A 40 TO 50 GHZ HEMT TEST FIXTURE

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Abstract:

A probe station has been built in the 40 to 50 GHz band to accurately measure the noise and S parameters of mm-wave HEMT's. The probe impedances are close to the optimum terminating impedance of the HEMT and have very low loss. This in turn is expected to enhance the accuracy of the measured noise and S parameters. A TRL calibration using micro-coax lines is being investigated. The fixture and the calibration procedure are described.

Introduction:

Two methods are conventionally used to measure the noise and S parameters of millimeter wave HEMT's. One is the standard 50 Ω wafer probe and the other is a test amplifier with a known embedding impedance and bond wire connections to the device. Both of these have disadvantages in the measurement of mm-wave devices. Wafer probes are lossy and poorly matched to the device impedance, requiring very careful calibration. The test amplifier can be well matched to the device, but is difficult to calibrate accurately because the bond wire connections are rather variable in their effective inductance. This paper describes a new HEMT test fixture combining the two techniques, in which the device is probed rather than bonded, but where the circuit is that of a matched test amplifier.

The fixture has very low loss for accurate determination of noise parameters, and is designed for the insertion of TRL (thru-reflect-line) standards using micro-coaxial lines. We expect to use a slightly modified version of this fixture for characterizing HEMT's at cryogenic temperatures. A device model based on the procedure detailed in [1] and the *Pospieszalski noise model* [2], using the cryogenic noise and S parameter measurements, will then be derived. The fixture described here may be scaled to 115 GHz where it may form a basis for the fabrication of low noise cryogenic amplifiers using discrete devices.

Fixture:

The fixture uses coaxial lines and WR-22 waveguides, with a split line along the waveguide broad walls. The bottom block of the fixture is shown in Fig.1. A three section transformer lowers the waveguide impedance and makes a transition to a coaxial line of square outer conductor and circular inner conductor. The backshorts are used to tune out the inductance of the center conductors in the waveguide-to-coax transition region. A two-stage quarter-wave transformer in coax further reduces the impedance to the desired level. Finally, probe wires attached to the ends of center conductors contact the device under test. The device under test is mounted on a post and is inserted from the bottom. A viewing-hole in the top block assists in properly orienting the device for probing. The source pads are connected to ground through eight short bond wires to the post. This connection is not very critical and may be easily altered if needed.

On the opposite side of the waveguide the center conductors form a five-section coaxial low-pass filter and are terminated with a highly lossy material as well as a lumped RC circuit to ensure stability below waveguide cutoff. The center conductors are mounted on micro-manipulators, and have approximately 150 μm clearance on all sides, so that a small amount of motion is possible to contact the device under test. Some variation in position is unavoidable from one contact to the next; however 10 μm of variation should have little effect.

Design and Performance:

Waveguide and coaxial discontinuity capacitances and the properties of the waveguide to coax transitions were evaluated using the HFSS (Hewlett-Packard High Frequency Structure Simulator) program. Then the lengths of various coax and waveguide sections

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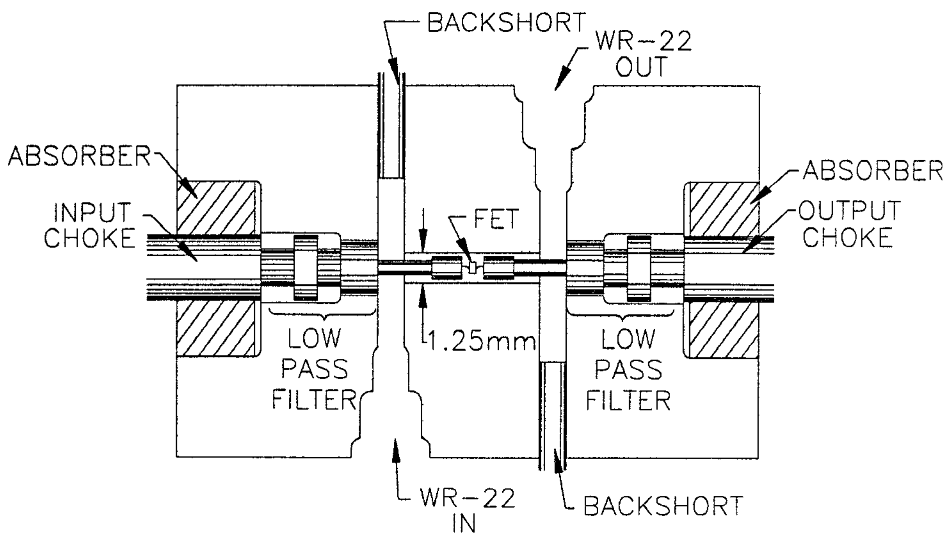

Fig.1 Cross-sectional top view of the fixture.

