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Very Compact UWB Antenna with Group Delay Improvement

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Abstract: In this paper, very compact (12mm×17mm) and simple UWB antenna is proposed. The achieved bandwidth of the presented antenna is from 3.05 GHz to 12.5 GHz and in the most of the bandwidth, the return loss is less than –20dB. In addition to frequency characteristics, time characteristics such as group delay variations for three different antenna positions, namely, front to front, back to back and side by side using CST MW studio are simulated and discussed. To improve the group delay variations, by changing the radius of the circle on the back side of the antenna, the antenna gain in different frequencies will be tuned, therefore, the time domain characteristics of the proposed antenna are greatly improved.

Keywords: UWB antenna, Group delay variation, Gain.

1 Introduction

Since the Federal Communications Committee (FCC) permitted the unlicensed use of the ultra-wide band (UWB) frequency band for short-range and high-speed wireless communication in 2002 [1], large interests in both academic and industrial fields have been attracted to research various UWB devices.

UWB antenna with good frequency and time characteristics is one of the more important parts of any UWB system. Until now, various types of the UWB antenna using different methods have been reported. Compactness [2, 3] and good frequency characteristics such as large bandwidth and high return loss [4, 5] have attracted the most attentions of the researchers in UWB antenna field. Nevertheless, for the time domain characteristics, namely, group delay variations for different directions of transmitter antenna relative to receiver antenna, fidelity and pulse width stretch ratio less attentions have been paid. It should be noted, although, some of the literatures [6, 7] have probed time domain characteristics, but there isn't any conceptual method for improving these characteristics. In this paper, first, a very compact UWB antenna (12mm×17mm) with good return loss over wide band (3.05 GHz to 12.5 GHz)

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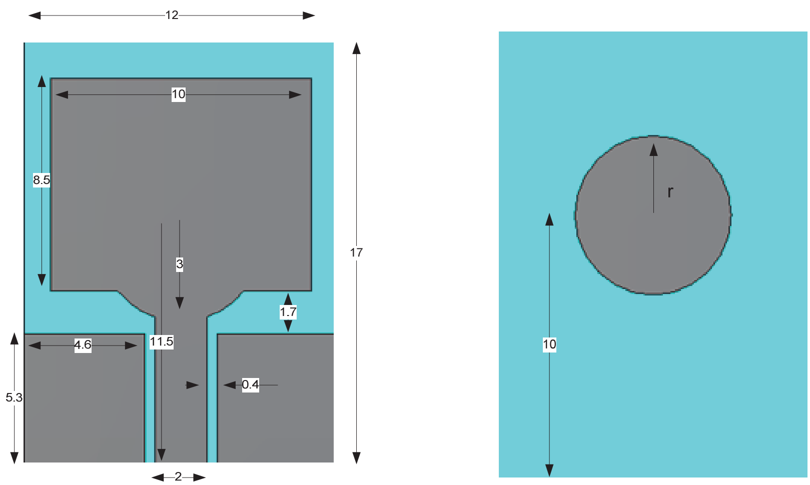
is presented. Then a method for reduction of group delay variations in all directions of receiver antenna relative to transmitter antenna will be proposed and the validity of the method will be verified by means of CST MW simulation results.

2 Antenna Design

The square antenna fed by a coplanar line is shown in Fig. 1 which is printed on a FR4 substrate with thickness of 1.6 mm and permittivity of 4.4. The coplanar line should be designed for input impedance of 50 Ω. For better impedance matching, a semicircle has been put in connection point of the line and square patch.



(a) (b)

Fig. 1 – *Proposed antenna*: a) *Front side*, b) *Back side*.

The semicircle extremely influences on the bandwidth and return loss of antenna. In addition to this semicircle, a circle has placed on the back of the antenna that after optimizing, it can improve bandwidth and group delay variation, as will be discussed in the next section.

2.1 Results and discussion

The proposed antenna is simulated using CST MW software and with changing some antenna parameters, the effects of different parts of antenna can be understood. Fig. 2 shows S_{11} parameter with and without semicircle for proposed antenna. As discussed in previous section, in the case of antenna with semicircle, because of better impedance matching, the bandwidth apparently increases. The S_{11} parameter for different values of circle radius, namely, $r = 2.5$, 3, 3.5 mm, can be seen in Fig. 3.

