A TRANSFERRED-ELECTRON FREQUENCY MEMORIZER*

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ABSTRACT

Transferred-electron oscillators capable of single frequency operation at any of a large number of closely spaced frequencies are being developed for microwave frequency memory applications. Switching between different frequency states has been achieved with pulsed RF input signals as short as 0.1 μs in X-band (8.2-12.4 GHz).

INTRODUCTION

In many microwave signal-processing systems such as ECM systems it is desirable to acquire the input signal and to retain it for a long period of time. One technique for retaining a pulsed RF signal is called the "loop" memory system and it consists of an amplifier with a delay line in the feedback path. The purpose of the present study is to investigate the feasibility of an alternate method for frequency memory - the transferred electron device (TED) frequency memorizer.

The TED frequency memorizer consists of a TED oscillator capable of operation at any of many closely spaced rf frequencies. An input rf signal switches on the closest frequency state and this state remains until the next input signal causes switching to the frequency state closest to that input signal. It is a multiposition frequency memory or register. Since the memorizer has a limited number of frequency states, their spacing must be close enough to give the accuracy required in the memory application. Magarshack[1] has demonstrated one type of TED frequency memory oscillator.

DESIGN

The simplest method of producing a multifrequency resonator with reasonably similar Q-value for each mode is to utilize a long section of transmission line with either an open or short circuit at the end. Figure 1 shows the two basic types of TED frequency memorizers that can be constructed with a T-line (transmission-line). In the case of the series-loaded TED [Fig.1(a)], R_L will be small compared with Z_o to maintain large circuit Q. In the shunt-loaded case [Fig.1(b)], R_L will be larger than Z_o for the same reason. The T-line has attenuation that limits the circuit Q value. For long T-lines and close frequency states, the attenuation becomes the limiting factor.

An approximate derivation of the mode separation, ΔF, can be made, assuming that the line length corresponds to an integral number of half-wavelengths at each mode. It can be shown that

$$\Delta F = \frac{1}{\tau} ,$$

where τ = the round-trip time delay of the T-line. Thus, a 10-ns delay line (i.e., 1.5 meter length TEM air line) is required for 100-MHz frequency spacing.

In the design of a frequency memorizer, it is important to maintain the stability as uniform as possible over the operating band. If this is not achieved, there is a strong tendency for the memorizer to jump to the most stable operating frequency during switching. This causes the oscillator to jump to frequencies quite different from the input frequency. When such behavior was observed in the experiments, it was always found that the modes with largest external Q were favored. This is consistent with theory. This behavior can be eliminated by proper design of the output transformer so as to equalize the values of external Q across the operating band.

Conventional TEDs of 100 mW capability were used in this study. An example of load impedance characteristics for one such device is presented on the Smith chart in Figure 2. The most stable operation occurs for light loading (i.e., small R/Z_o values) which can only be obtained with low-loss RF circuits.

Figure 3 shows the calculated circuit impedance for each mode for two experimental circuits. The microstrip circuit has ΔF = 108 MHz, is shunt loaded by 100 Ω, and is fabricated on a piece of 2"x2"x.025" alumina. The waveguide circuit has ΔF = 80 MHz, is also shunt loaded by 100 Ω, and consists of five feet of WR-90 waveguide.

For good oscillator stability, the circuit load lines (Fig. 3) should intersect the device lines (Fig. 2) at angles close to 90°. The number of operating frequency states will be determined by the number of circuit modes which intersect device lines at common frequencies.

RF PERFORMANCE

Figure 4 shows the equipment layout used for evaluating the frequency memorizer. The TE device is operated CW and pulsed RF signal is used for switching. The RF input power and frequency accuracy required for switching depend upon the degree of external loading of the oscillator. Switching is found to occur by a nonlinear mixing effect and not by the injection locking process. Thus, far less RF input power is required to switch 1 GHz range than would be estimated from the equations for injection locking.

Each memorizer tested was found to have a set of stable frequency states. A state was deemed stable if, after switching, the memorizer would continue to oscillate in that state when the input signal was removed. Some states exist only with the presence of additional signals at other states. These states have multiple frequency output.

The number of stable frequency states were affected by the bias voltage of the TED as well as by circuit tuning. The RF frequency and RF power output for each stable state is measured for fixed bias value and circuit tuning condition. This measurement shows the number, range and separation of the frequency states instantaneously available for an input signal.

The best memorizer performance in each type of RF circuit is summarized in Table 1.

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TABLE 1. Comparison of Properties of Four Different TED Frequency Memorizers

T-Line	ΔF (MHz)	Freq. Range (MHz)	No. of Missing Modes	No. of States
Microstrip on 2"x2"x.025" alumina	132	2120	4	17
5 ft. of WR-90 waveguide	71	1070	0	16
7 ft. of 0.141" diameter semirigid coaxial line	45	770	0	18
15 ft. of 0.25" diameter semirigid coaxial line	22.4	425	0	20

All of these memorizers operate above 10 GHz and contain several frequency states with multi-frequency output. A single RF pulse of duration 0.1 μs is adequate to switch all of the above memorizers except for the last one, which required about 0.5 μs pulse duration. The rf power required for switching depends upon the frequency separation from the closest state. About 200 mW was adequate to switch states if the input signal was within several MHz of the frequency state.

