Designing Halfring Artificial Magnetic Conductor for RFID Application

M. Abu, E.E. Hussin, M Saari M Isa, Z.A. Baharudin, Z. Zakaria
Universiti Teknikal Malaysia Melaka,
Hang Tuah Jaya, 76100
Durian Tunggal, Melaka.
Email: maisarah@utem.edu.my, eryana88@hotmail.co.uk, saari@utem.edu.my, zikri@utem.edu.my, zahriladha@utem.edu.my

***Abstract*—This paper proposed and discussed the new structure of halfring AMC for RFID application. The use of AMC is designed to overcome the problem of cancellation of the image current by redirecting back the electromagnetic wave reflected by the metal plate. Low profile dipole antenna is used to represent the RFID transponder. Three size of optimized AMC is presented to study the characteristics of the halfring AMC. The best result obtained by implementing the optimized halfring in lamda,λ and half-lamda, 1/2λ size. The gain is higher than 7dB with return loss of -16dB proved that this structure can be used onto the RFID technology system for metal or non-metal object.**

Keywords—Artificial Magnetic Conductor, metallic detection, RFID, transponder, low profile antenna

I. INTRODUCTION

The use of Radio Frequency Identification, RFID technology has been widely applied into automatic identification based system such as in baggage handling in airport, tolling system (Dallas) and asset management. The communication happens when the reader emit electromagnetic wave in free-space and makes all the transponder within that range become active. Then, the transponder will reflect back the electromagnetic wave together with the data carried. This process is called backscattering modulation [1]. Figure 1 shows the transmission and respond of RFID reader and three transponders at different location. The reader transmits electromagnetic wave in all direction. Transponder A and Transponder B are in the transmission area so they can respond back to the reader. While Transponder C does not receive the electromagnetic wave, so it stays inactive. Todays, many RFID readers are fitted with additional interface such as RS 232, Universal Serial Bus (USB) and Local Area Network (LAN) hub to process the data received into another system such as a robot or database system. The unique features of RFID system is that it provides wireless communication between the reader and transponder with longer reading distance (more than 1 meter) for Ultra High Frequency and Microwave system. However, the use of RFID system is limited for some kind of materials.

This paper discuss about the effect of transponder when it is placed near to or on metallic object or PEC (Perfect Electric Conductor) which behave as a reflector. The PEC element introduces the negative image current to the source (antenna) that will cancel out each other resulting in poor impedance. Hence, the performance of the transponder becomes poor and failed to radiate efficiently [2]. This problem can be solved by adding spacer or air gap between the transponder with distance of spacer must be $\leq \lambda/4$ which may lead to larger size. The studies of metamaterial structures such as EBG, FSS and AMC as the ground plane have been studied to redirect back the electromagnetic wave reflected by the PEC. In addition, the distance of spacer also can be reduced [3-5].

Artificial Magnetic Conductor, AMC solve the metallic object detection by suppressing the surface wave between the reader and transponder by removing the unwanted radiation. AMC is a high impedance structure which act as an open circuit with magnitude and phase of +1 and 0° at resonant frequency. The important parameter for designing the single cell of the AMC is to get higher bandwidth that relies between ±90° of the reflection phase. The reflection phase is determined by the difference between the incidence plane waves of the structure's surface to the reflected wave.

AMC also have been introduced to increase the performance of antenna. In [6] the stacked ring-patch two layer planar AMC reduced the mutual coupling by improving the ration pattern of the microstrip patch antenna. The use of AMC also can improve the current distribution of omnidirectional monopole antenna [7].

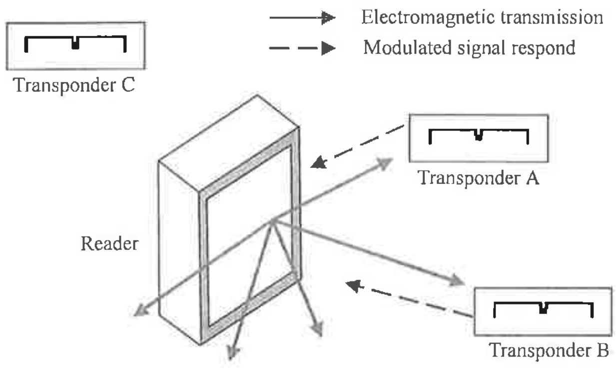


Figure 1: The transmission of electromagnetic wave by reader to the transponder at different distance.

II. Design Structure and Result

In this paper, the new structure of AMC operates at RFID frequency band of 2.45 GHz is proposed. The design structure is started by designing the basic square AMC. Then the structure is exploited to rectangular structure. The differences of incidence of angle between these two structures are studied. Next the new halfring structure is designed and parametric study is conducted. The performance of the AMC is investigated by using dipole antenna which represent as the transponder of RFID.

