Degrees of Freedom in Linear Array Systems with Traveling Wave Polarized Antennas

G. Gupta, A. Rajagopalan, B. L. Hughes, and G. Lazzi
Department of Electrical and Computer Engineering, North Carolina State University, Raleigh, NC 27695-7914, USA

Multiple Input Multiple Output (MIMO) antenna systems have received considerable interest due to their ability to support increased channel capacity in rich multi-path scattering environment. Recently it was proposed that the use of tri-polarized antennas can lead to a potentially three-fold increase in capacity (M. R. Andrews, Nature, 409, 316-318, Jan, 2001). These tri-polarized antennas consist of multiple co-located elements which respond to different components of the incident electromagnetic field and can be employed to achieve the same effect as that of traditional MIMO systems which have spatially separated antennas.

Linear array antennas are very versatile and find a variety of applications in beamforming and direction-of-arrival estimation. On the other hand, traveling wave antennas provide a broad-band response. In this paper, we study the benefits that tri-polarized traveling wave antennas can provide when used in linear array configuration. First, a general expression is derived for the electric-field generated by a linear array of tri-polarized traveling wave antennas in the far-field region. Then we introduce the concept of degrees of freedom and develop the tools which are used to analyze traveling wave antennas. We show that under certain conditions tri-polarized traveling wave antennas can offer a three-fold increase in the degrees of freedom when used in linear arrays as compared to an equivalent array of uni-polarized antennas only. This increase in the degrees of freedom implies the existence of three orthogonal channels under suitable scattering conditions which can be exploited to potentially lead to a three-fold increase in capacity at high signal-to-noise (SNR) ratio.