Y-Tree Cable Defect Detection with NGD Analysis as a TR Method Alternative

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The negative group delay (NGD) is the most today uncommon electronic function. Therefore, research effort has been made to make the NGD concept to be familiar to electronic and EMC engineers by establishing an analogy between the classical electronic filter [1]. The NGD function was generated with transmission line (TL) based passive circuits [2-4]. This paper introduces an innovative NGD application for the defect detection of R_0=50 Ω matched Y-tree cable as shown in Fig. 1(a). Time Reversal (TR) was successfully used to detect soft fault for wire diagnosis [5]. The tree is constituted by branches $TL_k(R_0,d_k)$ with physical length d_k, k=1,2,3. In our case of study, the cable branch TL_3 is supposed defected at position x from M_0 with characteristic impedance becoming $R \neq R_0$. The defected TL can be modeled as shown in Fig. 1(b) by considering that the defected part as a piece of TL $TL_3(R,y)$ with $y << d_3$. The defected structure S-matrix:

$$[S] = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \quad (1)$$

from port M_1 and M_2 can be established by considering the structure behaving as a typical NGD topology shown in Fig. 1(c) with input impedance Z_{in} of TL_3. Position x and impedance R can be determined from the S-parameter and group delay (GD) $GD(\omega) = \partial \arg[S_{21}(j\omega)] / \partial\omega$.

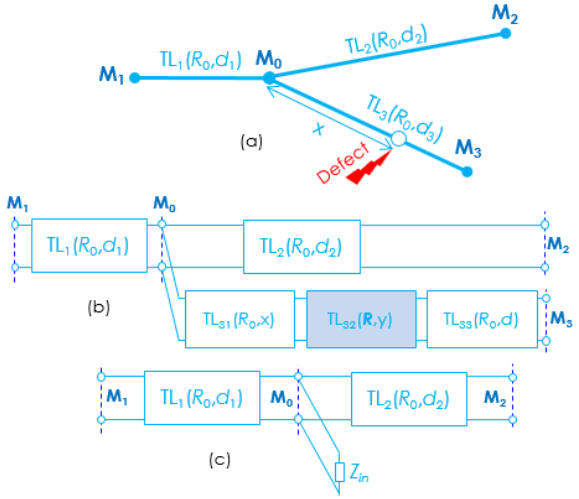

Figure 1. Defected Y-tree cable configuration.

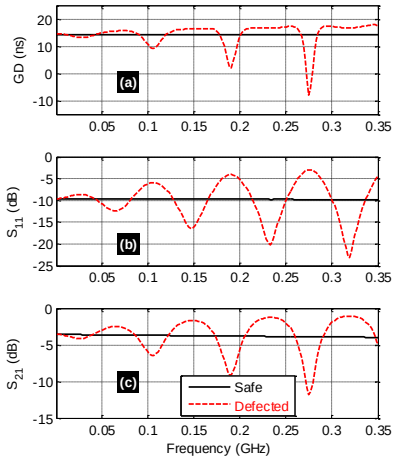

Figure 2. Typical NGD responses of cable configured in Fig. 1.

To illustrate the innovative NGD application, a Y-tree proof of concept constituted by cable (d_1=1 m, d_2=2 m, d_3=3 m) defected at x=1.2 m with characteristic impedance dropped to R=1 Ω was simulated with the commercial tool ADS® from Keysight Technologies®. The simulated results from 0 to 0.35 GHz showing the difference between the "safe' and "defected" cable structure are plotted in Figs. 2. The safe structure presents a flat GD of about 14 ns and transmission coefficient -3.8 dB. However, the cable defect induces NGD spikes with f_0=76 MHz frequency period. The detailed NGD analysis and the cable defect characterization will be developed in the final version of the paper.

References

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