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Speech Processing, Transmission and Quality Aspects (STQ); A Study on the Minimum Additional Required Attenuation on the Antenna Path of the Field Test Equipment

Reference

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Speech and multimedia Transmission Quality (STQ).

Modal verbs terminology

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1 Scope

The present document presents a theoretical model to be used for the estimation of the minimum required additional attenuation on the antenna path of the field test equipment in order for this to emulate the real life scenarios.

The model takes into consideration propagation within different environments, such as dense or spread urban areas, as well as in car and pedestrian scenarios. In addition, in order to provide the estimator, the model uses previously determined and known values for a set of parameters such as measurement and phone antenna gain, cable loss, car penetration, body loss.

The model is not applicable in the HSPA environments requiring MIMO technology and in the LTE environment.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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The following referenced documents are necessary for the application of the present document.

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The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

3 Abbreviations

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

CDMA Code Division Multiple Access
HSPA High Speed Packet Access
LTE Long Term Evolution
ME Measurement Equipment
MIMO Multiple Input Multiple Output
PCS Personal Communication System
RF Radio Frequency
RSSI Received Signal Strength Indicator

4 Typical measurement scenario

To ensure accurate network monitoring and testing, the field equipment needs to be set up to emulate real-life mobile phone utilization scenarios as closely as possible. The complexity of this emulation increases with the number of elements present in the mobile phone antennas which use e.g. dual-polarized MIMO and automatic band switching techniques or other smart functions.

Generally, non-MIMO equipment uses a single external antenna mounted on the roof of the drive test vehicle. This external antenna is connected to the RF input of the equipment box, which then connects to the RF input of the phone that is found inside the equipment box (see figure 4.1).

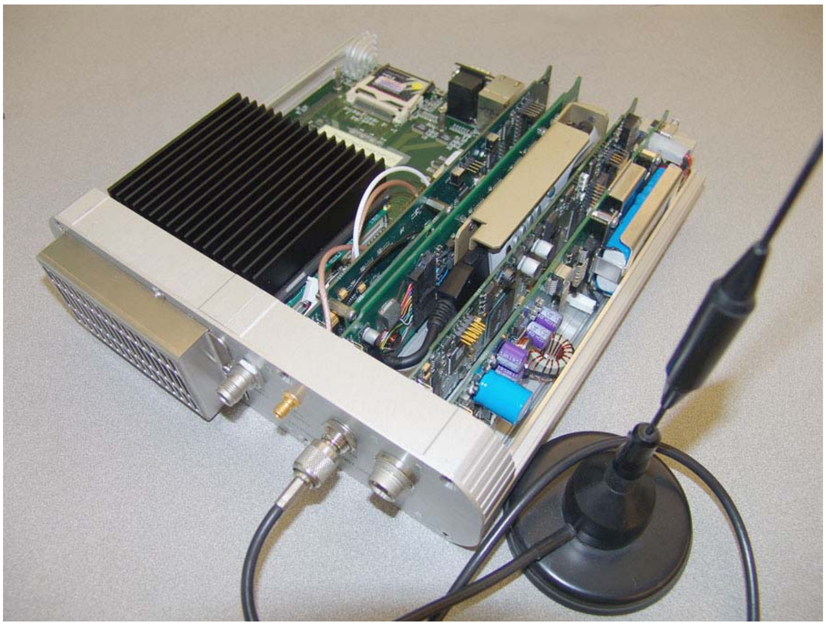

Figure 4.1: Measurement equipment

This set-up is beneficial to the signal strength (the RF power) that the phone receives and generates more optimistic results than a normal subscriber would experience. Therefore, an additional attenuator, characterized by the appropriate attenuation value, is required to ensure that the measurement configuration reproduces as closely as possible the real-life scenario. It should be noted, however, that there are a set of RF and electrical components involved in the measurements that compensate for the measurement's imperfections to a certain extent.

This is why a proper measurement set up requires the evaluation of the impact of these components (such as measurement antenna gain, cable loss, phone antenna gain, car penetration, and body loss) in order to estimate the minimum required additional attenuation to be inserted on the measurement path.

