CONCLUSIONS

The microwave applicators described herein have resulted in the simultaneous sacrifice and rapid inactivation of brain enzymes in the rat. Present results demonstrate control levels of cyclic AMP to be approximately 0.6-pmole/mg wet weight in the cerebellum. This is indicative of both the very rapid inactivation of the brain enzymes involved and the prevention of postmortem increase associated with more conventional methods of sacrifice. We have been able to measure levels of two cyclic nucleotides, cyclic AMP and cyclic GMP, in 13 distinct regions of the brain: cerebellum, brainstem, midbrain, substantia nigra, thalamus, hypothalamus, hippocampus, amygdalapyriform cortex, septal nuclei, nucleus accumbens, olfactory tubercle, striatum, and cortex. Applicability of the technique to many putative central nervous system transmitters is being investigated in our laboratory [15].

Users of high-power microwave inactivation systems should be aware of the factors affecting the uniformity and reliability outlined here. We are continuing attempts to modify our microwave parameters to accomodate an increased mobility of the rat with improved uniformity and speed of inactivation.

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Letters

Dynamic Microwave Frequency Division Characteristics of Coplanar Transferred-Electron Devices in a Resistive Circuit

C. I. HUANG, J. TSUI, R. T. KEMERLEY, AND G. L. McCOY

***Abstract*—It is shown that dynamic microwave frequency division (divide-by-K) can be achieved by employing a transferred-electron device (TED) in a resistive circuit. The absolute bandwidth over which the input signal will be divided by a particular integer K and the maximum output frequency is the device transit time frequency. The percentage bandwidth is $200/(2K-1)$ percent. With two-terminal TED's, divide-by-K ($K = 2, 3, 4, 5$) was demonstrated with substantial bandwidth.**

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INTRODUCTION

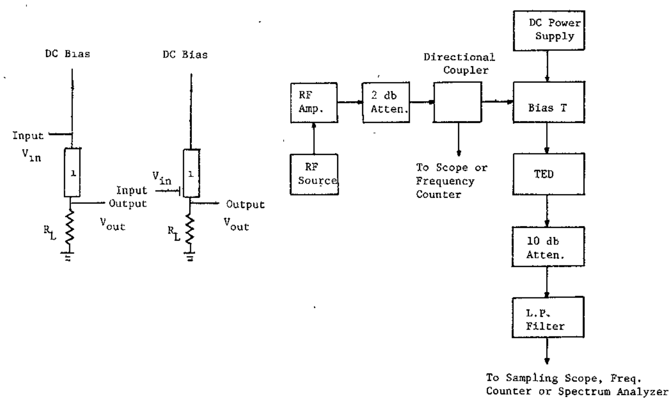
The use of transferred-electron devices (TED's) to perform dynamic microwave frequency division has been demonstrated by Upadhyayula and Narayan [1]. In their work, two-terminal sandwich-type GaAs TED's were tested in a coaxial cavity circuit. About 10-percent input bandwidth was reported at X band. The bandwidth capacity of the TED frequency divider has not been fully explored.

It is the purpose of this letter to derive the ideal frequency response and maximum bandwidth characteristics of an ideal TED in a resistive circuit. Experimental results are also included to substantiate the derivation.

SIMPLIFIED THEORY

It is well known that in the high-field-domain-mode GaAs TED's, a domain in transit must be quenched at the anode before a second domain can be nucleated [2]. Using this unique TED characteristic, frequency division can be easily achieved.

Placing a TED with a finite domain transit time in a circuit such as that of Fig. 1(a) with the device biased just below threshold, an input pulse is applied either to the anode (for two-terminal TED's) or the gate (for Schottky-barrier-gate TED's). A domain is nucleated near the cathode or the anode edge of the gate. The device current drops to a low value and remains low while the domain is in transit. As soon as the domain reaches the anode, the current level returns to the original bias current value. During the domain transit period, no matter how many input pulses are applied to the device, they cannot nucleate a new domain. The input and output signal waveforms of a two-terminal TED versus time are shown in Fig. 2



(a) (b)

Fig. 1. (a) TED biasing; input and output circuits. (b) Experimental setup for studying the TED dynamic division.

