DESIGN AND ANALYSIS OF SLOT LOADED RECTANGULAR PATCH ANTENNA FOR WIRELESS COMMUNICATION SYSTEM

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ABSTRACT
A multiple-input multiple-output (MIMO) technique has been considered one of the most promising technologies to enhance the performance of wireless communication systems with high-speed transmission rates. A MIMO system utilizing several antenna components is more advantageous than a single-input single-output (SISO) system in terms of increasing channel capacity and reducing transmitting power. Conventional universal serial bus (USB) dongles are attractive for providing plug and- play functionality in mobile communication devices such as laptops. Future wireless USB dongles should be capable of accommodating higher data rates than the current systems owing to the advent of various multimedia services. Up to date, most MIMO antenna systems with more than two antennas are three-dimensional rather than planar. However, the basic problem with the MIMO systems is the requirement of electrically small antennas which usually have several constraints. Hence, these antennas are considered in our project work.

In this work the design, optimization, fabrication & testing of electrically small antennas suitable for MIMO (multiple input multiple output) applications are presented. When the transceiver uses more than one antenna, the antennas must be placed at least half of the carrier wavelength apart, in order to transmit/receive uncorrelated signals. Such antenna systems are required to fit within the hand-held (mobile) terminal which occupies a small size (typically not more than 60x100 mm^2). Since antenna integration and miniaturization are two major challenges in MIMO systems, we propose a slot loaded electrically small rectangular patch antenna that operates in the 0.8GHz to 2.6GHz band which is suitable for most of the commercial wireless applications. The antenna developed & tested here has an operating frequency of 1.7GHz with impedance bandwidth of 105%, and the total size of 20x40 mm^2.

KEYWORDS-Electrically Small Antenna, SLOT ANTENNA, VSWR, USB, MIMO applications.

INTRODUCTION
A multiple-input multiple-output (MIMO) technique has been considered one of the most promising technologies to enhance the performance of wireless communication systems with high-speed transmission rates. A MIMO system utilizing several antenna components is more advantageous than a single-input single-output (SISO) system in terms of increasing channel capacity and reducing transmitting power. Conventional universal serial bus (USB) dongles are attractive for providing plug & play functionality in mobile communication devices such as laptops. Future wireless USB dongles should be capable of accommodating higher data rates than the current systems owing to the advent of various multimedia services. Up to date, most MIMO antenna systems with more than two antennas are three-dimensional rather than planar. In practice, low-profile planar antennas are more preferred so that antenna radiators can easily integrated with other printed circuit board (PCB) components in USB dongles.

Multiple-input-multiple-output (MIMO) transmission is one of the promising antenna technologies used for wireless communications. Through spatial multiplexing, MIMO achieves high capacities. The only limitation is that, the transmitting and receiving antennas should be placed at least half the wave length of the carrier signal in order to transmit or receive uncorrelated signals. Apart from that, each of transmit or receive antenna requires a separate circuit which means, higher the no of antennas used higher the cost. It is indisputable that antenna plays a significant part in communication system. Therefore, an increasingly number of technicians begin to do some research and development of antenna. However, with rapid development of the communication industry, the requirement of antenna will be achieved with high quality. Nowadays, there are different kinds of antennas in the market such as dipole antenna, patch antenna, loop antenna, meander-line antenna and so on.

BASIC GEOMETRY
A meander line antenna shrinks the electrical length of a regular monopole or dipole antenna by folding its length back and forth to create a structure with multiple turns. This method has advantages when antennas with low frequency of operation are of interest as it will reduce the size of the antenna significantly. The geometry of meander antenna structure is shown in Figure 2.1 [6]. The dimensions of the antenna as reported in [6] are L=43mm, W=23.5mm, L_g=16.2mm, W_1=15.5mm, W_2=16.5mm, W_3=W_4=W_5=1mm, L_1=12.27mm, and L_1=5.93mm and the antenna was simulated as suggested there. These characteristics are depicted in Figure 2.2 and radiation patterns in two planes are presented in Figure 2.3.

