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Microstrip patch antenna with metamaterial using superstrate technique for wireless communication

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ABSTRACT

This work builds a metamaterial (MTM) superstrate loaded on a patch of microstrip antenna for wireless communications. The MTM superstrate is made up of four G-shaped resonators on FR-4 substrate with a relative permittivity of 4.4 and has a total area of (8×16) mm^2, and is higher than the patch. The MTM superstrate increases antenna gain while also raising the input reflection coefficient. When it is 9 mm above the patch, the gain increased from 3.28 dB to 6.02 dB, and when it is 7 mm above the patch, the input reflection coefficient was enhanced from -31.217 dB to -45.8 dB. When the MTM superstrate loaded antenna was compared to the traditional unloaded antenna, it was discovered that metamaterials have a lot of potential for improving antenna performance.

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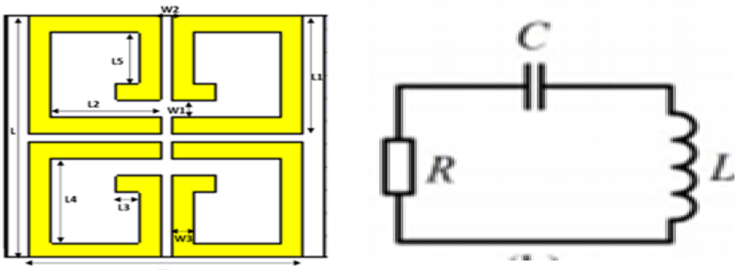
1. INTRODUCTION

The special properties of metamaterials have enticed scientists to develop highly efficient antennas for future wireless communication [1]. No other ordinary/naturally occurring metamaterial has the property that a metamaterial does [2]-[6]. Metamaterials are man-made structures that are engineered to have properties that aren't found in nature. Veselago introduced the first metamaterial definition [7]-[9]. Metamaterials are made up of unit cells that are organized in a regular pattern [10]-[15]. Tiny metallic resonators with a duration much shorter than the wavelength make up the unit cells. Different shapes are possible for the unit cell. Metamaterial structures may be used to miniaturize a large antenna, add a second resonance to a multiband antenna, increase the gain of a conventional antenna, increase the bandwidth of a narrow band antenna, and add a second resonance to a multiband antenna [16]-[25]. The metamaterial's exotic properties can be removed to achieve all of the antenna's aforementioned properties. In this study, we propose a metamaterials unit cell to obtain resonances at 6 GHz. The unit cell is a G-shaped split ring resonator (GSRR). The dielectric constant of the usable FR4 substrate is 4.4 and the height is 1.6 mm.

2. DESIGN OF THE METASURFACE UNIT CELL

The proposed metamaterial unit cell is made up of four symmetrically aligned GSRR. Placing the cell in the middle determines the medium parameters. In Figure 1, the proposed GSRR's extensive dimension layout and the electrical circuit represented it is. Table 1 shows the dimensions of the proposed metasurface unit cell. The input reflection cofficient (S11) of the metasurface unit cell as shown in Figure 2.



(a) (b)

Figure 1. These figures are; (a) front view for the unit cell, (b) the unit cell's equivalent circuit

