Chapter 3

Design and Fabrication of Underwater Ultrasonic Transducer and Array

3-1 One-dimension transducer array design and Simulation

From chapter 2 we can know the piezoelectric resonant frequency and piezoelectric parameters, etc., besides, we can build mathematical model descriptions for ultrasonic field and signal, then, before the preparation of emission array, we use first the Field C function program [1-2] written by Jensen to call application simulation in Matlab, this function program system is proposed by Tupholme and Stepanishen [3-5] and written based on their spatial impulse responses theory, it can be used to calculate and draw the sound field value of the ultrasonic wave of array formed by two signal sources such as pulse and continuous wave. The simulation result can be used as reference and comparison in the array preparation in the future.

From section 2-3 and 2-4 of chapter 2 we know the characteristics of energy converter and its array, in order to let one dimensional array have larger image scanning scope, the vertical direction of the one dimensional parallel emission array must be designed to have large main peak width, therefore, in the array element, that is, the length of the energy converter of the piezoelectric ceramic must be as smaller as possible. Then consider the number of array element, the center spacing between array element, the width and driving period of array element, they will all affect the array characteristic. Then, perform the simulation of all kinds of parameters, use Matlab 6.5 to call Field C function

program database to perform the editing of all kinds of applications, the program process flow is as shown in figure 3-01, the process is as shown in the followings:

(1) Set up the ultrasonic wave transmission speed, system sampling speed, number of array element, and parameters such as the length, width, height of element and spacing between elements.

(2) xdc_focus function can be used to set up array focus and calculate the time difference between each array element, the operation will be in certain θ direction.

(3) xdc_excitaiton function gives the array all kinds of emission pulse signal forms, for example, 2.5 period sine wave, square wave of width 1ms, etc., besides, xdc_impulse function is an impulse response form of the conversion of voltage to acoustic pressure in energy converter, usually, hanning windows is given.

(4) This step is used to build the array that is to be simulated, one dimensional emission array xdc_linear_array function can be used to cut the element in the array into several faces to enhance the simulation accuracy.

(5) Usually, the simulation of the acoustic field intensity of the one dimensional wavelet is based on the array center as a reference point, under fixed distance, calc_hp function can be used to calculate the pressure filed values of each point on the hemisphere of the xz plane.

(6) We use the definition of equation (2.43) to find the passed maximum pressure field value in each point location, then logarithm is taken to make normalizec, the result is represented in dB value.

(7) Use approaching method, the angle when it is dropped to -6dB is found, then the main peak width is calculated.

(8) Finally, plot or mesh function is used to draw our desired power wavelet field form.

Through the above procedures, on the coordinate drawing figure 2-14, assume 19 elements forming an one dimensional emission array of equal spacing, put them on the y axis, each element has a rectangular surface, with length 5mm, width 1mm and thickness 2.8mm, the center spacing of each element is 1.25mm, they are all adjustable parameters, the center frequency of the emission signal is 600kHz, when sine wave impulse of one period is emitted, the impulse response on the energy converter is hanning windows of two periods, the simulation environment is water, acoustic speed is 1504m/s. The array wavelet strength drawing at $\theta = 0°$ and $\phi = 0°$ simulated is used as a reference, the simulation results of different parameters are compared respectively.

(1) Simulation of the main peak width of vertical wavelets of different length of parallel emission array element.

The main peak widths of array elements of lengths 2.5mm, 5mm and 10mm are compared respectively, acoustic field intensity drawing of one dimensional wavelet in the z direction is then simulated, and the main peak width is also calculated. From the simulation result of figure 3-02, we know that the acoustic field intensity drops faster along with the increase in length, this can help us understand the scanning scope in the vertical direction of this design of array.

(2) The simulation of the effect of the number of array element on the wavelet acoustic field intensity

Compare the main peak widths at different number of array elements of 8, 16 and 32, simulate the acoustic field intensity drawing of one dimensional wavelet in the z direction and calculate the main peak width. From the simulation result in figure 3-03, we know that the acoustic field intensity and the main peak width becomes narrower and the side wavelet strength decreases too along with the increase in the number of array element, but the location of the side

wavelet will not change, this can help the selection of element number in the preparation of array.

(3) The simulation of the effect of the center spacing of the array element on the acoustic field intensity

Compare the main peak widths at different spacing between element center of 0.5mm, 2.5mm and 5mm, simulate the acoustic field strength drawing of one dimensional wavelet in the z direction and calculate the main peak width. From the simulation result in figure 3-04, we know that the acoustic field intensity and the main peak width becomes narrower and the side wavelet strength decreases too along with the increase in the number of array element, but the location of the side wavelet will not change, this can help the selection of element number in the preparation of array.

(4) The simulation of the effect of different pulse periods of the array on the wavelet acoustic field intensity

The main peak widths of array elements of periods 1, 3 and 5 are compared respectively, acoustic field intensity drawing of one dimensional wavelet in the z direction is then simulated, and the main peak width is also calculated. From the simulation result of figure 3-05, we know that the acoustic field intensity and the main peak width does not change too much along with the increase in the pulse period, but when the pulse width is increased, the number of side wavelets will increase, this result satisfies the theory in section 2-4-3.

After the completion of the simulation of the emission array, section 3-2 will explain the preparation and packaging of piezoelectric ceramic energy converter array.

3-2. Fabrication of Transducer and Array

The preparation and packaging of piezoelectric ceramic energy converter array will be described [27] in the following accompanied with figure 3-06:

Step1. Pre-treatment, the piezoelectric ceramic piece will be analyzed first according to section 2-1 and 2-2, pick up piezoelectric ceramic pieces of similar characteristics.

Step2. Select piezoelectric ceramic pieces of resonant frequency 600 kHz. Its major composition is $PbZr_{0.5}Ti_{0.5}O_3$ powder, it is long rod cubic sintered at high temperature, as shown in figure 3-06(A).

Step3. As shown in figure 3-06(B), silver paste is deposited on both the upper and the lower surfaces of the PZT, it is used as electrode.

Step4. As shown in figure 3-06(C), add solder to the upper electrode of the PZT.

Step5. As shown in figure 3-06(D), by following the array on the piezoelectric ceramic piece, use silver paste to paste the lower electrode onto the negative electrode of the PCB and have it connected with other lower electrodes to the PCB by using hard waterproof glue, meanwhile, solder is connected with Cu wire to the positive electrode of the PCB, then have it baked in the oven 90　for half hour before it is taken out.

Step6. As shown in figure 3-06(E), package other conductive copper wires and the PCB with hard waterproof glue, a dented slot is left, then put it in the baking oven at 90　for half hour before it is taken out.

Step7. As shown in figure 3-06(F), coat the first soft waterproof layer on the dented slot, then put it in the baking oven at 90　for half hour, then wait 10 minutes before it is taken out.