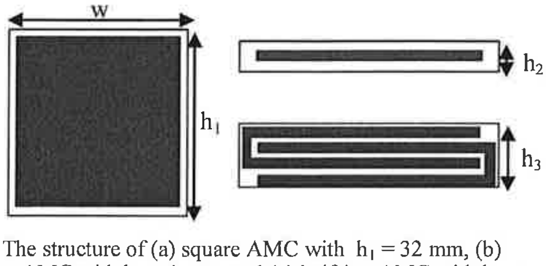


Figure 2: The structure of (a) square AMC with $h_1 = 32$ mm, (b) rectangular AMC with $h_2 = 4$ mm and (c) halfring AMC with $h_3 = 6.6$ mm. The width,w for all structures are remain equal = 32 mm.

A. Square and Rectangular Unit Cell

AMC structure is a representation of a distributed parallel LC network at certain resonant frequency. At resonant frequency the characteristics of the AMC is in high impedance and in-phase reflection bandwidth. The value of bandwidth is inverse proportional to $\sqrt{L/C}$. Wider AMC bandwidth can be obtained by increasing the value of L while decreasing the value of C. The value of L can be increased by reducing the thickness of the substrate. Then C can be reduced by using substrate with smaller relative permittivity or increasing the gap between the PEC and substrate [8]. By taking these considerations, the new halfring structure proposed in this paper is designed by using Rogers RO03003 as a substrate with thickness, t = 1.52 mm and permittivity, $\varepsilon_r = 3$. Each side of the substrate has copper cladding with thickness, h of 0.035 mm. First of all, the basic square AMC is designed with size of $\lambda/4$ for each side. The variation of gap between the substrate and PEC patch of the square AMC are shows in Figure 4. Figure 3(a) shows that the frequency is increased when the gap increases. While in Figure 3(b) shows that the bandwidth of square AMC is decreased as the gap is increased. By maintaining the same width, the rectangular AMC is designed as in Figure 2(b). The studies on varying the vertical and horizontal gap are shows in Figure 4. Increasing to 1.5 mm of vertical gap increase 5 % of frequency but the bandwidth reduced 22 %. Further increase the vertical gap with 1 mm for each increment shows smaller percentage different which is lower than 1% and 10% of frequency and bandwidth respectively. The study for horizontal gap in Figure 4(b) shows the same respond. These situations satisfy the theory of equation (1) and (2) where *Bw* is the bandwidth and *f* is the frequency.

$$Bw = \frac{1}{\eta_0}\sqrt{\frac{L}{C}} \quad (1)$$

$$f = \frac{1}{2\Pi\sqrt{LC}} \quad (2)$$

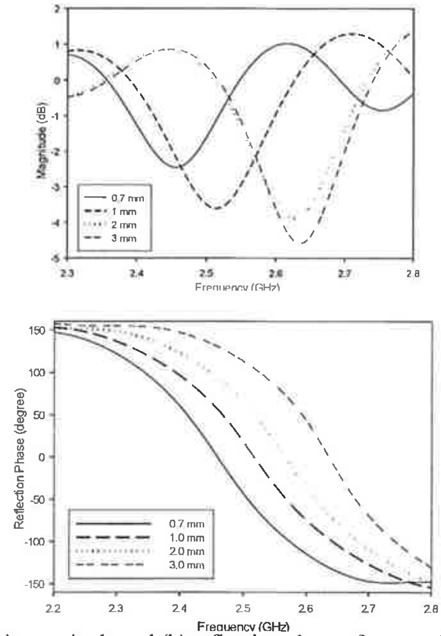
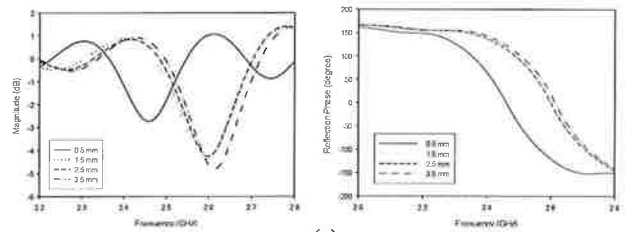
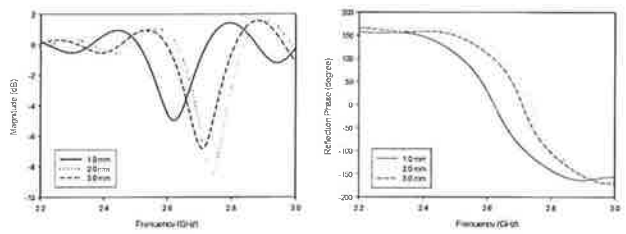


Figure 3: (a) magnitude and (b) reflection phase of square AMC



(a)



(b)

Figure 4: Parametric study on varying the (a) vertical gap and (b) horizontal gap.

