Indonesian Journal of Electrical Engineering and Computer Science
Vol. 5, No. 3, March 2017, pp. 661 ~ 665
DOI: 10.11591/ijeecs.v5.i3.pp661-665

Bandwidth Enhancement of Metamaterial loaded Microstrip Antenna using Double Layered Substrate

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Abstract

Communication has become a key aspect of our daily life, becoming increasingly portable and mobile. This would need the use of micro strip antennas. The rapid growth has led to the need of antennas with smaller size, increased bandwidth and high gain. In this paper, a new version of micro strip patch antenna is designed by adopting double layered substrate concept and adding a layer of metamaterial structure to a square micro strip antenna. The antenna properties gain, return loss and bandwidth are studied to achieve better performance. The designed patch antenna has an improved bandwidth of 60% at a resonant frequency of 2.47 GHz. This antenna is designed and simulated by using HFSS software.

Keywords: *microstrip, doublelayered substrate, metamaterial, CSRR*

1. Introduction

Metamaterials are finding various applications for modern antennas. One such application would be the use of material having negative permittivity or negative permeability, for compact antennas [1]. Different methods have been adopted for miniaturization of micro-strip antennas. One such method be the use of substrate with high value of permittivity, thereby decreasing guided wavelength in substrate, so that size of the antenna has been greatly reduced [2]. However the above mentioned method has a drawback ensuing in the energy, which is to be delivered to antenna be surrounded in substrates with high value of permittivity, which finally decreases impedance bandwidth of antenna. Various remedies have been developed for patch antenna, employed on high permittivity substrates [3-6]. In this paper, we propose a new design approach to enhance bandwidth of micro-strip patch antenna using artificial structures based on complementary split-ring resonators(CSRR).

First theoretically derived the properties of metamaterials, and has shown that they have negative electric and magnetic permeability. They are artificial materials engineered to provide properties which “may not be readily available in nature”. These materials usually gain their properties from structure rather than composition, using the inclusion of small non-homogeneities to enact effective macroscopic behavior. Metamaterials are basis for further miniaturization of microwave antennas with efficient power and acceptable bandwidth. By using metamaterial as a substrate or cover we can enhance the gain while also increasing the bandwidth and directivity of patch antennas [7].

Metamaterials exhibit inimitable electromagnetic properties which make them popular in antenna engineering. Two important features of metamaterial are [8, 9].

1. Increasing of the transmission rate
2. Control of the direction of the transmission which enable one to design directive antennas

2. Antenna Design

In order to obtain enhanced characteristics and good performance, the double layered substrate concept is applied to a metamaterial loaded micro strip antenna as shown in the Figure 1. Initially micro strip antenna, which is a square patch with a resonant frequency of 2.4GHz, has been designed. Then it was loaded with a metamaterial Complementary Split Ring

Received December 5, 2016; Revised February 7, 2017; Accepted February 23, 2017

Resonator (CSRR) structure between the ground and patch in the substrate. The inclusion of the metamaterial has shown an increase in the bandwidth, but there has to be a tradeoff with the gain, as it was found to reduce, thereby becoming a drawback.

Another substrate was then added over the previous one, which increased the effective dielectric constant, thereby increasing the gain along with the bandwidth. The effective dielectric constant is found to increases shown by [10, 11]. The substrate used for the second layer, FR4 Epoxy substrate having a dielectric constant of 4.4 that was used in the first layer. The height of the substrate selected as 3.2mm and the dimensions of the substrate to be 48mm which is a Square Patch with dimensions 24mm. The micro strip feed, which is essentially a micro-strip line, 12mm in length and 1.5mm thick. To match the impedance of the feed line is extended to 4.5mm towards the edge of the feed [12, 13].

Metamaterial structure chosen is the complementary split ring resonator (CSRR) as shown in the Figure 2 with the following dimensions

