MINIATURIZATION OF PATCH ANTENNA USING SRR AND CSRR

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Abstract - *The microstrip antennas are low profile, conformable to planar and nonplanar surfaces, simple and inexpensive to fabricate using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC (Mono-lithic Microwave Integrated Circuit). There are numerous substrates that can be used for the design of microstrip antennas, and their dielectric constants are usually in the range of 2:2<= E_r <=12. The ones that are most desirable for good antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space but at the expense of larger element size. For the home users and commercial business 2.4GHz is the frequency band used for WiFi, Bluetooth, etc. The proposed project involves the design and development of a compact microstrip patch antenna (MSA) using complementary split ring resonator*

***Key Words*: Split ring resonator, Complementary split ring resonator, Microstrip antenna**

1. INTRODUCTION

Microwave is a line-of-sight wireless communication technology that uses high frequency beams of radio waves to provide high speed wireless connections that can send and receive voice, video, and data information. Microwave links are widely used for point-to-point communications because their small wavelength allows conveniently- sized antennas to direct them in narrow beams, which can be pointed directly at the receiving antenna. This allows nearby microwave equipment to use the same frequencies without interfering with each other, as lower frequency radio waves do. Another advantage is that the high frequency of microwaves gives the microwave band a very large information-carrying capacity; the microwave band has a bandwidth 30 times that of all the rest of the radio spectrum below it.

Microwave radio transmission is commonly used in point-to-point communication systems on the surface of the Earth, in satellite communications, and in deep space radio communications. Other parts of the microwave radio band are used for radars, radio navigation systems, sensor systems, and radio astronomy. The higher part of the radio electromagnetic spectrum with frequencies is above 30GHz and below 100GHz, which are called “millimeter waves" because their wavelengths are conveniently measured in millimetres , and their wavelengths range from 10mm down to 3.0mm. Radio waves in this band are usually strongly attenuated by the Earthly atmosphere and particles contained in it, especially during wet weather. Also, in a wide band of frequencies around 60GHz, the radio waves are strongly attenuated by molecular oxygen in the atmosphere. The electronic technologies needed in the millimeter wave band are also much more complex and harder to manufacture than those of the microwave band, hence the cost of millimeter Wave Radios are generally higher.

Microwave frequency bands are designated by specfic letters. Microwaves are found at the higher end of the radio spectrum, but they are commonly different with radio waves based on the technology using them. Microwaves are divided into sub-bands based on their wavelengths which are providing different information. The frequency bands of microwaves are as follows:

Band	Frequency Range (GHz)
L	1 to 2
S	2 to 4
C	4 to 8
X	8 to 10
Ku	12 to 18
K	18 to 26.5
Ka	26.5 to 40
Q	30 to 50
U	40 to 60
V	50 to 75
E	60 to 90 (millimeter waves)
W	75 to 110
F	90 to 140
D	110 to 170

Figure 1: Frequency Range

2. Micro Strip Patch Antenna

These antennas are also known as patch antennas. A microstrip patch antenna consists of a radiating patch that is bonded to a dielectric substrate on one side and has a ground plane on the other side. The patch is generally composed of conducting materials like copper or gold. The operational frequency of these antennas ranges between 100MHz and 100GHz. Due to the advantages like less weight, low volume, and low fabrication cost, these antennas can be manufactured in large quantities.

The microstrip patch antennas are well-known for their performance and extent of usage. The usage of microstrip antennas in the wide range could take over the usage of conventional antennas in applications. There are several applications that use the microstrip patch antennas, such as global positing satellites, cellular phones, personal communication system, and paging devices.

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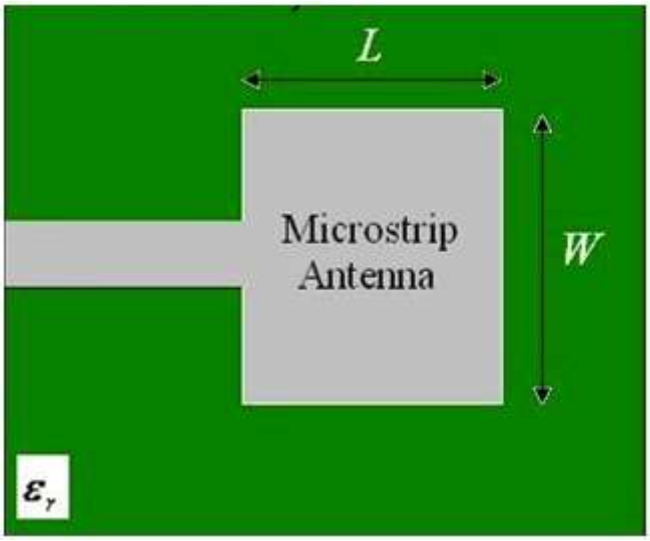