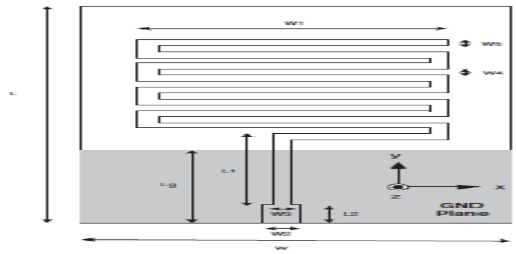


Figure 2.1 Basic geometry of MLA [13].

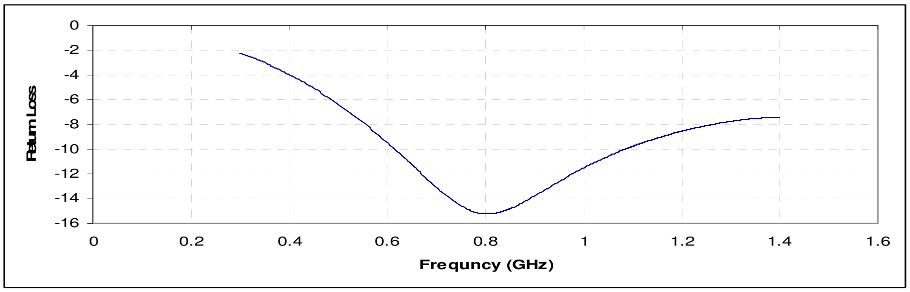


Figure 2.2 Simulated return loss of MLA shown in Figure 2.1.

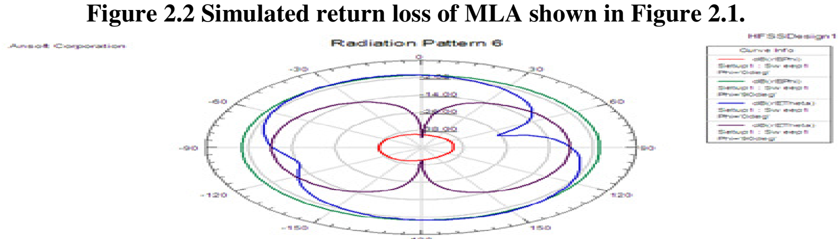


Figure 2.3 Radiation patterns of antenna shown in Figure 2.1.

2.1 EFFECT OF TURNS

In this study number of turns of meander line was varied. Return loss characteristics for all the cases studied are depicted in Figure 2.4. From the Table 2.1 it may be noted that 5 turns case proves to be the best one. Hence in the turns of meander line optimization, 5 turns has been used and kept constant while varying the turns of mender line.

Table 2.1: Design parameters for various curves presented in Figure 3.6 showing the effects of the turns of meander line antenna.

Curve No	No. of Turns	RL Freq. Range(GHz)	%Bandwidth
1	5	0.64-1.08	51.16
2	4	0.60-1.08	57.14
3	3	0.76-1.20	44.8
4	2	0.78-1.20	42.42

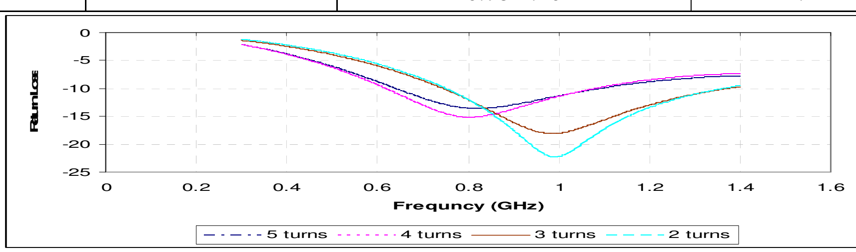


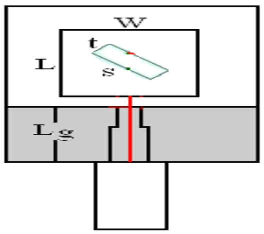
Figure 2.4 Return loss characteristics for increase or decreases turns.

