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Foreword

This ETSI Technical Report (ETR) has been produced by the Special Mobile Group (SMG) Technical Committee (TC) of the European Telecommunications Standards Institute (ETSI).

This ETR Describes the radio network planning aspects within the European digital cellular telecommunications system (phase 2).

This ETR is an informative document resulting from SMG studies which are related to the European digital cellular telecommunications system (phase 2). This ETR is used to publish material which is of an informative nature, relating to the use or the application of ETSs and is not suitable for formal adoption as an ETS.

This ETR correspond to GSM technical specification, GSM 03.30 version 4.2.0.

The specification from which this ETR has been derived was originally based on CEPT documentation, hence the presentation of this ETR may not be entirely in accordance with the ETSI/PNE rules.

Reference is made within this ETR to GSM Technical Specifications (GSM-TS) (NOTE).

NOTE: TC-SMG has produced documents which give the technical specifications for the implementation of the European digital cellular telecommunications system. Historically, these documents have been identified as GSM Technical Specifications (GSM-TS). These TSs may have subsequently become I-ETSs (Phase 1), or ETSs (Phase 2), whilst others may become ETSI Technical Reports (ETRs). GSM-TSs are, for editorial reasons, still referred to in current GSM ETSs.

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1.1. Scope

This is a descriptive recommendation to be helpful in cell planning.

1.2 References

This ETR incorporates by dated and undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this ETR only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

[1] GSM 01.04 (ETR 100): "European digital cellular telecommunication system (Phase 2); Definitions, abbreviations and acronyms".

[2] GSM 05.02 (prETS 300 574): "European digital cellular telecommunication system (Phase 2); Multiplexing and multiple access on the radio path".

[3] GSM 05.05 (prETS 300 577): "European digital cellular telecommunication system (Phase 2); Radio transmission and reception".

[4] GSM 05.08 (prETS 300 578): "European digital cellular telecommunication system (Phase 2); Radio subsystem link control".

[5] CCIR Recommendation 370-5: "VHF and UHF propogation curves for the frequency range from 30 MHZ to 1000 MHz".

[6] CCIR Report 567-3: "Methods and statistics for estimating field strength values in the land mobile services using the frequency range 30 MHz to 1 GHz".

[7] CCIR Report 842: "Spectrum-conserving terestrial frequency assignments for given frequency-distance seperations".

[8] CCIR Report 740: "General aspects of cellular systems"

2. Traffic distributions

2.1 Uniform

A uniform traffic distribution can be considered to start with in large cells as an average over the cell area, especially in the country side.

2.2 Non-uniform

A non-uniform traffic distribution is the usual case, especially for urban areas. The traffic peak is usually in the city centre with local peaks in the suburban centres and motorway junctions.

A bell-shaped area traffic distribution is a good traffic density macro model for cities like London and Stockholm. The exponential decay constant is on average 15 km and 7.5 km respectively. However, the exponent varies in different directions depending on how the city is built up. Increasing handheld traffic will sharpen the peak.

Line coverage along communication routes as motorways and streets is a good micro model for car mobile traffic. For a maturing system an efficient way to increase capacity and quality is to build cells especially for covering these line concentrations with the old area covering cells working as umbrella cells.

Point coverage of shopping centres and traffic terminals is a good micro model for personal handheld traffic. For a maturing system an efficient way to increase capacity and quality is to build cells on these points as a complement to the old umbrella cells and the new line covering cells for car mobile traffic.

3. Cell coverage

3.1 Location probability

Location probability is a quality criterion for cell coverage. Due to shadowing and fading a cell edge is defined by adding margins so that the minimum service quality is fulfilled with a certain probability.

For car mobile traffic a usual measure is 90% area coverage per cell, taking into account the minimum signal-to-noise ratio Ec/No under multipath fading conditions. For lognormal shadowing an area coverage can be translated into a location probability on cell edge (Jakes, 1974).

For the normal case of urban propagation with a standard deviation of 7 dB and a distance exponential of 3.5, 90% area coverage corresponds to about 75% location probability at the cell edge. Furthermore, the lognormal shadow margin in this case will be 5 dB, as described in CEPT Rec. T/R 25-03 and CCIR Rep. 740.

3.2 Ec/No threshold

The mobile radio channel is characterized by wideband multipath propagation effects such as delay spread and Doppler shift as defined in GSM 05.05 Annex 3. The reference signal-to-noise ratio in the modulating bit rate bandwidth (271 kHz) is Ec/No = 8 dB including 2 dB implementation margin for the GSM system at the minimum service quality without interference. The Ec/No quality threshold is different for various logical channels and propagation conditions as described in GSM 05.05.

3.3 RF-budgets

The RF-link between a base transceiver station (BTS) and a mobile station (MS) including handheld is best described by an RF-budget as in Annex A which consists of 4 such budgets; A.1 for GSM 900 MS class 4; A.2 for GSM 900 MS class 2, A.3 for DCS 1800 MS classes 1 and 2, and A.4 for GSM 900 class 4 in small cells.

The antenna gain for the hand portable unit can be set to 0 dBi due to loss in the human body as described in CCIR Rep. 567. An explicit body loss factor is incorporated in Annex A.3

At 900 MHz, the indoor loss is the field strength decrease when moving into a house on the bottom floor on 1.5 m height from the street. The indoor loss near windows (< 1 m) is typically 12 dB. However, the building loss has been measured by the Finnish PTT to vary between 37 dB and -8 dB with an average of 18 dB taken over all floors and buildings (Kajamaa, 1985). See also CCIR Rep. 567.

At 1800 MHz, the indoor loss for large concrete buildings was reported in COST231 TD(90)117 and values in the range 12 - 17 dB were measured. Since these buildings are typical of urban areas a value of 15 dB is assumed in annex A.3. In rural areas the buildings tend to be smaller and a 10 dB indoor loss is assumed.

The isotropic power is defined as the RMS value at the terminal of an antenna with 0 dBi gain. A quarter-wave monopole mounted on a suitable earth-plane (car roof) without losses has antenna gain 2 dBi. An isotropic power of -113 dBm corresponds to a field strength of 23.5 dBuV/m for 925 MHz and 29.3 dBuV/m at 1795 MHz, see CEPT Rec. T/R 25-03 and GSM 05.05 Section 5 for formulas. GSM900 BTS can be connected to the same feeders and antennas as analog 900 MHz BTS by diplexers with less than 0.5 dB loss.

3.4 Cell ranges

3.4.1 Large cells

In large cells the base station antenna is installed above the maximum height of the surrounding roof tops; the path loss is determined mainly by diffraction and scattering at roof tops in the vicinity of the mobile ie the main rays propagate above the roof tops; the cell radius is minimally 1 km and normally exceeds 3 km. Hata's model and its extension up to 2000 MHz (COST231-Hata model) can be used to calculate the path loss in such cells (see COST 231 TD (90) 119 Rev 2 and Annex B).

