

V. SOLID-STATE MICROWAVE ELECTRONICS*

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A. HIGH DYNAMIC RANGE TECHNIQUES

Several projects are now under way. They include mixers, linear amplifiers, detectors, filters, and log-amplifiers designed and built to have the widest possible dynamic range. During the last quarter, a phase detector with nearly 140 db of dynamic range was completed, and preliminary results are available on both a linear and a logarithmic amplifier.

The linear amplifier utilized a push-pull MOSFET stage with 10-db gain and a bandwidth of 2-20 MHz. A +13 dbm two-tone signal applied to the input gave third-order intermodulation products more than 45 db down from the two-tone signal. A simple low-frequency logarithmic amplifier with 11-decade range has been constructed in order to test theoretical calculations.

A crystal filter using high dynamic range interstage and output amplifiers is now under construction. We hope that the completed amplifier-filter will have 20-db gain, a 2-to-1 shape factor, 10-kHz bandwidth (center frequency of 30 MHz), and an out-of-band response 150 db down from the passband behavior. Considerable care during the construction phase will be necessary in order that grounding, shielding, and filtering be sufficient to maintain the 150-db out-of-band attenuation.

Wideband high dynamic range phase detectors have been built in the past by our group. At the present time, the same technology is being investigated, in order to provide similar dynamic range for square-law and peak detectors.

R. P. Rafuse

B. HIGH-POWER VARACTOR MULTIPLIERS

Devices that have theoretical power-handling capabilities of 12 watts per diode have been purchased and characterized (see Sec. V-C). Results of the characterization indicate that these diodes will be "circuit-limited" in terms of efficiency and the design frequency of 250-1500 GHz. An interdigital output filter has been designed and is under construction. An input filter is being designed. Idler circuit synthesis awaits

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construction and measurement of the input and output filters.

In addition to the single diode, times-6 multiplier, a four-diode, 100-watt doubler is being designed as the first stage of a times-8 chain to S-band. The output power of this chain is expected to be greater than 60 watts.

D. H. Steinbrecher

C. DEVICE CHARACTERIZATION

Preliminary measurement of high-power, punch-through varactors in a new test jig at 500 MHz indicate cutoff frequencies of as much as a factor of 2 higher than those reported by the manufacturer. The measurements indicate that the high-power high-efficiency transmitter for 2 GHz will be relatively easy to realize. A selected and modified General Radio Series 900 slotted line has been received and will soon be in operation as a 3-GHz varactor (and other two-port device) measurement arrangement. All of the measurements now being carried out on varactors, Schottky-barrier diodes, MOSFETS and other solid-state devices are being analyzed by computer programs generated by the group and run on the M. I. T. Computation Center's CTSS system.

R. P. Rafuse

D. COMPUTER DESIGN OF VARACTOR CIRCUITS

Two analysis programs for high-order punch-through varactor multipliers were developed during the past quarter. One program, called SAMPLE, operates on a measured varactor current waveform to recover the instantaneous varactor voltage, the power flow at each harmonic, and the network impedance seen by the varactor junction at each harmonic. The other program, called MULTAN, works from the imbedding impedances and the junction characteristics to synthesize the junction voltage and current waveforms, and, consequently, the complete power distribution for the multiplier.

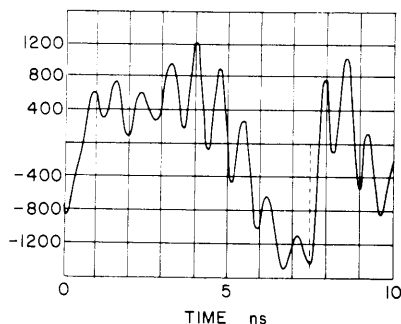


Fig. V-1. Diode current.
[Reprinted from "hpa Application Note No. 8," Fig. 7, p.3.]

MULTAN allows a designer to test a theory before construction, while SAMPLE permits a complete diagnostic of a working multiplier. Both programs are intimately related to the High Power Varactor Multiplier project.

MULTAN is not completely operational, because of its idealized concepts. During the next quarter methods for including discontinuity susceptances, line loss, and other nonideal

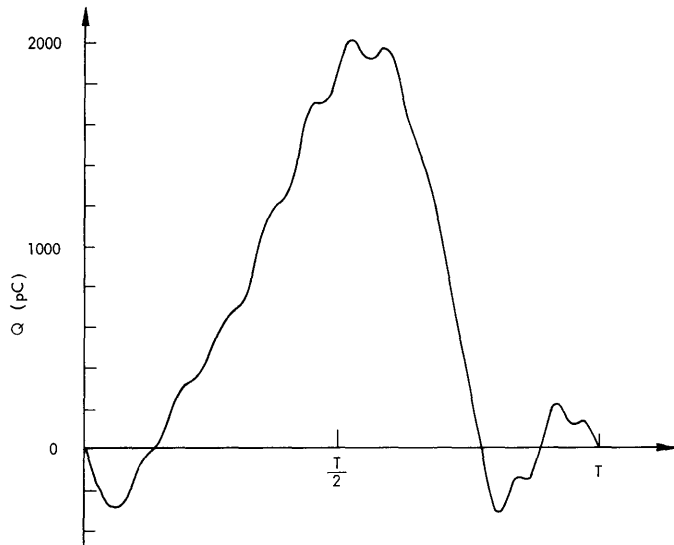


Fig. V-2. Charge waveform.

