A Novel Double C-Shaped Compact Wearable Substrate Antenna using Metamaterial for Dualband Applications

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Abstract **- In this paper, we are designing a double negative compact metamaterial which could be able to operate in a dual band microwave frequency span with wearable characteristics. A new double-C-shaped metamaterial unit-cell is being introduced with polypropylene substrate. The proposed metamaterial structure consists of polypropylene substrate offers miniaturization factor with bending characteristics compared with other metamaterial designs. It operates at ISM band 5.5 GHz- WLAN, 5.3 GHz WiFi and can use for future IOT applications and in radio communication new band 10 GHz. Commercially available High Frequency Structural Simulator (HFSS) is used to investigate the design of the metamaterial. Various parameters such as S-parameters, gain and directivity is to be studied. The dimensions and scattering parameters of the proposed double negative compact wearable metamaterial could be suitable for dual band applications.**

Keywords- Metamaterial, Dualband, S-parameters; WLAN Applications; Wearable Polypropylene substrate

I. INTRODUCTION

Metamaterials are artificial materials with unusual electromagnetic responses that are not possessed by natural materials. A synthetic composite material with a structure such that it exhibits properties not usually found in natural materials, especially a negative refractive index. Materials with negative εeff could be found, but the challenge remained to make artificial material with negative μ . In 2000, Smith et al succeeded to construct such a material with simultaneous negative ε & μ experimentally. A composite medium, based on a periodic array of inter spaced conducting nonmagnetic Split Ring Resonators (SRRs) and continuous wires, works as a double negative material in a frequency range in the microwave regime, where Doppler effect, Cherenkov radiation, Snell's law are inverted, and can be tested experimentally. These materials are also called Left-Handed materials. The concept of controlling electromagnetic (EM) waves opened up a new way of utilizing the flexible EM properties of MTMs for practical application. A series of fascinate functionalities, for example, invisibility, illusion optics, and EM black hole, have been proposed, realized and demonstrated in laboratory. Meanwhile, functional devices and antennas have also been created for engineering. Metamaterial are being used as antenna substrate that provides with increased directivity & gain Electrically small antenna, constructed by compact resonators and metamaterial-loaded waveguides offer the possibility of previously unavailable applications..

Metamaterial consists of Split Ring Resonators (SRRs) to produce negative permeability and thin wire elements to generate negative permittivity. It has high gain and used to design compact antenna. The slots are cut in rectangular patch to reduce the bending effect. In the past decades, researchers have engaged in planar metamaterials composed of sub wavelength periodic resonant or non-resonant unit cells. In this paper, we present a dual-band antenna integrated with a metamaterial on ground plane. It functions in the Wireless Local Area Networks (WLAN) band of 4.8-6.1 GHz being able to use in WiFi applications and in band 9.8-10.6 GHz used for amateur services in our case emergency radio signal respectively, following the IEEE 802.11a standard. The research of wearable computing systems has experienced rapid development over the past decade due to their great potential applications such as health monitoring, wireless communication and other intelligent terminals.

Flexible electronics can currently be considered a well-established technology that has reached a certain degree of maturity in meeting the requirements of tightly assembled electronic packages, providing reliable electrical connections where the assembly is required to flex during its normal use or where board thickness, weight, or space constraints are the driving factors. In practice, textile materials such as nylon, cotton, Jean, Polyester, Nomex, liquid crystal polymer (LCP), fleece fabric etc. are used as a substrate to manufacture the wearable antennas for industrial scientific and medical (ISM) band applications. In our paper, a geo-textile material that is polypropylene substrate based wearable antenna. The polypropylene is a non-woven type of geo-textile which is used as a substrate because of its features such as light weight, the polypropylene sheets are available in different thickness which avoids the processes like sewing to obtain the substrate of desired thickness.

ANSYS HFSS 13.0 3D simulator is used in simulation of Return loss, VSWR, directivity and gain. ANSYS HFSS utilizes a 3D, full-wave, frequency domain electromagnetic field solver. It is the industry standard for simulating 3-D full-wave electromagnetic fields. It offers state of the art solver technologies based on finite element, integral equation, asymptotic and advanced hybrid methods to solve a wide range of microwave, RF and high speed applications.

