Optimizing Small Wideband Antenna Performance for Both RIMP and Random-LOS

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Optimizing Small Wideband Antenna Performance for Both RIMP and Random-LOS

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***Abstract*—Rich Isotropic Multipath (RIMP) environment like reverberation chamber (RC) has proven to be useful for characterizing mobile LTE devices. The user statistics have larger effect in environments with stronger Line-Of-Sight (LOS), because the angle of arrival (AoA) and the polarization of the LOS contribution become randomized due to the user. Thus, we introduce the term Random-LOS. The present paper elaborates on characterization of an example antenna in both RIMP and random-LOS. We show how to characterize the micro BTS by the probability of detection (PoD) of one and more bitstreams in both RIMP and random-LOS, by considering the user randomly located and oriented within the angular coverage sector. We limit the treatment to a wall-mounted BTS antenna, and assume a desired hemi-spherical coverage.**

***Index Terms*—antenna, propagation, measurement.**

I. INTRODUCTION

Thanks to MIMO (Multiple Input Multiple Output) technique [1] people nowadays are benefiting from much higher data rate. The present paper deals with the characterization of wideband micro base transceiver stations (BTS) in the 4G LTE systems and beyond. The micro BTSs are different from the traditional macro BTSs in the sense that they are located inside the multipath environment between buildings and even indoors, in contrast to traditional macro base stations. Thus the wireless environment of micro BTSs resembles that of wireless user-held terminals, except that the BTS antennas are in fixed locations rather than being arbitrarily distributed and oriented like the user terminals. Antennas in multipath environments are known to be better characterized by their total embedded element efficiencies [2] instead of antenna far-field functions.

The reverberation chamber (RC) [3] emulates a rich isotropic multipath (RIMP) if it is well designed. Its measurement procedures have the last years been extended to test throughput of LTE systems [4]. We have developed a theoretical model for the throughput based on the ideal digital threshold receiver [5]. The model plays an important role in the evaluation of the probability of detection (PoD) of bitstreams, which we will use as the quality metric for the designed BTS antenna. These models include the effects of antenna diversity and OFDM, and the algorithms for achieving multiple bit streams [6], [7], and the results agree with measurements on commercial LTE devices [5], [6] as well as using Software-Defined Radio (SDR) [7], [8].

The micro BTS and the user may even be located in the very same room or hall. This means that there may be a significant LOS contribution to the wireless channel between them. The LOS contribution will in a mobile wireless system be random due to the arbitrary orientation and location of the user, and it is therefore referred to as a random-LOS. It was proposed to introduce both the RIMP and the random-LOS as reference environments, referred to as limiting environments (or edge environments) [4]. The real-life environment is neither RIMP nor pure LOS, but something in between. Nevertheless, it is advantageous to have well defined reference environments, inside which one can get unique results from quality assessments. We assume a hypothesis that *"if a wireless device works well in both RIMP and random-LOS, it will also work well in real-life environment"*[9]. We will in the present paper characterize an example micro BTS antenna in these two edge environments.

II. RIMP AND RANDOM-LOS CHARACTERIZATION

The group error rate (GER) is known to go very abruptly from only errors (1) to no errors (0) for the additive white Gaussian noise (AWGN) channel case in digital communication systems, and therefore we defined an ideal threshold receiver in [5], as

$$GER_{ideal}(P_0) = \begin{cases} 1, & P_0 < P_t \\ 0, & P_0 > P_t \end{cases} \tag{1}$$

where P_0 is the received power in the AWGN channel, and P_t is the threshold value. The average throughput in a fading channel and the CDF of the power of the received channels voltages is related as

$$T_{put}(P_{av}) = T_{put,\max}(1 - CDF(P_t/P_{av})) \tag{2}$$

where $T_{put,\max}$ is the maximum achievable throughput, the *CDF* is the cumulative distribution function after the digital processing, and P_{av} is the average received power on the ideal reference antenna in the fading environment. The relative throughput becomes equal to the probability of detection (PoD), i.e.

$$PoD(P_{av}) = T_{put}(Pav)/T_{put,\max} = (1 - CDF(P_t/P_{av})) \tag{3}$$

In the present work, we provide an example of performance characterization in the RIMP and the LOS channels based on the self-grounded bowtie antenna shown in Fig.1 [10]. The Zero Forcing (ZF) multiplexing algorithm is assumed for the threshold receiver model. This bowtie antenna has a simple mechanical structure, and it works over wide bandwidth. We use it herein as a 4-port MIMO antenna working from 1.7 to 2.7 GHz.

