

# Novel Low-Cost Ultra-Wideband, Ultra-Short-Pulse Transmitter with MESFET Impulse-Shaping Circuitry for Reduced Distortion and Improved Pulse Repetition Rate

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**Abstract**—A new ultra-wideband, ultra-short-pulse transmitter has been developed using microstrip lines, step-recovery and Schottky diodes, MESFET, and monolithic microwave integrated circuit (MMIC) amplifier. This transmitter employs a novel MESFET impulse-shaping circuit to achieve several unique advantages, including less distortion, easy broadband matching, and increased pulse repetition rate. The transmitter produces 300-ps monocycle pulses with about 2 V peak-to-peak and a pulse repetition rate of 10 MHz. The measured pulses have good symmetry and low ringing level.

**Index Terms**—Ground penetrating radar, MIC, pulse generator, transmitter, ultra-wideband radar.

## I. INTRODUCTION

ULTRA-wideband (UWB), ultra-short pulses are very attractive for radar and wireless communications applications. An UWB, ultra-short-pulse radar has spectrum extending from very low to very high frequencies and, thus, can penetrate deeply lossy materials and achieve very fine resolution. An UWB, ultra-short-pulse wireless communications system is attractive for short-range applications, especially in a crowded spectrum environment, due to its low power spectral density that results in negligible interference with existing communications signals.

In general, there are three kinds of pulse waveform: Gaussian-like, monocycle, and polycycle. The monocycle and polycycle pulses have band-pass frequency spectrums, which result in less demanding design specifications for other system components (e.g., antennas). Furthermore, the monocycle waveform is commonly employed, as compared to the polycycle, due to its simpler realization and wider spectrum which is advantageous for high resolution and deep penetration. Monocycle pulses have been generated using spark gaps [1]. Recently, a monocycle pulse generator has been developed using Schottky diode, step-recovery diode (SRD), and coplanar waveguide [2].

In this paper, we report the development of a novel UWB, ultra-short monocycle-pulse transmitter. As in [2], this transmitter employs SRD to form a step function necessary for the generation of the monocycle pulse and a new concept of switching the transmission line automatically using charging and discharging circuits based on a Schottky diode. However, in this new transmitter, we implement a novel impulse-shaping network using MESFET to achieve several unprecedented advantages. First, the MESFET impulse-shaping network converts the input voltage source into a current source, which drives the SRD and hence allows the generation of the monocycle pulse's half-cycle with very little distortion. Second, it facilitates a broadband matching to the transmission line. This permits the use of high pulse repetition frequency (PRF) up to the limit of the employed SRD, which, in general, is several hundred MHz. The use of this novel impulse-shaping circuitry thus makes this newly developed transmitter more suitable for a system than that in [2]. Additionally, a wide-band MMIC amplifier is used in the transmitter for amplification and isolation. The transmitter is realized on microstrip lines for low-cost manufacturing and produces monocycle pulses with 300-ps pulse width, about 2-V peak-to-peak amplitude, small ringing level, and good balance between the positive and negative half-cycles. It has been successfully used in a short-range UWB radar for nondestructive subsurface sensing.

## II. CIRCUIT DESCRIPTION AND DESIGN

Fig. 1 shows a circuit schematic of the new UWB monocycle-pulse transmitter, which consists of an impulse generator, an impulse-shaping network, a monocycle-pulse forming circuit, and a wide-band amplifier.

The impulse generator consists of a SRD and three transmission lines *A*, *B*, and *C*. The SRD, driven by an external local oscillator, generates a step function. This step function divides into two equal step functions propagating into the transmission lines *B* and *C*. The step function traveling in the transmission line *B* is reflected back from the short circuit, and eventually combines with the other step function in the transmission line *C* to form a negative impulse at the impulse generator's output (i.e., at the gate of the MESFET). To prevent the gate-to-channel junction of the MESFET from entering the conduction region, which may damage the device, and to maintain a reverse-biased junction without using an external negative bias voltage at the

