Bandwidth optimization of an ultra-wide band microstrip antenna

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2 authors:

J.M.J.W. Jayasinghe
Wayamba University of Sri lanka

Omar Saraereh
Hashemite University

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Jeevani W. Jayasinghe
Department of Electronics,
Wayamba University of Sri Lanka,
Kuliyapitiya, Sri Lanka.
jeevani@wyb.ac.lk

Omar A. Saraereh
Department of Electrical engineering
The Hashemite University
Zarqa, Jordan
ELOAS2@hu.edu.jo

***Abstract*—Thispaper presents an Ultra-Wide Band (UWB) microstrip antenna designed by optimizing four antenna parameters. The antenna was etched on an FR4_epoxy substrate with relative permittivity of 4.4 and thickness of 1.6 mm. The design process starts with a conventional microstrip antenna which has a S_{11}< -10 dB fractional bandwidth of 5%. The performance improvement methods are described presenting the resonant behavior at each development stage.The ground plane has been truncated and a slot has been placed on the patch. The size of the ground plane, position of the slot and size of the slot have been optimized. In the optimized design, a fractional bandwidth of 117% has been achieved. The UWB performance has been analyzed with the help of the S_{11} plot and the current patterns.**

Keywords—ultra-wide band;microstrip antenna; bandwidth; optimization; wireless communication

I. INTRODUCTION

Ultra-Wide Band (UWB) technology facilitates high-speed data transmission rate with low power consumption. As the Federal Communications Commission (FCC) approved the frequency band of 3.1 to 10.6 GHz for UWB radio applications [1], there a big demand for UWB antennas in emerging fields of wireless communications, radar applications, medical imaging and indoor positioning. Microstrip antennas are very attractive to be developed for UWB applications with their light weight, low cost, small size and low profile [2]. Further, they can be easily integrated with modern compact electronic devices.

However, conventional microstrip antennas have a narrow bandwidth, low gain and poor radiation efficiency. Microstrip antennas with classical shapes have an inherent drawback of narrow bandwidth with a S_{11}< -10 dB fractional bandwidth of only few percent.Therefore, design of UWB microstrip antennas with a fractional bandwidth higher than 100% is a challenging task for antenna designers.

Numerous performance improvements have been used by the antenna research community to increase the bandwidth of microstrip antennas. Use of truncated or defected ground plates [3-4], etching slots or slits on the patch radiator [5-7], stacking multiple patch elements [8-9], use of non-conventional shapes for the patch [10-11] and inserting shorting pins connecting the patch to the ground [12-13] are some of the widely usedbandwidth enhancementtechniques. These performance improvement techniques creates several current paths with different lengths making the antenna resonates at multiple frequencies [14]. The antenna parameters can be designed to make several resonant frequencies closer to each other. Then the multiband antenna starts to perform as a wideband antenna.

This paper proposes design of a microstrip line-fed UWB antenna by incorporating a truncated ground and a slot and optimizing properties of them. Section II describes the optimization process of antenna parameters. Section III presents a discussion on the results. Finally, Section III concludes the findings.

II. ANTENNA DESIGN METHODOLOGY

An FR4_epoxy substrate with relative permittivity of 4.4 and thickness of 1.6 mm has been used to design the UWB antenna. Dimensions of the substrate were 35.6mm × 56.6mm and initially a full ground plane on one side of the dielectric substrate was considered. A patch with a size of 15.6mm × 12mm has been etched on the other side of the substrate. The patch size was designed in order to make the antenna resonate in the fundamental mode. A 50Ω microstrip line with a width of 4 mm and length of 30 mm has been used to feed the radiating patch element (Fig. 1).Width of the microstrip feeding line w has also been calculated by using the standard equations (1).

$$Z_c = \begin{cases} \dfrac{60}{\sqrt{\varepsilon_{reff}}} \ln\left[\dfrac{8h}{w} + \dfrac{w}{4h}\right] & \dfrac{w}{h} \le 1 \\ \dfrac{120\pi}{\sqrt{\varepsilon_{reff}}\left[\dfrac{w}{h} + 1.393 + \dfrac{2}{3}\ln\left[\dfrac{w}{h} + 1.444\right]\right]} & \dfrac{w}{h} > 1 \end{cases} \tag{1}$$

where Z_c is the characteristic impedance, ε_{reff} is the effective substrate permittivity and $h$is the substrate thickness.

