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A Low-Temperature Thermal Noise Source for Use at the Goonhilly Satellite-Communication Earth Station*

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A matched waveguide termination was required as part of the noise temperature calibration facility in the receiving system at the Goonhilly earth-station. For routine measurement of overall system noise temperature, this termination is at ambient temperature. For other noise measurements, and in particular for the measurement of the effective input noise temperature of the maser, the waveguide termination is cooled to 77°K by immersion in liquid nitrogen.

AUTHOR

DESIGN OF THE TERMINATION

The termination consists of an absorptive pyramidal load mounted inside a length of thick-walled copper waveguide, which provides an approximation to a constant temperature enclosure, even when only partially immersed in refrigerant. The adjacent section of waveguide has thin walls, made of an alloy of low thermal conductivity, in order to reduce the rate at which heat leaks into the refrigerant. A thin internal layer of silver ensures adequate electrical conductivity. The internal dimensions of the waveguide are those of RCSC WG_{11}, (i.e. 2.372″ by 1.122″). Fig. 1 shows two slightly different mechanical constructions of the waveguide structure.

Before deciding on the type of absorptive material to be used, samples of various materials were tested by repeated cycles of immersion in liquid air. Of the two materials which were found suitable, one was a suspension of iron powder in a synthetic resin ("poly-iron"), cast in the laboratory, in a suitable mould, and the other was a commercial material, machined into the appropriate shape.

The samples were alternately cooled and warmed for several days, until it was established that when the temperature changes were not

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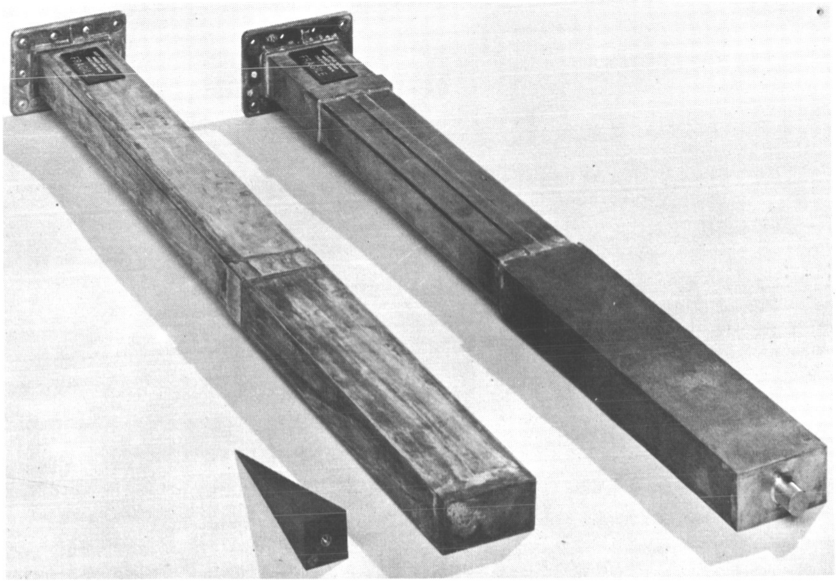

Fig. 1 — Alternative types of cold termination and a poly-iron pyramid load.

too sudden, serious cracking was unlikely, provided that water was excluded. However, if the samples were wet, the surface of the material became crazed and eventually broke up. It was therefore necessary to take suitable precautions to exclude condensed water vapour from the completed termination.

The shape chosen for the polyiron load is shown in Fig. 2. A symmetrical pyramidal shaped load, mounted centrally in the waveguide was found to be preferable to an assymetric, wedge-shaped load attached to the side of the guide. The pyramidal load appears to be less likely to introduce small changes in impedance due to the absorptive material twisting or warping when cooled. The mounting screw is sealed with solder to prevent refrigerant leaking into the waveguide.

The residual VSWR of a termination using this type of load is, in general, better than 0.99 across the 3.8-4.3 Gc/s band.

INSTALLATION AT GOONHILLY

The general arrangement of the installation at Goonhilly Radio Station is shown in Fig. 3. The equipment is located in the receiver cabin on the back of the parabolic reflector. The termination is mounted

