On the influence of active and passive aperture size of the focused wave field sent from lineare phased array probes

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Abstract
Linear phased arrays consist of several single transducers. By exciting each single transducer at its particular time wave fronts can be tilted, focused or both combined. The required set of delays is called „focal law”. Hence, the shape of the resulting wave front depends significantly on focal law calculation.

The typical single transducer in linear phased array probes has a rectangle shape with a width-to-length-ratio of approximately 0.01. The width of the short side is called „active aperture size”, the larger one is called „passive aperture size”. In state of the art calculations of the focal laws only the pitch between the single elements is considered. The elements were approximated with a point source in the center of its aperture and the real size of active and passive aperture has no further leverage.

The EFIT (elasto dynamic finite integration technique) in combination with PSS (point source synthesis) enables the flexible and fast simulation of four-dimensional sound fields in homogeneous and layered half spaces, respectively. Thereby all wave physical effects like scattering and mode conversion will be considered. The calculations with different geometrical parameters for the probes show that both the active as well as the passive aperture size impact the time and frequency characteristic of the signal in the focus point.

Based on the focal laws calculated with and without respect to the aperture size, sound fields were simulated for selected focus points. The results were qualitatively and quantitatively compared whereby the difference between both methods will be distinguishable.

The feasibility of corrections for the focal laws with respect to time and frequency characteristics in the focus point as well as the improvement of resolution will be discussed. The results allow an estimation about the optimal width-to-length-ratio for the single transducers of linear phased arrays.

Keywords: Linear phased array, Focal law, Aperture size, EFIT, PSS
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**Introduction**

Up to now for the focal law calculation single elements of linear phased array probes have been approximated by a centered point source. The real aperture size has not been considered.

In this work it will be shown that the active as well as the passive aperture size affects the time and frequency characteristic of the wave field. By means of comprehensive 4D-CEFIT-PSS simulations these impact will be demonstrated and discussed.

### Wave field and its components of a normal force $F$, excited point source (CEFIT simulation) [2]

$c = 5900 \text{m/s}, t = 8.47 \mu\text{s}$

- **Vertical component**
- **Radial component**

### Focal law $t$ as a function of focal point $F$ and pitch $d$ [1]:

$$t = d \left( \frac{1}{F} \right)^\frac{1}{3}$$

### Example: linear phased array wave fronts simulated with EFIT-PSS

Tilted with $\Delta t = \text{const.}$ and focused with $t$, by [1]

#### Modeling of aperture geometry

Comparison of time and frequency characteristics depending on model type with intention to improved resolution in phased array applications.

**Modeling of rectangular apertures with**
- single point source
- line sources in direction of active or passive aperture
- full area

### Literature


**Simulation**

- calculation of wave fields based on different aperture models (point, line and area)
- separate analysis of longitudinal and transversal component in time and frequency domain

### Example: single element and measurement point $F$ with angle $\beta = 30^\circ$ and focus $F = 20\text{mm}$

- time signals of different aperture shapes

### Example: linear phased array with 16 elements and focal point $F$ with angle $\beta = 30^\circ$ and focus $F = 20\text{mm}$

Time and frequency of maximum amplitude of the longitudinal component for each element as a function of passive aperture size (active aperture size is const. $l_{\text{act}} = 1.92\text{mm}$)

### Conclusion

The 4D-EFIT-PSS simulation enables a detailed analysis of the wave field sent from monolithic and linear phased array probes. Hence it’s recognizable that both, active and passive aperture size affect the signals in the time and frequency domain. With the shown results width-to-height-ratio of the single transducer geometry can be optimized for manufacturing. And finally, the modified focal laws enable an improved signal performance with respect to the defined focal point.