IJARSCT

ISSN (Online) 2581-9429

International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)

IJARSCT
Impact Factor: 6.252

Volume 2, Issue 9, June 2022

Compact Dual-Band Antenna Design using Metamaterial

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Abstract: *Here, provide a composite right/left-handed trans- mission line (CRLH - TL) technique for a small, short-ended, coplanar waveguide (CPW) fed dual-band antenna boosted with metamaterial. Metamaterial, which is used in the suggested design to achieve miniaturisation, also enables the antenna to function at double band frequency. In comparison to the conventional antenna, the size reduction of the suggested design is improved by the implementation of slots and vias in the structure. The antenna operating in dual band frequency 5.4 GHz - 5.6 GHz and 6.7 GHz to 6.9 GHz with reflection coefficient of 5.5GHz and 6.8GHz.This can be used for WLAN and wireless application of STM link. The antenna exhibits stable radiation properties over the operational bandwidths, reasonable gain, and good impedance matching.*

Keywords: Metamaterials, Dual-Band Antenna, Antenna Miniaturization

I. INTRODUCTION

The quality of contemporary wireless communication tech- nologies is constantly improving. As a result, high-performing antennas that are smaller, more affordable, and have more bandwidth and gain are becoming more and more impor- tant. As a result, modern antennas must have a small size, exceptional gain, greatly enhanced directivity, and a large operational bandwidth. Over the past ten years, researchers have used a variety of strategies to improve the performance of antennas and metamaterials. Metamaterials are used in antenna design to enhance antenna characteristics like gain, impedance matching, and bandwidth as well as to potentially reduce antenna size. A metamaterial often consists of a number of discrete components, known as "MetaAtoms," each of which is much smaller in size than the wavelength it interacts with. Microscopically, these unit cells are constructed from common materials like metals and dielectrics like plastics. However, the precise geometry, size, orientation, and arrangement of these objects might have unexpected macroscopical effects on light, such as resonances or out-of-the-ordinary permittivity and per- meability values. Negative index metamaterials, chiral meta- materials, plasmonic metamaterials, photonic metamaterials, etc. are a few examples of the several types of metamaterials that are currently in use [1].

Metamaterial can be use effectively in antenne structure to improve its performances.Since they are employed with various types of antennas to drastically improve performance metrics including impedance matching, gain, and bandwidth along with downsizing and limit the effects of surface current density [2], MTMs have become extremely popular over the past ten years [3]. To achieve negative effective permittivity and permeability values in antenna structures, split ring res- onators (SRR) and thin wire structures are used . SRR can also be used in arrays to diminish mutual coupling by thwarting surface wave propagation [4] . In recent years, various re- searchers have investigated various forms of antennas inspired by SRR and published numerous articles in which the ground plane is determined, taking the aforementioned into mind. Series elements are employed to regulate the ZOR frequency in the composite right/left-handed transmission line with a short end (CRLH-TL). Designer can alter ZOR frequency by adjusting dimensions according to the CLRH model's shunt/series parameter [5], [6]. As a result, a new class of thoughtfully designed devices were established using the CRLH transmission line. Different planar structures for CRLH- TL were introduced and studied in [7], [8] to address the problems of contemporary wireless communication systems. Also the structural changes done by using slots and vias.IEEE Standard WiMAX and WLAN bands are achieved by using the slotted ground structures.

1.1 Contributions

Although the multiband, miniaturised antennas described in the literature offer downsizing, there is a trade-off between device size, operating band count, average gain, and unwanted radiation characteristic distortion. By adding slots and meta- material into the design of a miniature multiband antenna with acceptable gain across all operating bands, the proposed re- search seeks to address the aforementioned design difficulties. This paper's primary contributions are; It is suggested to use a small dual-band metamaterial slot antenna for WLAN and STM link wireless applications. The antenna consists of simple rectangular antenna modified by introducing two slots and vias in the structure. The antenna exhibits resonance at about 5.5 GHz for WLAN application and 6.8 GHz for wireless applications of STM link in simulation.The antenna has less size, more number of operating bands and good gain.

1.2 Metamaterials for Antenna Design

Metamaterials are unique manmade one-, two-, or three- dimensional objects with electromagnetic properties that are often absent from nature. Due to the fact that permeability and permittivity are both simultaneously negative values.A metamaterial can be thought of as an artificial medium with a negative index of refraction since it is a substance with negative permittivity and permeability. Snell's Law was used to determine negative refraction. Metamaterials have a wide range of potential uses, including medical devices, remote aerospace applications, sensor detection and infrastructure monitoring, smart solar power management, crowd control, radomes, high-frequency combat communication, and lenses for high-gain antennas. The various types of metamaterials that are currently in use include negative index metamaterials, chiral metamaterials, plasmonic metamaterials, photonic meta- materials, etc. When natural materials like copper or silicon are formed into "cells" that are the same size as or smaller than particular electromagnetic waves, it is possible to control certain wavelengths and construct metamaterials.

