TR 101 037 V1.1.1 (1997-07)

Technical Report

Radio Equipment and Systems (RES);
European Radio MEssaging Service (ERMES);
Two Way Paging system

European Telecommunications Standards Institute

Reference

DTR/ERM-RP04011 (9lo00ics.PDF)

Keywords

ERMES, paging, radio

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X.400

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Contents

Intellectual Property Rights 5

Foreword 5

Introduction 5

Executive summary 5

1 Scope 7

2 References 7

3 Abbreviations and definitions 7
3.1 Abbreviations 7
3.2 Definitions 8

4 Justification 8
4.1 Applications 8
4.2 Market 9
4.2.1 Survey from ERMES MoU and EPPA 9
4.2.2 Paging penetration 9
4.3 Market position of Two Way Paging 10

5 Compatibility requirements 11

6 The Two Way functions 11
6.1 Acknowledgement 11
6.1.1 System acknowledgement 11
6.1.2 Location acknowledgement 12
6.1.3 User acknowledgement 12
6.2 Initiated message 13
6.2.1 System call (mobile initiated) 13
6.2.2 User call (user initiated) 14
6.3 Canned messages 14

7 ERMES Two Way Protocol 15
7.1 Time slot technique 15
7.1.1 Protocol A 16
7.1.2 Protocol B 17
7.2 The forward channel modifications, general data 17
7.2.1 Protocol A 18
7.2.2 Protocol B 19
7.3 New data format for the forward channel, message header 19
7.3.1 Protocol A 20
7.3.2 Protocol B 21
7.4 The return channel data format 22
7.4.1 System acknowledgement 22
7.4.1.1 Protocol A 23
7.4.1.2 Protocol B 23
7.4.2 User acknowledgements 23
7.4.2.1 Protocol A 23
7.4.2.2 Protocol B 24
7.4.3 Mobile and user initiated data 24
7.4.3.1 Protocol A 24
7.4.3.2 Protocol B 25
7.5 The return channel messages format 26
7.6 Transmission sequences 26

8 Traffic calculations 28
8.1 The estimated number of Two Way subscribers in a network 28
8.2 The estimated usage of the return channel 28

8.3 Implementation of usage of the return channel in the protocol 30
8.4 Systems with differentiated functionality 32

9 Return channel, data rates and output power 32
9.1 Protocol A 34
9.2 Protocol B 34
9.2.1 Low data rate applications 35
9.2.2 Variable data rate applications 35

10 Spectrum use 35
10.1 Frequency bands 35
10.1.1 The ERMES band 35
10.2 Frequency requirements 36
10.2.1 Narrow band concept 36
10.2.2 Broadband concept 36

11 General 36
11.1 Mobile battery life 36
11.2 Link budget 36
11.3 Effect of acknowledgement and re-transmissions on system capacity 37

12 Trials 39

13 Consequences for the different I-interfaces 39

14 Proposed structure for an updated ERMES standard 39

Annex A: Flowcharts 41

A.1 Forward message to Two Way ermes pager 41

Annex B: Details protocol A 42

B.1 Required number of subslots in MITS 42

History 44

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Radio Equipment and Systems (RES).

Introduction

The present document was approved by TC-RES in its meeting in Noordwijk (25-29 March 1996).The present document has been prepared by a working group of STC/RES 04 during the period April 1996 to January 1997

The objective of the work was to investigate the feasibility of an ERMES Two Way Paging system, to define a system concept and to propose a system design and a standardization structure.

The present document is demonstrating that a Two Way ERMES Paging system, with performance features satisfying the market requirements, can be realized.

The present document is as detailed as the working group thought was necessary to prove the feasibility. To do further analysis and in order to determine the details, much more work has to be carried out. This should be done in different groups, each dealing with a certain item, in order to get a detailed specification in an acceptable time frame.

Executive summary

A Two Way ERMES Paging system can be realized, which is capable to handle the basic acknowledgement functions, extended acknowledgement functions (canned- and canned + messages) and capable to handle mobile initiated messages, short as well as longer messages.

The main feature of the proposed system is a variable data rate for the return channel, which gives the opportunity the design a system with a minimum set of functions with a system layout requiring one base receiver per base transmitter and with the opportunity to extend such a system with more functionality (e.g. messaging) requiring more base receivers per base transmitter. This gives the possibility for network operators to start with a system with the functionality required at that time and to extend the functionality if so required by the market.

The proposed system is fully compatible with the present one-way ERMES system. Two Way pagers will be able to operate in a present one-way system, with the functionality of a one-way pager and present pagers will operate in a Two Way ERMES system.

The features of Two Way ERMES can be summarized as follows:

- Matched return channel and forward channel range. The range from a base station that transmits to a pager can be the same as the range from a pager that transmits to a base station.

- Variable up-link data rates. Provision is made so that applications requiring a higher data rate from the pager may be implemented. Note that such applications may require more receiver sites.

- Low pager transmission power. The battery life of a Two Way ERMES pager will be of the same order as current pagers.

- Simple transmission scheme. This will minimize the cost of a Two Way ERMES pager and maintain the convenient portability of current pagers.

- Multiple Two Way messages. It is possible to send a Two Way message to a pager before responses from a previous Two Way message have been concluded. This also applies to fragmented messages and to group calls.
- Local and Roaming facilities: Registration, re-transmission of missed messages.
- Transmission of simple messages: canned message, canned + messages (numeric and alpha numeric).
- Free format data for numeric, text, and binary data.

1 Scope

The present document covers a feasibility study of an ERMES Two Way Paging system. The system design should be sufficiently detailed to prove the feasibility of the solutions chosen.

The present document also contains a proposal how the actual standardization work should be carried out and what the standard structure should be.

2 References

References may be made to:

a) specific versions of publications (identified by date of publication, edition number, version number, etc.), in which case, subsequent revisions to the referenced document do not apply; or

b) all versions up to and including the identified version (identified by "up to and including" before the version identity); or

c) all versions subsequent to and including the identified version (identified by "onwards" following the version identity); or

d) publications without mention of a specific version, in which case the latest version applies.

A non-specific reference to an ETS shall also be taken to refer to later versions published as an EN with the same number.

[1] ETS 300 133: "Radio Equipment and Systems (RES); European Radio Message System (ERMES)".

[2] RES-TR 002: "Radio Equipment and Systems (RES); European Radio Message System (ERMES); The globalization of ERMES".

3 Abbreviations and definitions

3.1 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AII	Additional Information Indicator
AIS	Additional Information Sequence
AIT	Additional Information Type
AT&T	American Telephone and Telegraph
BH	Buried Heterostructure (IC Process)
bps	bits per second
CDMA	Code Division Multiple Access
CP	Probability of no Collision
CTA	Common Temporary Address
CTAP	Common Temporary Address Pointer
DS	Direct Sequence
DTW	Data for Two Way
EPPA	European Public Paging Association
ERMES MoU	ERMES Memorandum of Understanding group
ERMES	European Radio MEssaging Service
ERP	Effective Radiated Power
FEC	Forward Error Correction
FH	Frequency Hopping
FM	Frequency Modulation

FSK	Frequency Shift Keying
GPS	Global Positioning System
GSM	Global System for Mobile communications
MITS	Mobile Initiated TimeSlot
NATS	Network Assigned TimeSlot
O&M	Operation and Maintenance
OPID	Operator Identity
PNC/PAC	Paging Network Controller/
POCSAG	Post Office Code Standardization Advisory Group
RIC	Radio Identity Code
SSI	Supplementary System Information
SSIF	Supplementary System Information Field
SSIT	Supplementary System Information Type
TBD	To Be Defined
TETRA	Terrestrial Trunked Radio
UHF	Ultra High Frequency
VHF	Very High Frequency
VIF	Variable Information Field

3.2 Definitions

For the purposes of the present document, the following definitions apply:

forward channel: The radio link from the base station transmitter to the portable (terminal).

return channel: The radio link from the portable (terminal) to the base station receiver.

4 Justification

4.1 Applications

This non-exhaustive list of user applications will give an impression of the possibilities and will position Two Way Paging between other mobile services:

- summoning of staff who are on-call for assistance (fire brigade/hospitals);
- dispatching acknowledgement;
- control of mobile staff, give instructions and getting back status of work;
- closed user groups (with a dedicated software package);
- telemetry, polling and initiated on certain criteria;
- remote control of equipment;
- alarm/status from equipment and/or people;
- location information (combined with GPS);
- consumer applications (family messaging, messaging between teenagers, deaf mute application etc.);
- interactive information retrieval;
- advertising with individual response.

These applications will favour Two Way Paging because of the low cost service, long battery life of the terminal and because of the in building reliability.

There are, besides the user applications, system applications which will have a positive influence on the efficiency of paging system, like:

- selective repeated transmission of a message;
- retransmission of lost (missed) messages (during switch-off time) when the pager is switched -on again;
- validation of each submessage;
- confirmation of over the air programming;
- acknowledgement gives location information, which can mean: no-broadcasting.

4.2 Market

4.2.1 Survey from ERMES MoU and EPPA

There were carried out two market surveys one by the ERMES MoU and one by EPPA addressing resp. the ERMES (signed) operators and the public paging operators in general. The result of these surveys are given in table 1:

Table 1: Market Surveys

item	ERMES MoU	EPPA
	see RES04TWP(96)002	see RES04TWP(96)022
Important for paging business	87 %	nearly all
Costs of the terminal (expected max. bearable increase)	+26 %	+24 % (10-40 %)
Costs of the infrastructure (acceptable increase)	+18 %	+21 % (10-30 %)
Migration of present customers to 2-way	19 % (note)	23 % (10-40 %) (note)
New customers because of 2-way	22 % (note)	22 % (10-30 %) (note)
Requested functions (ranked)	automatic call acknowledgement manual call acknowledgement canned, menu selected responses	automatic call acknowledgement manual call acknowledgement short reply canned response messages long reply user composed messages
Remarks		e-mail is an important feature
NOTE: Of the current subscriber base.		

4.2.2 Paging penetration

Several studies on penetration and growth of the paging services around the world are carried out. Figures, as they are summarized in RES-TR 002 [2] are shown in table 2:

Table 2: Total number and penetration of public pagers

	Total number of public pager and the penetration					
Region/Country	1994		1996		1999	
W. Europe	3 m	~ 0,8 %	4 m	~ 1 %	12 m	3 %
USA	22 m	~ 6 %	25 m	~ 7 %	44 m	12 %
Asia/Pacific	30 m	~ 0,8 %	40 m	~ 1 %	100 m	3 %
Rest of World	2 m		2 m		7 m	

That the figures given are quite conservative is indicated by Economic and Management Consultants Incorporated, who have analysed an annual growth of 30 % during the last years. The present prediction for Asia in the year 2000 varies from 140 m to 200 m

Based on the growth of the paging market in Europe (8M in 3 years) and based on the announcement of some European countries to close the POCSAG services between 2001 and 2004 and to switch over to ERMES, it is expected that ERMES in Europe will have an estimated market share in 1999 between 20 and 35 % of the public paging market, resulting in a number of pagers in use in 1999 between 2,4 and 3,6 million. Taking the average of the prediction of users of Two Way pagers from the market surveys (see subclause 4.2.1), being 43 % of the subscriber base, the number of ERMES Two Way pagers in use in the year 1999 will be 1 - 1,5 m, assuming the availability of Two Way pagers beginning 1998. After 1999 the market share of ERMES will grow as well as the paging penetration.

