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HIGH POWER SUBNANOSECOND GENERATOR FOR UWB RADAR

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INTRODUCTION

Subnanosecond pulse generator is one of the most important elements of ultra-wideband (UWB) radar. Parameters of impulse generator influence to radar performance since it depends on radiation power and receiver sensitivity. There are some ways to get high performance factor of the UWB radar. It can be achieved as increasing of radiation power as multiply sampling data accumulation. In this paper we shall describe solid state, high power subnanosecond generator for portable UWB radar design.

PROBLEM BACKGROUND

There are two methods to reach high value of UWB radar performance factor (PF) that we understand as ratio of peak radiation power to receiver sensitivity. Usually PF increasing is achieved by additional signal processing and post-processing of acquiring data. Radiation power increasing is more attractive method since lead to linear rise of PF value. However it is difficult way because range of commercial available nanosecond and subnanosecond pulse generators are hardly limited especially for application in portable UWB radar. It should be simultaneously satisfied some conditions: high peak power and pulse repetition rate (PRR), compact size, time stability and long lifetime, high efficiency and reliability.

THEORY OF THE GENERATOR OPERATION

It is known a lot of components that is successfully used for nanosecond pulse generation (Meixier L., 1991; Litton A.B. et al., 1995; Agee F.J. et al., 1998). However everyone has some disadvantages. For example step recovery diodes (SRD) are stable and reliable, form impulse with as small duration as 100 picoseconds but only some dozens volts in magnitude. Krytron or hydrogen thyratrons conversely generate extremely powerful impulses with low repetition frequency. There were no pulsers that could generate powerful impulses with high repetition frequency simultaneously.

However at the beginning of 1980's new type of semiconductor opening switches has been discovered (Grekhov *et al.*, 1983, 1984). This commutator so called Drift Step Recovery Diodes (DSRD) gave a rise to a new generation of all solid state nanosecond pulsers with peak power up to hundred megawatts (Brylevsky *et al*, 1996). The main advantages of these switchers are long lifetime, excellence time stability (low jitter) and small size. Besides they have no need restoration time and after pulse generation are ready for the next cycle. Generally speaking it is possible to generate power pulses with megahertz PRR (Kardo-Sysoev *et al,* 1997).

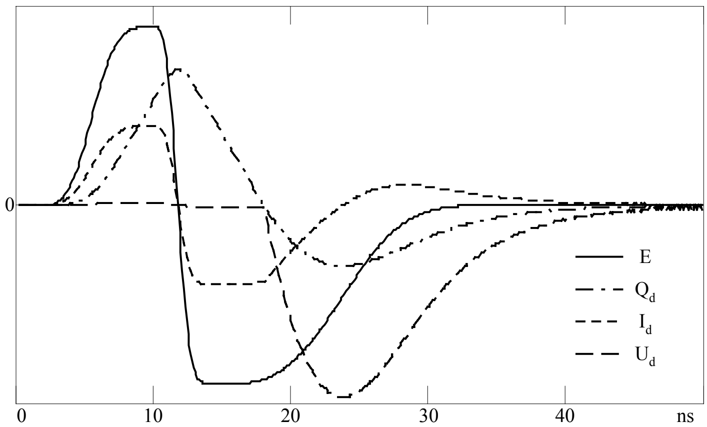
Principle of the DSRD operation is similar to SRD one. However there is essential difference. Since drift diodes function on slow carrier pumping current should to be pulse but not continuous. The main idea of the DSRD operation can be explained as following. Short impulse of current applied in forward direction "pumping" p-n junction or, another words, "charges" p-n junction capacity. Then the current changes direction into a reverse and accumulated charges remove from base region. As soon as accumulated charge is equal zero the diode closes rapidly. Thanks to self-induction effect a high voltage appears impulse on the diode terminal. The bigger commutation current and shorter forward to reverse switching time the higher impulse magnitude and generator efficiency (Kardo-Sysoev *et al*., 1997).