Table 1. Dimensions of metasurface unit cell

W1=0.55	W2=0.28	W3=0.55	L=8	W=8
L1=3.86	L2=2.76	L3=0.55	L4=2.76	L5=1.65

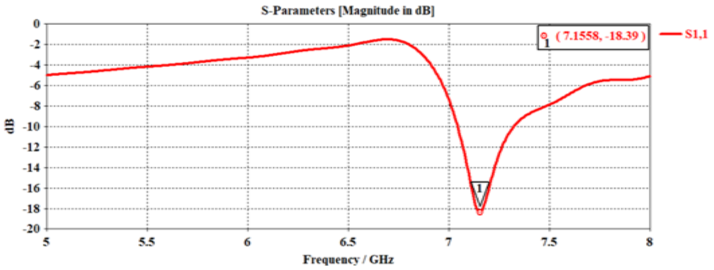
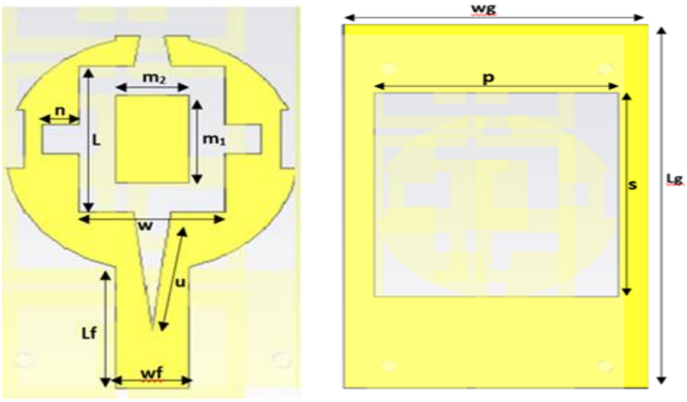


Figure 2. (S11) of the metasurface unit cell

3. DESIGN OF PROPOSED MICROSTRIP ANTENNA

The proposed antenna consists of a ground plane and a 1.6 mm thick FR4 dielectric substrate, and a relative permittivity of 4.4. The microstrip antenna operates at 7.26 GHz, the microstrip patch antenna was developed. Table 2 and Table 3 display the design parameters for the microstrip antenna as shown in Figure 3.



(a) (b)

Figure 3. These figures are; (a) the patch for proposed microstrip antenna, (b) the ground plane for proposed microstrip antenna

Table 2. Dimensions for the proposed microstrip antenna

Symbol	Value (mm)
m_1	3
m_2	2
L	5
N	1
W	4
U	4.03
S	9
P	8

Table 3. Dimensions for the proposed microstrip antenna

Parameter	Quality	value (mm)
Lg	Length of ground	16
Wg	Width of ground	10
Ht	thickness of the copper	0.035
Ls	Length of substrate	16
Hs	Height of substrate	1.6
Ws	Width of substrate	10
Lf	Length of the feed line	4.13
Wf	Width of the feed line	2

The microstrip antenna's input reflection coefficient was calculated at 7.26 GHz, and it was discovered that the proposed antenna had an input reflection coefficient of -31.217 dB, as shown in Figure 4. The gain of the microstrip patch antenna at 7.26 GHz is 3.28 dB as shown in Figure 5.

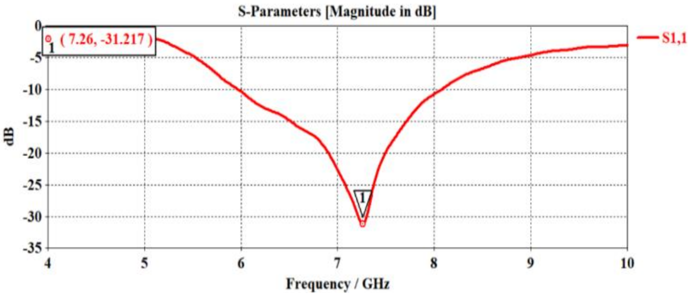


Figure 4. Input reflection coefficient for proposed antenna

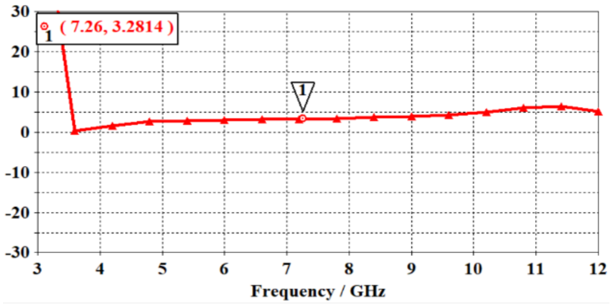
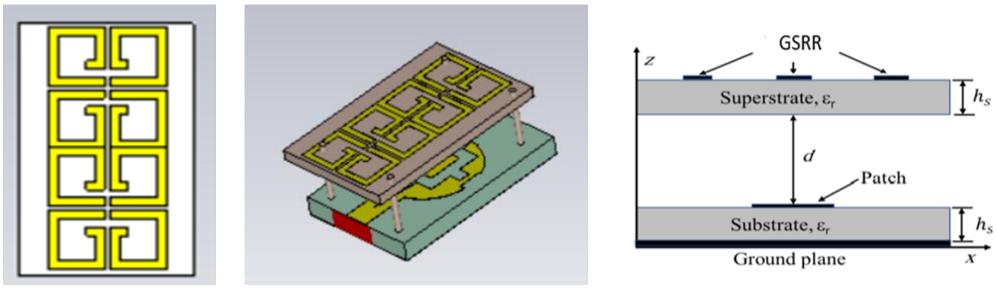


