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Field Test Results and Analysis of A Semi-Automatic Effective Diversity Gain Measurement System for MIMO and Diversity Antennas

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Abstract – **An improved version of effective diversity gain (EDG) evaluation system is proposed for multiple-input multiple output (MIMO) and diversity antennas. By enhancing the sensitivity of the RF power detection module and increasing rejection of background noises, measurements can now be conducted in actual propagation environments. The control computer is replaced with a laptop to improve system mobility. A data acquisition card with a USB interface is also adopted so that the number of measurable antennas is virtually unlimited. Measurements of various setups are presented to discuss the pros and cons of the proposed system.**

Index Terms — **Multi-antenna system, diversity antennas, MIMO antennas, antenna diversity, propagation fast fading.**

1. Introduction

The use of multi-antenna system has been rapidly adopted for mobile communication. By means of antenna diversity, the fast fading issue can be resolved with the use of diversity antennas. The implementation of MIMO technique also requires supports from diversity antennas. Recent MIMO antenna implementations tend to increase the number of antenna used to support higher order MIMO schemes. Note, simply increase the number of antenna used does not guarantee proportional incensement in throughput. Certain degree of diversity, which can be spatial, polarization and pattern diversities, must exist to provide uncorrelated or not-so-correlated channels.

Various measures have been developed to assess antenna diversity among closely spaced antennas. The envelop correlation coefficient (ECC) defined in terms of S-parameters [1], which address couplings between two antennas, is the most fundamental and convenient method. However, S-parameters are affected by matching and radiation efficiency conditions. This metric is only valid for fully efficient antennas. The ECC can also be defined in terms of radiation patterns [2]. By acquiring patterns either from simulations or measurements, ECC values can be calculated via spherical integrations. Note, this alternative definition assumes an ideal Rayleigh propagation environment.

The effective diversity gain (EDG), as defined in [3], takes into account both the antenna characteristics and the propagation environment. It's therefore regarded as the ultimate metric for diversity performance evaluation. However, it can be a labor intensive task to actually record received signal strengths from antennas in an actual propagation space [4]. A semi-automatic EDG measurement system was hence devised to save the trouble [5]. Though successful measurements are demonstrated, the system suffers from sensitivity issues. As a result, measurements can only be conducted within shielded chambers, which makes it less convenient to use. Therefore, the goal is to improve the performance and capability of the existing measurement system.

2. Measurement System

The configuration of the proposed EDG evaluation system is adopted from [5]. As shown in Fig. 1, it contains a transmitting and a receiving end. The transmitting end comprises a signal generator and a transmitting antenna. The receiving end, which is developed in this work, contains multiple RF power detecting modules, a data acquisition card, and a control laptop. Antennas-to-be-tested and a reference dipole antenna are connected to RF power detection modules.

(1) Hardware

Unlike the original system in [5], major components of the measurement system are replaced with either more cost-effective ones or more compact models. For example, the RF power detector used in [5] are packaged coaxial components. Though they are easy to use, each detector cost more one hundred US dollars. In this work, detector modules were made with Linear Technology's LT5538 IC, which costs less than \$7 each. Furthermore, the reported sensitivity is as low as -75 dBm. Fig. 2 shows one of the fabricated RF power detecting modules.

(2) Software

Upgrade efforts were also spent on improving the user interface. Because the measurement process may take up to tens of minutes. Real time feedbacks from the controlling computer are critical. The operator can monitor statistics of data collected so far and decide if more samples are needed. Fig. 3 shows the user interface of the measurement system. The operator can setup the measurement and observe the collected data.

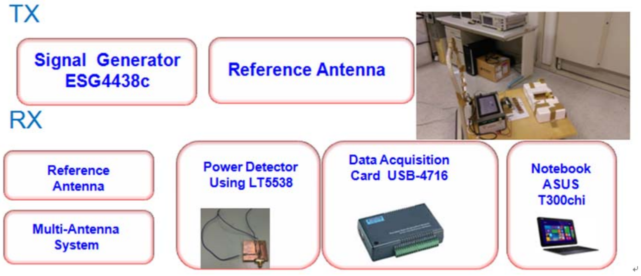


Fig. 1. Multi-antenna system EDG evaluation measurement system configuration

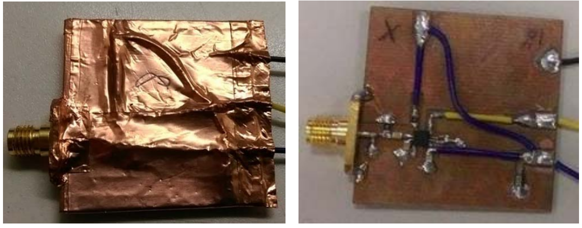


Fig. 2. Fabricated RF power detecting modules (LT5538) with and without copper foil shielding.

