

# Single Layer Slot-Loaded Gap-Coupled Microstrip Array Antenna for Tri-Band Application

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## Abstract

A novel method for tri-band microstrip array antenna with improvement in the bandwidth by incorporating wide slots and additional resonators which is gap-coupled to the non-radiating edges of a radiating element is presented. The experimental results show that two element slot-loaded gap-coupled microstrip array antenna gives a  $-10$  dB return loss bandwidth for three bands. The design specifications, radiation patterns and gain of the proposed antennas are presented and described.

## Keywords

Tri-Band, Microstrip Array, Slot-Loading, Gap-Coupling, Corporate Feed

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## 1. Introduction

This template Demand for compact and multifunctional wireless communication systems has spurred the development of multi-band and wide-band antennas with small size. Microstrip patch antennas are widely used as they offer compactness, low profile, light weight and economical efficiency. However, the microstrip patch antenna is limited by its narrow operating bandwidth. There are numerous and well known methods to increase the bandwidth of microstrip patch antennas, including increase in the substrate thickness, the use of a low dielectric substrate [1], the use of various impedance matching and feeding techniques [2], the use of multiple resonators [3] [4] [5] [6] and the use of slot antenna geometry [7]. However, the bandwidth and the size of an antenna has generally mutually conflicting properties, that is, improvement of one of the characteristics normally results in degradation of the other. However, a single layer slot-loaded gap-coupled microstrip array configuration for enhancing the

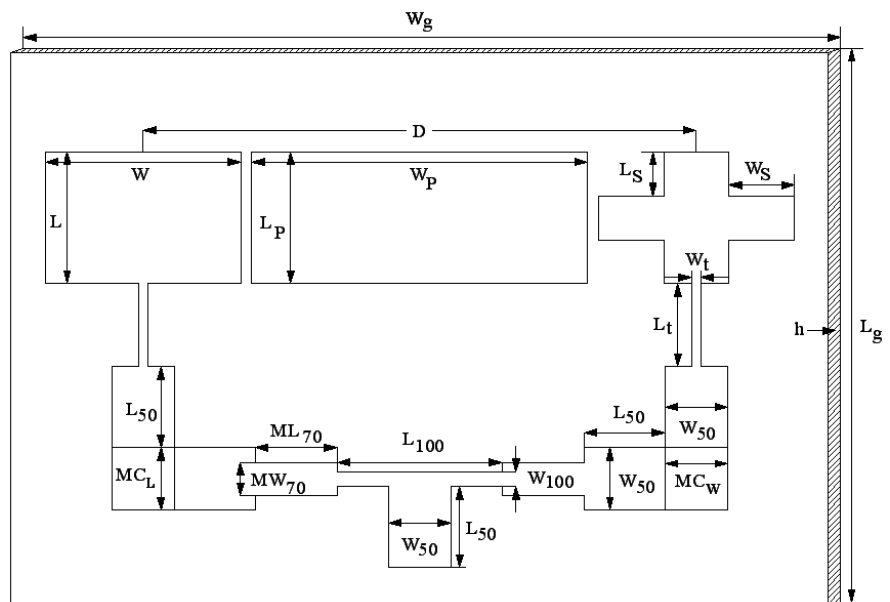
bandwidth is found rarely.

In this paper, a new configuration has been proposed for tri-band operation without increasing the effective area. The concept of slot-loading and gap-coupling is used for designing a single layer two element linear array and the obtained experimental results are presented and discussed.

## 2. Design Specifications

The proposed antenna is designed using low cost glass epoxy substrate material having dielectric constant  $\epsilon_r = 4.2$  and thickness  $h = 0.16$  cm. The geometry of two element slot-loaded gap-coupled microstrip array antenna (TSGMSAA) is shown in **Figure 1**.

