WiMax Based Meta Material Antenna on IE3D using Lithography

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Abstract

Meta material is an artificially designed structure found not to have properties available in nature. They usually gain their properties from structures rather than composition. It provides solutions to all its antenna parameters for the disadvantages found in commercial patch antennas. The WiMAX frequency band designated for this antenna is of Bluetooth, WLAN, Mobile application & Radar, RFID, GPS, Zigbee. The frequency range will be designed from 1.5GHz to 5Ghz. Hence, the arrayed Meta Material antenna comes into picture. In this paper we intend to design an arrayed based Meta material antenna for WiMAX application on the IE3D simulator and check all concerned parameters in ways to differentiate it with commercial antennas. After simulation, we aim to practically fabricate it through lithography, test its antenna parameters and finally its application as a Transmitter.

Keywords— Meta Material, Antenna, Array, WiMAX, IE3D

I. INTRODUCTION

By definition, an antenna is a device that is used to transform an RF signal travelling on a conductor into an electromagnetic wave in free space. The IEEE standard definition of Terms for Antenna (IEEE STD 145-1983) defines the antenna or aerial as a mean for radiating or receiving radio waves
[1]. An antenna supports a wide range of body centric applications such as WLAN, Wi-Fi, Wi-Max, BAN, HYPER LAN, GSM, UWB, UMTS-LTE, Bluetooth, Mobile communication and Telemedicine and depending upon the application of specific frequencies taken into consideration the antenna can be determined to be either a single band or multi band application [2].

In this paper we will be designing the meta material antenna for the WiMAX frequency band and India's Department of Telecom (DoT) has short-listed four different frequency bands (2.5-2.69, 3.4- 3.6, 2.3-2.4GHz and 700MHz) from its spectrum, with DoT requesting the Department of Space (DoS) to keep the following spectrums available for these authenticated frequency bands only:- 95 MHz for 2.5 to 2.69 GHz band for the application of 3G and WiMAX, 150MHz for 3.4 to 3.6 GHz band for the application of WiMax and especially for 700 MHz band, DoT has specifically designated 40 MHz rural WiMax applications. The WiMAX frequencies designated for India are 2.3 - 2.5 - 3.3 - 3.5 & 5.8 GHz specifically but in this proposed paper we will be designing the antenna with different center frequencies of 2.402-2.48GHz (Bluetooth), 2.412-2.4835GHz (WLAN), 4.2GHz (Mobile Application/ Radar), 2.45GHz (RFID), 2.4GHz (Zigbee).

Today, we see WiMAX competing with the 3rd Generation Partnership Project (3GPP)'s Long-Term Evolution (LTE) in the 4G market proving and making one believe that there is and will be a drastic change in all its communication and application factors making it one of the most desired broadband wireless technologies for the future.

IE3D is a Moment of Method Simulator which solves the Maxwell's Equations in an integral form through the use of Green's functions. The results are analyzed and discussed in terms of return loss, bandwidth, 3D radiation pattern, Smith Chart [3]. Thus depending on the type of radiated field of the antenna, its shape is decided to be rectangular or circular in shape; linear, circular or elliptical polarized. The most common of all patches is the rectangular patch as it is used frequently due to their ease of analysis, fabrication and excellent radiation pattern but of all; the dipole patch displays properties of a large bandwidth and minimum space requirement. Conventional antenna methods use linearly polarized wave and circular/ elliptical polarized are obtained from various feed arrangement through slight modification of the patch.

The meta material antenna hails from the family branch of patch antennas but the outstanding factor that makes it stand out from all the patches in it'd field is that it takes in all the limitations of its other branches and showcases then as its advantages, making it in future a highly recommended antenna for mobile application.

To finally describe this proposed paper, the antenna is to be designed on IE3D simulator without the authenticated frequency bands of WiMAX making it an arrayed designed antenna having multiple antennas connected together so as to work as a solo antenna for transmission and reception.

II. SELECTION BEFORE DESIGNING

Remember as a child, the type of fascination that we would get on figuring and coming across an antenna especially when travelling through hilly regions coming across mobile towers or even on-top building dish antenna right up to the old analog radios at home. All this seemed to be an interest and dream where one aspired to be an engineer but now what if we could design an antenna which will very soon take over commercially in the market. Seems interesting right? This is exactly what this paper is all about.

Previously, before selecting this project we had designed a dual band micro strip antenna for WLAN & UMTS and in the process came across many disadvantages and while trying to evaluate its parameters we realized the meta material to be another antenna which could provide better performance for its limitations.

The following stages describe exactly the process for making the antenna ideally on simulator and practically:

A) Designing the antenna dimensions mathematically.

