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Design of a Rectangular Microstrip Antenna with Artificial Magnetic Conductor Ground Plane

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Abstract- For wireless communication system such as 3G, GSM 1800, UMTS and Industrial, Scientific and Medical (ISM) band 2.4 technologies the reduced antenna size and good performance is needed. To improve the performance of antenna for short distance wireless communication artificial magnetic conductor(AMC) as ground plane.is preferred. The performances of the proposed antenna are studied using finite element method ANSOFT High Frequency Structure Simulator (HFSS). The proposed antenna is designed for frequency band between 2GHz. to 3 GHz. details of antenna design are described in this paper.

Keywords: *Artificial Magnetic Conductor, Rectangular Microstrip Antenna, Radiation, Bandwidth,*

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1. Introduction

Worldwide 3G technology has been on use in recent years with the combination GSM technology, so that the frequency bands are used more efficiently. ISM 2.4 technologies is able to establish the connection to wireless local area networks (WLANs) without the need GSM or 3G technologies and allows high speed internet access. The mobile devices which can operate on these communication technologies provide great advantages for users. It is desired that the mobile devices should be light weight and small. The size of mobile devices depends on antenna size too.Microstrip antennas have some advantages like havingsmall size, low weight being durable, being mounted easilybecause of their geometry and being produced easily using printed circuit technique. Therefore they are widely used on mobile devices. But they have some disadvantages such as lowradiation power, low bandwidth, surface waves and spurious radiation[4].

Microstrip monopole antennasare widely used in wireless communication applications, because they radiate in wide frequency band and have an appropriate radiation pattern. A conductive patch and microstrip feeding lines which are directly connected to the patch are on one of the surfaces of the dielectric layer of the microstrip antenna. The ground plane being coated with metal only along the microstrip feed line is the main feature which separates these antennas from microstrip patch antennas. This structure of microstrip antenna provides radiation in both planes. In addition, the ground plane which has large sizereduces the frequency of resonance, and also affects the impedance bandwidth [1]. Due to planar structure, light weight, small dimensions,having multi or wide frequency band and appropriate radiation pattern, microstrip antennas are preferred. One of the most important problems in microstrip antenna design is the fact that at lower resonant frequencies, the antenna size has to be very large. One of the ways to decrease the antenna size is to use a dielectric profile with a high dielectric constant. On the other hand, despite the increase in dimensions, dielectric profile with a low dielectric constant provides higher efficiency and bandwidth. Increasingthe height of the dielectric layer also increases the efficiency and bandwidth. However, the surface waves which are due to the increase of the height of the dielectric layer are not desirable,since the surface waves consume radiation power, comprise scattering at the corners of dielectric profile and causedistortions on the antenna radiation pattern and polarization characteristics [3]. On the other hand, at higher resonant frequencies, the directivity of microstrip antenna increases and omni-directional radiation pattern is distorted.

In this paper, we present a rectangular microstrip antenna with artificial magnetic conductor (AMC) ground plane to reduce antenna size and decrease the resonant frequency to lower frequencies. Furthermore this new antenna has lower distortion in its omni-directional radiation pattern at higher resonant frequencies.

2. Conventional rectangular microstrip antenna

RMSA is the simplest and widely used MSA configurations; the rectangular patch is defined by its length *L* and width *W*. The width of RMSA is comparable to thewavelength to enhance the radiation from the edges. Since the substrate thickness is much smaller than the wavelength.[2]

The conventional designed antenna, figure 1, covers the frequency band of 2GHz to 3 GHz to operate in desired communication technologies. The operating frequency of the conventional rectangular microstrip antenna is chosen to be 2.4GHz to cover the desired frequency band.

Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable since this provides better efficiency, larger bandwidth and better radiation. However, such a configuration leads to a larger antenna size. In order to design a compact Microstrip patch antenna, substrates with higher dielectric constants must be used which are less efficient and result in narrower bandwidth. Hence a trade-off must be realized between the antenna dimensions and antenna performance.[2]

For the fundamental TM10 mode, the length L shouldbe slightly lessthan l/2, where l is the wavelength in the dielectric medium. Here, l isequal to l0 /$\sqrt{\varepsilon_{eff}}$, where l0 is the free-space wavelength and $\varepsilon_{eff}$is the effective dielectric constant of the patch. The value of $\varepsilon_{eff}$is slightly less than ε_r,because the fringing fields around the periphery of the patch are not confinedn the dielectric substrate but are also spread in the air. The expression for calculating the value of $\varepsilon_{eff}$is given[1,2]

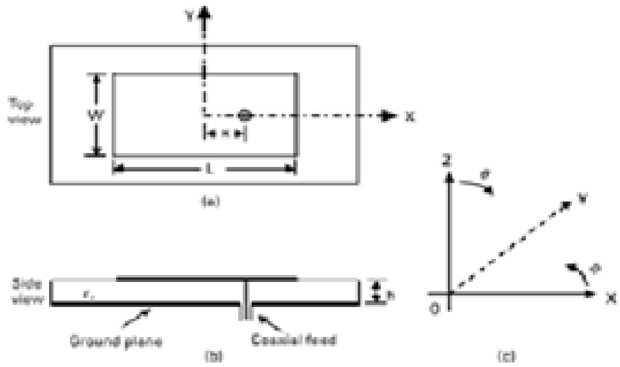

Figure 1. (a) Top View, (b) Side View, (c) coordinate system [2]

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1+12\frac{h}{w}]^{\frac{1}{2}} ....(2.1)$$

Where,

ε_{reff} = Effective dielectric constant

ε_r= Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

The edges along the width can be represented as two radiating slots, which are λ/2 apart and excited in phase and radiating in the half space above the ground plane. The fringing fields along the width can be modelled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given empirically as:[1]

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{w}{h}+0.8)} ....(2.2)$$

The effective length of the patchL_{eff}now becomes:

$$L_{eff}=L+2\Delta L$$

For a given resonance frequency f_o, the effective length is given by:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

For a rectangular microstrip patch antenna, the resonance frequency for any TM_{mn} mode is given by [2]:

$$f_o = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2+\left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}} ....(2.3)$$

Where m and n are modes along L and W respectively.For efficient radiation, the width W is given by [3]:

$$w = \frac{c}{2f_0\sqrt{\frac{(\varepsilon_r+1)}{2}}} ....(2.4)$$

3. Rectangular microstrip antenna with Artificial magnetic conductor ground plane

The artificial substrate miniaturized antenna size and improves the gain, bandwidth, and efficiency.

In our design, the optimum operating point is 2.4 GHz, where a 0° phase in reflection coefficient in AMC surfaces occurs. It corresponds to the operating frequency where the EBG structure behaves like an AMC surface. The results show that the phase reflection coefficient of the AMC surfaces crosses 0° at just one frequency (for one resonant mode). The useful bandwidth of an AMC is in general defined as +90° to —90° on either side of the central frequency, because these phase values would not cause destructive interference between direct and reflected waves. It is apparent from these results that the EBG structures behave as an AMC surface at least within a narrow frequency band near 2.4 GHz. This is true because the reflection coefficient magnitude is one while the phase angle is zero.[7],[9]

The unit cell dimensions shown in figure 2, are 2.25 mm for the hat length and width, along with a 0.38 mm diameter via. The gap between neighbouring hats is 0.15 mm. The substrate used is a 1.6 mm thick version of a common radio-frequency (RF) PCB core called FR-4 (from the NAN-YA

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Plastic Corporation china).It has a dielectric constant (ε_r) of 4.4 and a loss tangent (tan δ) of 0.02. This EBG was fabricated by etching away the gap regions of the copper on the top side of a FR4.4N core. The conductive via are "through holes" drilled and then plated through with nickel plus HAL green coat.

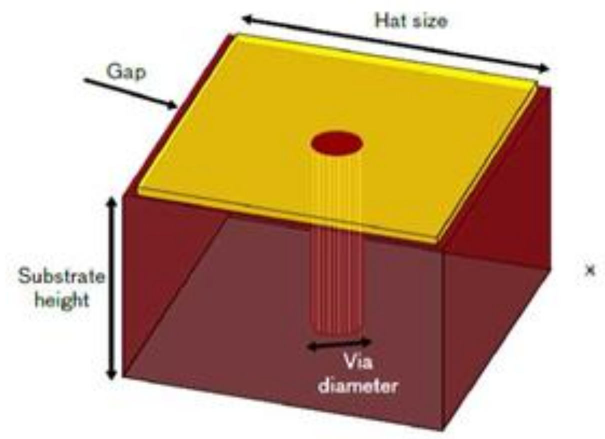

Figure 2. One unit cell Of AMC

The AMC structure is actually a simple unit cell repeated many times to form a surface. Each unit cell has three parts: the bottom metal ground plane layer, square metal hat on top, and a conducting via between the two, as shown in Figure 3. The dimensions of the hat are carefully determined such that there is a specific gap.

