DEVELOPMENT OF WIDE BAND PULSER WITH STEP-FUNCTION WAVEFORM

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INTRODUCTION

The broad band transducer has generalized in the ultrasonic non-destructive testing these days. A received waveform of 1.5 cycles has widely been used, and a received waveform of one cycle is near completion for practical use. The market demands a higher resolution and a wider band transmitted and received pulse than they are. Under these circumstances, this development was carried out for the purpose of generation and receiving of a 0.5 cycle or shorter pulse.

It is known that a 0.5 cycle sound pressure may be generated when a step-shaped pulse is applied to the broad band transducer. However, this short wave is not always observed with the normal broad band transducer. Before setting about doing development, we made a simulation test by the PSpice to examine the behavior of waveforms of both the electrical pressure impressed to a transducer and the ultrasonic pressure to be generated. We developed a transmitter/receiver circuit based on this examination results.

We carried out the following examinations.

1) The waveform and field of ultrasound pressure generated by the device developed were observed using the ultrasound visualization system.
2) The received waveform reflected from a proper reflector was observed and the frequency analysis was carried out.
3) The comparison test of power consumption was carried out between the device developed and an RF amplifier which is usually used for application of the step-type waveform in may laboratories.
4) The interrelation between the discharge impedance and received waveform was determined.

We confirmed from the results of the above mentioned examinations that the technique we developed allows thickness measurement to be efficiently made and an easy phase discrimination of the reflector.

SIMULATION BY PSPICE

We assumed that the transducer was a simple LCR electrical resonator and a parallel capacitor. We used a parallel capacitor of 300pF which is an approximate value to the value measured with a 5MHz transducer on the market. The value of each element of the equivalent circuit should meet the following conditions; 1) The critical damping can be obtained, and 2) the impedance at resonance is 300Ω. The transducer we have ranges 50 to 300Ω. We presumed that the electrical pressure waveforms appeared across the both R ends of the LCR circuit is close to the sound pressure waveform, or at the least, the proportionality can hold for the number of the waveforms. Figure 1 shows the output voltage values appeared across the both R ends measured when the spike pulse and step pulse are applied through the output resistance Ro to the assumed transducer. Ro was 50Ω. With the spike-type applied voltage, the waveform is 1.0 cycle, while with the step-type applied voltage, it is 0.5 cycle.

The cycle numbers of these waveforms coincide with the general knowledge.

Next, it was supposed that the transducer on the market was not at the critical damping.

