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Design and Fabrication of Microstrip Planar Antenna with Meander – Line Structure in GSM Band

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Abstract: ***A slotted meander-line antenna geometry for GSM/ISM application is presented. The novelty of design is obtained by creating G shaped meander line with partial ground plane. In this paper we propose two design, first resonating at GSM 900 MHz band and the other design with conventional reduction in the size of meander antenna with size reduction 30% as compared to design 1 resonating in dual band GSM 1900 MHz and ISM 2.4GHz band with change in the substrate thickness and constant. The proposed Antenna design is carried out in HFSS and fabricated in FR4 (2.4) epoxy substrate measuring a return loss of -18.724 and VSWR 1.26 for design 1 in GSM 900 MHz band with gain of -3.14dB and measuring return loss -14.74 and -10.80 in 1800MHz and 2.4 GHz band with gain -3.521 dB respectively.***

Keywords: ***Meander Line Antenna, GSM, ISM, VSWR.***

I. INTRODUCTION

Printed antenna are well known for its operation in certain frequency such as GSM-900MHz DCS-1800MHZ and ISM-2400MHz. Printed antenna is widely preferred mainly its attractiveness in small size, low-cost and easy fabrication. MLA is a type of micro strip patch antenna it is more preferred for its easy integration as it allows designing antennas with a small size and provides wideband performance[1].one of the promising structure of meander line antenna is that it is more suitable for dual band operation[2].The size (dimensions) of micro strip antenna can be further reduced by various techniques like use of 1.shorting pins 2.high permittivity substrates 3.meander line .usually in meander line structure suitable slots are inserted in radiating patch to reduce the dimension , These slots creates a parasitic capacitance over the radiating patch which in turn reduces the resonant frequency of the antenna[3]. The resonant frequency of the patch is related to the surface current flowing in the patch. Meandering technique increases the current flow over the patch eventually lowering the resonant frequency than a straight wire antenna of same size.

II. MEANDER ANTENNA DESIGN AND APPROACH

The meander-line antenna can be in a dipole or ground plane format. To make the antenna more compact in dimension fold the conductors back and forth, which is shown in Fig. 1. It occupies smaller area, but the radiation resistance, efficiency and bandwidth decrease [4]. The parameters of meander shape, for example H, La, Lb and Lc as shown in the Fig. 1 will affect the antenna performance parameter [5]. To find the best antenna solution, different values of meander width are simulated and studied. A Meander line antenna can be achieved by bending the conventional linear monopole antenna to decrease the size of the antenna [6]. The impact of the meander part of the antenna like a pregnancy and the meander line sections are considered shorted-terminated transmission lines as shown in Fig.2. A meander line section can be modelled as an equivalent inductor. The transmission lines of meander line antenna do not radiate fields in the far-field pattern, in the result of the cancellation of magnetically fields. From the vertical parts of MLA the radiation fields will be radiated. Growing currents vertical cut can be clearly seen in Fig. 3.

The electrical small antenna defines as the largest dimension of the antenna is no more than the one-tenth of a wavelength [5].Meander antenna is electrically small antenna. The meander antenna design is formed by a linear set of horizontal and vertical lines as shown in Fig.1.The combination of Horizontal and vertical lines in ML antenna form turns. The radiation efficiency and the resonant frequency of meander line rely on the number of turns, increasing the number of turns increases the efficiency at the same time the resonant frequency decreases with increase in the meander spacing [6].The basic folded antenna is extended to form meander antenna whose frequencies are much lower than resonance as compared to single element antenna with same length. But any how the radiation efficiency of meander antenna is far better as compared to a conventional half wave and quarter wavelength antenna. The main advantage of mender antenna is it size reduction factor. Antenna size reduction depends on the number of meander elements per wavelength and its width between the elements in rectangular loops.

