CPW-fed ground short-circuited staircase rectangular monopole UWB antenna

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Abstract

In this paper, a planar CPW-fed ground short-circuited staircase rectangular monopole antenna is proposed for UWB systems. By connecting ground plane at the edge of a staircase rectangular monopole, lower edge resonance frequency moves from 3.5GHz to 2.66GHz in the proposed antenna, hence wide impedance bandwidth can be obtained. The proposed antenna, which includes two-step impedance transformed CPW feed and four-step rectangular patch, experimentally reaches a measured -10 dB impedance bandwidth of 12.11 GHz (from 2.66 to 14.77 GHz) covering the entire UWB band. Also, a moderate gain variation from 1.87 to 5.18 dBi and a monopole-like radiation pattern are obtained. The measured results are in good agreement with the simulated results.

1. Introduction

For many years, the Ultra-Wideband (UWB) communication systems have much attention because of their low spectral power density and higher data rates. Designed for short-range, wireless personal area networks (WPANs), UWB is the leading technology for freeing people from wires, enabling high-speed wireless connection of multiple devices for transmission of video, audio and other high-bandwidth data. The UWB system complements other longer range radio technologies such as Wi-Fi, WiMAX, and cellular wide area communications. It is used to relay data from a host device to other devices in the immediate area (up to 10 meters). This system provide fast transmission speed (more than 500 Mb/s), which is 10 times faster than the wireless local area network (WLAN) standard. A traditional UWB transmitter works by sending billions of pulses across a very wide spectrum of frequencies several GHz in bandwidth. The corresponding receiver then translates the pulses into data by listening for a familiar pulse sequence sent by the transmitter. Specifically, UWB is defined as any radio technology having a spectrum that occupies a bandwidth greater than 20 percent of the center frequency, or a bandwidth of at least 500 MHz. UWB's combination of broader spectrum and lower power improves speed and reduces interference with other wireless spectrum. In the United States, the Federal Communications

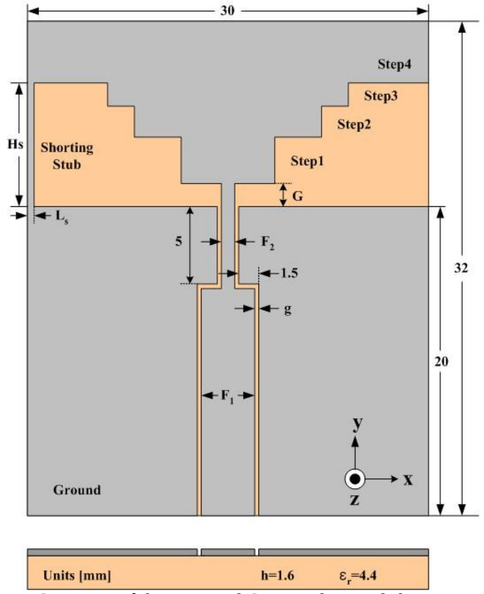

Fig. 1: Geometry of the proposed CPW-Fed ground short-circuited staircase rectangular monopole UWB antenna

Commission (FCC) has mandated that UWB radio transmissions can legally operate in the range from 3.1 GHz up to 10.6 GHz, at a limited transmit power of -41dBm/MHz. Consequently, UWB provides dramatic channel capacity at short range that limits interference. To support this system, an UWB antenna has to satisfy wide impedance bandwidth of 3.1-10.6 GHz, phase linearity and gain flatness with compact size, easy fabrication and low cost. For the trade off between gain (bandwidth) and antenna (patch) size to design the UWB antenna, it is important to select the feeding type and matching technique. So, many planar broadband antennas have been studied and reported for UWB communications that using monopole and dipole based structures. Normally CPW-fed and microstrip-fed UWB antennas are the basic feeding techniques for the monopole and dipole antennas. The techniques for UWB antenna were such as a probe-fed bevel with a shorting post [1], microstrip-fed rectangular monopole with a shorting hole [2], microstrip-fed monopole with narrow slit [3], CPW-fed rectangular monopole with two parasitic elements and three slots [4] and CPW-fed

trapezoidal monopole with two steps [5]. The use of shorting pin and posts has been shown to reduce the lower-edge frequency by introducing an extra mode, and this makes the antenna smaller. For UWB antennas, the matching technique of short-circuiting with ground plane was introduced in coaxial-feeding [1] and microstrip-feeding [2], but CPW-feeding type antenna was not reported. It motivates this study.
In this paper, a planar CPW-fed ground short-circuited staircase rectangular monopole UWB antenna is proposed. It looks like a single layered inverted-F antenna. The proposed antenna consists of a two-step impedance transformed CPW-fed line and four-step staircase rectangular patch with a ground short-circuited stub at the one side of the fourth staircase edge. Both of the simulation and measurement results with return loss and radiation patterns are presented and discussed.

