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Hybrid Microstrip Array Antenna for Multi-band and Wide-band Application

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ABSTRACT: A novel method for increasing the bandwidth of microstrip array antenna by incorporating wide slots and additional resonators which are gap-coupled to the non-radiating edges of a radiating element is described. The experimental results show that four element gap-coupled hybrid microstrip array antenna (FGHMSAA) gives a -10 dB return loss bandwidth of 21.13 %. The bandwidth is improved to 50.79 % with eight elements array. The design specifications, radiation patterns and gain of the proposed antennas is presented and described.

KEYWORDS: Cognitive Radio, Spectrum Sensing, Efficient Communication, System Security.

I.INTRODUCTION

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 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 [3-5] and the use of slot antenna geometry [6]. 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.

Recently, in [7] authors proposed a combination of aperture-coupled slot-loaded gap-coupled microstrip array antenna for improving the bandwidth. However a single layer slot-loaded gap-coupled microstrip array configuration for enhancing the bandwidth is found rare.

In this paper, a new configuration has been proposed for wide band operation without increasing the effective area. The concept of slot-loading and gap-coupling is used for designing a single layer four element linear array [8-9]. The study is further extended for eight element array and the obtained experimental results are presented and discussed.

II.SYSTEM MODEL AND ASSUMPTIONS

The proposed antennas are designed using low cost glass epoxy substrate material having dielectric constant $\varepsilon_r = 4.2$ and thickness h = 0.16 cm. The geometry of FGHMSAA is shown in Fig. 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 alternate elements which results into plus shape [10] and the array appears to be hybrid i.e., combination of both rectangular shape and plush shape. The dimensions of wide slots are taken in terms of λ_0, where λ_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 [11]. A common parasitic element of optimized 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 λ_g, where λ_g is the operating wavelength in cm [12]. The length L_g = 4.27 cm and width W_g = 12.76 cm of the ground plane of antenna is calculated using $L_g = 6h + L$ and $W_g = 6h + W$ [9].

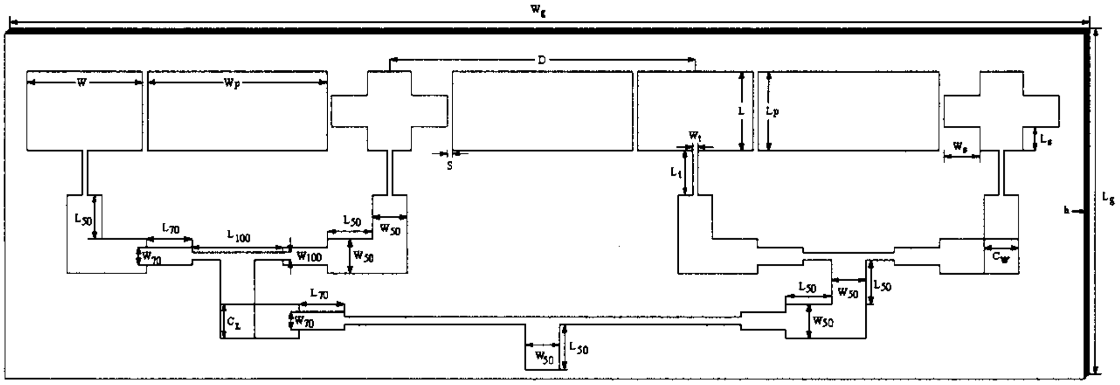

Fig. 1 Geometry of FSGMSAA

The elements of this array antenna are excited through simple corporate feed arrangement. This feed arrangement consist of matching transformer, quarter wave transformer, coupler and power divider for better impedance matching between feed and radiating elements [13]. A two-way power divider made up of 70Ω matching transformer of dimension L70 = 0.41, W70 = 0.16 cm is used between 100Ω microstrip line of dimension L100 =0.83, W100 = 0.07 cm and 50Ω microstrip line of dimension L50 = 0.41, W50 = 0.32 cm. A coupler of dimension CL = CW = 0.32 cm is used between 50Ω microstrip lines to couple the power [14-15]. The 50Ω microstrip line is connected at the centre of the driven element through a quarter wave transformer of dimension Lt = 0.42, Wt = 0.05 cm for better impedance matching. At the tip of microstrip line feed of 50Ω, 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 centre point. This optimized distance is selected in order to add the radiated power in free space [16]. Further the study is carried out for eight element slot-loaded gap-coupled microstrip array antenna (ESGMSAA).

