if no new messages enter the network, the network will eventually empty itself. It is important to prevent locks in the network state by providing means to bring the network to a known state on centralised command, for example stopping every new message transmission for decided intervals. The satellite on-board processing has minimum requirements. A high degree of fault tolerance (survivability) results from the non-deterministic routing because end-to-end throughput does not depend on the availability of connectivity of single paths. The main problem with this approach is the reduced throughput that makes the network not well suited to real time high speed traffic (such as voice). The flooded network routing scheme applies well to user data and paging services.

The orbit-independent routing implements a shortest path routing. In the orbit-independent routing scheme a satellite, irrespective of its orbit, knows whether it is a node along the shortest path by looking up the routing tables available on board. When receiving a message on the shortest path route, if the destination address is not the address of the receiving satellite, the message is forwarded to the next nearest neighbour along the path.

The orbit-dependent routing scheme identifies the orbital planes and the satellites addresses to route the message. The orbits of the originating and terminating satellites are identified as originating and destination orbits. A message is forwarded along satellites of the originating orbit until it reaches a satellites that can switch it to the destination orbit. Then the message is forwarded along the destination orbit to the destination satellite. The resulting path is not, in general, a shortest path. The main advantage is the simplification due to the main use of intra-orbit ISLs, the satellite in the originating or destination orbit has just to forward the message along its orbit "highway" if it is not possible to switch to the destination plane. Depending on the type of orbit this algorithm may lead to an iso-delay routing, with advantages for the end to end communications protocols.

Figure 3 shows in diagrammatic form the differences between orbit-independent and orbit-dependent routing.

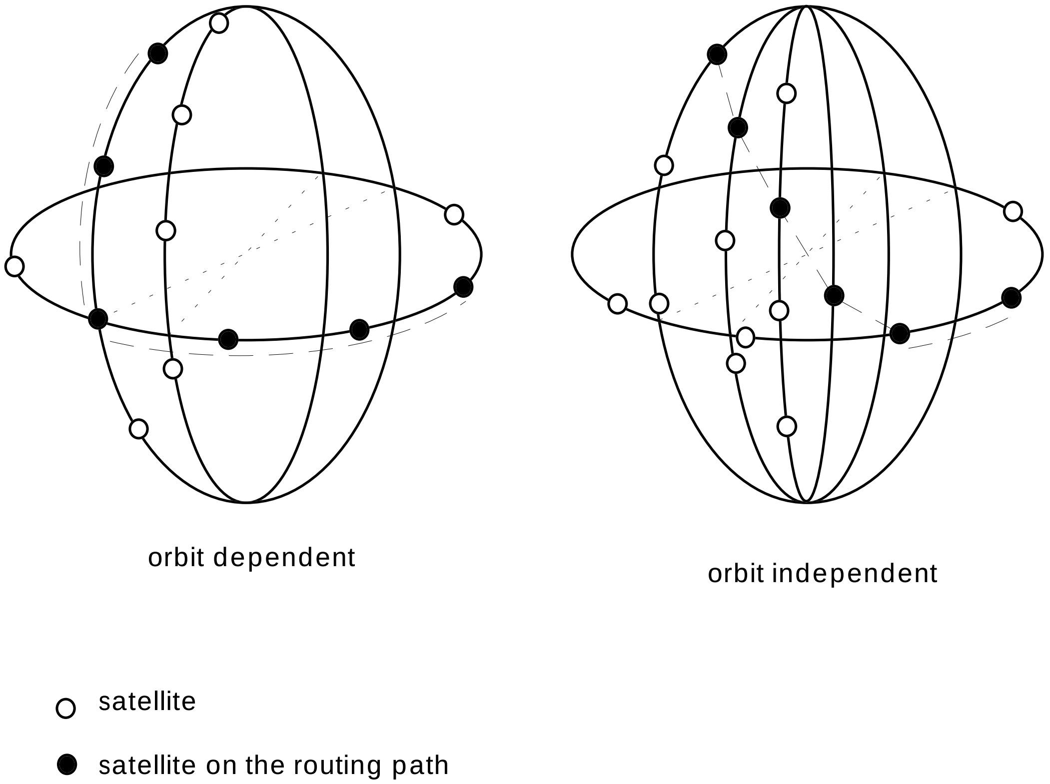


Figure 3: Orbit routing

5.2.5.4 Integration with GSM

The GSM network is the pan-European digital mobile cellular network based on a standard developed by the CEPT GSM Group and later continued within the ETSI Special Mobile Group (SMG). The network development is in advanced stage in several European countries. A European interest in the integration of S-PCN with PLMN, at any level (referring to subclause 5.2.5 terminology), will be addressed towards GSM as GSM probably offers the most attractive scenario.

Options for integration range from the re-use of the air interface at a different carrier frequency to the re-use of GSM network infrastructures, switches and databases. The compatibility of the air interface developed for GSM with the NGSO channel has not been addressed as a unified subject because of the different channel environment in the NGSO scenario. Although it may lead to the definition of an integration at system level, a statement about possible common air interface requirements is also heavily system dependent. Integration at network level assuming a re-use of GSM network functions, protocols and infrastructures, is independent of the radio interface. Different access and modulation techniques can be employed to optimise the satellite access.

In GSM there is a functional split between databases and switches, and this represents the first step in the Intelligent Network (IN) concept. One of the main features of IN is the separation of call handling functions and information handling functions leading to an architecture where Service Switching Points (SSPs) and Service Control Points (SCPs) are separately identified. SCPs provide SSPs with databases and control.

The GSM database structure is two layered; corresponding entities are the Home Location Register (HLR) and Visitor Location Register (VLR). The HLR contains all the information about the subscriber, including the address of the VLR, and optionally MSC, serving the mobile. The VLR contains information relevant to local mobile service provision, mostly duplicating information in the HLR. The protocol to support transfer of information between GSM mobile management entities (MSCs, HLR, VLRs) has been defined within GSM as the Mobile Application Part (MAP) protocol, making use of services provided by the common channel Signalling System 7 (SS7) protocol. GSM signalling interfaces are represented in figure 4.

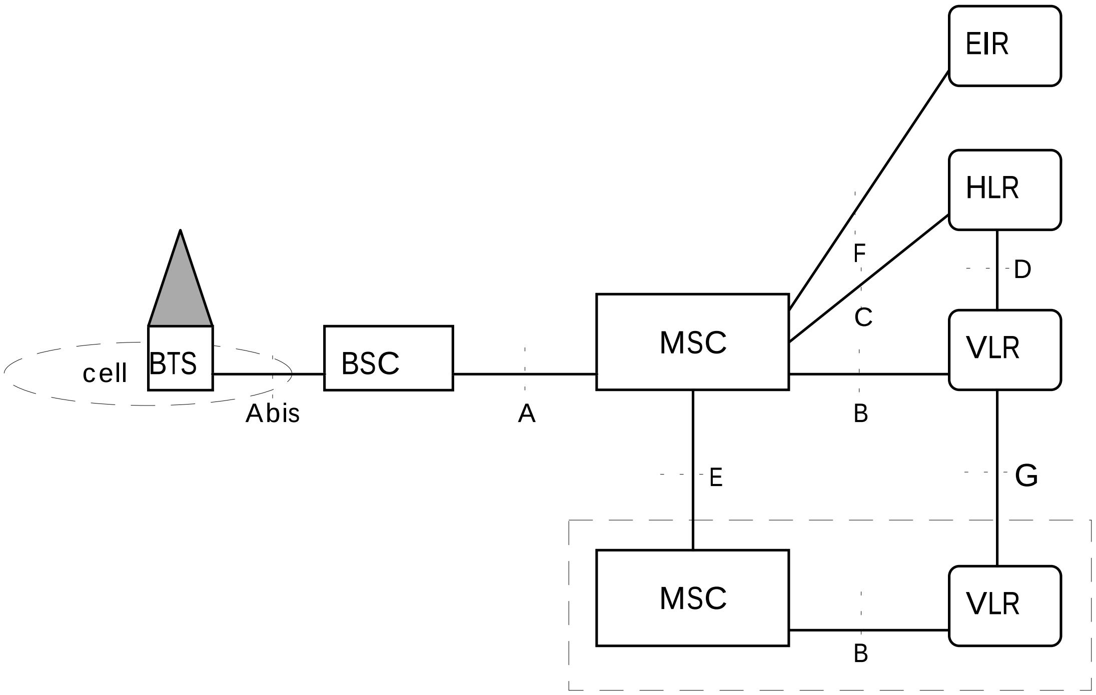


Figure 4: GSM signalling interfaces

The MAP protocol provides functionalities for mobile personal communications including:

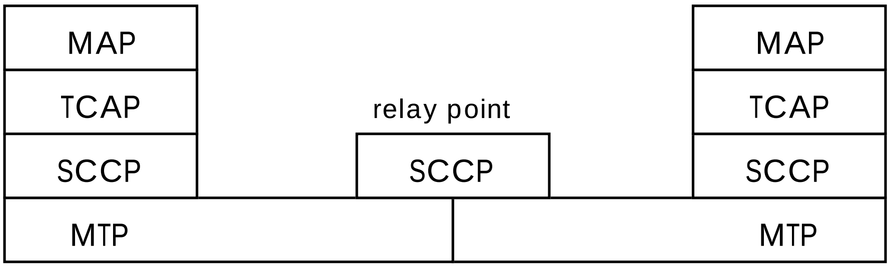
- mobility management;
- personal communications;
- multiple services;
- supplementary services;
- security provisions;
- general mobile network requirements (data consistency, restoration).

The S-PCN integrated with GSM is supported by MAP protocol, providing a set of procedures that can be grouped in some main functional blocks:

- mobility management;
- basic services support;
- supplementary services support;
- short message services;
- authentication and security;
- operation and maintenance.

The complete MAP protocol stack is represented in figure 5. The Message Transfer Part (MTP) is the layer for information exchange between adjacent nodes of the signalling network. The Signalling Connection Control Part (SCCP) corresponds to the layer three of the OSI stack (Network Layer Service (NLS)), it provides addressing that supports connectionless or virtual signalling connections between arbitrary nodes of the signalling network. The Transaction Capabilities Application Part (TCAP) provides support to dialogues between applications. The MAP corresponds to the OSI layer 7; it consists of messages (in ASN.1 syntax) specifying a set of procedures for each of the functional blocks listed above.

The applicability of MAP procedures to S-PCN needs to be addressed in greater detail.



MAP: Mobile Application Part
TCAP : Transaction Capabilities Application Part
SCCP : Signalling Connection Control Part
MTP : Message Transfer Part

Figure 5: MAP interfaces and protocol stack

5.2.6 Network access and co-ordination

The access and co-ordination problem posed by multiple NGSO S-PCNs is original in many ways. It has not been greatly investigated in the open literature, but is considered here because of its implications on system operation management and identification of possible European standardisation areas (Clause 6). It is difficult and inflexible to conceive a feasible centralised solution while a distributed solution seems most suited to be implemented on a wide scale. Because of the characteristics of NGSO coverage it is not possible to employ the access and resource co-ordination schemes of cellular networks, but their knowledge and investigation is believed to help the design of possible solutions to the present problem.

In the following subclauses the access and co-ordination are dealt with in an effort to keep matters as general as possible.

5.2.6.1 Network access

In general terms it is possible to identify two levels of assignment for network access for any service other than RDSS (where it is not really appropriate to define an association relationship between NGSO satellite and mobile terminal):

- 1st order: assignment of a mobile terminal to one (or more) satellite(s);

- 2nd order: assignment of one (or more) satellite(s) to an earth station, or vice versa.

The first order involves the mobile terminal and (possibly the satellite) procedures. The second order involves the earth station and possibly the satellite.

First order assignment establishes assignment procedures, including the service access channel(s) to be used by the mobile terminal wishing to issue a service request. An access channel may be setup differently according to the modulation and multiple access scheme employed; the assignment procedure is in general independent of a scheme's design. The association between a satellite and a mobile terminal may be transparent to the mobile terminal and mastered by the earth station or it can be partially under control of the satellite, but it seems impractical to include such a function in the mobile terminal. A shared multi-satellite NGSO constellation may be considered as a radio coverage provider, with a defined capacity, the local access control may be included among the functionalities of the earth station if it integrates network management functions.

Second order assignment establishes the procedural criteria to implement association of an earth station to one or more satellites of the NGSO constellation or vice versa. The association defines the sharing of the multi-satellite NGSO space segment (among earth stations in different regions and in the same region among different earth stations at the same time), including the definition of coverage area of the earth station, still identified as an LA.

Second order assignment implements the space segment sharing. It trades off efficiency requirements, due to high cost of capacity of the space segment, flexibility and simplicity, due respectively to the network development requirements and the expected limited complexity of the earth station. The opportunity to control the assignment for voice and user data services is considered here to be of the highest importance.

For GC the two levels of assignment may also be established temporarily on the basis of the availability of the coverage. In a data store and forward global system the coverage may not be guaranteed continuously so that the access may be performed during time windows. Even in a GC some services may be performed in a non-continuous way.

5.2.6.1.1 Resource assignment

Capacity is a critical resource of S-PCN, mainly due to its cost and availability. An efficient and flexible resource assignment is required by a satellite public network with direct access as a part of capacity management. As a part of those procedures relevant to network management, resource assignment is believed to be one of the main areas relevant to standardisation of S-PCNs.

Resource assignment has to account for requirements such as:

- frequency sharing and co-ordination (traffic channels assigned randomly or forced to occupy a compact portion of the available band, depending on the region);

- frequency co-ordination inside the S-PCN (assignment of traffic channels according to a frequency plan defined within the NGSO system);

- handover inter-satellite and intra-satellite (traffic channel booking algorithms).

Resource assignment may be based to a certain extent on present digital mobile networks developments, at call setup the first assignment can be:

- Early Assignment (EA);

- Off Air Call Set Up (OACSU).

In EA the calling party is assigned a traffic channel based on information derived on the calling party side, for example when the request has been authenticated and authorised. The other option, OACSU, is based on information on either side. For example, the request may be assigned a traffic channel after an authentication, authorisation pass and an answer message issued from the called party side.

Assignment of traffic channels to a defined portion of the available band (for example at L-band) as a general co-ordination and sharing procedure may be extended to some modulation and access schemes, such as CDMA, to allow occupancy of the available band within decided power spectral density levels.

Intra-satellite handovers are to be treated, generally, almost as deterministic synchronous events, as pointed out in subclause 5.2.5.3, traffic channels are therefore handed from one spot-beam to the following one following a regular, foreseeable pattern. The assignment of traffic channels to handover calls may employ a channel booking with some flexible priority scheme, taking into account service quality objectives and call duration statistics. Some "spurious" randomness exists in the process due to the random call duration time and other factors such as for example the irregular shape and distribution of spot-beams and unpredictable local propagation conditions.

5.2.6.1.2 Resource sharing and co-ordination

The need for capacity and network resource sharing principles, depending on the S-PCN design, is based on the possible, and probable, multi-operator environment of S-PCN. The hypothesis of a multi-operator scenario can be justified just by the geographic extension of the S-PCN. The S-PCN design should make provisions for sharing of resources among different operators providing a range of services to areas with different requirements. Resource sharing of:

- capacity resources;
- network resources;

is an important area for network management, with various possible elements relevant to agreements, if not standardisation.

A multi-operator environment means that each operator may be given authority to operate a portion of the network, associated perhaps to a defined geographical area, providing the subscribers with a set of services. The S-PCN operator domain is therefore, in general, identified by the set coverage/services. Operators may themselves make use of some common network services, shared for convenience or other purposes, such as Telemetry, Telecommand Control and Monitoring (TTC&M) facilities to maintain certain nominal constellation parameters of phased constellations. Common network services are provided to all Operators at the same time, they ensure a common layer of nominal features on top of which single independently operated S-PCNs may be setup world-wide.

Common network resources include those to perform:

- TTC&M;
- space segment fault recovery (de-orbiting, spares insertion/launch and general space segment performance maintenance);
- spectrum monitoring;
- centralised data base maintenance (update, consistency and security);
- regional registers data bases;
- ground network configuration (routing tables);
- ground network co-ordination;
- ground network operation monitoring (emissions, routing);
- ground segment fault isolation and recovery (alternative routing);
- ISL routing (tables), when applicable;
- ISL maintenance, when applicable;
- user segment fault isolation and recovery (identification of defective handsets);
- system operational data collection and analysis;
- billing.

Those indicated above in brackets are only some of the possible functions. Some functions may be provided by dedicated Network Service/Control Centres (NS/CC), others may be provided by shared physical entities.

S-PCN earth station capacity resource sharing functions have to be designed to cope with all possible sharing situations. In a general global system the earth station is at least locked onto two satellite transmissions to ensure service continuity, one carrying most of the earth station traffic while tracking the next to hand-over. Because of the relatively large coverage area of a satellite (as shown in Annex G, Clause G.2) its capacity may be shared among several earth stations for operators' managing convenience. Shared earth stations in fact do not optimise terrestrial tails with respect to the operator network and pose some additional administrative problems.

Co-ordination of sharing earth stations is necessary. It is not possible to find any analogy with cellular operation in this field mainly because radio resources are strictly locally managed in the cellular environment. Each cell has a unique identity that cannot be shared between different MSCs. In S-PCN two options are possible for each satellite:

- satellite not shared among earth stations, one earth station at a time uses the full capacity of the satellite;

- satellite shared among earth stations, satellite capacity is potentially available to all earth stations that may establish a link (that have geometrical visibility, for example).

The second solution is the most flexible but needs a functional entity that clears and co-ordinates multiple access of S-PCN earth stations to satellite transponders. Assignment of capacity among earth stations may be accomplished on a call by call basis or on a semi-permanent long term basis.

5.2.6.2 Network Co-ordination

Referring to the possibility to logically separate LAs in a LEO system (see subclause 5.2.5.3.1), the network co-ordination function may be accomplished by a dedicated regional station or performed in a distributed way. In either cases a call by call or semi-permanent "long term" co-ordination is possible. According to the expected multi-operator scenario, a semi-permanent co-ordination seems appropriate for the network. If each operator has independent access to the space segment by a gateway, it can be assigned a decided capacity according to:

- capacity of the operated gateway;

- covered region (possible limitations due to latitude dependent coverage);

- spectrum availability constraints.

In the European region it is likely that several relatively small gateways (hundreds of circuits in capacity) may be operated by several independent NGSO S-PCN Operators, making network co-ordination and monitoring an important requirement.

Network co-ordination may also be employed to control band occupancy of the second order assignment, referring to subclause 5.2.6.1. Co-ordinated feeder links may be forced to occupy a decided compact portion of the spectrum, if required by interference constraints.

Network co-ordination allows the operator to be the primary customer of the S-PCN. Once capacity has been allocated to the operator it can be managed locally and tailored to offer different services. For transparent NGSO satellites the flexibility of multiple service provision is maximum.

5.2.7 NGSO satellites

It has been questioned (in the literature) whether or not it is conceivable that a "line" production for satellites to be deployed in constellations may be developed. It has been considered important to address these matters because of the high degree of integration of the various elements that contribute to the definition of a NGSO personal communications system.

Limited power requirements, simplified attitude control and L-band antennas have been identified as the main factors leading to:

- weight reduction;
- size reduction; and
- simplified space bus construction, integration and testing.

In Annex E it has been considered important to address these matters because of the high degree of integration of the various elements that contribute to the definition of an NGSO personal communications system.

The purpose of Annex E, is to provide some brief background on the technologies used in NGSO satellite buses (especially little and big LEOs), as they are different from those used in GSO satellites to a large extent.

6 Review of international activities relating to NGSO systems

6.1 ITU activities

In this subclause an outline of the current ITU activities (i.e. within the CCIR) relating to satellite personal communications systems/NGSO systems is made. It is essential to consider this international standardisation work in the context of development of standards within Europe. References are made to these activities, where possible, in the later sections of this ETR.

Main areas of work are as indicated below; WARC-92 Resolutions are listed against the CCIR Study Group having lead responsibility for dealing with the issues raised (other Study Groups will, of course, also be concerned):

Study Group 4 (SG4):

Draft New Question - Frequency sharing between non-geostationary satellite feeder links in the Fixed Satellite Service used by the Mobile Satellite Service;

Draft New Question - Sharing between non-geostationary satellite feeder links in the Fixed Satellite Service used by the Mobile Satellite Service and networks of the Fixed Satellite Service using geostationary satellites Study Group 8 (SG8).

WARC-92 Res. COM4/4 - Implementation of FPLMTS:

- to continue studies with a view to developing suitable and acceptable technical characteristics for FPLMTS that will facilitate world-wide use and roaming, and ensure that FPLMTS can also meet the telecommunications needs of the developing countries and rural areas;
- Question 39-2/8 has been revised to take this work into account.

WARC-92 Res. COM5/8 - Interim procedures for the co-ordination and notification of frequency assignments of non-geostationary satellite networks in certain space services and the other services to which the bands are allocated:

- to study and develop recommendations on the co-ordination methods, the necessary orbital data relating to non-geostationary systems, and the sharing criteria;
- question 83-2/8 has been revised to take this work into account;
- question 84-2/8 has been revised to take this work into account.

WARC-92 Res. COM5/11 - Establishment of standards for the operation of low-orbit satellite systems:

- to carry out, as a matter of priority, technical and operational studies to permit the establishment of standards governing the operation of low-orbit satellite systems so as to ensure equitable and standard conditions of access for all countries and proper world-wide protection for existing services and systems in the telecommunications network;
- question 83-2/8 has been revised to take this work into account;
- question 84-2/8 has been revised to take this work into account;
- question 39-2/8 - Future Public Land Mobile Telecommunication Systems;
- question 83-2/8 - Efficient use of the radio spectrum and sharing of frequency resources within the Mobile Satellite Service (MSS) and between MSS and other services;
- question 84-2/8 - Use of non-geostationary satellite orbits in Mobile Satellite Services.

Study Group 12 (SG12):

WARC-92 Res. GT-PLEN/B - Sharing criteria in frequency bands shared by the Mobile Satellite Service and the Fixed, Mobile and other Radio Services:

- to study and issue Recommendations as a matter of urgency on the appropriate criteria for sharing between the MSS and other services in the same frequency bands, including power limits and power flux-density as indicated in Articles 27 and 28 of the RR, while placing minimum restrictions on services operating in these bands;
- question 83-2/8 (SG8) has been revised to take this work into account;
- question 84-2/8 (SG8) has been revised to take this work into account;
- question 7/12 - Frequency sharing criteria within the range 1 - 3 GHz.

6.2 Federal Communications Commission (FCC) activities

Additionally, work is being undertaken in the FCC and this should be taken into account in later stages of the study.

7 Proposals for S-PCN

As part of the process of determining the need or otherwise for S-PCN standards in Europe it is clearly important to undertake a review of the current proposals which have been made by companies and other organisations for such S-PCN systems.

When discussing these proposals, it has become conventional to talk of "little-LEOs" and "big-LEOs" as a means of discriminating between classes of system and the kinds of services they provide.

Within this definition, "little-LEOs" are usually taken to be systems not providing voice services but restricted to user data (real time and/or store and forward), paging and positioning services. They are usually assumed to be "small" in mass (e.g. 50 to 100 kg) and to operate in the MHz MSS bands, below 1 GHz.

Conversely, "big-LEOs" are take to be those providing a full range of services including voice, facsimile, paging, real time user data and positioning. They are assumed to be "large" in mass (e.g. 300 to 500 kg and over) and to operate in the GHz MSS bands, above 1 GHz.

Unfortunately, these "little-LEO/big-LEO" definitions are not very practical for a number of reasons. Firstly because not all S-PCN systems can accurately be described as "LEOs" and moreover because it is always possible to find a system that does not fit in well with the description (e.g. a data only service with a "big-LEO" mass).

For this reason, this ETR classifies proposals only by their operating frequency; those systems planned to operate above 1 GHz will generally be of the "big-LEO" class and those below 1 GHz of the "little-LEO" class.

System Descriptions

To produce the system descriptions that follow, the organisations making the system proposals were approached with a request to answer a questionnaire to provide a comprehensive system description. The organisations were also offered the possibility to make a 1 day presentation to ETSI to more fully describe their system proposals.

Where organisations have made a presentation and/or provided written information to ETSI, this is clearly indicated in the text. Where it has not been possible to contact organisations or they have not responded or they have declined to provide any information this is also indicated; in these cases a brief description has been compiled from the published literature.

Where information has been provided by organisations, they have been given an opportunity to review the descriptive material regarding their proposals to ensure that the descriptions are correctly presented and do not break commercial confidentiality; this facility has not been extended to organisations where the description has been compiled solely from the published literature.

In some cases, those organisations who responded positively to the questionnaire were unable to answer specific questions, generally either because the element in question had not been finalised or because of reasons of commercial confidentiality. Where either of these cases applies, this is clearly indicated in the text.

Different systems are at different stages of development; consequently it becomes complex to refer to some items in the present tense (e.g. ... is implemented ...) and others in the future tense (e.g. ... will be implemented ...). On this basis, the descriptive texts always use the present tense; this simplification is not intended to make any implication about the current status of development of any particular system.

In referring to specific system proposals it is necessary to use names and terms which might be registered trade or service marks. In such cases it is acknowledged by ETSI that such trade or service marks are the property of their respective owners. Finally, the attention of the reader is drawn to the disclaimer printed on page 2 of this ETR.

7.1 Proposed NGSO systems above 1 GHz

7.1.1 Aries (Constellation Communications Inc.)

7.1.1.1 Overall system description

The system called Aries, proposed by Constellation Communications Inc., is being designed to provide mobile voice, data communications and positioning through a constellation of 48 light (200 kg), transatellites in circular polar orbits providing seamless global coverage. Communications links are established between the user terminal and a gateway interconnected to the PSTN and other gateways via the terrestrial network. Two types of user terminals are planned, a portable unit and a mobile unit to be mounted on various mobiles. A hand held user terminal is not foreseen. The service is expected to be particularly useful in developing countries and areas not served by cellular networks as the target cost per call is anticipated to be between that of PSTN and cellular.

The following details have been compiled from published and publicly available sources and have not been reviewed by the organisation proposing the system concerned.

7.1.1.1.1 Space segment

The space segment is composed of 48 satellites weighting about 200 kg, with a target lifetime of 5 years. Further information on space segment is not available.

7.1.1.1.1.1 Frequency bands

The bands used in the Aries system are as follows (exact band occupancy is not available):

Table 1: Aries frequency bands

	Band
Service up-links	1 624,5 - 1 626,5 MHz
Service down-links	2 483,5 - 2 500 MHz
Feeder up-links	C (6,5 GHz)
Feeder down-links	C (5,1, 5,2 GHz)

Thus, the bandwidth needs of the system are:

Table 2: Aries bandwidth requirements

	Bandwidth requirement (MHz)
Service up-links	2
Service down-links	16
Feeder up-links	Information not available
Feeder down-links	Information not available

7.1.1.1.1.2 Frequency sharing

Information not available.

7.1.1.1.1.3 Frequency re-use

Information not available.

7.1.1.1.1.4 Coverage/spot beam configurations

The coverage provided by the constellation of 48 satellites is global, with a minimum elevation angle of 7,5 degrees. The maximum delay introduced by one satellite hop is about 25 ms. Each satellite has 7 antenna beams. Further information, including the antenna beam pattern are not available.

7.1.1.1.1.5 Orbits

The Aries system uses a 4 plane circular polar constellation as follows:

Table 3: Aries constellation

Orbit	Altitude (km)	Period (hours)	Inclination	Number of Planes	Plane spacing (deg.)	Satellites per Plane
Polar Circular	1 020	1,75	90	4	45	12

7.1.1.1.1.6 Sample link budgets (forward and return direction)

See tables 3bis(a) and 3bis(b) for preliminary link budgets extracted from the Aries FCC filing.

7.1.1.1.2 User segment

7.1.1.1.2.1 Terminal characteristics

Two types of user terminals are planned, one for mobile use and one portable unit. Hand-held units will be supported by later generations of Aries satellites. The mobile unit is intended to be installed on various types of mobiles and consists of three modules. A dashboard module including the handset, indicators and controls, the electronics module containing the baseband IF and RF subsystems, the antenna module to be mounted on the top of the vehicle. The portable unit will integrate the three modules in one package. The cost of the user terminal is anticipated to be about $1 500 assuming a base of 100 000 user terminal world-wide. No more terminal characteristics are available.

7.1.1.1.2.2 Unwanted emissions

Information not available.

7.1.1.1.2.3 Physical considerations

Information not available.

7.1.1.1.3 Gateways

7.1.1.1.3.1 Traffic/network co-ordination

Information not available.

Table 3bis(a): Aries forward link budget

TDM Forward Link (EOC)

Elevation	10,0	deg.
Range	2 797,0	km
data rate	4,8	kbit/s
coding rate	3/4	
DSI factor	1,5	
transmission rate	110,0	kbit/s

Uplink

frequency	6 555,0	MHz
gateway tx power	0,1	W
antenna gain	50,1	dBi
EIRP	40,1	dBW
misc. losses	2,0	dB
free space loss	177,7	dB
satellite rx gain	1,2	dBi
rx noise temp.	400,0	K
sat. G/T	- 24,8	dB/K
sat. rcvr. level	- 138,4	dBW
uplink C/No	64,1	dBHz

Downlink

frequency	2 491,7	MHz
total HPA RF power output	50,0	W
output backoff	0,0	dB
total available power	50,0	W
no. of RF carriers in transponder	1,0	
power/channel	50,0	W
VOX factor	1,0	
effective power per channel	50,0	W
line loss	0,5	dB
sat. antenna gain	4,5	dBi
sat. EIRP/channel	21,0	dBW
free space loss	169,3	dB
misc. loss	2,0	dB
rx antenna gain	2,5	dBi
rx noise temperature	240,0	K
G/T	- 21,3	dB/K
receive level	- 147,8	dBW
downlink C/No	57,0	dBHz

Overall Link

interference degradation	0,5	dB
link C/No	55,7	dBHz
implementation loss	1,0	dB
link Eb/No	4,3	dB
required Eb/No	2,0	dB
BER	0,01	
link margin	2,3	dB

Table 3bis(b): Aries return link budget

FDMA Return Link (EOC)		
Elevation	10,0	deg.
Range	2 797,0	km
data rate	4,8	kbit/s
coding rate	3/4	
DSI factor	1,0	
transmission rate	6,4	kbit/s
Uplink		
frequency	1 618,0	MHz
mobile tx power	2,0	W
antenna gain	2,5	dBi
EIRP	5,5	dBW
misc. losses	2,0	dB
free space loss	165,6	dB
satellite rx gain	4,5	dBi
rx noise temp.	400,0	K
sat. G/T	- 21,5	dB/K
sat. rcvr. level	- 157,6	dBW
uplink C/No	45,0	dBHz
Downlink		
frequency	5 160,0	MHz
total HPA RF power output	5,0	W
output backoff	25,1	dB
total available power	0,027	W
no. of RF carriers in transponder	27,0	
power/channel	0,001	W
VOX factor	1,5	
effective power per channel	0,00085	W
line loss	0,5	dB
sat. antenna gain	1,2	dBi
sat. EIRP/channel	- 30,0	dBW
free space loss	175,6	dB
misc. loss	2,0	dB
rx antenna gain	48,7	dBi
rx noise temperature	120,0	K
G/T	27,9	dB/K
receive level	- 158,9	dBW
downlink C/No	48,9	dBHz
Overall Link		
interference degradation	1,0	dB
link C/No	42,5	dBHz
implementation loss	1,0	dB
link Eb/No	3,5	dB
required Eb/No	2,0	dB
BER	0,01	
link margin	1,5	dB

7.1.1.1.3.2 Functionality

Information not available.

7.1.1.1.3.3 Number and deployment

Information not available.

7.1.1.1.3.4 Geographical distribution

Information not available.

7.1.1.2 Network operation

7.1.1.2.1 Description

Information not available.

7.1.1.2.2 Call setup/routing/handover/cleardown algorithms

Information not available.

7.1.1.2.3 Inter-working

Information not available.

7.1.1.2.4 Air interface

The access scheme is TDM/CDMA (direct sequence spreading over 16 MHz, (3/4 rate FEC Viterbi soft decision decoding, K=7) in the forward direction and FDMA/SCPC QPSK (FEC as in the forward link) with 50 % filtering in the return direction. The terminal has memory stored codes to acquire a CDMA carrier at switch on.

The channel rate for 4,8 kbit/s vocoded voice is 6,4 kbit/s.

Further information on the air interface is not available.

7.1.1.2.5 Control and monitoring

Control of the space segment will be performed by a master TT&C station, and an operation control station. Further information on control and monitoring functions is not available.

7.1.1.2.6 Numbering and billing

Information not available.

7.1.1.3 Services specifications

7.1.1.3.1 Voice

Voice is vocoded at rate of 4,8 kbit/s. Further information on voice service is not available.

7.1.1.3.2 Additional services

Remote sensors data collection and forwarding. Further information on additional services is not available.

7.1.1.3.2.1 Data (real time/store and forward)

Data/facsimile transmission services will be provided in both directions as part of the same basic network architecture that provides telephony. Data collection, distribution and control services are provided on a polled basis using two way channels or on a random basis using packet messaging over a channel configured for signalling operations. The data rate is 2,4 kbit/s with a BER of 10^{-5}.

7.1.1.3.2.2 Positioning/position reporting

Aries provides both an RDSS and position reporting service either by Doppler ranging on the TDM channel or by including a Global Positioning System (GPS) or Local Radiodetermination Network (LORAN) circuit board in the user terminal or by other means currently being tested.. Further information, including RDSS accuracy is not available.

7.1.1.3.2.3 Other services

No other services are provided.

7.1.1.3.3 Quality and availability

Information not available.

7.1.1.4 FCC or other national filings

An FCC licence filing has been made, also an experimental FCC license has been obtained by Constellation Communications Inc.

7.1.1.5 ITU/IFRB filings

Information not available.

7.1.2 Diamond (British Aerospace Satellite Systems Ltd.)

7.1.2.1 Overall system description

Diamond is an S-PCN system utilising HEOs and is proposed by British Aerospace Satellite Systems Ltd. of the UK.

The proposals for Diamond are still relatively new and thus much remains undefined; the following description is, therefore, somewhat brief.

British Aerospace Satellite Systems Ltd. provided a written input to ETSI and answered further questions in writing.

7.1.2.1.1 Space segment

7.1.2.1.1.1 Frequency bands

The frequency bands required for the Diamond system are as follows:

Table 4: Diamond frequency bands

	Band
Service uplinks	L-Band
Service downlinks	L-Band
Feeder uplinks	Ku-Band
Feeder downlinks	Ku-Band
Intersatellite links	Optical, if needed

Thus, the bandwidth needs of the system are:

Table 5: Diamond bandwidth requirements

	Bandwidth requirement (MHz)
Service uplinks	25
Service downlinks	35
Feeder uplinks	200
Feeder downlinks	200
Intersatellite links	Not applicable

7.1.2.1.1.2 Frequency sharing

Frequency sharing is principally between the coverage regions and to some extent between beams within a coverage region.

Studies within British Aerospace demonstrate that the out of plane angular separation between Diamond and a system using the GSO is similar to the angular separations proposed for a 4 satellite MSS GSO network. It is therefore expected that Diamond will be able to co-ordinate/share L and Ku-band capacity with existing and planned GSO services.

7.1.2.1.1.3 Frequency re-use

Diamond re-uses frequencies between high gain spot beams and different coverage areas. A frequency re-use factor of between 3 and 4 is expected.

7.1.2.1.1.4 Coverage/spot beam configurations

Coverage is through clusters of spot beams in 3 separate regions covering North America, Northern Europe west of the Urals and CIS east of the Urals to Japan. Principle targets are north of 35°.

7.1.2.1.1.5 Orbits

Six satellites are used in a 48 hour repeat HEO to provide continuous coverage of 3 regions as described above.

Three close launches of satellite pairs provide for a full constellation or as an alternative there is an initial deployment of 3 satellites in a Molniya 8 hour orbit which are then boosted to a 48 hour orbit after a second deployment of 3 satellites.

An initial configuration of 3 satellites in an 8 hour HEO provide coverage of only one region.

The configuration of the constellation ensures that there is always at least one satellite visible to a user or a gateway at a minimum elevation angle for a usable service of approximately 55°.

7.1.2.1.1.6 Sample link budgets (forward and return direction)

See tables 6(a) and 6(b).

7.1.2.1.2 User segment

Information on the user segment is yet to be defined.

7.1.2.1.3 Gateways

Information on the gateways is yet to be defined.

7.1.2.2 Network operation

Information on network operation is yet to be defined.

7.1.2.3 Services specifications

7.1.2.3.1 Voice

Diamond will provide 10 000 voice circuits for the whole system. In the forward direction (fixed to mobile) these are carried in a COFDM matrix; in the return direction via FDMA.

7.1.2.3.2 Additional services

7.1.2.3.2.1 Data (real time/store and forward)

Diamond can provide real time user data services.

7.1.2.3.2.2 Positioning/position reporting

Diamond does not provide positioning/position reporting services.

Table 6(a): Diamond forward link budget

Uplink		
FES EIRP	51,4	dBW
Satellite G/T	- 4,2	dB/K
uplink C/No	65,9	dBHz
Downlink		
RF power/channel	- 6,7	dBW
satellite EIRP	23,6	dBW
MES G/T	- 14,0	dB/K
downlink C/No	44,3	dBHz
Downlink C/Io	56,1	dBHz
Downlink C/(No+Io)	44,0	dBHz
Total link		
Forward link C/(No+Io)	44,0	dBHz

Table 6(b): Diamond forward link budget

Uplink		
MES EIRP	10,0	dBW
Satellite G/T	3,9	dB/K
Uplink C/No	48,5	dBHz
Uplink C/Io	57,6	dBHz
Uplink C/(No+Io)	48,0	dBHz
Downlink		
RF power/channel	- 17,2	dBW
satellite EIRP	2,8	dBW
FES G/T	24,8	dB/K
Downlink C/No	48,1	dBHz
Downlink C/Io	50,7	dBHz
Downlink C/(No+Io)	46,2	dBHz
Total link		
Forward link C/(No+Io)	44,0	dBHz

7.1.2.3.2.3 Other services

The provision of road traffic information services is being studied under the DRIVE II initiative. This may provide services such as dynamic route guidance and automatic car park booking.

Diamond will also provide digital audio broadcast (DAB) services over its coverage areas. Up to 200 DAB channels will be available on the whole system using the EUREKA 147 COFDM scheme.

7.1.2.3.3 Quality and availability

Information on quality and availability is yet to be defined.

7.1.2.4 FCC or other national filings

A UK national filing is in preparation; other filings are yet to be defined.

7.1.2.5 ITU/IFRB filings

No ITU/IFRB filings have been made for Diamond.

7.1.3 Ellipso (Ellipsat Corporation)

7.1.3.1 Overall system description

The Ellipso system, proposed by Ellipsat Corporation is a satellite based network intended to extend and complement existing commercial terrestrial mobile communications services. It is conceived as a global system and provides voice, real-time and store and forward data, positioning and position reporting and paging services.

Ellipsat Corporation make an important note that information they have presented to ETSI is tentative and subject to change pending the outcome of the US "negotiated rulemaking" procedures, which relate particularly to spectrum allocation and sharing issues and possible standardisation.

Ellipsat Corporation provided a written input to ETSI and answered further questions in writing.

