Picosecond-Pulse Sequential Waveform Generation

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Abstract—**This short paper describes a novel method of generating a pulse sequence using step-recovery diodes (SRD's) shunting a transmission line. Individual pulses in the train may have rise times less than 60 ps with amplitudes greater than 10 V. The many potential applications of the device include a short RF pulse generator, an FM generator, and a high-speed word generator.**

INTRODUCTION

Various applications in short-pulse technology, such as high-resolution radar and time-domain metrology utilize very short ($\lesssim$1-ns) RF bursts. The sequence generator described here was developed to fill the need for an electronically tunable solid-state device that would provide microwave pulses with peak-to-peak amplitudes greater than 10 V. The technique utilizes the reflected waves from a series of step-recovery diodes (SRD's) mounted in shunt across a transmission line. The diodes change from a low- to a high-impedance state in the presence of an incident pulse.

The sequence generator described has important advantages over previous means of generating an RF pulse, such as the pulse-forming network (PFN) [1], shock-excited filter, and travatron [2]. While a PFN consisting of open and shorted stubs is useful for furnishing a few short pulses, the usefulness decreases as the desired number of cycles increases since, for N junctions, the amplitude decreases by 2^{-N}. On the other hand, it is difficult to obtain only a few cycles from the shock-excited filter. The output of the sequence generator can provide as many or as few cycles as desired. Moreover, since both the PFN and the shock-excited filter are passive networks, the output spectral density can never be greater than the input spectral density. The sequence generator provides spectral density gain. The travatron produces a pulse sequence from many transmission line segments separated by series spark gaps operated as switches. This spark gap device is used exclusively for generating very high power levels and is impractical at lower voltage levels. Adjusting individual pulsewidths can only be done by the time-consuming process of changing electrode spacing or gas pressure. Furthermore, like the PFN, the output sequence can only be changed mechanically by replacing hardware. The sequence generator offers convenient electrical tuning of the output.

DESCRIPTION

For purposes of illustration it is helpful to describe the device in two parts: the sequence generator and an input–output section as shown in Fig. 1. The output can be thought of as a chopped version of the input but with faster rise time. A circuit diagram of the generator portion is shown in Fig. 2. The entire structure is fabricated in a TEM transmission line for dispersionless propagation. The SRD's $D_1, D_2, \cdots, D_n$ are connected in shunt across the line with polarity shown for a positive input signal and negative bias supply voltages. The number of diodes n depends on the number of individual pulses required with each diode producing 1 pulse, while the distance between diodes (l_{12}, l_{23}, etc.) determines the interpulse spacing. Each diode D_k has its own dc blocking capacitor C_k and bias limiting resistor R_k for individual adjustment. R_0 acts as a terminating resistor for the transmission line. One version of a simple input–output device is shown in Fig. 3, where a filter separates the lower frequency input waveform from the higher frequency output.

The generation of a particular sequence from a combination of

Manuscript received April 2, 1975; revised July 28, 1975. This work was supported by the U.S. Army Metrology and Calibration Center, Army Missile Command, Redstone Arsenal, Ala., under Contract DAAH01-71-C-1414.

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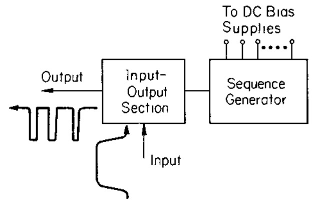

Fig. 1. Block diagram of the device.

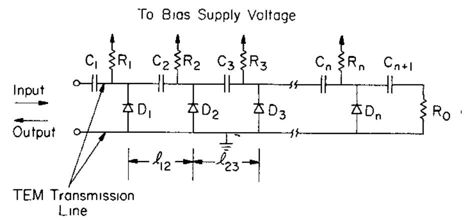

Fig. 2. Sequence generator circuit diagram.

