

SLOT LOADED ELECTRICALLY SMALL RECTANGULAR PATCH ANTENNA FOR MIMO APPLICATIONS

Mahesh C. Bhad and Veeresh G. Kasabegoudar
P. G. Dept., MBES College of Engineering, Ambajogai, India

ABSTRACT

This article addresses the design and optimization of electrically small antenna suitable for MIMO (multiple input multiple output) applications. The proposed antenna was designed and optimized using HFSS software. Simulation results presented in this paper show that the optimized antenna operates in the 0.8GHz to 2.6GHz band with good radiation characteristics. The antenna has an operating frequency of 1.7GHz with impedance bandwidth of 105%, and the total size of 20x40 mm².

KEYWORDS: MIMO, Microstrip Antennas, Long Term Evolution (LTE), and Wideband Antennas

I. INTRODUCTION

The integration of more than one antenna (multiple input multiple output (MIMO) system) in each mobile terminal is a challenging task. Electrically small antennas are the right candidates for these applications. There are several works on electrically small antennas [1-12] and MIMO antennas [4-8] available in the literature. Meander line antennas are typical electrically small antennas which are being preferred in MIMO systems. For example in [4], a meander line antenna (MLA) that has a resonant frequency of 1 GHz was presented. The equations presented there will give a prohibitively large antenna if used for the 800 MHz band. While in [5] a spiral-like printed antenna that was electrically small was proposed to operate in the 700 MHz range with a size of 40x40 mm². The antenna had an extremely narrow bandwidth that will not be suitable for the application at hand that requires at least 40 MHz of bandwidth to cover the downlink and uplink in LTE channels. A multi-band printed bow-tie antenna was proposed in [6] to cover the 800 MHz and 1.9 GHz bands. The size of such an antenna will occupy the whole mobile terminal size since it covers a board area of 130x77 mm². While in [7] a dual band ESA was proposed that covered 800MHz and 2GHz bands with a size of 25x43 mm². The antenna suffers from narrow bandwidth in both bands. Thus, previous work shows that the proposed antennas will not be suitable for LTE mobile terminals due to their large size or narrow operating bandwidth.

In this paper we propose an electrically small antenna with center frequency around 1.7GHz, has very high bandwidth (105%) in comparison with bandwidth reported in [8] which has 59.9%. Although, the proposed antenna in this paper works on the similar principle of work reported in [8], has much simpler geometry, less number of optimization parameters and has better performance (nearly twice the impedance bandwidth reported in [8]). Section 2 presents the basic geometry [8]. Geometry of the proposed antenna is presented in section 3. Simulation results of the proposed antenna are presented in Section 4 followed by conclusions in Section 5.

II. 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 1 [8]. The dimensions of the antenna as reported in [8] are $L=43\text{mm}$, $W=23.5\text{mm}$, $L_g=16.2\text{mm}$, $W_1=15.5\text{mm}$, $W_2=16.5\text{mm}$, $W_3=W_4=W_5=1\text{mm}$, $L_1=12.27\text{mm}$, and $L_2=5.93\text{mm}$ and the antenna was simulated as suggested there. These characteristics are depicted in Figure 2 and radiation patterns in two planes are presented in Figure 3.

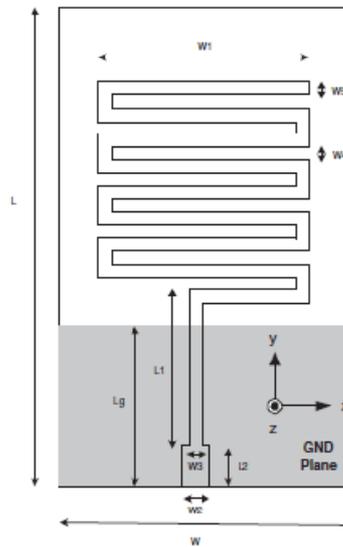


Figure 1: Basic geometry of MLA [8].

