ADVANCED PHASED ARRAY TECHNOLOGIES

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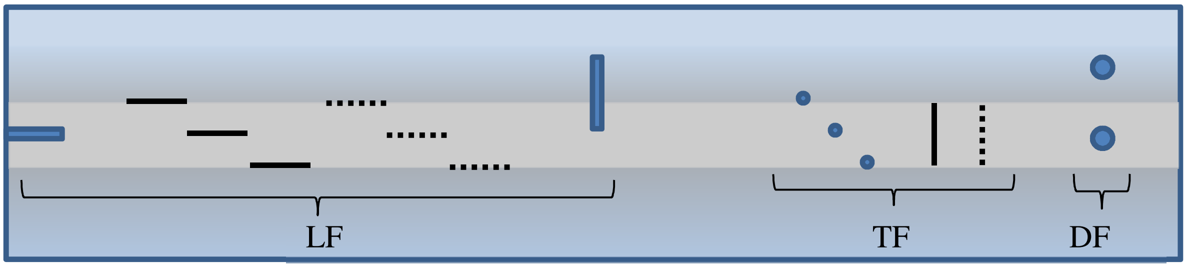
ABSTRACT

Acoustical Imaging by means of Phased Array Techniques are applied for material inspection purposes for many years. Now advanced techniques are available for stationary test systems and also for portable instruments, enabling high test speeds, high contrast and high resolution.

STATIONARY SYSTEM

Stationary test systems are equipped with the powerful Phased Array system **Multi2000**. According to the test task these systems can contain up to 1024 parallel channels, which enable the application of multiple and large array probes. As an example a test system is presented in this paper for the inspection of longitudinal tube welds.

Test Reflectors



Typical test reflectors are notches and drilled holes:

Fig. 1: Test reflectors on longitudinal tube weld

LF: Longitudinal Flaws, TF: Transverse Flaws, DF: Delamination Flaws

Detection of longitudinal flaws

Longitudinal flaws are detected using squirter probes with water coupling performing sector scans. The probes are coupled to the curved surface. The Multi2000 system provides correct data processing for curved surfaces.

Fig. 2: Squirter probes for the detection of longitudinal flaws

The overall test result can be presented as a C-Scan:

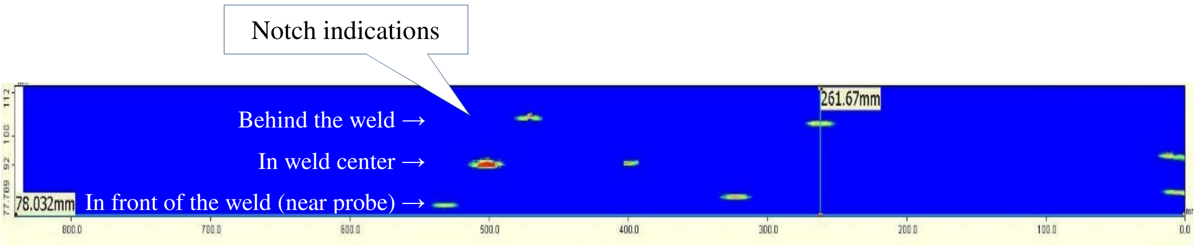


Fig. 3: Typical C-Scan as top view on the weld

Detection of transverse flaws

A typical test reflector for transverse flaws is a through drilled hole (TDH). The upper and lower corner is detected by means of the following arrangement.

