# Mean Effective Gain Calculation in Realistic Environments based on Ray-Tracing

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## 1. Introduction

In the mobile communications environment, multipath fading occurs due to reflections, diffractions, and scatterings caused by surrounding buildings and geographical elements. These environmental features are the main reasons of poor transceiving performance. The antenna gain is one of the key parameters in the evaluation of antenna performance together with radiation pattern, impedance, and sensitivity and the gain measurement is usually performed in anechoic chamber. But antenna gain measurement in conventional anechoic chamber cannot give full credit to the actual mobile communication environment. This is because the anechoic chamber cannot accommodate the real environment for mobile terminal operation. Thus antenna gains measured in anechoic chamber and real environment are different to each other in its character.

MEG (Mean Effective Gain) is the antenna gain that concerns the surrounding environment of the receiving antenna [1] and is different from the conventional one measured in free space. With calculated and measured MEG, one can figure out how well the receiving antenna could be fit to the surrounding environment and offers a full understanding on the interaction between the antenna and its surroundings. To calculate the MEG, an angular density function (which represents distribution of transmitted wave that has reached the receiving antenna) should be defined first. In previous studies, various statistical models have been chosen to represent the angular density function such as Gaussian distribution or Laplacian distribution [2]-[4]. But with these models, it is difficult to define precise angular density function of the transmitted wave, so it is hard to reflect the effect of surrounding environment in MEG calculation.

In this paper, DRT (Deterministic Ray-Tube) method, which is one of the ray tracing methods based on image concept [5], has been used to find all the wave paths from a transmitting station to a receiving station and by using these transmitted wave distributions in MEG calculation, the effect of surrounding environment can be analysed accurately.

## 2. Replacement of Statistical Model with Realistic Model

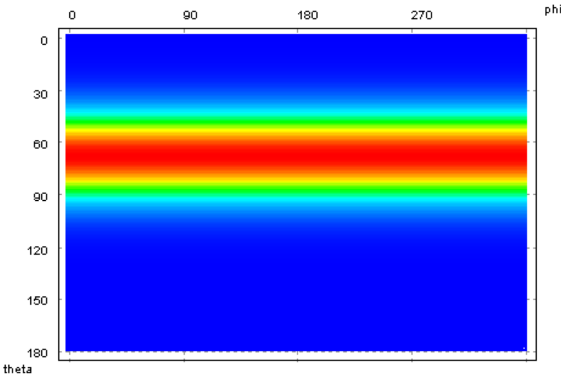
The concept of the MEG was first introduced by Taga, who defined it as the average power received by the antenna under test in the propagation environment of interest to the sum of the average powers that had been received in that same route by two isotropic antennas, vertically and horizontally polarised, respectively. Taga defined the MEG as

$$\begin{aligned} G_e &= \frac{P_{rec}}{P_V + P_H} \\ &= \frac{\int_0^{2\pi}\int_0^{\pi}\left\{P_V G_\theta(\theta,\phi)P_\theta(\theta,\phi) + P_H G_\phi(\theta,\phi)P_\phi(\theta,\phi)\right\}\sin\theta d\theta d\phi}{P_V + P_H} \\ &= \int_0^{2\pi}\int_0^{\pi}\left\{\frac{XPR}{1+XPR}G_\theta(\theta,\phi)P_\theta(\theta,\phi) + \frac{1}{1+XPR}G_\phi(\theta,\phi)P_\phi(\theta,\phi)\right\}\sin\theta d\theta d\phi, \end{aligned} \tag{1}$$

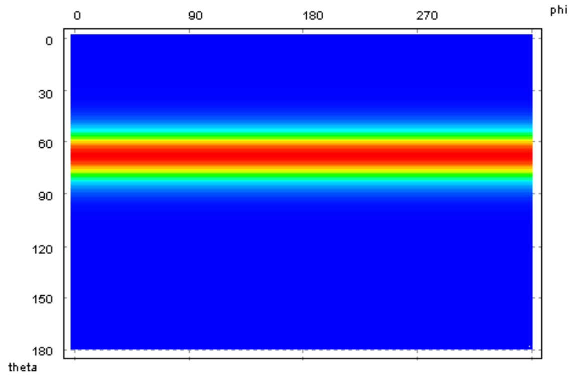
where $XPR = \frac{P_V}{P_H}$ is the cross-polarization power ratio.