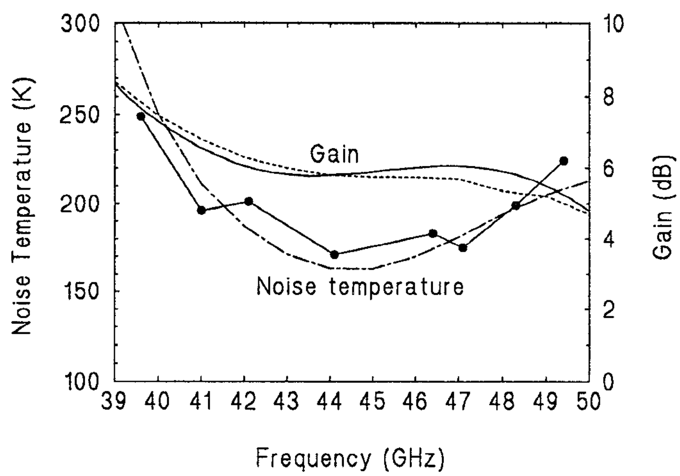

Fig.2 Comparison of the measured (solid) and simulated (broken) response.

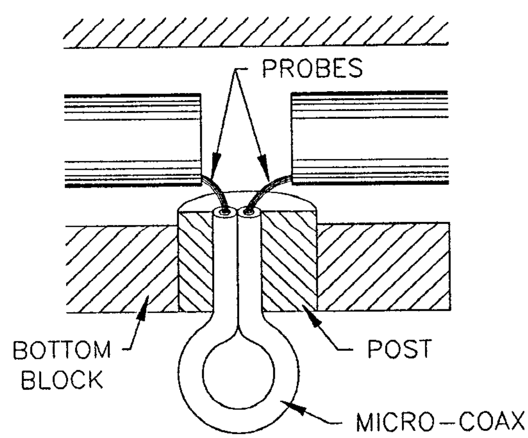

Fig.3 The approach to TRL calibration.

as well as the backshort positions were optimized in a linear simulator program (MDS, Hewlett-Packard Microwave Design System) for good performance between 40 and 50 GHz. The response of the fixture from DC to 50 GHz was simulated and a stability analysis using the Nyquist criterion was carried out. The initial design was based on a Fujitsu FHR10X device, but the fixture has been verified to be stable using the published equivalent circuits of some of the best mm-wave devices [3]. The gate and drain probe wire lengths have to be optimized for each different family of FETs.

Fig.2 shows the measured and simulated gain and noise temperature of the fixture with a sample pseudomorphic HEMT having gate dimensions 0.15 X 75 μm. The simulated data uses the equivalent circuit of this HEMT [4] combined with the expected terminating impedance from the HFSS and MDS simulations. The noise temperature is measured with a second stage consisting of an isolator and a mixer with a 125 MHz IF output. The mixer noise is typically 500 K (DSB), and the data is corrected for its contribution. The variation in input impedance required to determine the noise parameters may be accomplished by changing the gate probe wire length and by adding dielectric tuners within the input waveguide [5].

Calibration:

Accurate calibration of the fixture is an essential part of the FET characterization and will serve to verify the terminating impedance used above. A TRL calibration procedure [6] is under investigation. Since the probes cannot be moved to contact each other, or between measurements, a non-zero length *thru* has to be used. Standards using microstrip would be convenient; however no configuration is practical for the *line* standard which does not require moving the probe. Instead we have chosen to use micro-coaxial lines embedded in posts similar to the ones that hold the HEMT for *thru* and *line* standards. This approach is shown in Fig.3. The diameter of the post is 0.9 mm which severely constrains the size of the coaxial standards. In addition, the pads on the HEMT (0.05 mm square) are 0.2 mm apart, and the standards should be similar. All these requirements can be satisfied by 50 Ω coax with 0.2 mm OD and 0.05 mm ID, which is commercially available. The *thru* standards will use a relatively long loop of coax to avoid an extremely tight bend, while the *line* standard is $\lambda/4$ longer. The propagation constants of the standards are important, but may easily be measured using a much longer line, and thus corrected in the calibration.

Conclusions: A new test fixture for the measurement of HEMT noise and S parameters has been developed. Initial results show that the fixture behaves very much as designed. Accurate calibration of this fixture should be possible using TRL standards which are now being fabricated.

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References:

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