THE PERFORMANCE COMPARISON OF PRINTED DIPOLE ANTENNA WITH TWO DIFFERENT STRUCTURES OF AMC GROUND PLANE

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Abstract—**The performances of the triple-band meandered dipole antenna backed by two different Artificial Magnetic Conductor (AMC) structures are discussed in this paper. Two kinds of AMC structures are presented namely rectangular-patch with rectangular slot and rectangular-patch with slotted rectangular and I-shaped slot. The AMCs are designed to operate at 0.92GHz and 2.45GHz. The performances of the antenna with and without the dual-band AMC ground plane are investigated in terms of return loss, realized gain and power received. It clearly shows that the printed dipole antenna has a lower gain compared to the printed dipole antenna with high-impedance structure ground plane (GP). Furthermore, the received power of the dipole antenna backed by the 2x2 rectangular-patch with slotted rectangular and I-slot AMC receives a slightly higher power compared to the dipole antenna backed by the 2x2 rectangular-patch with rectangular slot AMC.**

Keywords: Artificial Magnetic Conductor (AMC), printed dipole antenna and Radio Frequency Identification (RFID)

I. INTRODUCTION

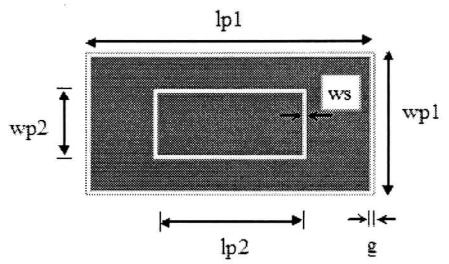
Printed dipole antennas have been actively studied since they are simple, easy to fabricate, and easy to integrate with the Application Specific Integrated Circuit (ASIC) microchip. However, it is categorized as a low gain antenna where it is fundamentally limited by the size, radiation patterns and the frequency of the operation [1]. In addition, the radiation characteristics and input impedance of the dipole antenna will be distorted when the antenna is placed on a metal object [2-3]. This is because, the electromagnetic wave is reflected almost entirely by the metallic surface and a 180° phase shift is occurred. By nature, the conventional ground planes exhibit the property of phase reversal of the incident currents resulting destructive interference of both dipole antenna and image currents. The same scenario happen when the dipole tag antenna is attached to a metallic object, the tag cannot be powered up by the field strength emitted by the Radio Frequency Identification (RFID) reader since the metallic object reflects Radio Frequency (RF) wave. The impedance of the tag antenna, resonant frequency of the antenna and radiation efficiency will be changed due to the parasitic capacitance between the tag antenna and the metallic object. To overcome this problem, the antenna must be placed at a quarter-wavelength above the metallic ground plane, making the antenna bulky at low frequencies [4]. Another way to minimize effects of the parasitic capacitor between the dipole antenna and metallic object and the effect of the reflection of the RF wave by metallic object, a gap between tag antenna and the metallic object is placed and dielectric material between them is added [5].

Thus one way to reduce the size of the antenna, the high-impedance surface (HIS) structure is introduced to act as Perfect Magnetic Conductor (PMC) which does not exist in nature [6-8]. Its structure can be realized by artificially engineered, thus it is called as Artificially Magnetic Conductor (AMC). The AMC or PMC condition is characterized by the frequency or frequencies where the magnitude of the reflection coefficient is +1 and its phase is 0°. It has high surface impedance and it reflects the external electromagnetic waves without the phase reversal. In contrast, the Perfect Electric Conductor (PEC) has a reflectivity of -1 and has electromagnetic waves out of phase with the incident waves. As the metallic plate, the AMC also can be used as a ground plane to redirect the back radiation and provide shielding to the antennas.

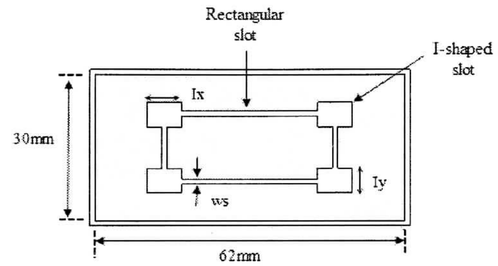
II. A UNIT CELL OF THE DUAL-BAND AMC

Figure 1 shows a unit cell of the rectangular-patch with rectangular slot and rectangular-patch with slotted rectangular and I-shaped slot AMCs. The slot is loaded in the main patch of the AMC to create the other resonant frequency. By using this technique the resonant frequency can be lowered, and hence reduce the size of the AMC. Both the textured structures are designed using the same dielectric substrate that is Taconic

TLC-32. The operating frequencies of these AMCs are 0.92GHz and 2.45GHz. The rectangular patch with the rectangular slot AMC-HIS structure has a unit cell size of 64mm x 32mm, the main rectangular-patch size of 62mm x 29.5mm, the second rectangular-patch size of 31.5mm x 14.5mm and slot width of 1mm.