We define the MIMO efficiency of the bowtie antenna as the degradation of the PoD in dBiid (i.e. in dB relative to the corresponding curve for the i.i.d. case based on Rayleigh-distributed channels) at 95% PoD level (i.e. the 5% CDF level) [11]. The result is calculated versus frequency and shown in Fig. 2, where M×N implies M ports of bowtie antennas and N bitstreams generated at N ports of a transmitting antenna. The latter antenna is assumed to be ideal with no correlation between the ports. We see that the 4-port bowtie antenna is good in detecting 2 bitstreams, but very bad for detecting 4 bitstreams. This is because a single 4-port bowtie antenna receives rank-3 MIMO channel in RIMP most of the time, especially at low frequencies.

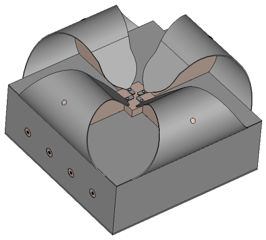

Fig. 1. Drawing of the bowtie antenna.

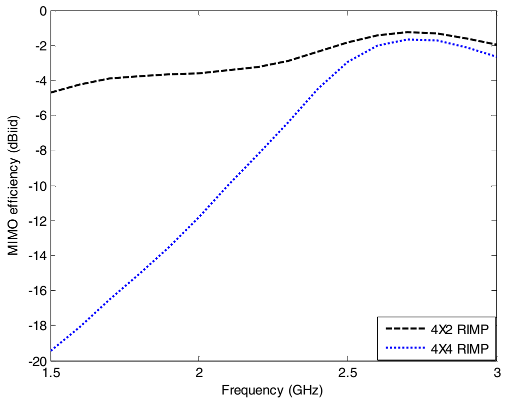

Fig. 2. 2- and 4-bitstream MIMO efficiencies in dBiid at 95% PoD for the 4-port bowtie antenna in RIMP as a function of frequency. The i.i.d. reference for the M×N bowtie configuration is the M×N MIMO system for the i.i.d. case, where M denotes the number of ports of the bowtie antenna and N denotes the number of bit streams.

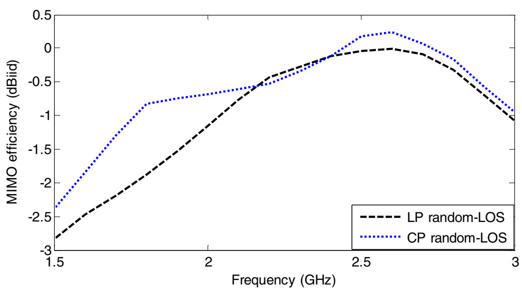

Fig. 3. MIMO 2-stream efficiency at 95% PoD of the 4-port bowtie antenna for the wall-mounted scenario in random-LOS over half-sphere.

For co-located antennas in random-LOS, the maximum number of bitstreams we can achieve is 2 by utilizing 2 orthogonal polarizations. Furthermore, we assume that the bowtie is wall-mounted, i.e., it covers half space, namely, the random-LOS waves impinging on it only comes from half of the space. Fig. 3 shows the corresponding MIMO efficiency of the bowtie antenna for detecting 2 bitstreams in random-LOS. We see that the curves for circularly-polarized (CP) incident waves are almost overlapping the curves for linearly-polarized (LP) incident waves, and that the 4×2 cases are up to 3 dB lower than the 4×2 i.i.d. cases, due to the correlations between the ports. This worst MIMO efficiency appears at the lowest frequency. It is much better at 2.6 GHz. Much more results are given in [11], including measured results.

III. CONCLUSIONS

In this work, we use the compact wideband 4-port bowtie antenna as an example to demonstrate antenna characterization in RIMP and random-LOS. We show how to characterize the antenna by the PoD of one and two bitstreams by considering the user randomly located and oriented within the angular coverage sector. It is clear that the performance of the example antenna could be better in terms of its MIMO efficiency performance, but taken into account its wide bandwidth and compactness we think it is difficult to achieve better performance. We are sure that the performance of such wideband antennas can be improved in the future when the characterization method has become more mature.

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