6.1: SUBTLE DIFFERENCES IN SYSTEM NOISE MEASUREMENTS AND CALIBRATION OF NOISE STANDARDS

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There is an increasing need for precise, accurate, and reliable noise measurements especially with the advent of parametric amplifiers (abbreviated as paramps) and other low noise devices. Important applications of such devices, primarily due to their extreme sensitivity to low level signals, are in deep space probe, radar, and communication systems.

The technical "know how" and engineering skill in the fabrication of paramps have developed to such an extent that not only is involved the difficult task of designing and developing such devices but also there are requirements of adapting such devices as subsystems to complicated existing systems. In addition, associated equipment must be incorporated to provide automatic measurement of excess noise temperature of the overall system which includes the paramp subsystem and the input antenna noise required for the measurement. Paramps and its associated noise temperature monitoring equipment (designated as Automatic System Excess Noise Temperature or ASENT) have been successfully developed by the Microwave Components Department at L- and S-band frequencies for the Jet Propulsion Laboratory, a prime contractor of NASA. The technique involves a comparison system of total noise power or temperature (at the input to the paramp subsystem) with calibrated noise power which is injected into the system. The measurement aspect of such a scope of work involves essentially the following:

1. The development of a suitable noise standard or the calibration of an equivalent commercial noise standard to determine the specified noise figure of the system.

2. The measurement of the reference noise power source to be incorporated as a part of the system. An argon gas discharge tube was used, and its output power injected into the system through the decoupled arm of a coupler was the system reference noise power.

3. The verification of the overall system noise temperature by the ASENT equipment and the noise figure of the paramp. The noise figure of the paramp can be measured independently or computed from the ASENT indication if the source temperature at the input to the paramp subsystem is accurately known.

Noise standards were fabricated for X-band as well as for L- and S-band frequencies. The standard operating temperatures of the matched loads which were developed for the noise standards were at liquid nitrogen temperature (77.3° K) and room temperature of 293° K. Inverted tapered loads were used to insure good contact of the load with its accommodating metal casing in order to assure operation of the load at 77.3° K. Experiments were performed to substantiate the load temperature at 77.3° K and 293° K.

A novel switching technique for the coaxial noise standard was developed in order to avoid errors in repeatability problems in noise measurements that could arise from the use of a coaxial switch in switching from a load at 77.3° K to another but similar load at 293° K. The technique required the use of a single load since the center conductor of the coax was made removable so that an open circuit condition (upon disconnecting the center conductor) would reflect into the system the ambient temperature of the paramp components. Restoring the center conductor to its normal position permits the same load to inject 77.3° K into the system.

A hot-cold noise source generating temperatures at 77.3° K and 373.1° K through a coaxial switch became available at a later date and was used throughout the measurement tests.

The system for determining the noise figure of the paramp and the excess noise temperature of the argon gas tube was arranged in the following manner. The hot-cold noise source was connected to the paramp receiver through the main ports of a nominal 20 db coupler and an argon gas tube was connected to the decoupled arm of the coupler.

The procedure in calibrating the gas tubes involved essentially two measurements of noise power ratios (or Y factors), attenuation and coupling measurements for the system described above. The first Y factor measurement is obtained with the gas tube turned off and the 373.1° K load substituted for the 77.3° K load. The second Y factor measurement is made with the standard noise load at 77.3° K and the gas tube turned on and off. The attenuation measurement from the hot-cold source to the paramp input port determines the dissipative loss which attenuates the standard noise temperature and simultaneously raises the system temperature by the amount of the ambient temperature of the lossy components preceding the paramp input. The coupling measurement determines the amount by which the noise temperature is lowered when injected into the main line with the gas tube on. The excess noise temperature of either the gas tube or the paramp can be determined from a generalized equation which takes into account all the parameters of the measurements described above. The following results were obtained as part of the measurement program:

1. Noise figures of the order of 0.8 to 1.8 db for the paramps at L and S bands.

2. Agreement within 0.05 db of the excess noise temperature of different noise standards.

3. Variation of relative excess noise temperature of argon gas tubes (in db) as much as + 0.9 db at L band and + 0.6 db at S and X bands from tube specification of 15.2 db.

4. Variations as much as 0.7 db in excess noise output of argon gas tubes when several tubes were checked for uniformity. The discrepancies are possibly due to the criticalness in the mounting of the tubes rather than due to the lack of uniformity of the tube characteristics.

5. Discrepancies of the order of 0.5 db in noise figure measurements depending upon the use of gated or nongated receivers with argon gas tubes used as noise sources. This difference was due to ionization and deionization time of the gas discharge tube.

6. 0.1 db accuracy was obtained in an independent calibration of the automatic noise temperature monitoring meter by pulse technique.

7. Measurement agreement within 0.5° K of the theoretical temperatures of known liquids. Measurements were performed with ice water substituted for the liquid nitrogen. The previously calibrated argon gas tube, with the same procedure described earlier, was used to verify the ice water temperature. The experiment was repeated with dry ice and acetone mixture substituted for the liquid nitrogen.