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Design of High Gain and Wideband Microstrip Antenna Using Metamaterials

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Abstract

In this paper, a new technique is proposed by exploring the advantages of artificial materials i.e., Metamaterials. In spite of many advantages of planar structures, it suffers mainly from radiation efficiency and has very less fractional bandwidth. The novelty in this structure is, the Complimentary Split Ring Resonators are placed above the ground plane i.e., immediately below the substrate by which the desired characteristics are obtained. Using this approach the return loss is increased to -34 dB and the fractional bandwidth is increased to 66%. The antenna is designed for WiMAX applications and can also be used in short range Ultra wideband applications. The simulations were carried out in Ansoft HFSS. HFSS simulation of the proposed antenna shows improved bandwidth and gain at the frequency of 5GHz.

Index Terms: Complementary split ring resonators (CSRR), Metamaterials, Microstrip Patch Antenna

Introduction

In wireless communication the antenna plays an important role. For point to point wireless communication and Wi-Fi the antenna should be compact and efficient for convenience. Due to the need for reduced size of antenna in both commercial and military spheres, the demand for compact, small size, low cost antennas has increased over the past years. In today's world of wireless communication Microstrip patch antennas play an important role. Due to low weight, low cost, dual band operation, circular polarizations, these patch antennas are used for the most demanding applications. Though there are many advantages of Microstrip patch antennas a few drawbacks like low gain, narrow bandwidth, low efficiency limit the applicability [1].

A Microstrip patch antenna is a very low profile, wide beam and narrowband antenna. In the frequency range of 1GHr to 6 GHz, Microstrip patch antennas are most common types in use today. Deschamps initial proposed the idea of the Microstrip antenna in 1953. However practical antennas were developed by Munson and Howell within the Nineteen Seventies. Usually Microstrip antennas also are known as Microstrip patch antennas or just patch antennas. Microstrip antenna in its simplest type consists of radiating patch on one side of a dielectric substrate and a ground plane on the opposite side. When the relative dielectric constant of the substrate increased the length of the antenna decreased. These antennas are mounted on the spacecraft, aircraft and built in mobile radio communication devices because of their very low profile.

The size of the Microstrip patch antenna is tied to the wavelength directly at the resonant frequency so these antennas are generally in use at higher frequencies. Patch antennas have polarization diversity that is the capability of these antennas. By using many feed points or a single feed point with asymmetric structures of patch these antennas can designed to have horizontal, vertical, left hand circular polarization or right hand circular polarizations. Having polarization diversity is the unique property of Microstrip patch antennas due to which these are used in many types of communication links. The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular or any other configuration. To feed Microstrip antennas there are many configurations, most popular configurations are Microstrip feed line, aperture coupling, proximity coupling and coaxial probe [2]. Two-dimensional structure of the Microstrip patch antenna is the unique property of it [3].

A Microstrip patch antenna has a number of advantages over other antennas. Microstrip antenna found application in different fields due to its compact size. The most important factors like bandwidth and gain are low for patch antennas. To solve these problems there are different ways but each leads to other problem where future attention is required. As compared to the conventional microwave antennas Microstrip antennas have many advantages like they allow both circular and linear polarization, they have small volume and a low profile configuration, and they allow dual and triple frequency operations. Microstrip antennas have some disadvantages like lower gain, narrow bandwidth and low power handling capability as compare to conventional microwave antennas [4].

Metamaterials

Metamaterials are recently developed artificial materials having negative permittivity (ε) and permeability (μ) which leads to negative refractive index. As a result of having these negative properties it exhibits unusual properties compared to available materials. It supports backward waves due to negative index means inside Metamaterials phase velocities and group velocities are antiparallel. Like Metamaterials no other material in the world shows the above properties. The electric and magnetic properties of electromagnetic wave passing through Metamaterials can change and because of these when Metamaterials are used in the fabrication of antennas and microwave components the required properties can be enhanced. Metamaterial was developed in 1967 by Russian theorist Victor Georgievich Veselago [5]. The dimensions of these artificial metallic structures are much smaller than the wavelength of incident radiation. These materials gain their properties from structure rather than composition.

