New Customizable Phased Array UT Instrument Opens Door for Furthering Research and Better Industrial Implementation

Gavin Dao[a] & Robert Ginzel[b]

[a]Advanced OEM Solutions
8044 Montgomery Road #700
Cincinnati OH 45236
USA
Phone: (513)846-5755
email:gavin.dao@aos-ndt.com
&
[b]Eclipse Scientific
97 Randall,
Waterloo, Ontario,
Canada
N2V 1C5,
Phone: (519) 886-6717,
email:rginzel@eclipsescientific.com

Abstract. Phased array UT as an inspection technique in itself continues to gain wide acceptance. However, there is much room for improvement in terms of implementation of Phased Array (PA) technology for every unique NDT application across several industries (e.g. oil and petroleum, nuclear and power generation, steel manufacturing, etc.). Having full control of the phased array instrument and customizing a software solution is necessary for more seamless and efficient inspections, from setting the PA parameters, collecting data and reporting, to the final analysis. NDT researchers and academics also need a flexible and open platform to be able to control various aspects of the phased array process. A high performance instrument with advanced PA features, faster data rates, a smaller form factor, and capability to adapt to specific applications, will be discussed.

Keywords: Phased Array, Ultrasonics, Phased Array UT
PACS: 43.35.Zc, 81.70.Cv, 89.20.Kk, 81.20.Vj, 43.60.Fg, 43.35.Yb

INTRODUCTION

As Phased Array Ultrasonic Testing (PAUT) gains traction as an NDT method a growing need has arisen for a fundamental change in mindset on how applications and solutions are implemented. There are so many various ways PAUT can be applied to NDT that it becomes difficult to meet everyone's particular need with one software application or one solution. Closed hardware and software can be difficult for companies to create unique and innovative solutions. Furthermore, this causes difficulties for researchers where flexibility is needed. Advanced phased array systems are also typically larger in form factor creating challenges for systems integration and very costly, hindering new adopters.

OEMPA (pronounced reading the letters O-E-M-P-A) and meaning **O**riginal **E**quipment **M**anufacturer **P**hased **A**rray, was created to solve these problems and as a concept can promote innovation and lead to new and improved solutions. Some important features of OEMPA are:

- Customizable software with an Application Programming Interface (API)
- Small form factor and lightweight
- Fast data rates and other advanced phased array features
- "OEM" concept – Incorporate bare electronic modules and brand OEMPA in other products

FIGURE 1. OEMPA 64/64 with a Data Acquisition Notebook PC

OPENNESS

A sense of openness promotes widespread advancements in technology. ‘Innovation happens elsewhere’ is a concept that although a company may try to hire the best, brightest, most creative and innovative people, there always exists that many more outside those confines[1] It’s important to create a playing field that allows more opportunities in providing new and state-of-the-art solutions that fit end-user needs. Hoarding technology and keeping it closed does not spur an industry to advance. It has been seen in other markets (information technology, software and internet) that when ‘systems integrators’ are given the proper tools they can create an echo-system of powerful technology. In NDT this would be taking the best instrument, software, and mechanical system, and creating an optimal solution. Experts now have an opportunity, without reinventing the wheel, to focus on what they know best, their particular application.

OEMPA as a concept promotes this openness. From a software standpoint, there is an open API that allows software developers to customize a Graphical User Interface (GUI), data visualization and data analysis. This can be done without worrying about the low level intricacies of a PA instrument. As an example, if someone wants to create a portable phased array system that only inspects one repetitive and dedicated application it is possible with a more open system.

FIGURE 2. Bare OEMPA 64/64

From a hardware point of view, why force everyone to purchase features they don’t need? If someone has expertise in designing a particular aspect of the system, let’s say a DCDC power supply module that supplies the voltage rails of the entire system or an input/output board with signal isolation, they should be given the opportunity and freedom to implement as they please. From a research and academic point of view, this OEM concept naturally brings openness that provides a means for those to adjust various aspects of the PA instrument with a lot of freedom and flexibility. As an example, if someone is studying about focal law generation, they can create their own focal law calculator, output the delay pattern and input it into OEMPA.

