AN IMPULSE GENERATOR FOR THE GROUND PENETRATING RADAR

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Abstract

In last time ground penetrating radars (GPR) are widely used for search and analysis of varied underground objects of natural and artificial origins. Caves and cavities can also be found and investigated with the GPR's aid. Impulse generator is the key unit, which determine GPR's parameters: depth of penetrating, accuracy et al.

Serial power drift diodes are used for generation step voltage with nanosecond rise time. Peak power a few kilowatts and frequency repetition near 20 kHz with portable power supply using have been achieved. Such generator can be used in the simple GPR for caves finding applications.

1. Introduction

In recent time an electromagnetic sensing technique by the ground penetrating radars (GPR) are widely used for engineering geophysics tasks decision (DANIELS at al., 1988). GPR utilize a very burst of electromagnetic energy pulses send into the ground from a transmitter antenna located on the surface. Subsurface structures, such as bedding, cementation, changes in moisture and clayey content, cavities, voids, fractures, intrusions man-made objects and many other interface possessing a contrast in dielectric properties cause some of the pulse energy to be reflected back to the surface, while the test of the energy continues to penetrate deeper. The reflected pulse energy is picked up by a receiver antenna on the surface. These signals are then processed and plotted in a distance versus time-depth display. Thus, as the radar antenna is slowly towed across the surface, a continuous cross-sectional "picture" of subsurface conditions is generated. GPR can be used for mapping geologic strata, aquifers, aquicludes, voids, shallow, bedrock units and fractures, site clearance for drilling. mapping utilities and rebar, locating underground storage tanks, archaeology et al.

Depth of penetrating is dependent on conditions found at each site. Electromagnetic pulse launched by GPR are attenuated (absorbed or scattered) by certain properties of the site's soil; the most important of which is the electrical conductivity of the material. Generally, better overall penetrating is achieved in dry sandy soils; reduced penetrating is achieved in moist, clay or conductive soils. Considerable depth may be attained in saturated sands or through lake water if the specific conductance of the water is low. Radar penetrating is excellent in massive dry materials such as granite, limestone, and concrete.

GPR operating abilities are depended on impulse transmitter (pulser), antennas, receiving electronics and data processing algorithm using. Pulser for engineering geophysics applications has to generate kilowatts impulse with duration from 1 to 10 nanosecond at a repetition rate more than 10 kHz.

High power impulse generation possibilities by drift diodes are considered and simple pulser for portable GPR for various caves and voids location is proposed.

2. Power nanosecond pulse generation

High power nanosecond pulses are mainly generated with various gas-filled or vacuum electric switches. However, amplitude and shape unstability, low repetition rate and efficiency create obstacle to use these devices in the GPR. Semiconductor devices, such as step-recovery diodes, avalanche diodes and transistors, generate step voltage only ten's volt per unit. Frequently this power level is not enough for engineering geophysics applications.

A new effect for power high voltage nanosecond impulse generation was discovered in 1983 (HREHOV et al., 1983). This effect is similar other one used in step-recovery diodes, but applicable to power drift diodes. It is called as step-recovery drift-diodes effect. Peak power more than 1.6 megawatt (10 Ohm loading) with 2 nanosecond rise time was achieved with using step-recovery drift diodes (BRYLEVSKY et al., 1988). The step-recovery effect in drift diodes may be observed only with satisfaction of the specific conditions. Because charge carriers mobility in the drift diodes are low straight direction currents through p-n junction not constantly but briefly. Moreover for drift diodes with a long life time of charge carrier the straight direction current time has to be as short as possible, but no more 500 nanosecond. If the diode has a short life time of charge carrier (approximately 500 nanosecond) the straight direction current time is limited with p-n junction overheating and may be more than 10 microsecond (HREHOV et. al., 1984). The best results may be obtained with special diodes, but I have not any information about manufacturing such devices at presence time.

There are many serial produced diodes may be used as step-recovery drift-diode (ZIENKO, 1984). Differences of serial diodes from ideal cause pulse shape distortion and efficiency decreasing. This defects may be eliminated with carrying-out the following conditions (BELKIN et al., 1992): a) straight direction current time and charge brought into the diode base region have to be as smaller as possible; and b) back direction current time has to be more than ten times smaller in comparison with straight direction current time.