Section I describes introduction. Section II describes in detail of the basic geometry. Section III describes in detail modified geometry of the antenna. The results obtained from our proposed antenna are listed and discussed in Section IV. Finally concluding remarks are presented in Section V.

MODIFIED GEOMETRY

Figure 3.1 shows the geometry of modified antenna. In modified antenna meandered structure is replaced by rectangular patch. Antenna dimensions were optimized using An soft HFSS. An optimized set of dimensions for the proposed antenna design are listed in Table 3.1. The effects of key design parameters (L, W, and a diagonal slot) on the return loss and bandwidth of this antenna are investigated in the following paragraphs by numerical simulations.

The substarte used in simulations is FR4 with relative dielectric constant of 4.4 (loss tangent=0.01) and hieght of the substrate equal to 1.56mm. The design starts with the selection of patch dimensions. Initially, the length and width of rectangular patch are chosen equal to that of total area below the meander structure. A diagonal slot has been introduced to enhance the impedance bandwidth.



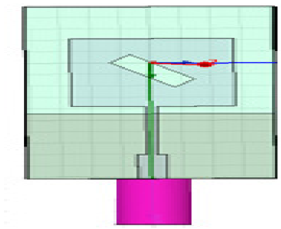


Figure 3.1 Geometry of the modified antenna. (b) Simulation setup

Table 3.1: Optimized dimensions of the modified antenna

Parameter	Value(mm)
Length of Rectangular patch(L)	17.0
Width of Rectangular patch(W)	15.5
Length of ground (L_g)	16.2
Length of slot (s)	6.0
Width of slot (t)	2.0

3.1 EFFECT OF PATCH WIDTH (W)

In this study patch width was varied by keeping patch length (L=17mm) constant. Patch width was varied in steps of 1mm. All the results are presented in Table 3.2. Return loss characteristics for all the cases studied are depicted in Figure 2.4. From the Table 3.2 it may be noted that W=15.5mm case proves to be the best one. Hence in the patch length optimization, W=15.5mm has been used and kept constant while varying the patch length.

Table 3.2: Design parameters for various curves presented in Figure 3.2 showing the effects of the width of patch antenna.

Curve No	Width of patch (W)(mm)	Length of patch (L)(mm)	RL Freq. Range (GHz)	%Bandwidth
1	18.5	17	0.8-2.4	100.0
2	17.5	17	0.85-2.3	92.0
3	16.5	17	0.85-2.3	92.0
4	15.5	17	0.8-2.6	105.8
5	14.5	17	0.85-2.7	104.2
6	13.5	17	0.9-2.8	102.7

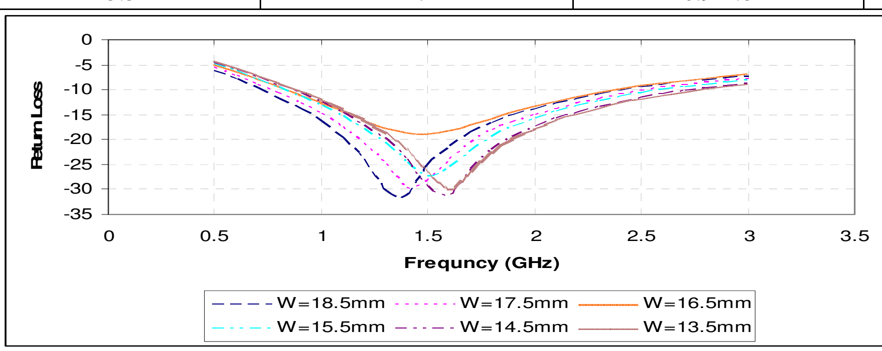


Figure 3.2 Return loss characteristics for different values of W.