(a)



(b)

Figure 1: A unit cell of the: (a) rectangular patch with the rectangular slot and (b) rectangular-patch with slotted rectangular and I-shaped slot AMC design at 0.92GHz and 2.45GHz

The reflection phase diagram is a well known graph plotted for the AMC structures and it is usually simulated using a time-domain solver. The reflection phase graph of the dual-band AMC-HIS is shown in Figure 2. At the AMC resonant frequency, the reflection phase equals to 0 and the surface impedance approaches infinity (∞). When the surface impedance equals to the impedance of the free space, the phase crosses within 90° to -90°. The image currents are in-phase rather than out of phase within this range. When the surface impedance is low, the reflection phase is ±180°. The bandwidth of the HIS structure is determined between -90° and +90° from the phase reflection graph.

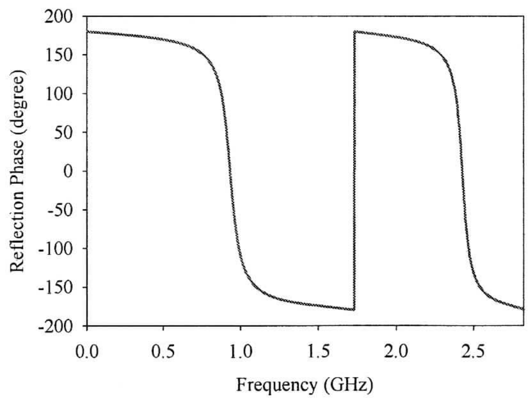


Figure 2: The reflection phase graph

From the designed dual-band AMC in Figure 2(a), the new structure of the AMC as shown in Figure 2(b) is carried out by the rectangular patch with the rectangular and I-shaped slot. This AMC structure is a little bit smaller than the rectangular patch with the rectangular slot AMC where more slots are applied (by introducing I-shaped slot at the perpendicular of the rectangular slot). It is important to optimize the performance of AMC-HIS over the frequencies of the interest. Thus, to achieve the desired operating frequencies, this structure is designed with a rectangular slot width (ws) of 1mm at the centre of the rectangular patch, Ix of 7mm and Iy of 4.5mm.

The lower AMC band obtained for rectangular patch with the rectangular slot is 0.88GHz - 0.98GHz (10.77%) and the upper AMC band is 2.40GHz - 2.48GHz (3.28%). While the rectangular-patch with slotted rectangular and I-shaped slot AMC is resonated well at the desired first AMC band of 0.87GHz – 0.96GHz (9.85%) and at the second band of 2.38GHz – 2.47GHz (3.71%).

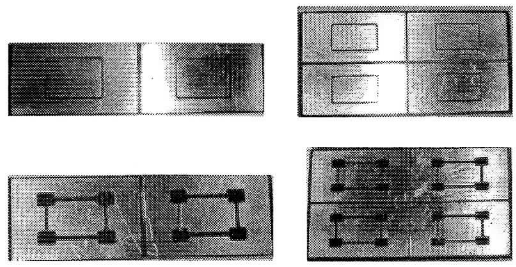


Figure 3: The fabricated dual-band AMCs

III. PRINTED DIPOLE ANTENNA WITH AMC GROUND PLANE

The aim of this part is to present the performance of the designed meandered dipole antenna with and without the dual-band AMC ground plane. As illustrated in Figure 4, the printed dipole antenna is placed just above the AMC layer. The antenna and the AMC are designed using a different substrate material. The dipole antenna is designed at three different RFID frequencies; at 0.92GHz, 2.45GHz and 5.8GHz. The dipole antennas are designed based on the multi-branch technique which has three dipole elements printed on the Taconic RF-35 substrate.

