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SUGGESTIONS FOR A NEW COOLED K-BAND MIXER FOR THE VLA FRONT ENDS

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Under the right circumstances, the present VLA mixers are capable of excellent performance. Receiver noise temperatures of 180 degrees have been frequently measured on both K and Ku bands, and optimum conversion losses less than 3 dB have been measured at room temperature. However, their performance is far from ideal. The K mixer does not really cover the entire observing band; its loss increases significantly above 23 GHz, and at 24 GHz the receiver noise temperature is twice what it is at 22.5 GHz. The Ku mixer often exhibits conversion loss of 2.5 dB; however, its effective diode noise temperature is exceptionally high, and as a result its noise temperature is not much different from that of the K mixer.

This "anomalous noise", as it is called, which is evident in the Ku mixer, has only recently been well understood. Therefore, in the past two years, the mixer development effort has been centered on the K mixer. Some improvement in the high-frequency response has been achieved at the expense of a modest decrease in the low-frequency response. A significant improvement in the output VSWR has been achieved. However, it has become obvious that no further significant improvement can be expected without major changes in the mixer. Part of the problems result from the prescribed signal, L.O., and I.F. frequencies, which can't be changed. The rest result from compromises in the mixer design.

K Mixer Design

In order to understand the mixer's limitations it is necessary to examine its design. A schematic representation is shown in Figure 1; a more detailed discussion can be found in VLA Technical Report No. 15, "K and Ku Band Mixers".

These are single diode, image enhancement mixers. Gallium arsenide Schottky diodes are used in both the K and Ku mixers. The design of both mixers is similar; the major difference is that the Ku mixer uses a corrugated-waveguide low-pass filter at its input; the K mixer uses a cutoff waveguide high-pass filter. The L.O. power is applied to the diode via a direct-coupled cavity bandpass filter and a tuned "T" junction. The diode is mounted transversally in the waveguide in the diode mount. A conventional low-pass choke assembly is used to present the desired output impedance (about 200 ohms) to the intrinsic diode, and to minimize signal and L.O. frequency currents in the I.F. circuit.

Ideally, the intrinsic diode should be terminated at the image frequency in a short or open circuit,depending on the mixer configuration. This image termination, across the image frequency band, is critical to the conversion loss and bandwidth of the mixer. It is determined by the electrical distance from the diode to the input filter, the response of the "T" junction across the image band, and the electrical distance from the diode to the backshort.

The two factors which most strongly affect the image termination in the K band mixer are dispersion in the waveguide in which the diode is mounted, and the fact that all the frequencies of concern, image, signal and L.O., are propagating in the "T" junction. The dispersion is caused by the fact that the waveguide cutoff frequency is 12.0 GHz, necessitated by the requirement that the cutoff frequency to the next higher mode (TE_{20}) be greater than 24.0 GHz. Image frequencies can be as low as 12.5 GHz, and consequently the dispersion of the waveguide close to cutoff frequency creates a large phase shift across the image band. In fact, the reflection coefficient at the diode can vary more than 180 degrees across the image band! The "T" junction becomes a problem because it must be designed for prescribed response over an octave bandwidth. Clearly this is impossible for this type of structure, and one must attribute the mixer's good performance over even a small bandwidth to pure luck.

The dispersion problem can be ameliorated somewhat by reducing the cutoff frequency of the waveguide. This change results in the possibility of TE_{20} mode propagation in the waveguide at the signal frequency. This modification has been made in a test mixer and some modest improvement has resulted. No evidence of unwanted mode propagation has been observed. The "T" junction is still a problem, and a less frequency-sensitive coupling structure is desirable.

A simple way to eliminate the problem of the "T" junction is to use a hybrid-coupled balanced mixer as in Figure 2. The general advantages of balanced mixers are well known, and at least a few of them are valid for the VLA mixers. The use of a balanced configuration would eliminate the need for a very sharp L.O. filter, and improve the mixer response close to the bottom of the signal band, as well as the upper frequencies, thus giving better performance at the water spectral line frequency, 22.235 GHz. Because of the wideband nature of the junction, pumping of the diode would be more consistent across the band, and performance would be more uniform. Finally, even the dispersion problem would be reduced because the input filter could be made closer to the diode.

The disadvantages are simply the requirement of two diodes and a little more hardware. Two bias supplies would be necessary, but because of the more uniform response, the number of bias settings now necessary to cover the band optimally could be reduced. There should be no serious problems in fitting this somewhat larger mixer into the available space in the Dewar. Although the prescribed choke design is somewhat larger than the original, it can and should be shortened by using dielectric insulation in the coaxial line. This insulation would additionally provide protection from short-circuits in the low-impedance line sections.