Step8.As shown in figure 3-06(G), coat the second soft waterproof layer on the dented slot, then put it in the baking oven at 90 for half hour, then wait 10 minutes before it is taken out.

After the completion of step 1~8, the preparation and packaging of ceramic piece array is then complete. The waterproof layer can be divided into soft and hard layer, the dented slot structure is first coated with soft waterproof layer, the hard waterproof layer has very high adhesive force, it will form very tough solid after it has been baked in the oven, the back side of the lower electrode will then be tightly fixed on the PCB, therefore, when ultrasonic vibration is generated, the piezoelectric piece will not suspend and lose its energy, however, the soft waterproof layer is mainly to prevent the vibration interference among array elements, this is because the soft waterproof layer can absorb the vibration, and the dented slot structure is mainly to let the ultrasonic vibration be concentrated on the exact front side. The whole structure is shown in color picture as in figure 3-07. The energy converter array before packaging and the emission and reception array after packaging are shown respectively in figure 3-08(A) and figure 3-08(B).

3-3. Sensitivity Characteristics

3-3-1. Sensitivity Characteristics

Self-made ultrasonic energy converter array sensitivity will be tested [28-30], underwater sound-receiver will be used as the main tool for the measurement and comparison, the tools used in this experiment, are a low frequency underwater microphone of model no. 8104 manufactured by B&K Corporation and a high frequency underwater sound receiver manufactured by Specialty Engineering Associates corporation, the needle tip type underwater microph9one has a model no.

of PZTZ44-1000, it is connected to a Preamplifier for signal amplification.

The sensitivity of ultrasonic wave energy converter [31] is measured and compared by underwater sound receiver and self-made energy converter array, the real test is performed in a water tank, the important parameters are pulse and continuous wave duration control and the distance among arrays. In the followings, the sensitivity measurement theories will be listed one after another.

Sensitivity can be represented as [32]:

$$Sen. = Vout/Pa \qquad (3.1)$$

Wherein $Sen.$ is sensitivity and $Vout$ is the reception voltage, Pa is the sound pressure of the water sound receiver.

$$20\log_{10} Sen. = S_{dB} \qquad (3.2)$$

Wherein $Sen.$ and S_{dB} are all sensitivities, but there units are uV/Pa and dB respectively.

In the water sound receiver sensitivity drawing, unit in dB can be converted to uV/Pa through the following equation.

$$Pa = 1/Sen. \times Vout \qquad (3.3)$$

Wherein Pa is the measured acoustic pressure value, $Vout$ is the received voltage.

Put the measured voltage into the above equation to get its acoustic pressure, then change to self-made energy converter and perform the measurement in the same condition, then put the obtained voltage into equation (3.1) to obtain the sensitivity relative to the water sound receiver.

3-3-2. The measuring system of underwater test

For the signal measurement in this experiment, waveform generator is used to generate continuous signal and have it amplified by pulse signal analyzer to excite the energy converter. When the acoustic wave emitted by the energy converter is transmitted in the water, it will be received by the underwater microphone, such analog signal will be displayed and sampled by digital oscilloscope and pass through RS-232 transmission line and GPIB card, the converted digital signal will be stored in PC. The triggering time of the signal is controlled by the waveform generator, therefore, through the selection of time domain interval on the oscilloscope, one can acquire the desired signal. After the signal acquisition process is completed, use rotating stage to change the location of the energy converter in the water tank, perform the same signal acquisition process at different spatial location, therefore, the signal acquired by this process is the acoustic field distribution in the space and time domain. The equipments used in this experiment are going to be introduced in the followings.

Hardware

(1) High frequency probe type water sound receiver (Transducer)

Model no.: NHZ-0200 (Frequency range 0 ~ 10MHz)

Function: Reversible change measurement tool for converting voltage to acoustic pressure.

(2) Amplifier (Preamplifier)

Model no.: AH-17DB

Function: Amplify the input signal and the received ultrasonic signal.

(3) Low frequency water sound receiver (Transducer)

Model no.: B&K-8104 (Frequency range 0 ~ 120 KHz)

Function: Reversible change measurement tool for converting voltage to acoustic pressure.

(4) Pulse Signal Receiver

Model no.: JSR-PR35

Function: It can drive a pulse signal and receive signal, it can amplify the signal 0 Db to 70 Db, then perform low pass and high pass filtering, the emission and reception action can be separated.

(5) Function Wave Generator

Model no.: Tektronix-TDS3012B

Function: Select the desired range frequency to generate sine wave continuously in order to drive the water sound receiver.

(6) Digital Oscilloscope

Model no.: AMREL-FG513

Function: Input and output signal

(7) General-Purpose 8-Slot Chassis for PXI

Model no.: NIPXI-1042 Series

Function: Accompanied with data acquisition card and designed for sampling frequency, it is used to display data platform and store the data for further analysis.

(8) AD/DA data acquisition card (100 MHz, 100 MS/s 8-Bit Digitizers)

Model no.: NIPXI-5112

Function: Accompanied with lab-view program control to perform data acquisition.

(9) Plastic Tank

Spec: L80cm×W50cm×H50cm, rectangular water tank.

Function: For performing underwater array acoustics characteristics

experiment.

Processes for sensitivity experiment

The experimental architecture is as shown in figure 3-09, a comparison calibration method is used, high and low frequency underwater microphones are used for sensitivity test. Function wave generator is used to generate wave in the frequency range 120kHz to 1MHz, it is used together with probe type underwater microphone; function wave generator is used to generate wave in the frequency range 0kHz to 120kHz, it is used together with low frequency underwater microphone.

Take the measurement of emission sensitivity 600kHz and distance 40cm as an example, water sound receiver has a sensitivity of -232dB at 600kHz, put it into equation *(3.2)* to convert it to unit of dB, the sensitivity of water sound receiver is then $2.51\,uV\!/\!_{Pa}$. The measured voltage is amplified by a post amplifier for 30dB, the amplification is 31.62 times, therefore, the measured voltage is 84.7mV, it must be divided by 31.62, the actual value is 2.68mV, put it into equation *(3.3)*, the obtained acoustic pressure is 1.067KPa.

Under the same condition, amplify the measured voltage by post amplifier for 50dB, the amplification is 316.2 times, therefore, divide 40.6mV by 316.2 to get 0.128mV, at this moment, take the acoustic pressure of the water sound receiver as a reference, put it into equation *(3.1)* to get the sensitivity of one piezoelectric piece of the self-made

piezoelectric array at 600K, the sensitivity is $120\frac{uV}{kPa}$, put it again into equation *(3.1)* to get, at frequency 600kHz, -78.41dB. Then change to the reception energy converter, use the same method to measure the sensitivity at different range, figure 3-10(A) is the sensitivity of emission energy converter at frequency 0 to 90kHz, figure 3-10(B) is the sensitivity of emission energy converter at frequency 0 to 90kHz, figure 3-11(A) is the sensitivity of reception energy converter at frequency 200kHz to 1 MHz, figure 3-11(B) is the sensitivity of reception energy converter at frequency 200kHz to 1 MHz.