Tables I and II tabulate the performances of the triple-band meandered dipole antenna with and without the dual-band AMC-HIS GP at 0.92GHz and 2.45GHz. From the simulation results obtained, with AMC GP the dipole antenna operates well at 0.92GHz and 2.45GHz with a return loss below than 10dB. Interestingly, the realized gain of the dipole antenna increases significantly. This is because, the image current of the AMC is in-phase with the incident current and thus it enhances the gain of the antenna. Moreover, a higher gain is achieved with more unit cells. Based on the tabulated results, the reading distance of the dipole tag antenna (when the antenna is fed with the microchip at the centre of the antenna) is then calculated using the Frii's formula [9]. By using the AMC as a ground plane for the dipole tag antenna, a longer reading distance is achieved. This is because the tag antenna with higher gain will give a higher reading distance besides depending on the reader antenna's gain and reader's output power.

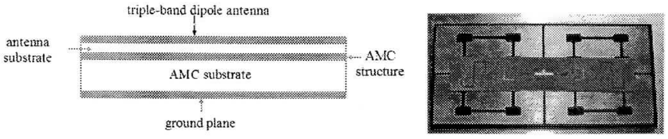


Figure 4: The structure of the dipole antenna or tag with AMC-HIS GP

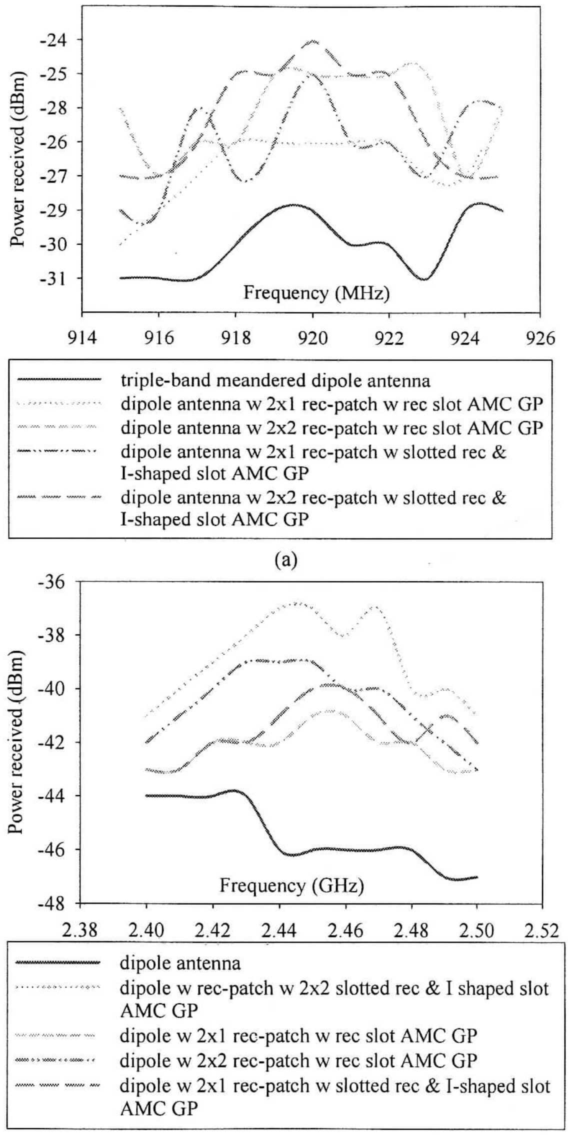
TABLE I. THE PERFORMANCES OF THE TRIPLE-BAND MEANDERED DIPOLE ANTENNA WITH AND WITHOUT THE AMC GPs AT 0.92GHz

	Return loss (dB)	Realized gain (dB)	Calculated reading distance (m)
Triple-band meandered dipole antenna	-11.15	1.49	5.90
Dipole antenna with 2x1 rectangular-patch with rectangular slot AMC-HIS GP	-19.79	4.41	8.55
Dipole antenna with 2x2 rectangular-patch with rectangular slot AMC-HIS GP	-17.05	5.19	9.30
Dipole antenna with 2x1 rectangular-patch with slotted rectangular & I-shaped slot AMC-HIS GP	-15.71	4.40	8.46
Dipole antenna with 2x2 rectangular-patch with slotted rectangular & I-shaped slot AMC-HIS GP	-26.98	5.46	9.68