As the feeding line is etched in the same plane as that of the patch, it may affect the radiation.ANSYS HFSS software has been used to model antennas, to run simulations and to create reports.

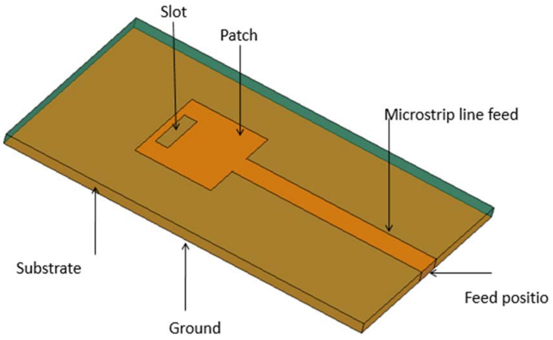


Fig. 1. Antenna Configuration

The design approach was optimization of the position of the slot as the first antenna parameter. A slot with a random size of 6 mm × 8mm was embedded at five different locations in which *P*= 2 mm, 4 mm, 6mm, 8mm and 9mm and compared with the performance of a microstrip antenna with no slots. The maximum bandwidth can be obtained when the slot is placed 6mm away from the edge of the antenna(Fig. 2). Compared to the single resonance behavior at no slots situation, the antenna resonates at three frequencies between 8 GHz and 12 GHz when a slot is placed at the optimum position.

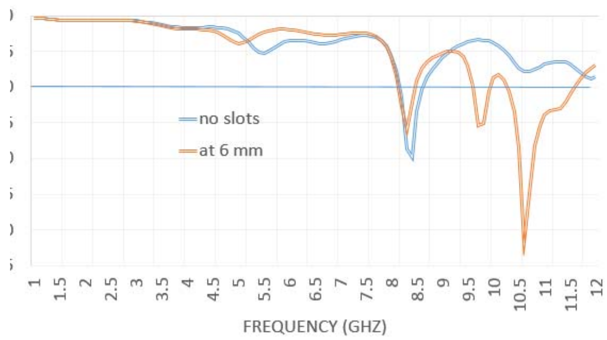


Fig. 2. Optimization of the slot position

The next experiment was to find the best width of the slotP_w. Six different slot widths of 1mm, 2mm, 3mm, 5mm and 6mm were tested by placing the slot in the middle of the patch.

The highest bandwidth can be obtained when the slot width $P_w$is 2 mm. Fig. 3. Shows the resonant behavior of the antenna for three different P_w values. When a large slot is embedded, the patch area reduces resulting low bandwidth.

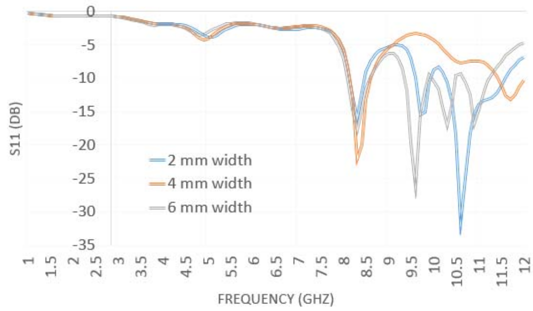
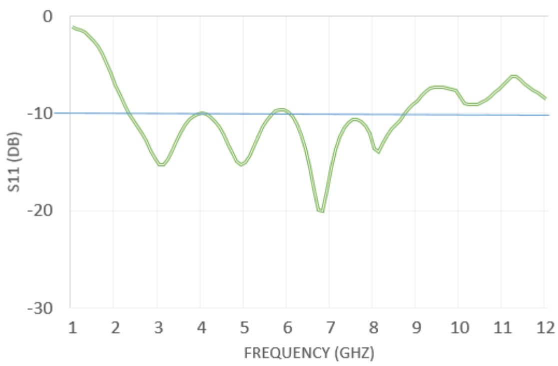


Fig. 3. Optimization of the slot width

Ground planes with different sizes were considered thereafter. According to the simulation results, the best performance is shown when the size of the ground plane is 35.6mm × 29 mm. With the truncated ground, the bandwidth has been improved considerably resonating at four frequencies (Fig. 4). More importantly, the resonance has been shifted to the lower frequencies between 2GHz and 9 GHz. However, still the antenna shows multiband performance instead of



expected UWB performance.