7.1.3.1.1 Space segment

7.1.3.1.1.1 Frequency bands

The frequency bands required for the Ellipso system are as follows:

Table 7: Ellipso frequency bands

	Band
Service uplinks	1 610 - 1 626,5 MHz
Service downlinks	2 483,5 - 2 500 MHz
Feeder uplinks	6 452 - 6 725 MHz
Feeder downlinks	5 150 - 5 216 MHz
Intersatellite links	none

Thus, the bandwidth needs of the system are:

Table 8: Ellipso bandwidth requirements

	Bandwidth requirement (MHz)
Service uplinks	16,5
Service downlinks	16,5
Feeder uplinks	273
Feeder downlinks	66
Intersatellite links	Not applicable

7.1.3.1.1.2 Frequency sharing

Ellipsat corporation state that no sharing is planned with terrestrial services and that there is no sharing with GSO based satellite services.

Sharing with NGSO based satellite services is subject to proposed sharing rules currently under negotiation before the US FCC. These proposed rules require:

- allocation to each sharing system within the band a maximum total allowable power flux density at any point within the sharing region from all visible satellites averaged over a small interval of time (seconds);
- allocation to each sharing system within the band a maximum total allowable EIRP spectral density per unit area of around 10 000 square km;
- co-ordination of polarisation;
- co-ordination of spreading codes;
- co-ordination of other possible factors (under review); and,
- the possible allocation of a separate portion of the service spectrum for the use of non-CDMA based systems.

7.1.3.1.1.3 Frequency re-use

All frequencies are re-used in every service beam of every satellite.

7.1.3.1.1.4 Coverage/spot beam configurations

Ellipso provides service coverage through an eight beam circular array with one beam in the centre and seven beams around the outside edge. The beams are weighted to provide a constant power flux spectral density on the Earth's surface regardless of slant range.

The feeder link beams are Earth coverage global beams.

7.1.3.1.1.5 Orbits

The Ellipso system uses two classes of orbits: inclined elliptical sun-synchronous orbits and equatorial circular orbits. The constellation is as follows:

Table 9: Ellipso constellation

Orbit	Apogee (km)	Perigee (km)	Period (hours)	Inclination	Ascending Node	Argument of Perigee	Number of Planes	Satellites per Plane
Inclined Elliptical	7 800	520	3	116,5°	under review	~270°	3	5
Equatorial Circular	8 068	8 068	4,8	0°	not applicable	not applicable	1	9

The constellation is designed to cover latitudes of the Earth in proportion to population by latitude. An additional feature is the adjustment of the inclined elliptical orbits arguments of perigee and right ascensions of the ascending nodes to favour a daytime service.

The Ellipso constellations are designed to offer flexibility in deployment. Marketable services will be introduced in phases, corresponding to deployment level; deployment will begin in 1995. Ellipso satellites will be launched up to five at a time to build the constellation. Replenishment will use smaller boosters to launch satellites one or two at a time.

As a baseline, launch of the first eight satellites will initiate a full northern hemisphere service north of the Tropic of Cancer, using inclined elliptical orbits. A further six satellites in the complementary equatorial orbit will enhance this to complete and continuous northern hemisphere coverage and will initiate coverage of the tropical and southern latitudes. Further satellites will be added, up to the number shown in table 9, to complete the full constellation.

Additional satellites will add capacity to additional regions with additional demand and will be deployed in appropriate combinations of inclined elliptical and equatorial circular orbits. In fact the baseline described may be adjusted to balance northern and southern hemisphere coverage to the distribution of actual demand with the minimum number of satellites needed.

7.1.3.1.1.6 Sample link budgets (forward and return direction)

See tables 10(a) and 10(b).

7.1.3.1.2 User segment

7.1.3.1.2.1 Terminal characteristics

The Ellipso user terminals are comparable to those used for terrestrial cellular telephony. Ellipso is designed to facilitate seamless switchovers from terrestrial cellular to Ellipso communications when cellular becomes unavailable to the user.

Ellipso supports two types of user terminals:

- mobile terminals are designed for vehicular use and are capable of 5 W or more of RF power;

- hand-held terminals are limited to a maximum of 1W.

In both cases, Ellipso terminal antennas provide hemispheric coverage.

7.1.3.1.2.2 Unwanted emissions

Unwanted emission limits are under review by the FCC. For Ellipso they are in accordance with applicable existing regulations and any standards adopted for MSS sharing.

7.1.3.1.2.3 Physical considerations

Detailed specifications for Ellipso are as yet unpublished; however, Ellipsat indicated that the terminals conform to the evolving equipment safety standards. Handsets use an antenna design and configuration that minimises head and body exposure to radiation. Both the standards and the terminal design are under review.

7.1.3.1.3 Gateways

Each market served by Ellipso has its own Ground Control Stations (GCS) and Network Control Centres (NCC) for interconnecting satellite links to terrestrial networks and for managing resources and customer records for the regional Ellipso operating entity.

Each country or group of co-operating countries served by Ellipso has one or more GCS and a Regional Network Control Centre (RNCC) for providing service through the satellite to its subscribers.

Detailed information on gateway traffic/network co-ordination, functionality, number, deployment and geographical distribution was not provided.

7.1.3.2 Network operation

The Ellipso GCS handles the connections to the satellite including the functions of satellite acquisition, tracking, handover, signal modulation and multiplexing. The GCS is essentially a ground entry point for the system and typically tracks and uses two satellites while acquiring a third.

The CGS in turn connects to the RNCC which handles call processing, satellite and call resource management for its market, satellite tracking and handover calculations, time management, connection to and co-ordination with the market's PSTN, market service monitoring and troubleshooting, GCS management and market transaction accounting.

Table 10(a): Ellipso forward link budget

FORWARD PATH

	factor	dB	
Eb/(No+ Io) and margins	3,548	5,5	
TWs	267	24,3	
A	1,17		
b/B	0,125		
a	0,4		
Afb	3,4		
P(t,GCS)	200		
G(GCS), dBi		43,0	
EIRP(GCS/user)		39,0	
G(sat fwd rcv nadir)		9,2	
L(path, C, nadir)		186,6	
L(polarization)		1,0	
L(GCS, pointing)		1,0	
L(atmospheric)		0,3	
L(ant pattern inaccuracies)		2,0	
T(satellite reciever)		26,0	
Wn, MHz	1	60,0	
C/N(per user, up)	0,983	-0,1	
P(S band, sat)	20	13,0	
G(S band, sat)		18,2	
L(Path @ nadir)		178,2	
L(polarisation)		1,0	
L(atmospheric)		0,1	
L(modem)		1,0	
L(sat ant patt inaccuracies)		0,5	
G/T(mobile)		-23,9	
T(mobile), Kelvin	350	25,4	
C/N(per beam down)	0,321	-4,9	
Capacity			
M(fwd)=	439		Using independent codes
	483		Using orthogonal codes

Altitude, km	7 823
Frequencies, MHz	
C up	9 999
S down	2 491
C down	5 200
L up	1 618
c, m/s	299 792 500
bit rate	4 800
chip rate	1 280 000
# channels	13
Error correction:	
Convolutional	
R-1/3	
K = 9	
Soft decision	
Range compensated antenna patterns	

Ellipso uses orthogonal codes on the forward path

Table 10(b): Ellipso return link budget

RETURN PATH

	factor	dB
TWs	267	24,3
Eb/(No+ Io) and margins	5,01	7,0
A	1,2	0,8
p	0,4	
a	0,4	
EIRP/user		4,0
G(satellite return rcv)		18,2
L(uplink path, nadir)		174,5
L(polarization)		1,0
L(atmospheric)		0,1
L(sat pattern inaccuracies)		1,0
T(satellite reciever)	400	26,0
Wn	1	60,0
C/N(per user, up)	0,07	-11,8
P(satellite feeder link)	2	3,0
G(satellite feeder link)		9,2
EIRP(sat feeder link)		12,2
G(GCS, rcv)		41,1
L(Path @ nadir)		184,6
L(polarisation)		1,0
L(atmospheric)		0,3
L(modem)		1,0
L(sat beam inaccuracies)		2,0
L(GCS pointing)		1
T(GCS), Kelvin	350	25,4
Wn, MHz	1	60
C/N(per chan group, down)	10,51	10,2
Capacity		
M(return)=	1 204	

Altitude, km	7 823
Frequencies, MHz	
C up	6 500
S down	2 491
C down	5 200
L up	1 618
c, m/s	299 792 500
bit rate	4 800
chip rate	1 280 000
# channels	13
Error correction:	
Convolutional	
R-1/3	
K = 9	
Soft decision	
Range compensated antenna patterns	

At least two constellation management centres manage the inclined elliptical orbit system and two the equatorial circular system. It is likely that these centres are be co-located with RNCCs.

Satellite control centres for managing the inclined elliptical and equatorial circular orbiting spacecraft will be located in the USA and in other served markets. These centres participate in satellite launch activities and manage their constellations of satellites (including system planning, resource allocation amongst markets and RNCCs, satellite and system health monitoring, orbit maintenance, and traditional TTC&M).

Detailed information on general network operation, call setup/routing/handover/cleardown algorithms, inter-working, air interface, numbering and billing was not provided.

7.1.3.3 Services specifications

7.1.3.3.1 Voice

Ellipso provides a voice service using an advanced coded voice technique, using, for example, the CELP algorithm operating at 4,8 kbit/s. Higher quality voice is available at extra cost. Voice quality compares favourably with digital cellular voice quality.

7.1.3.3.2 Additional services

7.1.3.3.2.1 Data (real time/store and forward)

Ellipso data services are both real time and store and forward. The real time service supports data rates from 300 to 9 600 bit/s for data and facsimile services at error rates of 10^{-5} or better. Ellipso supports data messaging on a store and forward basis through the Network Control Centre.

7.1.3.3.2.2 Positioning/position reporting

The position of each user is determined by the Ellipso system on call placement. Upon request the position is furnished to the user. Positioning is accurate to within 100 m with two satellites in view and somewhat less with only one satellite in view.

7.1.3.3.2.3 Other services

A paging service is available; terminals are available to provide only paging and positioning.

7.1.3.3.3 Quality and availability

Information on quality and availability was not provided.

7.1.3.4 FCC or other national filings

FCC filings were submitted in November 1990 and June 1991. Currently these are entered into the "negotiated rulemaking" process of the FCC.

7.1.3.5 ITU/IFRB filings

IFRB filings have been submitted.

7.1.4 Globalstar (Loral/Qualcomm)

7.1.4.1 Overall system description

The Globalstar system, proposed by Loral Qualcomm is a CDMA based transparent satellite network designed to integrate deeply into the PLMN to provide voice, data and positioning services.

Globalstar made a presentation, provided a written input to ETSI and answered further questions in writing.

7.1.4.1.1 Space segment

7.1.4.1.1.1 Frequency bands

The frequency bands required for the Globalstar system are as follows:

Table 11: Globalstar frequency bands

	Band
Service uplinks	1 610,0 - 1 626,5 MHz
Service downlinks	2 483,5 - 2 500 MHz
Feeder uplinks	6 484,0 - 6 541,5 MHz
Feeder downlinks	5 158,5 - 5 216,0 MHz
Intersatellite links	none

Thus, the bandwidth needs of the system are:

Table 12: Globalstar bandwidth requirements

	Bandwidth requirement (MHz)
Service uplinks	16,5
Service downlinks	16,5
Feeder uplinks	57,5
Feeder downlinks	57,5
Intersatellite links	Not applicable

7.1.4.1.1.2 Frequency sharing

In the uplink service band sharing is required with the Radio Astronomy Service (RAS), the fixed service, GLONASS-M and radar; in the downlink service band sharing is required with the fixed service and Industrial Scientific and Medical (ISM) services.

To protect the RAS, CCIR protection ratios are considered and a number of techniques are used to provide the necessary protection;

- frequency planning is required (e.g. to avoid the hydroxyl radical near 1,6 GHz);
- the transmitted spectrum from the user terminal is filtered implying linear amplification and 65 to 80 dB attenuation in the secondary lobes; and,
- second harmonics are filtered to avoid specific spectral lines.

To protect the fixed service, the user terminals satisfy the new sharing criteria (4s interference per day) and Globalstar estimates that with 2500 circuits per satellite they better this criteria by a factor of 10. PFD limitations at low and high elevation angles protect the fixed service from Globalstar satellite transmissions. In the reverse direction, Globalstar acknowledge that fixed service transmissions into user terminals effectively limits their service provision in certain areas but note that fixed service interference into Globalstar satellites is marginal, mainly because of the limited periods when the Globalstar satellites pass through the FS beams.

Sharing with GLONASS/GPS is not a problem even if within close proximity of an airport during a non-precision landing.

A potential for serious interference into the Globalstar satellites due to co-frequency radar in Sweden exists. To protect the satellites it may be necessary to use clipping receivers to gate out the radar interference, resulting in the loss of a few bits very second. Globalstar expect that this will have minimum impact on voice quality but have still to investigate the effects on data integrity. The impact of interference from Globalstar user terminals into the radar receivers has yet to be analysed.

Current CCIR models show that ISM services (domestic microwave ovens) may cause unacceptable interference if operated within approximately 100 m of a receiving user terminal. This is only expected to be a problem in densely populated areas near to meal times; experimental measurements are planned to quantify the constraints to Globalstar operation.

Sharing with GSO based satellite services other than those providing a similar mobile service is not expected to be a problem. The feeder link bands selected by Globalstar are currently very lightly used and sharing with GSO services is not expected to be a problem.

For NGSO based satellite systems sharing is more difficult and is likely to result in a 20 % loss of capacity for two systems sharing. Globalstar indicated that they expected a serious sharing problem with one other proposed S-PCN system.

7.1.4.1.1.3 Frequency re-use

Two frequency re-use options are currently under review, either full frequency re-use in each spot beam or a frequency planning regime. A world-wide frequency re-use factor of 220 is obtained in the full frequency re-use case as a result of a frequency re-use factor of 4,4 for each satellite.

7.1.4.1.1.4 Coverage/spot beam configurations

Globalstar provides its nominal coverage between ± 70° latitude; each satellite utilises a fixed beam pattern to ensure that PFD is reduced at low elevation angles to facilitate sharing with fixed services. The beam pattern is still under consideration, but it is expected to be similar to the one shown in figure 6. Globalstar anticipate that 90 % of traffic will be carried in the inner beams and 10 % in the outer ring.

7.1.4.1.1.5 Orbits

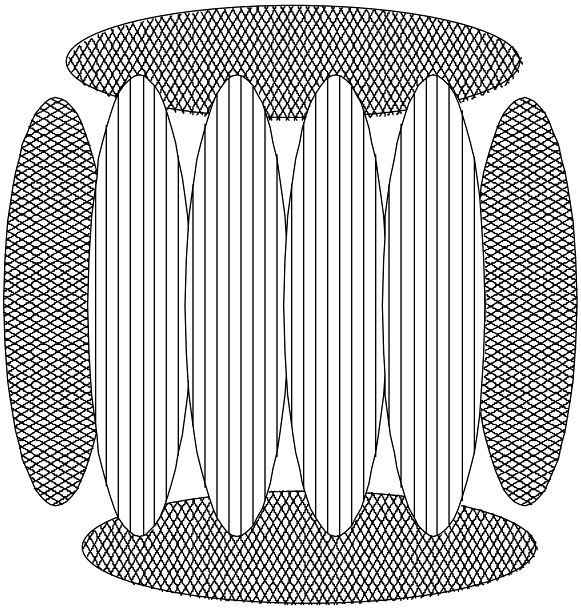
The Globalstar system uses a (48,8,1) "Walker" constellation as follows:

Table 13: Globalstar constellation

Orbit	Altitude (km)	Period (hours)	Inclination	Number of Planes	Satellites per Plane
Inclined Circular	~ 1 400	~ 2	52°	8	6

Under current plans, Globalstar will launch their first satellite around 1997 with the full constellation in place by around 1998. Plans for a progressive setup of the constellation are under consideration. A pre-operational launch (~8 satellites) is planned prior to full constellation setup.

The final constellation is still under review.



External ring provides reduced PFD at low elevation angles

Figure 6: Example Globalstar coverage

7.1.4.1.1.6 Sample link budgets (forward and return direction)

See tables 14(a) and 14(b).

7.1.4.1.2 User segment

7.1.4.1.2.1 Terminal characteristics

Three categories of user terminal are supported by the Globalstar system:

- hand-held;
- fixed;
- installed (i.e. vehicle mounted).

The terminals have an antenna gain of 2,5 dB; the peak power input to the antenna is 1 W for the hand-held and fixed terminals and 15 W for the installed terminals. The noise factor is 1,5 dB.

Various processing capabilities are provided including interleaving, open & closed loop power control, path diversity and soft hand-off. Open loop power control deals with short term fading and closed loop power control deals with long term fading.

Table 14(a): Globalstar forward (mobile downlink) link budget

Frequency	2,5	GHz
Eb/No	3,5	dB
R useful	4 800,0	bit/s
coding rate	2,0	
W	1,25	MHz
processing gain	260,4	
power control accuracy	1,5	dB
circuits	80,0	
activity	0,38	
self-interference	30,0	dB (C/IoR)
adjacent spots interference	7,9	dB (C/IoR)
intersystem interference	25,0	dB (C/IoR)
uplink contribution and intermod.	22,0	dB (C/IoR)
Thermal Noise	5,6	dB (C/IoR)
C/T	- 186,2	dBW/K
mobile G/T	- 22,5	dB/K
spreading losses	- 134,0	dB/m²
isotropic area	- 29,4	dB/m²
average margin	- 3,0	dB
satellite EIRP	2,7	dBW
activity	- 4,3	dB
average satellite gain	10,5	dB (ref isoflux)
Average RF power/circuit	- 12,0	dBW
number of channels	2 500,0	
signalling equiv. overhead	14,0	%
diversity	25,5	%
total RF power	223,7	W
Equivalent satellite power	1 230,0	W dc

7.1.4.1.2.2 Unwanted emissions

Unwanted emissions are controlled in order to facilitate sharing with RAS and fixed services (see subclause 7.1.4.1.1.2).

7.1.4.1.2.3 Physical considerations

Power control in the terminal always reduces the radiated power to the lowest level needed to maintain a successful link and this helps protect users from unacceptable RF emissions. For service links above 40° elevation the power reduction is such that RF protection is not a problem. Below this elevation the RF exposure depends on the available margin but in any case a "flux evaluation" process is implemented in the hand-held terminal to encourage the co-operative user to move to a better position or orientation in the event of a low margin link, thus allowing a reduction in the emissions. If necessary the terminal shuts down transmissions to ensure that RF protection levels are not exceeded.

The maximum power flux exposure to a user is limited to 8 W/m² averaged over a 6 minute period, in accordance with present IEEE/ANSI regulations.

Other general safety aspects are according to the appropriate regulations and standards.

Table 14(b): Globalstar worst case return (mobile uplink) link budget

Frequency	1,6	GHz
Eb/No	3,5	dB
R useful	4 800,0	bit/s
coding rate	3,0	
W	1,25	MHz
processing gain	260,4	
power control accuracy	1,5	dB
circuits	64,0	
activity	0,38	
self-interference	0,89	dB (C/IoR)
adjacent spots interference	0,89	dB (C/IoR)
intersystem interference	12,0	dB (C/IoR)
uplink contribution	25,0	dB (C/IoR)
Thermal Noise	9,1	dB (C/IoR)
C/T	- 182,7	dBW/K
terminal max. EIRP	0,0	dBW
spreading losses	- 134,0	dB/m²
isotropic area	- 25,6	dB/m²
Tsat	- 26,3	dBK
Gsat (ref isoflux)	8,5	dBi
path combination improvement	2,0	dB
margin	- 3,0	dB
Spot beam max. capacity	832,0	
Satellite max. capacity	5 491,0	

7.1.4.1.3 Gateways

7.1.4.1.3.1 Traffic/network co-ordination

Several architectures are under analysis. The target design for Globalstar is:

- best use of the system transparency;
- de-localised system management with space segment conservative measures; and
- the use of a network co-ordination centre to allocate long-term capacity resources to the gateways.

7.1.4.1.3.2 Functionality

The Globalstar system is designed to integrate closely with national PLMN networks. In the GSM environment the gateways provide GSM standard A interfaces to the MSC between the PLMN and the satellite system. The functionality of a Globalstar gateway is similar to a GSM BSC + BT bloc but with some specific aspects due to the LEO nature of the space segment. Thus, the typical gateway configuration inside the GSM network is as shown in figure 7.

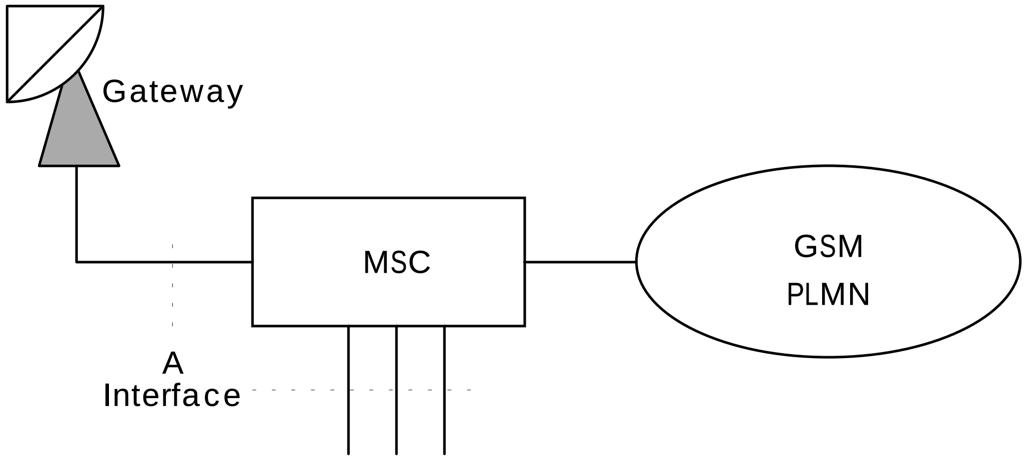


Figure 7: Globalstar Gateway interfacing

7.1.4.1.3.3 Number, deployment and geographical distribution

The coverage radius of a Globalstar gateway varies with latitude from around 2 000 km (at 15° latitude) to around 5 000 km. Gateways will be deployed more densely near to the equator and in areas of high traffic density.

To provide world-wide coverage ~ 50 gateways are required; the minimum number required for Europe is one, the expected number is one per country.

7.1.4.2 Network operation

7.1.4.2.1 Description

Globalstar is conceived as a set of regional mobile segments supported by a transparent satellite network. The present interworking design is based around D-AMPS in the Americas and GSM in Europe and the rest of the World.

Globalstar integrates deeply into the national or regional PLMN networks; the Globalstar gateways are associated with Globalstar MSCs which are almost identical to, and integrated with the existing PLMN MSCs. Globalstar will share HLR/VLR databases, numbering, etc. with the national or regional PLMN and as such it could be, in principle, completely transparent to the user whether service is provided by Globalstar or through the PLMN.

The high integration level of Globalstar with the PLMN has an implication for global roaming, which is only supported in the same manner as, for example, GSM roaming; i.e. the Globalstar system cannot be considered as a single separate PLMN but is composed of segments integrated into different national PLMNs; roaming between these national PLMNs is permitted only as much as it is permitted within the same terrestrial system.

Globalstar do not see a problem in the more complex accessibility to global roaming since they anticipate that 90 % of their traffic will be local (i.e. within the coverage of one gateway).

7.1.4.2.2 Call setup/routing/handover/cleardown algorithms

Network registration of a mobile terminal is essentially as in GSM with the addition of the need for the user to acquire and synchronise to a satellite. The process is as follows:

1) the position of the mobile is determined at switch on (through RDSS co-operation with any gateway in the satellite coverage) to establish the gateway through which the possible call should be routed;

2) the mobile then attaches to the gateway and is registered by the network (including the updating of HLR/VLR databases as necessary);

3) the mobile is then processed by the network as a standard PLMN user.

Call set-up is again similar to GSM; for mobile originated calls the steps are:

1) radio resource request (MS);
2) mobile authentication (register/MSC);
3) transmission of the dialled number (MS);
4) routing and setup on the called party side;
5) ringing the called subscriber;
6) reservation of radio resources and terrestrial circuits;
7) called subscriber answering; finally,
8) communications are established.

For a mobile terminated call the steps are:

1) paging from the network;
2) radio resources request from the mobile;
3) mobile authentication;
4) reservation of radio resources and terrestrial circuits;
5) ringing and acknowledgement; finally,
6) communications are established.

Traffic handover is a procedure controlled entirely by the gateway; communications are established on the new satellite (with or without the provision of new resources) and there is a progressive handover of each traffic carrier (CDMA "soft" handover). The GSM signalling structure is powerful enough to handle the change-over without modifications.

First/second choice routing may be implemented in a dual mode terminal, as requested by national Administrations, for example all calls may first be offered to the terrestrial cellular network (if it is available and there is a channel) with Globalstar as a second choice.

7.1.4.2.3 Interworking

Because of the deep integration between Globalstar and the PLMN, interworking is a fundamental part of the Globalstar network operation. A Globalstar gateway presents a standard GSM A interface to the MSC.

Signalling exchanges between each entity of the ground segment (e.g. link establishment between the gateway and the terrestrial subscriber) are provided using CCITT SS7. Figure 8 shows the protocol stack for interworking. A specific protocol (MAP or a derivative of it) are used on SS7 for mobility (HLR/VLR information) and roaming (location of mobile before paging) purposes.

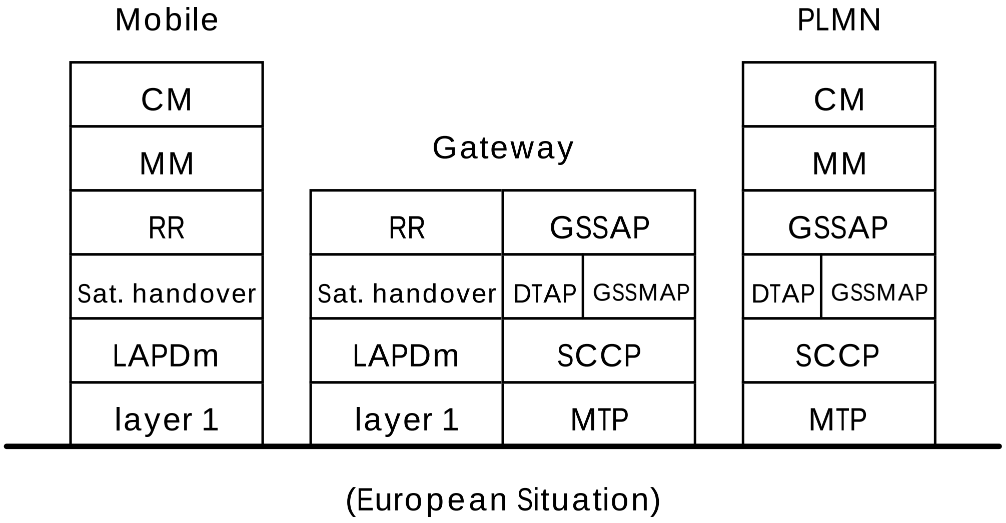


Figure 8: Globalstar Gateway/PLMN connection signalling

7.1.4.2.4 Air interface

The Globalstar air interface defines the exchange between a mobile station and a gateway. It supports a number of logical channels, both traffic and control, which respectively carry encoded voice and user data or signalling and synchronisation data.

7.1.4.2.5 Control and monitoring

Network control and monitoring is provided through the AOM centre. Facilities provided include:

- security management;
- operation performance and management;
- supervisory actions related to resources management; and,
- automatic restoration.

7.1.4.2.6 Numbering and billing

Numbering and billing on the Globalstar system is essentially defined by the integration of Globalstar in the PLMN. Each mobile subscriber is assigned a unique International Mobile Subscriber Identity (IMSI) and within each national PLMN telephone, ISDN and roaming numbers are assigned to stations as part of the national PLMN numbering scheme.

Call durations are determined after the call is released to permit billing of the mobile user in the PLMN of station registration. Generally, call duration billing is similar to GSM.

7.1.4.3 Services specifications

7.1.4.3.1 Voice

The Globalstar voice service is provided through an adaptive 1,2 to 4,8 kbit/s voice codec using the Qualcomm Q-CELP algorithm.

7.1.4.3.2 Additional services

7.1.4.3.2.1 Data (real time/store and forward)

Real time data transmission is provided in a voice channel at a basic speed of 2,4 kbit/s. Fixed stations may support higher rate user channels of up to 18 kbit/s.

Store and forward data services are not explicitly provided although these could be implemented through the gateway.

7.1.4.3.2.2 Positioning/position reporting

A positioning service is available as part of the user localisation process in call setup. Position reporting can be provided in a data channel. Positioning accuracy is in the km range.

7.1.4.3.2.3 Other services

No other services are provided by Globalstar.

7.1.4.3.3 Quality and availability

Voice quality is comparable to terrestrial cellular services and will permit recognition of the speaker as well as of the message. Acceptable voice quality will be achieved at a BER of 10^{-2} or better. Data quality will be with a BER of 10^{-5} or better for standard and higher rate user channels.

Availability is 99 % of time and places for co-operative and fixed users and 90 % of time and places for un-co-operative and mobile users.

The design criteria are taken for worst case links which provide a margin of 2,5 dB for a hand-held and 10 dB for a mobile terminal, both for a 20° elevation service path. On average margins will be better than 15 dB for a hand-held and better than 20 dB for a mobile terminal.

7.1.4.4 FCC or other national filings

An FCC filing for Globalstar was submitted on 3 June 1991.

7.1.4.5 ITU/IFRB filings

No IFRB filing has yet been made for Globalstar.

7.1.5 Inmarsat-P (International Maritime Satellite Organisation)

7.1.5.1 Overall system description

Inmarsat-P is a proposed hand-held global satellite phone service, currently under development by the International Maritime Satellite Organisation (Inmarsat).

Inmarsat-P is still in the midst of a very detailed final phase of studies relating to system and market issues, and various concepts and configurations are being analysed prior to the completion of the service and network definition, leading to Inmarsat-P implementation. Because of this, it is difficult to produce a description of Inmarsat-P in a format entirely analogous to that used to describe the other system proposals. The approach adopted, therefore, is to follow as closely as possible the outline structure used to describe other systems, but to adapt this where necessary to encompass descriptions of the broad ranges of options currently being studied by Inmarsat.

Inmarsat provided a written input to ETSI and also answered further questions in writing.

7.1.5.1.1 Space segment

Inmarsat are currently studying 3 orbital configuration options (see subclause 7.1.8.1.1.5) for the implementation of Inmarsat-P; these are geostationary, intermediate circular and low earth orbit configurations. A number of the space segment elements are dependant on the orbital configuration.

7.1.5.1.1.1 Frequency bands

The baseline frequency bands being considered for the Inmarsat-P system are as follows:

Table 15: Inmarsat-P baseline frequency bands

	GSO	ICO	LEO
Service uplinks	1 616,5 - 1 626,5 MHz possibly down to 1 610,0 MHz alternatively 1 980,0 - 2 010,0 MHz [4]		
Service downlinks	2 483,5 - 2 500,0 MHz alternatively 2 170,0 - 2 200,0 MHz [5]		
Feeder uplinks	6 425,0 - 6 575,0 MHz	14,0 - 14,5 GHz alternatively options at C, Ku and Ka-band	
Feeder downlinks	3 600,0 - 3 650,0 MHz	10,95 - 11,2/11,45 - 11,7 GHz alternatively options at C, Ku and Ka-band	
Intersatellite links	If ISLs are required they will be in the Ka-band ISL allocations		

System bandwidth requirements are estimated as follows:

Table 16: Inmarsat-P bandwidth requirements

	GSO	ICO	LEO
Service uplinks	5 MHz but up to 10 MHz in peak traffic areas		
Service downlinks	5 MHz but up to 10 MHz in peak traffic areas		
Feeder uplinks	information not provided	200 MHz for CDMA 50 MHz for TDMA	
Feeder downlinks	information not provided	200 MHz for CDMA 50 MHz for TDMA	
Intersatellite links	not yet determined		

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[4] The use of the band 1 980,0 - 2 010,0 MHz may be contingent upon the nature of decisions made at WRC-93.

[5] The use of the band 2 170,0 - 2 200,0 MHz may be contingent upon the nature of decisions made at WRC-93.

7.1.5.1.1.2 Frequency sharing

Inmarsat state that the issues involved in sharing GSO and non-GSO Inmarsat-P MSS networks in both service and feeder-links with systems of both terrestrial and space services are under careful analysis. To a significant extent the spectrum selection for Inmarsat-P will be driven by the non-MSS usage patterns in the candidate frequency bands as well as the feasibility of technical sharing with such non-MSS services and other MSS systems. Inmarsat is also therefore actively following CCIR and related activities with respect to frequency sharing studies as well as engaging in dialogues with Administrations to assess the compatibility issues. It is however clear that the use of any of the candidate service-link and feeder-link frequency bands would appear to pose potentially serious constraints on MSS operation.

Inmarsat has been actively seeking support for the following:

- an early decision to advance the 2005 date of access to the 2 GHz MSS bands in order to facilitate MSS/FPLMTS use; and

- an early consideration of frequency allocation and regulatory co-ordination aspects of non-GSO MSS feeder links, given that the current interference avoidance regime 6) could place too onerous a co-ordination burden on such systems.

7.1.5.1.1.3 Frequency re-use

No information on frequency re-use was provided.

7.1.5.1.1.4 Coverage/spot beam configurations

For the GSO option, coverage will, at a minimum, be provided over land masses and adjacent coastal waters between latitudes of approximately ± 70°. The baseline design provides for coverage of land masses only through a limited coverage per satellite; service link beam sizes would vary and feeder links would be provided through a global beam.

For the ICO constellation option, coverage will, at a minimum, be provided over land masses and adjacent coastal waters globally. The baseline design provides for each satellite to cover the whole field of view down to 20° elevation for service links through 1 or 2 phased array antennas per spacecraft using an isoflux design. Feeder links would be supported through spot beams or through a global coverage beam with a nulling band to avoid GSO interference.

For the LEO constellation option, coverage will, at a minimum, be provided over land masses and adjacent coastal waters globally. The baseline design provides for each satellite to cover the whole field of view down to 10° elevation for service links through 19 separate Tx/Rx phased array antennas per spacecraft using the isoflux concept between beams for 19 beams. Feeder links would be supported through a global coverage beam.

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6) Under Radio Regulation No. 2613.

7.1.5.1.1.5 Orbits

Inmarsat is investigating a number of different orbital configuration options, as shown in the following table.

Table 17: Inmarsat-P orbital configuration options

Orbit Option	Altitude (km)	Period (hours)	Inclination	Number of Satellites
GSO-P Circular	~ 35 786	~ 24	0°	4
GSO-C Circular	~ 35 786	~ 24	0°	4
ICO Circular	~ 10 355 or ~ 13 892	~ 6 or ~ 8	50,7°	15 or 12
LEO Circular	~ 1 800	~ 2	55°	54
LEO-ISL Circular	~ 1 800	~ 2	90°	54

For the ICO constellation option, 2 or more satellites will always be visible to a user within the service area at an elevation angle of ~ 20° or greater. The ICO constellation parameters indicated above would provide minimum acceptable satellite visibility, but other constellations providing similar or better visibility, with heights in this range, may be considered.

For the LEO constellation option, 2 or more satellites will always be visible to a user within the service area at an elevation angle of ~ 10° or greater and 1 or more at an elevation angle of ~ 20° or greater. The LEO constellation parameters indicated above would provide minimum acceptable satellite visibility, but other constellations providing similar or better visibility may be considered.

Details of possible phases of system deployment are not yet defined.

7.1.5.1.1.6 Sample link budgets (forward and return direction)

Sample link budgets were not provided.

7.1.5.1.2 User segment

Inmarsat expect that Inmarsat-P terminals will be available in both satellite only and dual mode (satellite plus terrestrial) versions.

Modulation and access schemes in forward and reverse directions will depend on the orbital configuration adopted.

7.1.5.1.2.1 Terminal characteristics

The hand-held Inmarsat-P terminal supports a range of personal communications services and offers the user a number of features such as integrated digital cellular communications, medium penetration call announcement (i.e. this is intended to mean that a call alert would be received within a building, close to a window when the antenna is not deployed), and internal buffer for data, paging and fax, smartcard control, a digital port for connection to PC and printer and an expansion port for peripheral devices and car cradle. Key terminal parameters are as follows:

Size:	< 300 cm³ (both satcom only and dual mode versions)
Weight:	< 300 g (both satcom only and dual mode versions)
Battery life:	Idle mode, 24 hours between charges Talk mode, 1 hour minimum
Max. Average EIRP:	- 1 dBW (talking) - 5 dBW (voice activation)
Max. Average Power:	0,5 W (talking) 0,2 W (voice activated)
G/T:	- 22,8 dB/K (TDMA options, switch loss 1,5 dB) - 24,2 dB/K (CDMA) options, diplexer loss 2,5 dB)
C/No:	39 dBHz

7.1.5.1.2.2 Unwanted emissions

Information on unwanted emissions was not provided.

7.1.5.1.2.3 Physical considerations

Inmarsat are undertaking detailed work, and have commissioned a number of external studies, to investigate the radiation hazard problems posed by the use of hand-held transmitters by the general public.

The baseline design for the Inmarsat-P hand-held terminal takes into account this work and the Inmarsat-P power levels will meet the International Non-Ionising Radiation Committee INIRIC RF protection standard (250 mW average power providing the antenna is 3 cm away) assuming a conservative voice activation factor.

7.1.5.1.3 Gateways

For the GSO option, standard Inmarsat Coast Earth Station (CES) antennas will be used. These antennas have diameters of 10 to 11 m but the system design should allow lower cost antennas, down to around 7 m diameter to be employed.

For the ICO option, 4 antennas will be needed per site for path diversity and to provide a good hub station range. The system design should allow antennas of around 5 to 7 m diameter or less to be employed.

For the LEO option, 4 antennas will also be needed per site for the same reasons as for ICO. The system design should allow antennas of around 3 to 5 m diameter to be employed.

Detailed information on gateway traffic/network co-ordination, functionality, number, deployment and geographical distribution was not provided.

7.1.5.2 Network operation

7.1.5.2.1 Description

The Inmarsat-P network architecture is proposed to be based on Common Channel Signalling System No. 7 (SS7). Inmarsat believe that this offers the maximum network flexibility and optimum performance.

Figure 9 illustrates the outline network architecture proposed for Inmarsat-P. SS7 is used to interconnect the gateway sites with service control points (SCPs) which provide the required routing information and may also provide advanced network functions such as billing. The Inmarsat-P baseline network design assumes that the SCP will provide the HLR functionality and also include VLR functions.

