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Implementation of Printed Small Size Dual Frequency Antenna in MHz Range

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Abstract—**This paper presents a printed dual band monopole antenna working below 250 MHz using meander line and an added stub. Meander line approach is used to reduce the size of the low frequency monopole. The proposed antenna is fed by microstrip line and printed on FR-4 substrate with an overall size of 290 x 83 mm^2. The added stub tuned dual band operation at 114 MHz and 221 MHz with measured reflection coefficient of -19 dB at both bands. The antenna has omni-directional characteristics with efficiency greater than 90% and gain of 1.87, 1.7 dBi at both bands respectively. The antenna design is optimized through a detailed parametric study. This study includes varying stub, Meander, feed and ground dimensions. The antenna has been fabricated and measured where dual band operation in the MHz range is verified.**

Keywords—**Dual Frequency, Meander Line, MHz range, Monopole Antenna**

I. INTRODUCTION

SEVERAL civil & military systems require low frequency antennas operating in UHF and VHF bands. Antennas working below 250 MHz can be used for aerial vehicles, indoor reception for smart meters, Automatic Identification Systems (AIS) as well as surveying systems. Designing low profile antennas in such bands is a challenging task where wavelengths are in meters. For such applications, miniaturization of antenna is a mandate.

Meander line is reported in literature [1-10] as an attractive candidate to miniaturize size of antenna. A meander line antenna is constructed by consciously folding a conventional monopole/dipole antenna [1], which can be 3D wires [2] or printed on a dielectric substrate in planar form [3]. Meander antennas have gained widespread in literature [3 – 10] where space is limited or a low frequency operation is required. Meandering concept proved to be an efficient method to reduce the resonant frequency of the antenna [1 – 3]. On the other side, the reported drawbacks for Meander antennas are low efficiency values and difficulty to tune for multi-band operation [10]. However, several multi-band meander designs are reported in GHz as well as UHF and VHF bands [11 – 20].

These reports offer designs for RFID, GPS, WLAN, LTE, Radar, smart meters applications as well as wearable medical devices [15, 18]. This is realized using log periodic shaped Meander lines [10], stubs [11, 12], vias [13] and Multi-meander lines [14 – 16, 19 – 20].

In [10], changing length of vertical segments of classic meander shape provides dual band operation at 3 GHz and 5 GHz. However no information is reported on the bandwidth or efficiency for printed log periodic meanders in [10]. In [11] printed meander line with an added stub offers dual band operation at 900 MHz and 1800 MHz. The antenna acquires considerable gain and bandwidth for the operating bands. However the role of the design parameters in tuning multi-band operation was not presented. The idea is revisited in [12] where a detailed parametric study is conducted. The effect of tuning parameters such as stub length, stub width, meander line width, turns numbers is studied. In [12], the first band could be tuned for 300 MHz around 900 MHz, while the second band could be tuned for 400 MHz around 1800 MHz. Using optimized parameters, 1.4 dBi maximum gain is realized at 1800 MHz while maximum gain of 0.82 dBi is realized at the lower band. In [14], folded printed Meander monopole with a stub operates simultaneously at 5 bands with the lowest at 900 MHz. The antenna offers compact structure and serves different applications. However the highest realized efficiency at 900 MHz range is below 50%.

The antenna in [15] acquires dual and triple band operation at 900, 1800 and 2400 MHz by combining different meander lines with different dimensions. However all the proposed designs in [15] are 3D wire structures. In addition, no information is given on radiation characteristics and efficiency values. In [16], three meander lines are grouped and printed to realize compact multi-band antenna for laptops. The antenna is tuned for 5 bands, however all of them in the GHz range. In [19], Meander line antenna for tag applications at 867 MHz and 915 MHz is presented. Such operation is realized by coupling spiral resonator to the antenna. This resonator changes characteristics impedance and electrical length of the main meander line and creates dual resonances. However, the highest realized efficiency is 70% for the dual MHz bands. In [20], a printed dual band meander line monopole antenna for emerging smart metering applications at 169 and 433 MHz is presented. Dual band operation is realized using dual Meander lines, inductive loading and a via. Though the antenna acquires 49% efficiency and 4.6 dBi gain at the 433 MHz band, only 20% radiation efficiency and -1.8 dBi gain are realized at the 169MHz band.

