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A Miniaturized 878 MHz Slotted Meander Line Monopole Antenna for Ultra High Frequency Applications

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Abstract—A slotted meander line printed monopole antenna for low frequency applications of 878 MHz is presented. The novelty of the design is obtained by evaluating numerous slots and meander line that produces a new structure of double E-shaped meander line antenna backed by a defected partial ground plane. The operating frequency of the conventional printed monopole antenna is greatly reduced by the presence of the slots and meander line which lead to the reduction of the antenna size. The size reduction of 70% compared to the conventional reference antenna is achieved in this study. The antenna has a simple structure and small antenna size of 46.8 mm × 74 mm or $0.137\lambda_0 \times 0.217\lambda_0$. The antenna has been fabricated on a low-cost FR4 substrate and measured to validate the simulation performances. Measured results display that the proposed antenna produces omnidirectional radiation pattern of impedance bandwidth of 48.83 MHz and the maximum gain of −1.18 dBi.

1. INTRODUCTION

Ultra High Frequency (UHF) bands are extensively used in countless applications including LTE700/GSM850/900 band [1], wireless M-Bus [2], and wireless body area network [3]. The wavelength of the UHF frequency is much larger than the antenna available space leading to complexity of small antenna design [4]. Antenna miniaturization is required particularly for low frequency band systems where the size of the antenna is very large at this operating band. Beforehand, wire antennas were used for low frequency band applications including UHF band. Nevertheless, there were a number of matters need to be taken care of such as difficulties in integration with microwave integrated circuit board, and complexity in manufacturing. Planar antennas are one of the solutions to overcome these issues however with a limitation in terms of bulky size.

In this study, a miniaturized printed monopole antenna based on slotted meander line patch at 878 MHz is proposed for UHF band. A small square defected ground structure is introduced to improve the impedance matching of the antenna. The evolution of the miniaturization techniques using slots and meander line is demonstrated in Section 2. Section 3 displays simulated and measured results of the proposed antenna. The proposed design has a small antenna size of $46.8 \times 74\,\text{mm}^2$ or about $0.137\lambda_0 \times 0.217\lambda_0$.

2. ANTENNA DESIGN AND APPROACH

The miniaturization of a printed monopole antenna based on slotted patch and meander line is presented in this section. The antenna structures as revealed in Fig. 1 were designed and fabricated on an FR-4 substrate with dielectric constant $\varepsilon_r = 4.3$, substrate height $h = 1.6$ mm and loss tangent of 0.025. The antenna is fed by a 50 Ω microstrip line which partially backed by a defected ground plane. The small

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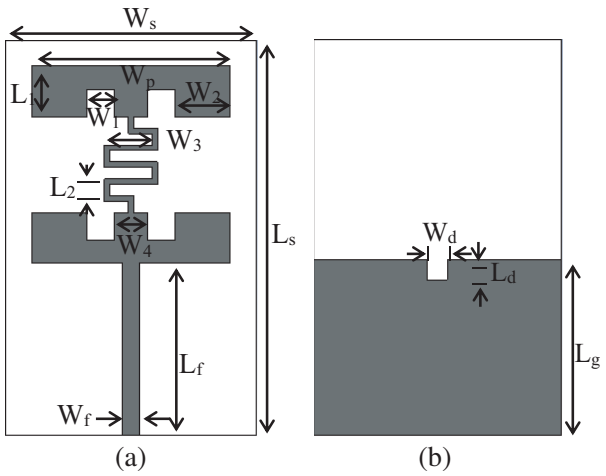

Figure 1. Configuration of the proposed antenna. (a) Front view. (b) Back view.

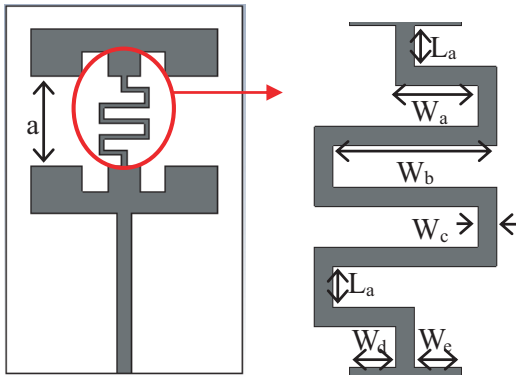

Figure 2. Configuration of the radiator (meander line is enlarged for visibility).

rectangular slot with width and length of 3.7 mm is realized on the back side of the antenna to improve the impedance matching of the design. The proposed antenna has smaller and compact size of only 46.8 mm × 74 mm ($0.137\lambda_0 \times 0.217\lambda_0$) where λ_0 is a free-space wavelength at 878 MHz. All antenna configurations use the same substrate and feed dimensions. They have been simulated using Computer Simulation Technology (CST) Microwave Studio (MWS) software.