3-4. The measurement of underwater transducer and array acoustical field

The driving source of commonly seen ultrasonic wave can be divided into continuous wave and impulse [33-35], in the last section, continuous wave is used as the excitation source, it is mainly to observe the sensitivity when the frequency is changed. But in this section, pulse wave is used, the main reason is to reduce the resonant interference of the water tank and to enhance the accuracy of acoustic field intensity. Two main methods are used in the water tank test, namely, **Pulse-through Method** and **Pulse-echo Method,** figure 3-12(A) is **Pulse-through Method**, figure 3-12(B) is **Pulse-through Method,** at the same test environment, we can find the location of the bouncing wave, figure 3-12(B) is about two times of figure 3-12(A), next, let's take a look at the amplified bouncing wave signal, figure 3-13(A) is a direct reception of the water sound receiver, its amplitude change from large to small, we know that the water sound receiver receives the maximum acoustic pressure at the first moment, then it gradually reduces. In figure 3-13(B),

water sound receiver is impacted and the bouncing wave is received, if we observe the amplified bouncing wave signal, its amplitude changes from small to large and then weakens gradually, therefore, we know that the bouncing wave must contain the object information of the water sound receiver.

3-4-1. Near field and far field

According to the descriptions in section 2-3 on ultrasonic wave acoustic field theory, the pulse signal in each channel is used to decide its acoustic field and focus characteristics, if the whole experimental array is connected to the wavelet emitted by circuit of no time difference, then, software can be used to simulate the incident wavelet drawing. The so-called Gaussian distribution [36-37] of acoustic wavelet is the acoustic field distribution of a surface parallel to the array direction, this is as shown in figure 3-14, the acoustic field distribution emitted by the array is irregular in the near field but is Gaussian distribution in the far field, therefore, Gaussian distribution is defined as the acoustic field out of the emission probe array. The far field distance taken by this experiment is the commonly seen definition of far field, that is

$$N = d^2 F \big/ 4c \qquad\qquad (3.4)$$

Wherein N is the far field scope of the array, d is the array width, F is the driving frequency of the array, c is the acoustic speed in the water.

In the experimental process, the acoustic speed in the water is 1504m/s, array width is 27cm, take the driving frequency of 600kHz, and put all these parameters into equation (3.4), we can obtain the near field distance to be 7.27cm, the distribution drawing is as shown in figure 3-15.

3-4-2. The underwater acoustical field [38]

Single element water acoustic field

Use the same experimental architecture, we perform the underwater radiation acoustic field of piezoelectric ceramic energy converter and its array and change the continuous wave signal to impulse signal, we also select one of the energy converters in the array to be connected to the pulse signal from the pulse signal analyzer, meanwhile, we use mechanical device to let the emission array have a distance of 40cm to the emission source, measurements of equal distance at 0~180 degrees are then performed, from figure 3-16 we can obviously see the amplitude change of bouncing signal received at different angles, then the signal is received by a water sound receiver and sent to an impulse signal amplifier, the signal is finally acquired by a digital oscilloscope and sent to a PC, then take a logarithm on the peak to peak value of the amplitude and perform normalization on the result. Collect all the signals from all angles, then draw the water radiation acoustic field drawing and compare it with the ideal simulation drawing, the water acoustic field of the emission piezoelectric ceramic is as shown in figure 3-17(A), polar coordinate is used to represent it, as shown in figure 3-17(B).

Water acoustic field of array component

Use the same experimental architecture to perform the underwater radiation acoustic field of the energy converter of the piezoelectric

ceramic and its array and change the continuous wave signal to impulse signal, , meanwhile, select an array and connect it to pulse signal of no time difference, and use mechanical device to let the emission array have a distance of 40cm to the emission source, measurements of equal distance at 0~180 degrees are then performed, then the signal is received by a water sound receiver and sent to an impulse signal amplifier, the signal is finally acquired by a digital oscilloscope and sent to a PC, then take a logarithm on the peak to peak value of the amplitude and perform normalization on the result. Collect all the signals from all angles, then draw the water radiation acoustic field drawing and compare it with the ideal simulation drawing as shown in figure 3-18(A), polar coordinate is also used to represent it, as shown in figure 3-18(B). This figure can show the directionality of the array.

3-5. Measurement Result and Discuss

In the sensitivity test experiment, function wave generator is used to generate continuous wave of frequency in the range 0Hz to 1MHz and amplitude of 15V as the outer driving triggering of driving pulse/signal reception analyzer, the main purpose is to verify the characteristic of the designed energy converter and to meet the requirements of emission system and acquisition system. From the sensitivity drawing of this chapter we know that it has the highest sensitivity at 600kHz, and the received sensitivity has a specific feature in the range 480kH to 640kHz, it generates a maximum mechanical electrical coupling with the designed array at 600kHz, which in turn generates ultrasonic wave of maximum energy, meanwhile, it meets a frequency range of 160kHz on the

reception array. The advantage of using continuous wave for the sensitivity measurement is that the frequency range is adjustable, but the disadvantage is that the continuous ultrasonic wave is easily affected by the resonance in the water tank.

For the water acoustic field of ultrasonic wave array, pulse/signal reception analyzer is used to generate pulse signal for far field experiment in order to enhance the acoustic field intensity accuracy, from the figure we know that in the near field range the array acoustic field can be calculated by equation (3.4), it is 7.27cm, within 7.27cm the acoustic wave acoustic field does not have uniform distribution, out of 7.27cm the acoustic field is Gaussian distribution and starts to decrease and approach a steady state, far field will be taken in the future underwater acoustic field measurement.

For the water acoustic field of ultrasonic wave array, the voltage pulse amplitude signals collected from all angles are acquired by the oscilloscope and transferred into the PC to be converted to dB unit, from the figure, we can clearly see that there are several wavelets there, besides, the main peak width at -6dB can be calculated, in the next section, this main peak width is going to be used to perform parallel line scanning.

Chapter 4

Underwater ultrasonic signals analysis and

underwater imaging system design

4-1 Ultrasonic image format

Based on different needs, the ultrasonic imaging is always in various forms and specifications. For example, the ultrasonic wave used in industrial non-destructive inspection [39] is transmitting in a solid object impenetrable to light, so it is frequently used in pulse reflection ultrasonic inspection equipments for detecting defects [40]. The uses in medical aspect are even more diverse, such as B-mode scanning for fetus imaging, M-mode for scanning internal organs, colored Doppler imaging mode, amplitude-mode used in ophthalmology and the constant depth-mode for deep scanning [41-44], etc. In this thesis, the amplitude-mode and brightness-mode will be used in applications in detecting underwater objects.

