Techniques for Characterizing Microwave Printed Antennas

Slot-line and other printed antennas can be characterized quickly and inexpensively.

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The combination of a de-embedding technique and a direct on-substrate measurement technique has been devised to enable measurement of the electrical characteristics (impedances, scattering parameters, and gains) of microwave printed antennas that may be formed integrally with feed networks that include slot lines, coplanar striplines, and/or coplanar waveguides. The combination of techniques eliminates the need for custom test fixtures, including transitions between (1) coaxial or waveguide feed lines in typical test equipment and (2) the planar waveguide structures of the printed circuits under test. The combination of techniques can be expected to be especially useful for rapid, inexpensive, and accurate characterization of antennas for miniature wireless communication units that operate at frequencies from a few to tens of gigahertz.

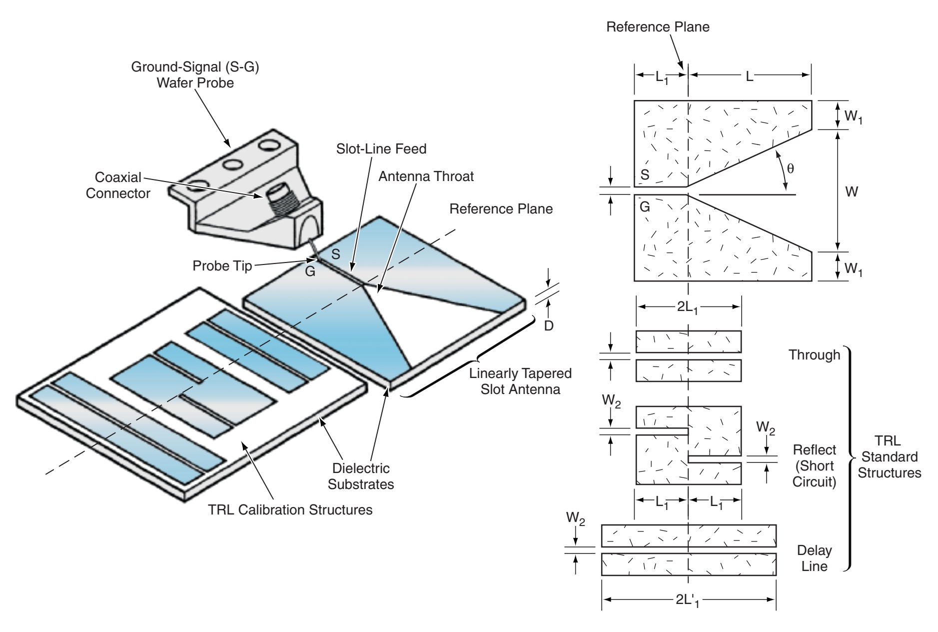


Figure 1. **Measurements at the Input Terminals** of the slot-line feed of a linearly tapered slot-line antenna are referred to a plane at the antenna throat (the narrow end of the taper) by means of (a) calibration measurements on TRL standard structures and (b) de-embedding software.

Both techniques involve the use of an automatic network analyzer (ANA) coupled with a wafer probe station and a pair of ground-signal microwave probes. The de-embedding technique includes the established through-reflect-line (TRL) calibration technique, which involves the fabrication and testing of standard calibration structures on the same substrate alongside an antenna that one seeks to characterize (for example, see Figure 1). The dimensions of the calibration structures are related to those of the antenna in a predetermined way. For the TRL measurements, the ANA is operated under the control of de-embedding software developed by the National Institute of Standards and Technology (NIST). This software processes the TRL measurement data to establish an electrical reference plane in the antenna, to which plane all de-embedded scattering parameters and impedances are meant to be referred. Thereafter, the de-embedding software can be used to obtain the reference-plane characteristics of the antenna from ANA measurements taken at the input terminals of the slot-line feed.

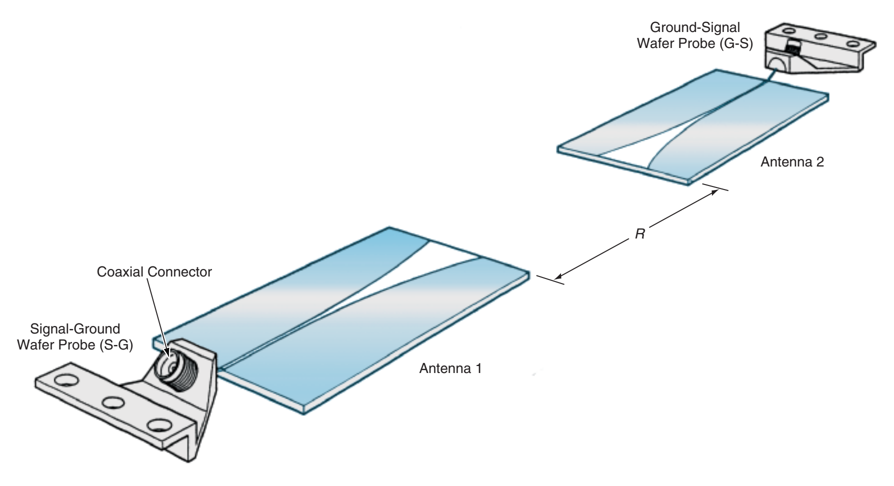


Figure 2. The **Gain of Two Identical Vivaldi Antennas** (exponentially tapered slot-line antennas) can be measured by the direct on-substrate measurement technique and this geometric arrangement. The distance *R* must be made large enough that far-field conditions prevail.

