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

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Abstract

The design and characterization of a novel broadband microstrip antenna with artificial magnetic conductor ground plane (AMC) is presented in this paper. It is suitable for applications which include GSM 1800, UMTS and ISM 2.4 technologies. An artificial magnetic conductor ground plane is used to improve the antenna performance and reduce antenna size. The performances of the proposed antenna are studied using finite element method ANSOFT High Frequency Structure Simulator (HFSS), and then the designed antenna is realized and validated by measurements. It was observed in the network analyzer measurements of the proposed antenna that the designed antenna has 1.1 GHz impedance bandwidth which is obtained between the frequencies of 1.7 GHz and 2.8 GHz. Details of the proposed antenna design are described, and experimental results are presented.

1. Introduction

In our country and around the world, beside GSM technology which has been widely used for many years, 3G technology has been on use in recent years and today a combination of both technologies is used. Low bandwidth and slow data transmission speed of GSM technology is sufficient for normal calls, whereas 3G technology is used in cases where high data transmission rates and bandwidth is required such as video calling, video messaging, video sending and sharing applications. Thus, 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 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. Beside the properties above that are provided by a mobile device, it is mostly desired for a mobile device to be light and small. The main factor that determines the size of mobile devices is the antenna's dimensions which are used in mobile devices. Microstrip antennas have some advantages like having small size, low weight, being durable, being mounted easily because 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 low radiation power, low bandwidth, surface waves and spurious radiation.

In wireless communication applications in which different frequency bands are covered with a single antenna, the antenna has to be multiband or wideband. Microstrip monopole antennas are 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 monopole 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 monopole antenna provides radiation in both planes. In addition, the ground plane which has large size reduces 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, monopole microstrip antennas are preferred. One of the most important problems in microstrip monopole 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. 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, since the surface waves consume radiation power, comprise scattering at the corners of dielectric profile and cause distortions on the antenna radiation pattern and polarization characteristics [2]. On the other hand, at higher resonant frequencies, the directivity of monopole microstrip antenna increases and omni-directional radiation pattern is distorted.

In this paper, we present a new broadband microstrip monopole antenna with artificial magnetic conductor (AMC) ground plane to reduce antenna size and decrease the resonant frequency to lower frequencies [3,4,5]. Furthermore this new antenna has lower distortion in its omni-directional radiation pattern at higher resonant frequencies. Firstly, conventional circular monopole antenna which supports the desired communication technologies is designed. Secondly, a broadband circular monopole antenna with artificial magnetic conductor ground plane is designed to reduce antenna size, minimize the cross polarization and prevent the distortion in its omni-directional radiation pattern. Finally, positive and negative effects of the artificial magnetic conductor ground plane are examined.

2. Conventional Circular Monopole Antenna Geometry and Design

The basic parameters of a broadband microstrip antenna design procedure are operating frequency, bandwidth, dielectric constant and dielectric layer height. In addition, the designed antenna must satisfy the following properties: operating in the desired frequency band, having the sizes which are suitable for use in mobile devices, being durable and mounted easily [1].

The designed antenna covers the frequency band of 1710-2500 MHz to operate in desired communication technologies. The operating frequency of the conventional circular monopole antenna is chosen to be 2100 MHz to cover the desired frequency band. Due to being cheap, readily available and simple production process, FR4 epoxy with a height of 1.6 mm is preferred for the dielectric layer. The conventional circular monopole antenna structure is given Fig. 1.

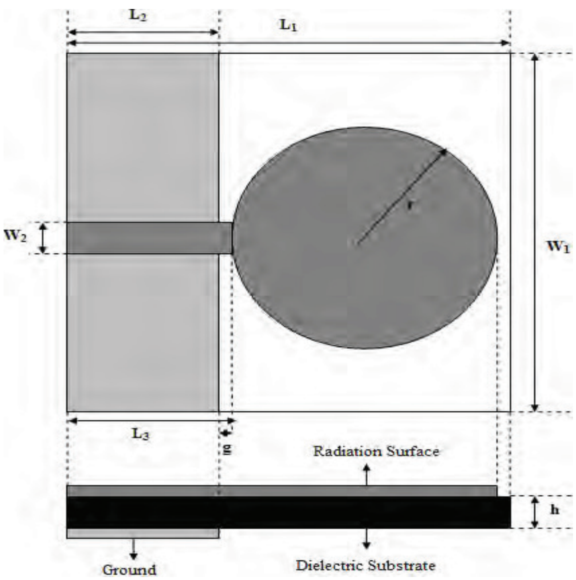


Fig. 1. The conventional circular monopole antenna structure.