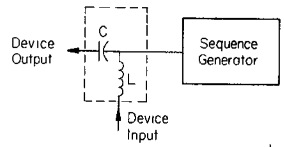

Fig. 3. Filter input–output device.

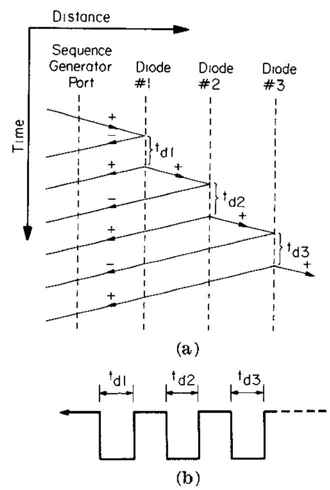

Fig. 4. Time history of sequence generation. (a) Sequence generator bounce diagram. (b) Reflected waveform.

SRD charge depletion times and transmission line lengths can be understood with reference to the bounce diagram shown in Fig. 4(a). A unit-incident positive pulse entering the generator in the upper left corner of the figure is reflected as a negative unit pulse from the forward-biased diode 1. After a time t_{d1}, the stored charge is depleted and diode 1 changes state abruptly producing two positive pulses of unit amplitude traveling away from the diode. The backward pulse cancels the original negative reflected pulse for all times $t > t_{d1}$, so that the net reflection from diode 1 is a negative pulse of unit amplitude and width t_{d1}. Meanwhile, the sharpened positive pulse continues to diode 2, where it is reflected as a negative unit pulse. Note that the beginning of this second reflected pulse will follow the end of the first reflected pulse by a time $t_{12} = 2l_{12}/v$, where l_{12} is the length of line segment between diode 1 and diode 2, and v is the propagation velocity. Diode 2 will remain in the low-impedance state until time t_{d2} after the arrival of the pulse and then generate two positive pulses in the same manner as diode 1. These processes are continued for each diode in the line. The total reflected

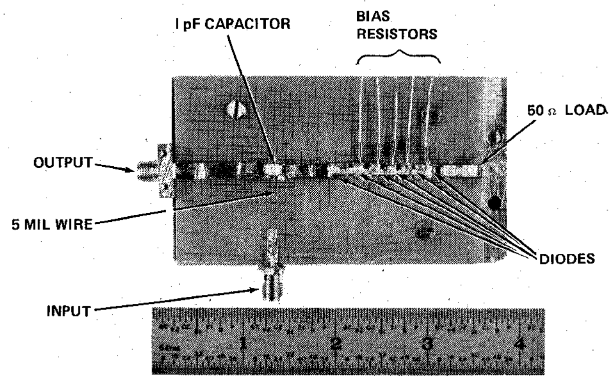

Fig. 5. Fabricated device on microstrip.

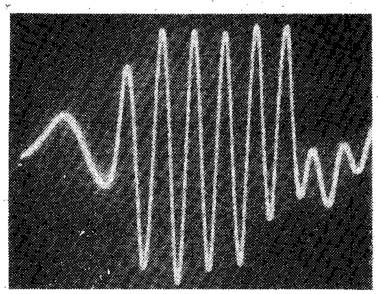

Fig. 6. *C*-band sequence-generator waveform. Vertical: 2 V/div; horizontal: 200 ps/div.

