A Novel Coplanar Slot Antenna Structure for Wireless Applications

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Abstract

This paper presents a new compact broadband coplanar slot antenna for multiple wireless communication applications which include WIMAX, RFID, WLAN and ISM bands. The antenna structure is based on the CPW-fed combined with a slot technique and a modified geometry antenna in order to enlarge the bandwidth. The antenna parameters have been investigated and optimized by using Momentum software integrated into ADS" Advanced Design System" from Agilent Technologies with a comparison of the results using another simulator CST Microwave Studio. The measured input impedance bandwidth, ranging from 2.15GHz to 4.4GHz, is obtained with a return loss less than -10dB, corresponding to 66.7% at 3.27GHz as a center frequency. The design considerations for achieving broadband antenna and both experimental, simulated results are presented.

1. Introduction

Patch antennas suffer from narrow bandwidth which can limit their uses in some modern wireless applications [1-6]. Therefore, there has been a great demand of broadband antennas designing for supporting wideband applications such as Wireless Local Area Network, World Interoperability for Microwave Access Radio Frequency Identification Data, and Industrial, Scientific and Medical bands in order to meet the specifications of the WLAN at (2.4GHz-2.483GHz), the WIMAX at (3.4GHz-3.7GHz), the RFID at 2.45GHz and ISM bands at (2.4GHz-2.5GHz). Many research studies have come up with techniques to achieve wideband operation for printed antennas [7-13]. In this paper, a novel compact CPW-fed slot printed antenna structure is presented. The development of this broadband planar antenna has been achieved by the combination of a new geometry, slot technique and modified dimensions of the CPW transmission line to match and to wide input impedance of the antenna, to achieve a simple structure with a single metallic layer and to have an easy integration with microwave integrated circuit. The proposed antenna was miniaturized and the dimensions were optimized by using the ADS and CST Microwave Studio. Details for simulation and measurement results of the proposed antenna are presented and discussed.

2. Antenna Design

The geometry of the proposed broadband antenna slot structure is shown in Figure.1. It is implemented on a low cost FR4 substrate with an area of 40x50 mm2, a dielectric constant $\varepsilon r = 4.4$, a thickness h=1.58mm , a loss tangent $\tan\delta=0.001$ and the copper thickness of 35µm. The antenna is fed by a 50Ω CPW transmission line with the fixed strip W=3.2 mm and the gap distance S=0.4mm between the feeding line and the ground. The antenna and feeding structure are implemented on the simple plane; therefore only one layer single-sided metallization is used. The optimization parameters design is done by using Momentum electromagnetic software integrated into ADS, which contains different techniques and calculation methods [14]. For comparison, we have conducted another study by using CST Microwave Studio in frequency domain where the numerical analysis is based on FIT [15]. After many optimizations and miniaturizations, the dimensions of the final optimized design structure are listed in Table.1.

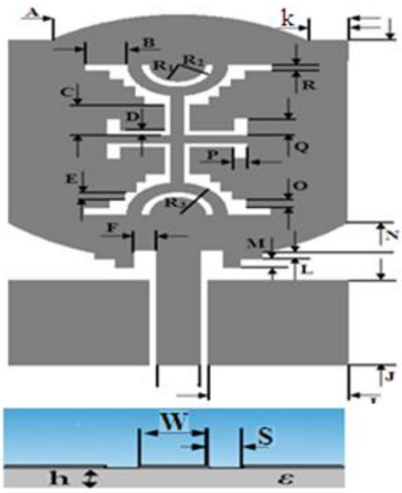


Figure 1- Geometry of the proposed antenna

Table 1- The optimized dimensions (unit: mm)

Parameters	Value	Parameters	Value
A	8.1	**M**	0.6
B	3	**N**	19
C	3.3	**O**	0.5
D	0.5	**P**	0.7
E	0.5	**Q**	1.2
F	1.1	**R**	0.5
I	10	**R1**	1.2
J	8	**R2**	1.4
K	2.9	**R3**	4
L	0.5		