The field strength on 1.5 m reference height outdoor for MS including handheld is a value which inserted in the curves of CCIR Rep. 567-3 Fig. 2 (Okumura) together with the BTS antenna height and effective radiated power (ERP) yields the range and re-use distance for urban areas (Section 5.2).

The cell range can also be calculated by putting the maximum allowed path loss between isotropic antennas into the Figures 1 to 3 of Annex C. The same path loss can be found in the RF-budgets in Annex A. The figures 1 and 2 (GSM900) in Annex C are based on Hata's propagation model which fits Okumura's experimental curves up to 1500 MHz and figure 3 (DCS 1800) is based on COST231-Hata model according to COST 231 TD (90) 119 Rev 2.

The example RF-budget shown in Annex A.1 for a GSM900 MS handheld output power 2 W yields about double the range outdoors compared with indoors. This means that if the cells are dimensioned for handhelds with indoor loss 10 dB, the outdoor coverage for MS will be interference limited, see Section 4.2. Still more extreme coverage can be found over open flat land of 12 km as compared with 3 km in urban areas outdoor to the same cell site.

For GSM 900 the Max EIRP of 50 W matches MS class 2 of max peak output power 8 W, see Annex A.2.

An example RF budget for DCS1800 is shown in Annex A.3. Range predictions are given for 1 W and 250 mW DCS1800 MS with BTS powers which balance the up- and down- links.

The propagation assumptions used in Annex A1, A2, A3 are shown in the tables below :

For GSM 900 :

	Rural (Open Area)	Rural (Quasi-open)	Urban
Base station height (m)	100	100	50
Mobile height (m)	1.5	1.5	1.5
Hata's loss formula (d in km)	90.7+31.8log(d)	95.7+31.8log(d)	123.3+33.7log(d)
Indoor Loss (dB)	10	10	15

For DCS 1800 :

	Rural (Open Area)	Rural (Quasi-Open)	Urban (*)
Base station height (m)	60	60	50
Mobile height (m)	1.5	1.5	1.5
COST 231 Hata's loss formula (d in km)	100.1+33.3log(d)	105.1+33.3log(d)	133.2+33.8log (d)
Indoor Loss (dB)	10	10	15

(*) medium sized city and suburban centres (see COST 231 TD (90) 119 Rev2). For metropolitan centres add 3 dB to the path loss.

Note 1 : The rural (Open Area) model is useful for desert areas and the rural (Quasi-Open) for countryside.

Note 2 : The correction factors for Quasi-open and Open areas are applicable in the frequency range 100-2000 MHz (Okumura,1968).

3.4.2 Small cells

For small cell coverage the antenna is sited above the median but below the maximum height of the surrounding roof tops and so therefore the path loss is determined by the same mechanisms as stated in section 3.4.1. However large and small cells differ in terms of maximum range and for small cells the maximum range is typically less than 1-3 km. In the case of small cells with a radius of less than 1 km the Hata model cannot be used.

The COST 231-Walfish-Ikegami model (see Annex B) gives the best approximation to the path loss experienced when small cells with a radius of less than 5 km are implemented in urban environments. It can therefore be used to estimate the BTS ERP required in order to provide a particular cell radius (typically in the range 200 m - 3 km).

The cell radius can be calculated by putting the maximum allowed path loss between the isotropic antennas into figure 4 of Annex C.

The following parameters have been used to derive figure 4 :

Width of the road , w = 20 m
Height of building roof tops, Hroof = 15 m
Height of base station antenna, Hb = 17 m
Height of mobile station antenna, Hm = 1.5 m
Road orientation to direct radio path , Phi = 90°
Building separation, b = 40 m

For GSM 900 the corresponding propagation loss is given by :

Loss (dB) = 132.8 + 38log(d/km)

For DCS 1800 the corresponding propagation loss is given by :

Loss (dB) = 142.9 + 38log(d/km) for medium sized cities and suburban centres
Loss (dB) = 145.3 + 38log(d/km) for metropolitan centres

An example of RF budget for a GSM 900 Class 4 MS in a small cell is shown in Annex A.4.

3.4.3 Microcells

COST 231 defines a microcell as being a cell in which the base station antenna is mounted generally below roof top level. Wave propagation is determined by diffraction and scattering around buildings ie. the main rays propagate in street canyons. COST 231 proposes the following experimental model for microcell propagation when a free line of sight exists in a street canyon :

Path loss in dB (GSM 900) = 101.7 + 26log(d/km) d > 20 m
Path loss in dB (DCS 1800) = 107.7 + 26log(d/km) d > 20 m

The propagation loss in microcells increases sharply as the receiver moves out of line of sight, for example, around a street corner. This can be taken into account by adding 20 dB to the propagation loss per corner, up to two or three corners (the propagation being more of a guided type in this case). Beyond, the complete COST231-Walfish-Ikegami model as presented in annex B should be used.

Microcells have a radius in the region of 200 to 300 metres and therefore exhibit different usage patterns from large and small cells. They can be supported by generally smaller and cheaper BTS's. Since there will be many different microcell environments, a number of microcell BTS classes are defined in GSM 05.05. This allows the most appropriate microcell BTS to be chosen based upon the Minimum Coupling Loss expected between MS and the microcell BTS. The MCL dictates the close proximity working in a microcell environment and depends on the relative BTS/MS antenna heights, gains and the positioning of the BTS antenna.

In order to aid cell planning, the micro-BTS class for a particular installation should be chosen by matching the measured or predicted MCL at the chosen site with the following table.

The microcell specifications have been based on a frequency spacing of 6 MHz between the microcell channels and the channels used by any other cell in the vicinity. However, for smaller frequency spacings (down to 1.8 MHz) a larger MCL must be maintained in order to guarantee successful close proximity operation. This is due to an increase in wideband noise and a decrease in the MS blocking requirement from mobiles closer to the carrier.

Micro-BTS class	Recommended MCL (GSM 900)		Recommended MCL (DCS 1800)	
	Normal	Small freq. spacing	Normal	Small freq. spacing
M1	60	64	60	68
M2	55	59	55	63
M3	50	54	50	58

Operators should note that when using the smaller frequency spacing and hence larger MCL the blocking and wideband noise performance of the micro-BTS will be better than necessary.

Operators should exercise caution in choosing the microcell BTS class and transmit power. If they depart from the recommended parameters in 05.05 they risk compromising the performance of the networks operating in the same frequency band and same geographical area.