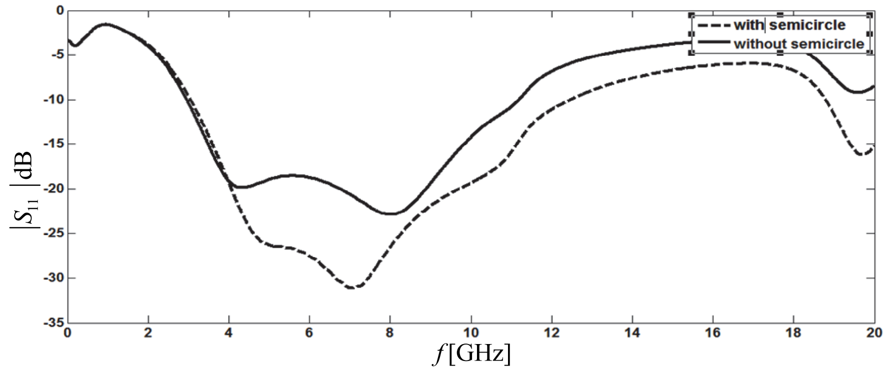


Fig 2 – *S_{11} parameter with and without semicircle.*

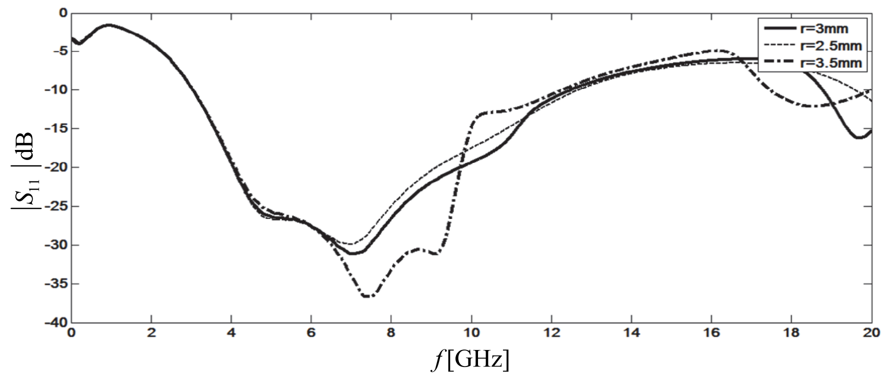
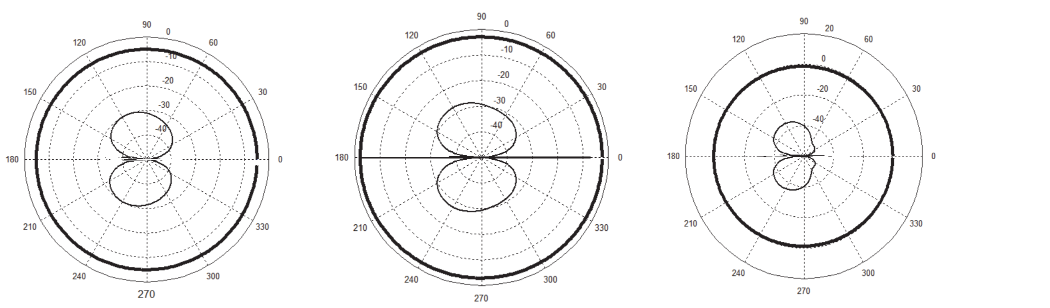


Fig. 3 – *S_{11} parameter for different values of circle radius on the back side of antenna.*

As can be seen, for $r = 3$mm, the antenna bandwidth and return loss show optimum values. Fig. 4 shows co and cross patterns of the designed antenna at the three different frequencies, 3.5, 5.3 and 8.2GHz for $r = 3$ mm.



(a) (b) (c)

Fig. 4 – *Antenna pattern for r* = 3 mm: a) f = 3.5 GHz, b) f = 5.3 GHz, c) f = 8.2 GHz.

To have low group delay variations, the amplitude of transmission parameter ($|S_{21}|$) should behave very flat and it's phase shows linear variation versus frequency. According to Friis transmission equation (1), when frequency increases, λ decreases. So, for keeping receiving power and subsequently, $|S_{21}|$ approximately constant, the transmitter and/or receiver gain should be increased to compensate for changes due to wavelength subsided. Therefore, for minimizing the group delay variations, the product of transmitter and receiver antenna gain increasing rate should be approximately equal to wavelength decreasing rate

$$\frac{P_r}{P_t} = \left(\frac{\lambda}{4\pi R}\right)^2 G_t G_r \,. \tag{1}$$

Tables 1 – 3 show antenna gain for different frequencies, angles and *r*.

