Bulletin of Electrical Engineering and Informatics
Vol. 8, No. 1, March 2019, pp. 166~171
ISSN: 2302-9285, DOI: 10.11591/eei.v8i1.1409

Gain enhancement of microstrip patch antenna using artificial magnetic conductor

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Article Info

Article history:

Received Oct 17, 2018
Revised Nov 20, 2018
Accepted Dec 21, 2018

Keywords:

5G
Artificial magnetic conductor
Gain and bandwidth enhancement
Microstrip patch antenna

ABSTRACT

The paper presents an artificial magnetic conductor (AMC) structure to enhance the gain of the double microstrip patch antenna. By placing this kind of metamaterial in between the two Rogers RT5880 substrates, the antenna achieved lots of improvement especially in terms of size miniaturization, bandwidth, return loss, gain and efficiency. The antenna is intended to operate at 16 GHz where the prospect fifth generation (5G) spectrum might be located. Integration of AMC structure into the proposed antenna helps to improve nearly 16.3% of gain and almost 23.6% of size reduction.

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1. INTRODUCTION

Thanks to the superb data rates in some developed countries, fourth generation (4G) and Long Term Evolution (LTE) play important roles especially in wireless communication system. However because of high demand from users, the capacity of those types of technologies reaches to its maximum. For that reason, the researchers are now starting to explore the newest technology, fifth generation (5G), which possibly could take over the current technology [1]. According to [2], the exploitation of 5G network will emerge between 2020 and 2030. Since 4G LTE can be downloaded and uploaded with the data speed of 300 Mbps and 150 Mbps, respectively, 5G technology is estimate to have 1 Gbps data rates [3]. By having higher and faster data speed, it's an assign for this new technology to have higher frequency range. As explained in [3-5], the frequency band for 5G is now considered above 6 GHz as large blocks of spectrum are hard to find at lower frequencies.

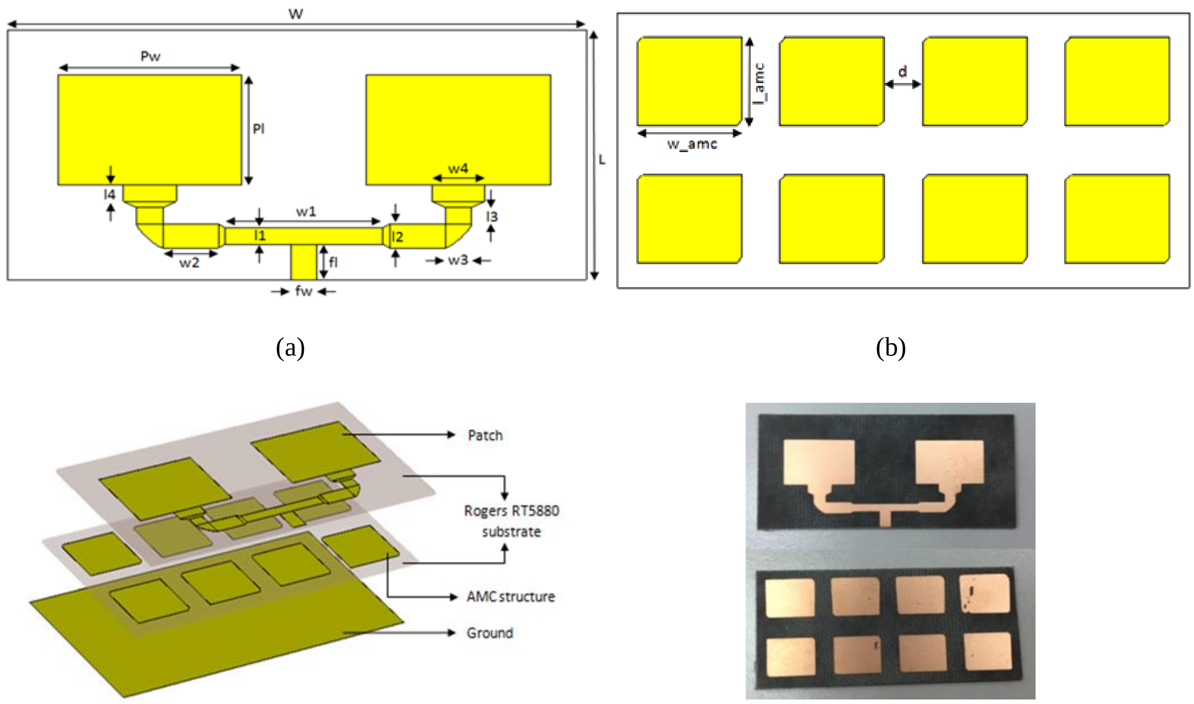
This latest technology can be accomplished by using the microstrip patch antenna. This kind of antenna can be one of the possible choices as it offers many benefits such as light weight, low profile and low cost fabrication [6, 7]. Nevertheless, due to the limited efficiency, low gain and narrow bandwidth, the conventional microstrip patch antenna cannot be the best preference for 5G applications. Hence numerous methods have been invented to overcome the drawbacks mentioned. To boost the microstrip patch antenna gain and bandwidth, some researchers add the parasitic strips to the left and the right of the patch [8]. Besides that, various shapes of slot have been created into the patch because up to 25% of bandwidth can be obtained by creating those slots [6, 9]. Other well-known techniques to enhance the gain and bandwidth among the analysts are by using multilayer structures [10-12] and thicker substrate with low permittivity [13]. However those methods bring to alignment and antenna sizing problems.

