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# Relationship between output impedance of pulse generator circuit and emitted ultrasound pressure waveform
# 超音波パルサーの出力インピーダンスと音圧波形

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## 1. Introduction

Basically rectangular pressure wave is generated by long duration spike pulser (Fig.1). This is predicated on pulser output impedance is enough lower than the impedance of transducer in base frequency. But when the impedance is too low, lead inductance between piezoelectric element and pulser drive electric circuit are treat as resonance circuit. By this reason, electric engineers design the circuits as output impedance of pulser is not low. Typical output impedance of equipment is somewhere between 10ohm to 40ohm. We made special pulser which output impedance is as low as 0.1ohm for this experiment. Then several non-inductive resistances are inserted between the pulser and transducer. Also long cable makes distortion of signal. So we used 25cm coax cable.

## 2 Highly damped transducer

We tested a wide band commercial transducer with backing material. The backing acoustic impedance is about 60% of piezoelectric material. As a protect layer makes deformation of wave form, we removed the protect layer carefully. Q of the piezoelectric element is about 10 without the backing and about 1 with the

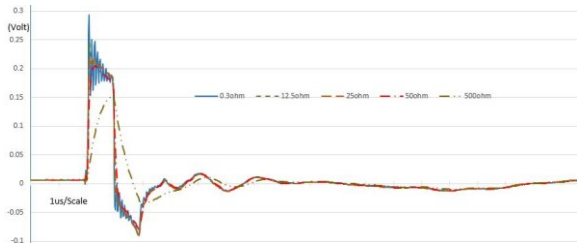


**Fig.1** Pressure waveform by pressure sensor of wide band transducer with 0.5MHz 40mm Dia.

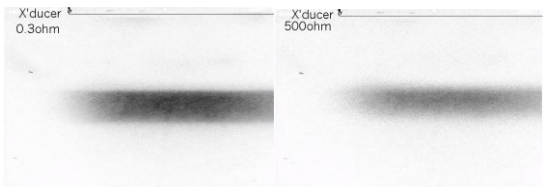


**Fig.2** Photo elastic method(UVS) image of wide band transducer 0.5MHz 40mmDia.

backing. We changed output impedance as 0.3, 12.5, 25, 50, 500 ohms. We measured output pressure wave by 20MHz 3mm diameter wide band transducer with high impedance amplifier.

With 0.3ohm output impedance, we observe 20 times higher resonance of the base frequency. With 12.5ohm output impedance, there is no resonance. With 500 ohm, we observe saw-tooth waveform. The curve time constant is as same as the multiplication by output impedance (50ohm) and capacitor(1nF) of piezoelectric element. To confirm wave form, we capture by CCD with Ultrasonic Visualization System (UVS) based on photo elastic phenomenon as Fig.2.

## 2 Transducer without backing

We used a piezoelectric element without backing. The element sensitivity is higher for medical use. The dielectric constant is 18 timer larger than it of above

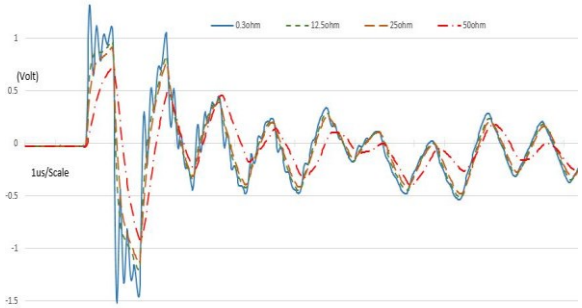


**Fig.3** Piezoelectric element only 0.5MHz

mentioned commercial transducer. The result is shown Fig.3 With low output impedance of 0.3 ohm, we see resonance. The capacitance is 18 times lager, then lower resonance frequency is observed (about 20/√18). With any resistance inserted, we observe saw-tooth wave form, not rectanguler.

## 3 Point of Measurement

**Fig.3** was measured at point near element outside. In the center of element, wave propagation into diameter direction is large and not attenuated in short time. Fig.4

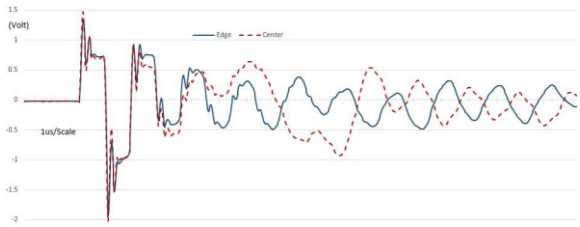


**Fig.4** Effect of Resonance in diameter direction; element only 0.5MHz 40mmDia.

shows wave form in the center and near edge.

To test round shape object by ultrasound, we place a transducer not in center. This is common knowledge of inspector of concrete pillar or steel bar.

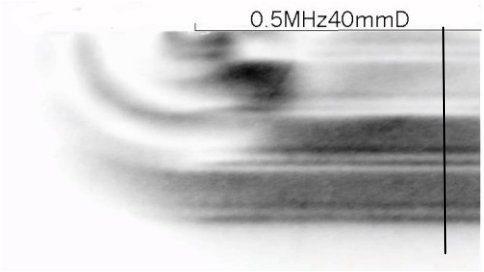


**Fig.5** UVS image; element only 0.5MHz 40mmDia. Picture area 40x25mm. Vertical line is center of the element

To know which is the typical wave form of the element, we observed UVS image as Fig.5. In the element center, nothing is happened. Pressure sensor detect surface wave or different mode wave. Especially in the center all wave came from periphery are concentrated. On the right edge of element we observe Beam Edge Diffusion and shear wave. We can say solid line of **Fig.4** is typical.

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## 4 Drive Duty of Pulser

**Fig.6** shows effect of drive duty of pulser MOS FET. Each maker designs pulser or flaw detector with different philosophy. The drive duty is somewhere between 5 to 100%. We changed drive duty lectric. Dependence was measured at point near element outside. In element without backing. When drive duty is too short, pulser cannot generate high pressure. When drive duty is too long in burst mode excitation, pulser absorbs energy from element. Then output pressure is not so increase in burst mode.

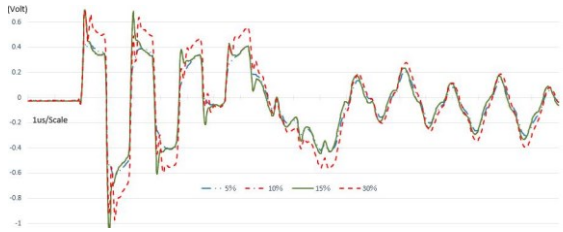


**Fig.6** Drive duty of Pulser FET; element only 0.5MHz 40mmDia.

In case of **Fig.6**, with 5% drive duty, no overshoot is observed. With 10% drive duty, we see a overshoot at each half cycle. With over 15% drive duty, we observe resonance. With over 30% drive duty, we observe higher pressure because of stopping drive at a peek of ringing.

## 5. Conclution

Ultrasonic Inspector for flaw detection doesn't care with hard wares supplied from makers. They only operate his machine without knowing about the wave generation and travelling wave form.. The result of combination use from different makers makes deformation of wave form and effects inspect result. There will be many younger engineer in a maker without knowing the wave form changes above mentioned.

### Reference

[1] Y.Udagawa: *Introduction to Ultrasonic Wave Technique – Transducer, Pulser, Receiver and Device-*, Nikkan Kogyo Shimbun Ltd, Tokyo (2010)

*[2]* Y.Udagawa and Guy Reim: *Wave Propagation Simulation in Coarse Grain (attenuative) Materials」IUS October 2012*