EVALUATION OF THE TELIA SCATTERED FIELD MEASUREMENT METHOD FOR ESTIMATION OF IN-NETWORK PERFORMANCE OF MOBILE TERMINAL ANTENNAS

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ABSTRACT

In this paper we present and evaluate a method for estimation of in-network performance of mobile terminal antennas developed by the Swedish telecom operator Telia.

The Telia Scattered Field Measurement (TSFM) Method is intended to give a better estimate of the performance of the mobile terminal antenna as in an in-network fading scenario. The parameter measured from the TSFM method is referred to as the Scattered Field Measurement Gain, SFMG, i.e. the Mean Effective Gain, MEG, measured relative to a half wave dipole antenna. MEG includes the radiation pattern of the mobile terminal antenna as well as an estimate of polarization and directional losses that occur due to the propagation environment.

In this study it is found that the TSFM method provides a good measure of the in-network performance of the mobile terminal antenna. Furthermore, it is shown that the SFMG measured with this method is found to be well correlated with the Total Radiated Power Gain, TRPG, or radiation efficiency. This suggests that the Total Radiated Power, TRP, may be a good measure of the in-network performance of mobile terminal antennas if measured with proper adjustment to the antenna and propagation channel mismatch.

Keywords: Antenna Measurements, Mean Effective Gain, Mobile Terminal Antenna, SFM method, Total Radiated Power.

1. Introduction

In mobile communications, the mobile networks require highly efficient and reliable mobile terminals since their radio performance may reduce the coverage and/or the capacity of the whole network, [1]. The performance of the mobile terminal is determined by the efficiency of its antenna. However, there are currently no standardized and reliable methods to determine the over-the-air performance. Therefore, a reliable test method is of interest for estimating the in-network performance of mobile terminal antennas.

Recently, the specifications have been accepted within both the CTIA and the 3GPP standardization bodies, [2, 3] specifying test procedures for mobile terminals including the antenna. The focus is on two figures of merit:

1. Total Radiated Power (TRP), which is the maximum power transmitted by the mobile terminal in the uplink.

2. Total Radiated Sensitivity (TRS), which determines the lowest received power in the downlink for a given BER performance.

However, the 3GPP standard is also considering a more complete figure of merit known as Mean Effective Gain, MEG, [6]. The MEG, as well as the TRP, takes into account the radiation efficiency in the presence of the user's head (or body). However, the MEG also includes the impact of the propagation environment into the overall antenna performance. This makes the evaluation of the antenna performance more complete but also more complex since the evaluated antenna performance becomes highly dependent on the environment and the models that are used to characterize its behaviour.

The Telia Scattered Field Method, TSFM, is a method designed to be used for estimation of the in-network mobile terminal antenna performance [4]. The method can be used to directly estimate the performance in terms of MEG and body loss, and indirectly the TRP.

The method was developed by the Swedish telecom operator Telia in the mid 90-ies [4] and numerous results from measurements undertaken with this set up on different phones have previously been published [4, 5]. However, until now no thorough analysis of its validity has been published in the open literature, and in this paper an attempt is made to fill this void.

2. Definition of Parameters

2.1 Mean Effective Gain (MEG)

The mean effective gain refers to all radiated (received) power over all directions and polarizations weighted by a factor corresponding to a real field distribution divided by the sum of the total available power in vertical and horizontal polarizations that would be received by isotropic antennas, [6].

$$G_{MEG} = (\chi\gamma_\theta + \gamma_\varphi)/(\chi + 1) \quad (1)$$

where the total (or average) partial gain in polarization x is given by,

$$\gamma_x = \oint G_x(\theta,\phi) P_x(\theta,\phi) d\Omega \quad (2)$$

Here $G_\theta(\theta,\phi)$ and $G_\phi(\theta,\phi)$ are the elevation and azimuth components of the antenna power gain pattern respectively. $P_\theta(\theta,\phi)$ and $P_\phi(\theta,\phi)$ are the elevation and azimuth components of the angular density functions of incoming plane waves respectively. The cross-polarization ratio (χ) or XPR of the channel is defined as the ratio of the total power available in the vertical polarization (P_V) to the total power available in the horizontal polarization (P_H), both measured with isotropic antennas.

$$\chi = P_V / P_H \quad (3)$$

Hence, MEG besides radiation efficiency takes into account the polarization mismatch losses between the transmitted and received signals, the body loss and the polarization losses.