4.3 Market position of Two Way Paging

For the purpose of the present document, Two Way Paging is taken to be a conventional paging system with the addition of a return channel. The primary functionalities provided by Two Way Paging are either or both:

- one way messaging with either a system a user controlled acknowledgement of receipt;
- Two Way messaging.

These functions can also be provided by other telecommunications systems such as public cellular systems (e.g. GSM with its Short Message Service, private trunked systems such as TETRA, and special purpose data systems).

Although it is difficult to make an absolute distinction between Two Way Paging and other messaging systems, in practice they can be distinguished by a combination of the following factors:

- The non-real time nature of the communications (i.e. the use of store and forward) which gives very high spectrum utilization (Paging provides the highest number of subscribers per channel of any mobile system. (200 000 subscribers per channel can be achieved).
- The absence of the need for continual location updating by the network.
- The use of simulcast techniques in the network to mobile direction.
- Larger coverage areas for each base station.
- Smaller size for the mobile unit (although this difference will remain. it will reduce in the future).
- Lower power consumption giving long battery life for the same size and weight of battery. The long battery life avoids the need for frequent recharging.
- Efficient group call (point to multipoint) capabilities.

These factors result in a relatively low infrastructure cost per subscriber for paging systems, which leads to low tariffs for the user.

Using this distinction, table 3 gives a list of the current Two Way Paging systems and their main technical characteristics.

Table 3: Other Two Way Paging systems

General		Mobile Transmitter		
System	**Manufacturer**	**frequencies**	**technology**	**power**
ReFLEX	Motorola	901-902 MHz	4-level FSK (12,5/25/50 kHz)	1 Watt
InFLEXion	Motorola	901-902 MHz	4-level FSK (12,5/25/50 kHz)	1 Watt
RAMP	Philips	any	CDMA-DS (25 kHz)	0,1 Watt
pACT	AT&T	901-902 MHz	2-level FSK (12,5 kHz)	1 Watt
NEXUS	Glenayre/Nexus	800-1 000 MHz	CDMA-FH Pseudo Random (0,5-2 MHz)	500 mW
APTEL	APTEL	900 MHz	CDMA-DS (1-2 MHz)	1 Watt

5 Compatibility requirements

The proposed ERMES Two Way Paging system has to be compatible with the present (one-way) ERMES in such a way that:

1) Present ERMES pagers (one-way) will operate in a Two Way Paging system without loss of functionality.

2) Two way pagers will operate in a present (one-way) system with the specified one-way functionality of the receiver part.

6 The Two Way functions

The return-channel message functions can be divided in the two main groups: Call acknowledgement and Mobile initiated messages. The summarized return-channel functions will be further examined in relation with the system concept, which could lead to an implementation of a subset of the mentioned possibilities in the system specification.

6.1 Acknowledgement

This Acknowledgement function is used to acknowledge the reception of a call by the paging receiver. There are three acknowledgement types.

6.1.1 System acknowledgement

Definition:

Acknowledgement of the reception of a message by the mobile.

Purpose:

- to enable the system to confirm the calling party that the message was successfully received;
- to improve the reliability of paging by retransmission of the message without significantly increasing the network load;
- to create the possibility for improved network management by selective transmission (a cellular concept).

Details:

The system acknowledgement is generated by the mobile on successful reception of a tone only-, numeric-, alphanumeric- and transparent data message in the following cases:

- single RIC call;
- single RIC programming over the air;
- CTA (Common Temporary Address) groupcall.

Depending on final choices in the evaluated protocols it might be possible to also generate system acknowledgement after reception of a Common RIC groupcall.

Procedure:

The paging system will transmit, with every message that is sent to a Two Way terminal, the information if a system acknowledgement is required and when (at what time) the acknowledgement has to be returned (transmitted by the mobile). The system acknowledgement will contain one of the following informations:

- message received correctly;
- message received, but incorrect, please retransmit;
- message received, but mobile is in unattendance mode or in do not disturb mode.

The network will not acknowledge the system acknowledgement message received from the mobile.

If the network does not receive an acknowledgement message, the network will repeat the transmission of the original message.

6.1.2 Location acknowledgement

Definition:

Acknowledgement of the reception of a location call from the network "where are you".

Purpose:

To determine the location of the mobile to enable the network to transmit a message only in the specific paging area or paging sub-area and/or to receive messages from the mobile only in the specific paging area or paging sub-area.

Details:

The location request message can be used by the network to increase the capacity of the forward channel and/or the return channel. To get this increased capacity a more or less detailed cellular structure of the network is required.

This function can also be used e.g. in case a mobile did not answer, to check if the mobile is available (in reach) again. In fact the message is than "are you there".

Procedure:

The network will transmit the message: "where are you" or "are you there" and the mobile will confirm the reception with "I am in paging area xx". The paging system than knows the paging area and more detailed location information could be determined by the network by determining which base receivers have received that acknowledgement.

6.1.3 User acknowledgement

Definition:

An acknowledgement manually initiated by the called party after reception of a message. Only one acknowledgement is possible after the reception of a message. If the called party want to give further information after an acknowledgement it is called a mobile initiated message (see subclause 6.2).

Purpose:

To inform the calling party what the called party will do with the received message.

Details:

The user acknowledgement can be generated by the user after the reception of a tone only-, numeric-, alphanumeric- and transparent data message in the following cases:

- single RIC call;
- CTA (Common Temporary Address) group call.

This response can be given in one of the following ways:

- as a confirmation that the message was read by the called party;
- as a selection of one of the options if the received message was a multiple choice question;
- as a canned message (an answer is selected from the predetermined (and prestored on the mobile) messages;
- as a canned + message; one of the predetermined messages is selected and numeric data (numeric or alpha numeric) is added;

- as a free format message (numeric, alpha numeric or transparent data).

Procedure:

The paging system will transmit, with every message sent to a Two Way terminal, the information if a user acknowledgement is required and when this acknowledgement has to be transmitted (at what time, or in which timeslot).

There are two groups of user acknowledgements. The fixed length user acknowledgement and the variable length acknowledgement.

The **fixed length** user acknowledgement will contain one of the following informations:

- message read, contents not confirmed (no, disagree, not accepted);
- message read, contents confirmed (yes, agree, accepted);
- message read, and selected answer option given (at multiple choice message answer);
- message read and canned message number included.

If the timeslot, allocated by the network, for the transmission of the acknowledgement message has expired, without being used by the mobile, due to the fact that the message was not read or the answer was not selected or formulated in time, the acknowledgement will be handled as a mobile initiated call (see subclause 6.2), with reference to the received message.

The **variable length** user acknowledgement will contain the following information and will always be handled as a user initiated call:

- message read and canned message number and additional data included;
- message read and free format message included.

It is possible to use a different approach for this fixed- and variable length user acknowledgements. The message received by the mobile can be acknowledged with a request to send a message of a defined length. This is the two step user acknowledgement approach. See clause 7 for further details

The network has to transmit an acknowledgement after reception of the user acknowledgement

6.2 Initiated message

This type of message is used by the mobile (or mobile user) if information has to be send to another party or to the network. There are two type of mobile initiated messages.

6.2.1 System call (mobile initiated)

The function of the system call is to tell a network that that the mobile is available and where it is (location). An overview is given of the definitions of the possibilities to use this function. A decision still has to be taken what possibility (or possibilities) will be implemented in the protocol and alternative ways have to be investigated.

a

Definition: A call automatically generated by the mobile to make itself known to the home-network after the mobile is **switched-on** and after the mobile was **out of range** or of the home-network or **coming back** in the homenetwork.

Purpose: To tell the **homenetwork** that the mobile unit is ready to receive messages (again) and to tell the homenetwork in what paging area it is located.

Procedure: The mobile will transmit a message with the relevant information (identification etc.) in an ERMES returnchannel timeslot for mobile initiated messages and the homenetwork will respond which an acknowledgement. Information has to be transferred via the I3 interface.

b

Definition: A call automatically generated by the mobile to make itself known to a non- homenetwork. This call will be sent when the mobile switches-on, or is in range (again), not being in range of the homenetwork.

Purpose: To support **roaming**.

Procedure: The mobile will transmit a message with the relevant information (identification etc.) in an ERMES returnchannel timeslot for mobile initiated messages and the network will respond with a message containing the level of acceptance (at least three levels). This message will be acknowledged by the mobile.

c

Definition: A call automatically generated by the mobile when it **changes from paging area** in the **homenetwork**.

Purpose: To inform the home-network in what paging area it is located.

Procedure: The mobile will transmit a message with the relevant information (identification etc.) in an ERMES timeslot for mobile initiated messages and the network will respond with an acknowledgment.

Remark: Changing paging area in a non-home network will not be notified to the network, due to the fact that there is hardly anything to gain.

6.2.2 User call (user initiated)

Definition: A call initiated by the user of the mobile.

Purpose: To pass information to another party.

Details: This user call consists of a destination address and a message. This message can be:

- a canned message (a message is selected from the predetermined (and prestored on the mobile) messages;
- a canned + message; one of the predetermined messages is selected and numeric data (numeric or alpha numeric) is added;
- a free format message (numeric, alpha numeric or transparent data).

Procedure:

1. The mobile will transmit a short message to the network in an ERMES timeslot for mobile initiated messages, indicating that it wants to transmit a message and indicating the type and length.
2. The network will answer with a message when (at what timeslot) the mobile can transmit its message.
3. The mobile will transmit its message in the determined timeslot.

4 The network will send an acknowledgement to the mobile.

A retransmission procedure will be included if one or another message reception fails.

6.3 Canned messages

Canned messages may be used in the return channel as well as in the forward channel. There are several types of canned messages:

- basic canned message: message defined by a reference number;
- canned + message: a simple canned message with user added numeric or alpha-numeric data;
- an answer on a received message in the form of a multiple choice message, where one of the options is selected by the user and transmitted back to the system (and to the call initiator).

7 ERMES Two Way Protocol

In the present document two different protocols will be evaluated, and one protocol is mentioned without further evaluation. The aim is the come to a better argumented conclusion, for one of the protocols or for a protocol combining the best of all. All protocols will use a 25 kHz frequency channel, although with some adaptions it might be possible to use other (wideband) solutions.

The first protocol (called protocol A) is based on a further to be defined FM modulation technique with an access to the return channel based on time division. In annex B more details about time division and data rates and coding is given.

The second protocol (called protocol B) is based on a CDMA-DS modulation technique. The return channel access is time divided between mobile initiated messages and acknowledgements. Within these two groups a multiple access principle is used. Both protocols have common parts and specific parts. Every protocol item will be handled in the following subclauses, which will be divided in three parts: common, specific protocol A and specific protocol B.

The third protocol proposal was received late in this process. This protocol is also based on a CDMA approach in a 25 kHz channel. The specific feature of this protocol is the implicit transmitter identity concept, eliminating the need for transmitting the local address. Details of this protocol are not included in the present document. In the process of determining the final ERMES Two Way protocol this third protocol will be taken in consideration.

