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Rostov-on-Don, Russia, September 27 – 30, 2013

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11th IEEE EAST-WEST DESIGN & TEST SYMPOSIUM (EWDTS 2013)
Rostov-on-Don, Russia, September 27-30, 2013

The main target of the **East-West Design & Test Symposium** (EWDTS) is to exchange experiences between the scientists and technologies of the Eastern and Western Europe, as well as North America and other parts of the world, in the field of design, design automation and test of electronic systems. The symposium aims at attracting scientists especially from countries around the Black Sea, the Baltic states and Central Asia. We cordially invite you to participate and submit your contribution(s) to EWDTS'13 which covers (but is not limited to) the following topics:

- Analog, Mixed-Signal and RF Test
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- Built-In Self Test
- Debug and Diagnosis
- Defect/Fault Tolerance and Reliability
- Design for Testability
- Design Verification and Validation
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- Embedded Software Performance
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- FPGA Test
- HDL in test and test languages
- High-level Synthesis
- High-Performance Networks and Systems on a Chip
- Low-power Design
- Memory and Processor Test
- Modeling & Fault Simulation
- Network-on-Chip Design & Test
- Modeling and Synthesis of Embedded Systems
- Object-Oriented System Specification and Design
- On-Line Test
- Power Issues in Testing
- Real Time Embedded Systems
- Reliability of Digital Systems
- Scan-Based Techniques

- Self-Repair and Reconfigurable Architectures
- Signal and Information Processing in Radio and Communication Engineering
- System Level Modeling, Simulation & Test Generation
- Using UML for Embedded System Specification

CAD Session:

- CAD and EDA Tools, Methods and Algorithms
- Design and Process Engineering
- Logic, Schematic and System Synthesis
- Place and Route
- Thermal, Timing and Electrostatic Analysis of SoCs and Systems on Board
- Wireless Systems Synthesis
- Digital Satellite Television

The Symposium will take place in Rostov-on-Don, Russia, one of the biggest scientific and industrial center. Venue of EWDTS 2013 is Don State Technical University – the biggest dynamically developing centre of science, education and culture.

The symposium is organized by Kharkov National University of Radio Electronics and Science Academy of Applied Radio Electronics http://anpre.org.ua/ in cooperation with Don State Technical University and Tallinn University of Technology. It is technically co-sponsored by the IEEE Computer Society Test Technology Technical Council (TTTC) and financially supported by Aldec, Synopsys, DataArt Lab, Tallinn Technical University, Aldec Inc.

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CONTENTS

Design and Optimization of a Planar UWB Antenna

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Abstract

In this paper, we present our design on a simple, low-profile wideband planar antenna with a pure circular radiator fed by a 50Ω microstrip line. By investigating the feeding position and ground plane dimensions, the antenna is optimized to have a very wide bandwidth that covers the whole FCC-allocated ultra-wideband (UWB) spectrum. Because of the additional patch beneath the radiator, the bandwidth can be further extended towards the lower side of the frequency spectrum. This antenna is finally modified to have a bandwidth from 2 to 12 GHz, which satisfies system requirements for S-DMB, WiBro, WLAN, CMMB and the entire UWB with S11 < -10dB.

1. Introduction

Since the Federal Communications Commission (FCC) of United States allocated the unlicensed frequency spectrum from 3.1 GHz to 10.6 GHz for commercial applications of ultra-wideband (UWB) technology in 2002 [1], ultra-wideband (UWB) technology has gained great popularity in research and industrial areas because of its high data rate wireless communication capability for various applications. As a crucial part of the UWB system, UWB antennas have been investigated extensively by researchers and numerous proposals for UWB antenna designs have been reported [2-5]. In [2], a new ultra-wideband antenna consisting of two steps, a single slotted patch and a partial ground plane is designed to operate from 3.2 to 12 GHz. In J. N. Lee's work [3], an ultra-wideband antenna composed of a modified trapezoidal radiating patch, a PI-shaped matching stub, CPW feeding, and two steps for impedance matching has been proposed for UWB applications. In [4], an ultra-wideband microstrip-fed monopole antenna with a narrow slit and a modified inverted U-slot on the patch is presented.