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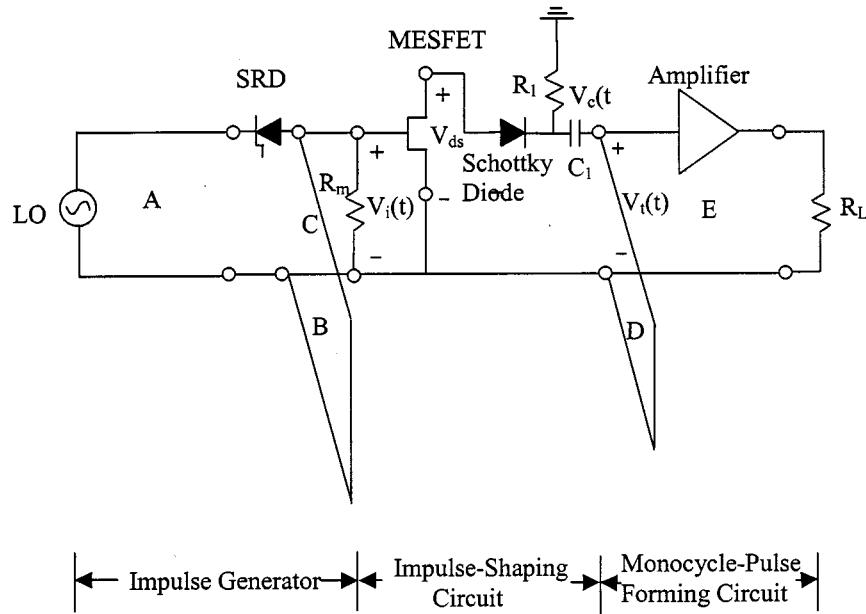


Fig. 1. Schematic of the new UWB, ultra-short-pulse transmitter. Bias circuits for the MESFET and amplifier are not shown.

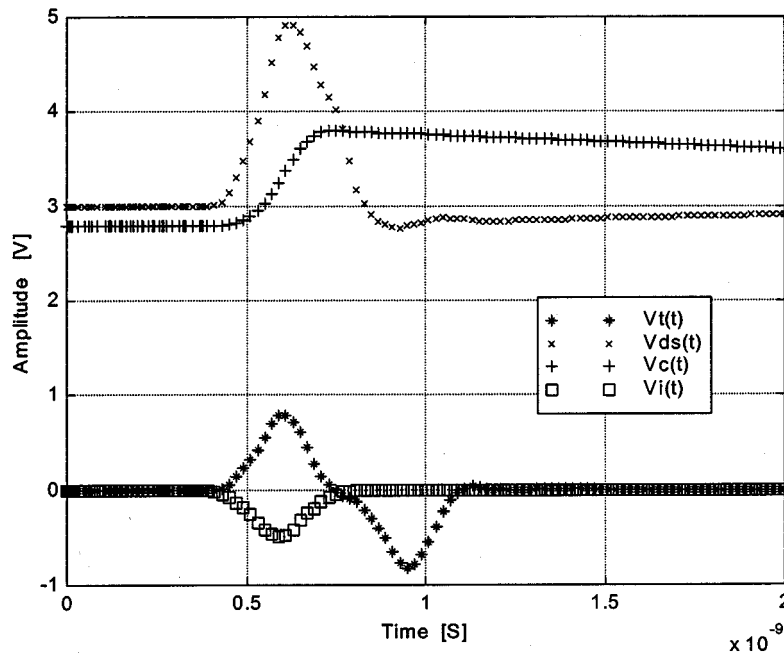


Fig. 2. Transient voltages indicated in Fig. 1.

gate, the polarities of the SRD are arranged so that a negative step function is generated. It should also be noted that the combination of this negative voltage and the drain-source voltage should not exceed the avalanche breakdown level between the gate and drain.