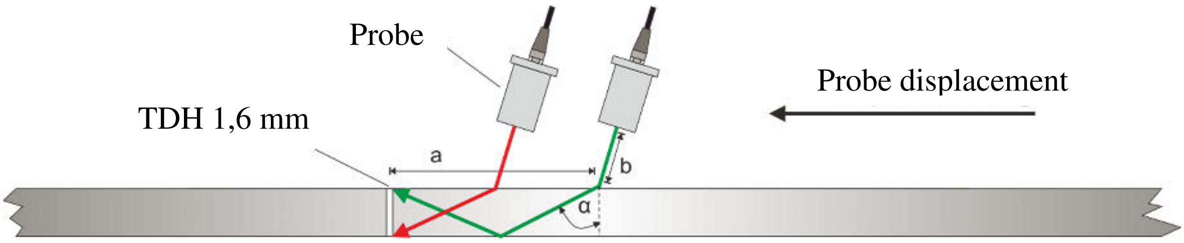


Fig. 4: Test arrangement for transverse flaws

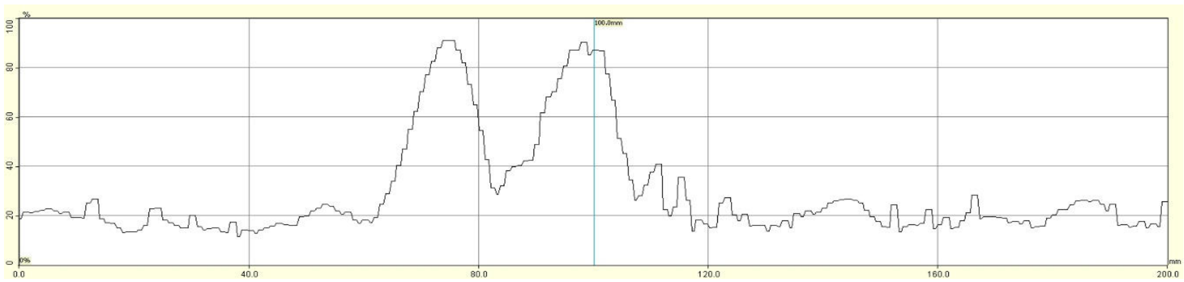


Fig. 5: Echo dynamic curve with indications of upper and lower TDH corners

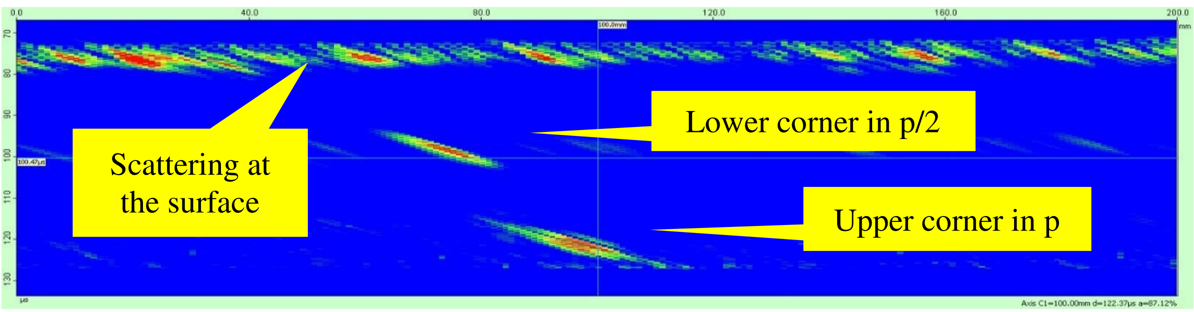


Fig. 6: Mechanical B-Scan with indications of upper and lower TDH corners

Detection of delaminations

Delaminations in the heat affected zone and also lacks of fusion, if the pipe is cladded inside, are detected by straight beam insonification. Using a plane linear array and according focal laws, the sound enters perpendicularly to the curved surface, thus always providing an optimal reflection of the flaws which are parallel to the surface.

