Design and Measurement of Novel Type EBG Reflector using Artificial Magnetic Conductor

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Abstract

Novel artificial magnetic conductor (AMC) as the reflector are designed and measured. We designed a transformed symmetrical mushroom-like surface without a via hole on the cell. Each slot in the structure plays a key role in modeling at the desired frequencies. The structure of the unit cell is focus on the wireless LAN band (2.4 GHz). The antenna on the AMC reflector is working within a quarter-wavelength. For the measured result, a reflection coefficient shows 3 dB differences between the AMC and the PEC reflector. Moreover, a radiation pattern has similar shape with the calculated result.

Keywords : Artificial Magnetic Conductor, Electromagnetic Bandgap, Reflector, Mushroom-like Surface, High Impedance Surface, Wireless LAN

1. Introduction

In modern wireless communication systems, light weight, small size, and low profile antennas with good radiation efficiency are desired due to easily integrated with RF and microwave circuits [1-2]. New types of ground planes, which are artificial magnetic conductors (AMCs) or electromagnetic bandgap (EBG), have been studied roundly. The EBG surface is consisted of periodic AMCs. The AMC has an unusual boundary condition; therefore, the AMC is able to use a new type of ground plane. The realization of new ground planes has been an active area instead of perfect electric conductors (PECs) for antennas or microwave applications due to a back-radiation shield and a gain increase [3].

The most special characteristic of the AMC structure is that the reflection phase changes from +180 ° to -180 ° as the frequency linearly decreases. When we compare the AMC and PEC reflector with the dipole antenna, the AMC reduces the antenna's profile to about λ/10 without affecting its performance; however, the PEC separates a quarter-wavelength for optimized radiation because of the reverse image currents which reduce the radiation efficiency [4-6].

Synthetically, these surfaces have two special characteristics. The first is to behave as perfect magnetic conductors, so the parallel image currents appear in-phase rather than out-of-phase. Therefore, this structure could be possible efficient radiation close to antennas or surfaces. The second is to control the propagation from electromagnetic waves at the frequency band, so that the multipath interference eliminates and the radiation patterns are clear.

In this paper, we present a novel AMC surface. To verify the properties of the designed AMC, the structure of a unit cell has been simulated and analyzed; also, the dipole antenna above the designed AMCs is simulated and analyzed.

2. Design and Characterization of AMC

Depending on the structure of the unit cell used to implement the high impedance surfaces, the behaviours of AMCs should appear in the desired frequency band. The geometry of the basic cell is shown in Fig. 1. The unit cell is printed on the FR-4 PCB (dielectric constant=4.6, thickness=2.54 mm). Its centre frequency is 2.4 GHz, with a bandwidth of 12.6 %.

Table 1: Summary of specific values of patches

Section	Specific values(mm)	Section	Specific values(mm)
W	21	H	21
a	2	b	2
s	1	g	0.5

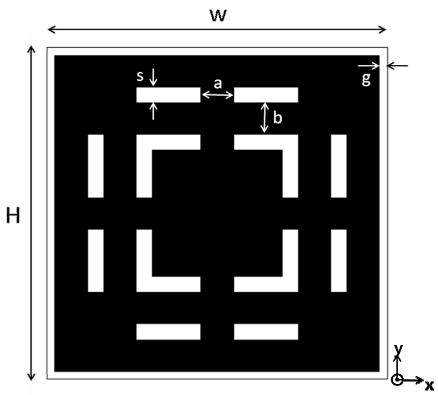

Fig. 1. Mushroom-like surface without via

The frequency in which the reflected phases for all cases are 0 ° is fixed to the same value. Using the simulation tool by the FDTD method, we have designed all structures to contain in-phase reflection on their surfaces for normal incident planes at 2.4 GHz. In order to fix the desired resonant frequency, the basic cell size is required to determine about 0.133 λ × 0.133 λ (wavelength of 2.4 GHz) or 20 mm × 20 mm at least. The distance between cells are 0.003 λ and 0.003 λ in x and y direction, respectively. The complete array has a size of 294 mm × 294 mm or 1.96 λ × 1.96 λ, and 14 × 14 cells.

The reflection phase determines the frequency range in which the characteristics of AMC are observed. Figure 2 shows the simulated and measured reflection phase of the designed AMC. For a frequency of 2.4 GHz, in-phase reflection is observed in all surfaces. When the ground planes are periodic, the reflection phases have periodic repeat from +180° to -180°. When l patches are connected to other patches, that is, the AMC surfaces would be a planar type, the zero degree reflection phases have become to move higher frequency bands. Otherwise the frequency band has become small and short period. In case of the absence of via, there is not a special difference as compared with the presence of via in proposed models. Therefore, we could fabricate the structure easily.