4. Channel re-use

4.1 C/Ic threshold

The C/Ic threshold is the minimum co-channel carrier-to-interference ratio in the active part of the timeslot at the minimum service quality when interference limited. The reference threshold C/Ic = 9 dB includes 2 dB implementation margin on the simulated residual BER threshold The threshold quality varies with logical channels and propagation conditions, see GSM 05.05.

4.2 Trade-off between Ec/No and C/Ic

For planning large cells the service range can be noise limited as defined by Ec/No plus a degradation margin of 3 dB protected by 3 dB increase of C/Ic, see Annex A.

For planning small cells it can be more feasible to increase Ec/No by 6 dB corresponding to an increase of C/Ic by 1 dB to cover shadowed areas better. C/(I+N) = 9 dB represents the GSM limit performance.

To permit handheld coverage with 10 dB indoor loss, the Ec/No has to be increased by 10 dB outdoors corresponding to a negligible increase of C/Ic outdoors permitting about the same interference limited coverage for MS including handhelds. The range outdoors can also be noise limited like the range indoors as shown in Section 3.4 and Annex A.1.

4.3 Adjacent channel suppressions

Adjacent channel suppression (ACS) is the gain (Ia/Ic) in C/I when wanted and unwanted GSM RF-signals co-exist on adjacent RF channels whilst maintaining the same quality as in the co-channel case, i.e. ACS = = C/Ic - C/Ia. Taking into account frequency errors and fading conditions in the product of spectrum and filter of wanted and unwanted GSM RF-signals, ACS = 18 dB is typical as can be found in GSM 05.05.

1st ACS >= 18 dB, i.e. C/Ia1 <= -9 dB for C/Ic = 9 dB in GSM 05.05, imposes constraints of excluding the 1st adjacent channel in the same cell. However, the 1st adjacent channel can be used in the 1st adjacent cell, as C/Ic <= 12 dB and ACS >= 18 dB gives an acceptable handover- margin of >= 6 dB for signalling back to the old BTS as shown in GSM 05.08. An exception might be adjacent cells using the same site due to uplink interference risks.

2nd ACS >= 50 dB, i.e. C/Ia2 <= -41 dB for C/Ic = 9 dB in GSM 05.05, implies that due to MS power control in the uplink, as well as intra-cell handover, it is possible that the 2nd adjacent channel can be used in the same cell. Switching transients are not interfering due to synchronised transmission and reception of bursts at co-located BTS.

4.4 Antenna patterns

Antenna patterns including surrounding masts, buildings, and terrain measured on ca 1 km distance will always look directional, even if the original antenna was non-directional. In order to achieve a front-to-back ratio F/B of greater than 20 dB from an antenna with an ideal F/B > 25 dB, backscattering from the main lobe must be suppressed by using an antenna height of at least 10 m above forward obstacles in ca 0.5 km. In order to achieve an omni-directional pattern with as few nulls as possible, the ideal non-directional antenna must be isolated from the mast by a suitable reflector. The nulls from mast scattering are usually in different angles for the duplex frequencies and should be avoided because of creating path loss imbalance.

The main lobe antenna gains are typically 12-18 dBi for BTS, and 2-5 dBi for MS. Note that a dipole has the gain 0 dBd = 2 dBi.

4.5 Antenna heights

The height gain under Rayleigh fading conditions is approximately 6 dB by doubling the BTS antenna height. The same height gain for MS and handheld from reference height 1.5 m to 10 m is about 9 dB, which is the correction needed for using CCIR Rec. 370.

4.6 Path loss balance

Path loss balance on uplink and downlink is important for two-way communication near the cell edge. Speech as well as data transmission is dimensioned for equal quality in both directions. Balance is only achieved for a certain power class (Section 3.4).

Path loss imbalance is taken care of in cell selection in idle mode and in the handover decision algorithms as found in GSM 05.08. However, a cell dimensioned for 8 W MS (GSM 900 class 2) can more or less gain balance for 2 W MS handheld (GSM 900 class 4) by implementing antenna diversity reception on the BTS.

4.7 Cell dimensioning

Cell dimensioning for uniform traffic distribution is optimised by at any time using the same number of channels and the same coverage area per cell.

Cell dimensioning for non-uniform traffic distribution is optimised by at any time using the same number of channels but changing the cell coverage area so that the traffic carried per cell is kept constant with the traffic density. Keeping the path loss balance by directional antennas pointing outwards from the traffic peaks the effective radiated power (ERP) per BTS can be increased rapidly out-wards. In order to make the inner cells really small the height gain can be decreased and the antenna gain can be made smaller or even negative in dB by increasing the feeder loss but keeping the antenna front-to-back ratio constant (Section 4.4).

4.8 Channel allocation

Channel allocation is normally made on an FDMA basis. However, in synchronised networks channel allocation can be made on a TDMA basis. Note that a BCCH RF channel must always be fully allocated to one cell.

Channel allocation for uniform traffic distribution preferably follows one of the well known re-use clusters depending on C/I-distribution, e.g. a 9-cell cluster (3-cell 3-site repeat pattern) using 9 RF channel groups or cell allocations (CAs), (Stjernvall, 1985).

Channel allocation for non-uniform traffic distribution preferably follows a vortex from a BTS concentration on the traffic centre, if a bell-shaped area traffic model holds. In real life the traffic distribution is more complicated with also line and point traffic. In this case the cell areas will be rather different for various

BTS locations from city centre. The channel allocation can be optimised by using graph colouring heuristics as described in CCIR Rep. 842.

Base transceiver station identity code (BSIC) allocation is done so that maximum re-use distance per carrier is achieved in order to exclude co-channel ambiguity.

Frequency coordination between countries is a matter of negotiations between countries as described in CEPT Rec.T/R 25-04. Co-channel and 200 kHz adjacent channels need to be considered between PLMNs and other services as stated in GSM 05.05.

Frequency sharing between GSM countries is regulated in CEPT Rec. T/R 20-08 concerning frequency planning and frequency coordination for the GSM service.

4.9 Frequency hopping

Frequency hopping (FH) can easily be implemented if the re-use is based on RF channel groups (CAs). It is also possible to change allocation by demand as described in GSM 05.02.

In synchronised networks the synchronisation bursts (SB) on the BCCH will occur at the same time on different BTS. This will increase the time to decode the BSIC of adjacent BTS, see GSM 05.08. The SACCH on the TCH or SDCCH will also occur at the same time on different BTS. This will decrease the advantage of discontinuous transmission (DTX). In order to avoid this an offset in the time base (FN) between BTS may be used.

If channel allocation is made on a TDMA basis and frequency hopping is used, the same hop sequence must be used on all BTS. Therefore the same time base and the same hopping sequence number (HSN) shall be used.