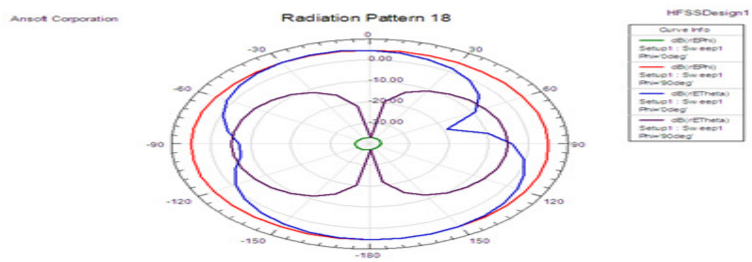


Figure 3.3 Radiation pattern of modified antenna.

3.2 EFFECT OF PATCH LENGTH (L)

As explained in Section 2.1, here the patch length was varied by keeping patch width (W=15.5mm) constant. Patch length was varied in steps of 1mm. All the cases are presented in Table 4. Return loss characteristics for all these values of patch length are depicted in Figure 3.4. From the Table 3.3 it may be noted that L=17.0mm case provides the highest bandwidth among all cases considered. Hence the optimized patch dimensions are L=17mm and W=15.5mm

Table 3.3: Design parameters for various curves presented in Figure 3.4 showing the effects of the length of patch antenna

Curve No	Width of patch (W) (mm)	Length of patch (L) (mm)	RL Freq. Range (GHz)	%Bandwidth
1	15.5	15	0.9-2.55	95.6
2	15.5	16	0.85-2.56	100.2
3	15.5	17	0.8-2.6	105.8
4	15.5	18	0.85-2.4	95.3
5	15.5	19	0.8-2.4	100.0

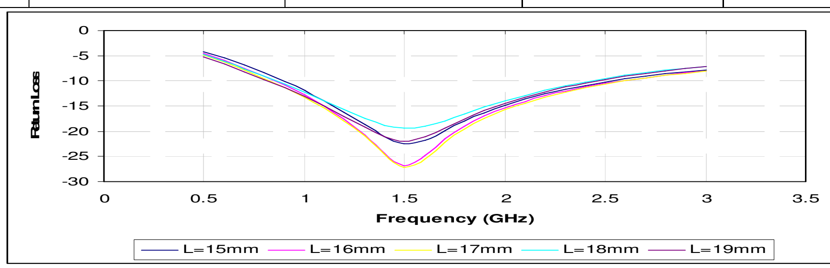


Figure 3.4 Return loss characteristics for different values of L (in mm)

3.3 EFFECT OF SLOT DIMENSIONS

In order to tune the resonant frequency and slightly enhance the impedance bandwidth a slot was introduced with dimensions length (s) and width (t) as shown in Figure 3.1 Slot length was varied in steps of 1mm and it was observed that center frequency may be tuned up to 10%. This is basically due the fact that a slot introduces the reactance to the patch element. The effect of slot length variation is shown in Figure 3.5 Also, an effort has been made to vary the slot width, however no significant changes were observed.

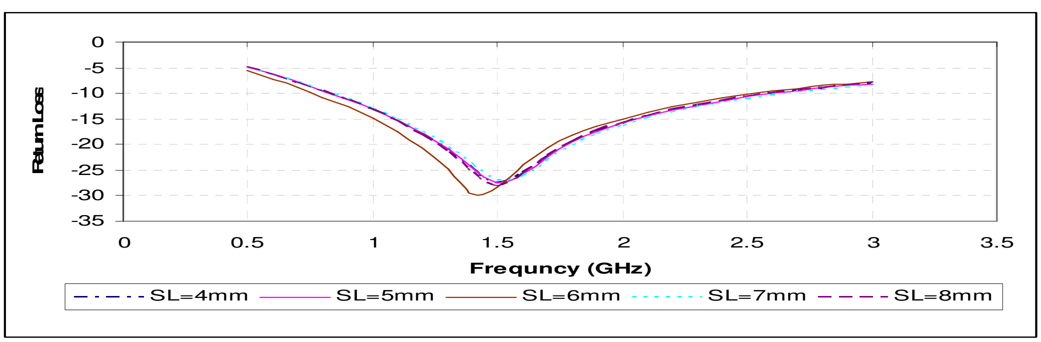


Figure 3.5 Effect of variation of slot length s.