Non-Contact Characterization of Antenna Parameters via Network Calibration

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We present a novel, non-contact antenna characterization method based on a 1-port network analyzer calibration procedure. A single, uncalibrated vector network analyzer (VNA) port is used to illuminate the antenna under test using a standard gain antenna, typically a horn operating over the frequency band of interest. The test antenna is then placed on a rotator stage in the far field of the VNA horn. We note that the test antenna port is not connected to the VNA, thus enabling non-contact characterization. The 1-port, uncalibrated VNA, in addition to the test antenna illuminated by the VNA port are treated as an open air fixture, with the test antenna port as the desired calibration plane. With this setup, it is possible to apply standard/known loads to the test antenna port to calibrate the open-air fixture using any conventional network analyzer calibration approach. Here, we use a self-defined calibration process using 4 offset-short standards, as described in (A. Lewandowski, W. Wiatr, D. Gu, N.D. Orloff, and J. Booth, "A multireflect-thru method of vector network analyzer calibration", IEEE Trans. Microwave Theory Techn., 65(3), 905-915, 2017). As part of this particular calibration, the propagation constant at of the transmission line feeding the test antenna can be calculated, and can be used for verification. In addition, in the calculated error correction network, the port match e_{22} corresponds to the input impedance of the test antenna. To measure the test antenna pattern, the reflection coefficient at the uncalibrated VNA port is recorded by rotating the test antenna over the desired angular range. At this step, two such recordings are needed, using two different terminations of the test antenna port. Since the test antenna port impedance is independent of rotation angle, the two angular scans can be used to normalize the through branch of the error correction network ($e_{21}e_{12}$) as a function of angle. The error parameter $e_{21}e_{12}$ is in fact proportional to the test antenna's gain. Its reference level can also be calculated using Friis' transmission formula, leading to full pattern and gain characterization, provided the VNA port antenna gain is known and the proposed antenna-port calibration is carried out after an initial VNA port calibration. We also note that the remaining error parameter e_{11} also provides the VNA port antenna match as a second verification of the procedure. Perhaps most importantly, this simple-but-effective approach is particularly useful for higher frequencies, such as the millimeter-wave and terahertz bands (55GHz-1.1THz) where connectorized antennas are either not available or contact probe-based testing is not feasible. A similar method was developed in (W. Wiesbeck and E. Heidrich, "Wide-band multiport antenna characterization by polarimetric RCS measurements", IEEE Trans. on Antennas and Propagat., vol. 46, no. 3, pp. 341–350, 1998) using a sophisticated radar system. We also note that our approach is similar in sprit to the one developed by George Sinclair (G. Sinclair, E. Jordan, and E. Vaughan, Proceedings of the IRE pp. 1451–1462, 1947), where the test antenna is terminated with a varying load impedance and the re-radiated fields from the antenna structure can be used to extract its characteristic parameters.