Printed Circuit Antenna for UWB Systems

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***Abstract*—A Printed-Circuit antenna for UWB systems is presented. The antenna consists of a rectangular slot etched out from the ground plane of a RT/Duroid 5880 (dielectric constant = 2.2) and a CPW-fed bowtie stub for excitation. The antenna is successfully designed, implemented and measured. A compact antenna area of 31.8 x 34.2 mm^2 is obtained. The proposed antenna in this study is capable of measured a very wide operating bandwidth approximately 2.93–11.97 GHz.**

I. Introduction

The recent allocation of frequency band from 3.1 to10.6 GHz by the Federal Communications Commission (FCC) for ultrawideband (UWB) radio applications has presented an opportunity. The FCC first approved rules for the commercial use of UWB in February 2002. By April of that year, the FCC gave formal approval for the unlicensed use of the technology between 3.1 and 10.6 GHz. Since then, the feasible design and implementa- tion of UWB system has become a highly competitive topic in both academy and industry communities of telecommunications. In particular, the antenna of ultrawide bandwidth is the key component of the UWB system and has attracted significant research power in the past few years. Challenges of the feasible UWB antenna design include the ultrawideband performances of the impedance matching and radiation stability, the compact appearance of the antenna size. Among the planar UWB antenna designs in the recent literature, the slot antenna type [1]–[5] is one of the most promising candidates for UWB applications. The advantages of slot antennas include wide bandwidth performance and a fork-like stub for excitation such that a broad bandwidth can be achieved [3]–[5]. The latter approach has significant progress on the bandwidth enhancement and has reached theUWB bandwidth requirement recently [5]. However, the design of using fork-like stub requires relatively large aperture and contains many parameters for the complex geometry. In this paper, a coplanar waveguide (CPW)-fed rectangular slot antenna with a bowtie exciting stub is proposed. Compared to the fork-like stub, the proposed bowtie stub has advantages because the exciting bowtie stub has a simple geometry with less parameters releasing the computation load in the optimization process and wider bandwidth.Furthermore, the proposed antenna in this study is capable of measured a very wide operating bandwidth (with the definition of 10-dB return loss) of larger than 9.04 GHz (approximately 2.93–11.97 GHz), which easily covers the UWB band of 3.1–10.6 GHz for WPAN communications. The proposed antenna is successfully designed, built, and verified. A compact antenna area of 31.8 by 34.2 mm^2 is achieved. The antenna performs promising characteristics on the impedance matching, radiation patterns over the entire UWB band.