3. Impulse generator based on drift step-recovery diodes

Earlier drift diodes are used as sharpener of a step voltage generated with power semiconductor switchers (e.g. modulator thyristor) (ZIENKO, 1984; HREHOV et al., 1986; KARDO-SYSOEV & CHASHNIKOV, 1986). Schemes used thyristor as active element are optimal as step voltage former if pulse duration is longest than it rise time. If pulse duration and rise time are comparable quantities thyristor generators have low efficiency. Energy losses deal with thyristor switching losses and dissipation energy into the drift diode. Low efficiency and comparatively slow work limit impulse repetition rate.

BRYLEVSKY et al. (1988) have proposed to use intermediate inductance energy accumulator. Energy transmission from inductance accumulator to loading was realized with step recovery drift diode. In this case losses determined earlier were decreased, efficiency was increased and impulse voltage amplitude of the generator significantly exceeded power supply voltage. Impulse voltage near 1300 Volt with 2 nanosecond rise time on the 50-Ohm loading was formed with the generator using 50 Volt power supply. The scheme efficiency was more than 20 per cent with 20 kHz repetition rate. The generator was used switching two powerful bipolar transistors (V_{CE} = 70 V, I_C = 20 A, f_1 > 90 MHz) assembly connected with Darlington's scheme. Commutation currents was a several tens of amperes and control currents was a few amperes.

BELKIN et al. (1992) have proposed scheme decision with single active commutator. Current reverse through drift diode was provided with saturation core transformer. Capacitor connected sequentially with secondary winding of the transformer and drift diode was charging when commutator was switched on. Thus straight direction current through p-n-junction of the diode was realized. Further the capacitor fast discharged through the low inductance of the transformer's saturated secondary winding and drift diode. Because charges accumulated with the capacitor and passed through the diode are approximately equal the diode recovered when the capacitor discharged. When the diode recovered due to the self-induction effect on the loading resistance connected in parallel with diode nanosecond pulse was generated. The impulse voltage 700-1000 Volt with 1-1.5 nanosecond rise time on the 50-Ohm loading was formed with the generator using 100-150 Volt power supply. Repetition rate was 50 kHz and efficiency was near 50 per cent. Power pulse bipolar transistor (V_{CE} = 150 V, I_{CM} = 25 A, P_{TOT} = 450 W) was used as commutator. Capacitor's discharge time was approximately 100 nanosecond.

As a result of the described schemes analysis nanosecond pulse generator have been made and researched. Principle of operation is explained on the figure 1. During the time t_1 when commutator S1 is switched on energy is accumulating in the primary winding of transformer TV1. Due to the self-induction effect when commutator S1 is switching off capacitor C1, connected to secondary winding TV1, is charging. Time t_2 after commutator S2 is switching on and capacitor C1 during the time t_3 fast discharges through primary winding of transformer with saturation core TV2. Further processes, described earlier, are occuring.

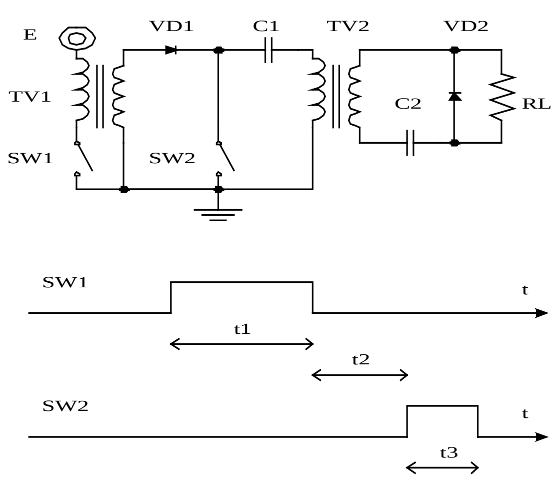

Figure 1 : Operation principle of the impulse generator based on step-recovery drift diode

Output circuit parameters of the generator are tuned so that transformer TV2 core saturation has placed by the moment when the capacitor C2 charges. Interval duration t_3 does not influence on the impulse forming. This time has to be enough for the full capacitor C2 discharge. Unit efficiency will be maximum if C1 and C2 capacitances will be approximately equal.

Impulse generator scheme is represented on the figure 2. N-channel enhancement mode field-effect power transistor BUK456-100A (V_{DS} = 100 V, I_{DM} > 130 A, tr < 60 ns) was used as commutator S1. For capacitor C2 discharge was selected fast-switching N-channel insulated gate bipolar power transistor (V_{CE} = 800 V, I_{CM} = 50 A, tr = 45 ns). Commutator's control unit was realized on fast-TTL logic elements. Control voltage for the transistors has to have amplitude from 5 to 30 Volt. This volume is higher than standard fast TTL signals level. Level conversion was made on fast middle-power switching n-p-n transistors (V_{CE} = 60 V, I_C = 1 A, f1 > 200 MHz, R_{CE}(on) < 2 Ohm) with transformer loading, that provided galvanic outcome between control unit and output stage of the generator.