Amplitude-Mode(Point Scan)

In this thesis, the signals collected in sections 2 and 3 of Chapter 3 are A-mode signals, which can be used for calculating the time of flight for emission and reflection signals in order to determine the distance and position [45], as shown in Fig. 4-1. The advantages of A-mode is that the signals colleted are simpler, there are less data and calculation requiring analysis, the analysis methods are easier to understand and using the method of processing analogue signals will be enough to process all the works without complicated digital processor to analyze the signals. Even with less electronic circuit technology or hardware design and calculation ability, the distance of underwater object can still be determined. However, the disadvantages are that it cannot perform wide-range survey and this imaging mode cannot quantitatively analyze the tissue structure.

Brightness-mode (Line Detection)

The most common ultrasonic wave imaging mode is the images created by B-mode, as shown in Fig. 4-02(A), which is the ultrasonic image of the skin on a human arm, and Fig. 4-02(B), which is an image of

mouse embryo. This mode displays the level of ultrasonic beam signal reflection using grey scale. In ultrasonic imaging system, various methods are used to create this imaging mode. Conventionally, a linear motor drives the ultrasonic probe and several sets of A-mode signals can be obtained or use the advanced technology, which is stated in this thesis, of beam forming to control the beam to scan and acquire the required sets of A-mode signals, and then high speed electrical circuits are used to collected the signals. After being sampled, the combinations of A-mode signals from different locations are processed with block down, cutoff low pass filtering and transformation of image format and B-mode images are obtained. The benefit of doing so is that the display of images using logarithmic distribution and grey scale can be used for detecting and scanning underwater objects while combining various equipments for applications, such as combining an underwater robotic arm for salvaging [46].

Constant depth-mode (Area Scanning and Deep Scanning)

When designing an ultrasonic energy converter array, usually a strongly focused array will come out. A strongly focused array tends to have stronger signals at the focus, which can be used for observing the structure of a certain image at its depth profile. The orientation of vertical imaging plane is also multiply and linearly scanned. For image format processing, the readings of multiple 2-D images at a certain depth are recorded and a B-mode image at a fixed depth is re-generated at the orientation of the original vertical imaging plane using grey scale display. What is recorded is a whole signal under multiple profiles, as shown in Fig. 4-03(A), which is a scheme of multiple 2-D ultrasonic images overlapping, and Fig. 4-03(B), which is the 3-D ultrasonic image established after overlapping [47].

4-2 T-type transducer resolution of space of the array

In order to create a 3-D ultrasonic image, we have developed a T-type array, which is the combination of a 1-D parallel emission array and a 1-D vertical receiving array, as shown in Fig. 4-04, which is the

scheme of T-type array, and Fig. 4-05, which is the home-made T-type array. This t-type array is 1cm long, 1mm wide. The emission array is 2.8cm thick and the receiving array is 3.2cm thick. The distance between the center points of elements is 1.23mm. The parallel emission array use beam forming, so the beam is narrower at some angle but wider in vertical direction, and combined with vertical receiving array, then the T-type array is in shape. T-type array is point-focused, as shown in Fig. 4-06(A), which is the simulation of energy distribution of T array focus point, and Fig. 4-06(B), which is an isotropic view. From the figure, the point focus can be observed and the angle of direction for the maximum return signal, which is the contribution of the reflection of object at this point, can be obtained. The moment when the maximum occurs can be used to estimate the distance between object and array, and then beam forming is used to scan every direction to achieve amplitude images and range images and to create 3D ultrasonic images [48-49].

In order to 3D ultrasonic images, the range and pattern of must be defined. The parallel emission scans from +15° to -15°, and then a single energy converter in the vertical array is used to vertically receive. From this, therefore, it is found that one single ultrasonic image requires 31x19=589 pieces of data. To achieve this, the emission system and reception system have to be developed.

4-3 Phase Array Transmit System

4-3-1. System exploitation object and atmosphere

Beam forming mainly uses the time differentials between individual elements for control, whose scheme is shown as Fig. 4-07, while a 19-channel phase shifted scan emission system is developed with self-made ultrasonic energy converter array, and the emission system can generate the pulse signals of 600KHz ± 10% of frequency, the time differentials between channel ranging from 0.1us~23us and 150V ± 15% of amplitude, through the control of graphic window interface and RS232 cables. The block diagram is shown as Fig. 4-08. The phase array pulsing system is shown as Fig. 4-09. The software and equipments used are listed as follow:

Hardware

(1) Industrial computer with General-Purpose 8-Slot Chassis for PXI interface and surrounding accessories

(2) RS232 DB-9 transmission cable

(3) Phased Array Transmit System

Software

(1) Windows XP

(2) GUI (Graphics User Interface)

4-3-2. RS-232 Transmission Protocol

Transmission Protocol

A complete driving system contains transmission end, receiving end, data interpretation interface and solid channels for data transmission. The purpose of driving is for control of program, and information must be transmitted before it can reach another equipment. While transmitting, the transmission end always transmits data through fixed route and procedure regardless the data format at the origin and destination, and the receiving end receives the transmission based on the mutual protocol of communication. When transmitting, it can only be done through the mutually recognized communication interface.

Normally, there are two forms of data transmission: Parallel communication and Serial communication. Both forms of communication are shown in Fig. 4-10 and Fig. 4-11.
From the figures, it is clear that the so-called parallel communication can transmit 8 bits (1 byte) at one time, but serial communication can only transmit one bit. There is a 8-time difference by comparison. Regardless the huge difference, serial communication still survives. The reason is that although parallel communication can transmit 8 bits at one time, however, voltage drops and cross talking between frequencies may occur during the transmission due to the route structure, causing data errors. The situation will be worse if the distance of transmission is longer. Compared to this, serial communication transmits one bit at a time. Relatively speaking, there is only one level of data voltage to be dealt with at one time. Therefore, loss of data is unlikely from the data transmission accuracy point of view.

Typically, the common serial transmission protocols are RS-232, RS-485, USB and IEEE-1394, and the transmission interface used in this system is RS-232.

