Time Domain Analysis of Antenna Return Loss

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Abstract

We evaluate reflection coefficients of antennas based on time domain analysis with a sampling oscilloscope. The return losses of antennas were extracted by the Fourier transformation of reflection pulses from antennas with respect to the incident pulse signals. The three-error terms, which are commonly used for the correction of a microwave network, were determined using a 3.5 mm calibration kit. The reflection coefficients of antennas were compared with those measured with a commercial vector network analyzer.

Keywords: Time Domain Reflectometry, Return Loss Measurement, Vector Network Analyzer

1. Introduction

The matching and resonance characteristics of antennas have been primarily evaluated using vector network analyzers (VNAs). While such frequency domain measurement is useful, the technique of time domain analysis is also useful due to its unique advantages: it provides a direct and obvious view of the locations and magnitudes of each discontinuity as a function of time or distance [1]. Because of these merits, most modern VNAs offer functions for time domain analysis. However, there are some inevitable distortions that originate from artifacts due to frequency to time conversion [1]. In this paper, we present a direct temporal mismatch analysis of antennas and extend our data to extract complex return losses based on time domain reflectometry using a sampling oscilloscope (SOS).

2. Time Domain Return Loss Measurement System

The time domain analysis system and its error-correction modelling are shown in Fig. 1. There are two main discontinuity sections at the coupler and AUT (antenna under test) port sides. We employed the three-term error model (we used superscript p and c to indicate the port and coupler sides, respectively) at each section. The error terms at the coupler side can be selectively eliminated with the time gating technique; the remaining terms at the AUT port are determined with the calibration (=cal) kit.

Figure 1: Time domain reflection coefficient measurement system with oscilloscope: (a) configuration, (b) error-correction model.
We used 3.5 mm coaxial calibration open, short, and termination loads at the AUT port side; the three reflection pulse traces for a 20 GHz input pulse are shown in Fig. 2 (b). The pulses shown in Fig 3 (a) are leakage components due to the coupler. They are irrelevant to the cal kits and thus can be temporally ‘gated out’. The reflected pulses from the cal kit are shown in Fig 3 (b), (c). They exhibit maximum/minimum reflections with opposite phase over 1 ns timing due to the cal kit and air line delay. After this time window, the secondary round trip pulses follow as shown in Fig. 3 (d), but this part can also be gated out, as was done in the case shown in Fig. 3 (a).

Figure 2: Pulses at input and test port of the system in Fig. 1: (a) incident pulse at input port, (b) reflection pulses due to calibration kit at test port.

Figure 3: Detailed view of Fig. 2 (b): (a) coupler leakage pulses, (b) calibration kit pulses, (c) magnified view of (b), (d) secondary mismatch pulses.
3. Return Loss Measurement of Antennas

The three reflective pulses presented during the standard mismatch window, as shown in Fig. 3 (b), (c), possess effective components for calibration because the pulses in that time period are affected only by the cal kit. Each pulse is the summation of the distinct pulse components that travel along the multiple paths in Fig. 1 (b) : ‘input-a-b-c-c’-b’-a’-test (including e₀⁰'), ‘input-a-b-c-d-e-e'-d’-c’-c’-b’-a’-test (including Γ, e₁₀e₀⁰'), and ‘input-a-b-c-d-e-e’-d’-(d-e-e’-d')⁰-c’-b’-a’-test (including Γ, e₁₀e₀⁰', e₁¹, n=1,2,3,...). The three pulses for calibration are transformed into the spectral components by using the FFT algorithm to determine the port error terms using the conventional three term error model [1-3].

We employed two patch antennas designed at 4.4 GHz and 9.3 GHz. The reflective pulses from the AUTs are shown in Fig. 4 (b). Each pulse has ~18 ps of transition time, which corresponds to ~ 20 GHz bandwidth. However, the reflected pulses are devoid of each antenna’s resonant frequency components. The echo pulse from the 4.4 GHz antenna (black line) shows two main parts. The primary pulse indicates the amount of connector mismatch; the secondary pulse is in charge of antenna characteristics. The ~0.6 ns of the two pulse separation is due to the feeding line between the connector and the feeding point.

The echo pulse from the 9.3 GHz antenna (gray line) shows a connector mismatch similar to that of the 4.4 GHz antenna; however, quite different secondary pulses from the patch follow shortly after. These pulses are transformed into complex spectral arrays and are corrected using the error terms.

![Figure 4: (a) antennas, (b) reflection pulses due to antennas and system errors.](image)

The error-corrected spectral responses of the antennas are shown in Fig. 5. The magnitude and phase of each antenna are compared with those values measured with a commercial VNA. The results are found basically to match except for the mild ripples on the response by an SOS. The ripples are thought to have originated from the transformation of the finite time domain data into the spectrum. The truncated time window causes undesirable ‘sinc function shape’ over the spectrum. Fortunately, such ripples usually show own spectral periodicity, which can be improved by expanding the time window or by using a smoothing technique [1]. In addition, the linear phase shift becomes strongly distorted at the resonance, which indicates the degree of resonance at the antenna’s working frequency.

Because the reflection coefficients were extracted from the fast pulsed response, such time domain reflectometry analysis is inherently advantageous for fast and broadband measurement.
4. Conclusions

Time domain analyses of antennas have been presented based on a pulsed reflectometry system. The system requires only a broadband pulse source and an oscilloscope with a simple coupling setup. The system errors were determined by time gating and three-error term calibration procedure and were filtered out. The reflection coefficients of the antennas were compared with those measured with a commercial vector network analyzer; minor discrepancies were discussed.

References


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