Single Printed Monopole Antenna and Notched Antenna with Triangular Tapered Feed Lines for Triband and Pentaband Applications

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Abstract:

In this paper we have investigated printed monopole antennas, which is basically a printed microstrip antenna with etched ground plane for multi-band applications. In particular we have fabricated and tested printed monopole antennas for tri-band and penta-band applications. Printed rectangular monopole antennas are studied first for penta-band applications. Then double-T printed monopole antennas are studied for tri-band applications. Dual-band notched patch antenna with triangular tapered input feeding line is also studied for multiband operations. Triangular tapered feed lines are used for broadband impedance matching since conventional rectangular microstrip feed lines are matched to the patch antenna impedance for a single frequency region of interest. It has been observed that broadband matched double-notched patch antenna is suitable for tri-band operations from the IE3D simulation results verified by measured and experimental results.

Key Words: Printed rectangular monopole antennas, Double-notched patch antenna, Triangular tapered feed lines

I INTRODUCTION

Antennas, which can work properly in more than one frequency region either for transmitting or receiving electromagnetic (EM) waves, are termed as Multi-band antennas [1]. Such antennas are usually tri-band, penta-band etc. Multi-band antennas are much more complex than the single band antennas in their design, structures and operations. In this paper we will investigate printed monopole antenna (PMA), which is basically a printed microstrip antenna with etched ground plane [2]-[3] as shown in Figure 1(a) and 1(b) respectively for tri-band and penta-band applications. Dual-band notched patch antennas with coaxial feeds are reported by Palit and Hamadi [4]. In this paper, we will also report our investigation on patch antenna with double notches and triangular tapered input feeding line. Triangular tapered feed lines are used for broadband matching [5]-[6] since conventional rectangular microstrip lines are matched for a single frequency region of interest. It has been observed that broadband matched double-notched patch antenna is suitable for tri-band operations from the IE3D [7] simulation results verified by experimental results.

II. GEOMETRY OF MULTI-BAND ANTENNAS AND EXPERIMENTAL RESULTS

Printed Rectangular Monopole Antenna for Pentaband Applications (Simulation as well as Experimental Results):

Model 1:
The monopole antenna is designed for 2.4 GHz frequency of operation on a substrate with 4.4 relative permittivity and 1.6 mm thickness. Antenna impedance is exactly 50 Ω. The final dimensions of the entire monopole antenna are

1. Dimensions of Patch:
2. W = 38.01mm and L = 29.396mm.
3. Dimensions of Substrate:
4. W = 2 * 38.01mm and L =2 * 29.396 mm.
5. Dimensions of Ground:
6. W = 2 * 38.01mm and L =2 * 29.396 mm.

where gap between the ground plane and patch antenna, g values = 1, 2, 3, 3.5.

Width of Gnd plane mm	g value in mm	f_{low} (GHz)	f_{high} (GHz)	f_r (GHz)	Antenna Impedance in Ωs	% B.W.	η %
13.7	1	2.2	3.0	2.62	90	31	75
12.7	2	1.6	3.1	2.45	65	61.2	91.5
11.7	3	1.5	3.1	2.2	55	73	94.0
11.2	3.5	0.9	3	1.8	50	116	95.6

The values of g is changing or increasing step by step then the antenna impedance, % Bandwidth and Antenna Radiation efficiency are increasing proportionally. Here initially the gap (g) between the patch and the ground plane is 1mm and it is increasing up to 3.5mm in order to get the antenna impedance to be 50 ohms and maximum radiation efficiency.

Model 2:

The monopole antenna is designed for 2.4 GHz frequency of operation on a substrate with 4.4 relative permittivity and 1.6 mm thickness. Antenna impedance is exactly 50 Ω. The final dimensions of the entire monopole antenna are

Dimensions of Patch:
W = 38.01mm and L = 30mm.
Dimensions of Substrate:
W = 38.01mm and L = 30mm
Dimensions of Ground :
W = 42.01mm and L = (14.7-g)mm
where g values = 3, 3.5, 4.5, 5, 5.5.