2. Antenna Design

Fig.1 shows the geometry of the proposed antenna. The antenna is mounted on the FR4 dielectric substrate which is thickness of 1.6 mm and relative permittivity (ε_r) of 4.4. As shown in this figure, the antenna includes a planar four-step staircase rectangular monopole with a ground short-circuited stub and two-step impedance transformer at the CPW-fed line. The size of the staircase rectangular patch is only 30 × 10.5 mm^2 and the total antenna size is 30 × 32 mm^2. The CPW transmission line has two strip widths of F_1 = 4 mm and F_2 = 1 mm. The gap (g) between the feed line and ground plane is 0.3 mm to obtain 50Ω port impedance. The two-step impedance transformer of the CPW-fed line changes the feed line impedance from 47Ω to 64Ω. Each ground plane has two-step dimension 12.7 × 15 mm^2 (F_1 feed side) and 14.2 × 5 mm^2 (F_2 feed side). The impedance bandwidth for planar monopole has been shown to be dependent on the feed-gap separation G. The gap (G) between the step 1 rectangular patch and ground plane is optimized at 1.5 mm. Also, the ground short-circuited stub of H_s=8 mm and L_s=0.5 mm is connected to the step 4 rectangular left edge for lower resonance frequency enhancement. The upper resonance frequency is dependent on the geometry of the patch element close to the ground plane and feed, where the current density is greatest. In this paper, the mid and upper frequency band matching is controlled by changing the dimension of the simple staircase monopole. The four-step rectangular

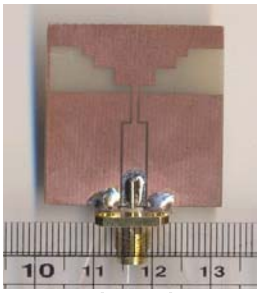

Fig. 2: Implemented Antenna

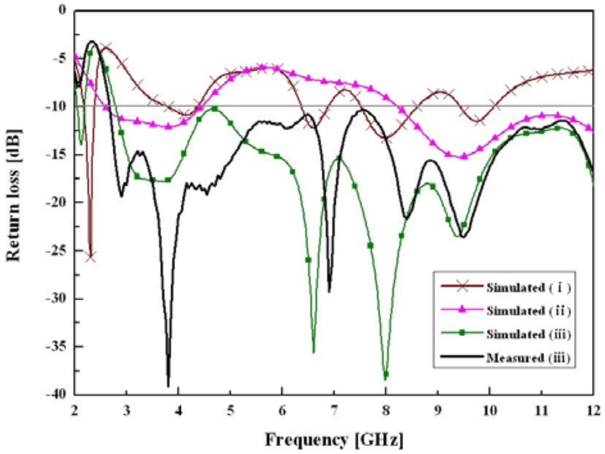

Fig. 3: Simulated and measured return loss for the proposed antenna
(□) single-step feed (4mm) and with ground short-circuited stub
(□) two-step feed and without ground short-circuited stub
(□) two-step feed and with ground short-circuited stub (proposed design)

staircases are composed of step 1 (7 × 3 mm^2), step 2 (14 × 2 mm^2), step 3 (18 × 1.5 mm^2) and step 4 (30 × 4 mm^2). Fig.2 shows the implemented antenna of the proposed design.

