Gain Enhancement of Microstrip Patch Antenna Array with AMC Structure Using Multilayer PCB Technology

Vaishali Ekke(✉) and Prasanna Zade

Department of Electronics and Telecommunication,
Yeshwantrao Chavan College of Engineering, Hingana Road, Nagpur, India
vaishali_dhede@rediffmail.com, zadepl@yahoo.com

Abstract. Placement of artificial magnetic conductor (AMC) structures at the inset feed line of the patch operating at 2.4 GHz is analyzed. Proposed design for four element patch array using AMC with multilayer PCB technology which gives improvement in return loss and gain. Analysis had done for low cost stack up material for multilayer purpose. FR4 epoxy finally used as stack up material which is low cost and ease to fabricate. In antenna array AMC structure at the feed line considerably reduce side lobe level and back lobe level and improves gain. Simulated results are validated experimentally.

Keywords: Antenna array · Artificial magnetic conductor · Gain · Multilayer PCB · Stack up structure

1 Introduction

Extensive growth of further generation WLAN applications requires patch antennas for its low profile, simple design and ease of fabrication on PCBs. Microstrip patch antennas are the better solution for compact and low-cost design [1]. To overcome the drawbacks or limitations of single element antennas multiple patches are connected in an array. Surface waves along the ground plane limit antenna gain and efficiency. It can be overcome by reducing the surface wave using AMC structures with or without vias. The designs using the AMC improves the gain of the patch antenna. Surface waves create ripples in the radiation pattern [2–5]. The development of surface waves causes a serious problem in the microstrip patch antenna array which reduces gain, efficiency, limits bandwidth, increases cross-polarization levels. Various approaches like designing probe-fed microstrip radiators [6], use of parasitic elements [2, 7] use of different substrates which lowers effective dielectric constant of the substrate or use of reduced surface wave antenna [3–5], photonic crystals are known as electromagnetic band gap (EBG) structures [8] which used significantly to improve antenna performance. Multilayer stack-up structure can be used to improve antenna performance [9]. Artificial magnetic conductor (AMC) structure [10], relative impedance surface (RIS) [11], uniplanar compact photonic band-gap structure [12] are used enhance antenna performance.

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AMC structure has in-phase reflection coefficient such as perfect magnetic conductor (PMC). The microstrip antenna with high impedance structure (HIS) or with AMC can give higher gain and larger bandwidth [13]. AMC structure when used as antenna ground plane, the periodic surfaces can enhance the radiation patterns, antenna gain and impedance bandwidth [13–16]. Improvement in return loss, gain, bandwidth is observed by implementing AMC along with inset feed in 4 × 1 microstrip patch antenna array and the concept of AMC along with feed line is analyzed and tested [17].

Based on this idea [17] AMC structure along with feed line with standard multilayer PCB prototype investigated and proved the improvement in the performance of antenna array is referred in proposed multilayer antenna.

2 Design of Proposed Antenna Array

Schematic of proposed technique of multilayer printed circuit board (PCB) technology is shown in Fig. 1.

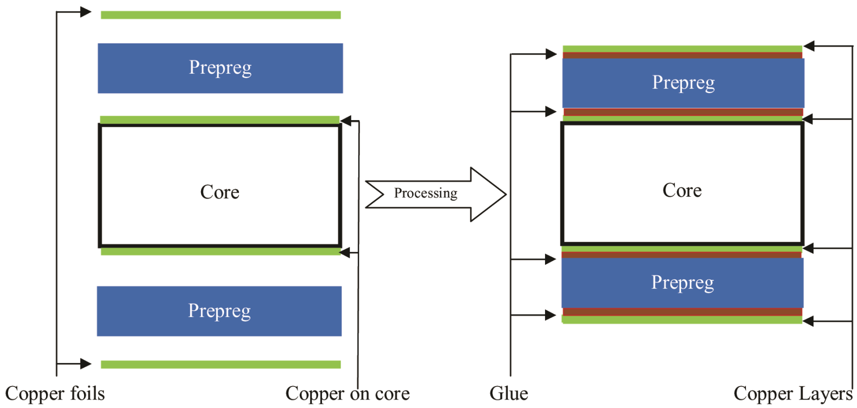

Fig. 1. Multilayer stack up structure.