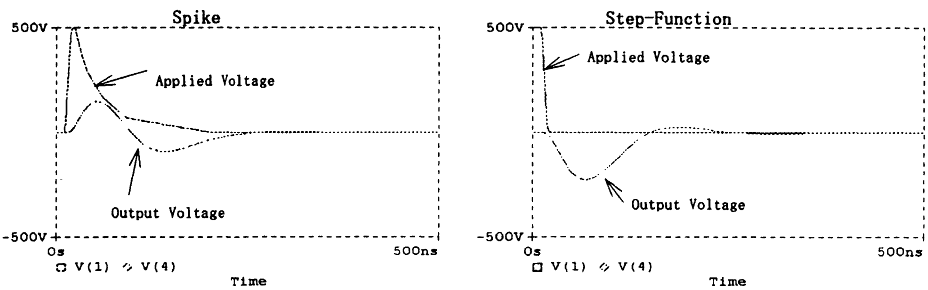


Figure 1. Analysis of spike- and step-function pulser by PSpice

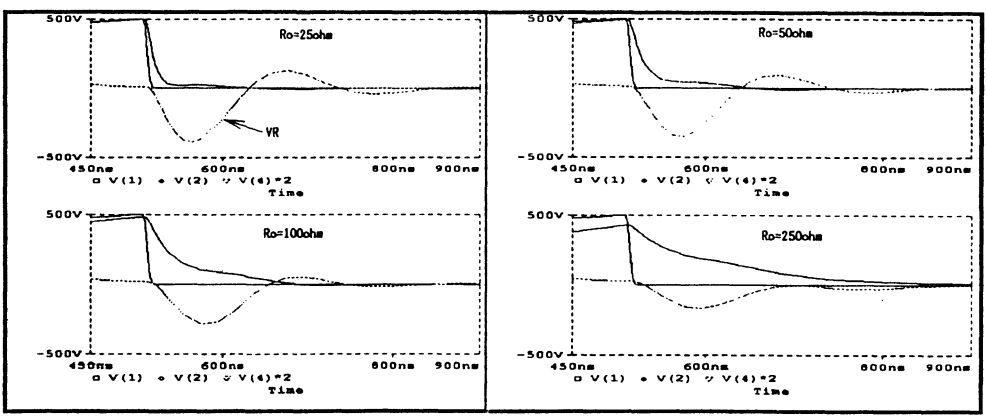


Figure 2. Waveform vs. discharge resister

Figure 2 shows the variation of waveforms measured when R is set for 200Ω and Ro is set for 25 Ω to 250Ω. It is shown that even with the transducer which is not in a critical damping condition, a waveform with less linking can be obtained by increasing the driving-point impedance.

IDEA OF STEP-FUNCTION GENERATION CIRCUIT

It is possible to generate step-shaped waveforms of high tension current by combining an A/D converter with an RF power amplifier. This method is carried out at many laboratories, but has the following problems.

1. The power consumption and size of the transmitter circuit is relatively large to the output of ultrasonic pulse. The portability is low.
2. It is hard to make the output impedance low.

We design a original circuit to solve these problems. The impedance of low frequency transducer elements is very high. The transducer absorbs the energy only at the applied voltage with a frequency which makes the impedance of parallel capacitance, or a frequency near the resonance frequency. Considering these points, we made a circuit by way of trial, which slowly charges the parallel capacitance of transducer with low current, and discharges the electricity charged at low impedance when a high voltage is charged to the transducer. The simplified block diagram of equivalent circuit is shown in Figure 3.

At the early stage of trial, a high resistance was simply used for the high voltage charging circuit. However, since the parallel capacitance of transducer on the market ranged some pF to some 1000pF, at the last, we made a forced charge in a fixed time. Figure 4 shows the outline of this circuit. The electricity is charged in the parallel capacitance of transducer and the coaxial cable from the high voltage source in approx. 10μ to 20μ seconds. After that, turn the discharge

