

Analysis and Design of E-shape Meander Line Antenna for LTE Mobile Communications

Ahmed Hamdi Abo absa¹, Mohamed Ouda², Ammar Abu Hudrouss³

¹Tech. Department, University of Palestine, Palestine, a.absah@gmail.com.

²Electrical Engineering Department, Engineering College, Islamic University-Gaza, mouda@iugaza.edu.ps

³Electrical Engineering Department, Engineering College, Islamic University, Gaza, ahdrouss@iugaza.edu.ps

Abstract—the meander line antenna (MLA) is an electrically small antenna. Electrically small antennas pose several performance related issues such as narrow bandwidth, low gain and high cross polarization levels. In this paper, we analysis and design an E-shape MLA as anew shape to achieve wider bandwidth and smaller gain at 2.5 GHz compared to the classical MLA. Parametric study has been done for the effect of changing each variable in the antenna structure and study the effect of this change on the antenna performance. The best' performance of separate variables is combined at the end which give suboptimal design. Professional design software (HFSS) is used to design and optimize the antenna and MATLAB codes were written to determine the resonant frequency and the bandwidth for each study in this paper.

Index Terms— E-shape; bandwidth; gain; meander line; parametric.

I INTRODUCTION

The bandwidth of microstrip antenna may be increased using air substrate [1]; however, dielectric substrate must be used if compact antenna size is required [2]. There are a few approaches exists in the literature that can be applied to improve the microstrip antenna bandwidth. These include increasing the substrate thickness, introducing parasitic element either in coplanar or stack configuration, and modifying the shape of a common radiator patch by incorporating slots. The last approach is particularly attractive because it can provide excellent bandwidth improvement and maintain a single-layer radiating structure to preserve the

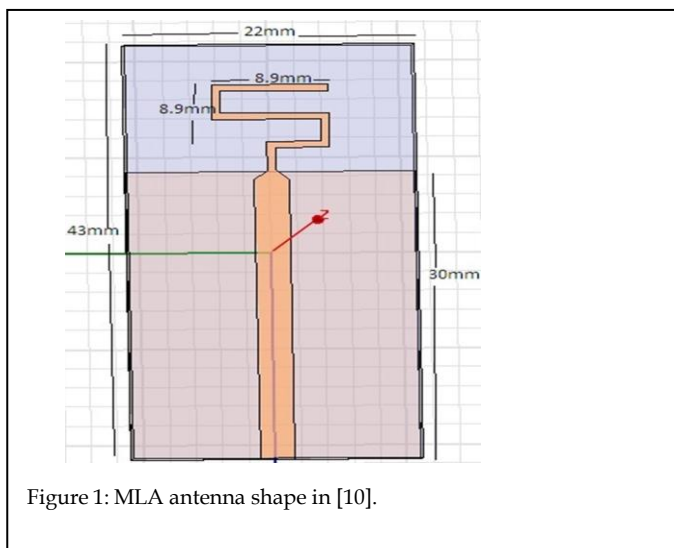


Figure 1: MLA antenna shape in [10].

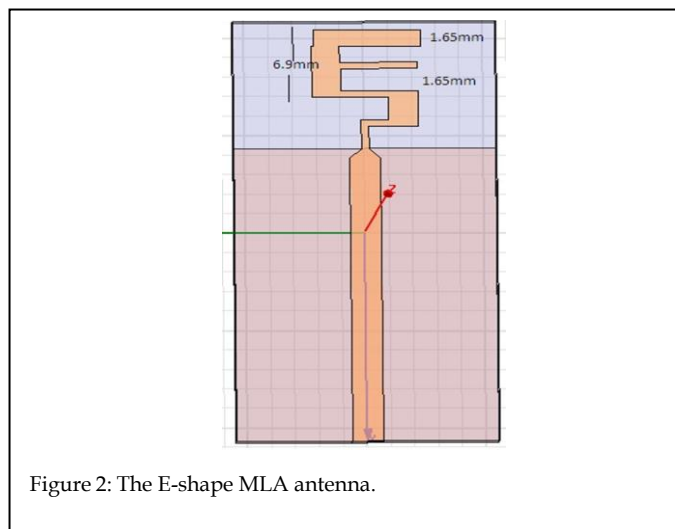


Figure 2: The E-shape MLA antenna.

antenna's thin profile characteristic. The successful examples include E-shaped patch antennas [3–7], U-slot patch antennas [8], and V-slot patch antennas [9].