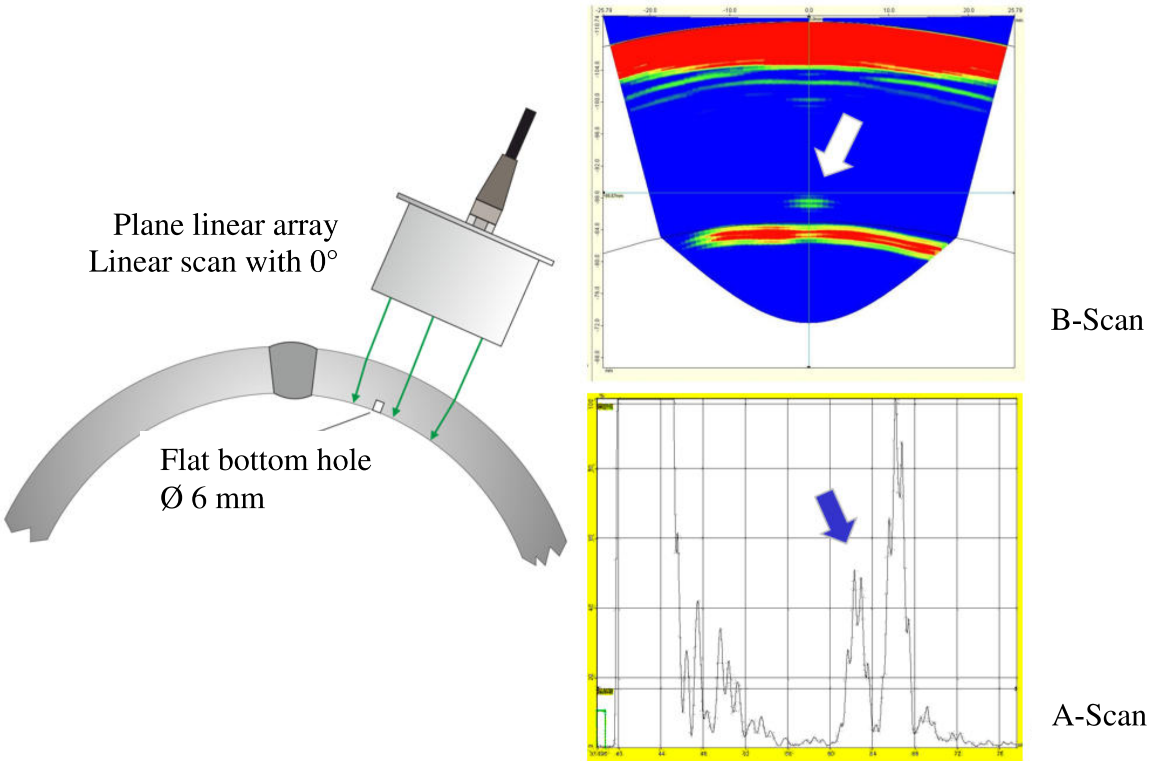


Fig. 7: Detection of delaminations – Test arrangement and test result

Fig. 8: Test system with moving pipe

PORTABLE SYSTEM

For on-site inspections the universal and portable instrument **GEKKO** is available. It supports the Phased Array Techniques by means of traditional sector scans and linear scans, TOFD (Time of Flight Diffraction) as well as the conventional UT-techniques with mono-element probes.

New and unique are additional features like for example the TFM method, which enables an acoustical imaging with extremely high resolution.

