An Analysis of Non-Periodic AMCs Structure on Array Antenna at 28 GHz

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***Abstract*— In this work, two designs of a 16x1 array antenna with non-periodic AMCs structures are designed at a frequency of the 28 GHz. Four types of AMC pattern are designed and arranged to the upper and lower sides of the substrate surface. The AMCs are arranged unevenly by size and shape of the designs. Both designs of the antenna with AMCs are compared with the antenna without AMC. In comparison, between the proposed designs of 16x1 array antenna integrated with AMC and antenna without AMC, it shows that there is slightly enhancement of the antenna performance in terms of gain, bandwidth and side lobe level. The maximum of gain is 19.33 dB compared to the antenna without AMC of 18.61 dB. The bandwidth is increased up to 1 GHz, which meet the requirement at the frequency of 28 GHz The side lobe level is reduced from -16.7 dB to -19.1 dB and -16.7 dB to -20.3 dB for both designs antenna with AMCs when compared to the antenna without AMC. It can be seen that, the antenna integrated with AMC able to use at 5G technology without adding any layer and the thickness of the antenna.**

***Index Terms*— Antenna Array; Artificial Magnetic Conductor; Bandwidth; Gain; Side Lobe Level.**

I. INTRODUCTION

There are currently many studies focusing on 5G technology. This is because this technology will produce something faster and more advanced in line with advances in science and technology. Other than that, the important criteria of 5G technology are beamforming capability of the radiation pattern in order to pass through the scanning space [1-2]. Therefore, in order to fulfil the demand of 5G technology, the antenna design should be more compact in size, low in cost, and good in the radiation pattern. Many researchers started designing an antenna for 5G technology at the frequency of 28 GHz [3-10]. This is because, the 28 GHz frequency band has a good potential to be a carrier frequency for the 5G in cellular network application [11].

Many types of research have been done regarding the implementation of AMC structure as a ground plane of the antenna in order to increase the gain, bandwidth and suppress the side lobe level of the antenna. In paper [12], a novel design of the printed slot antenna using wideband AMC surface is presented to improved radiation performance. The performance is increased by two radiating slots with three unequal arms loaded with the wideband planar AMC. The -10 dB impedance bandwidth is 86.48 % and gain is -10.65 dBi.

Ekke Vaishali R. and P. L. Zade (2014) [13] proposed the design of AMC structure along with feed line of 4 x 1 in order to enhance the antenna performance. By introducing vias, the gain does not get influenced, but cross polarization level is lowered by 5.35 dB. The gain is reduced by 12 dB compared to the antenna without AMC with 18.71 dB gain. The bandwidth is reduced 69 MHz for an antenna with AMC at band 1 and 44 MHz for band 2.

A compact microstrip antenna array using an AMC structure for dual-frequency operation is proposed in [14]. The designs proposed included of a single element, 1x2 and 2x2 array antenna which offer a good gain and compact in size. The AMC is used as the back plane of the antenna in order to increase the gain. The gain for the single antenna is increased by 38.7 % for the band at 2.45 GHz and 30 % for the band at 5.8 GHz. The gain for 1x2 array antenna is increased 14.6 % for the band at 2.45 GHz and decreased by 5.12 % for the band at 5.8 GHz. However, a gain a slightly decrease for 2x2 array antenna due to the coordinate of array elements is not align with the unit cell of the AMC.

Raimi Dewan, Sharul K. A. Rahim, , Siti F. Ausordin, and Teddy Purnamirza (2013) [15] studies the enhancement of array antenna performance with the integration of an AMC design structure. An AMC with defects ground structure (DGS) was designed in order to apply as the AMC ground plane and in-phase superstrate at the frequency of 5.8 GHz. The useful bandwidth of the reference antenna is considerably enhanced to 287% and the size is reduced by 37 % when integrated with an AMC ground plane. Besides that, the integration of AMC and the antenna of in phase superstrate increase the gain and bandwidth by 1 dBi and 44%, respectively.

