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Enhancing Antenna Performance using Metamaterials

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ABSTRACT

This paper is devoted for the design and implementation of two traditional antennas with and without Metamaterials. The first antenna is a traditional circular patch antenna is simulated and its performance is studied. When the antenna is backed up with Metamaterials, it provide a greater gain, directivity and a wider bandwidth. The second antenna is a traditional ultra-wide band circular patch antenna.it is simulated and its performance is studied. When the antenna is backed up with Metamaterials, it provides a specified bandwidth. All antennas are fabricated on Roger RO4350B and simulated by CST microwave studio. The traditional circular patch antenna with and without Metamaterials is measured using the network analyzer. All the measured and simulated results have a good agreement.

1. Introduction

Metamaterials are manufactured materials which are not found in nature to give some particular properties [1]. They are made of crystals that is periodically repeated that is called unit cell. The unit cells are not made like the other nature materials of physical atoms and molecules but it is made of small metallic resonators which interface with the electromagnetic wave that have wavelength λ. When an incident wave interacts with the unit cells, the medium of electromagnetic wave gain some properties such as the electric permittivity εr and the magnetic permeability μr both have negative signs [2-6].

When Metamaterial backed up an antenna structure, it enhances the antenna performance over the traditional ones. Many researchers' implemented antennas with Metamaterial support in different applications for wireless communication, space communications, GPS, satellites, space vehicle navigation and airplanes. Metamaterial enhances the gain and matching conditions [7-11].
This paper presents a traditional circular patch antenna. The enhancement is made up by backing it up with Metamaterial in a form of periodic square patches of different size and spacing on the ground layer of the traditional circular patch antenna. It conducts capacitance compensation for the antenna structure and exhibits a greater gain, directivity and a wider bandwidth. On the other

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hand, when backing the UWB defected ground circular patch antenna with the same Metamaterial unit cell, it notches some undesired frequency bands.

2. Antenna Design

A circular patch antenna is shown in Fig. 1. It is implemented on CST studio with dielectric substrate of relative permittivity εr of 3.48, loss tangent of 0.004 and substrate thickness h of 1.524 mm. The overall dimension of the antenna is 35×50m^2. The radius of the circular patch r =11.1mm. The ground occupies full size without any truncation.

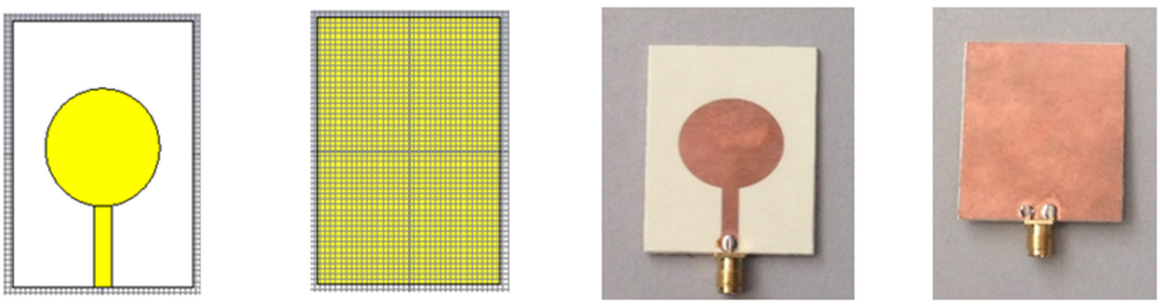

Fig. 1. Circular patch antenna; simulation structure of front and back layers (left), Fabricated traditional circular patch antenna (right)

The ground layer of the conventional circular patch antenna is replaced by square copper patches with side length a as shown in Fig. 2. The side length of square patch a=14mm. The gap between two square patch is g=0.85mm.