5 Real life scenario versus measurement scenario

5.1 Introduction

While the values of the RF and electrical characteristics are generally specified by the manufacturers of the measurement equipment's parts, the required additional attenuation value needs to be determined based on a measurement model designed to best emulate the real-life scenario. The model is based on the required equivalency between the real-life conditions and the measurement scenarios.

In a real-life scenario, which considers a subscriber using the phone inside the car, the power received by the phone's antenna is given by equation (1) below:

$$\text{Pin,phone} = \text{Prf 1} + \text{Atten(car)} + \text{Atten(human head)} + \text{Gain(antenna phone) [dB]} \quad (1)$$

where Prf1 is the RF power at the phone's location. The power is dependent on the path loss of the RF signal. The path loss depends on a set of environmental factors (such as the nature of the landscape, the type and the morphology of the measurement location, the geography of the location) described by the function F and the receiving antenna's height h (see equation (2) below):

$$\text{PathLoss(h)} = \text{F(landscape, morphology, geography)} + \text{A(h) [dB]} \quad (2)$$

The A(h) factor is also called the *correction factor* and an approximate value of this factor can be calculated using Hatta's equation for dense cities covered by micro cells with a small radius (about 1km) (see equation (3) below):

$$A\,(h) = (1{,}1 \times \lg\,(f)\ -0{,}7) \times h\ -1{,}56 \times \lg\,(f) + 0{,}8\ \text{[dB]} \quad (3)$$

where f(MHz) represents the carrier frequency. For spread cities covered by macro cells with radius larger than 1 km, the A(h) does not depend on the frequency anymore (see equation (4) below):

$$A\,(h) = 3{,}2 \times (\lg\,(11{,}75 \times h)\text{^}2 - 4{,}97\ \text{[dB]} \quad (4)$$

In the measurement's scenario, the received power by the phone comes through the external antenna mounted on the drive test vehicle's roof and is given by (equation (5) below):

$$\text{Pin,phone} = \text{Prf 2} + \text{Gain(external antenna)} + \text{Atten(ext antenna cable)} + \text{Atten(ME)} + \text{Atten(add atten) [dB]} \quad (5)$$

where Prf2 represents the RF power at the external antenna location, and the measurement equipment is denoted ME. The term Atten(ME) denotes the attenuation inserted by the path between the RF input of the ME box to the RF input of the phone, and includes connectors and cable loss.

The measurement scenario emulates the real-life condition if the Pin,phone given in the both scenarios is the same. The term Atten(add atten) represents the attenuation that is required in the measurement chain in order to ensure that the measurement scenario emulates the real live scenario.

5.2 Case 1 of the Measurement Scenario

If the measurements are performed using a car, then the antenna height is considered to be 1,5 meters and the equality 6 (6) takes place:

$$\text{Prf1} = \text{Prf2} \quad (6)$$

The value of the required additional attenuation can be therefore calculated using equations (1) and (5) and the equality (6) (see equation (7) below):

$$\text{Atten(add atten)} = -\ \text{Gain(external antenna)} - \text{Atten(ext antenna cable)} - \text{Atten(ME)} + \text{Atten(car)} + \text{Atten(human head)} + \text{Gain(antenna phone)} \quad (7)$$

5.3 Case 2 of the Measurement Scenario

If the measurements are performed using a van, mini truck, or bus, then the antenna is higher than 1,5 meters. Assuming that the environmental factors remain unchanged and using equation (2), the following equality (8), takes place.

$$\text{Prf2} = \text{Prf1} + \text{PathLoss(h)} - \text{PathLoss(1,5 m)} = \text{Prf1} + (\text{A(h)} - \text{A(1,5 m)}) \quad (8)$$

The equation (8) is equivalent to a correction of the external antenna gain as it is described by equation (9), below:

$$\text{Gain(external antenna)\_corrected} = \text{Gain(external antenna)} + (\text{A(h)} - \text{A(1,5 m)}) \quad (9)$$

