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Design of Metamaterial Based Bow-tie Antenna for UWB Communication

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Abstract- **High speed wireless communications with high accuracy for commercial applications can be provided by Ultra wide band (UWB) communication. These technologies possess a new challenge in antenna designs. UWB communication requires short- range and high data rate connections. Since a long interval, a lot of innovative ideas and miniaturization techniques for UWB antenna have been developed as it is an important area of research. Still there is a scope to work in this area for development of efficient antenna. In this paper, authors have taken an attempt to enhance the bandwidth. The antenna is designed as patch antenna for reduction of size as well as for efficient transmission the antenna is designed with the metamaterial substrate. From the result it has been observed that antenna is working efficiently for 9.8 GHz. Furthermore the feeding for the antenna has been analyzed and considered for centre feed.**

***Keywords* - UWB communication, Patch antenna, Bow-tie antenna, Feeding point.**

I. INTRODUCTION

Wireless systems continue to develop for higher data rates day-by-day. This objective is challenging for systems in terms of power, bandwidth, and complexity limited. Patch antenna is one of the solutions that have been exploited in this paper. UWB is an emerging wireless technology for high-data-rate and short-range communications. In February 2002, the Federal Communication Commission (FCC) of United States opened a spectrum of 3.1-10.6 GHz but with a limited emission level of lower than —41.3 dBm/MHz for commercial communication, imaging, and radar applications [1]. The advantage of this technology is with an low emission power level. The technology can be used within an ultra-wide spectrum but with low emission power level. The advantages of UWB include low-power transmission, robustness for multi-path fading and low power dissipation. The basic feature of the UWB system is the occupancy of extremely wide operating bandwidth due to the use of impulse signals as compared with conventional radio systems. The major advantage of such technique is that with the pulses being spread over a wide spectrum they can be difficult to detect, which is the implication of ideal and secure communication [2-3]. This communication may be used in intrusion detection, geo-location, avoidance radar, and data links. Microstrip antennas have been one of the most innovative topics in antenna theory and design for many years, and are increasingly finding application in a wide range of modern microwave systems. Like any other system or invention in this world till now, microstrip patch antennas also have some limitations among its numerous advantages. Several investigations are going on to improve the gain and bandwidth of patch antenna. Microstrip antennas are easy to construct, light weight, low cost. The Coaxial feed or probe feed is common technique for feeding the patch antennas. This type of feed can be placed at any desired location inside the patch in order to match with its input impedance [4]. Metamaterial antenna is a better solution for the patch antenna along with miniaturization. The unique electromagnetic properties provided by metamaterial attract good attention of researchers from multi-disciplines. This motivates to work in this field emphasizing the antenna design.

The paper is organized as follows: Section 2 presents the essence of antenna in UWB communication. Section 3 describes antenna design and section 4 describes the results. Finally, conclusion is drawn and reported in section 5.

II . Essence Of Antenna In Uwb Communication

The important aspect of a UWB antenna is impedance matching for the frequency range, a consistent gain over the matched frequency range, and a compact and inexpensive overall structure. The technology based on such a wideband bandwidth offers the great opportunity for achieving high-speed wireless communications and high-accuracy detections in principle. For example, the high speed wireless connections are expected to reach the data rate which is higher than 100 Mbps or even up to 500 Mbps with very short range wireless connections. Such UWB-based wireless communication systems are promising in consumer electronics, especially for handset-centric applications and home networks. For example, we can embed such a technology into next generation wireless universal serial bus (USB) dongles or Bluetooth in order to achieve extremely high-speed wireless connections between devices in home or offices, such as laptops and digital cameras, high-definition (HD) TV sets, high-speed printers, and so on. The design considerations for antennas in the UWB wireless communications must be based on unique system requirements [5]. The antenna designs should be evaluated by not only antenna but also system parameters such as system transfer functions in terms of system gain and group delay, in particular, for the pulsed systems even in time-domain. The research and development of UWB antennas in the past decade has already focused on the three top design challenges: ultra-wideband operation, small size, and low cost [5]. The design challenge involves (i) Ultra-Wideband Operation Challenge, (ii) Small Size Challenge, and (iii) Low Cost. The most challenging issue in UWB antenna design is to consider all the three challenges in one design to achieve the desired UWB performance with small size and low cost. Planar monopoles (dipoles) or disc antennas with broad bandwidths and small size have long been proposed for UWB applications [6-9]. The earliest planar dipole may be the Brown-Woodward bowtie antenna, which is a simple and planar version of a conical antenna [8]. Due to the specific applications of UWB systems, the planar versions of designs have attracted much attention in research and development of UWB antennas. The bow-tie antenna is the planar version of a bi-conical dipole antenna with greatly reduced volume [10]. However, the “ground plane” of a printed antenna suffers from the severe effects of changing the size and shape of the ground plane on the performance of the antennas. The major advantage of such technique is that with the pulses being spread over a wide spectrum they can be difficult to detect, which is the implication of ideal and secure communication. This communication may be used in intrusion detection, geo-location, avoidance radar, and data links.