There are two aspects that classify OEMPA as an OEM product. The first is that OEMPA can be purchased in its bare electronics form by another company and be integrated, added on or modified to create a completely new system or product. Secondly, that company has the opportunity to market the newly created product under their own brand. The focus no longer is on a “brand” but on the application itself and how well it works.

Value of Customization

Customization is important for systems integrators because they have an opportunity to add-value to their solutions by adding their own unique expertise and knowledge. The value is no longer necessarily in the instrument itself but in the end solution, what was constructed as an end-solution. Having a customized solution is important to end users because they need to improve their solutions. There are enough experts with either research or industrial goals to warrant the need for an instrument open enough to apply their unique ideas or to simplify a process, often the case in factory automation.

Cost Effectiveness

Cost effectiveness is important in spurring advancements in technology. Companies that are skilled and expert in conventional ultrasound, but have shied away from phased array because of cost, can now enter the market. By bringing this technology at a better price point it gives new opportunities to those that have felt the need to adopt phased array, but have not had the opportunity or resources.

BIGGER IS NOT ALWAYS BETTER

A smaller instrument can be mounted on a scanner or robot arm which can lead to cost savings, improvements in results, ease of integration and higher reliability. One particular application that can benefit from a small form factor is weld inspections for nuclear pressure vessels. Traditionally, it can require approximately 50 meters of cabling between the instrument and the sensor array. Within one of these cables there is typically a separate coaxial cable per phased array channel. It is well known that phased array has a large number of channels, in some cases as many as 128 or more. One can already imagine the thickness and diameter of such a cable. It is also important to consider the weight and the ease of handling. What happens when one of these cables fails or is damaged? It would require inspectors to have spare cables ready. When you add the cost of this complex cable with spares it can in some cases equal or exceed the cost of the phased array instrument itself.

FIGURE 3. OEMPA 32/32

An additional benefit is an improvement in Signal-to-Noise Ratio (SNR). By placing the probe closer to the instrument you have eliminated attenuation problems due to long cables. The separate coaxial cable per channel referenced earlier in some applications, can be eliminated, thus simplifying the probe design. Even more important than the attenuation is the dispersion. Standard PA cables are expensive, and provide a very high dispersion of the signal. Using a probe with a frequency of 5MHz, take a look at the other side of a 10 or 20 meter cable. Evaluate the shape of the transmit pulse, its frequency contents, and you will understand why it cannot be used. What happens with the transmit pulse also happens with the reception echoes, where the cable acts as a sharp filter.

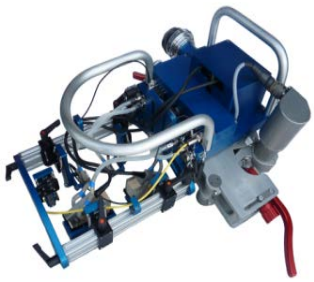

FIGURE 4. TrueView Pipe from Eclipse Scientific

Another application that can benefit from less complex cabling is girth weld pipeline inspection. The scanner is placed on the pipe and its job is to make one pass around the circumference of the pipe, thus inspecting the girth of the pipe. When the scanner makes this kind of circumferential travel the cable also moves with the scanner. Thicker and more complex cabling translates into less flexible and more rigid cabling. This constant motion will cause cables to fail; this again means more cost in down time, spares and replacement cables, and decreases ease of use.

ADVANCED PHASED ARRAY FEATURES

OEMPA has enough advanced phased array features to cover those particular applications that truly take advantage of the small size and ease of integration for automation. Some features worth mentioning are extremely low noise per channel, Dynamic Depth Focusing (DDF), Distance Amplitude Correction (DAC), up to 2048 cycles and more in some special cases, up to 20kHz Pulse Repetition Frequency (PRF), gates, and interface echo-tracking.