Fig. 1. Meander Line Antenna Structure

The meander antenna structure is formed like a linear sets of right angle bends due to its vertical and horizontal element line. The equivalent LC circuit of meander antenna is shown in Fig.2.a. The equivalent LC circuit of meander antenna is shown in Fig. 2.

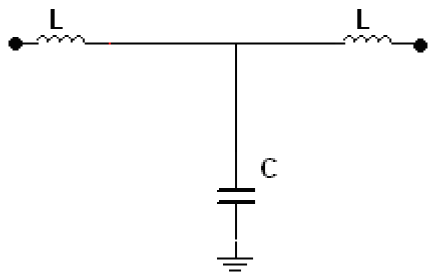

Fig. 2. (a). Equivalent Circuit of Meander Line Antenna

A meander line antenna can be modelled as an equivalent inductor as shown in Fig. 2.b.The loaded quarter wavelength parasitic element in both the side of planar meander line antenna produces double radiation at much lower resonance frequencies as compared to same length of single element antenna [7] therefore in MIMO antenna system planar line monopole antenna element is more preferred.

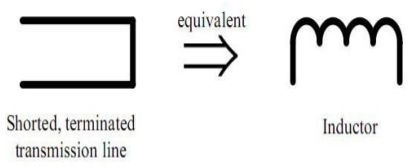

Fig. 2. (b). Equivalent Model of Meander Line Antenna

Slots and meander line are introduced to increase an effective length of the current path with the aim to miniaturize the antenna [8].

$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

It is clear from equation (1) that the resonant frequency decreases as a result of increase in effective capacitance and inductance which is a result of increment of current patch from the Equation (1).

III. Proposed MLA Design

The meander line antenna can be modelled as an equivalent of resonant LC circuit. The effect of inductance is introduced in the vertical elements and capacitance effect in horizontal elements. The horizontal lines are made short along the PCB and the vertical lines along the long length of the PCB.The meander line structure configured as a monopole allows more reduced size less than dimension 0.1 λo.

To analyse the effect of the Substrate thickness, we were designed two antennas with various height. Design-1shown in Fig. 3.a. uses cellulose Acetate dielectric Substrate with permittivity 2.9 and substrate thickness 6 mil which is equal to 0.1542mm.Design II shown in Fig. 3.b. uses Epoxy FR4 with dielectric constant 4.4 and Substrate thickness 3mm. By varying effective dielectric layer, we tend to get a maximum bandwidth of 187.9 MHz from frequency range 700 MHz to 1 GHz.

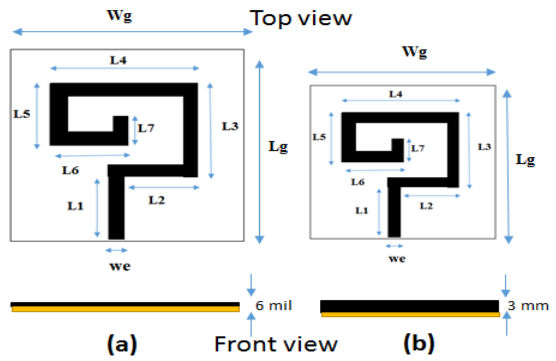

Fig. 3. Proposed Geometry of G Shape Meander Antenna

Fig. 4. Fabricated Meander Line Antenna

The antenna for design 1 is resonant at length 76.5 mm for which the parameters L1, L3, L5, L7 indicates the vertical length of meander line structure which is responsible for varying lumped inductance and L2, L4, L6 indicates the horizontal length of the meander line structure responsible for varying capacitance for resonance at frequency 900MHz are calculated given by as follows

$$La = L_l / 2 \quad (2)$$

$$Cb = C \times l \quad (3)$$

Where L is the inductance per unit length, C is capacitance per unit length, l is length of the line segment$_a$ is Lumped inductance and Cb Lumped capacitance. Antenna total length depends on the number of turns and its spacing between the meander lines given as

$$N * S = \lambda/10 \quad (4)$$

The characteristic impedance of each meander section relies on the diameter of wire given by:

$$Z_o = 276 \log \{2S / d\} \quad (5)$$

Here N is number of turns, S is the spacing between two meander lines and d is monopole wire diameter.

