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COMPACT UWB CHIP ANTENNA DESIGN USING THE COUPLING CONCEPT

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Abstract—This article describes a compact UWB chip antenna using the coupling concept. The inclined slot is inserted on the rectangular radiating patch of the UWB chip antenna. From experimental results, the measured impedance bandwidth of the antenna (defined by −6 dB return loss) is 2.5 GHz (3–5.5 GHz). Also, the proposed antenna exhibits good radiation patterns with small gain variation (2.5–3.5 dBi) in the operating frequency band. Details of the proposed antenna design and the simulated and measured results are presented and discussed.

1. INTRODUCTION

UWB technology has attracted much attention for use in short-range high-speed wireless communication applications. UWB has allocated 7.5 GHz of spectrum for unlicensed use by the FCC in February 2002 for communication applications in the 3.1 to 10.6 GHz frequency band. There are two main approaches as a solution for the IEEE 802.15.3a standard: MB-OFDM (Multi-Band Orthogonal Frequency Multiplexing) and DS-CDMA (Direct-Sequence Code Division Multiple Access). The DS-CDMA approach uses three spectral modes of operation, low band (3.1 to 5.15 GHz), high band (5.825 to 10.6 GHz), and multi-band (low band plus high band). MB-OFDM approach divides its full band 3.1 to 10.6 GHz into 14 sub-bands with each bandwidth of 528 MHz. Each sub-band consists of 128 tones and is modulated with OFDM. The MB-OFDM approach uses lower three bands (3.1 to 4.8 GHz) as a mandatory mode [1]. In this paper, we will focus on the UWB antenna design in the MB-OFDM system

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over $3.1 \sim 4.8$ GHz or low band of DS-CDMA. The UWB antenna for use in portable systems requires an omni-directional radiation pattern, ultra-wideband, small size, flat gain and linear phase, and low-cost.

Recently, many researchers have developed UWB antennas operating in the UWB frequency band such as UWB patch antenna [2, 3], omni-directional and low VSWR UWB antenna [4], various planar UWB antennas [5–12], UWB slot antenna [13], and UWB antenna using Sierpinski sieve fractal [14]. But the size of the published UWB antenna is large and there is a demand for the size reduction of the UWB antenna as the size of the mobile hanset becomes small. So, compact UWB chip antenna using LTCC techniques was proposed for UWB applications [15–19]. The proposed UWB chip antennas are small ceramic chip antenna [15], UWB slot antenna on LTCC substrate [16], UWB chip antenna using LTCC multilayer technology [17], LTCC planar UWB antenna [18], and a planar antenna in LTCC [19]. However, the proposed UWB chip antenna using LTCC technology is not easy to manufacture and expensive in cost.

In this paper, we have proposed a UWB chip antenna using the coupling concept. The target frequency band is $3.1 \sim 5.15$ GHz (DS-CDMA low band or MB-OFDM lower three bands). We have obtained the bandwidth enhancement of the proposed UWB chip antenna by using the inclined coupling slot on the rectangular radiating patch. The proposed UWB chip antenna is easy to manufacture and inexpensive. The target frequency band can be tuned by adjusting the width of the inclined slot. The prototype chip antenna has dimensions of 10 mm by 10 mm. The proposed antenna exhibits good radiation patterns with small gain variation (2.5–3.5 dBi) in the operating frequency band. To evaluate the dispersion performance of the designed UWB antenna, the path loss ($|S_{21}|$) and the group delay are simulated and measured. The path loss is almost constant across the frequency band and the group delay variation is less than 2 ns. The commercial simulator HFSS of Ansoft [20] is used to simulate and optimize the proposed antenna. The simulated results have a reasonable agreement with measured results.

2. ANTENNA DESIGN AND SIMULATED/MEASURED RESULTS

Figure 1 shows the geometry of the proposed UWB chip antenna. The proposed antenna including main board has dimensions of 40 mm $\times$ 100 mm and the dielectric substrate of FR-4 (thickness: 0.8 mm, $\varepsilon_r = 4.4$) is used. Top and bottom ground planes are connected via hole and the signal is excited into the chip antenna through CPWG feeding. The rectangular radiating patch of the UWB chip antenna has