Using the equation of the external antenna gain (9), the value of the required additional attenuation (7) becomes equation (10), below:

$$\text{Atten(add atten)} = -\text{Gain(external antenna)} - (\text{A(h)} - \text{A(1,5 m)}) - \text{Atten(ext antenna cable)} - \text{Atten(ME)} + \text{Atten(car)} + \text{Atten(human head)} + \text{Gain(antenna phone)} \quad (10)$$

The equation (10) gives the estimated additional attenuation value that needs to be inserted in the measurement configuration chain in order to ensure the equivalency between the subscriber's and the measurement scenario. This allows the network's performance to be evaluated and monitored from the subscriber's point of view.

6 Estimation of additional required attenuation based on the measurement model

Specific values for the electrical and RF characteristics of the field test equipment's components are generally available from the component manufactures, as it is the case of external antenna gain, phone antenna gain and cable loss. In the case of characteristics such as body loss and attenuation generated by the equipment itself (connectors and cable), the values are estimated by special designed tests and measurements. The electrical and RF characteristics exhibit specific dependencies on the frequency. Thus, only average values or a range of values can be provided. Table 6.1 presents the average values of the RF and electrical characteristics of the measurement equipment's components.

Table 6.1: RF and electrical characteristics of the measurement equipment

Atten(car) or car penetration	Atten(human head) or body loss	Gain (phone antenna)	Gain (external antenna) + Atten(ext antenna cable)	Atten(ME including cables, connectors)
5 dB See note 1.	3 dB See note 2.	1 dBi See note 3.	3 dBi See note 4.	1 dB See note 5.
NOTE 1: Usual average value across different types of cars. NOTE 2: Average value known from published results of different tests (RADCOM, VERIZON tests, Test Forum of CDMA Development Group 2004). NOTE 3: Average value, but it depends on the phone's type. Differences between phones might reach up to 3 dB. NOTE 4: Average value (see antenna specs such as the MaxRad combo). NOTE 5: Average value obtained from a set of measurements on the ME.				

Based on the values presented in table 6.1 and the model presented in the clause 5.3, equation (10), the minimum required attenuation value can be determined for different antenna heights, frequencies and environments. Table 6.2 presents these attenuation values (including the attenuation of the antenna cable).

Table 6.2: Model's results for the minimum required attenuation in different scenarios

Environment	Antenna height h	Frequency (MHz)	Min. Req. Attenuation (includes the cable attenuation)	Gain correction = A(h) - A(1,5 m)
Spread cities (macro cells)	1,5 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	12 dB	0 dB
	2 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	13,05 dB	1,05 dB
	2,5 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	13,93 dB	1,93 dB
	3 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	14,69 dB	2,69 dB
	3,5 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	15,37 dB	3,37 dB
Dense cities (micro cells)	1,5 meters	Cellular band (850 MHz)	12 dB	0 dB
		PCS band (1 900 MHz)	12 dB	0 dB
	2 meters	Cellular band (850 MHz)	13,28 dB	1,28 dB
		PCS band (1 900 MHz)	13,47 dB	1,47 dB
	2,5 meters	Cellular band (850 MHz)	14,55 dB	2,55 dB
		PCS band (1 900 MHz)	14,94 dB	2,94 dB
	3 meters	Cellular band (850 MHz)	15,83 dB	3,83 dB
		PCS band (1 900 MHz)	16,41dB	4,41 dB
	3,5 meters	Cellular band (850 MHz)	17,1dB	5,1 dB
		PCS band (1 900 MHz)	17,88 dB	5,88 dB

It can be seen that the determined required attenuations for an antenna height of 1,5 meters versus a height of 2 meters varies with less than 1,5 dB, depending on the frequency and the environment. The 1,5 dB value could be considered within the error limits with which the average values of other components used by the model (such as body loss, in car penetration, see table 6.1) have been estimated. Therefore, it could be concluded that (assumed a cable loss of 3 dB) an attenuator with an average of 10 dB attenuation is appropriate to cover up to 2 meters-antenna height, cellular and PCS bandwidth, within macro and micro cell environments.