III.EXPERIMENTAL RESULTS AND DISCUSSION

The impedance bandwidths over return loss less than –10dB 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 FSGMSAA and ESGMSAA is shown in Fig. 2.

From figure 2, it is observed that FSGMSAA offers multi-bands in the range 6GHz to 18 GHz at 6.76 GHz, 8.09 GHz, 12.43 GHz, 14.11 GHz and 17.30 GHz with a magnitude of 140 MHz (2.07 %), 210 MHz (2.60 %), 450 MHz (3.60 %), 560 MHz (3.79 %) and 1510 MHz (8.86 %) respectively. The overall impedance bandwidth is found to be 21.13 % which is 7.41 times more when compared to single radiating element (2.85 %). The improvement in the impedance bandwidth is due to embedding of slots at appropriate place and the additional resonators coupled to non-resonator edge resonate nearer to the fundamental resonance of radiating elements causing enhancement in the impedance bandwidth [10]. The minimum return loss measured in this antenna is -32.28 dB at 17.30 GHz.

Further, from the figure, it is clear that ESGMSAA also resonates for multi bands in the range 6 GHz to 13 GHz at 6.10 GHz, 6.73 GHz, 7.36 GHz, 8.06 GHz and a wide-band resonating for dual band at 9.56 and 10.75 GHz covering the entire X-band. The impedance bandwidth of each band is found to be 100 MHz (1.64 %), 140 MHz (2.08 %), 170 MHz (2.30 %), 420 MHz (5.16 %) and 4170 MHz (39.61 %) respectively. The overall impedance bandwidth of ESGMSAA is found to be 50.79 % which is 2.40 times more compared to FSGMSAA. The impedance bandwidth of last band which is resonating from 8.44 GHz to 12.61 GHz is found to be 39. 61% and is 1.16 times more when compared to [7] measured at X-band frequency. This improvement in impedance bandwidth is due to combined and closer resonance of all the eight elements gap-coupled with additional resonators fed by corporate feed network and the slots where all the elements resonate at their fundamental resonance and the slots resonates closer to it, which results into an improvement in the impedance bandwidth. The minimum return loss measured in this antenna is -39.29 at 10.75 GHz.