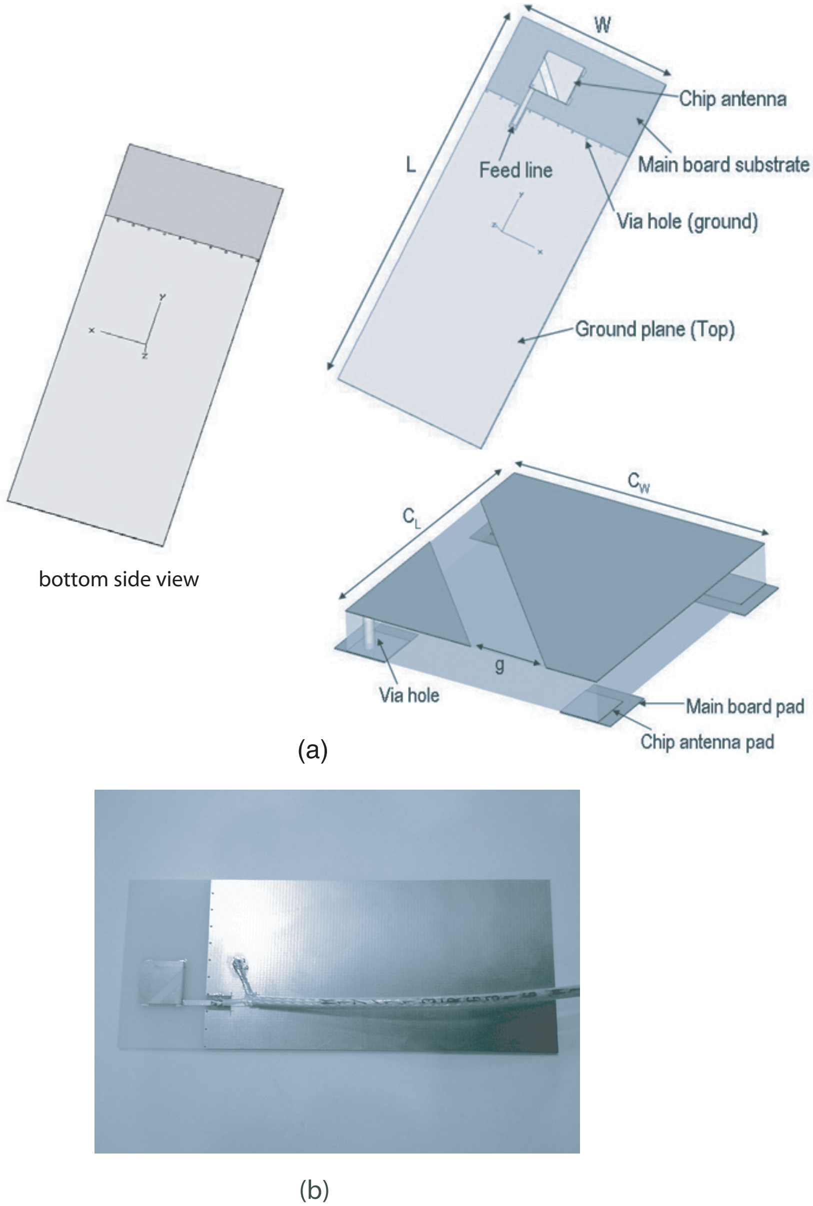


Figure 1. (a) Geometry of the proposed UWB chip antenna, (b) photograph of the fabricated chip antenna.

dimensions of 10 mm × 10 mm and the dielectric substrate of Rogers TMM 10 (thickness: 1 mm, $\varepsilon_r = 9.2$) is used. Figure 1(a) is the structure of the UWB antenna including main board. Figure 1(a) shows the detailed structure of the UWB chip antenna. As shown in the figure, the inclined slot is inserted on the rectangular radiating patch. The chip antenna pad and the main board pad are used to fix the UWB chip antenna on the dielectric substrate of main board. Via hole is used