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Some printed single band VHF antennas are also reported in literature [5, 21, 22] with operating frequencies below 300 MHz. In [21], the antenna is composed of two Meander lines and operates at 220 MHz. The radiation element has 3D wire structure of volume 30 mm x 30 mm x 55 mm. Though it acquires 90% reduction in length at the designated resonance, it has a low gain of -14 dBd. In addition, no information is given for the efficiency of the 200 MHz antenna. In [22], a 162 MHz low profile monopole antenna for AIS Marine applications is investigated. The antenna is based on a folded line structure fed by a very short monopole. The omnidirectional antenna has a compact circular footprint of diameter 90 mm with maximum measured gain of only -11.4 dBi and efficiency of 3.4%.

Moreover, a printed antenna operating at 100 MHz is reported in [5]. The design modifies conventional dipole by adding extra radiating arms. It has omnidirectional characteristics with radiation efficiency of 68% and gain of 2 dBi. Yet, the given characteristics is realized with a relatively large footprint of 665 mm x 220 mm. Up to our literature, the lowest resonant frequency for a Meander antenna is presented in [23]. A multi-band reconfigurable printed antenna realized a 60 MHz resonant frequency using PIN diodes. However, the reduction in resonant frequency is accompanied by low simulated radiation efficiency of 1.5% with an overall size of 300 x 300 mm.

Though Meander antennas are well-reported in literature, this paper presents a low profile printed Meander monopole design that realized dual band operation in the VHF band with gain above 1 dBi and efficiency above 90%. The antenna operates at 114 and 221 MHz simultaneously with an overall size of 290 mm x 83 mm. It has an omnidirectional characteristics at both bands with efficiency of 97% and gain of 1.75 dBi. The design is simulated and compared to measurements in terms of reflection coefficient and bandwidth. In addition, an investigation on the effects of varying the stub parameters has been conducted and will be presented in this paper.

II. PRINCIPLE DESIGN

Meander Line technology is proved to be an efficient method to reduce the resonant frequency of the antenna with increasing the number of bends while occupying the same physical size. This technology is chosen in this manuscript to design antenna with practical size for portable surveying systems operating in MHz range. Meander Lines were reported in Sine, triangular and square shapes [3]. However, the most common is the square shape having the most efficient space filling ratio [3].

For the proposed design, the number of Meander turns is mainly optimized to lower the resonant frequency within smallest area. Furthermore, a stub is introduced within the same antenna footprint to realize multi-band performance. The stub will offer additional path for current as well as additional tuning parameters to realize the targeted performance.

Figure 1 shows the front view of the preliminary design of a meander line structure with a total wire length of 1870.82 mm. The wire has 15 turns and overall length of 272.96 mm. The meander unit section has length L of 13.2 mm, width W of 43.99 mm and track thickness t of 4.8 mm. The antenna is printed on FR-4 substrate, with relative permittivity of 4.3 and thickness of 1.6 mm. The added stub has length of 272.96 mm and width of 3.62 mm. The separation between the stub and the main meander structure is 6.36 mm.

The antenna with the given dimensions is simulated using CST (Computer Simulation Technology) Microwave Studio. The reflection coefficient of the preliminary design is presented in Fig.2. By adding the stub, the proposed structure acquires two resonant frequencies at 75 MHz with reflection coefficient of -16 dB and 225 MHz with reflection coefficient of -17.5 dB. In addition to the number of turns, Meander width and length, ground width and length have been optimized to acquire resonant frequencies below 250 MHz range. In the following section, the effect of changing the stub parameters on the antenna output will be presented in details.