In general there are two types of control information that have to be transmitted to Two Way terminals:

- General information for all Two Way pagers related to specifications of the return channel.
- Information related to a data message send to a Two Way pager.

To maintain the full functionality and flexibility of the ERMES Paging system an integrated solution is required. General information is transferred to all Two Way pagers using the supplementary system information of the ERMES forward channel (see subclause 7.2). Message related information is transferred in the forward channel as part of the message header. Therefore in order to implement Two Way functionality on existing one way ERMES systems, the existing system shall be modified (see subclauses 7.2 and 7.3).

To minimize the overhead in the return channel, all synchonization of the return channel is derived from the forward channel.

7.1 Time slot technique

There will be two types of return channel transmissions:

1. Transmissions initiated by the mobile. These transmissions will take place in the Mobile Initiated TimeSlot (MITS). This MITS will be defined by the forward channel in the supplementary system information as general data for all (two way) mobiles.
2. Transmissions being an answer on a received message. These transmissions will take place in a subtimeslot of the Network Assigned TimeSlot (NATS) (being the remaining non-MITS time). The subtimeslots will be defined in every message send to a mobile requiring an answer.
3. Transmission by the mobile after the paging central has acknowledged the request from the mobile (see type 1) and indicated when it should transmit its message. These transmission will also occur in the NATS.

In the forward channel every transmission time can be defined by the hour and minutes, subsequence number (0-4) and batch number (A-P). Each subsequence has a length of 12 seconds and each batch is divided in a first part of 10 codewords (being 48 ms) followed by 16 blocks of 9 codewords (each 43,2 ms.). This gives each batch a total length of 739,2 ms (154 codewords). The last batch, however, has 4 additional blocks of 9 codewords, which gives this last batch a total length of 739,2 + 172,8 = 912 ms (15 × 739,2 + 912 = 12 000 ms, being the subsequence time). As the return channel transmission will be synchronized by the forward channel, a return transmission starttime and length has to be expressed in forward channel terminology, being sequence, batch, codeblocs and/or codewords.

The first protocol (called protocol A) will use several MITS subtimeslots to minimize the collision possibility. The second protocol (called protocol B) will use one MITS timeslot in which multiple access will be used. Also the NATS will allow for simultaneous multiple access.

7.1.1 Protocol A

For mobile initiated messages at least the local address and some additional information has to be transmitted. This will require about 30 info bits. To keep the data rate as low as possible (which will be determined by the required capacity) a division of a batch time in more subslots will not be possible. The basic sequence for the return channel will therefore be the forward channel subsequence timing.

Each subsequence in the forward channel will have an associated time slot of 12 seconds in the return channel which will start immediately after the end of the subsequence in the forward channel. This time slot of 12 seconds in the return channel is called the **return subsequence**. This arrangement is shown in table 4:

Table 4: The division of the return subsequence into MITS and NATS

	12 seconds	12 seconds	
Forward channel	Subsequence in forward channel		
Return channel		12 second Return subsequence	
Return channel		MITS	NATS

Transmissions on the return channel are divided into 2 parts:

1. Transmissions initiated by the mobile and transmitted during that part of the return subsequence time called MITS.

2. Transmissions by the mobile following a request from the network will be in a network determined position in the NATS.

For mobile initiated calls a pre-defined time area is available in the MITS. The length of this time slot shall be defined by the network in the SSIT. This MITS maybe divided up into sub time-slots. See subclause 7.4 for more details. The length of the MITS is defined from the beginning of the return subsequence. (See table 5). All transmissions in the 1st sub slot are 43 bits long. If a home terminal transmits in this sub-slot, then the home operator ID is also transmitted. Only home terminal may transmit in the 30 bit sub-slots.

Table 5: Example of MITS with 3 sub slots

Return subsequence 12 seconds			
MITS			NATS
sub slot	sub slot	sub slot	
43 info. Bits	30 info bits	30 info.bits	

NOTE: The length is now measured in terms of information bits. This will be modified when any coding is added to the data to be transmitted.

If a MITS is required, then the first slot is longer then any subsequent one. This is required for roaming mobiles. All roaming mobiles are limited to transmit their MITS information to the first MITS sub slot. For mobile initiated calls (in the MITS) there is a possibility of co-channel collision while, when the NATS is used, no collision is possible. When a mobile wishes to transmit it would choose one of the MITS sub slots at random. In order to increase the chance of a successful reception by one of the fixed receivers, the mobile may repeat the transmission in other return sub-sequences. When the network detects a transmission in the MITS, it will transmit a response to the mobile within a specified time. After this specified time has elapsed, the mobile may assume that its transmission had failed to be detected and can retransmit on another MITS. It should be noted that the total transmission time will be a little longer than the time required to transmit the data due to the finite time to switch the transmitter on and off.

The NATS transmissions will start at a time defined by the network and this is defined when the network transmits the message to the mobile. This time is a certain number of ERMES code words after the beginning of the message in the message partition. (This shall give sufficient time for the mobile to decode the message). For ERMES group calls, this time would be counted from the message with the CTAP definition. Clearly this return confirmation shall be after the transmission of the group message. All NATS data will be transmitted in one return subsequence.

7.1.2 Protocol B

For Protocol B, every batch can be defined individually as a MITS or as a NATS. Every mobile transmission will take the length of one or more batch time(s). The data rate will be variable (depending on the number of bits), while the CDMA chip-rate will be constant.

Table 6: The allocation of MITS and NATS to batches

subsequence	0																1							
batch	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	A	B	C	D	E	F	G	H	I
return channel	mits	nats	nats	mits	nats	mits	nats	mits	mits	nats	nats	nats	nats	mits	mits	nats									

7.2 The forward channel modifications, general data

All general data for the return channel like frequency and modulation technique is to be defined in the SSI code word. Using the reserved sequences of bits in the SSIT (see ETS 300 133 Part 4 6.3.2 [1]), a range of response frequencies and modulations can be defined.

The existing ERMES standard specifies two SSITs: 0000 zone/hour/date;

0001 day/month/year.

The rate and frequency of the SSI transmission sequences is not well specified in the standard and should be tightened up.

A precise sequence for transmission of the different SSIT needs to be defined. On the mobile side, it is assumed that until the mobile receives all the necessary data, it will examine each sub-.sequence and/or batch for the SSIT until it has found all the data. It will then enter its normal battery economy mode.

Up to fifteen SSITs will be transmitted. In each batch in a subsequence the SSITs will be transmitted. Since there are 16 batches in a subsequence, after 15 subsequences all SSITs will have been transmitted in all batches. If certain SSIT have a priority over other SSIT, then it would be possible to defined a minimum repeat time. For instance the SSIT 0001 can only change every 24 hours, and therefore once a pager has determined the time it is not necessary for the SSIT to be received again. In addition its reception is not critical to data transmission,, only to the setting up of the mobile clock. Thus this SSIT can be transmitted at a low priority.

Table 7: SSIT table

SSIT	SSIF
0000	zone/hour/date
0001	day/month/year
0010	Two way mobile type/return channel
0011	Two way parameters
xxxx	TBD (To Be Defined)
1111	Not used (only 15 can be specified)

A large number of combinations of different requirements may be demanded of a Two Way pager. In order to provide a structure for these demands, it is proposed that a set of classes/functions of mobile units is defined, each with a specific task A suggestion for different classes/functions is proposed in table 8

Table 8: Definition of mobile classes

Class or type	Definition
1	Acknowledgements
2	Canned messages
3	Free format messages
4	Registration
5	TBD
-	TBD
8	TBD

The proposed definitions of the SSITs are given in the following tables. There will be some differences in these definitions depending on the protocol that will be chosen. The Tables should therefore been used to demonstrate that all required options and definitions can be implemented. The final definitions should be specified during the standardization work.

Table 9: Supplementary System Information when SSIT = 0010

SSIT	SSIF		
4 bits	14 bits		
	Mobile type (see table 3)	Channel	Spare
0010	3 bits	8 bits	3 bits

It is proposed to use 8 bits for frequency channel identification. The requirement is to cover all 25 kHz channel possibilities within 2 MHz. With 8 bits more than 4 MHz can be covered. With the 8 mobile types, it would be possible to allocate 8 different return channels. For clarification, a mobile type might correspond to different editions of this specification or a different class of Mobile. For SSIT = 0011 there will be differences on the two described protocols. It is therefore defined in the relevant subclause.

7.2.1 Protocol A

To cope with modulation possibilities that might be interesting to use in the future 2 bits will define the type of modulation. The modulation can be defined in SSIT = 0010 or in SSIT = 011. In table 10, the latter is assumed.

To create a flexibility in the division of the subsequence time in MITS and NATS, to cope with different system configurations and to adapt dynamically dependent of the actual traffic, a number of MITS sub timeslots is defined. The actual number of sub-slots will be determined later based on traffic calculations.

Table 10: Supplementary System Information when SSIT = 0011

SSIT	SSIF				
4 bits	14 bits				
	Mobile type (see table 3)	Modulation	MITS subslots	Data rate	Spare
0011	3 bits	2 bits	3 bits	3 bits	3 bits

The MITS definition will be Mobile type independent while the Data rate could be mobile type dependent.

Table 11: SSIF details for SSIT = 0011

Modulation		Number of MITS sub slots		Information Bit rate	
00	25 kHz FM	000	0	000	10 bits/sec
01	TBD	001	3	001	32 bits/sec
10	TBD	010	6	010	100 bits/sec
11	TBD	011	9	011	320 bits/sec
		100	TBD	100	TBD
		---	TBD	---	TBD
		111	TBD	111	TBD

Table 10 and table 11 shows that the information defining the modulation can be directed at a particular mobile type. This will enable future development of systems so that when a higher data rate system is available it will still be possible to use older mobiles.

7.2.2 Protocol B

Besides the Mobile type and frequency channel as defined in table 8 and table 10 for this protocol B should be defined in SSIT/SSIF if the current batch is a MITS or NATS batch. For the same reason as for Protocol A the modulation should be defined. All other functions in this protocol are message related and will be defined in the message header. Some functions however having a more general nature (e.g. a for group of pagers) could be defined in the SSIT. As both approaches are possible this can be decided later on in the standardization process. Table 12 gives the details as far as they are currently established.

Table 12: Batch header Protocol B

SSIT (4 bits)		SSIF (14 bits)		
data	function			
0011	Two way parameters	MT - Mobile type (3 bits)	Batch is MITS (1 bit)	TBD

If there are no mobile type related definitions in this SSIT it might will be specified in SSIT = 0010. This can be decided later on in the standardization process.

7.3 New data format for the forward channel, message header

Each message transmitted to the mobile needs to have some additional data related to the requested reaction of the mobile, for example system acknowledgement and user acknowledgement. In addition there are new "types" of forward channel messages that are answers and acknowledgements of messages from the mobile (control messages).

The message header information conforms to the existing standard (ETS 300 133 [1]) but the reserved AIT (011) will be used for Two Way messages. The field following the AIT = 011 will be called AIS (Additional Information Sequence). Following the AIS there will be a number of bits of data to be used for the Two way system, followed by 8 bits which correspond to the AII and VIF for the outward going message. (See table 13).