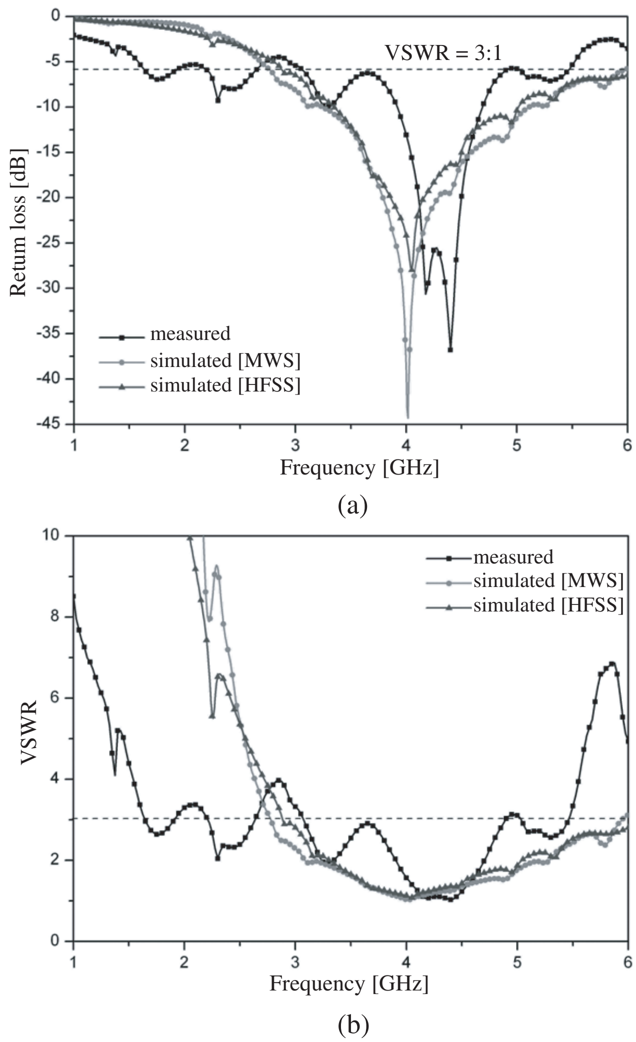


Figure 2. Measured and simulated results: (a) Return loss, (b) VSWR.

to connect the CPWG feed line to the small radiating patch separated by the inclined slot. Figure 1(b) is the photograph of the fabricated antenna. The optimal parameters can be chosen as $W = 40\,\text{mm}$, $L = 100\,\text{mm}$, $C_W = 10\,\text{mm}$, $C_L = 10\,\text{mm}$, and $g = 3\,\text{mm}$. The simulation results have been obtained from two different commercial softwares, HFSS of Ansoft and MWS of CST, making sure that the obtained results are trustable.

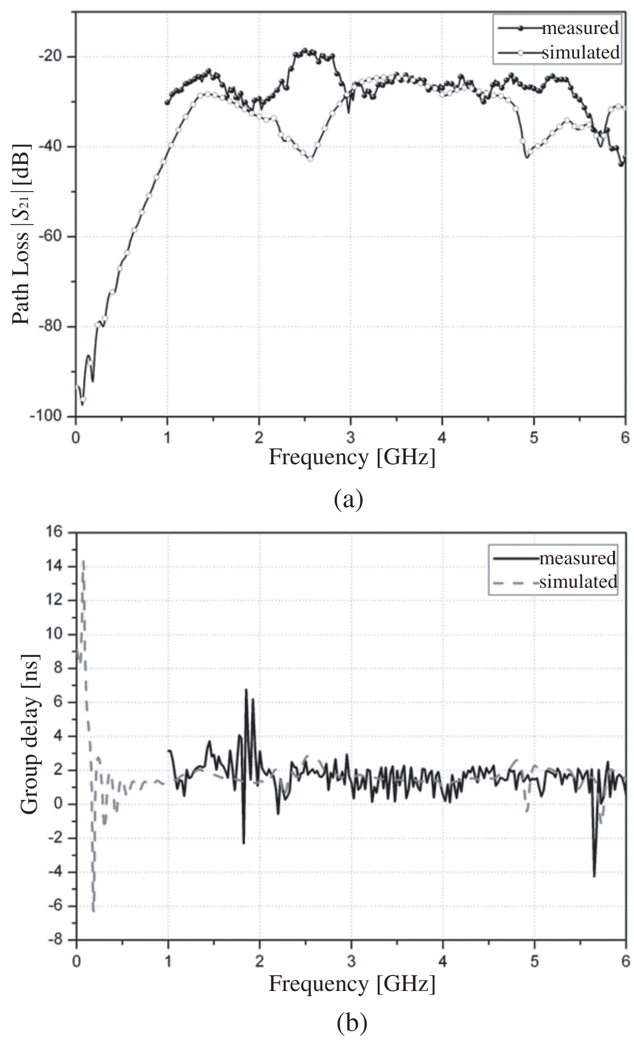


Figure 3. Measured results of the UWB chip antenna: (a) path loss ($|S_{21}|$), (b) group delay.

The antenna was measured using Anritsu Vector Network Analyzer (37397C) in an anechoic chamber. The measured and simulated return loss and VSWR of the designed antenna are shown in Figure 2. The proposed UWB antenna has the bandwidth of 3 to 5.5 GHz at below −6 dB where the VSWR is 3:1. The discrepancy between the measured and simulated results can be explained as follows. In the simulation, the dimension of the antenna structure was ideal and the loss of the coaxial feed cable was not considered and the size of the small chip radiating patch is very small so the effect of coaxial feed cable loss cannot be negligible.