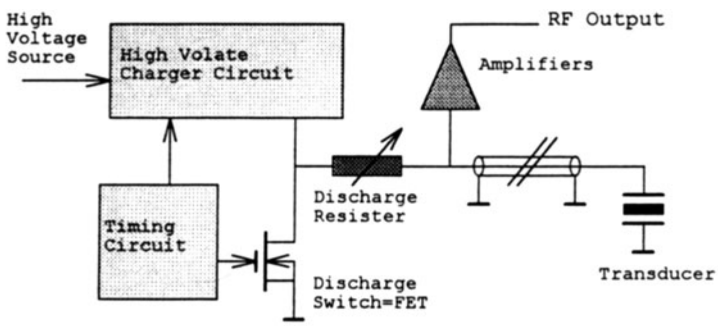


Figure 3. Simplified equivalent circuit of step-function pulser

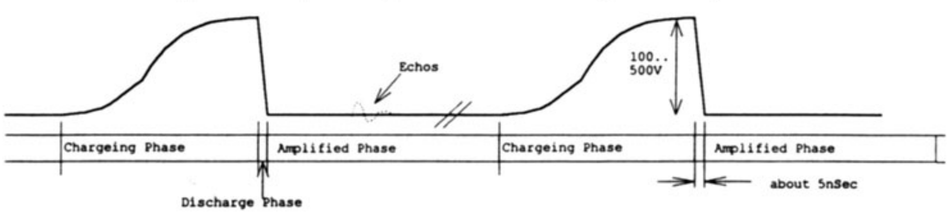


Figure 4. Electrical waveform at drain of FET

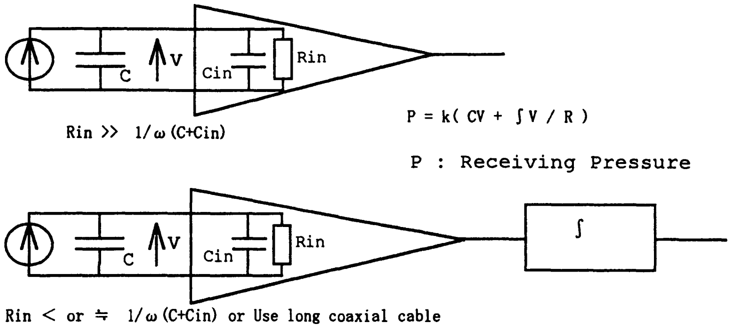


Figure 5. Two method for reproduction of receiving pressure

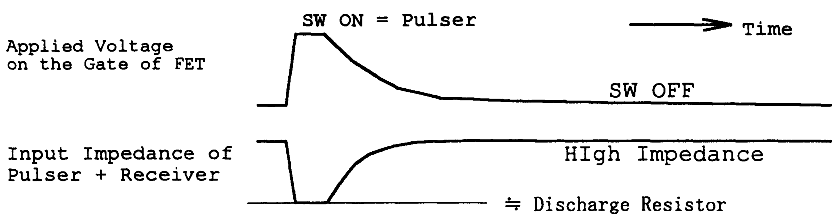


Figure 6. Input impedance

switch on. As the switch, the FET is suitable for driving transducers of about 50MHz and an avalanche transistor for driving over 50MHz. The electricity charged in the transducer and coaxial cable is discharged through a discharge resistor. This abrupt discharge generates ultrasounds from the transducer.

DEVELOPMENT OF RECEIVER CIRCUIT

As it is generally known, when the load at a broad band transducer is sufficiently high, the output of the transducer is proportional to the waveform of sound pressure. Therefore, an amplifier illustrated upper circuit in Figure 5 is suited to use. In high frequency range, it is difficult to keep the input impedance of amplifier higher. Especially, when the amplifier is connected to the transducer through a rather long coaxial cable, the load of transducer will be the characteristic impedance of the coaxial cable which is normally 50Ω or 75Ω. $Rin >> 1/\omega (C+Cin)$ does not hold. When a high frequency transducer is used, an integrating circuit should be integrated in a part of the amplifier so that a voltage output proportional to the sound pressure can be obtained.

On the other hand, as it is difficult to design an integrating circuit which works in lower and higher frequency range, a high impedance was used for low frequency application. The impedance of the switch shown on Figure 3 is set for low only at the discharging point and for high (OFF) just after that. See Figure 6.

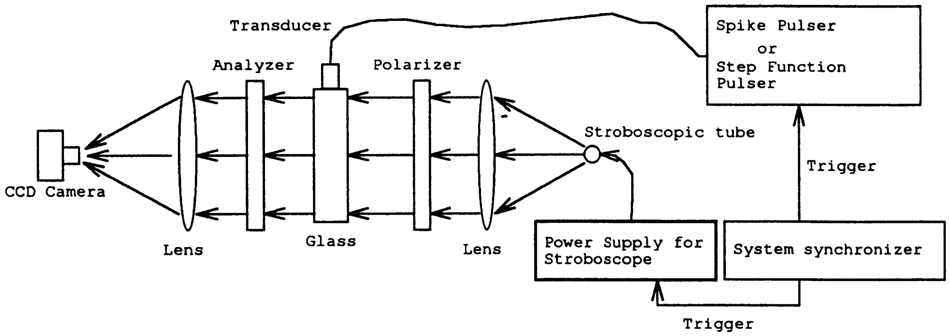
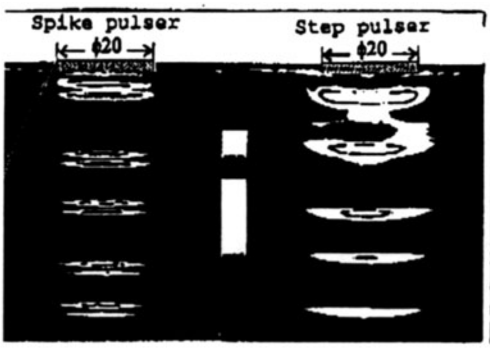


Figure 7. Block diagram of ultrasonic visualization system



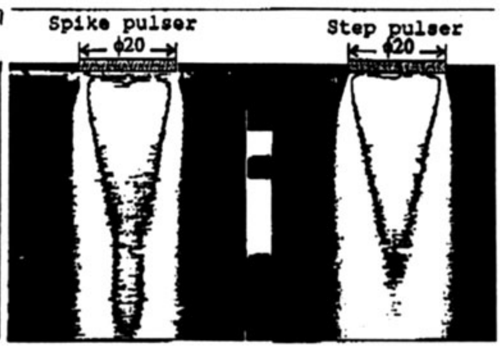


Figure 8. Transmission of sound wave by spike and step function pulsers

Figure 9. A disturbance of sound field by spike and step function pulsers

OBSERVATION OF SOUND PRESSURE WAVEFORM

We observed waveforms of sound pressure generated from the step-function pulser by using the ultrasound visualization system shown in Figure 7, and a wave of 0.5 cycle was observed. For comparison, the waveform image of sound pressure excited by a normal spike pulser with a rise time of 30ns at 500V is attached. The cycle of this wave was 1.0. A 1MHz and 25mm diameter broad band transducer was used for the both tests. The value of R is 50Ω.