Figure 2: Patch Antenna

Consider the microstrip antenna shown in the Figure, fed by a microstrip transmission line. The patch antenna, microstrip transmission line and ground plane are made of high conductivity metal (typically copper). The patch is of length L, width W, and sitting on top of a substrate (some dielectric circuit board) of thickness h with permittivity or dielectric constant Er. The thickness of the ground plane or of the microstrip is not critically important. Typically the height h is much smaller than the wavelength of operation, but should not be much smaller than 0.025 of a wavelength (1/40th of a wavelength) or the antenna efficiency will be degraded.

3. Why 2.4 GHz ?

For the home users and commercial business 2.4GHz is the frequency band used for WiFi, bluetooth, etc. indeed 2.4 GHz band has got a wide application and is unlicensed so that the operation of in this is preferred by all. You live your life at 2.4GHz. They're free to use. If routers and cordless phones and whatever else are relegated to a small band 2.4GHz, then their radio waves won't interfere with, say, cell phones operating at 1.9GHz, or AM radio, which broadcasts between 535 kHz and 1.7MHz. The ISM is, in effect, a ghetto for unlicensed wireless transmission, recommended first by a quiet little agency in a Swiss office of the UN, called the ITU, then formalized, modified and codified for practical use by the governments of the world, including, of course, our own FCC.

All these gadgets needed frequencies that didn't require licenses, but which were nestled between the ones that did. Frequencies that weren't so high that they sacrificed broadcast penetration (through walls, for example), but weren't so low that they required foot-long antennae. In short, they needed the ISM bands. So they took them.

4. Study of SRR

SRR was to designed for resonating at a frequency of 2.4GHz. The SRR was provided boundary of H planes and E planes simultaneously at 2 sides each and the excitation was provided at the other two ends. Wave port excitation was provided to the substrate and thin two concentric metallic rectangular rings along with a slit in between was designed over FR4 epoxy substrate with height 1.6mm. Trial and error method was used in order to get the required result. The sides were increased, decreased and given various proportions and the required 2.4GHz was achieved.

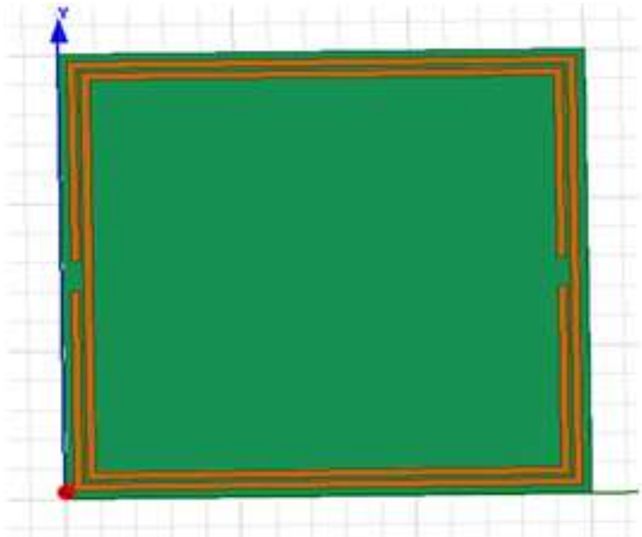

Figure 3: Rectangular SRR

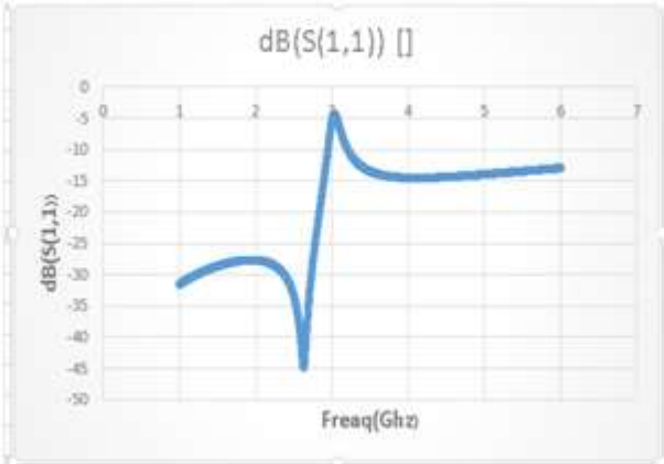

Figure 4: S_{11} Plot of Rectangular SRR

Further the study was made on different structures of SRR. After getting a little knowledge on the square shaped SRR the study was further progressed and the circular shaped SRR was taken to study. So two concentric circular metallic rings was designed on the FR4 epoxy substrate of Er=4.4 such that it resonate at the required 2.4GHz frequency. The same was also found using trial and error method.