A category of antennas that use Metamaterials to enhance performance like gain and efficiency of miniaturized antennas are known as metamaterial antennas. These special properties help Metamaterials to change the electric and magnetic property of electromagnetic waves passing through it. Due to high performance and small size metamaterial antennas are suitable to use in WLAN (Both 2.4 and 5 GHz). The drawbacks of ordinary patch antenna i.e. low gain and low efficiency can be overcome by using metamaterial antennas. The principle behind the work is that small planar antennas are proposed using Double Negative (DNG) Metamaterials. When we introducing unit cell structure we can obtain the double negative property. A unit cell consists of vias and Microstrip gaps. The behavior of these vias and Microstrip gaps is equivalent to the combination of shunt inductors and series capacitors respectively. The vias leads to negative permittivity and Microstrip gaps leads to negative permeability and this negative permittivity and permeability leads to negative refractive index due to this it exhibits uncommon properties compared to available materials.

Metamaterial Substrate Design

By choosing a high relative permeability μ_r or high relative permittivity ε_r material the size of the antenna can be reduced significantly. In the microwave region the materials that exhibit a high relative permeability do not exist in nature. Though miniaturization is achieving through high ε_r materials but it comes at the cost of raised dielectric losses which will effect on antenna efficiency [4].

Now, the materials that exhibit high magnetic permeability can be artificially engineered to fulfill the requirement of antenna miniaturization. When antenna miniaturization is the key design requirement then to match the resonance frequency of the material and the antenna is necessary. In this structure the resonance frequency can be controlled by metamaterial and substrate dimensions. For the intended antenna design the resonance frequency is 5GHz. Therefore the metamaterial structure designed to resonate in the 5GHz band is shown in fig. 1 and fig. 2. Teflon ($\varepsilon_r = 2.1$, $\mu_r = 1$, loss tangent $\tan \delta = 0.001$) was chosen as the host material for the substrate.

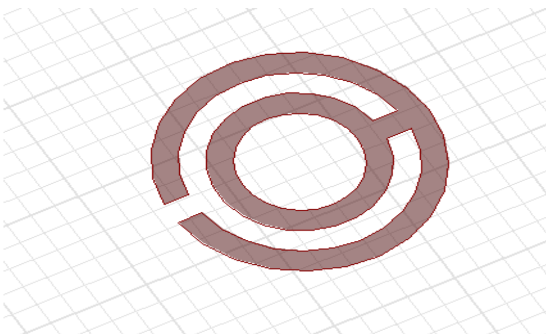

Figure 1: Geometry of the metamaterial

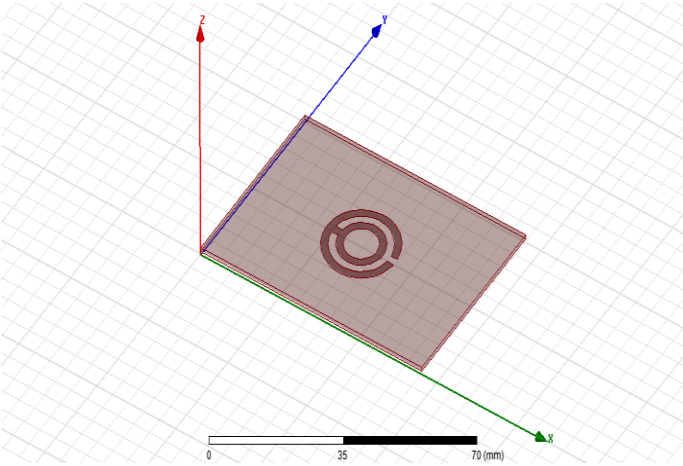

Figure 2: Metamaterial Structure with substrate and ground plane

Antenna Design

Fig.3 illustrates the proposed geometry of a Microstrip patch antenna. A radiating patch is placed above a rectangular dielectric substrate backed by a rectangular ground plane. To excite the patch a Microstrip feed line is used.