COMPARISON OF NEAR FIELD

The distribution of maximum sound pressure was measured using the above mentioned ultrasound visualization system, transducer and pulsers. Many images of sound waveforms shown in Figure 8 were acquired by continuously changing the timing of strobe photoemission. The final images shown in Figure 9 were obtained by chose the highest values of each image. With the spike pulser, a disturbance of sound field is observed just after pulse firing, while with the step-type pulser, it is not observed. We also found with the spike pulser, a high sound pressure appeared around the near field length, but with the step pulser, it was not observed.

COMPARISON OF POWER CONSUMPTION OE TRANSMITTER CIRCUIT

The comparison of power consumption was made between the pulser developed and the step-function generator with an RF amplifier which is widely used for usual experiments.

For the comparison tests, two type RF amplifiers, a 200V and 50Ω output type and a 50V and 50Ω output pulse driven type, were used. A 1MHz and Ø25mm broad band transducer with a direct interelctrode capacitance of 1790pF was used for loading. The direct interelectrode capacitance of normal transducers of 2MHz or higher is lower than 1000pF. Concerning the RF amplifiers, the power consumption of power amplification circuit only was measured and the measurement of waveform generating circuit was excluded. The power consumption measurement of the pulser developed included all transmission related circuits such as the step-shaped waveform generating circuit, the high voltage power circuit and the early stage of amplifier. The measurement results that the pulser we developed requires very low power consumption because it is only needed to charge and discharge the transducer. Therefore, this device can be used for portable flaw detectors and thickness gages. In addition, since a radiator like RF amplifier is not required, it is light and compact.

COMPARISON OF RECEIVED WAVEFORM

A 1MHz and Ø50mm contact transducer placed on a 50mm thick PEEK plate was excited by

Table 1. Comparison of power consumption of transmitter circuit

Power Consumption (W)	RF Amp. 200V type	RF Amp. 50V Pulse-Driven	Pulser Developed 500V, 10sn
PRF 1KHz	1900	78	4.1
PRF 10KHz	1900	83	9.8