Table 13: Format of forward message containing data for return message

Local address	Message Number	External bit	AII	AIT	AIS	Data for two way	AII	VIF	Message Data
22 bits	5 bits	1 bit	1	011	4 bits	n bits	1 bit	7 bits	n bits

For Two Way data messages the DTW field (Data field for Two Way) will be followed by the "normal" AII and VIF and if applicable the AIF field. For Two Way control messages the DTW field is the last field.

7.3.1 Protocol A

The data sent with the forward message may now include the necessary information for the return transmission.

Messages send to Two Way pagers will be either in the format of one-way messages (and the pager will react accordingly) or the message will be send as a Two Way message using the new format. In the latter case additional information related to the required reaction has to be send with the message. A Two Way messages will always require a system acknowledgement. The additional information relates to when the system acknowledgement has to be transmitted and if user acknowledgement is required and when. See table 14 for details.

Table 14: Two Way Data field definition (messages)

AIS		DTW field (Data for Two Way) for data messages	
0000	Only system acknowledgement required	Time in ERMES codewords from beginning received message to start of transmission (15 bits)	
0001	System and User acknowledgement required	Time specified for system acknowledgement as above (15 bits)	Time in ERMES codeblocks from beginning received message to start of user ack. transmission (15 bits)
0xxx	TBD		

The control messages can be defined as given in table 15:

Table 15: Two Way Data field definition (control)

AIS		DTW field (Data for Two Way) for control messages	
1000	Acknowledgement of registration or area info	000 general 001 acknowledgement accepted 010 (full agreement) accepted 011 (basic agreement) 100 emergency calls only forbidden	
1001	Acknowledgement of request to send data	Time from end of DTW field to start of transmission (in ERMES codeblocks) 15 bits	length of expected message in ERMES codewords (5 bits)
1010	Retransmit last message	Time from end of DTW field to start of transmission (in ERMES codeblocks) 15 bits	length of expected message in ERMES codeblocks (5 bits)
1011	General acknowledgement		
1xxx	TBD		

7.3.2 Protocol B

The data sent with the forward message may now include the necessary information for the return transmission.

Messages send to Two Way pagers will be either in the format of one-way messages (and the pager will react accordingly) or the message will be send as a Two Way message using the new format. In the latter case additional information related to the required reaction has to be send with the message. As this described protocol uses CDMA, some particular information could be forwarded to the mobile related to the CDMA sequence and/or phase of the required mobile answer. This leads to more functions to be transferred with the message to the mobile and this leads also to combinations of functions. Therefore it is required to be able to send multiple AIS/DTW sequences with one message. The first bit after the AIS defines if this AIS/DTW field is followed by another AIS/DTW field. This AIS continuation bit will be "0" if no additional field will follow and set to a "1" if an additional field will follow. As there is no clear split between control messages and data messages and as combinations will be possible all possibilities are given in table 16.

Table 16: Two Way Data field definition (data)

AIS		continuation		
Data	Description	bit	Data	
0001	Causes one ore more pagers to send a response (ICS)		length of data field (7 bits)	TBD
0010	Defines unique response parameters for the pager (RACS)		length of data field (7 bits)	TBD
0011	Embedded answer to message/Canned dictionary to use (EACS)		length of data field (7 bits)	TBD
0100	A combination of the ICS and RACS (FICS)			
0101	Used by the paging system to acknowledge a pagers transmission (ACKCS)			TBD
0110	End of command			TBD
0111	Allows an operator to inhibit or and Enable pager transmissions (TEICS)			TBD
1000	Allocates a temporary Sequence to a pager (TSACS)			TBD
1001	Allocates a temporary Phase to a pager (TPACS)			TBD
1010	Defines a sequence for the pager (PSACS)			TBD
1011	Defines a Phase that should be used by the pager (PPACS)			TBD
1100	Restore Defaults values			TBD
4 bits		1 bit		

7.4 The return channel data format

In subclauses 6.1 and 6.2 the functionality of the return channel is explained in detail. Table 17 summarizes the function as return message types 1a - 2b.

Table 17: Return channel functions

	1: system	2: user
a: acknowledgement	acknowledgement of message reception by the mobile	an answer from the user on the received message - confirmation - canned message - canned + message - alpha numeric message - free format data
b: initiated call	a call initiated by the mobile to inform the system od changed network, (sub)area or status	a call initiated by the user - canned message - canned + message - alpha numeric message - free format data

For a better understanding some flowcharts are added to the present document in annex A. Clause A.1 gives the flowchart for a forward message to a Two Way pager.

7.4.1 System acknowledgement

This transmission refers to message type 1a as indicated in table 17. When a receiver receives a Two Way message in the message partition it will automatically respond at a defined time after the beginning of the message reception. (See subclause 7.2.3). The automatic acknowledgement need not to include the RIC information. A few defined sequences should be sufficient (see subclause 6.1).

As an example, consider the situation when message is transmitted. There could be four possible outcomes from this transmission:

a) Message received correctly.

b) Message received correctly, (but pager is in unattendance mode).

c) Message not received correctly.

d) Message not received at all.

For these four outcomes, it would be sufficient to define one sequence which needs to be transmitted to enable the network to distinguish between the two results a and b.

If the message is received correctly (independent of the pager mode) then, the transmission sequence is as follows:

1. Transmission by Network of message.
2. Confirmation to network by mobile.

If the message is not received correctly, the transmission sequence is as follows:

1. Transmission by Network of message.
2. Retransmission request to network by mobile.
3. Retransmission of message by network.
4. Confirmation to network by mobile.

If the message is not received by the mobile:

1. Transmission by Network of message.

2. Retransmission of message by network.
3. Confirmation to network by mobile.

The above procedure applies to each sub-message of a message transmitted using the long message procedure. In this case all submessages need an acknowledgement. Acknowledgements shall be requested and sent before the next submessage is transmitted. In this way, the network is informed which submessage needs to be retransmitted.

7.4.1.1 Protocol A

The actual acknowledgement messages are shown in table 18:

Table 18: System Acknowledgement data

Message No.	Data bits	Meaning
1	01	Message received correctly
2	10	Message not received correctly
3	11	Message received correctly and pager in unattendence mode
4		TBD

7.4.1.2 Protocol B

A pager transmits one of several CDMA-codes each having a different meaning as described in table 18. The CDMA code is based on the pager-ID and also on other information that may have been sent in the message.

7.4.2 User acknowledgements

User acknowledgements are always related to a received message. Therefore it is superfluous to include in the acknowledgement any destination address. The paging system should remember who was the initiator of the call, being the destination of the user acknowledgement.

7.4.2.1 Protocol A

An overview of the acknowledgement possibilities is given in table 19. One should keep in mind, that only some types of return messages (acknowledgements) will use this procedure. See subclause 6.1 paragraph 3.

All these acknowledgements have a fixed length of 7 data bits. Fixed length is required as it should be up to the pager user which kind of acknowledgement will be given.

Other acknowledgements will use the user initiated procedure. See subclause 7.4.3.1.

Table 19: User acknowledgements

Data Identification		Data contents		
	Purpose			Function
0	User Acknowledgement (confirmation)	000	001 010 011	message read, no comments message read, agree/yes message read, disagree/no
0	User Acknowledgement with selected answer option	001	3 bits	1 of the max. 8 answers can be selected. The answer are included in the received message
		010	3 bits	To be defined
		111	3 bits	To be defined
1	User acknowledgement with canned message	6 bits		1 of the max. 64 canned messages, according a general table or a personalized table (note 1).
NOTE 1: Assumed is that the general canned message table contains less or equal than 64 messages, these message numbers can be used directly. If the table contains more messages always a personalized subset shall be used. If a personalized canned message table has to be used, it could be exceptable to limits to choice to 32, giving the possibility to reduce the number of bits for these types of acknowledgements to 6 instead of 7.				

To reduce the number of bits of the user acknowledgements in table 19 a sequence could be used, being an acknowledgement combined with the request to send a more extensive acknowledgement like canned and canned + messages. This allows a larger canned message library and this procedure will also reduce the number of MITS transmissions as all canned + acknowledgements are now planned to use the MITS first.

7.4.2.2 Protocol B

As with system acknowledgements, a pager transmits one of several CDMA codes that each have a different meaning as described in table 19. In addition a pager may send codes that request to send canned+ data or free format data. (See subclause 7.4.3.2).

7.4.3 Mobile and user initiated data

These transmissions refer to message types b as indicated in table 17. There shall be one format for all mobile/user initiated calls (system call and user call). The transmission sequence always starts with a transmission in the MITS, being a system call or being a request to send a message to the network.

7.4.3.1 Protocol A

Mobile and user initiated messages from a mobile in a visiting (non-home) network have to include the home network identification being the OPID. These messages have to be sent in the first MITS sub slot which is defined to be longer than the following subslots. The format used in protocol A is defined in table 20. The OPID field is conditional therefore the total number of bits is specified in table 20.

Table 20: Data Identification for Mobile/User initiated calls

Local address	Data identification		OPID	Data purpose		# of bits	total # of bits
22 bits	MI	Purpose					
	00	Registration Request		paging area			30 (43)
	01	Inform network of change of location, new paging area		paging area			30 (43)
	10	Request to re-transmit message (lost message) from network		0	Message No.		30 (43)
	10	Spare		1	TBD		
	11	Request to send message from mobile		Variable length of message. see remark (note 1)			30 (43)
	2 bits		13 bits			6 bits	30 (43)
	NOTE 1: Message type and destination address are part of the message. The destination address will be a message number in case the message is in fact a user acknowledgement.						

There are two basic transmission sequences for these initiated calls.

If the first transmission (from the mobile) is a system call (data identification type 00 and 01) an acknowledgement (receipt confirmation) will be send from the network to the mobile in the batch (related to the mobile RIC) of one of the following subsequences of the forward channel. (See table 15).

If the first transmission from the mobile is a request to the network to retransmit a (lost) message the network will answer with the requested message. If the first transmission (from the mobile) is a request from the mobile to send further data, the network will answer in the batch (related to the mobile RIC) of one of the following sequences of the forward channel, with a message containing information how and when the message can be transmitted by the mobile. (see subclause 7.3). The mobile will than transmit in the allocated timeslot its message and the network will respond with an acknowledgement (confirmation of receipt).

7.4.3.2 Protocol B

All calls sent by a pager that require a higher data rate use shorter concatenated sequences. Each sequence represents 3 bits. All calls sent in the MITS timeslot use a data packet based on 48 bits, using 8 Reed Solomon symbols. Such transmissions are contained in a single MITS time slot; 8 types of MITS calls are currently defined:

- Registration.
- Request for system to re-transmit message.
- Request to send Canned message.
- Request to send Canned message + 4 numeric digits.
- Request to send Canned message + 16 numeric digits.
- Request to send Canned message + 10 alphanumeric characters.
- Request to send Canned message + 24 alphanumeric characters.
- Request to send Free Format data.

The mobile will specifically ask to transmit a certain type of message. This enables the paging central to control the types of answers given in a certain NATS (remember, it is multiple access). The advantage is to make the decoding of the CDMA sequences easier in the base receiver. The paging system responds to the above transmissions with an acknowledgement that may take one of several forms. For example:

- Simple acknowledgement - for example to confirm registration, or allow canned or canned+ data to be sent.
- Negative acknowledgement - for example to reject a request to send message.