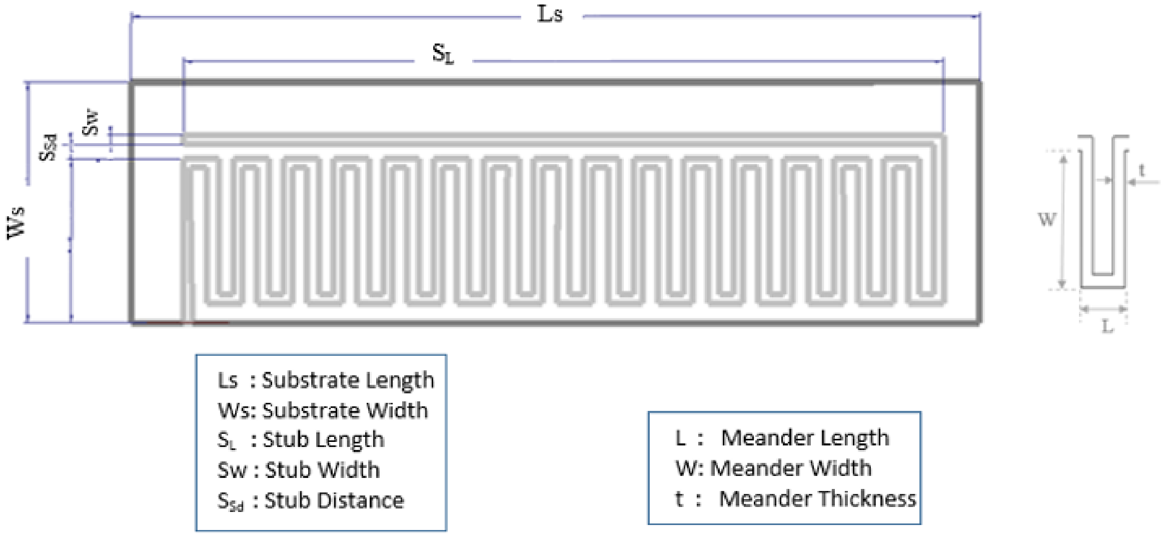


Fig. 1. Principle antenna structure.

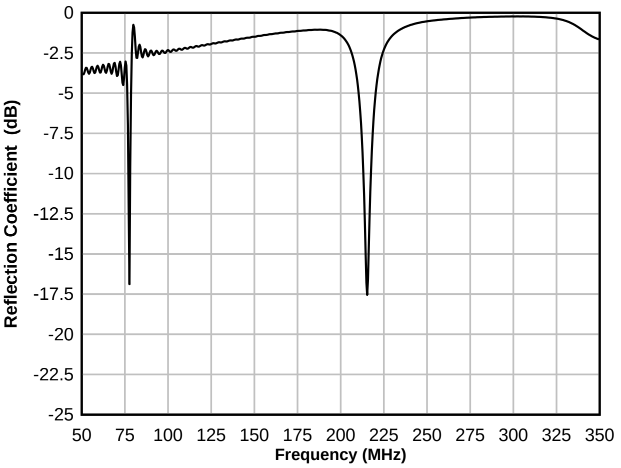


Fig. 2. Reflection coefficient in dB versus frequency for preliminary antenna design.