Group delay is an important parameter in UWB antenna design, which indicates the pulse distortion. To evaluate the dispersion performance of the designed UWB antenna, the path loss ($|S_{21}|$) and the group delay are simulated and measured. Figure 3 shows the measured group delay and the path loss of the UWB chip antenna. As shown in the figure, the variation of the group delay is less than 2 ns and the path loss is almost constant (−30 dB) across the operating frequency band. Thus, the UWB antenna is suitable for the UWB communication applications. For the measurement, the distance between the two antennas is 30 cm and the antenna orientation is face-to-face. We have measured the group delay by using Vector Network Analyzer as a function of the azimuth angle and presented the results in Figure 4. The group delay variation is increased as the azimuth angle approaches 90 and 180 degrees.

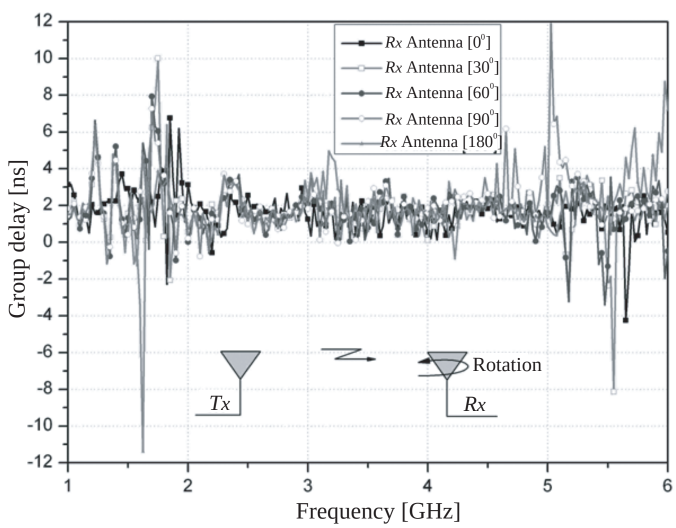


Figure 4. Measured group delay for different azimuth angle.

We have studied the effect of the inclined slot on the return loss. Figure 5 shows the variations of the return loss versus frequency as a function of the width of the inclined slot. It can be seen that as the

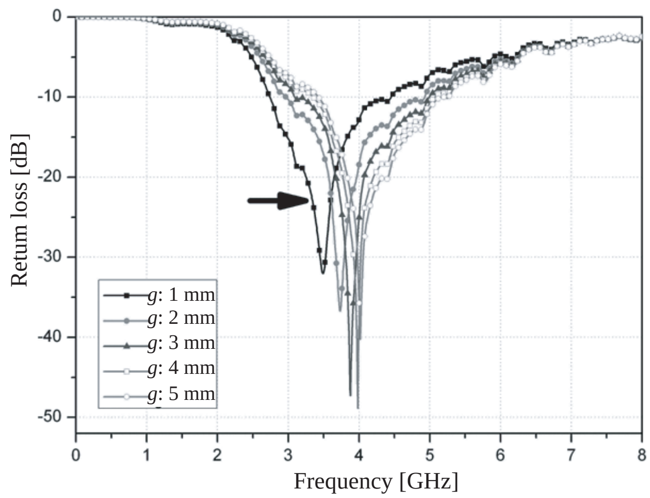
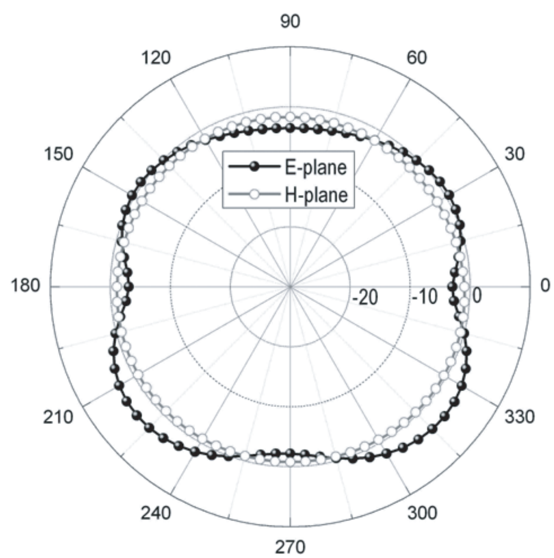
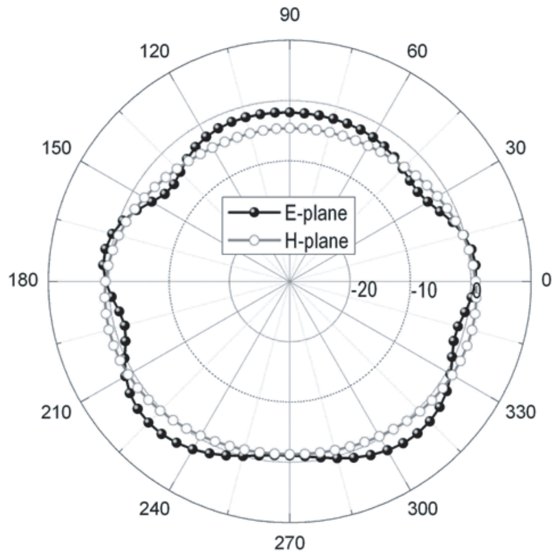


