Measurement of High-Impedance Surface Backed Microstrip Structures Using Multimode TRL Calibration

Kevin Keegan, and K.C. Kerby-Patel
University of Massachusetts Boston, Boston, MA 02125

The multiconductor transmission line model for an antenna backed by a high-impedance surface represents the combined antenna-surface structure as a microstrip line above a high-impedance ground plane (Kerby-Patel, Proc. Ant. Appl. Symp., 324-339, Sep. 2013). The model represents the combined structure as a "stacked microstrip line" with three layers: the microstrip line, the high impedance surface's conductive patches, and the ground plane. The multimode TRL algorithm (Wojnowski et al, IEEE Trans. Microw. Theory Techn., 60, 2220-2247) was used to perform measurements of the high-impedance surface backed microstrip structure. Since stacked microstrip line is not a standard transmission line structure, novel multimode TRL calibration standards were required.

This paper presents the techniques used to measure and experimentally verify the predictions of the multiconductor transmission line model over an approximately 2:1 bandwidth (3 GHz to 6.5 GHz). The vertically stacked, asymmetrical nature of the microstrip structure required extra care during the design of the connector placement and the grounding scheme to ensure that the structure could be excited correctly. While a traditional TRL calibration only requires three standards, the requirements of the multimode TRL algorithm requires four standards - a thru, line, and two unique reflect standards. The first reflect standard is required to exhibit high modal reflection and low modal conversion, while the second must exhibit high modal conversion with low modal reflection. In addition, the central layer of the reflect standards was prone to radiation, especially when a short termination was used, because the structure became too similar to a quarter-wavelength shorted patch antenna at certain frequencies. This tendency to radiate was circumvented by using an open circuit as the termination and by minimizing the length of all the calibration standards.

The multimode TRL standards were designed and their terminal S-parameters initially determined through simulation in HFSS. Their modal S-parameters were then verified using the multimode TRL calibration in MATLAB. A detailed description of the calibration standards design and measurement process is provided, followed by simulated and measured results.