4.10 Cells with extra long propagation delay

Cells with anticipated traffic with ranges more than 35 km corresponding to maximum MS timing advance can work properly if the timeslot after the CCCH is barred corresponding to a maximum total range of 120 km. From BTS timing measurements an MS with longer range than 35 km are guarded by one extra timeslot. This holds for all kinds of channels.

5. Propagation models

5.1 Terrain obstacles

Terrain obstacles introduce diffraction loss, which can be estimated from the path profile between transmitter and receiver antennas. The profile can preferably be derived from a digital topographic data bank delivered from the national map survey or from a land resource satellite system, e.g. Spot. The resolution is usually 500*500 m2 down to 50*50 m2 in side and 20 m down to 5 m in height. This resolution is not sufficient to describe the situation in cities for microcells, where streets and buildings must be recognised.

5.2 Environment factors

Environment factors for the nearest 200 m radius from the mobile play an important role in both the 900 MHz and 1800 MHz bands. For the Nordic cellular planning for NMT there is taken into account 10 categories for land, urban and wood. Further studies are done within COST 231.

Coarse estimations of cell coverage can be done on pocket computers with programs adding these environment factors to propagation curves of CCIR Rec. 370-5 Fig. 9 and CCIR Rep. 567-3 Fig. 2 (Okumura, 1968).

5.3 Field strength measurements

Field strength measurements of the local mean of the lognormal distribution are preferably done by digital averaging over the typical Rayleigh fading. It can be shown that the local average power can be estimated over 20 to 40 wavelengths with at least 36 uncorrelated samples within 1 dB error for 90% confidence (Lee, 1985).

5.4 Cell adjustments

Cell adjustments from field strength measurements of coverage and re-use are recommended after coarse predictions have been done. Field strength measurements of rms values can be performed with an uncertainty of 3.5 dB due to sampling and different propagation between Rayleigh fading and line-of-sight. Predictions can reasonably be done with an uncertainty of about 10 dB. Therefore cell adjustments are preferably done from field strength measurements by changing BTS output power, ERP, and antenna pattern in direction and shape.

6. Glossary

ACS	Adjacent Channel Suppression (Section 4.3)
BCCH	Broadcast Control Channel (Section 4.8)
BTS	Base Transceiver Station (Section 3.3)
BSIC	Base Transceiver Station Identity Code (Section 4.8)
CA	Cell Allocation of radio frequency channels (Section 4.8)
CCCH	Common Control Channel (Section 4.10)
COST	European Cooperation in the field of Scientific and Technical Research
DTX	Discontinuous Transmission (Section 4.9)
Ec/No	Signal-to-Noise ratio in modulating bit rate bandwidth (Section3.2)
FH	Frequency Hopping (Section 4.9)
FN	TDMA Frame Number (Section 4.9)
F/B	Front-to-Back ratio (Section 4.4)
HSN	Hopping Sequence Number (Section 4.9)
MS	Mobile Station (Section 3.3)
PLMN	Public Land Mobile Network
Ps	Location (site) Probability (Section 3.1)
SACCH	Slow Associated Control Channel (Section 4.9)
SB	Synchronisation Burst (Section 4.9)
SDCCH	Stand-alone Dedicated Control Channel (Section 4.9)
TCH	Traffic Channel (Section 4.9)

7. Bibliography

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CEPT Recommendation T/R 25-03 Coordination of frequencies for the land mobile service in the 80, 160 and 460 MHz bands and the methods to be used for assessing interference;

CEPT Recommendation T/R 25-04 Coordination in frontier regions of frequencies for the land mobile service in the bands between 862 and 960 MHz;

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Annex A.1 (class 4): Example of RF-budget for GSM MS handheld RF-output peak power 2 W

Propagation over land in urban areas

Receiving end:		BTS	MS	Eq.
TX:		MS	BTS	(dB)
Noise figure (multicoupl.input)	dB	8	10	A
Multipath profile 1)		TU50	TU50	(no FH)
Ec/No min. fading 1)	dB	8	8	B
RX RF-input sensitivity	dBm	-104	-102	C=A+B+W-174
Interference degrad. margin	dB	3	3	D
RX-antenna cable type		1-5/8"	0	
Specific cable loss	dB/100m	2	0	
Antenna cable length	m	120	0	
Cable loss + connector	dB	4	0	E
RX-antenna gain	dBi	12	0	F
Isotropic power, 50% Ps	dBm	-109	-99	G=C+D+E-F
Lognormal margin 50% -> 75% Ps	dB	5	5	H
Isotropic power, 75% Ps	dBm	-104	-94	I=G+H
Field strength, 75% Ps	dBuV/m	33	43	J=I+137
C/Ic min.fading, 50% Ps 1)	dB	9	9	
C/Ic prot. at 3 dB degrad.	dB	12	12	
C/Ic protection, 75% Ps 2)	dB	19	19	
Transmitting end:		MS	BTS	Eq.
RX:		BTS	MS	(dB)
TX RF-output peak power	W	2	6	
(mean power over burst)	dBm	33	38	K
Isolator + combiner + filter	dB	0	3	L
RF peak power, combiner output	dBm	33	35	M=K-L
TX-antenna cable type		0	1-5/8"	
Specific cable loss	dB/100m	0	2	
Antenna cable length		m	0	120
Cable loss + connector	dB	0	4	N
TX-antenna gain	dBi	0	12	O
Peak EIRP	W	2	20	
(EIRP = ERP + 2 dB)	dBm	33	43	P=M-N+O
Isotropic path loss, 50% Ps 3)	dB	139	139	Q=P-G-3
Isotropic path loss, 75% Ps	dB	134	134	R=P-I-3
Range, outdoor, 75% Ps 4)	km	2.0	2.0	
Range, indoor, 75% Ps 4)	km	0.7	0.7	

1) Ec/No and C/Ic for residual BER = 0.4%, TCH/FS (class Ib) and multi-path profiles as defined in GSM 05.05 Annex 3. Bandwidth W = 54 dBHz.

2) Uncorrelated C and I with 75% location probability (Ps). lognormal distribution of shadowing with standard deviation 7 dB. Ps = 75% corresponds to ca 90% area coverage, see Jakes, pp.126-127.

3) 3 dB of path loss is assumed to be due to the antenna/body loss

4) Max. range based on Hata. Antenna heights for BTS = 50 m and MS = 1.5 m. Indoor loss = 15 dB.

