ULTRASIM - a Toolbox for Ultrasound Field Simulation

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Ultrasim - What does it do?

- Finds sound field from transducers
- Aid in designing ultrasound transducer arrays and transducer geometry
- Will aid user in better understanding of properties of ultrasound fields
- Application areas:
  - Medical ultrasound
  - Sonar
  - Non-destructive testing

Ultrasound Imaging

GE Vivid 7 Dimension, GE Healthcare

Approaches to simulation

- Interactive tool, graphic user interface - Ultrasim
  - Simple for a new user to get started
  - Suited for small simulations with near real-time computation of result
- Provide a set of routines that the user may put together to form a batch program - e.g.Field
  - Effective for large processing-intensive simulations where many perturbations of parameters shall be tested
  - Harder to learn

Alternatives to Ultrasim

- The DREAM (Discrete REpresentation Array Modelling) toolbox is an open source toolbox for both Matlab and Octave for simulating acoustic fields radiated from common ultrasonic transducer types and arbitrarily complicated ultrasonic transducers arrays. The DREAM toolbox enables analysis of beam-steering, beam-focusing, and apodization for wideband (pulse) excitation both in near and far fields. The toolbox is also provided with a user friendly GUI.
- The DREAM toolbox uses a numerical procedure based on based on the discrete representation (DR) computational concept [1,2] which is numerical procedure that is based on the general approach of the spatial impulse responses [3].

1. B.Piwakowski and B. Delannoy. Method for Computing Spatial Pulse Response: Time-domain Approach, Journal of the Acoustical Society of Americ, vol. 86, no. 6, pp. 2422--32, Dec. 1989.
2. B. Piwakowski and K. Sbai. A New Approach to Calculate the Field Radiated from Arbitrarily Structured Transducer Arrays, IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control, vol. 46, no. 2, pp. 422--40, March 1999.
3. P.R. Stepanishen. Transient radiation from pistons in an infinite planar baffle, Journal of the Acoustical Society of America, vol 49, pp. 1629--38, 1971.

- Fredrik Lingvall, Post Doc Univ Oslo, PhD Univ Uppsala

Ultrasim demonstration

- Ultrasim built-in examples
- Examples of source geometries:
  - annular array - Ring transducer, Optoacoustic Control System for Selective Treatment of the Retinal Pigment Epithelium, Medical Laser Center Lübeck)
  - rectangular array, elevation focus, curvature, superelliptic, ...
  - 2D array
- S. Holm et. al: ”Sparse Sampling in Array Processing,” in ”*Nonuniform Sampling: Theory and Practice*”, Marvasti Ed., Plenum, 2001 : Figs. 3, 4, 5, 6

Ultrasim built-in examples

Circular array:

- e1-bpfoc
  - Annular array, beam pattern in focus
- e2-bpax
  - Annular array, find energy along axis

Linear array:

- e3-2dgr
  - Simulation of pulsed grating lobes, pitch = 2 λ, using 2D response command
- e4-2dcw
  - Simulation of CW field, pitch = $\lambda/2$, using 2D response command
- e5-2dmov
  - Movie simulation, 2D response command, compare fixed and dynamic focus
- e10-15d
  - Fig. 4 in Wildes et al ”Elevation performance of 1.25D and 1.5D ...”, IEEE UFFC, Sept 1997.

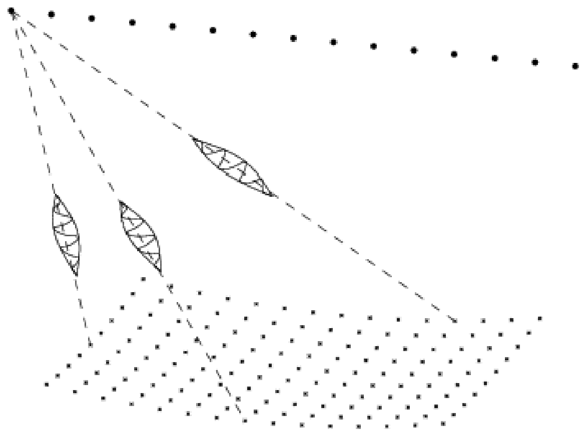
Rayleigh integral

- Velocity potential given by normal velocity integrated over active transducer surface:

$$\varphi = \frac{1}{2\pi} \iint_{Source} \frac{u_n(r_0, t - r/c)}{r} dS$$

- Single-mode vibration is assumed: $u_n(r,t)=O(r)*u(t)$
- Assumes planar sources: radius of curvature >> wavelength (Ok with all realistic curved sources in practice)

Discretized Rayleigh integral

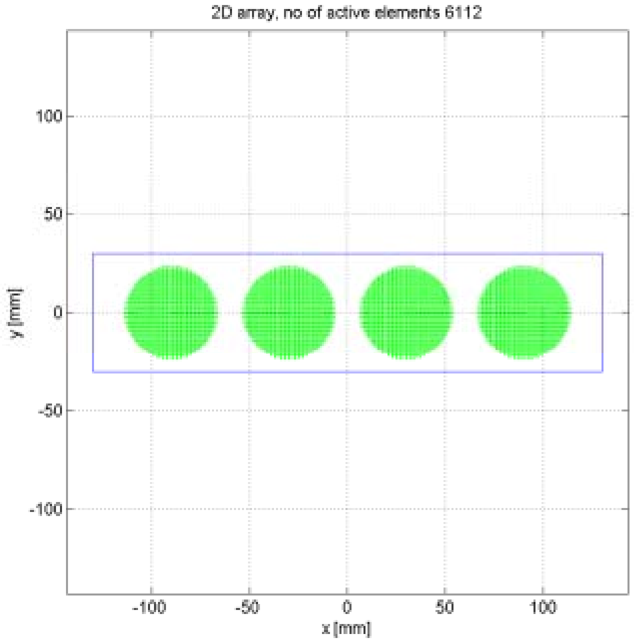


- Source plane is discretized (lower plane)
- Observation plane is also discretized (upper line)
- Find distance, apply (quantized) time delay, and sum
- Can handle inhomeogeneous media (aberrations)

Loudspeaker – sonar examples

http://www.mn.uio.no/ifi/english/research/groups/dsb/resources/software/ultrasim/pluto.html

http://www.mn.uio.no/ifi/english/research/groups/dsb/resources/software/ultrasim/geometry.html



Ultrasim - History and Status

- On-going development since the early 90's
- Freeware toolbox for Matlab 4, 5, 6
- http://www.ifi.uio.no/~ultrasim
- http://www.mn.uio.no/ifi/english/research/groups/dsb/resources/software/ultrasim/index.html

Ultrasim - Contributors

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  T. Kleveland.
- SINTEF: T. A. Reinen.

Ultrasim - Conclusion

- Interactive simulator for sound field from acoustic radiators in medical ultrasound and sonar
- Discrete version of Rayleigh integral
- Handles all array geometries in common use
- Finds acoustic field in nearfield or farfield
- Continuous wave or pulsed wave (broadband) excitation
- Freeware toolbox under the GNU public license