Figures 5 and 6 show data for two of these memorizers and Figure 7 shows a photograph of the memorizer constructed with an alumina circuit.

CONCLUSIONS

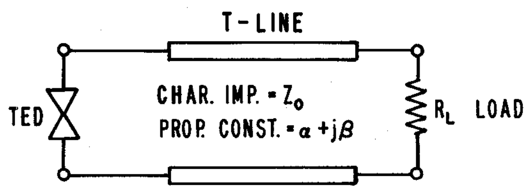
It has been demonstrated that a "frequency register" with as many as 20 frequency states can be constructed in X-band using conventional TE devices and any form of low-loss transmission line. Pulsed RF input signals cause switching to the nearest frequency state. The memorizer remains in the memorized state until a new input signal occurs.

ACKNOWLEDGMENTS

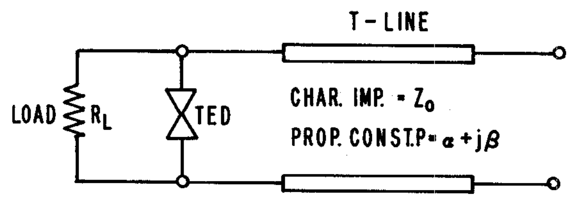
The preliminary feasibility tests performed by L. C. Upadhyayula are gratefully acknowledged. In addition, E. C. McDermott constructed all oscillator assemblies.

REFERENCE

1. J. Magarshack, "Gunn Oscillator as a Frequency Memory Device," IEEE Trans. on Microwave Theory and Techniques, Vol. MTT-16, No. 12, pp. 1055-1057, December 1968.



(a) Series-loaded TED.



(b) Shunt-loaded TED.

Figure 1. TED frequency memorizer circuits.

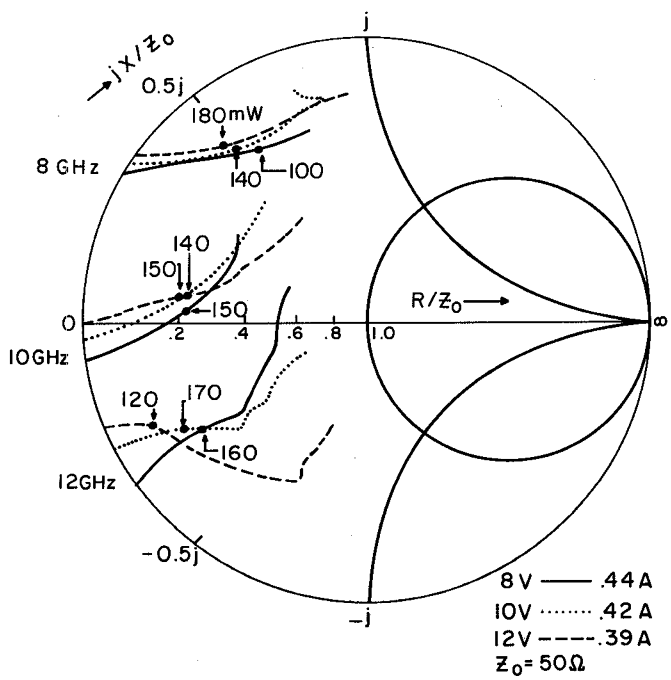


Figure 2. Smith chart display of measured load impedance characteristics for a packaged X-band TED. RF output power values are shown.

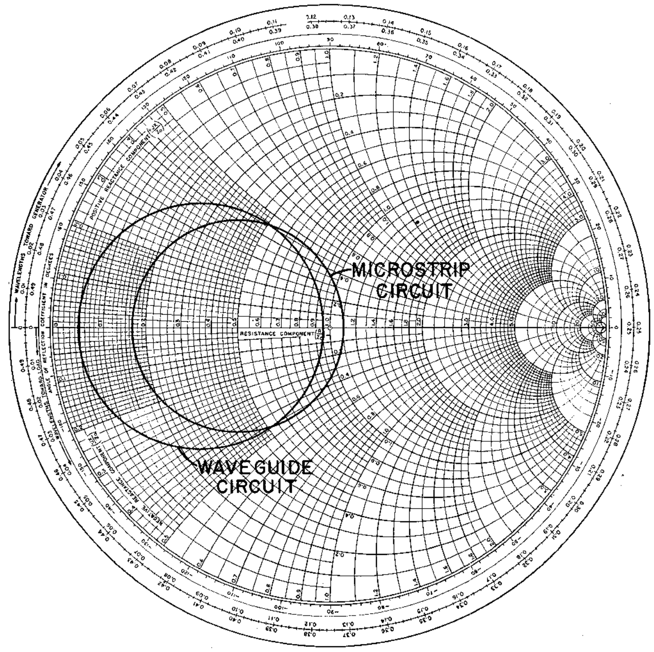


Figure 3. Smith chart display of the calculated circuit impedance for a microstrip circuit (with R_L=100 Ω at device) and a waveguide circuit (with a waveguide to 50 Ω transformer and R_L = 100 Ω at device). A full circle results for each mode (i.e., each ΔF).