Slots and meander line are introduced to increase an effective length of the current path with the aim to miniaturize the antenna. The increment of current path increasing the effective capacitance and inductance of the design leading to a decrement in the resonant frequency of the antenna as derived from the Equation (1).

$$f_r = \frac{1}{2\pi\sqrt{LC}} \tag{1}$$

The dimensions of the patch, slots, meander line and the ground plane as presented in Fig. 1 are organized in Table 1.

Table 1. Proposed antenna parameters.

Parameters	W_p	W_s	L_s	W_f	L_f	W_1	W_2
Unit (mm)	37.2	46.8	74	3	32	5.2	10.3
Parameters	W_3	W_4	L_1	L_2	L_g	W_d	L_d
Unit (mm)	10.6	6.2	9.55	4.18	32.63	3.7	3.7

Figure 2 illustrates the front view of the proposed antenna with enlarged radiating element. The widths and lengths of the radiator as shown in Fig. 1 and Fig. 2 are calculated based on the equation below

$$a = \frac{L_p}{2} - 0.5 \tag{2}$$

$$W_1 = 0.139L_p \tag{3}$$

$$L_a = \frac{a-5}{6} \tag{4}$$

$$W_a = \frac{a}{4.72} + 1 \tag{5}$$

$$W_b = \frac{a}{2.28} + 1 \tag{6}$$

$$W_d = W_e = 0.069L_p \tag{7}$$

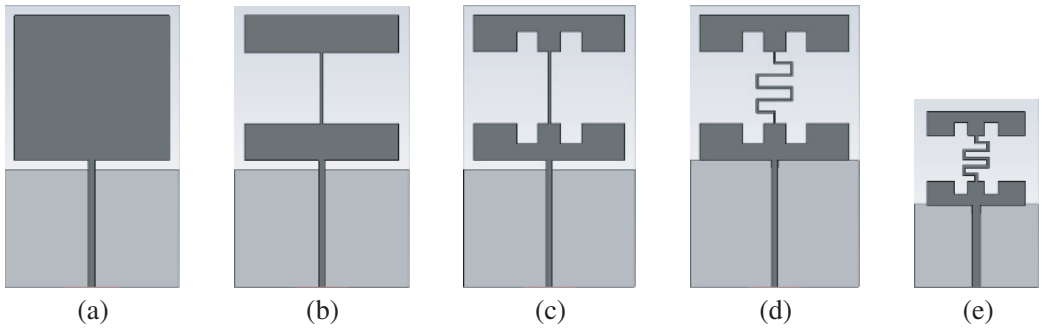

Figure 3. Evolution of the proposed antenna. (a) Ant. 1. (b) Ant. 2. (c) Ant. 3. (d) Ant. 4. (e) Ant. 5.

The proposed antenna shown in Fig. 3 has undergone a few evolutions before it was miniaturized. Ant. 1 represents a conventional printed monopole antenna covering wideband frequency including 878 MHz. Slots on the right and left side of the radiating patch are introduced as represented by Ant. 2 to increase the length of the current path hence decrease the resonating frequency. Another slot is introduced at the upper and bottom side of the patch as demonstrated by Ant. 3. To further reduce the resonating frequency a thin line at the center of the radiator is replaced by the meander line (Ant. 4). A square slot or defected ground structure is introduced to the back side of Ant. 4 to improve the impedance matching of the antenna. Ant. 1, Ant. 2, Ant. 3, and Ant. 4 have the same antenna size of 83.79 mm × 143.74 mm but with different resonant frequency. Due to the reduction in resonant frequency after the evolutions, the size of the antenna can be reduced to bring back the resonant frequency of the desired frequency. The antenna size is then reduced to 70% so that the ant (Ant. 5) works at 878 MHz. The size of the proposed antenna after has been reduced is 46.8 mm × 74 mm or $0.137\lambda_0 \times 0.217\lambda_0$.