If the antenna height is changed more than 0,5 meter: then the variations start to increase significantly, reaching differences higher than 3 dB, which represent variations larger than twice the signal strength. It should be noted however, that besides the height, only the environment affects the required attenuation value. Variations due to frequency changes are less than 1 dB.

The above observations show that some of the test scenarios generate close results regarding the minimum required attenuation. By close results it is meant that a variation of less than 1,5 dB (see "gain correction" column in table 6.2) has been found between scenarios. Therefore, these measurement scenarios could be merged into a single scenario which uses the average required attenuation value over the merged scenarios (such as different antenna heights, environments, and frequencies) as a minimum required attenuation.

Table 6.3: Model's results for the minimum required attenuation in merged scenarios

Environment	Antenna height	Frequency	Recommended min req. attenuation (includes the cable attenuation)
Spread and dense cities	1,5 to 2 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	13,2 dB
	2,5 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	14,6 dB
Spread cities	3 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	14,6 dB
	3,5 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	15,4 dB
Dense cities	3 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	16,2 dB
	3,5 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	17,4 dB

It should also be noted that any significant changes of the values in table 6.1 (such as another external antenna gain) directly impact the minimum required additional attenuation value.

7 Generally recommended additional attenuation values

There are two main scenarios that network operators are most likely to evaluate: the pedestrian case ("pedestrian coverage") and the in-car scenario ("in-car coverage").

In each of these scenarios, different components of the real-life environment are more important; therefore, only those components should be used to determine the required attenuation value.

For example, in the pedestrian scenario, the in-car penetration component (see table 6.1) doesn't need to be considered. In addition, there is no cable loss component. In the in-car scenario, emulating car penetration could be more important that considering the body loss component. Also, the cable attenuation represents an important attenuation component.

Based on these two most likely measurements scenarios, generally recommended values for the minimum required additional attenuation (without the cable attenuation) are presented in table 7.1.

Table 7.1: Recommended minimum required additional attenuation

Environment	Antenna height	Frequency	Recommended min. req. additional attenuation	
			Pedestrian coverage	In car coverage
Spread and dense cities	1,5 to 2 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	-8,2 dB	-10,2 dB
	2,5 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	N/A (see note)	-11,6 dB
Spread cities	3 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	N/A (see note)	-11,6 dB
	3,5 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	N/A (see note)	-12,4 dB
Dense cities	3 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	N/A (see note)	-13,2 dB
	3,5 meters	Cellular band (850 MHz), PCS band (1 900 MHz)	N/A (see note)	-14,4 dB
NOTE: Pedestrian coverage case is expected to cover antenna heights up to 2 meters.				

The results of an experimental test based on in car coverage performed by German Operators (see annex A) show that for spread cities, at 1 800 MHz, the estimated additional attenuation is about 10 dB, which matches the value found by the presented model (see table 7.1).

The results of the second experimental test based on in car coverage performed in Germany (see annex B) show that the measurement model based on external antennas is not applicable in the HSPA environments requiring MIMO technology and in the LTE environment as it does not reflect a real-life user experience.

8 Conclusions

Accurate network monitoring and optimization require that the measurement equipment is set-up to emulate as closely as possible the real-life scenario of the mobile phone utilization by the subscribers. The measurement equipment set-up involves a measurement model that is used to evaluate the parameters of the measurement equipment. These parameters comprise the RF and electrical characteristics of the measurement equipment's components (such as measurement antenna gain, cable loss, phone antenna gain, car penetration, and body loss) and the attenuation value of the additional attenuators that needs to be inserted on the measurement path.

Recommended average values for electrical and RF characteristics of the measurement equipment's components are provided. Based on these values and the measurement model, the required additional attenuation value is determined for different external antenna heights, frequencies, and environments. In addition, attenuation values are evaluated for two general measurement scenarios, pedestrian and in car coverage.

The measurement model with external antennas as described in the present document is applicable for scenarios that do not use MIMO technology and may not be applicable for respective services which utilize this technology.

