

Small Planar UWB Antenna with a Trapezoid Shape Ground

#Yangjun Zhang¹, Yoshinori Sakurai and Toyokatsu Miyashita²

Dept. of Electronics & Informatics, Ryukoku University

Seta, Otsu 520-2194, JAPAN

¹zhang@rins.ryukoku.ac.jp, ²miya@rins.ryukoku.ac.jp

Abstract — small planar UWB (Ultra Wide Band) antenna implemented on a FR-4 substrate is proposed in this paper. Two kinds of ground pattern, 1-stage trapezoid and 2-stage trapezoid, are studied to improve impedance matching. The antenna total size is $40 \times 30 \text{ mm}^2$, and the radius of radiating element is 6.2 mm. Both the radiation element and the whole antenna are much smaller than the antenna using a uniform feed line and a conventional square ground.

Introduction

Printed planar UWB (Ultra Wide Band) antennas are currently considered a good candidate for UWB system because it has the attractive features such as low-profile, light-weight and suitability for fabrication. A circular disc monopole antenna with 25 mm disc diameter made of 0.5 mm-thick brass plate, which was mounted over a $300 \times 300 \text{ mm}^2$ large ground plane, was reported to yield a very large impedance bandwidth from 2.25 to 17.25GHz [1]. A famous planar monopole antenna implemented on a FR-4 substrate was proposed and its operating principle has been analysed in detail [2][3]. The antenna reported in [2][3] is fed by a uniform microstrip line, and the ground is a conventional square pattern. The size of antenna is about $50 \times 40 \text{ mm}^2$, and the radius of the radiation disc element is 10 mm.

Feed line and ground shape of the planar UWB antenna have been studied to enhance impedance matching. It has been shown that bandwidth enhancement can be achieved by using a tapered feed line or a tapered slot [4][5]. It was also shown that ground shape affects impedance matching over wide frequency band [6],[7],[8]. For example, slot ground [6] and notched ground plane [7] have been proposed. With the development of the latest UWB communication system, there has been wide interest into small UWB antennas [8][9]. Antenna has to be small enough to be compatible to the UWB device.

This paper presents a miniaturized planar UWB antenna using a tapered feed line and a trapezoid ground. Two kinds of ground pattern, 1-stage trapezoid and 2-stage trapezoid ground shape, are studied to improve impedance matching. The simulated and measured results on impedance matching, radiation pattern and time domain characteristic over UWB band are given.

Antenna Design

The configuration of proposed antenna is shown in Fig.1. It has a circular radiating element and a tapered microstrip feed line as Fig.1 (a). The substrate is FR-4 with dielectric constant $\epsilon_r=4.4$ and 0.8mm thickness. The width of microstrip line at input port is 1.5mm to obtain a 50Ω characteristic impedance. The conventional ground pattern is a square as shown in Fig.1 (b). The planar UWB antenna with such ground pattern has a total size of $50 \times 40 \text{ mm}^2$ [2][3]. The input impedance matching becomes bad over UWB frequency band when the total size was reduced. Two kinds of ground pattern, 1-stage and 2-stage trapezoid as shown in Fig.1 (c) and (d), are studied to obtain good input property over wide frequency.

1-Stage Trapezoid Ground

The simulated results of return loss on trapezoid width w are shown in Fig.2. In the simulation, the radiating element is fed as Fig.1(a), and the antenna total size is reduced to $40 \times 30 \text{ mm}^2$.

$w=30\text{mm}$ means the ground is a conventional square shape as Fig.1(b). Fig.2 shows that the overlap of the two resonant modes leads to impedance matching over wide frequency range. Width w mainly affects the first and the second resonant frequency. Impedance matching over UWB frequency can be improved by choosing properly the value of width w .

Fig.3 presents the simulated result of return loss for different trapezoid height, h , while $w=8\text{ mm}$, $a=30\text{mm}$, $b=40\text{mm}$ and $\theta=16^\circ$. Different h changes the gap g between radiating element and ground, which significantly affects antenna input impedance [3]. Fig.3 indicates that h variation mainly affects frequency band between two resonant frequencies, and the upper edge of 10-dB frequency bandwidth.