Nowadays, metamaterials are very desirable materials be- cause they possess unique physical properties that are not present in natural materials. Examples include microwave in- visibility cloaks, cutting-edge electronics, negative refractive- index lenses, microwave components such as filters, compact, and effective antennas, and microwave components. One of the most significant applications of metamaterials is in the design of antennas. We can make antennas with innovative characteristics that are not possible with conventional materials because metamaterials have peculiar properties. The metamaterial antenna consists of one or more layers of metamaterials that are added to or utilised as substrates for the antenna in order to enhance its performance. The use of metamaterials in antenna design can increase the power that is radiated, improve some crucial parameters, and lower the size of the antenna, according to scientific studies. The choice of metamaterial structure and application technique vary depending on the an- tenna's intended use. Artificial magnetic conductors and high- impedance surfaces are the most pertinent and widely used components in antenna applications for microwave and radio frequency substrate materials. By positioning HISs or AMCs around or close to the antenna radiating elements, they are used to build small, low-profile antenna systems. Metamaterials can also be used as a component of the antenna system's feeding system or antenna construction. Metamaterials may be incorporated into the antenna structure in order to create a small antenna without sacrificing performance. In this in- stance, patch antennas' magneto-dielectric substrate is made of metamaterials with high permeability values. As a result, without using a high permittivity, the antenna's size is greatly decreased. Metamaterials can be used to produce multiband antennas, increase gain, increase bandwidth, and minimise antenna size. The metamaterials will be employed for a variety of antenna functions, depending on the technical specifications of the developed antenna.

The paper has been organized as follows: Section 2 dis- cusses the dual-band antenna design, the structure of antenna and all the dimensions. section 3 presents the results and discussions. Finally conclusion has been reported in Section 4.

II. DESIGN OF PROPOSED METAMATERIAL DUAL-BAND ANTENNA

The main goal of this effort is to achieve downsizing through metamaterial and multiband functioning through slots. Metamaterials are used to achieve miniaturisation because they offer a higher level of miniaturisation than traditional miniaturisation approaches. Because slots have the benefits of wideband, compact size, and ease of integration with various wireless handheld devices, they are a viable choice for the construction of multiband antennas and enable multiband phenomena. The suggested multiband antenna is shown in the figure along with a thorough explanation and characteristics.

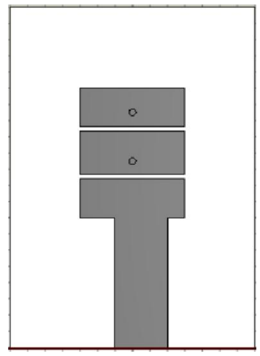

Fig. 1: Structure of metamaterial compact dual-band antenna

The suggested antenna is made of the FR4 material, which has a permittivity of 4.4 and a loss tangent of 0.02. This structure is the simple modification on rectangular antenna structure for getting multiband antenna for different wireless applications. By using conventional rectangular antenna we get only single band of frequency that can be used for single application. So, modifications are done in the rectangular antenna structure by adding two parallel slots. Addition of this two slots in the antenna structure help to achieve double band response and can be useful for different wireless applications. In this work not only considering the designing of multiband antenna also considering the miniaturization of antenna. Two distinct frequency bands are being generated in this instance, and they can be employed for various wireless applications. A very small antenna construction was also designed.

The suggested metamaterial antenna's complete set of pa- rameters is shown in Figure 2 and its parameter values are listed in the Table.

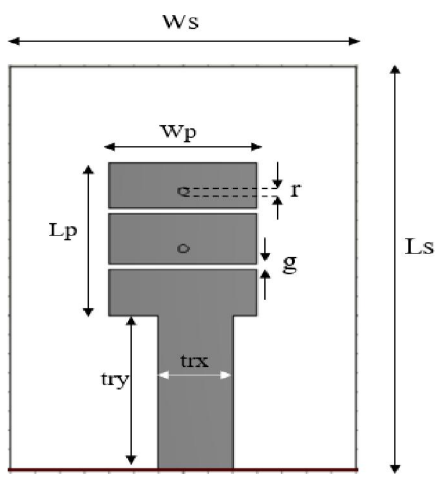

Fig. 2: Dimensions of proposed compact dual-band antenna

Parameter	value
Ws	14
Ls	21
sbh	1.6
Wp	6
Lp	8
trx	3
try	8
r	0.2
g	0.3

Table 1: Metamaterial compact dual- band antenna parameters

2.1 Effect of Radius of via

In this step, parametric analysis is carried out to choose a specific value for the parameter that produces the best results. In order to analyze the operational performance of the miniaturized multiband antenna with the variation in the optimized dimensions, its parametric studies are carried out. The radius of the via ”r” is parametrically analysed in first section to produce a wider bandwidth and more frequency bands. As shown in Figure 3, the value of ”r” has been changed from 0.15mm to 0.3mm with an increasing step size of 0.05mm.The reflection coefficient at r=0.15, r=0.2, r=0.25 and r=0.3 are studied, as seen in the figure 3.

