Artificial Magnetic Conductor for Improvement of Meander Line Antenna Efficiency

Shivshankar Tondare[1], Navale V S[2]

[1] AISSMS College of Engineering , Electronics Dept, Pune University, Pune, Maharashtra 411038, INDIA

[1]shivatondare@gmail.com, [2]vaishnavinavale4@gmail.com

Abstract- **Antenna is an inseparable part of communication systems. The (MLA) printed antennas is discussed with the goal of identifying which is suitable for use in a miniaturized wireless transceiver design and which is able to provide the better performance using minimal Printed Circuit Board (PCB) space. In a word, the main objective is to characterize tradeoffs and identify which antenna provides the best compromise among volume, bandwidth and efficiency. Meander line antenna is the most usage of antenna that use in design of the applications such as RFID and WLAN. The Objective of Paper is to design a meander line antenna for WLAN application that is 2.4 GHz has been achieved using Artificial Magnetic conductor for good efficiency and bandwidth.**

Keywords: MLA, LTE, WLAN, RFID, FR4, CPW

I. INTRODUCTION

Meander Line antenna (MLA) is an electrically small antenna. Electrically small antennas pose several performance related issues such as narrow bandwidth, high VSWR, low gain and high cross polarization levels. The proposed antenna is designed for WLAN and RFID applications. The antenna performance parameters are optimized to achieve reasonably wide impedance bandwidth, high gain, VSWR<2, and an omnidirectional radiation pattern. The designed antennas were fabricated on a double-sided FR-4 printed circuit board using standard PCB technique and tested with a Network Analyzer. The effect on the antenna radiation and reflection properties with varying the MLA length, Width, number of turns and conductor dimensions are also discussed in this paper. Meander line antennas (MLAs) are widely used in a variety of applications of radio-frequency identification (RFID), such as contactless rechargeable devices, security, and medical systems [5]. Due to their intended applications, certain characteristics of RFID devices, such as antenna size and impedance matching, are critical to their efficiency and working autonomy. The first characteristic influences the overall size and manufacturing costs of the device; the second defines limits on the power transfer efficiency between the antenna and the integrated- circuit (IC) tag to which it is attached. Ideally, antennas should be as small and as impedance matched as possible. These characteristics are usually defined in the optimization step in the design cycle of an RFID device, which relies on computational models of the antenna in order to simulate its characteristics. However, most models do not take into account the effects of the dielectric layer on which the antennas are built, mostly because of an increase in the computational cost of the antenna simulation. Artificial Magnetic Conductors are used to improve efficiency and bandwidth of MLA. Benefits include configuration simplicity, easy integration to a wireless device, inexpensive and potential for low Specific Absorption Rate (SAR) features. **SAR** is a measure of the rate at which energy is absorbed by the body when exposed to a radio frequency (RF) electromagnetic field. It is defined as the power absorbed per mass of tissue and has units of watts per kilogram. The artificial magnetic conductor (AMC) is a textured ground plane that presents a high impedance to incident waves and nearby horizontal antennas over a prescribed frequency range. In addition, it suppresses the propagation of both transverse electric (TE) and transverse magnetic (TM) surface waves, thus concentrating the radiation from a horizontal antenna into the upper half-space. The resulting reduced backlobe and reduced mutual coupling to any other antennas on the same surface, combined with the high input impedance, make the AMC an ideal gain-enhancing ground plane for ultrathin antennas.

II. DESIGNING OF MEANDER LINE ANTENNA

In a meander line antenna (also called rampart line antenna), the radiating element consists of a meandering micro strip line formed by a series of sets of right angled compensated bends, as shown in Fig 2.1 The fundamental element in this case is formed by four right angled bends and the radiation mainly occurs from the discontinuities (bend) of the structure.[1]

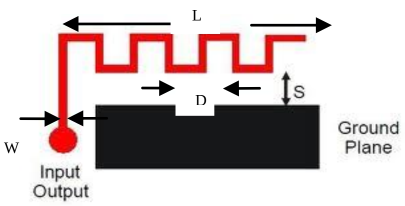


Fig 2.1 Meander Line Antenna

The right angle bends are chamfered or compensated to reduce the right angled discontinuity susceptance for impedance matching. The current directions are changing in every half wavelength and there are more than four half wavelength changes in this design. The radiations from the bend add up to produce the desired polarization depending on the dimensions of the meander line antenna.