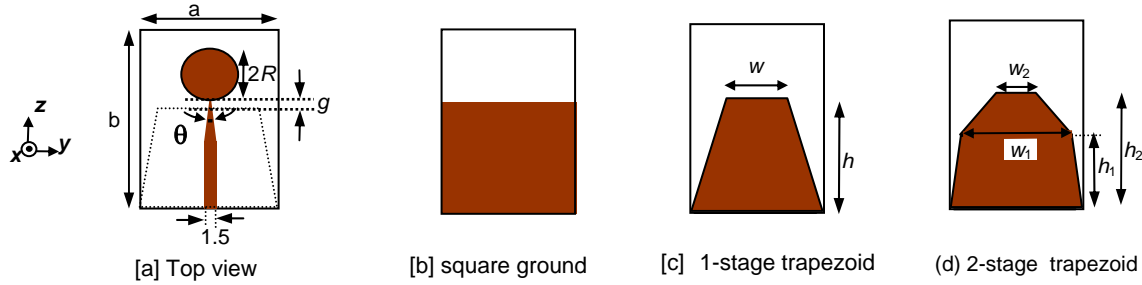


Fig.1 UWB antenna configurations. (a) radiator fed with a tapered microstrip line, (b) a conventional square ground, (c) 1-stage trapezoid ground and (d) 2-stage trapezoid ground

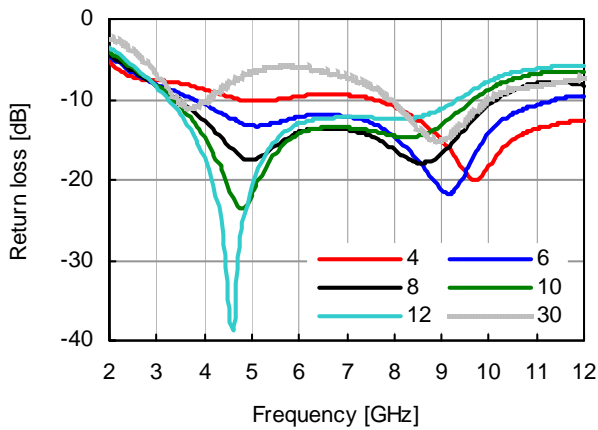


Fig.2 Simulated result of return loss for different w . The antenna total size is $40 \times 30\text{ mm}^2$

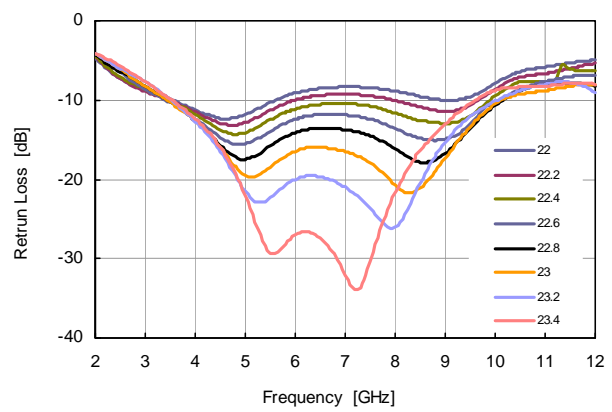


Fig.3 Simulated results of return loss for different trapezoid height h

2-Stage Trapezoid Ground

2-stage trapezoid ground pattern has 4 parameters, h_1 , w_1 , w_2 and h_2 . The simulated results on 5 kinds of ground shape are shown in Fig.4, while the feed line width is fixed as 1.5mm, $\theta=16^\circ$, $h_2=23.4\text{mm}$ and $R=6.2\text{mm}$. It is shown that ground shape affects impedance matching over whole frequency band, mainly around 7 to 8 GHz frequency band. The lower edge of 10-dB frequency band keeps almost the same value. It was thought because h_2 and R are fixed in these simulations.

According to the simulation results above, we obtained a configuration for a UWB antenna with 1-stage trapezoid ground, in which $h=23.4\text{mm}$, $w=8.0\text{mm}$. We also obtained a configuration for a UWB antenna with 2-stage trapezoid ground, in which $h_1=15.6\text{mm}$, $w_1=25.0\text{mm}$, $w_2=5.6\text{mm}$, $h_2=23.4\text{mm}$. In the both configurations, the radius of radiation disc is 6.2 mm, and the feed line is fixed as 1.5mm with 16° tapered angle. The total size of antenna is $40 \times 30\text{ mm}^2$.