TABLE I. Reflection Phase of Square, Rectangular and Halfring AMC

AMC	Bandwidth
Square	8.2 %
Rectangular	7.6 %
Halfring	9.5 %

B. Halfring AMC

One of the characteristic of AMC is by having zero reflection coefficient phase at resonant frequency. From the reflection phase graph, the value of bandwidth which lies between 90° to -90° can be calculated. he rectangular AMC presented in this paper had reduced 86.8% of square AMC size but when consider about the bandwidth, the square AMC give better result. So the halfring AMC is proposed in this paper with reduced size and increased the bandwidth. Figure 5 shows the full dimension of the single cell halfring AMC. Slots are introduced into the structure to reduce the frequency while maintaining the structure size. From the simulation, the bandwidth of halfring AMC increased to 9.9%. The calculated value of bandwidth from the simulation using CST Microwave software shows in Table 1.

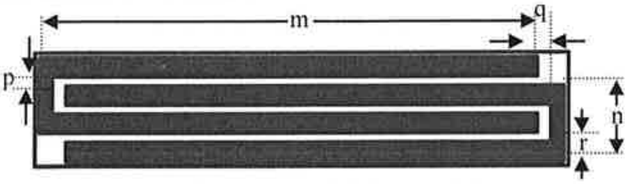


Figure 5: Dimension of Halfring Artificial Magnetic Conductor.

Figure 6 shows the parametric study on halfring to get the effect of varying the gap and slots around the structure. In Figure 6(a), by increasing the slot p with 0.5 mm increments, will increase the frequency and reduce the bandwidth. However, increasing the slot q shows in Figure 6(b) will decrease both frequency and bandwidth. Increasing the gap between halfring patch and substrate affects the result by decreasing the bandwidth while increasing the frequency due to the accretion of size.

C. Halfring AMC and Printed Dipole Antenna at 2.45GHz.

Further work continues by applying the halfring AMC to the back of low profile printed dipole antenna designed at 2.45GHz. The halfring that act as the ground plane to the antenna or in this case, RFID transponder will be periodically arranged until it gives the best result. Previous study proved that the optimized AMC will enhance the gain and performance of the antenna.

Three cases of halfring AMC with different periodic size is presented in this paper. The characteristics of antenna when places onto the metal plate shows in Figure 7 together with the result of applying the optimized halfring AMC. The three of halfring AMC is optimized at $\approx\lambda$ (130mm x 130 mm), $\approx 1/2\ \lambda$ (62.9mm x 62.9 mm) and $\approx 1/4\lambda$ (34.6 mm x 34.6 mm) size. The result of gain, return loss and directivity of the dipole antenna for all cases shows in Table 2.