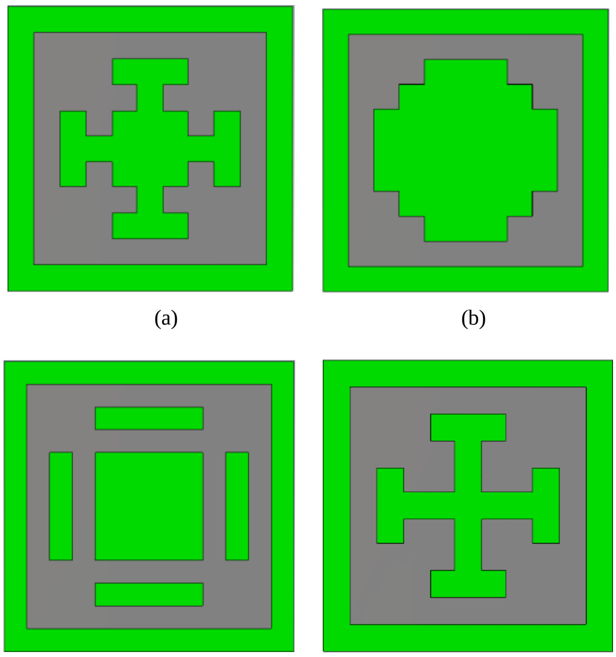
An AMC structure integrated with 2x2 Ka-band antenna array is designed using LTCC technology in [16]. The whole structure of mmW 2x2 antenna array with AMCs structure is designing which the feeding network and compact transition between LWG and rectangle waveguide (RWG) are integrated. The simulated bandwidth of the proposed structure is 11.43 %, which much larger than that antenna array with PEC plane. The maximum gain is 12.9 dBi with the stable of the radiation pattern.

In [17], a 2x2 antenna array was integrated with the four types of design AMC in order to enhanced bandwidth, gain and minimize the antenna size. The four types of integrated antenna and AMC are spiral-AMC (SAMC), a SAMC embedded with a large SAMC (LSAMC), a SAMC embedded with a small SAMC (SSAMC), and a SAMC embedded with small spiral EBG (ESEBG). The simulation results presented that an LSAMC offered better bandwidth and smaller in size, while SSAMC provided a good response in reflection phase and higher gain. However, ESEBG provided better performance compared to the others which the bandwidth extends from 0.50 GHz to 20 GHz, the size reduced by 85 % and the gain increased by 61.5 %.

In this work, two designs of a 16x1 array antenna with non-periodic AMCs structures are designed at a frequency of the 28 GHz. Four types of AMC pattern are designed and arranged to the upper and lower sides of the substrate surface. The AMCs are arranged unevenly by size and shape of the designs. Both designs of the antenna with AMCs are compared with the antenna without AMC. It shows that there is slightly enhancement of the antenna performance in terms of gain, bandwidth and side lobe level when integrated with AMCs structure.

II. Proposed AMC Design

Four types of AMC geometry pattern is presented in Figure 1 which printed over a RT 5880 substrate with a thickness of h = 0.254 mm, dielectric constant of ε_r = 2.2 and loss tangent of $\tan\delta$ = 0.0009. The patch size of design 1 AMC is 2.2221 mm x 2.2221 mm, design 2 AMC is 2.31644 mm x 2.31644 mm, design 3 AMC is 2.678 mm X 2.678 mm and design 4 AMC is 2.200522 mm x 2.200522 mm. The overall size of design 1 AMC is 2.7221 mm x 2.7221 mm, design 2 AMC is 2.8164 mm x 2.8164 mm, design 3 AMC is 3.1780 mm x 3.1780 mm and design 4 AMC is 2.7005 mm x 2.7005 mm. The gap between the patch AMC and the substrate for all structures is 0.5 mm.



(a) (b) (c) (d)

Figure 1: Unit cell proposed AMCs: (a) design 1, (b) design 2 , (c) design 3, (d) design 4

A Floquet technique is used in order to obain the reflection phase characterictics of AMCs structure. This technique is simulated by using CST Microwave Studio software. As shown in Figure 2, the plotted reflection phase varies continuously from +180° to -180° versus frequency. The bandwidth of AMC is obtained with a phase shift between ±90° which is based on the curve of the reflection phase [12]. This phase shift band is known as the AMC in-phase frequency band [18].