II. Antenna Structure

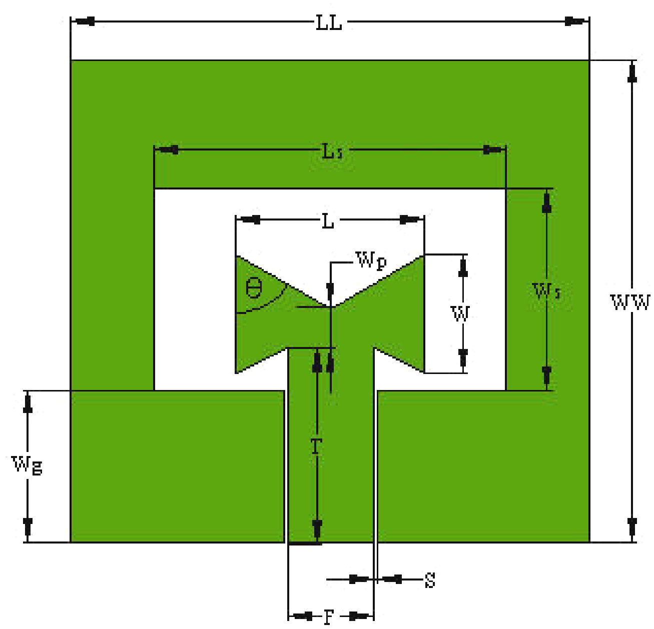

Figure 1. Geometry of CPW-fed slot antenna

Fig. 1 shows the geometry and configuration of the proposed antenna. The antenna consists of a rectangular slot etched out from the ground plane of a RT/Duroid 5880 (dielectric constant = 2.2) with thickness of substrate 3.175 mm. and a CPW-fed bowtie stub for excitation. Since the antenna and feeding structure are implemented on the same plane,only one layer of substrate with single-sided metallization is used, making the manufacturing of the antenna very easy and extremely low cost. The CPW transmission line is designed with 50 and terminated with a shape memory alloy connector for the measurement purpose in this paper. In practice, the CPW line is integrated with radio-frequency/microwave circuitry on the system board. Design of the rectangular aperture is determined by minimizing the aperture area while satisfying the input impedance matched for the entire UWB band, especially for the lower frequencies. In this paper, a compact slot area of 13.3x23.2 mm^2 is achieved, that is, the dimension is less than a quarter-wavelength for the lowest frequency (3.1 GHz).

III. PARAMETRIC STUDY

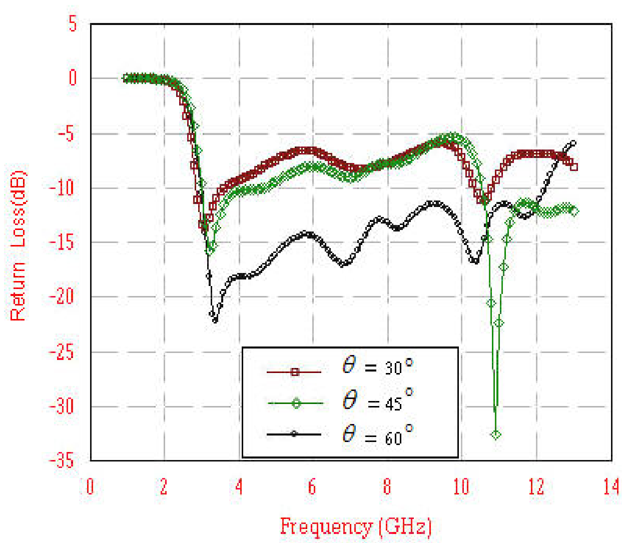

Figure 2. Effects of stub angle θ on the return loss. The dimensions of other parameters (unit:mm)
LL = 34.2, WW = 31.8, Ls = 23.2, Ws = 13.3,L= 12.4, W = 7.8, T = 12.8, Wp = 2.6, Wg = 10, F = 5.6 and S = 0.3

The commercial simulation tool IE3D base on MOM is employed in this paper to perform the design and optimization process. Since the bowtie shaped stub is the main factor in the optimization process, its three parameters L, W and θ are selected to perform the sensitivity study first. The effects of parameters on the return loss are simulated and shown in Figs. 2–4, respectively. Fig. 2 and 3 shows that the stub angle θ and stub length L may affect the return loss over the entire UWB band. Fig. 4 shows that the stub width W mainly influences in high bands at 8-11 GHz.

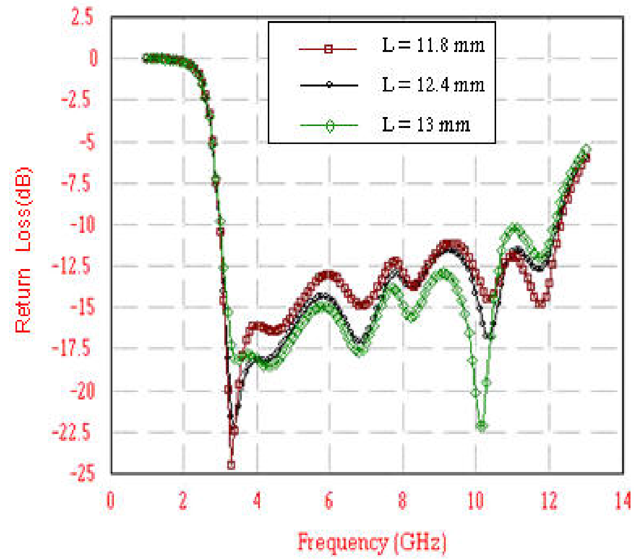

Figure 3. Effects of stub angle θ on the return loss. The dimensions of other parameters (unit:mm)
LL = 34.2, WW = 31.8, Ls = 23.2, Ws = 13.3, W = 7.8, T = 12.8, Wp = 2.6, Wg = 10, F = 5.6, S = 0.3 and θ = 60^0