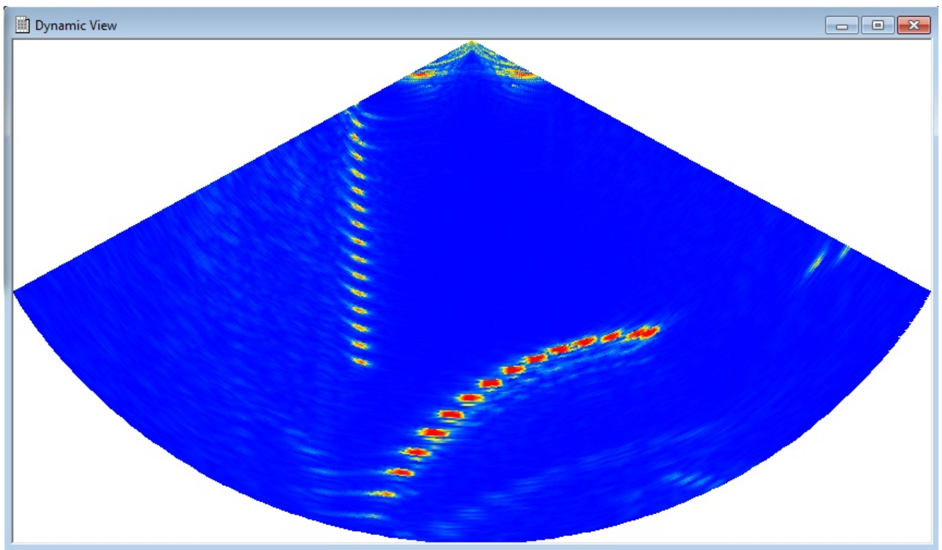

FIGURE 5. -60° to +60° S-Scan using OEMPA (with DDF) on Standard ASTM Test Block

Data Throughput

Without going into all the details of each feature, one that classifies an instrument's performance is the data throughput. OEMPA allows speeds up to 10MB/s of transferring A-scans from the instrument to the PC. In an automated system this is important to provide fast inspections while collecting the desired amount of data. As an example, assume each data point in an A-scan is 8-bits and that 100MHz sampling is used translating into a spacing of 10ns between each point. Let N represent the number of points in an A-scan. The range is defined as the length of an A-scan in a time based scale. The following relationship is simply:

$$\text{Throughput} = N \times PRF \tag{1}$$

Assuming no data compression or down-sampling, the number of points in an A-scan can be determined by

$$N = \frac{Range}{10ns} \tag{2}$$

MORE ABOUT AUTOMATION

Automation is another arena that can benefit from improvements in PAUT implementation. Having a more open and customizable instrument that provides seamless integration versus trying to integrate something not set out to be designed for integration can result in better automated solutions. The NDT industry has taken a back seat while all other areas of manufacturing have excelled and advanced. Many NDT processes still have a large manual aspect to them. Also, it has been noted that there is still too much focus on the instrument and the one and only software application that is paired with that instrument line.[2] With a customizable hardware the focus doesn't have to be on the instrument itself, but rather on the end application solution. Furthermore, this ties in well with a software platform that does support several NDT instruments, various automation technology and NDT disciplines. In today's world where we've seen the huge benefit of software and how it has made our lives easier, we can understand how in reality software drives the NDT application. What might have seemed as too difficult is now attainable because the right tools are being offered.