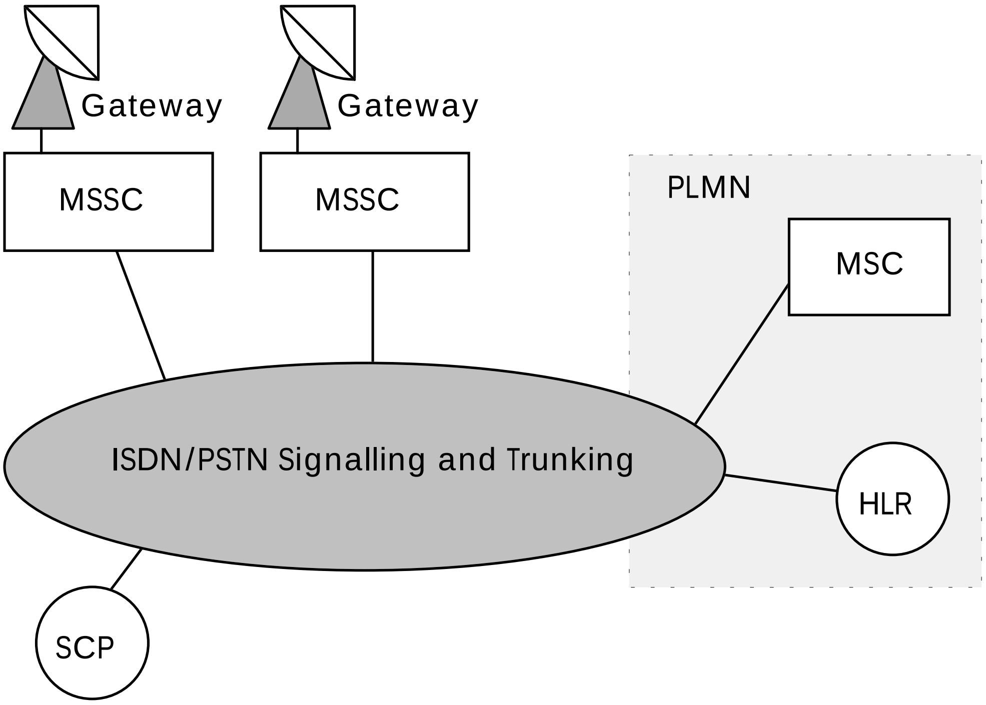

Figure 9: Inmarsat-P outline architecture

7.1.5.2.2 Call setup/routing/handover/cleardown algorithms

Information on call setup, routing, handover and cleardown algorithms was not provided.

7.1.5.2.3 Interworking

The degree to which cellular/satellite interworking may be implemented is dependant on the market requirements. It may vary from a simple call diversion function to the full integration of Inmarsat-P mobility management functions with the various terrestrial cellular networks, such that the service and feature profiles are identical for the two services.

The intention for the cellular extension network is to provide, if required, a seamless integration with the terrestrial cellular network with sole service provision for the cellular and the satellite services. The use of a "smartcard" is seen as one mechanism for defining common service profiles whilst still allowing flexibility in the service features between different users and service providers.

The terrestrial network will support the mobility management features which enables global automatic roaming coupled with a single number access.

Inmarsat is aiming in general to be a service provider for the satellite component of FPLMTS/UMTS. The ground segment/space segment implications of FPLMTS/UMTS compatibility are currently being evaluated. In particular the potential of the FPLMTS/UMTS is currently being considered.

7.1.5.2.4 Air interface

For the GSO option, an FDM/TDMA scheme is used in both the service up and downlinks providing eight 4 kbit/s information rate voice slots (each of 2,4 kbit/s coding rate) per 32 kbit/s channel. Modulation is filtered QPSK in a signal bandwidth of 30 kHz at a minimum C/No of 48 dBHz.

For the ICO and LEO options both FDM/TDMA and CDMA schemes are under consideration. The FDM/TDMA scheme is the same as described for the GSO option; information on the CDMA scheme was not provided.

7.1.5.2.5 Control and monitoring

Information on control and monitoring was not provided.

7.1.5.2.6 Numbering and billing

Inmarsat envisage a flexible network supported by a numbering plan that will support an international mobile satellite service, a national mobile satellite service and a separate terrestrial cellular number. Although the user may be given only one number, the Inmarsat-P network will support each of these different numbers.

The numbering plan suggested for the Inmarsat-P service aimed at the international roaming market is assumed to be based on dialling an existing Inmarsat prefix (870) followed by the subscriber number. For the cellular extension service only, the cellular number will be used which will be redirected to the Inmarsat-P service when the mobile is out of range of cellular.

Inmarsat state that the network should be able to provide split billing functions where, in certain circumstances, the called and calling party pay the bill jointly. The addition of advanced 'ISDN' supplementary services, including Calling Line Identification, are necessary to support the split billing function. More detailed information on billing was not provided.

7.1.5.3 Services specifications

7.1.5.3.1 Voice

The Inmarsat-P system design is driven by the need to provide a voice telephony service to hand-held users. The voice service offered, using a 2,4 kbit/s vocoder, will offer a quality similar to that of digital cellular telephony.

7.1.5.3.2 Additional services

7.1.5.3.2.1 Real time data

A duplex data service compatible with asynchronous V22bis will be provided.

7.1.5.3.2.2 Positioning/position reporting

Position determination will be provided through the incorporation of a GPS/GLONASS chipset into the Inmarsat-P terminal.

7.1.5.3.2.3 Other services

The Inmarsat-P terminal will be compatible with group 3 facsimile transmission.

Additionally, a high penetration paging service will be provided.

7.1.5.3.3 Quality and availability

Information on service quality was not provided.

The service availability target for the LEO and ICO orbit options is up to 90 % (and up to 95 % in rural areas), depending on the degree of blockage. In highly blocked areas the user may have to wait a few minutes before making a call.

For the GSO option, service is provided in line-of-sight to one of the geostationary satellites; in areas with blockages, the user may be required to move to a location with a view of the satellite.

7.1.5.4 FCC or other national filings

Inmarsat has made no national filings in regard of Inmarsat-P.

7.1.5.5 ITU/IFRB filings

The following documents have been filed with the IFRB:

- AR11/A/819 Inmarsat-4 LEO-1	3 March 1992;
- AR11/A/820 Inmarsat-4 LEO-2	3 March 1992;
- AR11/A/821 etc., Inmarsat-4 GSO-1A	3 March 1992;
- AR11/A/828 etc., Inmarsat-4 GSO-2A	3 March 1992.

Appendix 3 information has also been filed with the IFRB and AR11/C, documents are expected to be published very shortly.

7.1.6 IRIDIUM [7] (Iridium Inc.)

7.1.6.1 Overall system description

IRIDIUM is a global, digital, portable personal communications system in which subscribers use portable or mobile radio units with small antennas to reach a constellation of 66 satellites. The system provides voice, data, positioning and paging services through the digitally switched constellation. The system provides, generally, line-of-sight coverage to and from every point on the surface of the Earth.

Iridium Inc.. made a presentation and provided a written input to ETSI and also answered further questions in writing.

7.1.6.1.1 Space segment

7.1.6.1.1.1 Frequency bands

The frequency bands required for the IRIDIUM system are as follows:

Table 18: IRIDIUM frequency bands

	Band
Service uplinks	1 616,0 - 1 626,5 MHz
Service downlinks	1 616,0 - 1 626,5 MHz
Feeder uplinks	29,1 - 29,3 GHz
Feeder downlinks	19,4 - 19,6 GHz
Intersatellite links	23,18 - 23,38 GHz

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[7] IRIDIUM is a trademark and service mark of Motorola Inc.

Thus, the bandwidth needs of the system are:

Table 19: IRIDIUM bandwidth requirements

	Bandwidth requirement (MHz)
Service uplinks	10,5
Service downlinks	10,5
Feeder uplinks	200,0
Feeder downlinks	200,0
Intersatellite links	200,0

7.1.6.1.1.2 Frequency sharing

Iridium Inc. state that L-Band sharing studies, submitted by the US Administration to CCIR WARC-92 Working Parties show that IRIDIUM can share the spectrum with generic RDSS services such as GEOSTAR and LOCSTAR. The studies show that IRIDIUM would be able to use the spectrum in the same place and at the same time as the generic RDSS services without causing mutual interference.

Because of the need to incorporate other services in the band allocated to MSS (i.e. 1 610,0 - 1 626,5 MHz), IRIDIUM only uses the upper 10,5 MHz of the spectrum, thus affording protection to RAS and GLONASS.

Detailed information regarding sharing between IRIDIUM and other satellite services, GSO and NGSO, were not provided, although reference was made to a number of JIWP papers containing sharing studies.

7.1.6.1.1.3 Frequency re-use

On a global basis, the entire beam pattern of the constellation as projected on the surface of the Earth results in approximately 2 150 active beams with a frequency re-use factor of about 180. Within the contiguous US the re-use factor is about 5; over Europe a re-use factor of about 4 is achieved.

7.1.6.1.1.4 Coverage/spot beam configurations

Each satellite generates 48 beams to form a continuous overlapping pattern on the Earth; the entire constellation generating about 2 150 active beams. The 48 cell L-band footprint is shown in figure 10.

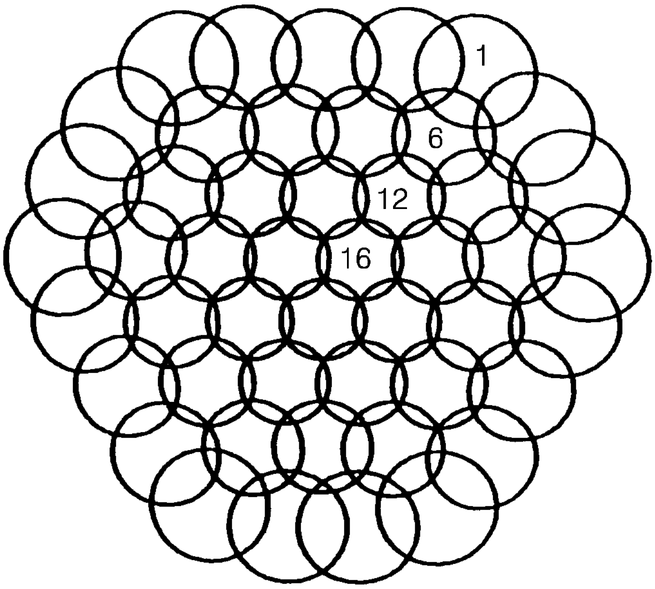

Figure 10: IRIDIUM 48 cell L-band footprint

7.1.6.1.1.5 Orbits

The IRIDIUM system uses a 6 plane circular polar constellation as follows:

Table 20: IRIDIUM constellation

Orbit	Altitude (km)	Period (hours)	Inclination	Number of Planes	Plane spacing (deg.)	Satellites per Plane
Polar Circular	~ 780	~ 1,7	86°	6	31,6 or 22,0 [8]	11

Commercial operation of the IRIDIUM service is currently planned to commence in 1998.

Iridium inc. provided no information on proposed phases of deployment of the IRIDIUM network.

7.1.6.1.1.6 Sample link budgets (forward and return direction)

See tables 19(a), 19(b), 19(c), 19(d) and 19(e) for representative link budgets.

7.1.6.1.2 User segment

IRIDIUM subscriber units under consideration include portable (hand-held) units, mobile units, solar powered 'phone booths, specialised aeronautical and marine units and numeric and alphanumeric pagers.

At present Iridium Inc. is only able to provide the characteristics of the hand-held "IRIDIUM Subscriber Unit" (ISU).

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[8] 31,6° between co-rotating planes and 22,0° between counter rotating planes (planes 1 and 6).

7.1.6.1.2.1 Terminal characteristics

The ISU offers world-wide RDSS, voice and data communications and is lightweight, economical and as easy to use as a cellular telephone. Communications between the ISU and a satellite is accomplished over a full-duplex FDMA channel in TDMA bursts of QPSK modulated digital data packets. Digitised voice is encoded and decoded using Motorola 4,8/2,4 kbit/s VSELP vocoder algorithms. The parameters of a typical ISU are:

Coded data rate	uplink:	50 kbit/s
	downlink:	50 kbit/s
Error correction coding:		Block, Rate 2/3
Modulation:		QPSK
Antenna	Type:	Quadrifilar Helix
	Gain:	+ 1 to + 3 dBi
	Coverage:	360° azimuth, + 8.2° to + 90° elevation
EIRP	Peak:	6,0 dBWic [9]
	Average:	- 4,4 dBWic
Receiver G/T:		- 23,0 dB/K
Eb/No for BER = 2 x 10^{-2}	4,3 dB	

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[9] Power is referenced to the carrier and with respect to an isotropic antenna.

Table 21(a): IRIDIUM satellite to user downlink budget (with shadowing) for a representative cell

Azimuth angle	38,3	deg.
Ground range	1 424,9	km
Nadir angle	56,4	deg.
Elevation angle	20,8	deg.
Slant range	1 696,2	km
Space Vehicle		
HPA burst power	3,5	dBW
Xmtr ckt. loss	2,1	dB
Eff. EOC antenna gain	23,1	dBi
EIRP	24,5	dBW
Propagation		
Space loss	164,5	dB
Prop. losses (link margin)	15,7	dB
Total prop. losses	177,0	dB
IRIDIUM Subscriber Unit		
Rcvd. signal strength	- 152,5	dBW
Antenna gain	1,0	dBi
Signal level	- 151,5	dBW
Req. Eb/(No+Io)	5,8	dB
Eb/Io	18,0	dB
Req. Eb/No	6,1	dB
Ts	250,0	K
Sig. level req.	- 151,5	dBW
Additional margin	0,0	dB
G/Ts	- 23,0	dB/K
SPFD at ISU	- 135,8	dBW/m²/4kHz

Table 21(b): IRIDIUM user to satellite uplink budget (with shadowing) for a representative cell

Azimuth angle	38,3	deg.
Ground range	1 424,9	km
Nadir angle	56,4	deg.
Elevation angle	20,8	deg.
Slant range	1 696,2	km
IRIDIUM Subscriber Unit		
HPA burst power	5,6	dBW
Ckt. loss	0,7	dB
Antenna gain	1,0	dBi
EIRP	5,9	dBW
Uplink EIRP density	- 3,1	dBW/4kHz
Propagation		
Space loss	161,3	dB
Prop. losses (link margin)	15,7	dB
Total prop. losses	177,0	dB
Space Vehicle		
Rcvd. signal strength	- 171,1	dBW
Eff. EOC antenna gain	22,6	dBi
Signal level	- 148,5	dBW
Req. Eb/(No+Io)	5,8	dB
Eb/Io	18,0	dB
Req. Eb/No	6,1	dB
Ts	500,0	K
Sig. level req.	- 148,5	dBW
Link margin	0,0	dB
G/T	- 4,4	dB/K

Table 21(c): IRIDIUM satellite to gateway downlink budget (with rain)

Slant range	2 326,0	km
Space Vehicle		
Power	0,0	dBW
Antenna gain	26,9	dBi
Ckt. loss	- 3,2	dB
Pointing loss	- 0,5	dB
EIRP	23,2	dBW
System		
Margin	3,2	
Space loss	- 185,8	dB
Prop. losses	- 14,2	dB
Polarisation loss	- 0,2	dB
Total prop. losses	- 203,4	dB
IRIDIUM Gateway		
Rcvd. signal strength	- 180,2	dBW
Pointing loss	- 0,2	dB
Antenna gain	53,2	dBi
Signal level	- 127,2	dBW
Ts	731,4	K
Noise density	- 200,0	dBW/Hz
Noise bandwidth	64,9	dBHz
Noise	- 135,1	dBW
Link Eb/No	7,9	dB
Eb/Io	25,0	dB
Comp. Eb/(No+Io)	7,8	dB
Req. Eb/No	7,7	dB
Excess margin	0,1	dB
SPFD at GW	- 134,3	$dBW/m^2/1MHz$

Table 21(d): IRIDIUM gateway to satellite uplink budget (with rain)

Slant range	2 326,0	km
IRIDIUM Gateway		
Power	13,0	dBW
Antenna gain	56,3	dBi
Ckt. loss	-1,0	dB
Pointing loss	-0,3	dB
EIRP	68,0	dBW
System		
Margin	2,1	
Space loss	- 189,1	dB
Prop. losses	- 30,0	dB
Polarisation loss	- 0,2	dB
Total prop. losses	- 221,4	dB
Space Vehicle		
Rcvd. signal strength	- 153,4	dBW
Pointing loss	- 0,8	dB
Antenna gain	30,1	dBi
Signal level	- 124,1	dBW
Ts	1 295,4	K
Noise density	- 197,5	dBW/Hz
Noise bandwidth	64,9	dBHz
Noise	- 132,6	dBW
Link Eb/No	8,5	dB
Eb/Io	16,0	dB
Comp. Eb/(No+Io)	7,8	dB
Req. Eb/No	7,7	dB
Excess margin	0,1	dB

Table 21(e): IRIDIUM ISL budget (with solar interference) for an E-W link

Range	4 400,0	km
Transmitter		
Power	5,3	dBW
Antenna gain	36,7	dBi
Ckt. loss	- 1,8	dB
Pointing loss	- 1,8	dB
EIRP	38,4	dBW
System		
Margin	0,0	
Space loss	- 192,7	dB
Polarisation loss	0,0	dB
Receiver		
Rcvd. signal strength	- 154,3	dBW
Pointing loss	- 1,8	dB
Antenna gain	36,7	dBi
Signal level	- 119,4	dBW
Ts	1 188,3	K
Noise density	- 197,9	dBW/Hz
Noise bandwidth	71,0	dBHz
Noise	- 126,9	dBW
Link Eb/No	7,5	dB
Eb/Io	27,0	dB
Comp. Eb/(No+Io)	7,5	dB
Req. Eb/No	7,7	dB
Excess margin	- 0,2	dB

7.1.6.1.2.2 Unwanted emissions

Iridium state that unwanted emissions comply with the limits set by the FCC.

Emission limitations for the IRIDIUM satellite at L-Band specified in the FCC filing minor amendments are as shown in table 22. More detailed information was not provided.

Table 22: IRIDIUM satellite emission limitations at L-Band

Channel Spacing from carrier	1x	2x
Level (dB)	- 30	- 60

7.1.6.1.2.3 Physical considerations

The equipment design is consistent with good engineering practices.

The equipment meets the ANSI/IEEE standard IEEE C95.1-1991 and the WHO requirement for exposure to electromagnetic fields. This standard requires that the specific absorption rate (SAR) will be below 1,6 W/kg over any 1 g of tissue.

7.1.6.1.3 Gateways

IRIDIUM Gateways connect the subscriber to a PSTN and handle subscriber related functions. To effect a connection to the PSTN, gateway equipment includes an Earth terminal controller to manage communications and a switch to connect with the PSTN. To handle subscriber related functions, the gateway equipment includes a subscriber database and is capable of subscriber verification and billing.

Gateways are configured to support the needs of a given region. Factors relevant to the selection of a configuration are capacity requirements, signal interfaces to the PSTN, the number and availability of switching trunks and local terrain elevation.

7.1.6.1.3.1 Traffic/network co-ordination

The gateways are responsible for traffic/network co-ordination only for current active calls. This includes calls originating or terminating in the PSTN being serviced by the gateway or mobile originating or terminating calls within a gateway service area.

7.1.6.1.3.2 Functionality

The gateway is responsible for call setup, cleardown, satellite to satellite handover, service provisioning and generation of call detail records. In all cases, the gateways are simply the real-time call controllers under direction of the system control segment.

7.1.6.1.3.3 Number and deployment

Each satellite has four feeder link antennas with which to communicate to the gateways. Therefore up to four gateways could be located within the satellite footprint, a circle having a diameter of about 5 000 km. In regions having several nations within a small geographic area it may not be feasible to locate a gateway in each nation. In this case a single gateway could provide service to neighbouring nations.

Antennas are spaced from about 100 m to 50 km apart depending on the degree of diversity needed to assure system availability.

7.1.6.1.3.4 Geographical distribution

In regions that have robust inter-exchange carrier networks, a few high capacity gateways will provide the most efficient connectivity to the PSTNs. In regions where inter-exchange carrier networking is limited or non-existent, a large number of small gateways would be more efficient.

7.1.6.2 Network operation

7.1.6.2.1 Description

The network is designed as a constellation of interconnected satellites that perform a packet routing and subscriber channel management function. Real-time call control as well as the PSTN interface is provided by the ground based gateways. A System Control Segment provides overall direction for both the gateways and the satellite constellation.

7.1.6.2.2 Call setup/routing/handover/cleardown algorithms

Call setup is performed under control of the gateways. Iridium Inc. state that the procedure used for call setup is virtually identical to the GSM call setup procedure.

Routing is provided by both the satellites and the gateways. The satellites provide packet routing between entities within the network based on routing tables provided by the System Control Segment. The gateways provide routing between the satellite constellation and the PSTN to which they are interconnected.

Handover of a mobile subscriber within the footprint of a single satellite is controlled by the satellite. Handover between satellites is controlled by the ground based gateway due to the network synchronisation requirements. Cleardown is controlled by the gateway as part of its normal call processing function.

7.1.6.2.3 Interworking

The IRIDIUM network is interconnected through its gateways on the international side of the International Switching Centre. Therefore, normal interworking functions are not relevant.

7.1.6.2.4 Air interface

The IRIDIUM system provides an L-Band link between the subscriber and the satellite constellation occupying a band of 10,5 MHz. The access format is FDMA/TDMA (frequency division multiple access/time division multiple access) for data transmissions and vocoded voice. The width of each frequency channel is 41,67 kHz, which includes 31,5 kHz occupied bandwidth and guard bands. The maximum number of L-Band service duplex channels per satellite is 3 840.

The same frequencies bands are used for both service uplink and service downlink transmissions. The 90 TDMA frame is divided into four transmit and four receive time slots which are controlled so that the ISU burst transmissions arrive at the satellite in proper sequence, with Doppler correction. The downlink format is similar.

The modulation scheme is differentially coded, raised cosine filtered, QPSK modulation, with a burst rate of 50 kbit/s (25 ksymbols/sec) in either direction. This format has been chosen as the best compromise for the transmission channel between satellites and the earth stations, which is subject to a combination of multipath fading and other transmission impairments.

Each subscriber unit operates in burst mode on an assigned frequency channel. Since the same frequency is used for the uplink and downlink the transmissions are offset in time. The TDMA frame lasts 90 ms and has four receive and four transmit time slots (burst times R1 - R4 and T1 - T4) which are synchronised so that each subscriber unit transmission is received at the satellite at the proper time. Two subscribers terminals talking to each other in the same satellite footprint could use the same frequency channel (e.g. C1) or two different frequency channels (e.g. C4 and C6) as shown in figure 11. The link is constituted by a single hop established through the satellite which also controls inter-satellite handovers occurring during the call.

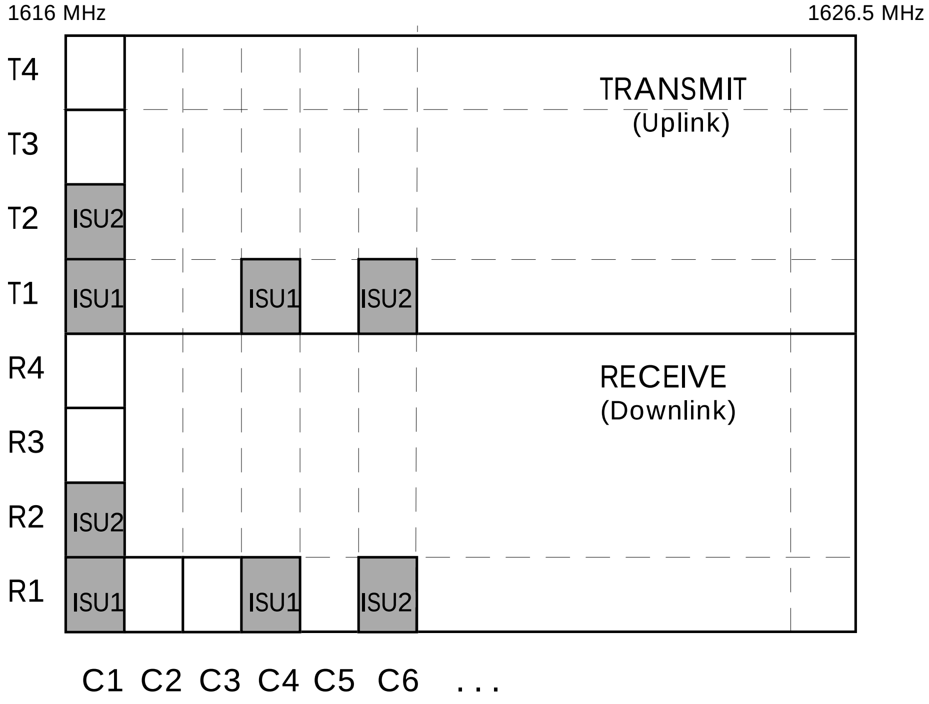


Figure 11: IRIDIUM TDMA/FDMA service channel plan, not including guard bands, guard times and framing slot

7.1.6.2.5 Control and monitoring

The System Control Segment is responsible for managing the individual satellites in the system; the network upon which both control/monitor data and subscriber telephone calls flow; and the facilities/equipment which comprises the Control Segment itself. The System Control Segment consists of a Master Control Facility, a Backup Control Facility, remote Telemetry, Tracking, and Control (TT&C) facilities, and a communications infrastructure including management and support personnel.

Among the functions of the control facilities are management of:

- the health and status of all satellites in the system throughout the four phases of their operation: launch, storage, mission, and de-orbit;

- all shared system resources which are used to provide service to subscribers, such as individual satellite beams (cells) and the number of subscriber channels in a beam; the mix of traffic between voice and paging; the routing of packets between space-based nodes; and the assignment of satellite links to gateways and TT & Cs;

- the identification and resolution of system anomalies which may involve gateway operations (by support personnel);

- co-ordination of frequencies, licensing, interference with external organisations and/or countries, and other management level matters.

7.1.6.2.6 Numbering and billing

The IRIDIUM system is designed to incorporate a numbering plan which is consistent with the principles of CCITT Recommendations E.163 [18], E.168 [19], and E.212 [20].

The billing plan under consideration is consistent with accepted telephony practices.

7.1.6.3 Services specifications

7.1.6.3.1 Voice

IRIDIUM provides two-way, high quality 4,8/2,4 kbit/s digital voice communications using hand-held and vehicle mounted terminals.

7.1.6.3.2 Additional services

7.1.6.3.2.1 Data (real time/store and forward)

Global data services are available through the addition of a modem to an IRIDIUM voice terminal; this will support facsimile and user data at 2,4 kbit/s. Data messaging is provided in conjunction with a positioning and paging service for applications such as truck fleet management.

7.1.6.3.2.2 Positioning/position reporting

IRIDIUM ISU position determination is provided as a required part of the call establishment process and will be offered to the subscriber as an option. It is accomplished by the determination of the time delay in the reception of a unique work at the start of each downlink frame. Positioning accuracy using this method is accurate to around 1,5 km.

For more accurate position determination optional GPS or GLONASS capability is available.

7.1.6.3.2.3 Other services

Alphanumeric paging is provided to units similar in size and performance to terrestrial pagers.

IRIDIUM also provides RDSS emergency location services for boats, aircraft and land vehicles equipped with IRIDIUM voice terminals.

7.1.6.3.3 Quality and availability

Digitised voice is encoded using a Motorola VSELP vocoder; FEC ensures a worst case BER of less than 10^{-2} and a typical BER of between 10^{-3} and 10^{-4}.

Service availability of IRIDIUM to any part of the Earth within sight of a satellite is 99,5 % of time.

7.1.6.4 FCC or other national filings

IRIDIUM has made the following FCC filings:

- Application for a LEO Mobile Satellite System	3 December 1990;
- Minor amendment to initial application	10 August 1992.

An experimental licence has been granted to Iridium for the following experimental system; 5 satellites, 100 user terminals, 2 airborne terminals and one system control terminal.

7.1.6.5 ITU/IFRB filings

The following document has been filed with the IFRB:

- Form AP3/II, HIBLEO-2 (IRIDIUM Network)	8 October 1992.

7.1.7 Loopus (Germany)

7.1.7.1 Overall system description

As well as being the name of a special HEO constellation where handover between descending and ascending satellites is performed at practically the same celestial points (see Annex F, subclause F.4.1.3), LOOPUS is also the name of an S-PCN proposed system utilising "LOOPUS" type HEOs.

There are proposals by Deutsche Aerospace/Germany (filing under the name LOOPUS Mobile D) and also by a LOOPUS initiative in Germany which is not yet institutionalised but is expected to become an international consortium (filing under the name QUASIGEO).

The following details have been compiled from published and publicly available sources and have not been reviewed by the organisation proposing the system concerned.

7.1.7.1.1 Space segment

7.1.7.1.1.1 Frequency bands

The frequency bands required for LOOPUS Mobile D are as follows:

Table 23: LOOPUS Mobile D frequency bands

	Band
Service up-links	Ku-band under RR 859
Service down-links	Ku-band on a non-interference basis
Feeder up-links	Ku-band
Feeder down-links	Ku-band
Intersatellite links	not used

The frequency bands required for QUASIGEO-L1, L2 and L3 are as follows:

Table 24: QUASIGEO frequency bands

	Band
Service up-links	Ka-band / L-band / FPLMTS-band
Service down-links	Ka-band / L-band / FPLMTS-band
Feeder up-links	Ku-band
Feeder down-links	Ku-band
Intersatellite links	not used

Detailed frequency band and bandwidth information is not available.

7.1.7.1.1.2 Frequency sharing

For both cases, frequency sharing is principally between coverage regions. Studies show that the out of plane separation to the GSO is of the order of 47°. Active service arcs appear, to an observer on the surface of the Earth, in the form of small loops which remain stationary above the same sites on the Earth. It is, therefore expected that co-ordination with Ka-, Ku-, L- and FPLMTS-band GSO and other HEO services is possible.

Information on sharing with terrestrial and LEO services is not available.

7.1.7.1.1.3 Frequency re-use

The frequency re-use factor will be in both cases at least 5, but could be a multiple thereof, subject to system implementation.

7.1.7.1.1.4 Coverage/spot beam configurations

Coverage is most probably through flying spots in five equal 72° segments (as seen from the North pole) covering the whole northern hemisphere.

7.1.7.1.1.5 Orbits

The LOOPUS systems will most likely use 3 plane HEO constellations in 14,4 hour orbits, providing five quasi-positions above the northern hemisphere and repeating their common sub-satellite track in 72 hour intervals. Each two neighbouring quasi-positions are so close that mutual backup is possible in case of failure. The constellation parameters are expected to be as follows:

Table 25: LOOPUS constellation

Orbit	Apogee (km)	Perigee (km)	Period (hours)	Inclination	Number of Planes	Plane spacing (deg.)	Satellites per Plane
LOOPUS HEO	41,449	5,784	14,4	63,4°	3	120°	3

7.1.7.1.1.6 Sample link budgets (forward and return direction)

Sample link budgets are not available.

7.1.7.1.2 User segment

Information on the user segment is not available.

7.1.7.1.3 Gateways

Detailed information on gateways is not available, but it is noted that for QUASIGEO the number of gateway stations is not limited.

7.1.7.2 Network operation

Detailed information on network operation is not available, but it is noted that for QUASIGEO the networks will be compatible with GSM and other terrestrial PLMNs in other continents and will be UPT capable. Depending on the progress of FPLMTS/UMTS standardisation within the QUASIGEO development timetable, compatibility or even compliance is envisaged.

7.1.7.3 Services specifications

Detailed information on services specifications is not available, but it is noted that for QUASIGEO GSM/FPLMTS/UMTS services will be supported with an equivalent quality and availability, as will UPT. The provision of other services such as position reporting etc. will depend on system implementation.

7.1.7.4 FCC or other national filings

International filings have been effected through the Federal Ministry of Posts and Telecommunications (BAPT) in Bonn.

7.1.7.5 ITU/IFRB filings

The following documents have been filed with the IFRB:

- AR11/A/634 etc., LOOPUS Mobile D	6 April 1990;
- Appendix 4 filing, QUASIGEO-L1-L3	filed but not yet published by IFRB.

7.1.8 Odyssey (TRW)

7.1.8.1 Overall system description

Odyssey is a satellite system which will provide high quality wireless communications services, through terrestrial cellular compatible handsets, to users world-wide providing them with services including voice, data, paging, radiodetermination and messaging.

TRW Inc. provided a number of source documents as an input to ETSI and also answered questions in writing. ETSI has used the source documents provided by TRW to draft this text, but TRW did not provide a detailed reply to the ETSI questionnaire.

7.1.8.1.1 Space segment

7.1.8.1.1.1 Frequency bands

The frequency bands required for the Odyssey system are as follows:

Table 26: Odyssey frequency bands

	Band
Service uplinks	1 610,0 - 1 626,5 MHz
Service downlinks	2 483,5 - 2 500,0 MHz
Feeder uplinks	Ka-band
Feeder downlinks	Ka-band
Intersatellite links	not used

Thus, the bandwidth needs of the system are:

Table 27: Odyssey bandwidth requirements

	Bandwidth requirement (MHz)
Service uplinks	6,5
Service downlinks	16,5
Feeder uplinks	information not provided
Feeder downlinks	information not provided
Intersatellite links	not used

7.1.8.1.1.2 Frequency sharing

Detailed information on frequency sharing was not provided however, TRW state that their use of CDMA permits sharing of the frequency spectrum resource by multiple service providers.

7.1.8.1.1.3 Frequency re-use

The beam pattern from a single satellite comprises 19 spot beams, each with a 5° beamwidth; each beam will be assigned one third of the total available bandwidth, leading to approximately a 6 fold frequency re-use per satellite.

7.1.8.1.1.4 Coverage/spot beam configurations

Each satellite generates a 19 spot beam coverage pattern over only a portion of the total area visible to the satellite. The satellite attitude is controlled such that the spot beam coverage is directed towards the particular region to which the satellite is assigned. Through the use of this approach Odyssey can provide a near global coverage over the major land masses although at the expense of not covering the polar and many oceanic regions. Figure 12 shows an example Odyssey coverage.

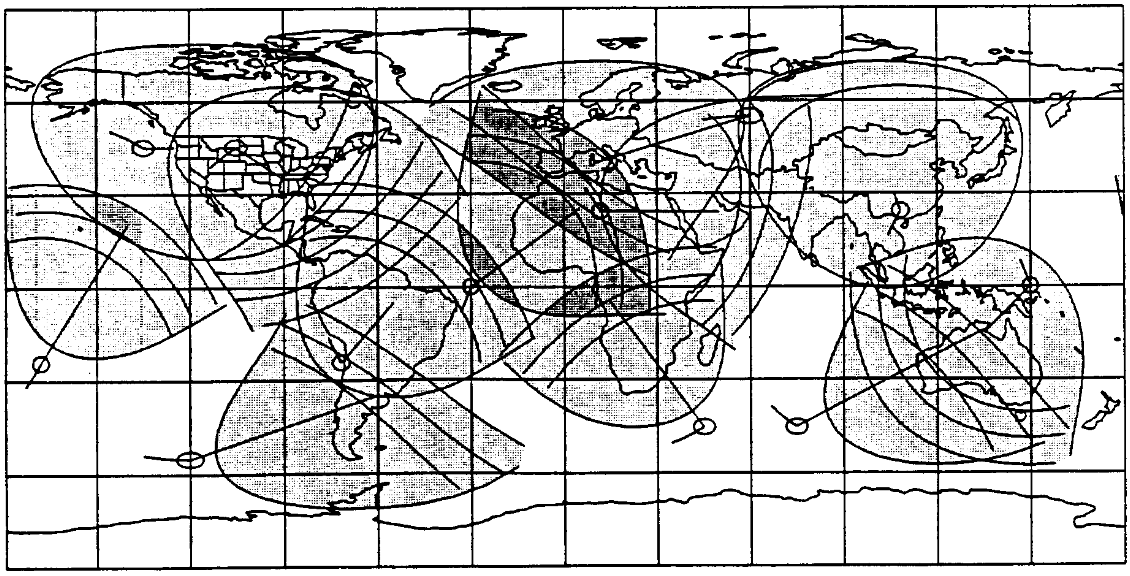


Figure 12: Example Odyssey coverage

7.1.8.1.1.5 Orbits

The Odyssey system uses a 3 plane inclined circular constellation as follows:

Table 28: Odyssey constellation

Orbit	Altitude (km)	Period (hours)	Inclination	Number of Planes	Plane spacing (deg.)	Satellites per Plane
Inclined Circular	10,354	~ 6	55°	3	120°	4

TRW state that the constellation guarantees a minimum line of sight elevation angle of at least 30° to at least one satellite visible in every location for more than 95 % of the time.

Commercial operation of the Odyssey service is estimated to commence in 1997.

TRW Inc. provided no information on proposed phases of deployment of the Odyssey network, other than to note that the constellation is operable, with a reduced minimum elevation angle, with only 9 satellites in orbit.

7.1.8.1.1.6 Sample link budgets (forward and return direction)

Sample link budgets were not provided.

7.1.8.1.2 User segment

7.1.8.1.2.1 Terminal characteristics

The Odyssey Hand-held Personal Telephone (HPT) is designed to be simple and low-cost. The user should perceive no apparent difference between HPT usage in the Odyssey system and today's terrestrial cellular system terminals. The Odyssey terminal is a modified version of a cellular terminal which an operate at either cellular or satellite frequencies. Some parameters of a typical Odyssey HPT are:

Modulation:		CDMA
Antenna Type:		Quadrifilar Helix
Average power:		0,5 W
Battery life	talking:	90 minutes
	standby:	24 hours
Compatibility	Europe:	GSM
	USA:	ADS/AMPS

Information on other handset parameters was not provided.

7.1.8.1.2.2 Unwanted emissions

Information on unwanted emissions was not provided.

7.1.8.1.2.3 Physical considerations

TRW note the concerns due to radiation hazards from hand-held cellular telephones. They state that testing remains to be performed but note that analysis shows that the fields radiated from cellular telephones are several orders of magnitude lower than for electric razors or fluorescent lights. TRW state that an EMF of less than 4 milliGauss at 10 cm is desirable and that an Odyssey phone should only radiate a field of about 1 milliGauss at 10 cm.

TRW state that they will meet health and safety standards.

7.1.8.1.3 Gateways

It is noted that to provide Continental USA (CONUS) coverage, two gateway stations, each with 4 antennas, are required, one on the East coast and one on the West. At each gateway station the four antennas are each separated by 30 km in order to provide a site diversity fade countermeasure at Ka-band. Three of the antennas would, at any time be working to three satellites with the other ready to acquire a new satellite or provide diversity.

Detailed information on gateway co-ordination, functionality, number, deployment and distribution was not provided.

7.1.8.2 Network operation

The gateway stations provide the connection between the Odyssey satellite link and the PSTNs in each region. Most calls will be directed towards the local PSTN; long distance calls will be directed towards the designated long distance PSTN in the gateway region. Odyssey to Odyssey calls will be routed to the appropriate Odyssey gateway through the use of dedicated inter-gateway leased lines.

For mobile originated calls, priority is given to the use of the terrestrial cellular services, identified by the presence of cellular frequencies. If there is no local cellular service, or if the call is blocked by the cellular network then the user terminal routes the call through Odyssey. User circuits established through a particular satellite enter the PSTN at a ground station located within the region served by the satellite.

Odyssey call setup is controlled by a separate order wire channel, assigned to each satellite antenna beam. To make a circuit request, a user terminal transmits requests to overhead satellites; the user is assigned to the beam which provides the strongest signal to the base station and is instructed to use a suitable power level and a particular spread spectrum code appropriate to that beam. This process is transparent to the user.

Information on PSTN originated calls was not provided.

Handover is not expected to be required very often; typical call duration is short, the Odyssey cells are relatively large and the satellite is continually re-oriented to maintain coverage of its intended region. Thus most calls will remain within one cell for their entire duration but the capability to handover calls to another cell or to another satellite will be provided.

More detailed information on general network operation, call setup/routing/handover/cleardown algorithms, inter-working, air interface, numbering and billing was not provided.

7.1.8.3 Services specifications

7.1.8.3.1 Voice

Odyssey will provide a voice service, but detailed information was not provided.

7.1.8.3.2 Additional services

7.1.8.3.2.1 Data (real time/store and forward)

Odyssey will provide a data service, but detailed information was not provided.