The direct on-substrate measurement technique involves the calibration of the ground-signal microwave probes to their tips. This calibration is done by use of the ANA with an open circuit, a short circuit, and a matched load as standards. The standards for direct measurements are provided by the probe manufacturer on an impedance standard substrate. Calibrated probes are then put in contact with the input terminals of the slot-line feed of the antenna, and the antenna is excited via the probes. The direct on-substrate measurement technique is best suited for designs in which the slot-line feeds are short enough to interfere only minimally with the probes.

Figure 2 depicts a setup for measuring the absolute gain of a pair of identical antennas. In this case, the antenna input and output measurements are made by the direct on-substrate probe measurement technique, the antennas are oriented facing each other and matched in polarization, and the antennas are placed far enough apart that, to a close approximation, far-field radiation conditions prevail. The gain is calculated from the geometric parameters of the setup, and from the transmitted and received power levels measured by the ANA via the probes connected to the terminals of the transmitting and receiving antennas, respectively.

This work was done by Rainee Simons of NYMA/Federal Data Corp. and Richard Q. Lee of **Glenn Research Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17040.

Cylindrical Antenna With Partly Adaptive Phased-Array Feed

The cost of a high-performance antenna could be reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed design for a phased-array-fed cylindrical-reflector microwave antenna would enable enhancement of the radiation pattern through partially adaptive amplitude and phase control of its edge radiating feed elements. Antennas based on this design concept would be attractive for use in radar (especially synthetic-aperture radar) and other systems that could exploit electronic directional scanning and in which there are requirements for specially shaped radiation patterns, including ones with low side lobes. One notable advantage of this design concept is that the transmitter/receiver modules feeding all the elements except the edge ones could be identical and, as a result, the antenna would cost less than in the cases of prior design concepts in which these elements may not be identical.

The basic antenna geometry (see figure) is that of a parabolic cylindrical reflector. The cylindrical axis is the y axis, and the geometric boresight axis is the z axis. The phased array of feed elements lies on the focal line, which is parallel to the y axis, at a distance F from the apex of the parabola. The boundary of the reflector and thus of the aperture, as projected onto the x,y plane, is specified by the superquadric curve

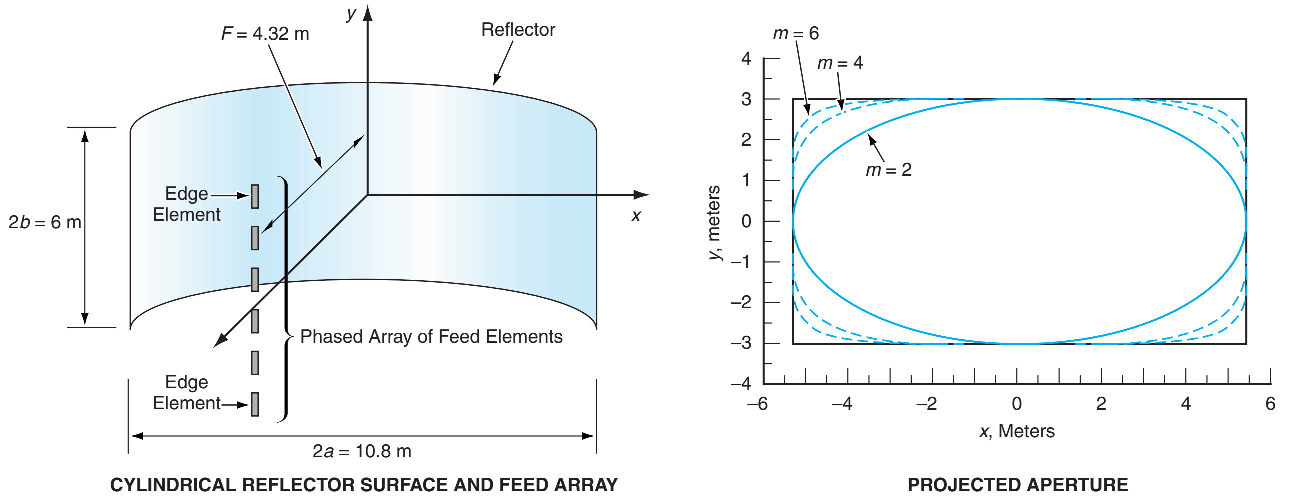
$$\left|\frac{x}{a}\right|^m + \left|\frac{y}{b}\right|^m = 1$$

where a and b are the lengths of the x and y semiaxes, respectively, of the aperture; and m is a parameter that can be chosen to control the rounded shape of the corners. These basic geometric characteristics are the same as those of the antenna described in "Low-Sidelobe Phased-Array-Fed Cylindrical-Reflector Antenna (NPO-20494), *NASA Tech Briefs*, Vol. 24, No. 2 (February 2000), page 5a.

For the non-edge radiating elements, the amplitudes may be chosen to obtain suitably shaped main and side lobes, and the phase difference between adjacent elements would be set at the value needed to point the main lobe in the desired direction. For the nth non-edge element, the excitation coefficient would be of the form

$$a_n e^{jn\alpha},$$

where a_n is the magnitude of the excitation, and α is the progressive phase



CYLINDRICAL REFLECTOR SURFACE AND FEED ARRAY

PROJECTED APERTURE

Figure 1. In an **Antenna With a Phased-Array Feed and a Parabolic Cylindrical Reflector** the amplitudes and phases of excitation of the edge elements can be chosen differently from those of the other radiating elements to reduce or cancel side lobes of the radiation pattern.