To design the broadband antenna, we have studied some important parameters which can influence the input impedance bandwidth of the antenna. Therefore, as shown in Figure.2, we have found some important parameters such as geometric antenna shape, slot technique, the feed line width and the dimension of the ground plane that can enlarge the bandwidth of the antenna. The return loss for successive cases by using the optimization and miniaturization techniques integrated into ADS is presented in Figure.2. The final circuit is operating in a large frequency band between 2.15 GHz and 4.4 GHz. It is clear that the improvement of the input impedance bandwidth is due to the slot technique. The simulated values are given in Table.2.

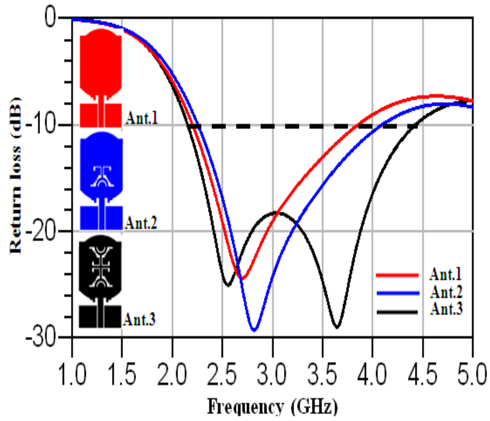


Figure 2- Return loss Vs frequency ”ADS results”

Table 2- The bandwidths of the proposed antenna for different cases

	Bandwidth	Frequency Center	Impedance Bandwidth
Ant.1	2.2-3.76GHz BW=1.58GHz	2.99GHz	52.84%
Ant.2	2.3-4GHz BW=1.7GHz	3.15GHz	53.96%
Ant.3	2.15-4.4GHz BW=2.25GHz	3.275GHz	68.7%

For the comparison of the following results we have conducted another simulation by using CST Microwave Studio. After the simulation, the following results are shown in Figure.3 and Table.3 respectively. We conclude that we have nearly the same results with ADS.

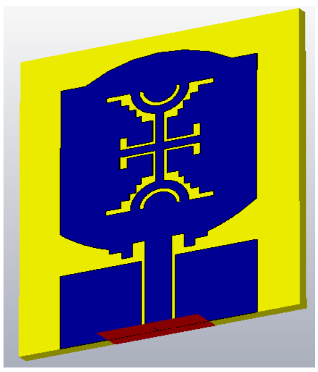


Figure 3- The final 3D antenna structure

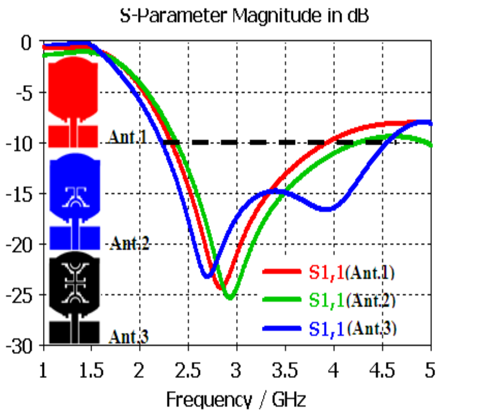


Figure 4- Return loss vs frequency"CST results"

Table 3- The bandwidths of the proposed antenna for different cases

	Bandwidth	**Frequency Center**	**Impedance Bandwidth**
Ant.1.	2.32-3.9GHz BW=1.58GHz	3.11GHz	50.8%
Ant.2.	2.36-4.1GHz BW=1.7GHz	3.27GHz	53.98%
Ant.3.	2.2-4.5GHz BW=2.3GHz	3.36GHz	67.9%

Figure.5. illustrates the simulated Voltage Standing Wave Ratio (VSWR) versus frequency of the final proposed antenna structure. Based on the simulated result, for a VSWR less than 2 the frequency range is 2.15GHz -4.4GHz.