W of Gnd plane mm	g value in mm	f_{low} (GHz)	f_{high} (GHz)	f_r (GHz)	Antenna Impedance in Ωs	% B.W.	η %
11.7	3	1.5	2.5	1.8	85	55.55	65.26
11.2	3.5	1.2	2.4	2	68	65	80.65
10.2	4.5	1.3	2.9	2.2	60	72.72	98.19
9.7	5	1.1	2.8	2.0	56	85	98.34
9.2	5.5	1.2	2.9	2.1	50	115	98.581

The values of g is increased step by step then the antenna impedance, % bandwidth and antenna radiation efficiency are increasing proportionally. These two models (monopole antenna) can be fabricated; here model 2 is the compact one due to its dimensions as well as in terms of its performance.

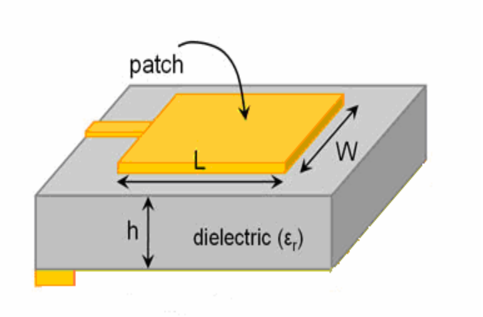


Fig. 2 (a)

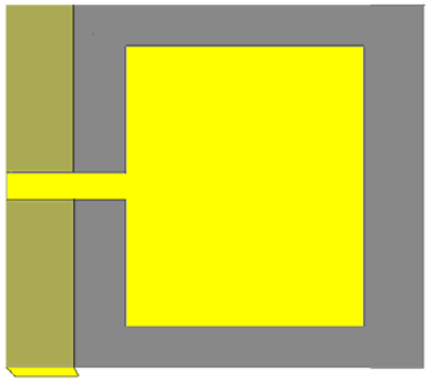


Fig. 2(b)

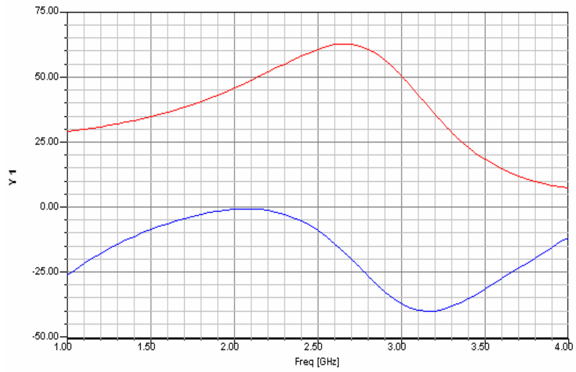


Fig. 2(c)

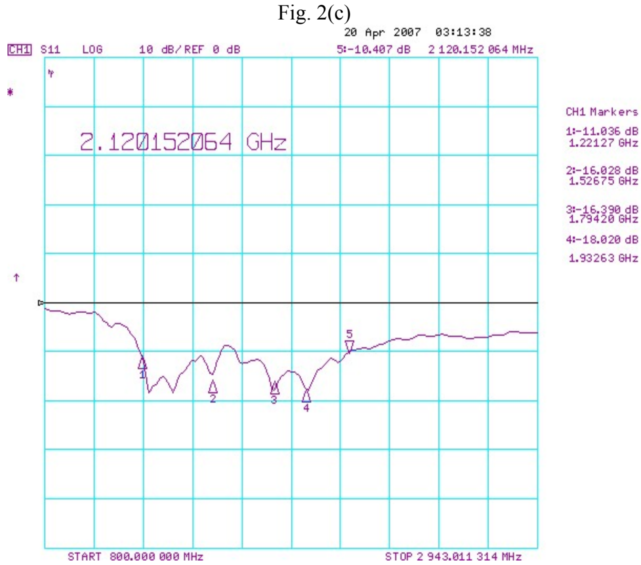
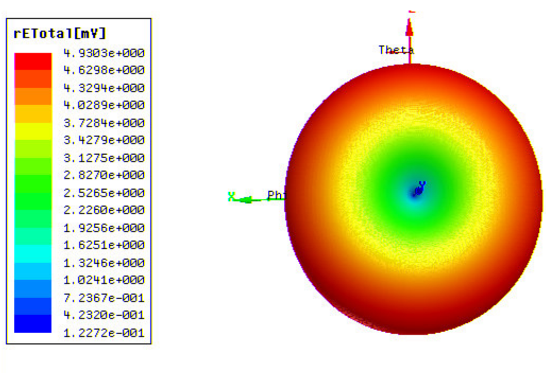