7.1.8.3.2.2 Positioning/position reporting

Odyssey will provide a radiodetermination service, but detailed information was not provided.

7.1.8.3.2.3 Other services

Odyssey will provide a messaging/paging service, but detailed information was not provided.

7.1.8.3.3 Quality and availability

Information on service quality and availability was not provided.

7.1.8.4 FCC or other national filings

Odyssey has made the following FCC filings:

- Application for a Mobile Satellite System	date not known;
- FCC experimental licence issued	date not known.

7.1.8.5 ITU/IFRB filings

The following document has been filed with the IFRB:

- IFRB Appendix 3 filing	date not known.

7.2 Proposed NGSO Systems Below 1 GHz

7.2.1 LEOSAT (Leosat Corporation)

7.2.1.1 Overall system description

The LEOSAT system is proposed by Leosat Corporation. It is being designed to be a low-cost system to provide two way data communications, smart vehicle applications, emergency messaging services and asset tracking world-wide. The first operating system will employ 2 small satellites, providing intermittent service, while the complete deployment of 24 satellites is foreseen towards the end of 1990s.

The following details have been compiled from published and publicly available sources and have not been reviewed by the organisation proposing the system concerned.

7.2.1.1.1 Space segment

7.2.1.1.1.1 Frequency bands

The frequency bands proposed for the LEOSAT system are as follows:

Table 29: LEOSAT frequency bands

	Band
Service up-links	137 MHz
Service down-links	148 MHz
Feeder up-links	Information not available
Feeder down-links	Information not available
Intersatellite links	not used

Information on the bandwidth needs of the system is not available.

Information on access and modulation schemes is not available.

7.2.1.1.1.2 Frequency sharing

Information not available.

7.2.1.1.1.3 Frequency re-use

Information not available.

7.2.1.1.1.4 Coverage/spot beam configurations

Information not available.

7.2.1.1.1.5 Orbits

The space segment of the fully developed system is composed of 24 small satellites (weighting between 25 and 50 kilograms) capable of on board processing for data messaging. Further information on spacecraft is not available.

Table 30: LEOSAT constellation

Orbit	Altitude (km)	Inclination	Number of Planes	Plane spacing (deg.)	Satellites per Plane
Circular Inclined	970	40 - 50	not available	not available	not available
Circular Polar	not available	90	not available	not available	not available

7.2.1.1.1.6 Sample link budgets (forward and return direction)

Information not available.

7.2.1.1.2 User segment

7.2.1.1.2.1 Terminal characteristics

Information not available.

7.2.1.1.2.2 Unwanted emissions

Information not available.

7.2.1.1.2.3 Physical considerations

Information not available.

7.2.1.1.3 Gateways

Information not available.

7.2.1.2 Network operation

Information not available.

7.2.1.3 Services specifications

The system is being designed to provide two way data communications, smart vehicle applications, highway system monitoring, pollution control, emergency messaging and asset tracking.

7.2.1.3.1 Voice

The LEOSAT system does not provide voice service.

7.2.1.3.2 Additional services

7.2.1.3.2.1 Data

Two way data communications, tracking.

7.2.1.3.2.2 Positioning/position reporting

It is provided as a part of tracking service.

7.2.1.3.2.3 Other services

Services for the implementations of smart vehicle applications, highway monitoring, pollution control, equipment malfunction detection. Further information is not available.

7.2.1.3.3 Quality and availability

Information not available.

7.2.1.4 FCC or other national filings

FCC filing.

7.2.1.5 ITU/IFRB filings

Information not available.

7.2.2 Orbcomm (Orbital Communications Corporation)

7.2.2.1 Overall system description

The ORBCOMM proposal comes from Orbital Communications Corporation (OCC), it was introduced in 1990. The totally developed system employs a constellation or 20 LEO satellites, with the system beginning service once the first spacecraft is launched. The ORBCOMM system has been designed to provide world-wide two-way data communications, position determination and emergency messaging world-wide through pocket size terminals. The system will allow transmission and reception of short data packets, compatible with the X.25 protocol standard.

The following details have been compiled from published and publicly available sources and have not been reviewed by the organisation proposing the system concerned.

7.2.2.1.1 Space segment

7.2.2.1.1.1 Frequency bands

The frequency bands proposed for the ORBCOMM system are as follows:

Table 31: ORBCOMM frequency bands

	Band
Service up-links	148 - 149,9 MHz
Service down-links	137 - 138 MHz
Feeder up-links	information not available
Feeder down-links	Information not available
Intersatellite links	not used

The bandwidth needs of the system are:

Table 32: ORBCOMM bandwidth requirements

	Bandwidth requirement
Service up-links	1,9 MHz
Service down-links	1 MHz
Feeder up-links	Information not available
Feeder down-links	Information not available
Intersatellite links	not applicable

Information on access and digital modulation schemes is not available.

7.2.2.1.1.2 Frequency sharing

Information not available.

7.2.2.1.1.3 Frequency re-use

Information not available.

7.2.2.1.1.4 Coverage/spot beam configurations

7.2.2.1.1.5 Orbits

The space segment comprises 20 satellites placed in two orthogonal polar orbits and 3 circular inclined orbits to achieve global coverage. Each satellite is launched with a Pegasus booster with the system beginning service once the first satellite is launched. The fully developed system constellation is being designed ass follows:

Table 33: ORBCOMM constellation

Orbit	Altitude (km)	Inclination	Number of Planes	Plane spacing (deg.)	Satellites per Plane
Polar Circular	970	90	2	90	1
Inclined Circular	970	40	3	40	6

7.2.2.1.1.6 Sample link budgets (forward and return direction)

Information not available.

7.2.2.1.2 User segment

7.2.2.1.2.1 Terminal characteristics

The user terminal is designed to be pocket-sized, it will provide two way data communications, position determination and emergency messaging. Further information about the user segment is not available.

7.2.2.1.2.2 Unwanted emissions

Information not available.

7.2.2.1.2.3 Physical considerations

Information not available.

7.2.2.1.3 Gateways

Information not available.

7.2.2.2 Network operation

Information not available.

7.2.2.3 Services specifications

The ORBCOMM system provides global coverage for two way data communications, position determination and emergency messaging. Further information on services specification is not available.

7.2.2.3.1 Voice

The ORBCOMM system does not provide voice service.

7.2.2.3.2 Additional services

The system provides emergency messaging. Further information not available.

7.2.2.3.2.1 Data

The system provides two way user data communications services allowing transmission and reception of short data packets, compatible with the X.25 protocol standard. Further information not available.

7.2.2.3.2.2 Positioning/position reporting

The system provides position determination. Further information not available.

7.2.2.3.2.3 Other services

No other services are provided.

7.2.2.3.3 Quality and availability

Information not available.

7.2.2.4 FCC or other national filings

FCC application in USA. ORBCOMM plans to manage the space segment and be the system operator in USA, it has also entered into agreements with 11 countries to provide ORBCOMM services in those markets. The agreement will probably include a national registration. The countries involved are Mexico, Honduras, Ecuador, Guatemala, Canada, Venezuela, Brazil, Argentina, Uruguay, Colombia and Panama.

7.2.2.5 ITU/IFRB filings

Information not available.

7.2.3 TAOS (CNES)

7.2.3.1 Overall system description

The TAOS system proposed by CNES, the French national space agency, is a system providing data messaging, position determination and reporting.

At present two frequency plans are being studied (scenarios 1 and 2) and thus in some cases it is necessary to indicate options in the descriptive text that follows.

CNES provided a written input to ETSI and answered further questions in writing.

7.2.3.1.1 Space segment

7.2.3.1.1.1 Frequency bands

The frequency bands proposed for the TAOS system are as follows:

Table 34: TAOS frequency bands

	Band	
	Scenario 1	Scenario 2
Service uplinks	148,0 - 149,0 MHz	148,0 - 149,0 MHz
Service downlinks	137,0 - 138,0 MHz	400,15 - 401,0 MHz
Feeder uplinks	148,0 - 149,0 MHz	149,9 - 150,05 MHz
Feeder downlinks	137,0 - 138,0 MHz	137,0 - 138,0 MHz
Intersatellite links	none	none

The bandwidth needs of the system are:

Table 35: TAOS bandwidth requirements

	Bandwidth requirement	
	Scenario 1	Scenario 2
Service uplinks	1 MHz (DS-SSMA)	1 MHz (DS-SSMA)
Service downlinks	1 MHz (DS-SSMA)	150 kHz or less
Feeder uplinks	1 MHz (DS-SSMA)	150 kHz or less
Feeder downlinks	1 MHz (DS-SSMA)	1 MHz (DS-SSMA)
Intersatellite links	none	none

7.2.3.1.1.2 Frequency sharing

Frequency sharing is within the provisions of the relevant provisions of the Radio Regulations relating to the bands under consideration, including the need to co-ordinate with other primary services and to limit PFD levels and interference in certain cases.

CCIR derived sharing and co-ordination procedures will be used in applicable bands.

7.2.3.1.1.3 Frequency re-use

In Scenario 1, frequency re-use is provided between forward and return links. Limited interference is provided by the use of different codes on these two DS-SSMA channels. Moreover, the same channel is used by all users on the return link.

In Scenario 2, frequency re-use is provided on the return link by using DS-SSMA techniques; no time synchronisation between accessors (random access) is required.

7.2.3.1.1.4 Coverage/spot beam configurations

Coverage is provided on each satellite by one spot beam for each link (service and feeder). Depending on the frequency plan, common antennas may perform multiple functions (transmit and receive).

The TAOS service is defined for a service zone composed of different service regions; presently three service regions are assumed: North America, Europe and Asia. Two types of service are thus defined:

- regional service: in which the TAOS services are available to a particular mobile only if it is located in one specific region. In this case, transactions between the gateways and the mobile only occur in the specified region, reducing the traffic on the radio links;
- global service: in which the TAOS services are available to a particular mobile in any of the TAOS service regions.

7.2.3.1.1.5 Orbits

Five satellites are utilised, each in its own non-polar LEO orbit (i.e. five orbit planes). The five orbits are as follows:

Table 36: TAOS orbit configuration

Satellite	Altitude (km)	Eccentricity	Inclination	Ascending Node	Argument of Perigee
1	1 250	0°	55°	0°	0°
2	1 250	0°	55°	72°	0°
3	1 250	0°	55°	144°	0°
4	1 250	0°	55°	216°	0°
5	1 250	0°	55°	288°	0°

Functionally, only one satellite is needed at a time to perform the TAOS services (positioning achieved by Doppler and ranging techniques). Moreover, the number of satellites is limited to one as far as possible to reduce the interference between multiple satellite-mobile links.

The worst case minimum elevation angles considered are 5° for a gateway and 10° for a mobile terminal. The system performances are assured for elevation angles greater than these values, assuming no blockages on the radio path, which are unpredictable in nature.

Information on the phases of system deployment was not provided.

7.2.3.1.1.6 Sample link budgets (forward and return direction)

See tables 37(a) and 37(b) which correspond to scenario 1 described earlier. Link budgets shown are those previously published in a paper of the IAF (ref. IAF-92-0424) and are preliminary and for information only.

Table 37(a): TAOS forward link budget for scenario 1

Uplink	148,0	MHz
Data rate	14,0	kbit/s
Convolutional code	28,0	kHz
Spreading code	1,0	Mchip/s
Earth station EIRP	12,8	dBW
Free space loss	- 147,4	dB
Other losses	- 2,0	dB
G/T satellite	- 30,5	dB/K
Boltzmann	228,6	
C/No uplink	61,5	dBHz
Downlink	138,0	MHz
Signal power	7,8	dBW
Free space loss	- 145,6	dB
Other losses	- 5,0	dB
G/T terminal	- 36,2	dB/K
C/No downlink	49,6	dBHz
Total link		
C/Io (example)	53,6	dBHz
C/(No+Io)	47,9	dBHz
Eb/No (BER 10^{-5})	4,4	dB
Margin	2,0	dB

7.2.3.1.2 User segment

7.2.3.1.2.1 Terminal characteristics

The user terminal transmits at VHF using DS-SSMA techniques (1 Mchip/s, QPSK) and depending on the scenario chosen receives either at VHF using DS-SSMA or at UHF using narrow band (28 ksymbols/s, BPSK or other to be defined).

The antenna is typically omni-directional, simple to implement and maintain. It complies with classical norms related to antennas used for terrestrial uses and depends on the final choice made for terminal implementation (e.g. containers, cars, etc.).

The terminal is designed for outdoor or indoor use and is powered either from an external source (e.g. truck battery) or internally (lithium or alkaline batteries).

Table 37(b): TAOS return link budget for scenario 1

Uplink	148,0	MHz
Data rate	1,2	kbit/s
Convolutional code	2,4	kHz
Spreading code	1,0	Mchip/s
Terminal EIRP	0,7	dBW
Free space loss	- 146,3	dB
Other losses	- 3,0	dB
G/T satellite	- 31,6	dB/K
Boltzmann	228,6	
C/No uplink	46,7	dBHz
Downlink	138,0	MHz
Signal power	- 6,0	dBW
Free space loss	- 146,7	dB
Other losses	- 4,0	dB
G/T Earth station	- 17,6	dB/K
C/No downlink	54,3	dBHz
Total link		
C/Io (example)	38,9	dBHz
C/(No+Io)	37,2	dBHz
Eb/No (BER 10^{-5})	4,4	dB
Margin	2,0	dB

7.2.3.1.2.2 Unwanted emissions

The conditions of the Radio Regulations will apply. More detailed information was not provided.

7.2.3.1.2.3 Physical considerations

Information on equipment safety and radiological protection was not provided.

7.2.3.1.3 Gateways

Information on gateway co-ordination, functionality, number, deployment and distribution was not provided.

7.2.3.2 Network operation

Information on general network operation, call setup/routing/handover/cleardown algorithms, inter-working, air interface, numbering and billing was not provided.

Regarding network control and monitoring, terminal emissions are controlled and limited by the Centre d'Exploitation. Dynamic flux control (limiting the number of simultaneous users) and individual access authorisation are taken into account in the definition of communications protocols.

7.2.3.3 Services specifications

7.2.3.3.1 Voice

TAOS does not provide a voice service.

7.2.3.3.2 Additional services

7.2.3.3.2.1 Data

User messages are transmitted in real time when the satellite passes over the gateway station and the mobile.

In the forward direction (towards the mobile) variable length messages of up to 256 bits maximum may be transmitted; in this direction, the system is dimensioned for an average message length of 128 bits. In the return direction variable length messages of up to 256 bits maximum may be transmitted; in this direction, the system is dimensioned for an average message length of 64 bits.

> NOTE: These message lengths are defined for user messages and do not include the protocol fields.

TAOS services delivery time (message or position reporting) depends on the type of service. Typically they will not exceed one hour for 90 % of the transactions.

7.2.3.3.2.2 Positioning/position reporting

A positioning/position reporting service is provided by dedicated measurements and algorithms on the TAOS radio links (i.e. Doppler/ranging) or through the use of an external system such as GPS.

TAOS dedicated positioning measurements have an accuracy of the order of magnitude of 1 km whilst the additional use of GPS will provide a resolution of 100 m.

7.2.3.3.2.3 Other services

TAOS offers no other services.

7.2.3.3.3 Quality and availability

No information was provided regarding system quality.

Defining system availability as the probability for the full system (five satellites and ground segment) to be operational, TAOS has a target availability of 0,8.

7.2.3.4 FCC or other national filings

No national filings exist at present although licence applications are planned for the future.

7.2.3.5 ITU/IFRB filings

TAOS has been notified by the IFRB under the name "S80-1" by the Administration of France. Relevant documents are:

- IFRB Notification (IFRB Bulletin, 15 December 1992);
- IFRB Weekly Circular 2002/12.11.91, Special Section AR11/A/756;
- IFRB Weekly Circular 2055/01.12.92, Special Section RES46/C/4.

7.2.4 Starsys (Starsys Global Positioning, Inc.)

7.2.4.1 Overall system description

The STARSYS system proposed by STARSYS Global Positioning, Inc. is a system providing data messaging, position determination and reporting with small, inexpensive user terminals intended to be built in millions of units. The system is being designed to employ 24 randomly distributed satellites in inclined orbits to provide world-wide coverage.

STARSYS Global Positioning provided a written input to ETSI and answered to further questions in writing.

7.2.4.1.1 Space segment

7.2.4.1.1.1 Frequency bands

The frequency bands proposed for the STARSYS system are as follows:

Table 38: STARSYS frequency bands

	Band
Service up-links	148,0 - 149,9 MHz
Service down-links	400,15 - 401 MHz
Feeder up-links	149,9 - 150,05 MHz
Feeder down-links	137 - 138 MHz
Intersatellite links	none

The bandwidth needs of the system are:

Table 39: STARSYS bandwidth requirements

	Bandwidth requirement
Service up-links	0,9 MHz (DS-SSMA, QPSK)
Service down-links	50 kHz (BFSK)
Feeder up-links	50 kHz (BFSK)
Feeder down-links	0,9 MHz (DS-SSMA, QPSK)
Intersatellite links	none

Modulation schemes other than those indicated in the table for service downlinks and feeder uplinks are under consideration.

7.2.4.1.1.2 Frequency sharing

Frequency sharing is within the provisions of the relevant provisions of the Radio Regulations relating to the bands under consideration, including the need to co-ordinate with other primary services and to limit

PFD levels and interference in certain cases. The sharing of the available band agreed with other systems is shown in figure 13, as provided by Starsys.

CCIR derived sharing and co-ordination procedures will be used in applicable bands.

7.2.4.1.1.3 Frequency re-use

Frequency re-use is provided on the return link by using DS-SSMA techniques. No time synchronisation is required.

7.2.4.1.1.4 Coverage/spot beam configurations

STARSYS provides world-wide coverage, not covering the polar regions. Coverage is provided within the coverage of one gateway on each satellite by one spot beam for each link (service and feeder). Common antennas may perform multiple functions (transmit and receive).

The STARSYS service is defined as global.

7.2.4.1.1.5 Orbits

Twenty four satellites are utilised, each in its own non-polar LEO orbit (i.e. 24 planes), and are characterised as follows:

Table 40: STARSYS orbit configuration

Orbit	Altitude (km)	Inclination	Number of Planes	Plane spacing (deg.)	Satellites per Plane
Inclined Circular	1 300	63	24	-	1

Orbit control is not used, and STARSYS states that this makes the constellation equivalent to a 12 satellite constellation with orbit control. The final trade-offs will be made when more accurate comparative figures on spacecraft cost and launcher availability and cost will be available.

Functionally, only one satellite is needed at a time to perform the STARSYS services (positioning achieved by Doppler and ranging techniques). The minimum mobile user link elevation angle is 10 degrees, while this angle is 5 degrees for gateway links.

The minimum deployment plan stated by FCC allows 6 years for the constellation build-up. Information on the phases of system deployment was not provided but Starsys state that this will depend upon their FCC licence.

7.2.4.1.1.6 Sample link budgets (forward and return direction)

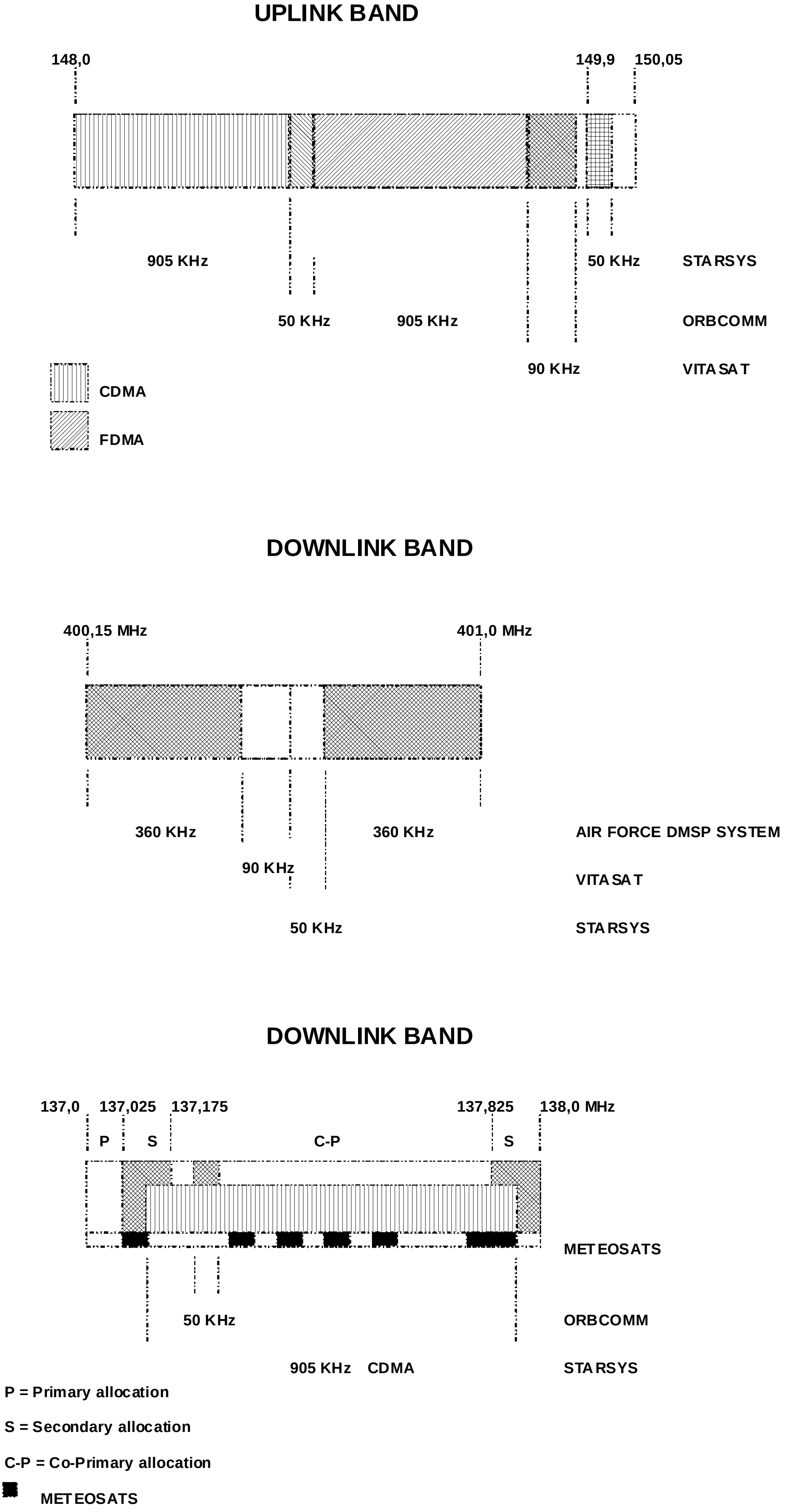
Sample link budgets were not provided.

7.2.4.1.2 User segment

7.2.4.1.2.1 Terminal characteristics

The user terminal receives at UHF, using narrow band techniques (28 ksymbols/s, BFSK). It transmits at VHF using DS-SSMA techniques (0,9 Mchip/s, QPSK), and is designed for short message (several 100 ms) transmitted with a low power (several Watts).

The principal elements affecting the terminal size and performance are use of the VHF frequency spectrum and the use of CDMA. The hand held terminal can be battery operated, there will be also versions integrated with other equipment installed on different "mobiles" (e.g. cars, containers, ships).



UPLINK BAND

DOWNLINK BAND

DOWNLINK BAND

Figure 13: Starsys frequency sharing

The antenna is typically omni-directional, simple to implement and maintain. It complies with classical norms related to antennas used for terrestrial uses (VHF/UHF mobile services, radio broadcasting).

The terminal is designed for outdoor or indoor use and is powered either from an external source (e.g. truck battery) or internally (lithium or alkaline batteries).

In most cases, the terminals will be unmanned.

7.2.4.1.2.2 Unwanted emissions

The conditions of the Radio Regulations will apply. More detailed information was not provided.

7.2.4.1.2.3 Physical considerations

Information on equipment safety and radiological protection was not provided.

7.2.4.1.3 Gateways

In the US region 2 to 4 gateways will be connected to one Exploitation centre operated by STARSYS GPI, in the European region 1 to 2 gateways will be connected to one Exploitation centre operated by CLS.

Information on gateway co-ordination, functionality, number, deployment and distribution was not provided.

7.2.4.2 Network operation

Information on general network operation, call setup/routing/handover/cleardown algorithms, inter-working, air interface, numbering and billing was not provided.

Regarding network control and monitoring, terminal emissions are controlled and limited by the Exploitation Centre. Dynamic flux control (limiting the number of simultaneous users) and individual access authorisation are taken into account in the definition of communications protocols.

Starsys do not foresee any interconnection with PSTN/PLMN.

Starsys GPI will be operator of the "space system" (satellites, gateways and exploitation centres), while Collect Localisation Satellites (CLS) will operate gateways and exploitation centres in Europe. Both companies will sell capacity to retailers (e.g. car rental companies, truck companies, etc.) who will in turn offer add-on services to end-users.

7.2.4.3 Services specifications

7.2.4.3.1 Voice

STARSYS does not provide a voice service.

7.2.4.3.2 Additional services

7.2.4.3.2.1 Data

User messages are transmitted in real time when the satellite passes over the gateway station and the mobile.

In the forward direction (towards the mobile) variable length messages of up to 256 bits maximum may be transmitted; in this direction, the system is dimensioned for an average message length of 128 bits. In the return direction variable length messages of up to 256 bits maximum may be transmitted; in this direction, the system is dimensioned for an average message length of 64 bits.

The transmission length complies with the FCC "Report and Order" specifying that transmission shall not exceed 450 ms.

7.2.4.3.2.2 Positioning/position reporting

A positioning/position reporting service is provided by dedicated measurements and algorithms on the STARSYS radio links (i.e. Doppler/ranging) or possibly through the use of an external system such as GPS, according to user's requirements.

STARSYS dedicated positioning measurements have an accuracy of the order of magnitude of 1 km on one transmission and of 100 m over a satellite pass.

7.2.4.3.2.3 Other services

Value added services will be provided by the Application Centres (retailers).

7.2.4.3.3 Quality and availability

With the non-controlled 24 satellite constellation the mean waiting time for data message transfer and delivery is of 5 min, with the waiting time never exceeding 15 min, 90 % of the time.

The location process may take a longer time as it may be necessary to wait until the geometric configuration of the satellite to user line has changed enough, depending on the accuracy needed this time varies between about 5 and 10 min.

Defining system availability as the probability for the full system (24 satellites and ground segment) to be operational, STARSYS has a target availability of 0,8.

7.2.4.4 FCC or other national filings

An FCC filing has been made for the STARSYS system on May 4, 1990.

7.2.4.5 ITU/IFRB filings

An IFRB filing for STARSYS is pending.

7.2.5 VITASAT (VITA, Volunteers in Technical Assistance)

7.2.5.1 Overall system description

The VITASAT system is proposed by the international organisation of Volunteers In Technical Assistance (VITA), an organisation providing technical support to about 5 000 volunteers in developing countries working with other organisations and government agencies. The system can be regarded as the evolution of an already operational data store and forward small satellite system. The prototype of the VITASAT satellites are under testing in the PacSat experiment, using UoSat-3 LEO satellites, launched in 1990. The system will provide store and forward data services (up to 380 pages) with very limited costs for ground stations and terminals. A network of about 500 ground stations is foreseen for the fully developed system.

The following details have been compiled from published and publicly available sources and have not been reviewed by the organisation proposing the system concerned.

7.2.5.1.1 Space segment

7.2.5.1.1.1 Frequency bands

The frequency bands proposed for the VITASAT system are as follows:

Table 41: VITASAT frequency bands

	Band
Service up-links	around 149,85 MHz
Service down-links	around 400,5 MHz
Feeder up-links	none
Feeder down-links	none
Intersatellite links	none

The bandwidth needs of the system are:

Table 42: VITASAT bandwidth requirements

	Bandwidth requirement
Service up-links	90 kHz
Service down-links	90 kHz
Feeder up-links	none
Feeder down-links	none
Intersatellite links	none

Information on access and modulation schemes is not available.

7.2.5.1.1.2 Frequency sharing

Information not available.

7.2.5.1.1.3 Frequency re-use

Information not available.

7.2.5.1.1.4 Coverage/spot beam configurations

Two satellites are employed. The coverage is global with a minimum of 2 passes every day for each satellite, service time during each pass is about 12 minutes, while the user terminal is in service interval up to 380 user data pages may be sent and stored on board. It can be estimated from subclause 5.1.5.3. that the worst case delivery time is 18 hours (time needed to have a descending pass after an ascending pass spaced 180 degrees apart, with an overlapping coverage, plus worst case time needed to enter satellite coverage).

7.2.5.1.1.5 Orbits

The VITASAT orbits are as follows:

Table 43: VITASAT orbital configuration

Satellite	Altitude (km)	Eccentricity	inclination (degrees)
1 - 2	815 to 796	0,153	99

7.2.5.1.1.6 Sample link budgets (forward and return direction)

Information not available.

7.2.5.1.2 User segment

Information not available.

7.2.5.1.2.1 Terminal characteristics

Information not available.

7.2.5.1.2.2 Unwanted emissions

Information not available.

7.2.5.1.2.3 Physical considerations

Information not available.

7.2.5.1.3 Gateways

Information not available.

7.2.5.2 Network operation

Information not available.

7.2.5.3 Services specifications

Data messages are stored on board and then transmitted to the destination station once in coverage. Two passes of the same satellite are guaranteed every day, total service time is about 48 minutes/day during which up to 820 data pages may be sent. Worst case message delivery time is 18 hours, and it is independent on the number of satellites employed.

7.2.5.3.1 Voice

No voice service is provided by the VITASAT system.

7.2.5.3.2 Additional services

No additional services are provided by the VITASAT system.

7.2.5.3.2.1 Data

Data service is store and forward. On board storage allows up to 380 data pages to be stored during each pass. Data are transmitted to the destination station as soon as it enters the satellite coverage area.

7.2.5.3.2.2 Positioning/position reporting

No positioning/position/reporting services are provided.

7.2.5.3.2.3 Other services

No other services are provided.

7.2.5.3.3 Quality and availability

Information not available.

7.2.5.4 FCC or other national filings

FCC recently recognised VITA as the first organisation to develop LEO communications technology by awarding the first "pioneer's preference" to its LEO system.

7.2.5.5 ITU/IFRB filings

Information not available.

7.3 Summary of S-PCN proposals

Table 44 indicates some of the key parameters of the S-PCN proposals above 1 GHz. Table 45 indicates some of the key parameters of the S-PCN proposals below 1 GHz.

The symbols used in these tables are as follows:

✓	Feature present;
×	Feature not present;
*	Information not provided by the organisation when asked;
-	Feature not yet technically defined or in definition;
(...)	Optional feature;
?	Information not available;
#	Depending on the configuration.

The following letters are used to describe orbit configurations; where multiple letters are used, all apply:

s	Sun synchronous;
p	Polar;
i	Inclined;
e	Equatorial;
h	Elliptical.

The following capital letters have been used to abbreviate access and modulation techniques:

CA	CDMA;
T	TDM;
TA	TDMA;
F	FDM;
FA	FDMA.

For example, TDM-CDMA becomes T-CA with this notation.

Table 44: Summary of S-PCN proposals above 1 GHz

Name Features		Aries	Diamond	Ellipso	Globalstar	IRIDIUM	Loopus	Odyssey	Inmarsat-P
S-PCN services	Voice	✓	✓	✓	✓	✓	✓	✓	✓
	Paging/Messaging	?	×	✓	✓	✓	-	✓	✓
	User Data	✓	✓	✓	✓	✓	-	✓	✓
	Fax	✓	✓	✓	✓	✓	-	✓	✓
	Positioning	✓	×	✓	✓	✓	-	✓	✓
	Posn. Reporting	✓	×	✓	✓	✓	-	?	*
Freq. Band	User terminal	L	L	L	L	L	L/Ku/Ka	L	L
	Gateway	C	Ku	C	C	Ka	Ku	Ka	C/Ku
	ISL	×	(optical)	×	×	Ka	×	×	(Ka)
Const-ellation	Orbit Type	LEO-p	HEO-i	LEO-hes	LEO-i	LEO-p	LOOPUS	MEO-i	-
	No. Satellites	48	3 → 6	8→14→24	8 → 48	66	9	12	-
	No. Planes	4	2	3 + 1	8	6	3	3	-
	Inclination (deg.)	90	63,4	116,5/0	52	86	63,4	55	-
	Orbit height (km)	1 020	Molniya	7 800/ 8 068	~ 1 400	~ 780	41 449	10 354	-
	Orbit period (h)	1,75	8 → 48	3/4,8	~ 2	~ 1,7	14,4	~ 6	-
Space segment	Earth coverage	100 %	1 → 3 R	<100 %	± 70°	100 %	5 R	<100 %	-/± 70°
	Satellite Mass (kg)	200	-	?	?	690	-	?	-
	Sat. lifetime (yrs.)	5	-	?	?	5	-	?	-
	1 hop delay (ms)	25	-	80	20	18	316	85	-
	ISLs	×	(✓)	×	×	✓	×	×	(✓)
	Srvc. coverage (%)	100	100	100	100	100	100	100	100
Ground segment	No. of gateways	?	-	#	~ 50	#	-	2/CONUS	-
	Deployment	?	-	#	#	#	-	#	-
	No. cntrl. centres	?	-	#	-	2	-	?	-
	TT&C	?	-	1/R	-	2	-	?	-
	PSTN int'connect	?	-	✓	✓	✓	✓	✓	✓
	PLMN int'working	?	-	✓	✓	✓	✓	✓	✓
	GSM int'working	?	-	?	✓	✓	✓	✓	✓
Terminal	Modulation	QPSK	-	*	-	QPSK	-	*	-
	Access	T-CDMA	-	CDMA	CDMA	F-TDMA	-	CDMA	CA/TA
	EIRP (dBW)	1/5,5	-	4	0	- 4,4/6	-	*	- 5/- 1
	Antenna gain (dBi)	- 2/2,5	-	*	2,5	1/3	-	*	*
	Hand-held	-	-	✓	✓	✓	-	✓	✓
	Portable	✓	-	✓	×	✓	-	*	×
	Transportable	×	-	×	✓	✓	-	*	×
	Vehicular	✓	-	✓	✓	✓	-	*	✓
Filings	National	✓	-	✓	✓	✓	✓	✓	×
	Nat. experimental	✓	-	?	?	✓	×	*	×
	ITU/IFRB	?	-	✓	×	✓	✓	✓	✓
Operation year		?	-	1995 →	1998	1998	-	1997	1998

Table 45: Summary of S-PCN proposals below 1 GHz

Name Features		LEOSAT	Orbcomm	TAOS	Starsys	VITASAT
S-PCN services	Voice	×	×	×	×	×
	Messaging	✓	✓	✓	✓	✓
	User Data	✓	✓	✓	✓	✓
	Fax	×	×	×	×	×
	Positioning	✓	✓	✓	✓	×
	Posn. Reporting	✓	?	✓	✓	×
Freq. Band	User terminal	VHF	VHF	VHF/UHF	VHF + UHF	VHF/UHF
	Gateway	?	?	VHF	VHF	×
	ISL	×	×	×	×	×
Const-ellation	Orbit Type	LEO-i+p	LEO-i+p	LEO-i	LEO-i	LEO-p
	No. Satellites	2 → 24	20	5	24	2
	No. Planes	?	3 + 2	5	24	2
	Inclination (deg.)	~ 45 + 90	40 + 90	55	63	99
	Orbit height (km)	970 + ?	970 + 970	1 250	1 300	815
	Orbit period (h)	1,74 + ?	1,74	1,84	1,86	1,66
Space segment	Earth coverage	100	100	3 R	100	100
	Satellite Mass (kg)	>50	?	150	?	?
	Sat. lifetime (yrs.)	?	?	5	?	?
	1 hop delay (ms)	18	18	20	20	18
	ISLs	×	×	×	×	×
	Service coverage	<100 %	<100 %	<100 %	<100 %	<<100 %
Ground segment	No. of gateways	?	?	*	#	0
	Deployment	?	?	*	#	×
	No. cntrl. centres	?	?	*	#	1
	TT&C	?	?	*	*	1
	PSTN int'connect	×	?	✓	×	×
	PLMN int'working	×	?	×	×	×
	GSM int'working	×	?	×	×	×
Terminal	Modulation	?	?	Q/BPSK	QP/BFSK	?
	Access	?	?	CDMA	CDMA	R-TDMA
	EIRP (dBW)	?	?	0,7	*	?
	Antenna gain (dBi)	?	?	*	*	?
	Hand-held	?	✓	✓	✓	?
	Portable	✓	✓	✓	✓	?
	Transportable	✓	×	×	×	✓
	Vehicular	✓	?	✓	✓	?
Filings	National	✓	✓	×	✓	✓
	Nat. experimental	?	?	×	×	✓
	ITU/IFRB	?	?	✓	✓	?
Operation year		end 90's	?	*	*	1990

8 Possible European standardisation of certain aspects of S-PCN

The principal aim of this ETR is to be used as a technical input to the process of decision making within Europe with regard to the areas in which S-PCNs might benefit from the development of possible standards.

This Clause has been approached from the definition of standards as voluntary; thus it follows that a consideration of the usefulness of a particular standard is not intended to impose a restriction or a limitation on any system provider or manufacturer. Instead, a study of possible standards has been made to try and identify areas where the existence of a voluntary standard could be useful to manufacturers or a system providers to provide a pre-defined and common framework, should they wish to incorporate a particular feature in their equipment or network. Possible standards could also result in benefits to the user community and be a way of easing the introduction of the new S-PCN services to Administrations and users; this should also be of benefit to the manufacturers and system providers. Standards could also be used as a basis for type approval.

This ETR seeks to be neutral on the issue of the desirability or otherwise of the development of any particular standard in any particular area; rather it seeks to present the options open to those who should take the final decisions regarding standardisation, presenting the consequences of standardising or not standardising in the different areas addressed. Thus, this Clause should enable decision takers to balance their decisions against the likely outcomes of such decisions.

When assessing the need for standardisation of S-PCN systems a number of important points should be borne in mind:

- for telecommunications terminal equipment a certain level of standardisation may be necessary to ensure compliance of the equipment with "essential requirements" established by Directives of the European Community;

- additional standardisation may be useful because of particular technical features of S-PCN systems, their use and their interworking with public networks, but this standardisation should remain voluntary and thus the need for it should be assessed in a detailed manner to ensure that it is really necessary.

If additional standards for S-PCN are to be implemented they should satisfy a number of requirements:

- because they are voluntary they should be required and supported by the organisations that will go on to implement them;

- they should serve recognised and useful functions; and,

- they should, at least for type approval purposes, be "measurable" (i.e. there is little sense in defining a standard if it is impossible to assess whether or not a piece of equipment meets it).

It should also be noted that not all technical standards areas for telecommunications equipment are the responsibility of ETSI (e.g. CENELEC is responsible for standards related to electrical safety). In this ETR, however, ETSI presents a broad review of many possible standardisation areas related to S-PCN, even where the areas are not ETSIs responsibility. This is done in order to offer a comprehensive "check-list" of areas where S-PCN standardisation might be considered, but this check-list always indicates where bodies other than ETSI have the lead.

It should also be noted that this is the first stage in a detailed review of standardisation aspects related to S-PCN in order to begin to define the areas within which more detailed work will need to be undertaken in the future. For this reason, the analysis presented in this ETR cannot be fully comprehensive in all cases, but often provides indications to directions where more detailed work is required.

