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Antoine Dumoulin
Technological University Dublin

Matthias John
Technological University Dublin, matthias.john@tudublin.ie

Patrick McEvoy
Technological University Dublin, patrick.mcevoy@tudublin.ie

See next page for additional authors

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An Enhanced Method to Measure Pulse Disperion in UWB Antennas

A. Dumoulin[1], M. John[1,2], P. McEvoy[1] and M. J Ammann[1,2]

[1]Antenna & High Frequency Research Centre, [2]CTVR, the Telecommunication Research Centre

Dublin Institute of Technology

Kevin Street, Dublin 8, Ireland

antoine.dumoulin@mydit.ie

***Abstract*—A de-embedding method is reported to isolate an antenna under test from the dispersive effects of the measurement equipment in a time-domain setup which is key to validation of the simulated fidelity factor of radiated patterns.**

I. Introduction

Accurate characterization of frequency- and time-domain (TD) radiation performances are critical for high-fidelity Ultra Wideband (UWB) antenna development for low-power, short range communications and ranging systems. Group delay measurements are easily made at the calibrated transmission network reference planes with a Vector Network Analyzer (VNA) [1]. However, the antenna must be isolated from the dispersive effects of the network when measuring with a real-time oscilloscope. This paper reports a method to enhance fidelity factor measurements of the radiated pulse from a UWB antenna using de-embedding.

II. Time Domain Measurement Setup

We consider a communications system of two antennas which were designed for this system. The transmitting antenna (AUT) is a novel planar monopole optimized for a -10 dB match in the UWB frequency range, and for best average pulse fidelity around its azimuth plane. On the receiving side, a tapered slot antenna was also optimized for a -10 dB match in the UWB range and optimal TD performance on bore-sight while operating in receiving mode. Both of these antennas were prototyped and, in an initial measurement, exhibit an average fidelity factor (FF) of 89.5% for the AUT and a FF of 98.6% for the receiving antenna when excited with an amplitude modulated Square Root Raised Cosine (SRRC) pulse. This signal was selected for its enhanced fit to the FCC power spectrum mask and as a test of the antenna capability to convey broadband a pulse with minimal TD distortion. The digitized SRRC pulse was used to stimulate an Arbitrary Waveform Generator (AWG) Tektronix AWG 7122C, then passed through a Picosecond 5865 wideband amplifier and fed to the AUT input port. The incident signal on the receiving antenna was measured by an Agilent DS081204A oscilloscope. The measurement setup is shown on Fig. 1. By analyzing the measurement setup at different points, it was shown that the SRRC signal delivered to the AUT was impaired by the transfer functions of the AWG, amplifier and cables as illustrated in Fig. 2a and b.

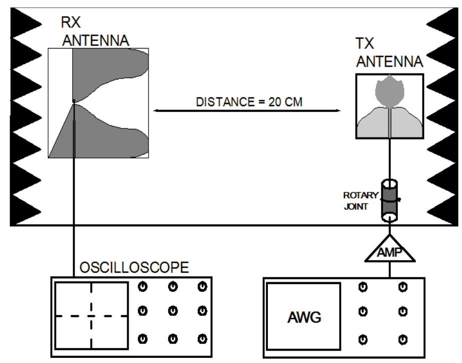
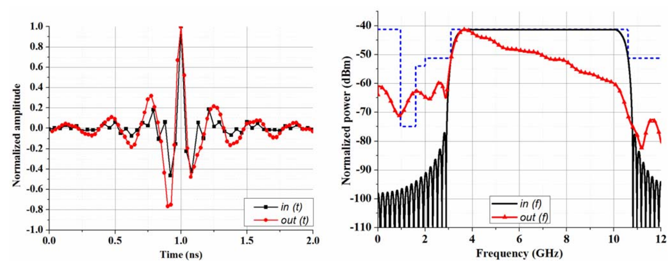


Figure 1: Time domain measurement setup.



(a) (b)

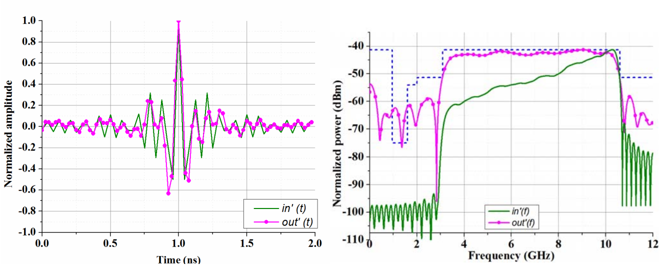
Figure 2: (a) Digitized SRRC waveform *in(t)* & amplified AWG output signal *out(t)* and (b) their respective normalized power spectrum density.

This measurement indicates that the amplified AWG output energy distribution *out(f)* is impaired by -8.45 dB at 6.85 GHz and by -18.7 dB at 10 GHz. From these results, it obvious that the signal *out(t)* differs too much from the original SRRC signal *in(t)*, and is unsuitable for the experiment. This result raises the need to compensate for the signal generation and transmission network losses up to the AUT.