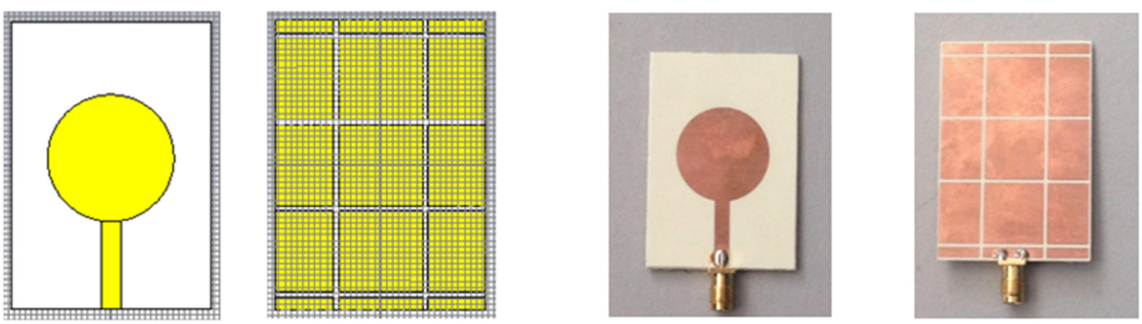

Fig. 2. Circular patch antenna backed up with metamaterials; simulation structure of front and back layers (left), Fabricated traditional circular patch antenna (right)

Moreover, the ultra-wide band (UWB) circular patch antenna with a truncated ground is implemented as shown in Fig. 3. The truncated ground has length l=15mm.on the same time, the bottom layer is backed with square copper patches with side length a as shown in Fig. 4. The side length of square patch a=10mm. The gap between two square patch is g=0.5mm

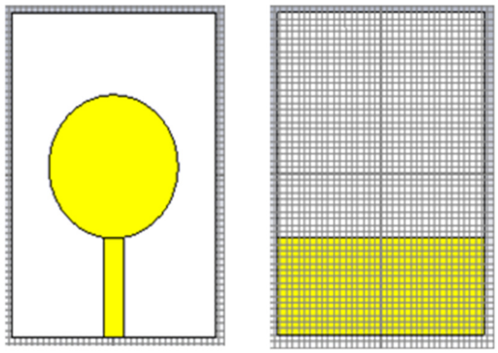

Fig. 3. UWB Circular patch antenna with truncated ground

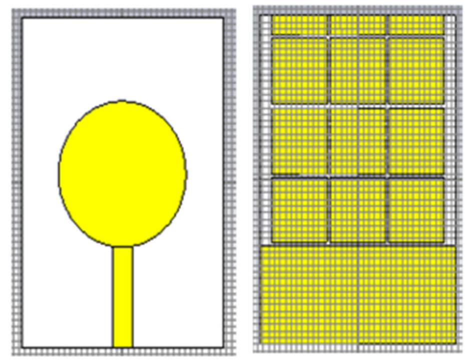

Fig. 4. UWB Circular patch antenna backed up with Metamaterials

3. Results and Discussion

This section is devoted to the results of the previously designed antennas. Firstly, the measured and simulated return loss S_{11} of the traditional circular patch antenna is shown in Fig. 5.The antenna resonates at f=8 GHz. The bandwidth of the antenna is from 7.8 GHz to 8.1 GHz. The fractional bandwidth is about 3.75 %. It conducts a good agreement between the measured and simulated return loss.

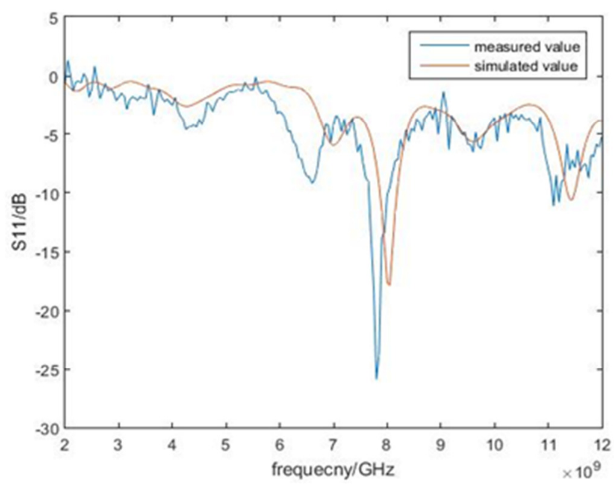

Fig. 5. The simulated and measured antenna return loss S_{11} results of circular patch antenna