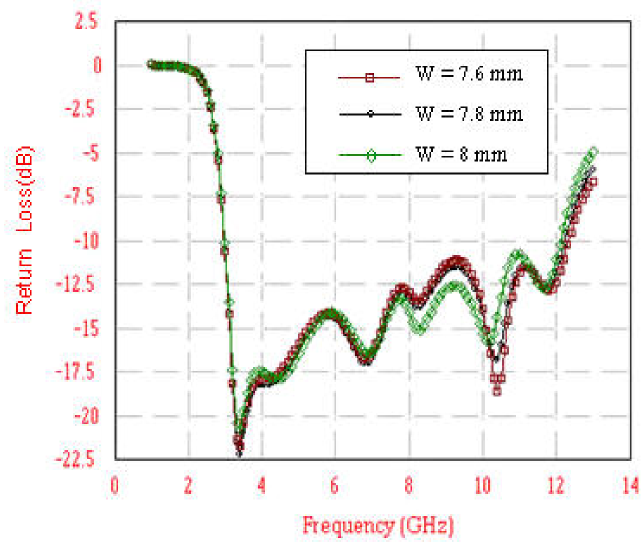

Figure 4. Effects of stub angle θ on the return loss. The dimensions of other parameters (unit:mm)
LL = 34.2, WW = 31.8, Ls = 23.2, Ws = 13.3, L = 12.4, T = 12.8, Wp = 2.6, Wg = 10, F = 5.6, S = 0.3 and θ = 60^0

The effects of parameter Ls and Ws on the return loss are simulated and shown in Figs. 5–6, respectively. Fig. 5 shows that the slot length Ls may affect the return loss over the entire UWB band. Furthermore, the slot width Ws is relatively sensitive to the return loss in low band at 3–7.5 GHz, as shown in Fig. 6. Note that the implementation tolerance and gap/line limit of fabrication should be controlled based on the aforementioned parametric study curves.

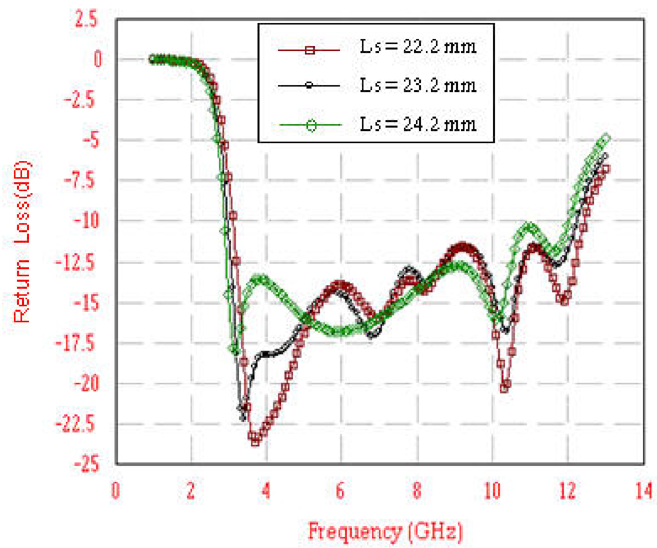

Figure 5. Effects of stub angle θ on the return loss. The dimensions of other parameters (unit:mm)
LL = 34.2, WW = 31.8, Ws = 13.3, L = 12.4, W = 7.8
T = 12.8, Wp = 2.6, Wg = 10, F = 5.6, S = 0.3 and θ = 60^0