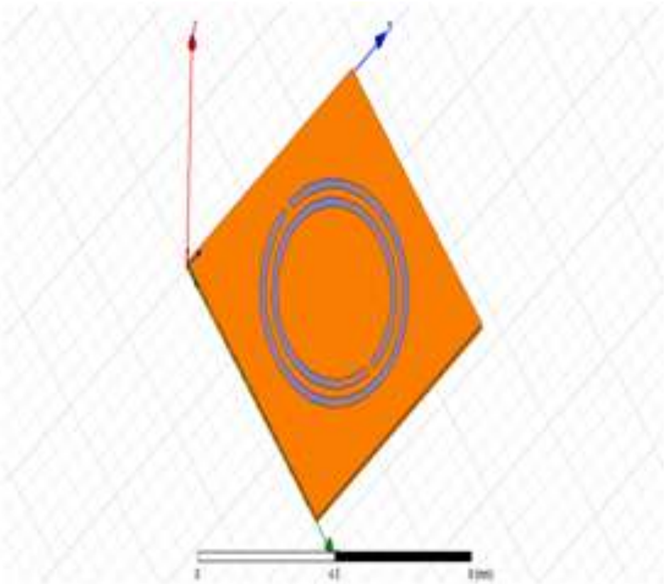

Figure 5: Circular SRR

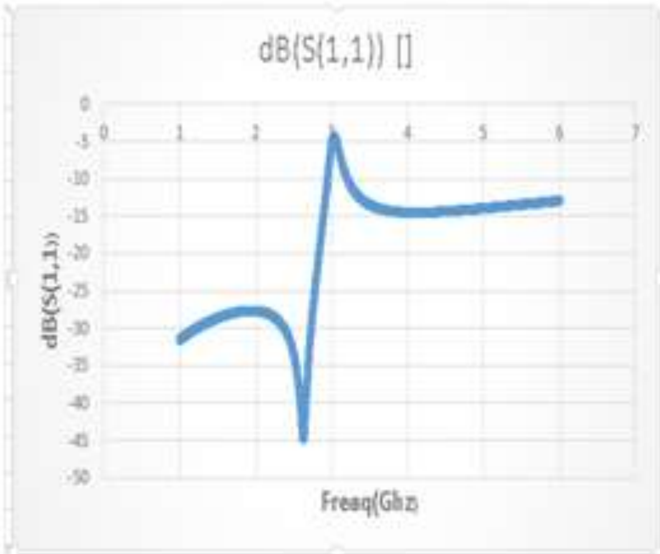

Figure 6: S_{11} Characteristics of Circular SRR

A paper based SRR antenna was simulated based on reference paper “compact split ring resonator antenna for wireless communication systems". The paper had a split ring of outer radius 3.65mm and a feed length of 14mm. By simulating the design over HFSS we obtained S11 value of -25 dB at 5GHz.

5. Prototype 1

The total size of antenna is 5cm_5cm forming a patch of size 3cm X 2.3cm and a feed width of 3mm. Two concentric circular rings were etched out of the patch of outer radius 8.5mm and width of 1mm. slit widths of outer ring is 2mm and 1mm of inner ring. The gap between rings are 0.4mm. Feed width of 12mm was provided.