Figure 1 consists of core (dielectric substrate) and two prepreg for PCB fabrication (uncured fiberglass epoxy resin) which is cost effective. Copper foil bonded with cured epoxy resin. To avoid mechanical stress, stack up arrangement is symmetric about centre of PCB.

Figure 1 shows multilayer PCB fabrication process. It consists of prepreg and laminate. Copper foil bonded on both sides of copper with epoxy resin (cured). Alternate layer of core and prepreg are mounted. Copper foils are bonded on both sides of prepreg which acts as surface foils. Glue of small thickness is used for bonding core and prepreg. There are insignificant losses due to glue where resonating frequency is low (<10 GHz).

Using this multilayer PCB fabrication technique, proposed antenna array with AMC is designed as shown in Figs. 2 and 3.

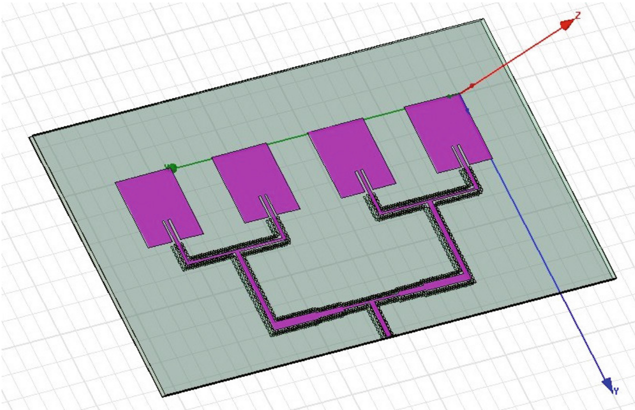

Fig. 2. Simulation model of the proposed designed antenna in HFSS.

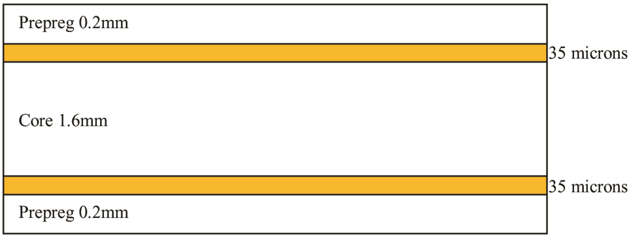

Fig. 3. Layers of the proposed designed antenna.

Before fabrication of the prototype, different materials are tested in the simulation model to obtain better radiation pattern. As antenna model is covered with different materials from the front and back side. Materials with different permittivity are selected also considering the other factors like cost of the material and durability also. Radiation pattern obtained using these materials is shown below. Simulated return loss plots and radiation patterns are given in Figs. 4 and 5. It shows no more increase in simulation parameters. But materials like glass, Rogers RT duroid are very expensive materials. To reduce the cost with the same performance it is concluded that epoxy resin is more cost effective and easy to fabricate.

Figure 2 shows simulation model, Fig. 3 shows layers and Fig. 6 shows prototype of array with AMC and proposed antenna array using multilayer stack up structure. It is resonate at a center frequency of 2.45 GHz. In proposed array, the height of FR4 epoxy is 1.6 mm top and bottom prepreg is 0.2 mm. Bonding glue of 35 microns. The performance of the fabricated antenna array is tested using Vector Network Analyzer (E5071C). Figures 7, 8 and 9 show the Simulated and measured results.