Annex A.2 (class 2): Example of RF-budget for GSM MS RF-output peak power 8 W

Propagation over land in rural areas

Receiving end: TX:		BTS MS	MS BTS	Eq. (dB)
Noise figure (multicoupl.input) Multipath profile 1)	dB	8 RA250	8 RA250	A (no FH)
Ec/No min. fading 1) RX RF-input sensitivity Interference degrad. margin	dB dBm dB	8 -104 3	8 -104 3	B C=A+B+W-174 D
RX-antenna cable type Specific cable loss Antenna cable length	 dB/100m m	1-5/8" 2 120	RG-58 50 4	
Cable loss + connector RX-antenna gain	dB dBi	4 12	2 2	E F
Isotropic power, 50% Ps Lognormal margin 50% -> 75% Ps	dBm dB	-109 5	-101 5	G=C+D+E-F H
Isotropic power, 75% Ps Field strength, 75% Ps	dBm dBuV/m	-104 33	-96 41	I=G+H J=I+137
C/Ic min.fading, 50% Ps 1) C/Ic prot. at 3 dB degrad. C/Ic protection, 75% Ps 2)	dB dB dB	9 12 19	9 12 19	
Transmitting end: RX:		MS BTS	BTS MS	Eq. (dB)
TX RF-output peak power (mean power over burst) Isolator + combiner + filter RF peak power, combiner output	W dBm dB dBm	8 39 0 39	16 42 3 39	 K L M=K-L
TX-antenna cable type Specific cable loss Antenna cable length	 dB/100m m	RG-58 50 4	1-5/8" 2 120	
Cable loss + connector TX-antenna gain	dB dBi	2 2	4 12	N O
Peak EIRP (EIRP = ERP + 2 dB)	W dBm	20 39	50 47	 P=M-N+O
Isotropic path loss, 50% Ps Isotropic path loss, 75% Ps	dB dB	148 143	148 143	Q=P-G R=P-I
Range, outdoor, 75% Ps 3)	km	30.7	30.7	

1) Ec/No and C/Ic for residual BER = 0.2%, TCH/FS (class Ib) and multi-path profiles as defined in GSM 05.05 Annex 3. Bandwidth W = 54 dBHz.

2) Uncorrelated C and I with 75% location probability (Ps). Lognormal distribution of shadowing with standard deviation 7 dB. Ps = 75% corresponds to ca 90% area coverage, see Jakes, pp.126-127.

3) Max. range in quasi-open areas based on Hata. Antenna heights for BTS = 100 m and MS = 1.5 m.

Annex A.3 (DCS1800 classes 1&2): Example of RF-budget for DCS 1800 MS RF-output peak power 1 W & 250 mW

Propagation over land in urban and rural areas				
Receiving end: TX:		BTS MS	MS BTS	Eq. (dB)
Noise figure(multicoupl.input) Multipath profile	dB	8 TU50 or	12 RA130	A
Ec/No min. fading RX RF-input sensitivity Interference degrad. margin	dB dBm dB	8 -104 3	8 -100 3	B C=A+B+W-174 D (W=54.3 dBHz)
Cable loss + connector RX-antenna gain Diversity gain	dB dBi dB	2 18 5	0 0 0	E F F1
Isotropic power, 50% Ps Lognormal margin 50% ->75% Ps Isotropic power, 75% Ps Field Strength 75% Ps	dBm dB dBm	-122 6 -116 27	-97 6 -91 51	G=C+D+E-F-F1 H I=G+H J=I+142.4 at 1.8 GHz
Transmitting end: RX:		MS BTS	BTS MS	Eq. (dB)
TX PA output peak power (mean power over burst) Isolator + combiner + filter RF Peak power,(ant.connector) 1)	W dBm dB dBm W	- - - 30/24 1.0/0.25	15.8/3.98 42/36 3 39/33 7.9/2.0	 K L M=K-L
Cable loss + connector TX-antenna gain Peak EIRP	dB dBi W dBm	0 0 1.0/0.25 30/24	2 18 316/79.4 55/49	N O P=M-N+O
Isotropic path loss,50% Ps 2) Isotropic path loss, 75% Ps	dB dB	149/143 143/137	149/143 143/137	Q=P-G-3 R=P-I-3
Range km - 75% Ps				
Urban, out of doors Urban, indoors Rural (Open area), out of doors Rural (Open area), indoors		1.91/1.27 0.69/0.46 19.0/12.6 9.52/6.28		

1) The MS peak power is defined as
   a) If the radio has an antenna connector, it shall be measured into a 50 Ohm resistive load.
   b) If the radio has an integral antenna, a reference antenna with 0 dBi gain shall be assumed.

2) 3 dB of the path loss is assumed to be due to antenna/body loss.

Annex A.4: Example of RF-budget for GSM 900 Class4 (peak power 2 W) in a small cell

Propagation over land in urban areas				
Receiving end: TX :		BTS MS	MS BTS	Eq. (dB)
Noise figure(multicoupl.input) Multipath profile	dB	8 TU50	10	A
Ec/No min. fading RX RF-input sensitivity Interference degrad. margin	dB dBm dB	8 -104 3	8 -102 3	B C=A+B+W-174 D (W=54.3 dBHz)
Cable loss + connector RX-antenna gain Diversity gain	dB dBi dB	2 16 3	0 0 0	E F F1
Isotropic power, 50% Ps Lognormal margin 50% ->75% Ps Isotropic power, 75% Ps Field Strength 75% Ps	dBm dB dBm	-118 5 -113 24	-99 5 -94 43	G=C+D+E-F-F1 H I=G+H J=I+137 at 900 MHz
Transmitting end: RX:		MS BTS	BTS MS	Eq. (dB)
TX PA output peak power (mean power over burst) Isolator + combiner + filter RF Peak power,(ant.connector) 1)	W dBm dB dBm W	- - - 33 2	12.6 41 3 38 6.3	 K L M=K-L
Cable loss + connector TX-antenna gain Peak EIRP	dB dBi W dBm	0 0 2 33	2 16 158 52	N O P=M-N+O
Isotropic path loss,50% Ps 2) Isotropic path loss, 75% Ps	dB dB	148 143	148 143	Q=P-G-3 R=P-I-3
Range km - 75% Ps Urban, out of doors Urban, indoors		 1.86 0.75		

1) The MS peak power is defined as
   a) If the radio has an antenna connector, it shall be measured into a 50 Ohm resistive load.
   b) If the radio has an integral antenna, a reference antenna with 0 dBi gain shall be assumed.

2) 3 dB of the path loss is assumed to be due to antenna/body loss.

Annex B: Propagation loss formulas for mobile radiocommunications

1. Hata Model [4],[8]

Frequency f:	150	-	1000 MHz
Base station height Hb:	30	-	200 m
Mobile height Hm:	1	-	10 m
Distance d :	1	-	20 km

Large and small cells (i.e. base station antenna heights above roof-top levels of buildings adjacent to the base station)

1.1 Urban

Lu (dB) = 69.55 + 26.16*log(f) - 13.82*log(Hb) - a(Hm) + [44.9 - 6.55*log(Hb)]*log(d)

a(Hm) correction factor for vehicular station antenna height.