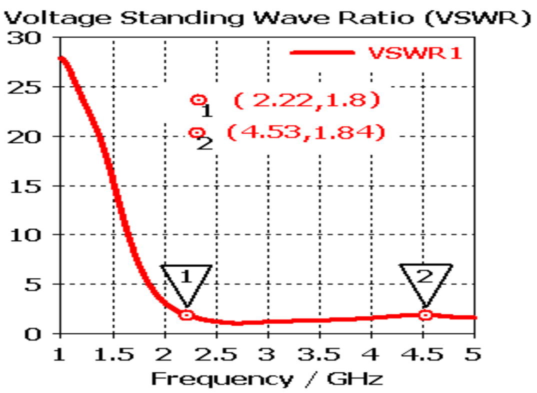


Figure 5- VSWR vs frequency

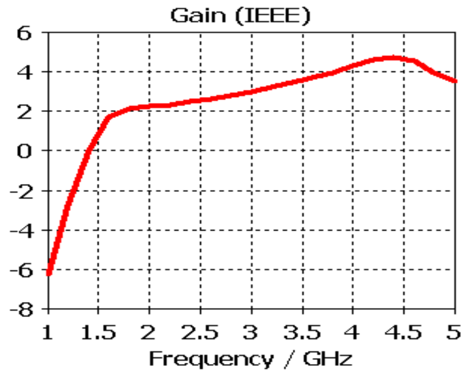
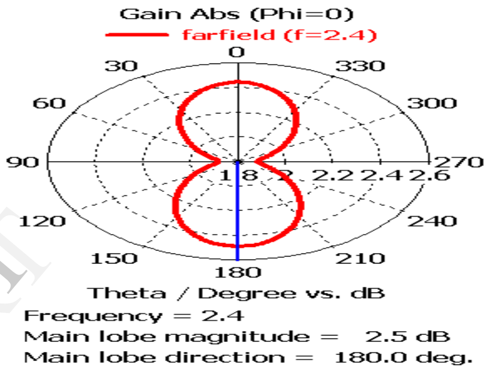


Figure 6- Gain vs frequency

The peak gain of the antenna for various frequencies is plotted in Figure.6. The simulated radiation pattern of the antenna at 2.4GHz, 3 GHz and 5.8 GHz are illustrated in Figure.7:



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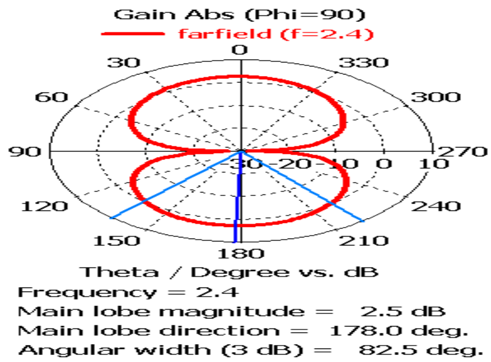

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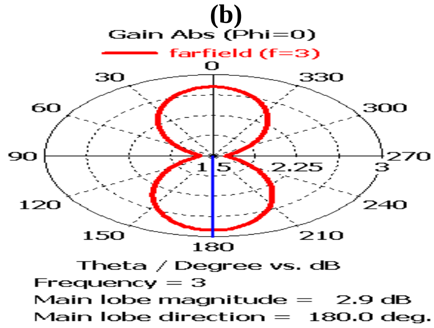

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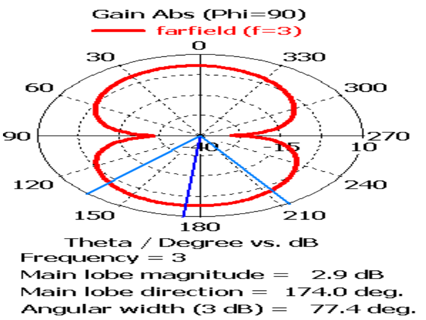

