Multi-band Characteristics of WB U-slot Patch Antenna with a Shorting Pin

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Abstract

Microwave U-slot patch antenna with a shorting pin can be installed on ceilings or facing air or on airplane and etc., which is suitable for WB (wideband) and UWB (ultra wideband) systems. The author has found the characteristics supporting multi-band and WB of the antenna in further study . This article introduces the simulation and the experiment of the multi-band antenna. Comparison of results between simulation and experiment are also provided.

Keywords : Antennas Wideband Multi-band

1. Introduction

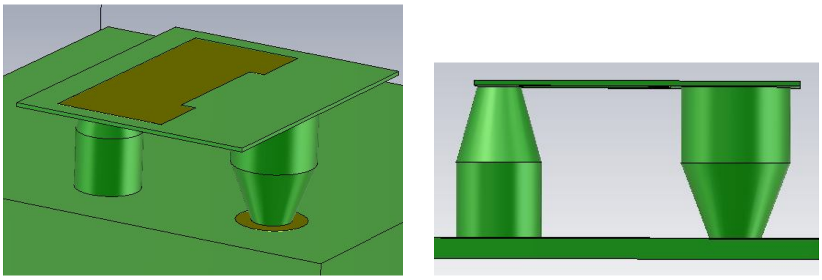
U-slot patch antenna with a shorting pin for microwave band is a new type of WB antenna[1,2]. This antenna provides omnidirectional radiating pattern. It is compact, small in size, may easily be made. It can be installed on the ceiling , facing air motorized platforms or air motorized platforms. It is applicable independently or in form of many types of arrays, such as line array, plane array, cylinder array and etc. This antenna is suitable for UWB communication, WB high speed data transmission, and phased-array radar, etc.

Concerning this antenna, reference [1] introduced its theory and experimental, and discussed its characteristics, such as impedance and radiating pattern. The early research suggested that this antenna may operate in UWB, the relative bandwidth is 30％ for VSWR less than 2.

Basing on the results introduced in reference [1], the author further has expanded its bandwidth[2]. The U-slot rectangle patch antenna with feeding and short-circuiting pins in abnormal shape is developed. The achievements through simulation show as follows: the relative bandwidth for VSWR less 2 is more than 71％ , and the relative bandwidth is more than 78％ while differential directive gain is within 3dB . Its impedance WB characteristics are also confirmed by some experiments. By this token, the author has made big advancement in expanding antenna bandwidth basing on the results of the antenna[2] introduced in reference [1]. In further simulation study, the author has found this antenna has WB characteristics of supporting multi-band . A model antenna has been made according to the simulation. The following test about the model has been proved successful, and the antenna has perfect performance and its bandwidth has also expanded.

2. Antenna Structure

Figure 1 shows the structure of the U-slot rectangle patch antenna feeded by an abnormal shape pin and loaded by a abnormal shapes shorting pin. The figure also shows its side view. The antenna has a single radiating patch element floating in the air, as a result, the attenuation is small and the efficiency is advance. It is rather simple compared with a normal UWB microstrip antenna. The length of radiating patch element is L, the width is W, the distance between patch and ground is h, and the feeding point is (0, Y_f,-h) (through a coaxial cable). The antenna is loaded by a shorting pin at (0, Y_s,-h). In order to expand its bandwidth, an “U” shape slot has been formed for producing change of the current. Therefore we call it an U-slot patch antenna. The hemline length of U-slot is L_s, the width C_s, the arm length W_s, the arm width B_s. The distance between the hemline of U-slot and origin of coordinate is d_s.