- Free format acknowledgement - includes permitted data rate.

If permitted, in the case of sending canned+ or free format data, the pager then transmits the information. The data rate that is used by the pager depends on the application, but all transmissions are contained in a NATS time slot. For example a canned answer + 4 numeric digits are sent at about 30 bps; but canned answer + 24 alphanumeric characters are sent at about 260 bps. Free format transmissions can be sent at various data rates as permitted by the paging system (currently approximately 130, 260, 530 bps). In order to reduce the data rate used, multiple NATS time slots are also permitted.

7.5 The return channel messages format

Mobile transmission in NATS:

System Acknowledgments and User Acknowledgments and Messages will be transmitted at a time in the NATS defined by the network. The acknowledgments are described in subclauses 7.4.1 and 7.4.2. Acknowledgments with more information (canned + message) and all mobile initiated messages will after the request to transmit is given by the paging central, transmit the return message. This message has a structure indication the message type, the total length and the destination address. The information length depends on the type of message to be returned to the network. The data structure is as follows:

Table 21: Return channel message format

Message Header					**Message content**	
Type of data		Type of address		Address	Length	Data
000	acknowledgment 1)	000	no. of received message	5 bits	0 bit	6 bits
001	canned+ num	001	fax.no	TBD	5 bits	
010	canned+ alpha	010	ermes mobile homenetwork	22	5 bits	
011	numeric	011	ermes mobile non-homenetw.	35	5 bits	
100	alpha	100	gsm mobile (sms)	TBD	5 bits	5n 2)
101	free format					
111	TBD	111	TBD			

Remarks: Type of data, Length and data are linked with each other.

Type of address and address do fit whit all types of data except with acknowledgment. Here only the first type of address can be used.

7.6 Transmission sequences

To show the transmission sequences examples of some Two Way functions are given. The given examples are valid for protocol A.

Table 22: Registration (Home pager, Accepted)

		Message sent	**Time transmitted**	**Data content**
1	Mobile initiated request	see table 20	Any MITS time slot	Local address, 00, Paging Area.
2	Acknowledgement from network	see table 15	Normal forward channel from defined paging area.	1000, acceptance level

Table 23: System acknowledgement of message (Home pager)

		Message sent	Time transmitted	Data content
1	Message transmitted by network.	see table 14	Normal forward channel	Position of system acknowledgement.
2	Auto acknowledgement by mobile	see table 18	In defined space in return channel	message received correctly

Table 24: Request for a user acknowledgement from a mobile (Roaming pager)

		Message sent	Time transmitted	Data content
1	Message transmitted by network.	see table 14	Normal forward channel	position of system and user acknowledgement.
2	Auto acknowledgement by mobile	see table 18	In defined space in return channel	message received correctly
3	Request to send user acknowledgement	see table 20	In MITS	length of acknowledgement
4	Acknowledged by network and time slot in NATS defined	see table 15	In forward channel	start time and length in NATS
5	Return transmission by mobile	see table 21	In defined slot in NATS	message number and user response.

Table 25: Request to send free format from mobile

		Message sent	Time transmitted	Data content
1	Request to send message by mobile	see table 20	MITS	length of message
2	Acknowledgement by network	see table 15	In forward channel	start time and length in NATS
3	Transmission from mobile	see table 21	In NATS	destination and message Message

8 Traffic calculations

8.1 The estimated number of Two Way subscribers in a network

In order to calculate the estimated number of Two Way subscribers we first have to calculate the capacity of one forward channel in a paging area. This calculation is based on a reference model of the forward channel traffic. This reference model is given in table 26:

Table 26: ERMES reference capacity model

ERMES Reference capacity model for one forward channel in a paging area				
message type	# of codewords	usage		
data	227	1 %	2,27	(# of codewords x usage)
text	51	49 %	24,99	(# of codewords x usage)
numeric	8	35 %	2,80	(# of codewords x usage)
tone	4	15 %	0,60	(# of codewords x usage)

	Average number of codewords per call		30,66	
	Total available number of code words per hour = 750 000 × loading 0,8 =		600 000	
	number of calls per hour		19 569,47	
	number of subscribers (BHCR = 0,1)		195 694	for one forward channel in a paging area

In order to avoid that the forward channel will be limited by the return path, the required capacity of the return channel shall be enough to serve the number of Two Way subscribers for one forward channel in a paging area. This number of Two Way subscribers can de determined, using the estimated percentages of total number of subscribers that will use Two Way facilities, which is given in the market survey (see subclause 4.2) being 43 %. This results in a number of Two Way subscribers for one forward channel in a paging area:

Number of Two Way subscribers 43 % (see subclause 4.2)	**84 148**	(per return channel)

Based on this model and based on carefully evaluated assumptions several tables can be made independent of the protocols, to indicate the all the Two Way functions and the corresponding number of functional bits required. The tables will be used later to evaluate in detail the different protocol solutions. The following tables will give an overview of:

1. the use of acknowledgements;
2. use of mobile/user initiated calls;
3. calculated max. data rates**;**
4. data rates in example systems.

8.2 The estimated usage of the return channel

To evaluate the proposed protocol solution the models in table 27 and table 28 will be used. These tables will give an overview of the number of bits that has to be used in the return channel for each return function.

Table 27 gives figures about the estimated use of the return channel for acknowledgement functions, based on the usage of the forward channel (type of calls) and based on assumed usage of acknowledgement is given in column 2.

Table 27: Use of Acknowledgements

	1	2a	2b		2c		2d	3a	3b	3c	4a	4b
1 2	acknowledgement function	% of forward call using the acknowledgement function						number of return info bits		bits total	# of ack.'s per 100	in
3 4		tone	num.		alpha		transp.	per return	per 100 forward calls to 2-w		forward calls to 2-w	BH
5		15 %	34 %	1 %	48 %	1 %	1 %	function	subscr.		subscr.	
6	system acknow.											
7	single RIC	25	50		100		100	2	139,50	209,25	69,75	5 869,32
8	gr.call CTA			80		100		2	3,60			
9	(10 addr.)								(X 10)	54,00	18,00	1 514,66
10	gr.call	0	0		0		0					
11	(common RIC)											
12	user acknow.											
13	confirmation	10	25		10		5	2	29,70	44,55	14,85	1 249,60
14	canned mess.	0	10		15		1	8	84,88	127,32	10,61	892,81
15	canned+mess.	(10)	(10)		(15)		(5)					
16	num.4	6	5		5		1	24	120,24	180,36	5,01	421,58
17	num.16	2	3		3		0,5	72	199,08	298,62	2,77	232,67
18	alpha 10	1,5	1,5		5		2	78	246,09	369,14	3,16	265,49
19	alpha 16	0,5	0,5		2		1,5	120	146,40	219,60	1,22	102,66
20	free format	(2)	(2)		(10)		(15)			0,00		
21	num 16	1,5	1,5		2		1	64	109,12	163,68	1,71	143,47
22	alpha 100	0,4	0,4		7,5		2	700	2 671,20	4 006,80	3,82	321,11
23	transp.100	0,1	0,1		0,5		12	1 000	409,00	613,50	0,41	34,42
24										6 081,62	131,29	11 047,79

- column 2 row 5 represents the use of the forward calls divided over the different type of calls;
- column 2 row 6-23 indicates the estimated use of acknowledgement in % of each type of forward call;
- column 3a gives the number of return info bits for each acknowledgement function;
- column 3b is the calculated number of info bits for each acknowledgement function per 100 forward calls;
- column 3c has added 50 % of coding for each acknowledgement function;
- column 4a gives the number of acknowledgements per 100 forward calls (= 3b/3a);
- column 4b gives the number of acknowledgements in the busy hour based on 84148 2-way subscribers from which 10 % will receive a call in the Busy Hour.

Table 28 gives figures about the estimated use of the return channel by mobile/user initiated calls, based on the number of initiated return calls per day/per Busy Hour.

Table 28: Use of Mobile/User initiated calls

	1	2	3	4	5	6	7
1 2 3 4	return function mobile/user initiated	% of users per day (note 1)	# of calls per day	# of calls per BH (note 2)	bits per call without ident.	 + ident. + 2/3 coding	# of bits per BH
5	system call						
6	switch-on (note 3)	25,0	21 037,00	5 259,25	8	54	283 999,50
7	change network	1,0	841,48	84,15	8	54	4 543,99
8							
9	user call						
10	canned	4,0	3 365,92	336,59	8	64,50	21 710,18
11	canned + message						
12	num.4	1,0	841,48	84,15	24	88,50	7 447,10
13	num.16	3,0	2 524,44	252,44	72	160,50	40 517,26
14	alpha 10	0,7	589,04	58,90	78	169,50	9 984,16
15	alpha 16	0,3	252,44	25,24	120	232,50	5 869,32
16	free format						
17	num.16	0,6	504,89	50,49	64	148,50	7 497,59
18	alpha 100	0,3	252,44	25,24	700	1 102,50	27 831,95
19	transp.100	0,1	84,15	8,41	1 000	1 552,50	13 063,98
20			30 293,28	6 184,88			422 465,03

NOTE 1: Number of Two Way subscribers for one forward channel in a paging area is 84148.
NOTE 2: Busy Hour = 10 % of calls per day (10 % of 84148).
NOTE 3: Busy Hour for switch-on is 25 % of # of users per day.

column 2 gives the estimated usage of each return call type in % of number of subscribers.
column 3 is column2 * # of users.
column 4 is column 3 * use in busy hour.
column 5 is the given # of info bits (without identification) required for the return call function.
column 6 is column 5 + identification bits (35) and 50 % of coding.
column 7 is column 4 * column 6.

8.3 Implementation of usage of the return channel in the protocol

Based on table 27 and table 28 a table can be made containing all the functions, how often the functions are used in the busy hour and calculating the no. of bits needed in the MITS and NATS timeslots according the protocol (see clause 7).