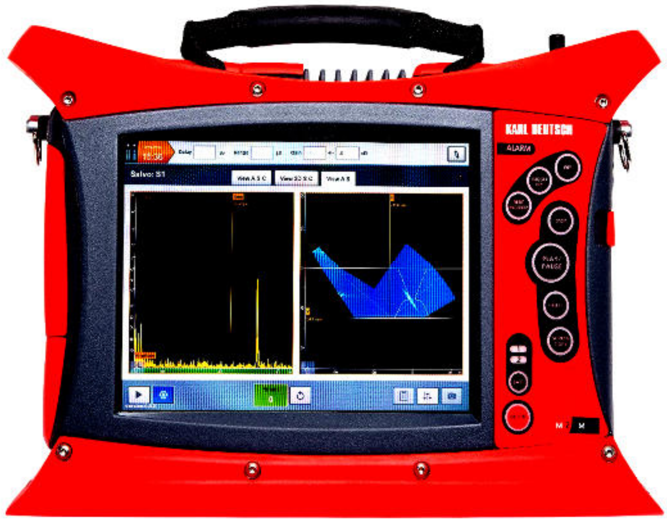


Fig. 9: Portable Phased Array System GEKKO

Traditional Sector Scans, Linear Scans, C-Scans and TOFD Scans

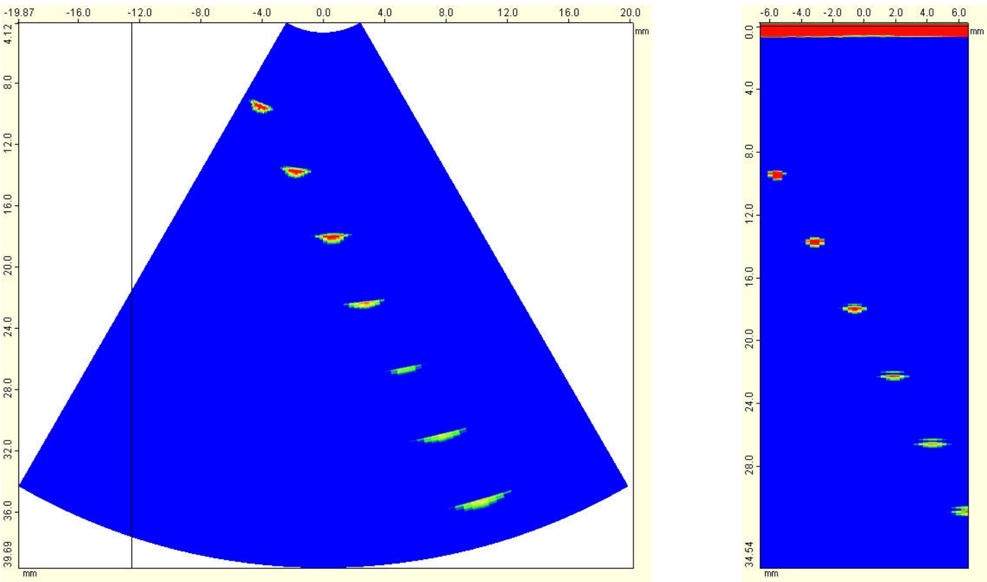


Fig. 10: Traditional sector scan (left) and 0° linear scan (right)

By mechanically scanning the linear Phased Array over the object many B-Scans based on sector or linear scans are obtained. The overall result can be presented as C-Scan. Full data analysis is possible by moving the cursors in the C-Scan. The three dimensional data then can be analysed slice by slice in the B-Scans and pointwise in the A-Scans.

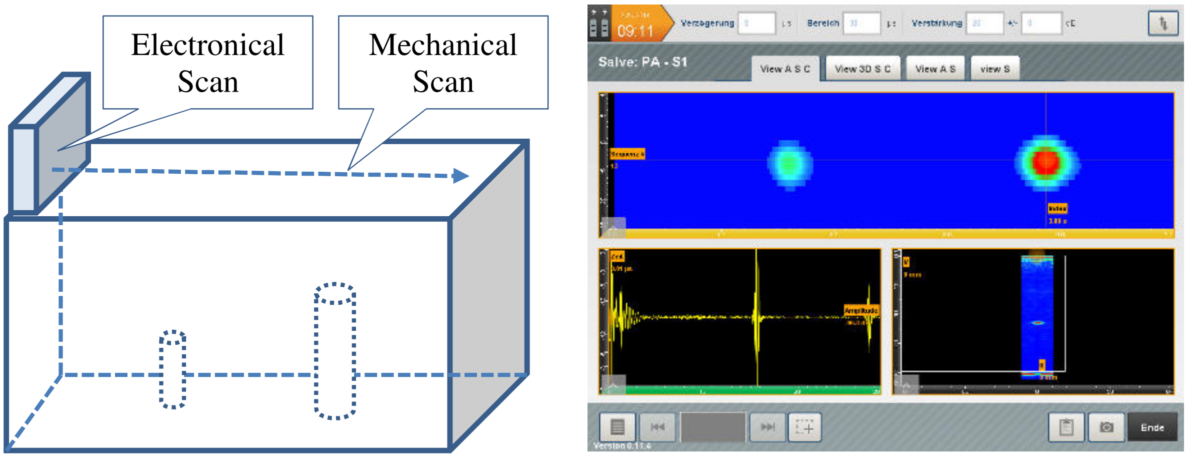


Fig. 11: 3D Imaging

Sector and electronical linear scans provide a lateral resolution according to the focused sound beam, which typically has a diameter of several wavelengths.