(a) 3-dimention view (b) Side-view

Figure 1 Structure of U-slot patch antenna with a shorting pin

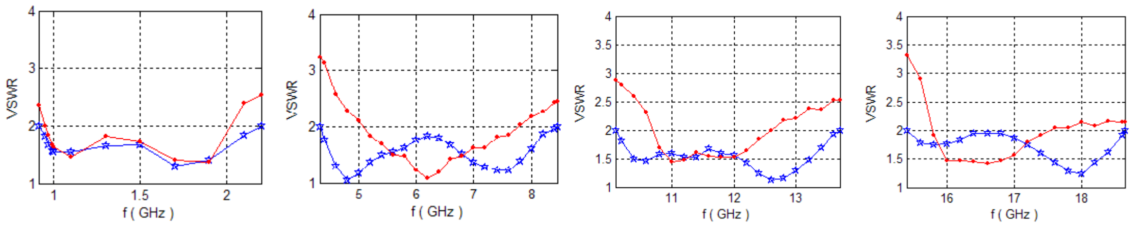
In the research of this antenna[2] , the auther has designed a shorting pin conductor load as a bottle and a feed pin conductor as inversion bottle. The diameter of the bottom of the shorting pin is D_{Ls}, the diameter of the top of the shorting pin is D_{Hs}. The diameter of the bottom the feed pin is D_{Lf}, the diameter of the top of the feed pin is D_{Hf}, as shown in figure 1 below.

The importance parameters to adjust the antenna bandwidth are the hemline length L_s, the width C_s, the arm length W_s , the arm width B_s of U-slot , the distance d_s , the diameter D_{Ls} of the bottom of the shorting pin , the diameter D_{Hs} of the top of the shorting pin , the diameter D_{Lf} of the bottom of the feed pin, the diameter D_{Hf} of the top of the feed pin and etc.

The reference [1] introduces that the antenna size is small, side length $0.24\lambda_0 \times 0.20\lambda_0$ (λ_0 is the center operating wavelengh) , the distance $0.12\lambda_0$ between the patch and the ground , the area $0.048\lambda_0^2$. There is a 80.8% reduction of the area as compared with the patch of half wavelength.

3. Characteristics of WB and Multi-band of the Antenna

Author's research includes simulation theory and experiment for further increasing bandwidth of the antenna introduced in reference [1], and founds WB characteristics supporting multi-band of the antenna. After repeatedly adjusting, they have been selected that $L=76.6$mm, $W=62.3$mm, $h=29.1$mm, $L_s=66.5$mm, $W_s=28.7$mm, $C_s=24.7$mm, $B_s=16.7$mm, $D_{Ls}=16.2$mm, $D_{Hs}=8.4$mm, $Y_s=4.2$mm, $D_{Lf}=10$mm, $D_{Hf}=21.1$mm, and $Y_f=49.8$mm.



(a) First band (b) Second band (c) Third band (d) Fourth band

Figure 2: VSWR frequency characteristics at the port of the antenna
(red dot curve is for simulation result and blue asterisk curve is for model test result.)

The VSWR in four band of the last simulated antenna of are shown in figure 2 with red dot curve for simulation result. In figure 2,The simulated four frequency ranges while VSWR is less than or equal to 2 are: The first frequency range is f_1 =0.95GHz ~ 2.01GHz, the bandwidth is BW_1 =1060MHz, the relative bandwidth is Bf_1 =72% and correspond to the relative bandwidth in reference [2].There is a 137% increase of the relative bandwidth as compared with that in reference [1]. Thus the research is biggish advancement. The second frequency range is f_2 =5.06GHz ~ 7.78GHz, the bandwidth is BW_2 =2720MHz,and the relative bandwidth is Bf_2=42% while VSWR is less than or equal to 2. The third frequency range is f_3 =10.68GHz ~ 12.60GHz, the bandwidth is BW_3 =1920MHz, and the relative bandwidth is Bf_3=16% while VSWR is less than or equal to 2. The fourth frequency range is f_4 =15.70GHz ~ 17.58GHz, the bandwidth is BW_4 =1880MHz,and the relative bandwidth is Bf_4=11% while VSWR is less than or equal to 2. They all have characteristics of WB.

The model with the same size made basing on the simulated result is shown in figure 3. The result measured by a vector network analyzer is shown in figure 2 with blue pentagram curve. From figure 2 we can see that frequency characteristics of the bandwidth of the real antenna model for VSWR still have WB characteristics supporting multi-band. Also each frequency band while VSWR less than 2 has been increased. From figure 2 we can find that the four frequency ranges of the model for VSWR less than or equal to 2 are: The first frequency range is f_1 =0.918GHz ~ 2.18GHz, the bandwidth is BW_1 =1262MHz, and the relative bandwidth is Bf_1=81% .The second frequency range is f_2 =4.32GHz ~ 8.45GHz, the bandwidth is BW_2 =4130MHz, and the relative bandwidth is Bf_2=65% .The third frequency range is f_3 =10.10GHz ~ 13.70GHz, the bandwidth is BW_3 =3600MHz, and the relative bandwidth is Bf_3=30% .The fourth frequency range is f_4 =15.40GHz ~ 18.64GHz, the bandwidth is BW_4 =3240MHz, and the relative bandwidth is Bf_4=19% .

