A New Ultra-Wideband, Ultra-Short Monocycle Pulse Generator With Reduced Ringing

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***Abstract*—We introduce a new ultra-wideband (UWB), ultra-short, step recovery diode monocycle pulse generator. This pulse generator uses a simple *RC* high-pass filter as a differentiator to generate the monocycle pulse directly. The pulse-shaping network employs a resistive circuit to achieve UWB matching and substantial removal of the pulse ringing, and rectifying and switching diodes to further suppress the ringing. An ultra-short monocycle pulse of 300-ps pulse duration, −17-dB ringing level, and good symmetry has been demonstrated. Good agreement between the measured and calculated results was achieved.**

***Index Terms*—Pulse generator, transmitter, ultra-wideband system, MIC.**

I. INTRODUCTION

ULTRA-WIDEBAND (UWB), ultra-short pulse generation—usually in the range of subnanoseconds—is a main issue in UWB radar and communications systems. In these systems, UWB pulses are needed not only for transmitters, but also for receivers. For instance, the sampling circuit in receiver, that down-converts RF signal directly to base-band, requires a short pulse generator. There are many applications of UWB radar—for example, unexploded ordnance (UXO), mine detection [1], [2], and pavement evaluation [2], [3]. UWB communication has recently been proven as a good and cost-effective communication method for short ranges, such as in-building communications [4].

Step, Gaussian, and monocycle pulses can be used in UWB systems. These pulse types have a common characteristic of very wideband spectrums. Among them, however, the monocycle pulse's spectrum does not contain low-frequency components including dc. This attribute is useful for some applications, as it facilitates the design of other system components—including antennas, amplifiers, and sampling downconverters. Better signal characteristics, such as more precisely defined pulse shape and reduced distortion for the transmitting and receiving signals, can thus be easier to obtain.

Monocycle pulses have been generated using step-recovery diode (SRD) by combining two Gaussian pulses having 180-degree out of phase and certain time delay between them [5]. The produced monocycle pulse, however, has pulse duration about twice of that of each individual Gaussian pulse.

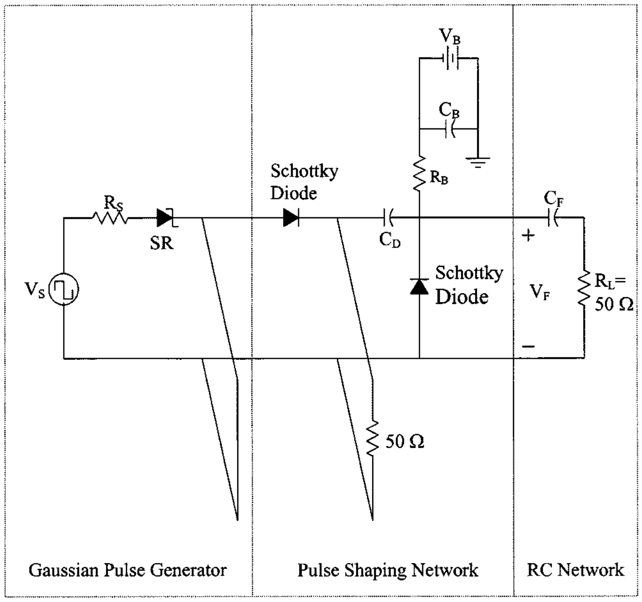

Fig. 1. Schematic of the new monocycle pulse generator.

In this paper, we describe a new UWB, ultra-short, SRD monocycle pulse generator. We implement a different approach as compared to [5], in which we use a simple RC high-pass filter—acting as a differentiator for the Gaussian pulse—to make the monocycle pulse directly. This is achievable because a monocycle-pulse waveform can be obtained by taking the derivative of a Gaussian pulse waveform. The pulse width resulted from the derivative is almost the same as that before the differentiation. This approach, therefore, significantly reduces the monocycle pulse duration to about 50% of that produced by the method of summing two Gaussian pulses reported in [5]. Furthermore, we employ a simple pulse-shaping network using resistive matching network together with rectifying and switching diodes to remove the pulse ringing substantially.