This example presents a scan which was obtained using longitudinal waves with straight beam insonification. Angle beam insonification with shear wave yield according results.

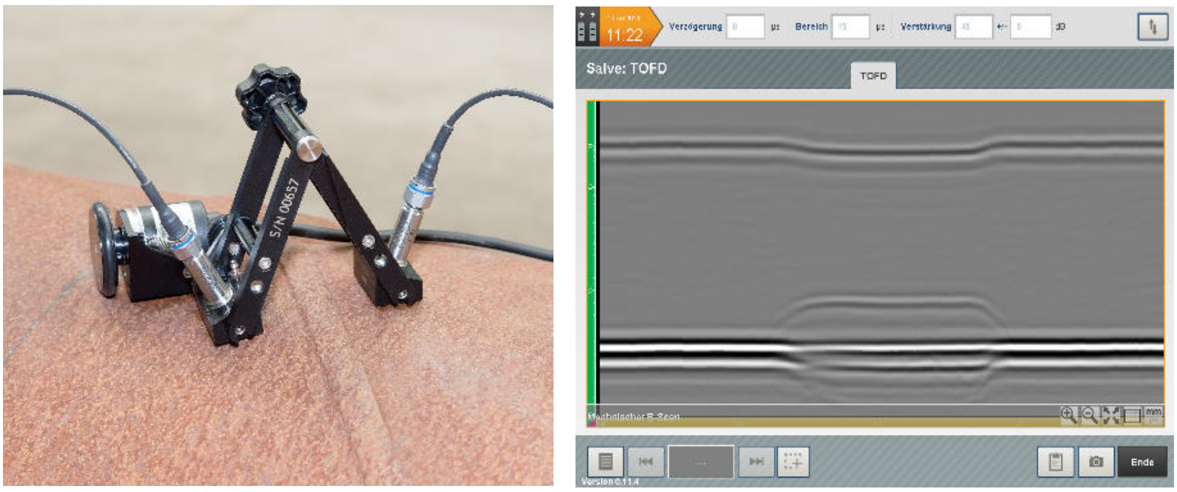


Fig. 12: TOFD imaging

Left: TOFD Scanner with 2 probes and position encoder

Right: Typical TOFD Scan with indications of surface, backwall and flaws

New: Total Focusing Method (TFM)

In order to improve the image resolution the Total Focusing Method TFM was developed and is now available in the GEKKO instrument. The ultrasonic data are captured and processed in such a way that an optimal <u>resolution of one wavelength</u> can be obtained.

