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DESIGN OF COMPACT U- AND MODIFIED U-SHAPED PLANAR MONOPOLE ANTENNAS FOR WIDE BAND APPLICATIONS

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ABSTRACT

This is a comparative design for two planar monopole antennas with small sizes, omnidirectional radiation patterns as well as wide-band performance. For purpose of selecting the best design, two slightly different structures were analyzed for size, bandwidths as well as radiation gain. Regardless of feed lines, the antenna structures are respectively referred to as U-shaped and modified U-shaped planar monopole antenna. They were analyzed at a common frequency of 4.6 GHz and individual central and resonance frequencies were finally set separately. The results show that both the antennas qualify for wideband standards. As we compare them, the U-shaped planar monopole presents the best impedance matching while the modified U-shaped is the smallest with much stable radiation fields. Both the models were manufactured and prototypes test results prove simulation results. Compared against some other antennas in similar area of research, our contribution are found in the improved antenna radiation fields throughout the whole wide-band (WB) together with very good WB bandwidth impedance matching. Upon requests, either model would be packaged for applications mentioned in the section of results and discussion.

KEYWORDS: Planar Monopole Antennas, Radiation Patterns, (Ultra-) Wideband Antennas

INTRODUCTION

Planar antennas are recognized from their flat appearance; printed circuit board microstrip antennas are typical examples. Besides, it is ascertained by researchers [1-2] that excellent antenna system design surely enriches the entire system's performance. Current efforts and novelty in designing planar wide-band (WB) and ultra-wide band (UWB) antennas lie in surpassing dual and multiple band antennas with narrow band performance; thus, more wireless standards would be covered at once [3].

For current trends, apart from targeting the far more improved bandwidth performances and stable ominidirectional radiation in the entire WB, antenna miniaturization [4] is a hot and significant research topic.

Due to advantages found in planar monopole antennas, noting their flexibility in size reduction done by putting together different radiating element shapes such as F-shaped Slot [5], printed inverted-F [6], Inverted-L [7], etc., ground reduction for these antennas plays a vital role to improve their bandwidth [8].

Planar antennas in general have much more applications in mobile communication systems [9-10]. The novelties in this research work generally complies with novelty in planar monopole antennas which is not only to solve radiated power drawbacks which is common in most compact WB patch antennas, but also to the size reduction by folding lines if radiating element [5-7], if not serpentine lines [11] and other methods that are used to squeeze the antenna size.

DESIGN PRINCIPLES

In agreement with researchers who worked on planar monopole antennas [9], this work illustrates two monopole antennas built from L-shapes merged together to make a U-shaped radiating element in different ways around the top corner of a microstrip feed line.

Brainstorming about L- and U-shaped structures of modern antennas, these are very recent and famously utilized as slots to make small planar monopole antenna [12]; the same idea was documented in [13] where parasitic elements were added to increase the number of resonant frequencies. In [14], the idea of U-shaped structure was used in designing a slot antenna by a coplanar waveguide which resulted in good performance.

Looking at the recent research trend based on U-shaped structures applied on antenna design, the role of this structure in improving the bandwidth gave us to work on a compact U-shaped planar monopole antenna and its modification which have been designed and tested. The main reason for two structures was just to demonstrate the practical impact of radiation elements pasted on top of the U- shaped radiator to generate the modified U- (M.U-) shaped monopole antenna. As a result, enhanced radiation gain, bandwidth as well as overall antenna size reduction are experimented.

Calculations according to [15] helped us to approximately fix dimensions of radiators which reached to final sizes after optimization. The utilized design tool is the Ansoft High Frequency Structure Simulator (HFSS); the optimally simulated models were printed on Rogers (RO3003C) substrate.

The dimensioned top views of the design models, which required additional software tools: Auto-CAD and Altium Design, are presented in Figure 1 (a) and (b) and related dimensions in table 1. The antennas manufacturing pictures are shown in Figure 2.

