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Full Length Article

Design of microstrip-fed printed UWB diversity antenna with tee crossed shaped structure

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ABSTRACT

A compact, Ultra Wideband (UWB) antenna system for multi-input multi-output (MIMO)/diversity application is proposed. The antenna system is a microstrip structure with two similar triangular shaped radiating elements and a common ground plane. The radiating elements are excited by tapered feed for better impedance matching. A T-crossed shaped stub is added in the ground plane to increase the isolation between the two radiators. The overall dimension of the proposed antenna system is 46 mm × 32.6 mm × 1.6 mm. The measured impedance bandwidth (reflection coefficient < −10 dB) is from 1.8 GHz to well beyond 12 GHz which covers the entire UWB region. A measured isolation of 15 dB or better is achieved in the UWB region. The diversity gain of the antenna system is close to 10 dBi and the envelope correlation coefficient is well below 0.2 in the operating band. Parametric study is also done to check the sensitivity of the antenna in terms of reflection coefficient and isolation to the different parameters. These characteristics show that the proposed antenna is suitable for the MIMO/diversity application.

1. Introduction

Recently, a lot of efforts have been devoted to the emerging technology of Ultra Wideband due to advantages such as high data transfer rate, low power consumption, low cost and high capacity. The Federal Communications Commission (FCC) has authorised the unlicensed use of the 3.1–10.6 GHz spectrum for UWB applications [1]. Channel fading caused by multi-path environments is the main problem in a wireless communication system. Antenna diversity is an effective technique to mitigate channel fading and enhance transmission quality. Combining multiple antennas to achieve Multiple-Input Multiple-Output (MIMO) using UWB is a good way to achieve high data rate of about 1 GB/s. This technique takes the advantage of using multiple antennas at the transmitter and receiver terminal. A significant improvement in the wireless link can be achieved using spatial polarisation and pattern diversity techniques. The performance of the MIMO system depends on various parameters such as number of antenna elements, antenna geometry and spacing between these elements.

In the past many MIMO/diversity antenna systems have been designed and reported [2–10]. In [2], two symmetric antennas are placed side by side with the overall dimension of 35 mm × 40 mm. This structure has impedance bandwidth from 3.1 GHz to 10.6 GHz using the treelike structure. The isolation is 16 dB within the operating band. In [3], a UWB MIMO antenna using asymmetric coplanar fed structure is proposed. The antenna with overall size of 43.5 × 43.5 mm^2 consists of stepped rectangular patch. The fence-type structure improves the operating bandwidth from 3.1 to 10.6 GHz and the isolation is found to be more than 15 dB. In [4], a diversity antenna system of dimension 62 mm × 45 mm is proposed. The system consists of two square monopole antennas with working band of 3.3–10.4 GHz. A T-shaped stub is employed to get the isolation better than 18 dB. The antenna in [5] shows the pattern diversity and polarisation diversity and covers the lower UWB of 3.1–5.15 GHz. The isolation for this diversity antenna is better than 26 dB. In [6], antenna system for pattern diversity is proposed having dimension of 80 mm × 80 mm. The antenna system has impedance bandwidth from 3 GHz to 12 GHz. To achieve the isolation better than 15 dB slant shorts are placed. In [7], antenna system for polarisation diversity is proposed having dimension of 48 mm × 48 mm. The antenna system has impedance bandwidth from 2.3 GHz to 11 GHz and isolation better than 15 dB in the operating band. A MIMO antenna in [8] is proposed having

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Table 1
Comparison of reported antennas with proposed antenna, λ_0: Wavelength at lowest operating frequency.

Sr. No.	Ref. No.	Electrical size (λ_0)	Bandwidth (GHz)	Isolation (dB)
1	[2]	$0.36\lambda_0 \times 0.41\lambda_0$	3.1–10.6	16
2	[3]	$0.45\lambda_0 \times 0.45\lambda_0$	3.1–10.6	15
3	[4]	$0.68\lambda_0 \times 0.5\lambda_0$	3.3–10.4	18
4	[5]	$0.26\lambda_0 \times 0.41\lambda_0$	3.1–5.15	26
5	[6]	$0.8\lambda_0 \times 0.8\lambda_0$	3.0–12	15
6	[7]	$0.37\lambda_0 \times 0.37\lambda_0$	2.3–11	15
7	[8]	$0.21\lambda_0 \times 0.39\lambda_0$	3.1–10.6	15
8	[9]	$0.37\lambda_0 \times 0.88\lambda_0$	2.3–7.7	20
9	[10]	$0.43\lambda_0 \times 0.73\lambda_0$	3.2–10.6	15
Proposed		$0.29\lambda_0 \times 0.21\lambda_0$	1.9 – 16.7	15
Modified		$0.29\lambda_0 \times 0.21\lambda_0$	1.9 – 16.7	20