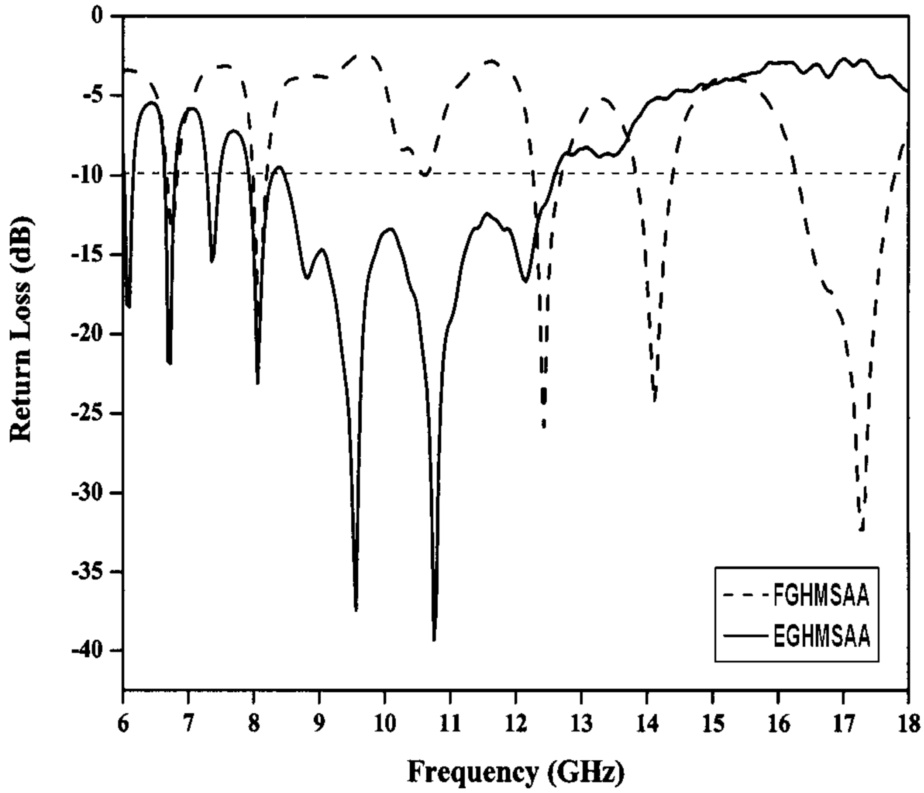

Fig. 2 Variation of return loss versus frequency of FSGMSAA and ESGMSAA

The H-plane co-polar and cross-polar radiation patterns of ESGMSAA are measured at their resonating frequencies and are shown in Fig. 3 to Fig. 8. These figures indicate that the antenna show broad side radiation characteristics. Fig. 5 show the radiation patterns of ESGMSAA measured at 7.36 GHz. At this frequency antenna shows split beam radiation pattern which is useful in SAR for generating a pair of forward and backward squinted beams and provide simultaneous measurement of both the along-track and the cross-track velocities [17].