Table 1
Antenna gain at θ = 90 (*front*) *for different frequencies and r.*

	f = 3.5 GHz	*f* = 5.3 GHz	*f* = 8.2 GHz	*f* = 10 GHz
r = 2.5	–4.85 dB	–2.45 dB	0.07 dB	–0.08 dB
r = 3	–4.85 dB	–2.46 dB	–0.05 dB	–0.16 dB
r =3.5	–4.85 dB	–2.5 dB	–0.25 dB	0.17 dB

Table 2
Antenna gain at θ = 270 (*back*) *for different frequencies and r.*

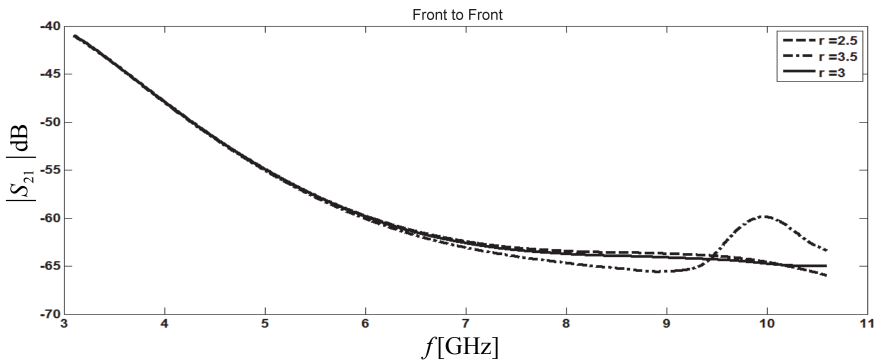
	f = 3.5 GHz	*f* = 5.3 GHz	*f* = 8.2 GHz	*f* = 10 GHz
r = 2.5	–4.8 dB	–2.2 dB	0.8 dB	1.1 dB
r =3	–4.8 dB	–2.2 dB	0.9 dB	1.8 dB
r =3.5	–4.85 dB	–2.2 dB	1.3 dB	0.5 dB

Table 3
Antenna gain at θ = 180 (*side*) *for different frequencies and r.*

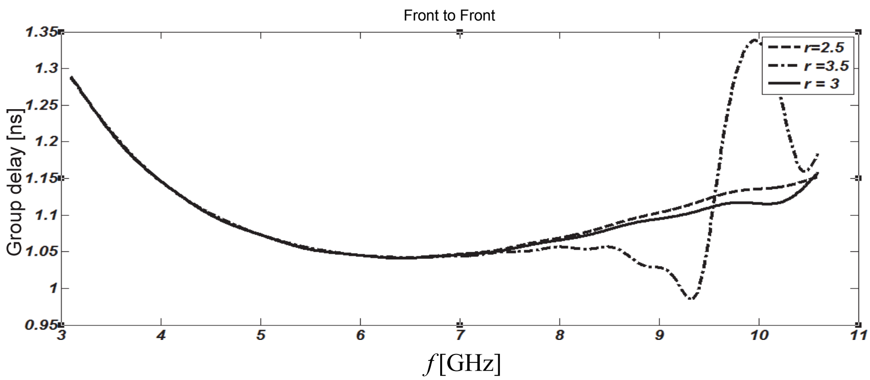
	f = 3.5 GHz	*f* = 5.3 GHz	*f* = 8.2 GHz	*f* = 10 GHz
r = 2.5	–4.99 dB	–2.94 dB	–1.36 dB	–2.57 dB
r =3	–5 dB	–2.95 dB	–1.38 dB	–2.66 dB
r =3.5	–5.01 dB	–2.96 dB	–1.42 dB	–7 dB

As can be understood from **Tables 1 – 3**, there is not any serious difference between rates of gain increasing for $r = 2.5$ and $r = 3$ mm, but, for $r = 3.5$ mm, the increasing rate of antenna gain for all frequencies is lower than two other values of circle radius, therefore, it can be expected that for $r = 3$ mm and 2.5 mm, $|S_{21}|$ and group delay show lower variations.

For simulation and discussion about group delay, two identical proposed UWB antenna are placed 300mm far from each other and in different directions, namely, front to front, back to back and side by side. For each case, $|S_{21}|$ and group delay variation are simulated and the results are shown in Figs. 5 – 7.



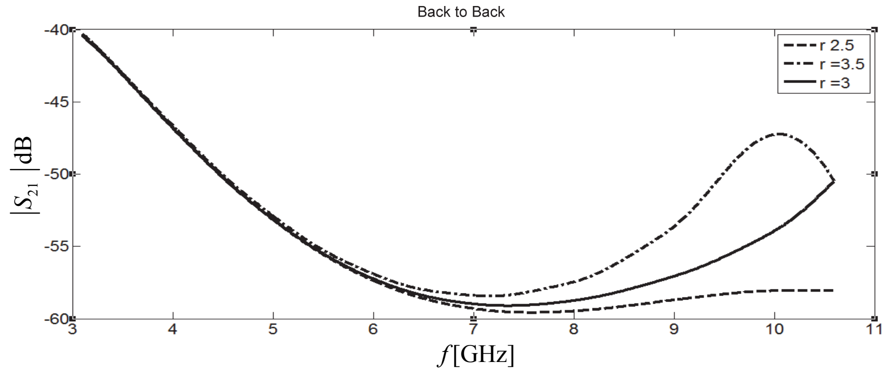
(a)



