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Wideband Directional Base-Station Antenna with Dual-linear and Circular-Polarization Capabilities

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A crossed-dipole antenna providing polarization diversity is presented. The antenna which employs a planar reflector yields high directivity and good isolation between ports over a wide impedance bandwidth, suitable for polarization-agile wireless base-station use. The dipole wing shape is optimised, which yields the wide bandwidth. Matching is achieved using a quarter-wave balanced-to-unbalanced section which also improves the port-to-port isolation. Radiation characteristics for linear and circular polarizations are presented.

I INTRODUCTION

The continued growth in wireless communication systems is increasing the demand for low-cost microwave components and antennas. The crossed-dipole antenna, printed on low-cost FR4 substrates is often used as radiating elements for network-point and base-station and antennas [1-4]. In this paper a printed crossed-dipole antenna operating in the 2.45GHz wireless and ISM (industrial, scientific and medical) band is presented experimentally. The polarization diversity is obtained due to the spatial orthogonality of the two printed dipole antennas. A quarter wave balanced-to-unbalanced resonant line section is used for matching and to improve both the the impedance bandwidth and the isolation between orthogonal elements of the dipole. The antenna is fed using microstrip feedlines, which are placed normal to the dipole wing. The two isolated feed ports can then be excited in various ways to launch linear polarizations with $\pm 45^\circ$ tilt or circular polarizations with right-hand or left-hand sense.

II ANTENNA STRUCTURE

The proposed wing shape of the dipole reduces the shunt capacitance at the gap. The impedance of short thick dipoles is smaller than that of thin dipoles with the same overall dimensions [5]. By using Schelkunoff's method [6], it is known, that for a

cylindrical dipole, a broader impedance bandwidth can be obtained by increasing the diameter. This also applies to planar structures [7]. The antenna is fabricated on a circular piece of FR4 laminate of 1mm thickness and radius $r=30$ mm. The relative permittivity is 4.3 in this frequency range. The dipole wing length $l = 17$ mm, the gap between dipole wings $g = 6$ mm. The maximum width of the wing $w= 12$ mm, which occurs at a distance $l_2 = 6.3$ mm from the end of the wing, as shown in Figure 1.

Figure 1. Dimensional layout for the printed crossed-dipole antenna

A parasitic planar reflector (70mm x 70mm x 1mm) is centrally mounted at the base of the structure and placed at a distance of $\lambda_0/4$ from dipoles. The quarterwave balanced-to unbalanced (balun) transformer was chosen for the feed system. The dipole is fed using two vertical elements connecting each dipole with the ground plane. Each vertical element comprises a shorting strip and an impedance transformer realized by employing a tapered microstrip line. The microstrip ground is connected to one of the dipole wings and the feed is connected to the opposite wing via a bridge as shown in Figure 2. The balun is based on the well-known resonant line section terminated by short circuit. Its double purpose is to transform the unbalanced current distribution of the input transmission line into the balanced one of the dipole while an impedance match is also provided.

Figure 2. Dipole feed arrangement and coordinate system.

III NUMERICAL ANALYSIS

The finite integration time-domain technique using CST Microwave Studio was used to simulate the structure. The influence of the relative permittivity of the dielectric substrate on the dipole resonant frequency was investigated. It can be seen from Figure 3, that at 2.45 GHz, the overall dipole length is reduced from 49 mm in free-space to 41 mm when printed on 1 mm thick FR4 (standard PCB material) substrate ($\epsilon_r=4.3$) which has a loss tangent of 0.2. This is based on simulation for a straight dipole wing of width 6 mm. The dielectric effect increases the electrical length. It also reduces the bandwidth of the dipole as shown in Figure 4. It can be seen that maximum bandwidth is achieved in

free-space. The bandwidth achievable when printed on a laminate of relative permittivity 4.3 is 370 MHz, according to simulated results. This is somewhat less than the free-space value, but the reduced size is necessary.

Figure 3. Simulated dipole length plotted against resonant frequency for different values of relative permittivity of the PCB on which the dipole is fabricated.