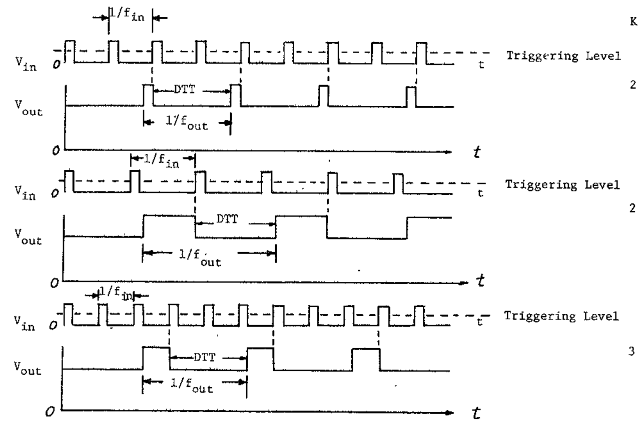


Fig. 2. Input and output signal waveforms of a two-terminal TED versus time for various input frequencies (pulse-repetition rates). *DTT* = device transit time.

for various input frequencies (pulse repetition rates). Here an ideal device is assumed, i.e., zero domain formation and extinction times. If input signals are sinusoidals, the output waveform will still remain the same. Hence the input–output (fundamental) frequency relation for an ideal TED can be shown as in Fig. 3 with the frequencies normalized to the device transit time frequency f_D. Thus frequency division by K, $K = 2,3,\cdots$, is achieved. The absolute bandwidth over which the input signal will be divided by a particular integer K is f_D. The maximum output frequency is f_D. The percentage bandwidth, centered at middle of the divide-by-K range, is

$$\text{BW} = f_D \Big/ \left[\frac{Kf_D + (K-1)f_D}{2}\right] \times 100 \text{ percent}$$

$$= \frac{200}{(2K-1)} \text{ percent.}$$

It is also interesting to note that for input frequencies between f_D and $f_D/2$, the divider acts as a frequency repeater or possibly an amplifier.

EXPERIMENTS

The GaAs coplanar two-terminal TED's used in this work were fabricated from n-type epitaxial layers on semi-insulating substrates using mesa-etch techniques. The carrier density, thickness, and effective length of the device are 2×10^{15} cm^{-3}, 5.5 μm, and 100 μm, respectively. An expanded active layer near the cathode and anode contacts and a tapered active layer were incorporated into the device design. They were intended for three-terminal TED development [3], [4], and, originally, were not for two-terminal operation.

The device was mounted on a copper carrier in a 50-Ω microstrip circuit with a 50-Ω load resistor. Fig. 1(b) shows the experimental setup. The operation procedures were similar to those used in [1]. The output was taken from the cathode of the TED. There were no special matching circuits built around the inputs and outputs of the devices. In order to accomplish the necessary isolation, a low-pass filter was placed in the output circuit to remove the input signal.

EXPERIMENTAL RESULTS AND DISCUSSION

It was found that the ratio K of input frequency to output frequency is an integer with values from 2 to 5. When the input frequency was increased from 1.5 GHz to 3.91 GHz, the value of K changed as shown in Fig. 4. The divide-by-4 waveform is shown in Fig. 5. In the transition regions between two working regions, the output from the TED was a noiselike, wide-band spectrum. The limitation of bandwidth probably was due to the circuit mismatch associated with the TED. The device transit time frequency f_D was measured under both dc ($V_D = 45$ V) and pulse-biased [pulse-repetition frequency (PRF) = 100 kHz, pulsewidth = 20 ns, and pulse-amplitude = 45 V] conditions; they were 0.7 GHz and 1.2

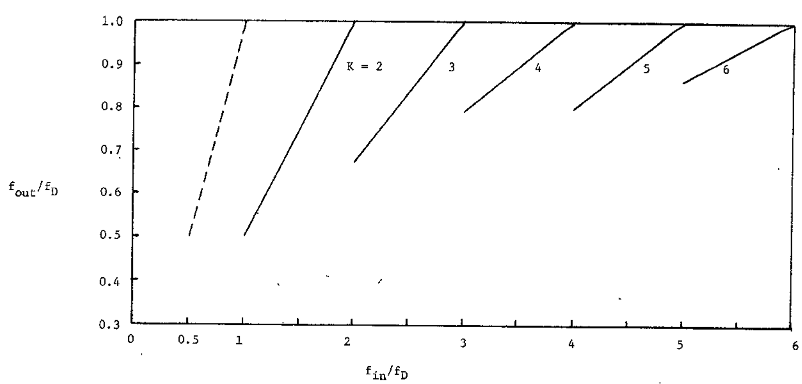


Fig. 3. Ideal input–output (fundamental) frequency relation for a TED with the frequencies normalized to device transit time frequency.

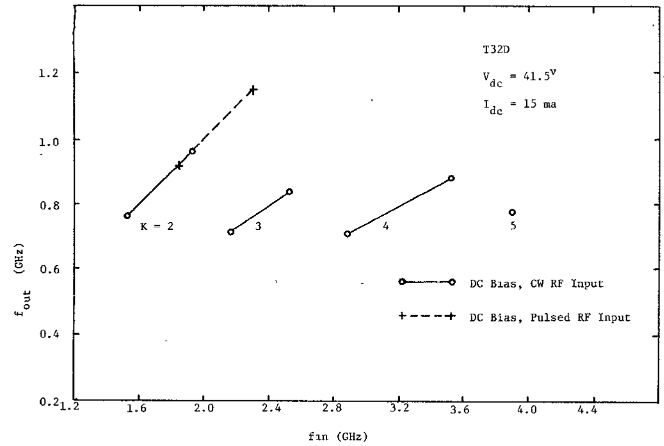


Fig. 4. Input–output frequency relation for TED T32D with indicated biasing condition. Data points between two ○ or two + are continuous.