A proposed patch antenna consisting of a circular copper patch of radius 10.8 mm etched on top of rectangular Teflon substrate of thickness 0.8 mm and other sides are 70 mm and 50 mm, backed by a copper ground plane. The dielectric constant of the substrate is $\varepsilon_r = 2.1$ and the dielectric loss tangent is $\delta = 0.0012$. A 50Ω copper Microstrip line of width 2 mm is used to feed the patch with a lumped port placed at the edge of the substrate. The radius of the patch is chosen such that the antenna resonates at 5 GHz.

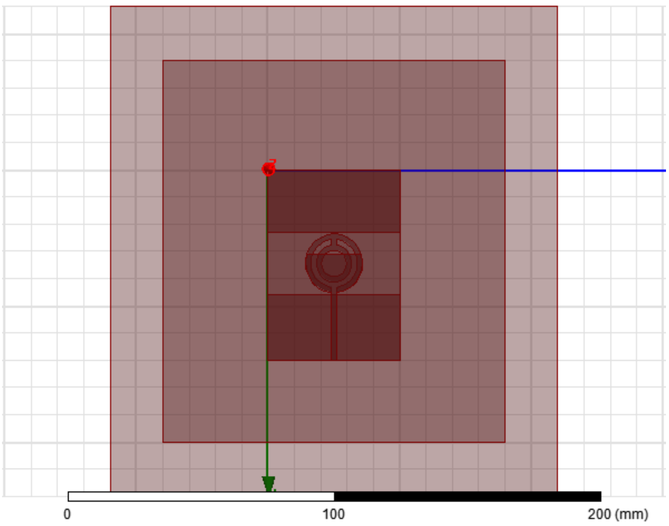

Figure 3: Geometry of the proposed patch antena (Top view)

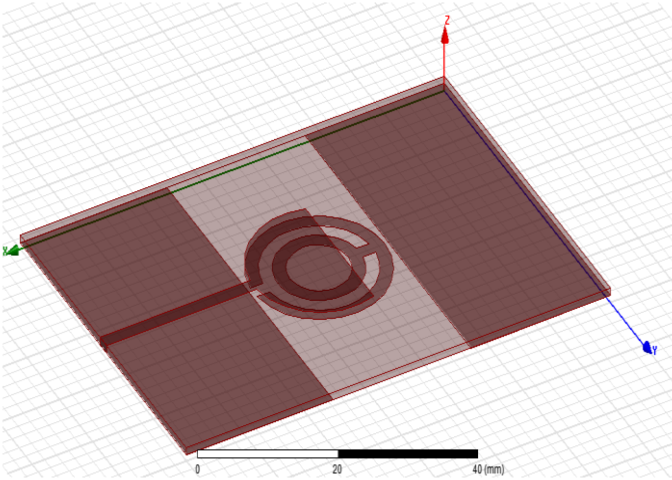

Figure 4: Side view geometry of the Microstrip patch antenna

Table 1: Antenna Design Specification

Operating frequency	5GHz
Radius of circular patch	10.8mm
Substrate dielectric material	Teflon
Substrate dielectric constant	2.1
Substrate thickness	0.8mm
Feeding technique	Microstrip feed line
Dielectric loss tangent	$\delta = 0.0012$
Width of Microstrip feed line	2mm

Results

VSWR and S parameter results of the patch antenna are shown in fig. 5 and fig. 6. The reflection coefficient of the proposed patch antenna is -34dB and VSWR is 1.041. By this we can conclude that the antenna is radiating appropriately at the desired frequency i.e., at 5 GHz. The gain of the antenna is increased to 8.6 dB.

