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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;

2   presented to TSG for approval;

3   Indicates TSG approved document under change control.

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.

[1]   [Reference to COST 259]

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

3   Definitions, symbols and abbreviations

3.1   Definitions

For the purposes of the present document, the [following] terms and definitions [given in ... and the following] apply.

<defined term>: <definition>.

example: text used to clarify abstract rules by applying them literally.

3.2   Symbols

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

   <symbol>   <Explanation>

3.3   Abbreviations

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

<ACRONYM>   <Explanation>

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 $[0, 4 \cdot \sigma_t]$, 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 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:

$$h(\boldsymbol{t}) = \sum_{i}^{N} a_i \boldsymbol{d}(\boldsymbol{t}_i)$$

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:

$$S(f) = 1/(1 - (f/f_D))^{0.5}$$

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

$$S(f) = \boldsymbol{d}(f_s)$$

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 $\left|a_i\right|^2$ and relative delays $\boldsymbol{t}_i$, 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. When the models are implemented, the relative time may be rounded off to the closest integer multiple of 0.05 µs.

Table 5.1: Default mobile speeds for the channel models.

Channel model	Mobile speed
TUx	3 km/h
RAx	120 km/h
HTx	120 km/h

5.1   Typical Urban channel model (TUx)

Table 1. Channel for urban area

TAP NUMBER	RELATIVE TIME (µs)	AVERAGE RELATIVE POWER (dB)	DOPPLER 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 2. Channel for rural area

TAP NUMBER	RELATIVE TIME (µs)	AVERAGE RELATIVE POWER (dB)	DOPPLER 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 3. Channel for hilly terrain area

TAP NUMBER	RELATIVE TIME (μs)	AVERAGE RELATIVE POWER (dB)	DOPPLER 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 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 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 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 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 2. For this case, a full description of the channel is given by specifying the parameter set (Figure 1):

$$\{P_i, \pmb{t}_i, \pmb{s}_{\pmb{t},i}\}_{i=1\ldots N_C}$$

The i:th cluster is described by its total power P_i, the delay of the first path $\pmb{t}_i$ and the cluster delay spread $\pmb{s}_{\pmb{t},i}$. The last parameter describes the slope of the exponentially decaying power in the cluster. The number of clusters present is given by N_C.
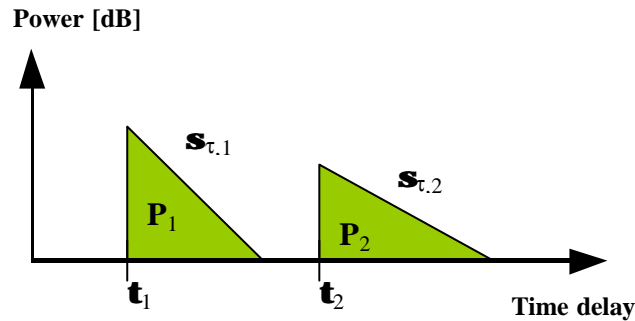

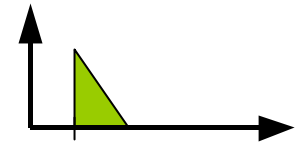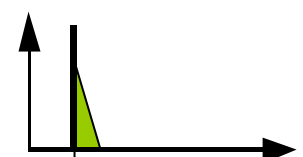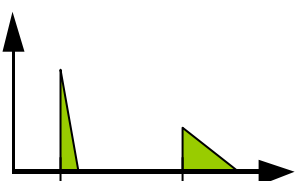**Figure 1. Channel shape (power delay profile) with multiple clusters.**

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 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 N_P independent Rayleigh-fading paths with Classical Doppler spectrum, randomly distributed in the interval $[\pmb{t}_i, \pmb{t}_i + k \cdot \pmb{s}_{\pmb{t},i}]$. Preliminary assignments are $N_P = 20$ and $k = 4$.

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

Table 3. Reduced complexity channel model parameters

ENVIRONMENT	CHANNEL SHAPE	CHANNEL PARAMETERS	
Typical Urban	One exponential cluster consisting of N_P Rayleigh-fading paths	$N_C = 1$ $P_1 = 1$ $\tau_1 = 0$ µs $\sigma_{\tau,1} = 0.5$ µs	
Rural Area	One exponential cluster consisting of N_P-1 Rayleigh-fading paths and 1 non-fading path.	$N_C = 1$ $P_1 = 1$ $\tau_1 = 0$ µs $\sigma_{\tau,1} = 0.1$ µs Add one deterministic (non-fading) path with: $f_D = 0.7 \cdot f_{Max}$ $P_2 = 0.43$ $\tau_2 = 0$ in order to get Ricean fading	
Hilly Terrain	Two exponential clusters each consisting of N_P/2 Rayleigh-fading paths each	$N_C = 2$ $P_1 = 1$ $\tau_1 = 0$ µs $\sigma_{\tau,1} = 0.29$ µs $P_2 = 0.04$ $\tau_2 = 15$ µs $\sigma_{\tau,2} = 1$ µs	

History

Document history		
v0.0.1	1999-12	First draft presented at RAN WG4 #9, Bath
V0.1.0	2000-03	Presented at RAN WG4 #11 for approval. To be submitted to TSG RAN #7 for approval.