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Microstrip Array Antennas for Triple Band Operation

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Abstract: *This paper presents a novel design of two elements rectangular microstrip array antenna with parasitic wire around (TERMAA) for triple band operation and omni directional radiation pattern. Further, quadruple bands are obtained by simply minimizing the area of ground plane of TERMAA. Later, by truncating the corners of minimized ground plane, the upper two bands are merged together resulting wider triple band operation. The magnitude of each operating band is found to be 19.1, 15.43 and 79.23% respectively with a maximum gain of 3.9 dB. This enhancement does not affect the nature of radiation characteristics. The proposed antennas may find applications for microwave systems operating at WLAN (2.4 – 5.2 GHz), HIPERLAN/2 (5.725 – 5.825 GHz) and X to Ku (8 – 18.5 GHz) band of frequencies. Details of antenna design are described and experimental results are discussed.*
Key Word*: microstrip antenna, array antenna, minimized ground plane, triple-band, omni directional.*

I. Introduction

Recent developments in wireless communication system often require antenna with planar geometry, light weight, ease in fabrication and capable of operating at more than one band of frequencies. The microstrip patch antenna can meet these requirements. Further, dual or triple band frequency operations have gained wide attention in many microwave communication system. When system requires operating at two or more distinct band of frequencies, dual or triple frequency patch antennas may avoid the use of separate antennas for each operating band [1].

Most of the dual frequency microstrip antenna design uses reactively loaded elements, while other design uses a multistructer or multipatches [2-5] and hence, becomes complex in their manufacturing procedure. To overcome this, in present study an experimental effort is made to get triple band operation by using simple two elements rectangular microstrip array antenna wound with a parasitic strip around the patches i.e. TERMAA. Further, by minimizing the ground plane of this antenna, the quadruple and enhancement of impedance bandwidth is achieved

II. Description of Antenna Geometry

The proposed antennas are designed using low cost glass epoxy substrate material of thickness h = 0.16 cm, permittivity $\varepsilon r = 4.2$ and area = A×B. The antennas may be designed using low dielectric constant substrate material but the use of high dielectric constant of substrate materials reduces radiation losses because most of the EM field is concentrated in the dielectric between the conductive strip and the ground plane [6]. The artwork of the proposed antennas is sketched using computer software Auto-CAD 2006 to achieve better accuracy. The antennas are fabricated using photolithography process.

Figure 1 shows the top view geometry of TERMAA comprising of parasitic strip around the radiating patches. The length L and width W of the patch is designed for resonant frequency of 5 GHz, using the equations available for design of rectangular patch [7]. The width of parasitic strip is Wp and is kept away from the side edges of the patch by a distance R. The gap between the edges of strip and quarter wave transformer is again R. The distance D between the two radiating elements from their centre should be

$\lambda o/2$ for minimum side lobes [8], where λo is the free space wavelength in cm. But in Figure 1, D is taken as $\lambda o/2.33$ in order to keep the feed line as compact as possible for minimum feed line loss. Further, when D is less than $\lambda o/2.33$; it becomes difficult to accommodate the feed arrangement between the array elements. Hence $D = \lambda o/2.33$ is treated as optimum in this case. The parallel feed arrangement has wideband performance over series feed and hence selected in this case to excite the array elements of Figure 1. The feed arrangement shown in Figure 1 is a contact feed and has advantage that it can be etched simultaneously along with antenna elements. The parallel feed arrangement of Figure 1 consists of a 50 Ω microstrip feedline of length L50 and width W50 is connected to 100 Ω microstrip feedline of length L100 and width W100 to form a two way power divider. A 100 Ω quarter wave matching transformer of length Lt and width Wt is connected between 100 Ω microstrip feedline and mid point of the radiating elements in order to ensure perfect impedance matching. The bottom plane of TERMAA is tight ground plane copper shielding. The ground plane shielding of TERMAA is minimized as shown in Figure 2 retaining its top geometry. This antenna is named as modified ground plane two elements rectangular microstrip array antenna (MGTERMAA). The size of copper area on the ground plane is taken as A1×B. Later, the corners of the ground plane of MGTERMAA are truncated as shown in Figure 3 retaining its top geometry. This antenna is named as corner truncated ground plane two element rectangular microstrip array antenna (CTGTRMAA). The corners are truncated by length Lc and width Wc. The various antenna parameters of Figure 1 to Figure 3 are given in Table 1.