4-3-2. RS-232 Transmission Protocol

RS-232 (Recommended Standard-232) is the standard asynchronous transmission interface developed by Electronic Industries Association (EIA), which is also widely equipped communication interface on most of PCs. On IBM-PC, a regular computer can connect up to 4 RS-232 interfaces, which are usually referred as serial ports. Since RS-232 was developed by EIA, sometimes it is called EIA-232 as well. The latest version of RS-232 is the 4th generation, RS-232D. Generally, RS-232 comes out with 9-pin (DB-9) or 25-pin (DB-25) configuration. It is normal that a regular PC has 2 RS-232 and they are referred as COM1 and COM2. And also, some PCs have COM3 and COM4. But since COM1/COM3 share IQR4 and COM2/COM4 share IRQ3, the user can only use as many as 2 of the 4 COM ports. This interface is usually connected to modems, serial port mice, other monitors and instruments and equipments supporting serial transmission. Since serial ports are widely used, there are many instruments and equipments with data transmission function that come with RS-232 as basic feature. Therefore,

the practical applications can be very extensive [47-49].

The serial communication of RS-232 can be either synchronous or asynchronous. Synchronous communication is that both ends of communication are based on synchronized signals as the basis of communication. The mechanical specification of synchronous connection ports is 25 pins (DC-25). The asynchronous communication is using start bit and stop bit for the judgment of communication and the mechanical specification of asynchronous connection ports is 9 pins (DC-9). The definitions of DB-9 pins and the corresponding pins are shown in Tables 1 and 2. Every pin of RS-232 has its specific function, which is explained as follows:

(1) Carrier wave detection, **CD**

This pin is controlled by terminal end. When communication route is connected, the data to be transmitted is attached to the carrier wave signal, and through this pin, the terminal equipment will tell the computer that there is a carrier wave signal detected. The system is on line at this moment. On the other hand, if the computer does not receive this signal, the computer will determine that it is now off line and the connection will be terminated.

(2) Receiving characters, **RXD**

The function of this pin is to receive the data transmitted from far end. During the transmission and receiving, the data is digitally transmitted. The high and low electric potentials represent 0 and after being transferred into ASCII code. In the electric specification of RS-232, the signal voltage of +3V   +15V stands for 1 and -3V   -15V stands for 0. According to the measurement of typical practical applications, the signal voltage falls between approximately +9V and -9V.

(3) Transmitting characters, **TXD**

The pin transmits the data tat computer wants to transmit. The actuation is the same as RXD.

(4) Data terminal ready, **DTR**

This pin is controlled by computer to inform the terminal end that it is ok to transmit. If this pin is at high potential, and that means the computer is ready to receive transmission.

(5) Grounding, **GND**

This pin serves as the signal reference level for computer and terminal end. The grounding levels of the equipments at both ends have to be the same. Since the data transmission of RS-232 is done by single-end

transmission and the voltage level of signal comes from the reference grounding level, therefore, the grounding cables of both transmission end and receiving end must be connected to avoid data errors due to different levels.

(6) Date string ready, **DSR**

This pin is controlled by terminal end. The terminal equipment will inform the computer through the high potential of this pin that the receiving end is ready and please start the transmission.

(7) Request for transmission, **RTS**

This pin is controlled by computer and is used to tell the terminal to transmit data immediately to computer. When receiving this signal, the terminal end will transmit the data collected to computer. All the data will be stored in the buffer of terminal before the above starts.

(8) Clear to transmit, **CTS**

This pin is controlled by terminal end for informing the computer to transmit the data to terminal equipment. When receiving this signal, the computer will start transmitting data to the terminal.

(9) Ringing detection, RI

This function is for modem, with which modem will inform the computer there is an incoming call and the computer will decide whether to take that call.

During the evolution of RS-232, since 25-pin configuration was defined for the need of synchronous communications, however, is has obsolete as the time progresses. Most modern day equipments are simplified to 9-pin asynchronous transmission. In PCs, the serial data transmission is controlled by Universal Asynchronous Receiver-Transmitter (ICUART) in asynchronous transmission, whose function is to control the data flow and data buffering.

The so-called data flow control is the key to ensure the correctness of data. During the transmission, in order to ensure that both transmission and receiving ends can correctly receive data without missing, both ends have to communicate with each other and proceed the transmission and receiving after confirming the working status of each other. This pattern is known as hand shaking. For RS-232, the hand shaking of hardware involves DSR, CTS, DTR and RTS. The flow is described as follows:

(1) The terminal end increases the potential level of communication port DSR, indicating that the terminal end is ready to receive

transmission.

(2) The computer increases the potential level of DTR, indicating that the computer has the data ready.

(3) The computer increases the potential level of RTS, notifying terminal end the transmission is about to begin.

(4) The terminal end increases the potential level of RTS, telling the computer to start the transmission.

(5) Then the transmission begins.

The flow of hand shaking is shown in Fig. 4-12.

4-3-3. Graphics User Control interface (GUI)

The graphic control interface window is shown in Fig. 4-13. The following will explain some of the important parameters:

Instruction for menu

[File]:	Options related to opening a file.
[Load Delay]:	Assign a file name (*.DLY) and save the data in the Delay Pattern Table in the data file.
[Save Delay As ...]:	Assign a file name (*.DLY) and save the data in the Delay Pattern Table in the data file.
[Verify Delay]:	View/modify the Delay Pattern Table in the program.
[Exit]:	Terminate the execution of PhaseTX program.
[Edit]:	Open the options related to Edit.
[COM port]:	Assign the COM port that communicates with emission control circuit system.
[Run]:	Assign the COM port that communicates with emission control circuit system.
[Start]:	Start the emission control circuit system to carry out 31 delay pattern emissions at pulse repetition rate.
[Set Timer]:	Set the pulse repetition rate of the emission control circuit system.
[Download]:	Download the data in Delay Pattern Table to the emission control circuit system.
[Help]:	Open the options related to Help.

[Manual]:	Open/View instruction of use in the program.
[About]:	The information about the version of PhaseTX

Instruction for buttons in the interface:

[Set Timer]:	Set the pulse repetition rate of the emission control circuit system.
[Load Default Delay]:	Load the default delay pattern data file (DelayPattern.DLY).
[Verify]:	View/Modify the Delay Pattern Table in the program.
[START]:	Start the emission control circuit system to carry out 31 delay pattern emissions at pulse repetition rate.

Instruction for interface parameters:

[Time of Flight]:	Time of Flight: Set the travel time needed for emitting/receiving ultrasonic wave in 1ms.
[Data Transfer Time]:	Data Transfer Time: Set the time needed for receiving signal data capture in 1ms.

The system can set up the pulse repetition rate of the system based on the sum of Time of Flight and Data Transfer Time.

Delay time pattern :

(1) Delay time pattern

(1.1) The setup of overall emission is primarily to control the range of scanning angle and the forming of beam by delay time pattern, which is the key technique of the entire system. With the request of emitting system, the target is set to be 19 emitting array elements, and the data format is TX1 to TX19.

(1.2) The scanning angle ranges from +15° to -15° and there are 31 scanning beams with the data format of L1 to L31.

