Enhancing Return Loss of Rectangular Microstrip Antenna Using AMC Ground Plane

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Abstract - *In wireless communication system especially in mobile communication system it becomes a challenge to reduce antenna size with enhancement of antenna performance. One of the method to improve antenna performance and reduce antenna size by using an artificial magnetic conductor (AMC) ground plane*
In this paper designing of rectangular patch antenna with AMC is described with the comparison of results found by using finite element method ANSOFT High Frequency Structure Simulator (HFSS) and results obtained from testing of fabricated antenna practically. The proposed antenna is designed for frequency band between 2GHz. to 3 GHz.

Key Words: Artificial Magnetic Conductor, Rectangular Microstrip Antenna, Radiation, Bandwidth

1. INTRODUCTION

Mobile technology is growing very fast globally so that the frequency bands are used more efficiently. ISM 2.4 technology is able to establish the connection to wireless local area networks (WLANs) without the need mobile service provider network and allows high speed internet access. The mobile devices which can operate on these communication technologies provide great advantages for users. It is preferred that the mobile devices should be light weight and small in size. The size of mobile devices depends on antenna size too. Microstrip antennas ensure some advantages as having small size, low weight with durability, mount easily as their geometry is easy and can be produced easily using printed circuit technique. Thus they are commonly used on mobile devices.

Microstrip monopole antennas are widely used in wireless communication applications, because they radiate in wide frequency band and have an appropriate radiation pattern. [1]. With all the advantages of microstrip antennas are preferred but there are few problems in microstrip antenna design; which at lower resonant frequencies, the antenna size has to be very large. The antenna size can be decreased by using a dielectric profile with a high dielectric constant. Whereas, the increase in dimensions, dielectric profile with a low dielectric constant provides higher efficiency and bandwidth. Increasing the 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 ,as the surface waves consume radiation power, consist of scattering at the corners of dielectric profile and cause distortions 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. The comparison of results found by using finite element method ANSOFT High Frequency Structure Simulator (HFSS) and results obtained from testing of fabricated antenna practically.

2. RETURN LOSS AND VOLTAGE STANDING WAVE RATIO[11]

Return loss is the best and convenient method to calculate the input and output of the signal sources; when the load is mismatched the whole power is not delivered to the load and there is a return of the power and that is called the 'Return loss'. The return loss and VSWR measurements are main measurements for cable and antenna. These measurements show the operator the match of the system and if it conforms the specifications. If problems show up during test, there are chances that the system has problems which can affect the end user. A poorly matched antenna or mismatched antenna will reflect more RF energy which will not be available for transmission but get collapsed in the transmitter. This additional energy reverted to the transmitter will distort the signal and reduces the efficiency of the transmitted power and the corresponding coverage area.

Importance of VSWR parameter is to show a maximum power transfer from transmitter to antenna for the antenna to perform powerfully. This happens only when the impedance Zin is matched to the transmitter impedance, Zs. In the process of achieving this particular configuration for an antenna to perform efficiently there is always a reflection of the power which leads to the standing waves, which is characterized by the Voltage Standing Wave Ratio (VSWR). This is given by

$$VSWR = \frac{V_{max}}{V_{min}} = \frac{1+|\Gamma|}{1-|\Gamma|} = \frac{1+S_{11}}{1-S_{11}}$$

3. CONVENTIONAL RECTANGULAR MICROSTRIP ANTENNA

One of the simplest and widely used MSA configurations is the RMSAA rectangular patch which is defined by its length *(L)* and width *(W)*. In RMSA, the width is comparable to the wavelength to enhance the radiation from the edges. [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.

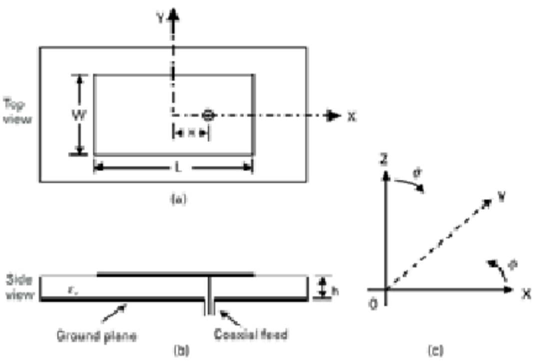

Figure 1. (a) Top View, (b) Side View, (c) coordinate system [2]

For the fundamental TM10 mode, the length *L* should be slightly less than l/2, where l is the wavelength in the dielectric medium. The expression for calculating the value of effective dielectric constant ε_{eff} is given [1,2]

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{\frac{1}{2}} \quad \text{.........(3.1)}$$

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 represents 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 so 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 Δ*L*, which is given empirically by Hammers tad as:

$$\Delta L = 0.412h\,\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad \text{.......(3.2)}$$

The effective length of the patch L_{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]:

$$f_o = \frac{c}{2\sqrt{\varepsilon_{reff}}}\left[\left(\frac{m}{L}\right)^2 + \left(\frac{n}{W}\right)^2\right]^{\frac{1}{2}} \quad \text{..............(3.3)}$$

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

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r+1)}{2}}} \quad \text{...(3.4)}$$

4. 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.