TABLE II. THE PERFORMANCES OF THE TRIPLE-BAND MEANDERED DIPOLE ANTENNA WITH AND WITHOUT THE AMC GPs AT 2.45GHz

	Return loss (dB)	Realized gain (dB)	Calculated reading distance (m)
Triple-band meandered dipole antenna	-12.44	1.44	1.32
Dipole antenna with 2x1 rectangular-patch with rectangular slot AMC-HIS GP	-10.51	3.87	1.72
Dipole antenna with 2x2 rectangular-patch with rectangular slot AMC-HIS GP	-9.81	5.61	2.09
Dipole antenna with 2x1 rectangular-patch with slotted rectangular and I-shaped slot AMC-HIS GP	-13.42	4.43	1.88
Dipole antenna with 2x2 rectangular-patch with slotted rectangular and I-shaped slot AMC-HIS GP	-8.56	6.43	2.25

The graph in Figure 5 plots the measured received power versus frequency. It is observed that, the power received by the dipole antenna with the absence of the AMC GP is lower than the power received by the dipole antenna with the AMC GP. More than that, the dipole antenna with more unit cells received more power than the dipole antenna with fewer cells. In addition, the received power of the dipole antenna backed by the 2x2 rectangular-patch with slotted rectangular and I-slot AMC receives a slightly higher power compared to the dipole antenna backed by the 2x2 rectangular-patch with rectangular slot AMC. From the measurement of the received power, it can be expected that the gain of the dipole antenna with the AMC GP is higher than the gain of the dipole antenna without the AMC GP.



(b)

Figure 5: The measured power received by the triple-band meandered dipole antenna with and without AMC GPs at the: (a) first band and (b) second band of the dipole antenna

The measured reading distance for triple-band meandered dipole tag antenna at 0.92GHz and 2.45GHz is recorded in

Table III and Table IV respectively. In this work, the passive UHF RFID Gen 2 Reader Module and 2.45GHz Reader are used with the reader antenna gain of 9dBi and 7.5dBi respectively. At UHF, the calculated reading distance for meandered dipole tag is 5.9m while the measured reading distance is 4.0m. In short, the performance of the dipole antenna with rectangular-patch with slotted rectangular and I-shaped slot AMC-HIS GP is better than the dipole antenna with rectangular-patch with rectangular slot AMC-HIS GP. This is because it has a longer reading distance and the dimension is slightly smaller. Generally, the measured reading distance is always lower than the calculated reading distance due to fabrication error, improper matching impedance between the microchip and dipole antenna, losses and environmental effects.

TABLE III. THE MEASURED READING DISTANCE OF 0.92GHz MEANDERED DIPOLE TAG ANTENNA WITH AND WITHOUT THE AMC GPs USING THE UHF RFID GEN2 READER MODULE

	Measured reading distance (m)
Meandered dipole tag	4.00
Meandered dipole tag antenna with 2x1 rectangular-patch with rectangular slot AMC-HIS GP	5.75
Meandered dipole tag antenna with 2x2 rectangular-patch with rectangular slot AMC-HIS GP	7.00
Meandered dipole tag antenna with 2x1 rectangular-patch with slotted rectangular and I-shaped slot AMC-HIS GP	6.00
Meandered dipole tag antenna with 2x2 rectangular-patch with slotted rectangular and I-shaped slot AMC-HIS GP	8.00

TABLE IV. THE MEASURED READING DISTANCE OF 2.45GHz MEANDERED DIPOLE TAG ANTENNA WITH AND WITHOUT THE AMC GPs USING THE MICROWAVE 2.45GHz RFID READER

	Measured reading distance (m)
Meandered dipole tag	0.80
Meandered dipole tag antenna with 2x1 rectangular-patch with rectangular slot AMC-HIS GP	0.90
Meandered dipole tag antenna with 2x2 rectangular-patch with rectangular slot AMC-HIS GP	0.95
Meandered dipole tag antenna with 2x1 rectangular-patch with slotted rectangular and I-shaped slot AMC-HIS GP	0.90
Meandered dipole tag antenna with 2x2 rectangular-patch with slotted rectangular and I-shaped slot AMC-HIS GP	1.25

IV. CONCLUSION

The AMC is useful as a ground plane for the printed dipole antenna to increase the antenna's gain. The finding suggests that the dipole antenna with more unit cells received more power than the dipole antenna with fewer cells. Thus longer reading distance is achieved for the dipole tag antenna with more unit cells of the AMC. But the downside is it makes the overall dimension of the antenna is large. From the results gained also, it is observed that the reading distance of the dipole tag antenna with 2x2 rectangular-patch with slotted rectangular and I-shaped slot AMC-HIS GP is longer than the dipole tag antenna with 2x2 rectangular-patch with rectangular slot AMC-HIS GP at both AMC frequencies.

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