EFFECTS OF ANTENNA RADIATION PATTERN ON THE PERFORMANCE OF THE MOBILE HANDSET

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1. INTRODUCTION

It has been evident for some years now that mobile phones have varying antenna performance when used in mobile networks. The performance of mobile phones is important in mobile networks, particularly in the environments characterized by severe multipath fading effects. Thus, it is important to know what antenna characteristics might improve the performance of the mobile phones. This topic has achieved wide interest in recent years.

The benefits of using diversity in mobile phone are discussed in [1]. In [2] the results from the measurements made with real persons were presented. In this paper the effects of the different antenna radiation pattern characteristics on the performance of the antenna in different measured environments at 2 GHz are investigated. The performance is based on the mean effective gain, which describes the performance of the evaluated antenna in one environment.

2. DEFINITION OF ANTENNA PERFORMANCE

The performance of an antenna can be defined in different ways [3]. The received power can be measured in real environments. However, the measurements made in many environments are time consuming. Radiation efficiency does not take into account the effects of the propagation environment. An important characteristic in comparing mobile phones is the mean effective gain (MEG) of an antenna. In a multipath environment the MEG defines the power received by the antenna compared to some reference antenna [4]. The MEG takes into account both the antenna radiation pattern and the effects of the propagation environment. MEG can be defined by comparison measurements in a test route or by calculating theoretically from the three-dimensional radiation pattern and the distribution of the incident field. A wideband channel sounder with a spherical antenna array developed in Radio Laboratory of HUT has been used to measure the signal direction-of-arrival distributions [5]. In [6] a formula is presented for calculating MEG, G_e, using signal distribution, P, and antenna radiation pattern, G, as parameters. XPR is cross polarization ratio and θ and φ are in Fig.2d.

$$G_e = \int_0^{2\pi}\int_0^{\pi}\left\{\frac{XPR}{1+XPR}G_\theta(\theta,\phi)\,P_\theta(\theta,\phi)+\frac{1}{1+XPR}G_\phi(\theta,\phi)\,P_\phi(\theta,\phi)\right\}\,\sin\theta d\theta d\phi \quad (1)$$

The following conditions must be satisfied when using the previous equation:

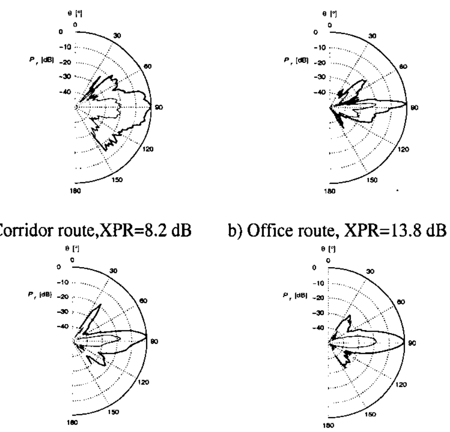
$$\int_0^{2\pi}\int_0^{\pi}\left\{G_\theta(\theta,\phi)+G_\sigma(\theta,\phi)\right\}\sin\theta d\theta d\phi = \eta_{tot}4\pi \tag{2}$$

$$\int_0^{2\pi}\int_0^{\pi} P_\theta(\theta,\phi)\sin\theta d\theta d\phi = \int_0^{2\pi}\int_0^{\pi} P_\phi(\theta,\phi)\sin\theta d\theta d\phi = 1. \tag{3}$$

Here η_{tot} is the efficiency of the antenna and includes all possible mechanisms (head, hand, internal losses, reflections) reducing the radiated power.

3. EFFECT OF DIFFERENT ANTENNA CHARACTERISTICS

In this study some synthetic Gaussian antenna patterns have been used in the evaluation. Using the synthetic radiation patterns the effect of changing beamwidth, main beam direction, and polarization ratio of the antenna on the performance of mobile terminal antennas in different propagation environments is studied. The signal distributions in measured environments are in Fig 1. The transmitting polarization in the measurements was vertical.



a) Corridor route,XPR=8.2 dB   b) Office route, XPR=13.8 dB

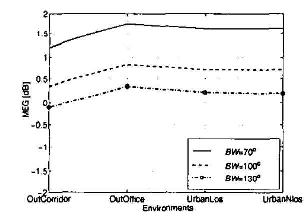
c) Urban LOS, XPR=11.3 dB   d) Urban NLOS, XPR=10.8 dB

Figure 1. Signal distributions (— = θ polarization, --- = ϕ polarization).

