FDTD Simulations for Ultrasonic Communication System Employing Metal Plates

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1 Introduction

Nowadays, there have no identified ideas for sand digital information across conductors material, such as metal, water and so on. But in some cases, it will not be a good idea to make some holes in such materials. So we need other sensor system which can send the information directly through them. But conventional wireless communication system cannot be applied because of the shielding provided by the conductors material, however the ultrasound propagates readily through them and it also can be used to convey information. For example, the use of ultrasonic singaling to transmit digital information across metallic barriers has been demonstrated by several groups[1-5].

Also there are few simulation methods can be used for ultrasonic communication. The most common ultrasound system method today is pulse-echo techniques[6,7], or other ultrasound simulation techniques use both the transmitted and reflected energy to form a two-dimensional image[8,9]. However, all of these techniques do not suit for ultrasound communication simulation. Because they assume that scattering is weak and do not account for strong diffraction and refraction. So we need another method for the ultrasound wave simulation.

In this paper, we choose the Finite Difference Time Domain method to simulate the ultrasound wave behavior. This method can be used easily to simulate ultrasound propagation in the conductors material. It can lead to better understanding of the effect of ultrasound signal. In this work, an implementation of FDTD into an application for ultrasonic communication is described.

2 FDTD Simulation for two different cases

In order to find the best position to send ultrasound signal throw metal, we want to study ultrasound wave behaviour in different metal objects.

2.1 Metal Bar

In this section, we are going to simulate the ultrasound wave behaviour in a metal bar. This is a very common structure, just like a metal pipe. Figure 1 shows the geometry and regions defined for the FDTD simulation. The width of transducer and the diameter of metal bar are both 3mm. The analysis grid spacing is 0.013mm. Each simulation is running for 20 thousand time steps, for about 20 μs

Fig. 1 The Schematic diagram of metal bar

At first, we simulate when a simple Gaussian source is been set on the left side of metal bar. So we can observe the ultrasound wave behaviour in a metal bar. The simulation result is showing in figure 2.

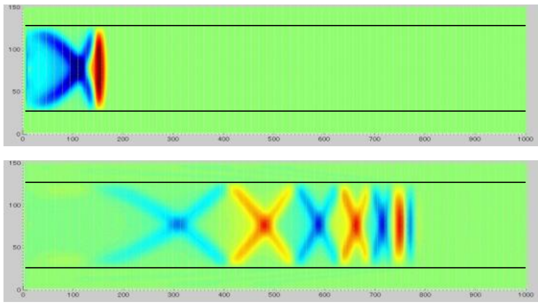

Fig. 2 Gaussian pulse propagate in bar

In figure 2, we can find that, ultrasound wave will reflect back on the border of metal bar. Because the diameter of metal is very thin. So as the ultrasound wave travelling along the bar, reflected wave will arrive the opposite side of metal bar and reflect back again. These reflected wave may cause intersymbol interference with subsequent transmissions.

Then we want to simulate how the echoes affect the ultrasonic wave when it carries signal information. In the simulation, we use a group of BPSK-modulated signal as the source. And we measure the acoustic force at the receiving transducer side.

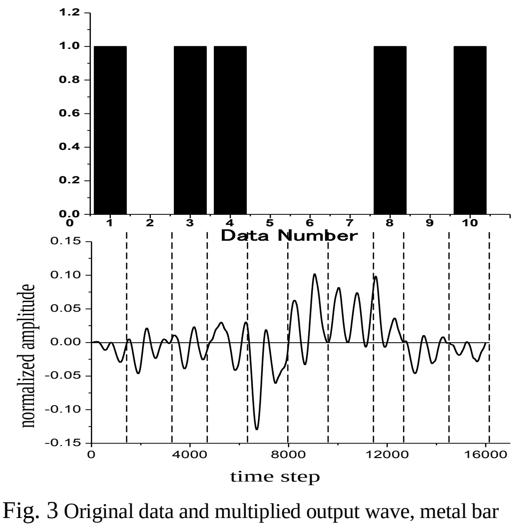

Fig. 3 Original data and multiplied output wave, metal bar

The received signal is multiplied by a reference frequency sine wave. If data is "1", the corresponding part of multiplied output should above zero. And if data is "0", the corresponding part of multiplied output should below zero. So the multiplied output can be used to compare with the original data.