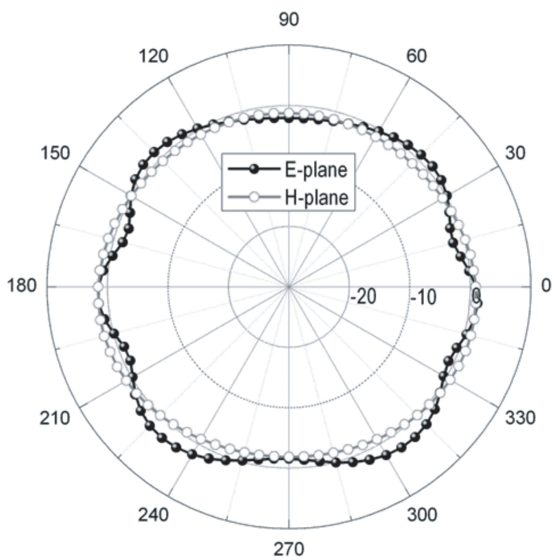
Figure 5. Variations of the return loss versus frequency as a function of the width of the inclined slot.



(a)



(b)



(c)

Figure 6. Simulated radiation patterns at: (a) 3 GHz, (b) 4 GHz, (c) 5 GHz.

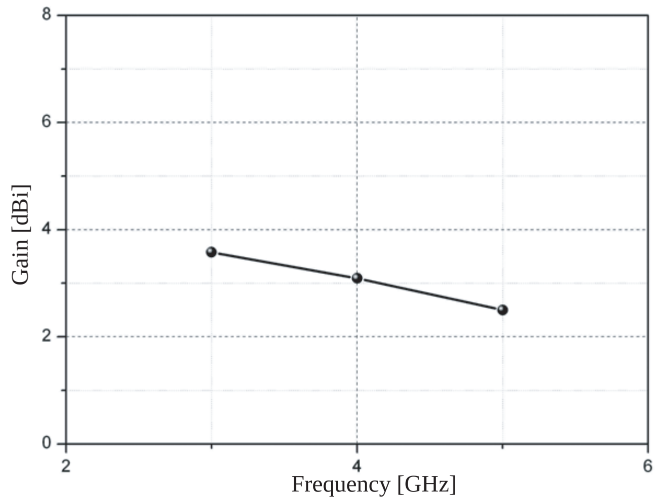


Figure 7. Simulated antenna gain of the designed UWB chip antenna.

slot width (g) increases, the resonance frequency moves to the higher frequency. Thus, the frequency tuning is possible by changing the width of the inclined slot.

Figure 6 shows the simulated radiation patterns at 3, 4, and 5 GHz, respectively. The radiation patterns are quasi-isotropic pattern and the shapes of the patterns are unchanged over the UWB frequency band. Figure 7 shows the simulated antenna gain of the proposed antenna. As can be seen from the figure, the gain of UWB chip antenna varies from 2.5 dBi to 3.5 dBi over the operating frequency range and the antenna gain variation is 1 dBi.

3. CONCLUSION

A compact UWB chip antenna using the coupling concept has been proposed for UWB systems. By using the inclined slot on the rectangular radiating patch, the bandwidth of the proposed antenna has been improved. A parametric investigations of the different azimuth angle and the inclined slot width have also been presented. The measured path loss is almost constant across the frequency band and the group delay variation is less than 2 ns. Good radiation characteristics of quasi-isotropic pattern and gain were obtained over the UWB frequency band, thus indicating that the UWB antenna is suitable for the UWB communication applications.

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