The authors in [10] proposed a meander-line structure for PCMCIA cards operating at 2.4 GHz as shown in Fig 1. The maximum gain and return loss of the antenna at the resonant frequency are 2.76 dB and -17dB, respectively. The substrate material was used is FR4 with $\epsilon_r = 4.5$, $\tan \delta = 0.0150$, and dielectric height, $H = 1.5$ mm, as shown in Fig. 1.

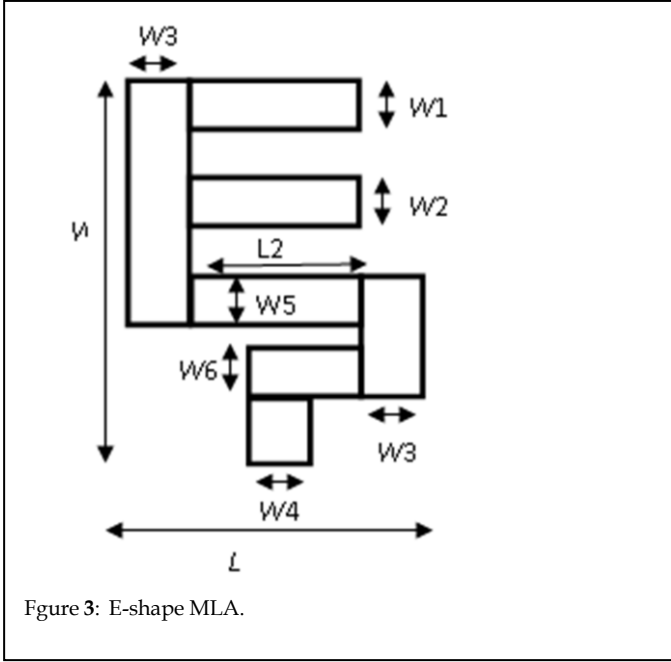


Figure 3: E-shape MLA.

In this paper, the modified E-shape MLA, Fig. 2, is designed at a resonant frequency 2.5 GHz. The analysis of the E-shape MLA is described in section II. A comprehensive parametric study has been carried out to understand the effects of various dimensional parameters as shown in section III. Finally the conclusion is written in Section IV.

II-E-SHAPE MLA ANALYSIS [13]

The width and length of the microstrip antenna are determined as the following [13]:

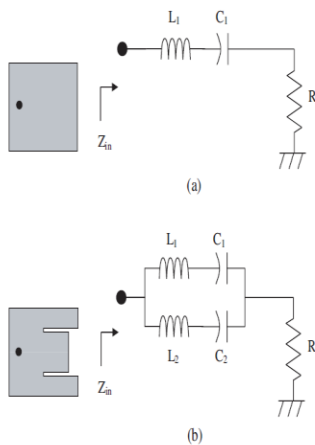


Figure 4: Equivalent circuits of (a) Rectangular patch and (b) E-shape antenna [14].

$$W = \frac{1}{2f_r \sqrt{\mu_0 \epsilon_0}} \sqrt{\frac{2}{\epsilon_r + 1}} = \frac{v_0}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}}, \quad (1)$$

where v_0 is the free space velocity of the light, ϵ_r is dielectric constant of substrate and f_r is resonant frequency. The effective dielectric constant is given as [13]

$$\epsilon_{r_{eff}} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{w} \right]^{-1/2} = \frac{v_0}{2f_r} \sqrt{\frac{2}{\epsilon_r + 1}}, \quad (2)$$

where the dimensions of the patch along its length have been extended on each end by a distance ΔL , which is a function of the effective dielectric constant $\epsilon_{r_{eff}}$ and the width-to-height ratio (W/h), and the normalized extension of the length, is

$$\Delta L = 0.412h \frac{(\epsilon_{r_{eff}} + 0.3) \left(\frac{w}{h} + 0.264 \right)}{(\epsilon_{r_{eff}} - 0.258) \left(\frac{w}{h} + 0.8 \right)}. \quad (3)$$

The actual length of the patch (L) can be determine as

$$L = \frac{1}{2f_r \sqrt{\epsilon_{r_{eff}} \mu_0 \epsilon_0}} - 2\Delta L. \quad (4)$$

E-shaped rectangular microstrip antenna consists of two symmetrical parallel slots incorporated as shown in Fig. 3.