The dimensions of elements of array are  $L = 0.66$  cm and  $W = 0.98$  cm. A rectangular wide slot of optimized dimensions  $L_s = 0.33$  cm and  $W_s = 0.22$  cm is placed at each edge of second element which results into plus shape [8] [9]. The dimensions of wide slots are taken in terms of  $\lambda_0$ , where  $\lambda_0$  is the free space wavelength in cm. These slots are considered as wide slots as their width is comparable to their length. The wide slot is selected because it is more effective in enhancing the impedance bandwidth than the narrow slot [10]. A common parasitic element of dimension  $L_p = 0.66$  cm and  $W_p = 1.72$  cm is placed between non-radiating edges of radiating elements, which forms the non-radiating edge gap-coupling. The distance between the parasitic and radiating element  $S$  is optimized and is taken as  $0.025 \lambda_g$ , where  $\lambda_g$  is the operating wavelength in cm [11]. The length  $L_g = 3.44$  cm and width  $W_g = 6.38$  cm of the ground plane of antenna is calculated using  $L_g = 6h + L$  and  $W_g = 6h + W$  [11]. The elements of this array antenna are excited through simple corporate feed arrangement. This feed arrangement consist of matching transformer, quarter wave transformer,



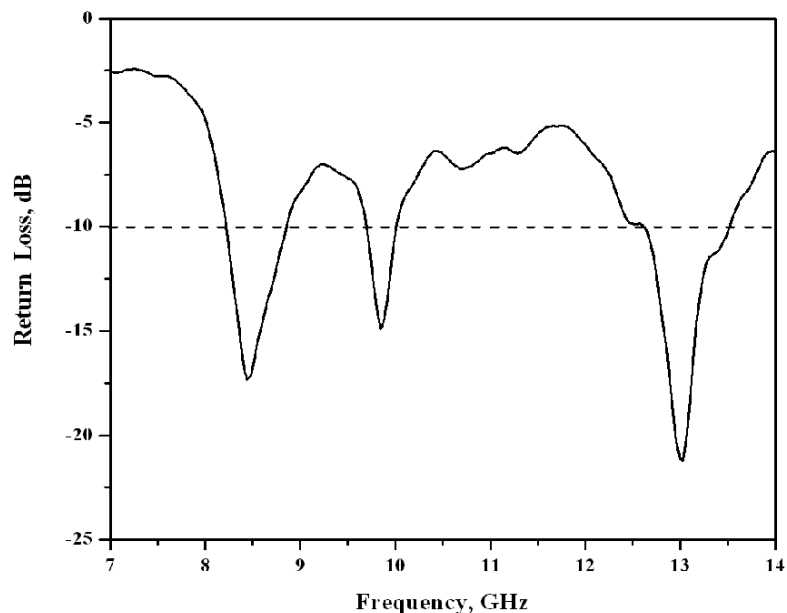
**Figure 1.** Geometry of TSGMSAA.

microstrip coupler and power divider for better impedance matching between feed and radiating elements [12]. A two-way power divider made up of  $70 \Omega$  matching transformer of dimension  $L_{70} = 0.41$ ,  $W_{70} = 0.16$  cm is used between  $100 \Omega$  microstrip line of dimension  $L_{100} = 0.83$ ,  $W_{100} = 0.07$  cm and  $50 \Omega$  microstrip line of dimension  $L_{50} = 0.41$ ,  $W_{50} = 0.32$  cm. A microstrip coupler of dimension  $MC_L = MC_W = 0.32$  cm is used between  $50 \Omega$  microstrip lines to couple the power [13-14]. The  $50 \Omega$  microstrip line is connected at the center of the driven element through a quarter wave transformer of dimension  $L_t = 0.42$ ,  $W_t = 0.05$  cm for better impedance matching. At the tip of microstrip line feed of  $50 \Omega$ , a coaxial SMA connector is used for feeding the microwave power. The array elements are kept at a distance of  $D = 2.79$  cm from their center point. This optimized distance is selected in order to add the radiated power in free space [15].

### 3. Experimental Results and Discussion

The impedance bandwidths over return loss less than  $-10$  dB for the proposed antennas are measured. The measurements are taken on Vector Network Analyzer (Rohde & Schwarz, German make ZVK Model No. 1127.8651). The variation of return loss versus frequency of TSGMSAA is shown in **Figure 2**.