Three types of feed structure can be implemented in proposed antenna:

1. CPW feed (Coplanar Waveguide)
2. Inset Feed
3. Microstrip Feed

Coplanar waveguide is a type of electrical transmission line which can be fabricated using printed circuit board technology, and is used to convey microwave-frequency signals. On a smaller scale, coplanar waveguide transmission lines are also built into monolithic microwave integrated circuits. [2]
Microstrip line feed is one of the easier methods to fabricate as it is a just conducting strip connecting to the patch and therefore can be consider as extension of patch. It is simple to model and easy to match by controlling the inset position. However the disadvantage of this method is that as substrate thickness increases, surface wave and spurious feed radiation increases which limit the bandwidth.
Advantages of CPW over Microstrip Feed:

a. Low Dispersion
b. Low Radiation Leakage
c. Ground plane not interdependent
d. Radiation from feed structure is negligible because of coplanar waveguide is excited in odd mode of coupled slot. This feature is useful in design of antenna arrays since mutual coupling between adjacent lines is minimized.

Inset fed is technique where the path of feed is pushed at a particular distance to match impedance This typically yields high input impedance. Since the current is low at the ends of a half wave patch and increases in magnitude toward the center, the input impedance could be reduced if the patch was fed closer to the center.

Basic dimensions and board type is FR4 board for the material substrates. The dielectric constant is ϵ = 4.4, loss tangent tan δ = 0.02 and the thickness d=1.6mm. [4]

III. WORKING PRINCIPLE

The meander-line antenna can be in a dipole or ground plane format. The idea is to fold the conductors back and forth to make the overall antenna shorter, which is shown in Fig 3.1. It is a smaller area, but the radiation resistance, efficiency and bandwidth decrease [9]. The parameters of meander shape, for example H, La, Lb and Lc shown as in the figure will affect the antenna performance parameter [8]. In order to find the best antenna solution, different values of meander width are simulated and studied. (actual report MLA)

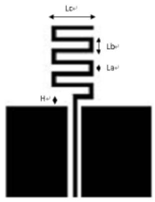


Fig 3.1 Shape of Meander Line Antenna (MLA)

A meander-line antenna can be realized by bending the conventional linear monopole antenna to decrease the size of antenna [5]. The influence of the meander part of the antenna is similar to a load and the meander line sections are considered as shorted-terminated transmission lines as shown in Fig 3.2. The meander line section can be modeled as an equivalent inductor. In the far-field pattern, in the result of the cancellation of magnetical fields, the transmission lines of a meander line antenna do not radiate fields. The radiation fields will be radiated from the vertical pars of MLA. The currents' intension of vertical parts can be clearly seen in Fig 3.3.

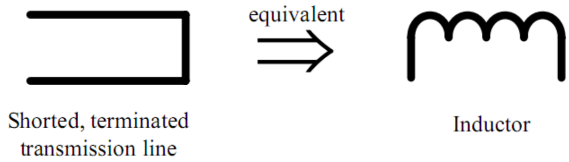


Fig 3.2 Equivalent Model of meander line sections

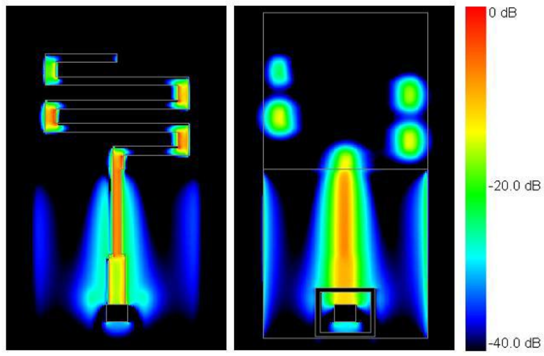


Fig 3.3 Electric Current Magnitude Plot for the MLA.

IV. PARAMETRIC ANALYSIS FOR 2.4GHZ MLA

1. By changing Width (gap) of MLA
2. By changing Height of MLA
3. S11 parameters calculations
4. $\lambda/4$ matching done in order to match impedance.