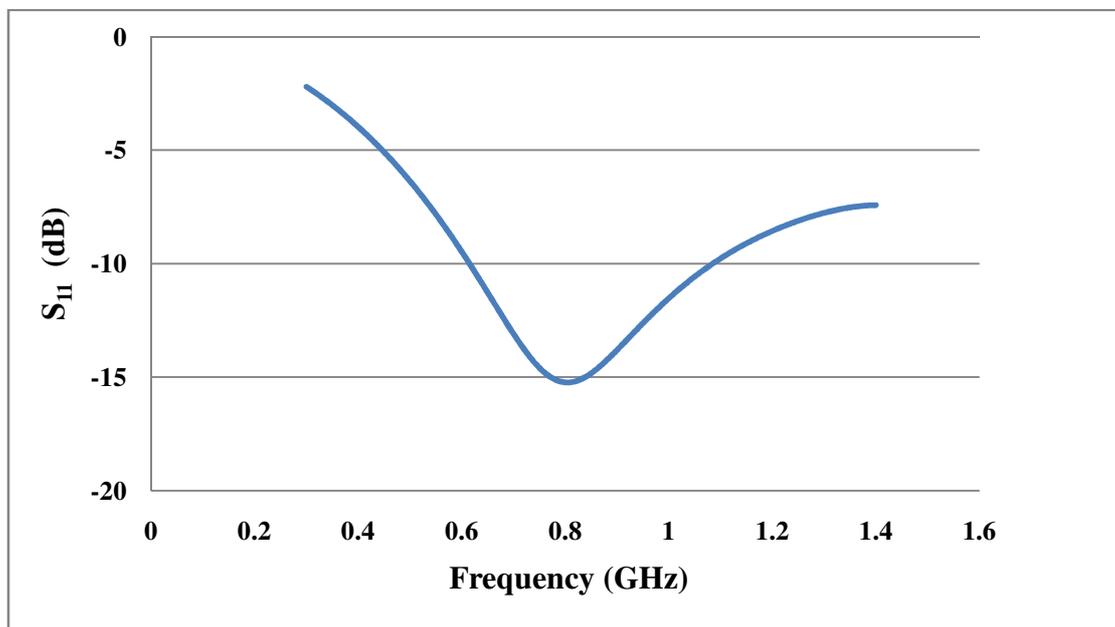


Figure 2: Simulated return loss of MLA shown in Figure 1.

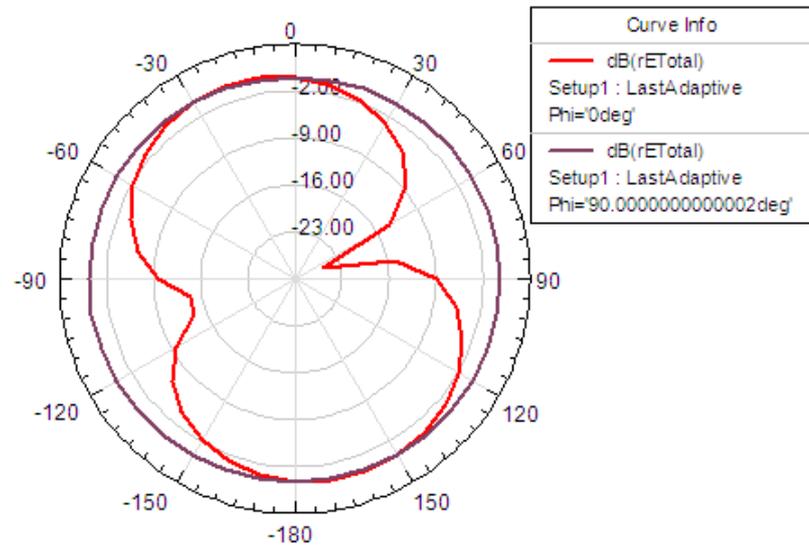


Figure 3: Radiation patterns of antenna shown in Figure 1.

III. MODIFIED GEOMETRY

Figures 4 (a) and (b) show the geometry of modified antenna and its simulation setup in HFSS. In modified antenna meandered structure is replaced by rectangular patch. Antenna dimensions were optimized using Ansoft HFSS. An optimized set of dimensions for the proposed antenna design are listed in Table 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 substrate used in simulations is FR4 with relative dielectric constant of 4.4 (loss tangent=0.01) and height 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.