(1.3) Data Structure of Delay pattern files: There are 31 sets of delay patterns and each pattern contains 19 delay values. The delay values are separated by commas. The accuracy is up to 0.1us. There is no comma behind the last value in each set of delay

pattern and each set of delay pattern is entered in different line, such as:

1.0,2.0,3.0,4.0,5.0,6.0,7.0,8.0,9.0,10.0,9.0,8.0,7.0,6.0,5.0,4.0,3.0,2.0,1.0 …

…

(2) Editing a delay time pattern data file

  (2.1) When editing, please use the built-in word editor of Windows: NotePad.EXE

  (2.2) Please refer to the data structure of delay pattern for editing data contents.

  (2.3) The delay values are in us.

  (2.4) The range of Delay values: no less than0.1us and no greater than 23.0us

  (2.5) When saving files, the extension of file name must be .DLY.

(3) How to edit a delay time pattern data file

  (2.1) Press [Verify] and open the Delay Pattern Table window.

  (2.2) Move the fields with direction keys or click the desired field with your mouse.

  (2.3) Double-click the mouse or press the Enter key on the keyboard to switch between the editing modes of date fields.

  (2.4) Enter the delay values in us

  (2.5) Enter the delay values in us; the range of Delay values: no less than0.1us and no greater than 23.0us

  (2.6) Run the menu [Save Delay As ...] to save the modified data.

To match the emission array, the phase array is utilized [50]. Depending on the needs of target, the frequencies of all 19 channel drivers require $600kHz \pm 10\%$. Each of the channels is connected to piezo-electric plate and the time differential of each channel ranges from

0.1us~23us for 150V ± 15%. The block diagram of phase shifted emission system is shown in Fig. 8. The system is mainly using the FPGA scan and feeding logic signals through 19 pins to control power MOS pass, and then the inductive magnetic coil generates high frequency driving voltage and pick pin number 10 as the synchronizing signal, finally the editing control interface in the industrial or personal computer will send out control through the transmission from RS232.

The working purpose of phase shifted emission system primarily is to use the delay time of each channel to make each of the piezo-electric plates in the array generate delayed vibration and to further control the direction and angle of beam deviation, and this is the said beam forming, as shown in Fig. 9. The t_n and T_n in Fig. 9 are the time of each piezo-electric plate and the time that the ultrasonic wave travels through water respectively. The above factors must be far greater than these times when designing B-mode scan.

After the system is completed, set the scanning angle of beam from +15° to -15°, totally 31 signals from the angles scanned, and then use the graphic control interface to establish the delay table for 31 channels and 31 angles, as shown in Fig. 4-14. The time for scanning 31 angles is as the time of flight in the window interface; the time for waiting signal processing is as the data transfer time shwon in window interface in fig. 9. The time for one linear scan is 1.5 seconds and the system test is successful.

4-4. Signal retrieval system

4-4-1. System exploitation object and atmosphere

In order to match the emission system and the self-made ultrasonic energy converter array, the high speed data capturing system is designed. The graphic control window LabView software design can generate the pulse signals of $600KHz \pm 10\%$ of frequency, the time differentials between channels ranging from 0.1us~23us and $150V \pm 15\%$ of amplitude through RS232 cables. The hardware used is listed as follows:

Hardware

(1) Industrial computer with General-Purpose 8-Slot Chassis for PXI and surrounding accessories

(2)NI PXI-5112 data capture card (100 MHz, 100 MS/s 8-Bit Digitizers)

Software

(1) Windows XP

(2) LabView 7.0 graphical development system

For the structure of PC-Based capture systems, in addition to the hardware installed as per system requirement, the choice of software is also a critical link of the chain. No matter what is the choice of platform or software, it will definitely have an influence on the stability, expandability, transplantability of the entire capture system and the limitations for data transmission and exchange, and also relate to whether the capture system is good enough. Therefore, a thorough consideration must be taken for this in order to match the necessary control function editing program to carry out the electric and mechanical control and the integration of human interface, while the control software ultimately have to be built on the platform. And also in data transmission, for example in industry, the current trend of capture system often opens up the data under Windows. Through DDE (Dynamic Data Exchange), DDL (Dynamic Data Link) and OLE (Object Linking and Embedding), the data can be captured and relayed to the self-developed program for calculations. The improvement of

efficiency and the security of operation make automation possible in this information network built with PCs, which has already been the inevitable trend in the industries [51-52].

4-4-2. LabView program design environment

Now it comes to the establishment of capture system. The capture system used in this research is edited using LabVIEW. This program is the cross-platform monitoring system developed by National Instrument, which can be built on Mac, Sun SPARC station, HP 9000/700 series work station and Windows-based PCs. Since LabView and its work environment is a 32-bit platform, therefore, it can run on PCs and give an excellent performance. And also, in Local Area Network, LabView supports the function of linking external signals through the driving and setup of Windows, such as TCP/IP (Transmission Control Protocol /Internet Protocol), DLLs (Dynamic Link Libraries) and Active X, in order to acquire more resources to enable the operation on network. And more, LabView also supports communication interfaces such as GPIB (IEEE-488, General Purpose Interface Bus), VXI (VME eXtensions for Instrumentation, VME-Versa Modular Eurocard), PXI, RS-232 and RS-485, as well as DAQ (Data Acquisition) and (Image Acquisition), etc.

(1) Virtual Instrument

The term LabView is the abbreviation for Laboratory Virtual Instrument Engineering Workbench, which stands for the applications of virtual instrument. The graphic instruments designed with LabView are similar to real instruments in all aspects regardless appearance or the method of operations. Therefore, it is also referred as Virtual Instrument, VI for short. Since monitoring systems requires various types of data, PCs are used for displaying data after the signals are measured and processed. As the result, the use of virtual instrument not only save the costs of real instruments, but also simplifies the operations and maintenance of real instruments while improving the flexibility of the use of monitoring system. In addition to signal measuring and monitoring, the addition of control procedure makes the monitoring system more complete. The operation of monitoring and

control is one of the advantages of LabView. This operation of running data collecting, monitoring and controlling with computers is normally referred as Supervisory Control and Data Acquisition or SCADA.

(2) Graphics Language

Graphics Language, also called G language, edits programs using graphics instead of using scripts.　The program describes the behavior of program solely based on graphics and symbols, and data is transmitted between graphic nodes in the program with data flow. The graphic virtual instrument has the characteristics of hierarchical and modular, so it can be the master program at the top or the lower subroutine. And with the modularized structure, the entire master program can be divided into strings of minor modules and each of these modules can be further developed as independent VIs. Each of these VIs can perform specific task independently, and also several VIs can be combined under the master program and becomes a specific function in the entire program. The additional benefit that comes with modularized program is that each of the sub-VIs can be executed, making debugging faster.