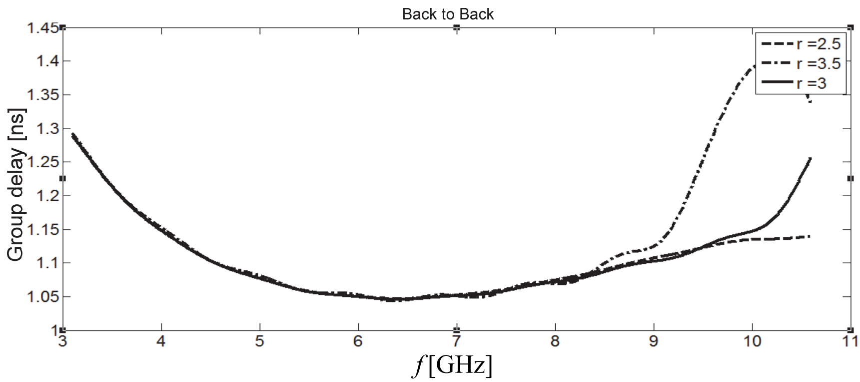
(b)

Fig. 5 – a) *Amplitude of transmission parameter* $|S_{21}|$,
b) *Group delay for front to front state of two identical antennas.*

According to these figures, the UWB antenna with both $r = 2.5$ mm and 3mm shows acceptable group delay variation, therefore, we can choose both of the values for circle radius. But, in this paper, the antenna has been designed with $r = 3$ mm, because, the return loss curve (Fig. 3) shows better behavior with this radius.



(a)



(b)

Fig. 6 –a) *Amplitude of transmission parameter* $|S_{21}|$,
b) *Group delay for back to back state of two identical antennas.*

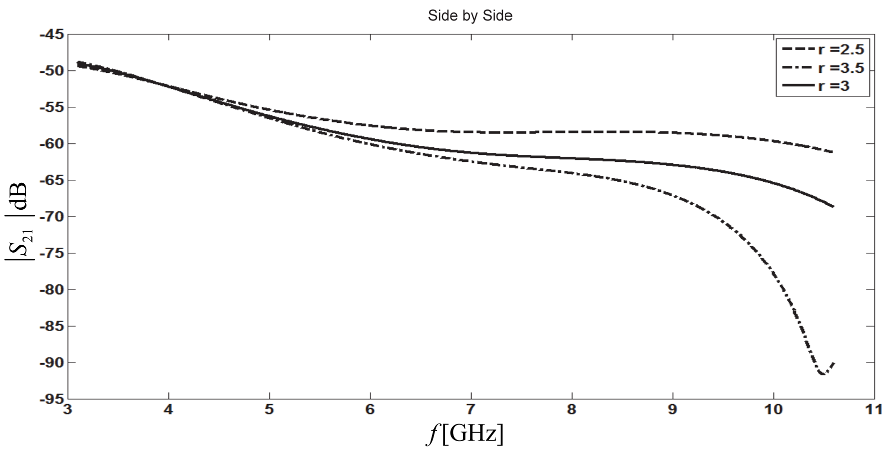
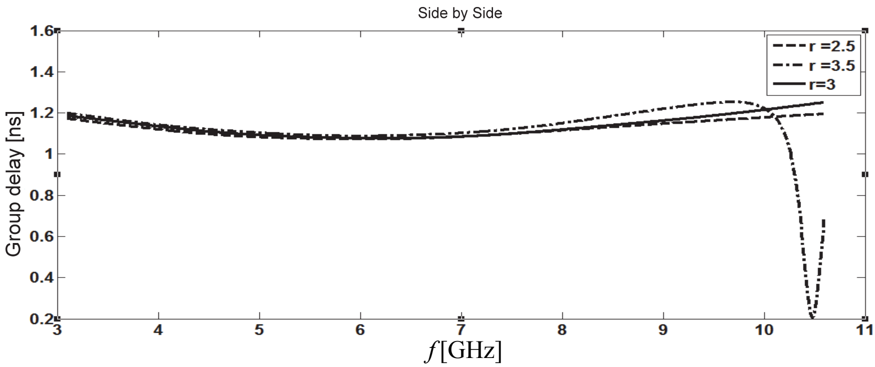


Fig. 7a – *Amplitude of transmission parameter* $|S_{21}|$.



(b)

Fig. 7b – *Group delay for side by side state of two identical antennas.*

4 Conclusion

In this paper, a simple and compact UWB antenna is proposed. By tuning the circle radius on the back side of the antenna, the increasing rate of gain with frequency is set to compensate the changes due to wavelength subsided. By means of this consideration, group delay variations for different directions of transmitter and receiver antennas will be greatly improved. Using CST MW simulation results, the design accuracy is verified. In the worst situation, the group delay variation is less than 0.25 ns.

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