Annex A: In car simulation test

A.1 Introduction

A simulation test aimed to estimate the additional attenuation on the antenna path has been performed by Vodafone D2 in September 2002.

A.2 Problem definition

Field tests are generally performed using mobiles with external antenna outside of car and defined additional attenuation in cable. Different operators used different attenuations such as:

- 10 dB all over at Vodafone D2;
- 20 dB all over at T-Mobile;
- 14 dB all over at E-Plus;
- no additional attenuation at O2.

Therefore, it has been decided to perform a test that simulates the in car measurement scenario in order to determine the appropriate attenuation value which should be used by the all operators.

A.3 Test set up

The test set up is presented in figure A.1 and figure A.2. The test configuration used two channels from one network operator with QVoice-System in parallel. Channel 1 had a mobile with internal antenna fixed to the plastic head filled with water (to simulate the human head); channel 2 used a mobile with external antenna outside the car.

A.4 Test description

The test had three phases:

(i) Phase 0: Quality check of head simulation during which drive tests with comparison of attenuation of the plastic head and the human head at 900 MHz and 1 800 MHz.

(ii) Phase 1: Determination of in-car attenuation during which drive tests with comparison of mobile with external antenna vs. mobile to the plastic head inside the car (in all 4 probing profile).

(iii) Phase 2: Verification of the determined in car attenuation during which drive test have been performed in the "large city" (or spread city) profile.

A.5 Results

The test's results showed a common attenuation of 10 dB, which needs to be added to the cable loss. Therefore, it can be concluded that an overall attenuation of 13 dB is recommended for common drive test scenarios in large cities, 1 800 MHz profiles.

Figure A.1: Human head emulator

Figure A.2: In car simulation set up

Annex B: In car simulation test in MIMO environment

B.1 Introduction

A simulation test aimed to estimate applicability of the measurement model with the external antennas in the HSPA environments requiring MIMO technology and in the LTE environment has been performed in December 2014 and January 2015.

B.2 Problem definition

Antenna technology of current mobile phones is based on the following techniques:

- Utilization of Multiple Input Multiple Output (MIMO) technology, requiring at least 2 antennas per phone
- Automatic use of different phone antennas for both uplink / downlink as well as different bands / technologies
- Introduction of "smart antenna" technologies such as integrated antenna tuners
- Usage of dual polarized antennas inside a single mobile phone

During the study period there were no external antennas commonly available featuring all the techniques mentioned above.

Therefore a measurement campaign was conducted in order to determine whether the typical user behaviour is represented by the usage of external antennas.

B.3 Test set up

Two measurement cars were set up with the same mobile phones (Samsung Galaxy S4™ GT-I9506).

NOTE : The mobile phone Samsung Galaxy S4 GT-I9506 is an example of a suitable product available commercially. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of this product.

Each car carried four mobile phones (one per operator). Car 1 used external antennas mounted outside the car with an attenuation of 6 dB added to the cable loss. Two external antennas were used per mobile phone. A distance of 30cm was ensured between any two external antennas. Car 2 used the original mobile phone antennas (non-modified phones) with the mobile phones mounted in the car near the window of the passenger seat.

B.4 Test description

The measurement campaign was conducted in Germany for a total duration of 10 days in several small and big cities as well as connecting roads for all four German operators. More than 1 100 samples were collected for each operator. Both measurement cars drove the identical routes on the same day, with a time distance of 15-30 minutes. A comparison of RSSI, MIMO Share and Download Throughput parameters was performed between Car 1 and Car 2 mobile phones for each operator to conclude if the setup with external antennas properly reflects user experience.

B.5 Results

The test’s result showed that the effort of simulating the behaviour of internal mobile phone antennas which use dual-polarized MIMO and automatic band switching techniques or other smart functions increased extremely and can no longer be achieved by usage of external antennas and a specific attenuation only. The measurement model based on the external antennas reliably reflects the user experience only in the environments which do not require MIMO technology.

