Electronics/Computers

On-Wafer S-Parameter Measurements in the 325-508-GHz Band

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New circuits have been designed and fabricated with operating frequencies over 325 GHz. In order to measure S-parameters of these circuits, an extensive process of wafer dicing and packaging, and waveguide transition design, fabrication, and packaging would be required. This is a costly and time-consuming process before the circuit can be tested in waveguide. The new probes and calibration procedures will simplify the testing process.

New on-wafer probes, and a procedure for their calibration, have been developed that allow fast and inexpensive S-parameter characterization of circuits in the 325-508-GHz frequency band. The on-wafer probes transition from rectangular waveguide to coplanar waveguide probe tips with 40-µm nominal signal-to-ground pin pitch so as to allow for probing circuits on a wafer. The probes with bias tees have been optimized for minimal insertion loss and maximum return loss when placed on 50-ohm structures to allow for calibration. The calibration process has been developed using the Thru-Reflect-Line Agilent algorithm with JPL determined calibration structures and calibration coefficients for the algorithm.

This new test capability is presently unique to JPL. With it, researchers will be able to better develop circuits such as low-noise amplifiers, power amplifiers, multipliers, and mixers for heterodyne receivers in the 325-508-GHz frequency band for remote sensing/spectroscopy.

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Reconfigurable Microwave Phase Delay Element for Frequency Reference and Phase-Shifter Applications

This technology can be used in high-resolution phase shifters, frequency references, and oscillators, and in low-temperature sensors.

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A technique was developed to provide a reconfigurable high-precision microwave electrical phase delay for resonators and phase shifters. The invention employs multiple branches of transmission lines with open-ended or ground-ended terminations as configurable bits or digits. This technique minimizes the errors due to limited precision of switching devices. In addition, the proposed linear analytical approach significantly produces a much simpler design than that of other prior inventions at the time of this reporting.

Microwave components such as filters, phase delay elements, or resonators require a method that can accurately adjust their frequency responses. Most tuning techniques offer very wide frequency tuning range; however, it is often difficult and expensive to tune their response in a very narrow operating frequency, especially when the tuning element reaches its minimum discrete step due to fabrication tolerances. The problem becomes worse as the operating frequency is in mm-wave frequency range (>26 GHz).

The electrical tuning sensitivity of a microwave line is dependent on the position of the tuning element with respect to the reference termination. By placing this tuning element away from this reference — with the main transmission line connecting the two elements together — the sensitivity of the tuning element can change significantly. This concept can be used in the system that requires multiple tuning sensitivities. In this case, multiple tuning branches are superimposed in the main transmission line. The proposed invention allows the transmission-line electrical length to be accurately programmed using switching elements that have limited accuracy.

The invention consists of multiple branches of transmission lines connected to discrete switching devices with open-ended terminations. They are used as discrete tuning elements. These elements are connected to the main microwave transmission line and are separated by a well-defined electrical degree spacing. Each branch is programmed to have different electrical degree sensitivity, such as a combination of discrete steps in each branch, which results in a reflective line with a unique effective phase response. To reduce the number of switching devices, it is desirable to program the devices in binary configuration where each branch represents one bit in the base-2 number system. This invention allows the transmission line electrical length to be tuned precisely with customizable sensitivity based on the known sensitivity of the base tuning circuit. The tuning resolution is dependent on the distance among tuning branches.

The novel feature of this invention is that the phase can be controlled in a very small electrical step of less than 0.5°. The sensitivity of the switching device can be scaled to minimize the errors due to fabrication process. The design technique simplifies the microwave design process. The typical microwave analysis of this device is highly non-linear and is difficult to develop in a closed-form solution. The new inven-