The new monocycle pulse generator has been designed and fabricated using microstrip line, and tested with good performance. An ultra-short monocycle pulse with small ringing level and good pulse symmetry has been demonstrated theoretically and experimentally.

II. CIRCUIT DESCRIPTION AND DESIGN

Fig. 1 shows the schematic of our new monocycle pulse generator. It consists of three parts: Gaussian pulse generator, pulse-shaping network, and RC network.

The Gaussian pulse generator produces a Gaussian pulse in two distinct steps. First, a step function with short transition time

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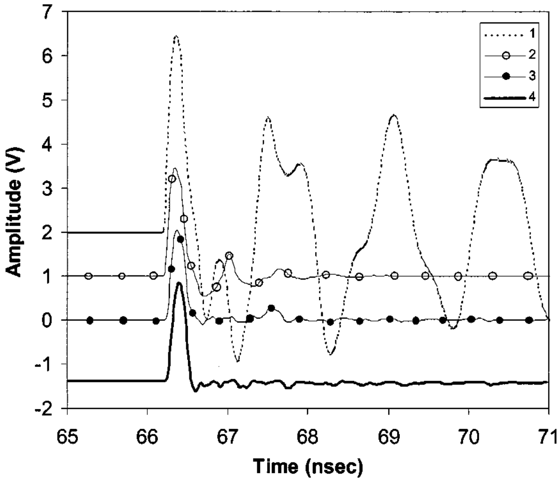

Fig. 2. Calculated voltage waveform at the input of the RC network (V_F in Fig. 1). 1: Without pulse-shaping network; 2: with 50-ohm terminated shunt stub; 3: with 50-ohm terminated shunt stub and series Schottky diode; 4: with pulse-shaping network. Note: Waveforms 1, 2, and 4 are shifted by 1.5, 1, and −1 V, respectively, from their calculated results for easy distinction.

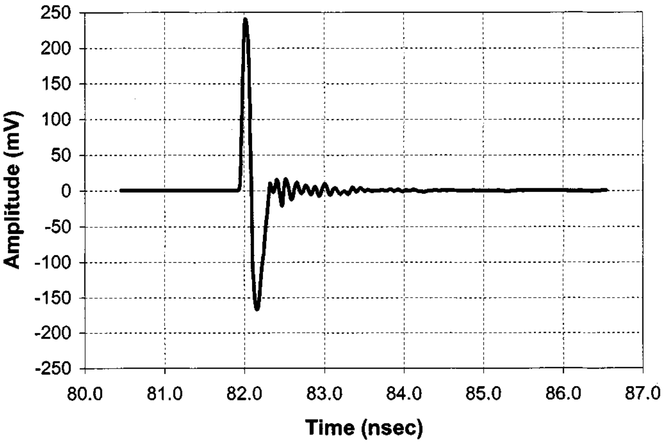

Fig. 3. Calculated monocycle pulse.

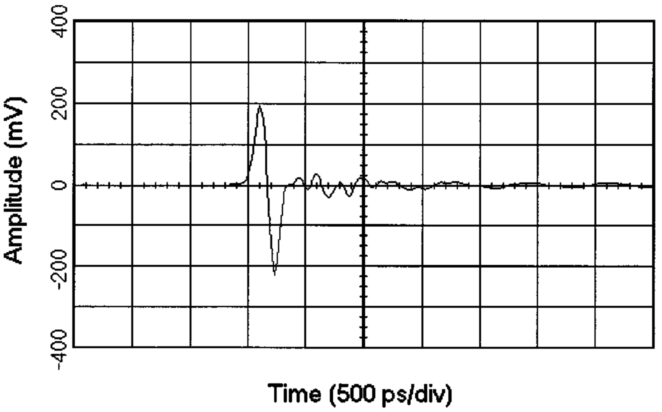

Fig. 4. Measured monocycle pulse.

is created by a SRD. Second, an impulse is formed by combining the step function reflected from the short-circuited stub and that transmitted across the junction between the short-circuited stub and the transmission line. The duration of the Gaussian pulse is determined by the length of the short-circuited stub.