1. l = 28.4mm
2. c = 1.5mm
3. g = 1.7mm
4. d = 2mm

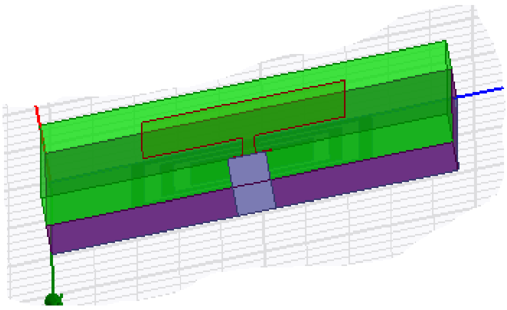

Figure 1. Metamaterial loaded micro strip Antenna with double layered substrate

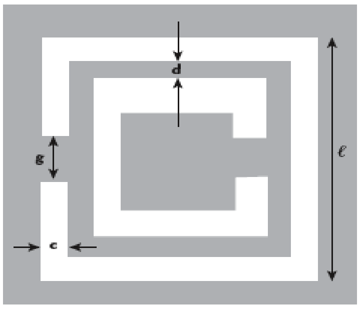

Figure 2. Unit cell of CSRR

3. Results and Analysis

The micro strip antenna with micro strip feed is designed using ANSOFT HFSS by using the above specifications and the designed antenna is as shown Figure 3 and the S11 graph and gain for micro strip feed is shown in Figure 4(a) & (b). In order to improve the bandwidth of the antenna a metamaterial loaded structure is employed as shown in Figure 5. The S11 graph and gain for the metamaterial loaded antenna is shown in Figure 6(a) & (b). The second substrate was added as shown in Figure 7. Though both substrates are of the same material, they have been represented in two colors for clarity in the figure. The S11 graph and gain for this structure is shown in Figure 8(a) & (b). Then the performance has been enhanced by loading a metamaterial in the double layered substrate as is shown in Figure 9 with Figure 10(a) & (b) representing its S11 graph and gain plot.

