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COMPLETE DISPERSION ANALYSIS OF VIVALDI ANTENNA FOR ULTRA WIDEBAND APPLICATIONS

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Abstract—Besides the return loss and radiation pattern, dispersion characteristic of the antenna is one of the most important factors which should be considered in ultra wideband applications. In this paper, dispersion behavior of two specific Vivaldi antennas has been fully investigated in both frequency and time domains. All simulations are carried out by CST MS software. Moreover, by fabricating the antennas, the simulation results are verified by experimental data.

1. INTRODUCTION

Recently the ultra wideband (UWB) systems have expanded rapidly, since Federal Communications Commission (FCC) allocated the frequency band of 3.1 to 10.6 GHz for the operation of devices with EIRP less than −41.3 dBm/MHz. Many kinds of UWB antennas have been introduced such as bow-tie, conical, TEM horn, spiral, fractal, log-periodic and Dragonfly antennas [1–7]. Owning the suitable design, these antennas show good impedance stability over the large frequency range. The Vivaldi antenna is one of the classical ultra wideband antennas with many applications [8]. The Vivaldi is a traveling-wave, leaky, end-fire antenna. Theoretically, the Vivaldi antenna has an unlimited range of operating frequencies, with constant beamwidth over the entire bandwidth [9, 10]. In UWB communications, in addition to achieving a good return loss and radiation efficiency, the ultra wideband antenna should be non-dispersive or dispersive in an acceptable range. On the other hand, for narrowband systems the traditional parameters are enough to assess the performance of the antenna but in the ultra wideband applications these parameters are inadequate for the applicability of the antenna. Actually the ultra wideband antenna transmits pulses with distortions and the antenna performance should be evaluated by means of dispersion parameters i.e., transfer function, group delay and fidelity factor as well. Having nearly constant transfer function and group delay, the signal is not distorted significantly. In [11, 12], the dispersion analysis of some Vivaldi antennas have been reported. In this paper, two modified types of Vivaldi antennas are simulated and fabricated and afterward the related dispersion characteristics are investigated in more detail. By preparing the simulation and measurement transmission/reception setups, the antenna dispersive behavior is evaluated completely in both frequency and time domains. In addition to displaying the shape of the signals, the fidelity factor between transmitted and received signals is calculated as an appropriate criterion to determine the similarity between signals. Moreover, in the other measurement setup, the dispersion analysis of two antennas is evaluated by using one standard Ridge Horn as a transmitter.

The organization of this paper is as follows, the used Vivaldi antennas and related Dispersion characteristics are presented in Section 2. Finally the paper is concluded in Section 3.

2. VIVALDI ANTENNAS

Two Vivaldi antennas are considered for analysis. We name these antennas as Vivaldi antenna Type I and Type II as shown in Fig. 1 and Fig. 2, respectively. In both antennas, the tapered microstrip line is applied as the antenna feeder and a 20-mil thick RO4003

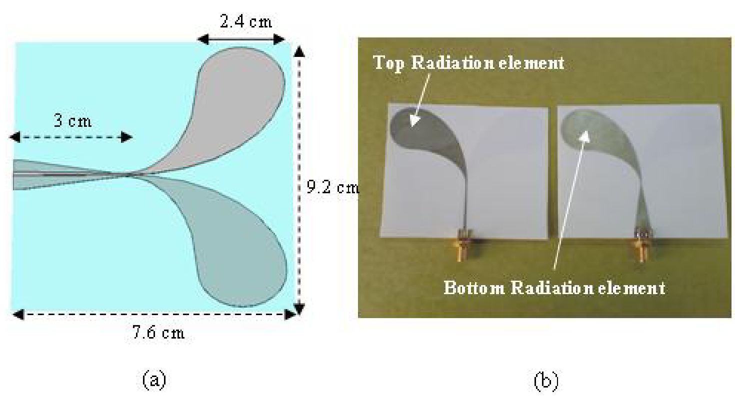


Figure 1. The Vivaldi antenna Type I, (a) Simulated antenna (b) Fabricated antenna.