2.2 Scattered Field Measurement Gain (SFMG)

In order to compensate for the XPR of the channel used in the measurement, the Scattered Field Measurement Gain, SFMG, is measured instead of MEG. The SFMG refers to all radiated (received) power over all directions and polarizations weighted by a factor corresponding to a real field distribution divided by the power measured by means of a reference antenna (usually a half-wavelength dipole antenna). Hence, the SFMG is the ratio of the MEG of the terminal antenna of interest and the MEG of a reference antenna, more specifically a half-wavelength dipole antenna:

$$G_{SFMG}^{AUT} = G_{MEG}^{AUT} / G_{MEG}^{ref} \quad (4)$$

The measurement of SFMG is carried out with the mobile terminal positioned at 55° tilt to the vertical. This is due to the fact that the average usage of the terminal in talk position is close to this scenario.

2.3 Total Radiated Power Gain (TRPG)

The Total Radiated Power Gain, TRPG, is defined as the power radiated (received) over all directions and polarizations divided by the total power accepted by the antenna at the input port, which is identical with the classical definition of radiation efficiency, e_{rad} , and mathematically represented as,

$$e_{rad} = G_{TRP} = \frac{P_{rad}}{P_{accepted}} = \frac{\oint (G_\theta(\theta,\phi) + G_\phi(\theta,\phi)) d\Omega}{4\pi} \quad (5)$$

where, the power radiated into space or total radiated power (TRP), P_{rad}, is measured using StarGate Anechoic chamber, SG 64, [7] by calculating the average transmitted power in all directions, that is by integration over all angles in the unitary sphere, where $G_\theta(\theta,\phi)$ and $G_\phi(\theta,\phi)$ are the elevation and azimuth components of the antenna power gain pattern respectively and G_{TRP} is the TRPG.

The TRPG can also be written in terms of partial gain of the antenna using equation (2) and (5). For an antenna, in an isotropic environment, TRPG can be written as follows interms of partial gains of the antenna:

$$G_{TRP} = \gamma_\theta + \gamma_\varphi \quad (6)$$

By substituting the total accepted power, $P_{accepted}$ as 33 dBm at 900 MHz and 30 dBm at 1800 MHz for power class (level 5), equation (5) can be written in [dB] as follows

At 900 MHz

$$G_{TRP}[dB] = P_{rad}[dBm] - 33[dBm] \quad (7)$$

At 1800 MHz

$$G_{TRP}[dB] = P_{rad}[dBm] - 30[dBm] \quad (8)$$

It is worth mentioning that the used values of the accepted power are nominal values. In practice, the accepted power may be lower. Hence, TRPG also measures the deficiencies in power amplifier of the mobile terminal.

3. Telia Scattered Field Measurement Method

The traditional way of measuring the mobile terminal antenna performance is to use a well defined environment such as an un-echoic chamber. These methods use one or two incident waves to the Mobile Terminal (MT). However, in general the MT is exposed to the multipath waves and detects the sum of all incident waves to the mobile terminal antenna [4].

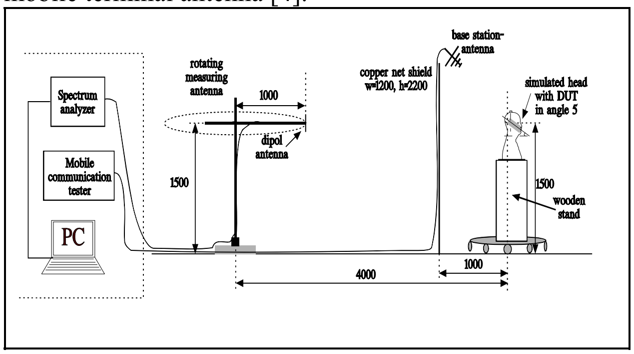

Figure 1 - Arrangement of test equipment. Note: Handset speaker centered at ear and above centre of turntable

The Telia Scattered Field Measurement (TSFM) method (see figure 1) is a more realistic approach for measuring the performance of a mobile terminal antenna. It uses an ordinary room with a "scattered field" [5], two calibrated dipole antennas for reference measurements and a base station antenna to communicate with Antenna Under Test (AUT).

The reference antenna is fed by a reference signal source transmitting with a power in line with the nominal power that the power class (level 5) of the mobile terminal corresponds.

The measuring antenna is mounted on an antenna rotator and connected to a spectrum analyser which in turn is connected with a PC that has special GSM measurement software. This software is used to measure the output power from the AUT.

