A 200-300 GHz HETERODYNE RECEIVER

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Summary

A heterodyne receiver for the 200-300 GHz region has been developed and used in astronomical observations. Two room temperature Schottky diode mixers are used to cover this range, with LO power provided by frequency multiplied klystrons. A single crossed-waveguide frequency multiplier covers the entire range, and is found to produce adequate output power by either doubling or tripling. Signal-local oscillator diplexing is done with a quasi-optical diplexer based on a Martin-Puplett interferometer. The best system sensitivities obtained with the two mixers have been 2500 K SSB at 230 GHz and 2900 K at 285 GHz.

Frequency Multiplier

Perhaps the most novel feature of this receiver is that local oscillator (LO) power is derived from frequency multiplied klystrons. The multiplier is a crossed waveguide construction, somewhat modified from a design by Custom Microwave (Longmont, CO). The construction is shown in Figure 1, and consists of an

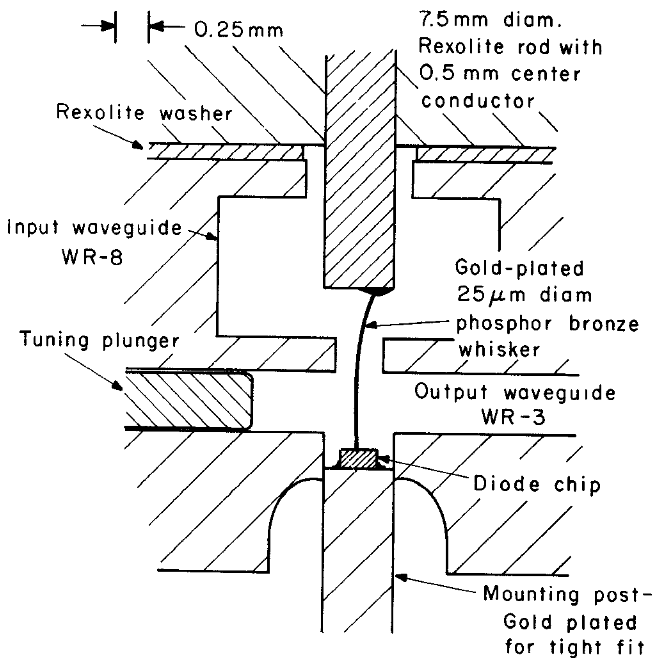

Figure 1. Crossed waveguide frequency multiplier with output in the range 200-300 GHz.

input WR-8 waveguide and an output WR-3 waveguide separated by a thin wall with a small hole joining them. The multiplier diode is a 2.5 μm diameter Schottky diode (Bell Labs batch B20-67) which is located in a hole in the bottom wall of the output waveguide. The diodes have $C_j(0)$ = 9 fF, R_s = 5Ω and a reverse breakdown voltage of 8.5 V at 10 μA. A 25 μm whisker connected to a post from the bias port passes through both waveguides and contacts the diode. This same unit has previously been described by Goldsmith and Plambeck,[1] who used it as a harmonic mixer at 230 GHz.

Since no chokes are used between the waveguides or in the bias port, it is unlikely the multiplication efficiency is nearly as high as could be attained in an optimized design. However this simplicity produces a wide usable bandwidth, and to a limited extent the efficiency may be optimized by varying the penetration of the bias port post into the input waveguide, and the position of the diode chip relative to the output waveguide.

Operating as a doubler, the peak power obtained has been 5.5 mW at 268 GHz, with an efficiency of 7%. Input and output powers were measured with an Anritsu ML81A power meter, with the high frequency power head calibrated to 260 GHz. Typical klystrons in the range 100-140 GHz produce sufficient drive to produce a doubled output of >1 mW, at most points within their tuning range.

Only limited operation as a tripler has been attempted due to lack of pump klystrons, and the cutoff of the input waveguide at 74 GHz. Tripling is always less efficient than doubling (eff. ~1%), but due to the much higher power of klystrons at lower frequencies it is possible to produce more power by tripling than by doubling at frequencies above 280 GHz. An output of 1-1.5 mW has been produced at 303 GHz with 100-200 mW drive at 101 GHz. Output power in this case was estimated from the video response of one of the mixers, assuming its video response is the same as at 268 GHz where the power meter calibration was available. Tripling has also been used to produce ~0.5 mW at 330 GHz. Bias conditions of the multiplier diode for these tests were -5 V at 10 mA, meaning that ~100 mW was actually reaching the diode. This power is close to the burnout level for these diodes.

For all conditions of operation of the multiplier the highest efficiency occurs for substantial forward current flow, typically 5 mA, while the bias voltage ranges from 0 V to -5 V. The mode of operation is thus a mixture of resistive and reactive multiplication.

