VII. RADIO ASTRONOMY[*]

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A. K-BAND RADIOMETRY AND OBSERVATIONS

The final results have been obtained for the observations of Venus, Taurus A, the Sun, and the Moon, made in December 1962. These are presented in Table VII-1.

Table VII-1. Results of observations at 1.18 cm wavelength, December 1962.

		Average Brightness Temperatures
Venus		$395 \pm {}^{75}_{55}$ °K
Sun		8870 ± 980 °K
Moon	3.5 days before full moon	240 ± 40 °K
	0.3 days before full moon	254 ± 30 °K
	1.8 days after full moon	254 ± 30 °K
		Flux density
Taurus A		275 ± 85
		$\times 10^{-26}$ wm^{-2} cps^{-1}
		Attenuation
Zenith attenuation of the atmosphere		0.2 ± 0.1 db

The radiometer and experimental procedure were described in Quarterly Progress Reports No. 68 (pp. 35-36) and No. 69 (pp. 23-25).
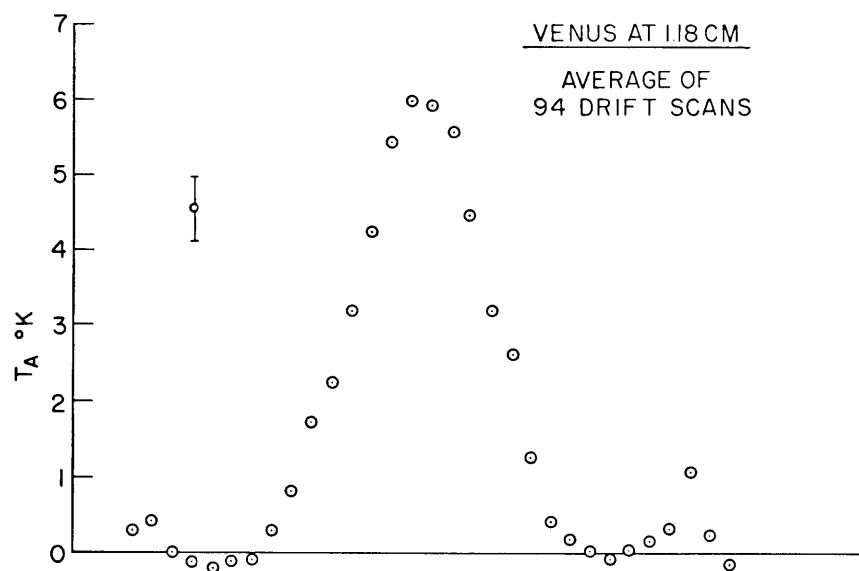

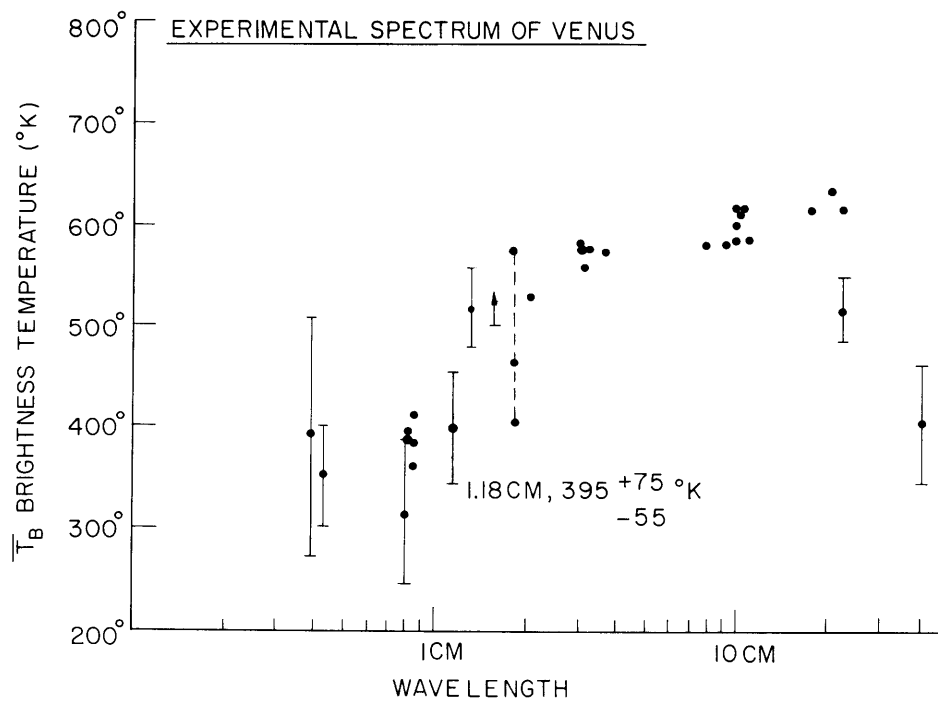
Fig. VII-1. Average of 94 drift scans of Venus.

