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Design And Improvement Low Radar Cross Section Antenna At 5.8 Ghz Using Metamaterial (Mm) Microwave Absorber

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ABSTRACT:

One method for reducing radar cross-section without affecting antenna radiation characteristics is presented in this article. In this antenna, we used MM technology to create a square unit cell with several rectangular branches and then made an array of the same unit cell consisting of 80 unit cell, with a square patch in the middle of this array operating at a specific frequency of 5.8 GHz and this antenna is fed using SMA Connector at a specific point in the square patch, where the gain of this antenna reaches the simulation results to a value of -25.3 dB. We increased the efficiency of this antenna from 7.62 dBi to 7.73 dBi using CST Microwave Studio 2019.

KEYWORDS:

microstrip patch antenna, Frequency 5.8 GHz, radar cross section Antenna (RCSA), Metamaterial (MM).

1.INTRODUCTION:

Since World War II, the concept of stealth technology has been one of the difficult goals in military applications and a subject of research[1]. When the backscattered electromagnetic (EM) wave reaches the radar can a target be detected. This fact has inspired a number of ways to be proposed as radar cross section reduction (RCS) methods to either absorb the incoming wave to produce low observable targets or deflect the backscattered wave away from the receiver. The evaluation of the backscattered radar signals from the target in the direction of the receiver is referred to as radar cross section, or RCS[2]. Over the past, a lot of techniques have been suggested to decrease RCS. In these, lumped loads and distribution loads[3] are important parts to achieve a particular level of RCS. Additionally, the use of radar absorbent material (RAM), which transforms radio frequency radiation into heat, is a useful method for reducing the RCS signature[4]. There were also numerous methods published in recent years to reduce RCS, including electromagnetic band-gap devices, frequency selective surfaces (FSS), [5-7] artificial magnetic conductors (AMC), [8-10]and electromagnetic band gap structures (EBG)[11, 12]. Artificial materials known as metamaterials (MMs) are designed to have special electromagnetic (EM) characteristics that are not present in naturally existing materials[13, 14]. In Reference 11, a substance that absorbs radar waves has been employed to lower an antenna's RCS, which transforms EM waves into thermal energy. Generally, there are two basic types of radar cross-section (active RCSR, passive RCSR)[15]. To produce a quad-band linear polarization rotation of the electromagnetic radiation, a novel PCM is designed and tested (EW). Remarkable RCS is created by manipulating [16]. There are numerous new, innovative, and distinct ideas for increasing the gain of some of these types of antennas[17, 18], and one of these techniques has been applied to increase the gain in the proposed antenna, by parameter sweep for the important and effective parameters that have the greatest influence on the antenna characteristics, particularly increasing the gain[19-21]. A proposed hybrid MM geometry is impinged on a low RCS microstrip patch antenna with unchanged gain[22].

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This paper focuses on the development of a gain-increasing a low RCS, non-variable gain fine line correction antenna with MM geometry that operates at a certain frequency. The content of this paper is as follows: design of the proposed MM antenna in the second section. it is divided into the following major features; design of the MM unit cell, design of a unit cell array, design of microstrip patch antenna and design of RCSA proposed. the third section discusses simulated results before drawing conclusions.

2.DESIGN OF THE PROPOSED MM ANTENNA

2.1.Design of the mm unit cell

Figure (1) depicts the horizontal view of one cell, which is consisting of three layers, so that the conductive material for the surface is the same as for the ground layer, while the substrate material is Roger Rt 5880 with a thickness of 0.5 mm (μ_r = 1, ε_r = 2.2), and the dimensions of the shape are shown in Table (1), and the cell shape is a square with four sides up to the cell's edge at an angle of 90^o each, and four additional.

