Three Dimensional (3D) Electromagnetic Field Distributions in the Air and Relative Diversity Gain

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Abstract— There exists 3-dimensional (3D) electromagnetic field distribution (EMFD) in the air and its components can be used for polarization discrimination (XPD) or equivalently diversity improvement. Measurements were carried out through shore roads and hillsides. The results show that the lowest XPD is obtained for hill side road area, and very high signal cross-correlation is achieved through shore road. Calculated values point out that 30 dB extra relative gain can be obtained by using suitable 3 dimensional antenna design at shore sides, while 4.6 dB by hill-side roads.

1. INTRODUCTION

Polarization discrimination (XPD) or equivalently polarization diversity is commonly used to improve quality in wireless communication systems such as mobile equipments' applications, LAN and WLAN applications. MIMO antennas have very big applications in wireless communications especially for broadening channel capacity. With similar reasons, people started to focus on designing new antennas having three dimensional (3D) electric field sensing capability for varying applications. Diversity reception especially polarization diversity, for mobile communication systems results in decreasing transmitting power as well as in receiving power which allows to control interfering signals [1, 2]. Space diversity applications basically require 10λ antenna separation, and that much of space requirement (equals to 3 m at 900 MHz) results in increased installation budget. In this case, de-correlation of polarized signal components become an attractive alternative for space diversity. It is noted that, environment as an obstacle affects the polarization diversity scheme performances [3, 4], and polarization discrimination (XPD) or equivalently the polarization diversity can also be applied to mobile equipments instead of BSS receivers. The partial evaluation of the possibility of usage of polarization diversity can be achieved by analyzing 3D EMF components. There are studies in the literature [3, 5, 6] focusing on the cross polarization discrimination and/or cross-correlation with horizontally or vertically polarized varying antenna configurations. Scattering of signals from different scatters rotates the polarization of waves through multipath fading, and it allows deriving cross-polarization diversity gain. A relationship between XPD and polarization diversity gain is evaluated experimentally by using cross polarized reception data at the base-station (BS) end. 5 dB to 15 dB XPD is reported in their study, and reported those varying values are depending on the scattering environment and on the radio propagation path between the BS and mobile station. Propagation path can be either line-of-sight (LOS) or non-line-of-sight (NLOS) [7].

Lotse et al. [8] and Jaana et al. [9] proposed a study for estimating polarization diversity gain, and NARDA SRM3000 with a type 18 isotropic E-field probe is used the studies [3, 4] for performing measurements. Jaana et al. [3] demonstrates that polarization diversity archives a gain performance comparable with the horizontal space diversity in urban and suburban environments. In this paper, discussion takes place on the distribution of 3D EMF radiated from a horizontally polarized BS transmitting antenna instead of two dimensional (horizontal and vertical) electromagnetic field distributions. The measurements were performed at The Antalya Gulf. Aim is to get RF planners' attention on how sea surface and mountain based reflections affect polarization diversity gain, and increasing their background and confidence about aforementioned subjects.

2. MEASUREMENT ENVIRONMENTS

The measurements were performed at the Antalya Gulf in 1800 MHz network. A Type-18 isotropic electric field probe compatible with NARDA SRM300 is preferred during the measurement. Aforementioned probe includes three mutually located perpendicular dipoles inside, and the head of each

Figure 1: Measurement path through shore side road.

Figure 2: Measurement path at hillside (Kemer intercity R).

dipoles connected to the basic unit through three channel switches and a coaxial cable. There are three high impedances fed by three sensor voltages down to the rod into the instrument to avoid distortion in the field. No measurement error is expected as a result of switching from one axis to the next, since the blind time is 20 milliseconds between switching one axis to the next. Given blind time is several orders of magnitude less than the blind time of classical spectrum analyzers.