Table 1: Dimensions for Figure 1 in Millimeters [mm]

U-Shaped Antenna		M.U-Shaped Antenna			
L	14	K	14	q	2.475
L1	11.4	K1	10	r	1.5
L2	13.4	W_{Sub-2}	32	S	7
L3	6	K_{Gnd}	10.9	S_1	5.93
D	5.6	K_{Up}	10.1	S_2	2.25
D1	5.5	u	2	i	0.75
D2	5.8	v	1.025	j	0.2
W	2.6	m	0.332	k	0.5
W_{Sub-1}	33.4	n	0.336	l	0.5
L_{Gnd}	11.3	o	0.525		
L_{Up}	22.1	p	2.475		

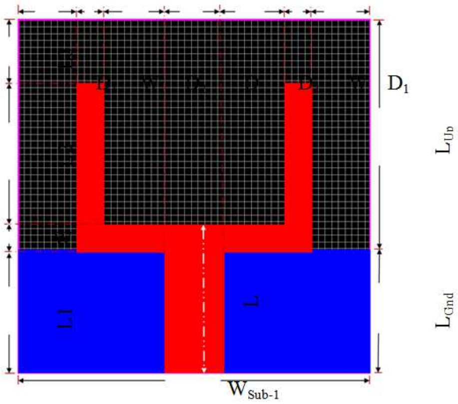

Figure 1(a): Top View for U-Shaped Monopole

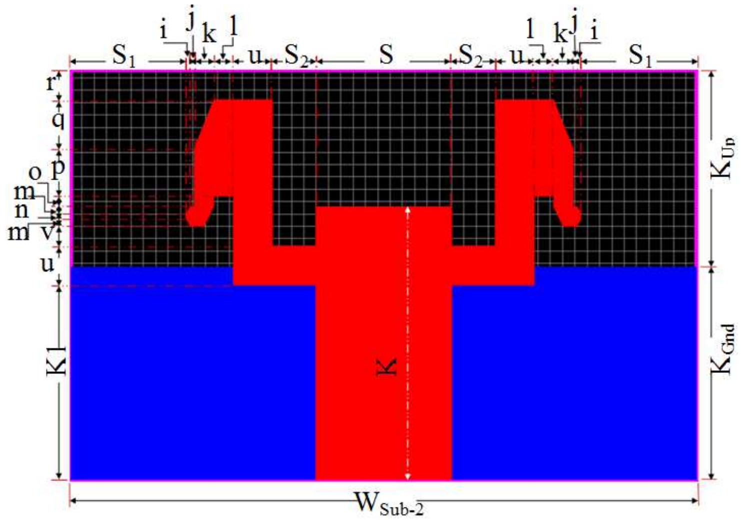

Figure 1(b): Top View for M.U-Shaped Monopole

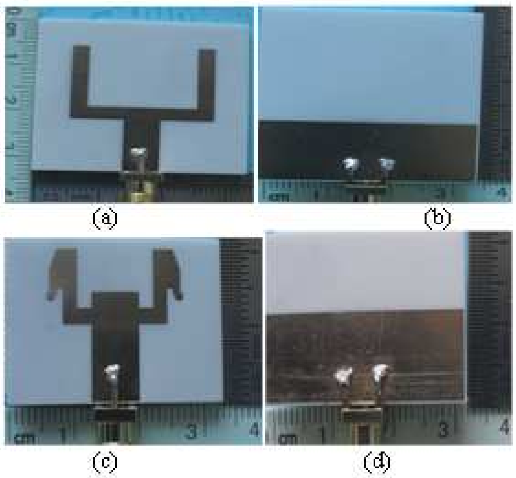

Figure 2: Manufactured Prototypes Pictures for: (a) U-Shaped Monopole's Top View; (b) U-Shaped Monopole's Bottom View; (c) M.U-Shaped Monopole's Top View; (d) M.U-Shaped Monopole's Bottom View

RESULTS AND DISCUSSIONS

Knowing the electric and magnetic fields are perpendicular to each other in (X, Y, Z) coordinates, Z-Axis is assumed for propagation direction of electromagnetic (EM) waves.

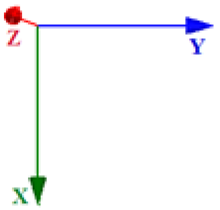

Figure 3: (X, Y, and Z) Coordinates Defined for EM Waves Propagation

EM waves in XoZ plane are referred to as vertical cut waves or XoZ-cut waves; EM waves in YoZ plane are hereby known as horizontal cut waves or YoZ-cut waves. For sake of illustration, (X, Y, Z) coordinates are defined by a diagram in Figure 3.

By the help of Origin Pro8 software, the return loss signals as well as radiation patterns resulting from both simulation and measurement are plotted together in Figure 4 ~ 6. In the same way, the measured peak gain signals are plotted together for both the antennas in Figure 7.