Fig. VII-2. Radiofrequency spectrum of Venus.

These values were computed by using an antenna gain derived from the gain measured at 35.2 kmc. This was only 0.2 db higher than the gain determined by using the solar and lunar data. The atmospheric attenuation was determined by brightness measurements of the sun and the sky as a function of elevation angle.

Figure VII-1 shows the average of 94 drift scans of Venus normalized to inferior conjunction. Figure VII-2 shows the final result for Venus and the results of other observers plotted as a function of wavelength. The sharp transition between Gibson and Corbett's measurement at 22.2 kmc and our measurement at 25.5 kmc may indicate the presence of resonant molecular absorption. A number of molecules have resonances in this frequency band. Measurements at several frequencies in this region are planned for the inferior conjunction in 1964, and any such strong features should be readily detected.

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B. A FOUR-MILLIMETER WIDEBAND MIXER

The noise figure of the 4-mm radiometer described in Quarterly Progress Report No. 69 (page 25), was 31 db, approximately 10 db greater than the design objective. The source of this difficulty was the crystal mixer. Development of an improved crystal mixer for use with this system is now complete, and the radiometer design objective of a 21-db noise figure has been realized.

Problems in the original mixer were rooted in the use of commercially available cartridge-type crystals designed for use with intermediate frequencies of a few tens of megacycles. Three odd picofarads of package capacitance shunting the I-F terminals of the crystal precluded suitable matching to the 50-ohm traveling-wave amplifier (TWT) I-F input over a 2-4 Gc passband.

It became apparent early that the answer to the I-F matching problem was to eliminate the diode package by building the diode in the waveguide. The diode whisker became the center conductor of a 151-ohm transmission line that was matched to 50 ohms with two quarter-wave transformers at the center of the I-F passband.

Since the I-F impedance of most mixer crystals is in the range 300-600 ohms, the 151-ohm output was too low to provide a 1:1 match, but did keep the missmatch below 2:1 over most of the I-F passband. VSWR measurements looking into the I-F terminals under operating conditions are shown in Fig. VII-3. The I-F impedance is strongly dependent on dc bias and local oscillator drive level, so that is was possible to get a very good match at the I-F port. However, the bias and drive levels for best I-F match did not agree with the levels giving the best system noise figure. Curves for each case are shown in Fig. VII-3.

Earlier work on harmonic mixers with microwave I-F outputs by Dr. J. C. Wiltse
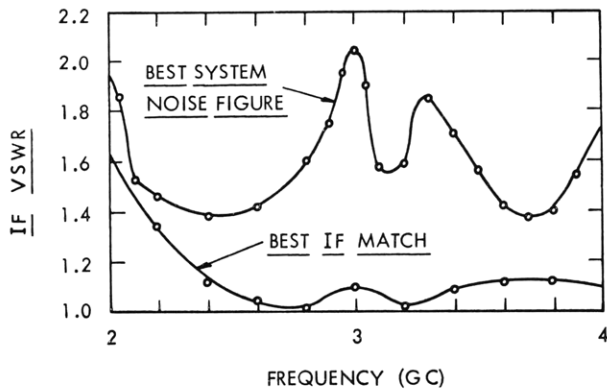
Fig. VII-3. VSWR at I-F port versus
frequency.

and his group at Electronic Communications, Inc., Tinonium, Maryland, indicated that, of the semiconductors available, gallium arsenide was best suited for this application. Results of their experiments were to the effect that the I-F impedance of GaAs crystals could generally be made lower than silicon on germanium crystals without the necessity of excessively high drive levels. Since GaAs also has better high-frequency characteristics than silicon or germanium, it was used without additional investigation.