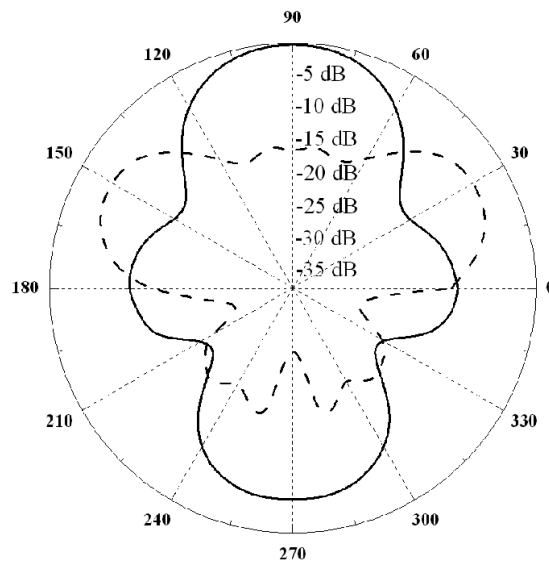
From **Figure 2**, it is observed that TSGMSAA offers tri-band in the range 8 GHz to 14 GHz at 8.44 GHz, 9.84 GHz, and 13.03 GHz with a magnitude of 630 MHz (7.37%), 320 MHz (3.24%) and 1090 MHz (8.40%) respectively. The obtained bandwidths are more compared to single radiating element (2.85%). The first band is obtained from element which is gap-coupled to the non-radiating edge and improvement in the impedance bandwidth is due to wider patch dimension [16]. The second band is due the fundamental resonance of the first element excited through corporate feed network, as it is resonating at 9.84 GHz



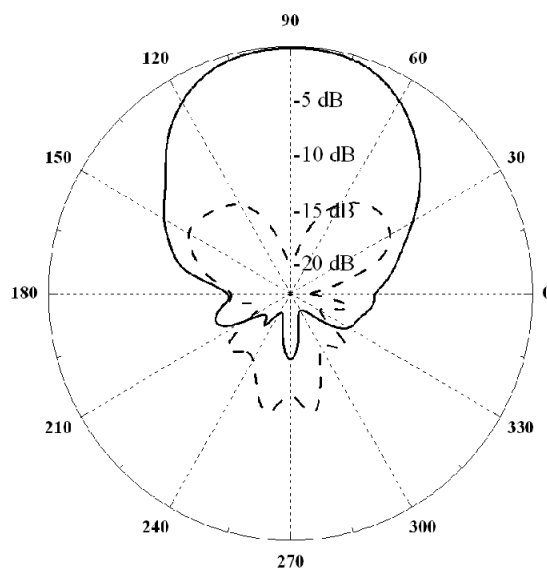
**Figure 2.** Variation of return loss versus frequency.

proves that the impedance is matching to  $50 \Omega$ . The third band is due to the second element, which is also excited through corporate feed network and shift in frequency and improvement in impedance bandwidth is due to embedding of wide slots at appropriate place resonate nearer to the fundamental resonance of radiating elements [11]. The return loss measured at resonating frequencies is  $-17.33$  dB at 8.44 GHz,  $-14.89$  dB at 9.84 GHz and  $-21.21$  at 13.03 respectively.

The H-plane co-polar and cross-polar radiation patterns of TSGMSAA are measured at their resonating frequencies and are shown in **Figures 3-5**. These figures indicate that the antenna shows broad side radiation characteristics. **Figure 5** shows the radiation pattern measured at 13.03 GHz. At this frequency antenna shows split beam radiation pattern which is useful in SAR for



**Figure 3.** Variation of relative power versus azimuth angle at 8.44 GHz.



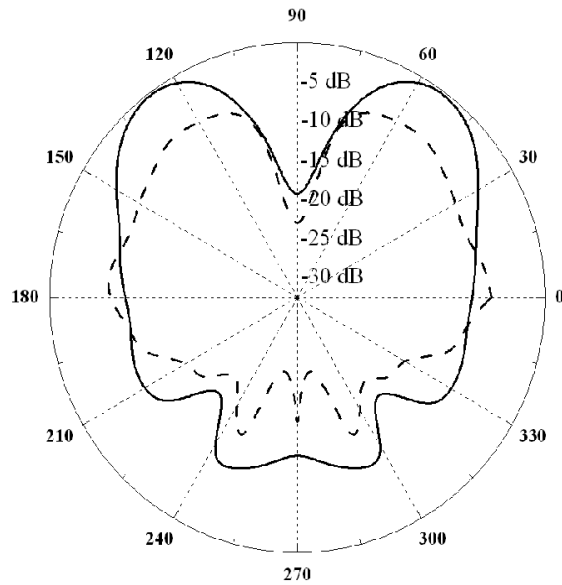
**Figure 4.** Variation of relative power versus azimuth angle at 9.84 GHz.

generating a pair of forward and backward squinted beams and provides simultaneous measurement of both the along-track and the cross-track velocities [17].