A summary of the areas considered in this ETR for possible standardisation is shown in figure 14.

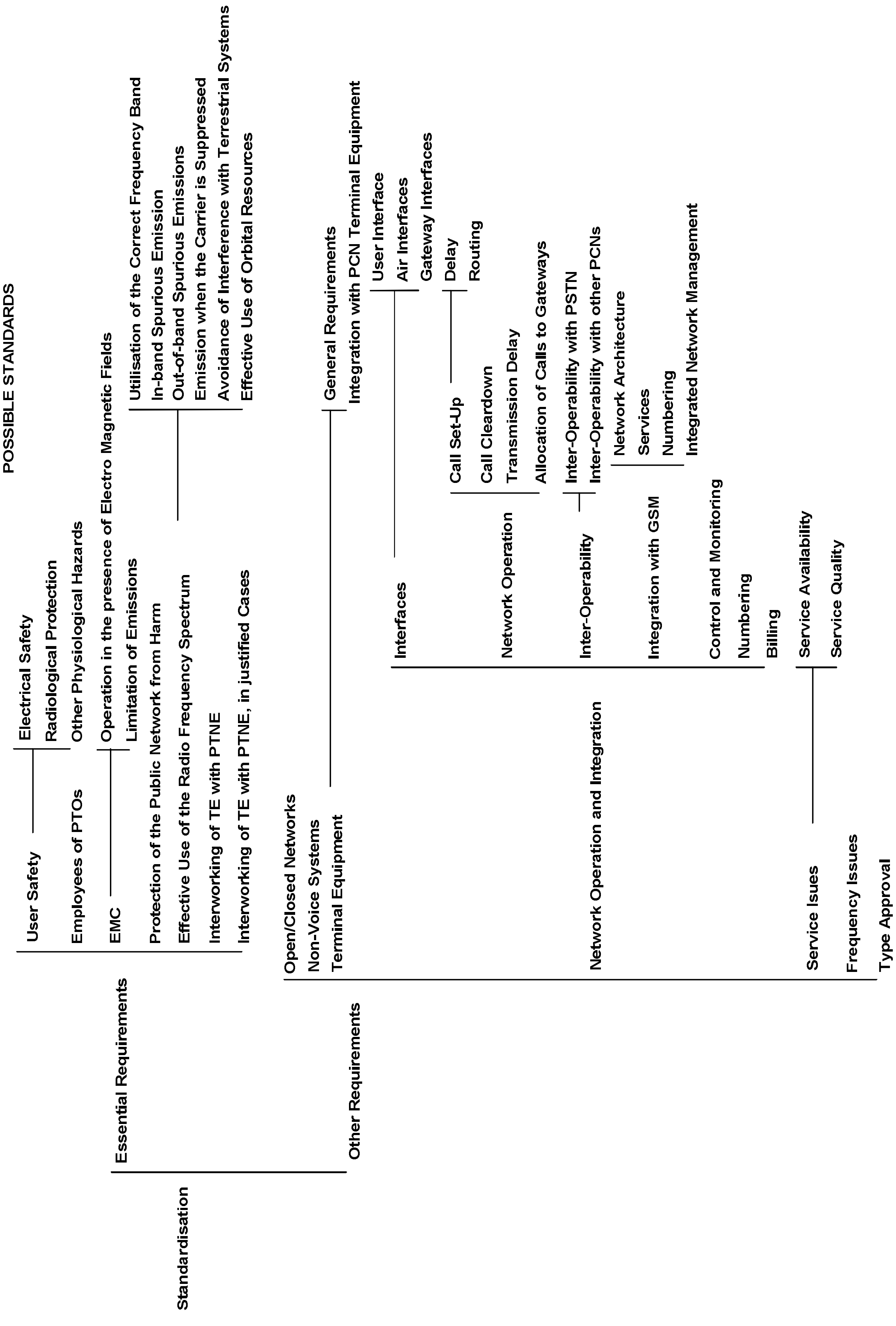


Figure 14: Framework for areas considered for possible European standardisation

8.1 Standardisation required to meet EC directives on "essential requirements"

Whilst the telecommunications standards produced by ETSI are voluntary in nature, some of them may go on to be adopted by the European Commission as the technical basis for conformance testing purposes as laid down in Directives or Regulations.

This is especially true in the area of telecommunications terminal equipment where the Commission is particularly active in promoting the development of a single market through the implementation of Directives setting down "essential requirements" that should be met by all terminal equipment.

8.1.1 "Telecommunications Terminal" Directive [10)]

This Directive defines a set of "essential requirements" that should be met by all telecommunications terminal equipment and is intended to allow free circulation and use (i.e. a single market) of terminal equipment that demonstrates conformity with the "essential requirements" by gaining type approval against a Common Technical Regulation (CTR). The "essential requirements" defined by the Directive are:

a) user safety insofar as this is not covered by the Low Voltage Directive;

b) safety of employees of public telecommunications networks operators, insofar as this requirement is not covered by the Low Voltage Directive;

c) electromagnetic compatibility requirements in so far as they are specific to terminal equipment;

d) protection of the public telecommunications network from harm;

e) effective use of the radio frequency spectrum, where appropriate;

f) interworking of terminal equipment with public telecommunications network equipment for the purpose of establishing, modifying, charging for, holding and clearing real or virtual connections;

g) interworking of terminal equipment via the public telecommunications network, in justified cases [11)].

The approval of terminal equipment to a CTR gives it the right of free circulation under the terms of the Directive without the application of further national procedures or national requirements within the scope of the CTR. Where no CTR applies to a particular terminal, there is no right of free circulation and national regulations apply, but because the "essential requirements" under the Directive still apply, it follows that the national regulations should not exceed the "essential requirements".

In order to harmonise the standards applicable to S-PCN terminal equipment and to ensure that national regulations do not exceed the "essential requirements" of the Directive, ETSI could begin to develop voluntary European Telecommunication Standards (ETSs) which encompass the areas of the "essential requirements" under the Directive.

The process for the production of a CTR to cover particular terminal equipment would begin by the European Commission giving ETSI a Mandate to develop the Technical Basis for Regulation (TBR). TBRs are expected to be based on existing and approved voluntary technical standards such as ETSs.

The decision to develop CTRs for S-PCN terminal equipment is the responsibility of the Commission and this ETR takes no view on whether or not such a decision should be made. Nevertheless, ETSI will need to develop harmonised voluntary standards to provide for the "essential requirements" and thus this ETR identifies those standardisation areas which fall under the scope of "essential requirements" and which could later be used by ETSI to enable the production of TBRs for S-PCN terminals, should this be required.

[10)] 91/263/EEC: Council Directive of 29 April 1991 on the approximation of the laws of the Member States concerning telecommunications terminal equipment, including the mutual recognition of their conformity.

[11)] "Justified cases" are defined as those where the terminal supports either a reserved service according to community law or a service for which the Council has decided that there should be a Community-wide availability.

In subclause 8.3 a review is presented of those areas where standards would need to be developed as "essential requirements" either to enable the development of TBRs for S-PCN terminal equipment, or to satisfy other Directives.

8.1.2 Proposed extension to the terminal directive [12)]

This proposed Directive extends the provisions of the Terminal Directive to specifically encompass SES equipment other than that forming part of the public telecommunications network infrastructure of a Member State.

The proposed extension ensures that the Terminal Directive applies to transmit/receive and receive only SESs but makes important additions to the "essential requirements", namely to ensure the effective use of orbital resources and the avoidance of harmful interference between space based and terrestrial systems.

The proposed extension to the Terminal Directive was published by the Commission on 8 January 1993; its status as it passes through the stages of discussion and approval needs to be monitored, as it has a direct impact on the possible standardisation of S-PCN.

8.1.3 Low Voltage Directive and Electromagnetic Compatibility (EMC) Directive

The Low Voltage Directive (with certain exceptions) applies to all electrical equipment which is designed for use with a voltage range between 50 and 1 000 V a.c. and between 75 and 1 500 V d.c. The Directive defines basic safety requirements (electrical and non-electrical) which equipment must meet. Equipment that meets these standards must not have its free movement within the Community impeded on the grounds of safety. The Terminal Directive extends the provisions of the Low Voltage Directive to telecommunications terminal equipment that would otherwise not be included because of its operating voltage range. Procedures within the Low Voltage Directive include "presumptions of conformity" and thus safety aspects are excluded from the scope of Terminal Directive CTR requirements since the Low Voltage Directive conformity procedures apply.

The EMC Directive defines EMC immunity and emission requirements for electrical equipment, including telecommunication terminals. In its normal environment, connected to the network, a telecommunications terminal is required by the EMC Directive to have appropriate immunity and emission characteristics for its intended application and in particular is required not to cause interference to telecommunications circuits. Within this fairly broad definition, proof of conformity is within the scope of the EMC Directive and is thus outside the scope of Terminal Directive CTR requirements. If, however, there are any EMC aspects specific to telecommunications terminals these must be considered within the scope of "essential requirements" for inclusion within the appropriate CTRs.

8.2 Possible standardisation in addition to that required by EC directives

The Terminal Directive, its proposed extension and their associated provisions define a framework within which the need for technical standards related to S-PCN terminal equipment may be identified. It is clear that, should the need for a CTR for S-PCN terminals be identified by the Commission, then the "essential requirements" should be incorporated, as a minimum, in the relevant standards that would need to be developed.

The need for further standards is much less clear. There are certainly arguments for concluding that no standards above those required by EC directives should be considered as this may impose unnecessary burdens on systems that will by their very nature be world-wide rather than specifically European. The converse to this argument is that additional standardisation may be useful because of the special nature of S-PCN systems and in particular their potential universality without regard for national boundaries and their need, in many cases, for close integration and interworking with the public networks. These additional standards could be regarded as an additional framework that might allow the development of S-PCN networks within Europe in a coherent and organised manner and would provide to system proposers and manufacturers clear guidance to ensure compatibility and interoperability of the systems they develop with elements of the public networks.

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12) 93/C 4/03: Proposal for a Council Directive on the approximation of the laws of the Member States concerning satellite earth station equipment, extending the scope of Council Directive 91/263/EEC.

It should be stressed that there is no necessity to implement any standards beyond those required to ensure conformity with the "essential requirements" under EC directives. Therefore decisions as to the need for additional standardisation should be taken on the basis of a broad consideration of the needs for such standards and the consequences that might arise from such additional standards being applied or not, as the case may be.

Subclause 8.4 provides a broad review of many areas in which it might be possible to envisage the development of technical standards and presents in a balanced way an initial analysis of the likely consequences of implementing or not implementing standards in each case.

This subclause can only be, because of its broad nature, an initial review of the options for standardisation. Through this initial broad review it is expected that a more focused viewpoint on the main issues concerned may be established. This should lead to a better definition of those areas where a more detailed analysis as to the pros and cons of standardisation may be undertaken.

8.3 Implementation of "essential requirements"

In the following sections each of the "essential requirements" relevant to the Terminal Directive and its proposed extension will be addressed in turn. For each requirement, a number of possible standards are proposed which could be used to demonstrate conformity with the requirement. The consequences of standardising and not standardising are not addressed explicitly, since it is assumed that standards should be developed to enable compliance of S-PCN terminals with the Directives to be demonstrated.

There is no clear ruling available to indicate precisely what particular standards are required to demonstrate compliance with each of the "essential requirements"; the proposals made in this subclause are not necessarily fully comprehensive and further detailed study is required.

8.3.1 "Essential requirement" on user safety

User safety of telecommunications terminal equipment, although an "essential requirement" is excluded from the scope of CTRs, since it is covered under other harmonised standards. Nevertheless, it would seem sensible for future work by ETSI to include a review of the applicable standards relating to user safety in order to see how they might be applied to S-PCN terminal equipment.

Standards that might be developed by ETSI in the future, particularly those for type approval of S-PCN equipment, could usefully contain references to the appropriate standards dealing with user safety, where these exist.

8.3.1.1 Possible standard on electrical safety

The definition of electrical safety standards for equipment, including terminal equipment is the responsibility of CENELEC. Where these standards are applicable to S-PCN terminal equipment reference could be included in ETSI standards; it is not expected that ETSI should develop any new standardisation in this area specifically for S-PCN.

8.3.1.2 Possible standard on radiological protection

The definition of radiological protection standards for equipment, including terminal equipment is the responsibility of CENELEC. Where these standards are applicable to S-PCN terminal equipment reference could be included in ETSI standards; it is not expected that ETSI should develop any new standardisation in this area specifically for S-PCN.

8.3.1.3 Possible standard on other physiological hazards

The definition of general physical safety standards for equipment, including terminal equipment is the responsibility of CENELEC. Where these standards are applicable to S-PCN terminal equipment reference could be included in ETSI standards; it is not expected that ETSI should develop any new standardisation in this area specifically for S-PCN.

8.3.2 "Essential requirement" on safety of employees of Public Telecommunications Networks O Operators (PTNO)

The requirements dealing with safety of employees should be broadly similar to those dealing with safety of users. Whilst it is certainly true that employees may react with equipment in a different way to users (e.g. opening equipment for repair purposes) the factors against which the employee must be protected are similar (electrical safety, radiological safety and other hazards). Thus it is necessary to consider if existing standards exist, e.g. within CENELEC, and to apply them to S-PCN terminal equipment in a manner similar to that under subclause 8.3.1 above.

It is not expected that ETSI should develop any new standardisation in this area.

8.3.3 "Essential requirement" on EMC

Under the Terminal Directive it is only necessary to consider as an "essential requirement" those elements of the EMC requirements that are specific to telecommunications terminals. Other requirements relating to EMC are covered by the EMC Directive and proof of conformity is assessed under that Directive.

Whilst the requirements of the EMC Directive are very broad and it may be that all elements relating to EMC conformity of S-PCN terminals can be dealt with under the terms of that Directive, it is necessary to consider if any additional factors need to be taken into account to meet the "essential requirement" of the Terminal Directive.

EMC areas "specific" to an S-PCN terminal might be considered to arise because of the fact that an S-PCN terminal contains a radio transmitting element and thus, as well as being more likely to radiate unwanted emissions there exists the possibility that a malfunctioning of the equipment due to the presence of other electromagnetic fields could lead to spurious transmissions and thus cause severe interference to other users of the radio spectrum.

In the following sections some initial thoughts regarding possible standards that might be useful to meet the EMC "essential requirement" are given. The need for the development of standards in these areas should be the subject of more detailed study.

It should be noted that responsibility for standardisation in matters relating to EMC is generally the responsibility of CENELEC, but where the equipment is a radio transmitter the responsibility is that of ETSI. Thus ETSI will have responsibility for defining EMC standards for S-PCN terminals and it may be possible to exploit existing work within ETSI in defining EMC standards for S-PCN.

8.3.3.1 Possible standard on the "normal" operation of terminal equipment in the presence of electromagnetic fields

It could be considered that, because of the anticipated ubiquitous nature of the S-PCN terminals the risks of problems such as interference to other users must be considered if the terminal is deflected from its "normal" operating state by the presence of electromagnetic fields in the environment.

This is not a new consideration, however, and will certainly have been faced when defining the standards for other hand-held radio terminals. The work already done in these areas within ETSI should be considered when the need for any special S-PCN standardisation (above that already imposed by the EMC Directive) in the area of EMC robustness is considered.

This is an area that requires more detailed study.

8.3.3.2 Possible standard on the limitation of emissions from terminal equipment

Work already existing within ETSI relating to terminal equipment that is similar in nature to S-PCN terminal equipment should be exploited to generate any necessary standards in this area. It should be noted that some possible overlap exists here relating to the definition of standards for spurious emissions from terminals under the "essential requirement" of protection of the RF spectrum.

Further study is required to identify any suitable work within ETSI which is of direct relevance to S-PCN and also to define the way in which spurious emission standards are to be dealt with.

8.3.4 "Essential requirement" on protection of the PTN from harm

This "essential requirement" deals with potential harm caused by improper characteristics of the equipment when used in its normal environment (rather than that caused by deliberate misuse).

In trying to define the standards that might be needed in to satisfy this "essential requirement" it is first necessary to define ways in which the characteristics of an S-PCN terminal might cause harm to the public network and, perhaps more importantly, to define the interface point at which the S-PCN terminal is deemed to interconnect with the public network for the application of the Terminal Directive. Thus it must be defined whether or not the terms of this "essential requirement" could impose a requirement on, for example, the S-PCN gateway as well as the terminal itself.

The scope and need for standardisation in this area needs to be clarified by further study.

8.3.5 "Essential requirement" on effective use of the RF Spectrum

For terminal equipment using radio frequencies, "essential requirements" in this area are intended to safeguard the effective use of the RF spectrum. The proposed extension to the Terminal Directive adds the effective use of orbital resources and the avoidance of harmful interference between space bases and terrestrial communications systems to this "essential requirement" .

The Directive is not explicit regarding the precise composition of the elements that should be considered to ensure that a terminal meets this "essential requirement" but elements such as utilisation of correct frequency bands, out of band emissions, in band spurious emissions with carrier on and off, frequency stability, etc. should be considered by ETSI.

ETSI will therefore need to develop standards, which might be based on already existing standards for similar equipment, which will ensure that the operation of S-PCN terminals meets the requirements of the Directive. The following possible standards relating to S-PCN terminal equipment should be considered for development by ETSI in order to meet the requirements of the Terminal Directive.

Sharing issues may fall within this "essential requirement" and this area needs further study (refer also to subclause 8.4.6).

8.3.5.1 Possible standard on the utilisation of the correct frequency band

The European harmonisation of particular frequency bands for particular services (within the scope of the Radio Regulations frequency allocations) is the responsibility of the European Radio Office (ERO) of the European Radiocommunications Committee (ERC) of the CEPT.

The ERO has already begun to develop a policy for the Mobile Satellite Services between 1 and 3 GHz [7] and this work should be taken into account by ETSI in identifying the relevant frequency bands for the application of standardisation for S-PCN systems.

ETSI could develop a conformance testing standard to meet the "essential requirement" to ensure that terminal equipment utilises the correct designated harmonised frequency band. This requirement could also be satisfied by application of a standard on out of band spurious emissions.

8.3.5.2 Possible standard on spurious emissions

Work to develop spurious emission standards for radio terminal equipment is being undertaken in a number of groups including CCIR, CEPT and ETSI. The definition of standards in this area is difficult, needing to balance the need to protect other users of the RF spectrum with the desire to enable terminal equipment to be developed at an economic cost.

A standard in this area may be necessary to provide for the level of protection that might be expected by a network operating in the vicinity of an S-PCN terminal.

In considering possible standardisation, ETSI could take into account work already existing in ETSI for similar types of equipment operating at different frequencies (e.g. DECT, GSM) and also for different types of equipment operating at similar frequencies (e.g. L-band low bit rate data terminals). Standards developed by ETSI should also take into account the relevant work from CCIR and CEPT.

8.3.5.3 Possible standard on emissions when the carrier is suppressed

It could be useful for ETSI to consider an additional standard relating to the level of carrier suppression when an S-PCN terminal is switched on but not transmitting. It is expected that there will eventually be a large user population of S-PCN terminals and the presence of any significant level of residual EIRP when the carrier is suppressed could lead to an interference problem leading to a restriction on the efficient use of the spectrum. It must be expected that a significant proportion of the population of S-PCN terminals that are switched on will be in the non-transmitting state at any given time. Any residual power radiated by these terminals will be received by the satellite and the aggregate effect of these residual powers could possibly be large when compared to the level of the carrier power.

Again ETSI should consider standards being developed in other groups and also work on other standards being made by ETSI such as DECT and GSM.

8.3.5.4 Possible standard on the effective use of orbital resources

If the extension to the Terminal Directive is implemented then a consideration of the effective use of orbital resources will become part of the "essential requirement" on effective use of the spectrum.

It is not clear at this stage how this requirement will be interpreted in the application of the Directive and the generation of standards, and clearly further work should be undertaken in this area.

One possible definition might be that an efficient use of the orbit resource maximises the number of co-frequency but separate systems that can operate within a given frequency band.

This definition is clear when related to the GSO, it is the ability to operate co-frequency satellite networks at the minimum possible orbital separation through the use of earth station antennas with suitable directivity (i.e. gain). The definition would also be appropriate for NGSO systems where the earth station has directivity. Relating this interpretation of the requirement to S-PCN terminal equipment with a near omnidirectional antenna operating to NGSO satellites poses some difficulties, since it is unlikely that more than one system can operate on one frequency due to the lack of isolation at the terminal.

Given that this requirement relates to terminal equipment it would seem inappropriate to propose standards that required a detailed analysis of the particular configuration of the orbit constellation supporting the S-PCN service since compliance with a standard of this kind could not in any case be easily demonstrated to the national testing authorities.

Nevertheless, it is possible to make some preliminary thoughts as to the kinds of technical standard that might serve to demonstrate compliance with this requirement. Such standards might include:

- for systems with directive antennas, a limit on the main lobe beamwidth and the roll-off of the sidelobes to ensure that RF power is directed primarily at the satellite of interest and does not, to an unacceptable degree, illuminate satellites in adjacent positions in the same orbit or in other orbits;

- for systems with directive and directable antennas, a limit on the beam pointing and tracking accuracy would also protect other satellites, particularly if this parameter is related to possible maximum rates of turn for hand-held and vehicle mounted equipment (these first two points are unlikely to be applicable to S-PCN terminals utilising near omni-directional antennas but may be appropriate for future generations of S-PCN terminals);

This area will require further analysis should the extension to the Terminal Directive be implemented. ETSI will need to establish what kinds of standard should be produced to enable effective use of orbital resources.

It will again be important for ETSI to take full account of the work being undertaken in other bodies such as CCIR and CEPT to define standards in this area.

8.3.5.5 Possible standard on the avoidance of interference with terrestrial systems

The possible consideration of the avoidance of interference with terrestrial systems as part of the "essential requirement" relating to effective use of the RF spectrum under the proposed extension to the

Terminal Directive must be considered in a way similar to that discussed for the effective use of the orbital resource in the previous section.

As before, it is not clear at this stage how the requirement will be interpreted in applying the Directive and further work will need to be undertaken in this area, particularly to define the types of standard that might be considered to demonstrate compliance with the requirement.

Much work regarding the avoidance of interference between satellite and terrestrial systems is being undertaken within other bodies such as CCIR and CEPT. On this basis it will probably not be necessary for ETSI to consider the development of any new standardisation, rather to refer to and apply suitable and relevant standards being developed within these other bodies.

8.3.6 "Essential requirement" on interworking of terminal equipment with PTN equipment for the purpose of establishing, modifying, charging for, holding and clearing real or virtual connections

The application of this "essential requirement" to S-PCN needs greater study. As has already been mentioned in subclause 8.3.4, the indirect connection of the S-PCN terminal to the public network through the satellite and gateway and the embodying of much of the functionality for call establishment etc. within the gateway leaves some uncertainty as to how this "essential requirement" should be applied.

If it is accepted that the provisions of this "essential requirement" apply to the interworking of the S-PCN with the public networks at the gateway interface point then there will clearly be a need for the development of some detailed standards to define precisely the basic functions of this interface in line with the "essential requirement".

The best way to proceed in this area could be to first clearly establish and define the scope of the Terminal Directive to S-PCN interconnect and then to develop the standardisation necessary to apply this scope to S-PCN.

The provisions of the ONP Directive 13) to provide voluntary standards relating to the interconnection with public networks needs to be considered in further study.

8.3.7 "Essential requirement" on interworking of terminal equipment via the PTN, in justified cases

If the service is defined as a "justified case" by the Commission (following procedures given in the Terminal Directive) then the end-to-end interoperability of terminal equipment via the public networks becomes an "essential requirement". In this case, the requirements cover only those characteristics which are essential for the correct operation of the service concerned and must not impose an unnecessary terminal performance or complexity.

It is noted that within the European Community "voice telephony" is already defined as a justified case, but it is not clear if this justification applies to S-PCN voice telephony services. This area requires more detailed study to determine its application to S-PCN and the resulting standards that might need to be developed.

8.4 Possible standardisation in addition to that required by EC directives

A consideration of the areas where additional standards might be useful (i.e. standardisation in addition to that needed to meet the "essential requirements" of EC directives) is more difficult to deal with.

Whilst the EC directives provide a clear but limited frame for a consideration of possible standardisation issues, the additional areas to be considered are very wide. Subclause 8.2 has described the basis on which this review of areas which might be considered for additional standardisation has been undertaken.

Areas identified here are those not covered by "essential requirements" set out in EC directives but still directly applicable to S-PCNs. Each area is examined in order to consider the possible consequences of the development and implementation of standards and the possible consequences of no standardisation.

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13) Draft Council Directive of 10 May 1993 on the application of Open Network Provision (ONP) to voice telephony.

The considerations regarding the voluntary nature and usefulness of any standards that might be developed (set out in subclause 8.1) must again be reiterated here. The possibilities and consequences of standards has been analysed from a consideration of standards as a useful framework to ease the development and introduction of S-PCNs rather than as a constraint on them.

The areas reviewed for possible standardisation are grouped into 7 categories to more clearly present the argument and to ensure that related items are considered together. They are:

- open and closed user group networks;
- voice and non-voice networks;
- terminal equipment;
- network operation and integration;
- service issues;
- frequency issues;
- type approval.

As has already been explained, this study only represents the initial review of the subject, thus any of these areas may possibly need further investigation.

8.4.1 Possible different standards regimes for open and closed user group networks

Open user group networks, are here considered to be those with public network interworking, closed user group networks are considered to be those not intended to have means to interwork with the public network (although closed user group networks may possibly be established through the linking of sub-networks through parts of the public network).

The regime established under the Terminal Directive is different for those networks that interwork with the public network and those that do not. It is proposed that in trying to consider the possible standards that might be implemented in addition to the Directive a similar difference is maintained.

The closed user group networks will only be used by members of those groups; there is no possibility of, for example, a PSTN originated call from outside the group being routed to a mobile terminal within the group. Thus the need to consider standards in areas dealing with maintaining quality and availability standards on public networks probably do not apply. In these cases the consequence of developing a detailed standards regime would probably be to place an unnecessary burden on the developers of these networks. Implementing only a minimum standards regime for closed user group networks would let the markets effectively decide the standards and would not, therefore, exclude the possibility of a service provider developing a cheap but low quality, low grade of service closed user group S-PCN application. The minimum standards regime for this kind of network probably only needs to contain those standards required within the framework of the "essential requirements" (i.e. guaranteeing user and employee safety, protecting other users of the RF spectrum, etc.); the other areas reviewed for possible European standardisation in this ETR probably are not applicable.

The open user group networks are effectively a full and integrated part of the public network. Calls may be routed from PSTN to mobile and from mobile to PSTN possibly without the knowledge of the user at the PSTN end that an S-PCN link is involved. Thus this kind of network requires a consideration of possible standards dealing with features that are already considered by other recommendations, that may be needed to ensure successful interworking between S-PCN and the public networks, or that are likely to be a part of the user expectations. This is likely to include areas such as:

- CCITT voice quality and delay;
- standards of interconnect networks (e.g. UMTS);
- user (fixed and mobile) expectations for availability and quality, call set up.

8.4.2 Possible different standards regimes for voice and non-voice systems

The same standards regime does not seem applicable to those systems providing voice services as to those providing only non-voice services (i.e. data, messaging, paging, etc.) owing to their fundamentally different features, as has been previously discussed.

It could therefore be envisaged as necessary to consider the provision of possible standards with parts explicitly specialised for each of the two systems or, as perhaps a better alternative, to address different standards explicitly to each class of systems. For those non-voice systems intended to inter-operate with terrestrial non-voice systems it could at least be required that the protocols adopted comply with those adopted in the terrestrial part.

8.4.3 Possible standard on terminal equipment integration with other PCN terminals

It is envisaged, as seen in the previous Clause, that the S-PCN terminal may be "integrated" with other mobile terminals in order to add flexibility to the services provided. The comparative analysis of the functional requirements of the S-PCN terminal and of other PCN terminals may lead to the identification of a common set of requirements to be satisfied by the same functional subsystems.

A standardisation of some (if not all of) the functional requirements could usefully lead to a re-use of technologies, subsystems of other PCN-terminals or functions already specified for other terminals (e.g. GSM). An example of such an approach could be the adoption of a common profile and functions in the Subscriber's Identity Module (SIM) of the terminal.

The consequence of no standardisation could be that the level and means of integration between S-PCN terminals and other PCN terminals would be left to the manufacturer or system provider. In the simplest case the integration might simply be to put two entirely separate terminal units into a single case; the most complex integration would be full integration as explained above. It might, then, be expected that system designers would make full re-use of terminal technologies, subsystems and functions as part of a sound engineering design and thus a standard to set out how to do this might then perhaps not be of particular use.

8.4.4 Possible standard on network operation and integration

8.4.4.1 Interfaces

This subclause considers those standards options related only to interfaces. The most important identified are the:

- user interface;
- air interface;
- gateway interface.

8.4.4.1.1 User interface

The user interface is the interface visible to the subscriber and through which the terminal equipment is operated.

Possible standardisation in this area could specify functional requirements to ensure that users find it simple to:

- operate the terminal;
- place a call.

(e.g. in order to ensure a market as wide as possible), taking into account possible intrinsic differences between an S-PCN terminal and other PCN terminals. This means having certain indicators or meters or functions that provide a user interface as similar as possible to that of other S-PCN terminals. The S-PCN terminal could have therefore at least the same complexity level to operate as any other PCN system.

This standardisation might be useful given the possible complexity of operation of S-PCN networks which could be designed so as not to be apparent to the user (e.g. the need to acquire the satellite without the user pointing the terminal or the provision of an easy way to find out where the system coverage is suited to establish a voice channel). Thus a standard could provide for a minimum set of functions or operating modes that a customer could expect to find on an S-PCN terminal.

The consequences of no standardisation may not be significant if in any case manufacturers are expected to design their S-PCN terminal equipment to be simple to operate by taking into due account the functions needed to provide a simple user interface.

8.4.4.1.2 Air interfaces

The air interface considered here is the radio signal format adopted for establishing the user service radio links.

A standard for the air interface could effectively imply the need to produce a GSM type specification. Possible standardisation in this area might cover areas such as:

- modulation and access methods;
- signalling;
- data framing and format;
- bit rates and coding.

Standardisation of this kind could have consequences similar to those of GSM, e.g. that no one manufacturer would be able to dominate the S-PCN market because they hold the IPR but it is likely to delay the implementation of S-PCN for some time whilst the required standards are written (i.e. manufacturers may stop their development work until the precise nature of the resulting standards becomes clear). A standard European S-PCN air interface (provided that it was adopted by system providers world-wide) could make possible inter-operability between different systems possibly giving the user the choice of:

- service provider;
- system provider.

(Perhaps through the use of a system specific smart card in a generic handset). This could enhance competition, could protect user investment in terminal equipment in the event of a system provider ceasing to operate, and could lead to possible lower end-user costs.

A clear consequence of not developing specific European standardisation for the air interface would be to recognise that the air interface forms a key part of the global study activities being undertaken by manufacturers to develop their own unique solutions in this area. The establishment of a standard for the air interface, although it would still be voluntary, might be expected to impose too great a restriction on the development of novel approaches by system designers and in any case such a standard might not be supported by manufacturers who wish to implement global systems incorporating their own IPR. No standards could also mean that a number of potentially very different systems could be implemented in an incompatible way, leading to possible difficulties in integrating S-PCN terminals with other mobile terminals (e.g. each manufacturer or system provider would have to independently develop their own approach to integrate an S-PCN terminal with a GSM terminal resulting in a number of different, non-standard techniques).

8.4.4.1.3 Gateways interfaces

The gateway interface is the interface between the S-PCN gateway earth station and the PSTN/PLMN.

If an S-PCN system is to be interconnected with a public network then a standard for some key features, if not all of, the gateway interfaces could be useful to:

- ease the process of integration (particularly if several S-PCN systems are to be integrated);
- guarantee the protection of the PSTN side and the capability of Administrations to plan the development of the mobile part of PCNs;
- allow multiple manufacturers to supply hardware for the gateway and gateway interface.

It should be noted that the basic functions relating to public network interworking may be dealt with under an "essential requirement" (see subclause 8.3.6); but see comments made in that section regarding the applicability of the Terminal Directive to the S-PCN gateway/PSTN interface.

Because there are likely to be a number of competing S-PCN systems which require a public network interconnect, a standard could be useful to Administrations, public network operators and S-PCN system providers in defining a common set of functions and interfaces that could be provided to ensure correct interworking and transparency of the PSTN/S-PCN interface to the particular S-PCN system involved.

The consequence of no standard would be to leave the choices on they key features of the interconnection to be defined and agreed individually between S-PCN system providers and Administrations/public operators each of whom may have different requirements. This in itself is not a major impediment to the successful integration of S-PCN with the public networks but it does mean that different solutions may need to be found to allow the interconnection of different S-PCNs to the PSTN. In this regard, it must be considered that in any case the S-PCN proposals from the different organisations are quite different, and different interconnect approaches are envisaged (ranging from a deep integration with S-PCN effectively being an extension of each national PLMN to a high level interconnect on the international side of the ISC). Thus a common approach to gateway interfacing may not be appropriate even if it is deemed desirable.

8.4.4.2 Network operation

8.4.4.2.1 Call setup

The call setup (phase) is the set of procedures followed to establish a call through the S-PCN.

Possible standards on the call setup phase might consider several areas, they are:

- call setup and processing delay;
- routing of the call.

Once again, elements of standardisation related to call setup may fall within the scope of the Terminal Directive (see comments made in subclause 8.4.4.1.3).

8.4.4.2.1.1 Call setup delay

The call setup (phase) delay is the delay from the access request issued by the terminal equipment to the assignment and use of the traffic channel by the terminal.

A standard could be useful to define the parameters necessary to ensure:

- meeting CCITT recommendations for telephony;
- delay for channel acquisition for data communication (possibly making a distinction between voice and non-voice systems);
- satisfactory PSTN interconnect (i.e. call setup within times expected by the PSTN).

Having no standards could pose some problems when considering PSTN interconnections but could give the service provider the flexibility to define a level of service. This could allow the S-PCN system provider to develop approaches that provide a setup delay driven by the markets (i.e. what the customer is prepared to tolerate and to pay for) whilst still ensuring PSTN compatibility).

8.4.4.2.1.2 Call setup routing

Routing at call setup time is considered here to be the choice of system through which the call will be established, if more than one system is available (e.g. the terrestrial cellular and the S-PCN).

Some possible aspects relevant to standardisation are those related to the choice of routing at call setup time (1st/2nd choice routing) for a GSM/S-PCN dual mode terminal. Routing could be made on the basis of:

- unified link quality algorithm;
- user choice (e.g. due to different charging);
- first choice GSM/cellular satellite on call drop or busy tone (congestion);
- other algorithms (based on other parameters to be defined).

One or more of these options could be considered by the standard in order to protect national GSM operator interests, if the S-PCN traffic is intended to be additive with respect to the cellular terrestrial traffic.

The decision to impose a "standard" such as the requirement to offer all mobile originated calls first to the terrestrial network and only to route via S-PCN if the terrestrial network is not available might be more appropriate to national licensing or regulations (if the national Administration wishes to protect the monopoly position of its PLMN operator) rather than to be a voluntary technical standard.

8.4.4.2.2 Call cleardown

Call cleardown is the procedure followed to terminate a call from either party (calling/called).

Again, this aspect may fall within the terms of the Terminal Directive (see comments under subclause 8.4.4.1.3).

A standard in this area could strictly define the call cleardown procedure to allow call cleardown from PSTN terminals as in any PSTN connection.

No standard could perhaps restrict PSTN interconnect possibilities but could leave the flexibility to the service providers, to develop their own designs to ensure PSTN interworking.

8.4.4.2.3 Transmission delay

The transmission delay is the system end to end delay of the connection (including any processing delay introduced by the terminal, satellite or gateway) provided by the system.

A standard on the end to end transmission delay could provide:

- delay within CCITT recommendations on voice communication channels;
- compatibility with data transmission protocols not specifically intended to operate on S-PCN mobile channels;
- meeting the requirements of echo cancellers;
- meeting of user expectation for PSTN originated calls when caller is not aware of routing via S-PCN.

No standards may be a way to balance the S-PCN quality with the ubiquitous availability of the service. This may lead to a certain service degradation but make the system easier to implement and could permit the system provider to balance the degradation against the customer expectation and willingness to pay more for a better system.

8.4.4.2.4 Allocation of calls to gateways

Allocation of calls to gateways is here the result of an algorithm that associates the call (the calling terminal) to a gateway earth station, from beyond which terrestrial tails are occupied by the call in a mobile to fixed call relationship.

This is perhaps a critical area because it touches on political and regulatory aspects that are essential for the S-PCN operation. These issues are difficult to overcome but have to be decided before any decision is taken on the actual system operation parameters, addressed in the other subclauses of this Clause. The capability of a system to cope with administrative borders (trans-border operation) and carriers rights and the recovery from a temporary unavailability of gateways is among the areas that could be addressed.

A possible standardisation in this area could be required by Administrations and PTOs in order to preserve the national carrier rights inside the sovereign area. Areas that could be considered are numerous:

- terms, permission and conditions to operate an S-PCN gateway within the national territory;
- assignment algorithm of mobile terminals to a national gateway to ensure compliance with national carrier rights;
- assignment algorithm of mobile terminals to a specified gateway when a national gateway is not operated or is temporary unavailable;
- monitoring of the traffic and of other network parameters;
- monitoring of the amount of space segment utilisation (particularly when is leased by an Organisation);
- allocation of a S-PCN call originated in one country to a gateway of that country.

As with issues relating to call set-up routing (subclause 8.4.3.2.1.2), these may well be matters more appropriately dealt with through national licensing or regulations rather than through a voluntary standard. No standards (or no accepted rule of any kind) in this area may turn out to be incompatible with national sovereign rights desired by some countries Administrations. However, no restrictions on the allocation of calls to gateways would leave the flexibility for the S-PCN system provider to offer the most flexible service to users, probably resulting in lower costs to users and may also allow full competition of service providers through Europe.

8.4.4.3 Inter-operability

8.4.4.3.1 Inter-operability with PSTN

Inter-operability is here intended as it has been defined and discussed in subclause 5.2.5.

Again this area may be partly covered by elements of the Terminal Directive (see subclause 8.4.4.1.3).

Additional standardisation in this area could possibly define useful features for the support of S-PCN by the PSTN; such as:

- capacity needed for S-PCN operation;
- a possible common set of services defined throughout all PSTN supporting S-PCN;
- further routing requirements, e.g. compatibility of a LEO call with a further GSO hop within PSTN or other routing.

The consequences of this type of standard could be to define clearly to PSTN operators the range of services and functions that could be expected from an interconnected S-PCN.

No standards could leave the flexibility to determine the services offered, routing compatibility etc. by agreement between S-PCN operators and the Administration where PSTN interconnect occurs, again allowing system providers to offer only those services and features required by the market.

8.4.4.3.2 Inter-operability with other PCNs

This area could be regarded as a case of inter-operability to which comments similar to those given in the previous subclause 8.4.4.3.1 apply.

Standardisation in this area could possibly define useful features for the support of S-PCN by PCN, such as:

- capacity needed for S-PCN operation;
- a possible common set of services defined throughout all PCN supporting S-PCN;
- further routing requirements, e.g. compatibility of a LEO call with a further GSO hop within PCN or other routing;
- roaming issues;
- billing and numbering.

