THE ELECTROMAGNETIC INTERFERENCE OF ULTRASONIC PULSER – PREAMPLIFIER

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Abstract

Electromagnetic interference inside the standalone ultrasonic pulser – receiver is investigated. Simulation of EMI situation inside the extruded aluminum case using several electromagnetic simulation software was done.

1. INTRODUCTION

Development of ultrasonics non-destructive testing (NDT) [1] has transformed the configuration and demands for ultrasound electronics: system usually is spread over large area; signal cable length can reach hundreds of meters. Along with high gain, wide bandwidth and large excitation powers these long distances are increasing the electromagnetic interference (EMI) coupling to signal path. Therefore EMI immunity performance is important here [2,3].

Ultrasonic pulser is using high voltage power supply. This high voltage is produced by step-up DC-DC converter from relatively low 5-12V power supply which is available in portable equipment. If pulser is combined with reception circuitry in one case, then DC-DC converter presence creates significant EMI. This was the case in our standalone ultrasonic pulser – receiver design. Design is placed inside of extruded aluminium case. Electromagnetic interference inside the case is investigated.

2. ULTRASONIC NDT SYSTEM

The ultrasonic non-destructive testing system (Figure 1) contains at least the excitation channels (usually square wave) for the generation of ultrasonic signal. Application of pulse or bursts with the square pulses excites the ultrasonic transducer.

Low noise amplifier (LNA) is used at the input to ensure a wide dynamic range of the input. Transmission-reception switch (can be only limiter) is used to prevent the receiving circuitry damage during excitation. These two units can be placed in separate box, located close to the ultrasonic transducer and received signals relayed to acquisition unit.

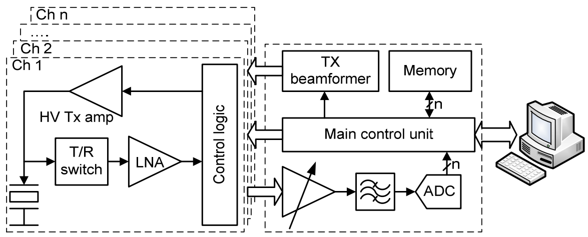

Fig. 1. Simplified system structure

The main acquisition unit contains control, excitation beam former, time variable gain amplifier (TVG), a band pass filter and analog-to-digital converter (ADC) with a corresponding memory and glue logic. Signal decay with distance is compensated by TVG. This unit includes variable (usually linear-in-dB) amplifiers.

3. PULSER

Piezoceramic ultrasonic transducers usually have high input impedance. Therefore, high voltage excitation is necessary to supply sufficient power for excitation. The most convenient way to get high voltage pulse [4] is two switches connected in totem-pole (Figure 2) topology.

Switches are commuting the high voltage power, produced by DC/DC step-up converter. To produce the high voltage on transducer terminals the switch S_1 is turned on and S_2 stays off. To remove this high voltage from the transducer terminals the S_2 is turned on and S_1 off. This is done after time interval defined by ultrasonic transducer operation frequency. To repeat, the pulse S_1 is turned on again and S_2 is off so we get another high voltage pulse.

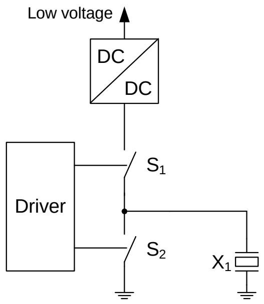

Fig. 2. Pulser circuit

Such excitation pulses penetrate to reception channel as EMI. But this EMI is not essential since can be separated in time by acquisition timing.

4. HIGH VOLTAGE CONVERTER

In addition to high voltage pulses DC-DC converter is producing additional EMI. Figure 3 present simple DC-DC converter to produce 200 V from 12 V input.

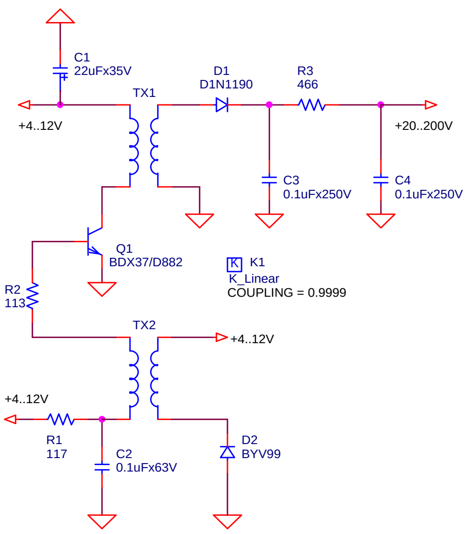

Fig. 3. HV DC-DC converter

Circuit above was used in simulation using P-SPICE to investigate the transistor Q1 current. Figure 4 present the simulation result for output voltage on capacitor C3.

