Design and Development of Meandering Antenna for Smart City Automated Streetlight System

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***Abstract*— This paper presents the design and development of a compact single-band meandering monopole antenna for wireless communication system. The antenna is to be used for bi-directional communication in automated streetlight monitoring system using Zigbee system on chip modules. The antenna is developed on double sided FR-4 substrate with dimensions of 41mm x 59mm. The proposed antenna resonates at 868 MHZ. The simulated return loss of the antenna for 868 MHz ISM band is found to be at -18db with an 80 MHz -10db return loss bandwidth. The resonating frequency of the proposed antenna can be further tuned by controlling the length L4.**

Keywords—Monopole, Microstrip antenna, Meander line antenna, Wireless communication, Zigbee.

I. Introduction

There has been a significant boom in the wireless communication industry in the recent years. There is a need to develop compact antennas for wireless communication. Meander line antenna is type of printed antenna that reduces the overall dimension by meandering a basic monopole. The benefits of using a meandering antenna is its basic structure, ease of integration to wireless devices and cost effectiveness [1]

In recent years there has been a lot of interest in deployment of wireless sensor nodes for wireless control of actuators and monitoring parameters. Range, directivity and energy consumption become crucial factors for the antennas used in these systems. Zigbee systems are generally preferred as they have less power rating, smaller size and high battery life. [2] Due to the selection of Zigbee devices, there are three frequency bands under Zigbee 868MHz ISM band, 915MHz ISM band and 2.4 GHz ISM band.

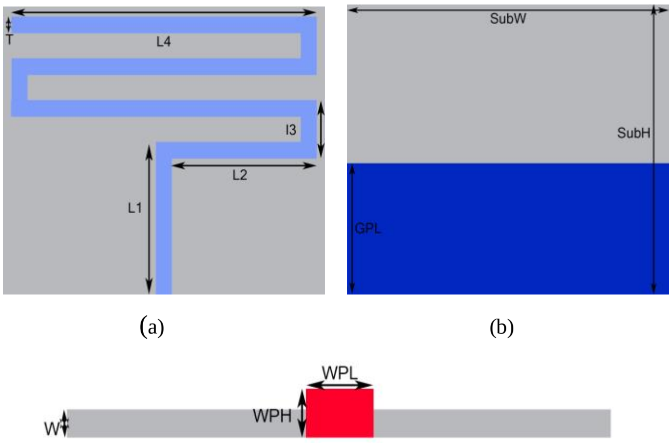
There are many proposed designs that are proposed for the given use [3-5]. A meandering structure is selected due to its good tradeoff with size, bandwidth and simplicity in structure. The proposed antenna is basically a monopole antenna, with the monopole made to meander to reduce size of the antenna.

II. Antenna Design

A. Antenna Struxture

The geometry of the proposed antenna is shown in fig. 1 (a) (b) (c). The basis of the structure is a simple meandering antenna. The antenna is developed on a double sided FR-4 substrate with a relative permittivity of 4.4 and thickness (W) of 1.6mm. A 50Ω CPW transmission line is used for exciting the antenna.

Meander patch is to be printed on top layer while the ground plane is to be printed on the back layer. A wave port is used for excitation of the antenna in the simulation software.



(a) (b)

(c)

Figure 1. Geometry of the proposed antenna.

Fig. 1(a) displays the top view of the antenna, fig. 1(b) displays the bottom view while, fig. 1(c) displays the side view. As seen in Figure 1, the total dimension of the structure is 41mm x 59mm. The feed line L1 is extended to accommodate for the ground plane. The length of L4 is fixed at 25mm to maximize the return loss. The thickness (T) of the meandering structure is set at 2mm. The dimensions of wave port are 4mm x 3mm. The length of the first meandering element (L2) is 29mm.

TABLE I. DIMENSIONS OF THE PROPOSED ANTENNA

Parameter	Value(in mm)
L1	25
L2	29
L3	7
L4	56
T	2
SubH	41
SubW	59
W	1.6
GPL	22
WPL	4
WPH	3

III. EXPERIMENTAL RESULTS AND PARAMETRIC ANALYSIS

In order to provide an efficient result, the parametric analysis of various components is considered. Different parameters were toggled with to find the optimum value. The parameters that are considered in this paper are the width of the meandering line structure (L4), Thickness of the meandering line (T) and the length of the ground plane (GPL).

Table 2 shows the effect of variation in width of the meandering structure and the corresponding return loss. It can be observed that, as we increase the width there is a drop in the resonant frequency. The width of meandering element is optimized at 56mm for 868 MHz ISM band with a maximum return loss of -18.21 dB at 868 MHz. The length L4 is the controlling element for frequency tuning.

TABLE II. EFFECT OF VARIATION IN WIDTH (L4) ON RETURN LOSS

Width (L4) (mm)	Frequency Response (MHz)	Return Loss (dB)
51	1000	-17.9db
54	950	-16.08db
56	868	-18.2db
57	858	-19.54

The effect of variation in the thickness of the meandering line structure (T) on return loss and frequency response is summarized in Table 3.