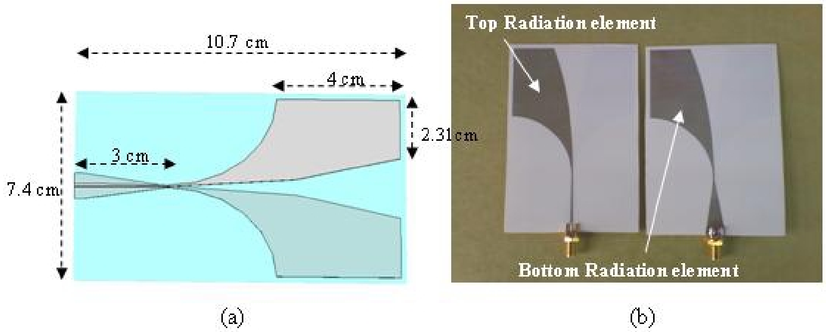


Figure 2. The Vivaldi antenna Type II, (a) Simulated antenna (b) Fabricated antenna.

($\varepsilon_r = 3.38$, $\tan\delta = 0.0027$) is used as substrate. Using CST MS software, the dimensions and structural parameters of the antenna are calculated to achieve the acceptable return loss. The measured and simulated VSWR of the assumed antennas are displayed in Fig. 3. The measurement results are obtained using HP8510C network analyzer. It can be seen that the Vivaldi antennas present good impedance stability over the wide frequency range.

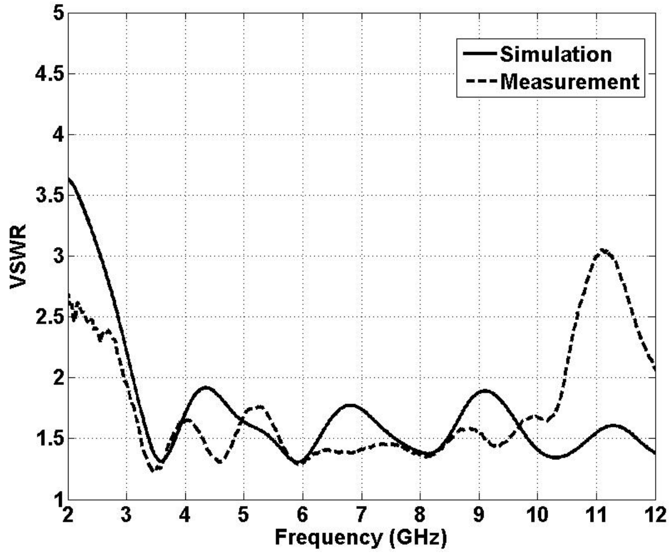
2.1. Frequency Domain Dispersion Characteristics

By performing the appropriate transmission/reception setups, we can evaluate the antennas dispersion behavior [13]. The frequency domain dispersion characteristics of the antenna are the transfer function (S_{21}) and group delay. In Tx/Rx setup, the received signal spectrum is obtained as follows:

$$S_r(f) = S_{21}(f) \cdot S_t(f) \tag{1}$$

where $S_t(f)$ is the transmitted signal's spectrum and S_{21} is the transfer function. Having a weak distortion in the transfer function's magnitude and phase makes less dispersion on the received signal. The distortion of phase can be evaluated by defining the group delay parameter as $-d\varphi/df$ where φ is S_{21} phase. Nearly constant group delay leads to the linearity of phase.

In Tx/Rx setups, two antennas should be located in a specific direction as shown in Fig. 4. It is due to this fact that the Vivaldi antenna is end-fire and directional antenna and the propagation is done through the slot between two radiation elements. Two similar antennas are located at 60 cm separation distance. The 60 cm



(a)