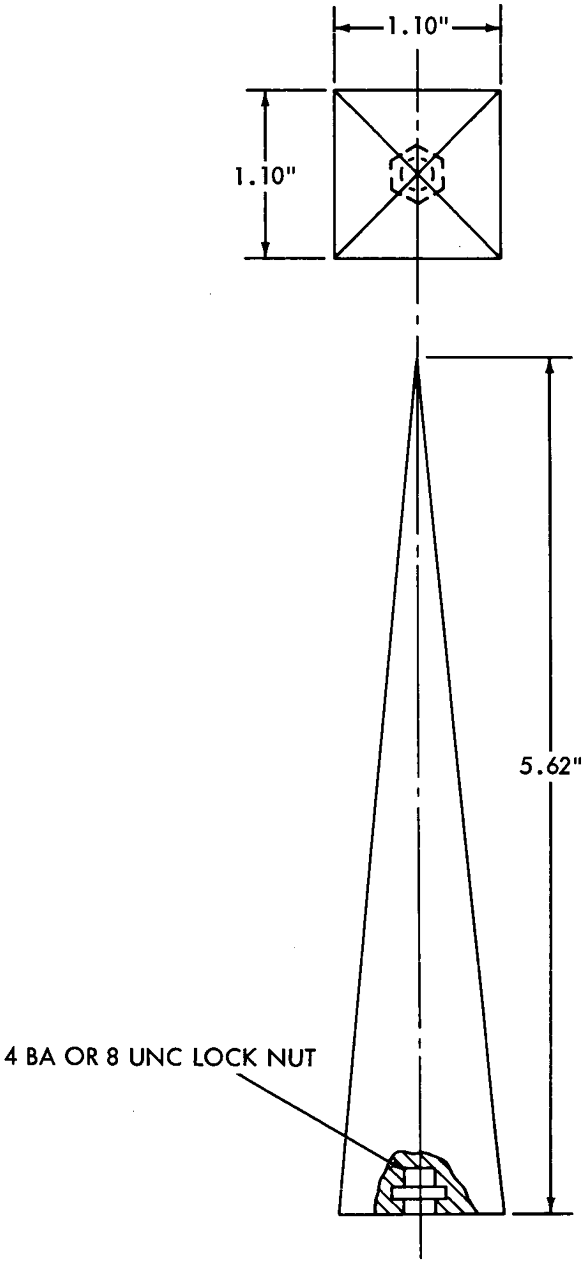

Fig. 2 — Poly-iron pyramid load.

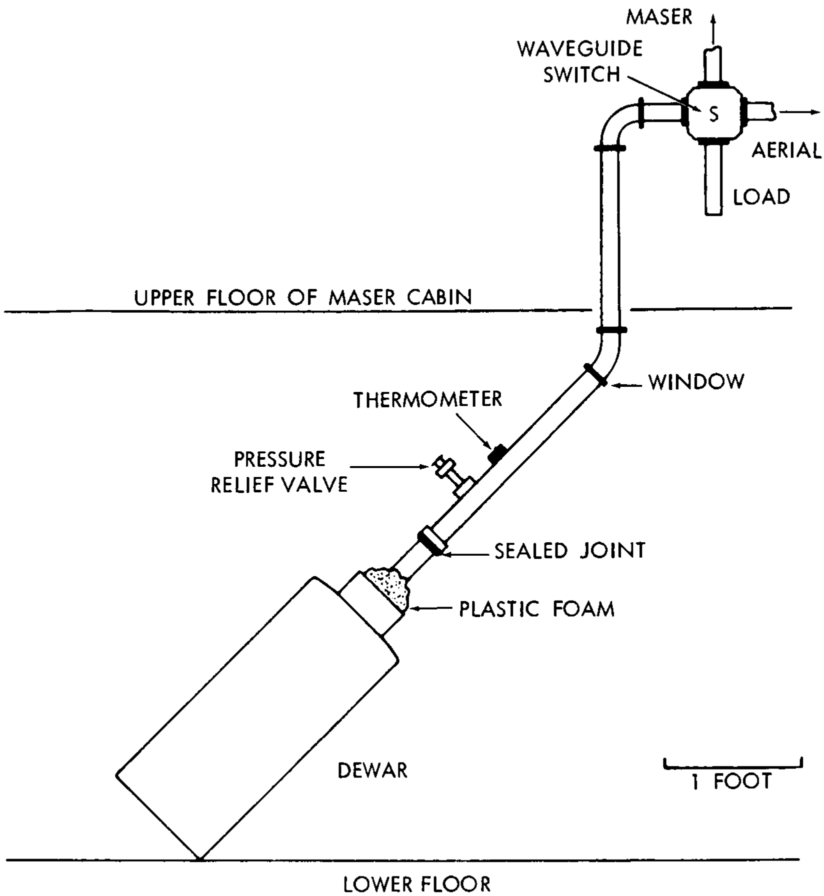

Fig. 3 — Layout of cold load at Goonhilly.

beneath the upper floor which is used for maser operation. To prevent loss of liquid nitrogen when the aerial is moved in elevation, the termination and the metal dewar vessel surrounding it are mounted at 45° to the axis of the aerial. A binomially-corrected 45° waveguide corner was designed (with optimum performance at the receiver centre frequency of 4.17 Gc/s.) to connect the termination to the remainder of the waveguide.

To prevent the continuous entry of water vapour and oxygen which would condense in the cooled section of waveguide, a window is required. A simple uncorrected window of "Melinex" (ICI trademark for polyethylene teraphthalate film) was found suitable. A thickness of 0.004″ introduced less than 0.005 db of attenuation, and no measurable change in the VSWR of the termination. The flanged joints between the window and the load were sealed with neoprene gaskets. A spring-loaded relief valve was provided to prevent an excess pressure accidentally arising inside the waveguide and possibly rupturing the window and damaging the maser.

The VSWR of the termination was measured at the waveguide switch, at a frequency of 4.17 Gc/s. The value, 0.970, remained constant when the termination was cooled from 290°K to 77°K.

When the termination is used for the two-temperature method of measuring the maser noise temperature, it is necessary to correct for the additional thermal noise generated in the uncooled waveguide between the load and the maser. This amounts to 10°K.

The second termination for the two-temperature measurements is provided by a second pyramidal load at ambient temperature. This can be temporarily installed in the main waveguide in place of the usual flexible connexion to the aerial feed. The thermal noise from the two loads can thus be compared by rotating the waveguide switch.

CONCLUSION

A waveguide-mounted termal noise source for operation either at 77°K or at ambient temperature has been devised and installed as part of the receiver equipment at Goonhilly earth station, and used for noise temperature calibration throughout the experiments with the Telstar and Relay satellites.