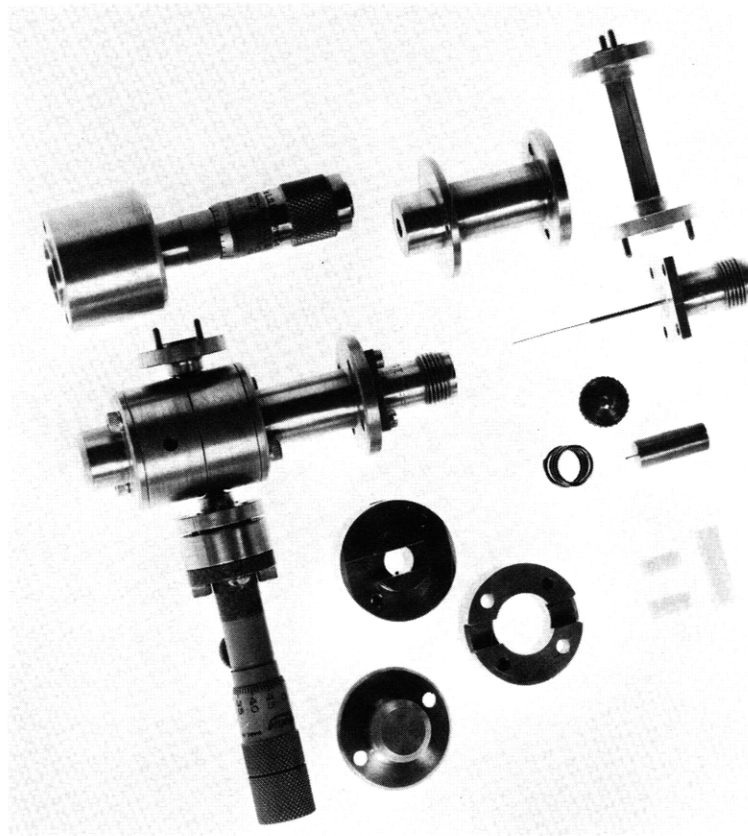A completed mixer and its component parts are shown in Fig. VII-4. The whisker

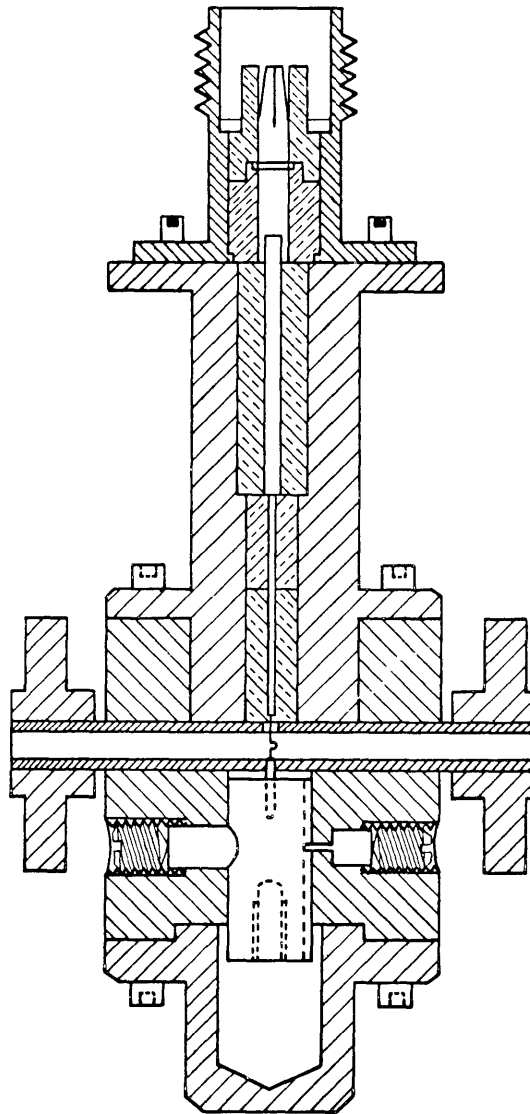Fig. VII-4. Assembled mixer and component parts.

Fig. VII-5. Mixer assembly.

material was 0.001-inch phosphor bronze wire with an electroformed point. Radius of the contact area was of the order of 50 microinches. The whisker was an integral part of the center conductor of the matching section and passed through a 0.0135-inch hole in the top of a section of RG-99-U waveguide. The GaAs crystal was soldered on the end of a 0.020-inch silver post that passed through a 0.0205-inch hole in the bottom of the waveguide. A micrometer adjustment was used to position the crystal. Location of parts in the final assembly is illustrated in the cutaway view of Fig. VII-5. Forming was accomplished by repeated current pulses in the forward direction.