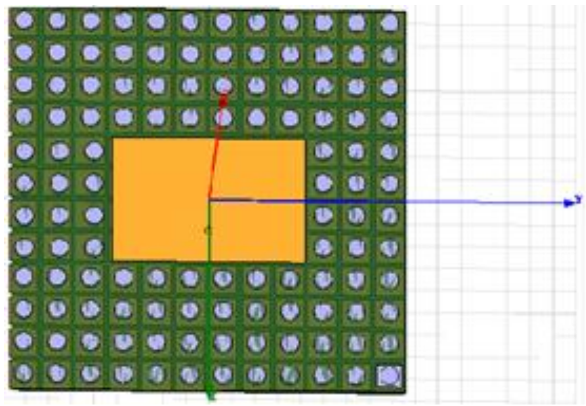

Figure 3. RMSA with AMC structure

4. Result Comparison and Conclusion

Simulations were done by using ANSOFT High Frequency Structure Simulator (HFSS).The parameter S_{11} of the conventional rectangular microstrip antenna which is obtained through HFSS simulations is given Fig. 4. The simulated impedance bandwidth, below 10 dB return loss, is between 2.4 GHz to 2.47GHzwhich meets the bandwidth specifications for ISM 2.4 and WIMAX.

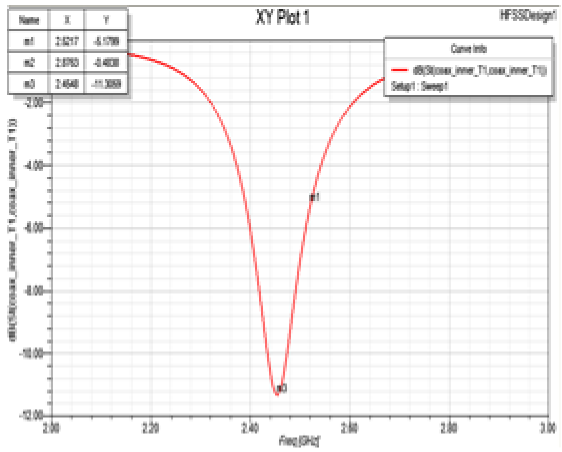

Figure 4. Simulated S11 response for conventional RMSA

The parameter S_{11} of the Rectangular microstrip antenna withAMC ground plane which is obtained through HFSSsimulations is given in Fig 5. The simulated impedancebandwidth, below 10 dB return loss, is between 2.3GHz to 2.88 GHzwhich meets the bandwidth specifications for ISM 2.4.

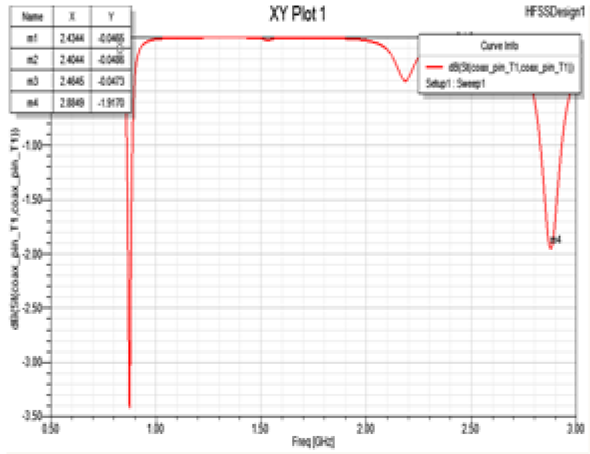

Figure5. Simulated S11 response for RMSA with AMC structure.

The radiation patterns also plotted and it is observed that the RMSA with AMC ground plane has better directivity and efficiency as compare to conventional RMSA. Hence, it meets the required properties for ISM 2.4.

By using AMC ground plane the antenna size is reduced but the bandwidth and efficiency are enhanced.

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