The antenna is capable of operating in the higher frequency band of WiMAX for wearable applications making the antenna to multipurpose for mobile application of Bluetooth, WLAN, Mobile Application/ Radar, RFID and Zigbee all embedded into a single antenna.

B) Simulation on IE3D

Electromagnetic stimulation is an advanced technology that yields high accuracy analysis and design for complicated microwave and RF printed circuits, antennas, high speed digital circuits and various electronic components ever. Since, its formal introduction in 1993; IEEE International Microwave Symposium (IEEE IMS 1993), IE3D has adopted an industrial standard in planar and 3D electromagnetic stimulation.

IE3D being based on MOM solution has excellent accuracy for frequency domain analysis. It also offers the capacity of performing higher simulation with fastest turnaround times for the broader applications. Now- a-days Zealand's IE3D software has become famous for computer aided design and also in engineering software in the field of antenna designing. It is a closed source application, and one of the simplest platforms for designing an antenna.

C) Manual Fabrication

After simulating the antenna on IE3D, the fabrication is also of due importance so as to test the antenna practically. IE3D has the feature of converting this design to Geber file so as to fabricate it precisely on a CNC machine.

Fig II shows the manually fabricated microstrip patch antenna for WLAN and UMTS that was designed before the selection of this project idea which showed us how to improve the antenna parameters by going for a better much futuristic antenna i.e. the meta material based antenna. The process for its fabrication will be done through lithography, due to the non-availability of meta material in the market as compared to a simple patch and this makes its fabrication process difficult and tedious; the only possibility of having it fabricated in a much better way is to go find a reputed research based organization that helps provide this material and already has analysis going on.

Fig II: Manually Fabricated Patch Antenna

III. META MATERIAL ANTENNA

Metamaterial is designed such that its properties are different from naturally occurring materials. Designing is done at very low cost with high gain. Making it attractive for broadband networks due to many inherent features; it is completely miniaturized in size where it can be used on limited space platform for onboard air plane or ships enabling capacity to overcome the gain, bandwidth, extra radiation, excitation of surface wave which was earlier not possible in the case of Microstrip patch antenna. The R&D on Meta Material antenna currently is the on-going topic for antenna designers. They are being used so as to improve the properties of antennas and filters in the case of microwave devices. []

The important parameters of any antennas in general are the return loss, bandwidth that plays a major role in determining the application success of the particular antenna. The parameters depend on the patches elements of structure and feed only.[] Meta material are designed in relation to Split Ring Resonator (SRR) and CSRR (Complementary Split Ring Resonator) so as to produce negative permeability and negative permittivity. Due to negative index refraction they are also called Negative Index Materials (NIM). SRR consists of 2 concentric rings with a split on each ring faced at opposite directions, due to this structure magnetic resonance at a particular frequency is exhibited which is called as resonator. This split ring resonator electrically displays small LC resonance with high Q factor with inductance and capacitance excited by time varying external magnetic field component from normal direction of the resonator. As mentioned the main component for having a material as negative is not only to have it as SRR but at times needs to be complementary as well and due to CSRR the negative impact of SRR is realized. []

A) Mathematical antenna dimensions

The parameters taken into consideration for this antenna mentioned below are a single SRR with center frequency 4.2GHz and dimensions as follows; 26.314mm X 31.5mm rectangular substrate with patch dimensions 16.714mm X 21.9mm. These calculated values were from below formulae that determined the width and length of the antennas dimensions. The selected dielectric constant is 4.3, hence glass epoxy i.e. FR4 is the dielectric material that is 1.59mm thick. Its loss tangent is 0.016 with ground conductivity as 0. The frequency range taken into consideration is 1.5GHz to 5GHz. The feed point and length/width of the antenna can be varied as per the antenna designer depending on the type of radiation pattern needed for its desired application.

A. Mathematical calculate the dimensions through the following formula

Step 1: Calculation of patch Width (W)

$$W = \frac{c_o}{2f_o}\sqrt{\frac{2}{(1+\varepsilon_r)}}$$

Substitute, *c* = 3.00e+008 m/s and f0 = 4.2 GHZ and Range of dielectric constant lies in between 2.2 to 12

Step 2: Calculation of patch Length (L)

$$L_{eff} = \frac{c_o}{2f_o\sqrt{\varepsilon_{reff}}} - 2dL$$

Substitute, *c* = 3.00e+008 m/s and f0 = 4.2GHZ

Step 3: Effective Dielectric constant

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

Substitute, εr=4.3 to 12, h=1.59mm

Step 4: Length extension

$$dL = 0.412h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Substitute, h=1.59mm

Step 5: Calculation of Ground Dimensions

Width of the ground: Wg = W + 6h

Length of ground: Lg = L + 6h

Step 6: Feeding Technique & Location

The impedance match depends on the feed point location of the patch. The feed point location has to match 50 ohm.