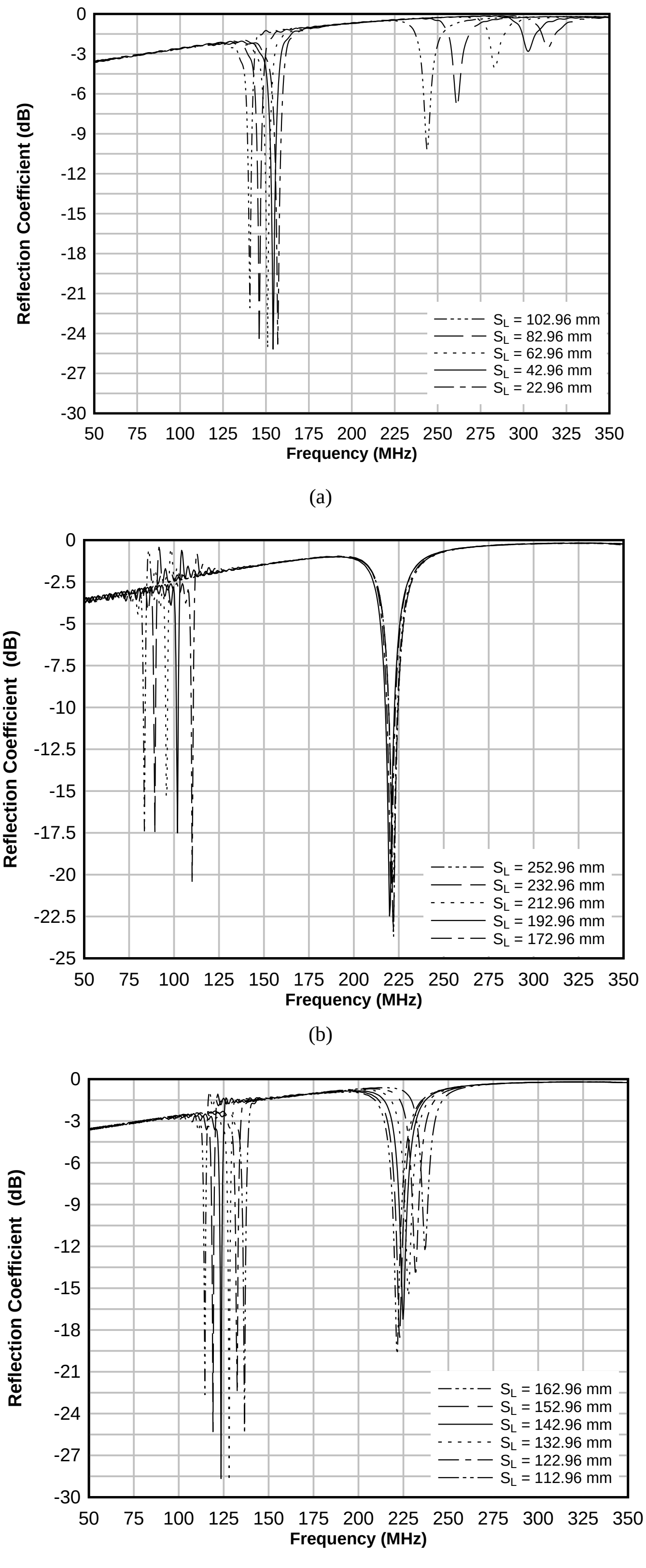
III. PARAMETRIC STUDY

The proposed design targets dual frequency operation around 125 MHz and 225 MHz used in low frequency EM surveying systems. Starting from preliminary design shown in Fig.1, the main parameters of the antenna have been varied to tune the output of the antenna. From the conducted study, the stub length, width, and separation from the meander line are the main tuning parameters for dual band operation. Due to large number of combinations for the above parameters, only relevant results will be presented.

First, the stub length "S_L" is varied while maintaining stub width and separation distance constant. Results of varying stub length are illustrated through Fig.3.a – 3.c. From Fig.3.a, changing the stub length in the range from 22.9 mm to 102.9 mm will tune the first resonance around 150 MHz while second resonance is not matched. By increasing the length higher than 172.9 mm, dual operation is recorded in Fig.3.b. The first resonance occurs around 100 MHz while the second occurs around 225 MHz. The chosen stub length values satisfy the design target for the second band while de-tune for the first. However changing the stub length in the range of 172.9 mm to 252.9 mm can tune the first resonance in the range of 85 MHz to 110 MHz.

Furthermore, by adjusting the stub length in the range of 112.9 mm to 162.9 mm, the required dual bands are realized. The first resonance occurs at 125 MHz with reflection coefficient of -28 dB while the second resonance occurs at 225 MHz with reflection coefficient of -18 dB as shown in Fig.3.c. By varying the stub length 50 mm, the first resonance can be changed by 22 MHz while the second resonance changed by 16 MHz.

Second, the stub width is varied in the range of 4.6 mm to 12.6 mm while keeping other parameters fixed with S_L = 137.96 mm and S_{Sd} = 7.36 mm. From Fig.4, varying the stub width can slightly tune the first resonance within 7 MHz. On the other hand, changing the stub width has no effect on the second band around 225 MHz.



(a)

(b)

(c)

Fig. 3. Reflection coefficient in dB versus frequency at different values for stub length with S_W = 8.62 mm and S_{Sd} = 7.36 mm (a) S_L = 22.96 mm – 102.96 mm, (b) S_L= 172.96 mm – 252.96 mm and (c) S_L = 112.96 mm – 162.96 mm.

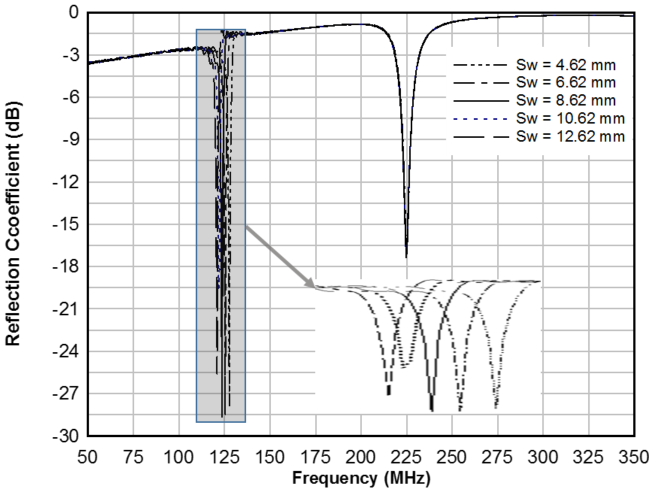


Fig. 4. Reflection coefficient in dB versus frequency at different values for stub width with S_L = 137.96 mm and S_{Sd} = 7.36 mm.