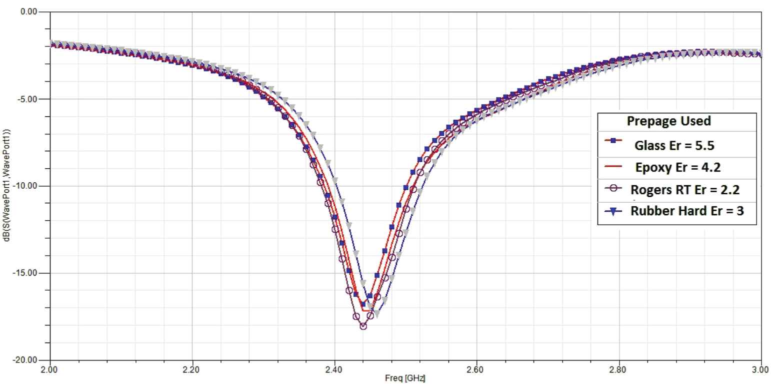

Fig. 4. Return loss using different materials as prepage

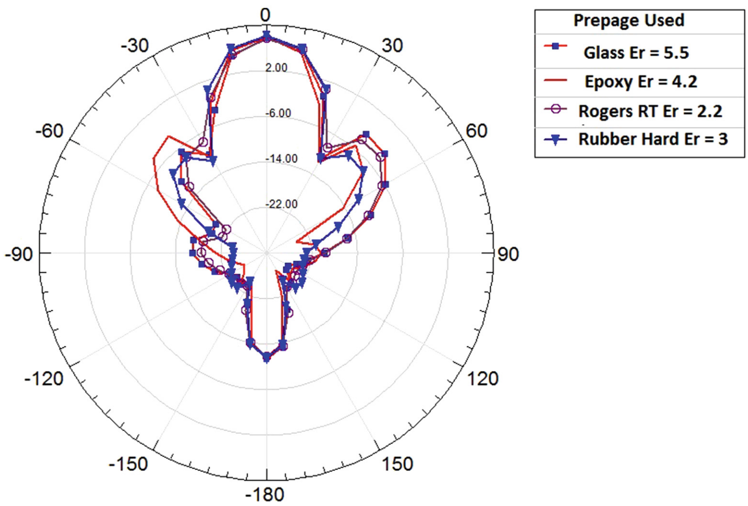

Fig. 5. Radiation patterns using different materials as prepage

Percentage bandwidth at 10 dB is 4.49% and 4.48% for simulated and measured antenna array respectively.

Addition of AMC improves the gain. Measured results of antenna with AMC along its feed line [17] and same with multilayer structure using PCB technology are given in Table 1. Cross polarization level reduced to −44.39 dB for proposed antenna. The difference between simulated and measured results was produced due to fabrication errors.

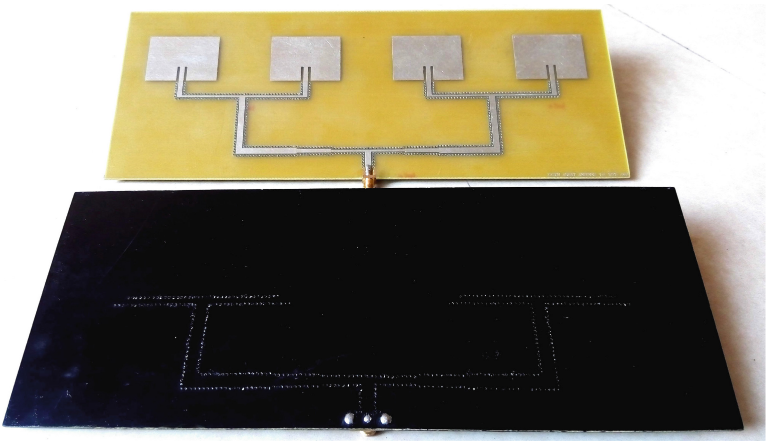

Fig. 6. Prototypes of array with AMC and proposed array antenna with stack up structure.

