IV. SOLID-STATE MICROWAVE ELECTRONICS[*]

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A. STATUS OF RESEARCH

During the past quarter the 23.8-GHz low-noise receiver project under P. W. Rosenkranz[1] was completed. Results are summarized in Section III-E.

An investigation of the "anomalous mode" oscillations in the avalanche region of the P-N junctions was initiated by R. Crochiere. His preliminary work is described in Section IV-B.

Work has continued on the 60-GHz low-noise solid-state receiver that was described in Quarterly Progress Report No. 89 (pages 29-30). Progress on the individual projects is described below by those responsible for the work.

D. H. Steinbrecher

References

1. P. W. Rosenkranz, "A Low-Noise K-Band Radiometer for the Measurement of Narrow Spectral Lines," S.M. Thesis, M.I.T., June 1968.

B. AN INVESTIGATION OF SUB-TRANSIT TIME OSCILLATIONS IN THE AVALANCHE REGION OF A PN JUNCTION

The object of this project is to investigate the relaxation oscillations observed in avalanche diodes. At present, a piecewise linear model of the DC diode characteristics is used to represent junction breakdown. Various circuit arrangements are being investigated to simulate the AC parasitics of the junction and the diode case. All calculations are being done by a computer program. Resulting waveforms are compared with measured waveforms in an attempt to determine an appropriate AC model of the encased diode.

R. E. Crochiere

C. 60-GHz MIXER

Schottky-barrier diodes are now being produced with uniform static characteristics. Typical values for a 5-μ diameter junction are a Schottky-diode exponent of 1.1, a zero bias junction capacitance measured at 1 MHz of 0.03-0.04 pF, a differential resistance measured at 60 Hz of 10-11 Ω with 10 mA of forward current, and an I_{sat} of 10^{-14}-10^{-16} A. The mechanical components of the balanced mixer are now 60% complete.

<div align="right">J. E. Rudzki</div>

D. S-BAND MIXER

A number of measurements of the intermediate-frequency impedance have been made. The impedance was measured (Fig. IV-1) as a function of short-circuit position in the image port Z_{if} (Z_{im}) and in the signal port Z_{if} (Z_s). The Z_{if} (Z_{im}) and Z_{if} (Z_s) should form circles close to the r = 1 and r = 0 circles on the Smith chart.
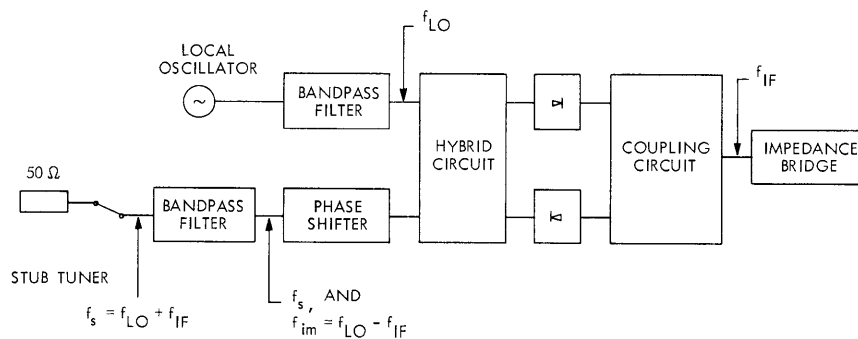

Fig. IV-1.   Intermediate-frequency impedance vs short-circuit position in the image and signal ports.

The results plotted on the Smith chart form small ellipses. The disagreement is probably due to the following factors:

1. uncontrolled termination of the higher frequency products at the input of the diodes (e. g. , ellipselike shape resulting from changes of sum termination when Z_s or Z_{im} changed);

2. unsymmetry of the diodes and consequent change of the drive when Z_s or Z_{im} is changed.

To solve these problems a new mixer design is under way. In the meantime, further measurements will be made with carefully paired diodes.

The single-sideband conversion loss of the existing mixer is approximately 4.0 dB.

<div align="right">J. W. Majer</div>

E. FREQUENCY DOUBLER

Two frequency doublers for 15. 2-30. 4 GHz and 30. 4-60. 8 GHz have been finished in the machine shop.