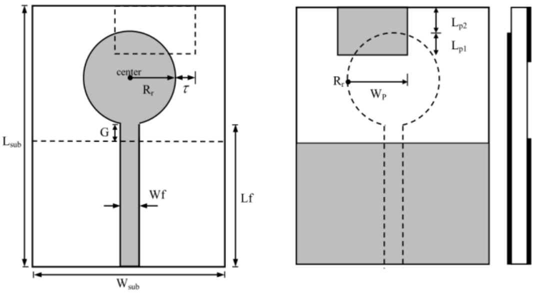
Recently, a small planar antenna fed by a microstrip line has been investigated and designed to exhibit dual-band operation for Bluetooth (2.4 - 2.484 GHz) and UWB (3.1 - 10.6 GHz) bands [5]. However, many of the proposed designs employed slots or other complicated modifications in the antenna radiator and/or ground plane. These designs may pose complications during fabrication of the antenna since the tolerance of the increased special features/variables could be problematic when it goes to mass production, and instability due to the fact that complicated antenna structures may also occur in practice. Therefore, we are motivated to design a low complexity, low cost and compact antenna with wide frequency coverage supporting various applications such as Satellite Digital Multimedia Broadcasting (S-DMB), Wireless Broadband (WiBro), Wireless Local Area Network (WLAN), China Multimedia Mobile Broadcasting (CMMB) and UWB.

In this paper, we present a very simple circular planar antenna with operating bandwidth ranging from 2 GHz to 12 GHz by integrating several techniques into one compact antenna. The design approach is very similar to our previously reported paper [6]. We start with a simple circular planar antenna fed by a 50Ω microstrip line with a truncated ground plane. Next, based on the study of the size of the radiator and current distribution, the antenna is designed to have an operating bandwidth covering the entire UWB band, i.e. 3.1 - 10.6 GHz. Then, the study on the size of the partial ground plane is conducted to increase the bandwidth towards the lower side of the frequency spectrum, to cover the bands for WLAN (2.4 - 2.484 GHz) and CMMB (2.635 – 2.66 GHz). With an extra patch printed on the back side of the substrate, underneath the circular radiator, the bandwidth can be further increased to cover Wibro (2.3 - 2.4 GHz) and S-DBM (2.17 -2.2 GHz) without significantly influencing other frequency bands. Thus the proposed antenna can be used for various applications such as S-

DMB, Wibro, WLAN, CMMB and the UWB. The operating bands are evaluated using computer software with the criterion of having return loss S11 less than -10 dB. Simulated radiation patterns over the whole frequency bands are acceptable.

2. Antenna configuration and design

Fig. 1 shows the top, bottom and side views of the proposed antenna as well as its dimensions. As stated before, the antenna structure comes from a conventional design: a simple pure circular planar monopole antenna. The radius of the radiator R_r is a critical parameter associated with the operating frequencies and input impedance of the antenna.



(a) Top (b) Bottom (c) Side

Fig. 1. Configuration of the proposed antenna where shaded areas are the conductors.

Accordingly, R_r is selected to have a reasonable value at f_{mid} = 7 GHz, which is the approximate center frequency of the UWB band. A good starting point for the dimension is as follows:

$$R_r \cong \frac{1.8412\, c}{2\pi f_{\text{middle}}\sqrt{\varepsilon_r}} \qquad (1)$$

where c is the speed of light in vacuum and is the dielectric constant of the substrate. R_r is optimized to have reasonable return loss for the whole frequency band.

Following optimization of R_r, the radiator radius ends up with a size of 8.2 mm (R_r) and it is then placed on top of a 70 mm x 60 mm (L_{sub} x W_{sub}) FR4 substrate with dielectric constant ε_r = 4.4 and height h = 1.58 mm.

In order to fulfill the requirements of a portable device, a microstrip feed line has been chosen for the antenna feeding network. The following synthesis equations help determine the dimension of the microstrip line [7]:

For

$$W_{eff} / h \geq 2$$

$$W_{eff} = \frac{2h}{\pi}\left\{ \begin{array}{l} \frac{\varepsilon_r - 1}{2\varepsilon_r}[\ln(B-1)+0.39-0.61/\varepsilon_r] \\ +B-1-\ln(2B-1) \end{array} \right\} \qquad (2)$$