Figure 5. The gain for microstrip proposed antenna

4. METAMATERIAL SUPERSTRATE ANALYSIS

The geometrical structure of a metamaterial superstrate made up of a (2×1) cell array of the GSRR unit cell is shown in Figure 6 (a), Figure 6 (b), and Figure 6 (c) show viewpoint and side views of the proposed antenna. The MTM superstrate is used to cover the typical antenna's patch without increasing the total antenna area, i.e. the planer areas. The CST microwave studio package, which is based on the finite integration technique, was used to analyze the proposed antenna.



(a) (b) (c)

Figure 6. These figures are, (a) MTM superstrate geometrical structure, (b) side view, (c) perspective view

5. PARAMETRIC STUDY

CST's parameter sweep option was used to carry out the parametric studies to obtain maximum enhancement in gain and the input reflection coefficient of the proposed antenna. Figure 7 and Figure 8 illustrate the variation of the gain and the input reflection coefficient, respectively, at 7.26 GHz of the proposed antenna with the amendment in the separation d (where d is the distance between the patch and the metamaterial superstrate). Maximum gain is obtained for d=9 mm and the maximum S11 is obtained at the distance d=7 mm.

To obtain the optimum gain enhancement of the proposed antenna, parametric studies were carried out using the parameter sweep option in CST. Figure 7 and Figure 8 show the difference in gain and S11, respectively, of the designed antenna at 7.26 GHz after the distance was modified. At a distance of 9 mm, the maximum gain is obtained, and the maximum S11 is obtained for d=7 mm.

The cavity effect can be used to describe the proposed antenna gain increase. Arises when the GSRR MTM superstrate is raised above the patch at a suitable distance. According to snell's law of refraction, a medium with a low refractive index scatters electromagnetic waves away from the main source and in the direction of the medium's normal. The surface this function increases the proposed antenna's directivity significantly. The MTM superstrate acts as a highly reflective surface, making the antenna extremely effective. The existence of MTM superstrate also affects the antenna's field distribution. The proposed antenna's overall gain would be improved by making it more homogeneous.

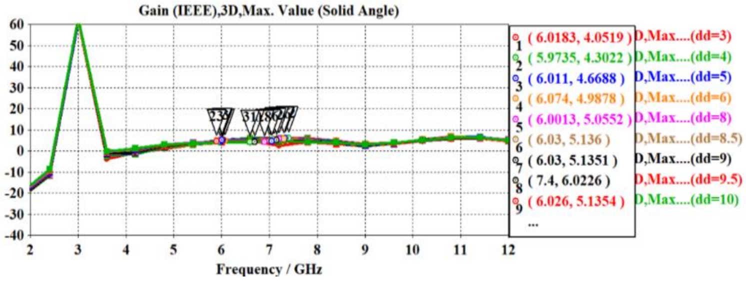


Figure 7. Gain parametric analysis for various distances

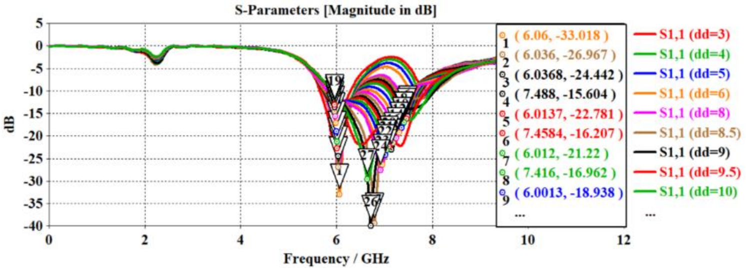


Figure 8. S11 parametric analysis for different distances

After reviewing the parametric study results, the distance to achieve the best result for S11 is d=7 as shown in Figure 9. Figure 10 shows the frequencies that will be used if we set a distance of 9 mm. At d=9, the maximum gain is reached, as illustrated in Figure 11.