$P_V$ and $P_H$, respectively, are the mean incident powers of the VP and HP incident radio waves received while the antenna moves along a random route in the environment. So, $P_V + P_H$, is the total mean incident power arriving at the antennas averaged over the same route, and $P_V$ is the mean received power of antenna over the random route. $G_\theta(\theta,\varphi)$ and $G_\theta(\theta,\varphi)$ are the $\theta$ and $\varphi$ components of the antenna power gain pattern, respectively. $P_\theta(\theta,\varphi)$ and $P_\theta(\theta,\varphi)$ are the $\theta$ and $\varphi$ components of the angular density functions of incoming plane waves, respectively. Taga used a statistical model of angular density function which is Gaussian in elevation and uniform in azimuth [1], as shown in Fig. 1(a). Another form of angular density functions are ; Laplacian in elevation and uniform in azimuth model as shown in Fig. 1(b), both Gaussian in elevation and azimuth model [3] as shown in Fig. 1(c), both Laplacian in elevation and azimuth model as shown in Fig. 1(d) and so on have been used for MEG calculation. On outdoor environment as shown in Fig. 2(a), by using ray-tracing method, we can find all the propagation paths from transmitting antenna to moving receiving antenna and it can be used for determining realistic angular density function as shown in fig. 2(b), and by using this distribution we can fully analysed the effect of propagation environment. In Fig. 2, the path of receiving antenna lies along the way, and there are no obstacle to block the ray path on forward direction and backward direction of receiving antenna, so the number of the incident rays are few on phi is around $0^{o}$ and $180^{o}$.

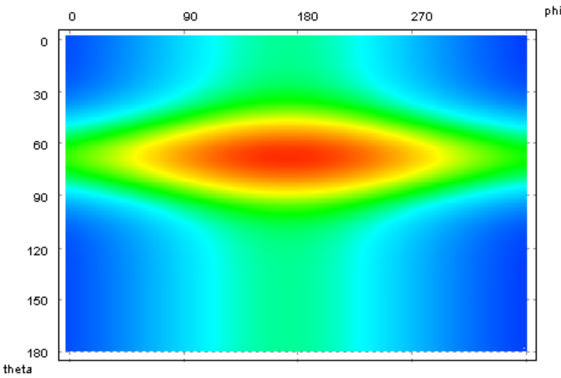
In the left direction and right direction of the path, there are buildings that can cause multiple reflections and diffractions of the ray. These buildings can generate lots of incident rays. Comparing distribution of incident rays in Fig. 2(b) with Fig. 1, this model is more close to the real building and topography scenario.



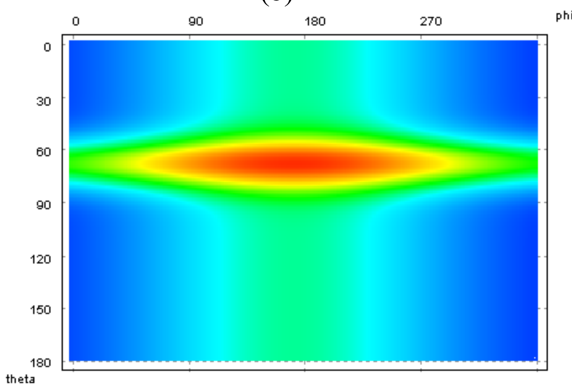

(a)




(b)

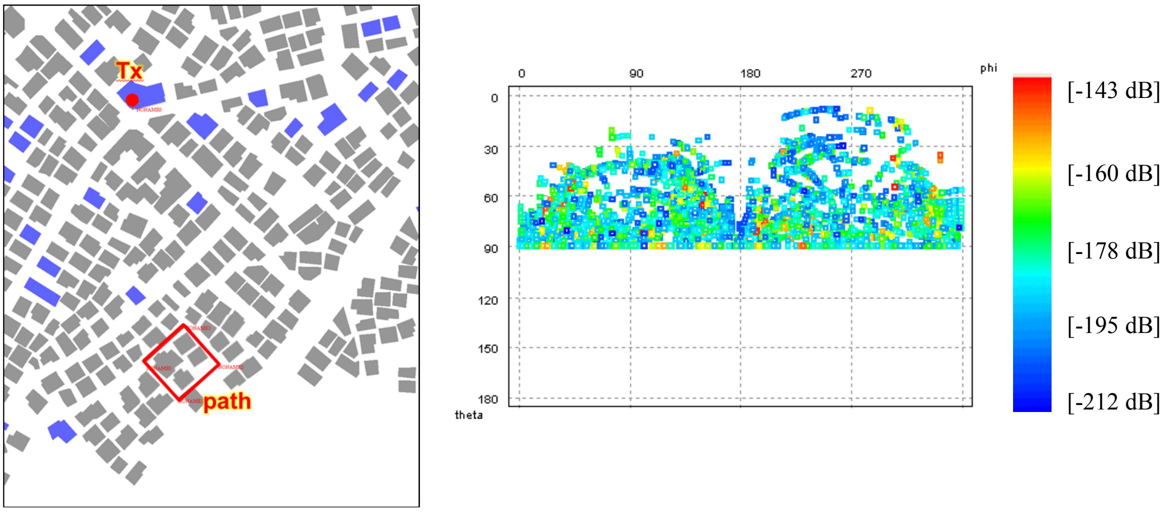



(c)