A vertically polarized indoor base station antenna is used for communication with the antenna under test, and connected to a mobile communication tester. This instrument is used to establish and maintain a call to the AUT. It is also used to determine the output power of the reference MT.

The mobile phone under test is physically mounted on a torso phantom [8] filled with a liquid mix of water and sodium to a concentration of 1.49 g/litres, simulating the dielectric performance of the human body.

A round wooden turning table is used for rotating the simulated human head (torso phantom) with the AUT and the reference antenna in 8 different angles with each angle of 45 degrees separation.

A Copper mesh screen, as shown in figure.2, is positioned in between the AUT on the turn table and measuring antenna to create the Non-Line of sight (NLOS) environment in the room.

3.1 Measurement Room

In order to emulate the Rayleigh fading pattern, the method uses a large room with natural scatterers and a copper mesh to obstruct the Line Of Sight (LOS) between the transmitter and the receiver antennas as shown in figure 1. The room in which the tests are performed needs to offer an open area of at least: width=4 meter, length=7 meter, height=2.5 meter. It must also facilitate reflections so that a scattered field can be obtained. In order to achieve the desired multi-scattering environment it can be necessary to put some metal sheet in the used room. In our case 5 corrugated sheets of metal (0.9x2.1 meter) were placed in the room to create the desired scattered environment.

During the measurements, nothing is allowed to move in the room except the rotating antenna. The reference and the AUT measurements should be performed in the same environment.

In order to achieve the Rayleigh distribution, a screen is introduced to obstruct the direct path between the transmitting and the receiving antenna to avoid the direct wave (see figure 2).

3.2 TSFM Measurements

The TSFM method is used to find the MEG of the AUT with respect to that of the half wave dipole antenna in a radio environment (also denoted as SFMG). Practically, the power received from the AUT, P^{AUT}, is divided by the power received from the reference dipole antenna, P^{ref},. Hence, SFMG is obtained as

$$G_{SFMG}^{AUT} = P^{AUT} / P^{ref} \qquad (9)$$

In order to obtain the MEG using the TSFM method, three kinds of measurements needs to performed:

- Propagation measurements in order to characterize the radio environment.
- Reference measurements used for calculating the MEG of AUT.

- AUT measurements.

3.3 Measurement Procedure

3. 3.1 Propagation Measurements Procedure

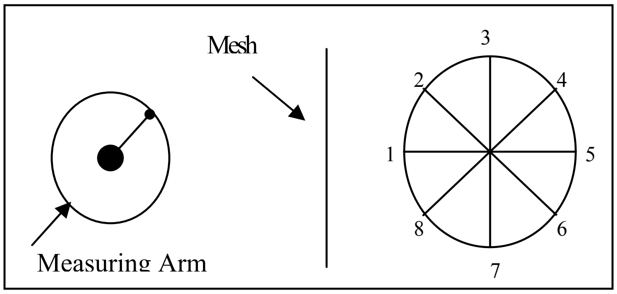

Figure 2 - Position of Turn table

The Propagation measurements are performed by tilting the electric dipole antenna horizontally as well as vertically to obtain P_H and P_V polarized powers respectively. These measurements are used to characterize the environment of the measurement room by computing the estimate of the XPR using equation (3).The fading pattern distribution in the room at the point of interest is obtained by computing the Ricean K-factor.

3.3.2 Reference Measurements Procedure

Received reference power is obtained with a half wave dipole transmit antenna in free space (Reference antenna; no phantom) fed with maximum nominal MT power. The reference antenna is tilted 55° from vertical and with its centre at the ear point as shown in figure 3, but without the phantom.

3.3.3 AUT Measurements Procedure

The handset is fixed to a phantom, placed on turn table, in “talk position” as shown in figure.3. When the handset is transmitting at nominal maximum power, the received power is sampled with the rotating receiver antenna (see figure 1). The mean power of the received samples is then calculated. This procedure is repeated for eight different azimuthal angles, separated 45°, and the average of the eight measured median received powers is obtained.

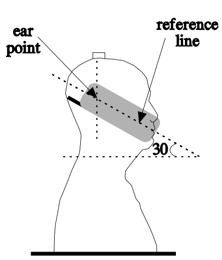

Figure 3 - Phantom with Handset in talk position

4. Initial Measurements and Results

The measurements were taken for channels TCH 33 at 900 MHz and TCH 637 at DCS 1800 MHz.

