International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 16 (2017) pp. 5676-5680

Proximity fed Gap Coupled Array Antenna with DGS Backed with Periodic Metallic Strips

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Abstract

This paper presents a novel microstrip patch array with defected ground structure backed with periodic metallic strips for modifying the direction of beam maxima. The proposed array configuration is obtained by employing two parasitic patches gap coupled to the driven elements of a single layer proximity fed 2 × 1 microstrip patch array configuration. The feed patches are excited by proximity feeding method and the parasitic patches are excited by gap-coupling. The basic array consists of a hexagon shaped slot in the ground plane. The developed dual band array antenna, the direction of beam maxima in both planes for lower band is in +Z direction, while that of the upper band is –Z direction. Additional substrate layer with vertical metal strips printed on one side is placed at the bottom of the ground plane. The additional layer acts as reflector and also introduces a third resonant band. The presence of the additional layer modifies the directions of the beam maxima and the all the three resonant bands radiate in the bore sight direction. The simulated results are in good agreement with the experimental ones.

Keywords: Corresponding author: Jacob Abraham; email: tjacobabra@gmail.com;

INTRODUCTION

Microstrip patch antennas play a very significant role in today's wireless world due to the large number of attractive features [1]. Gap coupled parasitic elements are used along with basic radiating elements to form array configuration, with enhanced bandwidth and gain [2]. Traditionally the proximity fed microstrip patch antennas are implemented using two layers of substrates, where the radiating elements are printed on the top surface of the upper substrate and the fed line is on the top surface of the lower substrate. A microstrip antenna consisting of radiating elements electromagnetically coupled in close proximity to a microstrip line with a coupling slot etched in the ground plane is reported in [3]. This coupling scheme is used to excite radiating elements in this work. Slots etched in the ground plane of microstrip patch antenna plays an important role in modifying various antenna parameters. Defected ground structure is implemented by creating defects in the ground plane. The shielded current distribution in the ground plane is disturbed which leads to controlled excitation and propagation of waves through the dielectric substrate layer [4]. The size of the defect etched in the ground plane is a key parameter in determining the direction of radiation beam. In some of reported papers with DGS, back radiation is an issue, which can be controlled by metallic reflector paced at the back side of the ground plane [5]. When reflectors are used the overall thickness of the antenna becomes larger to be used in a portable device. An alternative method of modifying direction of back radiation is suggested in this work. Significance of using multiple layer substrates in modifying characteristics of microstrip patch antenna have been reported in [6, 7].

The authors in their previous work as reported the basic concepts of single layer proximity fed gap coupled array antenna [8]. Both the radiating patches and microstrip fed are in the same plane. In the reported work a tapered dumbbell shaped slot is etched in the ground plane to form a defected ground structure. The developed array antenna resonates in dual band with both beam maxima radiating in the same direction. A modified version of the single layer proximity fed gap coupled array was reported in [9]. The tapered arrow headed dumbbell shaped slot is replaced with a hexagon shaped slot. The modified array antenna resonates at two frequencies. In the case of higher resonant frequency the direction of beam maxima in both E and H plane are in –Z direction while in lower resonant frequency the direction of beam maxima in both planes are in +Z direction. This is due to the fact that at lower band the antenna structure acts as a 2x2 microstrip antenna while at the upper band the slot in the ground plane acts as a radiator and the array configuration acts as a feed network. The proposed array antenna with hexagon slot can be used for simultaneous dual band bi-directional wireless communications at two different frequencies.

In this work, effect of an additional substrate layer with metallic strips printed on one side, placed at the bottom surface of the ground plane of the proximity fed gap coupled array antenna with hexagonal slot is examined. The other side of the additional substrate layer is plane. The proposed multilayer array antenna modifies the direction of radiation patterns and also introduces additional frequency band.