(d)

Figure 1: angular density function of statistical models. incident waves that are (a) Gaussian in elevation and uniform in azimuth, (b) Laplacian in elevation and uniform in azimuth (c) Gaussian in elevation and azimuth (d) Laplacian in elevation and azimuth




(a) (b)

Figure 2: map of incident rays distributions (a) outdoor environment (b) distribution of incident rays for MEG calculation in outdoor environment

## 3. Simulations and Results

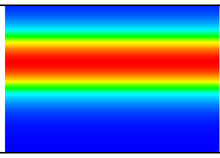
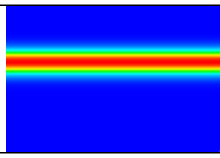
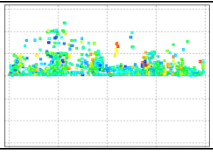
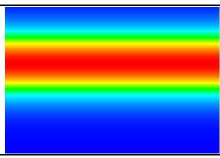
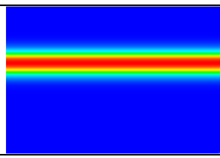
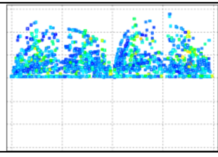
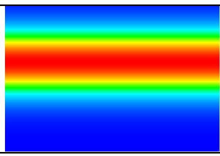
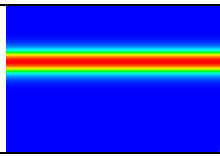
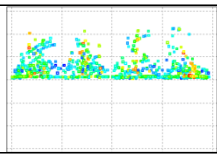
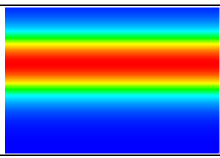
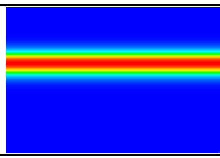
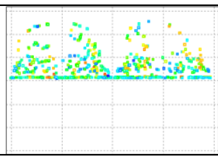
Fig. 3 is the map of Seodaemun-gu, Seoul, and the location of transmitting antenna is marked and two receiving paths are indicated. Simulation results are summarized in Table 1. An isotropic antenna was used for transmitting antenna and whereas a dipole antenna was used for receiving antenna. It would be difficult to relocate the transmitting antenna and to alter the path of receiving antenna in a conventional statistical model. However, the proposed method enables us not only to shift the position of Tx antenna but also to modify the path of Rx antenna, consequently this method calculates the MEG without adhering to the statistical model.

Table 1 shows the computed MEG for Tx 1 and Tx 2. In case that transmitting antenna is located at Tx 1, MEG on path 1 is greater than path 2. For path 1, the most incident rays are arrived in directly. However the most incident rays are arrived in uniformly for path2. Thus receiving antenna on path 1 has directive pattern and path 2 has uniform pattern. Generally antenna gain which has directive pattern is greater than which has omni-directional pattern. In case that transmitting antenna is located at Tx 2, it is surrounded by many buildings and thus uniform incident rays are received on both path1 and path2, thus the MEG for path 1 is similar to path 2.


Figure 3: Map used in the MEG simulation (Seodaemun-gu, Seoul, Korea).

Table 1: calculated MEG of each cases

[dBi]

| | | Gaussian distribution | Laplacian distribution | Real distribution |
|---|---|---|---|---|
| Tx1 | Path1 |  |  |  |
| | | 0.448 | 0.732 | 1.946 |
| | Path2 |  |  |  |
| | | 0.448 | 0.732 | -0.206 |
| Tx2 | Path1 |  |  |  |
| | | 0..448 | 0.732 | 1.952 |
| | Path2 |  |  |  |
| | | 0.448 | 0.732 | 1.457 |

## 4. Conclusion

In this paper, MEG calculation method closely reflecting the real environment was proposed. To represent the real environment, we have replaced the conventional statistical model with the realistic model. The realistic model was implemented by the DRT method. Proposed method takes the advantage of analysing the most influential parameters to the MEG. The parameters to be considered are the location of Tx antenna, path of moving receiving antenna, distribution of buildings, and height of Tx and Rx antenna, respectively.

## References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