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The formula for the length of the Meander – line antenna with respect to Frequency of the antenna is given by,

f = C / (4L) Hz

f = Operating Frequency of the Antenna

L = Total length of the antenna

The proposed meander line antenna structure is designed using Ansoft High Frequency Structure Simulator (HFSS) and the performance of designed antenna in GSM 900/1800 and ISM 2.4 GHz band is characterized and results are measured based on operational frequency, VSWR, Bandwidth, Reflection coefficient, Gain, and Radiation pattern parameters. Fig. 3 depicts the fabricated antenna with dimensions shown in table 1. Cost wise the prototype was etched on cellulose acetate for design 1 with thickness 6 mil and FR4 dielectric substrate for design 2 with thickness 3 mm and ground plane copper thickness 0.035 mm respectively.

IV. Simulated Results And Measurments

1. Design-1 Results:

It is also known as the S-Parameter and Reflection Co-efficient-Parameter defines how much power is reflected back form antenna to the source terminal describing a relation between the output ports and input ports in a two port network with antenna connected as a Load. Its value is always a real and positive number for antenna.

The S-Parameter obtained from the simulated results of Design 1 specification with for the resonant frequency 0.9 GHz is -22.72dB.

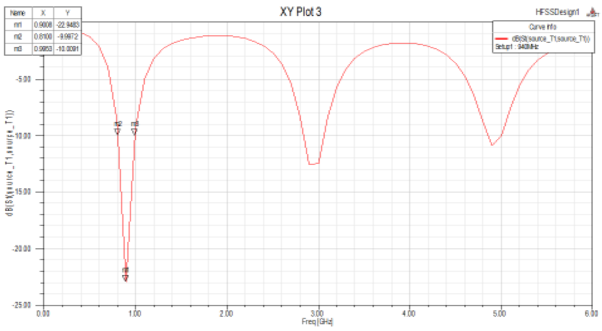

Fig. 4. Return Loss at 0.9 GHz

The value of VSWR describes how much the load antenna is matched to the transmission line, lesser the VSWR more impedance matching delivering maximum power to the antenna. The minimum VSWR should be ≤ 2.The VSWR obtained from the simulated results for the resonant frequency 0.9 GHz is 1.15. Fig. 6.2 Voltage Standing Wave Ratio at 0.9 GHz The gain obtained from the simulated results for the resonant frequency 0.9GHz is

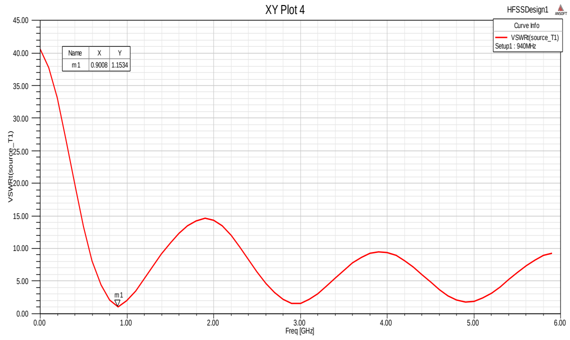

Fig. 5.. VSWR Plot at 0.9 GHz

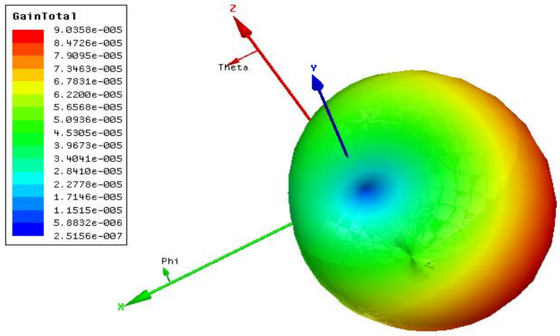

Fig. 6. 3D Gain Plot at 900 MHz

Table 1. Simulated Antenna Results for Single and Dual Band

Parameters	L1	L2	L3	L4	L5	L6	L7	We	Lg	Wg
Design I Size (mm)	12.75	9.75	12	18	10.5	9	4.5	2.5	30	26
Design II Size (mm)	11	8	10	16	9	8	4	2.5	27	23

