Broadband CPW-Fed Monopole Antenna for Indoor Applications

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***Abstract*—A broadband coplanar-waveguide CPW-Fed monopole antenna is presented in this paper. The proposed antenna consists of a rectangular monopole antenna, with an inverted L strip on right side of the ground plane and embedded slots in the left side of the ground plane. It has a simulated impedance bandwidth of 142.8% (1 – 6 GHz), which covers most wireless applications in the upper band of GSM and LTE, and both WLAN and WiMAX bands. This antenna can be used indoors, due to its advantages of wide bandwidth, simple structure, and low cost.**

***Index Terms*— CPW-Fed; Indoor Antenna; Monopole Antenna.**

I. INTRODUCTION

Demands to enhance indoor wireless communication technology have arisen due to increases in building density and the expansion of wireless communication. Designers are looking to design antennas which address these demands. New requirements include wideband or broadband omnidirectional antennas that cover more of a building with wireless communication bands.

In recent years, antenna designers have focused on monopole antenna for use in indoor applications, due to their advantages such as omnidirectional coverage, simple structure, low cost and the capability to support wideband, multiband, and broadband operations[1] [2] Many wideband and broadband monopole designs have been proposed to cover most in-building wireless communication bands. In [3] a wideband monopole omnidirectional antenna is proposed to cover most of these bands. The design has the ability to radiate in all directions with efficient radiations, and acceptable a gain. Nevertheless, the proposed antenna design has limited use due to its large size.

The author in [4] proposes a compact broadband monopole antenna with a range 0.360 to 5.1 GHz in order to cover most wireless applications as GSM, WiMAX, and the lower band of WLAN (2.4 band).

A sleeve has been used with this wire monopole antenna for size reduction, especially to decrease the height of wire monopole antenna. Moreover, many other techniques have been used to decrease the height of conventional monopole antenna, as in [5] with top loaded metal disc and short legs. These methods are used to minimize the waveguide monopole size, but the proposed designs are still quite large compared to planar monopole structures used for size reduction. Planar monopole elements do not have the same radiation pattern characteristics produced by a wire monopole antenna.

Many planar monopole antennas have been proposed in recent years with compact size, low profile, and low cost due to easy design and fabrication as well as wide impedance bandwidth.

As in [6], broadband monopole antenna designed with C shape radiator and two rectangular stubs offers wide impedance bandwidth (2.25-7.35 GHz) with a compact size.

Moreover, the design covers most wireless communication frequencies (WLAN, WiMAX, Wi-Fi); nevertheless, the low-frequency bands such as GSM and LTE applications are not covered.

Compact monopole antenna with broadband applications have been designed [7] with open loop and vertical stub on ground plan to enhance impedance bandwidth (4.26 to 10.92 GHz). The design has a small size which makes it suitable for broadband applications and upper WLAN band application,

In short, the previous two designs have not covered lower frequencies (GSM 660- 1100, GSM 1800, GSM 1900, LTE 700).

In order to face the relentless demand to achieve single antenna to cover many various bands, designers are looking for obtaining wideband or broadband single antenna to cover most of the indoor wireless application frequencies with keeping the compact in size and has good performance.

Before going to further development for monopole antennas, it is necessary to choose design has a capability to be modified and enhanced, in order to cover most wireless communication, especially the low-frequency bands mentioned above.