For points 1 and 2 simulation results as done in HFSS version 11 are shown in below tables Different simulation results obtained for varying height and spacing are shown in below table 4.1 and 4.2

Height	F-start	F-stop	Impedance	B/W
0.2	3.034	3.066	56.60	32MHz
0.4	3.444	3.492	68.43	48MHz
0.8	3.923	3.961	101	38MHz
1.6	4.517	4.603	99.89	86MHz
3.2	4.709	4.767	52.55	58Mhz

Table 4.1 Simulation for different height

Spacing	F-start	F-stop	Impedance	B/W
0.9	3.090	3.108	22.24	18 MHz
1.4	3.250	3.284	68.64	34MHz
1.7	3.032	3.066	42.03	34Mhz
2.5	3.186	3.220	38.93	34Mhz
3.2	3.086	3.118	38.81	32Mhz

Table 4.2 Simulation for different spacing

3. S11 Parameter Calculation

$$S_{11} = \frac{Z_{IN} - Z_O}{Z_{IN} + Z_O}$$ ....Equation 1

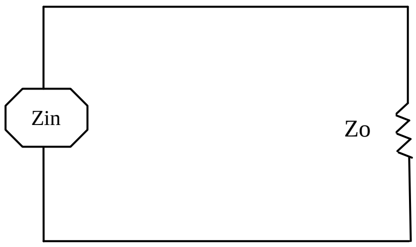
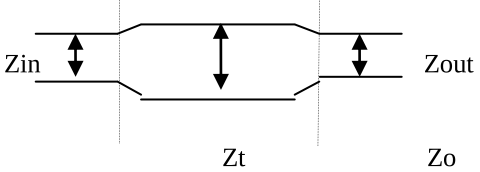


Fig 4.1 Load calculation

Now Z (Load) = 50
Assuming we get result for
Now 20 Log r = S11 ………………..Equation 2
Example: h = 0.4 and Zo = 59.8659..... from Tx Line software
From equation 1 we get r = 0.08
And further S11 from equation 2 we get = -21

4. Impedance Matching

λ/4 matching done in order to match impedance.



λ/4 Transformer

Fig 4.2 Impedance matching

$$Zt = \sqrt{Zin * Zo}$$

Tx Line Software Used for Impedance calculation with respect to Height and gap variation of Meander Line Antenna (MLA).

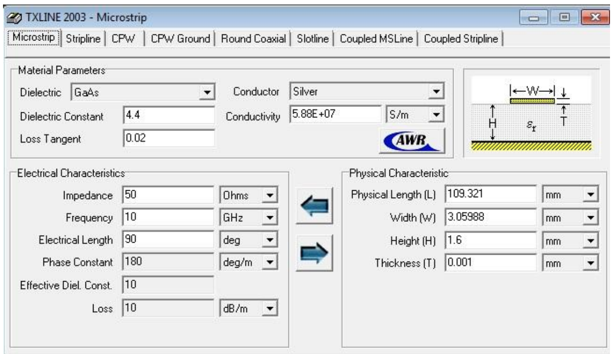


Figure 4.3 Tx line software

V. DESIGN OF DIFFERENT TYPES OF MLA

A. MLA with Different Thickness of Vertical Segment

An important application of meander line antenna is in wireless Communication systems such as WLAN. In these applications, bandwidth is an important factor. As it mentioned before meander line antenna has low efficiency [5]. So if this kind of antenna wants to use in WLAN systems, it must to improve it bandwidth. If we analysis current distribution of classic meander line antennas it could be observed that vertical segment of meander line antenna has more role in constructing electrical field of this antenna. Therefore, with applying some changes in this segment, such as different thickness, it might get better results. Fig.5.1 shows MLA with different thickness of vertical segment. In this structure, thickness of vertical segment and feed line are 2mm and thickness of horizontal segment is 1 mm.

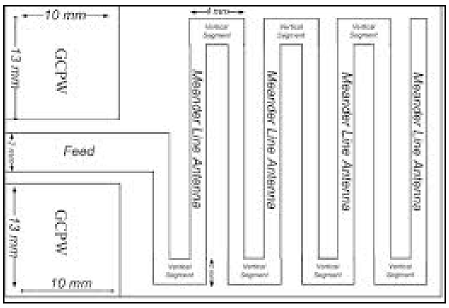


Figure. 5.1 Illustration of MLA with different length of vertical segment.

B. Log Periodic Meander Line Antenna

The increasing use of wireless communication systems, demands the antennas for different systems and standards with properties like compact, broadband and multiple resonant frequencies. Classic meander line antenna is able to perform in single band. Log periodic antenna is a kind of frequency independent antenna and is able to achieve multi-band performance [6]. Therefore, log periodic technique has been combined with classic meander line antenna to get dual band antenna. Fig.5.2 shows illustration of this antenna.