In more detail, the parameter evaluation of the data traffic showed better download results for Car 2 in both 3G and LTE due to higher MIMO share (see figures B.1, B.2 and B.3). Such results were unexpected due to the fact that RSSI values in Car 2 were 5 dB worse than in Car 1 (see figure B.4).

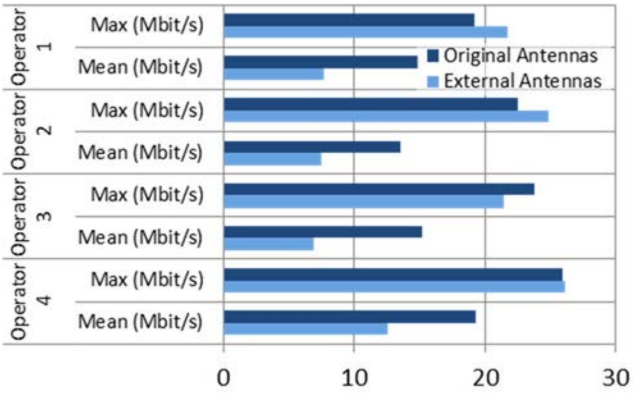

Figure B.1: 3G Download Data Rate

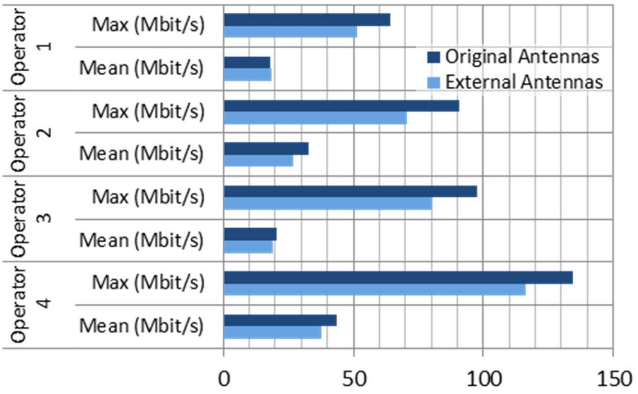

Figure B.2: LTE Download Data Rate

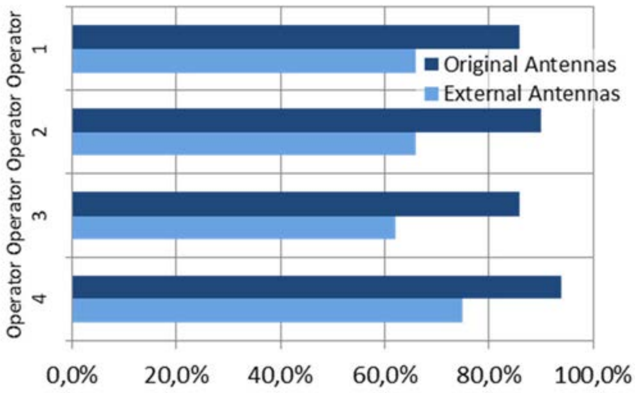

Figure B.3: MIMO share results (major German city)

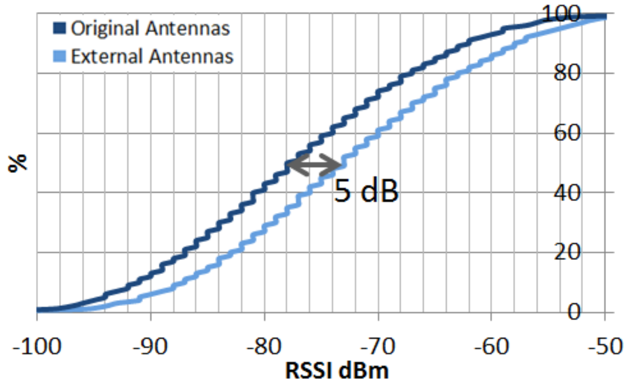

Figure B.4: RSSI

Annex A (informative): Bibliography

ETSI TS 102 250 series: "Speech and multimedia Transmission Quality (STQ); QoS aspects for popular services in mobile networks".

History

Document history		
V1.1.1	May 2007	Publication
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