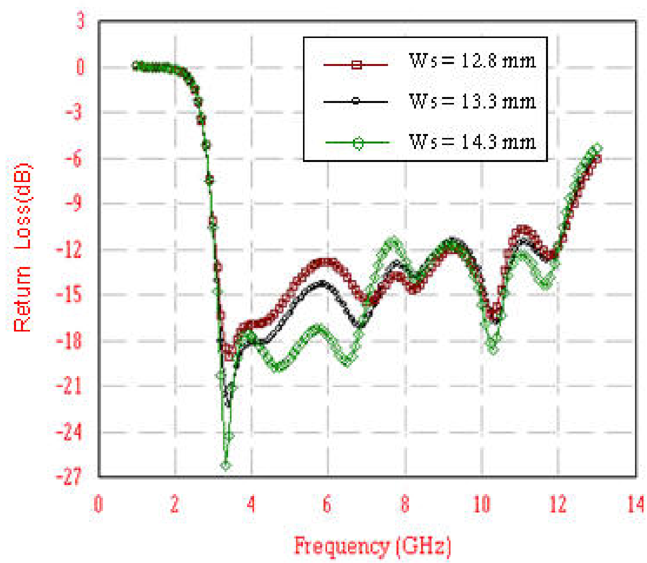

Figure 6. Effects of stub angle θ on the return loss. The dimensions of other parameters (unit:mm)
LL = 34.2, WW = 31.8, Ls = 23.2, L = 12.4, W = 7.8
T = 12.8, Wp = 2.6, Wg = 10, F = 5.6, S = 0.3 and θ = 60^0

IV. Radiation Patterns

Fig 7-9 show simulation radiation pattern at 3.5, 5.2 and 10 GHz. The radiation patterns at all bands are found to be bidirectional pattern. The direction of maximum radiation is constantly around the z-axis, normal to the slot plane.

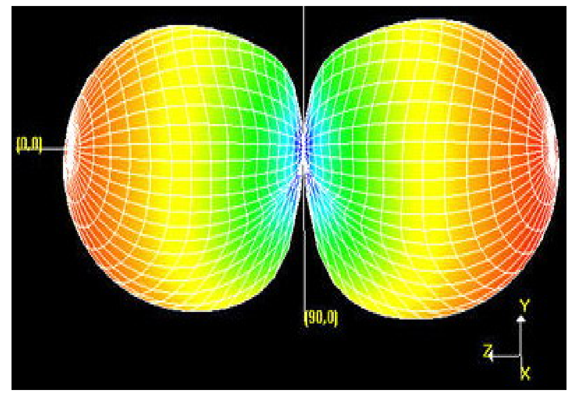

Figure. 7. Simulated radiation pattern at 3.5 GHz

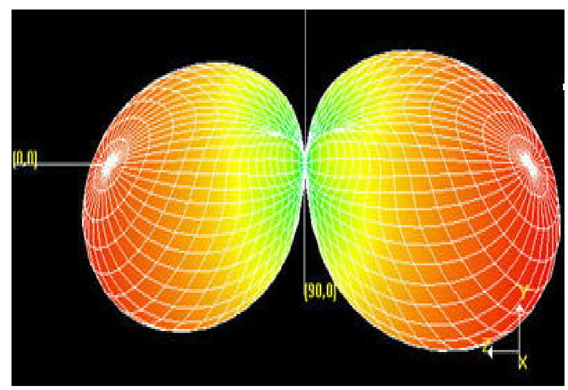

Figure. 8. Simulated radiation pattern at 5.2 GHz

Figure. 9. Simulated radiation pattern at 10 GHz

V. Measurement Results

The proposed antenna is implemented with a RT/Duroid 5880 substrate. Fig. 10 shows the photograph of the proposed antenna. Note that the ground plane dimensions are selected as 31.8 x 34.2 mm^2 for all the developed antennas in this paper. The measurement of return loss is carried out with an HP8720-C network analyzer. Fig. 11 shows the measured return loss of the designed antenna with a comparison with simulation results. A good agreement between simulation and measurement is achieved. Fig. 8-9 show that the input impedance is well matched as the 10-dB return loss bandwidth covers the entire UWB band (3.1–10.6 GHz) which simulated return loss has bandwidth between 2.98-12.25 GHz and measured cover bandwidth between 2.93–11.97 GHz.