The pulse-shaping network consists of a series-connected Schottky diode, a terminated shunt stub, a blocking capacitor, and a shunt Schottky diode with biasing circuit. It provides wide-band impedance matching between the Gaussian pulse generator and the RC network, preventing the Gaussian pulse from having a large ringing level and effectively shaping the pulse waveform. Fig. 2 shows the calculated voltage waveform at the input of the RC network, using HP-ADS [6], to illustrate the advantage of our novel pulse-shaping network. As shown in Waveform 1, a very large ringing results when the pulse-shaping network is not used. This is due to the severe impedance mismatch between the Gaussian pulse generator and RC network. Waveform 2 shows that the ringing is removed substantially by using a very wideband resistive matching network consisting of a simple shunt stub terminated by a 50-Ω resistor. A lossy matching network is essential because the Gaussian pulse and its ringing occur over an ultra-wide bandwidth. This lossy network, however, also attenuates the pulse amplitude as expected. The ringing level is further reduced by the series Schottky diode as seen on Waveform 3. This diode acts as a half-wave rectifier, passing only the positive parts (Gaussian pulse and positive ringing) and removing the negative ringing portion. Waveform 4 shows the final Gaussian waveform, with very small ringing, after passing through the shunt Schottky diode. This diode functions as a fast switch—only allowing passage of parts of the signal whose amplitudes are greater than a threshold voltage controlled by the dc bias voltage. This threshold level, inadvertently, also reduces the amplitude of the Gaussian pulse. However, since the positive ringing level arriving at the Schottky diode is very small in comparison with the amplitude of the Gaussian pulse, it can be removed by setting a small threshold level—thereby not sacrificing the pulse amplitude. Note that the Gaussian waveform is shifted down by the dc bias voltage. This voltage offset, however, can not pass through the capacitor in the following RC network and will, thus, not be seen in the monocycle pulse.

The RC network consists of a capacitor and a load resistor. The capacitance is determined by the load resistance and required time constant. This time constant can be estimated from the Gaussian pulse duration and the settling time of the exponentially decay response of a step function to the RC network.

Fig. 3 shows the simulated monocycle pulse using HP-ADS [6]. The ringing level was optimized by varying the threshold voltage through change of the dc bias level. Note that there is still a small amount of ringing following the monocycle pulse. This ringing is present, mainly due to the finite transition between the *on* and *off* states of the Schottky diode.

III. FABRICATION AND MEASUREMENT

We have fabricated the new monocycle pulse generator using microstrip line on FR-4 glass epoxy substrate having a relative dielectric constant of 4.5 and a thickness of 0.031 in. The Schottky diodes and SRD used are MSS50-048-E25 and MMD-0840, respectively, manufactured by Metelics Company.

Fig. 4 shows the measured monocycle pulse waveform. It has pulse duration of 300 ps, 200-mV (peak-to-peak), ringing level of -17 dB, and good symmetry (both amplitude and shape) between the positive and negative portions. The pulse duration is defined as the time interval between the 10 % points of the positive and negative peaks. The measurement was made using a 10-MHz square-wave signal and Agilent HP 54750A digitizing oscilloscope and HP 54753A TDR module. Measured result also agrees reasonably well with that calculated in Fig. 3.

IV. CONCLUSION

A new UWB SRD monocycle pulse generator has been designed, fabricated and tested. A simple, yet efficient, differentiator utilizing RC high-pass filter was used to generate directly the monocycle pulse with ultra-short duration. A pulse-shaping network employing a resistive matching network together with rectifying and switching Schottky diodes was used to reduce the ringing level substantially. The fabricated microstrip monocycle pulse generator produces an ultra-short monocycle pulse with 300-ps pulse duration, -17-dB ringing level, and good pulse symmetry—demonstrating the workability of the proposed circuit topology. Reasonably good agreement between the measured and calculated results was also achieved. The simplicity, low cost, and good performance of this circuit makes it attractive for various UWB radar and communications systems.

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