Equation (1) is used to calculate the radius of the circle of monopole antenna structure [2].

$$r = \frac{87.94}{f_0\sqrt{\varepsilon_r}} \qquad (1)$$

where f_0 is the operating frequency in GHz. As seen in the equation (1), at the low frequency values of operating frequency, the radius of the circle increases. As a result the antenna size increases. The dimension for the dielectric substrate is W_1 mm x L_1 mm. The circular patch is fed by a 50 ohm microstrip feed-line of width W_2 and placed at a distance L_3. The dimensions of the conventional circular monopole antenna are given in Table 1.

Table 1. Dimensions of conventional circular monopole antenna

W_1	W_2	L_1	L_2	L_3	g	r
60	3	60	16	17.4	1	20

3. Circular Monopole Antenna with Artificial Magnetic Conductor Ground Plane Design

An artificial magnetic conductor ground plane is often used to reduce antenna size, minimize the cross polarization, increase gain and bandwidth [4]. An artificial magnetic conductor ground plane structure which is used in our antenna design is given Fig. 2.

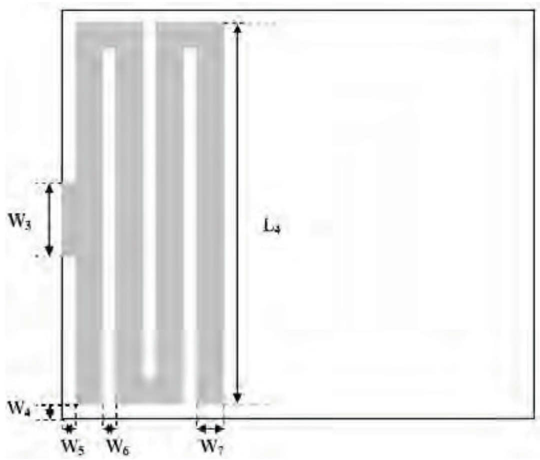


Fig. 2. The artificial magnetic conductor ground plane structure.

Considering the ground plane as perfect electric conductor (PEC), the electric field is normal to the plane whereas the magnetic field is parallel to the plane. By using AMC ground plane, magnetic fields which are normal to the ground plane are obtained. The circular monopole antenna with AMC ground plane design is given Fig. 3.

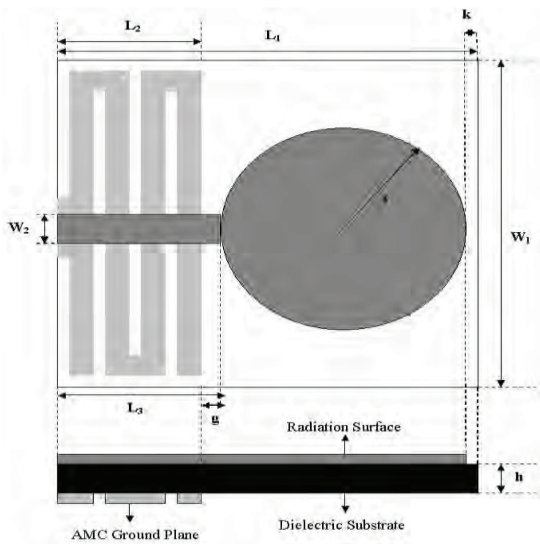


Fig. 3. The circular monopole antenna with AMC ground plane.

If an artificial magnetic ground plane is used instead of a conventional ground plane, the equivalent inductance increases and the antenna resonates at lower frequencies [4]. We have replaced the ground plane of the conventional monopole antenna with AMC ground plane without changing its size. As a result of this we have observed that the resonant frequency of the antenna is reduced to lower frequencies. However the bandwidth of the antenna became narrower in comparison to the conventional monopole antenna. Afterwards by decreasing the size, we tried to obtain an antenna with AMC ground plane which radiates in the desired frequency band. We observed that the designed antenna's size was reduced %18.

In circular monopole antenna with AMC ground plane design, the parameters of the dielectric substrate remain same as the conventional circular monopole antenna. The dimensions of the circular monopole antenna with AMC ground plane are given in Table 2.