Charge voltage of the capacitor C1 was set with time interval t_1 changing, that varied from 100 to 500 nanosecond.

4. Discussions

During carrying out of this work following results have been achieved:

Impulse with peak amplitude 500 V and 2 nanosecond rise time (12 nanosecond full pulse duration) was achieved on the 50 Ohm loading with 50 Volt power supply.

Time intervals was: t_1 = t_2 = 2000 nanosecond, t_3 = 300 nanosecond. A pulse generation cycle was less than 5000 nanosecond. Like this repetition rate may be increased to 100 kHz without characteristics deterioration by transistors heat mode providing.

Impulse amplitude changing was not furnished with shape distortion.

Power consumption was less than 4 W with 8 kHz pulse repetition rate.

The generator efficiency was approximately 2.5 per cent. This value is much smaller results achieved earlier. The scheme analysis shows that main losses deal with non-optimal choice of the output circuit parameters and element types. So in the model were used ferrites with smaller than prototype magnetic permeability and non-impulse capacitor types.

Potential possibilities of the scheme is more better than represented results. Parameters may be improved with control unit modernization and more thorough nominals selection.

Main merit of the design is better safety due to absence of external high voltage circuits. Impulse parameters may be stabilized with time duration t1 operation.

Simplicity and control convenience make it possible to use the generator as a transmitter of cheap impulse GPR for engineering geophysics.

Conclusion

Powerful nanosecond pulse generator controlled by the standard fast TTL signals has been considered. Due to scheme simplicity the generator can be actually made in the home conditions. It can be designed as impulse generators for different application by a few elements selection without the electric scheme changing. The impulse generator can be applied in the cheap portable GPR for caves finding.

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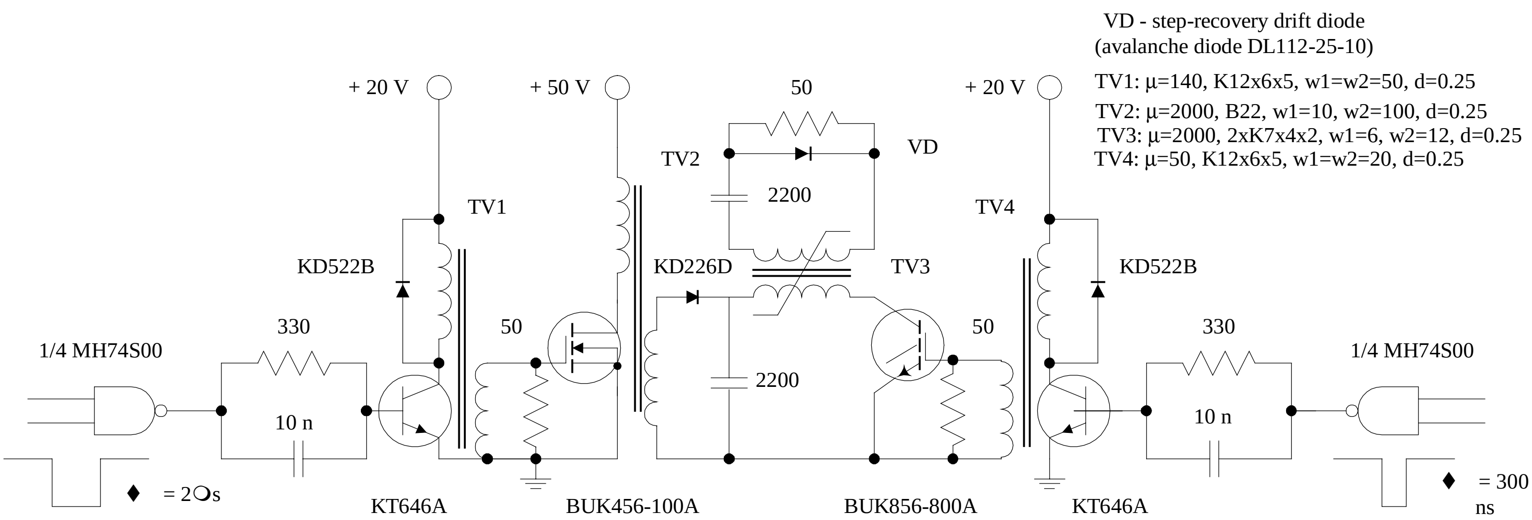

Figure 2 : Scheme of the impulse generator based on step-recovery drift-diode