No standards could be preferable if, possibly after further investigation, it is concluded that applying standards in areas above mentioned would not bring substantial benefits to the development of the satellite component of personal communications. In this case, as elsewhere, it has to be balanced the possible delay caused by developing and approving standards with the benefit that it is expected to derive from them.

8.4.4.4 Integration with GSM

Integration with GSM is an inter-operability of particular interest in the European context. It involves a system, GSM, in the stage of deployment and expected to deeply penetrate into urban as well as some sub-urban environments in the European region.

Four broad areas could possibly be considered when defining European options for standards, especially considering the expected level of development of the GSM network when S-PCN comes into operation. They are:

- network architectures;
- services;
- numbering;
- network management.

8.4.4.4.1 Network architectures

A set of standards in this area could ensure that S-PCN architectures are developed in a highly compatible way with GSM even if the S-PCN is developed as a separate world-wide PLMN.

Especially considering integration at network level (refer to subclause 5.2.5) it is necessary to underline the usefulness of approaches that allow to re-use network planning and existing infrastructures such as:

- Mobile Switching Centres (MSCs);
- Gateway Mobile Switching Centres (G-Mscs);
- network registers;
- Operation & Maintenance Centres (OMCs).

No standards could allow the operator to determine the requirements for GSM integration, choosing the level of integration, (possibly providing a low level of integration). This might result in potential lower-cost S-PCN service but at the expense of a possible non-homogeneous service through Europe (or other regions where GSM standards would be adopted in the future). In cases where deep integration is required by S-PCN system providers it might be expected anyway that they would design their networks to re-use existing terrestrial infrastructures (so as to reduce costs) and thus standards in this area may not be particularly useful.

8.4.4.4.2 Services

Services are here S-PCN basic services, such as authentication and security services, user services (possibly other than voice), such as short messaging service, and personal communications services (refer to subclauses 4.3 and 5.2.5.4.).

The consequences of standardisation in this area could be to ensure that some (if not all) S-PCN services will be developed in close compatibility with the present and future development of some GSM protocols (such as the Mobile Application Part, MAP). Additionally, there is the possibility to re-use existing GSM protocols, exploiting the possible similarities between two digital mobile communication networks. A suitable set of GSM services could be therefore identified and a set of S-PCN services could be defined consequently.

No standardisation could disadvantage European interests in developing the GSM network and its successors, such as DCS 1800, but such disadvantage needs to be balanced against the possible restrictions on the development of S-PCN networks that such standards could bring if a strong momentum will be decided in favour of S-PCN in Europe.

8.4.4.4.3 Numbering

A standard could provide a clear definition of numbering plans within the S-PCNs to enable them to be compatible with GSM numbering. Two cases are possible:

- where the S-PCN is an autonomous PLMN;
- where the S-PCN has to be considered as an extension of GSM coverage inside each PLMN.

In either cases, the numbering plan could define:

- an identification plan for mobile subscribers in the GSM/S-PCN integrated system;
- principles of assigning telephone and ISDN numbers to mobile stations in the country of registration of the mobile station (for card operated terminals the number is assigned to the holder of the card, PN);
- principles of assigning mobile station roaming numbers to visiting mobile stations;
- an identification plan for location areas and gateways in the GSM/S-PCN integrated system;
- an identification plan for MSCs and location registers in the GSM/S-PCN integrated system;
- principles of assigning international mobile equipment identities (such as Type Approval Code, TAC, Final Assembly Code, FAC, Serial Number, SNR).

Relevant GSM recommendations could be considered in this scope, in particular Recommendation GSM 03.03 [21] on "Numbering, Addressing and Identification", based on CCITT Recommendations E.213 [22], E.164 [23] and X.121 [24].

No standards could mean that the S-PCN operators are free to determine if GSM numbering compatibility is necessary for their systems and only to provide it if necessary. Although this could perhaps result in an inhomogeneity of S-PCN numbering inside Europe, this could be of little consequence if the only networks which did not have a GSM numbering homogeneity were those that, by definition, did not need it.

8.4.4.4.4 Integrated network management

Standards could possibly be useful to European operators who want to ensure an homogeneous operation and maintenance procedure through the S-PCN integrated with the national GSM network (fault alarms, isolation and recovery, capacity management, etc.).

No standardisation might lead to a reliance upon the existence of external operation and maintenance centres to support S-PCNs but this could again be a matter for agreement between S-PCN operators and national Administrations. It could be in the interests of S-PCN operators to integrate their network management facilities with those of the terrestrial operators in order to reduce costs, without the need of standardisation to ensure this.

8.4.4.5 Control and monitoring

A standard in this area could address control and monitoring parameters and the definition of what functionalities and components of the network could be subject to control and monitoring by the operators in Europe. In particular co-ordination of the communication network and routing algorithms could be of great interest for national operators. Also security management and location area identification and monitoring have been identified as areas where operators may have an interest in strong standards. Areas that could be subject to further study (refer also to subclauses 5.2.5 and 5.2.6) are:

- communications network co-ordination;
- administration LA identification and monitoring;
- routing algorithms;
- authentication management;
- security management;
- mobility management;
- capacity management;
- user management;
- network deployment and development;
- fault tolerance, detection and management.

Additional standardisation in the terminal equipment area might be useful to define control and monitoring functions that could benefit from a clear and standard approach. Consideration could be given to different topics such as:

- disabling transmissions of defective terminals (tele-disabling);
- control of frequency band usage to avoid specific sharing problems in specific geographical areas (e.g. avoidance of interference to RAS by leaving specific channels unused near to RAS sites).

Consideration could also be given to the minimum level of standards needed to satisfy national Administrations that effective control and monitoring for regulatory purposes could be achieved although this might be better dealt with through national licensing and regulations by those Administrations who require this kind of control and monitoring facility. Thus no standardisation in this area could be considered to be of little consequence.

8.4.4.6 Numbering

A standard in this area could be considered in the frame of already existing international standards, but also taking into account the differences between S-PCNs and other mobile networks. Areas that could be considered are:

- numbering plan structure;
- numbering plan requirements.

The absence of standards would leave these matters for agreement between S-PCN operators and national administrations.

8.4.4.7 Billing

As S-PCNs are expected to involve a great deal of signalling, as other mobile networks, standards in this area could focus on the requirements in terms of network resources while the actual billing procedures are more an operational matter. Areas that could be considered are:

- global billing requirements;
- local billing centres;
- billing co-ordination.

The billing procedures are a complex matter, involving a layered structure, that will require further study.

8.4.5 Possible standard on service issues

8.4.5.1 Service availability

A standard in this area could establish requirements for an acceptable level of services to be provided. Several elements could be considered (see Annex C). In particular the service availability is a result of the combination of the availability of several components depending on the S-PCN network architecture (refer to subclause 5.2.2.2). This could guarantee to national operators their investments and set the basis for the evaluation of the requirements for the general satellite component of UMTS.

No standard could let the service provider agree with the operator or the customers the availability of the service provided and this could have an impact in reducing user cost. But again, taking into account the ubiquity of S-PCN service this could lead to inhomegeniety when considering different operators networks. In Europe the situation could be worsened by the large number of national operators within the same region.

8.4.5.2 Service quality

A standard in this area could be based generally on some assumptions on service availability, as the service quality concept generally includes link nominal quality and link availability. Service quality could be defined for a subset (or every) service, taking into account already existing standards for other mobile services, setting limits to (acceptable) services balancing the quality with the ubiquitous availability of the channel.

Another option could be to draft a recommendation on how to measure service quality, leaving the issue of applying the measure to specific S-PCN services open for further discussion.

The consequences for having no standards are similar to those given for service availability. No standard could let the service provider agree with the operator or the customers the quality of the service provided. Taking into account the ubiquity of S-PCN service this could lead to inhomegeniety when considering different operators networks. In Europe the situation could be worsened by the large number of national operators within the same region.

8.4.6 Possible standard on frequency issues

A number of frequency issues are contained in the "essential requirements", but other matters relating to use of frequencies such as frequency co-ordination and the avoidance of interference between NGSO systems and between NGSO/GSO systems, although important (refer to subclause 4.5), have been considered here to be outside the scope of standardisation in ETSI as they are the responsibility of other global and regional bodies such as ITU and CEPT. These areas are listed below:

- frequency co-ordination with other NGSO systems;

- frequency co-ordination with other GSO systems;

- sharing methods, criteria, interference avoidance and interference tolerance.

However, standards that might be developed by ETSI in the future, could perhaps usefully contain references to these international regulations, where they exist.

8.4.7 Possible standards on type approval

Possible standards for type approval would be expected to contain a number of elements which are already described in the previous sections. These elements would, at a minimum, include the "essential requirements" for the terminal equipment, additionally if a decision is taken on standardisation of other areas under subclause 8.4 and where they are relevant to terminal equipment, they would probably have to be included in the type approval standard.

The need for type approval standards for other network components such as:

- system type approval;

- gateway earth station type approval;

- network control and monitoring type approval;

- database type approval;

should be the subject for further study. Furthermore, the elements which would be contained in such additional type approval standards also need to be determined. The complexity of such a task should not be underestimated.

9 Intellectual Property Rights (IPRs)

This Clause provides the current status of work within ETSI regarding Intellectual Property Rights (IPRs) and standards making policy. The position of ETSI is summarised with particular reference to identification of IPR holders and ETSI ownership of IPRs. Because of the complexity of the subject and the limited time available is not possible to provide any greater level of detail at the present time. Detailed description of the IPR Undertaking can be found in the ETSI document "Intellectual Property Rights Policy and Undertaking" [8].

9.1 Development of IPR policy

ETSI General Assembly (GA) has established an interim IPR Policy, coming into effect on the 1st April 1993, for a minimum duration of 2 years. The definitive IPRs Policy will be defined not later than 4 years from the date of adoption of the interim Policy. During this period the application of the interim Policy will be evaluated and, if necessary, a modification of the present Policy will be decided.

9.2 IPR definitions

IPR definition includes the definition of the terminology. Terms mentioned in the IPR Policy have the meaning set in the following, briefly summarising the most important.

"IPR" means any intellectual property right conferred by statute law including applications therefor other than trademarks. For the avoidance of doubt rights relating to get-up, confidential information, trade secrets or the like are excluded from the definition of IPR.

"Essential" as applied to IPR means that is not possible on technical but not commercial grounds, taking into account normal technical practice and the state of the art generally available at the time of standardisation, to make, sell, lease, otherwise dispose of, repair, use or operate Equipment or Methods which comply with a Standard without infringing that IPR. For the avoidance of doubt in exceptional cases where a standard can only be implemented by technical solutions, all of which are infringements of IPRs, all of such IPRs are considered Essential IPRs.

"Equipment" means any system, or device fully conforming to a Standard.

"Methods" means any method or operation fully conforming to a Standard.

"Standard" means any standard adopted by ETSI including options therein or amended versions and includes European Telecommunication Standards (ETSs), Interim ETSs (I-ETSs) and parts of "Normes Europeenes des Telecommunications" (NETSs), Common Technical Regulations (CRTs) which are taken from ETS, I-ETS or Technical Basis for Regulation (TBR), and including drafts of any of the foregoing, the technical specifications of which are available to all Members, but not including any standards not made by ETSI which may be referenced in such NETs or CTRs. The date on which a Standard is considered to be adopted by ETSI for the purposes of IPR Undertaking is the date on which the technical specification of that Standard was available to all ETSI Members.

"Standards Application Area" means all countries listed below and any and all countries whose national administration for telecommunications is, at the date of a request by a Party pursuant to Clause 2 of the Undertaking, a member of ETSI together with, in respect of a particular Standard, any other country in which:

- an officially recognised national standardisation body has formally adopted the Standard and implement it;

- a major telecommunications network operator has, or is about to, procure on a substantial scale, equipment to a specification compliant with that Standard.

Countries in the "Standards Application Area":

Andorra, Albania, Austria, Belgium, Bulgaria, Cyprus, Czechoslovakia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, Lithuania, Latvia, Estonia, Australia, New Zealand, Israel, Malta, Monaco, Norway, Netherlands, Poland, Portugal, Rumania, San Marino, Spain, Sweden, Switzerland, Turkey, United Kingdom, Vatican City, Yugoslavia.

9.3 IPR undertaking

Each applicant for membership of ETSI must sign the IPR Undertaking. The IPR Undertaking binds, on signature, in respect of all ETSI Standards. Any entity in the Standards Applications Area is entitled, at any time, without applying for ETSI membership, to apply to ETSI for the signature of an Undertaking similar to and with identical effect of the IPR Undertaking.

A detailed description of the IPR Undertaking can be found in Appendix A of the ETSI "Intellectual Property Rights Policy and Undertaking" [8].

9.4 Identification of IPR holders

When an Essential IPR relating to a particular Standard owned by an entity who is not a member of ETSI, or who is resident in the Standards Application Area and has given an Undertaking to ETSI of identical effect of the IPR Undertaking is brought to the attention of ETSI, the Director of ETSI immediately requests that owner to give a signed Undertaking in writing. The Undertaking must state that the owner is prepared to grant irrevocable licences to entities of all countries within the Standard Application Area to:

- manufacture, including the right to make or have made anywhere customised components and sub-systems to the licensee's own design for use in manufacture;

- sell, lease, or otherwise dispose of manufactured equipment in the Standards Application Area;
- use Methods in the Standards Applications Area.

9.5 ETSI ownership of IPRs

Regarding ETSI Standards, as stated in the ETSI IPR Policy and Undertaking.

"The ownership of the copyright in Standards documentation and reports created by ETSI or any of its Committees shall vest in ETSI but due acknowledgement shall be given to copyrights owned by third parties that are identifiable in ETSI copyrighted works".

With respect to IPRs other than copyright in Standards documentation and reports, ETSI seeks ownership only of IPRs generated by ETSI employees or secondees in ETSI from organisations who are not members of ETSI.

ETSI members and affiliates are allowed to use IPRs owned by ETSI free of charge.

9.6 Licensing

ETSI makes available, on request, standard model licences which have been approved.

When an entity who is a member of ETSI, or is resident in the Standards Application Area and has given and IPR Undertaking to ETSI, or does not in the previous two categories, notifies to ETSI that is not prepared to license an IPR in respect of a Standard the "Refusal to License " procedure applies. The mentioned procedure involves, as a first step, the Technical Assembly to review the requirement for the Standard and look for an available alternative technology not blocked by that IPR and satisfying ETSI requirements.

The signatory to the IPR Undertaking is entitled to refuse to grant a licence provided that certain conditions are fulfilled. Thus subclause 4.1 of the ETSI IPR Undertaking states:

> "4.1 The SIGNATORY is entitled to refuse the grant of licences for a STANDARD in respect of an IPR which it owns or controls on condition that the SIGNATORY has notified ETSI of:
>
> - the identity, in an unambiguous manner, of that IPR; and
> - the STANDARD to which that IPR relates;
>
> within 180 days after the date on which the Technical Assembly of ETSI decides to put into its work programme a draft STANDARD together with its precise scope and the milestones and target date of its elaboration.
>
> Where a work programme for a STANDARD is approved by ETSI's Technical Assembly before signature of the UNDERTAKING by the SIGNATORY any notification of IPRs as unavailable for licence must be made before signature of the UNDERTAKING.
>
> Where the Technical Assembly approves a substantial change to an item in the work programme, that is a change that can affect the IPR, the 180 day period will restart for that item at the date of that Technical Assembly."

If a licence from a third party is not available, with respect to a Standard, a suitable procedure starts, taking into account the interests of enterprises that have invested in the implementation of the Standard and possibly leading to action taken by European Community authorities.

9.7 Confidentiality, reproduction and violation of undertaking

Information submitted to all ETSI committee has to be treated as non-confidential and considered available for public inspection unless:

- when submitted the information is identified in writing as confidential; and

- the information is submitted and accepted by the Technical Committee or Sub-Technical Committee Chairman as confidential.

Starting from the date a Standard is published any confidential information possibly contained has to be regarded as non-confidential.

All members of ETSI may make copies of Standards documentation produced by ETSI for their own use free of charge but may not distribute such copies to others.

If an ETSI member violates an IPR Undertaking then the ETSI General Assembly has the authority to decide possible actions to be taken according to ETSI Statutes.

9.8 Preliminary S-PCN IPR areas

ETSI IPRs related to Standards are generally essential IPRs on Methods and Equipment features. IPRs relevant to S-PCNs will possibly be those related to other existing Standards or to an S-PCN proposed by an organisation. Most, if not all, of the S-PCN proposals come from private organisations. The number of proposal is relatively large (13 have been described in Clause 5), some of them are in direct competition because of the similarities in the type of service provided and the small amount of spectrum available. After the analysis of this ETR it can be concluded that the general common feature that groups together all these systems is the direct "public" access to the satellite resources from a large number of personal terminals to obtain a virtually ubiquitous set of services (as anticipated in subclause 4.2). Each system has IPRs associated to some of the technical solutions proposed to implement S-PCN. A Standard in areas presented in the previous chapter may have to embody Methods or other specifications for which an IPR already holds in which case the process set out in the previous sections would apply. Further study would be required as it becomes clear what standards for S-PCN will be developed and whether any of these standards will need to contain IPRs already owned by an organisation.

Annex A (informative): Frequency availability for S-PCNs

A.1 Service links

S-PCNs, whether operated from GSO or non-GSO orbits will utilise, for their service links, frequencies which are allocated to the Mobile Satellite Service (MSS). In allocating services to bands the Radio Regulations generally make no specification regarding the use of particular bands from particular orbits and thus in principle (and subject to a successful co-ordination) any type of orbit may be used by an S-PCN system operating at any frequency allocated to MSS.

It is true to say, however, that given the probable difficulty of co-ordinating NGSO and GSO networks, the bands newly allocated to the MSS at WARC-92 are likely to be of more interest to the NGSO operators and thus a de facto NGSO/GSO band segmentation may arise.

Following the conclusion of WARC-92 there is an increase in the spectrum available for MSS, but given that this spectrum must satisfy the requirements of "conventional" MSS from GSO as well as the demands of the emerging NGSO and GSO S-PCN systems it is by no means certain that sufficient spectrum is allocated to allow all proposed systems to co-exist.

Allocations to the MSS between 1 and 3 GHz are as shown in table A.1; note that allocations to non-generic MSS services (e.g. maritime, aeronautical) are omitted.

Table A.1: MSS frequency allocations between 1 and 3 GHz

Band (MHz)	link	Bandwidth (MHz)	availability
1 610 - 1 626,5	up	16,5	World-wide
1 613,8 - 1 626,5	down (secondary)	12,7	World-wide
2 483,5 - 2 500	down	16,5	World-wide
1 980 - 2 010	up	30	World-wide
2 170 - 2 200	down	30	World-wide
2 500 - 2 520	down	20	World-wide
2 670 - 2 690	up	20	World-wide
1 525 - 1 530	down	5	Region 2 / Region 3
1 626,5 - 1 631,5	up	5	Region 2 / Region 3
1 492 - 1 525	down	33	Region 2
1 675 - 1 710	up	35	Region 2
1 930 - 1 970	up (secondary)	40	Region 2
1 970 - 1 980	up	10	Region 2
2 120 - 2 160	down (secondary)	40	Region 2
2 160 - 2 170	down	10	Region 2

NOTE: ITU continental regions are the following 1: Europe and Africa; 2: Asia and Australia; 3: America.

The bands which may be regarded as being of principle interest to NGSO systems are 1 610 - 1 626,5 MHz and 2 483,5 - 2 500 MHz (i.e. those bands newly allocated globally, for immediate use, at WARC-92).

Below 1 GHz a number of MSS allocations are available, most of which are reserved expressly for operation from NGSO orbiting satellites. These allocations are, with one exception, all generic MSS allocations and are shown in table A.2.

Table A.2: MSS frequency allocations below 1 GHz

Band (MHz - MHz)	link	width (MHz)	type of allocation
137 - 137,025	down	0,25	primary (NGSO only)
137,025 - 137,175	down	0,170	secondary (NGSO only)
137,175 - 137,825	down	0,650	primary (NGSO only)
137,825 - 138	down	0,175	secondary (NGSO only)
148 - 149,9	up	1,9	primary (NGSO only)
149,9 - 150,05	up	0,15	primary (NGSO/LMSS only)
312 - 315	up	2	secondary
387 - 390	down	3	secondary
400,15 - 401	down	0,85	primary

At WARC-92, new allocations around 20/30 GHz were also made available for MSS so that the present availability is as shown in table A.3:

Table A.3: MSS frequency allocations around 20/30/40 GHz

Band (GHz - GHz)	link	width (MHz)	type/region
19,7 - 20,1	down	400	primary/region 2
19,7 - 20,1	down	400	secondary/region 1, 3
20,1 - 20,2	down	100	primary/region 1, 2, 3
20,2 - 21,2	down	1000	primary/region 1, 2, 3
29,5 - 29,9	up	400	primary/region 2
29,5 - 29,9	up	400	secondary/region 1, 3
29,9 - 30,0	up	100	primary/region 1, 2, 3
30,0 - 31,0	up	1000	primary/region 1, 2, 3
39,5 - 40,5	down	1000	primary/region 1, 2, 3

NOTE: ITU continental regions are the following 1: Europe and Africa; 2: Asia and Australia; 3: America.

Frequency bands allocated to the Mobile Service and the Mobile Satellite Service and intended for use on a World-wide basis for the development of FPLMTS [14]) are shown in table A.4 which provides details of allocations in both the terrestrial mobile and the mobile satellite services.

Table A.4: Frequency bands intended for FPLMTS use

Band (MHz - MHz)	Width (MHz)	Service
1 885 - 1 980	95	MOBILE
1 980 - 2 010	30	MSS (Up-links)
2 010 - 2 025	15	MOBILE
2 110 - 2 170	60	MOBILE
2 170 - 2 200	30	MSS (Down-links)

The satellite component of FPLMTS, which may be regarded as S-PCN, is expected to use the MSS segments of the bands intended for FPLMTS. It should be noted that these bands are already included in the list of general MSS bands indicated above and their use by non-FPLMTS MSS applications is not precluded by the Radio Regulations.

A.2 Feeder links

Feeder links from gateway stations to S-PCN satellites will generally be expected to be located within bands allocated to the Fixed Satellite Service (FSS) rather than within the limited bandwidth allocated to the MSS.

Spectrum for S-PCN feeder links will most probably be located in the C, Ku or Ka-band FSS allocations, subject to co-ordination and the ability to share with FSS services (primarily in the GSO) located within those bands and, in the case of the C-band (5 150 - 5 126 MHz) the ability to share with the aeronautical radionavigation service. Alternate frequency bands are being investigated as a substitute for the C-band feeder links.

A table is not provided to show the frequency bands available for the feeder links since this would require a reproduction of the FSS frequency allocations.

A.3 Inter-satellite links

For those S-PCN systems that require the provision of inter-satellite links, frequency allocations exist in the Inter-Satellite Service (ISS). As well as general allocations to the ISS, a new global primary allocation was made in the band 24,45 - 24,75 GHz, with the intention that it be used to support LEO systems, although no specific reservation to this effect is made in the Radio Regulations.

A.4 Frequency sharing issues for NGSO systems

As explained previously, the service link frequency bands that will be used by S-PCN systems are generic MSS bands; they are not generally allocated to S-PCN or NGSO systems. Additionally, these (and of course the FSS feeder link) bands are also allocated to other non-mobile services, both satellite and terrestrial. Moreover, the different S-PCN proposals are all likely to use the same MSS bands for their service links and a number of them will use the same feeder link band. Thus frequency sharing between S-PCN systems and other systems is inevitable.

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[14] Radio Regulation footnote 746A: "The frequency bands 1 850 - 2 025 MHz and 2 110 - 2 200 MHz are intended for use, on a world-wide basis by administrations wishing to implement the future public land mobile telecommunications system (FPLMTS). Such use does not preclude the use of these bands by other services to which these bands are allocated."

This Clause addresses briefly the main issues involving sharing between satellite services; the problems of sharing with non-satellite services are not considered here, although work is currently being undertaken in these areas (e.g. within CCIR SG12).

Table A.5: ISL allocations in the region of 20/30 GHz

Band (GHz - GHz)	width (MHz)
22,55 - 23,0	450
23,0 - 23,55	550
24,45 - 24,75	300
32,0 - 32,3	300
32,3 - 33,0	700

A.4.1 Sharing in MSS (service link) bands

The MSS service link bands are generally characterised by low gain or near omnidirectional antennas in the mobile ground segment. In analysing the sharing situations that thus arise it is necessary to consider that any mobile terminal will be likely to be able to see the whole visible sky and thus no advantage due to discrimination of unwanted signals at the terminal may be assumed.

Frequency sharing in these cases will thus depend on factors such as geographical separation of coverage areas, frequency, time or code segmentation between systems, etc. Note that most, if not all, of these kinds of approaches will result in a loss of potential capacity to each S-PCN system.

A.4.1.1 NGSO to GSO sharing

There are generally constraints on the power flux density at the earth's surface from GSO and NGSO satellites supporting mobile systems (intended primarily to protect terrestrial systems from satellite downlinks but also providing an upper limit for defining intra-MSS sharing).

Frequency sharing for communications services between GSO and NGSO (LEO in particular) has been analysed by the CCIR prior to WARC-92 with reference to the interference caused from a single NGSO system to a GSO system, the interference in the opposite direction, although expected to be significant, was not analysed.

The assumptions made for the analysis were based on current INMARSAT operating system characteristics but it is important to point out that realistic future systems will have different characteristics making necessary new analyses. For example if high gain spot beams will be employed this will raise the sensitivity of the system to interferences in the uplink. The analysis results are to be considered irrespective of the location of the GSO satellite on the geostationary orbit due to the type of coverage of a NGSO LEO system.

The interference in the GSO uplink band is assumed to be caused by:

- aggregate interference received by the GSO satellite from a large number of LEO mobile terminals with omni-directional antennas;
- aggregate interference received by the GSO satellite from the LEO satellite main radiating lobe, sidelobes and back lobe, in the case where the LEO utilises a nominal MSS uplink band in both uplink and downlink directions (bi-directional working) (see figure A.1).

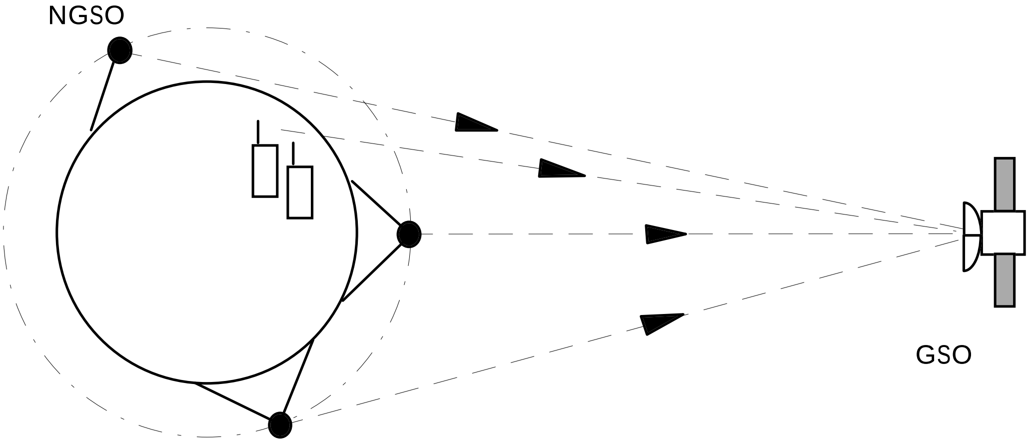

Figure A.1: Interference paths into a GSO uplink

The interference in the downlink band is assumed to be caused by:

- interference received by the GSO mobile earth station from the LEO satellite (cell) radiating lobe and sidelobes;
- interference received by the GSO mobile earth station from the LEO mobile terminals with omni-directional antennas located close by, in the case where the LEO utilises bi-directional working in a nominal MSS downlink band.

The main results are that a NGSO LEO system operating in a GSO uplink band will cause:

- significant interference (up to 7 dB excess interference in the case analysed, but potentially much higher) to the GSO system;
- a loss in effective EIRP due to the transponder loading from LEO satellites and mobile stations.

An NGSO LEO system operating in a GSO downlink band will cause a remarkable interference on GSO mobile earth stations (between 30 and 40 dB in the case analysed).

The MSS bands will be intensely used in the future by different systems implementing high gain small spots to enhance mobile earth station requirements and frequency re-use, so that there will be a further interference due to adjacent and co-channel interference among GSO systems. Sharing of the same channel band in the same region between GSO and NGSO systems seems therefore inadequate.

A.4.1.2 NGSO to NGSO sharing

The problems arising from NGSO to NGSO service link sharing are likely to be as difficult to overcome or even worse than those indicated above for the NGSO to GSO case.

The mobile terminals will be able to receive signals from all visible NGSO satellites operating in their receive bands and their transmissions will be received by all visible NGSO systems operating in their transmit bands. The interference paths are the same as those indicated for NGSO/GSO sharing, but with the added problem that the numbers of interfering and interfered with NGSO systems will not be constant with time; the actual situation will be statistical in nature and will depend on the individual constellations.

Again, no reliance may be made on discrimination at the mobile terminal (and also at the satellite in some cases) and so the sharing measures indicated previously are likely to be the only way to solve the problems that will arise.

A.4.2 Sharing in FSS (feeder link) bands

The FSS feeder link bands are generally characterised by high gain directional antennas in the ground segment. Thus discrimination at the earth station may be used to help achieve satisfactory sharing (in addition to the other approaches indicated above), but it must also be recognised that the interference potential from an interfering earth station main lobe is significant.

A.4.2.1 NGSO to GSO sharing

Interference into FSS GSO systems from NGSO feeder links could occur:

- to the GSO uplink when an NGSO feeder uplink station illuminates a GSO satellite directly with (or close to) its main radiating lobe;
- to the GSO downlink when an NGSO satellite downlink illuminates a GSO earth station directly along (or close to) its main receiving lobe.

Interference into NGSO feeder links from FSS GSO systems could occur:

- to the NGSO feeder uplink when the NGSO satellite passes through (or close to) the main radiating lobe of a GSO uplink station;
- to the NGSO feeder downlink when the main receiving lobe of an NGSO feeder downlink station points directly towards (or close to) a GSO satellite.

The potential for interference in these cases is very significant; work currently being developed within CCIR SG4 indicates that excess interference my be 50 dB or more in certain cases.

The major difference, however, between this sharing case and the service link situation is that because of the directivity in the earth stations, excess interference only occurs in the specific pointing situations outlined above. At other times, the directivity of the earth stations should provide sufficient isolation to allow sharing. Thus the analysis of the sharing problem becomes statistical in nature; it is necessary to consider the impact of the NGSO constellation on the resulting interference, since it is the specific configuration of the constellation that will determine how frequently and for how long the specific interference causing pointing cases will arise.

This is a complex problem and needs to be studied in more detail to develop suitable sharing criteria and interference avoidance strategies 15) .

A.4.2.2 NGSO to NGSO sharing

Feeder link sharing in the NGSO/NGSO case is very similar to that for NGSO/GSO sharing except that the analysis of the statistical nature of the interference becomes much more complex as it is now necessary to consider the complex interrelation of non-stationary constellations.

Again, this needs to be studied much further to determine the conditions under which sharing can be achieved.

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15) According to Radio Regulation No. 2613: "Non-geostationary space stations shall cease or reduce to a negligible level their emissions, and their associated earth stations shall not transmit to them, whenever there is insufficient angular separation between non-geostationary satellites and geostationary satellites, and whenever there is unacceptable interference [the level of accepted interference shall be fixed by agreement between the Administrations concerned, using the relevant CCIR Recommendations as a guide] to geostationary-satellite space systems in the fixed-satellite service operating in accordance with these Regulations".

Annex B (informative): Radio coverage

The number of satellites visible above the minimum specified elevation angle ("mask" angle) characterises the higher instantaneous elevation angle theoretically available at any location. This is purely a geometric parameter. It is a function of location and time, it assumes a possible instantaneous switch from one satellite to the other and it does not take into account the occupancy of the satellite (possible traffic channels congestion of the satellite with the higher instantaneous elevation angle). The requirement for a GC is for this figure to be always equal to or greater than one.

$$N_{EA}(\phi,\theta,t) \geq 1 \qquad \forall \phi,\theta,t$$

ϕ = longitude, θ = latitude, EA = minimum elevation angle

It is important to make clear the relationship between a Global System and a GCO. A Global System is not characterised by a GCO, but by

$$N_{EA}(\phi,\theta,t) \geq 1 \qquad \forall\, \phi,\theta \quad t \in \{T\}$$

the Global System provides therefore a communications channel to any location (globality) with no constraints on time set T (i.e. for some but not necessarily all time, t, there is more than one visible satellite).

The coverage definition can be made by means of a function that takes into proper account the possible multiple satellite overlapping coverage with different elevation angles, in what case the resulting elevation angle can be assumed to be the higher available (at all times), the traffic density distribution can be used to weight the coverage over different areas.

It can be observed here that the absolute lower boundary for the minimum number of satellites required to provide a GC, presented in Annex G, Clause G.5, has been derived with simplified assumptions compared to those made here.

Annex C (informative): Service availability

Parameters relevant to the availability of the service can be found if breaking down the entities involved in the call route, they include:

- availability of the call originating and terminating entities, A_{OT};
- availability of the up/down links of the constellation involved in the call route, $A_{UDl} = A_{Ul}\,A_{Dl}$;
- availability of the satellites involved in the call route(taking into account the provision of in-orbit spares or single replacement launches), A_S;
- availability of radio links involved in the call route other than up/down links (e.g. ISLs), A_{Rl};
- availability of the entities whose functionalities are essential to perform call setup, A_{CSU}.

Depending on the network architecture and the kind of routing performed by the S-PCN network these parameters can be combined to give the overall availability. A S-PCN employing the first option of subclause 5.1.2 will have a service availability for mobile to mobile call given by:

$$A = A_{OT}\,A_{UDL}^2\,A_{CSU}$$

while a S-PCN employing a the second option will have a service availability given by:

$$A = A_{OT}\,A_{Ul}^2\,A_{Rl}^K\,A_{CSU}$$

if K links are used in the call routing. All of these functions can be considered also functions of the location and of time.

$$A = A(\theta_1, \phi_1, \theta_2, \phi_2, t)$$

The function $A(\theta, \phi, t)$ does not account for local effects on availability. These effects are due to the local environment and are not included in the functions A_{Ul} and A_{Dl} that are related to macro environmental situations such are those that arise from a rough classification in city, vegetation, open field. Local environment is a building or a mobile.

As pointed out before, the availability of a single satellite A_S has a smaller impact on constellations employing a higher number of satellites, as a matter of fact the multiple satellite network concept has been used to satisfy system survivability requirements in military applications [9].

Given a constellation, the effect of multiple satellite failures causing radio coverage gaps, is more related to the distribution in the constellation (resulting in a certain space-time distribution) than to the number of failures itself.

Annex D (informative): NGSO multiple access

S-PCN multiple access is firstly a multiple access for a very large user community. Efficient modulation and multiple access techniques are necessary to share (within the system and, possibly, with other systems) the small amount of spectrum available to S-PCNs and to cope with mobile unit (and satellite) power and size constraints. The detailed comparison of multiple access techniques for S-PCNs is a matter of extremely large complexity because of the large number of system design parameters that are involved. Here are recalled a few features of different digital multiple access schemes with reference to the S-PCN scenario. Both voice and data networks are addressed. The FD-TDMA and FD-CDMA schemes are most studied. Access for a very large number of low data traffic density stations leads to generalised time-frequency Random Multiple Access (RMA) schemes. Duplexing is either time duplexing, frequency duplexing or code duplexing.

The design of the modulation and multiple access scheme for S-PCN has also to take into account the channel model. Effects introduced by the mobile satellite channel and by the system configuration may combine in a mobile satellite system such as S-PCN. The mobile satellite channel characterisation is to a first extent different from that of the terrestrial mobile channel because of the different bands employed, elevation angle, Doppler effect and because of the effects of the elevation angle on multipath effects. Fading situations can be characterised by different models depending on the carrier frequency and the nature of fading itself. The channel may be characterised, for example by the fade/non-fade event duration distributions, usually the more frequent the fade events the shorter their duration. The system configuration may add further effects such as the Doppler jump occurring at handover events. For a LEO system configuration the inter-satellite handover event is likely to cause a Doppler jump of twice the Doppler shift, further increasing the need for compensation. Intra-satellite handover events are not expected to cause significant Doppler jumps, mainly because of their short duration.

The FD-TDMA is being already used by some terrestrial digital mobile cellular systems. In the FD-TDMA access method a carrier is shared synchronously among mobile stations in the satellite coverage area. The channel is defined by the carrier frequency and the slot assigned to the mobile station. A frequency channel can be (in principle) either used for uplink (downlink) or for both up and downlink (bi-directional working). The channel may be re-used inside the coverage area of a satellite if frequency co-ordination (for example based on a cellular grid concept) is possible. The frequency-time slot may be re-used at a given minimum distance depending, among other, on the number of cells that constitute the cluster. For an (theoretically, but usefully approximating the circle) hexagonal cell the relation giving the re-use distance is the following

$$D = R \cdot \sqrt{3N}$$

where D is the cell re-use distance, R is the cell radius (e.g. hundreds of kilometres in a LEO system), N is the number of cells within the cluster (e.g. 7 cells) and

$$q_S = D / R$$

is the system Co-channel Interference Reduction Factor (CIRF). The carrier assignment within the coverage area of a single satellite could affects the re-use of frequencies in close satellites. Matching the carrier assignment of two adjacent (and moving) satellites means that the assignment should be done taking into account the neighbour satellites in a phased configuration or different situations that may occur in a non-phased orbit configuration.

For FD-TDMA mobile multiple access additional frequency guard-bands between carriers are imposed by Doppler shifts, these guard-bands are wider the higher the carrier frequency. Also time guard-bands are required to accommodate different user propagation delays, these guard-bands are wider the larger is the nominal satellite covered area. The LEO situation is less favourable than the GSO situation with respect to these guard-bands because in GSO mobile access geometries are more constant, as it is clear when considering the slant range variation in the two cases.

The CDMA is among the access and modulation schemes considered for the implementation of future terrestrial mobile systems. In principle, it allows to share the frequency allocation among all user by making every user's signal appear as wideband noise to every other user's receiver. This includes signals from spatially overlapping satellites' coverage areas. The effect of the slant range variation is mainly on the path loss (refer to Annex G, Clause G.6 for the plot of slant range path loss variation as a function of the orbital altitude). An accurate active power control is required to bring the received power of each terminal to the same nominal value.

CDMA can support signal diversity at the mobile, the signal from more than one transmitter (satellite) in view of the terminal (or the gateway earth station) can be regarded as multipath component and can be combined in a RAKE receiver structure. This combining may be exploited, in principle, to implement a "soft" or "make before brake" handover procedure. In order to have (possibly) several satellites transmitting the same call a link has to be established, during the call, between the mobile and the gateway earth station through a satellite different from the current one. The "soft" handover procedure has to be carefully designed to prevent premature handovers due to temporary mobile channel conditions, which would lead to large signalling overheads (effect often referred to as "ping-pong effect" in terrestrial systems).

Among multiple access schemes being studied particularly for mobile satellite data networks are Slotted ALOHA (S-ALOHA), slow Random Frequency-Hopping Multiple Access (RFHMA), Adaptive Mobile Access Protocol (AMAP), AMAP-RFHMA and Random Multiple Access (RMA). These access schemes are used on the return link to share channels among all mobile data users.