The research of bandwidth and gain enhancement becomes attractive as the used of metamaterial is found to be the best approach in improving the performances of microstrip patch antenna. One of the techniques to ameliorate the bandwidth of the proposed antenna is by integrating the artificial magnetic conductor (AMC) structure as patch antenna ground [14]. On the other hand, the researchers also use the AMC structure as reflectors on their wideband monopole antenna in order to obtain higher gain and better cross polarization levels [15].

In this paper, the integration of AMC into the proposed antenna helps in enhancing its gain. By adding AMC structure and its substrate layers, the performance of the antenna is much better than the conventional antenna. The antenna design geometry is presented in Section II while the simulated and measured results are showed in Section III. Finally this work ends by a conclusion.

2. ANTENNA DESIGN GEOMETRY

Figure 1. shows the design and fabricated double microstrip rectangular patch antenna with AMC structure using CST Microwave Studio software. The proposed antenna consists of five layers where the fully ground plane is placed at the bottommost layer. The AMC substrate is positioned at the second layer while the AMC structure is added on the third layer. This followed by another substrate on the fourth layer and the top layer consists of the patches. Rogers RT5880 with Ɛr=2.2, thickness h=0.508 mm and tanδ=0.0009 is used for both substrates. Due to its low permittivity, this type of substrate is chose as it can be well-used in high frequency. The proposed antenna is designed with 44x21mm2 in size, which is 23.6% smaller than the antenna without AMC structure. The dimension of all parameters is tabulated in Table 1.



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

Figure 1. Geometry of the proposed antenna (a) Patch structure, (b) AMC structure, (c) 3D view, (d) Fabricated antenna

Table 1. Dimension of the antenna

Parameter	L	W	Pl	Pw	fl	fw	w1	w2	w3
Value (mm)	21	44	8.22	12	3	2	11	4.211	2
Parameter	w4	l1	l2	l3	l4	w_amc	l_amc	d	
Value (mm)	4	1.4	2	1.4	1.4	8.05	6.8	2.95	

The AMC structure is formed by 2x4 AMC unit cells, as presented in Figure 1(b). The AMC unit cell is designed on 11x10.5 mm^2 Rogers RT5880 substrate with 8.05x6.8 mm2 patch. The gap of each patch, d, has been optimized in order to characterize the behavior of AMC. AMC is well performed when it gives zero degree reflection phase at 16 GHz, as shown in Figure 2. The graph of reflection phase presents then the bandwidth of AMC unit cell. As illustrated in the figure, the bandwidth of an AMC is determined when the phase shifts from +90° to -90°. As a result, the bandwidth of this proposed AMC unit cell is 10.46% at a frequency band from 14.98 to 16.634 GHz.

