

The Minimum Required Additional Attenuation on the Antenna Path of Field Test Equipment

A Study

Introduction

This document presents a theoretical model to be used to estimate the minimum required additional attenuation on the antenna path of the field test equipment in order to emulate real-life scenarios.

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

1 Typical measurement scenario

To ensure accurate network monitoring and testing, the field equipment must be set up to emulate real-life mobile phone utilization scenarios as closely as possible.

Generally, the equipment uses an 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 (Figure 1).

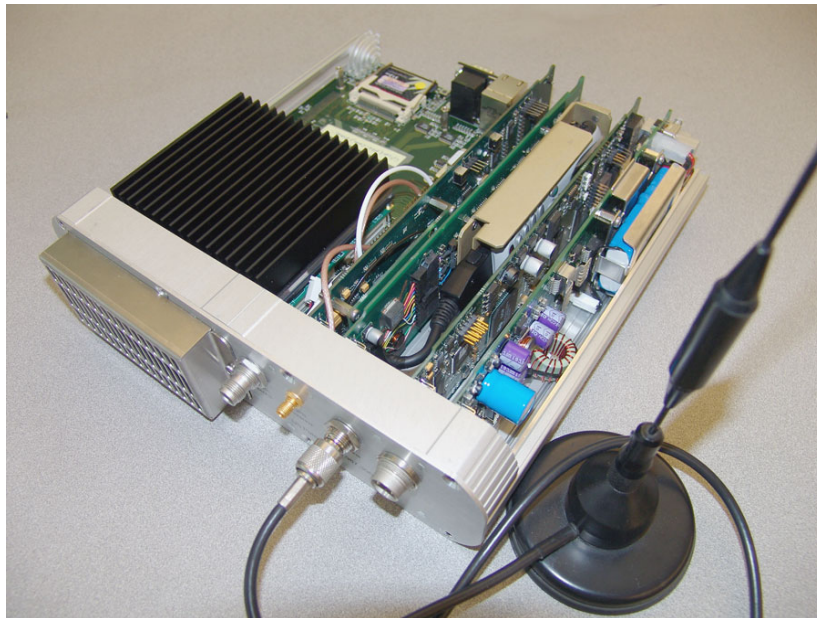


Figure 1

This setup 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 the real-life scenario as closely as possible. It should be noted, however, that there are sets 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 setup 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 into the measurement path.

2 Real-life scenario versus measurement scenario

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 a car, the power received by the phone's antenna is given by (1) below:

$$P_{in,phone} = Prf_1 + Atten(car) + Atten(human\ head) + Gain(antenna\ phone) \text{ [dB]} \quad (1)$$

where Prf_1 is the RF power at the phone's location. The power is dependent on the pathloss of the RF signal. The pathloss depends on a set of environmental factors (such as the nature of the landscape, the type and the morphology of the measurement location, and the geography of the location) described by the function F and the receiving antenna's height h , as shown in (2) below.

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

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

$$A(h) = (1.1 \cdot \lg(f) - 0.7) \cdot h - 1.56 \cdot \lg(f) + 0.8 \text{ [dB]} \quad (3)$$

where f (MHz) represents the carrier frequency. For spread cities covered by macro cells with radii larger than 1km, the $A(h)$ does not depend on the frequency any more. See (4) below.

$$A(h) = 3.2 \cdot (\lg(11.75 \cdot h))^2 - 4.97 \text{ [dB]} \quad (4)$$

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

$$P_{in,phone} = Prf_2 + Gain(\text{external antenna}) + Atten(\text{external antenna cable, connectors}) + Atten(\text{ME}) + Atten(\text{add atten}) \quad [dB] \quad (5)$$

where Prf_2 represents the RF power at the external antenna location, and the measurement equipment is denoted ME. The term $Atten(\text{ME})$ 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 $P_{in,phone}$ given in both scenarios is the same. The term $Atten(\text{add atten})$ represents the attenuation that is required in the measurement chain in order to ensure that the measurement scenario emulates the real-life scenario.

2.1 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) takes place

$$Prf_1 = Prf_2 \quad (6)$$

Therefore, the value of the required additional attenuation can be calculated using formulas (1) and (5) and the equality (6). See (7) below.

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

2.2 Case 2 of the measurement scenario

If the measurements are performed using a van, mini truck, SUV, or bus, then the antenna is higher than 1.5 meters. Assuming that the environmental factors remain unchanged and using formula (2), the following equality, (8), takes place.

$$Prf_2 = Prf_1 + PathLoss(h) - PathLoss(1.5\text{ m}) = Prf_1 + (A(h) - A(1.5\text{ m})) \quad (8)$$

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

$$Gain(\text{external antenna})_{corrected} = Gain(\text{external antenna}) + (A(h) - A(1.5\text{ m})) \quad (9)$$

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

$$Atten(\text{add atten}) = -Gain(\text{external antenna}) - (A(h) - A(1.5\text{ m})) - Atten(\text{external antenna cable, connectors}) - Atten(\text{ME}) + Atten(\text{car}) + Atten(\text{human head}) + Gain(\text{antenna phone}) \quad (10)$$

The expression (10) gives the estimated additional attenuation value that must be inserted into the measurement configuration chain in order to ensure equivalency between the real-life and measurement scenarios. This allows the network’s performance to be evaluated and monitored from the subscriber’s point of view.

