ETSI TR 102 581 V1.2.1 (2015-11)

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
RTR/STQ-00200m

Keywords
3G, antenna, GSM, MIMO, network

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Contents

Intellectual Property Rights 4
Foreword 4
Modal verbs terminology 4
1 Scope 5
2 References 5
2.1 Normative references 5
2.2 Informative references 5
3 Abbreviations 5
4 Typical measurement scenario 6
5 Real life scenario versus measurement scenario 6
5.1 Introduction 6
5.2 Case 1 of the Measurement Scenario 7
5.3 Case 2 of the Measurement Scenario 7
6 Estimation of additional required attenuation based on the measurement model 8
7 Generally recommended additional attenuation values 10
8 Conclusions 11
Annex A: In car simulation test 12
A.1 Introduction 12
A.2 Problem definition 12
A.3 Test set up 12
A.4 Test description 12
A.5 Results 12
Annex B: In car simulation test in MIMO environment 14
B.1 Introduction 14
B.2 Problem definition 14
B.3 Test set up 14
B.4 Test description 14
B.5 Results 14
Annex A (informative): Bibliography 17
History 18

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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

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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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 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).

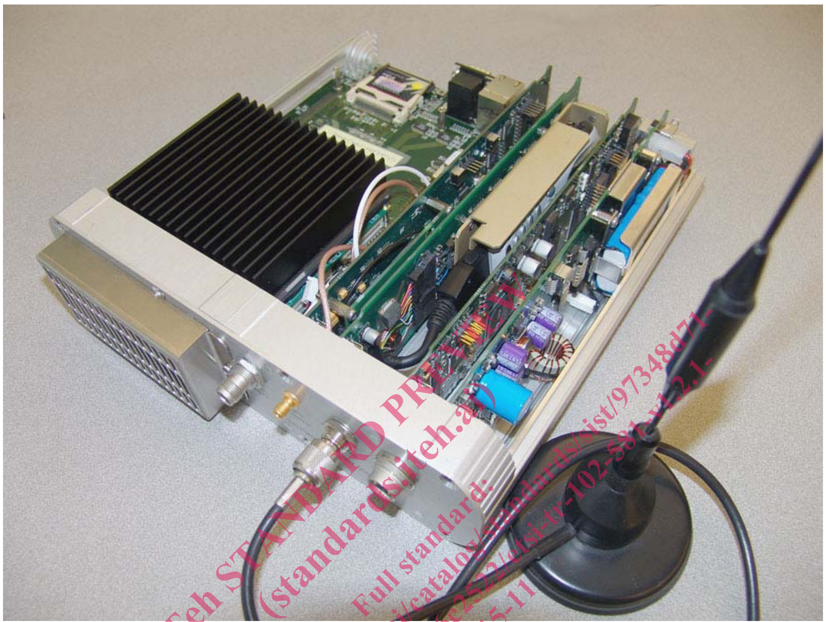

Figure 4.1: Measurement equipment

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):

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

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):

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

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.