(3) Front Panel

The front panel is the interface for communications between user and VI and is in charge of receiving order from user and displaying the result of execution on the panel, allowing user to identify the current status of monitoring system.

Like the control panel of a real instrument, the front panel consists of display module and control components. The control can simulate the input components on the conventional instruments, such as switches, knobs and keys, etc., for users to enter orders. The format of these orders is entered in numbers, Boolean components and character strings for monitoring program to process. After being processed, the display module will display the calculated data on the front panel to inform the user of the result of processing. The appearance can be thermometer, hygrometer, electrical meter and indicator lights, etc, and the appearance, dimensions, positions, colors and attributes can be altered as per user's request, as if real components are displaying on the computer screen virtually.

(4) Block Diagram

Block diagram is the core of data operations and processing of LabView VI. Since LabView works under graphic environment,

therefore block diagram is equivalent to the original programming code of conventional programming language. The components of block diagram include lower end of VIs, built-in functions and constants, and the program block attached to the control and display components of the front panel as well. This block is displayed as an icon. Every component on the front panel of LabView has a corresponding program block. When user changes the status of control components on the front panel, such as switch or knob, the data of value of the icon corresponding to the block will change accordingly. Through the connector, the data is transferred to program blocks of different functions for operations, and after being processed, the data is then transferred through the connector to the icon correspondent to display component, displaying on the front panel.

Other than regular operations, LabView also provides structured programming, such as flow control and loop control. In loop control, there are for loops (assigning the number of loops to run) and while loops (determining the loop conditions), and the flow control contains Sequence structures and Case. These structured programming designs contribute the editing of large programs, allowing the structure of program more orderly. And also, LabVIEW has a program structure that does not affect the program flow, which is Formula nodes framework, specialized in complicated mathematical operations. With this framework, all we have to do is to enter the mathematical formula in the nodes with specific format and then to connect the correspondent input and out nodes with connectors, and the mathematical formula will be processed. This is very helpful if there are many mathematical operations and analyses to be processed,

In data processing, like any typical programming language, LabView can process various data formats, such as local variables, global variable, arrays, matrices and clusters, and also can combine with database to carrying archiving and analysis management as well.

(5) Icon and Connector

Icon represents the display of the materialization of VI, equivalent to a subroutine in a program. The icon itself is also an independent program. Connectors define the input/output nodes of each icon as if they are the inlet/outlet of input/output parameters in the control program. Therefore, if each of the icons is to connect to external

program for communications or connections, it has to go through the connectors before making any data input/output.

Each of the icons with independent functions connects one another and shares the tasks, which is exactly the essence of modularization. Each module communicates one another through connections. The independent modules make debugging much easier and also simplify the structure of master program while making program operation more flexible.

4-4-3. Graphics User Control interface

The data capture is the front end operation of signal acquisition. Through the energy converter, the signals are captured and the captured physical measurements are quantified, so the signals can be quickly converted into images.

The purpose of this function is to receive the signals from 31 angels ranging from +15° to -15° and to carry out linear scan in conjunction of emission array beam forming for capturing the signals within the 2 second time frame for later definition of sampling space.

The block diagram is shown in Fig. 4-15 and the graphic control interface is shown in Fig. 4-16. The following will explain some of the important parameters:

[Setting Page]:	Set the parameter pages
[Main Page]:	The signal capture page

[Setting Page]	Includes the following parameter settings:
[Resource name]:	Address of hardware
[Channel Parameter]:	Basic settings of hardware
[Record length]:	The memory volume of capture card is 8MB.

[Simple rate]:	The density of sampling
[Reference position]:	The reference point of start
[Trigger lever]:	The voltage range of signal capture
[Max Time (s)]:	Max. time of waiting
[Duration Time / Peak (s)]:	The duration of sampling
[Display Duration (ms)]:	The display of conversion at all 31 angles
[File Folder Path]:	Address of file folder
[Name Group]:	Name of the file
[Main Page]	Includes the following parameter settings:
[Graph]:	Indicates which angle is now received, totally 31 angles.
[Signal]:	Signal capture display

During the experiment, the frequency of system sampling is the result of the memory on board of A/D card divided by sampling space, which can be adjusted from the Windows interface. The receiving time is the 8MB memory of the data capture card divided by he preset 5.33MB, which is equivalent to the signals captured in 1.5 seconds. The sampling frequency of this system is 5.56MHz. The sampling duration of a single data is 1 millisecond. The detectable range (speed of sound in water times time) is 1.5m. The signals that are linearly scanned in 1.5s are sampled and received by a piezo-electric plate, and then the signals within these 1.5s are captured after analyzed. There is initial pulse signal in the signals

of every angle. When the system is triggered by the initial signal, the signals within 1ms before and after the signal triggers the system will be sampled and saved, and totally 31 sets of signals are primary linear scan signals. The signals will then be switched to the vertically received signals by the sequence and a 31x19 3D ultrasonic image is formed.

4-5. Experiment process and signal retrieval

4-5-1. Ultrasonic signal

In this paragraph, the beam scan experiment will conduct the underwater uncovered square box ultrasonic (B-mode) scan using the emission system, signal capture system and 19x19 T-type piezo-electric array [53-55], as shown in Fig. 4-17. The scheme of measuring system is shown in Fig. 4-18. Before integrating the emission system and receiving system, the scanning and measuring are carried out with simple mechanical devices and the scanned signals are shown in Fig. 4-19(A) and (B). From the figures, the change of signals is clearly observed after being scanned since it is more time-consuming. Later, the automatic scan is executed with the integration of the emission system and data capture system and uses the one-dimensional 19-element piezo-electric plate emission array to scan 31 angles with beam forming and the one-dimensional vertical receiving 19-element piezo-electric plate array to receive the signals after the signals are amplified. The process takes only less than 2 seconds. From this, it is obvious that one 3D ultrasonic image requires 31x19 signals, which are 589 in total.

In the experiment, the center point of square box is 40cm away from

the array and tiled in 15 degrees. The reason for doing so is to reduce the ration between signals and to capture the signals with the assistance of control of computer interface to the times of emission system and capture system. The signal capture is shown in Fig. 4-20. Select any of the 589 signals, as shown in Fig. 4-21, and verify the signal with Fig. 4-21. It is known that the signal peak occurs at 536us on the time axis after emission, by multiplying the speed of sound in water 1504m/s, the result is 80.4cm, and then divided by 2, which is the round trip 40.2cm, it indicates the success of A-mode signal verification.

Due to the significant amount of data, one set of scan line (B-mode) is selected and from this set, 11 pieces of data are chosen every 3 degrees, and a 31x19 3D reflection amplitude graph (needed for imaging) is obtained as shown in Fig. 4-22. And then the signals are vertically converted by sequence and a 31x19 signal diagram is obtained. By now, the experiment has successfully captured B-mode signals.