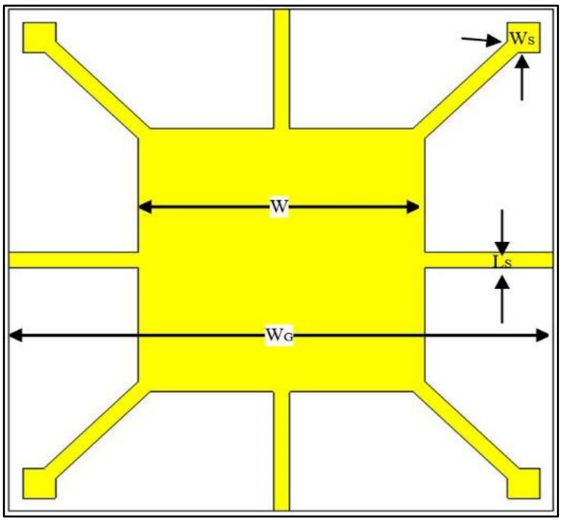

Fig. 1: Front view of the design.

Table 1: Proposed MM unit cell design

Parameters	Value (mm)
W	10.5
W_Q	1.2
L_S	0.603
W_{GS}	20

2.2.Design of a unit cell array

As given in Fig. 2, the 80-element MM unit cell group is created by repeating the MM unit cell more than once. But we relied here on that all these elements are connected, unlike previous research, in which the different forms of such cells are separate from each other.

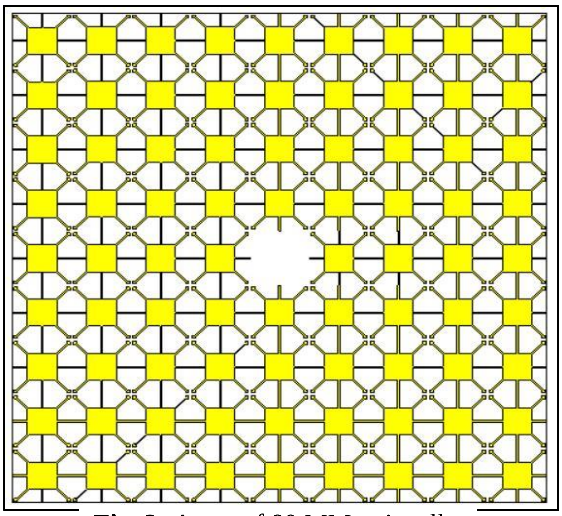

Fig. 2: Array of 80 MM unit cells.

2.3.Design Of Microstrip Patch Antenna At 5.8 Ghz

To produce the required operating frequency, we designed the antenna circuit shown in Fig. 3, which is fed and powered by an SMA connector. Table 2 displays the dimensions used for both the antenna and the connector together. The dimensions of the antenna in length and width were determined using the given following equations [23]:

$$Width = \frac{c}{2f_o\sqrt{\frac{\varepsilon_R+1}{2}}}; \quad \varepsilon_{eff} = \frac{\varepsilon_R+1}{2} + \frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{W}\right)}}\right] \quad (1)$$

$$Length = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{eff}-0.258)\left(\frac{W}{h}+0.8\right)}\right) \quad (2)$$

Table 2: Parameters of microstrip patch and SMA connector.

Parameters	Value (mm)
L	190.8
W_P	20.43
L_P	16
T	7
R	0.8
R_I	2.68
R_O	2.7

2.4.Design of rcsa proposed

As shown in Fig. 4, one unit cell in the middle of Fig. 4 (a) has been omitted and the patch antenna shown in Fig. 4 (b) is constructed in its place. Thus, the proposed circuit was designed by merging the shape and characteristics of the two previous circuits together in Fig. 4 (c)