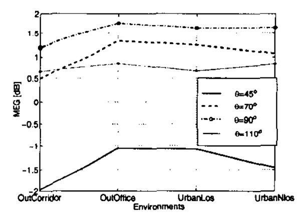
Values presented in Table 1 have been calculated using Eq. (1). The synthetic radiation patterns have been created based on Gaussian distributions. The radiation patterns do not have side lobes or back lobes. The patterns have been formed in such a way that either the beamwidth *BW*, main beam direction in elevation, θ, or polarization ratio, PR_a ($PR_a=\int_\Omega G_\phi / \int_\Omega G_\theta$), has been changed. All the patterns are Gaussian in elevation and omnidirectional in azimuth. All synthetic radiation patterns have been normalized using Eq. (2). The η_{tot} of the patterns have been 1 in the evaluations.

Table 1.Mean effective gain values for the synthetic antenna patterns.

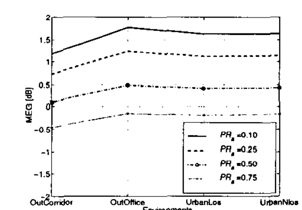
MEG [dB]	Corridor	Office	UrbanLos	UrbanNlos	dB_Average
$PR_a=0.1, \theta=90°, BW=70°$	1.18	1.77	1.63	1.64	1.56
$PR_a=0.1, \theta=90°, BW=100°$	0.35	0.84	0.71	0.71	0.65
$PR_a=0.1, \theta=90°, BW=130°$	-0.10	0.35	0.23	0.21	0.17
$PR_a=0.1, \theta=45°, BW=70°$	-1.97	-1.05	-1.07	-1.45	-1.39
$PR_a=0.1, \theta=70°, BW=70°$	0.50	1.32	1.24	1.08	1.04
$PR_a=0.1, \theta=110°, BW=70°$	0.66	0.85	0.67	0.84	0.76
$PR_a=0.25, \theta=90°, BW=70°$	0.72	1.24	1.12	1.14	1.06
$PR_a=0.50, \theta=90°, BW=70°$	0.08	0.49	0.41	0.43	0.35
$PR_a=0.75, \theta=90°, BW=70°$	-0.45	-0.14	-0.18	-0.15	-0.23



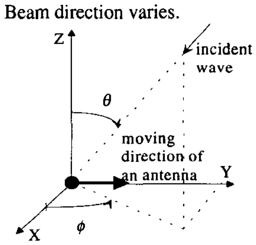
a) Beamwidth varies.



b) Beam direction varies.



c) Polarization ratio varies.



d) Angles for Eq. 1-3.

Figure 2. MEG values for synthetic antenna patterns.

In Fig.2a the main beam direction is $\theta = 90^{\circ}$ but the beamwidth has been changed. The narrowest beamwidth seems to work best in all evaluated environments. As the beamwidth is kept constant at 70° but the main beam direction of the antenna is changed, differences in MEGs between the environments can be seen in Fig.2b. Clearly the antenna whose main beam is in horizontal level or slightly above that is the best. As the effect of the polarization was studied (Fig.2c), the power gain patterns in θ- and ϕ-polarizations were similar in shape but the power ratio between the patterns was varied. In all environments the difference between the best and worst antenna is about 2 dB. Generally the mainly θ-polarized antenna has the highest MEG in all environments. The larger part of the power is in ϕ-polarization the lower is the MEG in that evaluation environment.

4. SUMMARY

In this paper the effects of the properties of the antenna radiation pattern on the performance of the antenna in different environments have been presented. Measured signal distributions and synthetic antenna radiation patterns have been used in the analysis. In the synthesis no superior way of improving the performance of a mobile terminal could be found by means of different radiation patterns. However, some small improvements can be found. As the main beam is narrowed, the performance becomes slightly better. Also tilting the beam somewhat above the horizontal level increases the performance. The more the polarization of the antenna is vertical, the better the performance is. Therefore, polarization diversity with maximum ratio combining might be useful in compensating the handset tilting.

Considering the performance of the terminals operating at 2.15 GHz the improvement of approximately 2 dB between the best and worst synthetic antenna can be achieved by narrowing and tilting the beam and considering the polarization. At 5 GHz the improvement could be larger, because narrow adaptive beams are easier to produce for small mobile terminal antennas at 5 GHz than at 2 GHz. However, high efficiency seems more significant in achieving high MEG than any beam shaping. Furthermore, good diversity solution outperforms all single antenna configurations [1].

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