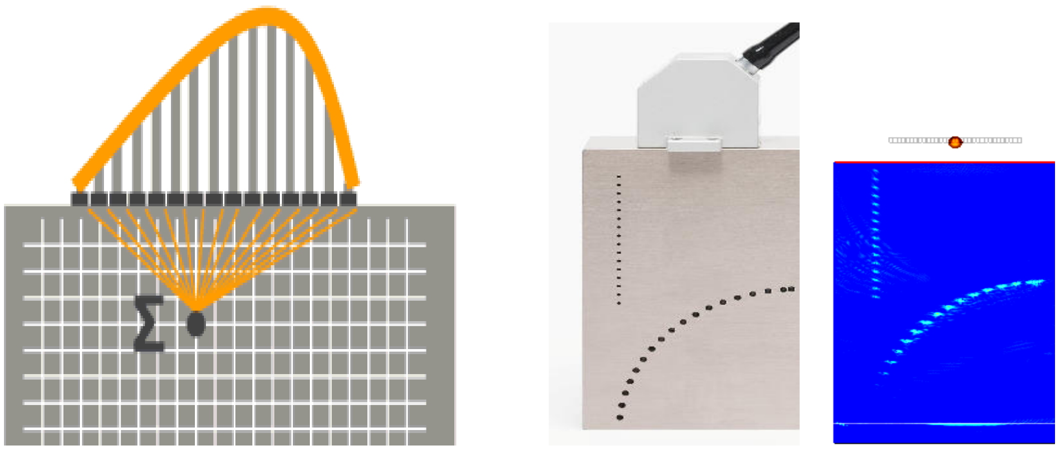


Fig. 13: TFM imaging (left: Principle, middle: PA probe on testblock, right: TFM B-Scan)

The lateral resolution is one wavelength. In the given example an array with 5 MHz was applied for straight beam insonification with longitudinal waves in steel. This yields a wavelength of λ=1.2 mm. The side drilled holes in the vertical row have diameters of 1 mm.

Due to this extremely high resolution TFM provides a defect sizing capability which is much more accurate compared to the standard echo amplitude methods DAC and DGS. In the following example a row of side drilled holes with diameters of 1.5 mm is imaged by TFM. The size and also the distance between the indications can be measured by means of cursors. Here the reflector size is determined exactly as 1.5 mm:

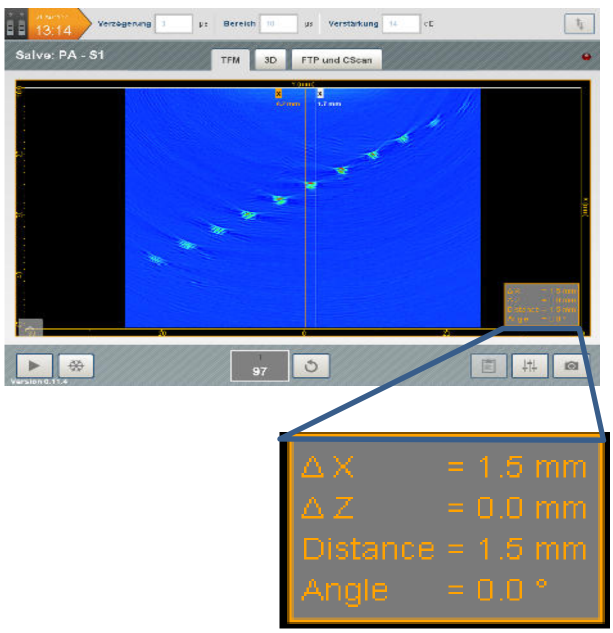


Fig. 14: Sizing capability in a TFM B-Scan

New: Application of Phased Array Matrix Probes

The GEKKO instruments is designed for 64 parallel channels. This allows the application of matrix probes with 8 x 8 = 64 piezoelectric elements.