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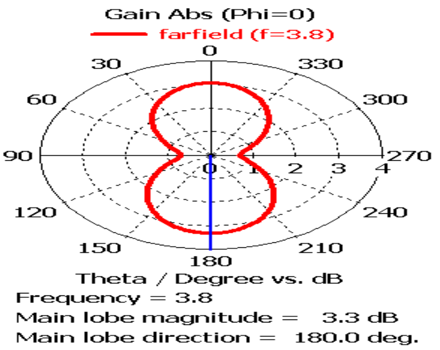

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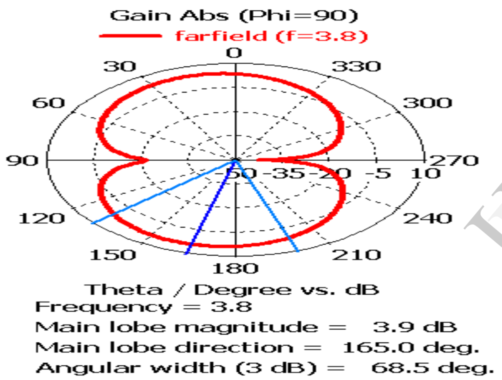


(f)

Figure 7- Simulated radiation pattern for the proposed antennas in Φ=0 and in Φ=90 @ 2.4 GHz, 3 GHz and 3.8 GHz

3. Experimental Results and Discussion

After the conception, optimization of the broadband antenna by using ADS and CST, the prototype of the investigated antenna was achieved and measured to verify the performance of the results obtained from simulation. The return loss was measured by using Vectorial Network Analyzer (VNA) R&S@ZVB20 from Rohde& Schwarz, and the radiation patterns were measured in Anechoic chamber as shown in Figure.8. The photograph of the fabricated broadband antenna is given in figure.9.

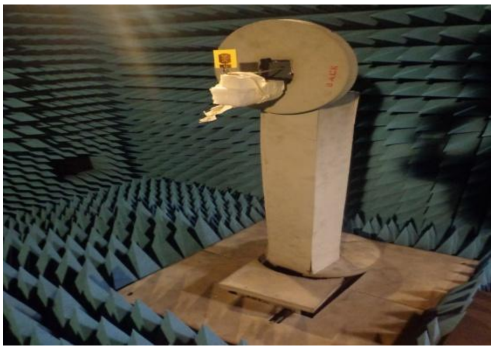


Figure 8- Anechoic chamber

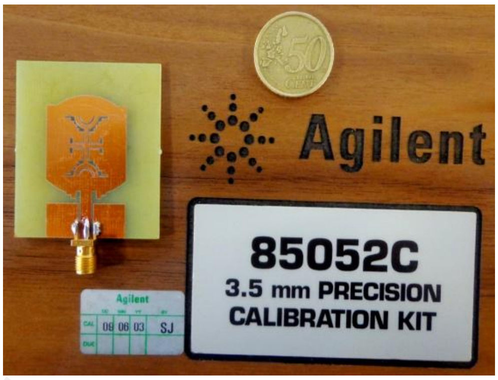


Figure 9- Photograph of the achieved broadband antenna

The measurement results, compared with the simulation of the planar broadband antenna configuration are presented in Figure.10. It is clearly observed that the simulation results are in agreement with measurement. This allows the validation of a novel broadband antenna structure operating from 2.15GHz to 4.4GHz. A comparison between measured and simulated input impedance bandwidth is shown in Table.4, we can conclude that the proposed antenna simulated gives a slightly lower frequency band in comparison with the measured one.