An avoiding Rayleigh fading during measurements requires having enough samples over the wavelength, and thus a vehicle speed was kept as 30 km/h. Thus, results have a good correspondence on slow-moving equipment [7]. BSS transmitting antenna tower height is 30 m. The first measurement set was conducted in a cell which is serving a road next to shore demonstrated in Fig. 1. The second measurement set was conducted in a cell which is serving a part Antalya-Kemer road. It is also assumed as Hill Side road that south of road is Antalya Gulf (Calticak Bay) and north side is 1000 m height Taurus Mountains. Driving area is illuminated from the other side of bay which is shown in Fig. 2. Illumination angle of transmitting antenna is 30 degree in order to overcome escaping signals to the city of Antalya.

3. EXPERIMENTAL RESULTS

The signal mean level difference between 3D polarized components specifies the value of XPD. The propagation environment has an influence on the calculated XPD, and thus, the area-type description is important [8]. XPD can be approximated as in Eq. (1a), Eq. (1b) and Eq. (1c). Cross polarization discrimination values are relative to one another, and given in Table 1.

$$\mathrm{XPD}_{xy} = 20\log\left(\frac{E_x}{E_y}\right) \tag{1a}$$

$$\mathrm{XPD}_{xz} = 20\log\left(\frac{E_x}{E_z}\right) \tag{1b}$$

$$\mathrm{XPD}_{yz} = 20\log\left(\frac{E_y}{E_z}\right) \tag{1c}$$

An average XPD values and standard deviation are presented in Table 1. Through shore side road average XPD value is about 23 dB which extremely high than expected values, and 4.69 dB through hillside road is also important value for solving communication problems. Fig. 3 and Fig. 4 both plot relative gain value variation with respect to distance from transmitting antenna. As represented in Fig. 3, relative gain varies between 0–30 dB and there is about 25 dB relative gain on the average. Compared to Fig. 3, Fig. 4 represents that relative gain at hill side road varies between 0–10 dB and relative gain average obtained at hill side is about 10 dB. Relative gain plots both at shore road and hillside road has their own fading-like values.

Table 1: Environment dependent XPD values.

Propagation Environments	**Calculated Average XPD Values (dB)**	**Standard Deviation**
Shore Through Road	23.16	6.19
Hillside	4.69	2.72

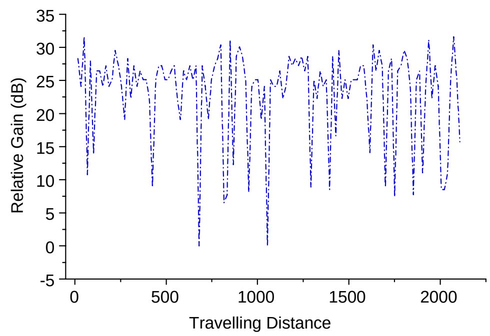

Figure 3: Relative gain through shore road.

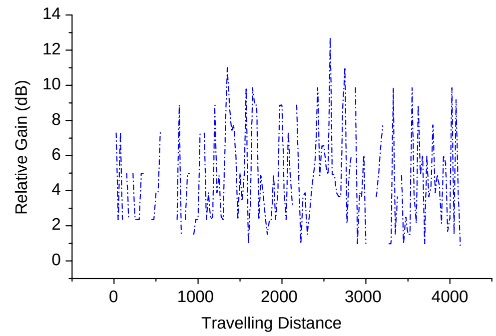

Figure 4: Relative gain through hillside intercity road.

4. CONCLUSIONS

The relationship between XPD assumed as 3D polarization diversity gain at 1800 MHz has been investigated. The results show that the lowest XPD is obtained for hill side road area, and very high signal cross-correlation is achieved through shore road. Since antennas are generally preferred to be placed below rooftops in dense urban area, multiple wall reflections [10–12] are occurred. As a result, propagated waves are strongly affected by street structures wall reflectivity, and diffraction at the vertical edges of street corners. Obtained XPD from such an environment depicts that 3 dimensional antennas may allow to obtain better diversity gain and resolves quality problems especially in such kind of shore area/shore roads. Thus, cross polarization discrimination gain depends mostly on the signal mean difference between two receiver branches, and it offers a good choice for radio frequency design engineers by not requiring additional space between two antennas and extra bandwidth [13]. 30 dB relative XPD/gain on the average can be achieved by suitable antenna design.

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