In S-ALOHA the channel is divided in time slots of the same duration of the packet transmission and packets can be transmitted at the beginning of the slot. If a collision occurs or noise causes incorrect reception by the hub, the packet is transmitted again, after a random delay time interval. Some modifications to this "classic" satellite S-ALOHA scheme are also being studied, such as reservation schemes. In AMAP the satellite channel bandwidth is divided into N equal size channels, N_r, out of these N, are dynamically defined as reservation channels and used in S-ALOHA and the remaining N_d are data channels. The mobile station wishing to transmit data messages first sends the request on one of the N_r reservation channels, upon receipt of the request the hub station assigns the mobile station a time slot on one of the N_d data channels in an acknowledgement packet. The reservation is repeated if no acknowledgement is received by the mobile station. The AMAP-RFHMA is a combination of frequency - hopping and the access protocol described above, with the message being sent at the first attempt on a group of N_1 frequency channels and, upon incorrect reception of the whole message, on one of a group of N_2 TDMA channels. A time-frequency access method making use of both time and frequency division with deterministic "signatures" is usually referred to as Random Multiple Access (RMA). Each "signature" is a set of time-frequency elements out of the possible total number given by the product of time and frequency divisions. A set of "signatures" is assigned, in general, to each station in the satellite data network.

Annex E (Informative): NGSO satellites

E.1 General requirements

The purpose of this section is to provide some background on the technologies used in NGSO satellite buses (especially little and big LEOs). It has been added for completeness and is intended only to provide a very brief introduction to a complex subject.

Technologies may be different from those used in GSO satellites at the extent that the question has been raised (in the literature) whether it is conceivable that a "line" production for satellites to be deployed in constellations is possible. It has been considered important to address these matters because of the high degree of integration of the various elements that contribute to the definition of a NGSO personal communications system.

Limited power requirements, simplified attitude control and smaller size service band antennas can been identified as the main factors leading to:

- weight reduction;

- size reduction;

- simplified space bus construction, integration and testing.

E.2 Launch vehicle requirements

The multi-satellite space segment can be designed to be deployed is several stages providing modular coverage and capacity. It is possible to plan mission launches accordingly, adding flexibility to the project for cost-effective solutions. Satellite S-PCN mission launches are, in general, multiple launches, a launch vector is employed to carry and distribute into orbit several small satellites at a time. The capability to deploy several small satellites in LEO has been already demonstrated [10].

The constellation properties to support multi-stage deployment are mainly related to the capability to provide continuous coverage within a region with a number of satellites smaller than the nominal number required by the constellation to provide full coverage (whether it is multi-regional, latitude bounded or global) and with no or small alterations of the constellation parameters (such as orbital plane inclinations or spacing between co-planar satellites). It seems reasonable to state that a multiple stage deployment involves also the capability to reach the full coverage from any stage with almost no interruption of the service in the already served regions. This assumption is to stress that a multi-stage deployable constellation is also a gradual coverage constellation. The multi-satellite launch plan includes an appropriate number of spares per each operating satellite.

Single unscheduled launches via small vectors are possible for NGSO satellite replacement. This option, foreseen in many LEO constellation keeping plans, is not usually accounted for in GSO satellite system operation and has some important consequences on the requirements to the spacecraft and communications payload. A single unscheduled launch is characterised by the short launch delay and by the limited cost on the overall system. The replacement launch can also be used to replace small satellites with an upgraded version. Vectors are already available to carry a single satellite of several hundred kilograms dry mass payload to LEO (e.g. Pegasus).

The availability requirements of a NGSO LEO satellite, given what is pointed out above, are to be based on assumptions different from those made for a GSO satellite platform and payload. The redundancy added to the payload and space bus design is based on a not recoverable not substituting hypothesis for any of the subsystems. The main objective being the availability of the whole system. In a single unscheduled replacement hypothesis the availability assessment has to be made assuming the replacement of the satellite as a fully redundant "cold standby" option and including the cost of the replacement in the balance of costs of "internal" redundancy.

E.3 Power requirements

NGSO, especially LEO, satellites have modest power requirements generally. On board DC power requirements may vary considerably when considering small store and forward data satellites or voice application S-PCN satellites but can be considered to be placed roughly in the range of 100 to 1 000 watts. Operation conditions lead to several eclipse cycles every 24 hour interval, as the orbit period is generally between one and two hours (see Annex G, Clause G.1).

RF power requirements are considerably reduced by the small free space loss factor but have to take into account the slant range variations losses (see Annex G, Clause G.6) which become significant at low minimum elevation angles. The free space loss factor is plotted below as a function of orbital height for some service carrier frequencies of interest.

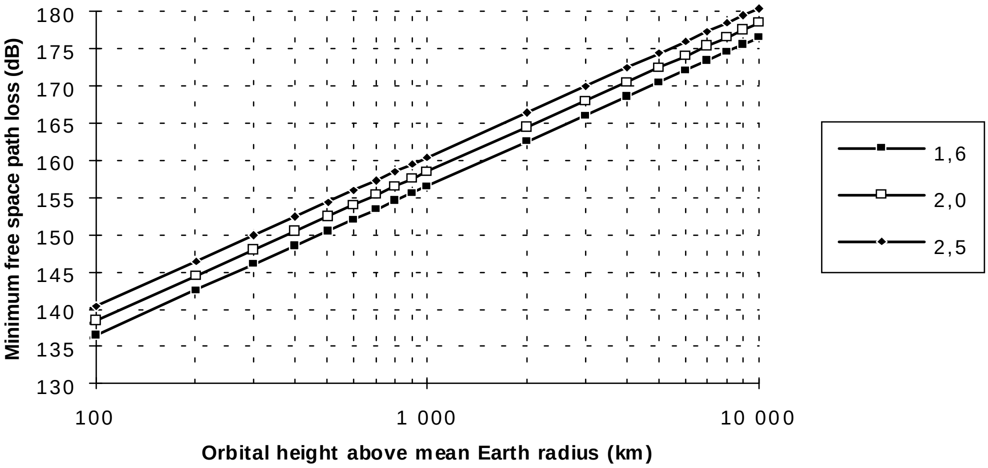

Figure E.1: Orbital height versus Minimum free space path loss for certain MSS frequencies

E.4 Attitude control

Attitude control is needed when proper compensation of perturbations of the orbit is required. Among perturbations there are those due to:

- atmospheric drag (upper layers of the atmosphere);
- forces due to the "real" Earth which is neither a sphere nor homogeneous (uneven geoid);
- gravitational forces of sun and moon (effective at apogee);
- solar radiation pressure.

In particular the shifting of the nodal points in the equatorial plane around the earth's axis varies with circular orbit altitude and inclination.

Space buses to be deployed in a large number at relatively low altitudes have either active or passive attitude control. Passive attitude control guarantees some control on the bus antenna pointing but does not work on the relative phasing between satellites. Active attitude control may guarantee different level of relative phasing between satellites, absolute phasing of the orbit with respect to the Earth and pointing accuracy. Here some active and passive attitude control schemes are addressed:

- gravity gradient boom;
- solar sails;
- electromagnetic coils;
- reaction wheels;
- thrusters (monopropellent, bipropellent, ion thrusters).

A simple passive attitude control exploits the gravity gradient existing at different distances from the centre of the earth gravity field. If two masses are placed at a certain relative distance in the gravity field they tend to align along the radius of the symmetric field. The gravity gradient boom is a rigid structure deployed in orbit (or already in position) from the spacecraft bus main structure holding a stabilising mass at the end. The stabilising mass is smaller that of the main bus structure.

Solar sails make use of the pressure of cosmic radiation on an extended sail to generate a rotational torque that may be used to align or rotate the spacecraft. Generally the angle of the sail to the solar flux may be varied in order to change the strength of the force generated.

Electromagnetic coils provide a torque through the interaction of the magnetic field of the Earth with the magnetic field generated by the on-board coils. Their use is generally limited to relatively low altitudes where the strength of the Earth's field is sufficiently strong to achieve a force of useful magnitude.

Reaction wheels are spinning devices which make use of the gyroscopic effect, in which a spinning body tends to maintain its alignment in inertial space. They may also be used for control purposes through the generation of a torque caused by increasing or decreasing the speed of rotation.

Thrusters provide a reaction force that can either be used to generate a torque or to translate the spacecraft in its orbit. The force is provided by the emission of pressurised gas, a chemical or combustion reaction, or (in the case of an ion thruster) through the emission of electrically charged particles.

E.5 Antennas

NGSO satellite antennas have to cope with different effects, depending on the type of orbit. The type of antenna is developed depending on the operating frequency to obtain the nominal (multi) beam pattern and to simplify deployment. Here are briefly shown general antenna requirements for frequencies and coverage patterns of interest and no attempt is made to generally address antenna design parameters.

NGSO HIO/HEO multi-spot coverage is modified by the following effects:

- zoom effect;
- relative beam-to-beam depointing due to zoom effect;
- residual, uncompensated Doppler;
- limited slant range path loss variation.

The zoom effect is a periodic coverage size variation due to the variable spacecraft to ground distance during orbit service intervals.

For a multi-spot coverage the zoom effect has the further consequence of relative beam to beam depointing due to varying beam intersections in the footprint during zooming.

The Doppler effect is significant and has to be compensated on earth or on board. Compensation could be done however with reference to a site (perhaps the beam centre) so there will be an uncompensated Doppler residual increasing in the radial direction, towards the beam edge.

The high elevation angle resulting from HEO HIO systems and orbital height limits slant range path loss variation to a negligible value. It is possible to observe, in Annex G, Clause G.6, that an HEO HIO coverage with minimum 50 degrees elevation in intermediate orbit results in a slant range path loss variation of the order of magnitude of one dB.

NGSO circular LEO coverage is mainly affected by slant range path loss variation (as shown in Annex G, Clause G.6).

The slant range path loss variation can be compensated with the so called isofux design. It is an antenna design that ensures theoretically constant power flux density over the earth coverage. It is achieved practically with the use of a number of spot beams with those near the edge of coverage radiating more power than those towards the centre, with a profile following the slant path loss variation diagram in Annex G, Clause G.6.

For the uplink a similar approach, varying the receive gain, will compensate for slant range path loss variation.

ISL links could be either radio or optical links. ISL antennas have to be in general steered because of the relative dynamics of LEO satellites. Antennas linking to an adjacent satellite in the same orbit require very little movement, whereas those linking to satellites in adjacent planes require considerably more.

E.6 Other requirements

Here are briefly considered other requirements, mainly related to the LEO environment and general HIO/HEO perigee and handover environment.

In HIO/HEO handover and in polar LEO constellation the dimensions of the spacecraft and the accuracy of orbital control may have a significant effect on the probability of collision.

LEO requires shielding against effects due to the environment of high layers of the atmosphere. At low altitude the main effects are due to the density of debris, the erosion due to atomic oxygen and the radiation environment. Corpuscular radiation causes damage to on board electronic devices and solar cell arrays (energy conversion efficiency, spectral response, maximum power output, short-circuit current and open-circuit voltage outputs).

Thermal control could be different from GSO systems because of the frequent eclipse cycles.

Fuel requirements in a phased orbit are also to be determined.

Annex F (informative): Principles of NGSO

This Annex describes the types and configurations of NGSO, identifies their main parameters (height, period, coverage, transit time, etc.), shows how these orbits may be used in systems called constellations to achieve regional or global coverage. Annex G provides a set of reference charts which may be used to assist in making an analysis of any specific NGSO proposal.

F.1 General terminology and parameters of earth orbits

As a first step, it is useful to define the general terms and parameters which may be used to describe the path of any general body orbiting around another body. Reference should be made to figure F.1 which shows how these parameters relate to the orbit and to each other.

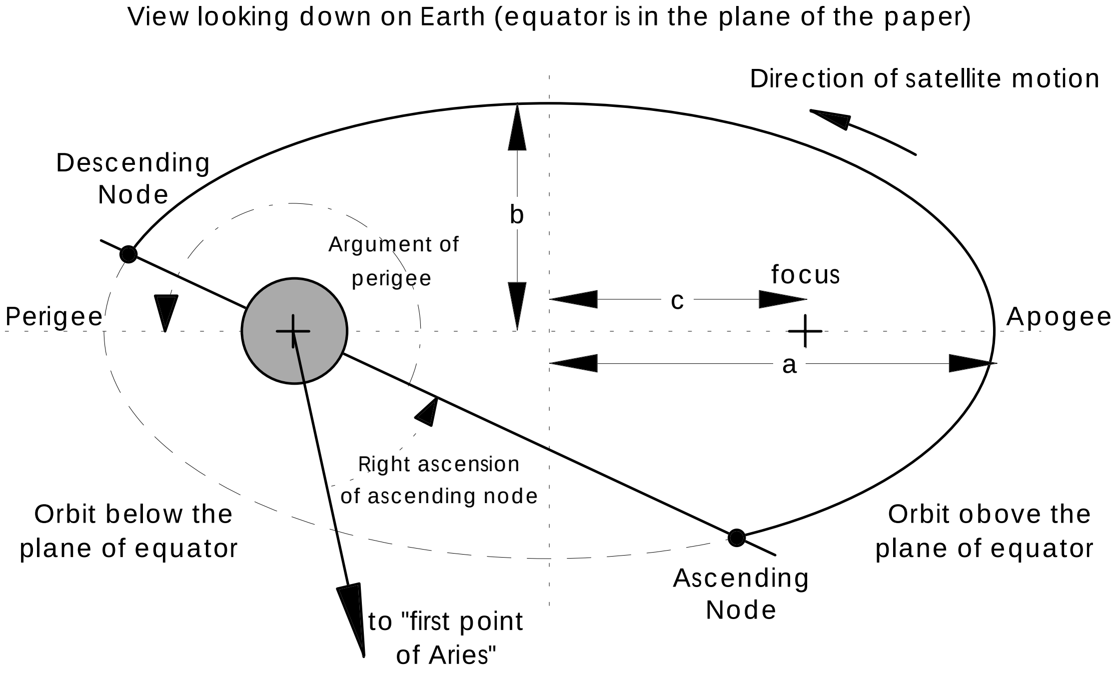

Figure F.1: Terminology for a General Elliptical Orbit

- Apogee height:

  the apogee is the point on the orbital ellipse at which the distance of the satellite from the geocentre is maximised; the apogee height is the height above the (nominal) surface of the Earth at apogee.

- Perigee height:

  the perigee is the point on the orbital ellipse at which the distance of the satellite from the geocentre is minimised; the perigee height is the height above the (nominal) surface of the Earth at perigee.

- Major and minor axes:

  the major axis is the largest width across the ellipse; the minor axis is the smallest width. These parameters are usually expressed as 2a and 2b respectively, where a is called the semi-major axis and b the semi-minor axis.

- Eccentricity:

  the orbital ellipse's eccentricity is a measure of its flattening; it is usually expressed as e and takes the range 0 < e < 1. An ellipse with an eccentricity of 0 is a circle, while that with an eccentricity of 1 is a line (i.e. the ellipse is totally flattened). The eccentricity is related to the semi-major axis and the semi-minor axis by the relationship:

$$e = \sqrt{1 - \frac{b^2}{a^2}}$$

- Primary focus:

  the primary focus of the orbit is the point at which the Earth will be positioned in the orbit plane; this is not the same point as the centre of the ellipse (except for the special case of a circular orbit). An ellipse has two focal points or foci whose positions are defined solely by the dimensions of the major and minor axes of the ellipse. The distance of each focal point from the centre of the ellipse, usually expressed as c, is given by the expression:

$$c = \sqrt{a^2 - b^2} = a \cdot e$$

- Period:

  the period of the orbit, T, is the time taken for the orbiting body to make one complete revolution about the geocentre. The period is related to the semi-major axis of the orbit:

$$T = \sqrt{\frac{4 \cdot \pi^2 \cdot a^3}{G \cdot M}}$$

- Inclination:

  the inclination is the angle between the plane of the orbit and the equatorial plane of the Earth (i.e. the plane of the Earth's equator).

- Ascending and descending nodes, line of nodes & right ascension of ascending node:

  the point at which the orbit passes through the Earth's equatorial plane whilst moving in a south to north direction is called the ascending node. The point at which the orbit passes through the Earth's equatorial plane whilst moving in a north to south direction is called the descending node. The line of nodes is the line joining the ascending and descending nodes (which will also pass through the geocentre. The right ascension of the ascending node is an angular measure used to identify the alignment of the plane of the orbit in space; it is the angle (measured in the equatorial plane) between a fixed stellar reference point on the celestial sphere (the first point of Aries) and the line of nodes in the direction of the ascending node (i.e. the angle is subtended at the geocentre but is independent of the rotational position of the Earth).

- Argument of perigee:

  the argument of perigee is an angular measure used to identify the alignment of the apogee and perigee positions relative to the equatorial plane; it is the angle subtended at the geocentre (measured in the orbital plane) between the ascending node and the point of perigee.

- Procession of orbit plane and argument of perigee:

  an orbiting body is subject to a number of forces which tend to cause the orbit to deviate from that predicted by classical "regular two body theory". These forces include the non-regular shape of the Earth, the gravitational effects of the moon and sun, the pressure of the solar wind, etc. Two of the major deviations caused by these additional forces are the tendency for both the right ascension of the ascending node and the argument of perigee to be time variant; these rotations of the orbital plane and the argument of perigee are known as precessions. For a given orbit it is possible to calculate with reasonable accuracy the expected rates of precession of these parameters and it is possible to identify specific orbits which reduce these precessions either to zero or to useful rates of change, and it is these orbits which are often exploited for telecommunications purposes.

- Ground track:

  the ground track is the projection of the path of the satellite (in the direction of the centre of the Earth) drawn on the surface of the Earth; it is the locus of the sub-satellite point on the Earth. The ground track is used to relate the relative movements of the satellite in its orbit and the rotation of the Earth and shows, over a period of time, the path on the Earth where the satellite passes directly overhead. The ground track may be used to assess the coverage and visibility of a satellite from the Earth.

The foregoing definitions have identified the key parameters and concepts which may be used to describe the orbital motion of a single satellite around the Earth (or indeed around any other body). However, for communications purposes it is usually the case that more than one satellite is required to provide continuous 24 hour coverage world-wide or over a specified region. A group of satellites organised in an orbit or orbits which enables the provision of telecommunications services over a period above and beyond that which would be provided by a single satellite is generally referred to as a constellation. It is necessary to define a number of terms and geometric parameters which describe the configuration of satellites into a constellation.

- Number of planes and number of satellites per plane:

  rather than all orbiting in a single plane (i.e. all satellites moving along the same ellipse in space) the satellites of the constellation may be distributed amongst a number of planes. It is usual for the constellation to have the same number of satellites in each plane and to have the planes equally distributed in angle around the Earth although these are not essential requirements.

- Minimum guaranteed evaluation angle:

  from an observer at any given point on the Earth (within the constellation's service area) it will generally be possible to "see" at least one satellite at all times (for continuous coverage constellations). Because the visible satellite(s) will move relative to the observer, the elevation angle of the transmission path to the satellite will also vary accordingly. For any constellation, it is possible to define a minimum guaranteed elevation angle above which there will always be (for any observer within the service area) at least one visible satellite available. Thus no user will be required to operate a service link to a satellite below the minimum elevation angle.

- Minimum guaranteed number of visible satellites:

  some constellations will also guarantee that for any observer on the Earth (within the constellation's service area) it will always be possible to "see" at least a given minimum number of satellites at elevation angles above the minimum guaranteed elevation angle. This number defines the minimum guaranteed number of visible satellites for the constellation.

- (N, P, m), nomenclature for rosette constellations:

  A rosette constellation is a member of a family of constellations that may be described by a vector (N, P, m) which uniquely describes the configuration of the constellation. In this vector, N is the total number of satellites in the constellation, P is the number of orbit planes and m is a harmonic number representing the initial starting positions of satellites in their planes.

  By implication, the number of satellites per plane, Q, is such that N = PQ, and the parameters are related by the following set of expressions:

$$\begin{array}{ll} \alpha_i = 2\pi i/P, & i = 0 \text{ to } N-1 \\ \beta_i = \beta, & \text{for all } i \\ \gamma_i = m\alpha_i = mQ(2\pi i/N), & m = (0 \text{ to } N-1)/Q \\ N = PQ, & \text{a product of integers} \end{array}$$

where: α_i = right ascension of the ascending node of satellite i;

β_i = orbital inclination of satellite i; and

γ_i = angular displacement from the ascending node of satellite i around its orbit at time zero.

F.2 Definition of type of orbit

When discussing types of satellite orbit, classifications such as "low-Earth orbit," "intermediate or medium orbit", etc. are used relatively freely, but there seems to be little firm agreement in the literature about what precisely constitutes a "low" rather than a "medium" or "high" orbit.

A concern must arise that the concepts of LEO, MEO, etc. might in the future be used as a basis for the implementation of certain standards to certain orbits only, and if this is to be done then a clear basis for classifying an orbit as LEO, MEO, etc. is needed.

This ETR proposes one approach which is based not upon an arbitrary selection of an orbit height (which would anyway leave the problem of how to deal with non-circular orbits) but through a consideration of the effect of a particular classification of type of orbit on the way in which the communications parameters of an orbit might be analysed.

It is clear that the lower in altitude is an orbit (i.e. for non-circular orbits, the smaller is the major axis length) the faster is the orbital velocity and the shorter is the orbital period. When considering the motion of a passing satellite relative to an observer on the ground, it is possible, if the satellite is moving fast enough, to ignore the movement of the Earth (and, of course, the movement of the observer relative to the Earth), which will greatly simplify any analysis which is made. For example, the horizon to horizon transit time for an overhead satellite pass will be simple to calculate if the Earth is assumed stationary but will be much more complex (and dependant on the inclination of the satellite and the position of the observer on the Earth) if the Earth is moving below the satellite track.

This ETR therefore proposes to consider the maximum error in calculating the overhead transit time with the Earth assumed to be stationary as a useful indicator of the class of orbit type (see figure F.2 for a summary of the orbit classes defined here).

F.2.1 Low Earth Orbits (LEO)

In Annex G, Clauses G.3 and G.4 of this ETR charts are presented that show, for orbit heights between 100 and 10 000 km, the maximum horizon to horizon transit time for that orbit height and the maximum error in that transit time that could be caused by the movement of the Earth (this is estimated for an equatorial observer and an equatorial orbiting satellite moving in the same plane as the observer); the chart also shows the maximum percentage error in the estimate of the transit time shown.

It is proposed to regard as a "low-Earth" orbit, an orbit in which the error in transit time estimation does not exceed 10 % of the transit time calculated. This corresponds to an orbit height of around 2 000 km or a major axis of around 10 400 km.

Below this height it is not necessary to take into account the movement of the Earth relative to the satellites when making an analysis but above the height the movement of the Earth must, of course, be considered.

NOTE: The so called "Very Low Earth Orbit" (VLEO) is a family of LEOs with orbital altitude inside the Earth's atmosphere.

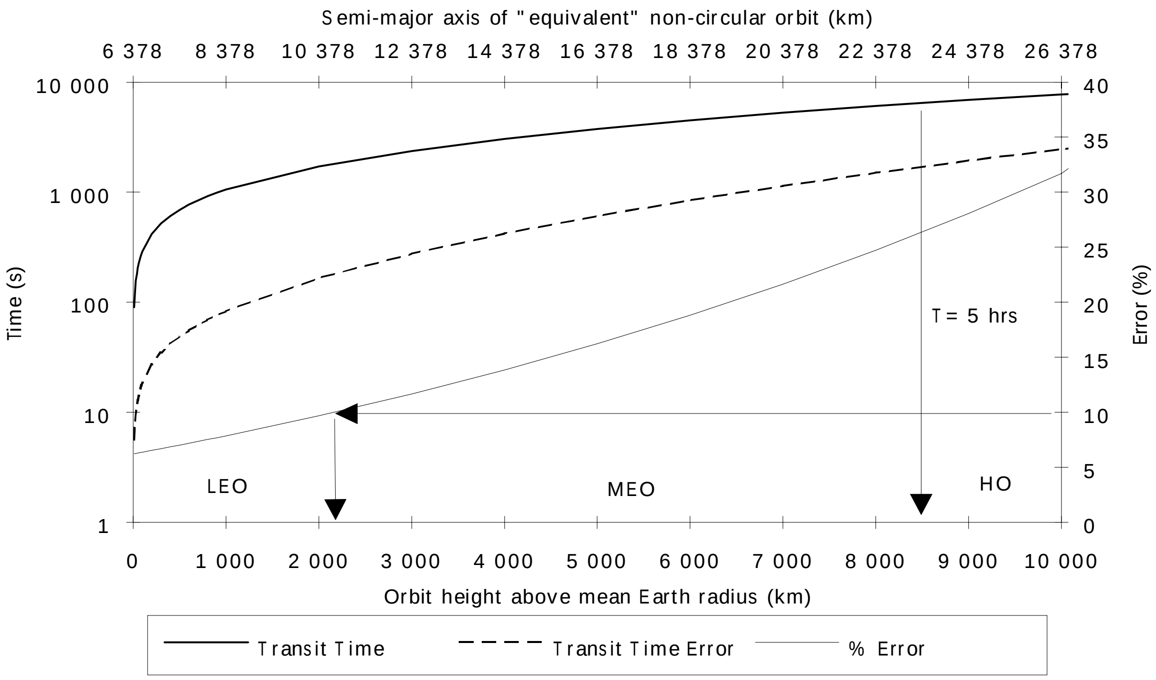

Figure F.2: Summary of orbit types related to transit time

F.2.2 Medium Earth Orbits (MEO)

As a consequence of the definition for LEO, this report assumes that medium Earth orbits are those with an altitude above 2 000 km (i.e. a major axis of 10 400 km or more). The upper bound of this type of orbit is more difficult to quantify; for the purposes of this report it is assumed that MEOs have their upper limit at the point where the period of the orbit becomes large in comparison with the period of the rotation of the Earth, since this make it necessary to take careful account of the Earth's rotation.

This point has been taken to be when the period of the orbit exceeds 20 % of the Earth's rotational period (i.e. ~ 5 hours) and this corresponds broadly to an orbital altitude of 8 500 km (i.e. a major axis of 23 400 km or more).

F.2.3 High Earth Orbits (HO) [16)]

By implication, the definition of a high Earth orbit is taken to be one with an altitude in excess of 8 500 km.

[16)] The nomenclature HO has been used to designate high Earth orbits in this report since the acronym HEO is in conventional use to mean "highly elliptical orbits".

F.3 Circular orbits and constellations

Circular orbits represent the most simple class of orbit configuration since the altitude and velocity of the orbit remains constant over time. Thus the combination of a number of such orbits into a constellation may be achieved relatively easily and will yield a simple, symmetrical structure.

Circular orbits my be divided into a number of different classes and for each of these this part of the report will describe their typical parameters and features; their advantages and disadvantages; their use for particular applications and the ways in which they are used in constellations with a number of satellites and orbit planes.

The constellation "launch modularity" could be analysed in further work (i.e. can useful coverage - regional or global - be achieved with fewer satellites than the full constellation; will this modularity be at the expense of limited opportunities for multiple launches).

An assessment of which constellation provides the optimal coverage (see subclause 5.2.2.1) for a given application (e.g. voice, data, positioning) is a highly complex matter that is considered to be outside the scope of this ETR. A number of approaches (each one often very different from the others) have been taken in the past in several studies to model mathematically the problem of the "optimum constellation search". The search has been addressed towards a continuous (global) coverage or a latitude bounded coverage for single and multiple satellite visibility by a number of authors each providing an analytic treatment:

- for polar circular constellations by Rider [11], Adams and Rider [12] and Lüders [13];
- for inclined circular and rosette constellations by Rider [11], Lüders [13], Ballard [14], Walker [15] and Beste [16].

Matters related to this subject may need to be studied in greater detail in later stages of the work.

F.3.1 Very-Low-Earth orbits

Some proposals exist for very low "orbiting" systems for the provision of telecommunications services. These systems, with "orbital" altitudes of some tens of kilometres, fall within the Earth's atmosphere and must thus be continuously powered to maintain their flight altitude and heading. As such they are more akin to aircraft than to satellites and it is believed that they fall outside of the scope of the present study. No consideration will be given to this type of "orbit" in this ETR.

F.3.2 Low Earth polar

Low Earth polar orbits are generally placed above the atmosphere and below the radiation belts (e.g. van Allen belt), typically, they have the following parameters:

- altitude below about 2 000 km;
- 90° inclination (or very close to it);
- round trip transmission delay up to 36 ms (theoretical 0° elevation angle);
- orbital periods between 80 and 130 minutes;
- one satellite may cover between 2 % and 18 % of the Earth (at 10° minimum elevation angle);
- Doppler effect involves a shift of 0,002 % (at 2 000 km altitude) of the carrier frequency and is more significant al lower altitudes (as may be seem from the figures G.7 and G.8);
- provide "true" global coverage (i.e. all locations on the earth have from time to time satellite passes at 90° elevation);
- constellation would normally be a number of equi-spaced polar planes each with satellites spaced so as to give "just overlapping" coverage between adjacent satellites in one plane;

- because of the concentration of coverage near the poles may require adaptive beams or switch-off of satellites;
- at least two adjacent planes will be counter-rotating, imposing complexity if ISL are required between those planes (e.g. the requirements for ISL antenna steering will be much greater).

F.3.3 Low Earth non-polar and Rosette constellations

Low Earth non-polar orbits have altitudes, period, round trip transmission delay, coverage and Doppler similar to those quoted above for polar LEO but less overlapping. Other typical parameters are:

- orbit planes at inclinations away from 90°, around 40° to 60° (for a Rosette constellation - see below);
- polar coverage is always at elevation angles reduced from 90° but a constellation may be designed for an acceptable worst elevation angle;
- a Rosette constellation is a special constellation of LEO non-polar orbits in which all planes are equi-spaced around the orbit and all are at the same fixed inclination angle; the satellites are phased with respect to each other around their individual planes and between planes to achieve maximal coverage with the minimum number of satellites; parameters are described in Clause F.1 above.

F.3.4 Intermediate Circular Orbits (ICO)

Intermediate Circular Orbits are generally within the radiation belts so satellites must be radiation hard. They are characterised typically by the following parameters:

- altitude between about 2 000 km and 8 500 km;
- same sub-divisions for orbit inclination as for LEO (i.e. polar and non-polar);
- round trip transmission delay up to 90 ms (at theoretical 0° elevation angle);
- orbital period between 130 to 300 minutes;
- one satellite may cover between 18 % and 30 % of the Earth (at 10° minimum elevation angle);
- Doppler effect involves a shift of 0,0009 % (at 8 500 km altitude) of the carrier frequency and is more significant al lower altitudes (as may be seem from the figures G.7 and G.8).

F.3.5 High earth Orbits (HO)

High earth Orbits are placed outside radiation belts; their parameters are typically:

- altitude above 8 500 km;
- same sub-divisions for orbit inclination as for LEO (i.e. polar and non-polar);
- period in excess of 300 minutes;
- one satellite may cover from 30 % to 40 % of the Earth (at 10° minimum elevation angle);
- Doppler effect involves a shift of 0,0008 % (at 10 000 km altitude) of the carrier frequency and is more significant al lower altitudes (as may be seem from the figures G.7 and G.8).

F.3.6 Stationary and synchronous orbits

Stationary and synchronous orbits are a special class of HO which have the following typical parameters:

- period of one sidereal day (i.e. 23 hours, 56 minutes, 4 seconds);

- true stationary is circular, zero degrees inclination, altitude 35 800 km;

- synchronous will have same period but non-zero elevation (up to ~ ± 5° is still generally regarded as stationary) and may be non-circular (e.g. Tundra, see Annex F, subclause F.4.1.2).

F.3.7 Sub and super synchronous orbits

Sub and super synchronous orbits are a class of orbits ranging from LEO to HO characterised by:

- sub-synchronous: orbit period (T) is an integer division (n) of an integral number (m) of sidereal days (of duration S) i.e.
$$= \frac{m \cdot S}{n}$$

- super-synchronous: orbit period (T) is an integer multiple (k) of an integral number (m) of sidereal days (of duration S) i.e.
$$= k \cdot m \cdot S$$

F.3.8 Phased and random constellations

A phased constellation is a constellation where the relative satellite phases (plane to plane) are defined and maintained in time within specified values around their nominal values. This implies:

- orbit control for each satellite;

- the presence of a control station network.

A random constellation is a constellation where no phasing is defined in time. The possible effects such as:

- in-orbit injection imprecisions (depending on the launcher and the satellite altitude);

- orbit perturbations (such as those referred to in Annex E, Clause E.4 and Annex F, Clause F.1);

turn a phased constellation into a non-phased if no orbit control is applied after a certain time interval. Random parameters are therefore:

- altitude (± h km);

- inclination (± d°);

- eccentricity (gradually decreasing);

- orbital plane (from 0° to 360°);

- relative phasing between satellites in the orbit plane.

A random (non-phased) constellation may be considered practical, for a particular system, if the costs savings in:

- launching (due to the expected smaller and lighter satellite bus);

- earth segment (due to the absence of a control station network); and

- single bus design and construction (due to the expected smaller complexity of the bus);

compensate the need for the higher number of satellites to reach the same performance figures.

If the mean visibility time as a function of latitude (for a decided minimum elevation angle) is taken as the comparison parameter, a non-phased constellation may be considered equivalent to a phased constellation with always a smaller number of satellites.

F.4 Non-circular orbits and constellations

Non-circular orbits are, naturally, more complex than circular orbits; their altitude varies with time and the speed of the movement of the satellite also varies with time through one period of the orbit.

F.4.1 Highly elliptical "quasi-stationary" orbits

One of the main benefits of non-circular orbits is that they may be used to provide constellations which exhibit quasi-stationary properties with the quasi-stationary region at a non-equatorial latitude.

In the past the main proponent of these types of orbit has been the C.I.S. (former Soviet) states, since they have a requirement for quasi-stationary coverage at high latitudes which cannot be provided by satellites in a geostationary orbit.

In recent years, however, there has been a growing interest in the use of these orbits mainly for mobile applications since they are able to provide high elevation communications paths over, for example, Europe or North America, leading to potentially better link availability in urban areas.

These quasi-stationary orbits are normally placed in an orbit of inclination 63,4° since it is here that the precession of the argument of perigee theoretically reduces to zero (i.e. the apogee may be maintained over its required location with the minimum of station-keeping fuel).

F.4.1.1 Molniya

The Molniya orbit is highly eccentric, passing through both the inner and outer radiation belts twice per orbit so satellites must be radiation hard. It is characterised typically by the following parameters:

- apogee height around 39 300 km;
- perigee height around 1 100 km;
- 63,4° inclination;
- round trip transmission delay up to 300 ms (theoretical 0° elevation angle);
- orbital period of approximately 12 hours (half of one sidereal day);
- one satellite may cover up to 40 % of the Earth (at 10° minimum elevation angle);
- Doppler effect involves a non-negligible shift of the order of 0,001 % of the carrier frequency (this would be maximum at handover point);
- handover between satellites occurs at different points in space so at least two antennas are needed per Earth station.

F.4.1.2 Tundra

The Tundra orbit although not as eccentric as Molniya still passes through the outer radiation belt twice per orbit so satellites must still be radiation hard. It is characterised typically by the following parameters:

- apogee height around 53 600 km;
- perigee height around 18 100 km;
- 63,4° inclination;
- round trip transmission delay up to 400 ms (theoretical 0° elevation angle);
- orbital period of approximately 24 hours (one sidereal day);
- one satellite may cover up to 41 % of the Earth (at 10° minimum elevation angle);

- Doppler effect involves a non-negligible shift of the order of 0,001 % of the carrier frequency (this would be maximum at handover point);

- handover between satellites occurs at different points in space so at least two antennas are needed per Earth station.

F.4.1.3 LOOPUS

The "geostationary Loops in Orbit Occupied Permanently by Unstationary Satellites" (LOOPUS) orbits, are a class of highly eccentric orbits. They are designed to have an active region which appears as a single loop remaining stationary in space with respect to an observer on the Earth. Apogees, perigees, etc. are variable depending on the number of satellites and the number of coverage areas (loops) in the system. A satellite in a LOOPUS orbit passes twice per orbit through both the radiation belts. A typical LOOPUS orbit is characterised by the following parameters:

- apogee height of 41 500 km;

- perigee height of 4 784 km;

- 63,4° inclination;

- round trip transmission delay up to 316 ms (theoretical 0° elevation angle);

- orbital period of approximately 14,4 hours;

- one satellite may cover up to 40 % of the Earth (at 10° minimum elevation angle);

- Doppler effect involves a non-negligible shift of the order of 0,001 % of the carrier frequency (this would be maximum at handover point);

- LOOPUS is a special case of HEO which is designed to exhibit handover at a single point in space so that, in principle, only a single antenna is required at each Earth station.

F.4.2 Highly elliptical LEOs

For some applications, it is useful to have a longer passing time from a LEO orbit than would be otherwise be achieved by a circular LEO of the same orbit period. In this case an elliptical LEO exhibits a reduction in velocity relative to the Earth as it passes through the apogee and thus a longer passing time may be achieved (although the orbit will not be quasi-stationary as for the HIO). The orbit active part is reduced because the velocity at perigee increases with respect to the "equivalent" circular LEO. Also the perigee may be very low, leading to problems with atmospheric drag. Otherwise, the parameters of this kind of orbit are broadly similar in terms of period, coverage, altitude, etc. to those described for circular LEOs.

Annex G (informative): Non-geostationary satellite Orbit reference data

In this Annex a number of charts will be presented; these will permit the reader to compare and contrast the effects of the selection of different height orbits on parameters that are fundamental to the complexity and utility of the resulting communications system.

The number of variable on the chart axes have purposely been kept limited; in almost all cases the x-axis shows the orbital altitude.

The possible range of orbit altitudes for S-PCN systems is very large ranging from around 100 km to several tens of thousands of km. For the purposes of these charts (given the scope of the report), and primarily in order to ensure that a readable range of values is shown, the charts limit the orbital altitude range considered to 100 km to 10 000 km.

These charts have generally assumed a circular orbit of fixed altitude, since it is for this kind of orbit that parameters remain constant throughout the orbit.

G.1 Orbit height versus Orbit period

Figure G.1 shows the most fundamental relationship for a satellite orbit; the orbital period for a given orbital altitude. The chart is presented primarily to let the reader convert between orbital period and altitude in the other charts that follow.

G.2 Orbit height versus Maximum available service area per satellite

Any satellite can "see" a broadly circular region of the Earth, centred on the sub-satellite point; any observer within this circle can also see the satellite. On the very edge of the circle an observer will see the satellite on the horizon (i.e. 0° elevation angle). Depending on the minimum elevation angle defined for the constellation, the available service area will be less than the visible area. Figure G.2 shows the maximum available circular service area for different altitudes and minimum elevation angles. Naturally, particular systems may implement smaller service areas than that indicated by the chart.

G.3 Orbit height versus Maximum satellite transit time (for an assumed stationary earth)

Figure G.3 requires a few words of clarification. For any satellite orbit, a user on the ground will (generally) see the satellite rise above the local horizon, make a transit of the sky and then drop below the local horizon. In cases where the rotational speed of the Earth is small in comparison with the orbital speed of the satellite, it is valid to regard the Earth as being stationary and to consider the maximum time of visibility for a single satellite pass (this corresponds to a pass directly overhead of the observer).

The chart presents this information for cases where the local horizon is regarded as being between 0° and 60° in elevation. For orbits above about 2 000 km this chart should be treated with some caution, since the effects due to the rotation of the observer with the Earth will begin to become more significant (see next section).