Finally the effect of changing the stub separation distance from Meander structure "S_{Sd}" is illustrated in Fig.5. Changing the stub separation distance noticeably tune the second resonance for 27 MHz around 225 MHz. However, the first resonance at 125 MHz is slightly varied by changing S_{Sd} in the range of 2.36 mm to 10.36 mm.

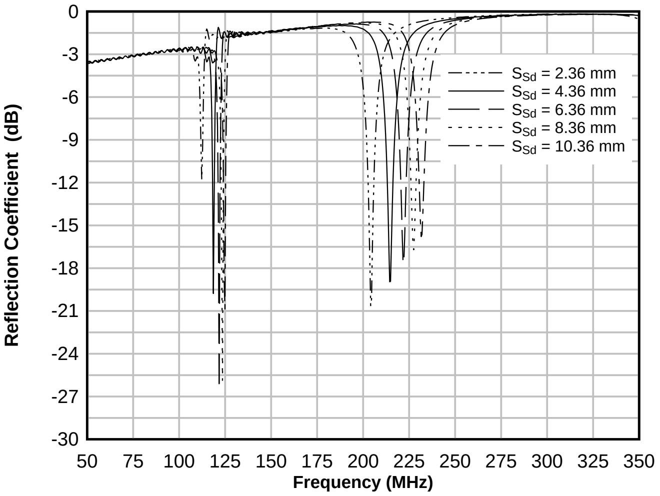


Fig. 5. Reflection coefficient in dB versus frequency at different values for stub separation distance with S_L = 137.96 mm and S_W = 8.62 mm.

IV. FINAL ANTENNA CONFIGURATION

From the previous parametric study, adding a stub with length of 137.96 mm, width of 8.62 mm and a stub separation distance of 7.36 mm is optimum for the required operation bands. The front view of the final design is shown in Fig. 6. The antenna has a ground with optimized size of 30.6 mm x 64.88 mm. The reflection coefficient and far field radiation patterns are shown in Fig.7 and Fig.8 respectively. The proposed antenna has two resonant frequencies, one at 125 MHz with reflection coefficient of -19.48 dB and the second one at 225 MHz with reflection coefficient level of -19.71 dB.

For the radiation characteristics, only simulated results are presented as our Anechoic chamber is unable to operate below 700MHz. The radiation patterns in both the E-plane and the H-plane are shown in Fig.8. The simulated patterns shows omnidirectional characteristics with radiation efficiency of 97.5% at 125 MHz and 91% at 225 MHz. The antenna has gain of 1.87 dBi for the first band and 1.7 dBi for the second band. The realized gain values are comparable to conventional dipoles and in good range for the targeted applications.

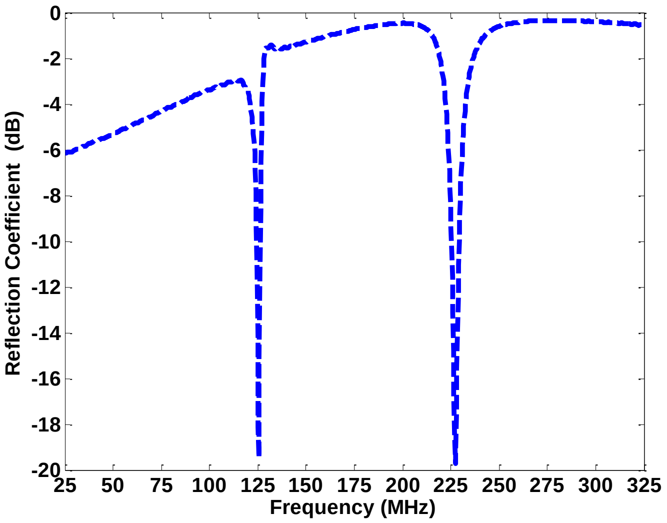


Fig. 7. Simulated reflection coefficient in dB versus frequency of the final antenna configuration.