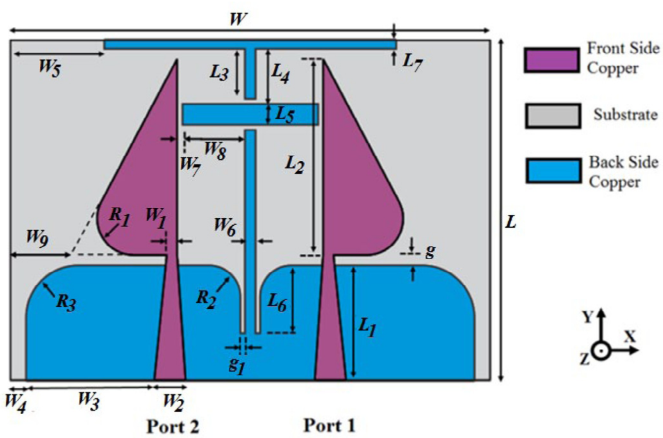

Fig. 1. Diagram of antenna geometry.

dimension of 21 mm × 38 mm. The antenna consists of two quasi self complementary monopoles having a T-shaped ground plane. The impedance bandwidth of the antenna system is from 3.1 GHz to 10.6 GHz. Isolation of better than 15 dB in the operating band is achieved by placing two slots in the ground plane. A spatial diversity antenna having dimension of 48 mm × 115 mm is proposed in [9] by placing two monopoles orthogonally. The antenna operates between 2.3 GHz and 7.7 GHz with isolation better than 20 dB. In [10], a 40 mm × 68 mm antenna system for MIMO application is designed. The antenna system has impedance bandwidth from 3.2 GHz to 10.6 GHz. The isolation of better than 15 dB is achieved by using Y-shaped stub. Most of the above discussed antennas have relatively larger size and also do not cover the lower Frequencies.

In this paper, a MIMO antenna system of compact size is designed and experimentally validated. The impedance bandwidth of the proposed antenna system is from 1.8 GHz to well beyond 12 GHz. A T-shaped stub in the ground plane is added to achieve isolation better than 15 dB in the operating band. A comparison of above discussed MIMO antenna system with the proposed antenna is given in Table 1. From the table it can be seen that the proposed antenna has smaller size with lowest operating frequency.

2. Antenna geometry

The antenna geometry with Cartesian co-ordinate system is shown in Fig. 1. The antenna is printed on the FR-4 substrate with dielectric constant of 4.4 with thickness 1.6 mm and loss tangent 0.02. The antenna system consists of two microstrip fed similar triangular radiating patches. The two triangular radiating patches are symmetrically positioned with respect to y-axis and are separated by 14 mm. The radiating patches are fed by tapered microstrip lines for better impedance matching. Lower corners of the radiating patch are blended for increasing the current in the patch, i.e. to improve the return loss in the working frequency band especially in the mid frequency range. Separation between the ground and the radiating patch is optimised for the maximum impedance matching. To improve the isolation between the two radiating patches a narrow slot is etched in the ground plane and an additional T-shaped stub is added. This T-shaped stub works as a reflector and hence it reduces the mutual coupling between the two radiating patches. Finally the antenna dimensions are optimised for maximum impedance matching and isolation. The optimised dimensions are given in Table 2.

3. Evolution of the antenna

The two antennas share a common ground plane shown in Fig. 1. Fig. 2 shows the improvement in the return loss and isolation achieved through step-by-step ground changes. In Fig. 2a, graph-1 is for the antenna with the linear ground plane and has return loss of about 10 dB at all the frequencies.

The major improvement in the return loss at higher frequencies is accomplished due to the cut in the ground plane, blending the inner edges of the cut in the ground and by blending the outer edges of the ground plane. As shown in Fig. 2a and b, graph-4 shows the best results for the return loss as well as for the isolation. The working band with a 12 dB return loss starts from 3 GHz and goes beyond 12 GHz, the isolation is better than 15 dB from 4 GHz. To improve the isolation over the entire working band, a T shaped reflector is added in the ground. The ground with cuts and blended edges is modified by adding this vertical strip, due to which the return loss at 9 GHz just touches the −10 dB line and isolation is 15 dB excluding the range of 3 GHz–4.1 GHz. A horizontal line is added at the top of the reflector to make it T shaped; this improves the isolation in the lower frequency band. Finally, a second horizontal line is added in the T shaped stub and it improves the return loss (graph-8) shown in Fig. 2c.

The dimensions of the antenna are chosen to have the first (or the fundamental) resonance near 3.5 GHz so that the operating band starts from 3.1 GHz. In case of the return loss characteristic of the final stage in Fig. 2c, the resonance seen at 4 GHz is due to the triangular radiating patch acting like a monopole. The resonance frequency of a monopole is given by

$$f_r = \frac{c}{4h}$$

where c is the velocity of light in free space and h is the monopole height. For the proposed antenna, from Fig. 1, $h = L_2 + g$ which is equal

Table 2
Antenna dimensions (mm).

Parameter	L	L_1	L_2	L_3	L_4	L_5	L_6	$L7$
Value (mm)	32.6	11	18.8	4.8	5.3	2	6.5	0.8
Parameter	R_1	R_2	R_3	W	W_1	W_2	W_3	W_4
Value (mm)	3.5	3	5	46	1	3	12.3	1.5
Parameter	W_5	W_6	W_7	W_8	W_9	g	g_1	
Value (mm)	9	1	0.5	6	6	1	0.45	