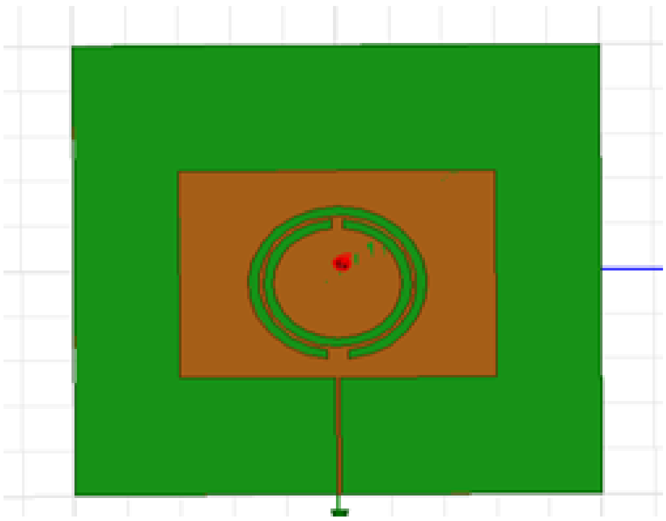

Figure 7: CSRR incorporated Patch

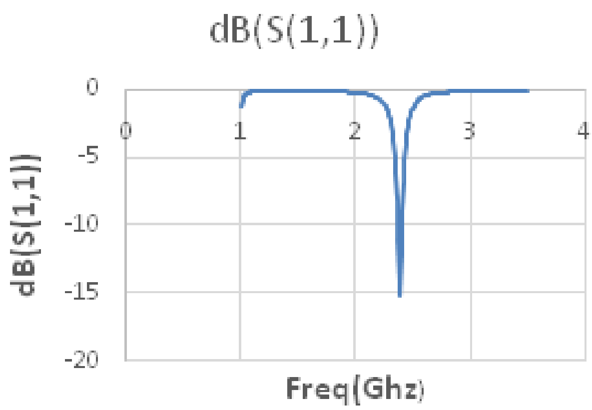

Figure 8: S_{11} characteristics of CSRR incorporated Patch

At a frequency of 2.39 GHz, -15.19 dB value of reection parameter was observed. The problem with this prototype was that the level of miniaturization was much lower and also the practical matching with the 50 ohm connector was as low as -4 dB value. The feedline width was 0.4mm so that the connector could not be properly soldered with the CSRR patch.

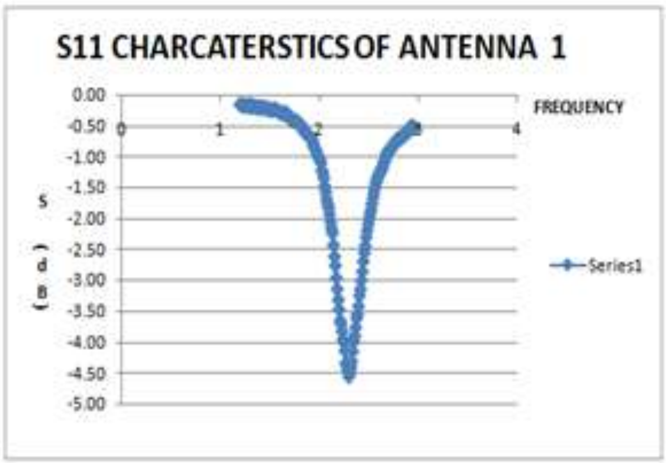

Figure 9: Measured S_{11} Characteristics of Prototype

6. Prototype 2

The whole size of antenna was miniaturized to a value of 2 cm_2 cm. The CSRR was placed at the ground and the above patch had a size of 8mm_8mm. The feed was capacitively coupled with a difference of 0.4mm from the patch. Feed width 3mm is given and rings of 5mm outer radius was taken with a slit width of 1mm and gap of 0.4mm. The feed was given as an offset from the middle of the patch.