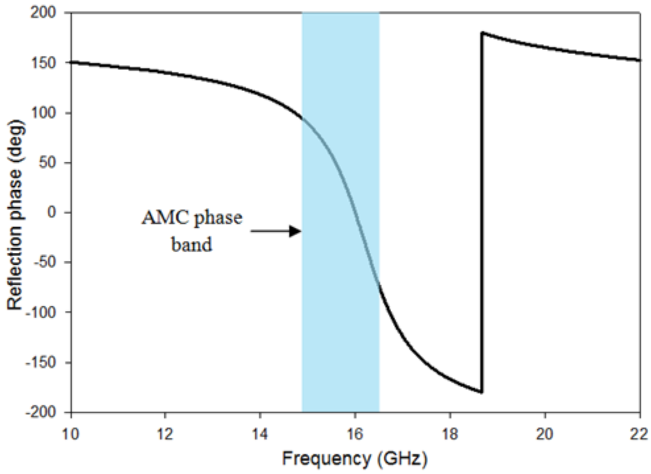


Figure 2. Reflection phase of an AMC unit cell

3. RESULTS AND DISCUSSION

The proposed antenna is simulated and measured at 16 GHz. All parameters have been compared with the conventional antenna. The simulation and measurement results of the reflection coefficient, S11 are presented in Figure 3. It is visibly indicates that the antenna with AMC structure performs better S11 of less than -10 dB at 16 GHz compared to the antenna without AMC structure. Thus the proposed antenna also improves its frequency bandwidth as 494 MHz is obtained for simulation and 137 MHz for measurement.

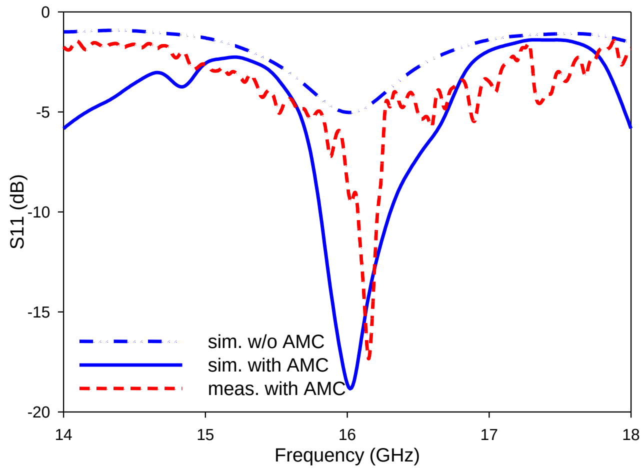


Figure 3. Simulated and measured reflection coefficient (S11)

Figure 4 shows the simulated gain, measured gain, radiation efficiency and total efficiency of the proposed double microstrip patch antenna. The measured gain improves a lot as 16.3% of enhancement is achieved by adding the AMC structure into the antenna. Moreover, the radiation and total efficiency give almost the same magnitude at 16 GHz with 84.3% and 83.1% of efficiencies, respectively. It means that only 1.2% of reflection efficiency loss is detected at that operated frequency.