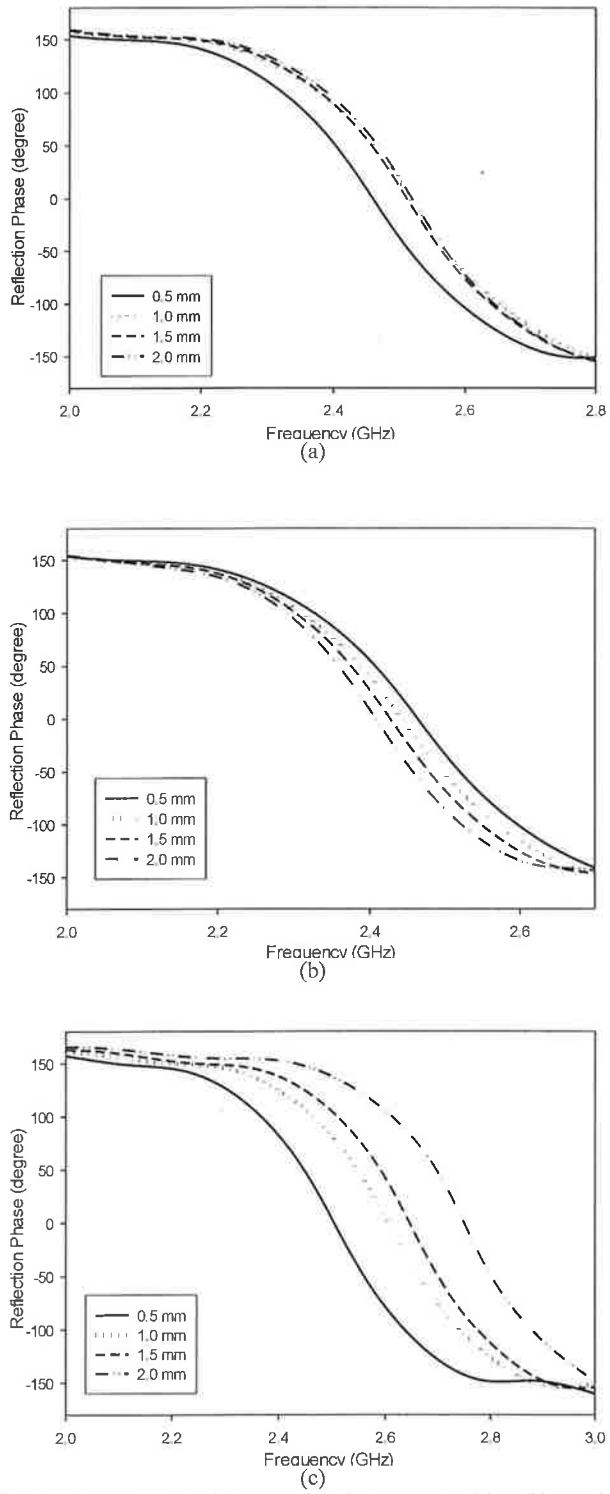
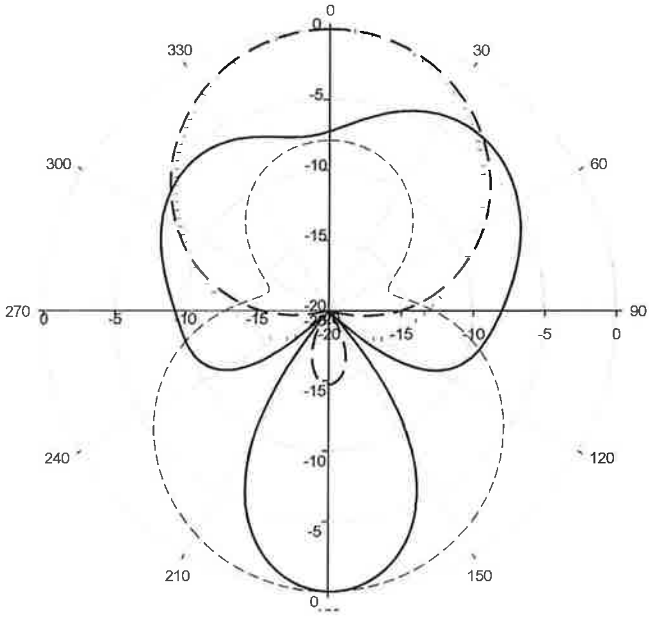
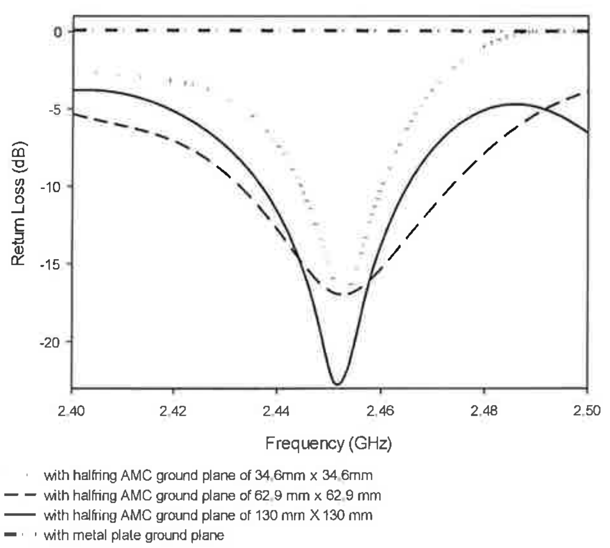


Figure 6: Parametric study on varying the parameter (a) p, (b) q and (c) gap around the halfring patch.



(a)



(b)

Figure 7: The result of (a) radiation pattern and (b) return loss of optimized halfring AMC.

Table II. Reflection Phase of Square, Rectangular and Halfring AMC

Ground Plane	Metal plate	Halfring AMC		
		34.6 mm x 34.6 mm	62.9 mm x 62.9mm	130 mm x 130 mm
Return Loss (dB)	-0.11	-16.45	-16.92	-22.61
Gain (dB)	-7.19	4.44	7.45	7.58
Directivity (dBi)	8.06	5.35	7.87	8.15
Efficiency (%)	1.84	95.53	96.88	96.36

III. Discussion and Conclusion

From Figure 7(b), good return loss and gain is shown by the halfring AMC at 130 mm x 130 mm and 62.9 mm x 2.9 mm. For halfring AMC at 34.6 mm x 34.6 mm size, even that the return loss is good, but the highest directivity of the antenna produced at 180° which means that the antenna radiate to the back of the antenna. When the metal plate at attach to the back of the antenna, it produce negative gain with close-to-zero return loss. In other word, the antenna would not radiate.

As for conclusion, the characteristic of the new halfring antenna is studied. Applying slot into the AMC structure will increase the capacitive element hence the resonant frequency can be reduced. This halfring AMC is fabricated and tested using RFID electronic system. This new structure is recommended to be used as a ground plane to RFID transponder operates at 2.45 GHz.

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