Metamaterials are artificial materials characterized by parameters generally not found in nature, but can be engineered. An antenna is the primary component in a wireless communication system. The trends of antenna design in today’s wireless applications are toward compactness, robustness, and ease of integration with RF circuit components. A patch antenna needs to be further reduced in order to use it for advanced technologies. All the metamaterial antennas are designed based on these substrate structures. 1-D structures are easier to fabricate and construct. Metamaterial structures can be used along with patch antennas in order to improve the performance parameters. The metamaterial is composed of copper grids with a square lattice. When electromagnetic wave propagates in free space, the electric field is enhanced by using metamaterial structure. The gain of antenna with metamaterial structure increases from the original 9.053 dB to 17.34 dB. Metamaterials are used for further miniaturization of microstrip patch antennas. The size of such an antenna reduces by a factor of 2.4 and the gain directivity increases from 4.17 dBi in conventional design approach to 5.66 dBi in metamaterial design [11].

It is known that the negative permittivity can be obtained in the artificial plasmas (for instance, thin-wire structures) for all frequencies smaller than plasma frequency of plasmon medium, but the negative permeability only occurs in a narrow magnetic resonant frequency band of artificial magnetic metamaterial resonators [12-14]. A metamaterial antenna is created by reactively loading the metamaterial structure over the substrate. There are various types of metamaterial substrates. Any changes to the metamaterial substrate will result in changes in the parameters of antenna. A broadband antenna can be constructed using a number of metamaterial unit cells together. Gain of a patch antenna increases by a value of 1.5dB to 7dB with the addition of metamaterial structures. Miniaturization is the primary function of metamaterial. The antenna is considered as microstrip bow-tie antenna with metamaterial substrate.

III . DESIGN OF ANTENNA

As described in section-2, in this work, the metamaterial has been chosen for the substrate. According to the desired frequency, the design found to be effective one. Metamaterials, artificial composite structures with exotic material properties, have emerged as a new frontier of science and engineering. The property of it is shown in Figure. 1.

The design is considered for compact and efficient bow-tie antenna in the range of 3.1-10.6GHz of UWB communication. For the planar structure the square patches have been placed on the substrate in such a manner that it will create the bi-directional triangular structure as required. The bandwidth is evaluated based on the frequency range and can be expressed as,

$$Bandwidth(\%) = \frac{(f_2 - f_1)\times 100}{\sqrt{f_2 \times f_1}} \quad (1)$$

The dimensions of the substrate have been calculated using the following relations.

Substrate Dimension Along x-axis= 2* h_0 *tan (theta/2) +2*Padding (2)

Substrate Dimension along y-axis=2* h_0 +2*Padding (3)

where ' h_0 '=Height of antenna arm
'theta'=Flare Angle

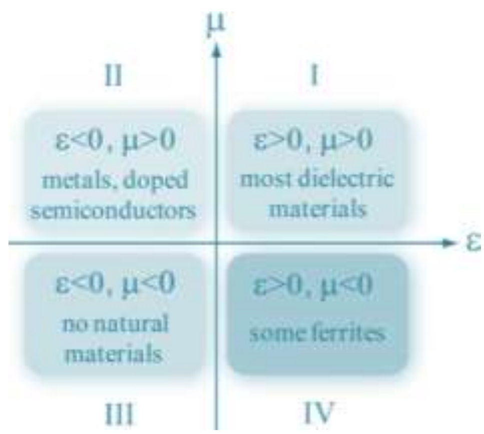

Figure 1: Material parameter space characterized by electric permittivity and magnetic permeability.

The bow-tie antenna is designed at 9.8 GHz on a 2mm substrate made up of metamaterial with negative dielectric constant of -1.002. The patch will be approximately a half wavelength long in dielectric. Assume width is $\lambda/2$. Patch non-resonant width will be,

$$W = \frac{c}{2f\sqrt{\varepsilon_r}} \quad (4)$$

Approximation for $\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}(1 + \frac{10H}{W})^{1/2}$ (5)

where H is the thickness of the substrate.

