Design and evaluation of antennas for communications with diversity and MIMO

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Introduction

This tutorial addresses the design and evaluation of antennas for communications. The gain of antenna has a direct impact on the link performance including the spectral efficiency. The classical directive gain and its measurement are reviewed with the natural progression to the distributed gain and the diversity gain for antennas designed for multipath situations. With most links operating in multipath, multi-element antennas with high distributed gain and good diversity performance are required. Developing compact multi-element antennas with statistical performance measures requires convenient experimental evaluation techniques.

Summary

To set the scene a review is provided of the role of the antenna in the spectral efficiency in wireless links. In general, the capacity efficiency is a statistical measure and antenna performance follows as a statistical measure as well. Antenna performance evaluation is not only part of the communications system analysis and design, but it is also part of the iterative process of compact antenna design. Consequently, convenient evaluation techniques are important to the antenna design. Both theoretical and practical aspects are addressed here for evaluating antennas for high capacity efficiency . This calls for an emphasis on the various efficiency and gain factors which feature in the multipath communications link analysis. Here, the antenna polarization efficiency becomes incorporated into the distributed gain of the antenna element and is a major difference between classical line-of sight links and diversity links for multipath.

The compactness of an antenna system is important for both the cost of the terminal and its market acceptability. The trade-off between impedance bandwidth and antenna compactness offers a helpful comparison for different types of antenna elements. For evaluating multi-element antennas for multipath environments, the diversity gain offers a robust performance measure. However, the diversity gain is a statistical quantity and to produce a direct estimate of it requires a considerable measurement campaign with considerable signal processing. Moreover, the diversity gain does not provide the specific information for how to improve the configuration of the antenna elements. The required information is the set of mean branch powers and in particular the set of correlation coefficients between the loaded antenna signals. Direct estimates of these statistics would be made from sampling the antenna signals when the antenna is operating in different multipath scenarios. However, gathering and using such samples brings difficulties in the interpretation and repeatability, and the sample size required for accurate estimates is large which means a large measurement effort. These factors highlight a need for a more convenient evaluation technique, especially for the antenna design process, which is normally iterative for getting the impedance and pattern finalized. Measuring the antenna impedances, together with modest off-line signal processing, offers such an alternative, although this approach requires certain conditions regarding both the propagation environment and the antenna elements. If these conditions hold, then the diversity gain can be estimated from the impedance measurement. For designing multi-element antenna configurations, the diversity gain can be couched as an equivalent number of ideal branches, i.e., an effective diversity order. The effective diversity order is a performance metric which is suitable for the

designer to trade-off against compactness of the multi-element antenna configuration. This is illustrated through the use of design examples in which the antenna is made sufficiently compact to force the effective order of diversity to be significantly reduced from the physical number of ports.