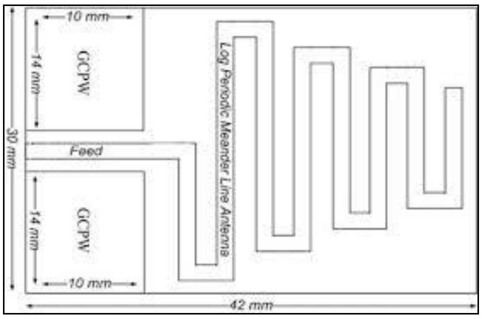


Fig. 5.2 Illustration of Log periodic Meander line antenna.

C. Symmetrical Meander Line Antenna

Nowadays, communication devices which have more properties are more usable than other devices. One of its properties is devices that able to operate in dual band frequencies [6]. As it mentioned before, log periodic MLA approach is one of them. Another technique to get dual-band resonance is two segment MLA. In this mode main antenna, composes in two sub MLA. Each one can be designed to operate in one resonance frequency. These segments can be symmetrical or asymmetrical [6].In this paper symmetrical meander line antenna has been presented. Fig 5.3 shows the illustration of this antenna. In this structure taper plane has been designed to get better matching network.

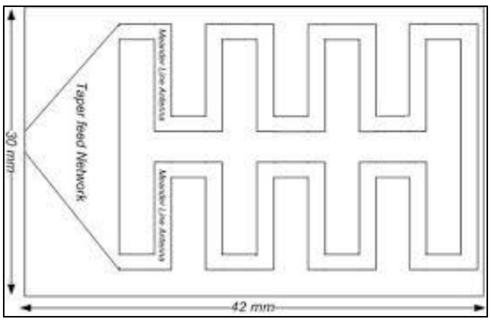
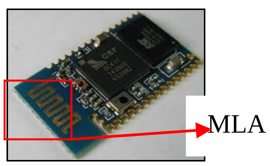


Fig. 5.3 Illustration of symmetrical MLA.

VI. FINAL HFSS DESIGN OF MLA WITH AMC SIMULATION RESULTS.

A. HFSS design:



AMC is an artificial, metallic, electromagnetic structure. The structure is designed to be selective in supporting surface wave currents, different from conventional metallic conductors. It has applications for microwave circuits and antennas. As an antenna ground plane it suppresses the propagation of surface waves, and deployed as an improvement over the flat metal sheet as a ground plane, or reflector. Hence, this strategy tends to upgrade the performance of the selected antenna. Strong surface waves of sufficient strength, which propagate on the metal ground plane will reach the edge and propagate into free space. This creates a multi-path interference. In contrast the AMC surface suppresses the propagation of surface waves. Furthermore, control of the radio frequency or microwave radiation pattern is efficiently increased, and mutual between antennas is also reduced First, AMC surfaces are designed to have an allotted set of frequencies over which electromagnetic surface waves and currents will not be allowed to propagate. These materials are then both beneficial and practical as antenna ground planes, small flat signal processing filters, or filters as part of waveguide structures. For example, AMC surfaces as antenna ground planes are able to effectively attenuate undesirable wave fluctuations, or undulations, while producing good radiation patterns. This is because the material can suppress surface wave propagation within the prescribed range of forbidden frequencies. Second, AMC surfaces have very high surface impedance within a specific frequency range, where the tangential magnetic field is small, even with a large electric field along the surface. Therefore, an AMC surface can have a reflection coefficient of +1.

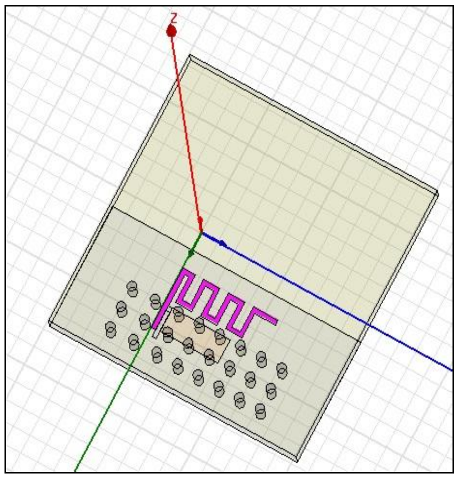


Fig 6.1 HFSS design of MLA with AMC

The final design in HFSS is as shown in figure 6.1 above. It shows the electric field distribution throughout the antenna.

