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Contents

Foreword

This Technical Report has been produced by the 3GPP.

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Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

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Y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

The present document establishes channel models to be used for deployment evaluation.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] L.M. Correia, ed., Wireless flexible personalized communications – COST 259: European co-operation in mobile radio research, John Wiley & Sons 2001.

[2] GSM 05.05, "Digital cellular telecommunications system (Phase 2+); Radio transmission and reception"

3 Definitions, symbols and abbreviations

3.1 Definitions

(void)

3.2 Symbols

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

σ_τ	R.M.S. delay spread.
Fd	Maximum Doppler shift
fs	Doppler frequency of the direct path, given by its direction relative to the mobile direction of movement

3.3 Abbreviations

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

COST	European Co-operation in the field of Scientific and Technical research
GSM	Global System for Mobile communications
HT	Hilly Terrain
RA	Rural Area
TU	Typical Urban
UMTS	Universal Mobile Telecommunications System

4 General

The channel models have been chosen as simplifications, or typical realisations of the COST 259 model [1] that is described in more detail in Annex A.

A large number of paths (20) in each model ensure that the correlation properties in the frequency domain are realistic. Path powers follow the exponential channel shapes in the COST 259 model. The delay spreads for each model are close to expected medians when applying the COST 259 model in reasonably sized macrocells. In the rural model a direct path is present, resulting in Rice-type fading when filtered to wideband channels. The hilly terrain model consists of two clusters, a typical situation in these environments.

With the chosen parameters the models will be quite similar to the GSM channel models [2], after filtering to the GSM bandwidth.

In Section 5, the channel models are specified explicitly. The tap delays have been determined by generating 20 independent identically distributed values from a uniform distribution in the interval $[0, 4 \cdot \sigma_\tau]$, where σ_τ is the rms delay spread. For the Hilly Terrain channel 10 paths have been generated for each cluster and for the Rural Area model there is a total of 10 taps. Relative powers have then been calculated using the channel shapes in Annex A, Table A.3. The channels have been normalised so that the total power in each channel is equal to one.

5 Channel model descriptions

Radio wave propagation in the mobile environment can be described by multiple paths which arise due to reflection and scattering in the mobile environment. Approximating these paths as a finite number of N distinct paths, the impulse response for the radio channel may be written as:

$$h(\tau) = \sum_{i}^{N} a_i \delta(\tau_i)$$

which is the well known tapped-delay line model. Due to scattering of each wave in the vicinity of a moving mobile, each path a_i will be the superposition of a large number of scattered waves with approximately the same delay. This superposition gives rise to time-varying fading of the path amplitudes a_i, a fading which is well described by Rayleigh distributed amplitudes varying according to a classical Doppler spectrum:

$$S(f) \propto 1/(1-(f/f_D)^2)^{0.5}$$

where $f_D = v/\lambda$ is the maximum Doppler shift, a function of the mobile speed v and the wavelength λ. In some cases a strong direct wave or specular reflection exists which gives rise to a non-fading path, then the Doppler spectrum is:

$$S(f) = \delta(f_s)$$

where f_s is the Doppler frequency of the direct path, given by its direction relative to the mobile direction of movement.

The channel models presented here will be described by a number of paths, having average powers $|a_i|^2$ and relative delays τ_i, along with their Doppler spectrum which is either classical or a direct path. The models are named Tux, Rax and HTx, where x is the mobile speed in km/h. Default mobile speeds for the models are according to Table 5.1. The relative position of the taps is for each model listed with a 0.001 µs resolution.

Table 5.1: Default mobile speeds for the channel models.

Channel model	Mobile speed
Tux	3 km/h
	50 km/h
	120 km/h
Rax	120 km/h
	250 km/h
HTx	120 km/h

The models may in certain cases be simplified to a specific application to allow for less complex simulations and testing. The simplification should be done with a specific time resolution ΔT, which should be stated to avoid confusion: e.g. Rax(ΔT=0.1μs). An example of such a simplified model is shown in Annex B.