3. RESULTS AND DISCUSSION

The simulated reflection coefficients of all antenna structures in Fig. 3 are explained in Fig. 4. Ant. 1 (reference antenna) and Ant. 5 (proposed antenna) resonate at the same frequency but with different physical size and structure. From the graph, it can be seen that the proposed antenna produce better reflection coefficient with better impedance matching. Although the bandwidth of the proposed antenna is narrow, it is does not affect the applications since it can be used for narrowband UHF applications.

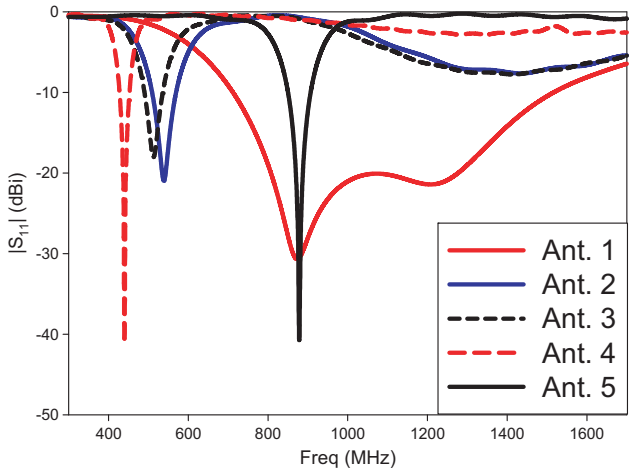

Figure 4. Simulated reflection coefficient for various antenna configurations.

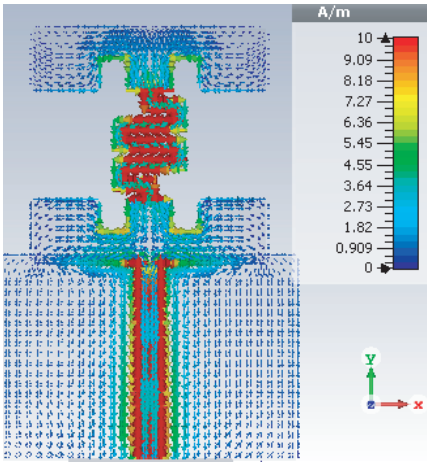

Figure 5. Simulated surface current distribution of the proposed antenna.

Ant. 2 produce lower resonant frequency compared to Ant. 1. Ant. 3 also operates at resonant frequency lower than Ant. 2 and Ant. 1 due to the slots. The presence of the meander line greatly reduces the resonant frequency of Ant. 4 from 510 MHz to 440 MHz. The size of Ant. 4 is then reduced so that it can operate at desired frequency of 878 MHz.

Figure 5 shows simulated surface current distribution of the proposed antenna. From the figure, the maximum current is dominantly concentrated on the meander line of the center of the radiator and on the feed line. The maximum current also noticed at the edge of the slots that explains the reason how slots and meander line increase the electrical length of the current path.

As mentioned earlier, the input impedance of the antenna is improved by the presence of defected ground structure. The input impedance can be seen in Fig. 6 with $Z_{in} = 50.67 + j0.35\,\Omega$ at 878 MHz. The antenna structures have been fabricated and measured to validate the simulated results. The fabrication is done using LPKF milling machine while the measurement is completed in the Anechoic Chamber using Vector Network Analyzer. The photographs of the fabricated antennas are shown in Fig. 7.

The measured results are compared with the simulated ones in the same graph. In Fig. 8, the simulated reflection coefficient is denoted by dash black lines while the measured reflection coefficient is denoted by solid red line. The simulated and measured resonant frequency are 878 MHz and 874 MHz,

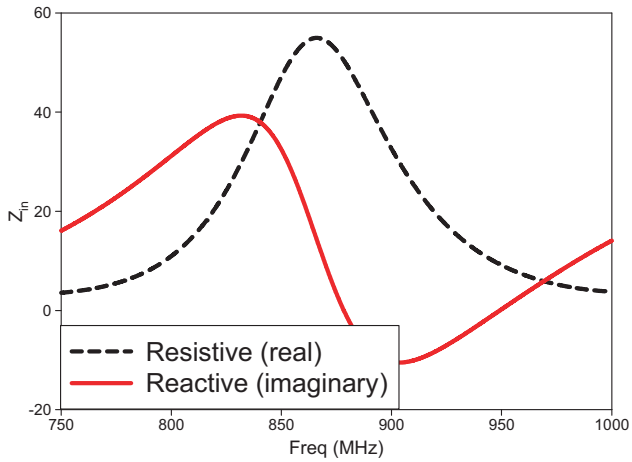

Figure 6. Simulated input impedance of the proposed antenna.