Design of Individual Components

The design of the components for the mixer is similar to that of the present mixer. The input filter consists of a reduced-height waveguide with cutoff frequency approximately 16 GHz. An input transformer reduces its height and width from that of standard K-band waveguide, and the output transformer increases the waveguide width, thus lowering the cutoff frequency to approximately 11 GHz. The distance from this transformer to the diode affects the image termination and should be adjusted empirically with spacers for best conversion loss.

The L.O. filter must be designed only to reject noise at the signal frequency or any other frequency whereby it could be converted to the I.F. Even this requirement is rendered less severe by the noise-rejecting properties of the balanced mixer.

The I.F. choke and bias assembly is similar in design to the present one, and need not be described in detail. It has been redesigned in recent development work to present a better match to the diode. A drawing of the new choke is given in Figure 3; it could be reduced in size, as mentioned above, by dielectric loading of the coaxial lines.

Not shown in Figure 2 is a 180 degree hybrid for recombining the signals from the two I.F.'s. A simple "rat-race" hybrid in microstrip or stripline on an alumina substrate should work well; its design is straightforward and thermal performance is proven.

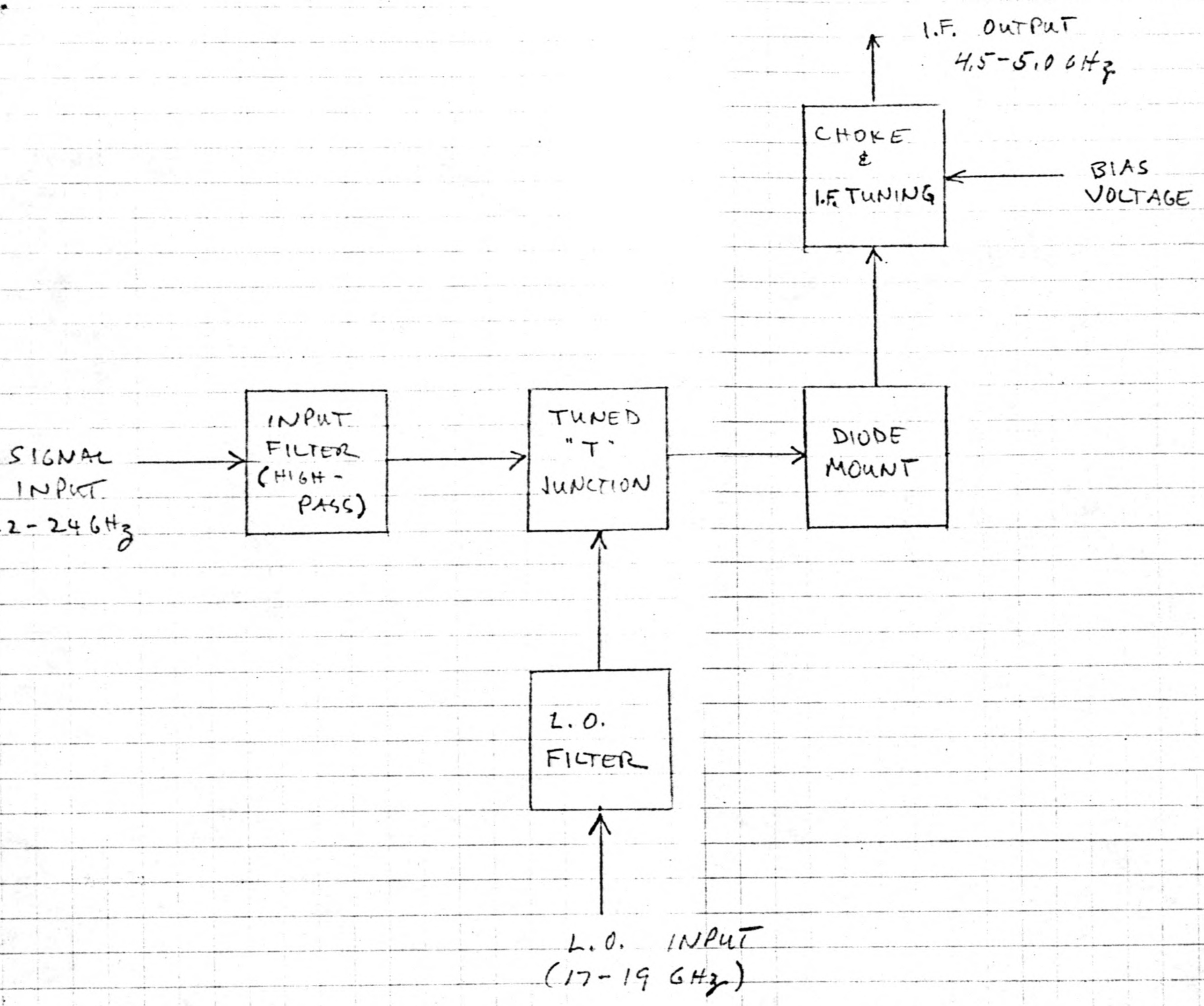

FIG. 1 - SCHEMATIC DIAGRAM OF K- MIXER

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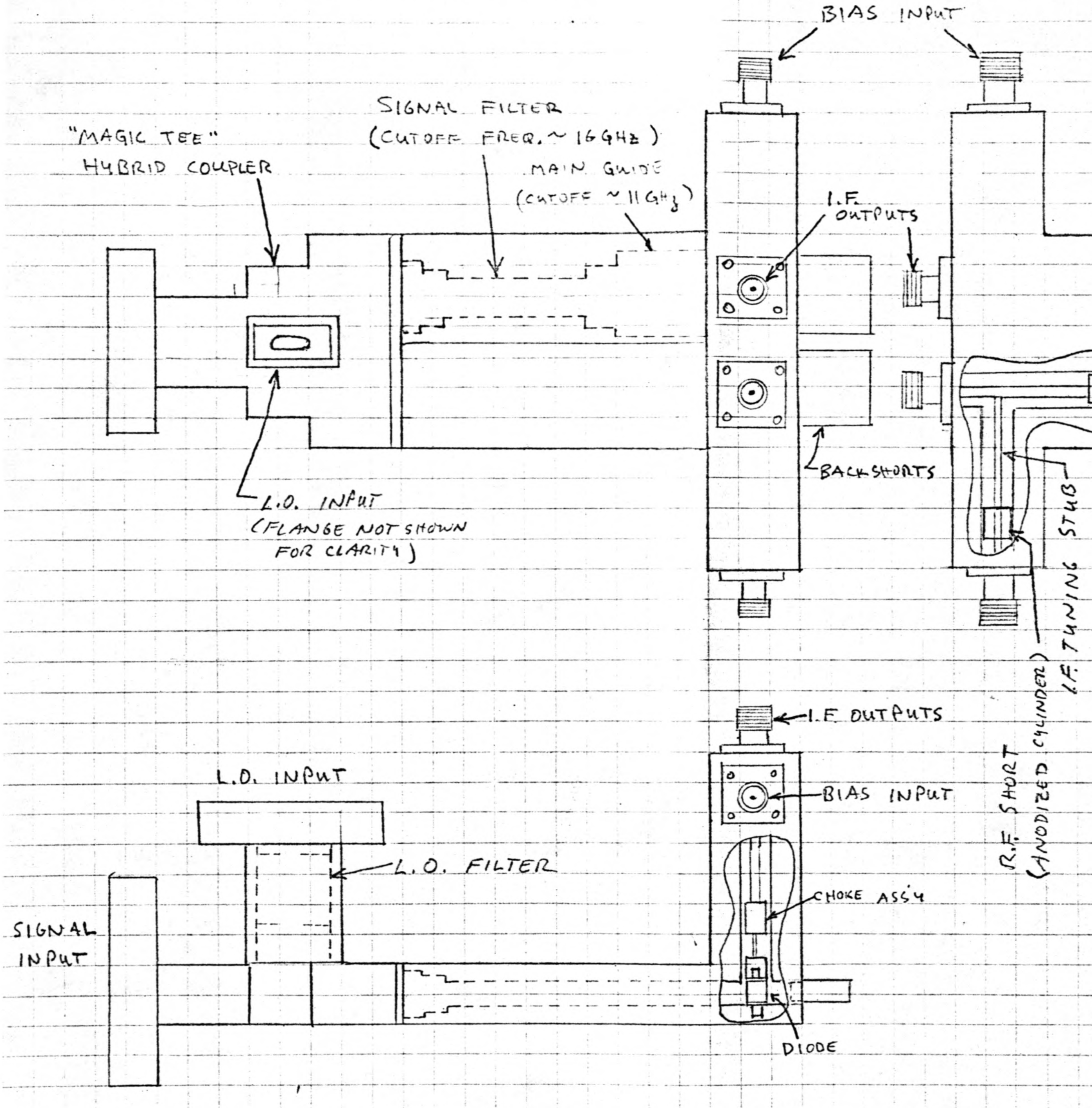