Design goals for mixer conversion loss, L_x, and noise-temperature ratio, t_x, were
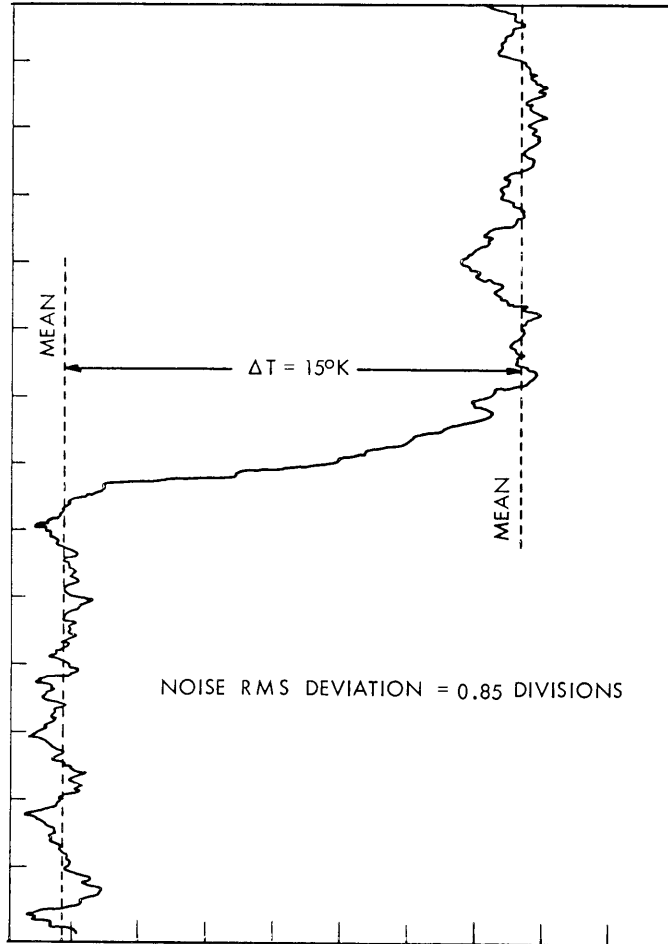
Fig. VII-6. Radiometer output with 4-sec integration time.

12 db and 2:1, respectively. For the mixers tested, L_x averaged approximately 12 db with the minimum around 9 db and the maximum around 13.5 db. Almost without exception t_x was less than 1.5:1.

The measured system noise figure for the mixer and the TWT S-band I-F amplifier, with a 5.5-db noise figure, was 15-16 db. The radiometer described in Quarterly Progress Report No. 69 (page 25), for which the mixer was designed, employs a narrow-band ferrite rf switch that prevents double sideband conversion. Measured radiometer noise figures were 19-20 db. Of the additional 4 db, 3 db were attributed to narrow switch bandwidth and 1 db to insertion loss between the mixer and the radiometer input.

The measured minimum detectable temperature for the radiometer was 1.5°K with an equivalent 1-sec integration time. This was well within the system design objective. A typical output record corresponding to an input temperature change of 15°K with an equivalent 4-sec integration time is shown in Fig. VII-6. The predetection bandwidth computed from measured minimum detectable temperature, radiometer noise figure,

and integration time was 1.8 Gc. This approaches closely the 2-Gc predetection band-
width that was the design objective.

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C. A BROADBAND FERRITE SWITCH

A ferrite switch with a bandwidth equal to that of the waveguide has been designed.
It is expected to have an insertion loss of less than 1 db over the band 18-26 kmc, a
VSWR less than 1.5, isolation greater than 20 db, and a switching speed of approxi-
mately 10 μsec.