ANTENNA GEOMETRY

The proposed multilayer microstrip patch array antenna is fabricated on FR-4 substrate with thickness h = 1.6 mm, loss tangent of 0.002 and relative permittivity of 4.3. The side view of the proposed array antenna is given in Fig.1. The multilayer microstrip array antenna consists of three planes, namely the top plane were the radiating elements including the feed patches and parasitic patches as well as microstrip fed line are printed. The second plane is the ground plane, where a hexagonal shaped slot is etched to form a defected ground structure. The third plane consists of number of periodic vertical metallic strips printed on the upper surface of the second substrate. Both the substrate layers are closely placed without air gap.

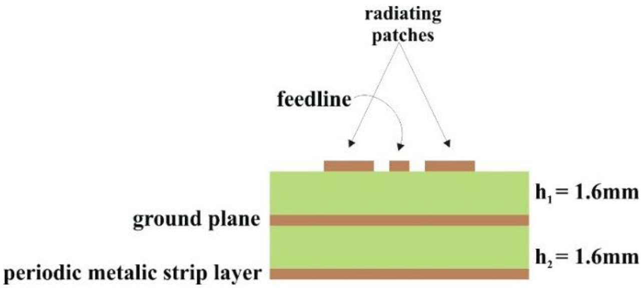
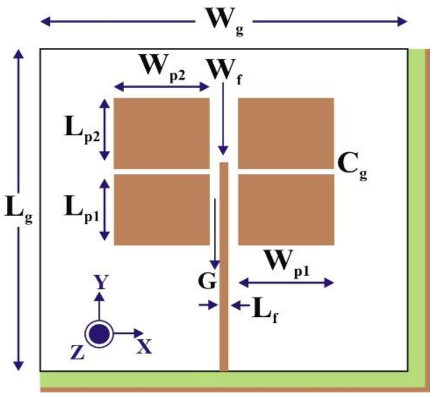
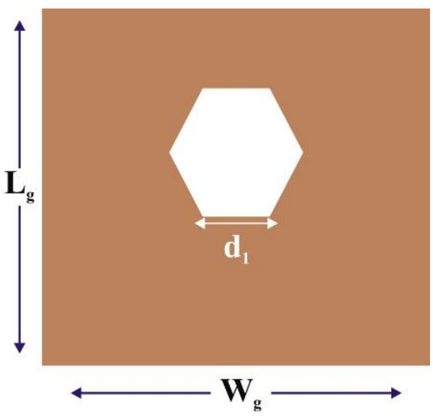


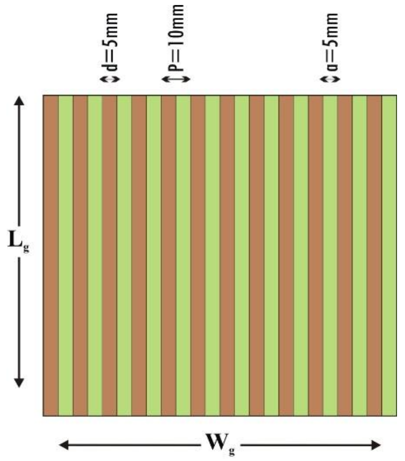
Figure 1: Side view of the proposed multi-dielectric layer array antenna



(a)



(b)



(c)

Figure 2: Geometry of the multilayer microstrip patch antenna (a) top view (b) view of ground plane (c) view of the periodic vertical metallic strip layer.