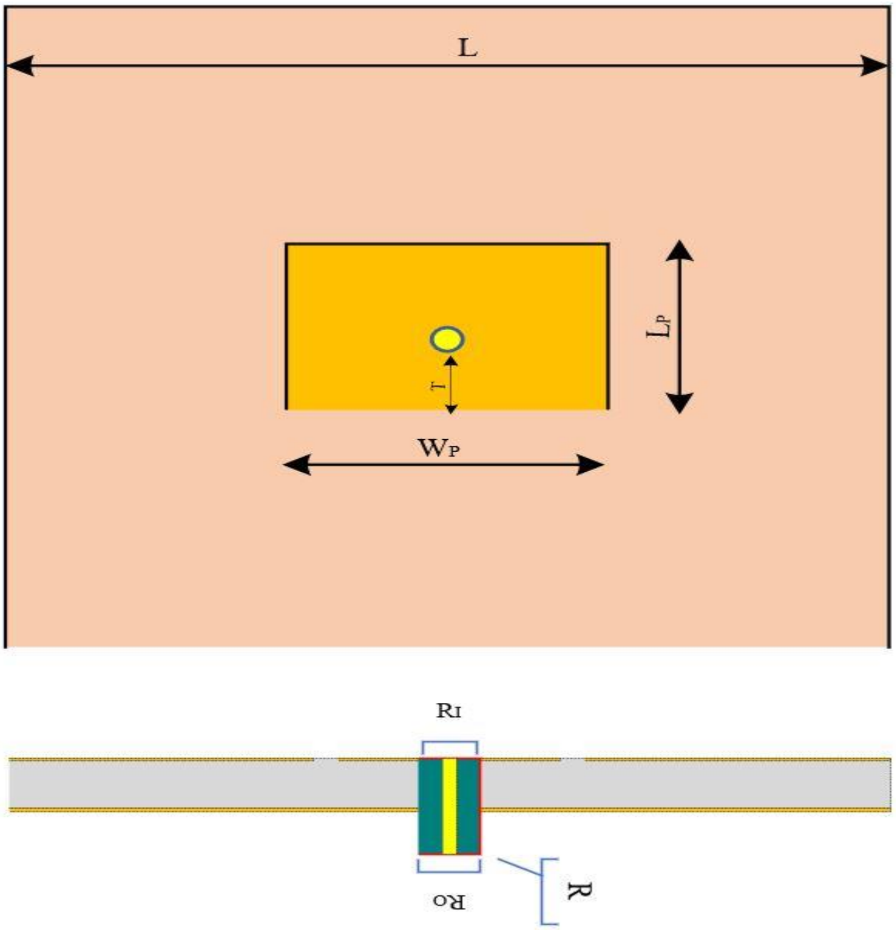

Fig. 3: Microstrip patch antenna and its full side view.

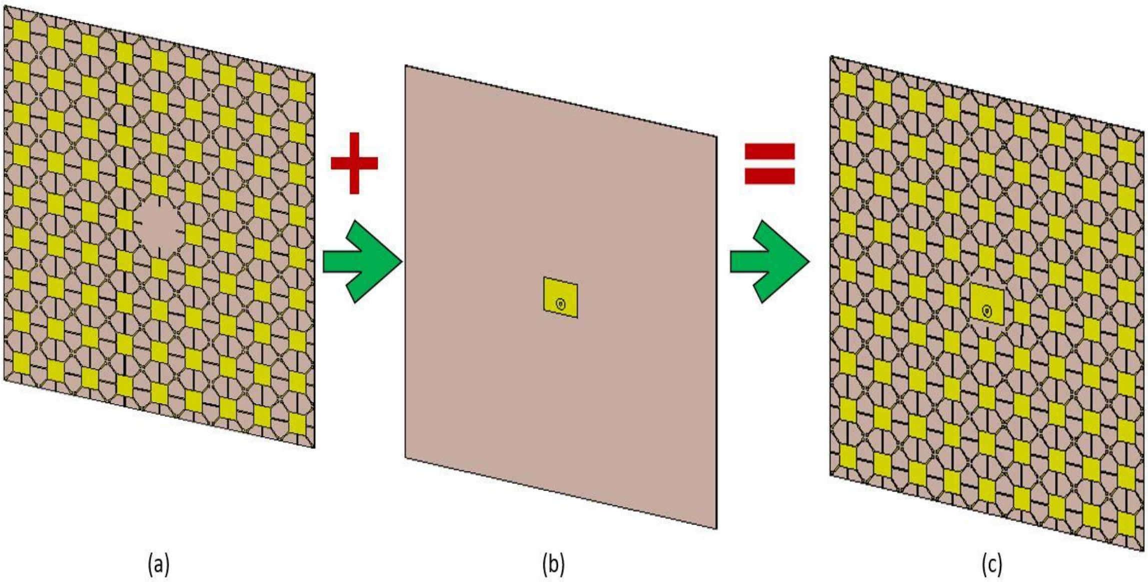

Fig. 4: Design steps of the radar cross section antenna, (a) array of 80 MM unit cells, (b) microstrip patch antenna and (c) full design of RCSA.

