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MICROSTRIP PATCH ANTENNA ARRAY WITH ARTIFICIAL MAGNETIC CONDUCTORS FOR LOW POLARIZATION USING MULTILAYER STACK UP STRUCTURE

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Abstract— This paper presents investigations on four element microstrip patch antenna array with artificial magnetic conductor (AMC) structure along with feed line for low cross polarization developed using multilayer printed circuit board (PCB) technology. The said antenna consists of a rectangular patch with AMC structure fed along with feed line in order to enhance the gain. Four layer antenna array prototype was fabricated using a low-cost standard multilayer PCB process which could be easily integrated with planar circuits. Measured gain of an antenna with AMC is 7.8 dB and for the newly developed antenna array with AMC using multilayer PCB technology was 14.492 dB. Also developed antenna array uses low-cost multilayer PCB with two very cheap prepreg and core. Thus, the developed antenna array is promising for indoor wireless application due to its merits of high gain and low cost. Developed antenna operates at 2.45 GHz, suitable for ISM band applications.

Keywords—Antenna array; artificial magnetic conductor; gain; multilayer PCB.

I. INTRODUCTION

Antennas are used as natural resources for the development of wireless communication system. To improve cross-polarization, AMC structure is integrated with an antenna array. In order to focus the beam microstrip patch antenna array is used. Other advantages of microstrip patch antenna array are compact configuration, low weight. Drawbacks like the development of surface wave cause a serious problem in microstrip patch antenna array, reduces gain, efficiency, limit bandwidth, increase cross-polarization levels. To overcome these problems magnetic conductor structure is implemented in developed antenna.

Undesired radiation produces a high level of cross-polarization. Artificial magnetic conductors (AMCs) received more attention in recent years and are known as high impedance surfaces. Use of AMC as a reflector improves antennas radiation pattern. AMC structures are either similar square cells of the perfect electric conductor (PEC) backed dielectric surface. Same can be fabricated with vias [1]. AMC structure also provides wider bandwidth and good impedance matching [2]. This work investigates the use of AMC structure with multilayer printed circuit board technology for low cross-polarization and gain improvement. The complex product of perfect magnetic conductors (PMC) is AMCs. AMC is an electromagnetic band gap material [3]. High impedance surface of an AMC can be realized using PCB technology, in which the vertical connections are formed by metal plated vias (vertical interconnect access). AMC structure shows good performance and improves cross-polarization in antenna array as [1] and [4]. In this paper, we propose simple 4 x 1 microstrip patch antenna array. First, AMC structure is implemented along feed line in 4 x 1 microstrip patch antenna array. This basic structure referred to as an antenna 1.

AMC structure along with feed line with standard multilayer PCB prototype improves the performance of antenna array referred as antenna 2. Therefore, it is a good solution for dual band and feeding network applications. It is also observed that AMC structure along with feed line gives advantages like dual bandwidth, high gain, low cost and ease for fabrication. After introducing antenna array structure and operation, the antenna array is designed and fabricated by use of AMC structure.

II. AMC STRUCTURE BASED 4 X1 MICROSTRIP PATCH ANTENNA ARRAY

AMC structure exhibits periodic structures which have high impedance surface (HIS). AMC structures are widely used to improve radiation performance of antenna [4 - 7]. AMC surface has forbidden frequency band, so currents and surface waves cannot propagate [8]. Due to suppression of surface wave propagation AMC surfaces have good radiation pattern. Ideal AMC structure exhibits reflection coefficient of +1 where the amplitude is 1 and phase zero degree. AMC reflects the back lobe pattern in the forward direction without phase reversal. Side lobe can be suppressed by AMC structure [9]. Fig. 1 shows AMC unit cell with its characteristics.