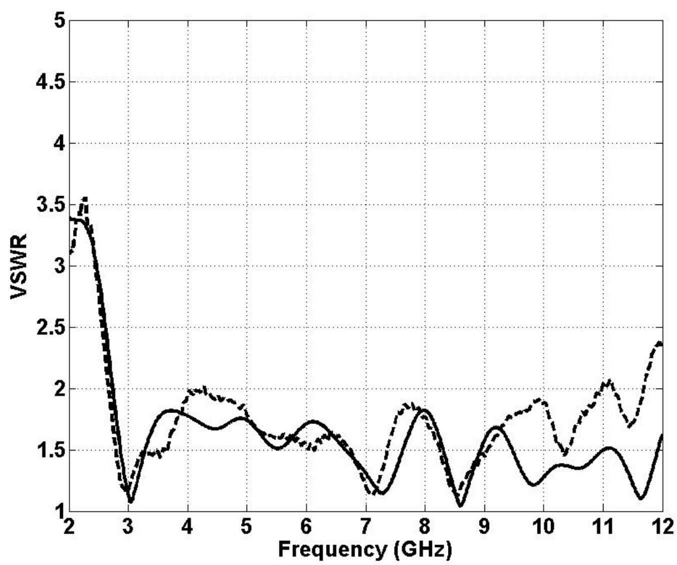


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Figure 3. VSWR of Vivaldi antennas, (a) Type I (b) Type II.

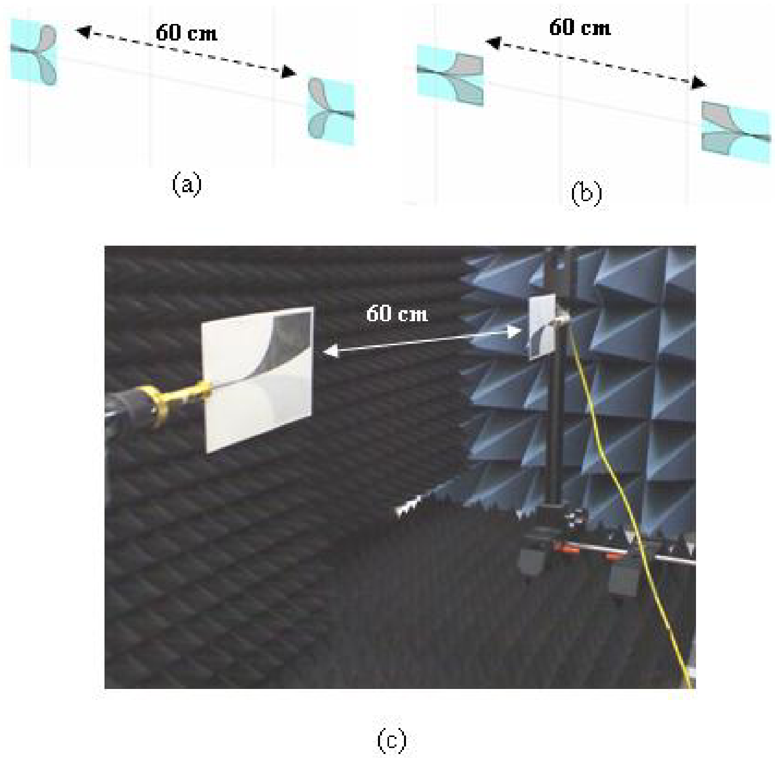
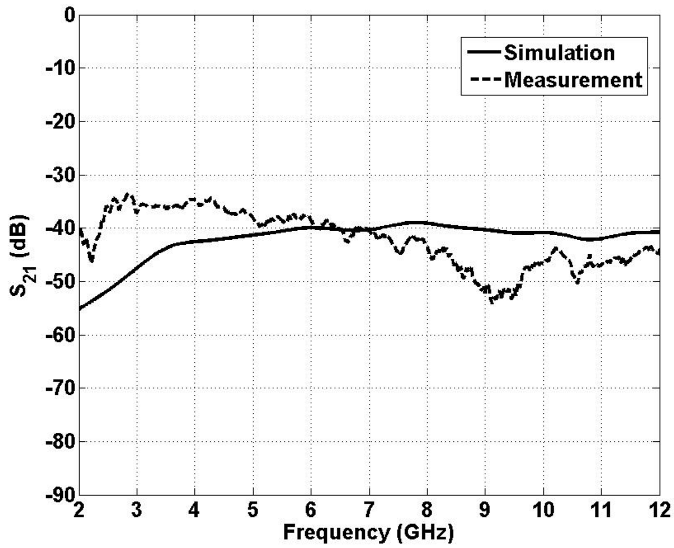


Figure 4. Tx/Rx setups, (a) Simulation setup for antenna Type I (b) Simulation setup for antenna Type II (c) Measurement setup for antenna Type II in anechoic chamber.