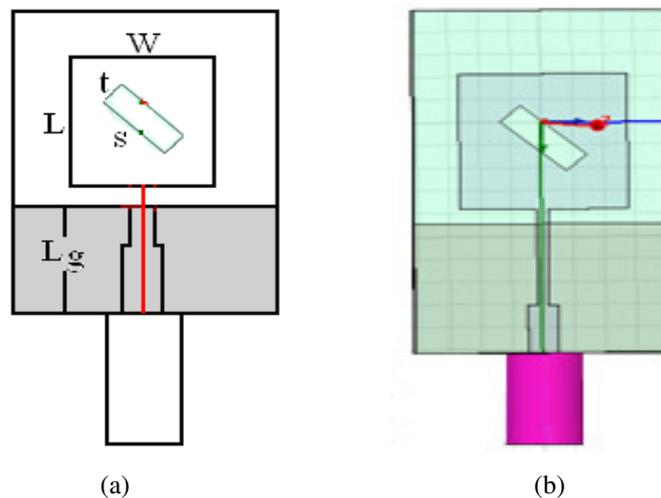


Figure 4: Geometry of the modified antenna (a) geometry (b) simulation setup

Table 1. Optimized dimensions of the modified antenna.

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

IV. SIMULATION RESULTS AND DISCUSSIONS

The geometry shown in Figure 4 was simulated using Ansoft HFSS software which is commercially available EM software. All key design parameters (patch width (W), patch length (L), and slot dimensions) have been investigated to analyze the effect on antenna performance and are discussed in the following subsections.

4.1 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 2. Return loss characteristics for all the cases studied are depicted in Figure 5. From the Table 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 2. Design parameters for various curves presented in Figure 5 showing the effects of the width of patch antenna.

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

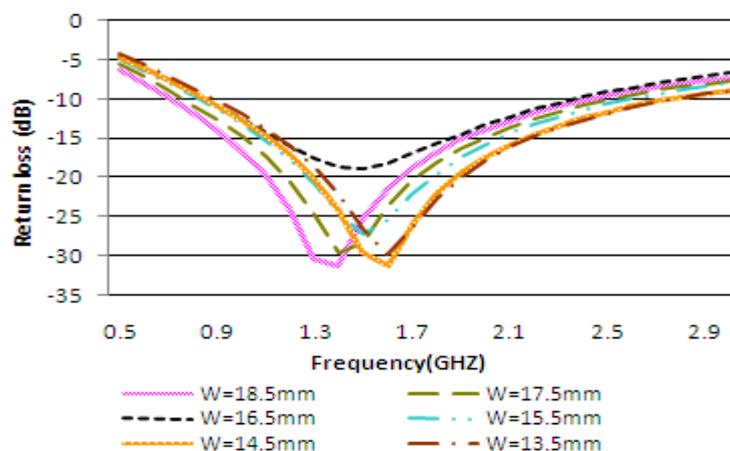


Figure 5: Return loss characteristics for different values of W.

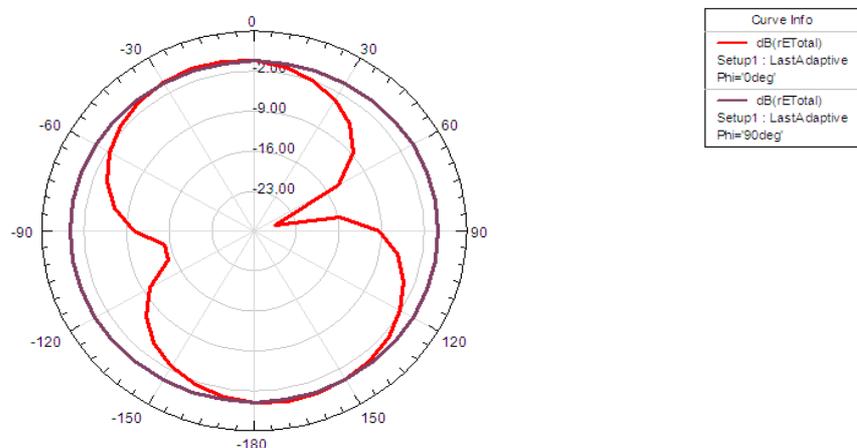


Figure 6: Radiation pattern of modified antenna.