III. Signal Equalization and Antenna Deembedding

To mitigate this problem, the signal *out(t)* has been equalized using Eq. 1 where *in'(t)* is the compensated input signal to the AWG:

$$in'(t) = IFFT\left[FFT\big(in(t)\big)/FFT\big(out(t)\big)\right]. \quad (1)$$



(a) (b)

Figure 3: (a) Digitized compensated waveform *in'(t)* & amplified AWG output compensated signal *out' (t)* and (b) their respective normalized power spectrum density.

Fig. 3a shows the compensated signal input *in'(t)* to the AWG alongside the compensated amplified AWG output *out'(t)* while Fig. 3b represents the normalized energy distribution of these signals.

It is clear that the *out'(t)* signal has a much more constant energy distribution across the UWB range than the signal *out(t),* and its characteristics are now adequate to provide an efficient TD stress test for the AUT. As was shown in [2], UWB radiated signals are time derivatives of the excitation signal. Therefore, the simulated FF values are the cross correlation between the input signal derivative and the signals radiated by the AUT. Hence it is essential that the transfer function from the receiving antenna and the cable are removed from the measured signals.

The transfer function of the receiving network cable $H_C(\omega)$ can be determined using a VNA. The transfer function $H_{RX}(\theta,\varphi,\omega)$ of the receiving antenna in receiving mode can be determined using the method found in [3] and by knowing the S21 of a pair of identical antennas setup in an antenna system configuration. The antenna transfer function for both transmitting and receiving mode can be calculated using:

$$H_{TX}(\theta,\varphi,\omega) = \sqrt{\left(\frac{S21\,(\theta,\varphi,\omega)}{H_{FS}(\omega)}\frac{j}{\lambda}\right)} \quad (2)$$

$$H_{RX}(\theta,\varphi,\omega) = \sqrt{\left(\frac{S21\,(\theta,\varphi,\omega)}{H_{FS}(\omega)}\frac{\lambda}{j}\right)}, \quad (3)$$

where θ and φ define the spatial orientation of the antenna, ω is the angular frequency, λ is the free space wavelength and the free space transfer function H_{FS} is define is by:

$$H_{FS}(\omega) = \frac{\lambda}{2d}\exp\left(-j\omega\frac{d}{c}\right), \quad (4)$$

where d is the antenna separation in meter, and c is the speed of light in meter per second. The measured radiated signals can be found using:

$$Erad(\theta,\varphi,t) = IFFT\left[\frac{V_{RX}(\omega)}{H_{RX}(\theta,\varphi,\omega)\times H_C(\omega)}\right], \quad (5)$$

which eliminates the influence of the receiving antenna and cable.

To assess the spatial TD performance of the AUT, the antenna was positioned at 15° steps in the radiation plane. A steady pulse reading was achieved by averaging the received pulse by 64 samples on the oscilloscope. To show the benefits of using the antenna de-embedding method, the pulse fidelity of the AUT is plotted, in Fig.4, for the measured received pulse and post processed received pulse alongside the simulated FF. The results in Fig. 4 show clearly that removing the receiving antenna and receive network transfer function from the measured pulse lead to better agreement between simulation and measurement. Also by analyzing Fig. 5a and Fig. 5b, it is seen that the energy distribution of the post processed received signal *out**(t)* is in good agreement with the 1st order derivative of the signal *out'(t)* at the AUT port.

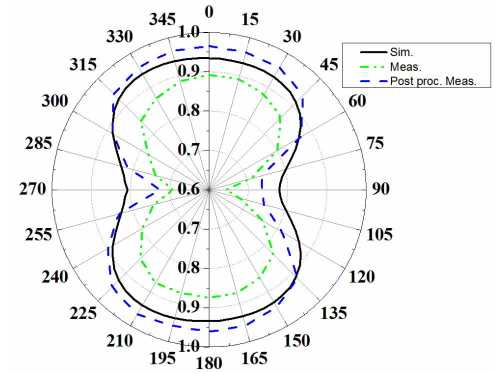
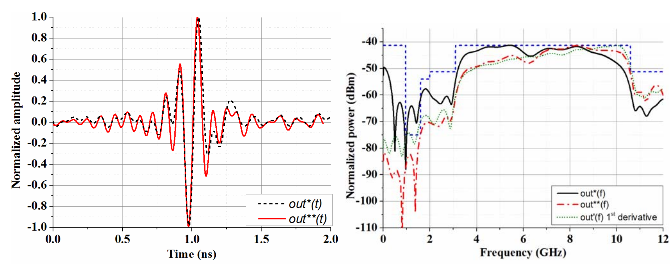


Figure 4: Simulated, measured and post processed FF.



(a) (b)

Figure 5: (a) Measured *out*(t)* and post processed received pulse *out**(t)* and (b) their normalized energy distribution versus the reference signal 1st order derivative.

IV. Conclusions

A method was demonstrated to remove the dispersive effects of antennas and measurement equipment like signal generator, cables and connectors in a real TD measurement setup. It was shown that by isolating the AUT transfer function, more accurate TD measurements can be achieved and agreement to simulation improved.

References

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