As presented in Figure 2, it is clear that all AMCs structure exhibits the reflection phase centered at the frequency of 28 GHz. Design 1 of AMC offers the bandwidth of 6.46 % within a frequency range of 27.023 GHz to 28.831 GHz. The design 2 of AMC gives the bandwidth of 7.13 % with the phase frequency band of 26.929 GHz to 28.925 GHz and design 3 of AMC structure provide the bandwidth of 9.46 % at a frequency band of 26.623 GHz to 29.271 GHz. The useful bandwidth of design 4 is 6.09 % within a band of 27.075 GHz to 28.779 GHz. compared to the others designs. This can be said that the bigger size of AMC offers more bandwidth compared to the smaller size of AMC. The summary of the results is tabulated in Table 1 below.

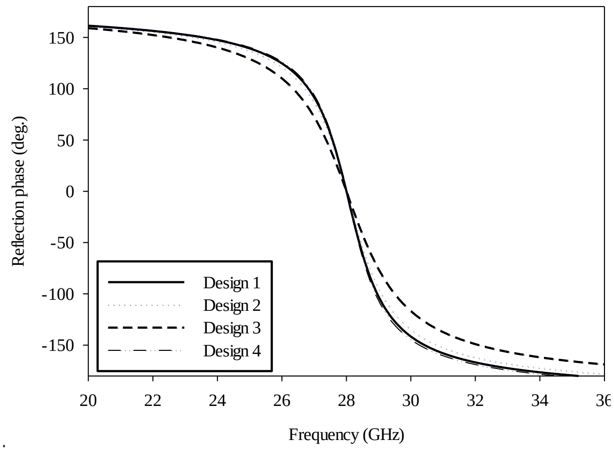


Figure 2: Reflection phase of proposed design AMCs

Table 1
The summary of the results of AMCs structure

	BW (%)	Size
Design 1	6.46	2.7221 mm x 2.7221 mm
Design 2	7.13	2.8164 mm x 2.8164 mm
Design 3	9.46	3.1780 mm x 3.1780 mm
Design 4	6.09	2.7005 mm x 2.7005 mm

III. Design Of 16 X 1 Array Antenna

Figure 3 shows a design of 16x1 patch array antenna without AMC structure.. Similar with an AMC unit cell, a high frequency laminates RT5880 substrate also is used as the antenna substrate. The 16 elements of inset feed radiating patch and the ground plane are placed on the top and bottom of the dielectric substrate, respectively. The size of each single antenna patch is 3.4685 mm x 4.462 mm and the overall size of the antenna is 34.5685 mm x 136.874 mm.

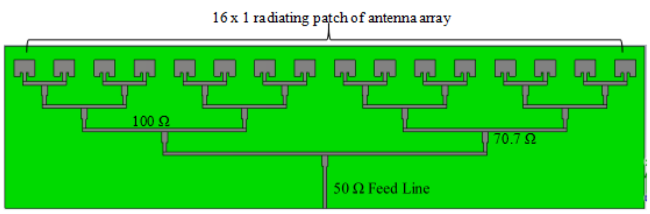


Figure 3: 16x1 antenna array without AMC structure

IV. ARRAY ANTENNA AND AMC STRUCTURE

Figure 4 and Figure 5 represents the construction of AMCs structure and a 16x1 array antenna. The array of unit cell AMCs is arranged to the upper and lower sides of the substrate surface. The AMCs are arranged unevenly by size and shape of the designs. The overall size of the antenna with non-periodic AMC 1 as shown in Figure 4 is 34.5685 mm x 137.1949 mm and the overall size of the antenna with non-periodic AMC 2 is 36.5685 mm x 137.0344 mm.

