New Technologies of ARIETTA Diagnostic Ultrasound System

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We developed ARIETTA※1 V70 and ARIETTA V60 diagnostic ultrasound systems, the best among the systems in this class, by inheriting the technologies and the performance of Hitachi Medical and Aloka, for realizing higher performance and downsizing. Following is the report on the new imaging technologies towards high image quality centering on the Symphonic Technology.

Key Words: Diagnostic Ultrasound, ARIETTA, Symphonic Technology

1. Introduction

Hitachi Aloka Medical, Ltd. (hereinafter referred to as Hitachi Aloka) was established in April 2011 as a result of the integration of Hitachi Group's diagnostic ultrasound business. Hitachi Aloka has now become Japan's largest ultrasound manufacturing company, marketing 12 different diagnostic ultrasound systems and more than 250 types of probes (transducers). However, to establish Hitachi Group's brand in the diagnostic ultrasound industry, it was necessary to integrate the different operability of systems developed by the two companies and harmonize overlapping functions and probes as soon as possible.

The process was started by Hitachi Medical Corporation and Aloka Co., Ltd. evaluating each other. Both had long but different experiences of global introductions of diagnostic ultrasound systems [1) 2)], and also differed in the performance of their systems in each discipline. In the venture to develop the ARIETTA series[*1], the goal was to integrate the basic capabilities, functionalities, usabilities, and new technologies of both companies to achieve a higher level of customer satisfaction.

The ARIETTA series comprises two models, ARIETTA V70 and ARIETTA V60. The former integrates the technical assets of the high-end systems of Hitachi Medical Corporation and Aloka Co., Ltd., and the latter features compactness and ease of use. Symphonic Technology encompasses the separate technologies that serve as the pillars of the ARIETTA series (Figure 1).

Figure 1. Diagnostic ultrasound ARIETTA series
Left: ARIETTA V70; Right: ARIETTA V60

2. Symphonic Technology

Symphonic Technology divides the process from ultrasonic signal transmission to image display on the monitor into the following five modules:

- Probe
- Frontend
- Beam Former
- Backend
- Monitor

It adopts and harmonizes the optimized technologies throughout the ultrasound system to achieve the highest possible image quality (Figure 2).

The most important challenge in this quest is how to secure efficiency and fidelity in energy transfer between the system and the subject — in other words, how to communicate energy with high sensitivity over a broad frequency range. For probes and the frontend, in particular, there are four factors to consider:

1. Efficiency of electrical energy transfer between the main unit and the probe
2. Efficiency of electromechanical energy conversion within the probe
3. Efficiency of mechanical energy propagation between the probe and the subject
4. Shaping and focusing of the ultrasonic beam in the subject

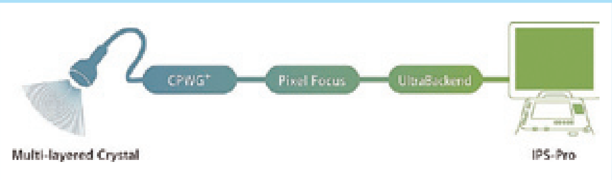

Figure 2: Symphonic Technology

Symphonic Technology, the imaging technology adopted in the ARIETTA series, consists of five high-performance modules.

(1) Probe

Probe design requires optimization of signal transmission efficiency between the main unit of the diagnostic ultrasound system and the subject, and calls for an advanced architecture built on engineering technologies in the fields of electricity, machinery, acoustics, etc[3]. We have developed a new group of probes called Smart Transducer series for the ARIETTA series. These probes use the newly developed Multi-layered Crystal Technology as standard for the medium-frequency convex probes, to achieve yet greater image quality.

A transmitted ultrasonic signal reflected by tissues in the body will be received back at the probe as echo signals. The energy of these echo signals are transferred through the matching layer that allows efficient propagation of ultrasonic waves, and the vibrations will be converted by the piezoelectric transducer to electrical energy. This electrical energy then passes through a cable to the preamplifier of the main unit of the diagnostic ultrasound system. The recent trend has been for transducers to be composed of multiple transducer elements to reduce artifact. However, the greater the number of transducer elements, the smaller the reception area per element. As a result, the output impedance of the transducer becomes higher than the load impedance of the cable and preamplifier, increasing energy loss due to poor matching and the likelihood of reduced sensitivity of the signal reception (Figure 3). The Multi-layered Crystal Technology, where the transducer element is composed of multiple layers, improves the impedance matching between the cable and the main unit. Sensitivity is improved especially for low-frequency probes where the electrical impedance of the transducer is increased, and for probes with transducers composed of multiple elements (Figure 4).