The impulse-shaping circuitry is composed of a MESFET, a Schottky diode, a capacitor ( $C_1$ ), and resistors ( $R_1$  and  $R_m$ ). The MESFET serves three functions. First, it generates a positive impulse by inverting and amplifying the negative impulse arriving from the impulse generator. Second, it transfers a voltage source to a current source, which facilitates the formation of a less-distorted impulse. Third, it provides the

isolation between the impulse generator and monocycle-pulse forming network. Fourth, it facilitates broadband matching to the transmission line due to a very large gate-source input impedance, thereby making it possible to increase the PRF. The resultant positive impulse turns on the Schottky diode and goes through a high-pass filter, formed by the capacitor  $C_1$  and the resistor representing the transient response of the transmission line  $D$ . This filter allows only the leading and trailing parts of the impulse to be transmitted into the following monocycle-pulse forming network. The resistor  $R_m$  at the gate of the MESFET serves as a wide-band lossy matching circuit. The calculated transient voltages are shown in Fig. 2.

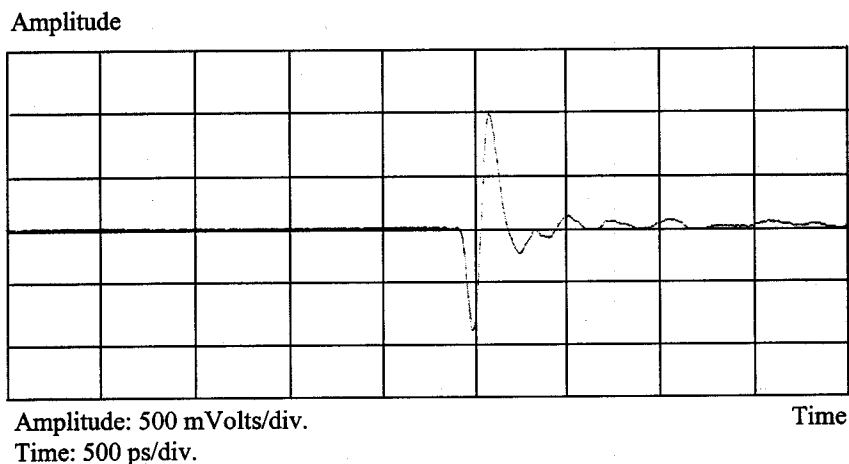


Fig. 3. Measured output pulse of the transmitter.

The monocycle-pulse forming circuit is realized using the short-circuited transmission line *D* and the transmission line *E*. It is used to convert an impulse into a monocycle pulse. The impulse from the impulse-shaping network splits into two equal impulses upon arriving at the junction of the transmission lines *D* and *E*. The impulse propagating toward the short circuit is reflected back and combines with the other impulse on the transmission line *E* to form a monocycle pulse at the input of the MMIC amplifier. The amplifier provides gain and also serves as an active isolator for the transmitter.

### III. FABRICATION AND EXPERIMENT

The monocycle-pulse transmitter is realized using microstrip lines on FR-4 Glass Epoxy substrate having a relative dielectric constant of 4.5 and a thickness of 0.031 in. The SRD used is MMDB30-B11 from Metelics Corporation and has a nominal lifetime of 10 ns, 30-ps transition time, and 0.25-pF junction capacitance. The MESFET is Excelics EFA018A-70, and the Schottky diode is Hewlett-Packard HSCH-5336 beam-lead diode. The MMIC amplifier is Stanford Microdevices SNA-686 whose gain is 11 dB from dc to 6.5 GHz.

Fig. 3 shows the output monocycle pulse when the transmitter was driven by a 10-MHz oscillator. The measured waveform has 300-ps pulse duration, about 2 V (peak-to-peak), good balance

between the positive and negative parts, and relatively small ringing level.

### IV. CONCLUSION

We have presented the development of a new UWB, ultra-short microstrip monocycle-pulse transmitter. This transmitter employs a novel impulse-shaping network to achieve less distortion, easy wideband matching, and improved pulse repetition rate. The transmitter produces monocycle pulses with 300-ps pulse duration and about 2 V peak-to-peak. The measured waveform has low ringing level and good balance between the positive and negative parts. The developed transmitter is useful for UWB radar and wireless communications systems.

### ACKNOWLEDGMENT

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