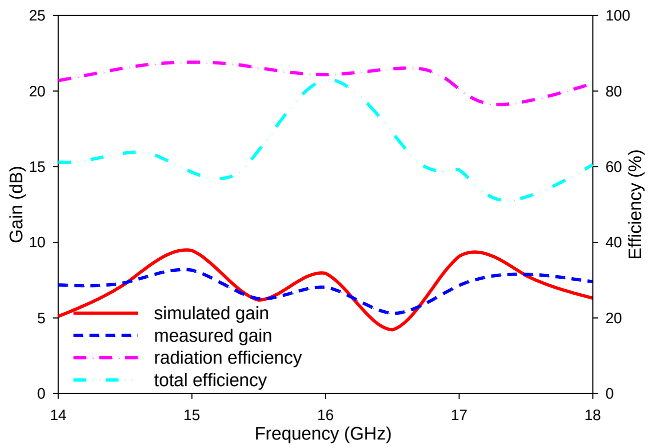
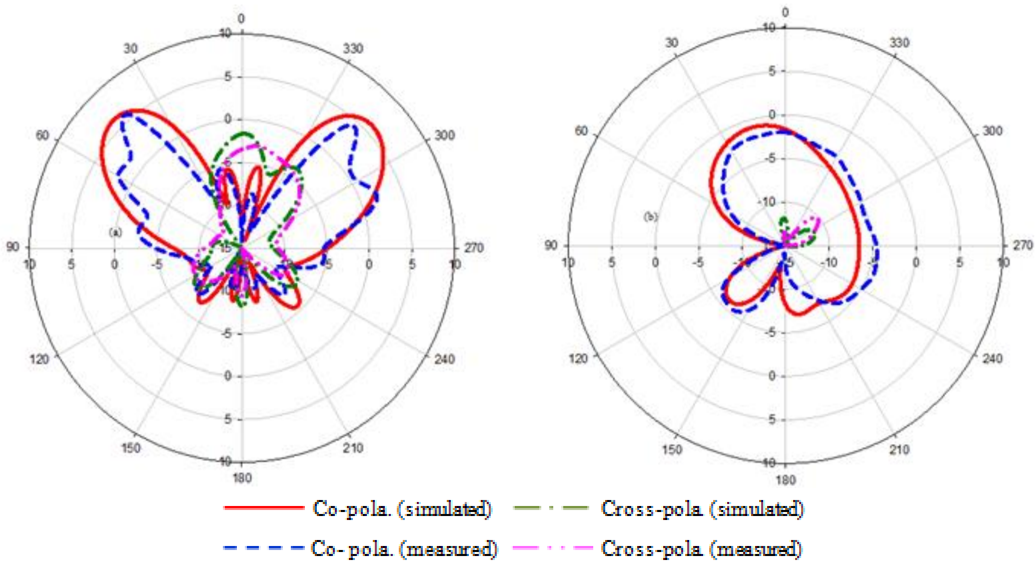


Figure 4. Gain and efficiency of the proposed double microstrip patch antenna

Simulation and measurement of radiation patterns are compared according to xz and yz planes as illustrated in Figure 5. A reasonable agreement between both results is observed in term of pattern shape. Based on those 2D polar plots, the radiation pattern in xz plane performs a butterfly-shape for co-polarization with main lobe directs at 42° while for yz plane the main lobe directs at 16°.



(a) (b)

Figure 5. Co-polarization and cross polarization of simulated and measured radiation patterns of the antenna, (a) xz plane, (b) yz plane

4. CONCLUSION

A double microstrip patch antenna with AMC structure is presented in this paper. To overcome the drawbacks such as low gain and narrow bandwidth produced by the conventional microstrip patch antenna, AMC structure is added in between two Rogers RT5880 substrates. The proposed antenna manages to obtain -17.33 dB in measurement, which is much better than the reflection coefficient obtained by the conventional antenna. Besides that, the implementation of AMC structure also offers advantage in antenna size miniaturization when the proposed antenna shrinks almost 23.6% of the overall size. Gain and efficiency obtain by this antenna also high hence it is very favorable to be used for 5G applications.

ACKNOWLEDGEMENTS

This work has been partly supported by the Malaysia Ministry of Education under FRGS/1/2017/STG02/UNIMAP/02/2 and UniMAP Research Incentive Fund of 9007-00141. The author Norfatihah would like to thanks the contributions of Ministry of Higher Education of Malaysia for Ph.D sponsorship.The authors also acknowledge Advanced Communication Engineering Centre (ACE) for the lab facilities.

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