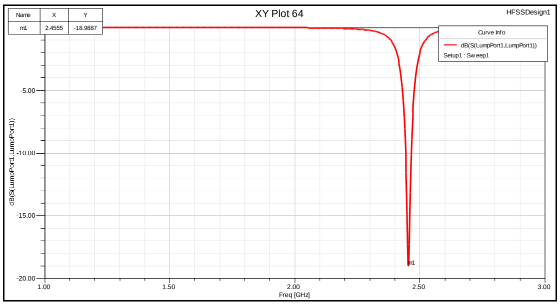


Fig 6.2 Return Loss Plot

The Return Loss (S11 Parameters) is as shown in above fig 6.2 where antenna can operate less than -18db.

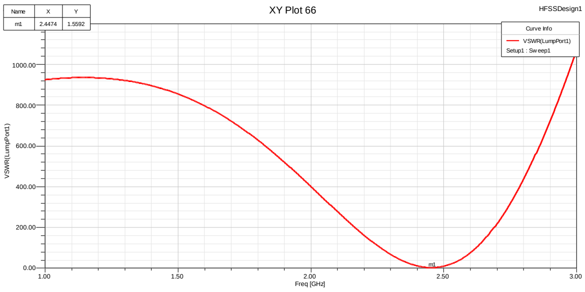


Fig 6.3 VSWR Plot

Above figure shows the simulated VSWR which is 1.5592 of MLA with artificial magnetic conductor.

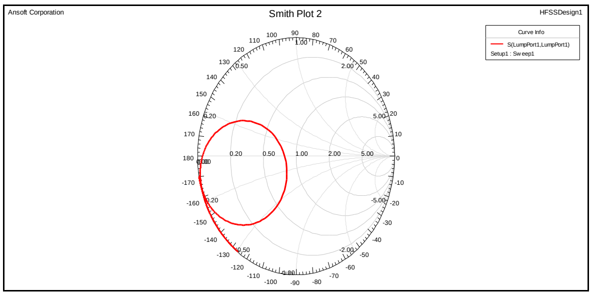


Fig 6.4 Smith Chart

Above figure shows the simulated smith chart of MLA with artificial magnetic conductor.

VII. RESULTS OBTAINED ON VNA

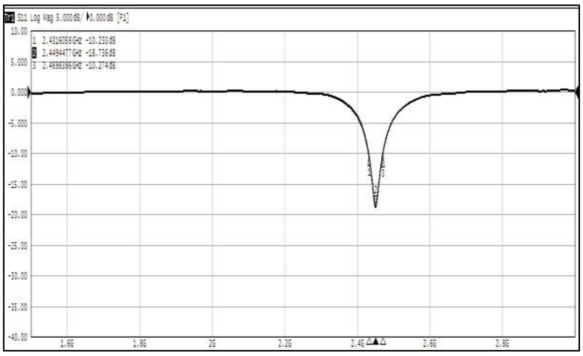


Fig 7.1 S11 Parameters (Return Loss obtained)

The actual S11 parameters measured on VNA plot is as shown in above plot fig 7.1 where the resonant frequency is 2.44 GHz at -18.779db.The S11 parameters are obtained by impedance matching done with a capacitor of 5pf mounted at feed to match impedance.

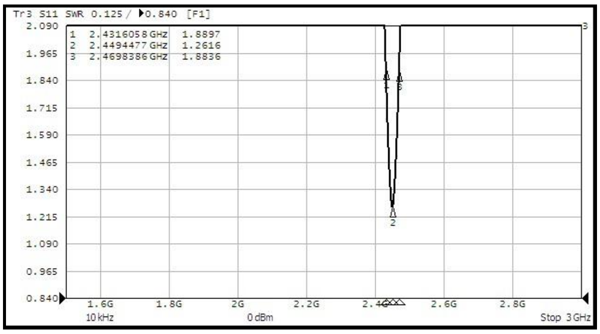


Fig 7.2 VSWR

The actual VSWR measured on VNA plot is as shown in above plot figure 7.2 where the VSWR at frequency 2.44 GHz at 1.88.

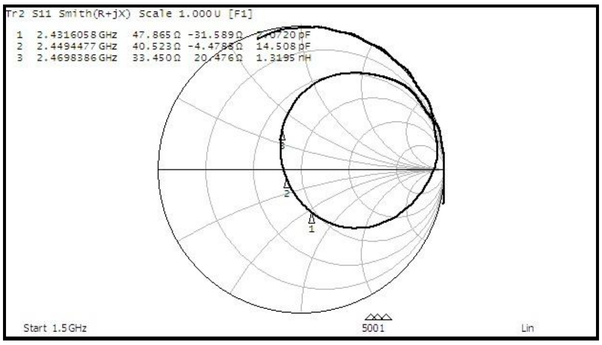


Fig 7.3 Smith Chart

The actual Smith Chart on VNA plot is as shown in above plot figure 7.3 at 2.4468 GHz.