5.1 Typical Urban channel model (Tux)

Table 5.2: Channel for urban area

Tap number	Relative time (μs)	average relative power (dB)	7oppler spectrum
1	0	-5.7	Class
2	0.217	-7.6	Class
3	0.512	-10.1	Class
4	0.514	-10.2	Class
5	0.517	-10.2	Class
6	0.674	-11.5	Class
7	0.882	-13.4	Class
8	1.230	-16.3	Class
9	1.287	-16.9	Class
10	1.311	-17.1	Class
11	1.349	-17.4	Class
12	1.533	-19.0	Class
13	1.535	-19.0	Class
14	1.622	-19.8	Class
15	1.818	-21.5	Class
16	1.836	-21.6	Class
17	1.884	-22.1	Class
18	1.943	-22.6	Class
19	2.048	-23.5	Class
20	2.140	-24.3	Class

5.2 Rural Area channel model (Rax)

Table 5.3: Channel for rural area

Tap number	Relative time (μs)	average relative power (dB)	7oppler spectrum
1	0	-5.2	Direct path, $f_s = 0.7 \cdot f_D$
2	0.042	-6.4	Class
3	0.101	-8.4	Class
4	0.129	-9.3	Class
5	0.149	-10.0	Class
6	0.245	-13.1	Class
7	0.312	-15.3	Class
8	0.410	-18.5	Class
9	0.469	-20.4	Class
10	0.528	-22.4	Class

5.3 Hilly Terrain channel model (HTx)

Table 5.4: Channel for hilly terrain area

Tap number	Relative time (μs)	average relative power (dB)	8oppler spectrum
1	0	-3.6	Class
2	0.356	-8.9	Class
3	0.441	-10.2	Class
4	0.528	-11.5	Class
5	0.546	-11.8	Class
6	0.609	-12.7	Class
7	0.625	-13.0	Class
8	0.842	-16.2	Class
9	0.916	-17.3	Class
10	0.941	-17.7	Class
11	15.000	-17.6	Class
12	16.172	-22.7	Class
13	16.492	-24.1	Class
14	16.876	-25.8	Class
15	16.882	-25.8	Class
16	16.978	-26.2	Class
17	17.615	-29.0	Class
18	17.827	-29.9	Class
19	17.849	-30.0	Class
20	18.016	-30.7	Class

Annex A: The COST 259 Channel Model

A.1 Background

COST 259 [1] is a research forum funded by the EU, in which there are participants from manufacturers, operators and universities. This forum is the second successor of COST 207, who did the work on which the channel models used in GSM standardization were based. One of the work items identified in COST 259 is to propose a new set of channel models which overcome the limitations in the GSM channel models, while aiming at the same general acceptance. The models are aimed at UMTS and HIPERLAN, with particular emphasis on adaptive antennas and directional channels.

A.2 Model descriptions

The main difference between the COST 259 model and previous models is that it tries to describe the complex range of conditions found in the real world by distributions of channels rather than a few "typical" cases. The probability densities for the occurrence of different channels are functions of mainly two parameters:

1) Environment

2) Distance

Given a certain environment (e.g. Urban Macrocell) and a certain distance (or distance range/cell radius), the parameters describing the distribution functions for this particular case can be extracted. Performing a sufficient number of channel realizations will give a distribution of channels which give a much better representation of reality than what would be possible using only one channel.

The environments identified so far in COST 259 are given in Table A.1, although these are by no means written in stone. The macrocellular environments have the same names as the GSM models. (It is being discussed if there should be a distinction between indoor and outdoor mobiles for the macrocellular environments.)

Table A.1: Preliminary environments identified by COST 259.

Macrocell	Microcell	Picocell
Typical Urban	(Street Canyons)	(Tunnel/Corridor)
Bad Urban	(Open Places)	(Factory)
Rural Area	(Tunnels)	(Office/Residential Home)
Hilly Terrain	(Street Crossings)	(Open Lounge)

In COST 259, a number of properties of the propagation channel has been considered in the model work. The full proposal will include all of these properties, but it is quite simple and straightforward to implement the model in a modular structure, so that each of the properties (listed in Table A.2) can be switched on or off individually depending on the application. Inherent in the model is also correlations between the properties, e.g. time dispersion and shadow fading are modelled as being partially correlated.