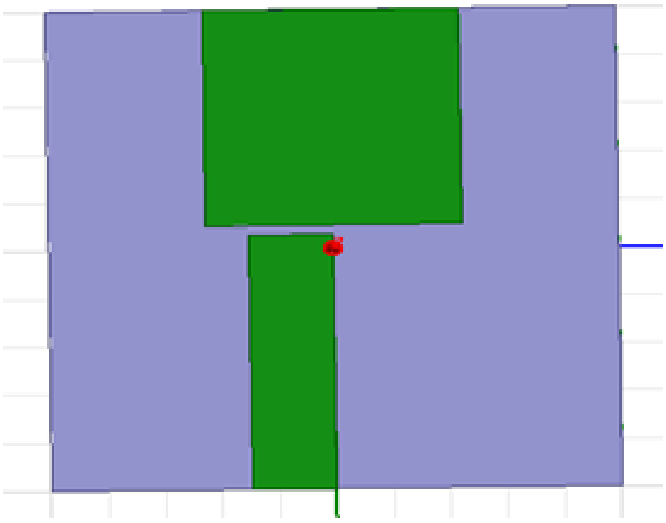

Figure 10: Top view of CSRR incorporated Ground Patch Antenna Model

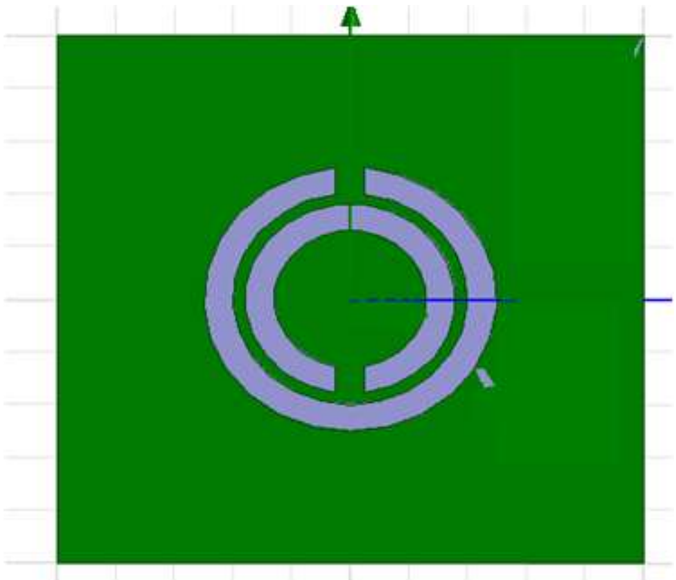

Figure 11: Bottom View of CSRR incorporated Ground Patch Antenna Model

A matching response of S_{11} = -20 dB was obtained. As the dimensions are low the radiation across the 2D surface and 3D surfaces were low.

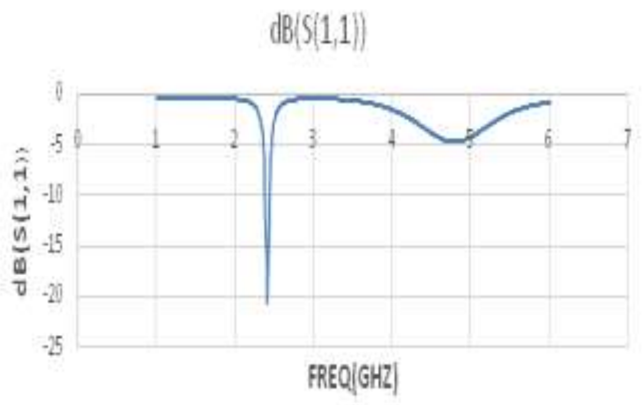

Figure 12: Simulated value of S11 value of the CSRR incorporated patch antenna
Model

The output 3D and 2D plots of the antenna were also taken and the 3D plot which was cut at $\phi=0$ and $\phi=90$ produced the 2D plots at different planes.

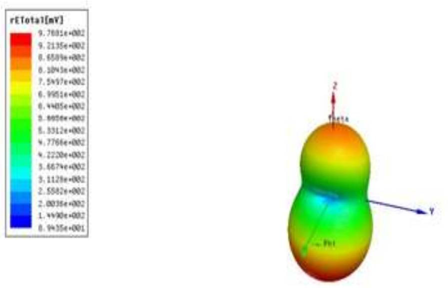

Figure 13: Simulated 3D radiation pattern of the final model

7. Comparison between Original Patch Antenna and Final Prototype

Our project aim was to get a good miniaturization for the patch antenna which resonated at the 2.4GHz band. The total size of the older patch was 7cm_7cm and the CSRR incorporated patch antenna has only a size of 2 cm X 2 cm size. The patch also gave better reaction parameter of -20 dB at 2.5 GHz compared to -17.26 dB at 2.18GHz. The size of the patch in regular case should be increased in order for resonating at lower frequencies but the size reduction was possible due to the CSRR at the ground plane which is designed to resonate at the 2.4GHz.

The miniaturization level of the patch antenna for the 2.4GHz band was met and the total antenna was reduced to a level of 91% . The project objective was met and simulation results showed improved results. The gain parameters showed negative gain as the gain was less than isotropic antenna measured gain. This is due to lower size of the antenna which need to be radiating at 2.4GHz frequency.

8. CONCLUSION

The project objective was to miniaturize the patch antenna for 2.4GHz band. The objective was met by miniaturizing upto 91% by size. The metamaterials were analysed and studied. They are a special type of materials which have negative permittivity and permeability which could alter the electromagnetic properties. The SRR and CSRR are well defined metamaterial structure. These were studied in depth and with the help of them designed miniaturized antenna radiating at 2.4GHz band. The antenna was designed and simulated using HFSS at 2.4GHz with S_{11} value of -20 dB and the antenna was drawn as 2D model with the help of CorelDraw and fabricated using laser cut technology. With the help of Center of Research in Electromagnetics and Antenna, CUSAT a S11 value of -8 dB at 2.5GHz was obtained. The gain enhancement and improved matching could be done as an extension to this project. In extent to the miniaturization further compensations could be done to the antenna for getting better results.

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