3 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 manufacturers, as 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 specially 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 1 below presents the average values of the RF and electrical characteristics of the measurement equipment’s components.

Table 1

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

Based on the values presented in Table 1 and the model presented in the Section 2.2, expression (10), the minimum required additional attenuation value can be determined for different antenna heights, frequencies, and environments (Table 2).

Table 2

Environment	Antenna height in meters	Frequency (MHz)	Minimum required additional attenuation	Gain correction = A(h)-A(1.5m)
Spread cities (macro cells)	1.5 m	Cellular band (850 MHz), PCS band (1900 MHz)	12 dB	0 dB
	2 m	Cellular band (850 MHz), PCS band (1900 MHz)	13.05 dB	1.05 dB
	2.5 m	Cellular band (850 MHz), PCS band (1900 MHz)	13.93 dB	1.93 dB
	3 m	Cellular band (850 MHz), PCS band (1900 MHz)	14.69 dB	2.69 dB
	3.5 m	Cellular band (850 MHz), PCS band (1900 MHz)	15.37dB	3.37 dB
Dense cities (micro cells)	1.5 m	Cellular band (850 MHz)	12 dB	0 dB
		PCS band (1900 MHz)	12 dB	0 dB
	2 m	Cellular band (850 MHz)	13.28 dB	1.28 dB
		PCS band (1900 MHz)	13.47dB	1.47 dB
	2.5 m	Cellular band (850 MHz)	14.55 dB	2.55 dB
		PCS band (1900 MHz)	14.94 dB	2.94 dB
	3 m	Cellular band (850 MHz)	15.83 dB	3.83 dB
		PCS band (1900 MHz)	16.41 dB	4.41 dB
	3.5 m	Cellular band (850 MHz)	17.1 dB	5.1 dB
		PCS band (1900 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 represents a variation of half of the signal strength. In addition, the values in Table 1 represent average values. It could be concluded, therefore, that an attenuator with an average –13dB attenuation could be appropriate to cover up to a 2-meter 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 summary of these conclusions is presented in Table 3, providing the minimum required additional attenuation as the average value over the scenarios (such as different antenna heights, environments, and frequencies) that could be aggregated based on the discussion above.

Table 3

Environment	Antenna height in meters	Frequency	Recommended minimum required additional attenuation
Spread and dense cities	1.5 m to 2 m	Cellular band (850 MHz), PCS band (1900 MHz)	13.2 dB
	2.5 m	Cellular band (850 MHz), PCS band (1900 MHz)	14.6 dB
Spread cities	3 m	Cellular band (850MHz), PCS band (1900 MHz)	14.6 dB
	3.5 m	Cellular band (850 MHz), PCS band (1900 MHz)	15.4 dB
Dense cities	3 m	Cellular band (850MHz), PCS band (1900MHz)	16.2 dB
	3.5 m	Cellular band (850 MHz), PCS band (1900 MHz)	17.4 dB

It should also be noted that any significant changes of the values in Table 1 (such as another external antenna gain) directly impact the minimum required additional attenuation value.

4 Possibly recommended additional attenuation values

There are two main scenarios that network operators are most likely to evaluate: the pedestrian scenario (“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 does not need to be considered. In the in-car scenario, emulating car penetration could be more important than considering the body loss component.

Based on these two most likely measurement scenarios, possibly recommended values for the minimum required additional attenuation are presented in Table 4.

Table 4

Environment	Antenna height in meters	Frequency	Recommended minimum required additional attenuation	
			Pedestrian coverage	In-car coverage
Spread and dense cities	1.5 m to 2 m	Cellular band (850 MHz), PCS band (1900 MHz)	-8.2 dB	-10.2 dB
	2.5 m	Cellular band (850 MHz), PCS band (1900 MHz)	N/A*	-11.6 dB
Spread cities	3 m	Cellular band (850 MHz), PCS band (1900 MHz)	N/A*	-11.6 dB
	3.5 m	Cellular band (850 MHz), PCS band (1900 MHz)	N/A*	-12.4 dB
Dense cities	3 m	Cellular band (850 MHz), PCS band (1900 MHz)	N/A*	-13.2 dB
	3.5 m	Cellular band (850 MHz), PCS band (1900 MHz)	N/A*	-14.4 dB

*Pedestrian coverage case is expected to cover antenna heights up to 2 meters.

5 Conclusions

Accurate network monitoring and optimization require that the measurement equipment is set up to emulate as closely as possible real-life scenarios of mobile phone utilization by subscribers. The measurement equipment setup 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 the measurement of antenna gain, cable loss, phone antenna gain, car penetration, and body loss) and the attenuation value of the additional attenuators that must be inserted into 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.