II. PROPOSED METHODOLOGY

A. *Geometry of the unit cell*

A unit cell having new double C-shaped circular resonator is proposed. A wearable material, polypropylene is used as a substrate having a permittivity value of 2.2 with a thickness value of 1mm. The radiating element is made up of Copper material having a thickness value of 0.035mm. The dimensions regarding the unit cell is proposed in Fig. 1

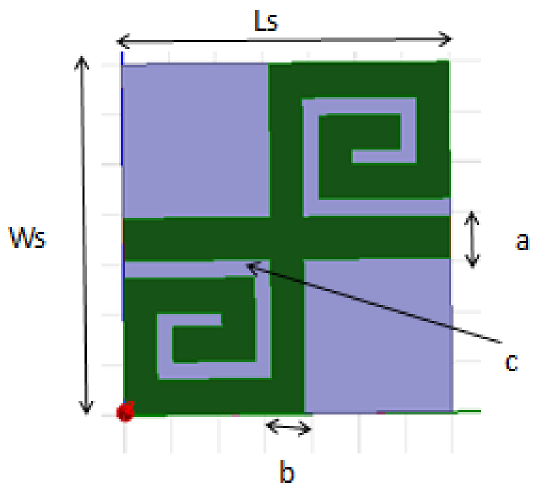

Fig1: Design of proposed antenna

Table :1 Dimensions of proposed antenna

Parameter	Value
Ls	14mm
Ws	14mm
a	1.7mm
b	1.4mm
c	0.7mm

In Table above, the design parameters of the unit-cell are reported. In our paper, the High Frequency Structural Simulator (HFSS) based on frequency domain method is adopted to investigate this design. The boundary conditions of the perfect electric conductor have been used along the x-axis and y-axis, respectively, and along the z-axis, two Lumped ports are placed. The impedance matching was set to 50 ohm. The frequency range 3–12 GHz was used to simulate the design of metamaterial. A 14x14 mm square substrate is designed with radiating element of 14x14mm dimensions. The wave is guided along the radiating element with dimension of 1.7mm.

B.HFSS Simulator

A unit cell of the design is simulated in HFSS 3D simulator. In frequency domain, simulation is done in frequency range of 3-12 GHz. Polypropylene substrate is selected with permittivity of 2.2 and dielectric loss tangent of 0.01. Placed in particular dimension of radiation box and simulated. Perfect E-electric field is applied with radiation in the surrounding box. Excitation is applied at the lumped ports.

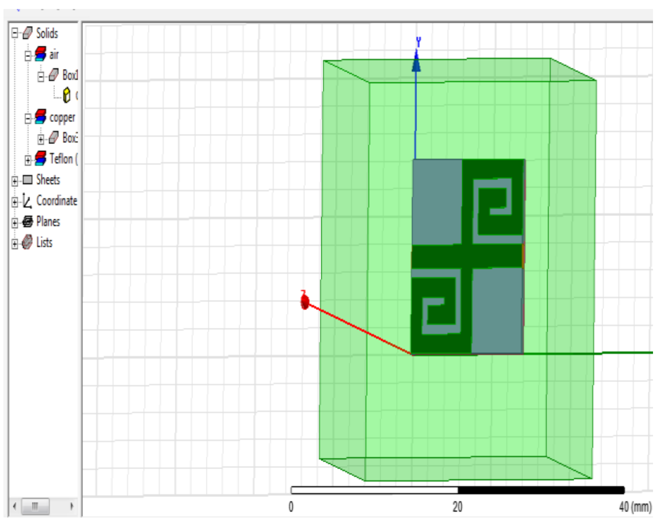

Fig2: Simulation in HFSS

III. SIMULATION RESULTS AND ANALYSIS

The simulated results of the antenna are discussed.Fig.2 shows the return loss of the antenna using polypropylene as substrates.