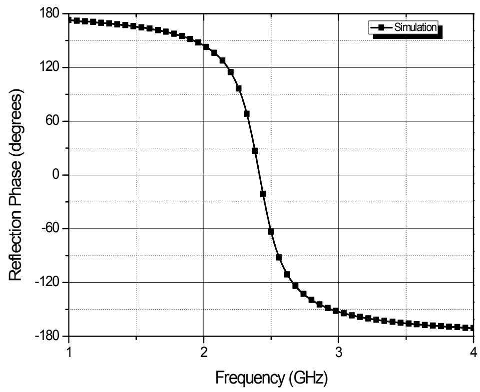

Fig. 2. The simulation results of the reflection phase.

3. Measurement and Analysis

The basic dipole antenna close to the conventional metallic reflector has very poor performance (smaller than a quarter-wavelength). The image currents appear out-of-phase rather than in-phase, so that the radiation in the antenna is cancelled out by the currents. However, the performance is greatly improved when the AMC surface as the reflector uses. In order to prove this fact, we measured and analyzed the radiation patterns of dipole antenna placed above the PEC and AMC reflector for comparison. By the calculation result, the length of the dipole antenna is about 62.5 mm at 2.4 GHz. For the measurement of radiation pattern in the laboratory, the vector network analyzer connected with two antennas for WLAN (2.4 GHz) is used.

First of all, we measured the radiation pattern of the AMC reflector. The measurement environment should be satisfied the far-field condition. The boundary of the far-field regions is defined as in many textbooks, and depends on the dominant wavelength (λ) emitted by the source. The far-field region is written as follows:

$$r \gg \lambda = \frac{c}{f} = \frac{3 \times 10^8 \,[\mathrm{m/s}]}{2.4 \times 10^9 \,[\mathrm{Hz}]} = 0.125 \,[\mathrm{m}]$$

Above expression from which the radiation region can be considered as far-field region, is applied to our measurement. The measurement is performed by the network analyzer and at every 15 degrees in the E-plane. One antenna is located on the reflector, and another antenna is placed over the reflector apart from 30 cm for enough condition. Therefore, the distance between two antennas our measurement environment is satisfied with the far-field condition.

Figure 3 shows the measured amplitude results of each reflector at 2.4 GHz. The results between the AMC and the PEC surface are -26.7 dB and -29.1 dB. These are almost 3 dB differences, that is, the AMC reflector worked within a quarter-wavelength.

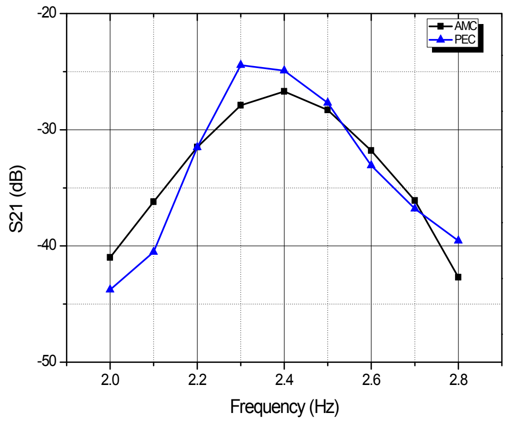

Fig. 3. Amplitude results of reflectors at 2.4 GHz

The radiation pattern of the antenna with the AMC reflector is shown in Figure 4. This result is similar with the calculation result. Then we analyze the difference between the AMC and PEC reflectors.

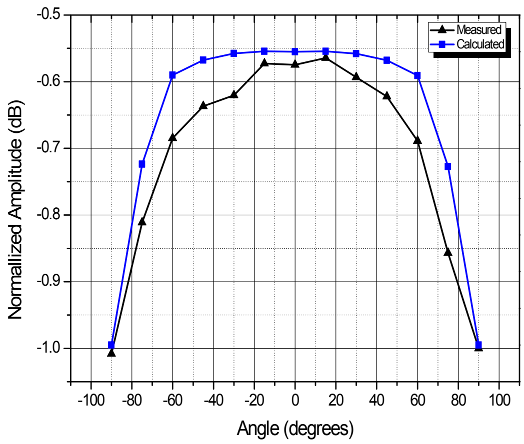

Fig. 4. Radiation pattern in the E-plane

4. Conclusion

We designed and investigated novel structures of the artificial magnetic conductor. The AMC structure has been designed for the reflector. By the simulated and measured results of the reflection phase, the designed structure is performed at 2.4 GHz band for WLAN application. For measuring the radiation pattern, the radiation patterns are measured by the network analyzer. The measured results of the radiation patterns at the angles from 180 degrees to -180 degrees have been showed a semicircular shape. By the results of the radiation patterns between the AMC and PEC reflector, we recognized that the AMC reflector is exactly performed within a quarter-waveguide. This reflector can be made a decrease in the size of systems of which is using a reflector.

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