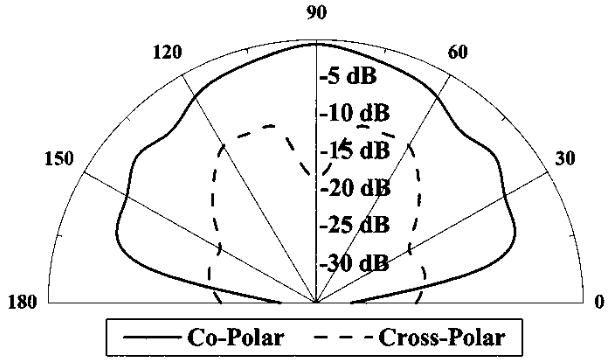

Fig. 3 Variation of relative power versus azimuth angle of ESGMSAA at 6.10 GHz

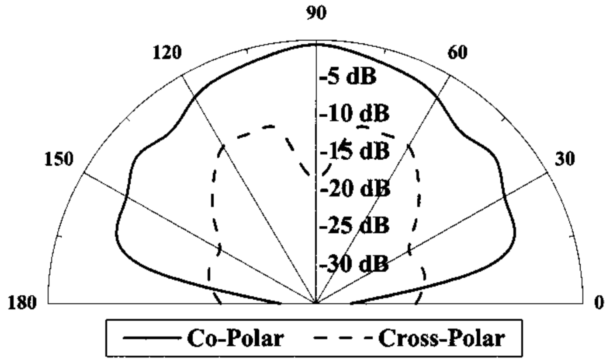

Fig. 4 Variation of relative power versus azimuth angle of ESGMSAA at 6.73 GHz

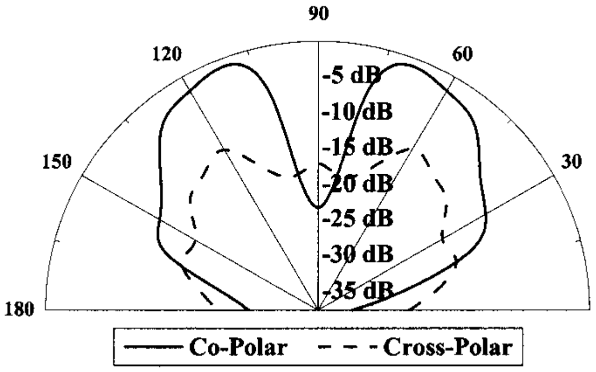

Fig. 5 Variation of relative power versus azimuth angle of ESGMSAA at7.36GHz

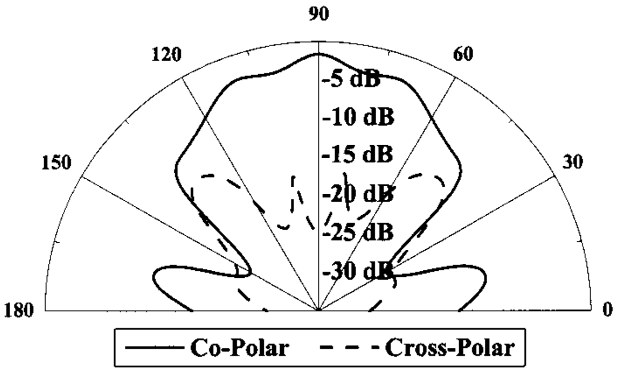

Fig. 6 Variation of relative power versus azimuth angle of ESGMSAA at 8.06 GHz

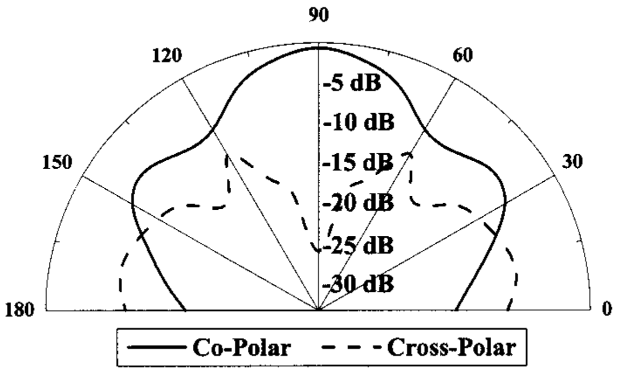

Fig. 7 Variation of relative power versus azimuth angle of ESGMSAA at 9.56 GHz

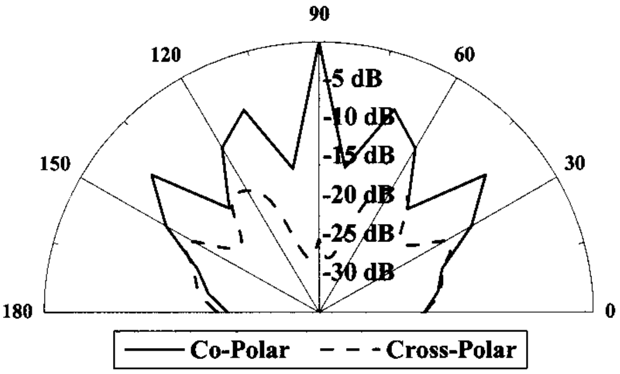

Fig. 8 Variation of relative power versus azimuth angle of ESGMSAA at 10.75 GHz

The half power beam widths (HPBWs) of ESGMSAA are calculated for the resonating frequencies and are found to be 12^0, 61^0, 38^0 and 4^0 respectively.

The gain of ESGMSAA is calculated at the resonating frequencies using the formula,

$$(G_T)_{dB} = (G_s)_{dB} + 10 \log (P_t/P_s)$$

where, G_s is the gain of pyramidal horn antenna. The variation of gain with respect to frequency is shown in Fig. 9. This shows the use of slots and additional resonators gap-coupled to array configuration also improves the antenna gain considerably [5].

As ESGMSAA gives improved impedance bandwidth, the variation of input impedance is shown in Fig.10. It is seen that the input impedance has multiple loops at the center of Smith chart that validates its wide-band and multi resonance operation.