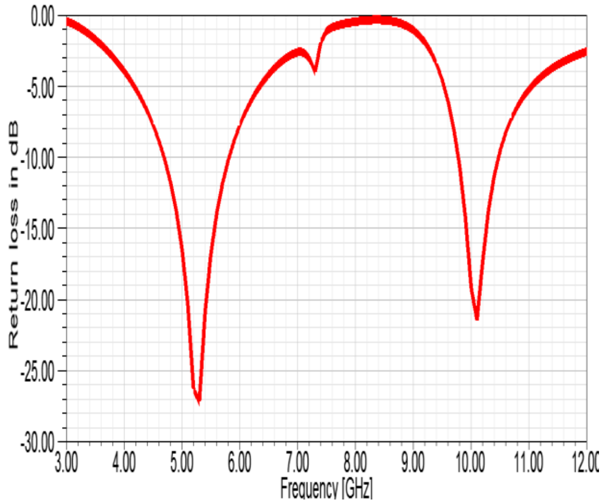

Fig-3: Return loss of antenna using polypropylene substrate

The results show that minimum return loss is obtained at 5.3GHz of -32dB and at 10.1GHz -23dB. It operates in frequency band 4.8-6.1 GHz and in band 9.8- 10.6 GHz. The 2D polar radiation pattern is given which is on the given direction, shown in Fig.4 and Fig.5.

The Voltage Standing Wave Ratio (VSWR) is also less at the specified frequency of operation. In Fig.4, red plot indicates Omni-directional and orange as in Bi-directional.

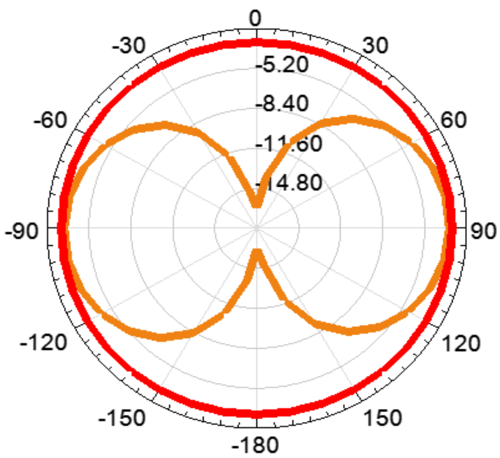

Fig 4: Radiation Pattern(Omni-directiona and Bi-directionall)- 5.3 GHz

In Fig.5, red plot indicates Bi-directional and orange as in omni-directional. Gain is given in 2D radiation pattern in polar plot is in Omni-directional and Bi-directional is given by.

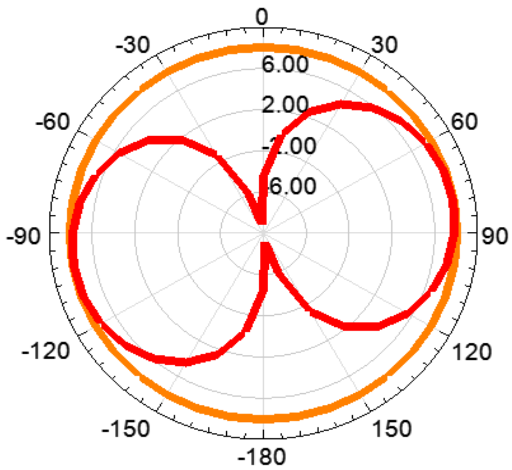

Fig5: Radiation Pattern(Omni-directional & Bi-directional)- 10.1 GHz

The reflection coefficient (S11) of the unit-cell is illustrated . Figure 3 demonstrates the two frequency span of resonance frequencies namely 4.8–6.1 GHz and 9.8–10.6GHz that indicates the C-band and X-band applications. And their minimum dB is at 5.3 GHz which is -32dB and 10.1 GHz which is at -23dB. Wi-Fi of standard 802.11.a can be utilized and thus used for wireless connectivity and applications. 5.5GHz is obtained in -18dB thus can be used for WLAN. IOT can also be implemented in future at 5.5GHz having wireless advantages. The band at 10 GHz can be implemented for upcoming future applications which we prefer emergency radio frequency for fire, hazards, emergency calls and women safety mobile signals.

IV. CONCLUSION

In this paper, metamaterial technology is used to develop small antennas with high efficiency. The mechanical properties of the polypropylene substrate make the antenna flexible. The proposed antenna operates at ISM band 5.5GHz WLAN, 5.3GHz WiFi and in radio communication new band 10.1 GHz. Thus in range of 3-12 GHz it operates in C band and X band. It is used for wireless applications and future frequency for such as IOT and mobile radio signals. The advantages of proposed antenna are small size, inexpensive, light weight, and easy integration.

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