Table 29: Calculated max. data rates

	1a	1b	1c	2	3a	3b	3c	4a	4b		5a	5b
1	Function			usage in BH	MITS # of bits	MITS bits/BH	MITS %	NATS # of bits	NATS bits/BH	NATS %	total bits/BH	% of total
1	System ack.											
3		Single RIC		5870	none			2	17610	2,9	17610	2
4		gr.call CTA		1515	none			2	4545	0,7	4545	0
5		(10 addr.)						20				
6	User ack. 2)											
7		confirmation		1250	none			2	3750	0,6	3750	0
8		canned mess.		893	none			8	10716	1,7	10716	1
9		canned+mess.										
10			num 4	422	34	21522	6,9	24	15192	2,5	36714	4
11			num 16	233	34	11883	3,8	72	25164	4,1	37047	4
12			alpha 10	265	34	13515	4,3	78	31005	5	44520	5
13			alpha 16	103	34	5253	1,7	120	18540	3	23793	3
14		free format				0	0					
15			num 16	143	34	7293	2,3	64	13728	2,2	21021	2
16			alpha 100	321	34	16371	5,2	700	337050	54,6	353421	38
17			transp.100	34	34	1734	0,6	1000	51000	8,3	52734	6
19	System call 1)											
20		switch-on		2104	34	107304	34,2	none			107304	12
21		change network		421	34	21471	6,8	none			21471	2
22		change area		1262	34	64362	20,5	none			64362	7
23	User call											
24		canned mess.		337	34	17187	5,5	8	4044	0,7	21231	2
25		canned+mess.										
26			num 4	84	34	4284	1,4	24	3024	0,5	7308	1
27			num 16	252	34	12852	4,1	72	27216	4,4	40068	4
28			alpha 10	59	34	3009	1	78	6903	1,1	9912	1
29			alpha 16	25	34	1275	0,4	120	4500	0,7	5775	1
30		free format										
31			num 16	50	34	2550	0,8	64	4800	0,8	7350	1
32			alpha 100	25	34	1275	0,4	700	26250	4,3	27525	3
33			transp.100	8	34	408	0,1	1000	12000	1,9	12408	1
34						----------			----------		-----------	
35					bits/BH =	313548	100		617037	100	930585	100
36									bits/sec	=	258	

NOTE 1: The Busy Hour for switch-on will probably be around 25 %, but this BH does not coincide with the busy hour for calls, therefor in calculating the overall busy hour 10 % of switch-on is used.

switch on:	10 % (BH) of 25 % of # of users =10 % of 25 % of 84148=	2104
change network:	10 % (BH) of 1 % of # of users = 10 % of 1 % of 84148 =	84
change paging area:	10 % (BH) of 5 % of # of users = 10 % of 5 % of 84148=	421

NOTE 2: A certain percentage of conformation and canned messages will be handled as mobile initiated messages. Assumed is 20 % of confirmation and 35 % of canned messages.

Column 2 gives for the acknowledgements the rounded figures from table 27 column 4b (# of ack's in BH) and for the system and user call it gives the rounded figures from table 28 column 4 with correction for system calls.

Column 3a is derived from the protocol see clause 7 and column 4a is derived from table 27 and table 28.

Column 3b and 4b are calculated values (usage in BH * # of bits * 3/2 for coding, 50 %).

8.4 Systems with differentiated functionality

From table 29, we can determine several systems each having implemented a different set of functions. Some of the possible examples are:

System 1: including System Ack, User Ack (confirmation and canned mess.)

System 2: as System 1, but System call (change network and change paging area added) added

System 3: as everything minus free format and minus switch-on

Several other combination can made. Table 30 gives the key figures for the above mentioned examples.

Table 30: Data rates in example systems

Function	MITS			NATS			Total		MITS / NATS
	# of trans.	bits/BH	%	# of trans.	bits/BH	%	bits/BH	%	
System 1									
system ack.		none		7385	22155	60,5	22155	60,5	
user ack.		none		2143	14466	39,5	14466	39,5	
# of trans.tot.				9528					
bits/BH tot					36621	100,0	36621	100,0	
bits/sec					10,2		10,2		only NATS
System 2									
system ack		none		7385	22155	60,5	22155	18,1	
user ack		none		2143	14466	39,5	14466	11,8	
system call	1683	85833	100,0				85833	70,1	
# of trans.tot.	1683			9528					2,3: 1
bits/BH tot		85833			36621		122454		
bits/sec							34		2,3: 1
System 3									
system ack		none		7385	22155	12,9	22155	6,4	
user ack		none		2143	14466	8,4	14466	4,1	
canned+		52173	29,5	1023	89901	52,2	142074	40,7	
system call	1683	85833	48,6				85833	24,6	
user call	337	17187	9,7	337	4044	2,3	21231	6,1	
canned+	420	21420	12,1	420	41643	24,2	63063	18,1	
# of trans.tot.	2440			11308					1: 1,03
bits/BH tot		176613			172209		348822		
bits/sec							96,9		

The last column in this table gives the ratio between the MITS timeslot (for one sub-slot) and the NATS timeslot.

9 Return channel, data rates and output power

The return channel capacity is depending from the number of bits in the Busy Hour (BH) and from the used data rate.

The number of bits are determined in subclauses 8.2 and 8.3 and the final result is depending on the functions to be implemented.

There is also a relation between data rate and output power. Using the assumptions and figures from subclause 11.2 (link budget) it is shown that an return path data rate of 6 bps and a transmit power of 100 mW provides about a 1: 1 ratio of forward and return path losses. The next table shows the variation in return path loss that occurs for different transmit powers (into the antenna) and data rates.

Table 31

Transmit Power (mW)	Data Rate (bps)							
	0,5	***1***	***2***	***6***	***16***	***64***	***256***	***512***
10	0,79	-2,22	-5,23	-10	-14,3	-20,3	-26,3	-29,3
50	7,78	4,77	1,76	-3,01	-7,27	-13,3	-19,3	-22,3
100	10,8	7,78	4,77	0	-4,26	-10,3	-16,3	-19,3
500	17,8	14,8	11,8	6,99	2,73	-3,29	-9,31	-12,3
1000	20,8	17,8	14,8	10	5,74	-0,28	-6,3	-9,31
10000	30,8	27,8	24,8	20	15,7	9,72	3,7	0,69

This can be translated into a ratio of required receive sites per transmit site as follows:

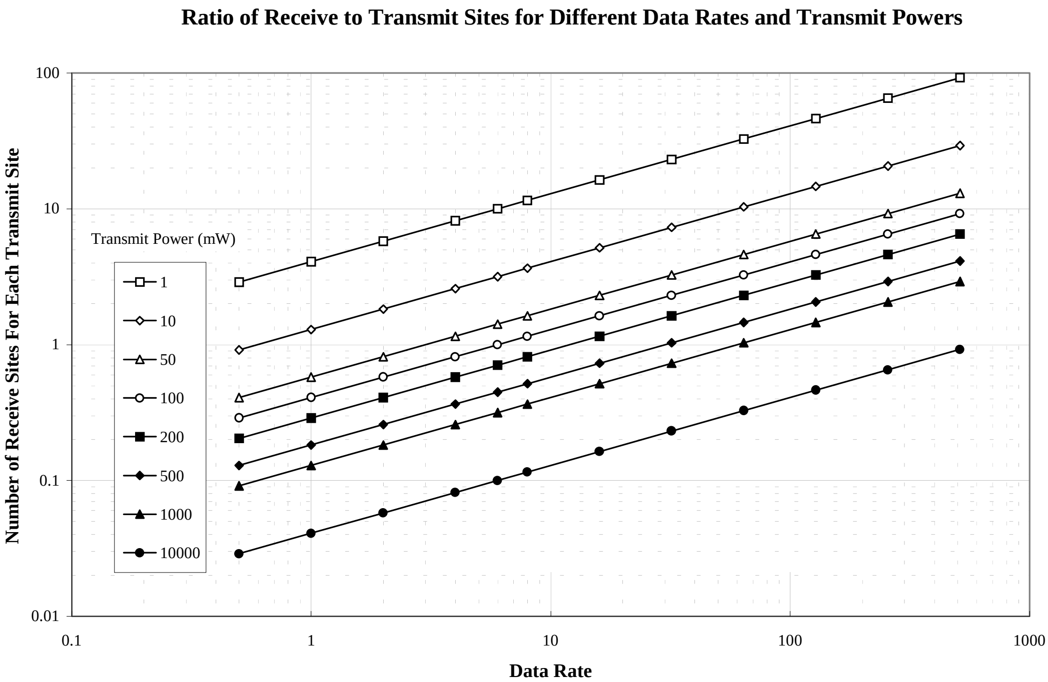

Figure 1: Receive sites versus data rates and transmit powers

In figure 2 the same data is used to express the data rate and receive sites in transmit power.

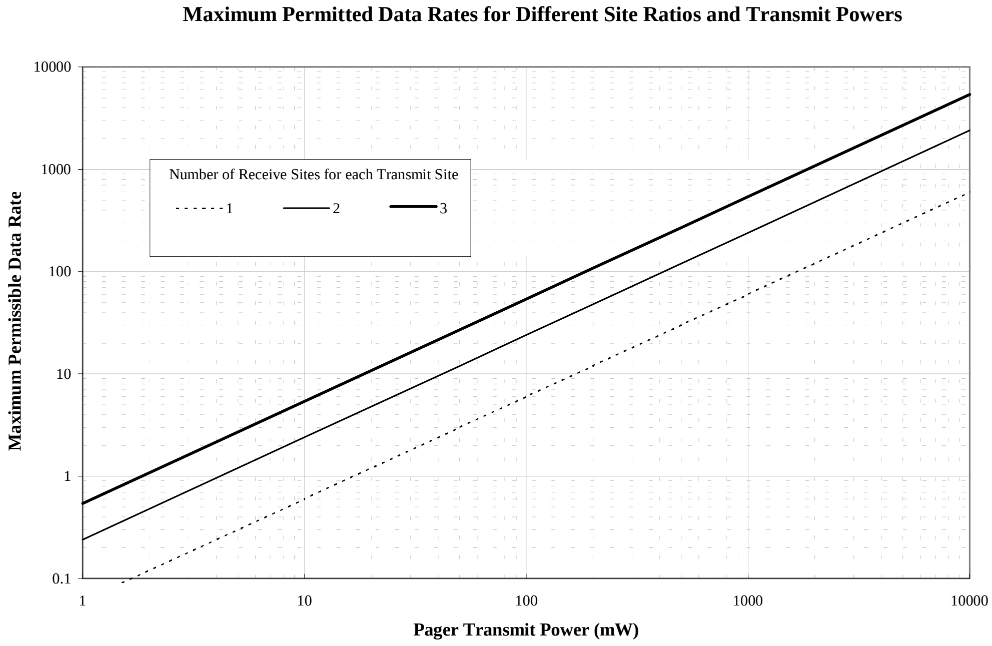

Figure 2: Data rate versus transmit power and receive sites

It is therefore proposed that applications are given an associated data rate and a corresponding minimum power at which to transmit. It is also proposed that a nominal ratio of transmit to receive sites are also defined that operators are expected to implemented. This means that the cost of both the pager and the paging system (the network) increase as the applications become more demanding.

9.1 Protocol A

In protocol A 5 types of messages are used each having its own number of bits:

- System acknowledgement 2 info bits 3 bits.
- User Acknowledgements 7 info bits 11 bits.
- Mobile request to send data in homenetwork 30 info bits 45 bits.
- Mobile request to send data in non-home network 43 info bits 65 bits.
- Mobile data to be determined.

For Coding, a suitable coding algorithm has to be determined, but for the time being an overhead of 50 % is assumed.

Different data rates will be used, mainly determined by the total system capacity required. This of course is related to the functions implemented. To maintain compatibility between different systems (operators) each of the 5 messages types can be transmitted at at least two different data rates.

To compensate for losses due to higher data rates, the mobile output power and/or the number of base receivers per transmitter can be raised.

9.2 Protocol B

For the return channel a flexible data rate approach based on CDMA technology is proposed. In essence, this scheme causes pagers to transmit CDMA chips at a constant rate, with the number of chips per bit (sequence length) being varied as required. Transmissions occur in pre-defined time-slots.