distance (approximately $6\,\lambda$ at the lowest operating frequency) is selected in order to have each antenna in the far-field of the other one. The simulated/measured transfer function and group delay of Vivaldi antennas Type I and Type II are illustrated in Figs. 5 and 6, respectively. A satisfactory agreement is observed between the measurement and simulation results. Moreover, it is seen that in the desired frequency range (3.1–10.6 GHz), the behavior of S_{21} and group delay is acceptable. In the other Tx/Rx setup, the Vivaldi antenna is located in the 60 cm distance with one standard Ridge Horn to evaluate the reception performance of the antennas. The magnitude of transfer functions and group delay between the Vivaldi antennas and Ridge Horn antenna are demonstrated in Fig. 7. The variation of S_{21} and group delay is in the reasonable range.



(a)

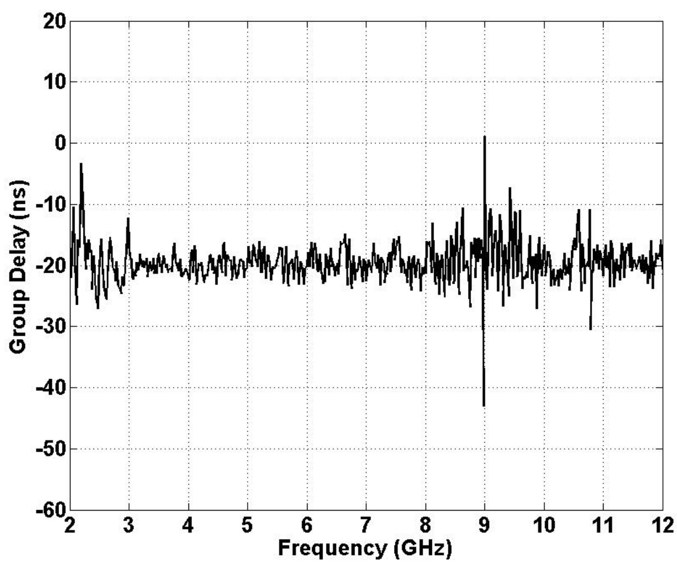


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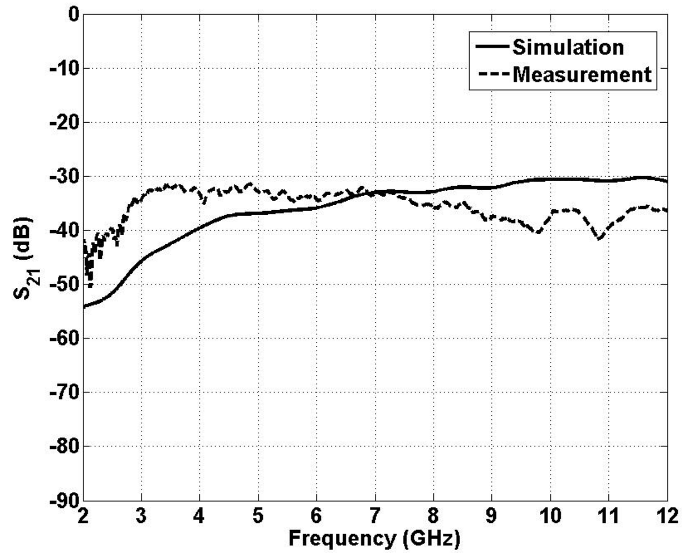
Figure 5. Transfer function of Vivaldi antenna Type I, (a) Magnitude of S_{21} (b) Group delay.