The 3D radiation pattern of the antenna at frequency 8 GHz is illustrated in Fig. 6. It conducts directivity of 4.301 dBi and gain of 3.3551 dB. Fig. 7 depicts the 2D radiation at both xy and xz planes at frequency 8 GHz.

Secondly, the measured and simulated return loss S_{11} of circular patch antenna backed up with Metamaterials is displayed in Fig. 8.The antenna becomes dual band antenna resonates at two frequencies. The first resonance occurs at f=5.2 GHz with bandwidth from 5.1 GHz to 5.3 GHz. The fractional bandwidth is about 3.84%. The second resonance occurs at f=7.05 GHz with bandwidth from 6.9 to 8.7 GHz. The fractional bandwidth is about 25.6% which exhibits UWB antenna. One notices the agreement between the measured and simulated results. It should be pointed out that the conduction of UWB is due to the capacitance compensation provided by the Metamaterial at different generated modes.

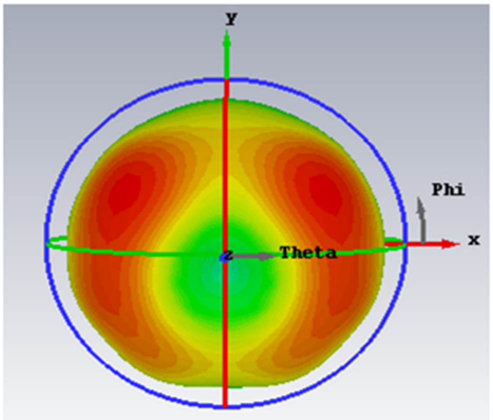

Fig. 6. 3D plane of the antenna at f=8 GHz

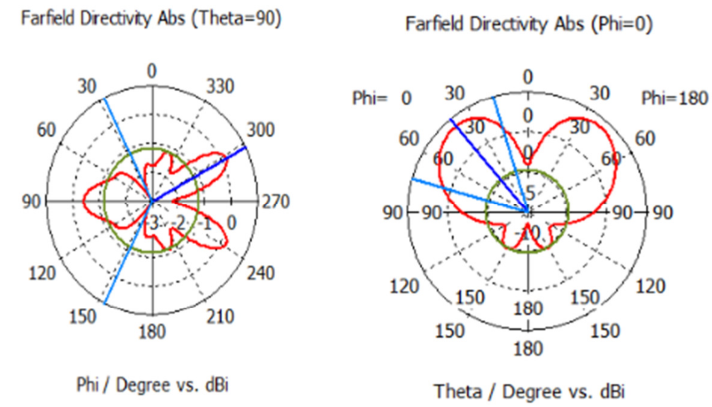

Fig. 7. 2D radiation of the antenna at f=8 GHz at xy and xz planes. (a) xy plane (b) xz plane

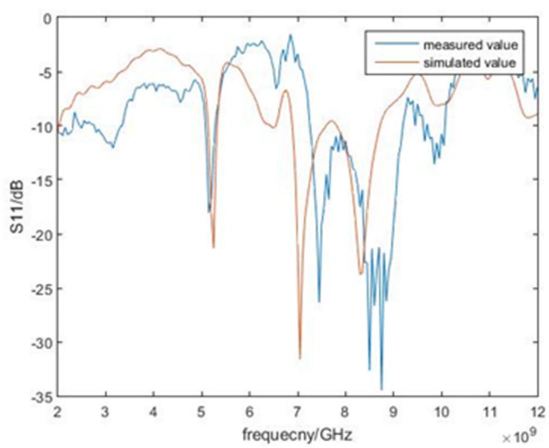

Fig. 8. The simulated and measured antenna return loss S_{11} results of circular patch antenna backed up with Metamaterials

The 3D radiation pattern of the antenna at frequency 7 GHz is offered in Fig. 9. Its directivity is 5.073 dBi and gain is 4.018 dB is. Fig. 10 shows the 2D radiation at both xy and xz planes at frequency 7 GHz.

