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DESIGN OF SINGLE-BAND STAR GEOMETRIC PATTERN ARTIFICIAL MAGNETIC CONDUCTOR

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ABSTRACT

Single-band Star Geometric Pattern Artificial Magnetic Conductors (Star GP AMC) resonated at 2.45 GHz has been presented in this paper. The simulation has been done to the basic star AMC design and Star GP AMC design. In this study, the reflection phase bandwidth, angular stability and band gap appearance were analyzed. The results reveal that the Star GP AMC has miniaturized about 8% with 3.27% reflection phase bandwidth and have significant angular stability from 0^0 to 60^0 incidence angles. It was also found out that no band gap appeared on frequency range of the resonance frequency.

Keywords: single-band, AMC, star geometric pattern.

INTRODUCTION

Various types of metamaterials are listed by Shridhar E. Mendhe and Yoogeshwar Prasad Kosta in their journal paper [1]. High Impedence Surface - Artificial Magnetic Conductor (HIS-AMC) is one of the applications to reduce coupling in various antenna arrays. AMCs are designed with periodic geometric pattern on the top of a grounded dielectric substrate in order to achieve zero degree reflection phase at their resonant frequency. The resonant frequency is actually the point where the AMC mimics the behavior of perfect magnetic conductor (PMC) characteristics, which does not naturally exist [2].

Align with the latest technology applications, high demands given to flexible and small size AMC. Furthermore in recent years, the motivation to study AMC design by most researchers are due to the applicability of AMC in increasing gain, reducing back lobe radiation, broadening bandwidth, and miniaturizing the size of the antenna [2-5, 7-9, 11]. Several AMC structures with few applications are studied and compared. There are many applications which make AMC to be interesting, such as Radio Frequency Identification (RFID) tags over metallic object [4-9], Wi-Fi applications [2,10], as well as for low profile antenna and microstrip patch antenna [2,3,11]application.

Focus has been given to the AMC miniaturization method, and also in bandwidth improvement method due to the new technology constraint. The method used by M. Abu et al. [5] in miniaturizing the structure size is by introducing variation of slots size to the AMC design. Meanwhile, [4] has presented the octagonal AMC by using bendable substrate with Defect Ground Structure (DGS). The bandwidth of the octagonal AMC has increased by 88.46%. Whereby in [2], DGS has been integrated at the bottom of the AMC unit cell and has successfully improves the bandwidth of the designed AMC by 70.27%.

Angular stability is the other AMC characteristic which is important in some application such as RFID tags, or wearable antenna [12]. Material with better angular stability is also called as isotropic materials [11]. The term isotropic material is used for those materials whose response to incidence EM waves is not a function of the angle of incidence.

In this study, a design of single-band Star Geometric Pattern (Star GP) AMC resonated at 2.45 GHz is presented. Bendable dielectric substrate is used to take the advantage of flexibility for the AMC structure. A star pattern is the basic idea in this design, and the design is possibly relatively small when introducing geometric slot pattern. The presented single-band Star GP AMC has good AMC operation bandwidth, with polarization angle independency, and high angular stability.

Basic Star Design

Rogers RO3010 has been used as a substrate in designing AMCs, where the dielectric permittivity ε_r = 10.2, loss tangent = 0.0023 and thickness = 1.28 mm. AMC design initially starting with tetragon shape design where the resonating frequency is at 2.45 GHz with structure size of 28 mm x 28 mm as shown in Figure-1(a). Then, by combining same size of tetragon and square shape, the design right now can be called as basic star pattern as shown in Figure-1(b). The basic star AMC design also is resonated at 2.45 GHz with 25 mm x 25 mm structure size.