For a medium-small city :

a (Hm) = [1.1*log(f) - 0.7]*Hm - [1.56*log(f) - 0.8]

For a large city :

a (Hm) = 8.29*[log(1.54*Hm)]^2 - 1.1 for f <= 200 MHz
a (Hm) = 3.2*[log(11.75*Hm)]^2 - 4.97 for f >= 400 MHz

1.2 Suburban

Lsu (dB) = Lu - 2*[log(f/28)]^2 - 5.4

1.3 Rural (Quasi-open)

Lrqo (dB) = Lu - 4.78*[log(f)]^2 + 18.33*log(f) - 35.94

1.4 Rural (Open Area)

Lro (dB) = Lu - 4.78*[log(f)]^2 + 18.33*log(f) - 40.94

2. COST 231-Hata Model [7]

Frequency f:	1500	-	2000 MHz
Base station height Hb:	30	-	200 m
Mobile height Hm:	1	-	10 m
Distance d:	1	-	20 km

Large and small cells (i.e. base station antenna heights above roof-top levels of buildings adjacent to the base station)

Urban areas (for rural areas the correction factors given in subparagraph 1.3 and 1.4 can be used up to 2000 MHz)

Lu (dB) = 46.3 + 33.9*log(f) - 13.82*log(Hb) - a(Hm) + [44.9 - 6.55*log(Hb)]*log(d) + Cm

with :

a(Hm) = [1.1*log(f) - 0.7]*Hm - [1.56*log(f) - 0.8]
Cm = 0 dB for medium sized city and suburban centres with moderate tree density
Cm = 3 dB for metropolitan centres

3. COST 231 Walfish-Ikegami Model [7]

Frequency f:	800	-	2000 MHz
Base station height Hb:	4	-	50 m
Mobile height Hm:	1	-	3 m
Distance d:	0.02	-	5 km

Height of buildings Hroof (m)
Width of road w (m)
Building separation b (m)
Road orientation with respect to the direct radio path Phi (°)
Urban areas

3.1 Without free line-of-sight between base and mobile (small cells)

Lb = Lo + Lrts + Lmsd (or Lb = Lo for Lrts + Lmsd <= 0)

with :

3.1.1 Lo free-space loss :

Lo = 32.4 + 20*log(d) + 20*log(f)

3.1.2 Lrts roof-top-to-street diffraction and scatter loss :

Lrts = -16.9 - 10*log(w) + 10 log(f) + 20*log(Hr - Hm) + Lcri

with
Lcri = -10 + 0.354*Phi for 0<= Phi < 35°
Lcri = 2.5 + 0.075*(Phi-35) for 35<= Phi < 55°
Lcri = 4.0 - 0.114*(Phi-55) for 55<= Phi <90°

3.1.3 Lmsd multiscreen diffraction loss :

Lmsd = Lbsh + ka + kd*log(d) + kf*log(f) - 9*log(b)

with

Lbsh	= -18*log(1 +Hb - Hroof)	for Hb > Hroof
	= 0	for Hb <= Hroof
ka	= 54	for Hb > Hroof
	= 54 - 0.8*(Hb - Hroof)	for d >= 0.5 and Hb <=Hroof
	= 54 - 0.8*(Hb - Hroof)*(d/0.5)	for d<0.5 and Hb<=Hroof
kd	= 18	for Hb > Hroof
	= 18 - 15*(Hb - Hroof)/Hroof	for Hb <= Hroof
kf	= -4 + 0.7*(f/925 - 1)	for medium sized cities and suburban centres with moderate tree density
	= -4 + 1.5*(f/925 - 1)	for metropolitan centres

3.2 With a free line-of-sight between base and mobile (Street Canyon)

Microcells (Base station antennas below roof top level)

Lb = 42.6 + 26*log(d) + 20*log(f) for d >= 0.020 km

Annex C: Path Loss vs Cell Radius

Fig 1. Path loss vs Cell Radius, BS height = 50 m, MS height = 1.5 m (GSM 900).