Fig. 4. Optimization of the ground plane

Finally, five slot lengths of 6mm, 7mm, 8mm, 9mm and 10 mm were testedon the antenna with a truncated ground. The best performance was found when the slot length P_l is 8mm. After optimizing the slot length, a continuous bandwidth could be obtained(Fig. 5).

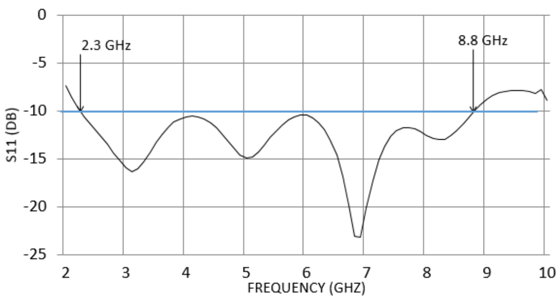


Fig. 5. Optimization of the slot length

The dimensions of the optimized microstrip antenna design is shown in Fig. 6. A slot with a size of 8 mm × 2 mm has been etched on the patch with a size of 15.6 mm × 12 mm to obtain UWB performance.

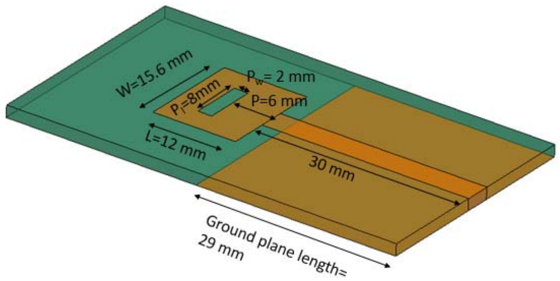


Fig. 6. Optimized UWB antenna

III. DISCUSSION

In the initial conventional microstrip antenna design with no slots and truncated ground planes, the fractional bandwidth was 5% showing narrow band performance. Four antenna parameters; size of the ground plane, position of the slot, length of the slot and width of the slot have been optimized to design a UWB microstrip antenna. After optimizing all of the aforementioned parameters, the antenna operates in the S_{11}< -10 dB frequency range of 2.3 GHz -8.8 GHz. Hence, the optimized antenna has an improved fractional bandwidth of 117%.

The UWB performance could be achieved as the microstrip antenna resonates at four discrete frequencies; 3.2 GHz, 5.1 GHz, 6.9 GHz and 8.3 GHz and at each resonance frequency it has a fair bandwidth to merge with each other.

The current pattern of the optimized antenna has also been studied(Fig. 7). The current flows starting from the feeding line towards the opposite edge of the microstrip antenna. The current path is elongated due to the disturbance created by the slot. As a result of the longer current paths, the antenna resonates at lower frequencies.

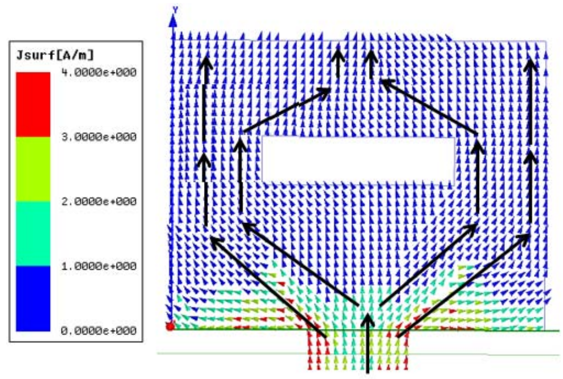


Fig. 7. Current patterns

IV. CONCLUSION

This paper presents optimization of multiple antenna parameters to achieve UWB performance and analyses the antenna characteristics. Among the considered antenna parameters, the size of the ground plane found to be the highest impact factor. When a microstrip line feeding method is used, a truncated ground plane increases the bandwidth. Placing a slot disturbs the classical current path and increases the electrical size of the microstrip patch. Therefore, the position, length and width of the slot also effect the bandwidth performance of a microstrip antenna.

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