The 3D radiation pattern of the antenna at frequency 8.3 GHz is displayed in Fig. 11. It exhibits directivity of 7.523 dBi and gain of 7.1038 dB. Fig. 12 illustrates the 2D radiation pattern at both xy and xz planes at frequency 8.3 GHz. One notices the improvement of the gain and directivity.

Thirdly, the simulated return loss S_{11} of UWB circular patch antenna with truncated ground is shown in Fig. 13. The antenna resonates at two frequencies. The first resonance occurs at f=5.4 GHz with bandwidth from 2.4 GHz to 8 GHz. The fractional bandwidth is about 103.7%. The second resonance occurs at f=10.9 GHz with bandwidth from 8.4 to 12.8 GHz. The fractional bandwidth is about 40.3%.

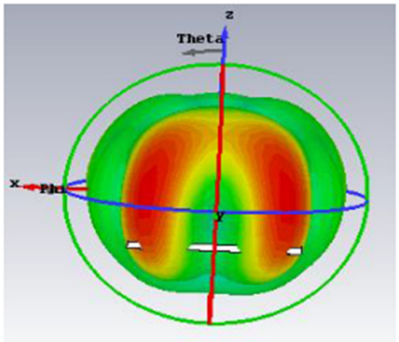

Fig. 9. 3D plane of the antenna at f=7 GHz

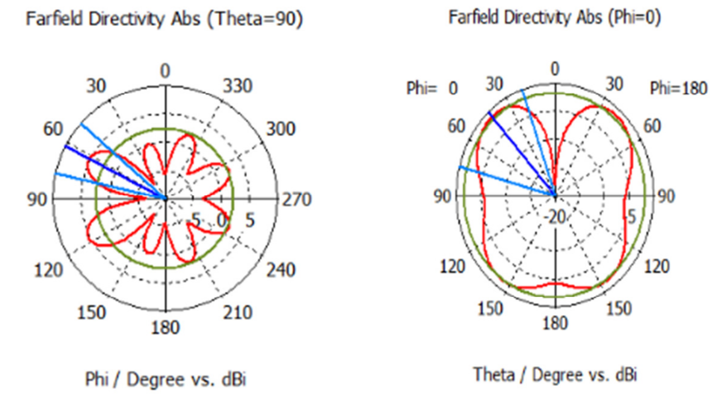

Fig. 10. 2D radiation of the antenna at f=7 GHz at xy and xz planes. (a) xy plane (b) xz plane