TABLE III. EFFECT OF VARIATION IN THICKNESS OF LINE STRUCTURE (T)

Thickness (T) (mm)	Frequency Response (MHz)	Return Loss (dB)
1.5	810	-31.4
2	868	-18.2
2.5	914	-12.34

It can be observed that as the width of the meandering line is increased there is an increase in the resonating frequency. The width of the meandering element (T) is selected at 2mm for the desired resonant frequency. The effect of variation in the length of Ground plane (GPL) is summarized in Table 4.

TABLE IV. EFFECT OF VARIATION IN LENGTH OF GROUND PLANE (GPL)

Width (T) (mm)	Frequency Response (MHz)	Return Loss (dB)
8	866	-16.2
12	866	-16.6
16	880	-16.9
22	868	-18.2

It is observed that as we increase the length of the ground plane there is an increase in the return loss with a slight deviation in the resonant frequency. The length of the ground plane is optimized at 22mm for 868 MHz ISM Band.

In general we notice that as we increase the thickness of the meandering element there is a rightward shift in the resonating frequency, while if we increase the length L4 of the meandering element there is a leftward sift in the resonating frequency, as shown in table 1 and 2. However, these results are constricted only to lower frequencies.[4] Based on the analysis that has been studied, the optimized values of the control elements are given in Table 5. Further, the antenna has to fabricated and the simulated results have to be tested and compared with experimental results. Antenna is fabricated using Etching Technique.

TABLE V. OPTIMUM PARAMETER VALUES FOR 868MHZ TUNED MONOPOLE ANTENNA.

Parameters	Values (mm)
L4	56
T	2
GPL	22

A. *Return Loss and Bandwidth*

Return loss signifies the degree to which the antenna is matched with the transmission line. It indicates how much of the incident power is reflected back because of a mismatch in impedance. Generally, the impedance of the transmission line is considered to be 50Ω, although the values can sometimes differ. Return loss is calculated as follows:

$$Rl(dB) = 10log_{10}\frac{p_i}{p_r} \quad (1)$$

In the above equation, p_i is the incident power and p_r is the reflected power.

The simulated results are carried over a frequency range of 0.8GHz to 1GHz with a frequency step size of 2000 KHz. The fig. 2 shows the graph of frequency vs. s11 parameter of the meandering monopole antenna.

As shown in the fig. 2, this meandering monopole antenna resonates around 868 MHz and exhibits a -10dB Return Loss bandwidth of around 80 MHz from 0.83GHz to 0.91 GHz.

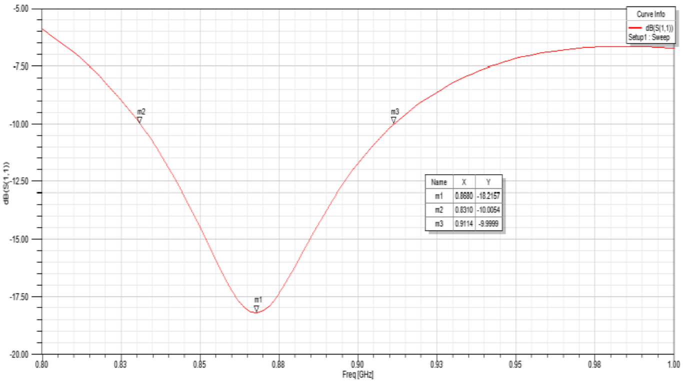
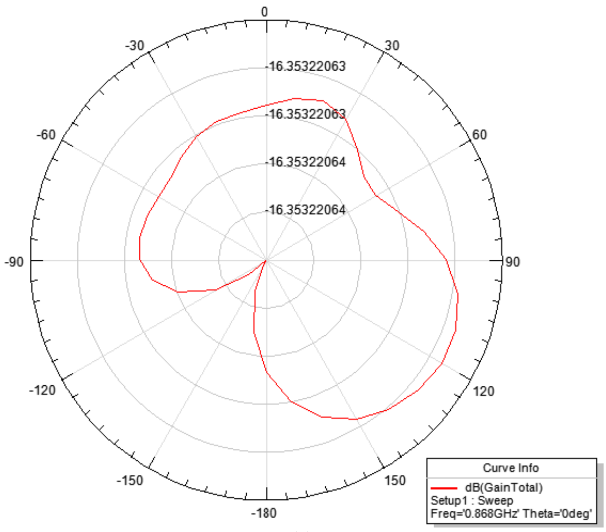


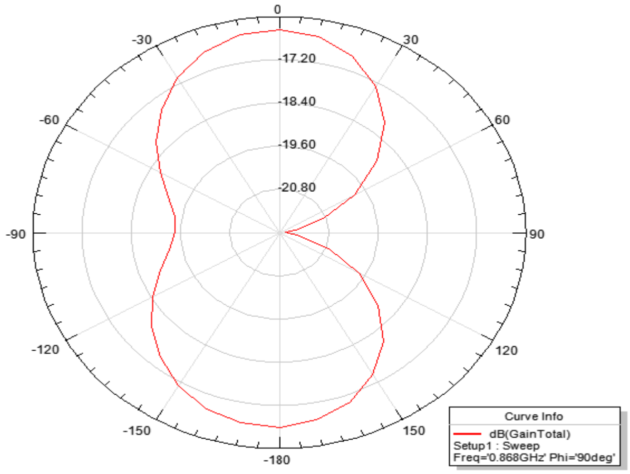
Figure 2. Simulated Return Loss of the proposed antenna.