3.SIMULATED RESULTS:

A microstrip rectangular patch antenna and an MM unit cell were built using printed circuit board technology to validate the theoretical simulation results. To find the parameters of the Microstrip Patch and SMA Connector for the antenna, try and error and parameter sweep methods are used until optimized results are obtained. For a comprehensive study, CST Microwave Studio 2019 was used to simulate the scattering properties of the original and proposed antennas, as well as their radiation performance. Furthermore, as shown in Fig. 6, there is an increase in return loss when using a single MM unit cell, as well as a difference when using multiple cells with connected cell technology.

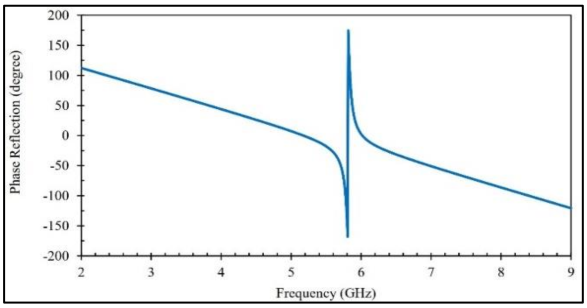

Fig. 5: Frequency dependent phase for unit cell.

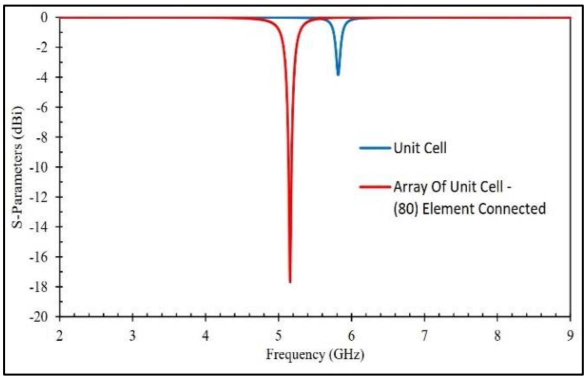

Fig. 6: Return loss for unit cell and an array of 80 MM unit cells vs frequency antenna.

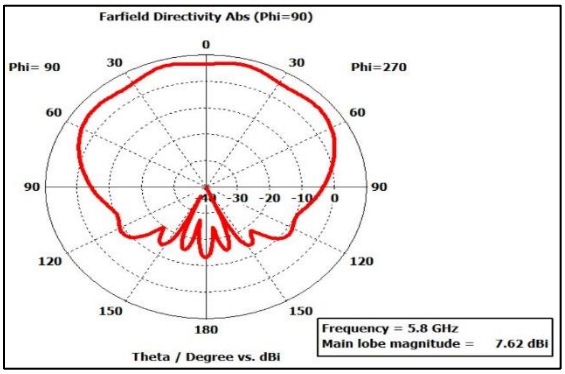

Fig. 7: Simulated gain at y-z plane for microstrip patch antenna (without MM surface).

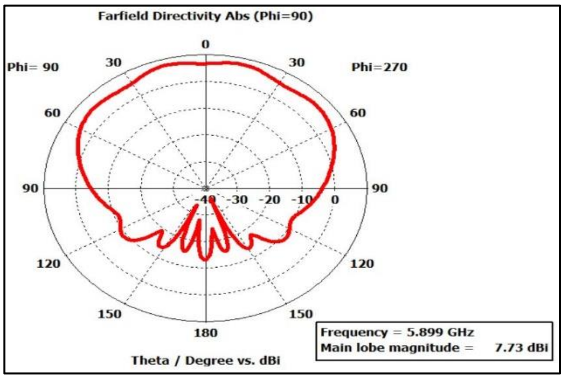

Fig. 8: Simulated gain at y-z plane for RCSA (with MM surface).

