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A Miniaturized 878 MHz Slotted Meander Line Monopole Antenna

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Abstract

A slotted meander line printed monopole antenna for low frequency applications at 878 MHz is presented. The operating frequency of the conventional printed monopole antenna was greatly reduced by the presence of the slots and meander line which lead to the reduction of the antenna size. The size reduction up to 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 x 74 mm or $0.137\lambda_0$ x $0.217\lambda_0$. The antenna has been fabricated on the 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.

Keywords: *Printed monopole antenna, size miniaturization, meander line, slot, UHF band*

1. Introduction

Ultra High Frequency (UHF) band is extensively used in countless applications including LTE700/GSM850/900 band [1], LTE Mobile Phones [2], wireless M-Bus [3], emerging smart metering and M2M [4], wireless medical vital signs monitors (VSM) [5], RFID [6], microwave stethoscope [7], and wireless body area network [8]. The wavelength of the UHF frequency is much larger than the antenna available space leading to complexity of small antenna design [9]. 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. However, wire antennas have difficulties interms of integration with microwave integrated circuit board, and complexity in manufacturing. Planar antennas are one of the solution to overcome these issues however with a limitation in terms of bulky size.

Wang et. al proposed cascaded two resonant structures with meander lines and shorting technique to miniaturize planar antenna for ISM 433 MHz applications [10]. The proposed technique introduces two neighbouring resonant frequencies while by changing the location of the ground, the resonant frequency can be moved. In [11], a size reduction by means of a rectangular inverted-F antenna with a square-spiral section is presented. A small capacitive stub is used to tune the antenna's resonant frequency.

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 II. Section III displays simulated and measured results of the proposed antenna. The proposed design has a small antenna size of 46.8 x 74 mm^2 or about $0.137\lambda_0$ x $0.217\lambda_0$.

2. Antenna Design and Approach

Explaining research chronological, including research design, research procedure (in the form of algorithms, Pseudocode or other), how to test and data acquisition [1, 3]. The description of the course of research should be supported references, so the explanation can be accepted scientifically [2], [4].

Tables and Figures are presented center, as shown below and cited in the manuscript.

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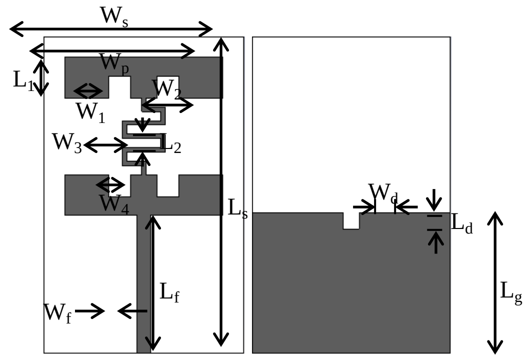
The miniaturization of a printed monopole antenna based on slotted patch and meander line is presented in this section. The antenna structures as revealed in Figure 1 was designed and fabricated on a FR-4 substrate with dielectric constant ε_r = 4.3, substrate height *h* = 1.6 mm and loss tangent of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



(a) b)

Figure 1. Configuration of the proposed miniature antenna, (a) Top view, (b) Bottom view

The proposed antenna (Ant. 5) has smaller and compact size of only 46.8 mm x 74 mm ($0.137\lambda_0$ x $0.217\lambda_0$) where λ_0 is a free-space wavelength at 878 MHz. All antenna configurations use the same substrate type. Ant. 1, Ant. 2, Ant. 3 and Ant. 4 have the same substrate and patch dimensions while Ant. 5 has smaller substrate and patch dimension compared to others. 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). The equation explains the relationship between the inductance and capacitance of the antenna with the resonant frequency. In order to reduce the antenna's resonant frequency, the effective capacitance and inductance of the antenna need to be increased. Hence, the antenna miniaturization can be achieved.

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

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

Table 1. Proposed Antenna Parameters

Parameters	Unit (mm)	Parameters	Unit (mm)
Wp	37.2	W_3	10.6
Ws	46.8	W_4	6.2
Ls	74	L_1	9.55
Wf	3	L_2	4.18
Lf	32	L_g	32.63
W_1	5.2	W_d	3.7
W_2	10.3	L_d	3.7

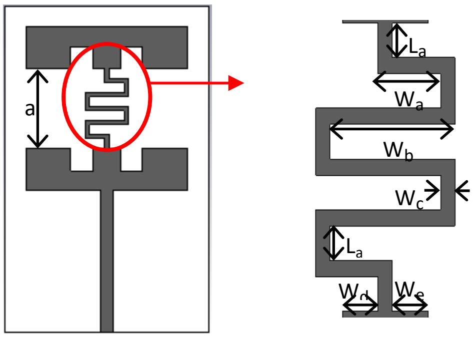


Figure 2. Configuration of the radiator (meander line is enlarged for visibility)