9.2.1 Low data rate applications

Response codes are generated in the pager using linear feedback shift registers to generate a pseudo-random code 4095 chips long. Pagers transmit at 5 625 chips per second. Thus one 4095 sequence lasts just under one ERMES batch. Pager transmissions occur in timeslots based on the ERMES batch, and are synchronized by the ERMES signal.

A code consists of both a sequence and a phase. There are 2^{18} possible sequences and 2^{10} available phases for use. Prior to transmission, pagers initialize the sequence generator to a given phase. Each pager has a default code based on the home identity. Roaming pagers are automatically assigned other sequences to use.

Pagers may use one of several codes to respond to a message. The responses available are application dependent and sometimes context sensitive. For example codes may be used for acknowledgements, message displayed, one of N answers to a message, etc. and to request to transmit information at a higher rate (canned+data responses to a message).

9.2.2 Variable data rate applications

For applications that require the pager to transmit at a higher data rate, shorter sequences are used to which Forward Error Correction (FEC) is applied.

The shortened Reed-Solomon RS(63,63-2t) error correcting code is suggested. This is a non binary code capable of correcting any combination of independent and burst errors in any t coding symbols. The original code is shortened according to the information packet size and a default of 4 parity symbols (t = 2, 24 bits) is appended to the information bits.

The pager generates one sequence at one of 8 phases, each corresponding to one of 8 three bit combinations. Table 32 gives some examples of the different data rates that can be obtained:

Table 32

Chips per Modulation Symbol	Transmitted Data Rate (bps)
64	263,67
128	131,84
256	65,92

The number of chips per bit and hence the data rate is application dependent.

In general all transmissions occur in a single batch time slot - although multiple batch transmissions are also possible. Uses for such transmissions are registration, canned answer + data, free format messages, requests to send data, etc.

10 Spectrum use

10.1 Frequency bands

10.1.1 The ERMES band

The possibility to use the present ERMES frequency band was investigated. Three possibilities were examined with the following results:

a. Frequency sharing/interleaving

   These methods were shown to be inappropriate due to high level of ambient noise from ERMES transmitters operating in adjacent channels.

b. Time sharing

   Besides loss of capacity, this system also suffers from ambient noise and co-channel interference from other ERMES networks.

c. CDMA

The power differential between mobile transmitters and base station transmitters together with the random distribution of these transmitters, can be shown to make this system unworkable.

The conclusion of all the above mentioned principles is that the ERMES band can not be used for the ERMES return channel.

10.2 Frequency requirements

The determine the frequency requirements for the ERMES return channel the principles have been evaluated for their possibilities and consequences, being the Narrow-band concept and the Broadband concept.

10.2.1 Narrow band concept

The present document, as already stated elsewhere, is assuming the use of sufficient number of 25 kHz channels (being one per forward channel). Although the preference is the UHF-low band, the VHF band might be possible to use as well as the UHF high band. A suitable harmonized frequency band is essential. In this band there are some options which are listed in order of preference based on most suitable operation and complexity (costs):

- a harmonized set of contiguous frequency channels;
- non - harmonized sets of contiguous frequency channels;
- a set of harmonized non - contiguous frequency channels;
- a set of non - harmonized, non - contiguous frequency channels.

10.2.2 Broadband concept

A broadband concept (>1 MHz) using spread spectrum is attractive for the return channel of Two Way Paging due to the beneficial effect in a fading environment, as well as for frequency planning if at least it is based on sharing the same broadband other services (narrow band or broadband). For the time being however, there is not available enough knowledge concerning the conditions under which sharing is possible. It will certainly be 1998/1999 before sufficient knowledge is gathered. This is outside the timeframe of the present document.

11 General

11.1 Mobile battery life

11.2 Link budget

By calculating the link budget for both the downlink and up-link, the consequences of the following design parameters can be assessed:

- Pager transmit power.
- Pager transmit data rate.
- Ratio of receiver sites to transmit sites.

The following formulae is used for the downlink:

E_b/N_o in pager = Base Station ERP

- Path Loss;

- Fade Margin;

+ Pager antenna gain;

- Pager implementation loss;

- Noise power in pager;

- 10 $\log_{10}$ (Data Rate).

A similar formulae is used for the up-link. Because the path loss is of most interest, the equation is adjusted accordingly with the following results:

Base Station to Pager	Value	169 MHz dB
Base Station Transmit Power (Watts)	*100*	*20*
Base Station Transmit Losses (dB)	*2*	*-2*
Base Station Transmit Antenna Gain (dB)	*5*	*5*
Base Station ERP (dBW)		23
Fade Margin (dB)	20	-20
Body Loss (dB)	10	-10
Pager Antenna Gain (dB)	-25	-25
Pager Noise Figure (dB)	6	-6
Total pager temperature (K)	298	
Noise power in pager (dBW/Hz)	-203,86	203,86
Downlink Data Rate (bps)	6250	-37,96
Required Eb/No in pager (dB)	7	-7
Maximum Acceptable Path Loss (dB)		**120,9**
Associated Range Urban		2,2 km
Suburban		3,3 km
Rural		10 km

Pager to Base Station	Value	169 MHz dB	450 MHz dB	900 MHz
Pager Transmit Power (Watts)	*0,1*	*-10*	*-10*	*-10*
Pager Transmit Losses (dB)		*0*	*0*	*0*
Pager Antenna Gain (dB)		*-25*	*-17*	*-7*
Pager ERP (dBW)		-35	-27	-17
Fade Margin (dB)	20	-20	-20	-20
Body Loss (dB)	10	-10	-12	-14
Base Station Receive Antenna Gain (dB)	5	5	7	9
Base Station Receive Coax loss (dB)		-1	-2	-3
Base Station Receiver Noise Figure (dB)		-2,5	-2,5	-2,5
Total base station receiver temperature (K)	298			
Noise power in base station receiver (dBW/Hz)	-203,86	203,86	203,86	203,86
Up-link Data Rate (bps)	6	-7,78	-7,78	-7,78
Required Eb/No in base station (dB)	12	-12	-12	-12
Maximum Acceptable Path Loss (dB)		**120,58**	**127,58**	**136,58**
Urban		2,2 km	1,4 km	1,5 km
Suburban		3,3 km	2,6 km	3,1 km
Rural		10 km	9 km	10 km

NOTE: These figures are based on the SE21 propagation model.

For every 12 dB increase in path loss, distances double. For every 3 dB increase in path loss, distances increase by 26 %.

Figure 3

11.3 Effect of acknowledgement and re-transmissions on system capacity

In this subclause the effect of acknowledgement and retransmissions is analysed.

Let P_{sf} = Probability of a message being successfully received by a pager on the forward channel.

and P_{sr} = Probability of an acknowledgement being successfully received by the paging system on the return channel.

The probability that a paging system does not need to re-transmit a message is:

$$P_{sf} \times P_{sr}$$

where the pager successfully receives its message, and the paging system successfully receives the acknowledgement. The probability that retransmission is required is:

$$P_{tx} = 1 - P_{sf} \times P_{sr}$$

(Alternative thinking: re-transmission is required if the pager fails to receive its message, or it receives it, but the acknowledgement is not received. This is expressed as:

$(1 - P_{sf}) + P_{sf} \times (1 - P_{sr}) \Rightarrow 1 - P_{sf} + P_{sf} - P_{sf} \times P_{sr} \Rightarrow 1 - P_{sf} \times P_{sr}$)

If an ERMES Paging system has a capacity C, then this is modified as follows when a single retransmission is permitted:

$$C_1 = \frac{C}{1 + P_{tx}}$$

For each message entered into the paging system, $1 + P_{tx}$ messages are sent by the paging system. For example if P_{tx} is 0,1, then the capacity would be reduced to 90,9 %. If a further re-transmission is permitted, then the capacity is further reduced as follows:

$$C_2 = \frac{C}{1 + P_{tx} + P_{tx}^2}$$

In the example this would mean that the capacity is reduced to 90,1 %. This can be extended to N transmissions:

$$C_N = \frac{C}{1 + P_{tx} + P_{tx}^2 + \cdots + P_{tx}^N}$$

as $N \Rightarrow \infty$, $C_\infty = C \times (1 - P_{tx})$

The following graph shows the effect when a maximum of 1, 2, 4 and limitless retransmissions are permitted by the paging system.

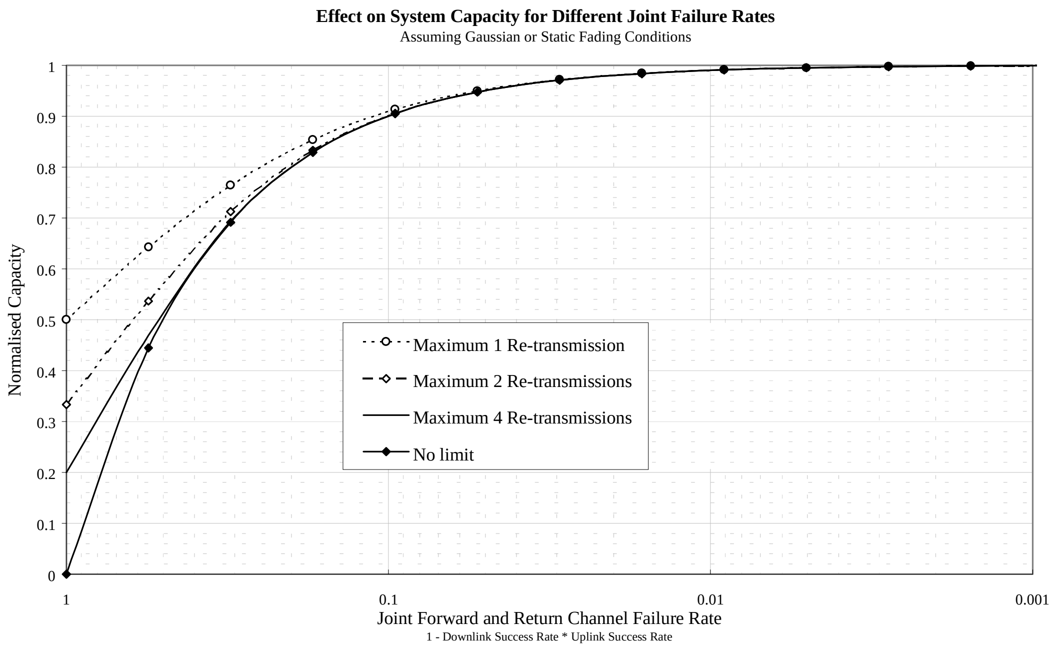

Figure 4: Joint Forward and Return channel Failure rate

This analysis assumes that the probability P_{tx} remains the same as pager retransmissions are requested by the paging system. Three scenarios need to be considered:

a) Gaussian Noise. Analysis valid.

b) Static Fading. Analysis valid for a given location only. It is not valid for the system as a whole, as in certain locations Two Way pagers will not function, no matter how often messages are re-transmitted. Further investigation is required.

c) Dynamic Fading. Analysis invalid - further investigation required.

This simple investigation has shown the effect on system throughput when message re-transmission is introduced for a few limited cases only. More detailed simulations are required to analyse the more complicated scenarios.

