Investigation of the Performance of Co-polarized, Co-located Electric and Magnetic Dipoles for Increasing Channel Capacity

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1 Introduction

Employing co-located antennas with elements which respond to more than one polarization has been proposed recently [1] as a means of increasing channel capacity in a richly scattering environment. In this situation, capacity can be increased in principle by up to N times by the use of N transmitting and N receiving antennas in a richly scattering environment [2]. In fact, when a plane wave from a transmitter encounters a scatterer in the far field, the subsequent scattering may introduce new components into the wave. The presence of a large number of scatterers may lead to a decrease in the correlation between corresponding electric and magnetic field components. It has been asserted [1] that by considering their covariance at a point, all six components of the electromagnetic field can be interpreted to vary independently and no vector component can be predicted from any other. Thus, if an antenna system which responds to all the six orthogonal field components (three electric and three magnetic) can be constructed, then more independent channels can be generated in the same frequency band leading to a capacity increase. Such an antenna could ideally be realized by means of three magnetic dipoles (loops–which respond to the magnetic field components) and three electric dipoles (which would respond to the electric field components).

Investigations of the performance of three orthogonal dipoles [1] and also an antenna system comprising of a loop and a dipole [3] have been reported. Also, antennas which respond to all six elements [4] have been investigated though they are large in size and are of a non-planar configuration. In this work, antenna systems consisting of co-located and co-polarized magnetic and electric dipoles (one loop and two orthogonal dipoles) arranged in a planar, stacked configuration is presented. While different configurations have been realized at different frequencies ranging between 1 and 2.5 GHz, in this paper we present an antenna system that operates at 2.1 GHz and is fabricated on a 9×9 cm substrate. At the operating frequency, the loop circumference and the dipole length are each a wavelength long. A center probe fed loop and slightly off-center probe fed dipoles constitute the elements of the system. Current results of their impedance matching characteristics and mutual coupling performances are presented.

2 Antenna Design

An electrically small loop, oriented in the xy plane has a radiation pattern of a magnetic dipole which is complementary to that of an electric dipole placed along the z axis. Such a loop responds predominantly to the E_ϕ component while a z axis dipole responds to the E_θ component of the electric field. In such an orientation, the electric and magnetic dipoles radiate cross polarized waves and are effectively decoupled and can act as a dual polarized

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radiating system. However, the purpose of this study was to investigate the mutual coupling performances of co-located and co-polarized electric and magnetic dipoles. Hence, an antenna system was designed with a loop (magnetic dipole) in the xy plane and two mutually orthogonal dipoles stacked on top of the loop (also in the xy plane). In this antenna system, each dipole is co-polarized with the loop however, they are not exactly co-located since slightly off-center feeding was used for each dipole. Both the loop and the dipoles were designed to operate at around 2.1 GHz.

2.1 Loop Design

It is well understood [5] that an electrically small loop or loop with a constant current distribution retains the radiation characteristics of a magnetic dipole. In this work, the loop was 2 mm thick and its circumference was almost a wavelength long ($C \sim \lambda$) at 2.1 GHz. A constant current distribution was achieved by breaking the loop into four sectors and feeding each of them. The loop was fed by a coaxial probe from the center and each of the four sectors was connected to the center by a pair of feed-lines drawn out from the center to the circumference. This arrangement ensured that the currents were directed in opposite directions along adjacent feed-lines, thus effectively nullifying any spurious radiation [6]. The four sectors for the loop and their feed-lines were realized on the top surface of a substrate. Impedance matching was achieved by a combination of varying the thickness of feed-lines and by the introduction of a small ground plane on the bottom surface of the substrate.

2.2 Dipole Design

The dipole lengths were restricted to a wavelength ($L \sim \lambda$) to retain the radiation characteristics of a small electric dipole. Both the dipoles were printed on separate pieces of substrate and stacked mutually orthogonally (on top of each other), and this dipole configuration was stacked on top of the loop. Since the loop was fed in the center, the dipoles were fed slightly off center using coaxial probes. Each of the two dipoles was 2 mm thick with an offset of 12 mm (0.08λ) between the feed point and the center of the antenna system. Since the two dipoles are stacked on top of each other, they will be referred to as dipole (top) and dipole (bottom) for the rest of the paper.

3 Results

This composite antenna structure comprising of co-located and co-polarized loop and dipoles was measured for mutual coupling performance using a HP 8510C Network Analyzer calibrated in the 2 to 2.6 GHz frequency range. Scattering parameters were measured for each of the two ports of the three port network with the third port terminated in a matched load. Figures 1, 2 and 3 show the current antenna system's individual elements' return losses and mutual coupling characteristics. They show good return losses for each of the elements and good isolation between the co-polarized elements.

4 Conclusion

An antenna system comprising of co-located and co-polarized magnetic dipole (loop) and electric dipoles has been implemented in a planar stacked configuration. All the three elements of the antenna system show good return loss and coupling between co-polarized elements is observed to be less than -10 dB. The feasibility of employing such a system to realize more information channels in the same frequency band has been demonstrated. It is expected that future work on the design aspect of the antenna elements will lead to improvement in the coupling performance of the co-polarized elements. Also, means of implementing another orthogonal loop will be explored with the eventual aim of realizing the six element structure using printed loops and dipoles.

5 Acknowledgement

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References

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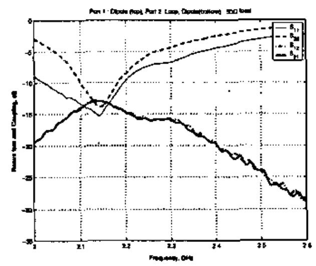

Figure 1: Measured scattering parameters for dipole (top) and loop

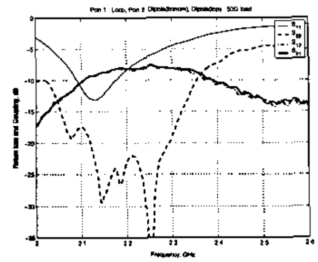

Figure 2: Measured scattering parameters for dipole (bottom) and loop

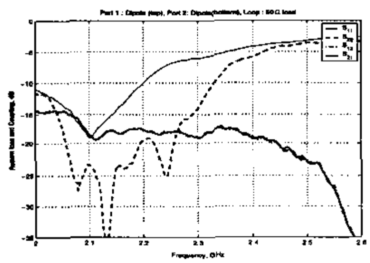

Figure 3: Measured scattering parameters for dipole (top) and dipole (bottom)