A 4 Element Compact Ultra-Wideband MIMO Antenna Array

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***Abstract*—In this paper, a compact planar Ultra-Wideband (UWB) antenna array with 4 monopole radiators is presented. To enhance the isolation, polarization of nearly placed elements is exploited. The proposed MIMO antenna array is electrically small $50 \times 39.8\ \mathrm{mm}^2$, printed on a low loss 1.524 mm thick Rogers TMM4 laminate with a dielectric constant of 4.5 and a loss tangent of 0.002. Simulation in HFSS and printed prototype results satisfy the return loss requirement of better than 10 dB and isolation better than 17 dB on the entire 2.5 to 12 GHz bandwidth. The calculated envelope correlation value of less than 0.03 and the compactness of the proposed antenna array makes it suitable for small portable handheld devices.**

I. Introduction

Multiple-Input Multiple-Output (MIMO) systems increase channel capacity allowing several users to access the various services at the same time. The Ultra-wideband technology in combination with MIMO techniques has proven to be a solution for the limitation of short range communications, which requires devices to transmit extremely low power. In such a system, the antennas are designed to ensure that the mutual coupling among their elements should be less than -15 dB. This can be achieved by placing the elements at least half a wavelength apart from each other; however this leads to an increase in the dimensions of MIMO antennas. Various techniques have been used to reduce the mutual coupling between the antenna elements while maintaining their small electrical lengths. Various stubs have been introduced on the ground plane to satisfy the bandwidth from 3 to 10.2 GHz as reported in[1]-[2]. In [3], parasitic elements are used to improve the isolation of a 2×2 UWB-MIMO antenna system but all these antennas have only two elements. However, a compact 4×4 MIMO-UWB antenna with WLAN notched characteristics using EBG structure is presented in [4] but has an overall size of $60 \times 60\ mm^2$. Another work in [5], presents a 4×4 MIMO antenna by introducing the discontinuities between the ground plane and antenna elements. Although the system shows better isolation but the size of a single element is $50 \times 52\ mm^2$ and it only works over the frequency range of 2 to 6 GHz.

In this paper a compact planar UWB-MIMO antenna with 4 elements, as shown in Fig. 1, is presented. An isolation of better than 17 dB over the wide band from 2.5 to 12 GHz is achieved by exploiting the polarization of nearly placed antennas. The proposed design has a smaller size than the MIMO antennas presented in [4]-[5].

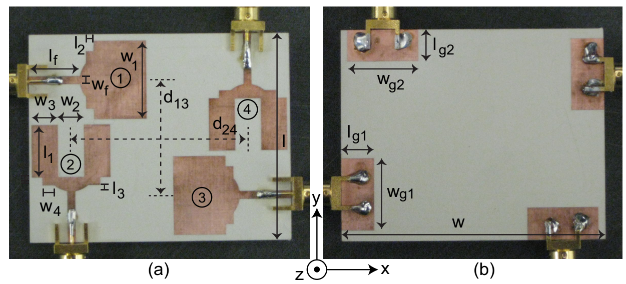

Fig. 1. Fabricated layout of the proposed antenna. (a) Top view, (b) Bottom view. Optimized dimensions in mm are: $w = 50$, $l = 39.8$, $w_1 = 15$, $w_2 = 4$, $w_3 = 5.5$, $w_4 = 2.26$, $l_1 = 10$, $l_2 = 1.5$, $l_3 = 1.1$, $w_f = 1.6$, $l_f = 9.85$, $w_{g1} = w_{g2} = 13.5$, $l_{g1} = l_{g2} = 6.25$, $d_{13} = 22.3$, $d_{24} = 33.95$.

II. Antenna Design

The printed layout of the proposed antenna array is presented in Fig. 1 along with the dimensions. Initially a monopole was designed with a partial ground plane. A step feed line was connected to the radiator to improve the wideband characteristics. Later on a second monopole was placed perpendicularly near to the first element. High isolation among the elements was observed due to polarization diversity but in radiator 2 there occurred a slight mismatch. A u-shaped slot was inserted in radiator 2 to rectify the mismatch and improve the wideband matching characteristics [6]. A separate partial ground plane was chosen for each radiator because it plays an important role in matching and also provides better isolation [7]. Similarly a mirror copy of radiators 1 and 2 was placed such that the centre to centre distance "d_{13}" between radiator 1 and its mirror copy remains 22.3 mm and radiator 2 and its mirror copy "d_{24}" remains 33.95 mm.

III. Experimental Validation

The prototype in Fig. 1 was fabricated on a Rogers TMM4 laminate (thickness 1.524 mm, dielectric constant 4.5 and loss tangent 0.002) and characterised in an anechoic chamber using a two-port Agilent N5230A PNA-L network analyser.