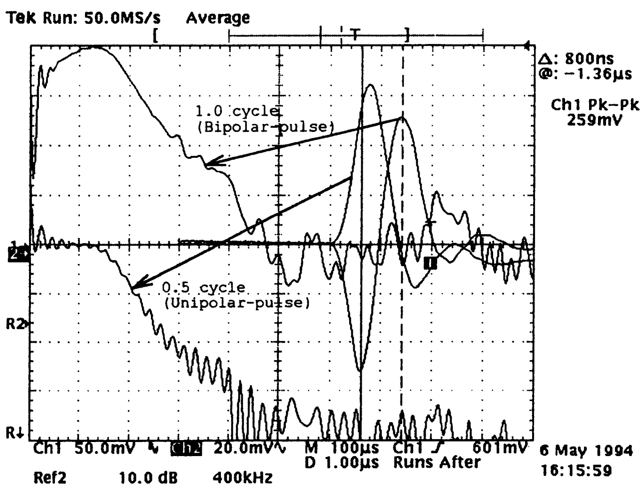


Figure 10. Received waveform of 0.5 and 1.0 cycle

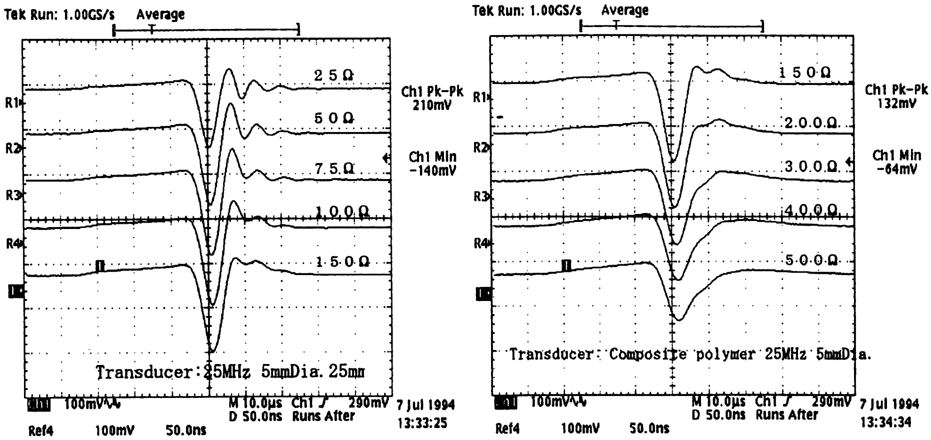


Figure 11. Waveform changes according to discharge resistor Ro

the spike pulser and the step pulser with an output impedance set for 50Ω, and received by an amplifier with a high input impedance. An oscilloscope fetched the first back echo signal. The results of measurement and frequency analysis of the waveforms are shown in Figure 10. A waveform of 1 cycle was obtained with the spike pulser and a waveform of 0.5 cycles with the step pulser. The frequency analysis show enery of the low frequency range of 0.5 cycle wave is stronger than 1.0 sycle. In higher frequency range than the resonance frequency of transducer, there were no remarkable differences between them.

INTERRELATION BETWEEN RECEIVED WAVEFORM AND DISCHARGE RESISTANCE

The waveform received was observed by altering the value of discharge resistance R0. A 25MHz and Ø5mm immersion polymer transducer with a focal point of 25mm was used. The direct interelectrode capacitance is 43pF, which has a value of 150Ω at 25MHz. The waveform measured at 25 to 500Ω is shown in Figure 11. Each signal is obtained from a aryl plate placed perpendicular to the sound beam at the focal point of transducer in water.

At larger Ro values, the waveforms are nearly 0.5 cycles. Even when changing the R0, the fall time of leading edge of the received pulse stayed almost unchanged, but the parts after the negative peak changed much. The Ro value changed to vary the amplitude only by 6dB.

The test data shows that it is possible to vary the received pulse by changing the discharge resistance Ro, with few drop of the total gain.

APPLICATIONS

With this new pulser, we solve many problems. We show some experiences.

1. The device developed provides better S/N ratio in testings of ununiform materials such as composites and concrete.
2. The discrimination of phase is easy. (It is easy to discriminate the acoustic impedance of couplant and reflector.)

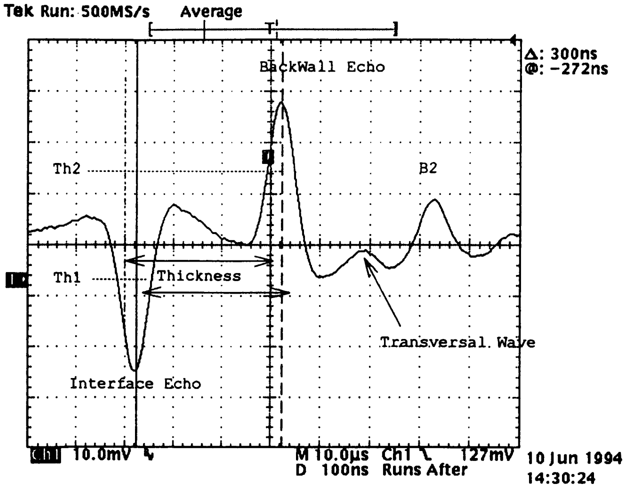


Figure 12. Multiple echo form of 1mm aluminum plate

3. It is possible to obtain on various transducer data with one transducer by taking a specified data out of received data.
4. The thickness measurement without interference of interface echo is possible.

The applications of the device developed to wall thickness measurement and concrete measurement are described below.

APPLICATION TO WALL THICKNESS MEASUREMENT

As one sample, we show waveform of thickness. The wall thickness measurement of a 1mm thick aluminum plate was carried out using a 10MHz and Ø5mm composite polymer transducer with polystyrene 10mm delay in direct contact method. The waveform obtained is shown in Figure 12. It is observed that the B1 echo can be measured without interference of interface echo.

CONCLUSION

A method for step function pulse generator using with ordinary wide band transducers was successfully developed. The pulser is very useful for many applications of quantitative ultrasonic testings.

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