In addition, the ARIETTA series comes with a selection of probes made from single crystal piezoelectric material. In engineering, a single crystal is defined as a material in which atoms are regularly aligned with the axes of all crystals oriented in the same direction in the material. A polycrystal is defined as a random aggregation of single crystals. The use of this single crystal piezoelectric material in the transducer allows the direction of the mechanical strains in the material to be aligned in the same intended direction to produce a high piezoelectric effect (Figure 5).

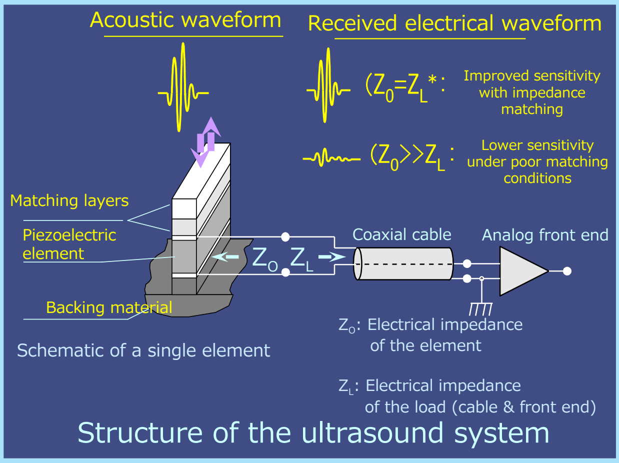

Figure 3: Impedance matching between the probe and the main unit

Poor matching results in an attenuation of the output waveform and reduced sensitivity.

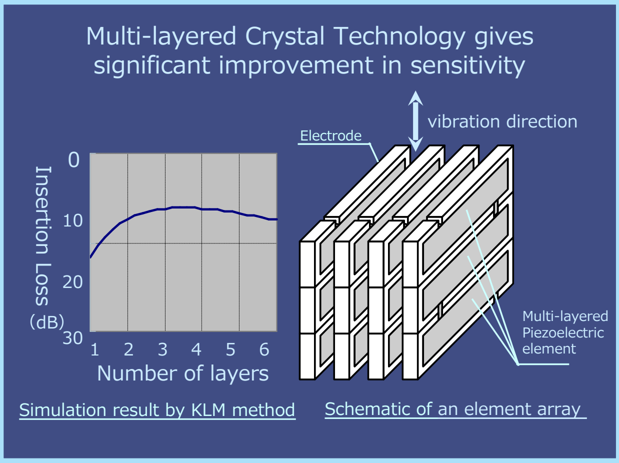

Figure 4: Lamination using the Multi-layered Crystal Technology

Reduced energy loss and improved sensitivity can be expected.

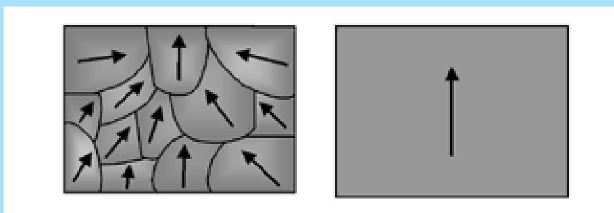

Figure 5: Diagram showing the orientation of mechanical strains in a piezoelectric material

A single crystal allows energy to be aligned in the same direction.

The electromechanical coupling factor (k33, a measure of the magnitude of electromechanical energy conversion) of lead zirconate titanate (PZT) is about 70-80%, whereas that of a single crystal piezoelectric material exceeds 90%. The latter material is responsive over a wider frequency range and is also higher in sensitivity.

(2) Frontend

Featured in the frontend is the Compound Pulse Wave Generator, or CPWG+, which uses programmable waveform transmission technology to enable high energy sound transmission. Programmable waveform transmission allows for fine control of the frequency, amplitude, and pulse form of the transmitted sound waves to meet the transducer characteristics.

Previously, it has been necessary to keep the transmitted sound pressure low to alleviate the effect of increased probe surface temperature. Setting such a limit, however, can compromise the full potential of the probe and may result in poor image quality due to a lack of sensitivity.

