Design and Analysis of FPC (Flexible Printed Circuit) Antenna for LoRa frequency: 865 MHz - 867 MHz Application

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Abstract- In this paper an antenna for LoRa (Long Range) frequency band 865 MHz to 867 MHz is presented. We present a flexible antenna as a wearable device. The antenna uses vertical polarization. It is a low power, low cost, narrow bandwidth, omnidirectional antenna. The substrate material used is polyimide having a dielectric constant of 3.5. Using Lora WAN, the data will be sent to gateway and the tag location can be traced. It is a modern RF application for IOT. The Inkjet printing technology is used for printing the antenna. Various parameters such as return loss, VSWR, radiation pattern, gain, efficiency is tested. Ansoft HFSS High Frequency Structure Simulator is used for knowing the parameter results.

Index Terms-LoRa, flexible antenna, Meander line Antenna, Capacitive loading, Conductor line.

I. INTRODUCTION

This article uses Meander Line Antenna (MLA) in place a simple patch .An MLA presents a lower resonant frequency in comparison to patch of same size. It also increases electrical length, thus reducing the space required. In order to do so, the patch is folded into horizontal and vertical sections with gaps intervening them. With increase in length meandered patch, the resonant frequency decreases. Traditionally, Meandered antenna have been part of patch antennas or as slots in patch antennas. The past few years have witnessed designs developed with use of the meandered patches themselves. Our design is an addition to such examples.

Compact antennas are attracting considerable interest due to its wide applicability. The next decade is likely to witness a considerable rise in such type of antennas. Also, low weight has become the need of the hour. Within the next few years, compact antennas will be an important component in the IOT (Internet of Things) Technology.

We present an interesting solution to achieve nearly all objectives we had in mind at the time of initiating the design.

MLA stands for Meander line Antenna and will be indicated by the word MLA following this paragraph. Throughout this paper we use the term “LoRa” to denote Long Range Transmission.

In [1] the authors studied the effect of capacitive loading and found an enhanced bandwidth without the need of any matching network. They developed a new method for MLA bandwidth enhancement with the conclusion that doubled layered MLA (MLA in ground plane) enhanced bandwidth 1.5 times much higher than the single layered MLA. In [2] use of conductor line along with symmetrical ground plane has been endorsed to achieve dual band frequency of operation from 900 MHz to 1800 MHz .It has been suggested in [3] that the use of conductor line with asymmetrical ground plane sets up additional resonant frequency and enhances impedance bandwidth of the antenna. In [4] the shortcomings of low data rate of about 50 Kbps has been recognized. A serious weakness of [5] is that the size can be reduced only with degradation in gain and antenna efficiency. In [6], their approach is not well suited as close proximity between feed and shorting pins causes disturbance and radiation pattern and reduced bandwidth. In [7] the experiments to enhance return loss were marred by narrow bandwidth of the antenna.

II. ANTENNA DESIGN AND ANALYSIS

A strikingly remarkable feature of the design is that it is compact in size. Its compact size accounts for use in IOT applications. This paper outlines a new approach in the way the design development has been carried out in the view of the use of two techniques simultaneously for the achievement of its purpose. The MLA has been analyzed to work on the LoRa band range in India, i.e. 865 MHz to 867 MHz by running successful simulation results in the High Frequency Structure Simulator (HFSS Software).

We believe we have found an innovative solution with very small size and succeeded in fulfilling bandwidth requirements of the area under application.

In the literature, any electrically small antenna refers to the antenna whose longest diameter is less than or equal to $1/10^{th}$ of the wavelength of the antenna of the antenna under operation. The term 'MLA' refers to an antenna which instead of a long thin wire length is adjusted horizontal and vertical manner such that the filed distribution causes to operate the antenna at the same frequency the straight-line antenna would operate. Ground plane was gradually shifted downwards vertically as no desired results were obtained with horizontal ground placement.

A. Antenna Design

The figure 2.1 shows the MLA design and structure.

The substrate thickness is 0.19125 mm whereas the patch thickness being $1/4^{th}$ oz i.e. 0.00875 mm. Electrically its dimensions being 0.147 λ x0.144 λ. The dimensions of the MLA are presented in Table 2.1

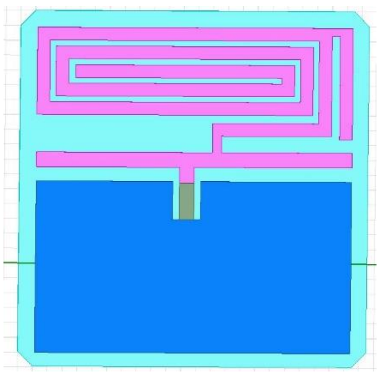

Figure 2.1 MLA design and structure

In the first step the simple MLA without any technique is constructed in HFSS.As soon as the central frequency is reached, we can think of expanding the bandwidth. After the fulfillment of bandwidth, the antenna can be checked for its radiation pattern. To reach successful simulation care must be taken that no overlap of structure takes place. Considerable attention must be paid when dimensioning the radiation box that is, it must be an integral of λ and design must lie in the exact center. Also, extreme caution must be taken when setting up the adaptive passes, number of passes must be enough to make solution converged at all frequencies. Microstrip feed is assigned to the MLA, a lumped port in HFSS Design Simulation. As thickness is assigned there is no need of boundary conditions for patch material.