The multiplied output on 5MHz is showing in figure 3. From this we can observe that the multiplied output is quite different from the original one. So it may be very hard to send ultrasonic signal throw a thin metal bar.

2.2 Subsection Two

Then we are going to simulate the ultrasound wave behaviour in a metal bulkhead, the schematic diagram of which is showing in figure 4.

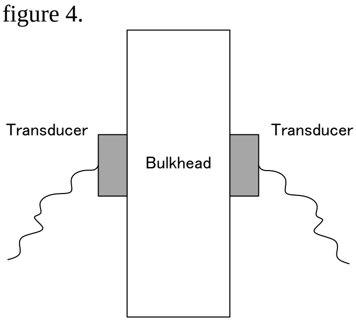

Fig. 4 The Schematic diagram of metal bulkhead

In Figure 5a, we can see the pulse entered the bulkhead. Because the impedance mismatch between transducer and bulkhead, only part of the incident energy has been coupled into the bulkhead. Figure 5b shows the ultrasonic pulse within the bulkhead. Figure 5c shows part of the ultrasonic pulse passes into the transducer on the receive side. Again, a portion has been reflected back into the bulkhead. At last, in Figure 5d, the pulse has been reflected form the receive side of the bulkhead. This part of pulse will travels back into the receiver side too.

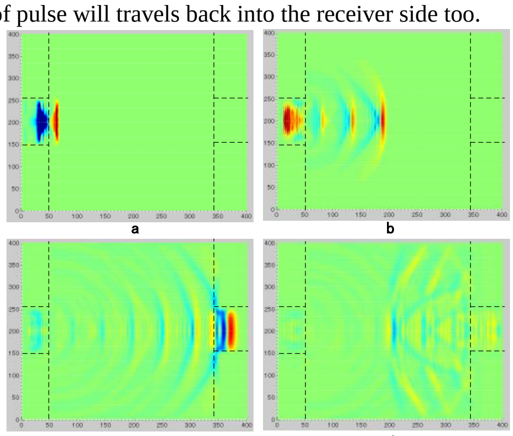

Fig.5 Gaussian pulse propagate in bulkhead

Figure 6 shows the result at 5MHz. From this we can observe that the multiplied output is almost the same with the original one. So a metal bulkhead may be better for sanding ultrasonic signal.

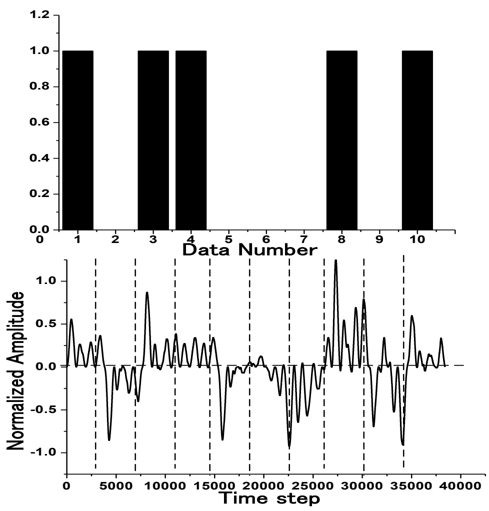

Fig.6 Original data and multiplied output wave, metal bulkhead

3 Conclusion

Presented evaluation shows that FDTD method is easily applicable for simulating ultrasonic problems. The simulation results shows that a metal bulkhead is convenient for ultrasonic communication.

Future work will include the use of ultrasonic wave in air for communication. This will offer advantage especially for security. And the slow propagation speed in air will also allows the location of sources to be tracked. Nowadays, there are some studies of the properties of ultrasonic communication system been published. For example, ultrasonic wave has been used for location tracking in hospitals, where time-of-flight from a moving source to a set of fixed receivers can be used[12]. And simple methods for designing an ultrasonic PC mouse using narrow bandwidth piezoelectric transducers[13]. We are going to design a ultrasonic system to supersede the radio frequency identification system using radio frequency electromagnetic wave. So it can offer advantage for security.

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