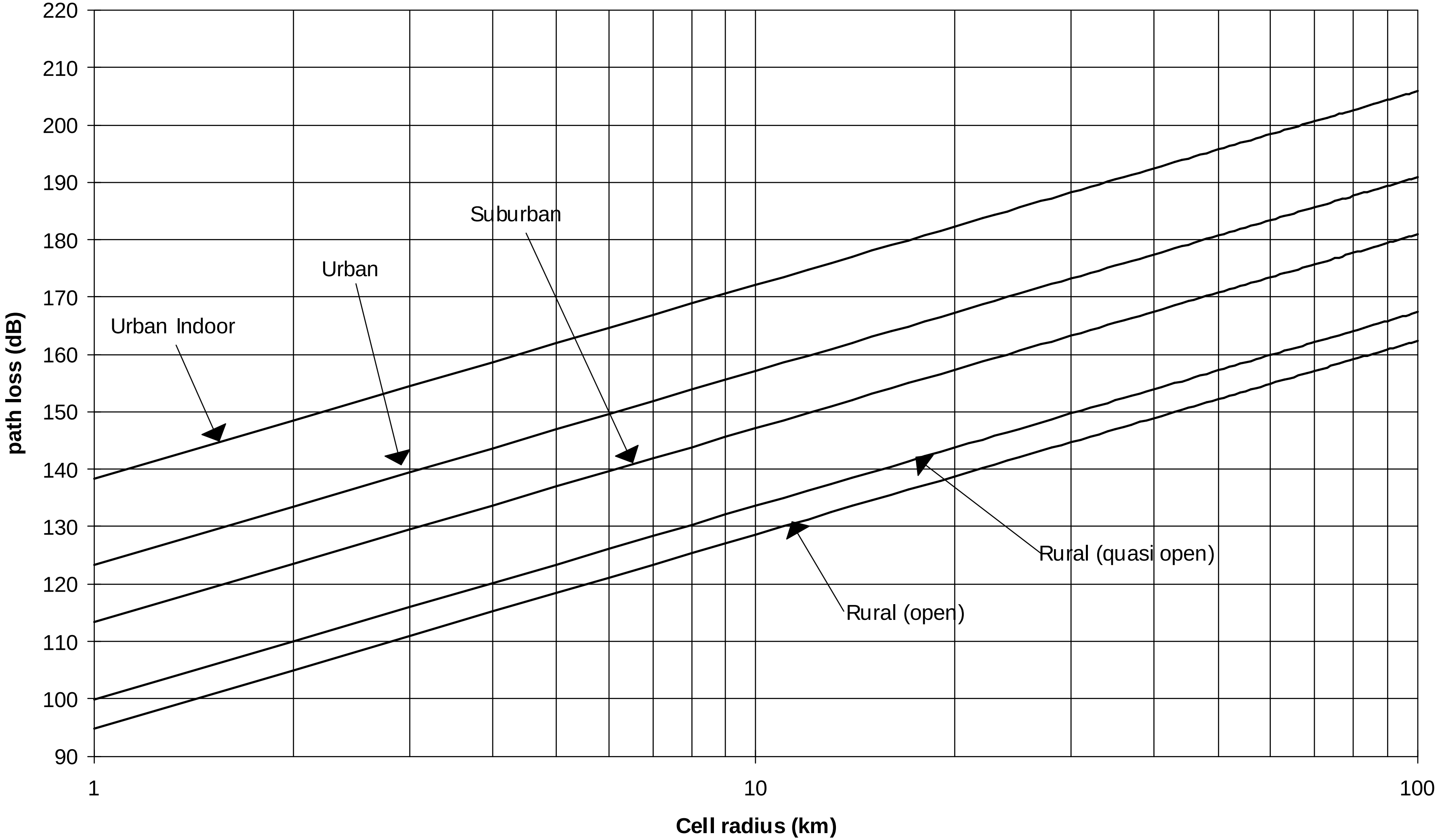


Fig 2. Path loss vs Cell Radius, BS height = 100 m, MS height = 1.5 m (GSM 900).

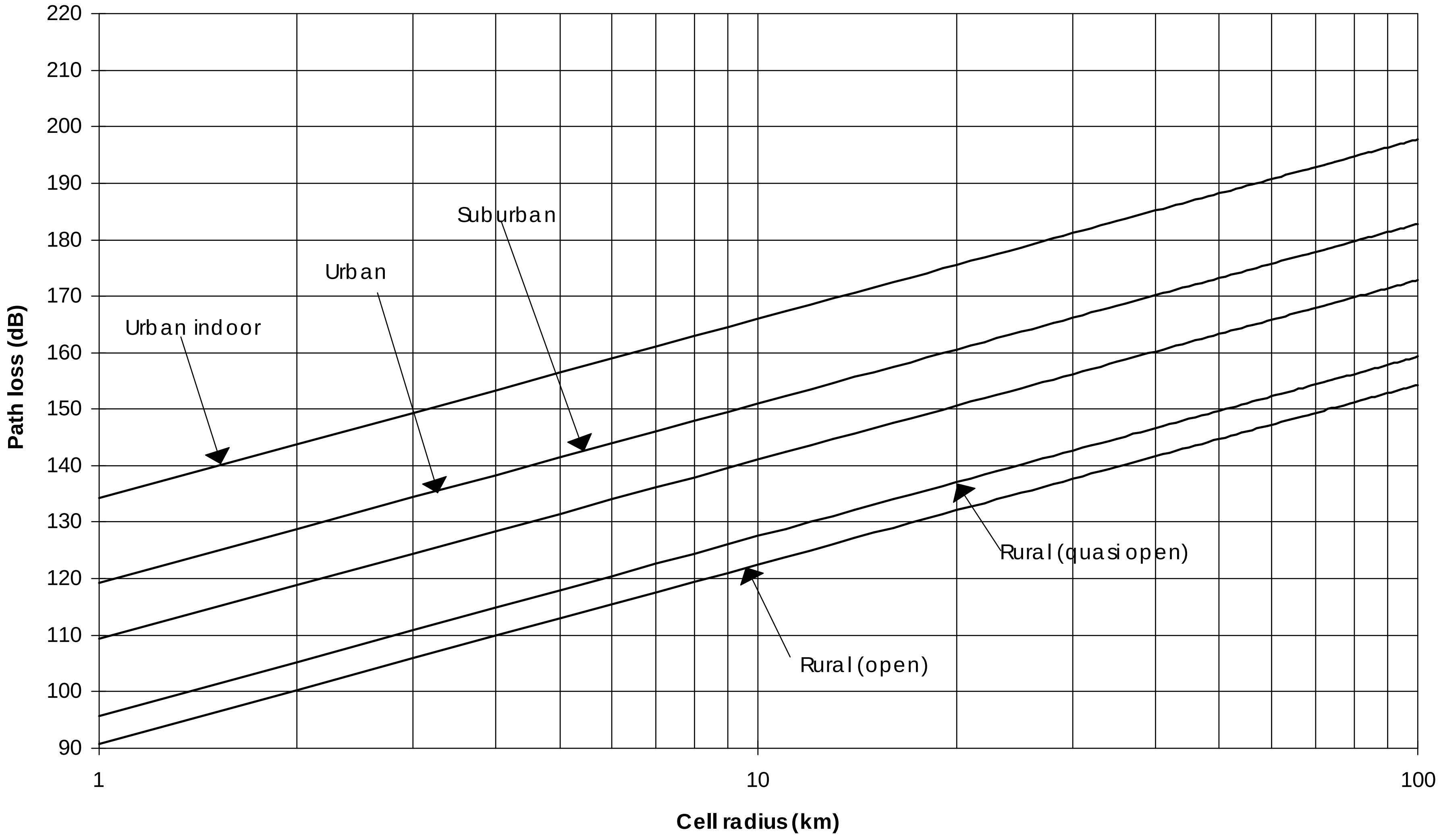


Fig. 3. Path loss vs Cell Radius, Urban BS height = 50 m, Rural BS height = 60 m, MS height = 1.5 m (DCS 1800)