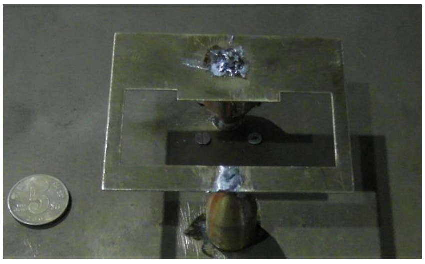
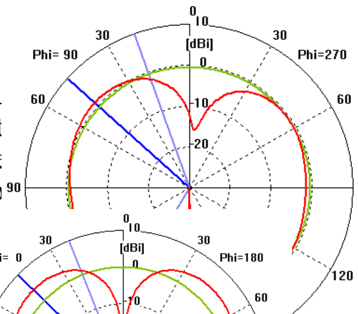
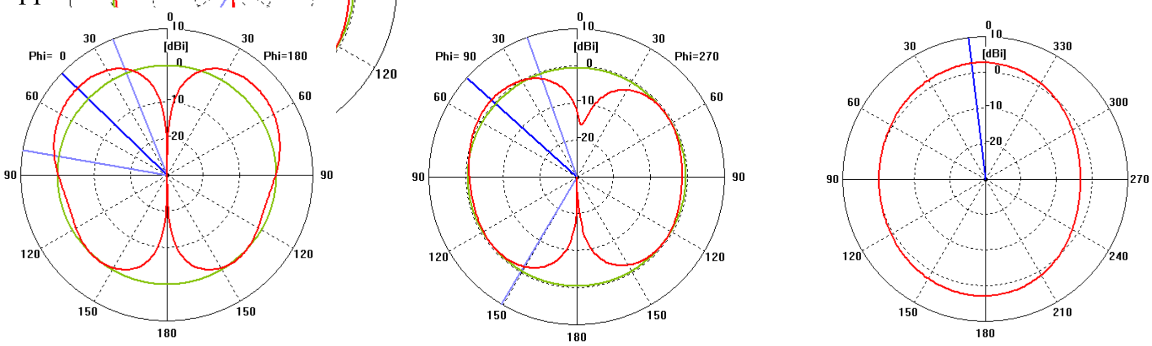


Figure 3: Picture of test model

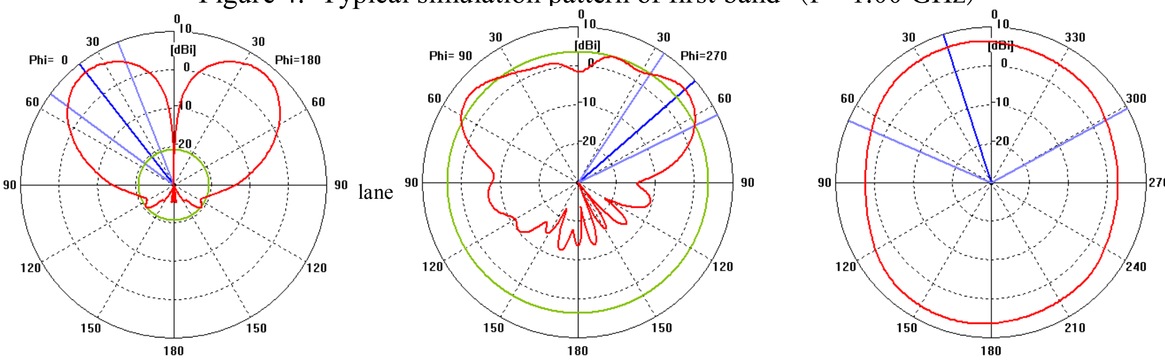


figu... the simulation pattern of each band respectively. As shown in inst... angle for each antenna pattern which is suitable for inversely orie... or facing air or on airplane and etc. In addition, comparable app... = 28° plane. And the WB characteristics of the antenna are all



(a) XOZ plane (b) YOZ plane (c) θ = 28° plane

Figure 4: Typical simulation pattern of first band (f = 1.00 GHz)