In order to design nanosecond pulse generator based on DSRD structure charge model of the p-n junction has been developed and analyzed (Prokhorenko *et al*., 2000). A result of the diode modeling is shown Figure 1. It is good seen (Figure 1b) a time correlation between excitation voltage and voltage drop on the diode terminal. Taking into account delay effect of diode switching off in a frame of this model allows analyzing current driving circuit that is used for the DSRD pumping. It has been arranged nonlinear transient, differential equation based on charge behavior in the circuit and compute by using finite-difference time domain approach. As a result of the calculation note that special attention to coil inductance and diode parameters. The main conclusion was possibility to generate powerful nanosecond pulses by help the DSRD diode on both high and low impedance loading.

$$U_d(t)=\begin{cases} r_d \dfrac{dQ_d(t)}{dt}, if\ Q_d(t)\geq 0 \\[2ex] \dfrac{Q_d(t)}{C_d}, if\ Q_d(t)<0 \end{cases}$$

where
r_d – forward biased diode resistance,
Cd – reverse biased diode capacitance

a)



b)

Figure 1. Charge model of the DSRD structure (a) and relative waveforms (b) getting in accordance to this model: excitation voltage (E), charge (Q_d) into p-n junction and current (I_d) flows through it, voltage drop (U_d) on the diode terminal.

SCHEME DESCRIPTION

The nanosecond pulse generator was based on two principles: using a ferrite transformer to provide bipolar current for DSRD pumping as it was proposed by Belkin *et al.* (1992) and monostable blocking-oscillator to increase scheme efficiency. Simplified scheme is shown in Figure 2. As a switcher we applied power MOSFET transistor BUK-456-60H by Philips Semiconductor that is characterized comparatively fast turn-on time (90 ns) and such high peak current as 240A. Since impulse transformer provides reverse current there is no hard requirements to switch-off time. Transformer was made with soft ferrite and consisted of three windings on doubled cores K7x2x2. Turn number of first and second windings and feedback winding were 4, 12 and 1 ones, accordingly. Power supply voltage was changed from 15 to 50 volts however MOSFET driving voltage was limited in 25 volts level.

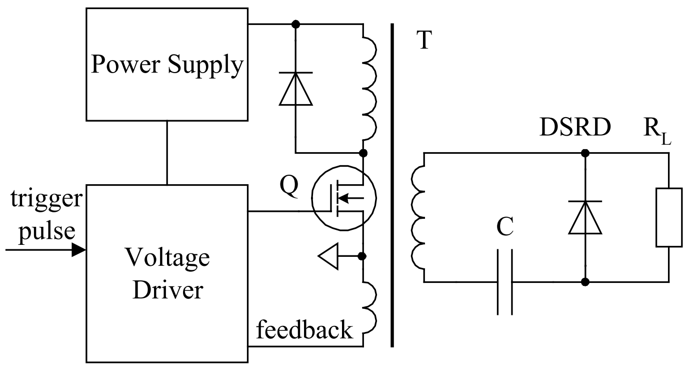


Figure 2. Simplified schematic diagram of the subnanosecond pulse generator based on DSRD sharpener.

The generator was triggered by positive pulse from external oscillator. Minimum pulse duration was 50 ns whereas maximum time may exceed 500 ns. Minimum value is determined by internal delay into the scheme elements and maximum one does not exceed time interval between trigger pulse and output impulse. The nanosecond generator timing is shown in Figure 3. Note that time delay between trigger pulse and output impulse is depended on power supply voltage and varied from 500 ns to 800 ns. Besides the smaller time delay the higher time stability. During the testing was got impulse jitter less than 0.5 ns.