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

$$a = \frac{L_p}{2} - 0.5 \quad (2)$$

$$W_1 = 0.139 L_p \quad (3)$$

$$L_a = \frac{a-5}{6} \quad (4)$$

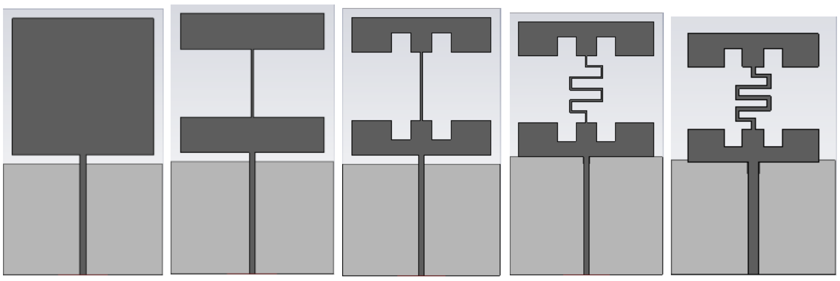
$$W_a = \frac{a}{4.72} + 1 \quad (5)$$

$$W_b = \frac{a}{2.28} + 1 \quad (6)$$

$$W_d = W_e = 0.069 L_p \quad (7)$$

Equation (2) to (7) are based on the radiator's dimension related to the operational wavelength. These equations are derived to help antenna designers to reduce simulation time for designing miniature antenna based on the proposed method.

The proposed antenna shown in Figure 3 has undergo 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 slots are 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 (An.t 4). Square slot or defeced ground structure is introduced at the back side of Ant. 4 to improve the impedance matching of the antenna. Ant. 1, An.t 2, Ant. 3, and Ant. 4 has the same antenna size of 83.79 mm x 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 to 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 x 74 mm or $0.137\lambda_0$ x $0.217\lambda_0$.



Ant. 1 Ant. 2 Ant. 3 Ant. 4 Ant. 5

Figure 3. Evolution of the proposed antenna

3. Results and Analysis

The simulated reflection coefficients of all antenna structures in Figure 3 are explained in Figure 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 Forward Scatter Radar Network. 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 operates 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.

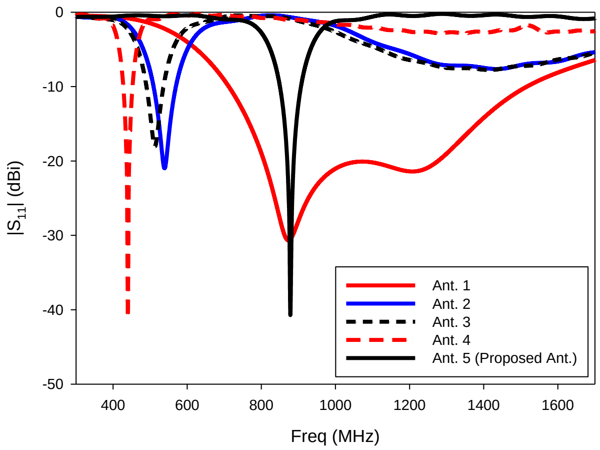


Figure 4. Simulated S11 for various antenna configurations

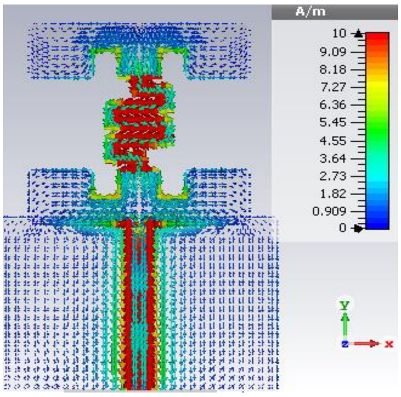


Figure 5. Simulated surface current distribution of the proposed antenna

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 Figure 6 with Z_{in}=50.67+j0.35 Ω 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 photograph of the fabricated antennas are shown in Figure 7.

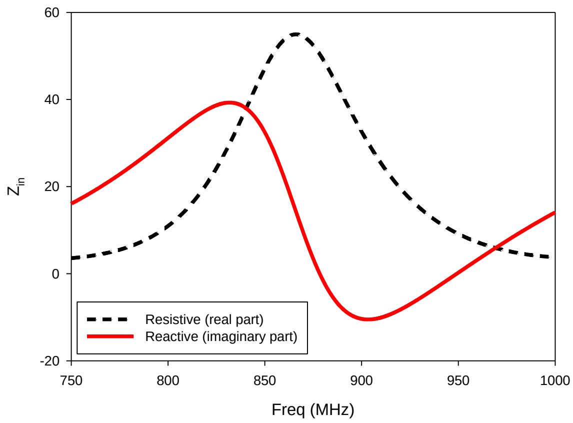
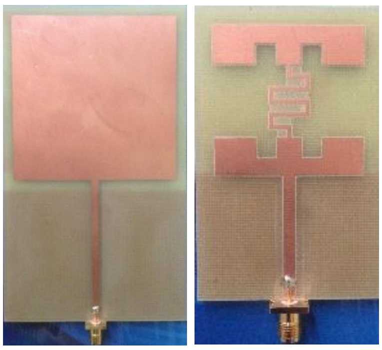


Figure 6. Simulated input impedance of the proposed antenna



(a) (b)

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

The measured results are compared with the simulated results in the same graph. In Figure 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, respectively.