And it is discovered that r=0.2 mm provides excellent impedance matching in all of the operational bands. Reflection characteristics for the parameter ” r=0.2mm” reveal dual-band resonance in the frequency range of 5-7 GHz. The best response is the S11 at 5.5 GHz and 6.8 GHz, which, for a radius of through 0.2 mm, is -25dB and -34dB, respectively. It is therefore selected as the ideal value of the via’s radius.

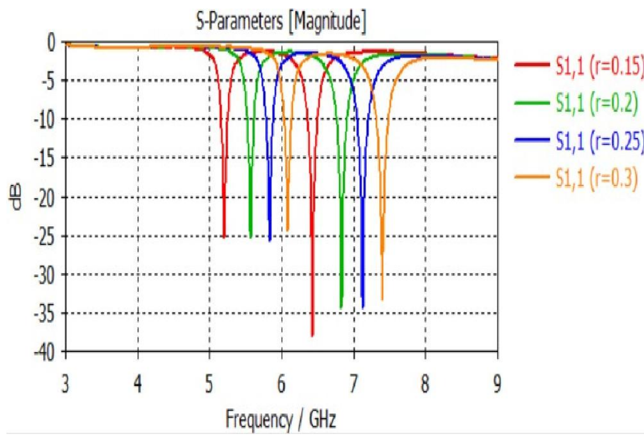

Fig. 3: Parametric analysis of radius of via

2.2 Effect of Slot Width

After that, the width of slot ”g” is subjected to a parametric analysis. Its parametric tests are done in order to examine the operational performance of the tiny multiband antenna with the change in the optimum dimensions. To find more frequency bands, a parametric analysis is conducted. Figure 4 demonstrates how the value of ”g” was modified from 0.1mm to 0.3mm with an increasing step size of 0.05mm. Figure 4 depicting the examination of the reflection coefficient at g=0.15, g=0.2, g=0.25, and g=0.3. Furthermore, it is found that all operating bands are perfectly impedance matched at g=0.3 mm. Dual-band resonance is found in the frequency range of 5-7 GHz according to the reflection characteristics for the parameter ”g=0.3mm.” The S11 has the best response, with -25dB and -34dB, respectively, at 5.5 GHz and 6.8 GHz at a slot width 0.3 mm. Because of this, it is chosen as the ideal slot width in the antenna structure design.

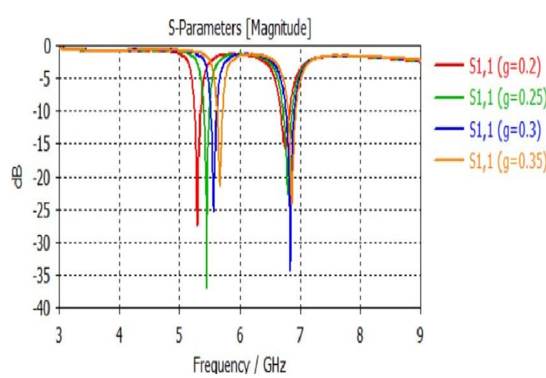

Fig. 4. Parametric analysis of width of slot

III. RESULTS AND DISCUSSIONS

3.1 Reflection Coefficient

The optimal response is found for the parameters radius of via r=0.2mm and width of slot g=0.3mm, as indicated in parametric analysis in the preceding section. Therefore, these parameter values are selected for the final design. Then the model was solved to produce the predicted results. The de- signed antenna is simulated in CST Microwave studio. Figure 5 displays the simulated reflection coefficient. It displays two frequency bands. At 5.5GHz and 6.8GHz, respectively, the S11 value is -25dB and -34dB. So the intended antenna operates in two frequency bands at 5.4 GHz-5.6 GHz and 6.7 GHz-6.6 GHz. The first band, which is where WLAN operates, has a resonance frequency of 5.5 GHz and a return loss of -25.36 dB. With a return loss of -34.29dB and a resonance frequency of 6.8 GHz, the second band is appropriate for wireless STM link applications.

3.2 VSWR

How well the antenna is matched to the transmission line it is attached to is expressed quantitatively by the VSWR. Figure 6 depicts the simulated VSWR for the proposed antenna, which is less than two for both frequency bands 5.5GHz and 6.8GHz. So these two values for voltage standard wave ratio are well matched.