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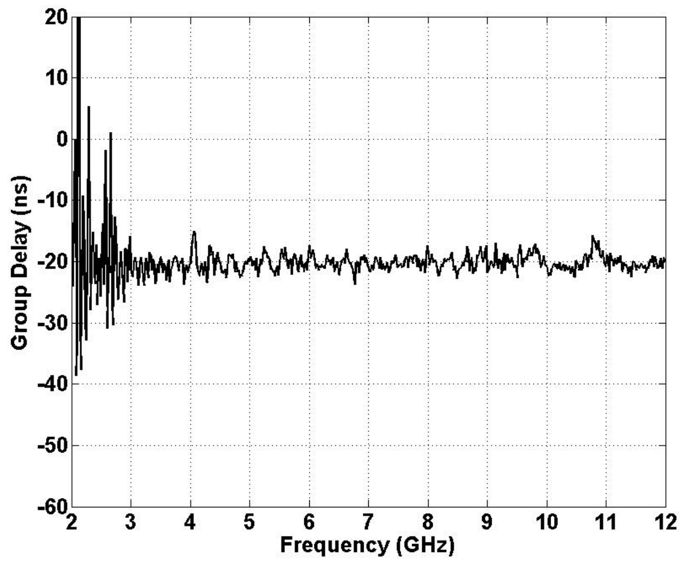
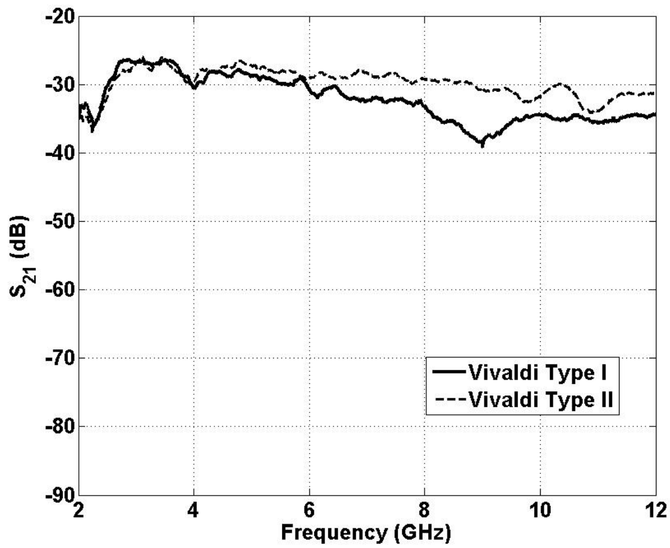
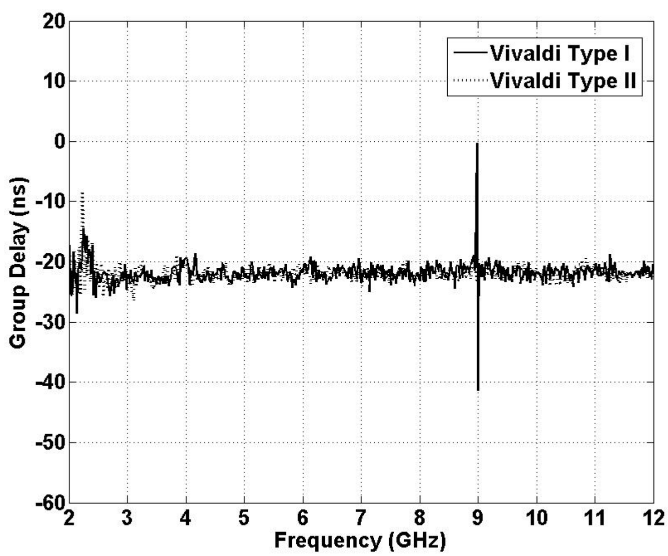


(b)

Figure 6. Transfer function of Vivaldi antenna Type II, (a) Magnitude of S_{21} (b) Group delay.



(a)



(b)

Figure 7. Tx/Rx setup of Vivaldi antennas with standard Ridge Horn, (a) Magnitude of S_{21} (b) Group delay.

2.2. Time Domain Dispersion Characteristics

The time domain characteristic of ultra wideband antennas is one of the most important factors which should be evaluated [14]. For dispersion analysis in time domain, the antenna is derived by input signal suggested in [15] as the UWB signal which meets the FCC spectral mask requirement for indoor systems. The transmitted and received signals of Vivaldi antennas Type I and II are depicted in Fig. 8. As can be observed from the pulse shapes, the transmitted pulse is not distorted considerably. The correlation coefficient between received signal and transmitted signal can demonstrate the amount of pulse distortion which the antenna induced. The fidelity factor (F) is defined by [16, 17]:

$$F = \max_{\tau} \frac{\int_{-\infty}^{+\infty} s_t(t)s_r(t-\tau)dt}{\sqrt{\int_{-\infty}^{+\infty} |s_r(t)|^2 dt \cdot \int_{-\infty}^{+\infty} |s_r(t)|^2 dt}} \tag{2}$$

where $s_t(t)$ and $s_r(t)$ are the transmitted and received signals, respectively. F demonstrates the similarity between two signals. When two signals are exactly the same, F coefficient becomes unity. Using (2), the fidelity factor between transmitted and received signals in Tx/Rx setups between two identical antennas is calculated and reported in Table 1. The Vivaldi antenna Type II presents better dispersion performance than antenna Type I.