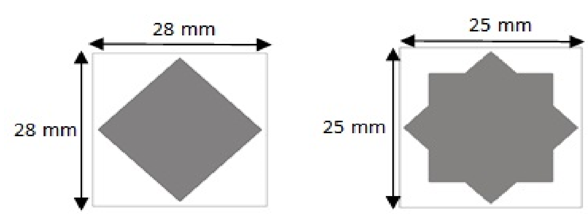

Figure-1. AMC design resonated at 2.45 GHz (a) Tetragonshape AMC design (b) Basic Star AMC design

The simulation results of reflection phase comparison between tetragon shape AMC and basis star AMC are shown in Figure-2.From the results, it shows that the reflection phase bandwidth of tetragon shape AMC is relatively small compared to the basic star AMC design. The reflection phase of basic star AMC falls from 2.4022 GHz to 2.4938 GHz at ± 90^0 respectively as in Figure-2. This given 3.74% bandwidth percentage for the basic star design. Meanwhile the tetragon shape AMC given 3.01% bandwidth percentage of reflection phase.

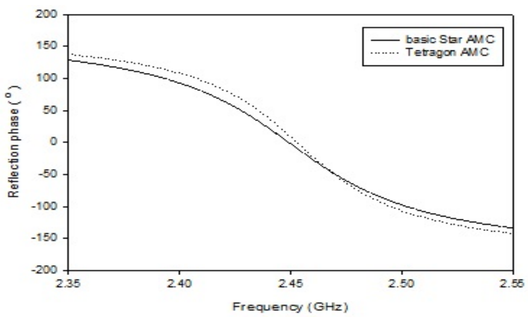

Figure-2. Reflection phase of tetragon and basic Star AMC design

The above finding can proved that the bandwidth of basic star AMC is increased by 24.25% with 10.71% decreased in structure size. Considering bandwidth Eqn. (3) in [4], the bandwidth has increased for basic Star AMC possibly due to the increment of the gap size between the metallization edge and unit cell-edge. The increment brings to the decrement of capacitance of the element, so that the bandwidth increasing correspondingly.

Referring to the previous research [2,4], Defect Ground Structure (DGS) given better bandwidth for the AMC reflection phase. With intention of that, DGS ground plane has been implemented to the basic star AMC design. Figure-3 shows the implementation of DGS ground plane with opposite metallization shape at the back of basic star AMC design. Then, the Effect of DGS ground plane implementation has been compared with the full ground plane as in Table-1.

Figure-3. DGS ground plane with opposite metallization shape at the back of AMC substrate.

Table-1. Comparison between basic star AMC with Full ground plane and DGS ground plane resonated at 2.45 GHz.

	Full ground plane	DGS ground plane
Structure size (mm x mm)	25 x 25	26 x 26
Bandwidth (%)	3.74	3.98

From the results, it shows that the reflection phase bandwidth of basic star AMC with DGS ground plane is slightly increased by 6.42% with the structure size increment of 4%. Therefore itcan be conclude that, basic star AMC with DGS ground plane has better bandwidth but the size will also need to be increased. With the aim of small size AMC, the usage of full ground plane is preferred for this study.

Star geometric pattern AMC design reflection phase at 0^O

Geometric slot pattern has been introduced to miniaturize the size of the basic star AMC. There are two kinds of slots which are triangle slot and arrow slot pattern as shown in Figure-4. The slots shapes are preferred with the objective to incorporate Islamic value to the Star Geometric Pattern AMC (Star GP AMC) design. Islamic design can be referred as the design that has always been used in Islamic environment or Islamic culture. Islamic culture is quite relative to Malaysian because more than 60% of Malaysians are Muslim.

Four triangle slots and four arrow slots are introducedin basic star AMC to beStar GP AMC. Through the slots combination, there is another basic star pattern appeared at the center of the Star GP AMC. By inserting the slots to the actual size of basic star AMC also makes the resonance frequency has been decreased. Hence, to increase the frequency back to 2.45 GHz, the size of Star GP AMC has to be reduced. This shows that, introducing slots to the design can miniaturize the AMC design. After the optimization process, the new size of the Star GP AMC is 23 mm x 23 mm, with 3.27% of bandwidth.