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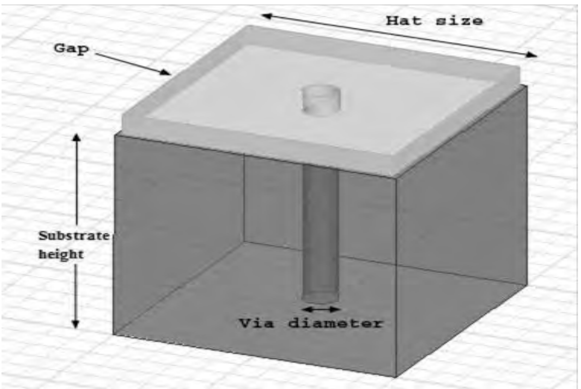

Fig. 1. AMC unit cell

A. Evaluation of microstrip patch antenna

Antenna uses FR4 substrate with permittivity ε_r = 4.4, height h = 1.6 mm and loss tangent tanδ = 0.02. Dimensions for the single radiating element is 39 x 28.2 mm with resonance frequency 2.45 GHz.

B. Analysis of AMC surface

AMC surface has three components, bottom metallic ground, square metal hat on top and conducting via between these two as shown Fig. 1.

EBG is fabricated by etching away the gap region of the copper on the top side of FR4 core. Conducting via are 'through holes' drilled and then plated through with Nickel plus HAL green coat. Simple circuit model shows an AMC unit cell when illuminated by normal incident TEM plane wave. PMC and PEC boundaries are established around unit cell for perpendicular to the incident magnetic field and electric field as shown in Fig. 2.

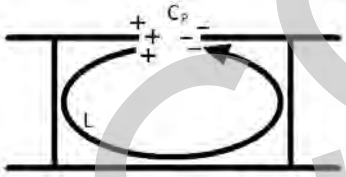

Fig. 2. Simple circuit model for AMC unit cell

The phase of the reflection coefficient ϕ is the difference between incident and reflected wave.

$$\Phi = \mathrm{Im}\left\{\ln\left(\frac{E_r}{E_i}\right)\right\} = \mathrm{Im}\left\{\ln\left(\frac{Z_s-\eta}{Z_s+\eta}\right)\right\} \quad (1)$$

Surface impedance

$$Z_s = \frac{j\omega L}{1-\omega^2 LC},\ \omega = \frac{1}{\sqrt{LC}} \quad (2)$$

$$\eta = \sqrt{\frac{\mu_0}{\varepsilon_0}} = \left|\frac{E_b(x)}{H_b(x)}\right| = \left|\frac{E_f(x)}{H_f(x)}\right| \quad (3)$$

Reflection phases are $\pm\pi$ for very low and high frequencies. Surface impedance much smaller than η indicates low impedance surface such as PEC plane, has 180^o phase shift while surface impedance much larger than η shows high impedance surface such as PMC plane. η has zero reflection phase coefficient when Zs exceeds η, phase value falls with $+\pi/2$ and $-\pi/2$ which called as AMC band. In this band, image current of an antenna placed on the plane is in phase which improves radiation performance.

C. Design of four element microstrip patch antenna array with AMC structure along with feed line (antenna 1)

Design for vias:

- Calculation of via radius
  r = 0.01 x 62.5
  r = 0.625mm

- Calculation of via height of AMC
  t = 0.03 x 62.5
  t = 1.875 mm
- Calculation of gap between cell gap
  g = 0.006 x 62.5
  g = 0.375 mm
- Calculation of AMC cell width area
  w=0.14 x 62.5
  w =8.7 mm

A simulation model of 4 x 1 microstrip patch antenna array with AMC has been carried out in High Frequency Structure Simulator (HFSS) showed in Fig. 3. Front profile and back profile of the fabricated antenna is shown in Fig. 4 and Fig. 5.

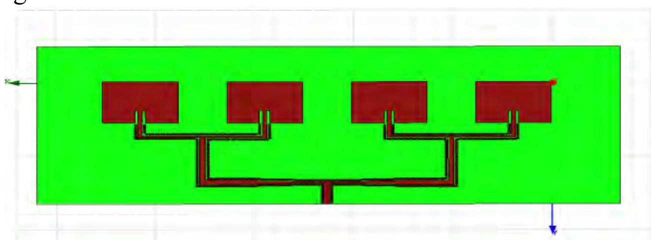

Fig. 3. Design of 4 x 1 microstrip patch antenna array with AMC (antenna 1) using HFSS