For

$$W_{eff} / h \leq 2$$

$$W_{eff} = 8he^{A} / (e^{2A}-2) \qquad (3)$$

$$W_f = W_{eff} - \frac{t}{\pi}\left[1+\ln(2h/t)\right] \qquad (4)$$

Where W_{eff} and W_f are the effective and physical widths of the microstrip line; *h* and *t* are the thickness of the substrate and patch respectively.

$$A = \frac{Z_{ol}}{60}\left(\frac{\varepsilon_r+1}{2}\right)^{0.5} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}(0.23 + 0.11/\varepsilon_r)$$

$$B = \frac{377\pi}{2Z_{ol}\sqrt{\varepsilon_r}}$$

Where Z_{ol} is the characteristic impedance. These equations provide the starting point for a 50Ω microstrip line with a width of 2.36 mm.

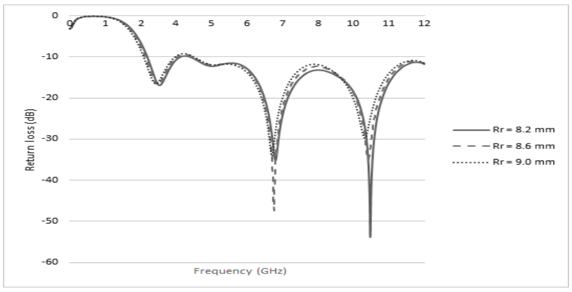


Fig. 2. Return loss due to different size of the radiator

3. Parametric studies and simulation results

The computer aided design and optimization are conducted using CST Microwave Studio 2009 [7].

A. *Learning the feeding position*

The feed position is then studied. Fig. 2 gives the return loss of the antenna due to different radiator sizes. It can be seen that the operating bandwidth is affected by the size of the radiator and when the radius of radiator is increased to 9 mm, the resulting bandwidth is increased from 3.1 GHz to 12 GHz, covering the entire UWB band.

It is worth mentioning that impedance matching is very sensitive to the dimensions of the antenna. For different stages, the antenna dimensions should be slightly re-optimized to achieve impedance matching.

B. Studying the size of the truncated ground plane

Fig. 3 gives the return loss of the antenna due to different lengths of the ground plane. Again, at this stage, to meet the impedance matching requirement, the antenna dimension must be slightly adjusted. It can be seen that the lower side of the operating bandwidth becomes even lower, following the increment in the length of the ground plane which determines the lowest usable frequency. When L_f = 25 mm and the radius of radiator is set to 10.8 mm, as seen from Fig. 3, the antenna is designed to cover 2.37 GHz - 12 GHz, which is then able to include the bands necessary for CMMB and WLAN applications.

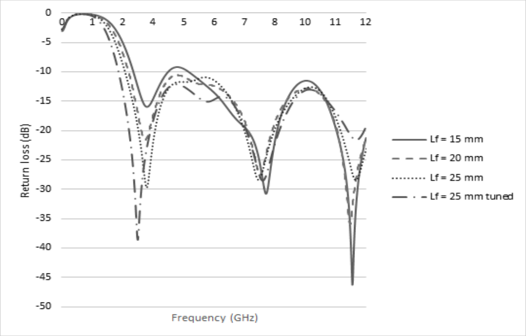


Fig. 3. Return loss due to varying ground plane length

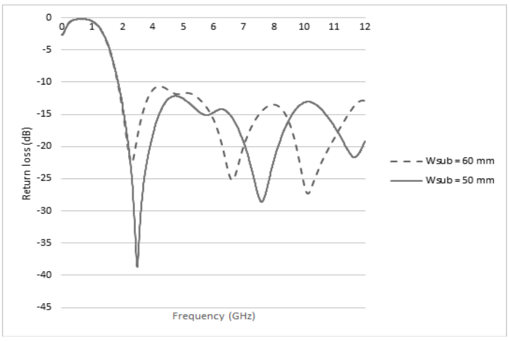


Fig. 4. Return loss due to reduced substrate width.

For space saving purpose, the substrate width is reduced to 50 mm. At the same time, the radius of radiator is increased to 11.2 mm while the feed line width is optimized to 2 mm for impedance matching purpose. Comparison with the unreduced substrate design is made in Fig. 4. When the width of the substrate is reduced, impedance matching is significantly affected. This is due to the influence on current distribution, since for a UWB planar antenna, the electric current is greatly affected by the shape and size of the system ground plane [8-9].