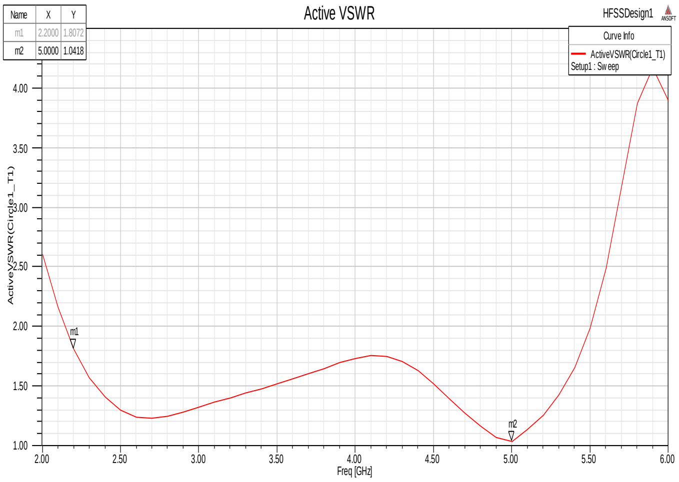

Figure 5: VSWR of the proposed patch antenna

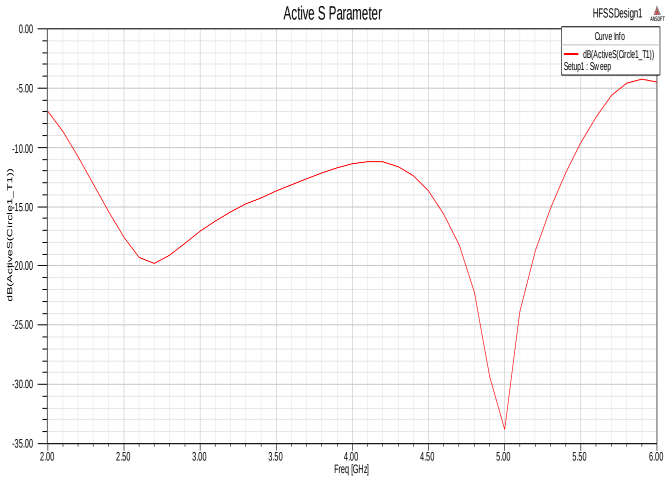

Figure 6: Active S Parameter of the proposed patch antenna

The simulated radiation pattern and 3D polar plot of patch antenna is shown in fig. 7 and fig. 8.

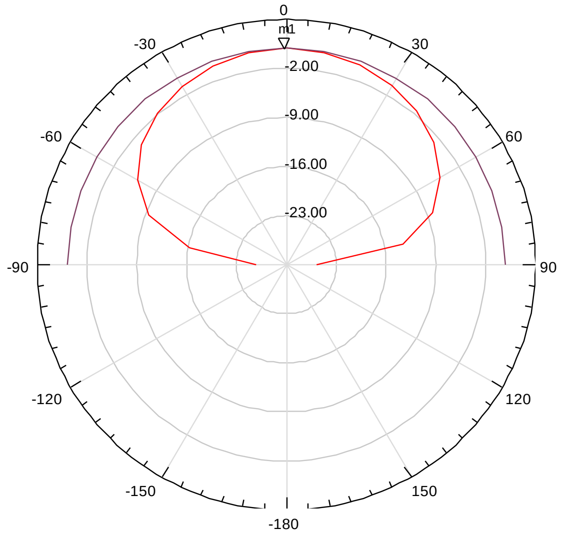

Figure 7: Radiation pattern

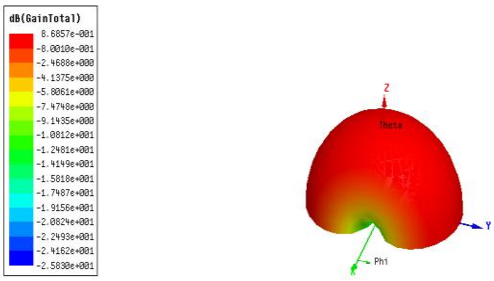

Figure 8: 3D polar plot

Table 2: Performance Characteristics of The Proposed Antenna

Frequency of operation	5GHz
Fractional bandwidth	66%
Return loss	-34dB
VSWR	1.041
Gain	8.685dB

Conclusion

In this paper, the technique proposed consists of simple structure to enhance the radiation characteristics of Microstrip patch antenna which is also suitable for low cost PCB processing. It is shown from the simulations that the circular patch antenna with complimentary split ring resonators above the ground plane gives a return loss parameter to be equal to -34 dB and also minimum VSWR of 1.04. From the radiation pattern it is also shown that the gain of the antenna is 8.68 dB. The simulations were carried out using the software Ansoft HFSS v13.

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