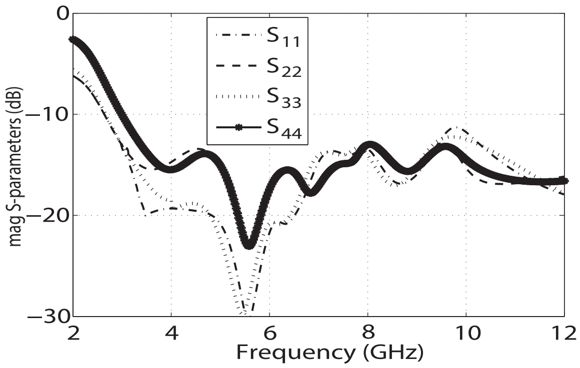

Fig. 2. Measured reflection coefficient.

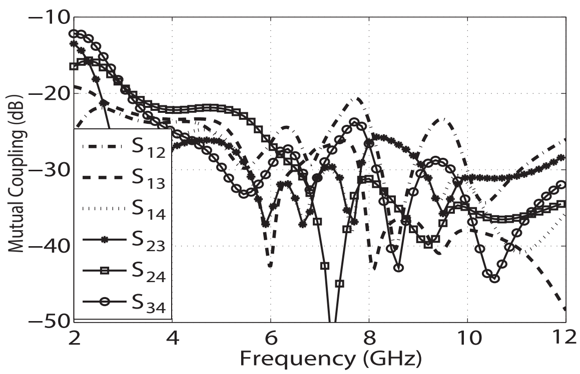

Fig. 3. Measured mutual coupling.

The measured scattering parameters of the proposed MIMO antenna are plotted in Fig. 2. The measured results show that the proposed antenna is well matched over the wide range from 2.5 to 12 GHz. Due to symmetry, $|S_{11}|$ should be identical to $|S_{33}|$ and $|S_{22}|$ should be identical to $|S_{44}|$, but there is a slight mismatch due to fabrication imperfection, soldering and connector losses. In Fig. 3 mutual coupling is plotted, and it can be seen that all the elements have very low mutual coupling (below -17 dB) amongst each other. Taking Fig. 1 as a reference for the co-ordinate system, antenna elements 1 and 3 are polarized along the x-axis, while elements 2 and 4 are polarized along the y-axis. Since the port to port distances for elements 1 to 3 and 2 to 4 are large, the coupling among these elements is very low. On the other hand, mutual coupling is very low among the elements 1 and 2 because each of these elements is polarized perpendicularly to each other.

Since the proposed antenna is for MIMO applications , it must be characterized for the diversity performance. Diversity performance of an antenna system can be evaluated by using the envelope correlation coefficient (ρ_e), according to [5]:

$$\rho_e(i,j,N) = \frac{|\sum_{n=1}^{N} S_{i,n}^{*} S_{n,j}|^2}{\prod_{k=(i,j)}[1-\sum_{n=1}^{N} S_{i,n}^{*} S_{n,k}]}. \quad (1)$$

Using (1), the envelope correlation between the antenna elements i and j in the (N,N) MIMO system can be calculated.

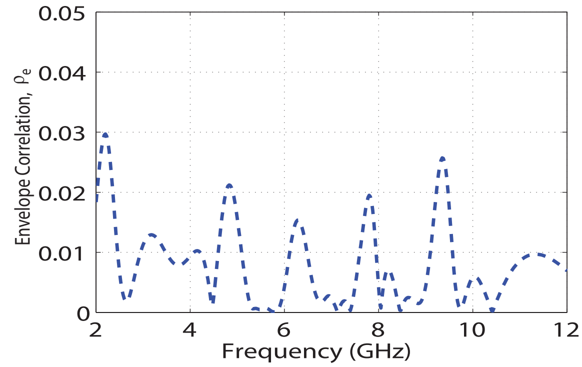

Fig. 4. Envelope correlation coefficient computed from measured S-parameters.

In the case of i = 1, j = 2, and N = 4, the envelope correlation of the proposed MIMO antenna is computed and shown in Fig. 4. The computed value of ECC for the proposed MIMO antenna from measured S-parameters is below 0.03 across the entire bandwidth as shown in Fig. 4. The correlation value of the proposed antenna system is very low, which supports good diversity performance over the entire bandwidth.

IV. Conclusion

A compact planar UWB-MIMO antenna array with 4 radiating elements is presented. The proposed antenna array measures only ($50 \times 39.8\ mm^2$). Mutual coupling is reduced by exploiting the polarization diversity of nearly placed antennas. The prototype is printed on TMM4 and satisfies the return loss requirement of better than 10 dB and isolation better than 17 dB on the entire 2.5 to 12 GHz bandwidth. The compactness of the proposed antenna array and low ECC value makes it suitable for small portable devices.

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