4.2 Effect of Patch Length (L)

As explained in Section 3.1, here the patch length was varied by keeping patch width ($W=15.5\text{mm}$) constant. Patch length was varied in steps of 1mm. All the cases are presented in Table 3. Return loss characteristics for all these values of patch length are depicted in Figure 7. From the Table 3 it may be noted that $L=17.0\text{mm}$ case provides the highest bandwidth among all cases considered. Hence the optimized patch dimensions are $L=17\text{mm}$ and $W=15.5\text{mm}$.

Table 3. Design parameters for various curves presented in Figure 6 showing the effects of the length of patch antenna.

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

4.3 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 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 8. Also, an effort has been made to vary the slot width, however no significant changes were observed.

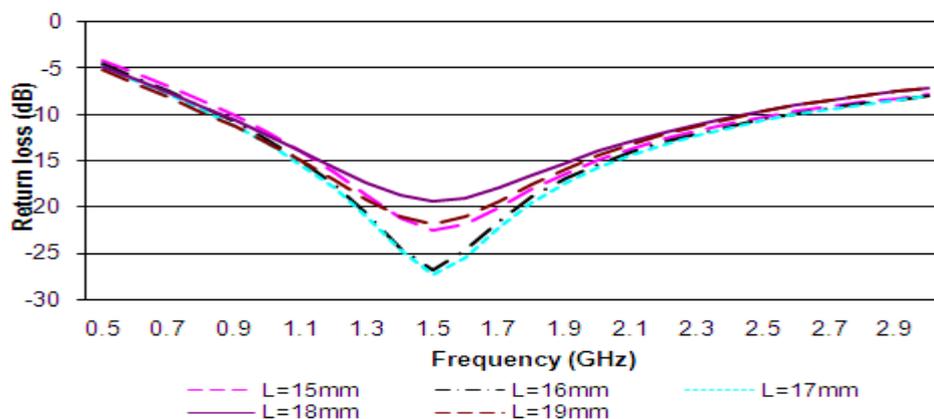


Figure 7: Return loss characteristics for different values of L (in mm).

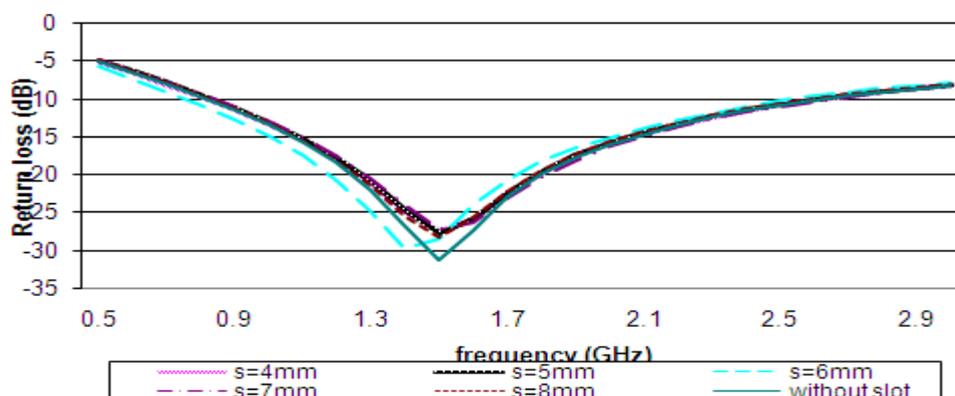


Figure 8: Effect of variation of slot length s.