4.1 Propagation measurement results

The cumulative distribution function, CDF, from the results of the propagation measurements at both 900 and 1800 MHz are plotted in figures 4 and 5. The Ricean parameter, K, and the Weibull parameter, β, are then obtained. The value of K is estimated using the moment-based method [9], while β is obtained by a maximum-likelihood estimator [10]. The results are shown in table 1 below.

TABLE 1 FADING DISTRIBUTION STATISTICS

f, [MHz]	antenna orientation	Weibull Parameter (β)	Ricean Parameter (K)
900	Vertical	2.05	0.67
	Horizontal	1.84	0.74
	Reference	1.97	0.66
1800	Vertical	2.00	0.74
	Horizontal	1.90	0.75
	Reference	1.82	0.72

As the obtained value of the Ricean parameter K<1, the results show that environment in the room is Rayleigh fading. This is confirmed from the results of the CDF plots in figures 4 and 5 which show that the data fits better in a Rayleigh distribution than a Ricean.

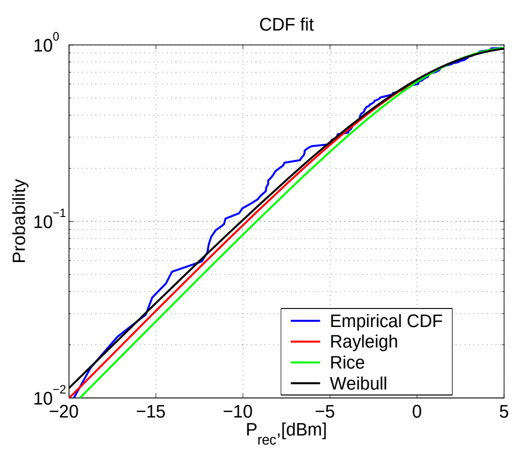

Figure 4 - Sample CDF Plot at 900 MHz

The estimate of cross polarization ratio (XPR) is calculated by taking the ratio of the vertical (P_V) and horizontal (P_H) power measured in the measurement room by a half wave dipole antenna. The result of the estimate of the XPR of the radio environment was about 4.8dB at 900MHz and 1.3dB at 1800MHz, indicating that the polarization is mainly vertically oriented at 900 MHz but “non polarized” at 1800 MHz.

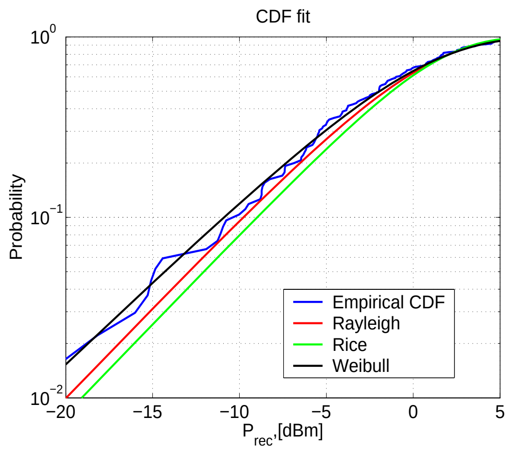

Figure 5 - Sample CDF plot at 1800 MHz

4.2 SFMG measurement results

Thirteen commercially available handsets of various models in both the left and right talk positions were measured in order to evaluate the TSFM method.

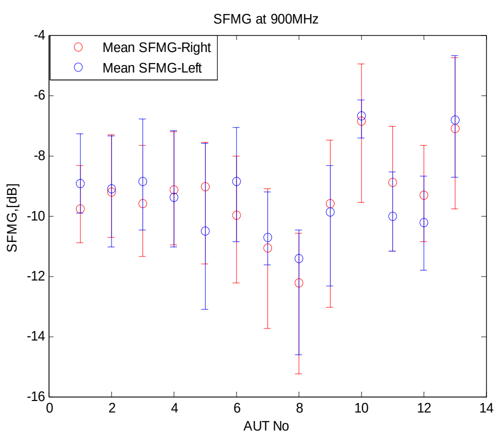

Figure 6 - SFMG at 900 MHz vs. AUT No.

The results of the SFMG measured in the right and left talk positions are plotted in figures. 6 and 7 at 900 and 1800 MHz respectively. The results indicate a high correlation between the left and right talk positions of handsets at 900 and 1800 MHz. The correlation coefficient between left and right talk position is found to be 0.83 and 0.91 at 900 and 1800 MHz respectively.

The plots in figures 6 and 7 also show the maximum, minimum and mean SFMG values measured for 13 mobile terminals with TSFM method at 900 and 1800 MHz respectively for both talk positions. These plots show the extent to which the SFMG value may vary for a given mobile terminal.