Along the width of patch:

$$X_f = \frac{W}{2}$$

Along the length of patch:

$$Y_f = Y_0 - dL$$

$$\text{Where } Y_0 = \frac{L}{\pi}\cos^{-1}\sqrt{\frac{50}{Z_0}}$$

$$Z_0 = \sqrt{50 * Z_{IN}}$$

$$Z_{IN} = 90 * \frac{\varepsilon_r^{\ 2}}{\varepsilon_r - 1}\left(\frac{L}{W}\right)^2$$

- The calculations obtained for Radar application meta material antenna:

1. Substrate Length: 26.314mm
2. Substrate Width: 31.5mm
3. Patch Length: 16.714mm
4. Patch Width: 21.9mm
5. Centre frequency: 4.2GHz

- The calculations obtained for WLAN application meta material antenna:

1. Substrate Length: 28.405mm
2. Substrate Width: 28.404mm
3. Patch Length: 18.805mm
4. Patch Width: 18.804mm
5. Centre frequency: 2.4GHz

Thus the above based calculations show the patches dimensions for radar and WLAN application designed antenna.

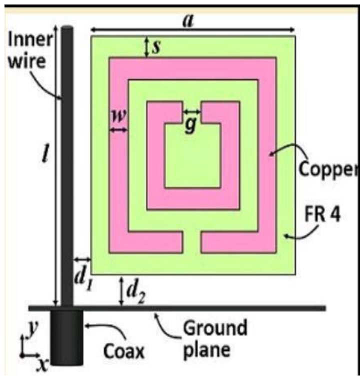


Fig III. A: Dimensions needed for patch designing

B) Technically simulating on IE3D

While doing the simulation of microstrip antenna for WLAN and UMTS last year and following investigation on its gain, bandwidth and return loss performance so as to improve limitations; we finally realize that another antenna (meta material antenna) features to the disadvantage of the microstrip antenna.

The return loss of meta material vs microstrip antenna that was obtained last year is shown in Fig III.B.1.1 & Fig III.B.1.2

1) Return Loss:

Return loss is the loss of power in the signal returned/reflected through discontinuity in a transmission line or an optical fiber. It is similar to VSWR parameter of an antenna which indicates the amount of power that is lost to the load. The value of return loss should be minimum, in order to minimize the reflection wave and ability to maximize the transmitting power enabling the antenna to perform better.

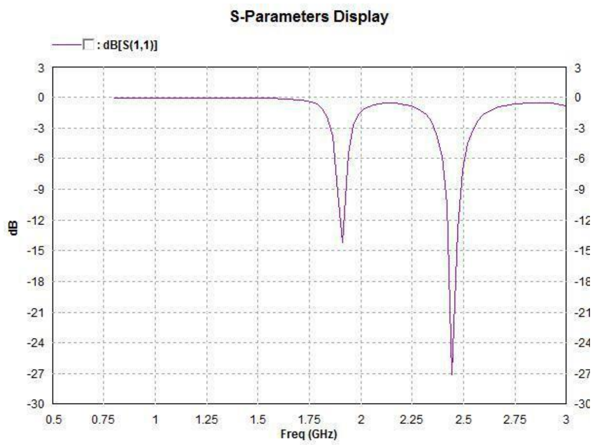


Fig III.B.1.1: Return loss characteristic of the microstrip patch obtained last year

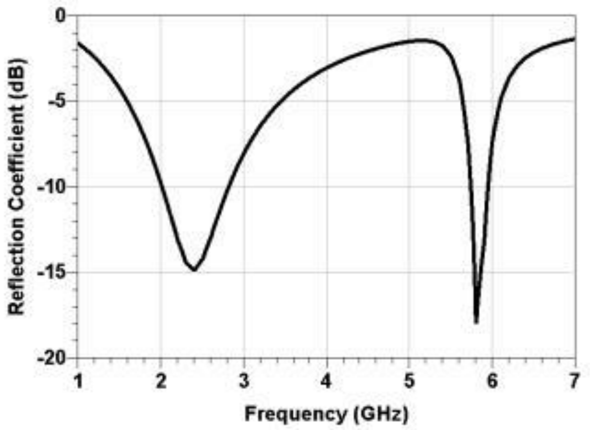


Fig III.B.1.2: Return loss characteristic of the meta material

As observed from the diagrams we realize the bandwidth for WLAN designed for the meta material patch has a much more Bandwidth as compared to microstrip antenna proving to the fact that meta material in reality does overcome the limitations of patches in its family tree.