Substituting ε_{eff} in eq.(5):

$$\frac{\Delta}{H} = o.412 \frac{\varepsilon_{eff} + 0.300 W/H + 0.262}{\varepsilon_{eff} - 0.258 W/H + 0.813} \quad (6)$$

The resonant length is obtained by the following relation,

$$L = \frac{c}{2f\sqrt{\varepsilon_{eff}}} - 2\Delta \quad (7)$$

The length is used as width to calculate the effective dielectric constant and will obtain some value that is close to the initial value.

The input conductance of the patch fed on the edge will be twice the conductance of one of the edge shit as,

$$G = \frac{\pi W}{\eta \lambda_0}[1 - \frac{(kH)^2}{24}] \quad (8)$$

where $k = \frac{2\pi}{\lambda_0}$

and the resistance is calculated by using the following relation,

$$R = \frac{1}{2G} \quad (9)$$

IV . Results

Table 1 shows the list of parameters used for the design of proposed antenna.

TABLE I: PARAMETERS FOR 9.8 GHz BOW-TIE ANTENNA

Parameters	Values
Height of antenna arm	20mm
Padding	2mm
Substrate thickness	2mm
Substrate dimension along x-axis	20.5mm
Substrate dimension along y-axis	44mm
Flare angle	45deg

TABLE 2: PARAMETERS FOR THE METAMATERIAL SUBSTRATE

Parameters	Values
Relative Permeability	-1.002
Relative Permittivity	-1.002
Electric conductivity	0.002S/m

TABLE 3: PARAMETERS OF CONDUCTOR

Parameters	Values
Relative Permeability	1
Relative Permittivity	1
Electric conductivity	5.998e7S/m
Thermal Conductivity	400W/(m*K)

The structure of the bow-tie antenna using metamaterial is shown in Figure. 2. It is in the frequency ranging from 3.1-10.6 GHz. The planar structure is designed using COMSOL Multi Physics software. The same is verified in HFSS-Ansoft design software. Also the radiation patterns have been shown after verification.

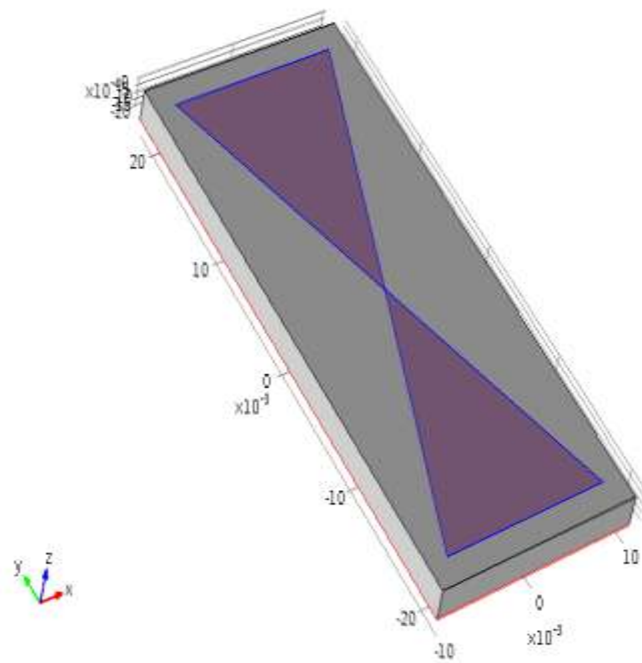

Figure 2: Structure Bow-tie antenna with metamaterial substrate using COMSOL at 9.8GHz

The return loss along with the desired frequency is obtained and the graph is shown in Figure. 3.