B. *Radiation Pattern*

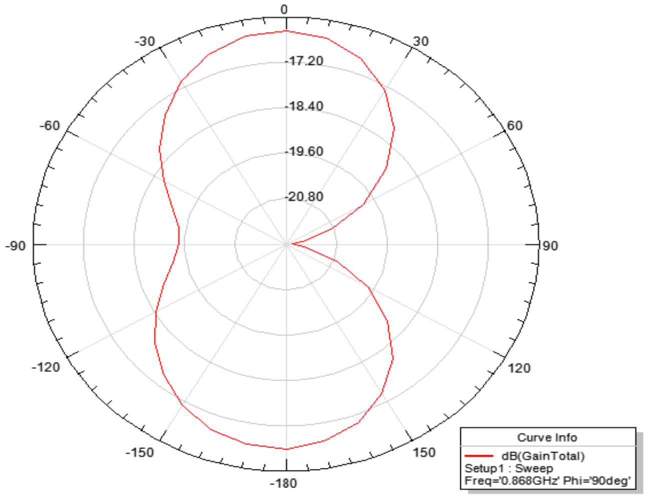
The directional property of an antenna is portrayed by its radiation pattern, fig. 3 (a) (b) (C), 3(a) shows the radiation pattern in XY plane. While, fig. 3(b) shows radiation pattern in XZ plane. Fig. 3(c) shows radiation pattern in YZ plane. Overall the antenna shows an omnidirectional radiation pattern. Which is consistent with monopole antennas.



(a)



(b)



(c)

Figure 3. Simulated 2D Radiation Pattern of the proposed antenna

C. *Gain*

Gain indicates the radiation in selected direction in comparison to an isotropic antenna. Gain provides us with a value to how efficiently an antenna converts input power into electromagnetic waves.

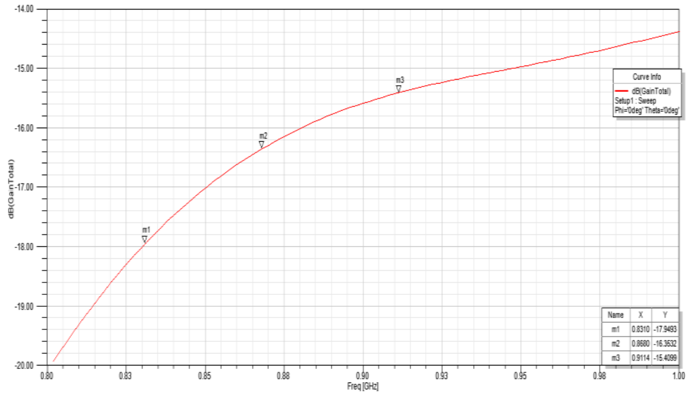


Figure 4. Simulated Gain of the proposed antenna

Fig. 4 shows the simulated gain vs frequency plot of the proposed meandering monopole antenna. The proposed antenna shows a gain of -18dbi to -16dbi over the 80MHz bandwidth of 830 MHz to 910 MHz.

Further studies are required to improve the gain. Techniques such as introduction of parasitic elements and further parametric analysis are considered for the same.

D. *VSWR*

The simulated graph of VSWR vs. Frequency is shown in fig. 5.

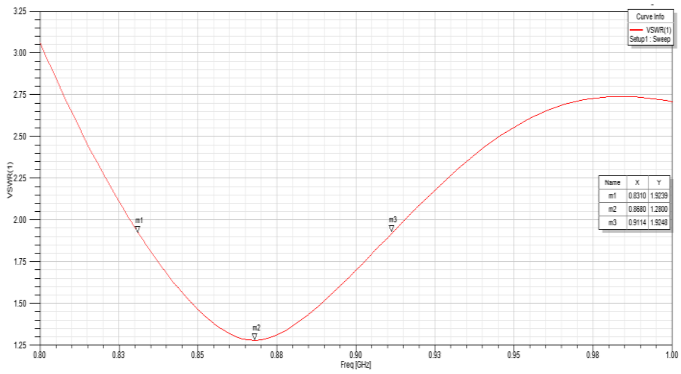


Figure 5. Simulated VSWR of the proposed antenna

IV. CONCLUSION

In this paper the simulated performance of a meandering monopole antenna is presented. The antenna operates around the 868 MHz ISM band with its resonating frequency at 868 MHz and a -10dB return loss bandwidth of 80MHz. The antenna is suitable for bi-directional communication. Further studies are required to improve the gain of the antenna to improve its working efficiency.

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