VI-5. A SUPERHETERODYNE 600 GC RADIOMETER RECEIVER

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A radiometer receiver using a superheterodyne circuit has been designed and constructed which detects thermal energy at 600 gc. The design is an extension to submillimeter wavelengths of principles used previously by workers at this laboratory in the design of millimeter wave radiometers (Reference 1). The radiometer was built on contract with the U. S. Army Munitions Command, Frankford Arsenal, for field evaluation as a possible means of detection of ground military targets. This paper described the design and performance of the radiometer in viewing a thermal calibrator. Field experiments with the radiometer will be reported at a later time by personnel of the contracting agency.

The block diagram of the radiometer is shown in Figure 1. The incoming signal is chopped as it passes from the lens in the receiving aperture to the collector horn. A small waveguide acts as a

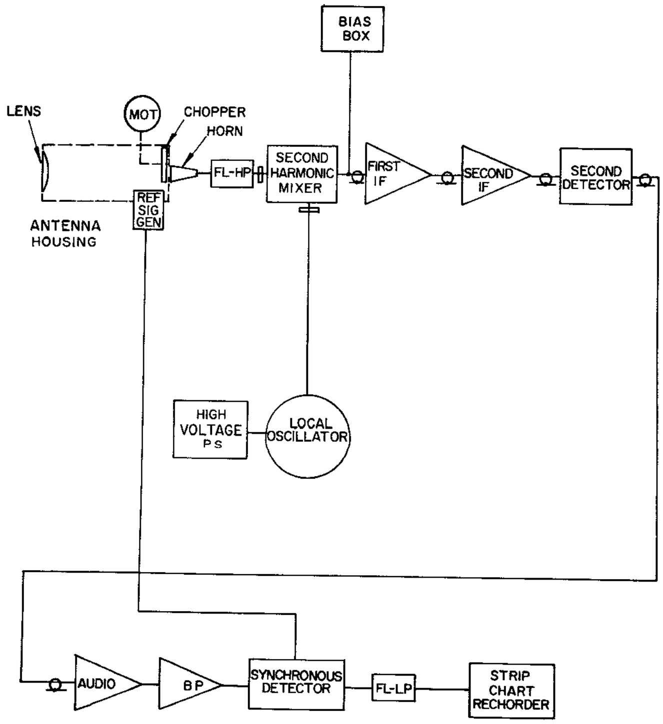

Figure 1. Submillimeter Radiometer Block Diagram

high-pass filter and conducts the signal to the first active stage, a point-contact diode harmonic mixer. The intermediate frequency band is 2 to 4 gc and is amplified by traveling-wave tubes. The second detector then demodulates the signal and produces an output at the chopping rate, 165 cps. This is amplified, detected synchronously, passed through a 0.1 cps low-pass filter, and recorded on a strip chart.

The radiometer is shown in Figure 2. The antenna housing is mounted on an azimuth-elevation gimbal mount. The mixer and local oscillator are hidden at the right behind the antenna housing. The local oscillator is a backward wave tube, CSF type COE-10. The first IF amplifier, on the shelf under the antenna housing, is a Watkins-Johnson type WJ-269 traveling-wave tube amplifier with integral power supply. The second IF amplifier is a Huggins type 209B at the right on the second shelf of the lab cart. The IF amplifiers have an overall gain of 60 db and a noise figure of 5 db. The second detector is a type 1N23C microwave cartridge diode in a coaxial detector mount. The radiometer signal processor is seen on the top of the lab cart. On the cart at the left of the antenna mount is the thermal calibrator.

The arrangement of absorbing chopper blade in the antenna housing may be seen in Figure 3. The lens is 10 inches in diameter and has a focal length of 30 inches. A plano-convex lens with a hyperboloidal surface was machined of Teflon. It is 10 inches in diameter and is 0.926 inch thick at the center. Its insertion loss measured about 1.6 db. Allowing for the amplitude taper due to the horn antenna pattern gives a calculated half-power beamwidth of one-seventh degree.