The reported radiated fields demonstrate stable omnidirectional radiation patterns throughout the useful WB, most notable on side of M.U-shaped monopole antenna. The antennas overall sizes, peak gains as well as bandwidth information at 4.6 GHZ are compared with some recent publications having the same themes, in table 2. As we compare the antennas where there are two prototypes and more than one band, [16], the best of all is considered.

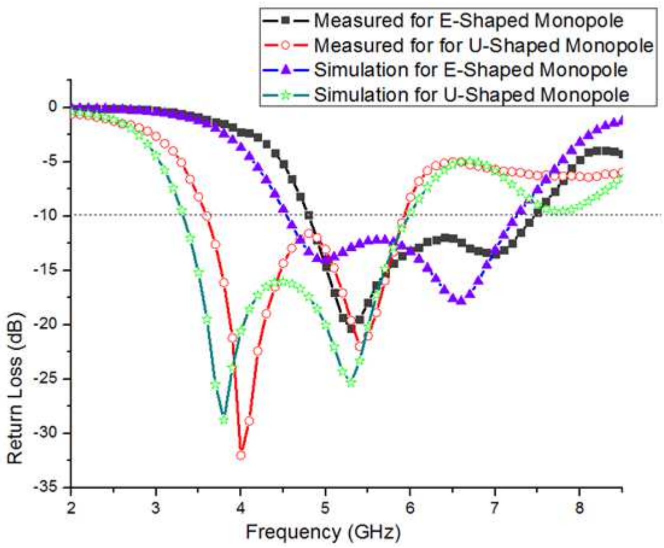

Figure 4: Compared Return Loss Signal from both Simulation and Measurement

Recommending the users to filtering the unwanted frequency bands at the receivers/transmitters circuit level, the U-shaped antenna, resonant at 4 GHz and 5.5 GHz; central at 4.8 GHz can excellently fit for all WB systems in the frequency spectrum range from (3.3 ~ 5.8) GHz, say WiMAX (3.3 ~ 3.8) GHz, wireless LAN (5.1~5.3 GHz and 5.7 ~ 5.8 GHz); however, the antenna is still useful until the frequency of 8.5 GHz.

Based on these performance specifications and considering the frequency spectrum utilization according to [17], either prototype can be a best choice depending on users of airport search radar (±3.3 GHz), microwave relays (±3.6 GHz), satellite down communication systems (±4.1 GHz), satellite up communication systems (±5.8 GHz) as well as studio-to-transmitter link (STL) Microwave relays (± 7.1 GHz).

The M.U-shaped antenna, resonant at both 5 GHz and 6.5 GHz; central at 5.8 GHz, is excellently fit for all WB systems in the spectrum range of (4.5 ~7.2) GHz; however, this antenna is still useful for the frequency of (3.5 ~ 8) GHz; additionally suitable for TV C-Band.

Compared to a few other antennas, in table 2, our antennas bandwidths are among the best. As for the sizes, these antennas fit in the family of small-sized antennas. As we compare our designs, the U-shaped monopole antenna's radiation EM field gains are better than those for M.U-shaped in the band of 4 GHz to 5.5 GHz; nonetheless, it has comparatively low band performance characteristics in the frequency spectrum higher than 5.5 GHz.

The smaller the size, the more difficult it is to maintain the desired bandwidth and gain performances without serious modifications of the radiating elements. This was practically experimented by modifying the U- into M.U-shaped monopole antenna, which caused the frequency shift as observable in Figure 4; however, it caused the more stable radiation patterns gain. The measured peak gain signals for both U- and modified U- shape antennas are comparatively plotted together in figure 7.