The radiation characteristics of the antenna are displayed in Figure 9. A good agreement is observed between the simulated and measured results. Figure 9 (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.

Table 2. Performances of the Simulated and Measured Proposed Antenna

Parameters / Performances	Simulated Proposed Antenna	Measured Proposed Antenna
Resonant Freq (MHz)	878	874
Reflection Coefficient (dB)	-40.47	-22.96
VSWR	1.02	1.16
Gain (dBi)	0.95	-1.18
Efficiency (%)	76.21	41.02
Impedance Bandwidth (%)	6.50	5.50

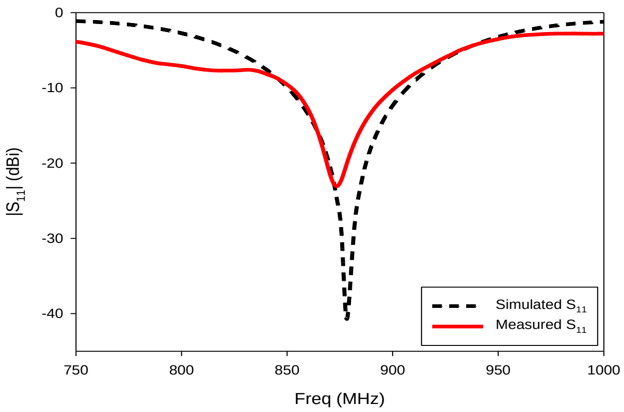


Figure 8. Simulated and measured reflection coefficient of the proposed antenna

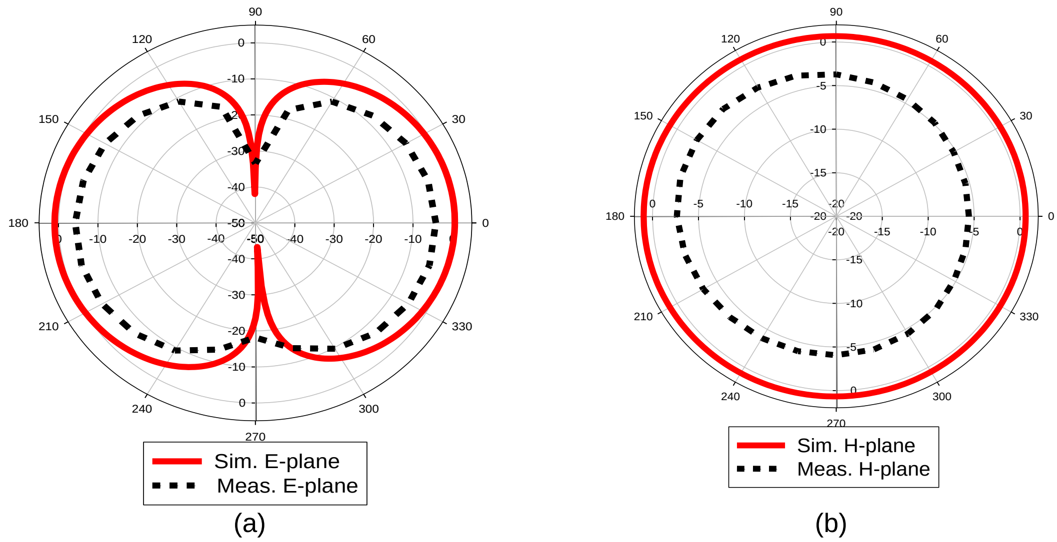


Figure 9. Polar plot of the proposed antenna (a) E-plane (b) H-plane

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 [9-12], [15, 16]. The proposed work consists of a simple structure of smaller size and easier to fabricate. The maximum gain of -1.18 dBi of the proposed antenna seem very small for the high gain applications. As a matter of fact, the antenna gain of -1.18dBi is sufficient for omnidirectional applications since it transmits and receives in all directions whereby higher antenna gain is unnecessary. This is also happens due to the smaller antenna size.

Table 3. Performances Comparison of the Proposed Antenna with Reference Antennas

Ref.	Size	Resonant Frequency (GHz)	Gain (dBi)	Bandwidth (%)
[9]	$0.029\lambda_0$ x $0.053\lambda_0$	0.433	-6.10	2.30
[10]	$0.033\lambda_0$ x $0.071\lambda_0$	0.433	-2.80	2.90
[11]	$0.074\lambda_0$ x $0.041\lambda_0$	0.433	-13	1.00
[12]	$0.139\lambda_0$ x $0.139\lambda_0$	1.90	-1.22	1.58
[15]	$0.074\lambda_0$ x $0.118\lambda_0$	0.433	-4.30	1.30
[16]	$0.077\lambda_0$ x $0.077\lambda_0$	0.250	-3.90	0.83
Proposed work	$0.137\lambda_0$ x $0.217\lambda_0$	0.874	-1.18	5.59

4. Conclusion

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 compared to reported antennas in literatures.

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