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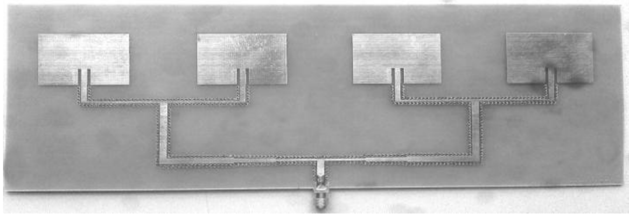

Fig. 4. 4 x 1 microstrip patch antenna array with AMC front profile (antenna 1)

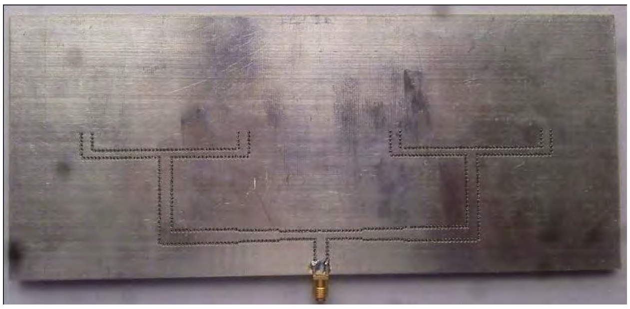

Fig. 5. 4 x 1 microstrip patch antenna array with AMC back profile (antenna 1)

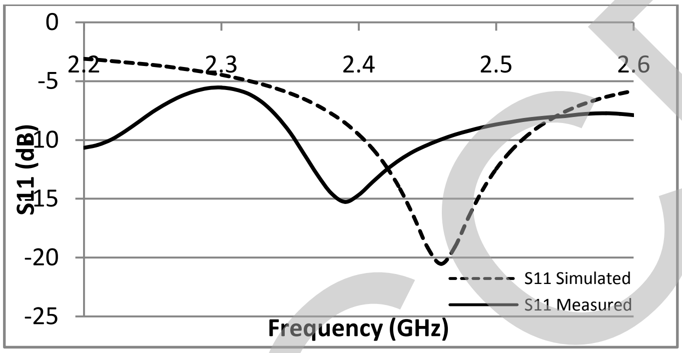

Fig. 6. Simulated and Measured return loss for (antenna 1).

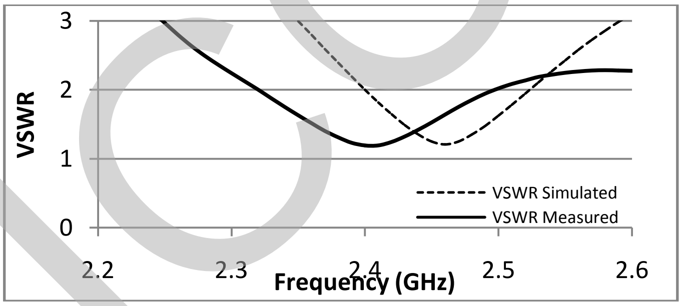

Fig. 7. Simulated and Measured VSWR for (antenna 1).

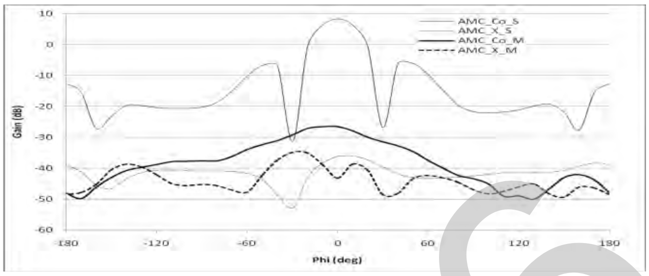

Fig. 8. Radiation pattern of simulated and measured Co and Cross polarization for antenna 1

Fig. 6 shows simulated and measured return loss -18.347 dB and -21.76 dB respectively. Fig. 7 shows simulated and measured VSWR of 1.28 and 1.188 respectively. While Fig. 8 shows measured co-polarization and cross-polarization as -26.566 dB and -43.189 dB respectively.