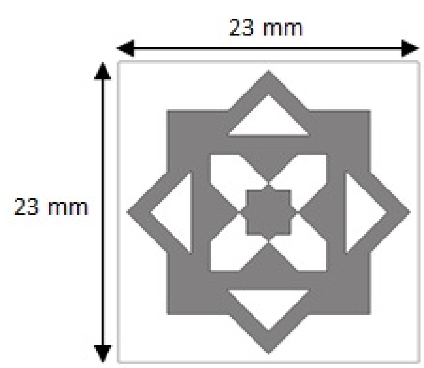

Figure-4. Star GP AMC with four triangle slots and four arrow slots.

Again, the DGS ground plane has been implanted to the design to see the effect. Unfortunately, with DGS ground plane and new size of 24 mm x 24 mm to resonate at 2.45 GHz, Star GP AMC with four triangle slots and four arrow slots has bandwidth percentage approximately equal to the full ground plane as shown in graph of Figure-5. So, it can reveals that there is no DGS effect to the reflection phase bandwidth of star GP AMC design, except the size need to be increased for 4.35%. As declared before, with the purpose to have the small size

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AMC, the Star GP AMC with full ground plane was preferred to be the sample for next analysis which are angular stability and band gap analysis.

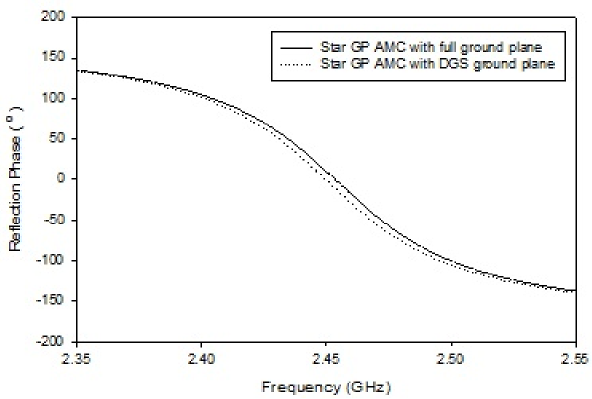

Figure-5. Reflection phase of Star GP AMC with different ground plane

Reflection phase for different angle of incidence

Angular stability of Star GP AMC is then being analyzed. The AMC performance under different polarization of the electric incident field with incidence angle varies from 0o to 60o has been analyzed. The simulation results of reflection phase at difference incidence angle of Star GP AMC are shown in Figure-6. From the obtained results, it shows that the resonance frequency did not really affect by the incident angle changes. However, there is some decreasing of bandwidth as the incidence angle increased. It can be conclude that the Star GP AMC design has high angular stability, and can be called as isotropic AMC.

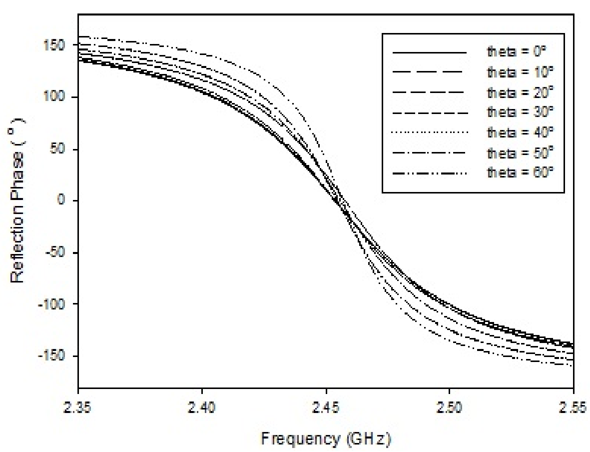

Figure-6. Reflection phase of Star GP AMC at difference incidence angle from 0° to 60°.