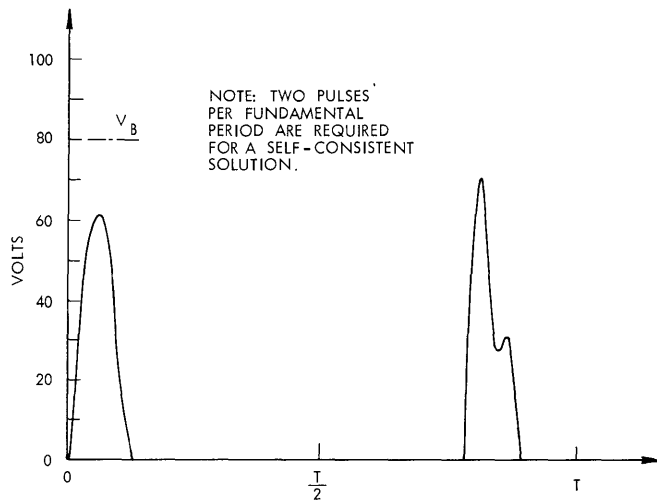


Fig. V-3. Voltage waveform (HP X-13 multiplier).

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circuit properties will be investigated.

SAMPLE has been tested on a current waveform published by Hewlett-Packard Associates.¹ The results were very interesting. They described the current waveform as that of a times-14 multiplier with 1.5 watts input at 100 MHz and approximately 200 mW output at the 14th harmonic. SAMPLE revealed that the order of multiplication was actually times-13 (which was confirmed later by a Hewlett-Packard spokesman) and that 40% of the input power was being dissipated in network losses at the 4th harmonic. The current waveform, from which all of the following information was obtained, is illustrated in Fig. V-1. The varactor charge and voltage waveforms, obtained by

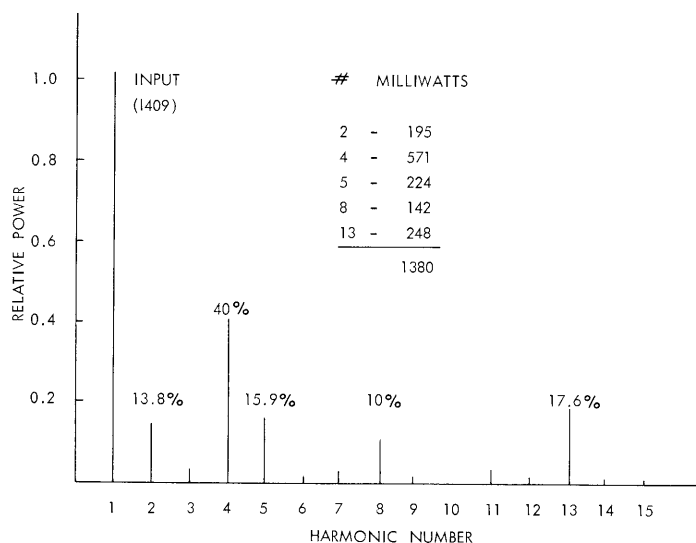


Fig. V-4.
Harmonic power distribution.
(HP X-13 Multiplier.)

SAMPLE are shown in Figs. V-2 and V-3. Figure V-4 illustrates the harmonic power distribution for the Hewlett-Packard X-13 multiplier.

This project led to the preparation of a joint paper. A summary of this paper appears in Section V-E.

D. H. Steinbrecher

References

1. "Frequency Multiplication with the Step Recovery Diode," hpa Application Note No. 8, Hewlett-Packard Associates, Palo Alto, California, July 1965.
- E. ITERATIVE SYNTHESIS OF VARACTOR-MULTIPLIER MICROWAVE NETWORKS AND A DOUBLER WITH 0.17-WATT OUTPUT AT 47 GHz

[This report summarizes a paper that will be presented at the International Symposium on Microwave Theory and Techniques (sponsored by the IEEE Professional Group on Microwave Theory and Techniques), Boston, Massachusetts, May 10, 1967.]

A method for the design and evaluation of the input and output networks of microwave

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frequency varactor multiplier circuits will be presented. This method permits a quantitative measure of circuit loss, input-output isolation and effective diode cutoff frequency. Furthermore, it enables the designer to establish the boundary conditions at the varactor junction which are required for optimum efficiency, independent of any specific knowledge of package parasitics, transmission-line characteristic impedances, or other difficult-to-quantize microwave circuit parameters. By using this method, a doubler from 23.5 GHz to 47 GHz has been designed and tested. Output power of 173 mW was obtained with an efficiency of 33%. The measured efficiency was within 0.5 db of the calculated value.

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