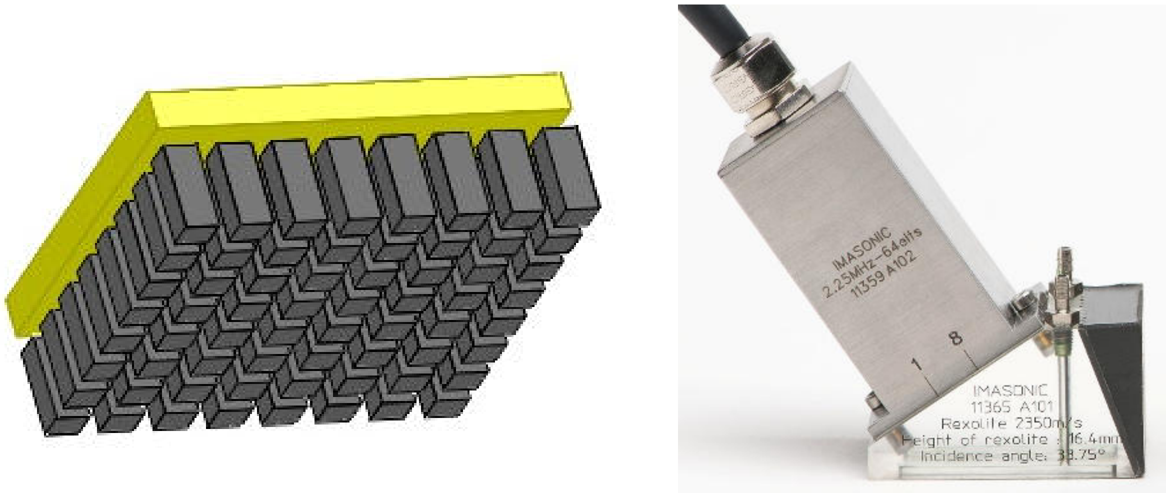


Fig. 15: Phased Array Matrix Probe with 8 x 8 Elements

The advantage of phased array matrix probes is that the sound beam can be steered in two directions:

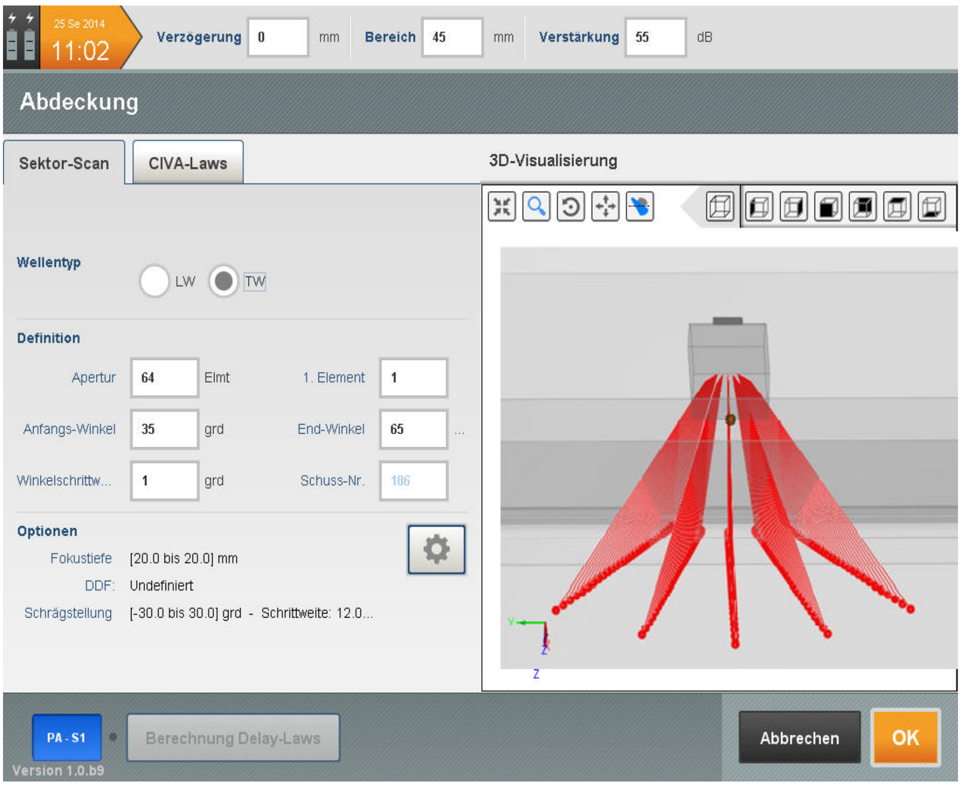


Fig. 16: GEKKO menu for matrix arrays, right: sector scans for various skew angles