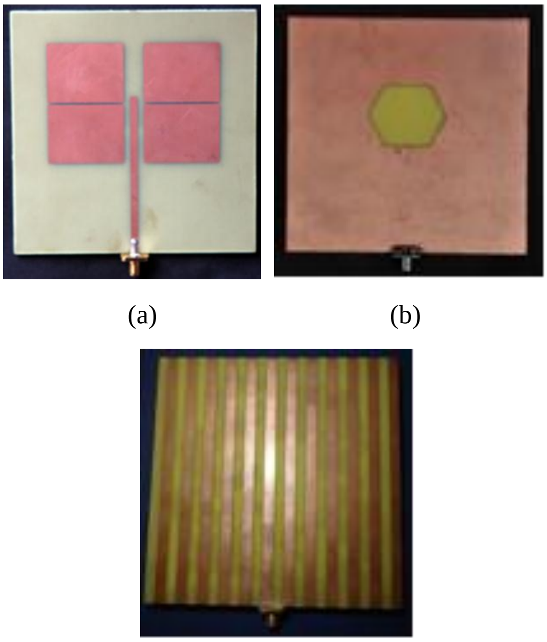
Top view of the proposed multilayer microstrip patch array antenna is shown in Fig.2 (a) where the two lower elements are the feed patches. The feed patches are electromagnetically excited by the centrally placed microstrip line as illustrated in the diagram. In order to enhance bandwidth two parasitic patches are gap coupled to the fed patches. The radiating and parasitic patches with same dimension form the basic array configuration. Fig.2 (b) show the geometry of the ground plane, which was printed on the bottom surface of substrate layer one. Fig.2(c) shows the periodic vertical metal strip layer printed on the bottom surface of the lower substrate. The metallic strip layer has a periodicity of 10mm with thickness of the metallic strips at 5mm each. The resonant properties of the proposed multilayer microstrip patch array configurations have been optimized using electromagnetic field solver CST microwave studio. The optimized dimensions of the proposed multilayer microstrip patch array antenna are given in the Table 1.

Table 1: Optimized dimensions of the proposed patch antenna (units: mm)

Lg	Wg	Lp	Wp	Lf	Wf	d1	G	Cg
120	120	26.4	34	71.75	3	23.3	3.5	1

RESULT AND DISCUSSION

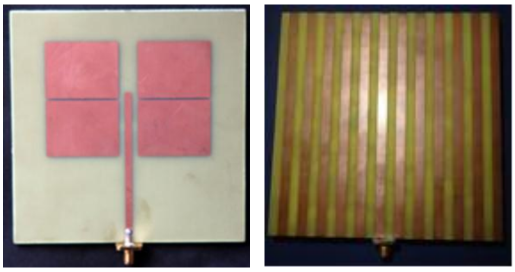
The plane by plane view of the fabricated prototype of the proposed antenna is shown in Fig 3. Using adhesive gum both the substrates are joined to free from air gaps. Fig 4 shows top and bottom view of the multilayer microstrip patch antenna. The measurement is carried out by using Agilent network analyzer E5071C.



(a) (b)

(c)

Figure 3: Photographs of the fabricated multilayer microstrip array antenna (a) top plane (b) ground plane (c) periodic metallic strip plane



(a) (b)

Figure 4: Photograph of the fabricated multilayer microstrip patch array antenna (a) top view (b) bottom view

Fig. 5 shows the measured S_{11} variations with frequency of the array antennas with and without additional substrate layer printed with vertical metal strips. The plot in red color shows S_{11} variations of proximity fed gap coupled array antenna and the one in blue color depicts the variations of the array antenna with additional substrate layer. It is seen that the presence of the additional substrate layer produces a third band and all the bands are shifted towers the lower side. The measured -10 dB impedance bandwidth of the proximity fed gap coupled array antenna without additional layer for the lower band is 54.4 MHz (2.002-2.0564 GHz) or 2.68% with peak resonance at 2.032 GHz, and for the upper band is 72 MHz (3.043 – 3.115 GHz) or 2.34% with peak resonance at 3.079 GHz.

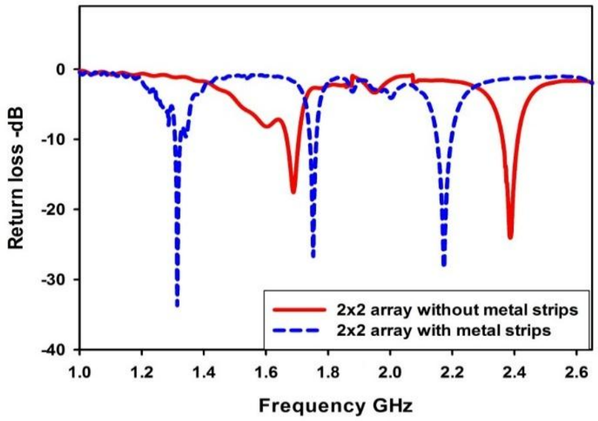


Figure 5: Measured return loss characteristics of the proximity fed gap coupled array antenna and modified array antenna with additional substrate layer.