III. DESIGN OF PROPOSED ANTENNA ARRAY

Schematic of proposed 4 x 1 microstrip patch antenna array using multilayer printed circuit board (PCB) technology (antenna 2) is shown in Fig. 9.

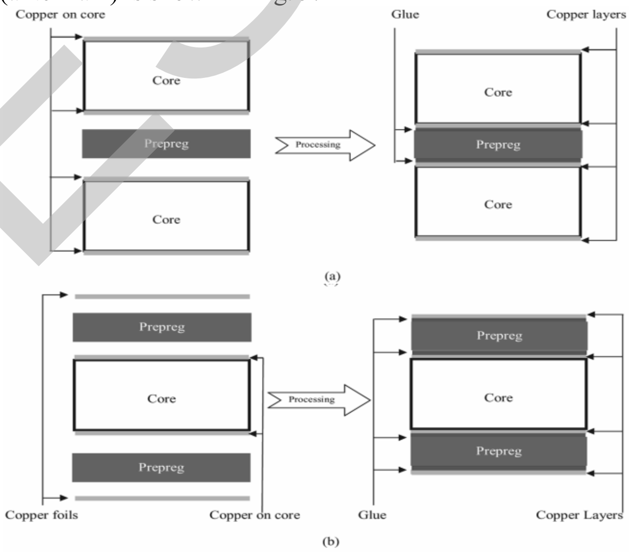

Fig. 9. Stack up structure for multilayer PCB fabrication, (a) common Stack up PCB fabrication for high frequency, (b) More cost-effective Stack up PCB fabrication.

The fabrication process for normal PCB is shown in Fig. 9 (a). It is used for high-frequency processing, but at high-pressure prepreg shrinks which affect its thickness. In the initial design, shrinkage is allowed. PCB fabrication process showed Fig. 9 (b) is used for low-frequency applications at low fabrication cost. For fabrication of normal multilayer PCB, low loss material with low dielectric constant is used for both laminate and prepreg. Multilayer PCB has few number of layers. It affects the flexibility of such type of PCB. Therefore,

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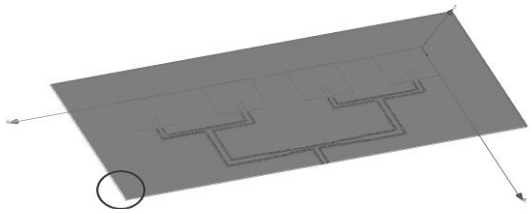
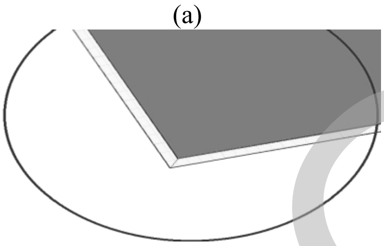
the design of such type of PCB should be done very carefully and smartly.

Fig. 9 (b) shows low-cost multilayer PCB with prepreg and usual laminate. Multilayer structure consists of the core as a dielectric substrate having copper foil bonded to both sides with cured epoxy resin. Prepreg means uncured fiberglass epoxy resin. After being heated and pressed, prepreg gets hardened. Core and prepreg are in alternating layers. When prepregs are in outermost layers then copper foils bonded on outer side acts as surface foils. Stack up arrangement is symmetric about the center of the board to avoid mechanical stress. Core and prepreg are bonded with the glue of small thickness. Different metal layers are stuck together with glue. So loss due to glue is insignificant for low resonance frequency (less than 10 GHz) [9].

Using above described multilayer PCB fabrication technique, 4 x 1 microstrip patch antenna array with AMC (antenna 2) is designed as shown in Fig. 10, 11 and fabricated as shown in Fig. 12.



(a)



(b)

Fig. 10. (a) Perspective view of the proposed designed antenna in HFSS, (b) shows the zoomed area of the multilayer PCB.