G.4 Orbital height versus Maximum error in transit time estimation if earth is assumed stationary

Figure G.4 indicates the maximum error that could occur in the previous chart when the movement of the Earth is ignored. The maximum potential error occurs when the orbit is equatorial as is the observer (i.e. the velocity components of the satellite and the observer are co-planar).

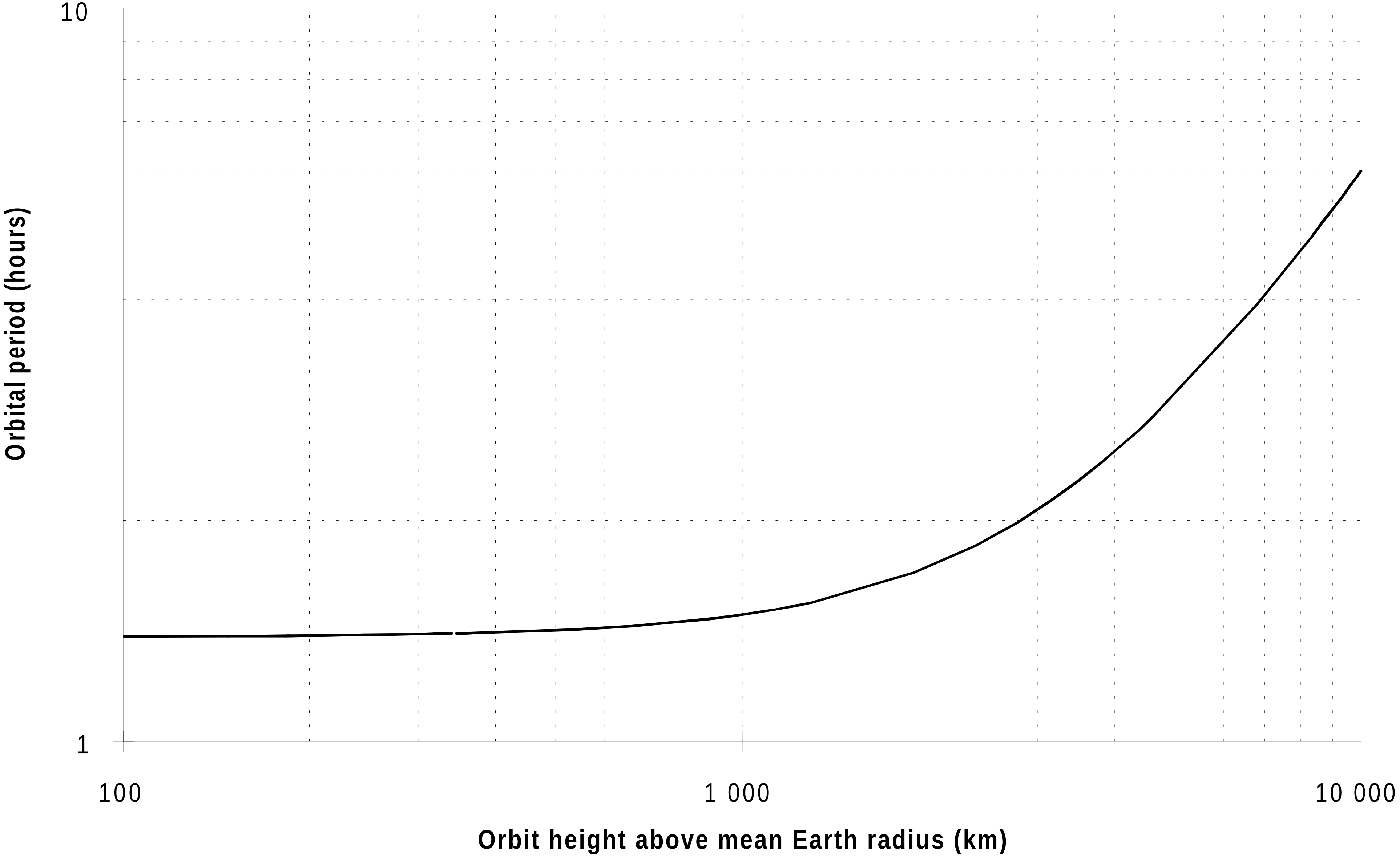

Figure G.1: Orbital height versus Orbit period

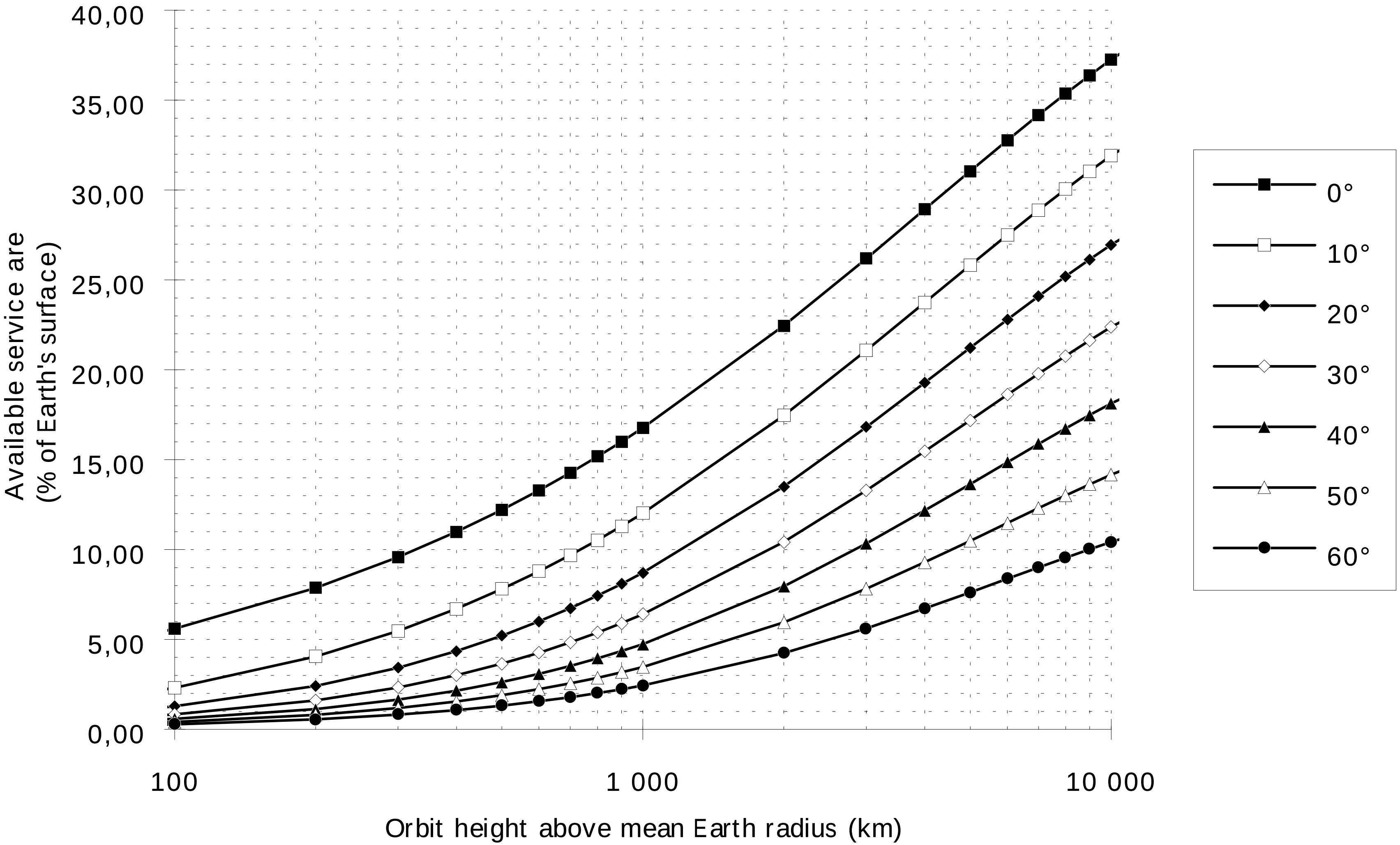

Figure G.2: Orbit height versus Maximum available service area per satellite

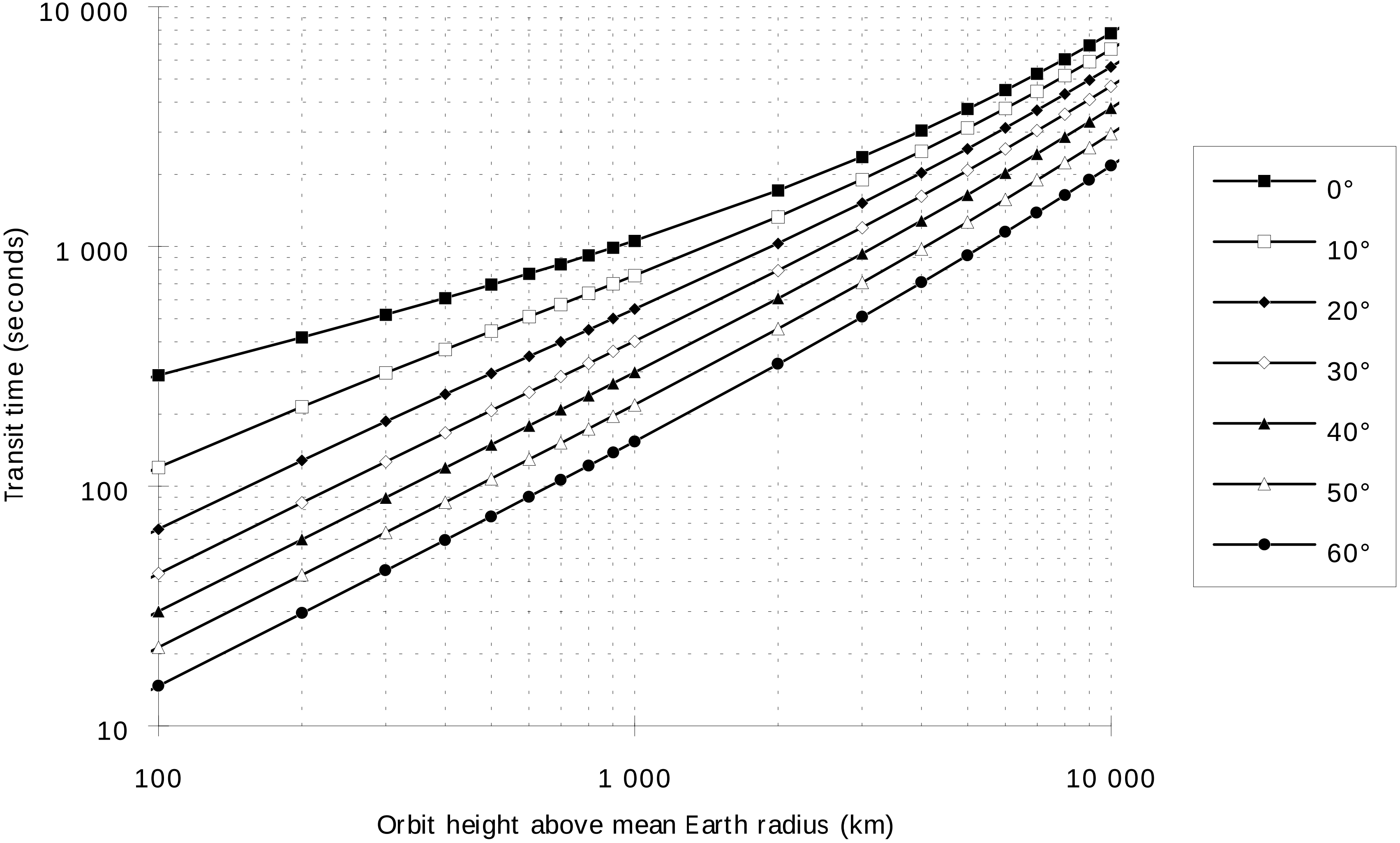

Figure G.3: Orbit height versus Maximum satellite transit time (for an assumed stationary earth)

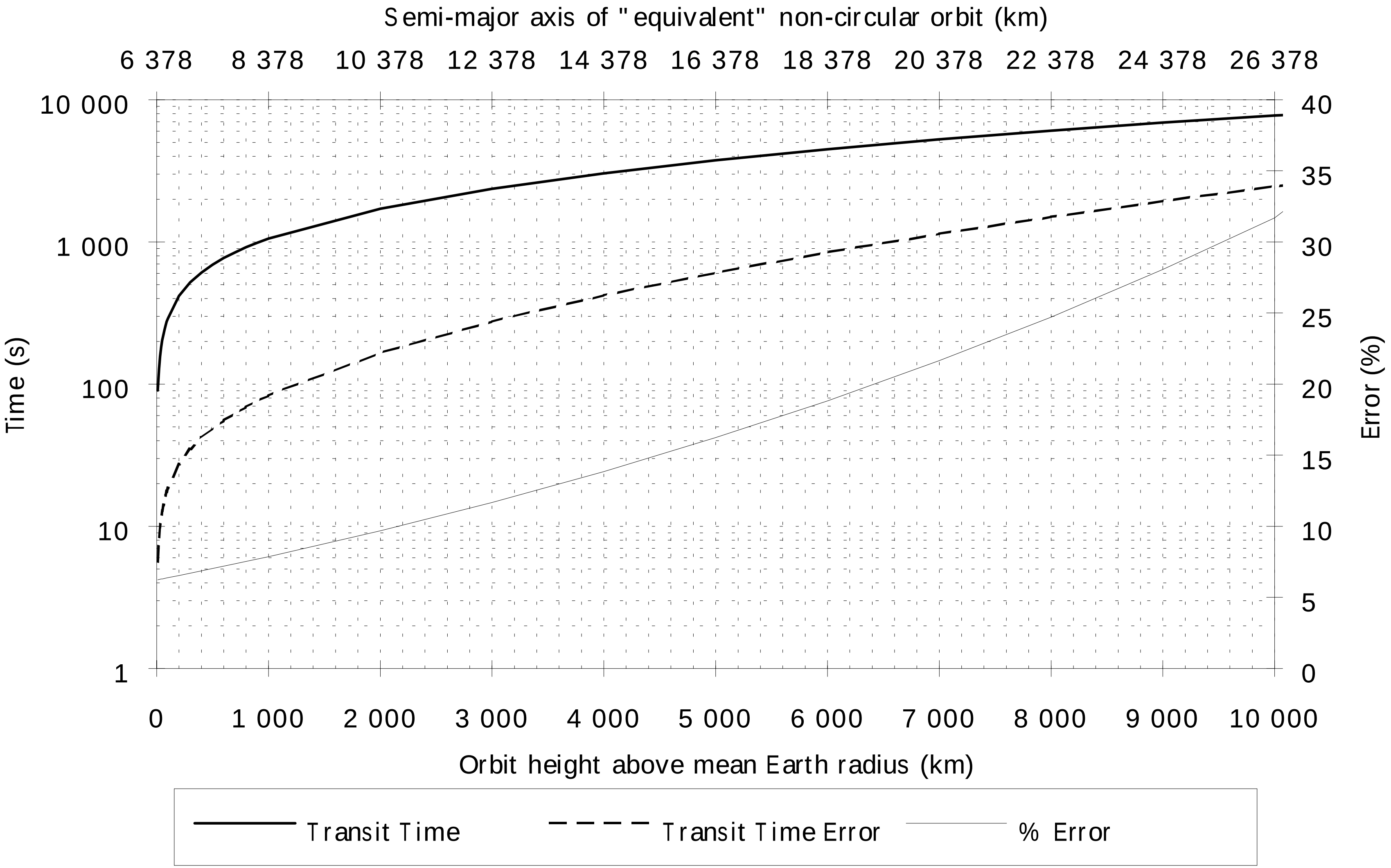

Figure G.4: Orbital height versus Maximum error in transit time estimation if earth is assumed stationary

G.5 Orbit height versus Absolute lower bound on the minimum number of satellites for global coverage

Different constellations exist which provide full global coverage for different minimum numbers of satellites and it is not practical to try and present a chart encompassing all of these. The approach adopted here (as may also be found in a number of the referenced analytical papers) is to consider an absolute stationary lower bound. This takes into account the area of the Earth which may be served by a single satellite and calculates the smallest number of satellites required to cover the entire surface of the Earth with a single coverage (assuming a stationary constellation, which is not realistically possible). The analysis assumes that a 35 % overlap between beams (approximating the actual case for circular beams) reduces the area uniquely covered by a single satellite and thus increases the number of satellites required.

Figure G.5 is useful to check system proposals, since it is not possible to design a constellation requiring fewer satellites (for a particular altitude and minimum elevation angle) than is shown here. Moreover, the "coverage efficiency" of a particular proposal may be determined by comparing the number of satellites proposed against the theoretical minimum indicated by this chart.

G.6 Orbit height versus Sub-satellite to edge of coverage slant path loss variation

For lower orbits, the variation in slant range length between the sub-satellite point and the edge of the service area is greater. Consequently there is a greater variation in slant path loss over the service area of a lower orbit satellite than for a higher orbit satellite. Since this variation will need to be accounted for in link margins it is useful to present a chart that quantifies this information.

Figure G.6 is drawn for 10° minimum elevation steps.

G.7 Orbital height versus Worst Doppler shift for given MSS frequencies at 10° minimum elevation

At lower altitudes the relative velocity between the satellite and an observer on the Earth are greater. Figure G.7 assumes that both the orbit and the observer are in the equatorial plane and counter-rotating (i.e. maximum relative velocity) and determines the worst Doppler shift that could arise in this case due to both the movement of the Earth and the satellite. The worst Doppler shift occurs just as the satellite crosses the minimum elevation line (i.e. just as the service area moves over the observer). The chart has assumed a minimum elevation angle of 10° and shows the worst Doppler for the main MSS frequencies likely to be associated with NGSO services.

G.8 Orbital height versus Worst Doppler shift as a percentage of carrier frequency for a given minimum elevation angle

Because the previous chart has made an assumption regarding the minimum elevation angle, figure G.8 shows Doppler shift for different orbital altitudes in a slightly different way. No assumption is made about the carrier frequency and so the Doppler shift as a percentage of carrier frequency is shown for a range of minimum elevation angles.

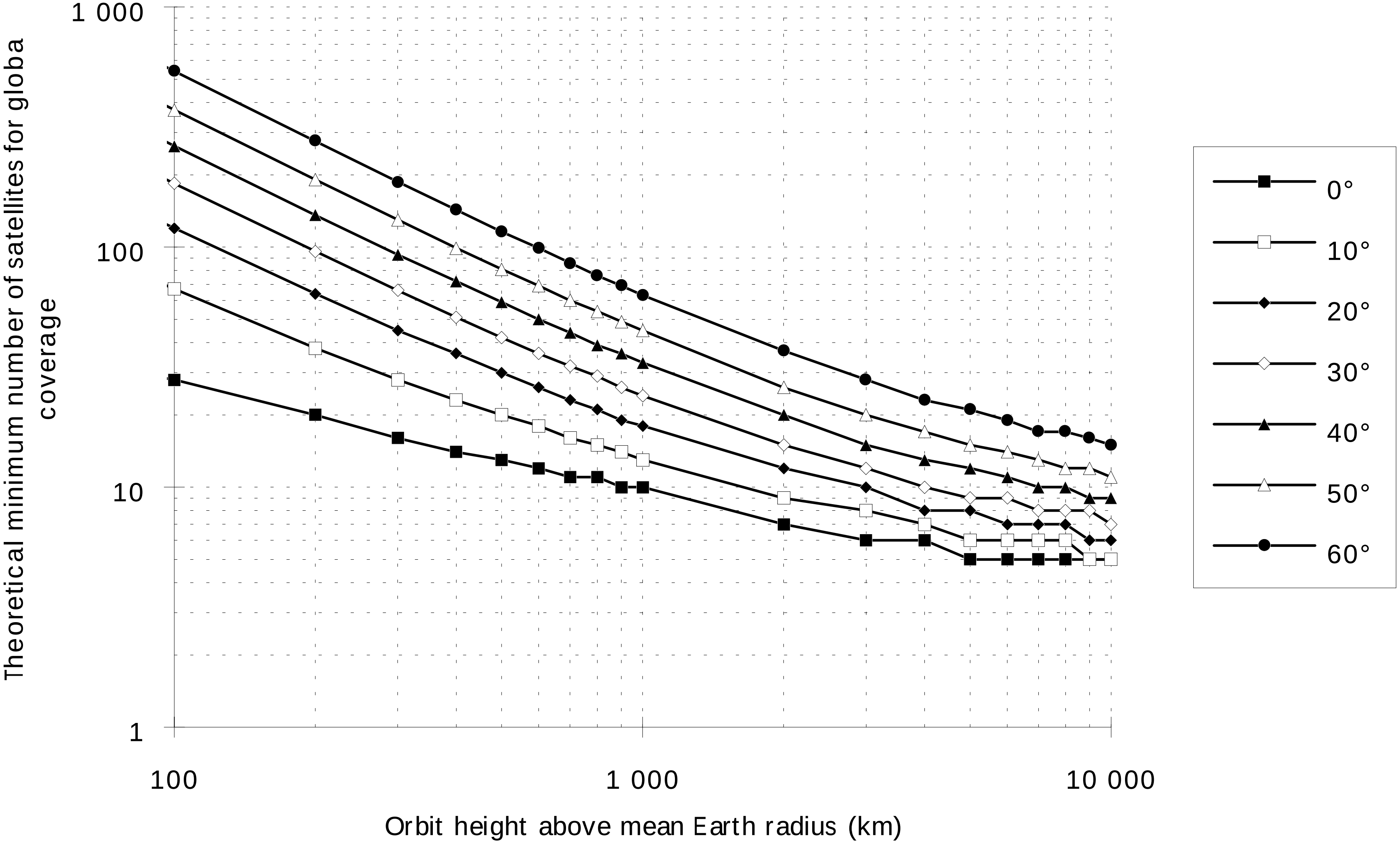

Figure G.5: Orbit height versus Absolute lower bound for the minimum number of satellites for global coverage

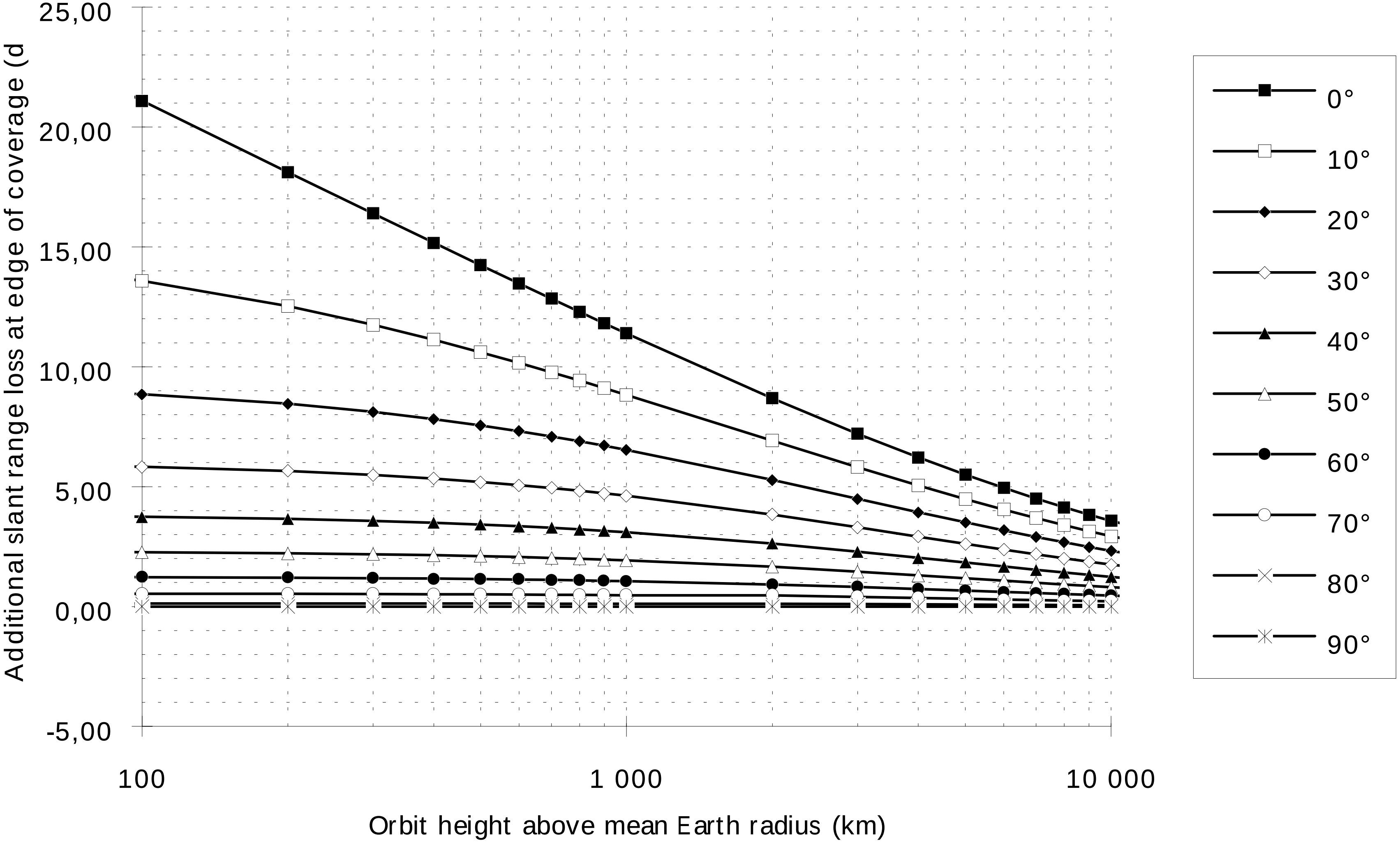

Figure G.6: Orbit height versus Sub-satellite to edge of coverage slant path loss variation

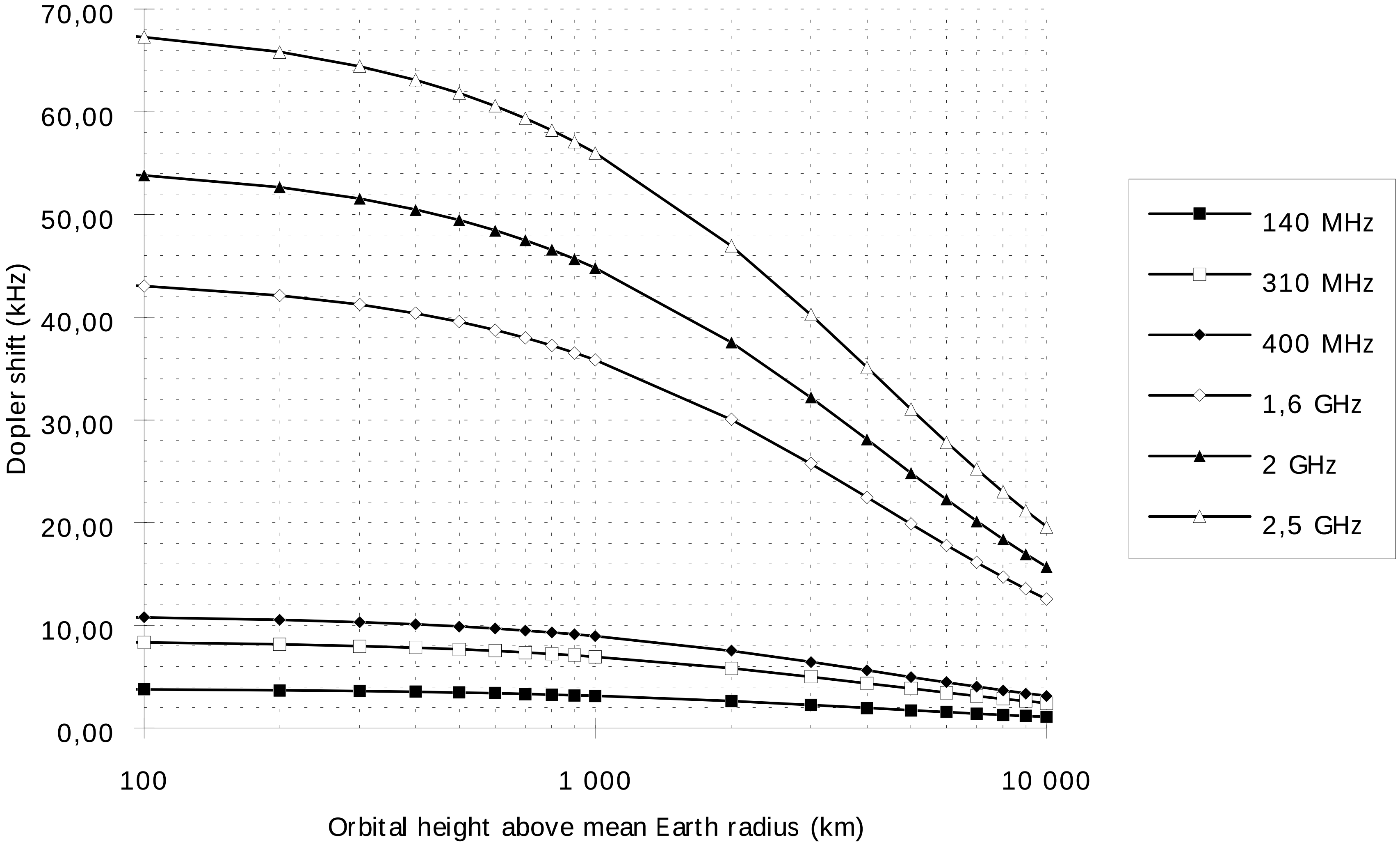

Figure G.7: Orbital height versus Worst Doppler shift for given MSS frequencies at 10° minimum elevation

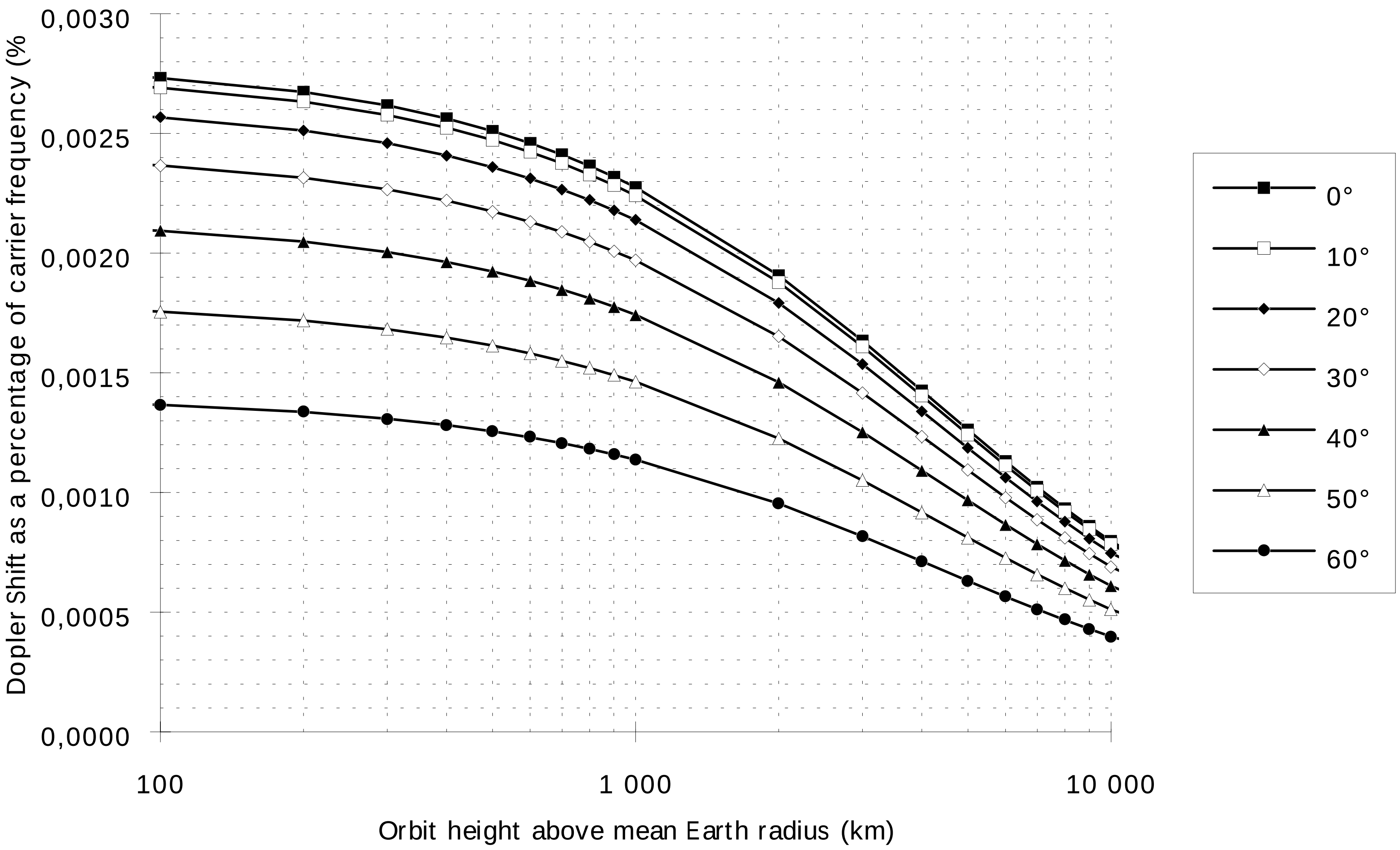

Figure G.8: Orbital height versus Worst Doppler shift as a percentage of carrier frequency for a given minimum elevation angle

G.9 Orbital height versus Round trip delay for given elevation angles

Figure G.9 shows how the round trip delay (i.e. earth-space-earth) changes for different orbital heights and different elevation angles on the ground.

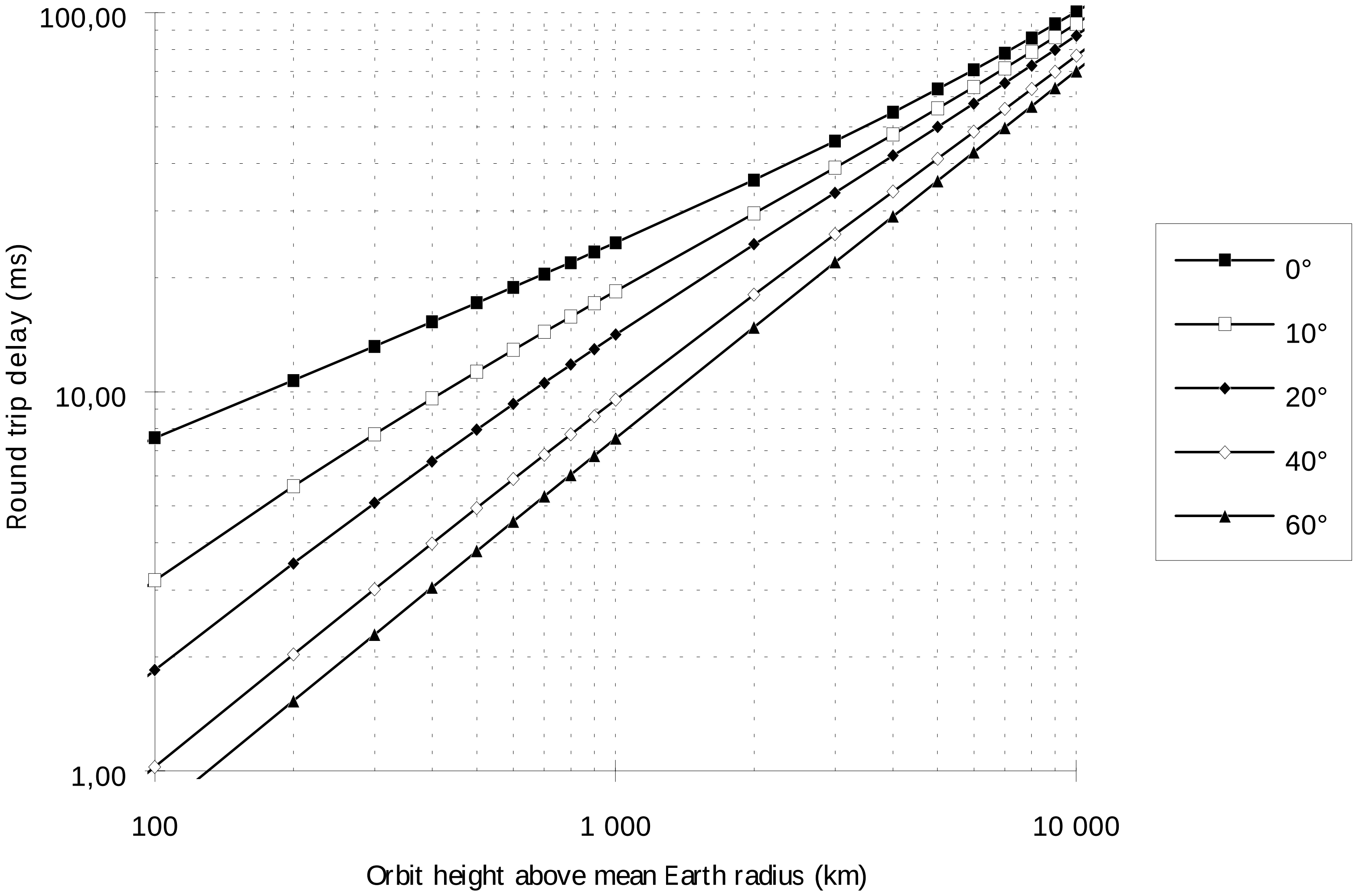

Figure G.9: Orbital height versus Round trip delay for given elevation angles

Annex H (informative): Bibliography

The following documents and reports were used as background references in the development of this ETR:

"91/263/EEC: Council Directive of 29 April 1991 on the approximation of the laws of the Member States concerning telecommunications terminal equipment, including the mutual recognition of their conformity", Commission of the European Communities, COM(92)451 Final, Luxembourg, 10 December 1992.

"93/C 4/03: Proposal for a Council Directive on the approximation of the laws of the Member States concerning satellite earth station equipment, extending the scope of Council Directive 91/263/EEC" Official Journal of the European Communities, No. C 4, 8 January 1993.

"Application of Constellation Communications Inc. for Authority to Construct the Aries Low Earth Orbit Satellite System in the 1 610 - 1 626,5 and the 2 483,5 - 2 500 MHz Bands", Before the Federal Communications Commission, Washington D.C., 3 June 1991.

"Application of Loral Cellular Systems Corp. for Authority to Construct a Low Earth Orbit Satellite System", Before the Federal Communications Commission, Washington D.C., 3 June 1991.

"Draft Common Position of 10 May 1993: Council Directive on the application of Open Network Provision (ONP) to voice telephony", Commission of the European Communities, Brussels, 14 May 1993.

"Final Acts of the World Administrative Radio Conference (WARC-92)", ITU, Malaga-Torremolinos, 1992.

"Handbook on CTRs, Draft Issue 2", TRAC Ad Hoc Group, Paris, 20 November 1992.

"Hearings on Non-Geostationary Mobile Satellite Systems (Low Earth Orbiting Satellite Systems: LEOs), Rapporteurs' Report", Commission of the European Communities, Brussels, 9-10 November 1992.

"Minor Amendment (to the) Application of Motorola Satellite Communications Inc. for Authority to Construct, Launch and Operate a Low Earth Orbit Satellite System in the RDSS Uplink Band", Before the Federal Communications Commission (File Nos. 9-DSS-P-91(87) & CSS-91-010), Washington D.C., 10 August 1992.

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