The major cause of increased probe surface temperature is energy loss during electroacoustic conversion within the transducer. To overcome this problem, a programmable waveform transmitter which reduces energy loss during the formation of transmission waveforms is a valid approach to maximize the potential of the probe. The combination of the above-mentioned Multi-layered Crystal technology or the single crystal probe with the CPWG+ to overcome the problem of increased probe surface temperature has allowed us to provide high quality images both in terms of resolution and sensitivity.

(3) Beam Former

During signal reception, the Pixel Focus technology used in the Beam Former contributes to improved resolution. A digital Beam Former is commonly used in many models. It receives the echo signals reflected by different targets at a time that is dependent on the distance of the target from the individual transducer elements and performs digital delay processing by which the difference in time taken by the signal to reach each individual transducer elements is stored in the memory for correction before the individual signals are summed in the main unit of the ultrasound system. In a full digital ultrasound system, received signals are summed without the use of an analog delay line, resulting in a greater degree of freedom in delay processing and a dramatic improvement in the precision of received signal focusing.

In addition to conventional capabilities, the Pixel Focus technology used in the ARIETTA series reduces the loss in focus precision by correcting refraction errors in the lens and matching layer of each probe, and allows for improved accuracy with multiple beams by individual apodiziation (weighting) in different beam directions during simultaneous reception of multiple signals. The combined use with a new phase-adjusting ASIC (Application Specific Integrated Circuit) for high-precision Focus technology allows for the formation of narrower reception beams.

Furthermore, ARIETTA's Beam Former achieves a maximum four-fold increase in frame rate compared to that achieved with the conventional method of simultaneous multiple processing. As stated above, the use of Pixel Focus technology has enhanced spatial resolution, azimuth resolution, and temporal resolution in all modes, and realized a dramatic improvement in image quality.

(4) Backend

When a scanned object is densely populated with multiple scatterers, the interference between carrier frequencies of individual scattered waves prevents calculation of the arithmetic sum for the envelope. As the value does not directly correlate with the scattering intensity, the resulting image takes on a fabric-like pattern called "speckle." Since many organs are closely packed with scatterers, most of what we see in a typical ultrasound image is speckle pattern. To solve this problem, a variety of technologies have recently been proposed for reducing speckle using image processing techniques such as filtering.

On the other hand, there are many clinical examinations — staging of cirrhosis, for example — in which visual experience of speckle patterns and their correlation to tissue properties has been accumulated and exploited as a diagnostic tool. In which case, unconditional removal of speckle may lead to loss of useful diagnostic information, leaving no room to apply the established image reading expertise.

To address this challenge, we equipped ARIETTA with HI REZ*2 as an image filter to selectively reduce speckle that affects the visibility of tissue structures without sacrificing the information in the speckle pattern that correlates with tissue properties (Figure 6). Since HI REZ requires sophisticated computation for simultaneous removal of speckle in multiple directions, it makes it difficult to secure real-time processing by software, so we have developed a dedicated UltraBackend hardware to realize the real-time image processing in clinical fields that require high frame rates, such as cardiology. HI REZ operates with linear, convex, and sector probes, so it is applicable in all clinical fields. HI REZ can be used in combination with spatial compound imaging to create genuine images with fewer artifacts.

Figure 6: HI REZ

Left: Speckle noise in an ultrasound image, Right: Clinical image of the gallbladder using HI REZ

(5) Monitor

The monitor features the latest 21-inch IPS-Pro*3 liquid crystal display, developed by reassessing the structural members of the drive system, electrode structure, liquid crystal material, and oriented film material, to provide a wider field of vision, increased brightness, and greater contrast performance. The resulting image is crisp and clear, even in a dark examination room.

In conclusion, the ARIETTA series of diagnostic ultrasound systems are designed without compromise to achieve the highest possible levels of image quality by strong performance in all modules from the probe through to the display monitor.

3. Ergonomics and environmental considerations

In recent years, increasing attention has been paid to musculoskeletal disorders amongst sonographers, mainly in Europe and the United States [4]. In the pursuit of ergonomic design of the system housing, however, it was difficult to quantify the operator's muscle fatigue. To address this challenge, we carried out a research study in 2010 to measure muscle load using electromyography and determined the ideal specifications for a diagnostic ultrasound system. In particular, the ARIETTA models are designed so that the monitor and the console panel can achieve positions and heights such that the operator can work with less muscle load in a seated position, and the increased adjustable range of the monitor arm allows the operator to view the screen at an optimal downward angle of 15 degrees (Figure 7). Looking slightly downward reduces the strain on the neck and shoulders and is expected to contribute to the prevention of VDT (Visual Display Terminal) syndrome.