Antenna Characteristics

The designed antennas with 1-stage and 2-stage trapezoid ground as Fig.1 were implemented with a low-cost FR-4 substrate with dielectric constant $\epsilon_r=4.4$, loss tangent $\tan\delta=0.02$, and thickness $h=0.8\text{mm}$.

The return loss, radiation pattern were measured with an HP8720ES network analyser in an anechoic chamber. The measured results of return loss are shown in Fig.5 with a comparison with simulation results. For the antenna with 1-stage trapezoid ground, the simulation result for 10-dB return loss bandwidth is 3.4 – 10.2 GHz, while the measurement result for 10-dB return loss bandwidth is 2.5 – 9.7 GHz. For the antenna with 2-stage trapezoid ground, the simulation result for 10-dB return loss bandwidth is 3.1 – 10.6 GHz, while the measurement result for 10-dB return loss bandwidth is 2.85 – 10.5 GHz.

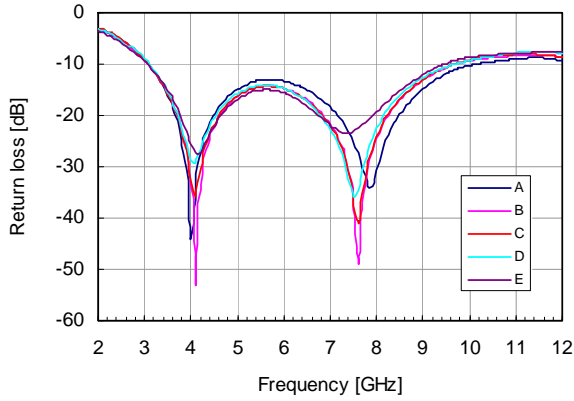


Fig.4 Simulated results of return loss for different 2-stage ground. A: $h_1=15.6$, $w_1=27.0$, $w_2=5.8$, B: $h_1=15.4$, $w_1=27.0$, $w_2=7.0$, C: $h_1=15.6$, $w_1=27.0$, $w_2=7.2$, D: $h_1=15.6$, $w_1=28.0$, $w_2=7.5$, E: $h_1=14.6$, $w_1=28.0$, $w_2=10.0$, (unit: mm).

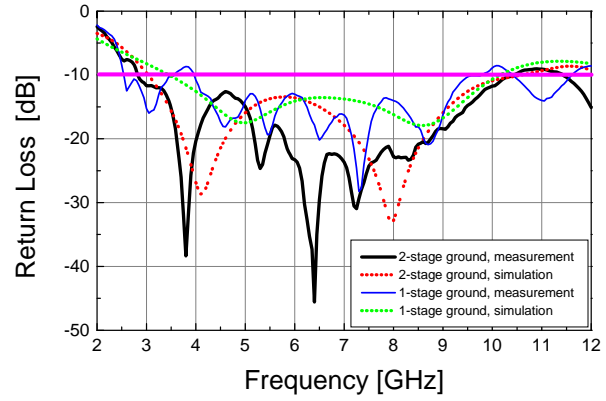


Fig.5 Simulated and measured return loss for planar UWB antennas

The radiation patterns of the antenna with 2-stage trapezoid ground are shown in Fig.6. The measured and simulated radiation patterns agree well. An omnidirectional radiation pattern in xy-plane is obtained. Similar results have been shown for the antenna with 1-stage trapezoid ground.

