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Design of Microstrip Patch Coplanar Antennas using Metamaterial with Complementary Split Ring ResonatorStructure to Avoid Interference

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ABSTRACT

This paper describes the design of a micro strip patch antenna with two coplanar patches radiating in two different frequencies grown above the same dielectric substrate. The two coplanar ports radiate in 0.9GHZ and 1.8GHZ frequencies respectively. To avoid the interference of the harmonics the design of plane which acts as a stop band filter in the desired bandwidth. The design optimization is accomplished by a return loss of -5dB. The substrate material used is RT/duroid with the permittivity of ε_r=2.2 and height=1.6mm.

INTRODUCTION

The technology manufactures devices with many numbers of applications that uses different frequencies for their operations. Metamaterial are artificial structure whose properties are not yet found in nature. The concept of Metamaterial was first used by Vector Veselago in 1967[1]. It is an assemblies of multiple elements on a repeated fashion. Due to the peculiar characteristics, metamaterials can be used for allowing wave propagation inside miniaturized waveguide operating below cut off [2,3]. As we use two patches that radiates at different frequencies leads to interference of harmonics of one patch on other. In order to avoid the interference between those frequencies caused due to the harmonics of the other, we here design a patch antenna with CSRR structure in the ground plane. The CSRR structure is a complementary split ring resonator used to avoid the harmonic interference. The microstrip inset-fed patch antenna with a complementary structure is formed by removing some portion or area in the ground plane in a circular dimension which produces electric and magnetic fields to stop band the harmonics caused in the undesired bandwidth of frequencies.

Antenna element construction:

As in figure 1, the patch is of rectangular size and had a feed line attached to it. The important parameters for the design of a microstrip inset-fed patch antenna are:

i. Resonant frequency (f_r):

The resonant frequency of the antenna is assigned based on the specified applications. The frequency of patch 1 is taken as 0.9GHz (GSM systems) and of patch 2 is taken as 1.8GHZ (DCS 1800 systems).

ii. Height of the dielectric substrate (h in mm):

The height of the substrate is chosen as 1.6mm (millimeter) which is very necessary for the calculation of the other dimensions like length and width of the patch.

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iii. Dielectric constant of the substrate (ε_r):

RT/Duroid is the dielectric material used for the substrate design. The corresponding dielectric constant is 2.2.

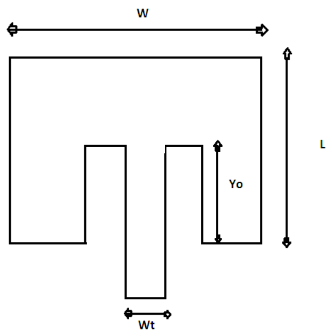

Fig. 1: Dimension of Rectangular Microstrip Patch Antenna.

The geometric parameters of the patch that radiates 0.9GHz of frequency are:

Width (W) = 131.7mm, Length (L) = 119.69mm, Width of the feedline (W_t) = 0.8mm, Length of the feedline inside the patch (Y_0) = 30.147mm and the total length of the feedline = 38.847mm.

The geometric parameters of the patch that radiates 1.8GHz of frequency are:

Width (W) = 65.88mm, Length (L) = 55.31mm, Width of the feedline (W_t) = 0. 79mm, Length of the feedline inside the patch (Y_0) = 14.8499mm and the total length of the feedline = 23.5499mm.

It is clear from the above specifications that as the frequency of operation increases the size of the patch decreases respectively.

The length and width of the substrate will be based on the size of the two patches that has been built on it. So, here the dimension of dielectric substrate is of Width = 297.18 mm and Length = 121.29mm.

Design specifications:

a) Width of the patch:

$$W = \frac{c}{2f\sqrt{\frac{\varepsilon+1}{2}}} \tag{1}$$

b) Effective permittivity (ε_{eff}):

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+12\frac{h}{w}\right) \tag{2}$$

\c) Effective length:

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{eff}}} \tag{3}$$

d) Extension length:

$$\Delta L = \frac{\varepsilon_{eff}+0.3}{\varepsilon_{eff}-0.258}\,\frac{\frac{W}{h}+0.264}{\frac{W}{h}+0.8} * 0.412 * h \tag{4}$$

e) Actual Length:

$$L = L_{eff} - 2(\Delta L) \tag{5}$$

f) Length of the feedline inside the patch (Y_0):

$$Y_0 = \frac{L}{\pi}\cos^{-1}\left(\sqrt{\frac{Z_0}{Z_t}}\right) \tag{6}$$

Where Z_0 = 50 ohms.

