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MEDT8007 Simulation Methods in Ultrasound Imaging

«Array beam profile vs. element effective size»

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Outline

- Introduction
- Problem description
- Concretization
- Conclusions

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Introduction

— The vibration pattern of the elements of a transducer array will not be a rectangular replica of its electrodes

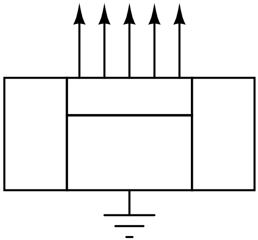

Figure: Ideal vibration pattern for an element in a stiff baffle.

Introduction

— For flexible materials, the neighborhood of the element will also be set in vibration

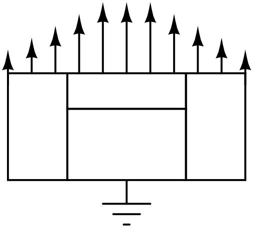

Figure: A more realistic vibration pattern for an element in a flexible baffle.

Introduction

- The observed radiation from an element in the azimuth direction is narrower than what one find from vibration a rectangular piston with the dimensions of the element electrode
- In practice, the directivity of the single element is measured, and an effective element size is estimated

Aim

Here the effect of the effective element size shall be investigated

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Problem description

- The exercise is to implement a function to investigate array beams in MatLab and verify the functionality by comparison with Field II
- Investigate beam profile and grating lobes as function of element pitch, effective element size, and number of elements. Compare with element acceptance angle.
- To have realistic data use a Gaussian pulse with approximately 40 % bandwidth, simulate in frequency domain and use Parseval's theorem to compare RMS value of pulses
- Use a linear array with up to 128 elements, centre frequency 7 MHz, and use pitch 0.26 mm and 0.33 mm. Assume effective element size 120 % and 150 % of pitch.

Array beamforming

- Beamforming with an array can be described as (Angelsen, 2000)

$$H(\mathbf{r},\omega) = \sum_m e^{-\imath\omega\tau_m} \frac{e^{-\imath k|\mathbf{r}-\mathbf{r}_m|}}{2\pi|\mathbf{r}-\mathbf{r}_m|} H_{el}(\mathbf{e}_{\mathbf{r}-\mathbf{r}_m}) \tag{1}$$

- Where m is the element number, H_{el} is the element directivity function, $\mathbf{r}$ and $\mathbf{r}_m$ is observation and element centre of gravity and τ_m is element focusing delay. Also, $\imath^2 \triangleq -1$
- Electronic apodization and attenuation is not taken into account here

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Concretization

- Assume directivity as for a rectangular piston in soft baffle

$$H_{el}(\boldsymbol{e}_{\boldsymbol{r}-\boldsymbol{r}_m}) = \mathrm{sinc}\left(\frac{d_{\mathrm{eff}}}{\lambda}\sin\theta_m\right)\cos\theta_m \tag{2}$$

- where

$$\cos\theta_m = \frac{\boldsymbol{r}\cdot\boldsymbol{r}_m}{|\boldsymbol{r}-\boldsymbol{r}_m|} \tag{3}$$

- Using the given pitch, d_{eff} will be larger than the wavelength (0.22 mm)

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Concretization

- Compute 1-way beam profile on a circle with radius 35 mm
- Verify function by comparison with Field II, here d_{eff} must be less than the pitch, use e.g. 0.9·pitch. Be careful to compare the spectre of the pulses used in both programs
- Observe beamprofiles as the aperture size is expanded. Both grating lobes and main lobe and the sidelobes

Field II simulation

— Firstly, the simulations were conducted in field II to get a rough estimate of the beam profile

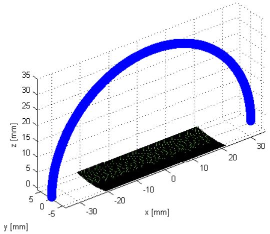

Figure: A sketch of the measurement points on the half circle with radius 35 mm.

— The field II simulations served as a reality check for the matlab script

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Conclusions

- When the aperture size is expanded, of course, the main lobe is getting narrower
- Increasing the pitch while keeping the number of elements reduces the distance to the grating lobe
- As the number of elements increases while keeping the pitch, the side lobe levels are reduced while the grating lobes are getting more pronounced

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References

— B.A. Angelsen: *Ultrasound Imaging*, vol.1, Emantec, Trondheim, 2000

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