The simulated and experimental return loss characteristics of the proximity feed gap coupled array antenna backed with periodic metallic strips are shown in Fig. 6.

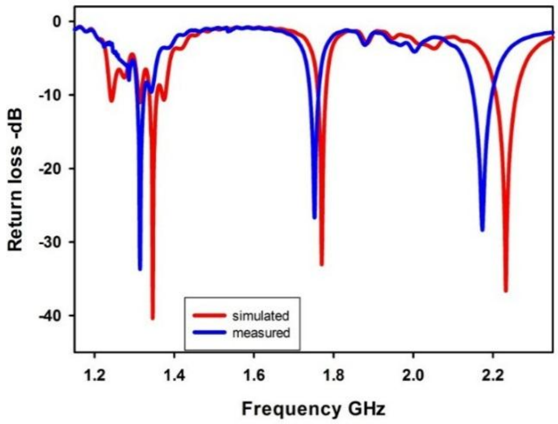
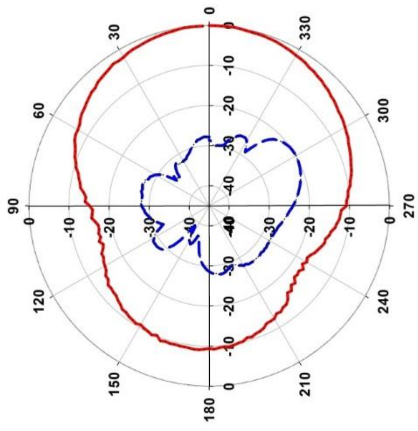


Figure 6: Measured and simulated return loss characteristics of the modified gap coupled array antenna with vertical metal strips

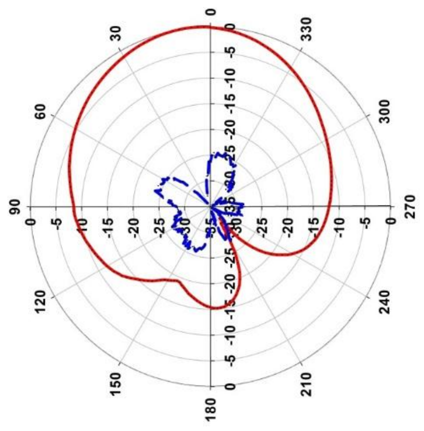
The measured -10 dB impedance bandwidth for the lower band is 20 MHz or 1.52 %, (1.306-1.326GHz) with peak resonance at 1.314GHz, in the case of middle band is 25MHz or 1.43% (1.741-1.766 GHz) with peak resonance at 1.752GHz and for the upper band is 46MHz or 2.12%, (2.152-2.198 GHz) with peak resonance at 2.174GHz.The simulated -10 dB impedance bandwidth of the proximity fed gap coupled array antenna backed with metallic strips for the lower band is 22 MHz or 1.64 %, (1.336-1.358 GHz) with peak resonance at 1.346GHz, similarly in the case of middle band is 31MHz or 1.75% (1.755-1.786 GHz) with peak resonance at 1.77GHz and for the upper band is 54MHz or 2.42%, (2.206-2.260GHz) with peak resonance at 2.232 GHz. The discrepancy between the measured and simulated results may be due to fabrication tolerance.