$$Za = 90\frac{{\varepsilon_r}^2}{\varepsilon_r-1}\left(\frac{L}{W}\right)^2 \tag{7}$$

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$$Zt = \sqrt{50 * Za} \quad (8)$$

g) Width of the feedline (W_t):

$$Z_t = \frac{60}{\sqrt{\varepsilon}} \ln\left(\frac{8d}{Wt} + \frac{Wt}{4d}\right) \quad (9)$$

h) Length and Width of dielectric substrate:

$L_g = 6h + L$ (10a)

$W_g = 6h + W$ (10b)

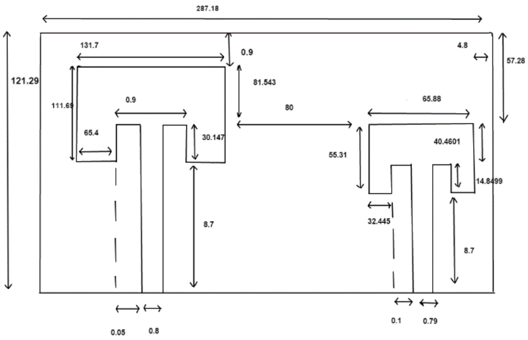

Fig. 2: Dimensions of two coplanar patches built on a same dielectric substrate.

Simulation and frequency responses:

The simulations for this structure have been achieved with the Finite element Method (FEM) - based HFSS (High Frequency Structure Simulator) commercial software of Ansoft. Figure 2 shows the configuration of two coplanar patches built on a same dielectric substrate made of RT/duroid with the permittivity of ε_r=2.2 and height=1.6mm. The frequency responses that shows the return loss of different patches are given as follows:

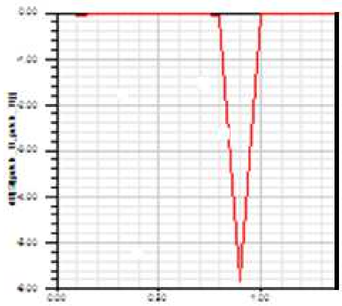

Fig. 3: Return loss curve for 0.9GHz frequency.

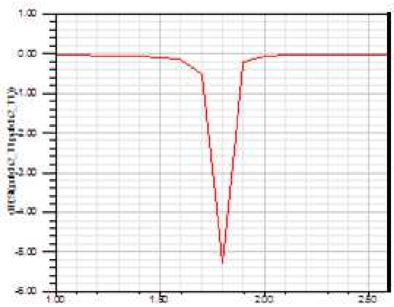

Fig. 4: Return loss curve for 1.8GHz frequency.

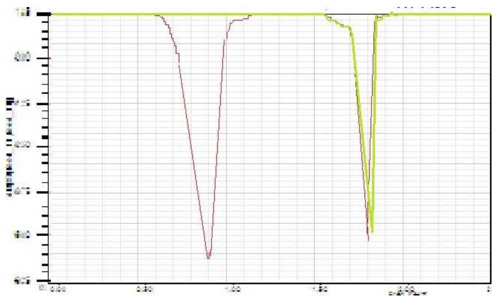

Fig. 5: Return loss curve for both 0.9GHz and 1.8GHz frequencies run at a same time with interference.

Figure 3 shows the return loss curve of the first patch that works at operating frequency of 0.9GHz. It has the return loss of -5.8dB. Figure 4 shows the return loss curve of the second patch that works at operating frequency of 1.8GHz. It has the return loss of -5.2dB. Figure 4 shows the return loss curves of both the coplanar patches. Here, red curve denotes the return loss of patch at 0.9GHz frequency and green curve denotes the return loss of patch at 1.8GHz frequency. It is noted that at 1.8GHz frequency there is the interference of both the curve. This leads to the collision of signals that reduces the efficiency of the device. In order to avoid the interference of these two, CSRR (Complementary Split Ring Resonator) is used.