4-5-2. Ultrasonic image

<u>Simulated ultrasonic wave</u>

Prior to the signal imaging, the ultrasonic imaging simulation is carried out using T-type array for scanning in order to simulate the ultrasonic imaging. The first step is to design the parallel emission and receiving arrays. The arrays feature 19 array elements, 1.25cm between array elements, and the emission and receiving arrays are perpendicular to each other. The surface of converter is rectangular and is 1mm wide,

2.8mm high and 5mm long. The center frequency is 600kHz and the system sampling frequency 5.56MHz, while the speed of sound under water is 1504m/s.

An uncovered square box of 17cm long at each side is built to simulate the actual environment. 4,000 scattering points are randomly distributed on each face and the strength of scattering is 1. The center of square box is 40cm away from the array and the square box of simulation is shown in Fig. 4-23.

Image the signals and the ultrasonic simulation image is shown in Fig. 24.

Actual ultrasonic imaging

The actual signal imaging is carried out using T-type array for scanning and MATLAB for ultrasonic imaging. In the underwater test environment, the framework of emission and receiving arrays is parallel emission array and receiving array. The arrays feature 19 array elements, 1.25cm between array elements, and the emission and receiving arrays are perpendicular to each other. The surface of converter is rectangular and is 1mm wide, 2.8mm high and 5mm long. The center frequency is 600kHz and the system sampling frequency 5.56MHz, while the speed of sound under water is 1504m/s.

In this measuring environment, the cube is an uncovered square box of 17cm long at each side, tilted 15 degrees to the X-axis. The actual setup is shown in Fig. 4-25. The range of scanning is mainly with linear scan, and then each element of the vertical receives the signals and the elements are connected to form a surface, totally 589 points, as shown in

Fig. 4-25. The center of the square box is 40cm away from the center of array. The actual ultrasonic image is shown in Fig. 4-26.

Chapter 5

Conclusion and Suggestion

5-1. Conclusion

The main goal of this article is to study the underwater imaging system and with the help from acoustics theory and simulation software, we can perform acoustic wave acoustic field simulation and energy converter array preparation and measure its acoustic characteristics. By using Phase Array emission system, in the exact front side of underwater array from 15 degree to -15 degree, a total of 31 sets of wavelet scanning is performed. Meanwhile, by using T-type architecture array, one dimensional 19 piezoelectric ceramic emission wavelet scanning is performed; in another one dimensional vertical emission array, 19 energy converters receive the signal respectively, therefore, a ultrasonic image drawing is completed, it takes $31 \times 19 = 589$ reflecting signal data. Linear

scanning B-mode is used as the scanning method, every set of B-mode scanning is connected to form an acoustic wave 3D gray scale image.

During the scanning, not only the signal at the start time and delayed reflecting time is recorded, but also the spatial location is recorded. This ultrasonic imaging system needs to perform precise wavelet scanning and acquisition of massive data, the measurement thus needs to be automated. Therefore, in this system, computer graphic control interface is used to control the emission circuit delay in each channel through RS232 to achieve the wavelet control function and perform wavelet scanning, besides, Labview graphic control interface is used to design automatic acquisition process flow and system. Meanwhile, data is analyzed after each experiment for improvement, this is to modify the design of experiment.

The experimental results of this study can be summarized as in the followings:

1 The design of piezoelectric energy converter and its array

(1) From the result of this study we know that when the number of the array element increases, it can make the main peak width narrower and reduce the interference from the side wavelet, besides, it has distinguished effect on the resolution of the gray scale image of the ultrasonic wave, although the increase in the spacing between the center of each element can make the main peak width narrower, it sacrifices the image quality instead; besides, the smaller the number of the period of the emitted pulse signal the better, the number should be at least smaller than the number of array element, it can increase the scope resolution of the system.

(2) There are many methods for improvement, but it needs to be taken into account if it can be realized in the hardware, for example, we know the larger the number of array element the better, but each element has to be connected to a high frequency and high voltage driver. However, just the design of this single emission pulse generator will cost a lot, not to say the integration of many sets of hardware, the hardware cost is high but the effect is low. Therefore, we select a 19 element emission array which has optimum reception, besides, considering the coupling characteristic, we adopt 19 element reception array which is a design that can be supported in the electronic circuit hardware.

2 The design of emission system:

(1)The higher the energy of the driver the better, it helps significantly to increase the signal to noise ratio of the received reflected signal and the later image formed becomes easily to be distinguished.

(2)The delay time of the high frequency and high voltage driver of each channel is to use Windows GUI interface to control 19 pulse generators through RS232. In the Windows adjustable range, that is, $0.1\mu s \sim 23\mu s$, each pulse generated signal can transfer the generated direction of controlled wavelet by using phase shift signal. By selecting the optimum delay time, the focus point of the wavelet, that is, the point with highest energy, can then impact the object to generate reflected reception of maximum energy.

3 Data acquisition system

(1)Integrate vertical one dimensional reception array, the sampling frequency of the system is 5.56MHz, the sampling frequency is the memory on the A/D card divided by the sampling space, the sampling

parameter can be adjusted by the Windows interface. One set of linear scanning will take about 1.5 seconds, acquire all the signals happened in this 1.5s and analyze them, signal in each angle has its start pulse signal, when system has the triggering of start signal, sample all the signals that are 1ms apart from this start signal and save them. (2) The time control between emission system and acquisition system comes from the triggering after data has come in.

4 Image

(1)Use MATLAB to compensate first the signal parallel shift, acquire the data as image matrix, then perform amplitude imaging, in the next step, acquire the signal distance as a matrix too, take product of both matrixes for compensation and correction.

(2) Use the filtering function to increase the signal to noise ratio of the ultrasonic wave image and further to obtain image of highest quality.

5-2. Suggestion

(1)Ultrasonic wave energy converter and its array are manufactured by integrating semiconductor processes or MEMs technology, high frequency capacitor type ultrasonic energy converter is integrated to be used as high frequency ultrasonic imaging system.

(2) Integrate the emission system and the reception system as a set of Windows control interface, besides, miniaturize the hardware and reduce the complexity of the hardware circuit, write smart database to store the scanner data.

(3) Underwater ultrasonic array system can be combined with internet

function and dynamic imaging in the future.

The underwater ultrasonic imaging system developed in this study, accompanied with ultrasonic piezoelectric ceramic array, has successfully used phase shift emission system through the B-mode scanning of reflected signals, the vertical array of 19 receivers has received the signals in sequence through Labview control and form the image, we hope that the results in this study can be helpful to people who want to find applications in the design or manufacturing of the underwater ultrasonic imaging system.