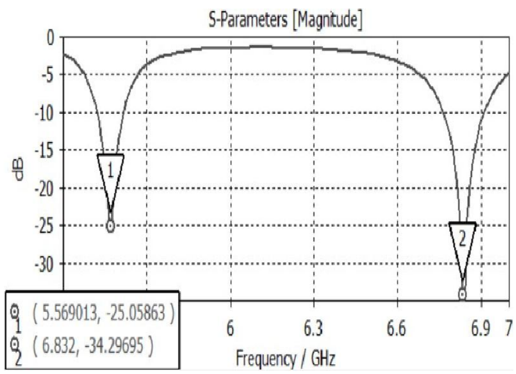

Fig. 5: Simulated S11 plot of antenna

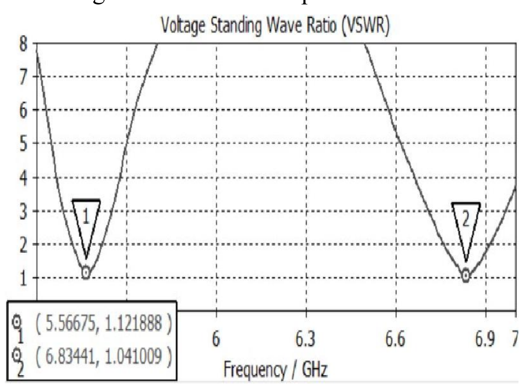

Fig. 6: Simulated VSWR of antenna

3.3 Radiation Pattern

The change in power radiated by an antenna as a function of direction is known as a radiation pattern. An antenna's output of energy is graphically illustrated in it. Figure 7 and figure 8 shows the proposed antenna's radiation patterns. From figure 7,the radiation pattern of the antenna at 5.5GHz resonating point indicate a directional pattern. The main lobe has magnitude of 2.5dB and more radiation in the direction of 154 degree. From figure 8,the radiation pattern of the antenna at 6.8GHz resonating point, also indicate a directional pattern. Here the main lobe has magnitude of 2.3dB and more radiation in the direction of 63 degree.

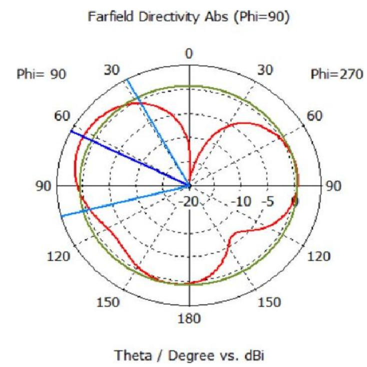

Fig. 7: Radiation pattern at 5.5GHz

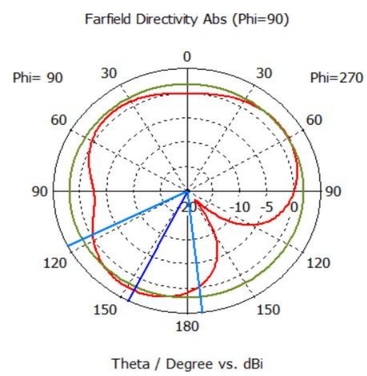

Fig. 8: Radiation pattern at 6.8GHz

3.4 Surface Current Distribution

This describes how current in an antenna is distributed. Fig- ures 9 and 10 display the antenna's surface current distribution at resonance frequencies of 5.5GHz and 6.8GHz, respectively. The concentration of current is larger in the red parts of the diagram and decreases in the blue ones. In the case of the 5.5GHz resonating point, the current is focused here around the first via and the slots. The current is concentrated more around the two vias and slots at 6.8GHz frequency band. It clearly indicate the impact of metamaterials on antenna performance.So a simple rectangular antenna structure was transformed into a dual-band antenna by using the metamate- rial concept in antenna design.

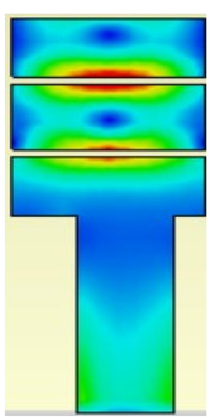

Fig. 9: Surface Current distribution at 5.5GHz

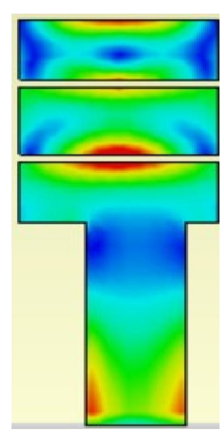

Fig. 10: Surface Current distribution at 6.8GHz

IV. CONCLUSION

For each specific wireless application, a traditional rectangular antenna provides only one frequency range. After improve- ments to the rectangular antenna structure and the use of the metamaterial idea, it now provides dual-band response. This dual-band response was also attained with a small antenna. The antenna's overall dimensions are just 21mm x 14mm x 1.6mm. The antenna that offers the frequency ranges 5.5 GHz and 6.8 GHz, which can be utilised successfully in WLAN and wireless STM link applications.

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