Table 1. Fidelity Factor between transmitted and received signals for Vivaldi antennas Tx/Rx setups.

Antenna Type	F
Vivaldi Antenna Type I	0.7904
Vivaldi Antenna Type II	0.8415

As mentioned before, because the Vivaldi antenna has not omnidirectional applications, evaluating the transmission/reception performance of the antenna in one direction is sufficient.

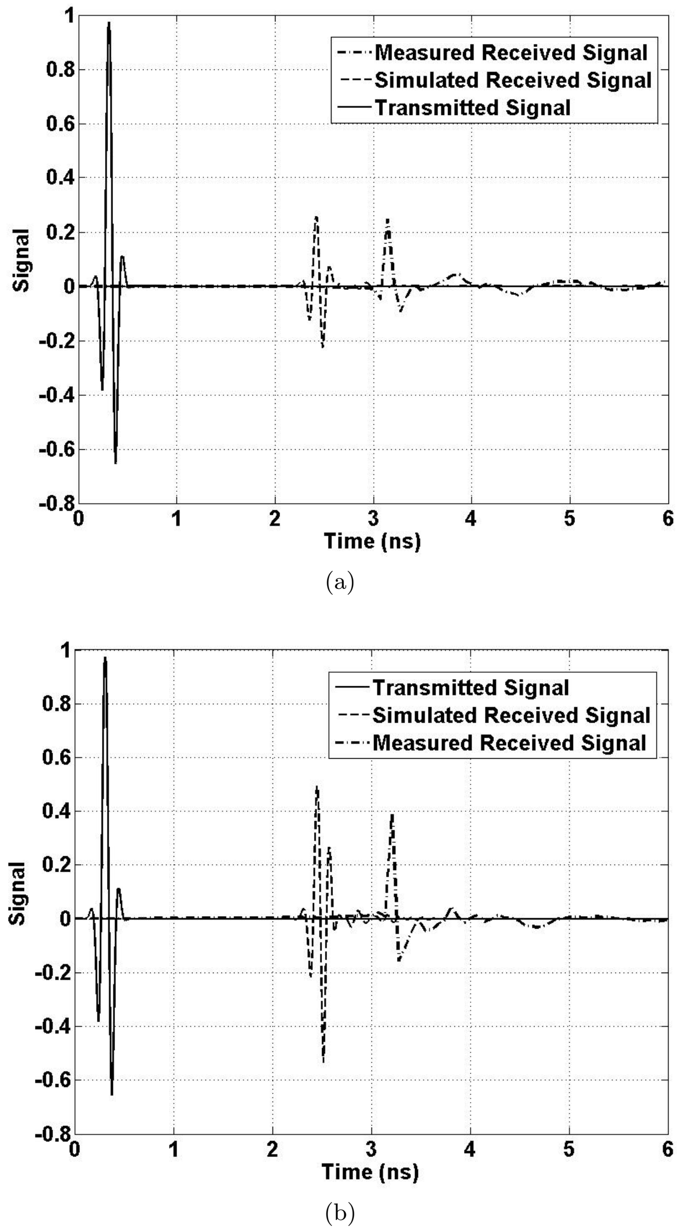


Figure 8. Transmitted and received signals in Tx/Rx setup, (a) Vivaldi antenna Type I (b) Vivaldi antenna Type II.

3. CONCLUSION

Because of the various applications of Vivaldi antennas in ultra wideband systems, we analyzed the dispersion performance of two Vivaldi antennas in this paper. To evaluate the dispersion characteristics and pulse distortions, transmitting/receiving setups of the antennas are performed. Furthermore, the dispersive behavior of the Vivaldi antennas is analyzed by using Tx/Rx setup with one standard Ridge Horn. To determine the exact amount of pulse distortion, time domain received signals are calculated as well. Good agreement is observed between simulation and experimental results. The reasonable results for the transfer function, group delay and fidelity factor demonstrate the good performance of the Vivaldi antennas for UWB systems.

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