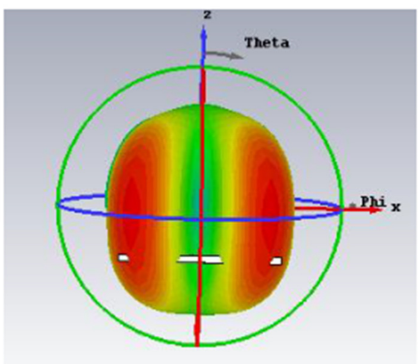

Fig. 11. 3D plane antenna at frequency f=8.3 GHz

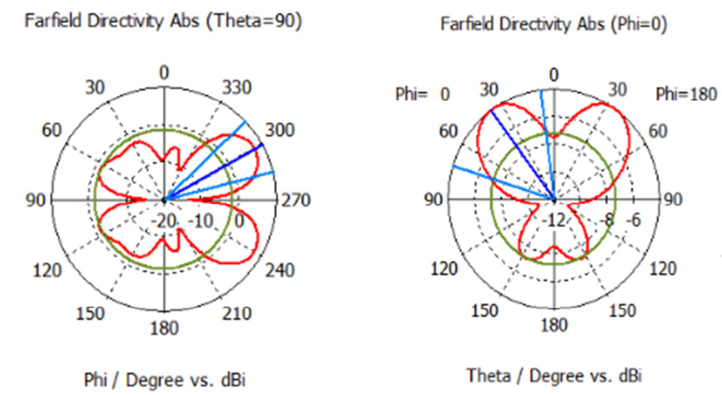

Fig. 12. 2D radiation of the antenna at f=8.3 GHz at xy and xz planes. (a) xy plane (b) xz plane

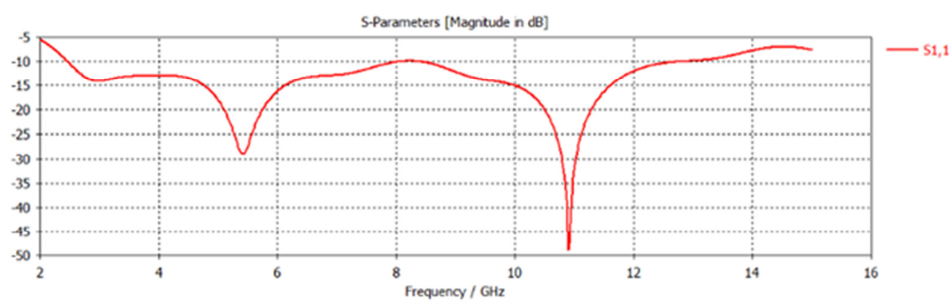

Fig. 13. Return loss; S11 of circular patch antenna with truncated ground

The 3D radiation pattern of the antenna at frequency 10.9 GHz is selected and illustrated in in Fig. 14. It conducts directivity of 7.426 dBi and gain of 7.0326 dB. Fig. 15 displays the 2D radiation at both xy and xz planes also at frequency 10.9 GHz.

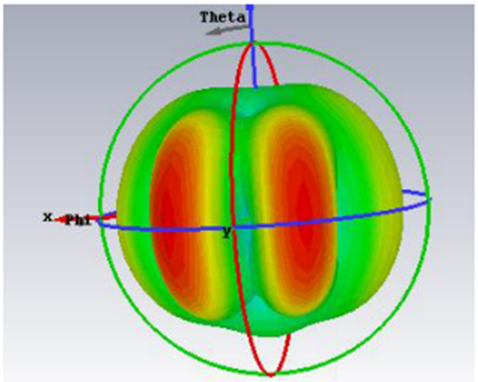

Fig. 14. 3D plane of the antenna at f=10.9 GHz

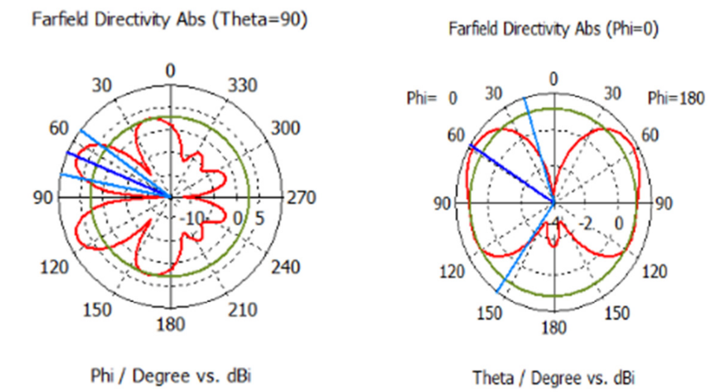

Fig. 15. 2D radiation of the antenna at f=10.9 GHz at xy and xz planes. (a) xy plane (b) xz plane

Fourthly, the simulated return loss S_{11} of UWB circular patch antenna backed up with Metamaterials is displayed in Fig. 16. The antenna becomes passing only specified band. The antenna resonates at two frequencies. The first resonance occurs at f=7.1 GHz with bandwidth from 6.9 GHz to 7.3 GHz. The fractional bandwidth is about 5.63%. The second resonance occurs at f=11.8 GHz with bandwidth from 11.5 to 12.3 GHz. The fractional bandwidth is about 6.77%.