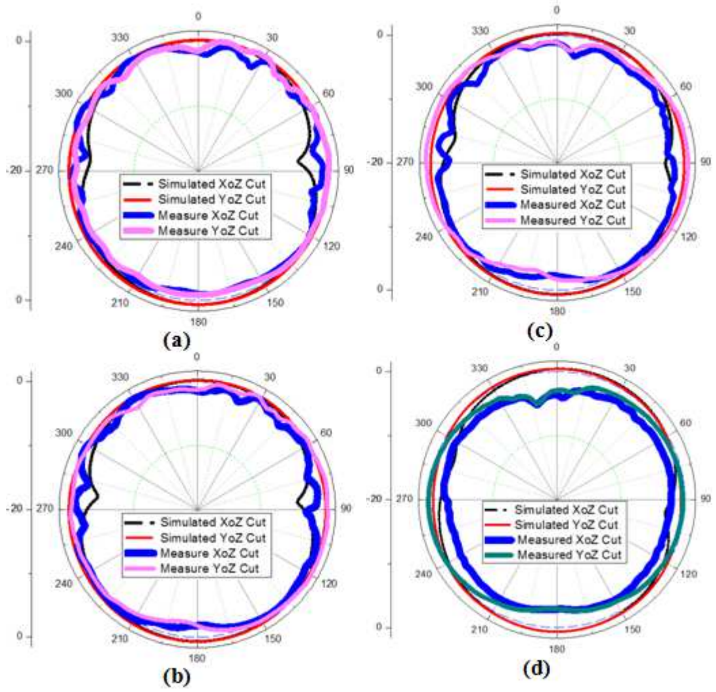

Figure 5: Measured Radiation Patterns for M.U-Shaped Monopole Antenna: (a) At 4.5 GHz;(b) At 5 GHz; (c) at 5.8 GHz; (d) at 6.5 GHz

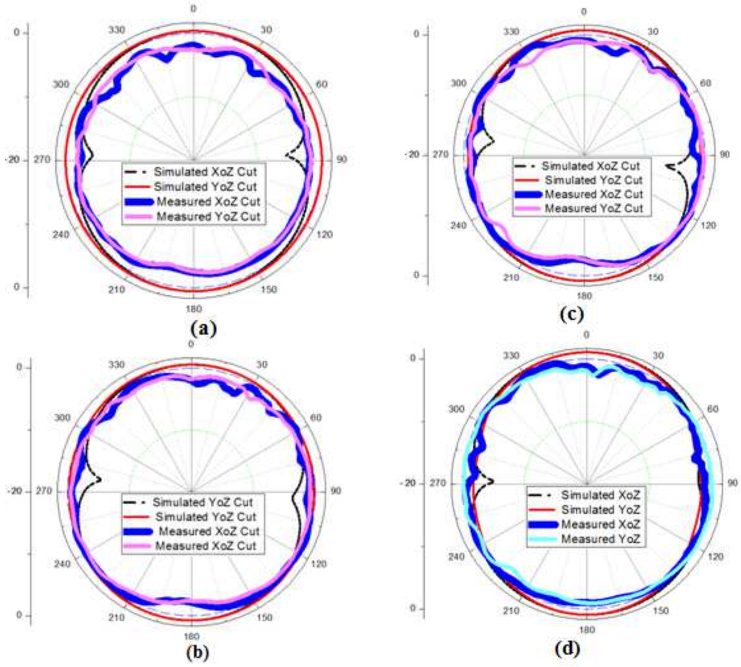

Figure 6: Measured Radiation patterns for U-Shaped Monopole Antenna: (a) At 3.5 GHz; (b) At 4.8 GHz; (c) at 5.5 GHz; (d) at 6.5 GHz

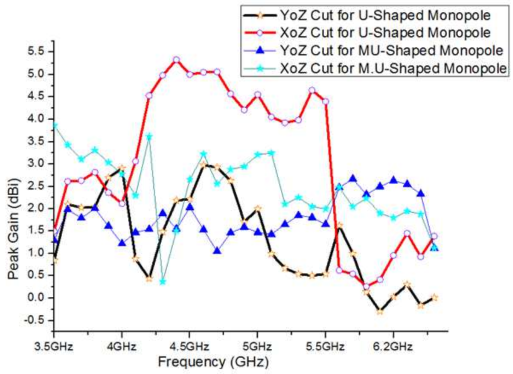

Figure 7: Peak Gains Plotted Together as Measured From Both U- And Modified U- Shaped Monopole Antennas

Table 2: Peak Gain, Overall Size and Bandwidth for Both the Antennas in Comparison with Some Other Publications

References	Size (Sq. mm)	Measu-red Peak Gain (dBi)	Absolute BW (MHz)	Fracti-onal BW (%)
U-Shaped Antenna	33.4*33.4	5.4	2634.7	57.2
M.U-Shaped Antenna	21*32.5	3.2	2863.5	63
[4]	19*25	unknown	960	27.5
[16]	12*60	4.2	400	16

CONCLUSIONS

For the three tested samples of each prototype, results are all coherently matching with simulation results. The manufactured prototypes only serve for research and experimental purposes.

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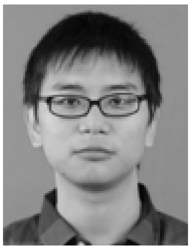

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