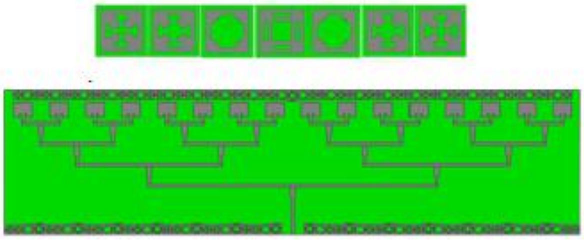


Figure 4: 16x1 antenna array with non-periodic AMCs 1

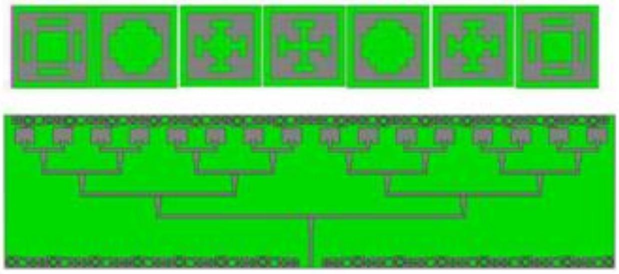


Figure 5: 16x1 antenna array with non-periodic AMCs 2

Figure 6 represents the comparison of simulated return loss between the 16x1 antenna without AMC and 16x1 antenna with non-periodic AMCs. The results show that the return loss for all designs is below than -10 dB which good performance for antenna designs.

The antenna without AMC structure is seen to have a return loss of -39.8950 dB and impedance bandwidth of 3.4 % at a frequency band of 27.55 GHz to 28.503 GHz. The return loss is -21.5560 dB and the bandwidth is 4.1 % when the antenna is designed with non-periodic AMC structures as shown in Figure 4. The bandwidth is increased by 20.6 % compared to the antenna without AMC.

The bandwidth of antenna with non-periodic AMC 2 is remaining same as an antenna without AMC that is 3.4 % with the range of 27.528 GHz to 28.485 GHz.

There are slightly increment of the bandwidth when compared with the antenna without AMC and antenna with AMC. However, it is still can prove that the bandwidth is achieved up to 1 GHz, which available bandwidth at a frequency of 28 GHz [19] without adds any layers and the thickness of the antenna. The summarization of the antenna performance in terms of return loss and bandwidth is listed in Table 2.

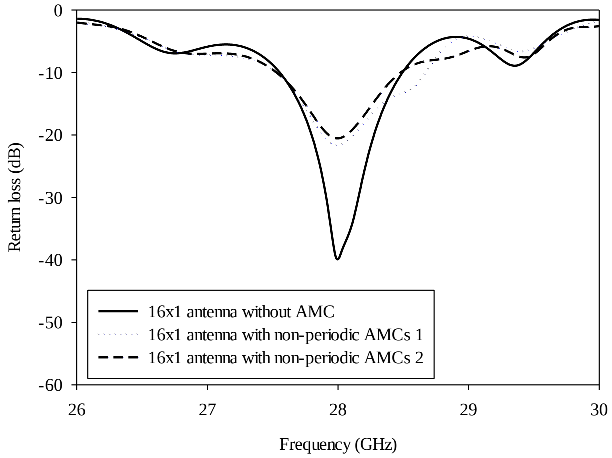


Figure 6: The return loss of the antenna without and with AMC structures

Table 2
The return loss and bandwidth of the designs

Design structure	Return loss (dB)	Impedance Bandwidth (%)
16x1 antenna without AMC	-39.8950	3.4 %
16x1 antenna with non-periodic AMC 1	-21.5560	4.1 %
16x1 antenna with non-periodic AMC 2	-20.5295	3.4 %

The gain and the directivity of 16x1 antenna array without AMC and the antenna with AM is illustrated in Figure 7 and Figure 8. It is seen that the gain and the directivity increased significantly after using the AMCs when compared to the antenna without AMC. The gain of the antenna without AMC is 18.61 dB while the antenna with non-periodic AMCs 1 is 19.33 dB and the antenna with non-periodic AMC 2 is 19.30 dB. The increment of gain is about 3.87 % and 3.7 % for both designs antenna with non-periodic AMCs structure.