Table A.2: Propagation properties considered in the COST 259 model

1	Path Loss
2	Shadow Fading
3	Fast Fading
4	Time Dispersion
5	Angular dispersion (azimuth and/or elevation at BS)
6	Polarization
7	Multiple Clusters
8	Dynamic channel variations (variations in 1-7)

The shape of the channel is given by one or several clusters, where each cluster is exponentially decreasing in delay and Laplacian (double-sided exponential) in azimuth. Each cluster consists of a number of Rayleigh-fading paths, plus a possible non-fading path to get Rice fading.

Of interest here are mainly the properties 4 and 7 in Table A.2. For this case, a full description of the channel is given by specifying the parameter set (Figure A.1):

$$\{P_i, \tau_i, \sigma_{\tau,i}\}_{i=1...N_C}$$

The i:th cluster is described by its total power Pi, the delay of the first path τI and the cluster delay spread στ,i. The last parameter describes the slope of the exponentially decaying power in the cluster. The number of clusters present is given by NC,.

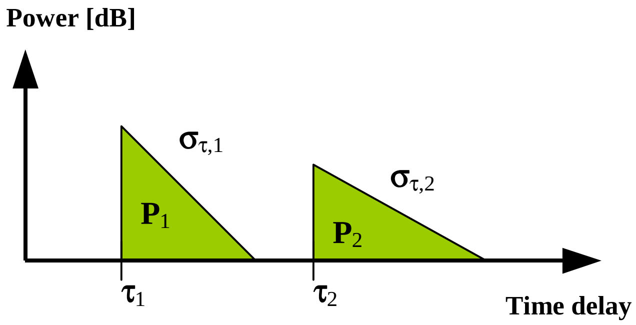


Figure A.1: Channel shape (power delay profile) with multiple clusters.

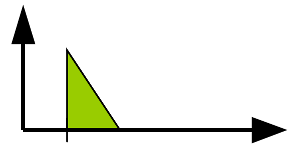
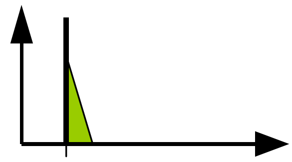
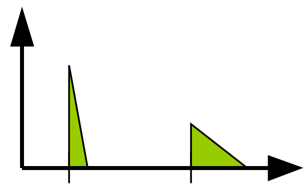
A.3 Reduced complexity models

It is possible to reduce the complexity of the COST 259 model by approximating the continuous distributions with a small number of cases, selected to be typical representations of the channel in common environments. We propose a set of models with fixed parameters as shown in Table A.3. The selected parameters correspond to the COST 207/GSM models with one important difference namely the delay spread value for the Typical Urban channel. This has been reduced to better correspond to typical measurement results.

A cluster in the models outlined here is represented by a number NP independent Rayleigh-fading paths with Classical Doppler spectrum, randomly distributed in the interval [τI , τI + k ·στ,i]. Preliminary assignments are NP = 20 and k = 4.

The fast fading (property 3 in Table A.2) should be included in the model as a Doppler frequency

Table A.3: Reduced complexity channel model parameters

Environment	Channel shape	Channel parameters	
Typical Urban	One exponential cluster consisting of NP Rayleigh-fading paths	NC = 1 P1 = 1 τ1 = 0 μs στ,1 = 0.5 μs	
Rural Area	One exponential cluster consisting of NP-1Rayleigh-fading paths and 1 non-fading path.	NC = 1 P1 = 1 τ1 = 0 μs στ,1 = 0.14 μs Add one deterministic (non-fading) path with: fD = 0.7· fMax P2 = 0.43 τ2 = 0 in order to get Ricean fading	
Hilly Terrain	Two exponential clusters each consisting of NP/2 Rayleigh-fading paths each	NC = 2 P1 = 1 τ1 = 0 μs στ,1 = 0.29 μs P2 = 0.04 τ2 = 15 μs στ,2 = 1 μs	