Figure 3. Micro strip antenna with micro strip feed

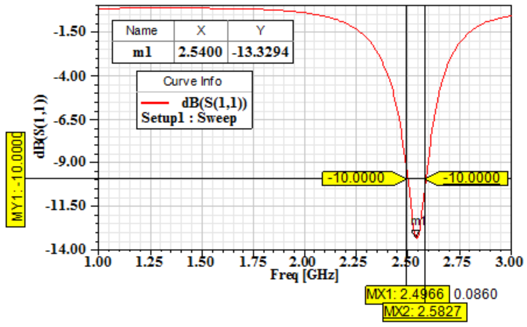

Figure 4(a). S11 graph for edge feed Micro strip Antenna

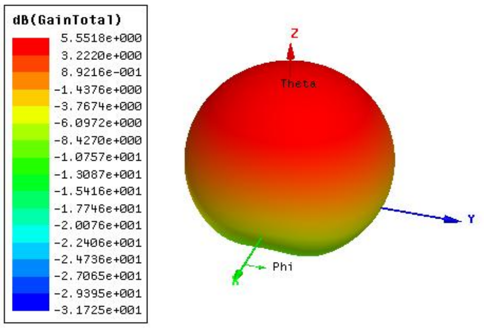

Figure 4(b). 3-D polar gain plot for edge Feed Micro Strip Antenna

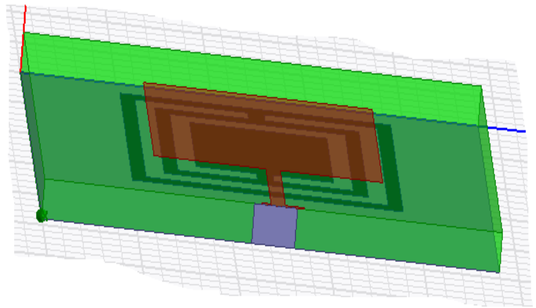

Figure 5. Metamaterial loaded microstrip antenna

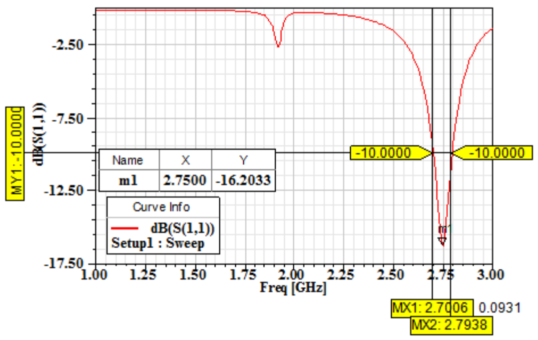

Figure 6(a). S11 graph for metamaterial loaded antenna

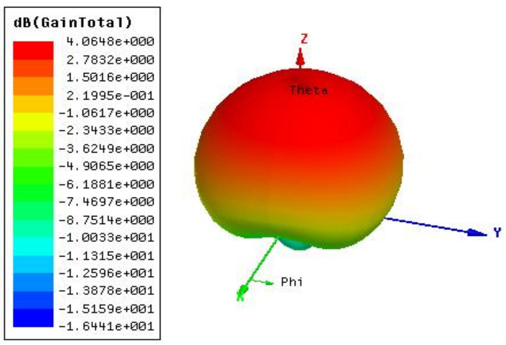

Figure 6(b). 3-D polar gain plot for Metamaterial loaded antenna

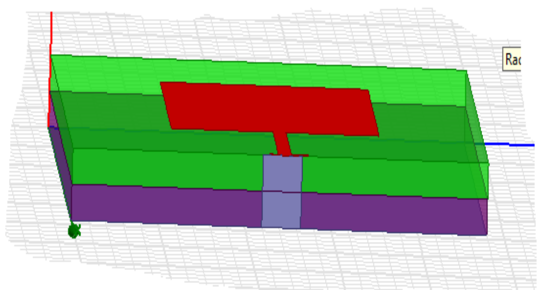

Figure 7. Micro strip antenna with double layered substrate

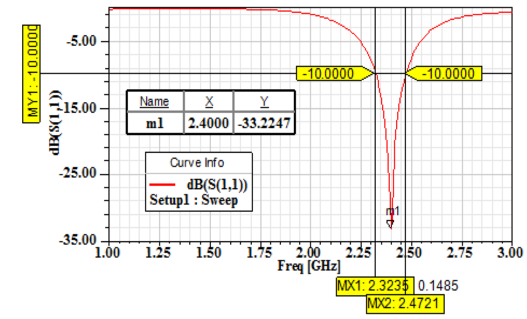

Figure 8(a). S11 graph for edge feed Micro Strip Antenna with double layered substrate

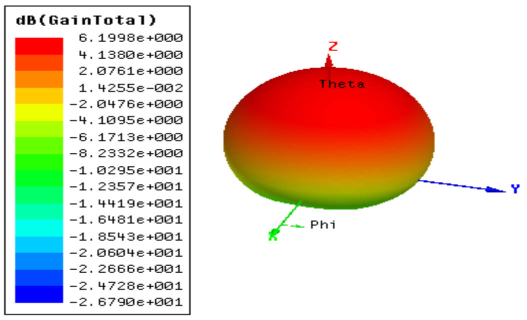

Figure 8(b). 3-D polar gain plot for edge feed Micro strip antenna with double layered substrate

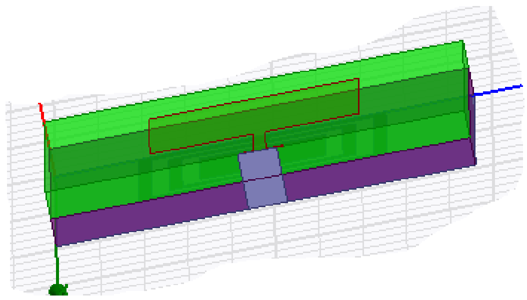

Figure 9. Metamaterial loaded Micro strip antenna with double layered substrate

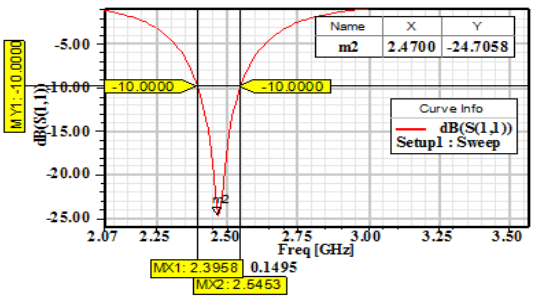

Figure 10(a). S11 graph for Metamaterial Micro strip Antenna with double layered Substrate

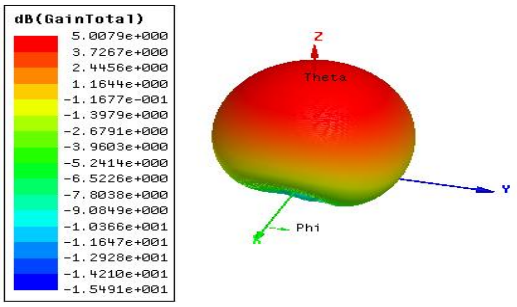

Figure 10(b). 3-D polar gain plot for Metamaterial loaded loaded Micro strip Antenna with double layered substrate

Table 1. Simulated Results For Single Substrate

Antenna Structure	Frequency(GHz)	Return loss(dB)	Bandwidth (MHz)	Gain(dB)
Without CSRR	2.54	-13.3294	86	5.5518
With CSRR	2.75	-16.2033	93.1	4.0648

Table 2. Simulated Results For Double Layered Substrate

Antenna Structure	Frequency(GHz)	Return loss (dB)	Bandwidth (MHz)	Gain(dB)
Without CSRR	2.4	-33.2247	148.5	6.1998
With CSRR	2.47	-24.7058	149.5	5.0079

4. Conclusion

CSRR loaded patch antenna with single and double layered substrates have been proposed in this research work. Nearly 10% of the bandwidth enhanced in single layered patch antenna with CSRR than single layer patch antenna without CSRR. Considering CSRR in the double layered substrate patch antenna bandwidth has been improved around 60% and gain of 1dB than single layered patch antenna with CSRR. Due to this proposed design methodology performance of the patch antenna is improved.

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