II. Design – II Results

The proposed design II results to resonate at dual frequency. As substrate thickness is related to its bandwidth [9] it is clear that a wide bandwidth operation is achieved by increasing the substrate thickness results in change in the dimension of the antenna so the antenna operating in centre frequency deviates from the desired actual resonance frequency resonating in dual band operation.

Table 2. Simulated Antenna Results for Single and Dual Band

Parameters	Design I (900 MHz)	Design II (1.9 and 2.4 GHz)
Return Loss	-22.72 dB	-29.87 and -9.8 dB
Gain	9.0 dB	1.6 dB
VSWR	1.262	1.096 And 1.95
Band Operation	Single Band	Dual Band

Henceforth with relative increase in the substrate dielectric (Epoxy glass FR4) and increase in the height of the substrate to 3mm, the dimensions of the antenna is reduced nearly by 10% with reference to design providing frequency resonance at 1.9 GHz and 2.4 GHZ.

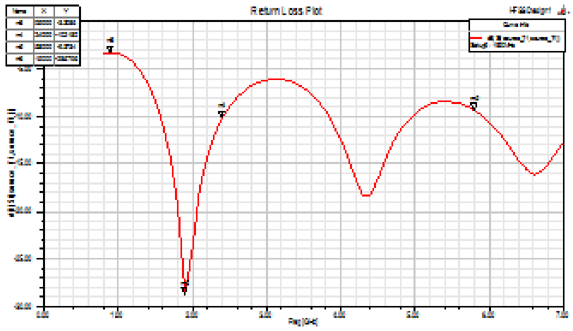

Fig. 7. Return Loss Plot at 1.9 & 2.4 GHz

The reflection coefficient S11 measures -29.87 dB and -9.8 dB correspondingly for 1.9 and 2.4GHz as shown in Fig..3.

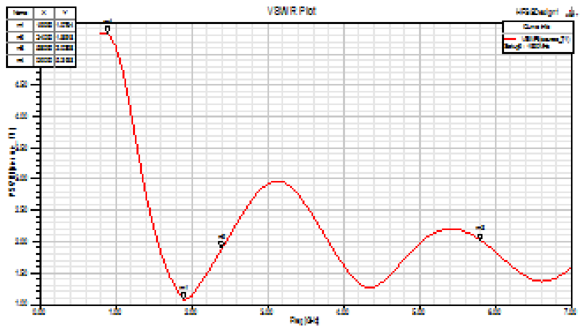

Fig. 8. VSWR Plot at 1.9 & 2.4 GHz

V. CONCLUSION

The Design and fabrication of Meander – line Antenna has been successfully carried throughout out the project. The detailed study of the meander type patch antenna and its real time applications has been completed. Here the micro strip feed line is used for feeding technique. Various materials have been used as a substrate to verify the effect of the substrate material in the antenna. Different results are carried out successfully.

The proposed antenna meets the required bandwidth of 187.9 MHz (i.e., 700 MHz to 1GHz). Maximum return loss co-efficient was achieved (18.7 dB). Overall Efficiency of the antenna has been increased to the maximum with the low profile design. So further, we can design a Multiband Antenna has to be carried out for the GSM/DCS/WiMAX bands. The complete system for the RF Energy harvesting (i.e., Antenna and Rectifying part with Impedance Matching Circuit) will be proceed further. We can improve the efficiency more by using the Antenna array.

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