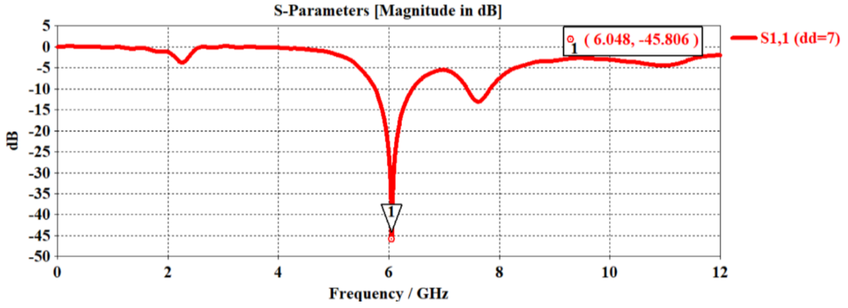


Figure 9. The input reflection coefficient at the distance 7 mm

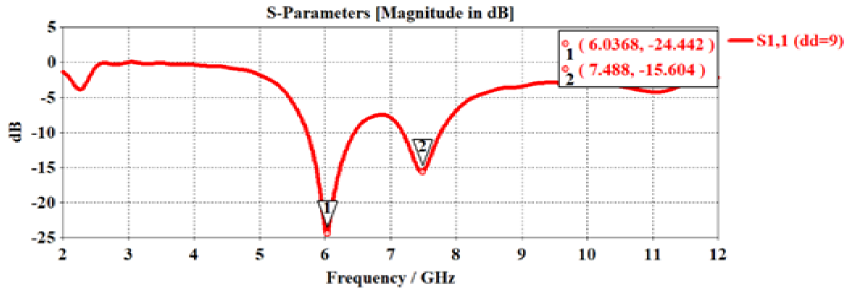


Figure 10. Input reflection coefficient at the distance 9 mm

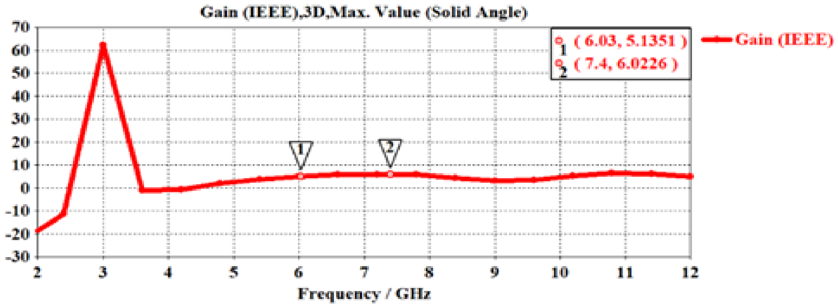


Figure 11. The gain at the distance 9 mm

6. CONCLUSION

For wireless communications, an MTM superstrate loaded on the patch of microstrip antenna is built in this paper. The MTM superstrate has a total area of (8×16) mm^2 and is made up of four G-shaped resonators put on a substrate that is made of FR-4 with a relative permittivity of 4.4. The MTM superstrate is higher than the patch. That increases the antenna gain while also raising the input reflection coefficient when it is located at 9 mm and 7 mm above the patch. When the MTM superstrate-loaded antenna was compared to the traditional unloaded power, it was discovered that metamaterials have a lot of potential for improving antenna performance.

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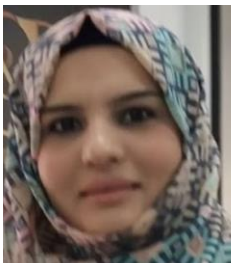

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