C. Investigating the additional patch

To cover more bands, a promising idea is to add an extra patch underneath the radiator, on the bottom side of the substrate (Fig. 1(b)). Intensive work has been done to investigate the antenna performance due to different dimensions of the additional patch.

We set Lp1 = 0 mm, Lp2 = 2.8 mm, Wp = 16 mm and τ = 0 mm as a starting point for our study. Then Lp1 is varied to see the differences in antenna performance. The return loss plots due to different values of Lp1 are shown in Fig. 5. From the plots, it is found that increasing Lp1 can help extend the lower bandwidth to the lower side. It should be noted that the overall bandwidth is hardly affected by further increments in Lp1 as long as it reaches 1 mm. However, impedance matching is improved at lower frequencies due to a larger Lp1.

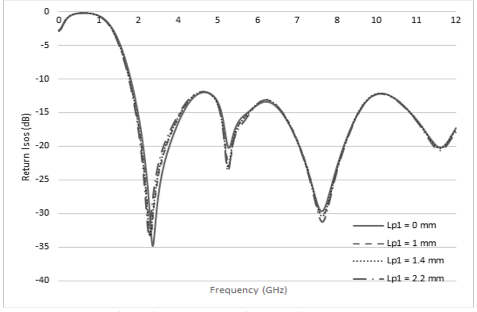


Fig. 5. Parametric study on L_{p1}.

Next, we hold L_{p1} = 1.4 mm, L_{p2} = 2.8 mm and τ = 0 mm and observe how W_p affects performance. Changes in return loss due to the variation in W_p concluded in Fig. 6 is clear that W_p affects the middle frequency band but hardly the lower and upper bands.

Next, we start to investigate how the extending part τ influences the return loss. Based on the above findings, we begin with L_{p1} = 2.2 mm, L_{p2} = 2.8 mm and W_p = 13 mm. The simulation results are put into Fig. 7. Again, it can be observed that the extending part τ can affect impedance matching in the middle frequency band while presenting negligible influence on the lower and upper bands.

Based on the above results, the parameters are set to L_{p1} = 2.2 mm, W_p = 13 mm and τ = 0 mm. Investigations are then made on L_{p2} to see if variations in L_{p2} influence the antenna performance. Fig. 8 gives the simulation results. It is clear that a larger L_{p2} helps move the lower bands towards the lower side of the frequency spectrum without influencing the upper bands, resulting in ultra-wide bandwidth ranging from 2 - 12 GHz. Moreover, impedance matching is greatly improved at lower frequencies.

Up to now, optimized dimensions for the UWB planar antenna with additional patch are as follows:

W_{sub} x L_{sub} = 50 x 70 mm^2; R_r = 11.2 mm
L_f = 25 mm; W_f = 2 mm; G = 0.8 mm

L_{p1} = 2.2 mm; L_{p2} = 15 mm; W_p = 13 mm
τ = 0 mm

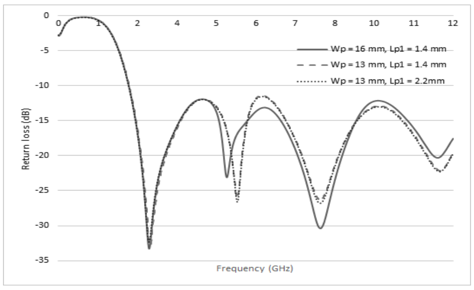


Fig. 6. Parametric study on Wp

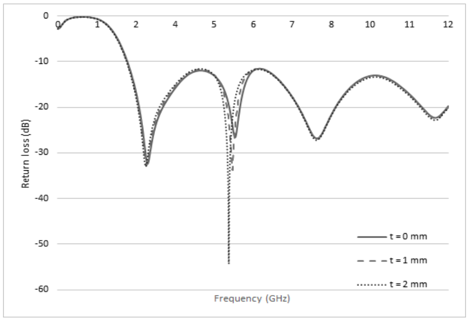


Fig. 7. Parametric study on τ.

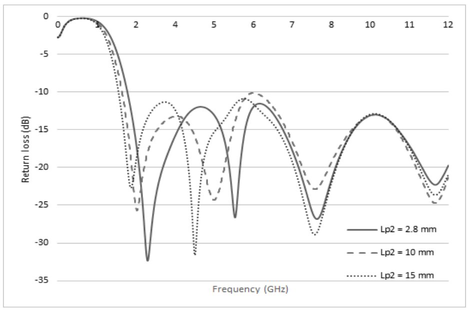


Fig. 8. Parametric study on Lp2.