V. CONCLUSIONS

A rectangular monopole patch antenna with a slot embedded in it has been proposed here after designing the basic geometry reported in literature [8] which is having narrow bandwidth. The impedance bandwidth of the proposed design is above 100% in all the cases studied with good radiation characteristics. Also, the proposed design requires a very less number of parameters to optimize the geometry in comparison with the meander line antennas. The proposed antenna needs to be fabricated and tested for its practical validation and should be modelled to investigate its performance in terms impedance bandwidth, gain, and radiation efficiency. The antenna presented here proves to be electrically small and is the best candidate for MIMO applications.

REFERENCES

- [1] Y. M. Chen, C. C. Huang, and W.S. Chen, "An electrically small impedance-matched microstrip antenna design," *Antenna and Propagat. Int. Sump.*, vol. 4, pp. 38-41, 2002.
- [2] G. Breed, "Basic principles of electrically small antennas," *J. of High Freq. Electronics*, pp. 50-53, 2007.
- [3] A. Jamil, M. Z. Yousuf, and N. Yahya, "An electrically small meander line antenna for wireless applications," *IEEE Asia Pacific Con. on Circuits and Sys.*, pp. 72-75, 2010.
- [4] K. K. Chandana, et. al., "Miniaturized circular antennas for MIMO communication systems – Pattern diversity," *Int. ITG Workshop on Smart Antennas*, pp. 331-334, 2010.
- [5] A. Singh, et. al., "Empirical Relation for Designing the Meander Line Antenna," *IEEE International conference on recent advances in Microwave Theory and Applications*, pp. 695-697, Jaipur, India, 2008.
- [6] G. Wang, et. al., "Coaxial-Fed Double-Sided Bow-Tie Antenna for GSM/CDMA and 3G/WLAN Communications," *IEEE Transactions on Antennas and Propagation*, vol. 56, no. 8, pp. 2739-2742, 2008.
- [7] H. K. Kan and R. B. Waterhouse, "Shorted spiral-like printed antennas," *IEEE Transactions on Antennas and Propagation*, vol. 50, no. 3, pp. 396- 397, 2002.
- [8] S.S. Mohammad et. al., "Design and fabrication of a dual electrically small MIMO antenna system for 4G terminals," *Proceedings of the 6th German Conf.*, pp. 14–16, 2011.
- [9] K. V. Caekenbergh, N. Behdad, K. M. Brakora, and K. Sarabandi, "A 2.45-GHz electrically small slot antenna," *IEEE Antenna and Wireless Propagation Letters*, vol. 7, pp. 346-348, 2008
- [10] J. J. Adams and J. T. Bernhard, "A model approach to tuning and bandwidth enhancement of an electrically small antenna," *IEEE Transactions on Antennas and Propagation*, vol. 59, no. 4, pp. 1085-1092, 2011.
- [11] C. Pfeiffer and A. Grbic, "A circuit model for electrically small antennas," *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 4, pp. 1671-1683, 2012.
- [12] C. R. Byrareddy, N. C. Easwar Reddy, and C. S. Sridhar, "A compact dual band planar RMSA for WLAN/WI-MAX applications," *Int. J. of Advances in Engg. & Tech. (IJAET)*, vol. 2, issue 1, pp. 98-104, 2012.

Authors

Mahesh C. Bhad Received the bachelor's degree from Dr. B. A. M. University, Aurangabad, in 2009, and currently pursuing his Master's degree from the Collage of Engineering Ambajogai. Since Sept. 2010 he has been working as the in charge Principal of V. J. Shinde Polytechnic Osmanabad, India. His research interests include Signal Processing, Microwaves and Antennas.



Veeresh G. Kasabegoudar received the Bachelor's degree from Karnataka University Dharwad, India, the Masters degree from the Indian Institute of Technology (IIT) Bombay, India, and the Ph.D. degree from the Indian Institute of Science (IISc), Bangalore, in 1996, 2002, and 2009, respectively. From 1996 to 2000, he worked as a Lecturer in the Electronics and Telecommunication Engineering Department, College of Engineering, Ambajogai, India, where, from 2002 to 2006, he worked as an Assistant Professor and, since 2009, he has been a Professor and Dean of PG Department. He has published over 20 papers in technical journals and conferences. His research interests include microstrip and CPW fed antennas, microwave filters, and Image/Signal processing.