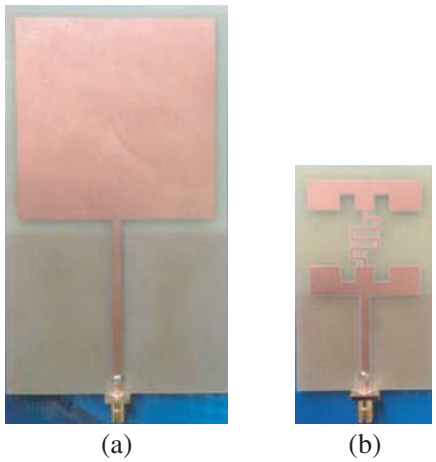

Figure 7. Photographs of the fabricated antennas. (a) Ant. 1. (b) Ant. 5.

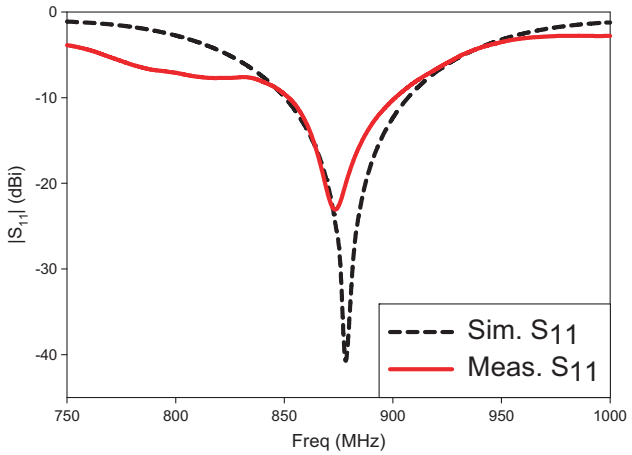

Figure 8. Simulated and measured reflection coefficient of the proposed antenna.

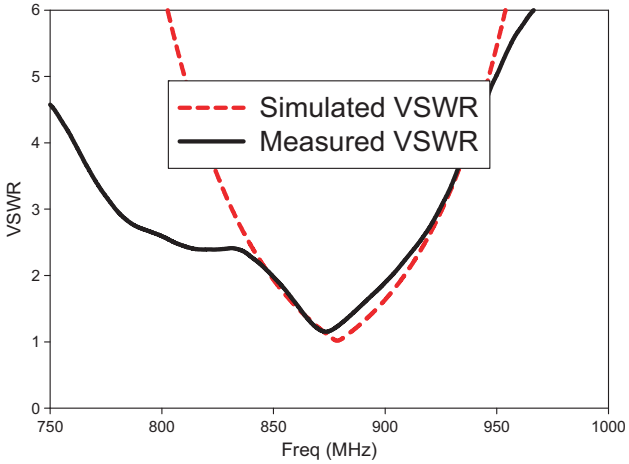

Figure 9. Simulated and measured VSWR of the proposed antenna.

respectively.

Figure 9 demonstrates the simulated and measured Voltage standing Wave Ratio (VSWR) of the proposed antenna. The results are agreed well with each other with VSWR less than 1.5.

The radiation characteristics of the antenna are displayed in Fig. 10. A good agreement is observed between the simulated and measured results. Figs. 10(a) and (b) display the radiation polar plot of the miniaturized antenna in E-plane and H-plane, respectively. The performances of the simulated and measured proposed miniaturized antenna are compared in Table 2. Discrepancies between simulated and measured performances occur due to the manufacturing and fabrication tolerances. Meanwhile, the discrepancies in antenna gain might be due to the electrically small antenna and ground plane effects. However, the measured antenna gain is still acceptable to the target application.