Table 2.1 Dimensions of simulated values of MLA Patch

Sr No.	**Parameters**	**Simulated Values**
3	Substrate Length	23.945mm
4	Substrate Width	23.5mm
5	Ground	21.285mmx11.547mm
6	Cut	1.895 mm x 2.561 mm
9	Patch	Copper
13	Meander line Width	0.86mm
14	Rectangle 1	14-0.1 mm x 0.86 mm
15	Rectangle 2	0.86 mm x 1.24 mm
16	Rectangle 3	15.25 mm x 0.86 mm
17	Rectangle 4	16.5 mm x 0.86 mm
18	Rectangle 5	6.265 mm x 5 mm
19	Rectangle 6	0.86 mm x 3.755 mm
20	Rectangle 7	17.755 mm x 0.86 mm
21	Rectangle 8	0.86 mm x 5.01 mm
22	Rectangle 9	19.01 mm x 0.86 mm
23	Rectangle 10	0.86 mm x 6.425 mm
24	Rectangle 11	0.555 mm x 0.545 mm
25	Rectangle 12	0.86 mm x 7.5 mm
26	Rectangle 13	8.0025 mm x 0.86 mm
27	Rectangle 14	0.6 mm x 1.11 mm
28	Rectangle 15	7.185 mm x 1 mm
31	Rectangle 16	1 mm x 1.05 mm

The antenna dimensions are assigned from center to outwards. The two techniques used in the paper for bandwidth enhancement are capacitive loading and conductor line, their effects are described in detail in the coming section.

III. RESULTS AND FINDINGS

Now we describe the reason for techniques used, their explanation and demonstrate the conforming results.

A. Initial Design and need for Impedance Matching

A simple spiral antenna was used to evaluate the tendency of an MLA antenna [see appendix] to achieve results. The analysis confirmed its feasibility to reach the desired solution. Our initial design gave a -6dB return loss, not sufficient for impedance matching. Impedance matching depends on several factors such as ground plane, substrate thickness, dielectric constant and feedline measurements. There were significant changes observed when capacitive loading and conductor line techniques were applied. The analysis highlighted the importance of bandwidth enhancement technique in achieving both higher return loss and bandwidth. The return loss and bandwidth are shown in figure 3.1. The VSWR is less than 2 for the 3 MHz bandwidth. The analysis did not reveal any significant difference between the results obtained with conductor line and without it. With conductor line higher return loss is at 867MHz and with-it higher return loss is at centered frequency of 866 MHz Thus, we have used the design with conductor line. The method of capacitive loading helps in removing the need for stub matching. One attractive feature is that it is easily assimilated in the design without increasing the fabrication complexity and affirming that no other essential parameter results such as radiation pattern or gain change. A nearly omnidirectional Radiation Pattern is observed as shown in figure 3.2. Our Antenna being vertically polarized, we need to place antenna vertically to obtain the desired omnidirectional pattern. We achieve a gain of 5.5 dBi at 0° angle. In the figure, the red line represents E plane and blue one represents H plane. An overall gain of nearly 0 dBi is obtained, as shown in figure 3.3. The efficiency of the MLA patch is 48.5%.

A less time-consuming alternative is simple patch at 866MHz It is less exhaustive in the sense, it owes a standard defined procedure for obtaining the design. One possible way is to use the patch antenna instead if size is not an issue.

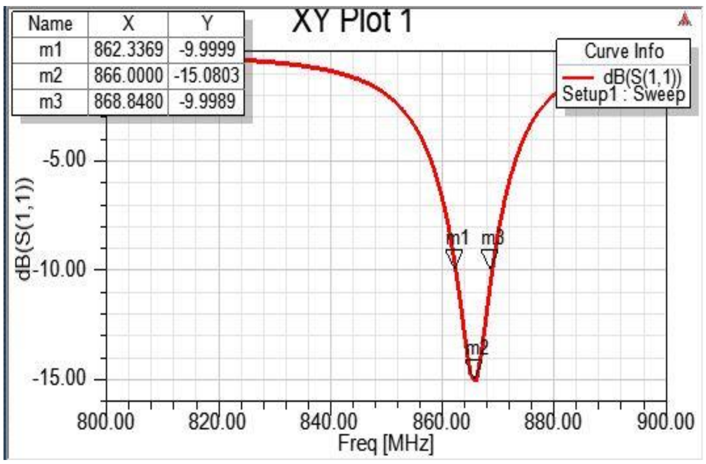

Figure 3.1 Return Loss of MLA Patch

Polyimide is known for its robustness, flexibility, low dielectric strength and thermal endurance. In our final design polyimide is used as a substrate having a dielectric constant of 3.5, dielectric loss tangent 0.008 and a mass density of 1400 Kg/m^3 which gives polyimide its required flexibility .It has a flexible strength 340 MPa and temperature durability from 65°C to 150°C.Overall thickness of antenna is 0.2 mm. Curiously, the correlation between the thickness and resonant frequency is reverse .In addition to this, we also found that with decrease in resonant frequency, return loss improves.