Comparison between the optimized design and the one without the extra patch in terms of the return loss is given in Fig. 9.

The antenna is then fabricated and the microstrip port is then connected to a Vector Network Analyzer (VNA) where the return loss is measured against simulated results.

Preliminary results show that the measured return loss does not match simulation results. Following refinements of the antenna, the finalized dimensions are eventually obtained:

W_{sub} x L_{sub} = 50 x 70 mm^2; R_r = 10.8 mm
L_f = 25 mm; W_f = 2.5 mm; G = 0.8 mm
L_{p1} = 2.2 mm; L_{p2} = 15 mm; W_p = 13 mm
τ = 0 mm

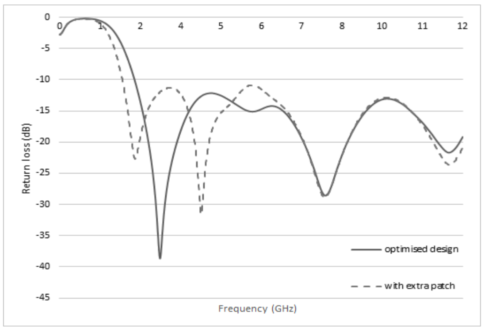


Fig. 9. Comparison between optimized design and the one without the extra patch.

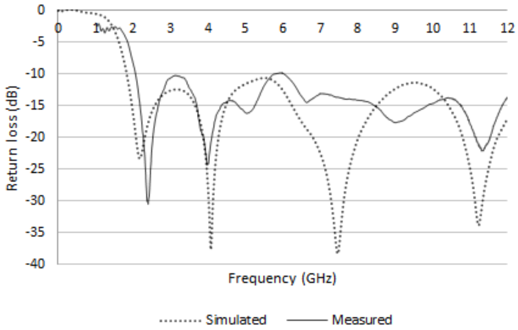


Fig. 10. Simulated versus measured return loss.

The measured return loss can be seen in Fig. 10 and it shows the antenna performing within specifications. Simulations for radiation pattern have been performed at 2.4 and 10 GHz (see Fig. 11 and 12). The radiation pattern at y-z plane (E-plane) is of donut shape, and the pattern at x-y plane (H-plane) is omnidirectional at lower frequencies, and shifted to -y direction which contributes more at higher frequency bands.

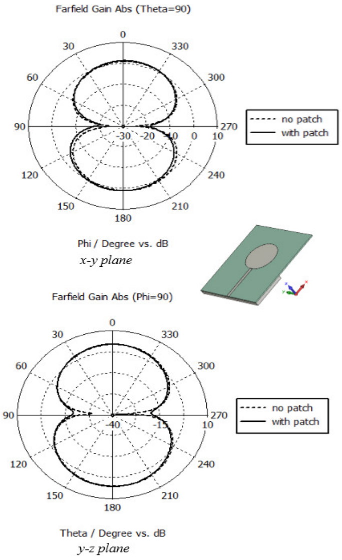
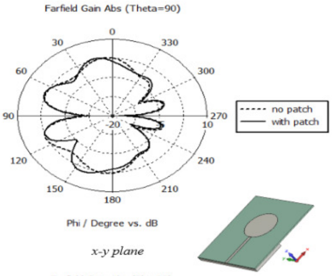
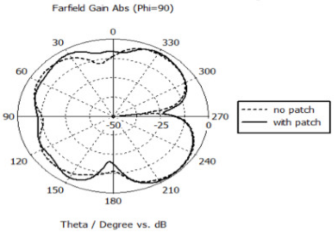


Fig. 11. Comparison of radiation patterns at 2.4 GHz



x-y plane



y-z plane

Fig. 12. Comparison of radiation patterns at 10 GHz.

4. Conclusion

In this paper, a wideband rectangular planar antenna fed by a simple 50Ω microstrip line for various applications has been presented. With the help of a parasitic patch beneath the radiator, the bandwidth has been optimized to cover WiBro and S-DMB bands, as well as WLAN, CMMB and the FCC UWB bands. The proposed design is simple and low-profile.

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