While the simulation results in Fig. 9 show the difference in RCS values when building two antennas, the first must be the proposed antenna that combines the properties of the two antennas, and the second must be a single patch antenna that operates at a frequency of 5.8 GHz. In it, we achieve a return loss improvement of -25.3 dB. Using the full antenna gain of 7.73 dBi, we improved the gain by creating an array for the same proposed antenna, the results of which are shown in Figures (7, 8) The purpose of using this shape of unit cell was to absorb electromagnetic radiation and then scatter it using the patch antenna.

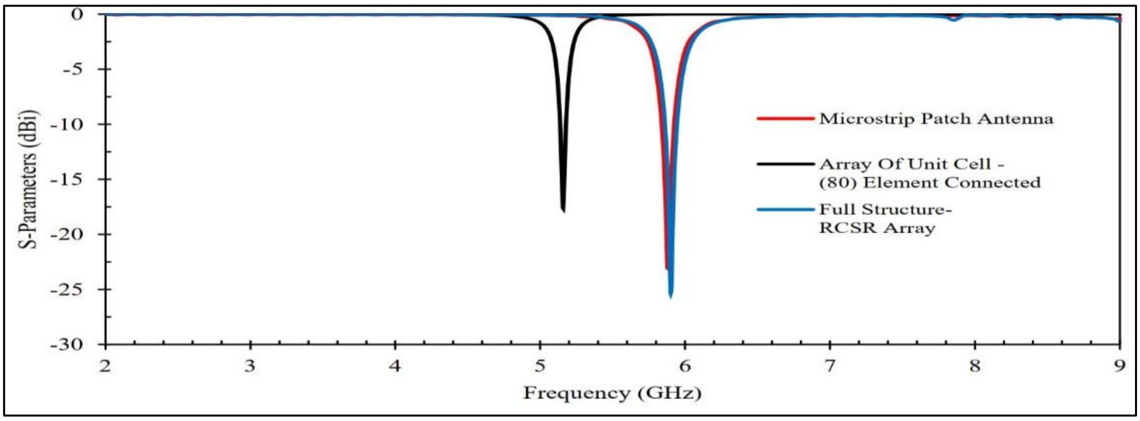

Fig. 9: Comparison of monostatic RCSA for microstrip patch antenna and an array of 80 MM unit cells, as well as the complete RCSA array structure.

4.CONCLUSION

A powerful RCSR working at 5.8 GHz with a different unit cell design joined together around the beam patch has been demonstrated via simulations of the Microstrip patch antenna with MM cells surrounding it. The results proves that the antenna works at a certain frequency with a gain of 7.62 dBi; this gain was then enhanced to 7.73 dBi. Efficiency increased at a high rate of 57.06 % (without MM) to 78.32% at Full design RCSA (with MM). design can be applied to RCS applications such as radar station design for civil and navigational communication.

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تصميم وتحسين هوائي المقطع العرضي للرادار المنخفض عند تردد ٥,٨ جيجا هرتز باستخدام المادة المصنعة للامتصاص للميكروويف

الملخص:

تقدم هذه المقالة طريقة واحدة لتقليل المقطع العرضي للرادار دون التأثير على خصائص إشعاع الهوائي. في هذا الهوائي، استخدمنا تقنية المادة المصنعة (MM) لإنشاء خلية وحدة مربعة بعدة فروع مستطيلة، ثم صنعنا مصفوفة من نفس الخلية تتكون من ٨٠ وحدة خلية، مع رقعة مربعة في منتصف هذه المصفوفة تعمل بتردد محدد يبلغ ٥,٨ جيجا هرتز ويتم تغذية هذا الهوائي باستخدام موصل SMA عند نقطة معينة في التصحيح المربع، حيث يصل كسب هذا الهوائي إلى نتائج المحاكاة بقيمة -٢٥,٣ ديسيبل. قمنا بزيادة كفاءة هذا الهوائي من ٧,٦٢ ديسيبل إلى ٧,٧٣ ديسيبل باستخدام CST Microwave Studio 2019.