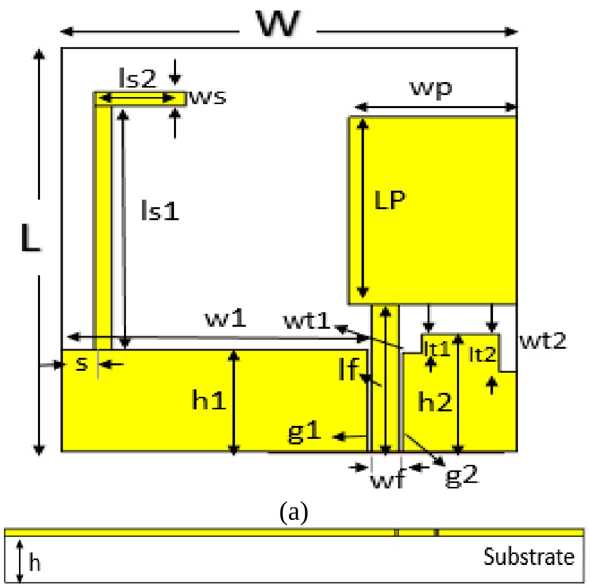
Based on new studies, coplanar waveguide CPW–fed techniques can be applied to monopole antennas due to their advantages of wide bandwidth, low profile, easy design and fabrication, reduced antenna size, easy modification and enhancement by patch slot added in the ground plan or by asymmetric ground plane [8][9]. By applying new technologies to achieve the desired design, these technologies can provide enough bandwidth and suitable polarization to facilitate modern wireless communication like circular polarization CP.

In recent works, there are many techniques used with CPW-fed, as in [10] asymmetric ground plane with a tuning stub applied to wide impedance bandwidth to create circular polarization CP. Moreover, inverted L strip used with CPW proposed design in [2] to enhance impedance bandwidth. However, the previous two designs provide wide bandwidth and can cover certain wireless communication frequencies, while first design does not cover LTE and GSM bands. Also, the WiMAX and upper WLAN bands are not covered by the second design.

A simple, low-profile, broadband CPW monopole antenna is presented by applying a modified CPW ground plan with a slot inserted in the right ground plan part to enhance the bandwidth for upper frequency band (4- 6 GHz), and applying inverted L strip to provide wide impedance bandwidth and can cover the lower frequency band, however. The proposed design is capable of operating at most in-building wireless frequencies, ranging from 1GHz to 6 GHz to cover GSM 1800, GSM 1900, LTE 1.7- 2.7, LTE 3.3 – 4.4, WiMAX (2.3,3.5,5.5), Wi-Fi (2.4, 5.5) and WLAN (2.4,5.2,5.8).

II. CPW MONOPOLE DESIGN STRUCTURE

CPW broadband monopole antennas were printed on a square microwave FR 4 dielectric substrate (permittivity 4.4, thickness 1.6 mm and loss tangent: 2.2). The overall size of the proposed antenna design is 50 x 55 x 1.6 mm. The geometry of the design is shown in Figure 1. Simulation of the proposed design was carried out use Computer Simulation Technology (CST). The antenna is fed by a 50 Ω CPW microstrip feed with width wf.



(a)

(b)

Figure1: Geometry of CPW-fed broadband monopole antenna (a) front view (b) side view

Table 1
The dimension of Proposed CPW-Fed Monopole Antenna (unit: mm)

Parameter	L	W	Lp	Wp	W1
Unit: mm	55	50	25.5	18.5	34
Parameter	h1	h2	g1	g2	wf
Unit : mm	14	16	0.35	0.35	3.06
Parameter	h	lf	ls1	ls2	ws
Unit : mm	1.6	20	33	10	2
Parameter	wt1	wt2	lt1	lt2	s
Unit : mm	2	2	2	5	3.5

As shown in Figure 1, the antenna design consists of a rectangular radiator patch, an asymmetric ground plane with inserted a slot in the right part of the ground plane, and inverted L strip placed on the left part of the ground plane.