Table 2. Dimensions of circular monopole antenna with AMC ground plane

W_1	W_2	W_3	W_4	W_5	W_6	W_7
50	5	3	0	1	1	2
L_1	L_2	L_3	L_4	r	g	k
50	15	15.4	50	17.4	0	0.2

The fabricated circular monopole antenna with AMC ground plane is shown in Fig. 4.

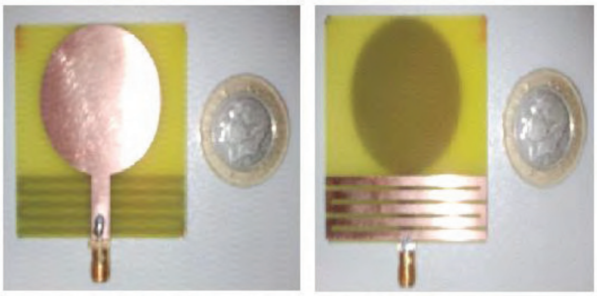


Fig. 4. The fabricated circular monopole antenna with AMC ground plane.

4. Simulation and Measurement Results

Both simulations and measurements investigated the designed antenna performance. Simulations were done by using ANSOFT High Frequency Structure Simulator (HFSS) and measurements were done by using HP 8510 network analyzer. The parameter $|S_{11}|$ of the conventional circular monopole antenna which is obtained through HFSS simulations is given Fig. 5. The simulated impedance bandwidth, below 10 dB return loss, is between 1560-4210 MHz and 4500-5900 MHz which meets the bandwidth specifications for GSM 1800, UMTS, ISM 2.4, WIMAX and ISM 5.2.

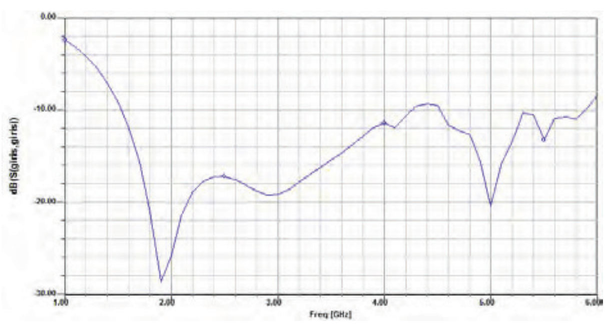


Fig. 5. The simulated parameter $|S_{11}|$ of the conventional circular monopole antenna.

The parameter $|S_{11}|$ of the circular monopole antenna with AMC ground plane which is obtained through HFSS simulations, is given in Fig. 6. The simulated impedance bandwidth, below 10 dB return loss, is between 1650-2580 MHz which meets the bandwidth specifications for GSM 1800, UMTS and ISM 2.4.

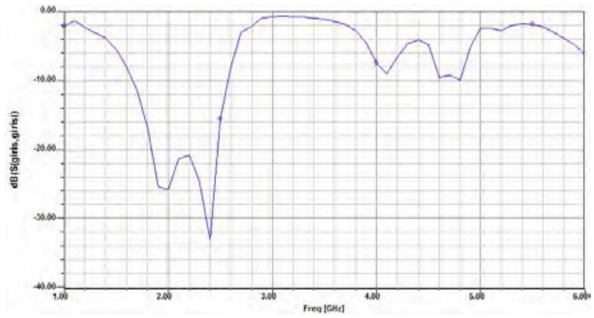


Fig. 6. The simulated parameter $|S_{11}|$ of the circular monopole antenna with AMC ground plane.

The simulated 3-D gain diagrams of the conventional circular monopole antenna are given in Fig. 7.