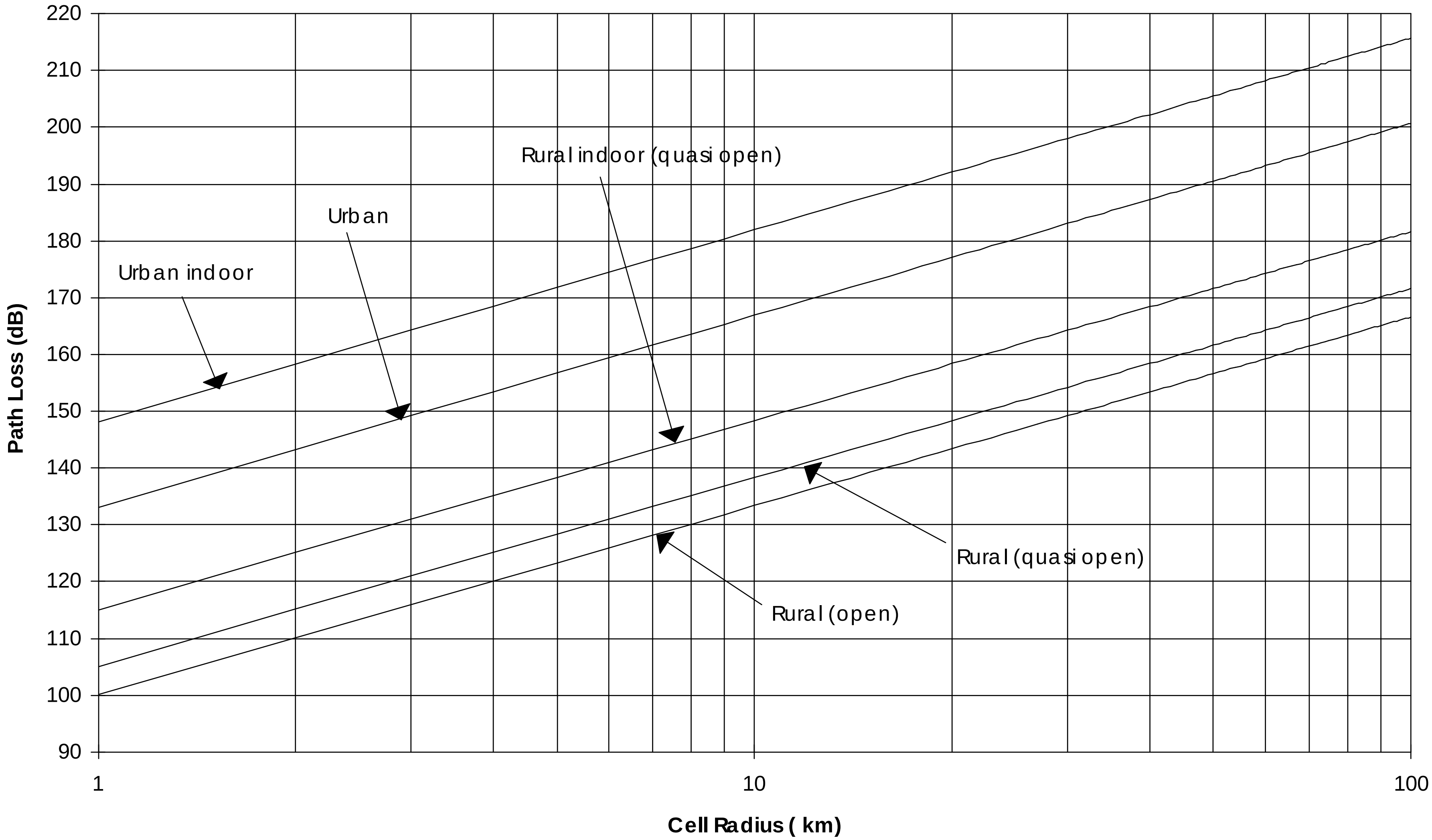
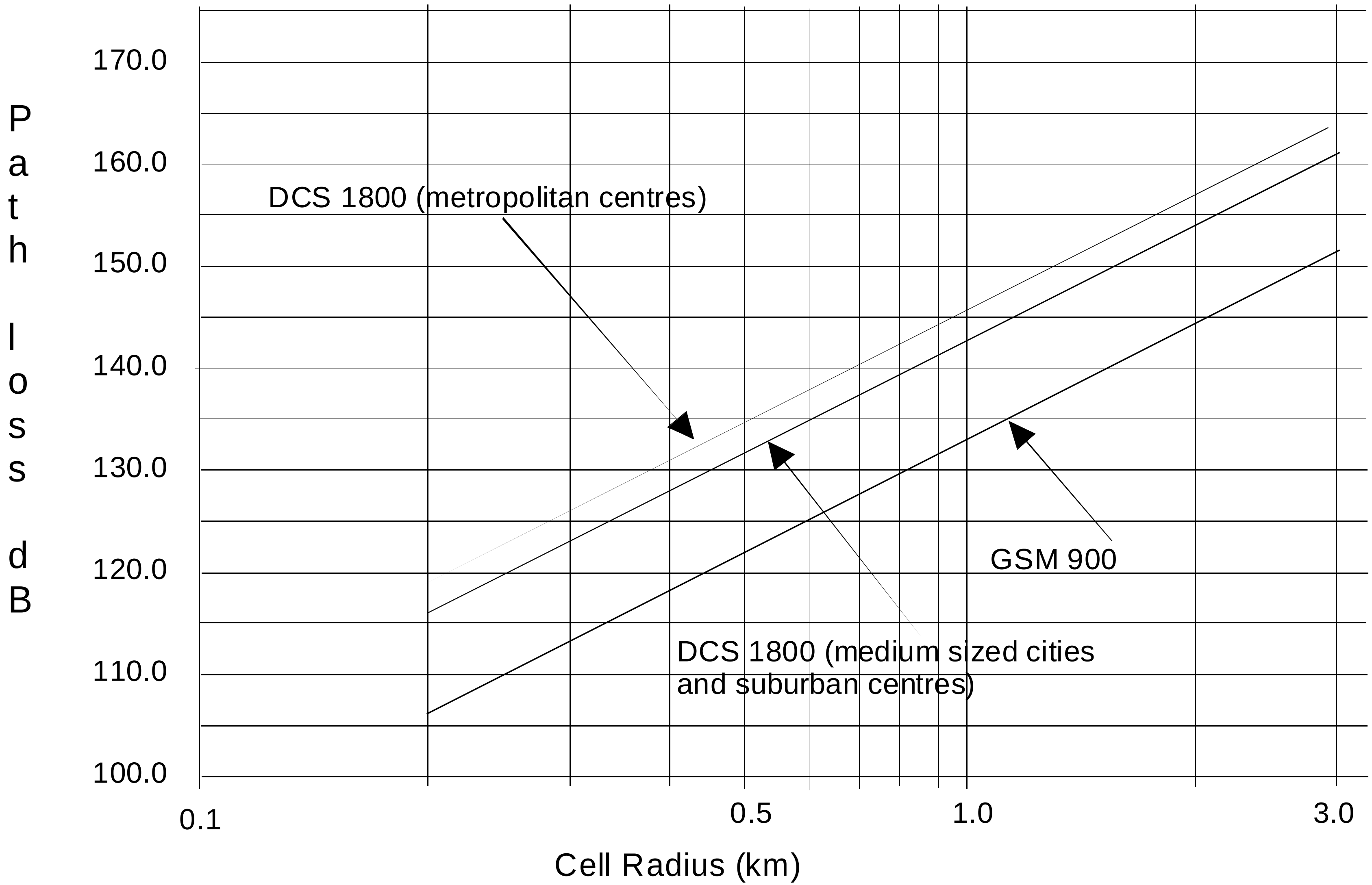


Fig. 4. Path loss vs Cell Radius for small cells (see section 3.4.2)



History

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