The proposed optimised wing shape also yields a shorter overall length of 39 mm. The wing shape combines the features of thick dipoles and biconical dipoles, which exhibit a broad bandwidth and a low profile.

Figure 4. The effect of printing the dipole on dielectric laminate is plotted against impedance bandwidth, for different values of relative permittivity.

IV MEASUREMENTS

Impedance and isolation

In order to achieve dual linear polarization or circular polarization, it is necessary to have 2 dipoles oriented orthogonally. In this case, the crossed dipoles structure is used, and a quadrature phase arrangement can be used to achieve circular polarization and two independent feeds used for dual linear polarization. When using cross-polarized dipoles, the isolation between dipole ports is a difficult and very important parameter to achieve. Generally, a 20 dB isolation between ports is necessary for polarization diversity. Otherwise, problems with pattern squint and crosstalk can arise. Optimizations and trade-offs were made in order to get a good compromise between return loss and isolation. It can be seen in Figure 5 that the measured 10dB return loss (S11 and S22) is achieved from about 2.25 GHz to 2.7 GHz, yielding an impedance bandwidth of greater than 450 MHz (more than 18% fractional impedance bandwidth) for both ports. The measured isolation (S12 and S21) is better than 20dB for most of the bandwidth, i.e. from 2.35 GHz to 2.55 GHz. This includes the wireless ISM band (2.40 to 2.488 GHz).

Figure 5. Measured impedance bandwidth and isolation between ports for the crossed dipole antenna.

Radiation characteristics

The radiation patterns were measured in an anechoic chamber at 2.45 GHz for both polarizations. Figure 7 shows the measured pattern for the xy plane, while the yz plane is shown in Figure 8. These may be configured in the ± 45 degree planes, instead of vertical/horizontal which would provide propagation advantages in flat regions. The linear cross-polarization rejection levels are better than 20 dB on

boresight and the front-to-back ratios are in excess of 20 dB for both planes. A larger groundplane would improve this, if necessary. The patterns are normalised to maximum measured gain, which was 6.5 dBi for both polarizations. A 10 dB per division scale is used. The gain was measured with a calibrated pyramidal horn antenna.

Figure 6. Photograph of the printed wideband crossed dipole antenna with planar reflector.

Figure 7. Normalised radiation pattern for the xy plane (10 dB per division)

Circular polarisation is achieved by exciting each dipole port with equal magnitude, but with a phase difference of ± 90 degrees, depending on whether right-hand circular polarization (RHCP) or left-hand circular-polarization (LHCP) is required.

Figure 8. Normalised radiation pattern for the xz plane (10 dB per division)

Figure 9. The measured axial-ratio is less than 4 dB from 2.4 GHz to 2.63 GHz.

A spinning dipole is often used to examine the axial-ratio performance for circularly-polarized antennas. The spinning dipole was excited by one port of the Rohde & Schwarz ZVA24 vector network analyser and port two is connected to the antenna. The analyser is frequency swept and the antenna response is shown in Figure 9. It can be seen that the axial ratio (S21, in this case) is less than 4 dB from 2.4 GHz to 2.63 GHz. The spinning dipole pattern is shown in Figure 9. The axial ratio is less than 3 dB over a beamwidth greater than 130 degrees.

V CONCLUSIONS

A wide bandwidth for a printed crossed-dipole has been achieved by optimising wing geometry, without significant degradation of port-to-port isolation, crosspolar performance, gain or circular-polarization performance. The antenna has a gain of 6.5 dBi, a front-to-back ratio of 20 dB, over the frequency range of 2.2GHz to 2.7 GHz, for linear

polarizations. The antenna produced circularly-polarized waves with an axial ratio less than 4 dB, from 2.4 GHz to 2.63 GHz as shown in Figure 8. The measured port-to-port isolation is greater than 20 dB over this range. Figure 10 illustrated the spinning dipole pattern taken at 2.53 GHz.

Figure 10. The measured axial-ratio is less than 3 dB over a beamwidth greater than 130 degrees. (scale dB)

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