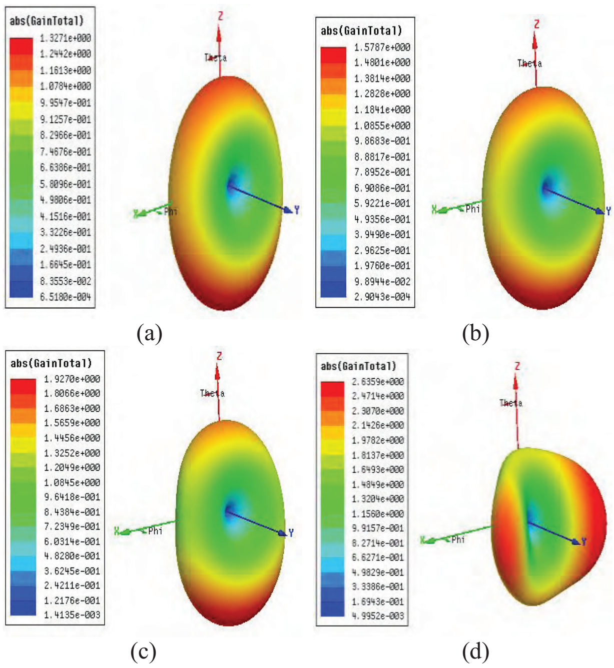
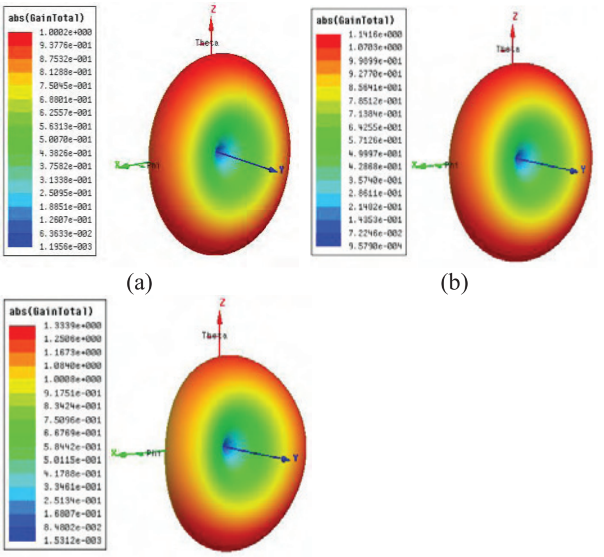


Fig. 7. The simulated 3-D gain diagram of the conventional circular monopole antenna. (a) 1790 MHz. (b) 2050 MHz. (c) 2450 MHz. (d) 3500 MHz.

The simulated 3-D gain diagram of the conventional circular monopole antenna with AMC ground plane are given in Fig. 8.



(a) (b) (c)

Fig. 8. The simulated 3-D gain diagram of the circular monopole antenna with AMC ground plane. (a) 1790 MHz. (b) 2050 MHz. (c) 2450 MHz.

Comparing Fig. 8 with Fig. 7, it is observed that the circular monopole antenna with AMC ground plane has a better omni-directional radiation pattern within the frequency band of interest than the conventional circular monopole antenna. The radiation pattern on x-y plane (end-fire radiation) is better when compared to the conventional circular monopole antenna. These properties apply to all three frequency bands, namely GSM 1800, UMTS and ISM 2.4.

Return loss of the circular monopole antenna with AMC ground plane which is obtained through network analyzer measurements, is given in Fig. 9. The simulated impedance bandwidth, below 10 dB return loss, is between 1700-2800 MHz which meets the bandwidth specifications for GSM 1800, UMTS and ISM 2.4.

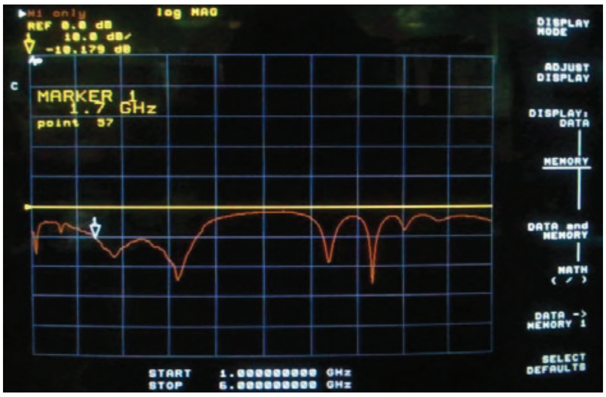


Fig. 9. The measured return loss of the circular monopole antenna with AMC ground plane.

5. Conclusions

In this paper, a novel circular monopole antenna with AMC ground plane is designed and manufactured. It operates in the frequency range of 1.7 GHz and 2.8 GHz. The AMC ground plane is used to reduce antenna size and decrease the resonant frequency to lower frequencies. The antenna has suitable size and omni-directional radiation pattern which allow us to use it for GSM 1800, UMTS and ISM 2.4.

6. References

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