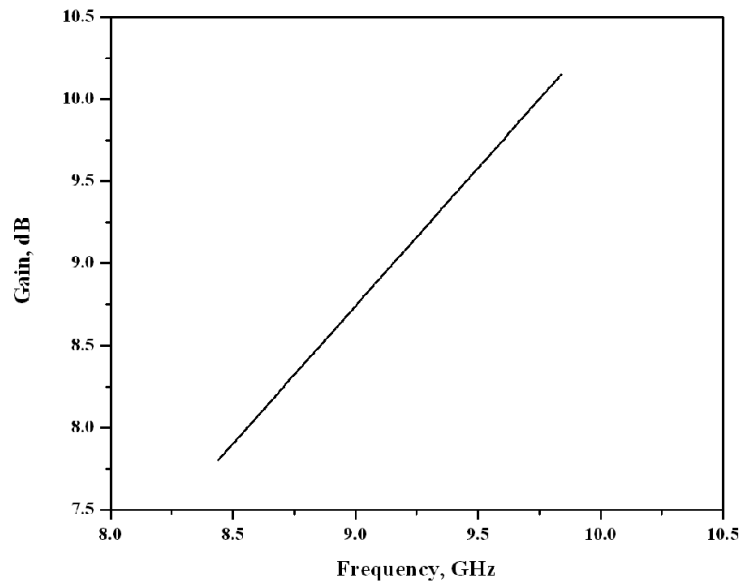
The half power beam widths (HPBWs) of TSGMSAA are calculated for the resonating frequencies and are found to be  $46^\circ$  and  $69^\circ$  for 8.44 GHz and 9.84 GHz respectively.

The gain of TSGMSAA is calculated at the resonating frequencies and the variation of gain with respect to frequency is shown in **Figure 6**. This shows the use of slots and additional resonators gap-coupled to array configuration also improves the antenna gain considerably [5].

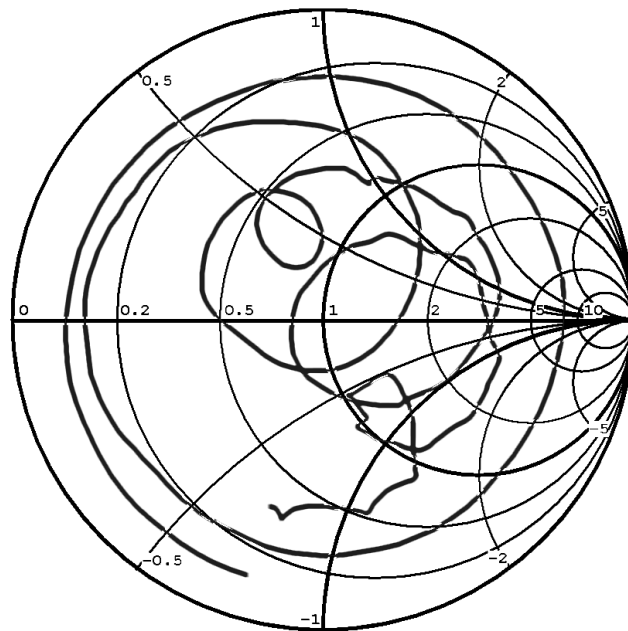
The variation of input impedance of the proposed antenna is shown in **Figure 7**.



**Figure 5.** Variation of relative power versus azimuth angle at 13.03 GHz.



**Figure 6.** Variation of gain versus frequency.



**Figure 7.** Input impedance profile of ESGMSAA.

It is seen that the input impedance has multiple loops at the center of Smith chart that validates its tri-band operation.

#### 4. Conclusion

The detailed experimental study shows that, the antenna is quite simple in design and fabrication and quite good in enhancing the impedance bandwidth and gives better gain with broadside radiation pattern at the resonating frequencies. This tri-band microstrip patch array antenna may provide an alternative to large bandwidth planar antennas in applications in which large bandwidths are needed for operating at two separate transmit-receiver bands. When the two operating frequencies are far apart, a tri-band patch array structure can be conceived to avoid the use of separate antennas. The proposed antenna is also superior as it uses single layer, low cost substrate material and finds applications in modern communication system, microwave wireless communication system and in radar communication systems particularly in monopulse tracking radar and SAR.

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#### Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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