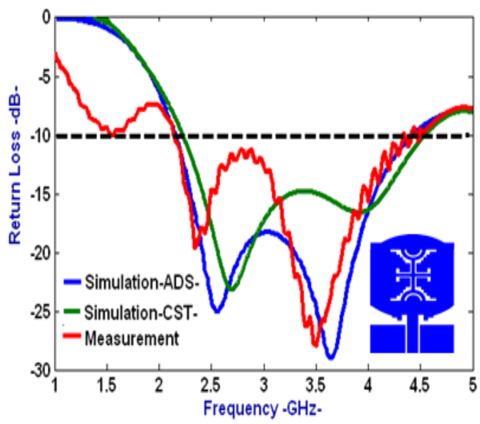
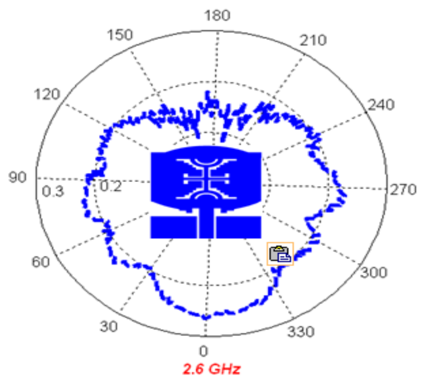


Figure10- Simulated and measured return loss vs frequency

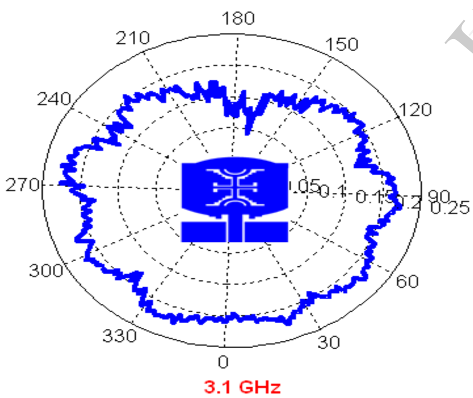
Table 4- Comparison between simulated and measured bandwidth

	The bandwidth/ Percentage
ADS	(4.38-2.15GHz) / 68.4 %
CST	(4.56-2.3GHz) / 66.2%
VNA	(4.4-2.15GHz) / 66.7%

The measured radiation patterns at 2.2GHz, 2.6GHz, 3.1GHz, 3.6GHz and 4.1GHz as shown in Figure.11. All these results allow the validation of the antenna structure with a large frequency band ranging from 2.15GHz to 4.4GHz and a bandwidth of 2.25GHz.



(a)



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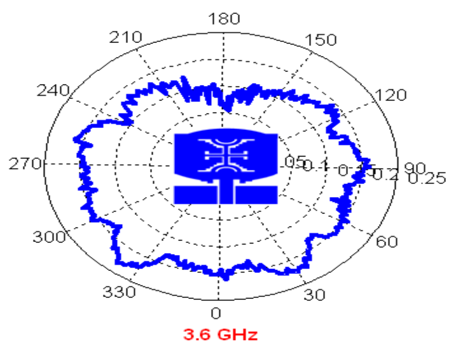

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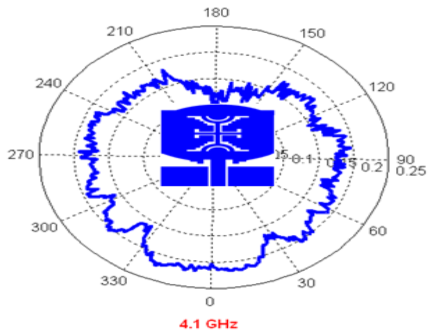

(d)

Figure 11- Measured radiation pattern at 2.6GHz, 3.1GHz, 3.6GHz and 4.1GHz

4. Conclusion

This work has presented a study of a new broadband antenna structure with a large input impedance bandwidth and gain enhancement. The different results are obtained by using an optimized CPW-fed transmission line combined with a new antenna geometry integrating slot technique. The measured results permit to validate a new wideband antenna structure from 2.15GHz to 4.4GHz. The final circuit can be integrated easily with passive and active components for wireless applications.

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