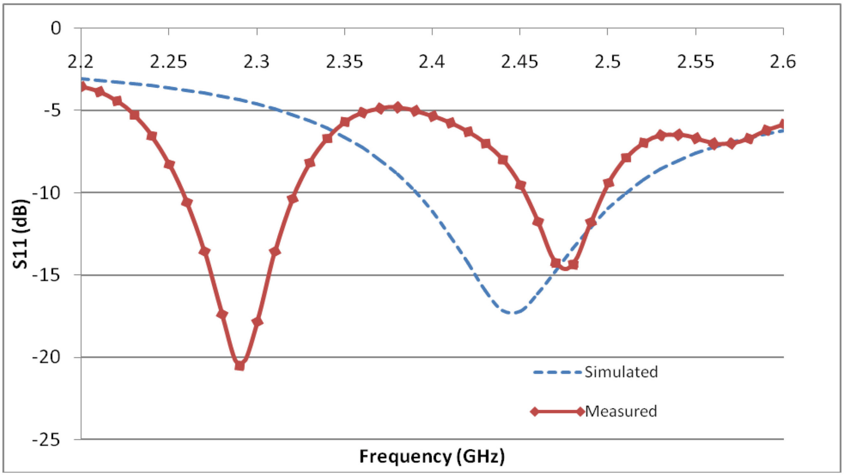

Fig. 7. Measured and simulated return loss for proposed antenna array

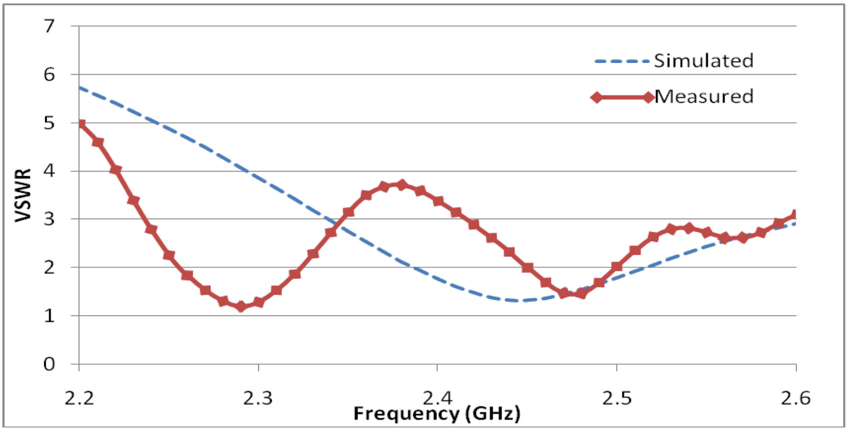

Fig. 8. Measured and simulated VSWR for proposed antenna array

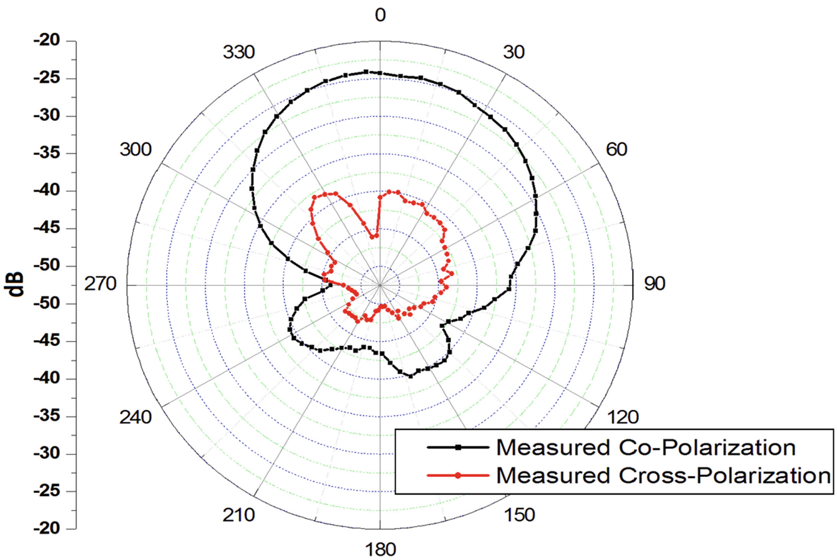

Fig. 9. Radiation pattern of measured Co and Cross polarization for proposed antenna array with stack up structure

Table 1. Comparison between different multilayer array antennas

	Frequency (GHz)	Size of array (mm^3)	No. of layers	No. of elements	Gain	Directivity (dB)
[6]	2.5	150 × 330 × 9.8	3	4	N.A.	12.
[7]	5.797	170 × 170 × 7.6	3	9	8.656	N.A.
[9]	2.4	200 × 125 × 45	3	4	10.4	N.A.
Proposed antenna	2.45	300 × 106 × 2	3	4	14.492	16.530

3 Conclusion

New AMC antenna array was developed with multilayer PCB technology. AMC structure with multilayer stack up reduces surface wave which improves gain and suppress cross polarization. Enhancement of antenna performance by multilayer stack up is economic with easy fabrication process. Developed antenna consists size of 300 mm × 106 mm × 2 mm with measured gain of 14.492 dB and impedance bandwidth 4.48% (from 2.26 GHz–2.32 GHz and 2.45 GHz–2.5 GHz).

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