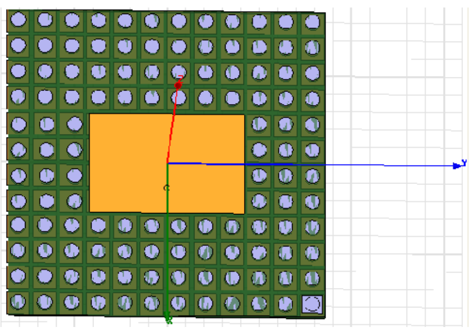

Figure 2. RMSA with AMC structure

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 2. The dimensions of the hat are carefully determined such that there is a specific gap.

5. 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 Figure 3. The simulated impedance bandwidth, below 10 dB return loss, is between 2.4 GHz to 2.47GHz which meets the bandwidth specifications for ISM 2.4 and WIMAX.

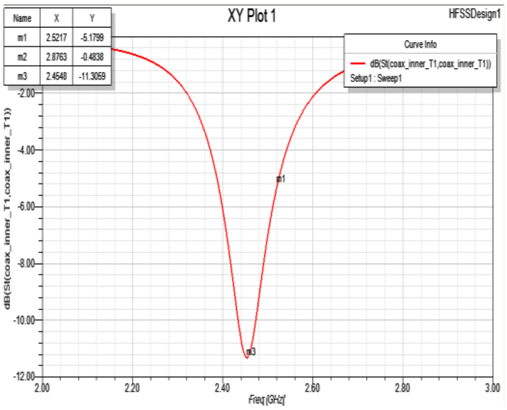

Figure 3. Simulated S_{11} response for conventional RMSA

The parameter S_{11} of the conventional rectangular microstrip antenna which is obtained for practical fabricated antenna are observed and measured on Network Analyzer and figure 4 shows the result observed. The impedance bandwidth,about 10 dB return loss, is between 2.4 GHz to 2.47GHz which meets the bandwidth specifications for ISM 2.4 and WIMAX.

Figure 4. Practically observed S_{11} response for conventional RMSA

The parameter S_{11} of the Rectangular microstrip antenna with AMC ground plane which is obtained through HFSS simulations is given in Figure 5. The simulated impedance bandwidth, below 10 dB return loss, is between 2.3GHz to 2.88 GHz which meets the bandwidth specifications for ISM 2.4.

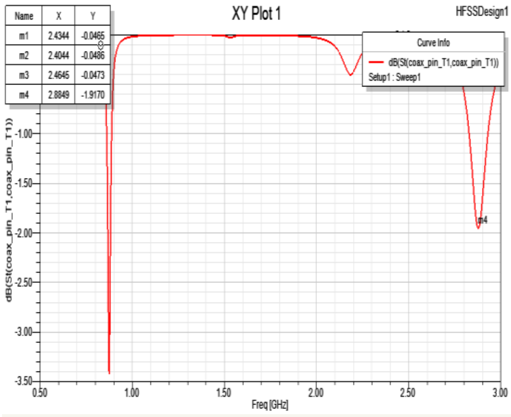

Figure 5. Simulated S_{11} response for RMSA with AMC

The parameter S_{11} of the Rectangular microstrip antenna with AMC ground plane which is obtained through practically and observations are given in Figure 6. The simulated impedance bandwidth, below 10 dB return loss, is between 2.3GHz to 2.88 GHz which meets the bandwidth specifications for ISM 2.4.

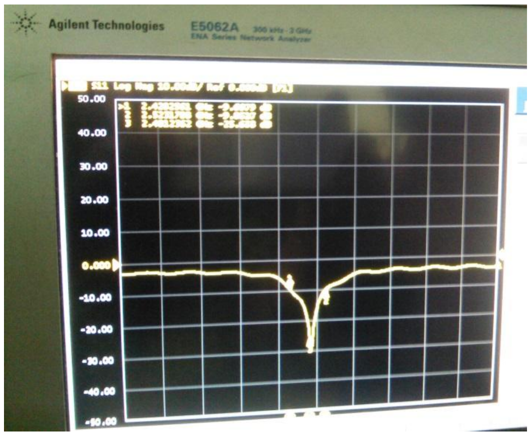

Figure 6. Practically observed S_{11} response for RMSA with

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, efficiency and VSWR are enhanced which are observed practically by testing designed antenna on Network Analyser.

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