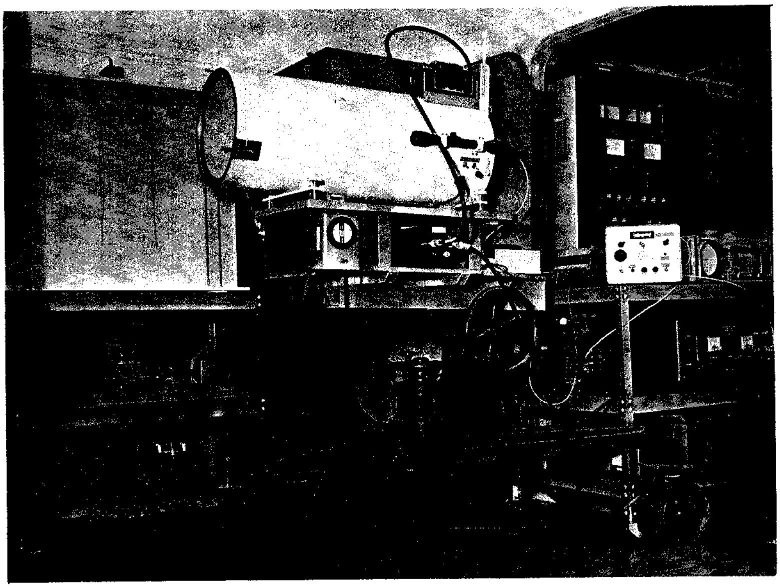

Figure 2. Submillimeter Radiometer

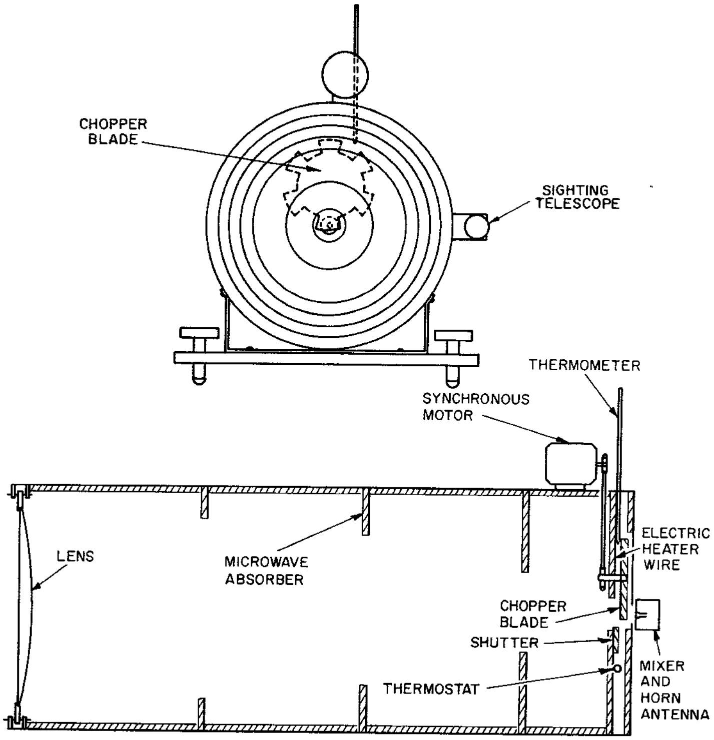

Figure 3. Antenna Housing, Internal Views

A second harmonic mixer of crossed waveguide configuration was built with a phosphor-bronze whisker and gallium arsenide die. See Figures 4 and 5. The signal waveguide from the horn is 0.016 by 0.0085 inch and has a calculated cutoff frequency of 393 gc. The horn and signal waveguide were formed as two halves in two strips of gold such that the joint is in the center longitudinal E-plane. The local oscillator waveguide was made oversize (0.080 by 0.040 inch) to reduce attenuation. A differential-screw driven tuner of the contacting short type is mounted in each waveguide. The waveguides are joined by a coupling hole in their common wall which is 0.008 inch in diameter and 0.008 inch long. The coaxial output line includes a single matching transformer before the type N connector. The VSWR looking into the IF port of the mixer when a point-contact diode is in place is less than 2.5 to 1 over the band 2 to 4 gc.

The radiometer was evaluated using a thermal calibrator built for the purpose. It consists of a 2-foot square sheet of emissive material mounted in a frame with a resistance wire heating grid spread over its back side. The emissive material is a structural insulating board composed of asbestos fiber, diatomaceous silica, and an inorganic binder. Its surface was roughened by scraping with a saw blade. Absorption and reflection measurements at 310 gc showed that its emissivity is about 0.99. The emitting surface may be heated to any temperature between ambient and 170°C.