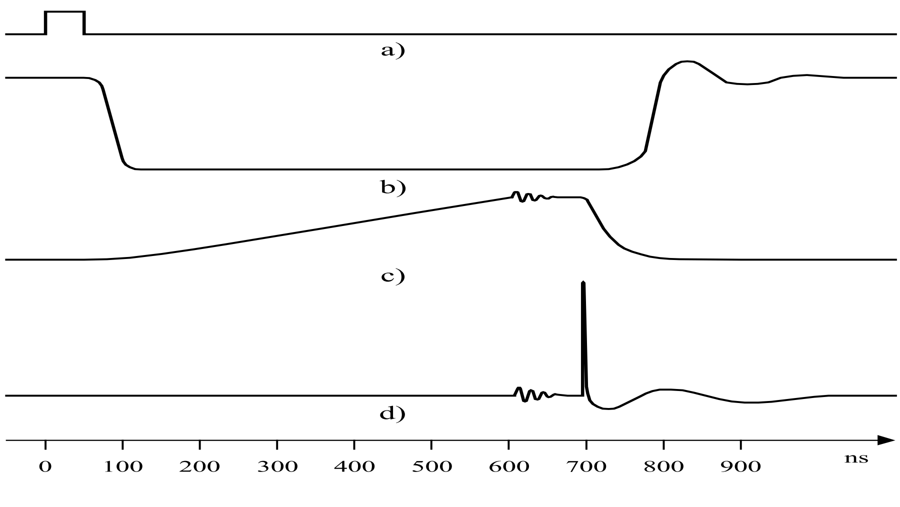


Figure 3. The nanosecond pulse generator relative timing in different points of scheme: trigger pulse (a), drain voltage (b), feedback voltage (c) and output impulse (d).

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Special attention was devoted to output circuit construction. It consists of four elements: impulse capacitor, loading, transformer output winding and naturally DSRD structure. Note that capacitor has to be suitable for impulse operation condition that is essentially limited types of components. We used metallized polypropylene film capacitor that has rated voltage pulse slope up to 1300 V/µs and 2200 Volts operation on DC current. As a DRSD was used 1N5408 high voltage impulse rectifier diode (reverse voltage V_R=1000V, forward current I_F=3A, reverse recovery time t_{rr}=200 ns).

Output circuit operation without DSRD (a) and when DSRD connect to loading terminal (b) are shown in Figure 4. Current reverse time was 80-150 ns when power supply voltage changed from 50 to 15 volts. Peak voltage of output impulse varied from 150 to 500 Volts with insignificant increasing of a rise time.

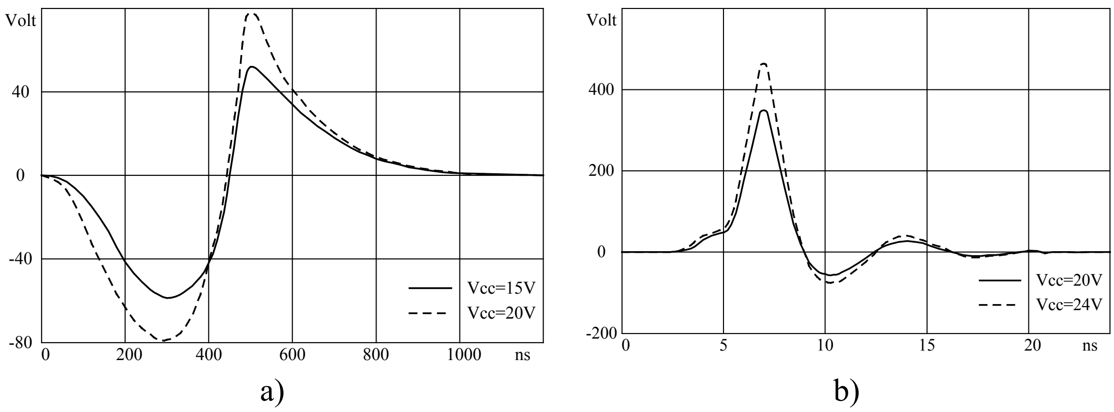

Figure 3. Output voltage waveform of the nanosecond pulse generator without DSRD (a) and when DSRD was connected to the loading (b).

DISCUSSION

During the series of the experiments have been got the following results. Minimum rise time was 1.6 nanosecond. As high maximum peak voltage as 550 Volts on the 50-Ohm loading has been achieved under 30 Volts power supply voltage. Power consumption was less than 6 Watts with 20 kHz PRR. Connection of two identical diodes in parallel improved impulse shape without visible rise time degradation.

Maximum PRR volume was 25 kHz and it is determined by output pulse transformer overheating. Note that peak pulse power decreasing did not allow increasing of the PRR value. Evidently higher PRR using proposed schematic can be achieved by utilization of other transformer with improved electrical parameters.

CONCLUSION

We have described a high power subnanosecond pulse generator based on monostable blocking-oscillator and drift step-recovery diode sharper. Have been discussed principles of the DSRD operation and the scheme functioning. It is shown that the generator can be used to form nanosecond impulse with peak power up to 6kW and more. Portable design and low power consumption make it attractive for hand-held UWB radar application.

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