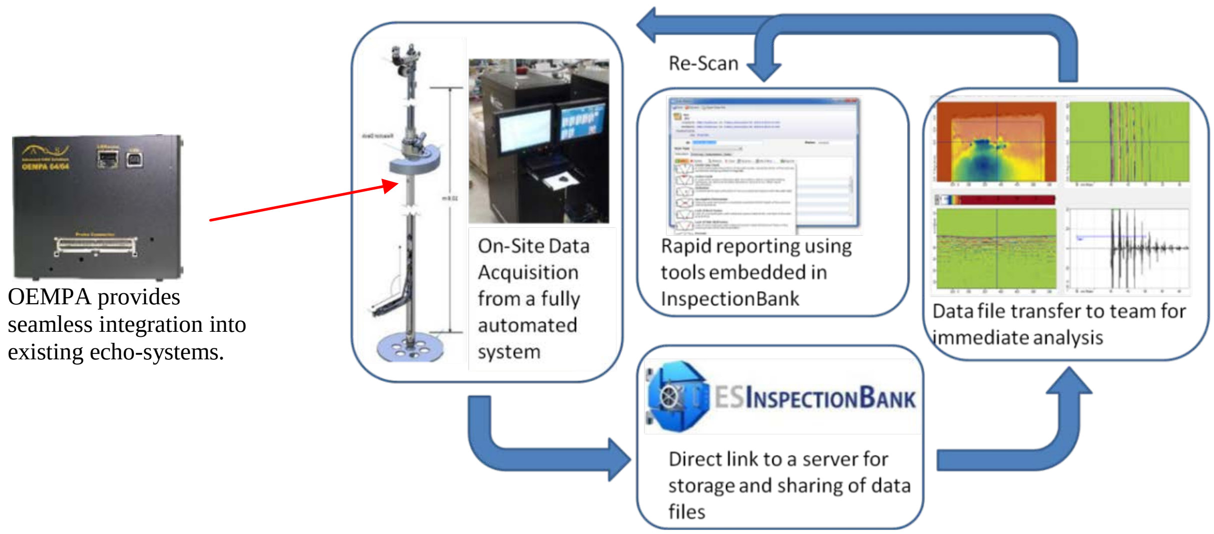

FIGURE 6. Integrating Management and Control Software into one solution

OTHER APPLICATION EXAMPLES

Some other applications not already discussed that can benefit from a small, customizable and cost-effective PA instrument are the following applications:

- Sub-Sea Mooring Chain Link Inspections
- Riser Recertification Inspections
- Photoelastic Visualization of Ultrasound

Sub-Sea Inspections

When space is limited in a remote operated vehicle (ROV) that is submerged into the ocean for non-destructive testing of sub-sea infrastructure, a compact and light weight instrument is very useful. Placing the instrument in the ROV provides the same benefits as previously discussed.

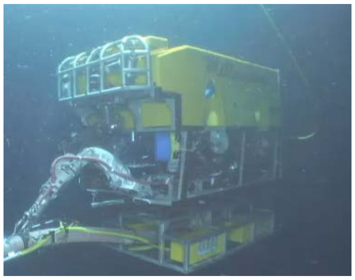

FIGURE 7. Underwater ROV

Riser

In applications like riser recertification inspections, where the instrument is often far from the scanning rig it is again advantageous to have a compact instrument mounted on the mechanics.

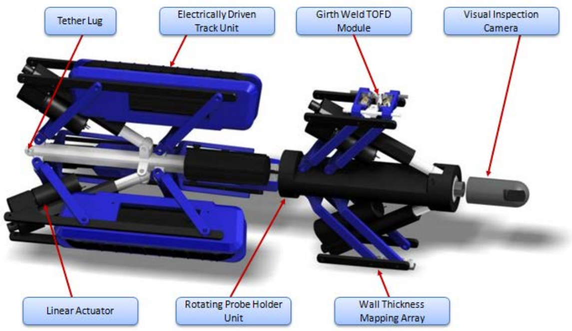

FIGURE 8. Riser Concept

Photoelastic Visualization

OEMPA can also be used to either input or output a trigger to synchronize with a light source in a photoelastic system to fire various phased array pulse patterns for academic or research endeavors in understanding the physics of ultrasound[3].

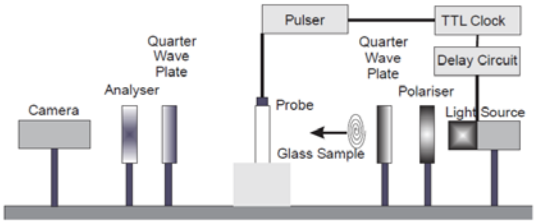

FIGURE 9. Photoelastic Visualization Instrument

CONCLUSIONS

We've identified some areas that NDT in both industry and academia can improve with a more open, flexible, small, and cost-effective phased array instrument that in its nature promotes innovation. Researchers can have full control and industry experts can create the application they've always wanted. Example applications and specific cases were given on how OEMPA can be integrated both using the software API and simple interfaces of the bare electronic module.

REFERENCES

1. R Goldman and R. P. Gabriel, *Innovation Happens Elsewhere*, San Francisco: Morgan Kaufmann, 2005.
2. W.H. Weber, H.D. Mair, D. Jansen and L. Lombardi, *Advances in Inspection Automation. The 39th Annual Review of Progress In Quantitative Nondestructive Evaluation, Denver, CO., USA (2012)*
3. R. Ginzel, Photoelastic Visualization of Ultrasound as a Supporting Tool for Advanced Modeling Software, ASNT 22nd Research Symposium, Memphis, TN., USA (2013)