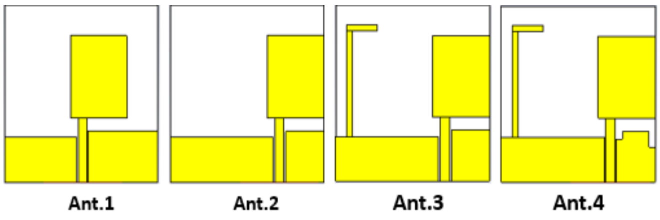


Figure 2. Four improved antenna prototypes of proposed antenna design structures

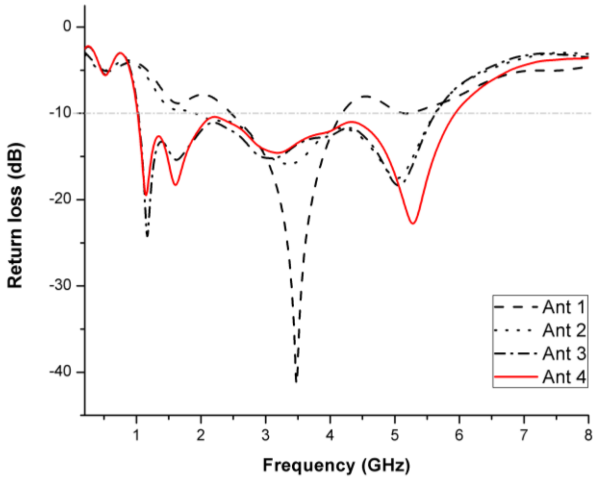


Figure 3. The simulated return loss for four improved antenna prototypes

To investigate the performance of the antenna structure, four prototypes are proposed and are shown in Figure 2. Ant 1 is a conventional CPW-fed monopole antenna with symmetrical width and an asymmetrical height ground plane; As shown in Figure 3, Ant 1 is proposed to realize the fundamental frequency band (2.6 – 4 GHz) at 3.5 GHz that bandwidth is 50.7%. A new resonant frequency mode in Ant 2 appeared centered at 5.25 GHz. The impedance bandwidth has been extended toward high frequency from 4 GHz to 5.8 GHz with enhanced bandwidth is 79% due to properly cutting the right CPW ground plane to the half, after employment inverted L strip on the left CPW ground plane in Ant 3, an additional impedance bandwidth extended toward the lower band. In addition to a new resonant mode has been appeared and centered at 1.17 GHz, a large impedance bandwidth could be achieved from 1 GHz to 5.65 GHz with bandwidth 139.8% as shown in Figure 3. The results of Ant 3 show the importance employment of inverted L strip with a ground plane as a great help for impedance bandwidth in order to extend the band from 2.6 GHz to 1 GHz. Little change has appeared for resonant modes. For Ant 4, the introduction of slots technique in the right ground plane is needed in order to mitigate the effects of employment inverted L strip. Use of the slots technique can enhance the impedance bandwidth in upper band side, however. The final enhanced bandwidth of the proposed antenna is 142% (5 GHz from 1GHz to 6GHz).

III. PARAMETRIC STUDY OF THE PROPOSED MONOPOLE ANTENNA

Several parameters including w1, h2, ls, and ls2 have very important effects on impedance bandwidth. Through parameter analyses, the optimal parameter values can be identified. For each parameter of these selected parameters, the other should be held constant. For greater clarification about parameters analyses, each parameter study is explained below.

A. The Effect of Right Ground Plane Cutting w1

As shown in figure 4, w1 has a great effect on impedance matching in both band (lower and upper band), with little changing at the center frequency. When the width of the right ground plane is decreased, the return loss RL will get more enhancement in most bandwidth ranges. The optimal value is w1=34 mm.

B. The Effect of Right Ground Plane Height h2

The influence of the right ground plane height h2 is observed in figure 5, which has an important effect on the return loss RL, where the bandwidth is significantly affected when h2= 10 mm. After that, when h2=13 and 16, the RL is enhanced. When h2= 19 the RL response is getting well at a higher frequency. Meanwhile, the RL is affected at a center frequency of 3.33 GHz. Based on parameter analyses, the optimal value for h2 was chosen, when h2= 16 mm.