Parameter	Result
Frequency	2.44 GHz
B/W	20 MHz
VSWR	1.88

Table 7.1 Final results

VIII. ANTENNA MEASUREMENT SYSTEM

A. Antenna Measurement System

An antenna measurement system is used to obtain radiation pattern and calculate the antenna factor (efficiency) and other parameters such as HPBW, antenna test wavelength, gain, directivity.

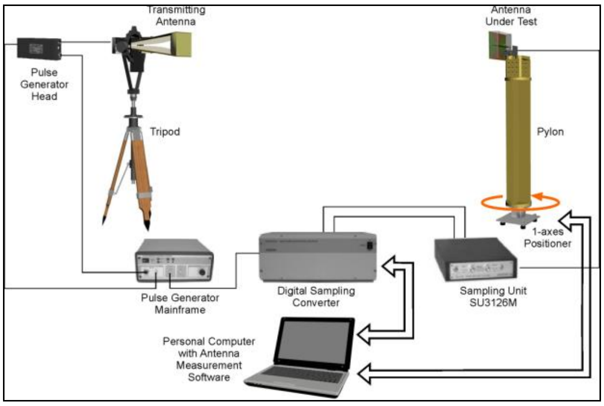


Fig 8.1 Antenna measurement system

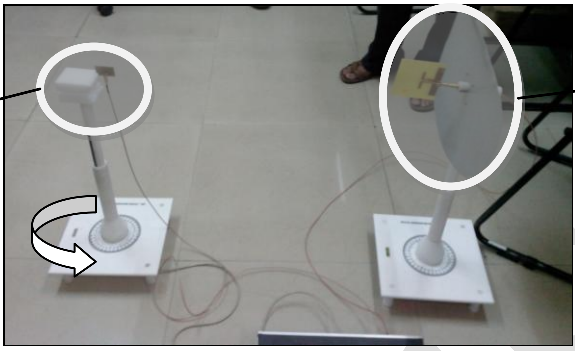


Fig 8.2 Setup for Testing

B. Antenna Factor

The antenna factor (K) is the figure that expresses the efficiency of the antenna. The antenna factor is calculated out of the antenna gain in dBi and the frequency in MHz.

$$K_e = -29{,}77 - g[dBi] + 20\log(f[MHz])$$ ......equation 8.1

The antenna factor is calculated by taking actual radiation pattern of both MLA i.e with and without artificial magnetic conductor.

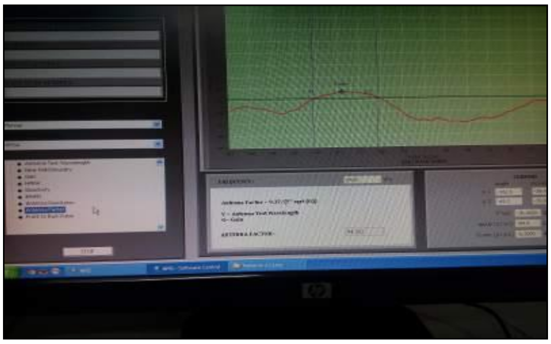


Fig 8.3 Antenna Factor for MLA with AMC

The antenna factor for MLA with AMC comes out to be **94.212%** as per testing in software as shown in fig 8.3.From the above testing we can conclude that as antenna factor i.e efficiency is increased due to artificial magnetic conductor than a simple MLA.

CONCLUSION

Meander line antenna has good properties such as, small, low profile, simple and cheap. These nice features make meander line antenna very popular and usable in many aspect of communication systems such as RFID and WLAN. In this project, planar MLA with inset feed has been designed. A Meander Line Antenna (MLA) with artificial magnetic conductor for 2.4 GHz is proposed and implemented. This research focuses on the optimum value of gain and reflection coefficient. Therefore, the MLA's parametric studies are discussed which involved the Height of substrate and Gap between turns and number of turns. Hence the return loss and other parameters are been improved with the help of artificial magnetic conductor. The MLA also resembles the monopole antenna behavior of Omni-directional radiation pattern. Measured and simulated results are presented. The proposed antenna has big potential to be implemented for Wireless devices such as mobile phones, tabs etc.

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