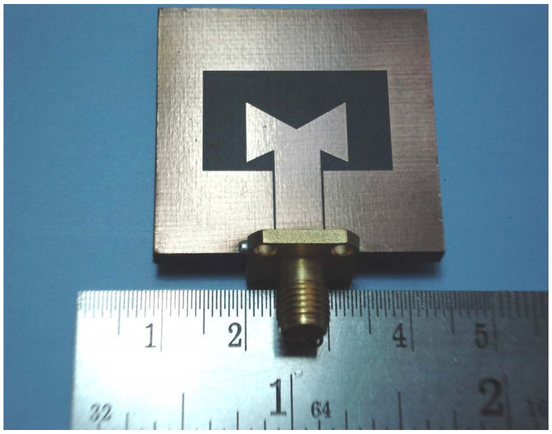

Figure 10. Photograph of the proposed antenna

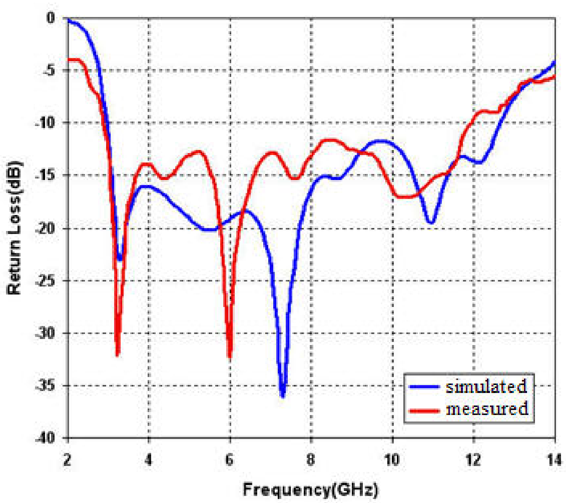

Figure 11. Measured and simulated return loss of proposed antenna with optimal dimensions (unit:mm)
LL = 34.2, WW = 31.8, Ls = 23.2, L = 12.4, Ws = 13.3, W = 7.8, T = 12.8, Wp = 2.6, Wg = 10, F = 5.6, S = 0.3 and $\theta = 60^0$

Fig. 12 and 13 show the measured radiation patterns for both vertical and horizontal components, in the E-plane at 3.5 GHz and 5.2 GHz. In horizontal component levels are still low but the radiation of the vertical component feature high levels. Moreover, the measured average gain of the proposed antenna over the entire UWB spectrum are between 2-6 dBi. Also, the direction of maximum radiation is constantly around the z-axis, normal to the slot plane.

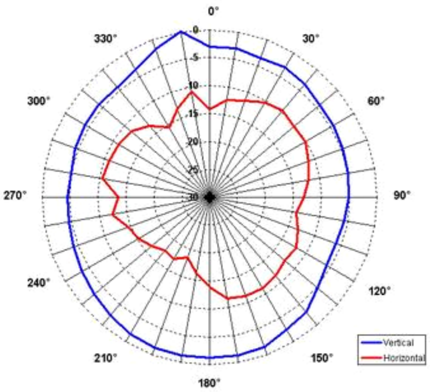

Figure. 12. Measured radiation patterm at 3.5 GHz

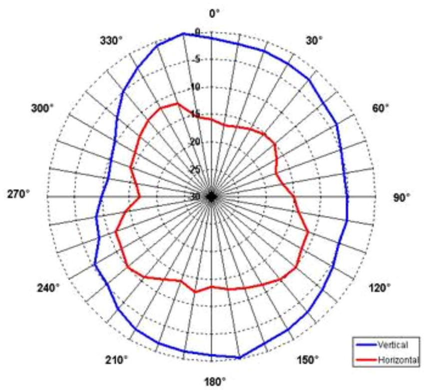

Figure. 13. Measured radiation patterm at 5.2 GHz

VI. CONCLUSION

In this paper, a printed circuit antenna for UWB systems is proposed. The antenna structure is simple and the size compact that antenna area of 31.8 x 34.2 mm^2 is achieved. The proposed antenna in this study is capable of measured a very wide operating bandwidth. The measured average gain of the proposed antenna over the entire UWB spectrum are between 2-6 dBi. The simulation and measurement results of the proposed antenna show a good agreement in terms of the return loss and radiation pattern.

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