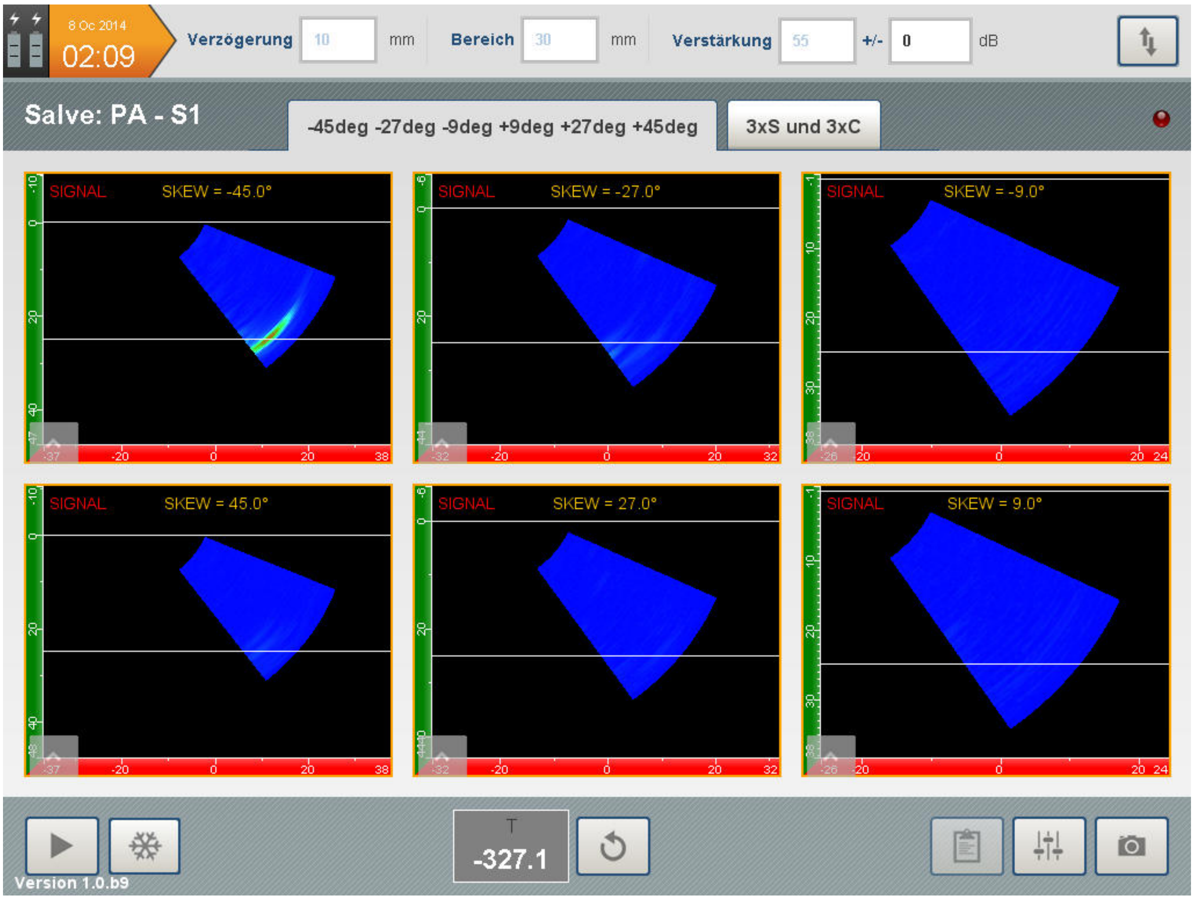


Fig. 17: Presentation of 6 sector scans at skew angles of -45°, - 27°, -9°, +9°, +27° and+ 45°

In Figure 17 the upper left sector scan presents an echo indication which is obtained at a skew angle of -45°.

The matrix technique enables for example a weld inspection with a detectability of longitudinal and oblique flaws at the same time. In the past an operator always swivelled his angle beam probe in order to capture also the oblique flaws. This can now be performed electronically and highly reproducible with the GEKKO.

CONCLUSION

This paper presents some new and advanced phased array technologies of the Multi2000 system for stationary testing machines and the portable instrument GEKKO for manual semi-mechanized testing.