Annex B: Example of simplified model using other time resolution

The models can be simplified to a specific application to allow for more efficient and less complex simulations and testing. The simplification should be done with a specific time resolution ΔT, which should be stated to avoid confusion: e.g. Rax(ΔT=0.1µs). The simplified application specific model is obtained by sampling the channel profiles in Tables 5.2, 5.3 and 5.4 at delays {0, ΔT , 2ΔT , 3ΔT, ... } as described in the example below. Only taps where the power is within 25 dB of the strongest tap need to be retained. Tap powers should be normalized so that the sum of all tap powers is equal to 1. All taps should have a classical Doppler spectrum, with the exception of the first tap in the simplified Rax channel which will be a superposition of a classical and a direct path Doppler spectrum (resulting in Ricean fading).

For a CDMA type system like UTRA, a typical ΔT used in simulations considered here may be ¼, ½ or 1 chip time.

For a Frequency Hopping or multicarrier system the ΔT should be set to consider the total system bandwidth to take the frequency correlation of the channel model into account.

An example of a simplified model is shown in Table B.1 for UTRA FDD. In the example, ΔT is ½ of the chip time of UTRA FDD.

Table B.1: Example of a UTRA FDD channel model for rural area, Rax(ΔT=130.2 ns)

Tap number	Relative time (ns)	Average relative power (dB)	Doppler spectrum
1	0	-2.748 composed of: -6.4 (Class) -5.2 (Direct path)	Class + Direct path, $f_s = 0.7 \cdot f_D$
2	130.2	-4.413	Class
3	260.4	-11.052	Class
4	390.6	-18.500	Class
5	520.8	-18.276	Class

The simplified channel model is sampled from the channel models listed in tables 5.2, 5.3 and 5.4. This sampling is accomplished by rounding the taps into the sample bins based on the value of ΔT. All taps from (i-1/2)ΔT to and including (i+1/2)ΔT would be sampled into the tap positioned at delay iΔT for all non-negative integers i.

For additional clarification, the computation of Table B.1 is demonstrated in the worksheet in Table B.2.

Table B.2: Detailed worksheet to compute the simplified channel model in Table B.1

Tap number (from Table B.1)	Tap Relative time (from Table B.1 in ns)	Relative time sampling range (from above sampling formula in ns)	Tap numbers from Table 5.3 sampled into this delay bin	Tap powers from Table 5.3 sampled into this delay bin (dB)	Total average relative power sampled into this delay bin (dB)
1	0.0	0.0 to 65.1	1, 2	-5.2 (direct path), -6.4 (Class)	-2.748 (-5.2 Direct path, -6.4 Class)
2	130.2	65.1 to 195.3	3, 4, 5	-8.4, -9.3, -10.0 (all Class)	-4.413
3	260.4	195.3 to 325.5	6, 7	-13.1, -15.3 (all Class)	-11.052
4	390.6	325.5 to 455.7	8	-18.5 (Class)	-18.500
5	520.8	455.7 to 585.9	9, 10	-20.4, -22.4 (all Class)	-18.276

Annex C: Change history

Table C.1: Document History

Time	Title	Curr	New	WI
RP-36	Rel-7 version created based on v6.0.0.	6.0.0	7.0.0	-
SP-42	Upgraded unchanged from Rel 7		8.0.0	
SP-46	Upgraded unchanged from Rel 8		9.0.0	
SP-51	Upgraded unchanged from Rel-9	9.0.0	10.0.0	
SP-57	Update to Rel-11 version (MCC)	10.0.0	11.0.0	
SP-65	Update to Rel-12 version (MCC)	11.0.0	12.0.0	
SP-70	Update to Rel-13 version (MCC)	12.0.0	13.0.0	
RP-75	Update to Rel-14 version (MCC)	13.0.0	14.0.0	

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2018-06	SA#80	-	-	-	-	Update to Rel-15 version (MCC)	15.0.0
2020-06	SA#88	-	-	-	-	Update to Rel-16 version (MCC)	16.0.0
2022-03	SA#95					Update to Rel-17 version (MCC)	17.0.0
2024-03	RAN#103					Update to Rel-18 version (MCC)	18.0.0

History

Document history		
V18.0.0	May 2024	Publication