During early tests of the assembled radiometer, a 2 millivolt deflection was recorded with the oven at 170°C and located in front of the antenna housing with no lens in place. The approximate

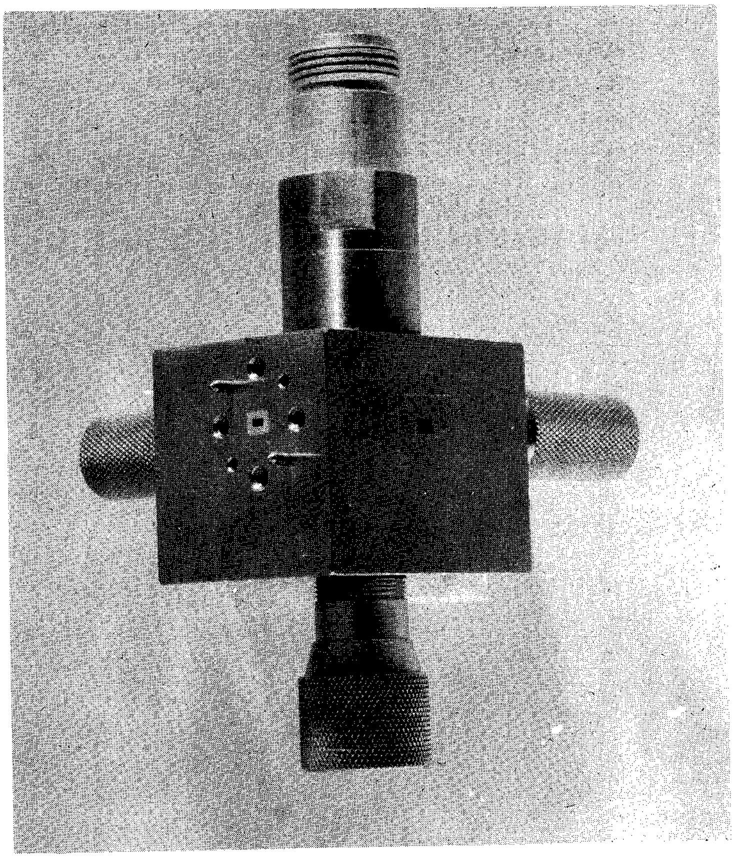

Figure 4. Six Hundred gc/s Harmonic Mixer

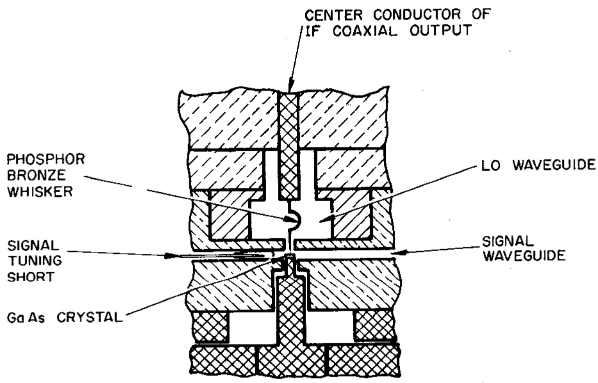

Figure 5. Cross Section of 600 gc Mixer

guide half wavelength of the thermal energy being received was checked by noting the tuner travel necessary to move from one maximum response to the next. The tuner travel was 0.0125 inch ± 0.008 inch which corresponds to a signal frequency of 616 ± 23 gc. The second harmonic of the local oscillator was 595 gc.

By reducing the temperature of the thermal calibrator the minimum discernible temperature difference was observed to be 26°K. Assuming that a signal-to-noise ratio between 2.5 and 8.3 existed for this measurement, the double sideband radiometer noise figure was therefore between 30 and 35 db. RF losses were estimated to be 3.6 db, mixer crystal noise ratio to be 2X, and IF noise figure to be 5.1 db. Therefore, the mixer crystal conversion loss was between 23 and 28 db.

REFERENCE

1. Cohn, M., Wentworth, F. L., and Wiltse, J. C., "High-Sensitivity 100 to 300 gc Radiometers," Proc. IEEE, Vol. 51, pp. 1227-1232, September 1963.