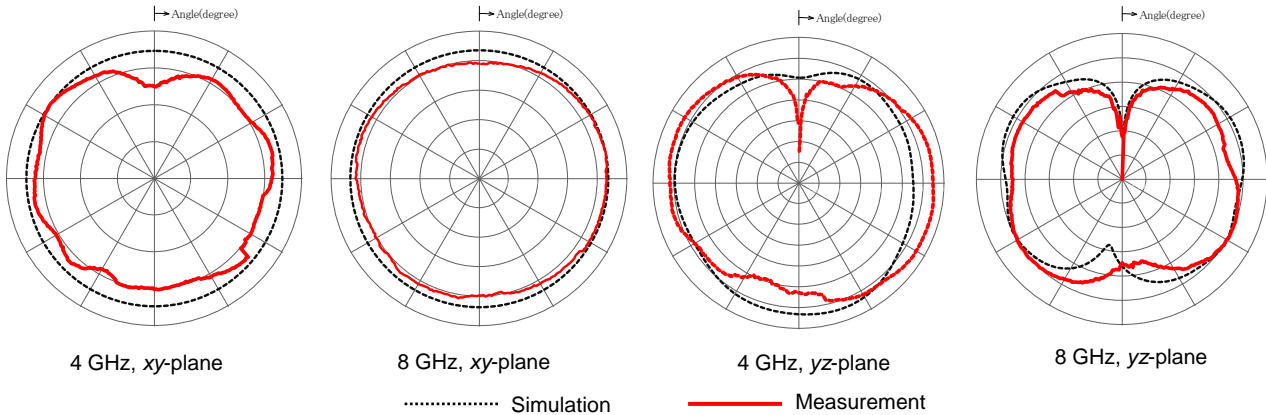


Fig.6 Radiation patterns in xy-plane and yz-plane of the antenna with 2-stage trapezoid ground at 4GHz, 8GHz.

Group delay is another important parameter for UWB communication. The measurement method of group delay has been outlined in some previous papers [2][4]. The time-domain performance of the proposed UWB antennas is measured as Fig.7. Two UWB antennas were set in Face-Face, Face-Side and Side-Side, as shown in Fig.7 (a), (b) and (c), respectively. The distance between the antennas is 16 cm because of low output power of Network Analyser. The measured group delay over the frequency range from 2 to 12 GHz for the antenna with 2-stage trapezoid ground is shown in Fig.8. Within the frequency range from 3 to 7.5 GHz, the group delay is about 1 ns. The group delay characteristic of the antenna with 1-stage trapezoid ground is similar to that shown in Fig.8.

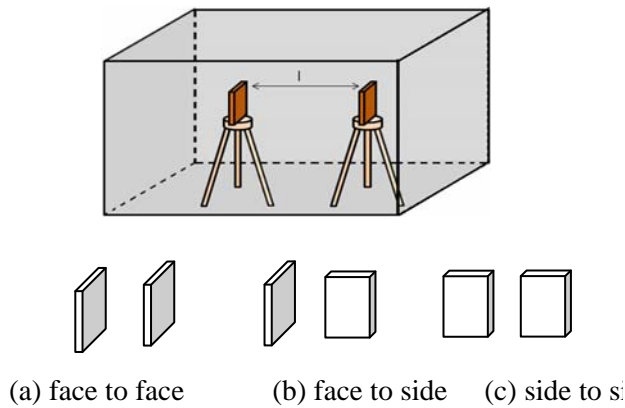


Fig.7 Group delay measurement in an anechoic chamber. The antennas are set as (a) face to face, (b) side to side, (c) face to side.

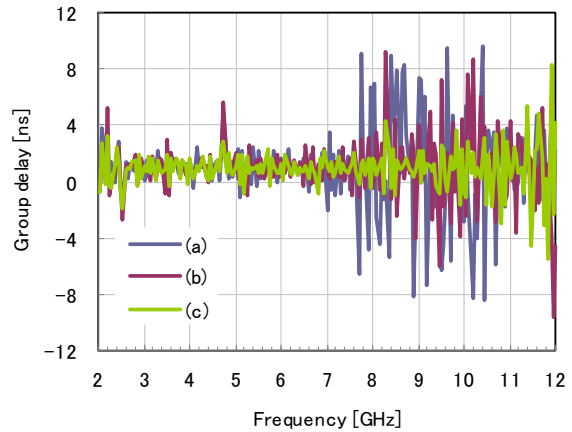


Fig.8 Measured group delay for the antenna with 2-stage trapezoid ground

Conclusions

Small planar UWB antenna implemented on a FR-4 substrate is proposed in this paper. Two kinds of ground pattern, 1-stage trapezoid and 2-stage trapezoid, are studied to improve impedance matching over UWB frequency band. The simulated and measured results of return loss, radiation pattern and ground delay for two types of antenna are given. The results show that a good impedance matching over UWB band (3.1-10.6GHz) was realized for the antenna with 2-stage trapezoid ground. The antenna total size is $40 \times 30 \text{ mm}^2$, and the radius of radiating element is 6.2 mm. Both the radiation element and the whole antenna are much smaller than the antenna using a conventional square ground.

References

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