V.CSRR (Complementary Split Ring Resonator):

CSRR is the complementary of the split ring resonator. The CSRR works as the band rejection operation. The effective ε medium is created by a strong component time varying electric field along the axis. A microstrip patch antenna radiates from the feed line and terminates on the ground plane. The substrate concentrates the field and maximizes the value of electric flux density. The CSRR structure is etched on the ground plane which limits the frequencies of particular bandwidth in which the filter is designed. The resonant frequency of the antenna is 0.9GHZ. The dimension of CSRR is made according to the stop-band bandwidth. The schematic diagram of CSRR is shown in figure 6A.

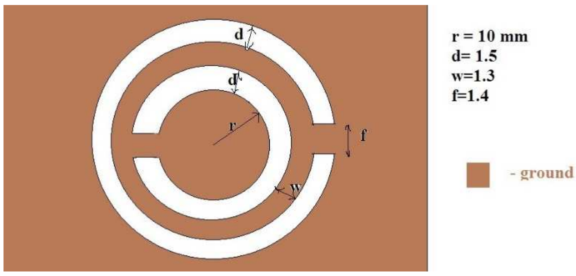

Fig. 6A: Schematic diagram of CSRR structure.

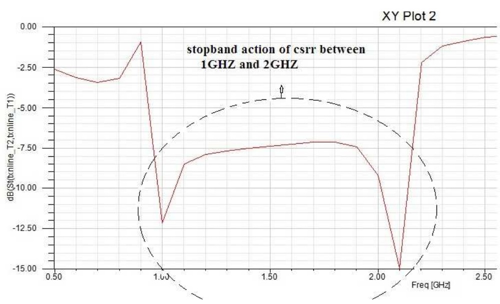

Fig. 6B: S_{21} characteristic of CSRR structure working as stopband in 1GHZ to 2GHZ frequency.

Implementation of csrr on antenna and its results:

CSRR act as the band rejection filter is placed on the feedline of the patch of operation frequency 0.9GHz so that it limits the radiation over 1.8GHz. The bandwidth of the filter is chosen as 1GHz to 2GHz so that it effectively limits the harmonics created by the patch while radiating. The physical dimension of CSRR is designed based on the dimension of patch and the ground plane and also depends on the frequency band of itself. Figure 7 shows the microstrip patch coplanar antenna with CSRR structure on the feedline.

Once the ground plane is defected with the CSRR structure beneath the feedline of the patch operating at 0.9GHz, the harmonics of the patch at the other frequency within the bandwidth of the filter gets limited. The simulation of this structure gives the clear result without interference and presence of harmonics as shown in the figure 8.

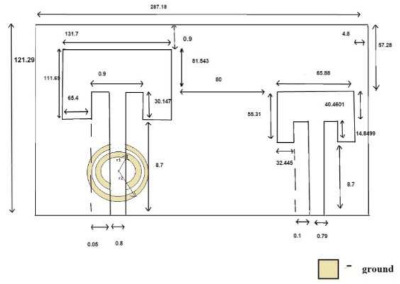

Fig. 7: Structure of microstrip patch coplanar antenna with CSRR structure.

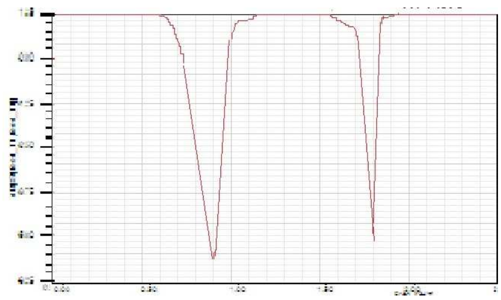

Fig. 8: Return loss curve for both 0.9GHz and 1.8GHz frequencies run at a same time without interference.

Conclusion and future work:

The design of a microstrip patch antenna with two radiating ports enhanced with the elimination of the harmonic interference using the complementary structure drawn in the ground. The simulation results clearly explain the individual simulation of the two ports which radiates at 0.9GHz and 1.8GHz independently. The next simulation results clearly explains the presence of the two frequencies which got interrupted when they are made on the same substrate. The CSRR simulation results, clearly pictures the elimination of first harmonic other than the radiation caused due to 0.9GHz.

The presented antenna is larger in dimension because of two antenna being designed on the same substrate. The future work can be done by placing the two patches in the stack manner which reduces the size of the radiating device enhancing the gain and increasing the stopband bandwidth of the CSRR structure so that the other harmonics can also be eliminated.

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