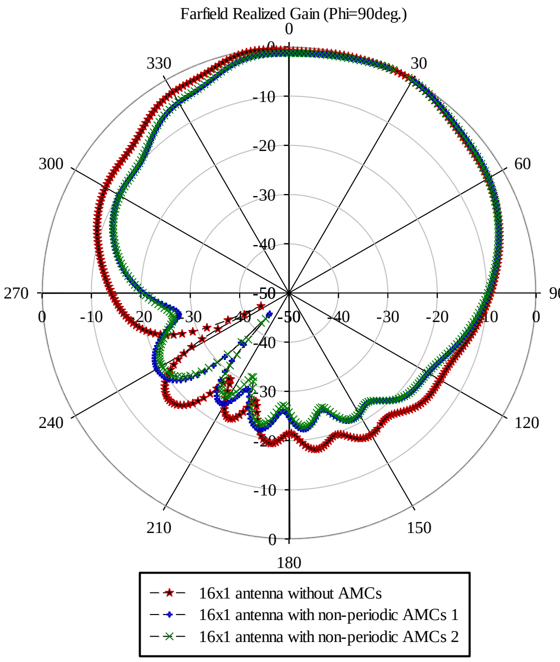


Figure 7: The gain of the antenna without and with AMC structures

The directivity of the antenna without AMC is 18.85 dBi and the directivity is increased by 19.52 dBi when integrated with non-periodic AMCs 1. The directivity also increased by 19.49 dBi for the antenna integrated with non-periodic AMC

2. The increment of directivity is about 3.55 % and 3.4 % for both designs antenna with non-periodic AMCs structure.

The side lobe level for both designs of the 16x1 antenna with AMC is reduced compared to the antenna without AMC. The side lobe level of the antenna without AMC is -16.7 dB, the antenna with non-periodic AMCs 1 is -19.1 dB and the antenna with non-periodic AMCs 2 is -20.3 dB. The increment of side lobe level is about 14.37 % and 21.56 % for both designs antenna with non-periodic AMCs structure. The summarization of the antenna performance in terms of gain and side lobe level is listed in Table 3.

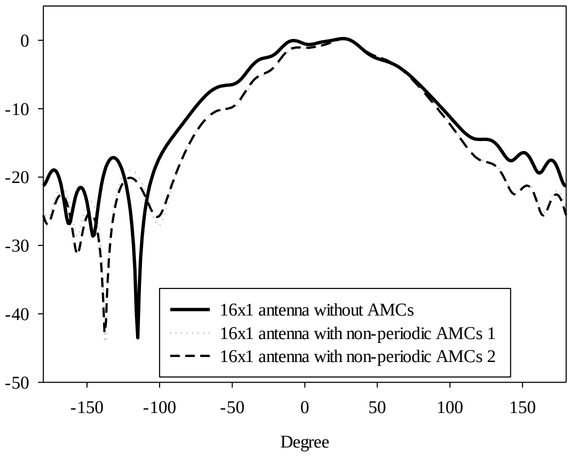


Figure 7: The directivity of the antenna without AMCs and the antenna with AMCs

Table 3
The gain and side lobe level of all the designs

Design structure	Gain (dB)	Side lobe level
16x1 antenna without AMC	18.61	-16.7 dB
16x1 antenna with non-periodic AMC 1	19.33	-19.1 dB
16x1 antenna with non-periodic AMC 2	19.30	-20.3 dB

V. CONCLUSION

The two configuration of the antenna with non-periodic AMCs is designed at a frequency of 28 GHz. Four types of AMC pattern are designed and arranged to the upper and lower sides of the substrate surface. The AMCs are arranged unevenly by size and shape of the designs. The simulated results show that the designs antenna with non-periodic AMCs structure enhancement in terms of gain, bandwidth and side lobe level. The maximum of gain is 19.33 dB compared to the antenna without AMC of 18.61 dB. The bandwidth is increased up to 1 GHz, which meet the requirement at the frequency of 28 GHz. The side lobe level is reduced from -16.7 dB to -19.1 dB and -16.7 dB to -20.3 dB for both designs antenna with AMCs when compared to the antenna without AMC. Therefore, all these characteristics make it a useful for the future 5G application.

ACKNOWLEDGMENT

The authors thanked the Ministry of Higher Education (MOHE) for supporting the research work, Center for Telecommunication Research and Innovation (CeTRI) and Universiti Teknikal Malaysia Melaka. This research is supported under the grant no PJP/2017/FKEKK/HI10/S01530.

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