2) Radiation pattern

The radiated energy of an antenna is characterized by the antennas radiation pattern. The radiation pattern of the antenna is a graphical representation of its properties as a function of space. It is important to state that an antenna radiates energy in all directions, at least to some extent, so the antenna pattern is actually 3 dimensional. The antenna patterns (Azimuth and elevation plane patterns) are frequently shown as plots in polar coordinates. Thus giving the viewer the ability to easily visualize how the antenna radiates in all directions as if the antenna was "aimed" or already mounted.

3) Antenna Gain:

Antenna Gain is the ratio of the amount of surface power radiated by the antenna to the surface power radiated by a hypothetical isotropic antenna

B) Manual Fabrication

Now the main requirement to keep in mind before the fabrication of the meta material is the substrate type and location of the feed point. These parameters are already taken into consideration while designing the antenna.

Thick substrates with low dielectric constant result in better efficiency, large BW and small antenna size; on the other hand thin substrates with high dielectric constant have reduced efficiency, small BW and small size. In short; for good antenna performance a thick dielectric substrate having low dielectric constant is desirable since it provides better efficiency, large BW and good radiation performance.

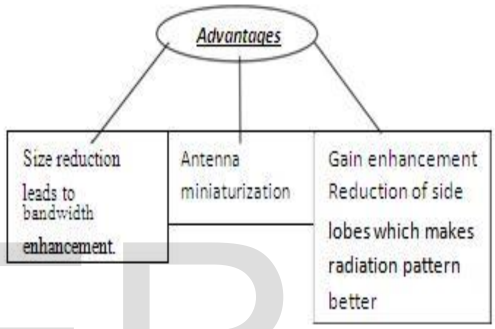
The feed point of the antenna is also of equal importance. In this project we have selected the co-axial as the medium to the feed point of the antenna. The main advantage is that this feed can be placed at any desired location in order to match its input impedance; along with it; it can be easily fabricated as well as possess low spurious radiation except for the fact that it retains a narrow bandwidth and displays asymmetries which generating higher order modes to produce cross-polarized radiation.

C) Conclusion

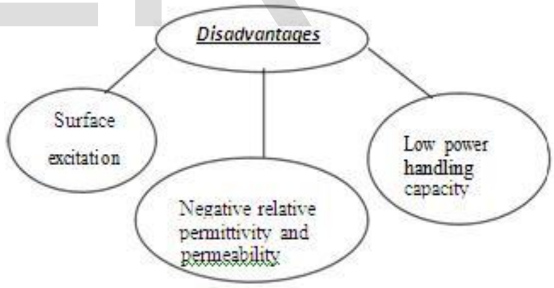
The advantages in meta material are possible only because of the unusual properties of it. The microstrip antenna designed and fabricated earlier showed numerous limitations in relation with BW. Designing the Meta material we realize the enhancement of the bandwidth as shown in the diagrams of fig *III.B.1.1 & Fig III.B.1.2*

WiMAX frequency band overall provides high data rate for broadband networks with low cost equipment, due to the large frequency band designated for WiMAX specially. The range taken into consideration in this proposed paper is the higher frequency band of WiMAX which enables us to use frequency applications of microwave based systems

D) Advantages:



E) Disadvantages



F) Limitations

1. We require a smaller unit to design a smaller unit.
2. Different wavelengths require meta atom for different conditions.
3. It is quite expensive.

G) Future Scope

1. Frequency reconfigurable antenna can be designed using different types of pin diodes and can be tested for real time applications.

2. Meta material also offers potential to the new technologies to be made smaller faster and efficient.

3. Highly researched/user friendly antenna for student projects

4. Overall commercial patch antennas in various fields of telecommunication

H) Applications:

Most of the rapid advances in meta material and array antennas took place in the early 20's. They were initially driven by defense and space application but today it is growing rapidly in the commercial as well as industrial sector. The specifications in defense and space antennas typically emphasize maximum performance with little constraint on cost. On the other hand commercial applications demand low cost components, at the expense of reduced electrical performance. Thus, the below table specifies the commercial application range that an antenna can be designed for

Table D.1: Micro-strip antenna applications for various frequencies

Wireless LAN	2.40-2.48 GHz &5.4 GHz
Cellular Video	28 GHz
Direct Broadcast Satellite	11.7-12.5 GHz
Automatic Toll Collection	905 MHz &5-6 GHz
Collision Avoidance Radar	60 GHz,77GHz,, 94GHz
Wide Area Computer Network	60GHz
Global Positioning Satellite	1575 MHz & 1227 MHz
GSM	890-915 & 935-960 MHz

WiMAX can be used for a number of applications, including "last mile" broadband connections, hotspots and high-speed connectivity for business customers. It provides wireless metropolitan area network (MAN) connectivity at speeds up to 70 Mbps and the WiMAX base station on the average can cover 5 - 10 km.

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