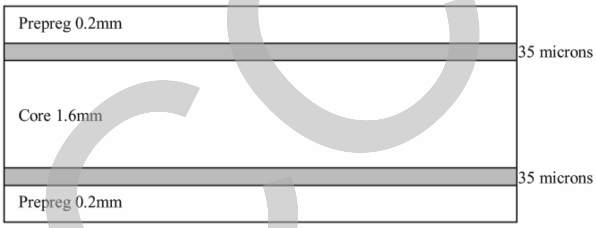


Fig. 11. side view with details of the proposed designed antenna (antenna 2).

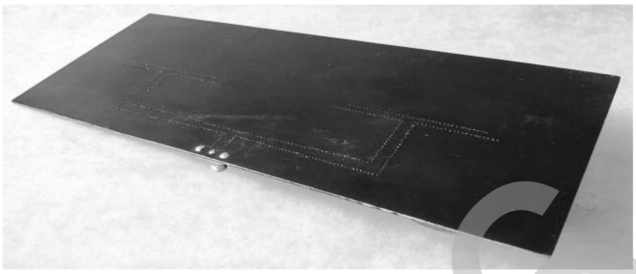


Fig. 12. perspective view of proposed designed antenna (antenna 2).

Fig. 10, 11 and 12 shows a perspective view and side view of proposed four copper layer 4 x 1 microstrip patch antenna array with AMC structure along with feed line which is designed at a center frequency of 2.45 GHz. The height of copper layer is 1.6 mm. The height of top and bottom prepreg substrates is 0.2 mm. It also has glue bonding of 35 microns. Simulation of proposed antenna has done using ANSYS HFSS. The performance of the fabricated antenna is tested using Agilent Vector Network Analyzer(E5071C). Fig. 13, 14 and 15 shows the Simulated and measured results.

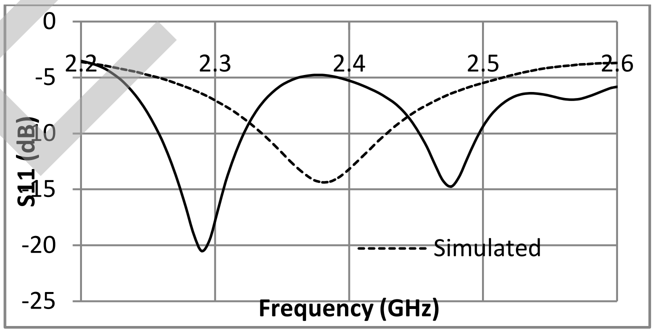


Fig. 13. Measured and simulated return loss for proposed antenna (antenna 2).

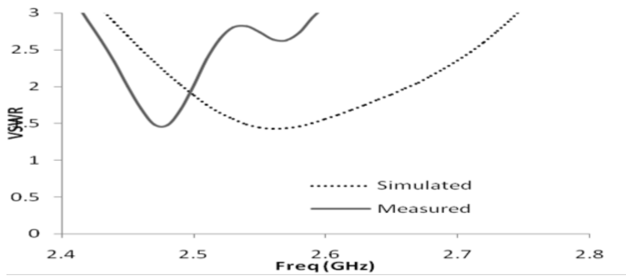


Fig. 14. Measured and simulated VSWR for proposed antenna (antenna 2).

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Percentage bandwidth at 10 dB is 6.53% and 4.48% for simulated and measured respectively.

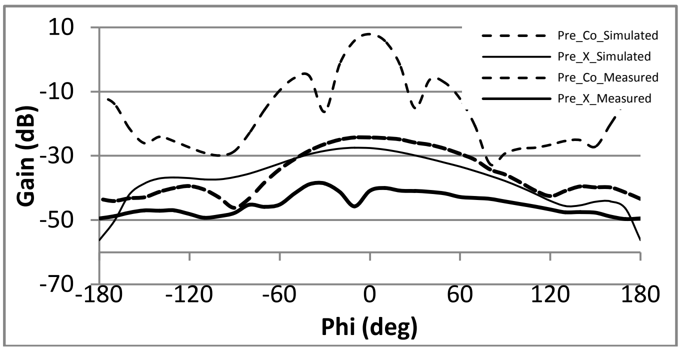

Fig. 15. Radiation pattern of simulated and measured Co and Cross polarization for antenna 2

Fig. 15 illustrates the radiation patterns for both the antennas. Integration of AMC makes it more directional which improves the gain. Significant suppression of Cross polarization level to -43.189 dB for antenna 1 and -44.39 dB for proposed antenna. The difference between simulated and measured radiation patterns was produced by faults in the fabrication process.