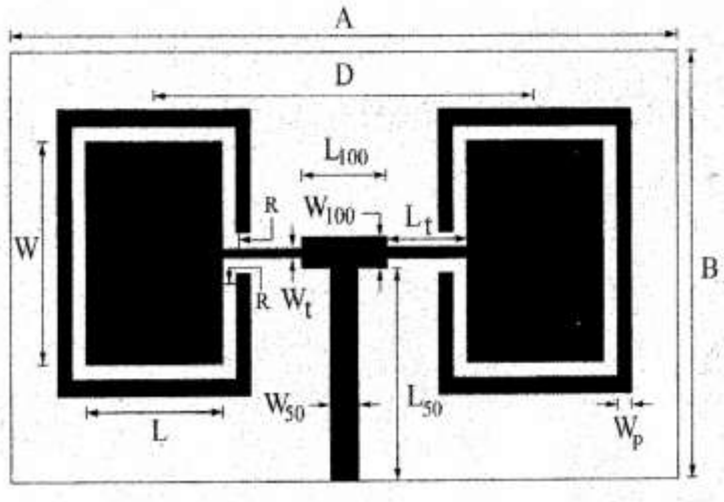


Figure 1 Geometry of TERMAA

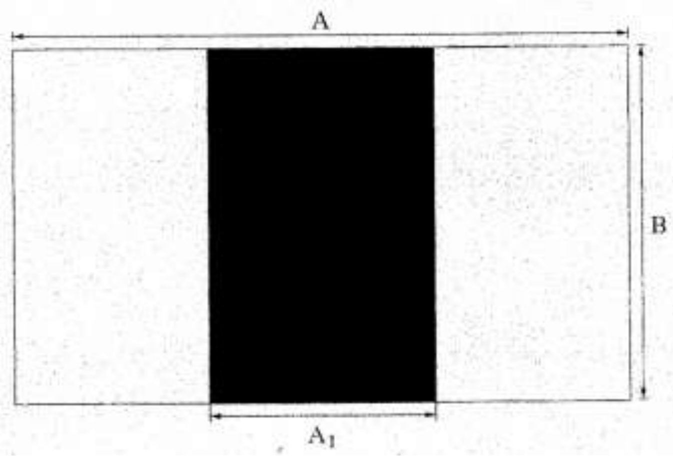
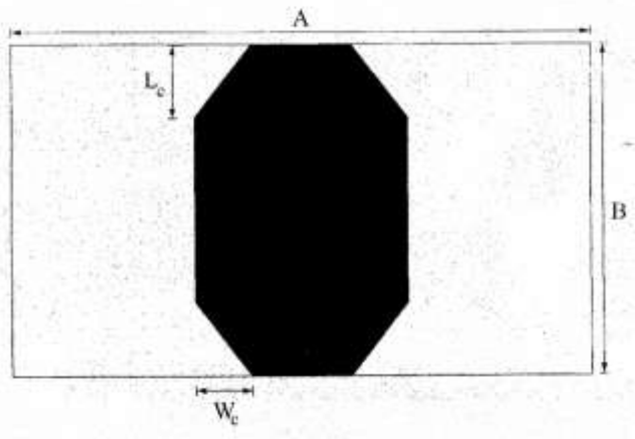


Figure 2 Ground plane geometry of MGTERMAA



III. Experimental Results

The impedance bandwidth over return loss less than -10 dB of the proposed antennas is measured on Vector Network Analyzer (Rohde & Schwarz, Germany make ZVK model 1127.8651). The variation of return loss versus frequency of TERMAA is as shown in Figure 4. From this figure, it can be seen that the antenna resonates for three band frequencies BW1, BW2, and BW3. The impedance bandwidth of each operating band is determined by using the equation.

Impedance Bandwidth=(|f2-f1|/fc)*100%
where, f1 and f2 are the lower and upper cut-off frequencies of the band respectively, when its return loss becomes -10 dB and fc is the center frequency between f1 and f2.

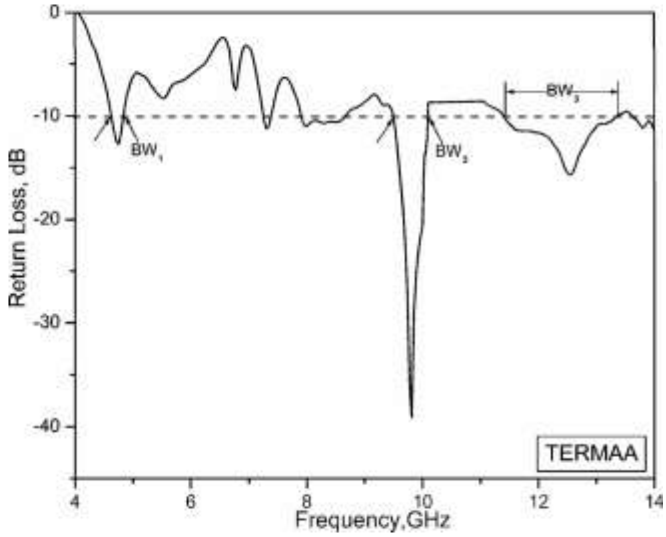


Figure 4 Variation of return loss verses frequency of TERMAA

The magnitudes of impedance bandwidth BW1, BW2 and BW3 are found to be 5.5, 14.04 and 16.08% respectively. These triple bands are due to the independent resonance of radiating elements and parasitic strip [9-10]. The variation of return loss versus frequency of MGTERMAA is as shown in Figure 5. From this graph, it can be seen that the antenna resonates for four bands of frequencies BW4, BW5, BW6 and BW7 with corresponding magnitudes of impedance bandwidth is found to be 17.22, 14.22,
10.38 and 67.76% respectively. The additional bands between BW4 to BW7 are due to the effect of modified ground plane in MGTERMAA.