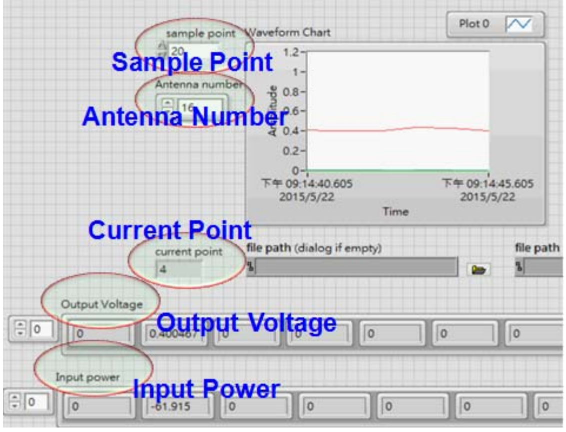


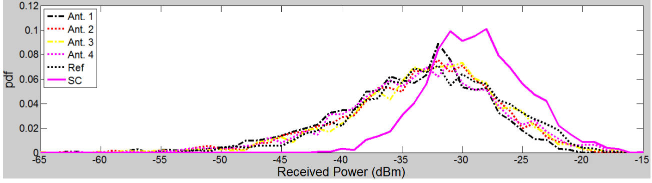
Fig. 3. User interface of the EDG evaluation system.

(3) Performance improvement

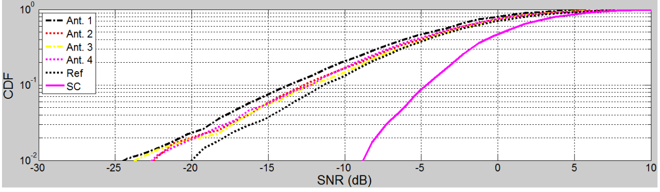
The major performance limiting issue about the original EDG evaluation system [5] is susceptibility toward background RF noises. Since the EDG measurement involve not only antennas but also the propagation environment, it's desirable to conduct measurements within actual environments such as corridors, classrooms and office cubicles. However, because the logarithmic RF power detector is a broadband device, it is subjected to background noise interference. Though the detector sensitivity used in [5] is supposed to detect signals as small as -60 dBm, by connecting the component with an antenna, the readout may be as high as -40 dBm without an apparent RF source nearby. As a result, EDG measurements can only be conducted within shielded chambers. Detector modules shown in Fig. 2 also suffer from the same problem. The cause is the circuit board of the module functions as an antenna by itself. To mitigate this problem, copper tapes are applied on the module to shield it from out-of-band noise. With the applied copper foil, the minimal reading can be as small as -65 dBm in ordinary meeting room without apparent RF sources, which permits EDG measurements without the shielded room.

3. Antenna Measurement Results

The four-antenna system proposed in [6] is used to validate the EDG measurement system performance. CDF curves of individual antennas and combined signals are similar to the ones in [6], which are taken in a shielded chamber. This verifies the improved system can perform EDG measurement in actual propagation environments. Fig. 4 shows both pdf and CDF of individual antennas. In the CDF plot, the reference antenna curve, which is shown in blue dash line, approaches the Rayleigh distribution. This suggest the propagation environment is rich in multipath. The solid magenta line, which is the CDF of combined signals from the four antennas, exhibit an 11 dB EDG.



(a) pdf,



(b) CDF

Fig. 4. Measured and combined pdf and CDF curves of a four-antenna system [6] in an ordinary propagation environment.

4. Conclusion

We demonstrate that the revised EDG evaluation system can be used to perform EDG measurements in ordinary propagation environments. The improved system is easier to operate, more compact, and cost less.

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