International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 16 (2017) pp. 5676-5680

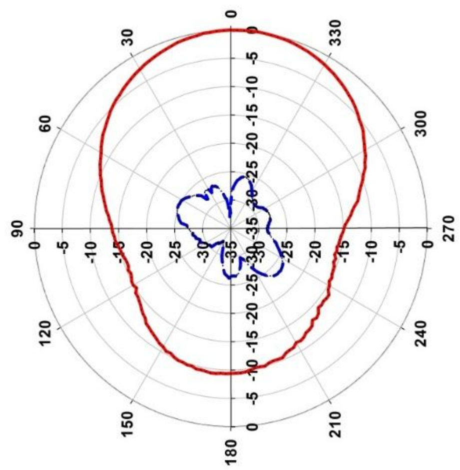
The measured normalized radiation patterns of multilayer microstrip patch antenna, in the E plane (y-z plane) and H plane (x-z plane) are plotted at the resonant frequencies of 1.314 GHz, 1.752GHz and 2.232 GHz is shown in Fig. 7.



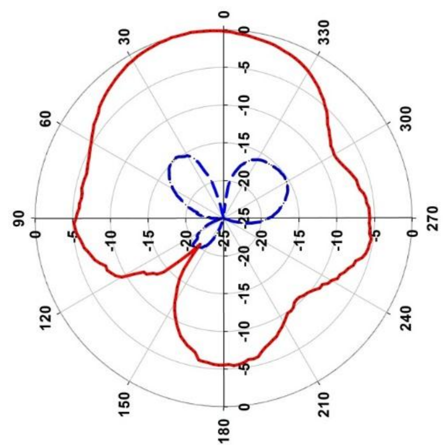
(a) E plane



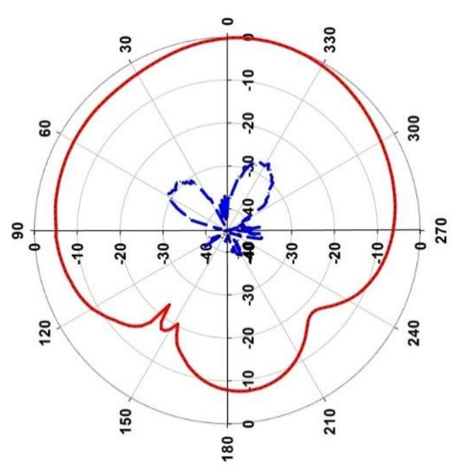
(b) H plane



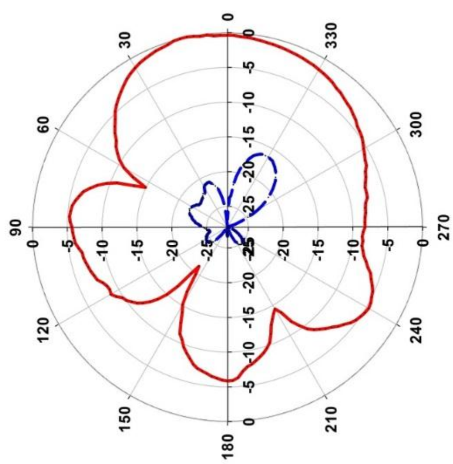
(c) E plane



(d) H plane



(e) E plane



(f) H plane

Figure 7: Measured radiation patterns in the two orthogonal planes at different resonant frequencies (a)-(b): 1.314GHz, (c)-(d): 1.752GHz, (e)-(f): 2.174GHz

It is seen that at all three resonant frequencies the direction of beam maxima in both E and H plane are in + Z direction. It is observed that if the additional substrate layer with vertical layers printed on it is not present, then the array configuration will be a dual band antenna. Were the beam a maximum in the lower band is in +Z direction and the beam maxima in upper band are in –Z direction. So the presence of the additional dielectric layer will be acting as a reflector.

CONCLUSION

With the introduction of additional substrate layer printed with periodic vertical metallic strips the direction of beam maxima can be changed from –Z to +Z axis. An additional resonant band is also produced due to the presence of this added substrate layer. When the added substrate layer is removed the antenna becomes bidirectional. The proposed antenna is suitable to be used in portable wireless communication devices.

ACKNOWLEDGMENT

The authors would sincerely express the gratitude to Mr. Sathyan Balakrishnan, Spectrum Antennas and Avionics systems (P) Ltd., for providing the measurement facilities

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