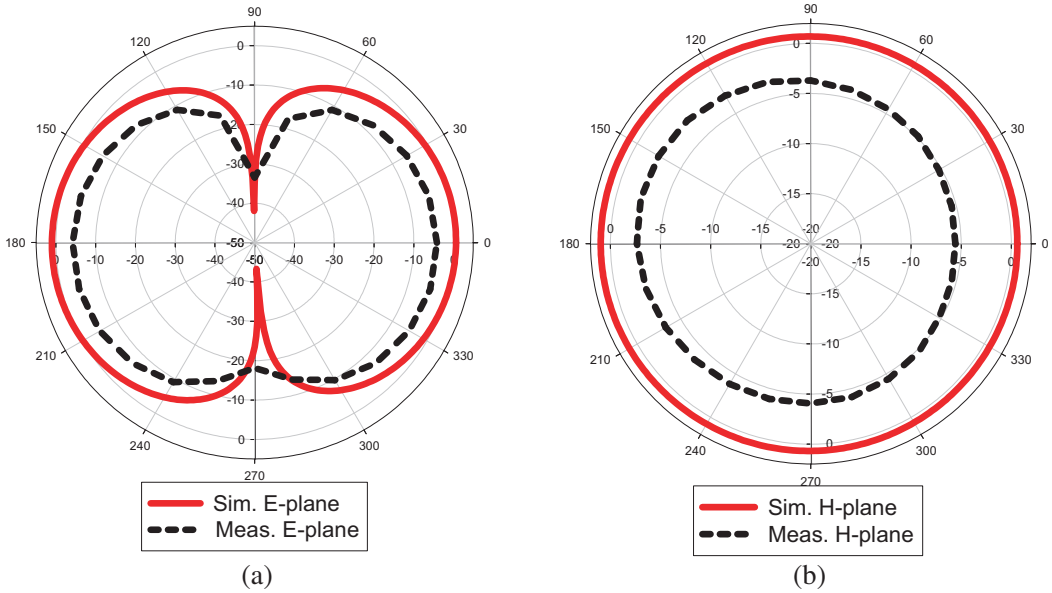

Figure 10. Polar plot of the proposed antenna. (a) E-plane (phi = 90°). (b) H-plane (phi = 0°).

Table 2. Performance of the simulated and measured proposed antenna.

Performances/ Parameters	Frequency (MHz)	S_{11} (dB)	Efficiency (%)	Gain (dBi)	VSWR	Bandwidth (%)
Sim. Proposed Antenna	878	−40.47	76.21	0.95	1.02	6.50
Meas. Proposed Antenna	874	−22.96	41.02	−1.18	1.16	5.50

Table 3 concludes the performances of the proposed antenna with other reported miniaturized antennas. It is discovered that the impedance bandwidth and gain of the proposed antenna are higher compared to [4–8]. The proposed work consists of a simple structure of smaller size approaching electrically small antenna and easier to fabricate. The size of the antenna can be further decreased but with degradation in antenna gain and efficiency. In order to not degrading the antenna gain and efficiency below than the acceptable range, the size of the antenna cannot be further decreased. As a matter of fact, wide bandwidth is not essential for most UHF applications such as Forward Scatter Radar Network. Therefore there is no necessity to have a wide band antenna where the size is more important.

Table 3. Performance comparison of the proposed antenna with reference antennas.

Ref.	[4]	[5]	[6]	[7]	[8]	Proposed work
Size	$0.029\lambda_0$ $\times 0.053\lambda_0$	$0.033\lambda_0$ $\times 0.071\lambda_0$	$0.074\lambda_0$ $\times 0.041\lambda_0$	$0.139\lambda_0$ $\times 0.139\lambda_0$	$0.074\lambda_0$ $\times 0.118\lambda_0$	$0.137\lambda_0$ $\times 0.217\lambda_0$
f_r (GHz)	0.433	0.433	0.433	1.90	0.433	0.874
Gain (dBi)	−6.10	−2.80	−13	−1.22	−4.30	−1.18
Bandwidth (%)	2.30	2.90	1.00	1.58	1.30	5.59

4. CONCLUSIONS

A miniaturized printed monopole antenna based on slots and meander line concept is presented for UHF band applications at resonant frequency of 878 MHz. The size reduction of 70% has been achieved using the aforementioned techniques. The proposed antenna offers omnidirectional radiation pattern of −1.18 dBi measured gain and 41% efficiency. It is observed that the proposed antenna produces higher antenna gain and impedance bandwidth than the reported antennas in literature.

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