The two slots are designed in this shape to disturb the surface current path and to introduce a local inductive effect that is responsible for the excitation of the first resonant mode. The slot length ($L2$), slot width ($W2$), and the center arm dimensions of the E-shape control the frequency of the second resonant mode and the achievable bandwidth [14]. The second resonant frequency is out of the our area of concern as it is located at 5.1 GHZ .

A common rectangular patch antenna can be represented by means of the equivalent circuit of Fig. 4(a) [14].

The resonant frequency is determined by $L_1 C_1$ [14]. At the resonant frequency, the antenna input impedance is given by resistance R . The equivalent circuit for the modified shape is modified into the form as shown in Fig. 4(b) [14].

The second resonant frequency is determined by $L_2 C_2$. The analysis of the circuit network shows that the antenna input impedance is given by [14]

$$Z_{in} = R + j \frac{(wL_1 - 1/wC_1)(wL_2 - 1/wC_2)}{w(L_1 + L_2) - (1/wC_1 + 1/wC_2)} \quad (5)$$

The imaginary part of the input impedance is zero at the two series resonant frequencies determined by $L_1 C_1$ and $L_2 C_2$, respectively [14]. This is not the exact model of the E-shaped antenna because the parallel-resonant mode that the equations show between the two series-resonant frequencies. Nevertheless, the model is considered to be sufficient to study the operating principle of the antenna design [14]. If the two series resonant frequencies are too far apart, this may leads to unsatisfactory reflection coefficient at the antenna input [14]. Meanwhile, if the resonant frequencies are set too near to each other, the parallel-resonant mode may affect the overall frequency response and this in turn may degrade the reflection coefficient near each of the series-resonant frequencies [14]. Therefore, each dimension of the E-shape antenna is important and should be carefully opti-

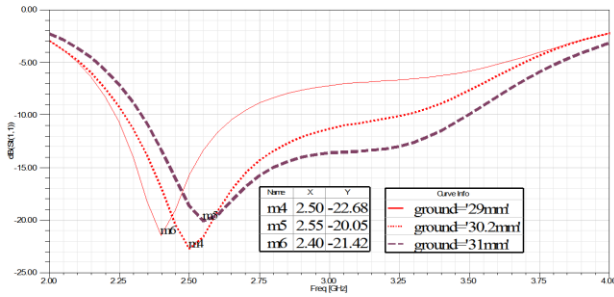


Figure 5: Return loss for the different height of the ground.

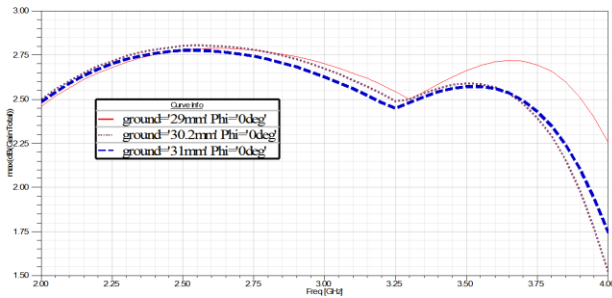


Figure 6: Max gain for each frequency input at phi = 0.

mized.

III PARAMETRIC STUDY

A substrate with a relative dielectric permittivity of 4.5 and thickness of 1.5 mm is selected to obtain a compact radiation structure that, at the same time, meets the required bandwidth specification. It is fed by a 50-Ω SMA connector. The technique of setting value of some parameters for the resonant frequency can be done step by step. The first consideration is to design the dimensions of antenna as shown in Fig.3. The parameters w_1 , w_2 , w_3 , w_4 , w_5 and w_6 are set as variables and to show how their effects on the bandwidth and the gain of the E-shape MLA.

A Step 1:

The length of the ground is changed from 29 mm to 32 mm with step 0.1 mm with all other parameters are fixed. The simulated result of the return loss S_{11} as a function frequency is shown in Fig. 5. Fig. 5 is shows the increase of the resonant frequency with the increase of the ground length. The bandwidth for each step is determined using MATLAB software. A bandwidth of 0.95 GHz was obtained at ground length of 30.2 mm, which shows a significant increase over the design given in [12] of is 0.6 GHz. The maximum gains are shown in Fig. 6, where the values are between 2.7 and 2.8 dB at the resonant frequency of 2.5 GHz.

B Step 2:

Choosing the optimum result of S_{11} from step 1 (length of the ground is 30.2 mm), and varying the width w_3 by step of 0.1 mm from 0.5 mm to 4.5 mm and fixing the other parameters. Similar to step 1, it has been found that when the width w_3 is increased, the resonant frequency is also increased. In this case, increasing width w_3 could affect the resonant frequency and bandwidth, where the best value for the bandwidth is obtained at $w_3 = 2.2$ mm .