Fig. 2 (d)



2(e)

Figure 2 Geometry of printed rectangular monopole antenna (a) 3-D and (b) 2-D (c) real part (red color) and imaginary part (blue color) of antenna impedance versus frequency of the monopole antenna (d)

Experimental results of fabricated printed rectangular monopole (s_{11} vs frequency) (e) Radiation patterns (simulation) of printed rectangular monopole antenna

The dimensions of the printed rectangular monopole antenna illustrated in Fig. 2 (b) using FR4 substrate after doing an extensive simulation study were calculated as W=38.01mm, L=30mm, substrate width chosen are W=42.01mm, L=44.7mm, gap between the ground plane and patch antenna g=5.5mm. The scattering parameters s_{11} in dB versus frequency in MHz from 800MHz to 3000MHz for the compact PRMA, which can be fitted in a cellular mobile phone, is obtained using Network Analyzer and is plotted in Figure 1(b). The PRMA bandwidth is from 1.1GHz to 2.12GHz at the mid frequency of 1.5GHz (%B.W. = 73.15). Note that the present L band (1-2GHz) PRMA can work well for pentaband applications, viz. digital communication system (DCS, 1710-1880MHz), personal communication system (PCS, 1850-1990MHz), universal mobile telecommunication system (UMTS, 1920-2170MHz), global positioning system (GPS, 1575.42MHz, 1227.60MHz, 1371.913 MHz, 1381.05MHz) and digital audio broadcasting (DAB L Band, 1452 MHz to 1490 MHz). The radiation pattern of the rectangular monopole antenna is depicted in Fig. 2(c).

Notched Antenna with Triangular Tapered Feed Lines for Tri-band Applications (Experimental Results):

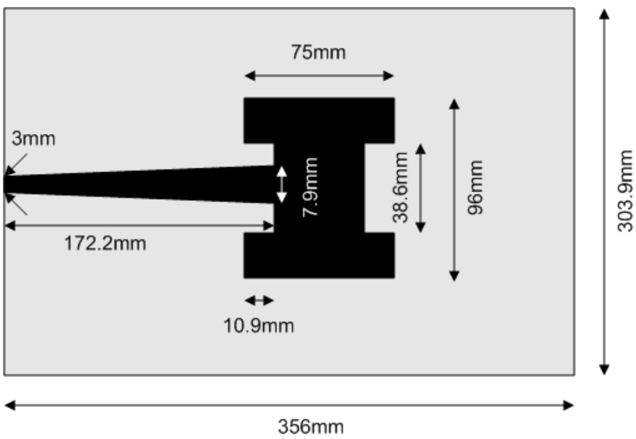


Fig. 3 (a)

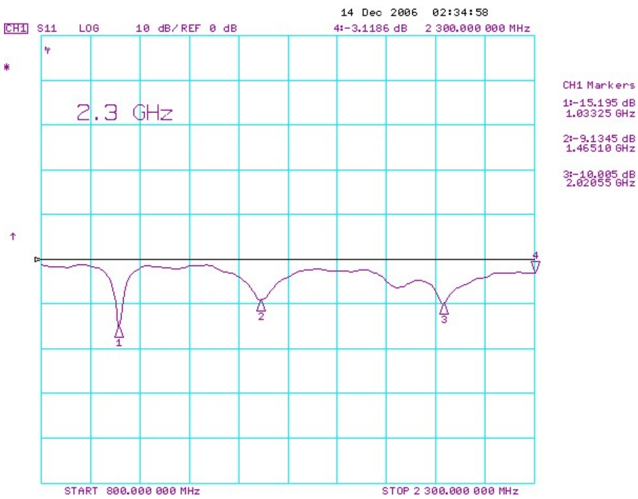


Figure 3 (a) Geometry of notched patch antenna with triangular tapered feed lines (b) Return loss of the tri-band patch antenna: Experimental results for notched patch antenna with triangular tapered feed line

The double-notched patch antenna with the triangular tapered feed (broadband matching) is shown in Fig. 3(a) along with its dimensions. It has been observed that broadband matched double-notched patch antenna is suitable for tri-band operations from the IE3D simulation results verified by experimental results. It shows a simulated and measured return loss well below –10 dB in all three-frequency bands of operation at 1GHz, 1.45GHz and 2GHz unlike the conventional rectangular microstrip line fed patch antennas with the same dimensions which do not show any insertion loss below –10dB in all the three frequency bands of operations.