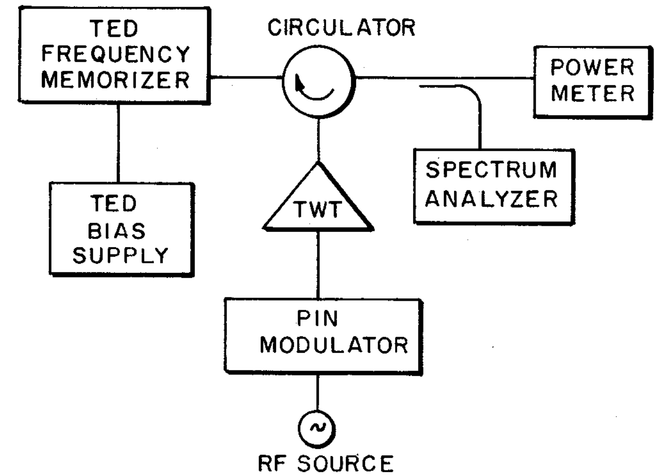


Figure 4. Equipment layout for switching tests of a TED frequency memorizer.

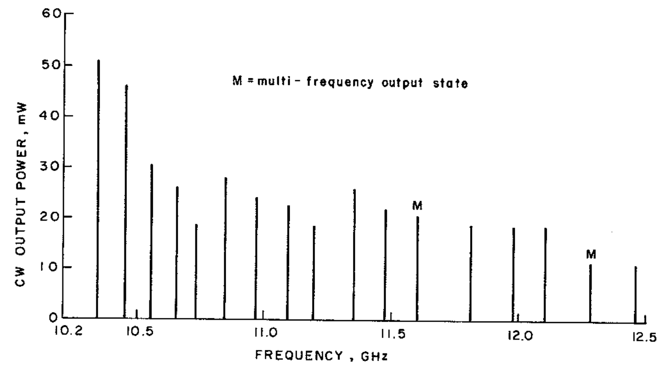


Figure 5. Frequency states of a frequency memorizer constructed with an alumina microstrip circuit. The TED is operated with 7.73 V and 0.43 A.

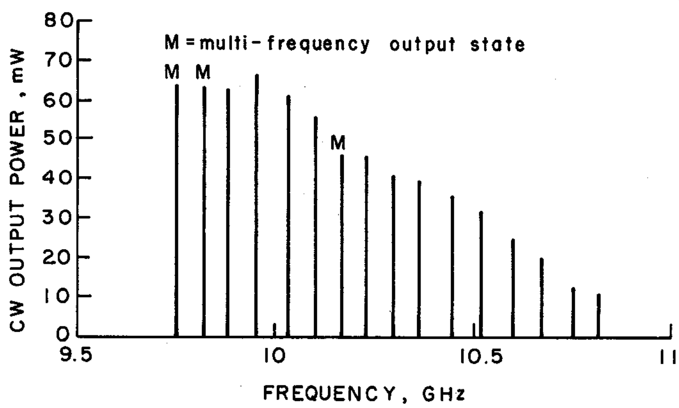


Figure 6. Frequency states of a frequency memorizer constructed with a 5-ft. waveguide circuit. The TED is operated with 11.59 V and 0.40 A.

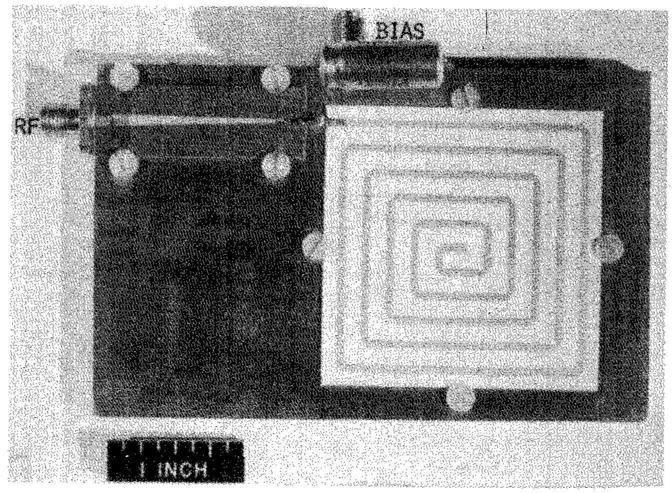


Figure 7. Photograph of a frequency memorizer constructed with a 2-in. x 2-in. alumina microstrip circuit.