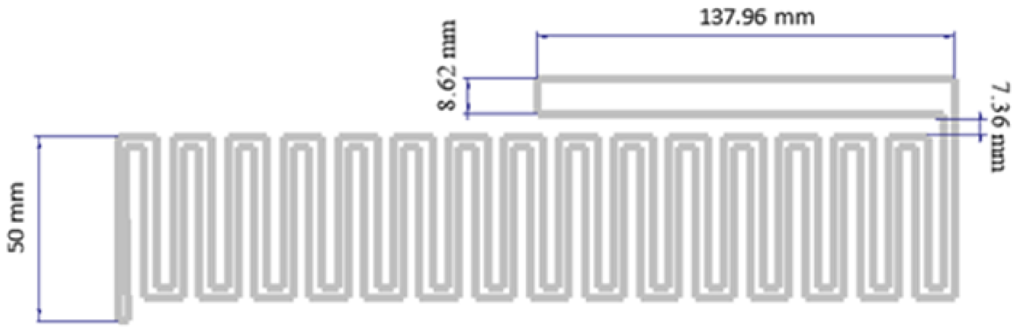


Fig. 6. Final antenna configuration.

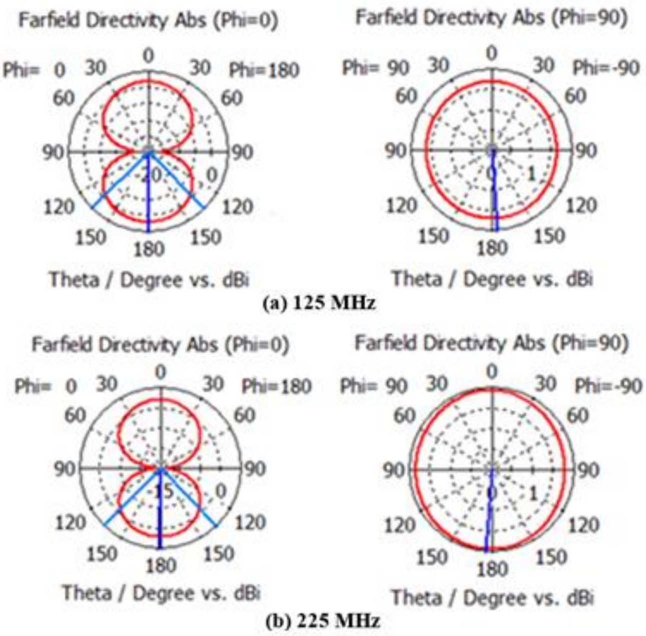


Fig. 8. E-plane and H-plane radiation Patterns at (a) 125 MHz and (b) 225 MHz.

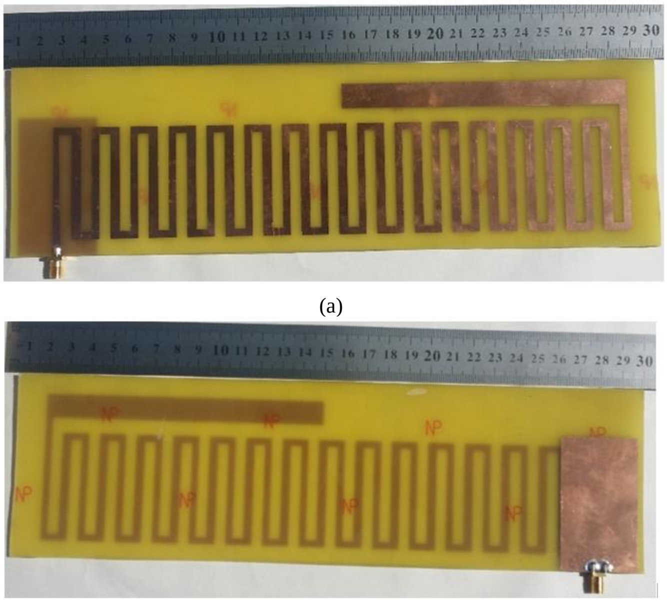
V. IMPLEMENTATION RESULTS

The proposed meander line antenna was fabricated as shown in Fig. 9. Table 1 summarizes antenna parameters that have been implemented. The reflection coefficient (S_{11}) in dB is recorded using Agilent N9918A Handheld Microwave Analyzer. It offers measurements in the range from 30 KHz to 26.5 GHz. Measurement versus simulation curves are shown in Fig.10.