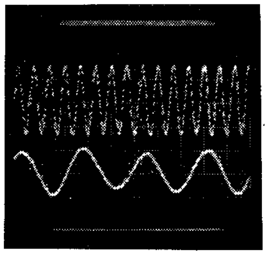


Fig. 5. Sampling scope waveforms of divide-by-4 operation. Horizontal: 0.5 ns/div; vertical: 100 mV/div; f_{in} = 3 GHz; f_{out} = 0.75 GHz.

GHz, respectively. f_D increase under the pulse-bias condition was observed also by Takeuchi *et al.* [4]. From Fig. 4, f_D was estimated to be 0.96 GHz.

A pulsed RF signal was also applied to the TED. The pulsewidth was 1 μs with a rate of 5.9 × 10^4 pulses/s. The actual divide-by-2 region was shifted upward in frequency as shown in Fig. 4. This was probably due to the shortening of the device transit time.

This experimental evidence indicated that f_D was a critical function of RF input power and bias condition. The results follow the temperature–electron-velocity relation of [5]. However, the exact physical mechanism was not known. The RF power measured at the input of the TED was 26 and 17 dBm at frequencies of 1.8 GHz and 3 GHz, respectively; however, the input of the TED was not matched to 50 Ω. Therefore, the triggering voltage applied to the input of the TED was not known. The conversion loss was estimated to be about 20 dB or greater. It is desirable that frequency division can be performed with gain. Hence further understanding and development of the TED are necessary for utilizing its full capacity and potential.

CONCLUSION

Frequency division by an integer K (K = 2, 3, 4, and 5) has been demonstrated using planar TED's in resistive circuits. The theoretical maximum output frequency of a divide-by-K circuit and the absolute bandwidth over which the input signal will be divided by K is the device transit time frequency. The percentage bandwidth is $200/(2K - 1)$ percent.

It has been pointed out that the domain trigger sensitivity is greatly enhanced by triggering a domain from a Schottky-barrier gate [3], [6], [7]. With optimization in TED device (including load resistor) design and fabrication, microwave frequency (up to 50 GHz) division with gain is possible. Subsequently, many applications (for example, the phase-locked loop of a microwave synthesizer) can be found for the TED frequency divider.

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A Broad-Band 40–60-GHz Balanced Mixer

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***Abstract*—A wide-band fixed-tuned millimeter-wave balanced mixer covering 40–60 GHz is described. Conversion loss of 8.5 dB ± 1 dB from 40–58 GHz was obtained using unencapsulated silicon Schottky-barrier diodes.**

This letter describes the design and measured performance of a fixed-tuned, broad-band balanced mixer covering the 40–60-GHz frequency band. A rapid-scan wide-band low-noise receiver front end was a principal objective of this work. To the authors' knowledge, a broad-band mixer for this band has not been reported previously in the literature.[1] The performance achieved in the work reported here results from the use of a frequency insensitive hybrid junction and high-cutoff-frequency silicon Schottky-barrier chip diodes. [1]–[3].

The design approach uses unencapsulated Schottky-barrier mixer chips mounted in a suitable RF hybrid structure in order to achieve a balanced mixer. Unpackaged diodes were selected to maximize bandwidth by eliminating the parasitic reactances of the packages. The RF hybrid is a symmetry-type junction between reduced-height TE_{10} rectangular waveguide (0.188 in × 0.094 in) and dielectric-supported air strip transmission line in a below-cutoff channel [4]. The configuration is shown in Fig. 1. Assuming perfect electrical balance, infinite isolation between signal and LO would result. The diode chips are bonded to the conductors on the dielectric with silver-conducting epoxy. The diode junction capacitance is ≃0.03 pF and $R_s \simeq$ 10–12 Ω. The chips are 15 mil square and 7 mil thick.[2] 1-mil-diam wire approximately a quarter-wavelength long at 40 GHz connects each conductor to the mount, providing a dc return for the diodes. The contacting whisker inductance series resonates

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[1] After submission of the original manuscript, the authors have received and tested a fixed-tuned mixer covering most of the 40–60-GHz band, developed by Spacekom, Inc., under contract to the Navy. This mixer used encapsulated GaAs Schottky-barrier diodes.

[2] Purchased from Hughes Electron Dynamics Division, Torrance, CA.