12 Trials

To test possible solutions a field trial group has been established consisting of Ericsson, Mtel, Motorola, Philips and Swissphone. Also Glenayre showed interest. The convenor of this group is Hans Persson (Ericsson).

Within the time frame of this feasibility study it was impossible to carry out field test, due to the fact that a frequency band has not yet been allocated, with the implications as explained below.

The performance of the proposed return channel needs to be verified by field trials. It should be noted that the proposed return channel operates at ERP-levels 60 dB below the forward ERMES channel (as well as to most of the other adjacently allocated services). Even if normalization to spectral power density (W per Hz, assuming one bit/s per Hz bandwidth) is made, the receiver antenna for the return channel operates at a 30 dB lower level than the forward channel receiver (the pager). "Man made noise" levels as well as interference from other (high powered) transmitters are thus of crucial importance for the possibility to utilize as much as possible of the calculated 130 dB path loss on the return channel.

As there are large variations in noise and interference levels depending on the spectrum segments that could be allocated for the return channel, it is not meaningful to conduct such trials until at least some knowledge about a likely allocation is at hand. Special consideration for the very low power link-budget of the return channel should be requested from the allocation authority.

A next level of trials considered important is field-test operation of an ERMES Two Way system, where the return channel is interconnected with the forward channel as well as with some PNC/PAC functions to enable tests of higher protocol levels, etc.

13 Consequences for the different I-interfaces

Although it is recognized that different I-interfaces have to be adapted the Two Way protocol, we have concluded after careful consideration, that all required adaptions should cause any difficulty. Conclusion is therefore that it is feasible to do these adaptions to the I-interfaces.

14 Proposed structure for an updated ERMES standard

It is proposed to modify the existing ETS 300 133 [1] according to the following proposal.

Part 1 General Aspects

Add definitions and new subclause 4.8 titled Return path. With relevant changes.

Part 2 Service Aspects

Add subclause 5.2.5 titled Two Way Paging and describing the service with relevant relationship with the other services.

Part 3 Network Aspects

Modifications required throughout this document detailing all the network aspects of Two Way Paging.

Part 4 Air interface

In this section, it is proposed that for clauses 5, 6, 7, 8, 9, 10, 11, 12,13, the existing information is placed under subclause X.1 for each clause X while the relevant Return information is placed under X.2.

Part 5 Receiver conformance specification (change to Mobile conformance specification)

Considering the status of the TBR regime, it is suggested that a set of tests and measurement procedures could be added to existing part 5 by simply adding to the existing clauses further subclauses.

Part 6 Base station conformance

An addition to part 6 is required to specify the base station receiver in much the same way as is suggested for part 4. For clauses 5, 6, 7.

Part 7 O&M

The addition here clearly are determined by the needs specified in part 3.

Annex A: Flowcharts

A.1 Forward message to Two Way ermes pager

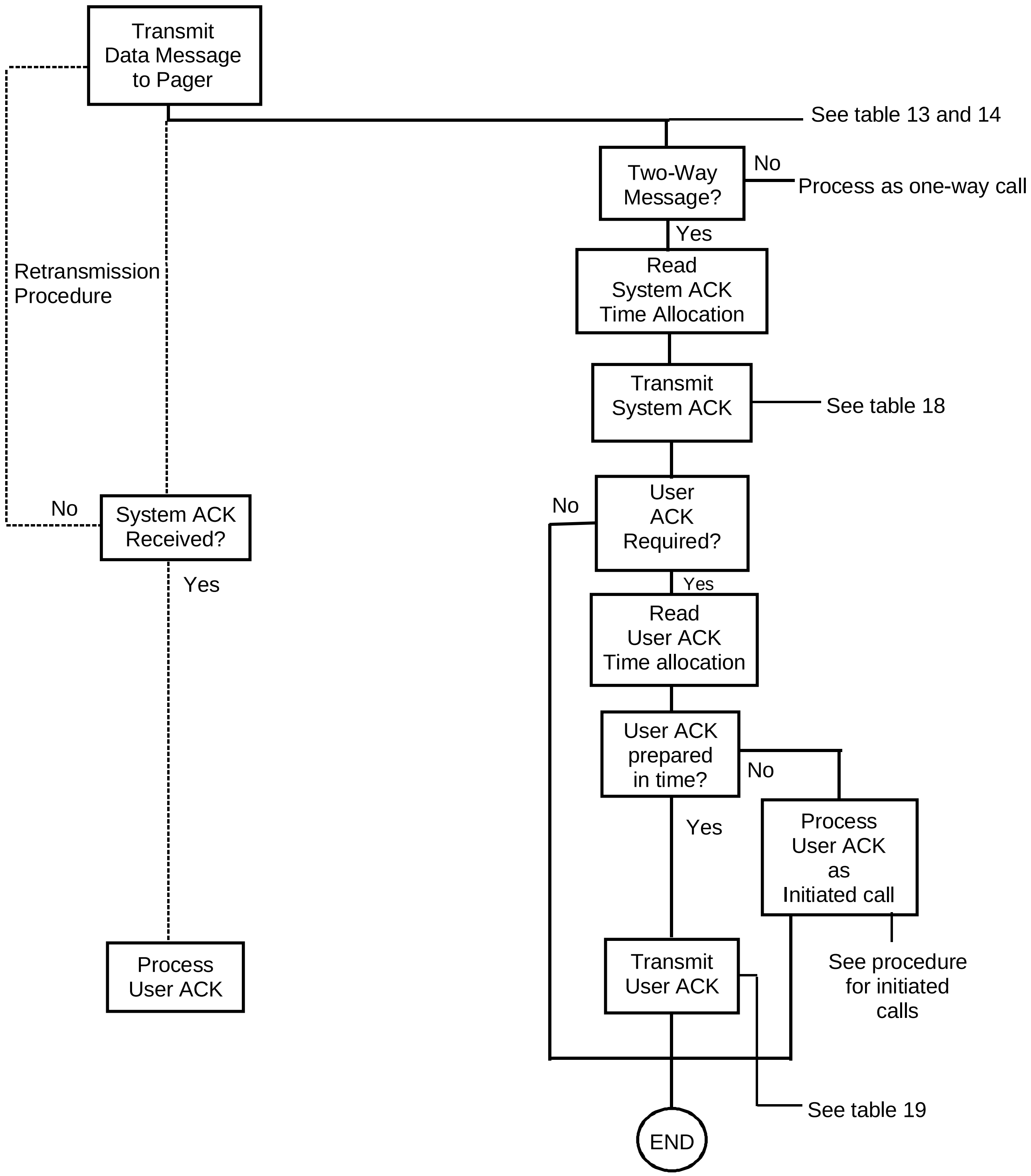

Figure A.1

Annex B: Details protocol A

B.1 Required number of subslots in MITS

The required number od subslots can be derived from the calculation of the probability of a collision of mobile initiated calls (in the MITS). This can be determined as follows:

The total number of MITS sub slots in one hour are: N = SL * B * SQ * CY

where: N is the total number of subslots

SL is the number of subslots

B is the number of batches = 16

SQ is the number of sequences = 5

CY isd the number of cycles = 60

This results in: N = SL * 16 * 5 * 60 ----> N = 4800 * SL

If the number of mobile initiated calls (in the MITS) is M and assuming that the calls are evenly distributed and assuming N > M, than the probability of no collision (CP) is:

$CP = N!/N^{M}. (N-M)!$ (expressed in N and M)

The number of mobile initiated calls in the busy hour are dependent of the implemented functions. Examples of typical systems (see subclause 8.3) give 0, 1 683 and 2 440 calls in the busy hour.

Assuming an evenly distribution in time and an evenly distribution per area (based on 50 basestations in a paging area) would mean 2 % of the mobile initiated will be received and have to be processed by one base receiver (also assuming one basestation receiver per basetransmitter). Take a factor of 2,5 for non even distribution of users over the geographical area, 5 % of the mobiles initiating a call have to be handled by one base receiver in the busy hour. Based on this we can do the following calculations:

The number of calls in one sequence of one minute (being 5 subsequences) for that one specified base receiver is for example system two equal to (1683/(60)/20) and for example system three (2440/(60)/20). See table B.1 for the figures. These table gives also the number of calls in a busy minute average and peak, being twice the number of calls.

Table B.1: Reference for Mobile initiated calls

Number of calls	BH/syst.	Rx/BH	RX/min.	
		5 %	5 %	10 %
system 2	1683	84	1,4	2,8
system 3	2440	122	2,0	4,1

To cope with Mobile initiated calls which are more unevenly distributed in area and/or in time, base receivers have to be added locally.

Table B.2 gives the collision probability for different number of subtimeslots in a sequence being 5 times the number od subslots in a subsequence. The collision probability is based on a random distribution of the calls in one minute.

Table B.2: Collision probability in MITS subslots

Number of calls	Number of MITS subslots in a sequence									
	5	10	15	20	25	30	35	40	45	50
2	20,0	10,0	6,7	5,0	4,0	3,3	2,9	2,5	2,2	2,0
3	52,0	28,0	19,1	14,5	11,7	9,8	8,4	7,4	6,6	5,9
4	80,8	49,6	35,3	27,3	22,3	18,8	16,3	14,3	12,8	11,6
5	96,2	69,8	52,5	41,9	34,7	29,6	25,8	22,9	20,5	18,6
6		84,9	68,4	56,4	47,8	41,4	36,4	32,5	29,4	26,8
7		94,0	81,0	69,5	60,3	53,1	47,3	42,6	38,8	35,6
8		98,2	89,9	80,2	71,4	64,0	57,9	52,7	48,3	44,6

For better understanding this can be put in the following graph.

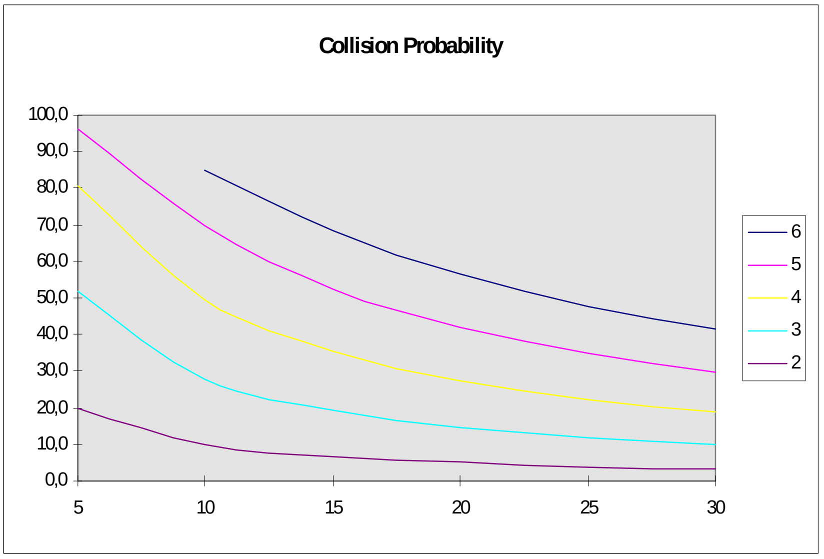

Figure B.1: Collision probability in MITS

History

Document history		
V1.1.1	July 1997	Publication

ISBN 2-7437-1414-X
Dépôt légal : Juillet 1997