Double-T Monopole Antenna for Tri-band Applications (Experimental Results):

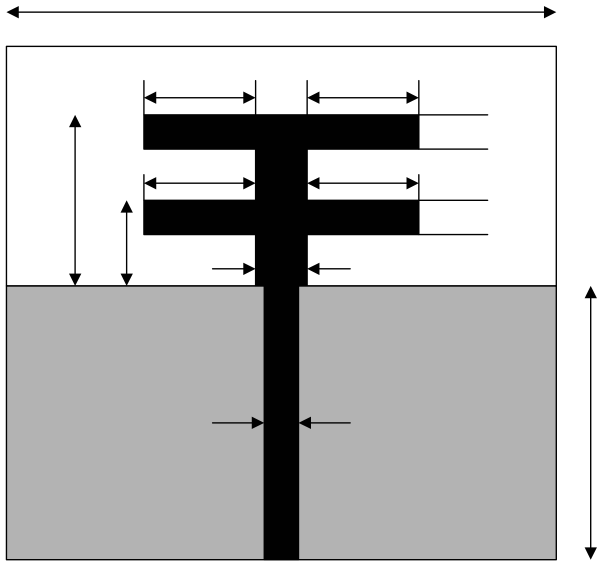


Fig. 1(a)

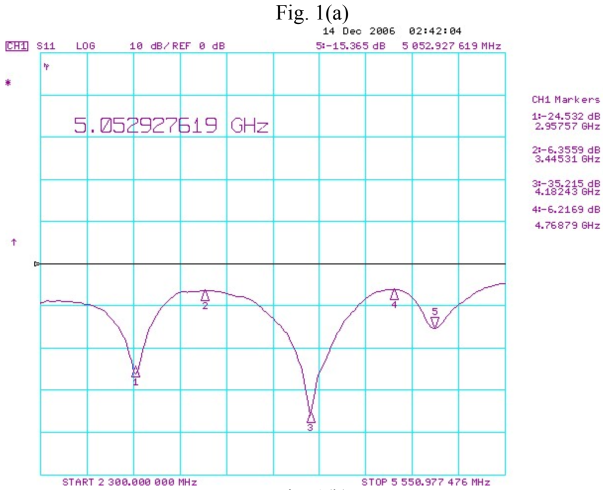


Fig. 1(b)

Figure 1 (a) Geometry of printed double-T monopole antenna (b) Experimental results of fabricated printed double-T monopole (s_{11} vs frequency)

The dimensions of the double-T printed monopole antenna configuration depicted in Fig. 1(a) using FR4 substrate (ε_r=4.4, thickness=1.6mm) after doing an extensive simulation study were calculated as W=75mm, L=50mm, $w_1=w_4$=1.5mm, $w_2=w_3$=3.5mm, h_1=14.5mm, h_2=5mm, $l_1=l_2$=5.3mm, $l_3=l_4$=7.3mm. The scattering parameters s_{11} in dB versus frequency in GHz from 2.3 to 5.55 for the compact PMA is obtained using Network Analyzer and is plotted in Figure 1(b). Note that this single PMA can work well for tri-band applications, viz. 2.95 GHz (s_{11}: -24.5dB, 10dB BW: 0.52GHz), 4.18GHz (s_{11}: -35.2dB, 10dB BW: 0.68GHz), 5.05GHz (s_{11}: -15.3dB, 10dB BW: 0.26GHz).

CONCLUSION

In this paper we have investigated printed monopole antennas, which is basically a printed microstrip antenna with etched ground plane for multi-band applications. Printed monopole antennas are less fragile, planar and can be integrated with the integrated circuits unlike monopole antennas which have non-planar or protruded structures above the ground plane. In particular we have fabricated and tested printed monopole antennas for tri-band and penta-band applications. Printed rectangular monopole antennas are studied first for such application. Then double-T printed monopole antennas are studied. Dual-band notched patch antenna with triangular tapered input feeding line is also studied for multiband operations. Triangular tapered feed lines are used for broadband matching since conventional rectangular microstrip lines are matched for a single frequency region of interest. It has been observed that broadband matched double-notched patch antenna is suitable for tri-band operations from the IE3D simulation results verified by measured experimental results.

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