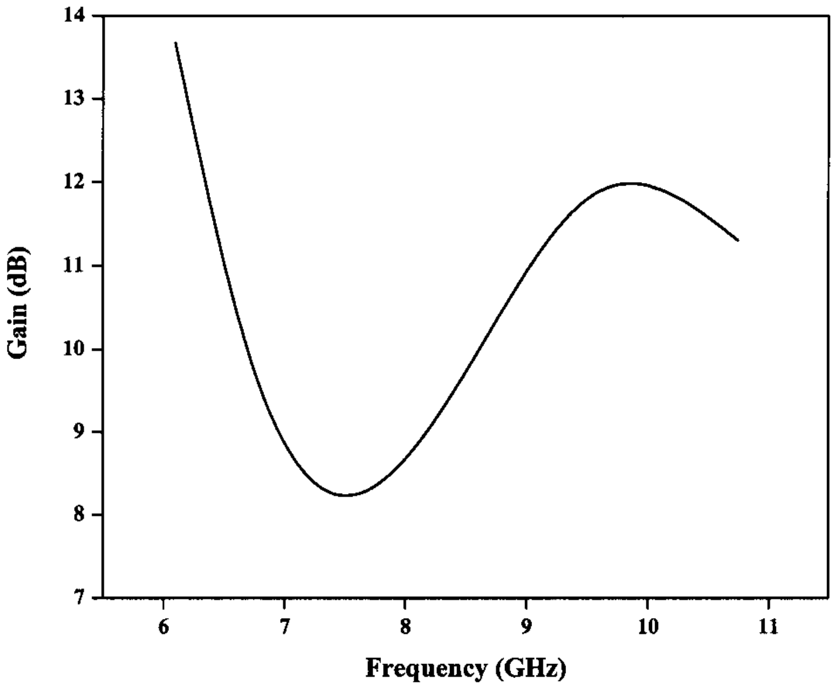

Fig. 9 Variation of gain versus frequency of ESGMSAA

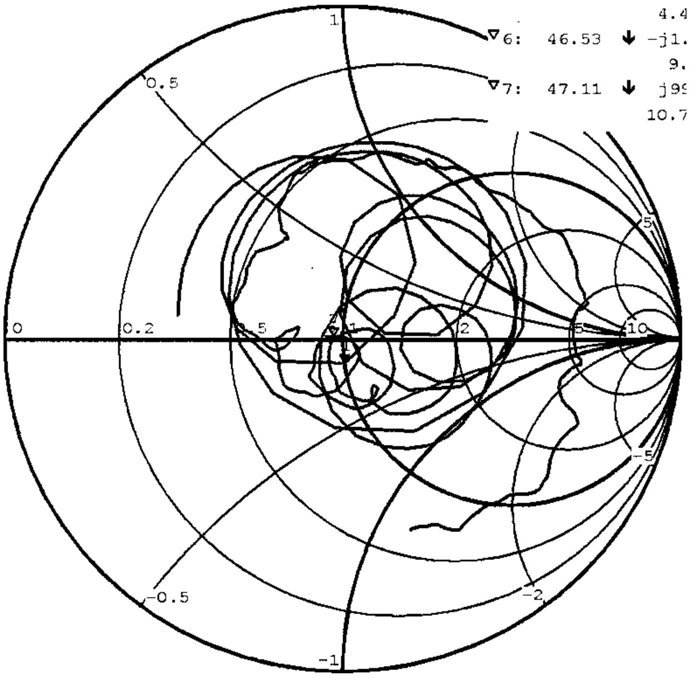

Fig. 10 Input impedance profile of ESGMSAA

VI.CONCLUSION

The detailed experimental study shows that, the antennas are quite simple in design and fabrication and quite good in enhancing the impedance bandwidth and give better gain with broadside radiation pattern at the resonating frequencies. The multi-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 multi-band patch array structure can be conceived to avoid the use of separate antennas. These antennas are also superior as they use single layer low cost substrate material and find 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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