Mixers

Two mixers provide low noise coverage of the 200-300 GHz range. The higher frequency mixer was actually built for use at 346 GHz and its performance in the 318-350 GHz range has been reported previously.[2] The mixer is of electroformed construction with 0.2 mm × 0.65 mm waveguide connecting to an integral horn. A radial mode choke is used in the IF port and diodes are contacted with 25 μm diameter phosphor bronze wire.

Tests on this mixer have now been performed in the 258-330 GHz range using improved diodes. The diode now being used is from U. Virginia batch MO-30, having $C_j(0)$ = 5 fF and R_s = 14Ω. A significant advantage of this diode is its low LO power requirement. Optimum LO drive is 1.5-2 mW with about a 5% increase in system noise at 1 mW drive.

Data is somewhat fragmented on the performance of this mixer over its full operating range, because tests at the highest frequencies were made some time ago using poorer diodes and a very noisy LO source. However mixer sensitivity is nearly constant over the range 265-305 GHz with ~30% increase in noise temperature at 330 GHz. The older tests showed relatively constant noise up to 350 GHz. Response at the low frequency end is limited by cutoff of the waveguide at 230 GHz, and a practical lower limit is near 258 GHz where the system noise has risen ~20% and the sidebands can have very different sensitivities. The best system noise temperature measured is 2900 K SSB at 285 GHz, using a 50 K IF amplifier at 1.3 GHz.

Based on these results, a second mixer was built to continue coverage to lower frequencies. This mixer is nearly an exact 1.25 times scale model of the first mixer. Only limited tests have been made on this mixer but its useful range is 200-300 GHz. The noise minimum occurs at ~230 GHz where a system temperature of 2500 K has been measured, using the same IF system as above. The noise temperature is below 3000 K between 220 GHz and 270 GHz. The diode used in this mixer is from U. Virginia batch 2P12 and is somewhat better than that used in the prototype, with $C_j(0)$ = 4 fF and R_s = 8Ω. Part of the difference in performance of the two mixers is probably due to the different diodes.

Diplexer

The diplexer used in this receiver is a modification of a Michelson interferometer, first proposed by Martin and Puplett,[3] in which the beamsplitter is a polarizing grid with wires oriented at 45°. Two corner reflectors rotate the plane of polarization 90° upon reflection, and the two beams are recombined in orthogonal polarizations with a variable relative phase shift. Thus a linearly polarized output of either polarization may be selected.

If the signal and LO are introduced in perpendicular polarizations (by combining them with a second polarizing grid), it it possible to rotate them into the same polarization at the output. The actual input-output characteristics of this diplexer are nearly identical to those of the offset Michelson diplexer described by Erickson.[4] The particular advantages of the polarizing interferometer are a very wide bandwidth for a single beamsplitter, and a smaller size. In addition, nearly perfect polarizing grids can be made using arrays of closely spaced wires, so losses can be limited to beam diffraction only. A diagram of this diplexer and the receiver focusing optics is shown in Figure 2. Optics to match the LO

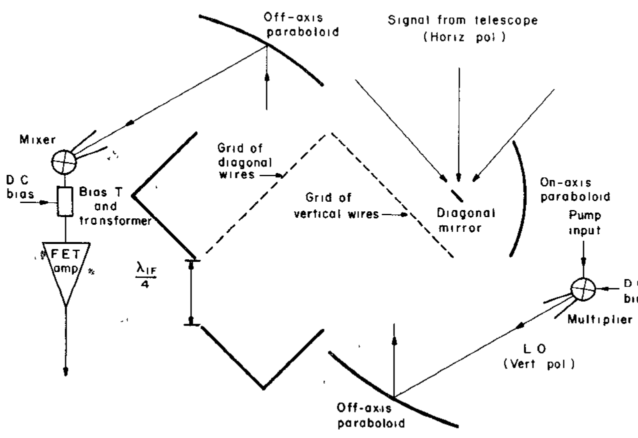

Figure 2. Schematic diagram of diplexer and optics for 200-300 GHz receiver.

and mixer horns to the nearly collimated beam within the diplexer are 60° off-axis paraboloids made using an analog technique.[5]

This receiver is being used on the U. Texas 4.9 m telescope during February-April 1980 to make extensive astronomical observations of molecules in interstellar clouds. This telescope operates in a prime focus configuration with f/0.5. This very low focal ratio is rather difficult to feed using optical techniques. In this receiver, the collimated beam within the diplexer is converted to f/0.5 using a small f/0.5 paraboloid with a diagonal mirror at its focus. The blockage and spillover within this feed system cause system temperatures at the actual feed to the receiver to be ~12% higher than the values given above.

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