Transmission Line Load Parameters Extraction using Time Domain Reflectometry and the Continuous Wavelet Transform

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Summary: Time domain reflectometry (TDR) is a well-known technique used to investigate the electrical characteristics of a signal propagation medium, such as an IC package interconnect, PCB trace or electrical cable, by analyzing the reflections caused by impedance discontinuities. A TDR equipment sends a pulse on the transmitter end of the investigated medium, which is regarded as a transmission line (TL), and acquires the reflected waveform, at the same end of the TL. This waveform contains information regarding transmission line parameters, impedance discontinuities along the line and load parameters, but the extraction of relevant information from this waveform requires complex mathematical analysis.

This paper presents the algorithm and implementation of load parameter extraction using the continuous wavelet transform (CWT) of the TDR waveform. The CWT leads to multi-resolution analysis (MRA) of the considered signal. The load is modeled as a passive R-L-C circuit connected at the far end of the investigated transmission line. Our algorithm, implemented in Matlab, analyzes the reflected signal and determines the R-L-C parameters of the load and the distance between the load and measurement point.

Keywords: Transmission line, time domain reflectometry, continuous wavelet transform, multi resolution analysis

Motivation

Previous attempts have been made to extract electrical parameters using automated processing of TDR waveforms. In [2] such analysis is used to extract the characteristic impedance of the transmission line, while in [3] TDR measurements made on odd and even coupled transmission lines are used to evaluate the self and mutual capacitance and inductance. Other works on this topic are related to fault identification on electrical distribution systems [4] or digital subscriber line (DSL) cables [5]. Those are all application specific approaches.

Our waveform decomposition method is more general than previous work known in the literature, in the sense that it can be applied to evaluate the electrical parameters of either IC packages, PCB interconnect discontinuities or electrical cables faults. Using time windowing in such a way that only the first reflection after the stimulus pulse is analyzed, any impedance discontinuity can be regarded as a load, so R-L-C model extraction can be used to evaluate the nature of the discontinuity.
Results

For this study, the reflected signals are acquired using a high bandwidth oscilloscope. The TDR waveform analysis algorithm, using the CWT, is implemented in Matlab and uses the acquired signal. Fig. 1 presents such a waveform, obtained by testing a coaxial cable with a 50 $\Omega$ to 75 $\Omega$ characteristic impedance discontinuity along its length, with an open end ($Z_{\text{end}} \to \infty$). Fig. 2 presents the CWT representation of the analyzed signal, using the Haar wavelet on a 32 scale decomposition. Using this representation, the discontinuity points in the analyzed signal (which correspond to the reflections) can be correctly identified (the highlighted areas).

After identifying the discontinuity points, a statistic analysis is performed to identify their characteristics, from a line termination load model point of view (purely resistive, or an R-L-C model can be derived).

References