Figure 5 is for Q1 simulated collector current spectrum presentation.

It can be seen that current is covering significant part of spectrum, so it will not be easy to get rid of it.

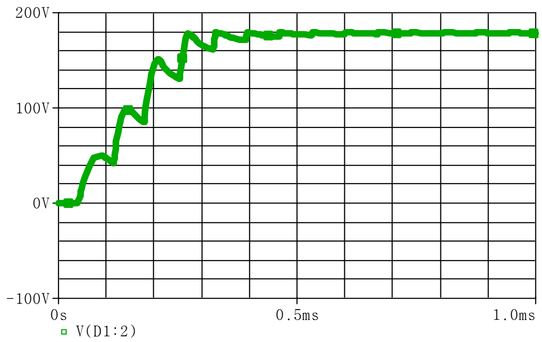

Fig. 4. HV output signal at startup

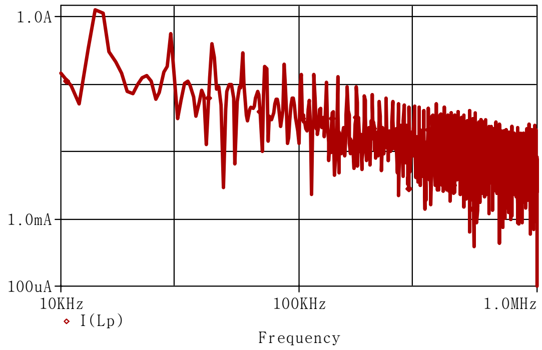

Fig. 5. Q1 collector current spectrum

5. PREAMPLIFIER

Amplifiers used in ultrasound reception should be low noise. Also the impedance, acting at amplifier input, should be accounted since it determines the noise level. Usually input impedance varies in range 50 Ω to few kΩ [6,7]. This creates perfect reception path for induced EMI pickup and amplification.

In systems operating in a pulse-echo mode the preamplifier is connected to high voltage pulser output. Of course, there is a protection circuit at the input (Figure 6).

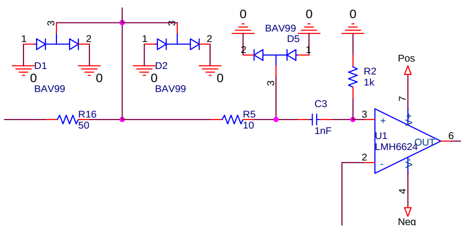

Fig. 6. Input protection circuit

But this circuit creates a local loop (R16-R5-C3-R2) which picks up the high current induced by Q1. Only 1uA induced in R2 circuit creates 1mV signal which is amplified further.

In order to decide what measures should be taken internal eigenmode analysis was done in high frequency structure simulator (HFSS). Decision was inspired by [8].

Three dimensional pulser-amplifier model was developed in SolidWorks (Figure 7).

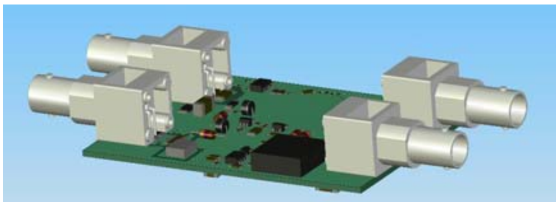

Fig. 7. PCB model in SolidWorks

Model was imported into HFSS environment. DC-DC converter power supply PCB track was assigned as excitation port. Unfortunately, due to multiple elements simulation time was too long to converge and memory limit was exceeded. Therefore simpler model of the box and the PCB was applied to investigate the fields in 0.1-2 GHz range. Results at 1.5 GHz are presented in Figure 8.

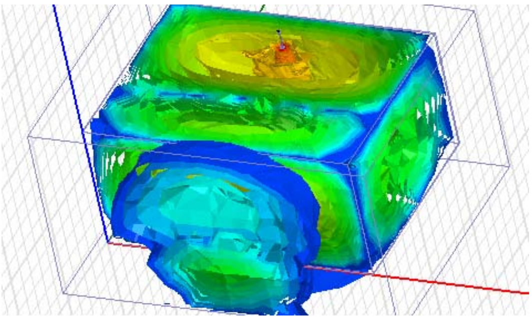

Fig. 8. E-field simulation result

The box front panel gap was simulated by placing the slot beneath coaxial connectors. It can be seen in Figure 8 that E-field is leaking out through the slot.

6. CONCLUSIONS

Simulation of electromagnetic interference of standalone ultrasonic pulser – receiver placed inside the extruded aluminium case has indicated, that presence of high voltage DC-DC converter in close proximity of receiving preamplifier creates significant EMI in reception channel. Application of simulation software can be of much help in problem location.

References

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