C Step 3:

The optimum parameters from step 2 were chosen (length of the ground is 30.2 mm and $w_3=2.2$ mm), and the widths w_1 , w_5 and w_6 were varied by step 0.2 mm from 0.6 mm to 2.5 mm and fix all other parameters. It has been found that when the width w_1 , w_5 and w_6 are increasing, the resonant frequency increases. The best values for the bandwidth is 1.3 GHz and $S_{11} = 19.6$ dB. These values are achieved at $w_1= w_5= w_6= 1$ mm. The maximum gains for the best values are the same as in step 1.

Step 4:

The optimum parameters from step 3 were selected and the width, w_2 was varied by step up of 0.1 mm from 0.6 mm to 2.5 mm and all the other parameters were fixed. It is shown that, increasing of w_2 has no effect on the resonant frequency and the bandwidth. So in this step, we will select the best width $w_2 = 1$ mm that give a gain of 2.96 dB.

D Step 5:

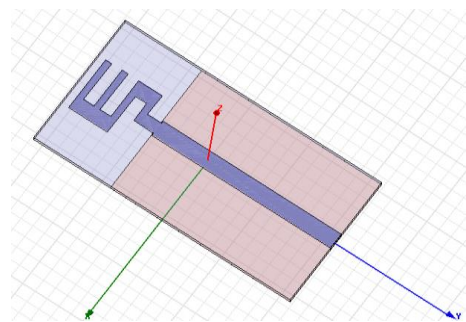


Figure 7: The final design for the E-shape MLA..

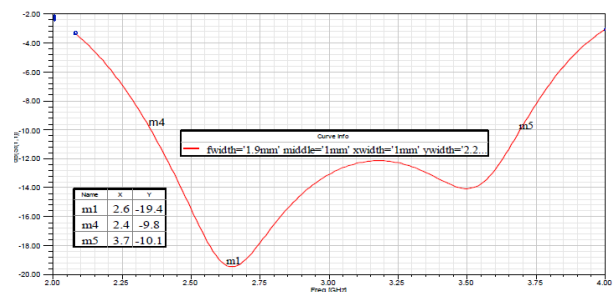


Figure 8: The return loss for the final design of the E-shape MLA.

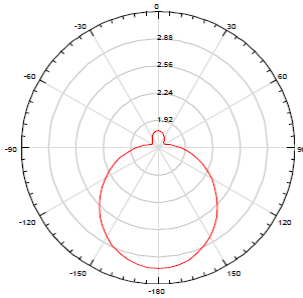


Figure 9: The radiation pattern for the final design for the E-shape

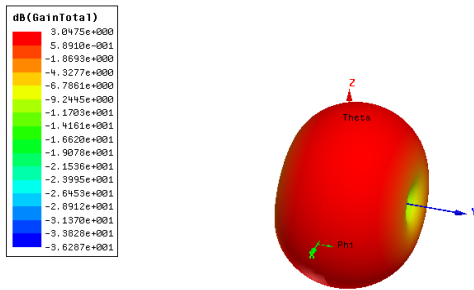


Figure 10: The gain for the final design for the E-shape MLA.

The optimum parameters were chosen from step 4 and the width w_4 was varied by step up of 0.1 mm from 0.6 mm to 2.5 mm and fix the other parameters.

It has been found that, when the width w_4 increasing, the resonant frequency shift to the right. In this case, increasing width w_4 could affect the resonant frequency and bandwidth. The best values for the bandwidth is 1.2 GHz and $S_{11} = 18.9$ dB. These values are achieved at $w_4 = 1.9$ mm. The maximum gain is 3.02 dB which occurs also at $w_4 = 1.9$ mm.

The final design of the E-shape MLA is shown in Fig. 7 where the return loss and the gain is shown in Fig. 8 and Fig. 9, respectively. The gain for the final design is depicted in Fig. 10.

V CONCLUSION

An electrically small E-shape MLA operating at the 2.5 GHz was designed and studied in this paper using HFSS software package. Parametric study was applied to achieve the optimum antenna design for the standard LTE mobile handset. The antenna provided a significant bandwidth enhancement and small gain enhancements. The E-shape MLA depicts an overall fair performance and it could be a promising candidate to overcome the deficiencies of the low profile small antennas.

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