ARIETTA's improved environmental performance includes the coexistence of compactness with high performance. We have worked to meet this challenge from the initial phase of development by considering every possibility that reduces the number of parts and boards used in the system, in order to downsize the system housing while fulfilling the demanding requirements for image quality, functionality, operability, recording, and so on. Fortunately, the last few years have seen advancement in mobile devices and terminals that have led to the development of programmable high-performance devices (e.g., integrated circuits) that can be used in diagnostic ultrasound systems, allowing for downsizing and improved functionality through optimal programming without compromising the scalability of the circuit. As a result of the enhanced efficiency and optimization of these individual parts or their integration by the use of integrated circuits, the ARIETTA series — especially ARIETTA V60 — has successfully reduced the number of boards and the volume of the housing to approximately 50% compared to our previous conventional model, the HI VISION Avius[*4], and decreased its weight to 89 kg. This downsizing has also led to approximately 40% reduction in electric power consumption, which is another great improvement in its environmental performance. The ARIETTA series of diagnostic ultrasound systems cause less fatigue to the user, are easy to use, compact, and are capable of storing the entire peripheral equipment required for the examination.

4. Summary

Our latest diagnostic ultrasound systems ARIETTA V70 and ARIETTA V60 feature the highest performance in their class, achieved through enhanced efficiency and downsizing without compromising the technologies and capabilities inherited from Hitachi Medical Corporation and Aloka Co., Ltd. We continue our efforts to meet challenges posed by advanced examination techniques in all disciplines of diagnostic ultrasound and create standards that will lead the increasingly competitive diagnostic ultrasound field.

*1 ARIETTA is a registered trademark of Hitachi Aloka Medical, Ltd.
*2 HI REZ, *4 HI VISION Avius, and Avius are registered trademarks of Hitachi Medical Corporation.
*3 IPS and IPS-Pro are registered trademarks of Japan Display Inc.

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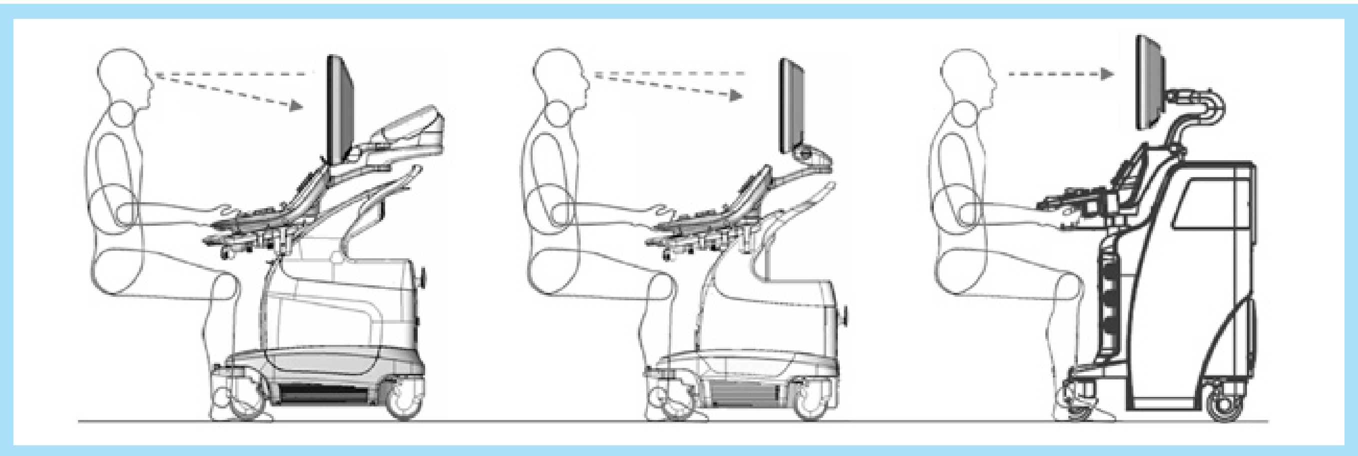

Figure 7: Ergonomic design

When seated at the ARIETTA models (left and centre) the hands can be placed on the console panel in a lower position than when seated at a conventional model (right: Alpha7), and the monitor can be viewed from a slightly downward direction to the recommended maximum angle of 15 degrees.