3. Results

The proposed antenna was designed and optimized using the Ansoft high-frequency structure simulator (HFSS) simulation software. The return loss was measured using the Agilent Technologies N5230A (10 MHz - 20 GHz) PNA-L Network Analyzer. The impedance matching of 2 ~ 5 GHz band is affected mainly by the dimension of step 3 and 4 and that of 5 ~ 15 GHz is affected by step 1 and 2 in the simulation. To investigate the effect of two-step impedance transformed CPW-feeding and ground short-circuited stub, each case was simulated and depicted in Fig.3. It shows the simulated and measured return loss of the antennas for the single-step (4 mm) feeding with ground short circuited stub (ⅰ), two-step feeding without a ground short circuited stub (□) and two-step feeding with a ground short circuited stub (□). In case of two-step feeding and ground short-circuited stub, the staircase monopole can have wide impedance bandwidth. Increasing the input impedance of the rectangular monopole, the ground short-circuited effect is maximized significantly. The simulated results are well agreed with the measured ones. The measured return loss of the two-step impedance transformer antennas with (□) and without (□) ground short-circuited stub is shown in Fig. 4. The measured -10 dB impedance bandwidth is 12.11 GHz (from 2.66 to 14.77 GHz). Due to the ground short-circuited stub the lower resonant frequency is moved from 3.49 to 2.66 GHz. With this lower frequency improvement the overall impedance bandwidth is also enhanced. The first resonance frequency is directly associated with the dimension of the staircase rectangular monopole because the current is mainly distributed along the edge of the staircase. The distance from the lower center point of step 1 to the right side edge of step 4 is 25.5 mm. This is

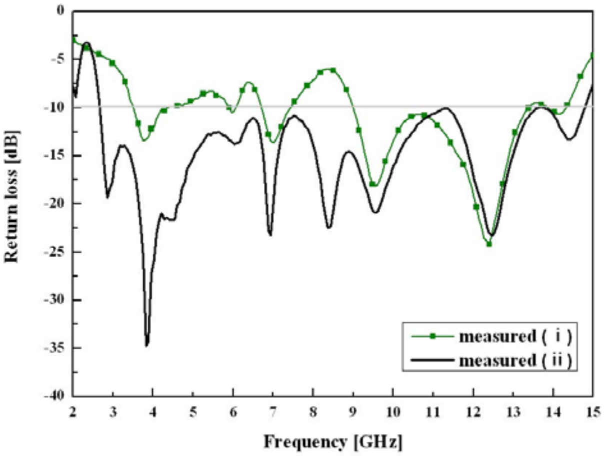

Fig. 4: Measured return loss
(□) without ground short-circuited stub
(□) with ground short-circuited stub (proposed design)

the 0.37 wavelength at the lower edge frequency of 2.66 GHz. In this design, the length of patch from ground plane is focused to minimize, hence 10.5 mm is only about 0.15 wavelength and 30 mm is 0.43 wavelength of the first resonance frequency. In commercial antenna design, the size of antenna is a critical factor for implementation. For example, mobile handset antenna is supposed to have smaller vertical length and height than horizontal length. With this ground short-circuited stub to the monopole antenna, more wide impedance bandwidth can be obtained while minimize the feed direction (vertical) length of the patch and enlarge the horizontal length. The simulated current distribution is shown in Fig. 5. Fig. 5(a) shows the current pattern near the first resonance at 3 GHz. The current pattern at 8 GHz is shown in Fig. 5(b). As shown in Fig. 5, the current is mainly distributed along the edge of the staircase patch and ground short-circuited stub, which indicates that the ground short-circuited stub acts as the part of the radiating structure. The current of 8GHz is mainly distributed from feed to the ground short-circuited stub. The measured radiation patterns of the proposed antenna in the x-z plane and y-z plane at 3.0, 5.5, and 8.0 GHz frequencies are illustrated in Fig. 6, respectively. The patterns, which are normalized to maximum gain, show acceptable variation in pattern with varying the frequency.

