Describing Asymmetric Faults with Multiconductor Transmission Lines for SSTDR

Hunter Ellis* [(1)], Cody LaFlamme [(2)], Cynthia M. Furse [(1)], and James R. Nagel[(1)]
(1) University of Utah, Utah, USA
(2) University of Florida, Florida, USA

Spread spectrum time domain reflectometry (SSTDR) has been used for fault detection and location in diverse electrical systems such as airplane wiring (P. Smith, C. Furse, and J. Gunther, IEEE sensors journal, vol. 5, no. 6, pp. 1469–1478, 2005). These systems stay energized during the fault detection process, which contributes to a harsh testing environment. SSTDR uses a spread spectrum signal transmitted through a transmission line (TL), where it will reflect off discontinuities in the characteristic impedance in the wiring, such as faults or other elements. A phenomenon in twin-lead cable where a small portion of the SSTDR signal is transmitted beyond an asymmetric fault (break in only one wire) has been recorded in (M.U. Saleh, Joel Harley, N.K.T. Jayakumar, S. Kingston, E. Benoit, M. Scarpulla, and C. Furse, Progress in Electromagnetics Research (PIER-M), 89, 121-130, 2020) (A.S. Edun, N.K.T. Jayakumar, S. Kingston, C. Furse, M. Scarpulla, and J. B. Harley, IEEE Sensors Journal, 2020) and is currently not well understood. TL theory would predict that the signal would completely reflect off the asymmetric fault. We used multiconductor TL (MTL) theory, which is a more general form of TL theory that allows for more than one transmission line in the system to explain how energy from the SSTDR signal is transmitted beyond the asymmetric fault (C. R. Paul, John Wiley & Sons, pp. 89-139, 2007). MTL theory would explain these results because these transmission lines could have coupled magnetically and electrically to some surrounding conductors allowing for a small transmission of energy beyond the asymmetric gap. A better understanding of how MTL theory would affect the SSTDR measurements would allow users to interpret results better when an asymmetric fault exists.

To test if MTL theory effectively explains the SSTDR results, we compared measured data of a system of twin lead cables with an asymmetric break at varying heights above a metal ground plane to a simulation of the MTL system. The simulation relied on a combination of a finite difference method (FDM) simulation of a two-dimensional cross-section of the twin lead ground plane system to determine the characteristic RLGC parameters of the system, along with finite difference time domain (FDTD) simulation of the SSTDR response of the system in the time domain. It was found that the MTL simulations produced similar data to the measured results showing that MTL theory could be used to examine SSTDR wiring systems.