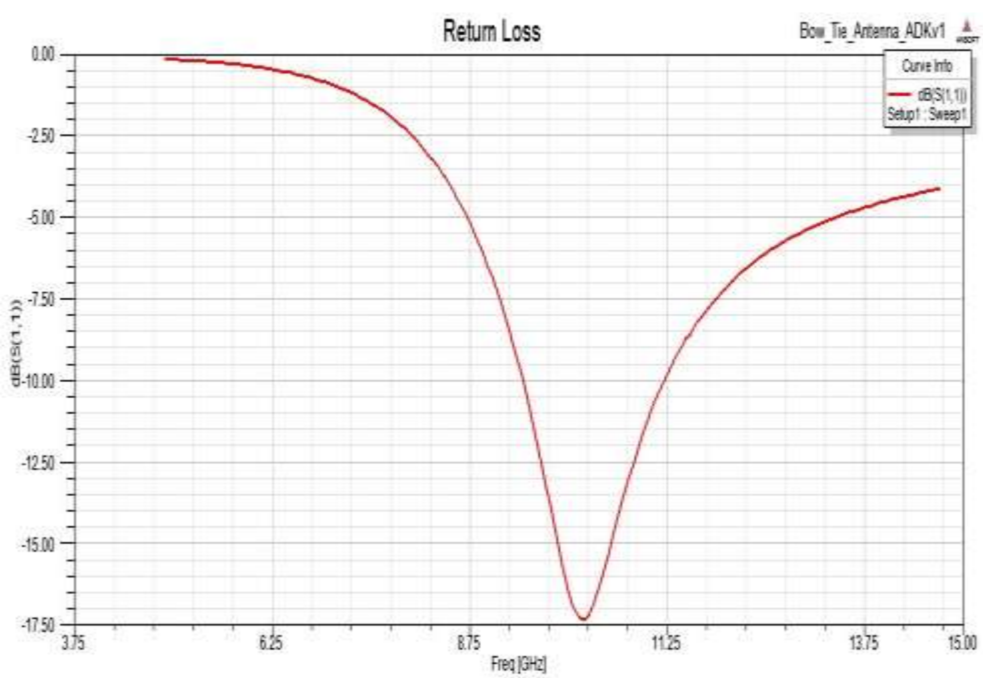

Figure 3: Desired frequency and the Return Loss

The corresponding radiation patterns of the proposed design are shown from Figure. 4 through Figure. 5 of the bow-tie antenna.

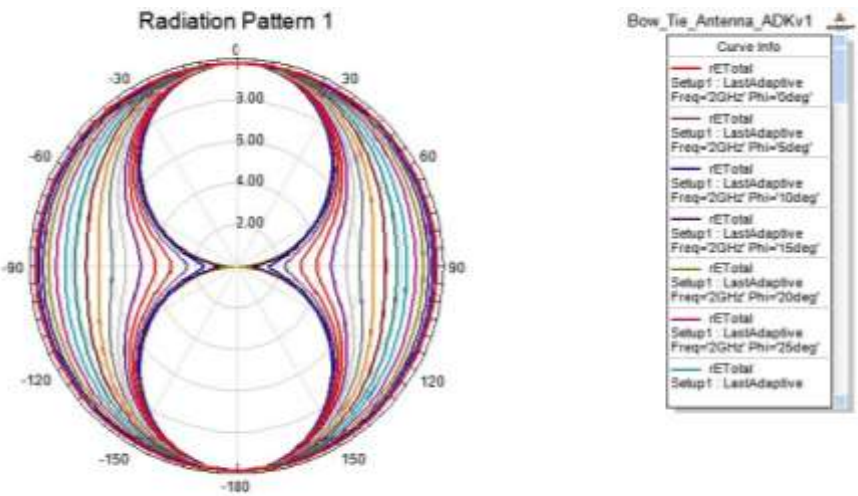

Figure 4: Radiation Pattern of proposed Bow-Tie antenna

The feeding positions have been analysed with co-axial feed technique. It is found that with centre-fed bowtie antenna is most suitable and its radiation pattern is shown in Figure. 5.

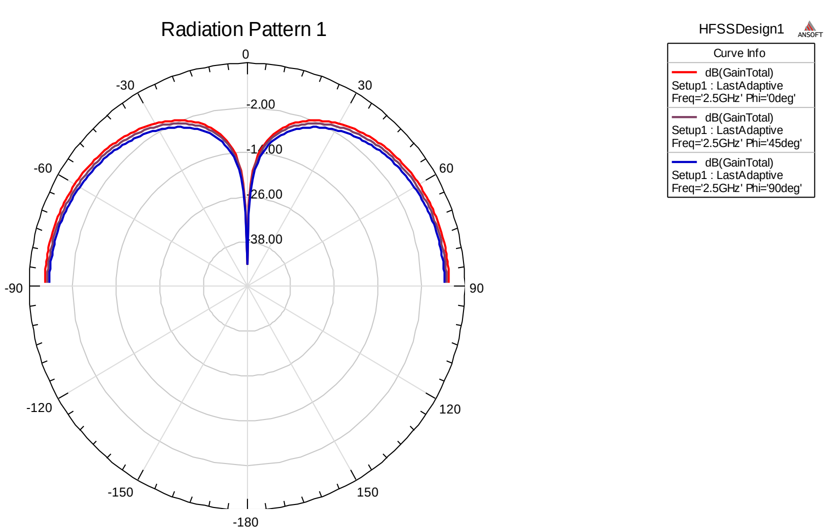

Figure 5: Radiation pattern of centre-fed bowtie antenna.

V. Conclusion

The antenna is successfully designed as patch antenna for reduction of size and for efficient transmission it is designed with the metamaterial substrate. Due to less dielectric constant of metamaterial substrate, bandwidth increases. For some special and unique electromagnetic properties of metamaterial, it is used for getting the compactness of the antenna. Also it increases the efficiency.

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