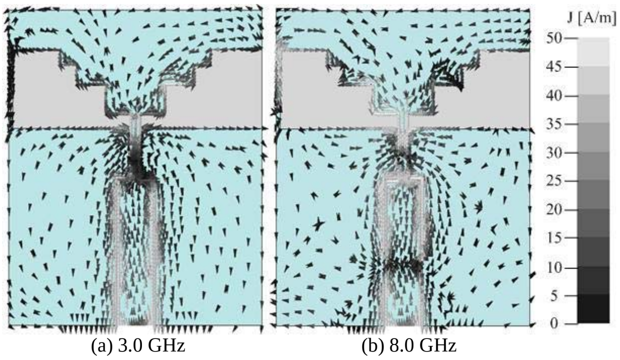

Fig. 5: Current distribution of the proposed antenna

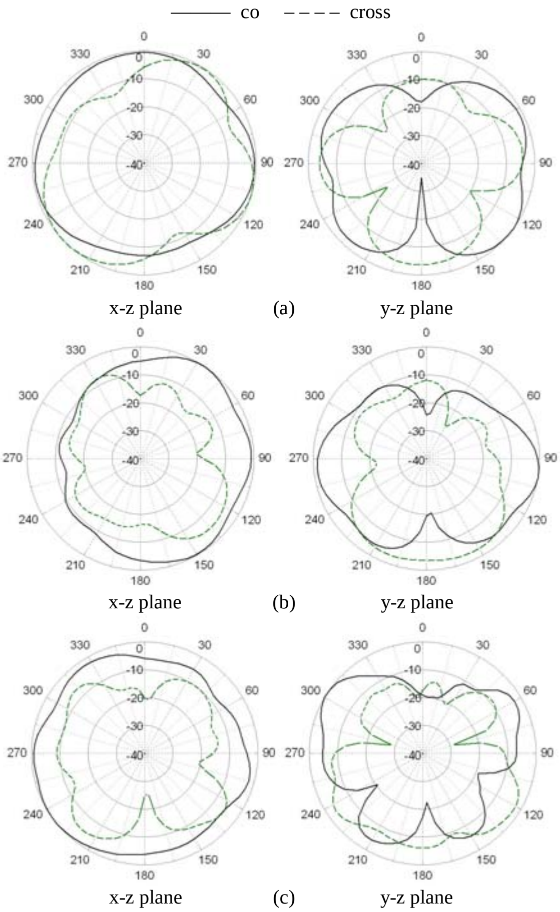

Fig. 6: Measured radiation patterns for the proposed antenna
(a) 3.0 GHz; (b) 5.5 GHz; (c) 8.0 GHz

Monopole-like radiation patterns in the y-z planes is shown at 3GHz, but the higher frequencies pattern (5.5 and 8 GHz) is distorted because of other current modes. The radiation patterns in the x-z planes are approximately omni-directional over the all frequencies. In Fig. 7 the measured antenna gains are about 1.87–5.18 dBi with small variation of 3.31 dB.

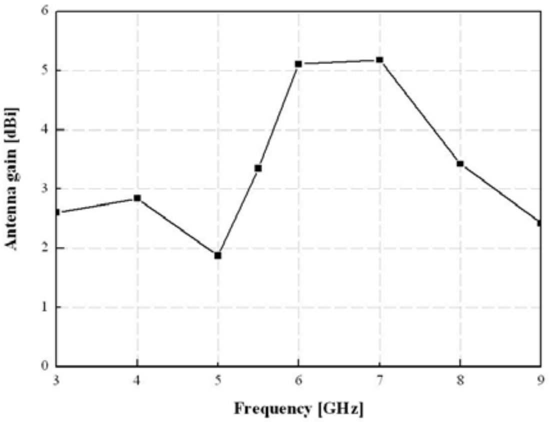

Fig. 7: Measured peak gain of the proposed antenna

4. CONCLUSION

A planar CPW-fed ground short-circuited staircase rectangular monopole antenna has been proposed and implemented for UWB applications. Using the four-step rectangular monopole, a ground short-circuited stub and a two-step impedance transformer, the proposed CPW-fed UWB antenna yield wideband impedance bandwidth of 2.66–14.77 GHz. Good radiation characteristics and moderate gain are obtained at the entire UWB band. The CPW-fed structure with ground short-circuited could be preferred in MMIC technology due to the ease of fabrication.

REFERENCES

[1] M.J. Ammann., and Z.N. Chen., "A wide-band shorted planar monopole with bevel", IEEE Trans. Antennas Propag., vol. 51, pp. 901-903, April 2003.

[2] K.L. Wong., L.C. Chou., and F.S. Chang., "Printed short-circuited wideband monopole antenna with band-notched operation", Microw. Opt. Technol. Lett., vol. 46, pp. 58-61, Dec 2005.

[3] K.H. Chung., H. Park., and J.H. Choi., "Wideband microstrip-fed monopole antenna with a narrow slit", Microw. Opt. Technol. Lett., vol. 47, pp. 400-402, May 2005.

[4] K. Chung., T. Yun., and J. Choi., "Wideband CPW-fed monopole antenna with parasitic elements and slots", Electron. Lett., vol. 40, pp.1038–1040, Aug 2004.

[5] S.H. Lee., J.K. Park., and J.N. Lee., "A novel CPW-fed ultra-wideband antenna design", Microw. Opt. Technol. Lett., vol. 44, pp. 393-396, Aug 2005.