When the switch is on, the magnetic field is zero, and the wave travels unimpeded
through the switch with the wave polarization perpendicular to the resistive sheet (see
Fig. VII-7). When the switch is off, the axial magnetic field twists the polarization
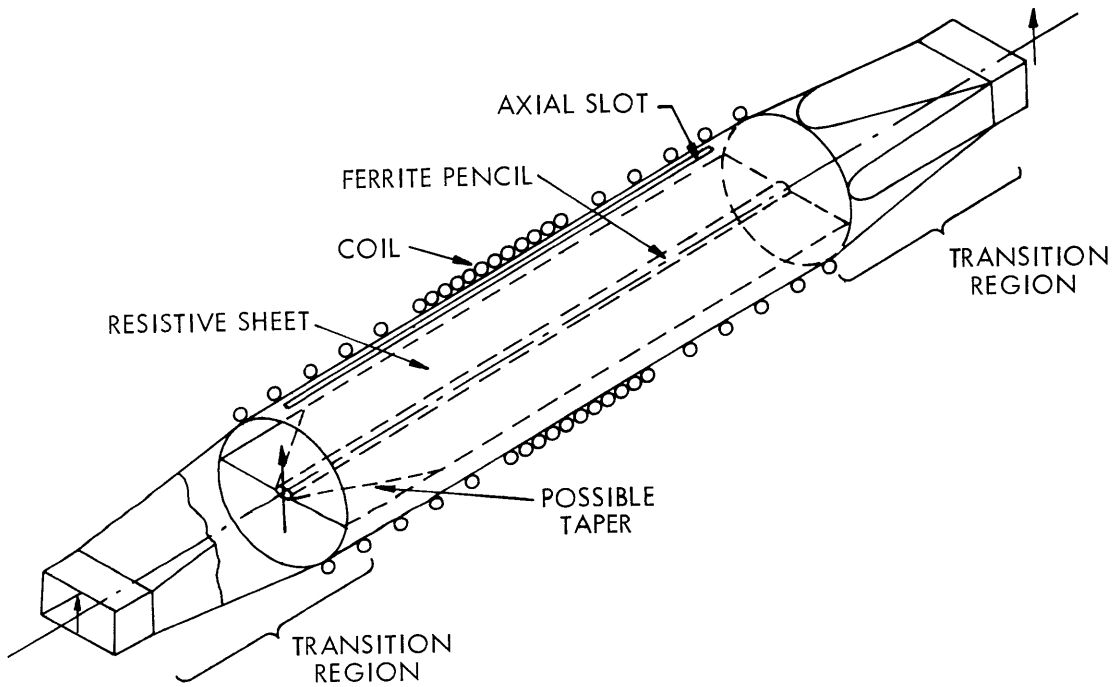

Fig. VII-7. Broadband ferrite switch.

around the axis approximately 0.5-1 turn, so that over the entire band the resistive
sheet attenuates the wave. Low VSWR is obtained by suitably tapering the ferrite pen-
cil, the resistive sheet, the magnetic field, and the waveguide. High switching speed
is obtained by axially slotting the waveguide at the surface current null line.

D. H. Staelin

D. INTERFEROMETERS EMPLOYING CLIPPED SIGNALS

An investigation of a method of eliminating the gain stability requirements for inter-ferometers by processing only the zero crossings of the original signals has been made. If the signals are clipped to a known level, it is possible to re-establish this level at the signal processer regardless of the channel gain. The two-level form created by infinite clipping is in a one-bit quantized form that is suitable for digital signal processing. For some interferometer systems it is desirable to measure the correlation of the two-antenna output signals as a function of antenna spacing and time delay. The correlation process can be performed by a simple coincidence detector when clipped signals are used.

In radio astronomy, the signals most often observed have a Gaussian probability distribution in amplitude. The relationship between the spatial crosscorrelation of the clipped signals and the spatial crosscorrelation of the unclipped signals is similar to the known formula for the temporal autocorrelation of clipped Gaussian signals. If the Gaussian signals have zero means and are symmetrically clipped at $\pm\ell$ volts, then this relationship has the form

$$\phi(\tau, d) = \left[\phi_{11}(0)\phi_{22}(0)\right]^{1/2} \sin\left[\frac{\pi}{2\,\ell^2}\,\phi_c(\tau, d)\right],$$

where $\phi(\tau, d)$ is the spatial crosscorrelation between the original unclipped signals, $\phi_c(\tau, d)$ is the crosscorrelation between the clipped signals, and $\phi_{11}(0)$ and $\phi_{22}(0)$ are the average powers in channel one and two, respectively, d is antenna spacing, and τ is time delay in one channel.

Once the spatial crosscorrelation has been determined, the angular power density spectrum $P(f, \ell, m)$ may be calculated from a three-dimensional Fourier transform of $\phi(\tau, d)$, where ℓ and m are directional cosines.

As far as it is known, this is the first time that such a technique has been applied to interferometer systems. This new system promises to be very interesting and is one of the first to utilize digital processing of high-frequency interferometric data.

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