FIG 2. PROPOSED K-BAND MIXER

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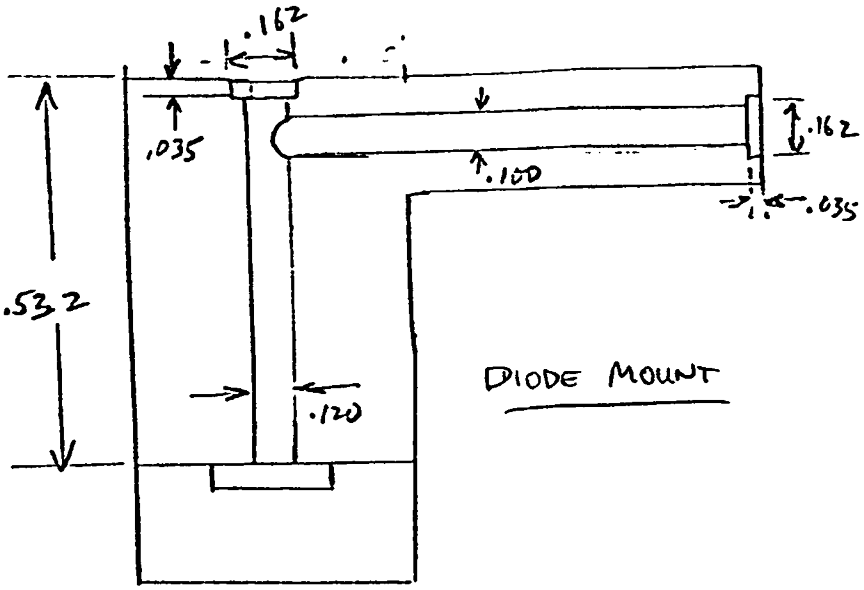
1. I.F. OUTPUT COUPLER NOT SHOWN



DIODE MOUNT

Make D = .120"

25Ω d = .079

100Ω d = .023

50Ω d = .052

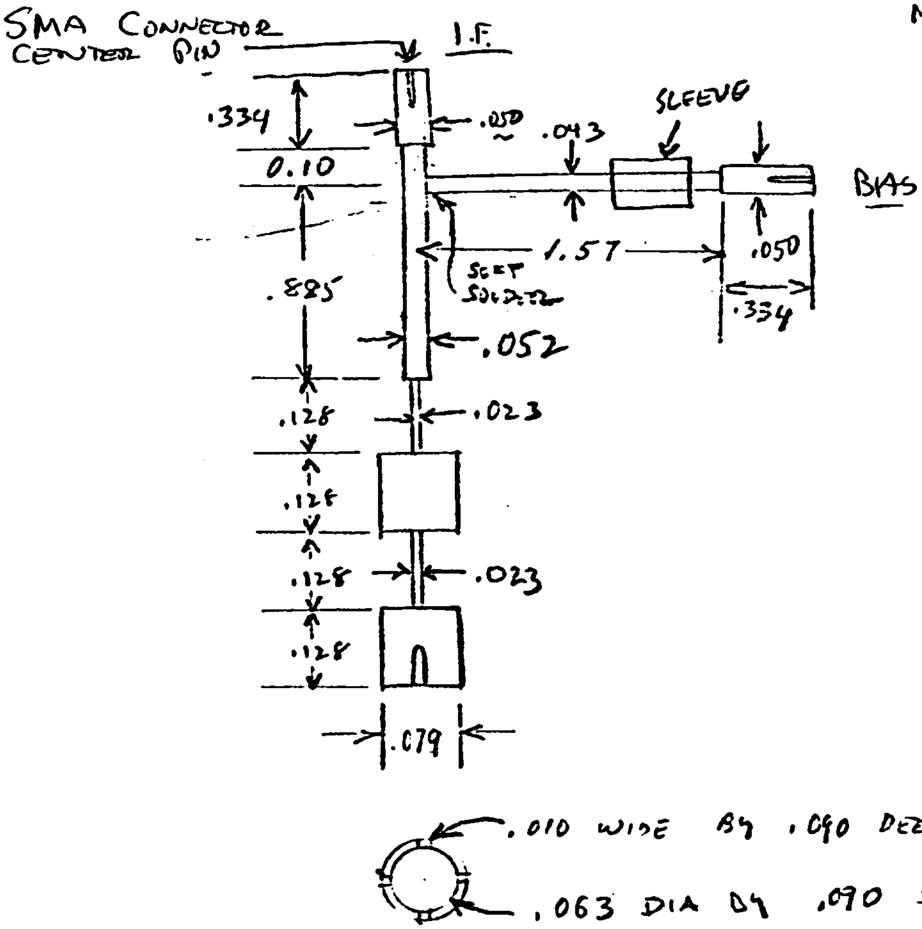


Figure 3 – Choke Assembly