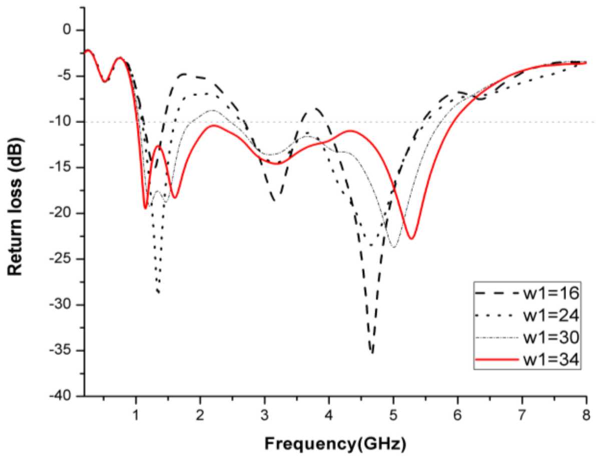


Figure 4: Simulated return loss with different w1

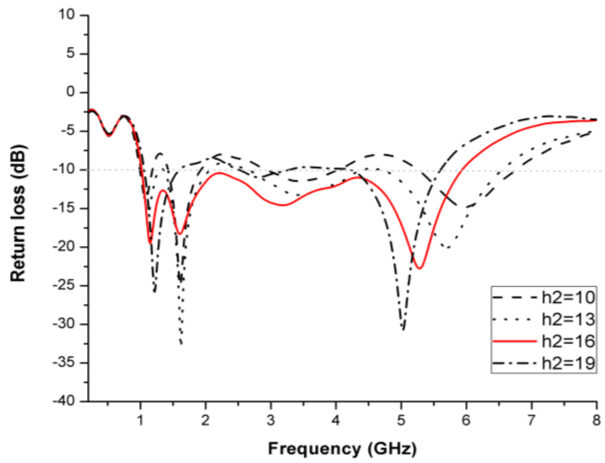


Figure 5: Simulated return loss with different h2

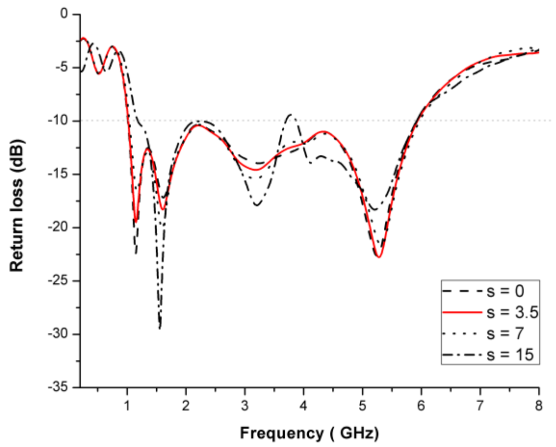


Figure 6: Simulated return loss with different S

C. The Effect of The Location of Inverted L Strip s

Adding the inverted L strip on the left ground plane has a great impact, as explained above. The effects of L location are shown in Figure 7, with little change in the lower band of S11. The strip is shifted twice by 3.5 mm toward the lift, while the return loss is unchanged at high frequencies. Return loss is affected when the strip is shifted more than 7mm. The optimized location for inverted L strip is s = 3.5 mm.

D. The Effect of Inverted L Strip Height ls

Changing the inverted L strip height ls has a great impact on RL. The effects are found in figure 6, as the length ls changed, the return loss changed at the lower frequency band, while the return loss at high frequency (upper band) is still unchanged. The lower band frequency is improved and tends to shift when the height ls is increased, meanwhile. Return loss is thus affected at the lower band when the ls=39 mm. The optimal value for strip length is ls=33 mm.

E. The Effect of Inverted L Strip Length ls2

Not only the height of inverted L strip s1 has effects on return loss performance. The length of inverted L strip has an important impact on return loss, as shown in figure 8. The increase in ls2 length in return loss RL mode in the lower band tends to shift toward low frequency. The return loss RL deteriorate with an increasing ls2 in a frequency range of 1 to 2 GHz, based on parameter study ls2=10.