Under bending conditions, the resonance is shifted downwards, yet bandwidth is the same. This further extends our knowledge of some few MHz bandwidth on the lower side of central resonant frequency i.e., 866 MHz in our case. For single layer antenna the minimum radius bend should be 3 to 6 times the thickness of the patch. i.e. 0.0525mm in our case.

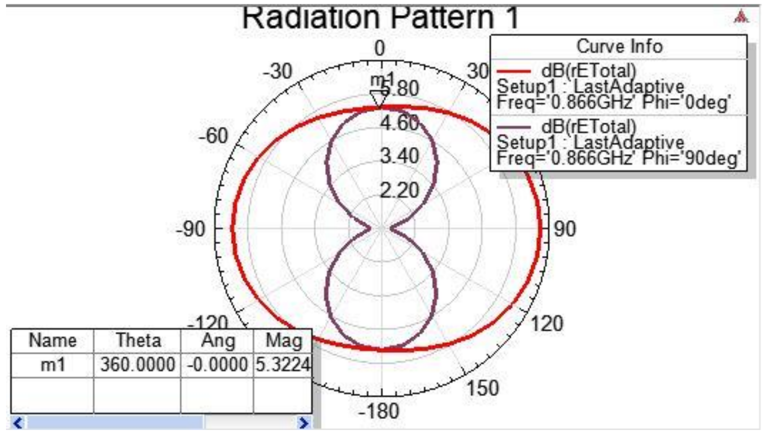

Figure 3.2 Radiation pattern of MLA Patch .An omnidirectional pattern is observed.

The results have further strengthened our confidence that the same MLA basic pattern can be used to obtain 433 MHz and 915 MHz band antennas with antenna size, meander spacing and meander width modifications.

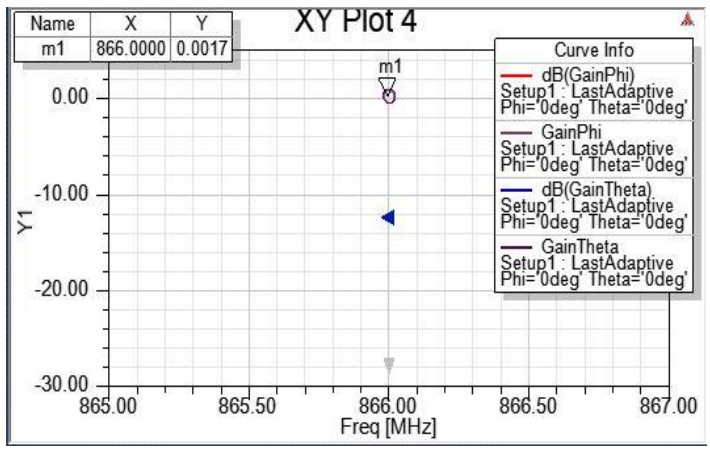

Figure 3.3 Overall gain of the MLA patch .A nearly 0 dBi gain is observed

By substituting the gap width and MLA width x axis meander length id derived. Similarly, by deciding MLA position y axis of MLA patch is decided. For the sake of simplicity reasons, initial formulations are given below.

Calculation for microstrip patch:

Step 1: Calculation of Rectangle 1:
X=14mm Y=0.86mm
Step 2: Calculation of Rectangle 2:
X=0.86mm Y=0.86+0.38=1.24mm
Step 3: Calculation of Rectangle 3:
X=14mm+0.39mm+0.86mm=15.25mm Y=0.86mm

The model with chamfer is selected because it is one of the most practical, feasible, economic in the way that it uses less substrate which will lead to low cost of antenna and less space. It is worthy to add that with modified chamfer design 4 mm capacitive loading is reduced and overall, with ground and substrate measurements about 6 mm space is reduced from design. We opted for a small antenna size as there is a strong need of compact size antenna for IOT and LoRa band Applications. LoRa band Applications include asset tracking in Airports and construction sites., fleet operation, preventive and predictive maintenance and theft prevention.

B. Use of Simulation software

There are numbers of software available for antenna design such as CAD, FEEKO, HFSS etc. We have used the High Frequency Structure Simulator for our simulation purpose. It's based on the Finite Element Method and Method of Moment.

IV. CONCLUSION

As anticipated our experiments show acceptable results for return loss, bandwidth occupancy and gain. Apart from slight discordance to the stringent omni-directional pattern, a good nearly omnidirectional radiation pattern is observed. There is also a satisfactory report of gain of about 0.0017 dBi though not exactly 0 dBi.

APPENDIX

How LoRa Technology Makes Supply Chains and Asset Management Smarter. (Semtech)

Signal Plus 2G 3G GPRS GSM Full-band Built-in Flexible Plate Antenna. (www.aliexpress.com)

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