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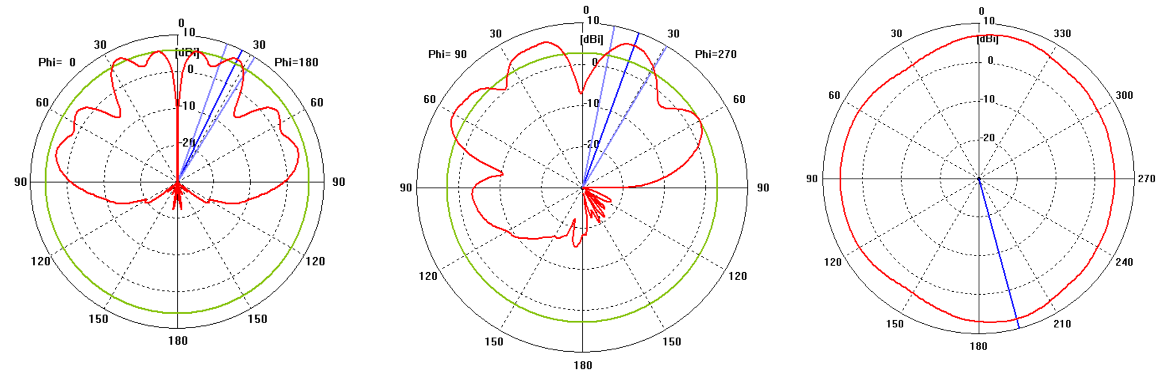
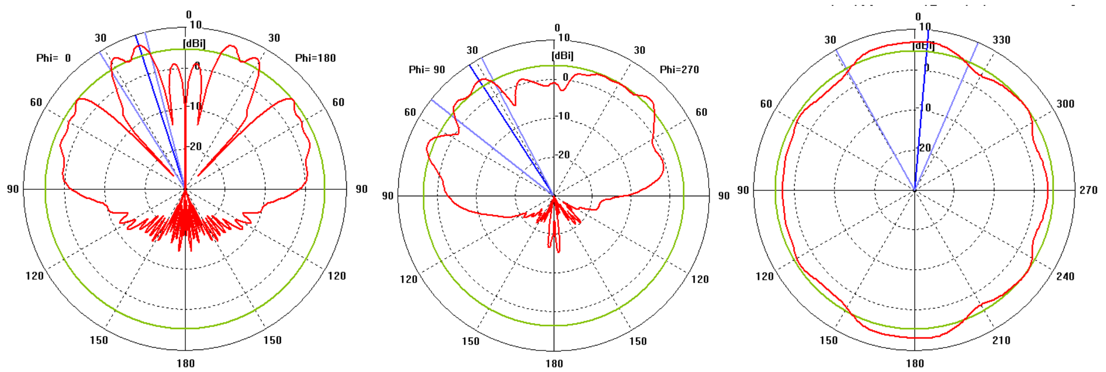
(a) XOZ plane (b) YOZ plane (c) θ = 28° plane

Figure 5: Typical simulation pattern of second band (f = 6.00GHz)



(a) XOZ Plane (b) YOZ Plane (c) θ = 28° Plane

Figure 6: Typical simulation pattern of third band (f = 12.00 GHz)



(a) XOZ Plane (b) YOZ Plane (c) θ = 28° Plane

Figure 7: Typical simulation pattern of fourth band (f = 18.00 GHz)

The antenna gain of each band is shown in table 1. As shown in table 1, the antenna gains of each band are middling. The distinction among the antenna gain of each band is smaller. This feature can be see from antenna patterns.

Table 1: Antenna Gain of Each Band

Band	First Band		Second Band		Third Band		Fourth Band	
Frequency f(GHz)	1.0	2.0	6.0	7.0	11.0	12.0	17.0	18.0
Gain (dBi)	4.3	7.3	7.5	5.8	8.7	7.2	9.2	7.4

References

[1] Chengli Yuan, "Ultra Wideband Antenna Theory and Technology", Publishing House of Haerbin Industry University, 2006

[2] XinAn Liu, "Research of UWB U-slot Patch Antenna with Shorting Pin", Proceedings of 2010 IEEE International Conference on Ultra-Wideband (ICUWB2010)