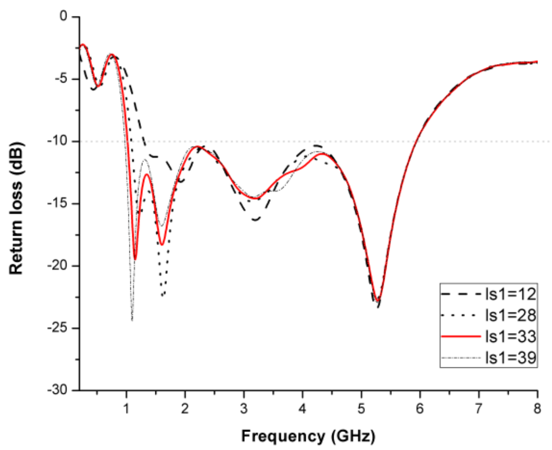
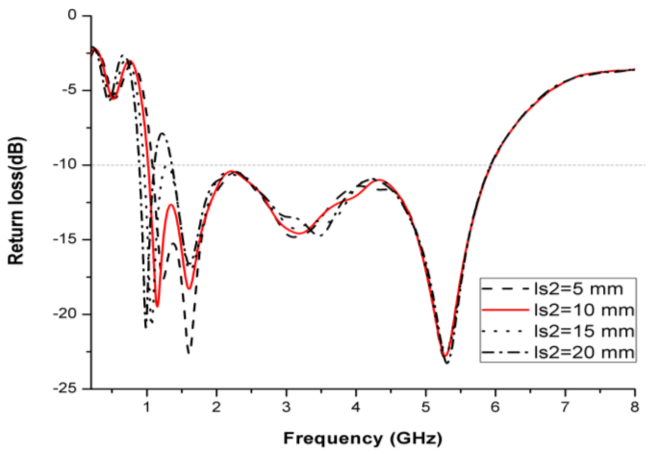


Figure 7: Simulated return loss with different ls1



.Figure 8: Simulated return loss with different ls2

Table 2
Comparison with Previous Works

Ref	type	Fc (GHz)	Frequency bandwidth (GHz)	10-dB RL bandwidth (%)	Size (mm^2)
[7]	CPW-Fed	2.9	1.48 - 4.24 (2.76)	96.5	50×55
[10]	CPW-Fed	4.8	2.13 - 7.46 (5.33)	111	50×50
[11]	CPW-Fed	4.6	1.9- 4 (2.1)	71.19	60×60
[6]	Monopole	4.3	7.35- 2.25 (5.1)	106.25	49 ×55
Proposed	CPW-Fed	3.5	1- 6	142.1	50 ×55

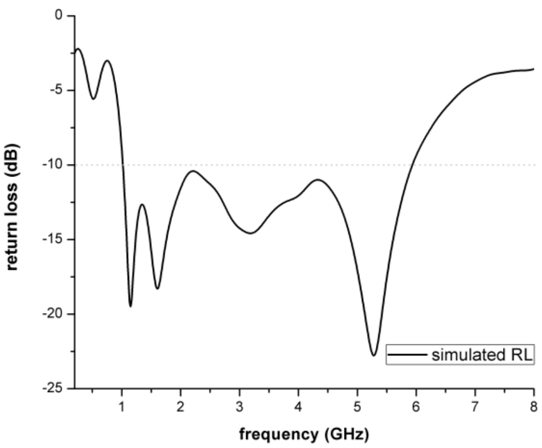


Figure 9: Simulated return loss for the proposed antenna

IV. ANTENNA RESULTS

Graphs of the effects of all structure parts on the antenna return loss show dimensional optimization for the proposed structure which covers the band range from 1GHz to 6GHz with whole dimensions (50× 55). In this study, we have tried to maintain a compact size compared to previous recent studies. The proposed design has wide bandwidth compared to previous studies, as shown in Table 2. Moreover, the proposed antenna has a peak gain of 2.3 dBi at 5 GHz.

Figure 9 depicts the return loss (RL) of the proposed antenna with a bandwidth of 5 GHz and fractional bandwidth 142.1%. Several planar monopoles offer more bandwidth than this work at the same size, but they employ high-frequency bands. Covering a low frequency with high-frequency applications with the same compact antenna is an important issue which challenges antenna designers.

V. CONCLUSION

A broadband CPW-fed monopole antenna has been proposed and simulated by properly cutting the right CPW ground plane, using an inverted L strip on the left ground plane, and incorporating slits embedded in the right ground plan. The performance of several parameters has been studied. The proposed antenna has wide impedance bandwidth with a range of 1 GHz to 6 GHz. The proposed antenna has more bandwidth compared to other structures, making it suitable for most indoor applications.

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