The measured S_{11} shows two resonant frequencies at 114 MHz and 221 MHz compared to 125 MHz and 225 MHz from CST simulations. S_{11} curve has reflection coefficient levels of -13.5 dB at the first band and -13.1 dB at the second band. The measured antenna delivers bandwidth about 7 MHz at VSWR ≤ 2 compared to nearly 3 MHz from simulation. This can be attributed to the optimized stub, ground and feed parameters.

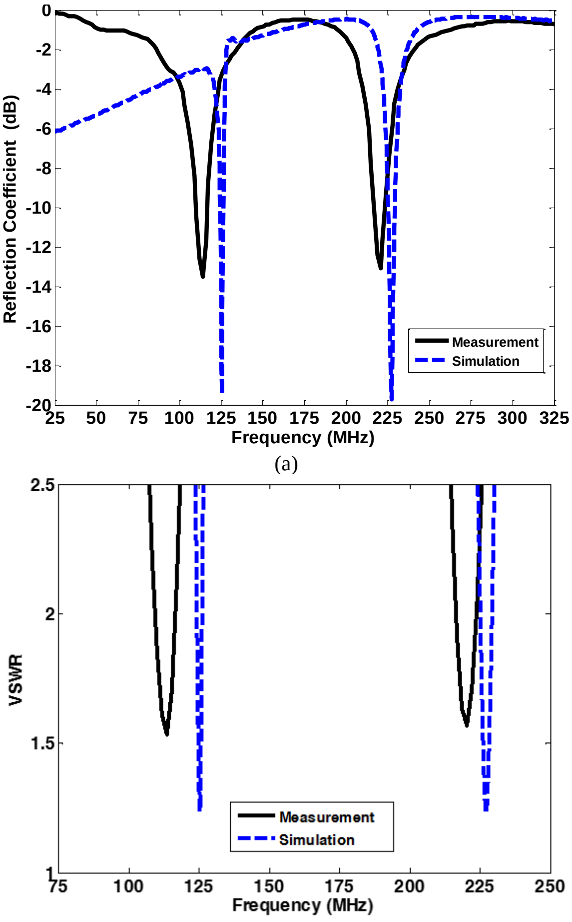
TABLE I
IMPLEMENTED ANTENNA DESIGN PARAMETERS

Parameters	Dimensions [mm]
Substrate (L_S x W_S)	290 x 83
Ground	30.6 x 64.88
Meander Unit Length (L)	13.2
Meander Unit Width (W)	43.99
Meander Unit Thickness (t)	4.8
Stub Length (S_L)	137.96
Stub Width (S_W)	8.62
Stub Separation Distance (S_{Sd})	7.36


(a)

(b)

Fig. 9. The prototype of the proposed meander line antenna (a) Front view, (b) back view.



(a)

(b)

Fig. 10. Measurement versus Simulation Results (a) Reflection coefficient (dB) and (b) VSWR.

VI. CONCLUSION

In this paper, printed dual-band monopole antenna based on Meander line with a stub has been presented. The antenna operates at 114 MHz and 221 MHz. The meander line structure provides 71% reduction in length compared to conventional dipole operating at same frequency. The stub not only supports dual band operation in VHF band but also enhances meander line gain to 1.87 dBi. The antenna radiates well with an omni-directional pattern and high efficiency above 90%.

Variation of different design parameters have been also investigated in this paper. From the analysis, stub parameters play important role in acquiring dual resonance for the proposed monopole antenna. Changing stub length in the range of 112.96 mm to 252.96 mm, can tune the first band as low as 85 MHz and the second band around 225 MHz. In order to realize the targeted performance of 125 MHz for the first band and 225 MHz for the second band, the stub length should be adjusted in the range of 112.96 mm to 162.96 mm. Moreover, changing the stub width can slightly varies the first band within 7 MHz while the second band could be tuned within 27 MHz by varying the separation distance from the Meander line. Other parameters such as ground, feed and meander dimensions also contribute to the performance of the antenna.

The antenna prototype is fabricated and tested. Measurements validate the operation of the proposed design and simulation results. From measurements, the resonant frequencies are slightly shifted. However they covered the interested frequency bands. With a foot print of 290 mm x 83 mm and realized gain, the antenna can serve for many applications in the designated bands. The paper also presents a set of practical data to design low profile efficient VHF antenna. The antenna design is low cost and easy to fabricate in addition to a frequency ratio f_2/f_1 of 2 which is easy to tune. Further work can be done to investigate reducing resonant frequency, elevating gain values as well as broadening operation bandwidth.

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