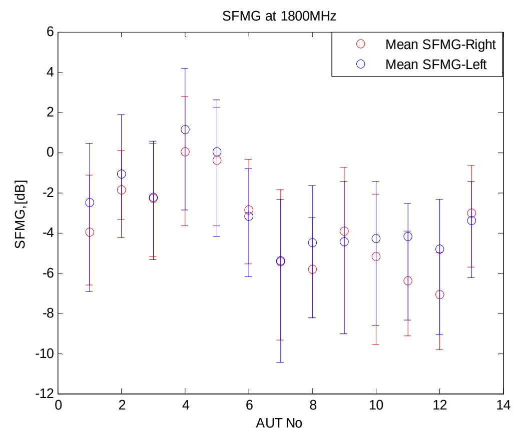

Figure 7 - SFMG at 1800 MHz vs. AUT No.

4.3 SFMG vs. TRPG measurement results

The TRP of the 13 commercially available mobile phones in transmit mode was obtained using an anechoic chamber with a StarGate SG64 [7]. The TRPG is computed for both 900 MHz and 1800 MHz using the equations (7) and (8) respectively.

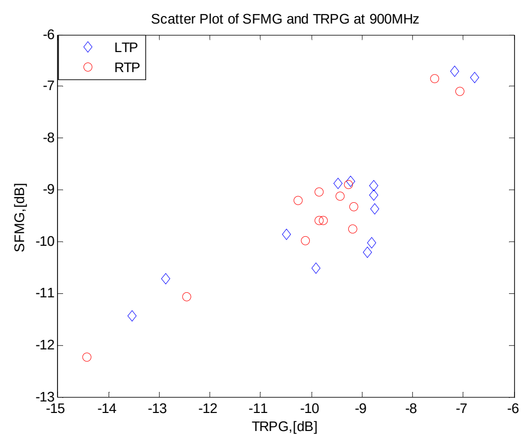

Figure 8 - TRPG vs. SFMG at 900 MHz for 13 mobile terminals

The validity of the SFMG results, obtained by TSFM method, is performed by plotting the scatter plot of the results between the TRPG and SFMG for both the left and right talk positions as shown in figures 8 and 9. The scatter plots in figures 8 and 9 show that the correlation between the TRPG and SFMG values is strong. It is found that the correlation coefficient between the TRPG and SFMG is 0.84 and 0.94 at 900 MHz and at 1800 MHz it is found to be 0.95 and 0.92 in left and right talk positions respectively.

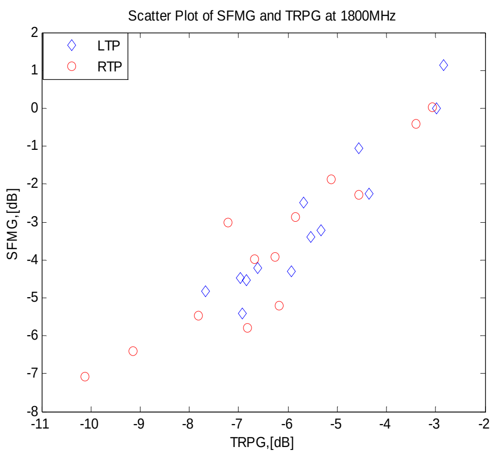

Figure 9 - TRPG vs.SFMG at 1800 MHz for 13 measured phones

5. Discussion and Conclusions

In this paper the Telia Scattered Field Method is described and briefly evaluated to estimate the in-network performance of mobile terminal antennas. This is achieved by conducting the measurements on 13 mobile terminals.

The measurements are conducted at 900 and 1800 MHz for both the right and left talk positions. For comparison the TRP of the mobile terminals is measured using StarGate SG64 anechoic chamber and hence, TRPG is computed.

High correlation is observed in the received power between the left and right talk positions, indicating that it is sufficient to perform measurements only in one talk position. Thus, the measurement burden is alleviated.

The variation in the SFMG values for individual mobile terminals suggests that the SFMG depends strongly on the configuration of the mobile terminals. Hence, the SFMG, obtained by TSFM method, can be used for estimating the cross polar discrimination (XPD) of the mobile terminal antenna and its impact on the performance of the mobile terminal.

Finally, the correlation between the SFMG and the TRPG is high suggesting that TRP can provide a better estimate of the in-network performance of mobile terminals if proper adjustment is made to the antenna and propagation channel mismatch.

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7. ACKNOWLEDGEMENT

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