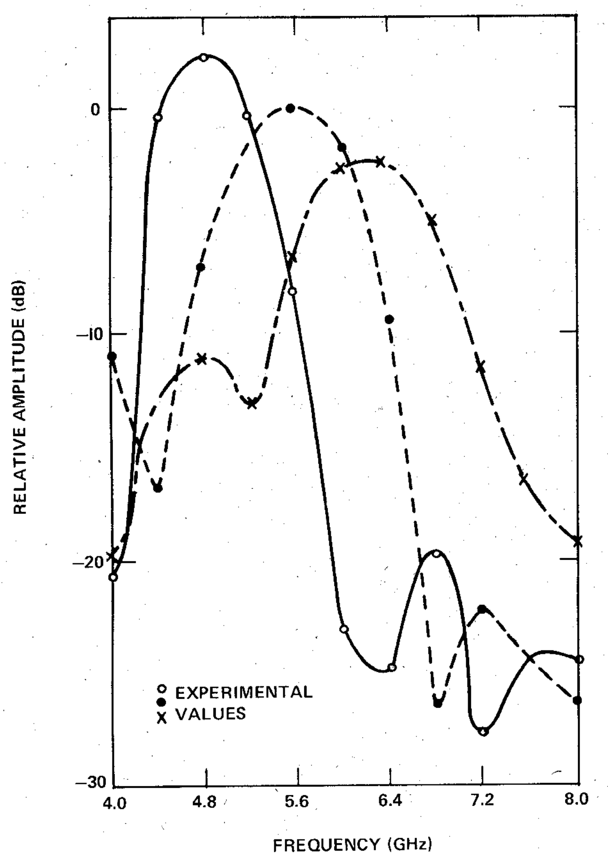

Fig. 7. *C*-band sequence-generator spectral amplitude for different biases.

waveform is found by summing all the reflected waves leaving the generator and is shown in Fig. 4(b). Note that the sequence can be modified by changing the bias currents. For example, if the bias is removed from diode 2, $t_{d2} = 0$, and the start of the reflection from diode 3 will follow the end of the reflection from diode 1 by a time $t' = 2(l_{12} + l_{23})/v$.

EXPERIMENTAL RESULTS

Several sequence generators have been constructed in microstrip in *L* and *C* band for use as RF pulse generators. A photograph of a 6-diode *C*-band generator is shown in Fig. 5. It was constructed on a 3/32-in polyolefin circuit board using Hewlett-Packard 5082-0335 SRD's spaced 0.17-in apart with 55-mil 100-pF ceramic capacitors. The bias to the first diode is supplied through the input SMA connector and 5-mil wire serving as an inductance in the input–output section. An output waveform (shown in Fig. 6) of this generator was photographed from a sampling oscilloscope. The spacing between and the amplitudes of the individual cycles can be varied by adjusting the bias. Fig. 7 illustrates the effects of different bias conditions on the spectrum computed from the Fourier transform of the time waveforms. Here, the individual biases were varied over a 2–20-mA range. A useful technique for adjusting the spectral peak of the waveform to a predetermined frequency f_0 is to make the time between the first and sixth positive peak equal to $5/f_0$ by varying the bias currents. In one application, this generator was used to obtain the transfer function of an isolated array phaseshift element over a 1-GHz bandwidth centered at 5.6 GHz. The spectrum was peaked to the desired center frequency by changing the bias currents to produce a 5/5.6 GHz = 890-ps period between the first and last peak. The unique features of the generator, the reasonable voltage amplitudes, and ease of tuning proved especially helpful for the foregoing application.

REFERENCES

[1] G. F. Ross, "Series and parallel pulse-forming networks for the generation of microwave energy," *Microwave J.*, vol. 10, p. 98, Sept. 1967.

[2] J. M. Proud, Jr., "Radio Frequency Generators," U. S. Patent 3 484 619, Dec. 16, 1969.

Depolarization Measurements on the ATS-6 20-GHz Downlink: A Description of the VPI & SU Experiment and Some Initial Results

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***Abstract*—This paper discusses the depolarizing effects of precipitation at millimeter wavelengths and describes an experiment in which depolarization on the ATS-6 satellite 20-GHz downlink is measured. Data are presented for unexplained clear weather variations in the observed polarization and for depolarization by rain and snow. A preliminary analysis indicates that for a given attenuation level, a satellite path exhibits more severe depolarization than experiments with ground systems would predict.**

Manuscript received April 14, 1975; revised August 4, 1975. This work was supported in part by NASA under Contract NAS5-21984.

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