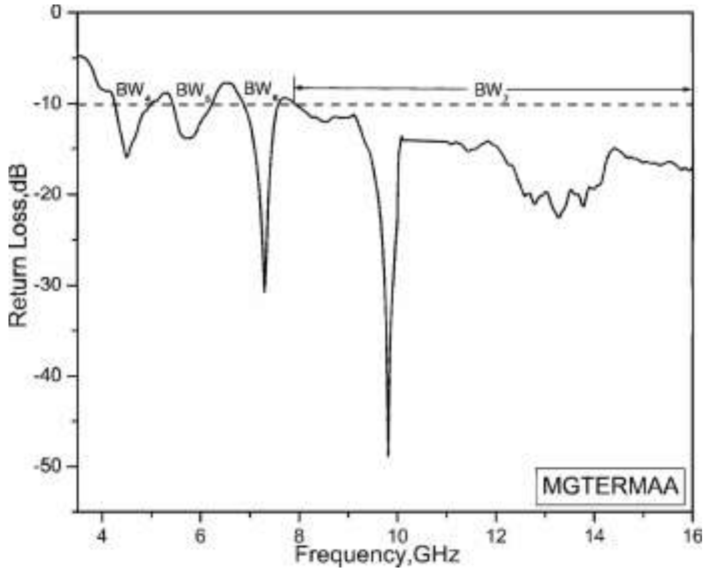


Figure 5 Variation of return loss verses frequency of MGTERMAA

The co-planar radiation pattern of antenna under test (AUT) is measured by connecting a standard pyramidal horn antenna in far field region. The AUT is connected in receiving mode and is kept in phase with respect to transmitting pyramidal horn antenna. The power received by AUT is measured from 00 to 3600 with steps of 100. The typical radiation patterns of TERMAA, MGTERMAA and CTGTRMAA measured at 12.55, 9.81 and 9.81 GHz respectively is as shown in Figure 7. From the figure, it can observe that the patterns are omni directional in nature. Hence the enhancement of impedance bandwidth of triple band operation through CTGTRMAA does not affect the nature of radiation characteristics.

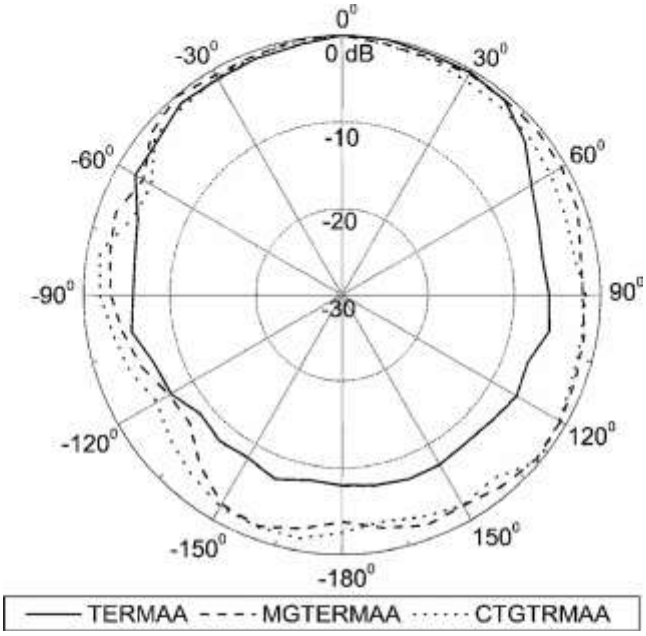


Figure 7 Radiation pattern of TERMAA, MGTERMAA and CTGTRMAA

IV. Conclusion

From the detailed experimental study, it is concluded that, triple band operation with omni directional radiation pattern of antenna is achieved by designing TERMAA. Further, by minimizing the area of ground plane, quadruple bands are observed. Later, by truncating the corners of the minimized ground plane, the enhancement of impedance bandwidth at each operating bands in the triple band operation is possible without changing the nature of omni directional radiation characteristics. This technique also enhances the gain from 0.71 t0 3.90 dB. The proposed antennas are simple in their design, fabrication and they use low cost substrate material. The proposed antennas may find applications for microwave systems operating at WLAN (2.4 – 5.2 GHz), HIPERLAN/2 (5.725 – 5.825 GHz) and X to Ku (8 – 18.5 GHz) band of frequencies.

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