The first of them (15. 2-30. 4 GHz) has been tested with and without the varactor diode. The measurements of input impedance at the 15. 2 GHz input port showed that (a) the diode is very weakly coupled, and (b) there are at least two mutually coupled resonant circuits representing a nearly matched load.

Further tests will include measurements of the input impedance with the diode placed directly in the 15. 2-GHz port, and attempts to find the appropriate coupling (which should also affect the spurious resonances).

The 30.4-60.8 GHz doubler will be tested after completing the measurements and the tuning of the first one.

<div align="right">J. W. Majer</div>

F. L-BAND QUADRUPLER

For the purpose of computing the input, output and idler network for a multiplier with discrete and distributed elements a computer program was developed.

A quadrupler was then designed. The configuration used for this quadrupler is determined by the desire to be able to sample the current through the varactor diode and to have outputs at the second and third harmonics of the input frequency. Construction of the quadrupler is under way.

The more general case of a multiplier delivering power at all harmonics of the input frequency below the output frequency was discussed. The resulting system of nonlinear equations has been solved for a quadrupler.

<div align="right">K. H. Gerrath</div>

G. AVALANCHE DIODE OSCILLATOR

Some preliminary measurements made on the avalanche diode oscillator have shown a dependence of the output power (at the fundamental frequency) on the second harmonic termination. The terminations used were a matched load, and an adjustable short representing all reactive loads. With the adjustable short terminating, the output power varied by a factor of about four (max/min) as the position of the short moved through a half wavelength. The maximum output using the short was generally 10-20 per cent higher than that available using a matched load, while the minimum output was 60-70 per cent lower than that corresponding to the other terminations. The efficiency using the matched load was approximately 0.3 per cent, which can hopefully be improved by better coupling to the cavity holding the diode. These measurements were made at a

fundamental frequency of 9. 8 Gc; the adjustable short is expected to have a more pronounced effect on the efficiency at the design frequency of 11 Gc.

<div align="right">D. F. Peterson</div>

H. HIGH DYNAMIC RANGE MIXER FOR THE 200-400 MHz BAND

At present, work is still being done on the construction of transmission-line transformers. Measurements on 50-Ω balanced to 50-Ω unbalanced transformers show standing-wave ratios of less than 1. 1 for frequencies less than 900 MHz, with matched balanced output. Mid-band insertion loss was 0. 3 dB, and the lower frequency limit of operation (the frequency of the insertion loss is 3 dB) was approximately 300 kHz. This agrees well with theory. Although the transformer was not tested above 900 MHz, it is expected to operate with low VSWR well above 1 GHz. Tests will soon be made on a 50-Ω unbalanced to 200-Ω balanced transformer.

<div align="right">R. E. Snyder</div>

I. MIXER THEORY

In a balanced mixer circuit there are four basic methods for terminating the out-of-band frequencies.

1. Short-circuiting them at both ends (Y-mixer).
2. Open-circuiting them at both ends (Z-mixer).
3. Short-circuiting those appearing at the input side and open-circuiting those at the output side (G-mixer).
4. The opposite of case 3 (H-mixer).

The designations Y, Z, G, and H come from the fact in the first case, for example, the Y-matrix of the mixer is the only matrix that can be written directly without solving any equations, and so on for the other cases.

It has long been known that the Y (or the Z) mixer can be built with one diode. It has been shown also that the G (or the H) mixer can be built with one diode and still give the same conversion loss as the balanced 2- or 4-diode circuits.

<div align="right">A. A. M. Saleh</div>

J. D-C AMPLIFIER

I have been engaged in determining the effects of using field-effect transistor bridges to modulate waveforms. There are areas of interest ranging from very low frequency inputs, "chopped" by a binary type reference for standard chopper amplifiers, to high-frequency mixers. In all of these areas of interest a good model is required and undesired effects such as intermodulation have to be studied. Future work will be concentrated on better models and methods of improving the FET bridge as a mixer.

<div align="right">R. D. Mohlere</div>