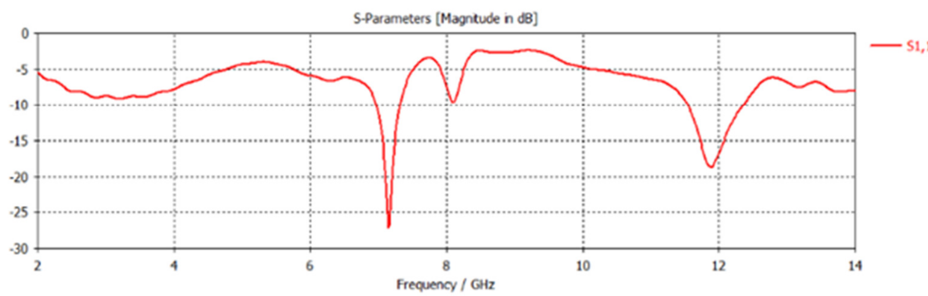

Fig. 16. Return loss; S11 of circular patch antenna with truncated ground backed up with Metamaterials

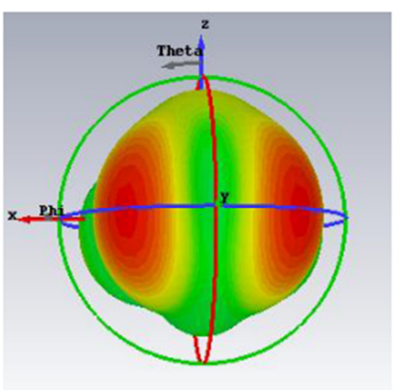

Fig. 17. 3D plane of the antenna at f=7.1 GHz

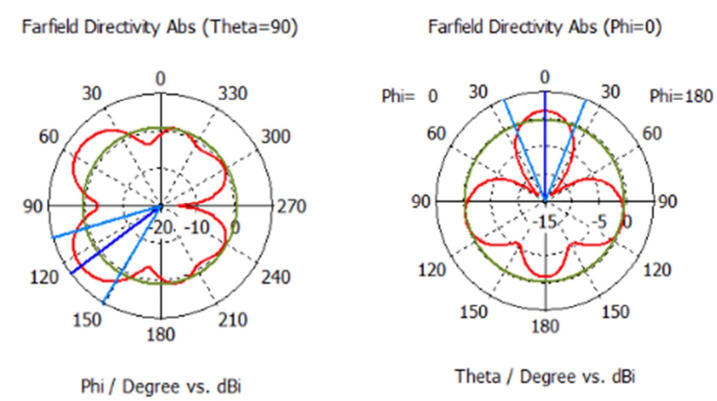

Fig. 18. 2D radiation of the antenna at f=7.1 GHz at xy and xz planes. (a) xy plane (b) xz plane

The 3D radiation pattern of the antenna at frequency 7.1 GHz is selected and illustrated in Fig. 17. It radiates directivity of 6.273 dBi and gain of 5.5644 dB. Fig. 18 shows the 2D radiation at both xy and xz planes also at frequency 7.1 GHz.

4. Conclusion

The Metamaterials enhance the traditional circular patch antenna. The gain is improved from 3.3551 to 7.1038 dB. The antenna starts operating from 6.9 GHz instead of 7.8 GHz. The directivity is enhanced from 4.301 dBi to 7.523 dBi.the bandwidth is improved from 6.9 GHz to 8.7 GHz instead from 7.8 to 8.1 GHz (1.5 GHz broader).

Concerning the UWB antenna, the Metamaterials change the performance of the UWB circular patch antenna. It allowed only specified bandwidth to operate from 6.9 GHz to 7.3 GHz instead of from 2.4 GHz to 8 GHz.

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