Band Gap analysis

Band gap can occasionally appear for certain AMC design as shown in previous research [10], where the hexagonal AMC design causing EBG band appears at the resonance frequencies when the suspended 50 Ω microstrip line method is applied. Meanwhile, band gap has also been studied by using transmission line method [6] (same method as suspended 50 Ω microstrip line method) where single-band zigzag dipole AMC is not showing any band gap at the specific frequency range.

Hence, by using the same method, band gap has been analyzed for the (3x4) periodic structure Star GP AMC as shown in Figure-7. The Star GP AMC has been layered with a layer of substrate and a transmission line on the top of the substrate. From the CST simulation, S11 and S21 results are as shown in Figure-8.

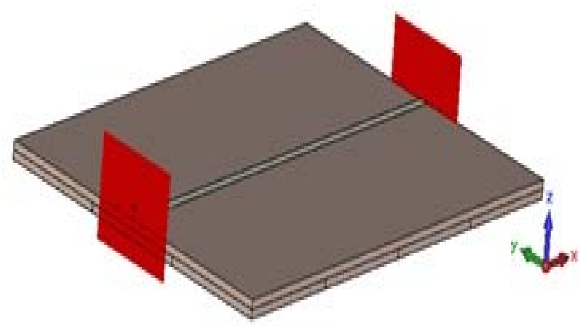

Figure-7. Array of (3x4) cells of Star GP AMC under micros trip line.

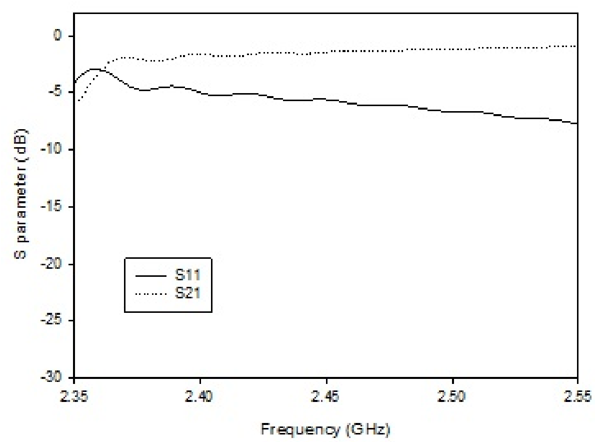

Figure-8. S11 and S21 coefficient of Star GP AMC.

The band gap bandwidth can be defined for S11 above -5dB and S21 below -30dB at the same time as reported in [13]. Results of the numerical simulation of Star GP AMC indicate that, there is no band gap appears at the specific frequency range. The electric field at the resonance frequency of 2.45 GHz is illustrated in Figure-9, where it shows that the current can flow from port 1 to the port 2 at 2.45 GHz of Star GP AMC.

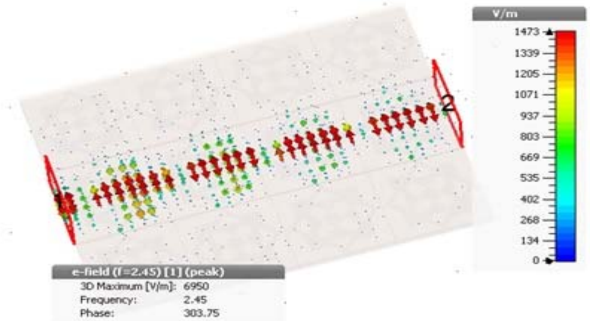

Figure-9. Electric field at the resonance frequency of 2.45 GHz for Star GP AMC.

CONCLUSIONS

In this paper, a new structure of single-band Star Geometric Pattern AMC operating at 2.45 GHz is proposed. The design is simulated by using RO3010 as the substrate. From the reported results, it is revealed that the Star GP AMC have good bandwidth and insensitive to the angle of incidence. It can also be proved that the Star GP AMC is not causing the band gap at the resonance frequency. The designed AMC will be more optimized in terms of bandwidth performance. It can also be optimized for dual-band or multi-band frequencies. Finally, Star GP AMC design also shows the unique property of Islamic value.

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