TABLE I. COMPARISON BETWEEN MEASURED RESULTS OF DEVELOPED ANTENNA (2) WITH ANTENNA (1)

Parameter	Antenna (1)	Proposed antenna (2)
Return Loss	-21.760 dB	-14.324 dB
VSWR	1.188	1.475
Bandwidth	6.45%	4.48% (lowered by
Gain	7.800 dB	14.492 dB (improved by 6.692 dB)
Directivity	12 dB	16.53 dB
X-polarization	-43.189 dB	-44.39 dB

IV. CONCLUSION

New AMC structure 4 x 1 microstrip patch antenna array and developed antenna array with multilayer PCB technology investigated for ISM band application. AMC structure along with feed lines reduces surface wave radiation which improves gain and cross polarization. Enhancement of front radiation pattern by restraining back lobe which is investigated by introducing multilayer stack up in proposed antenna. It uses cost-effective Stack up PCB fabrication process. Developed antenna consists of core laminate and two prepreg with an AMC structure having via along with feed line comprises size of 4.8λ x 1.76λ x 0.032λ with measured gain of 14.492dB, impedance bandwidth 4.48%.

REFERENCES

[1] GNANAM GNANAGURUNATHAN AND KRISHNASAMY T. SELVAN, "ARTIFICIAL MAGNETIC CONDUCTORS ON WIDE-BAND PATCH ANTENNA", PROGRESS IN ELECTROMAGNETICS RESEARCH LETTERS, VOL. 36, 9{19, 2013}.

[2] Risdy Reinaldi Ihsan And Achmad Munir, "Utilization Of Artificial Magnetic Conductor For Bandwidth Enhancement Of Square Patch Antenna" 7th International Conference On Telecommunication Systems, Services And Applications (Tssa), 2012, Published In Ieee Digital Xplorer 978-1-4673-4550-7/12.

[3] Sievenpiper, D., L. Zhang, R. F. J. Broas, N. G. Alexopolous, And E. Yablonovitch, "High-Impedance Electromagnetic Surfaces With A Forbidden Frequency Band," Ieee Trans. Microwave Theory Tech., Vol. 47, No. 11 2059–2074, 1999.

[4] M. F. Abedin And M. Ali, "Effects Of Ebg Reflection Phase Profiles On The Input Impedance And Bandwidth Of Ultrathin Directional Dipoles," Ieee Trans. Antenna Propag., Vol. 53, No. Ii, Pp. 3664-3672, Nov. 2005.

[5] F. Yang And Y. Rahmat-Samii, "Reflection Phase Characteristics Of The Ebg Ground Plane For Low Profile Wire Antennas," Ieee Trans. Antennas Propag., Vol. 51, Pt. I, Pp. 2691-2703, Oct. 2003.

[6] S. R. Best And D. L. Hanna, "Design Of A Broadband Dipole In Close Proximity To An Ebg Ground Plane," Ieee Antennas Propag. Mag., Vol. 50, No. 6, Pp. 52-64, Dec. 2008.

[7] A. Foroozesh And L. Shafai, "Application Of Combined Electric-And Magnetic-Conductor Ground Planes For Antenna Performance Enhancement," Can J Elect. Compul. Eng., Vol. 33, No. 2, Pp. 87-98, Spring, 2008.

[8] Huayan Jin, Kuo-Sheng Chin, "Differential-Fed Patch Antenna Arrays With Low Cross Polarization And Wide Bandwidths", Ieee Antennas And Wireless Propagation Letters, Vol. 13, 2014

[9] Luisa Deias, Giuseppe Mazzarella, Giorgio Montisci, And Giovanni Andrea Casula, "Synthesis Of Artificial Magnetic Conductors Using Structure-Based Evolutionary Design", International Journal Of Antennas And Propagation, Volume 2013, Article Id 607430, 7 Pages.