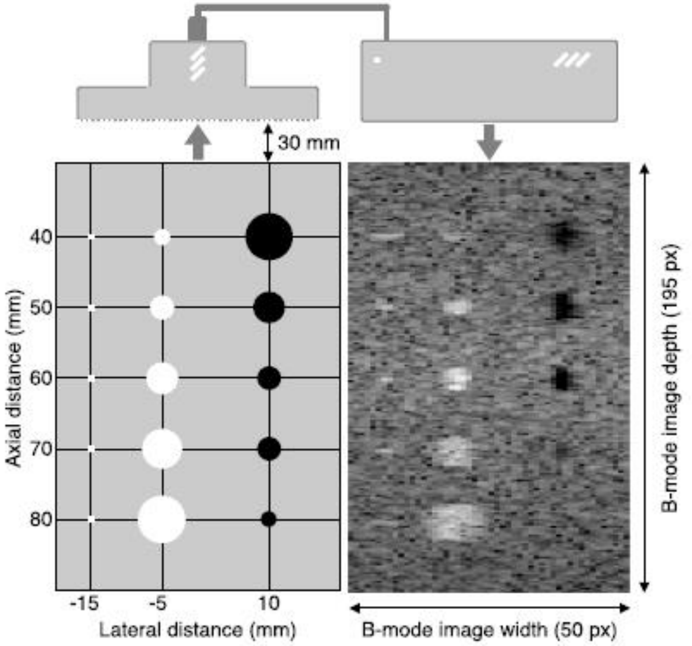
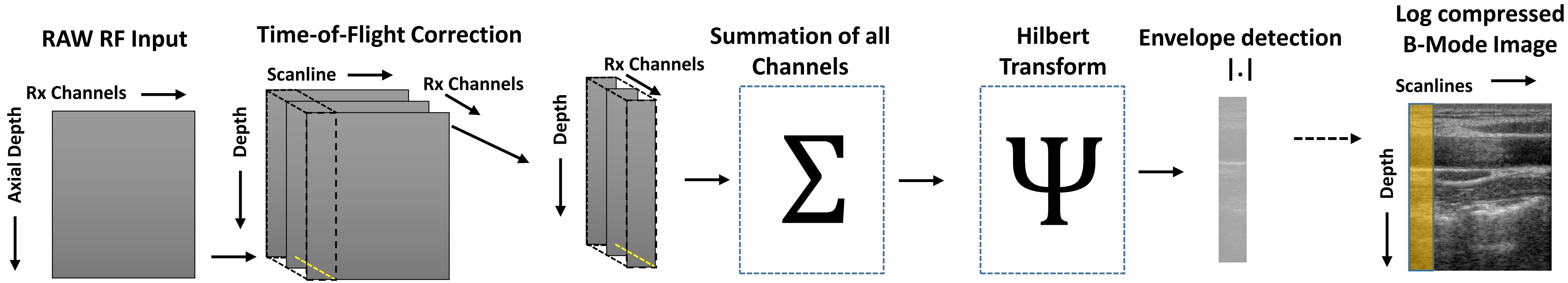
Ultrasound Imaging
delay-and-sum beam-former

Biomedical Imaging

delay-and-sum (DAS) beamforming

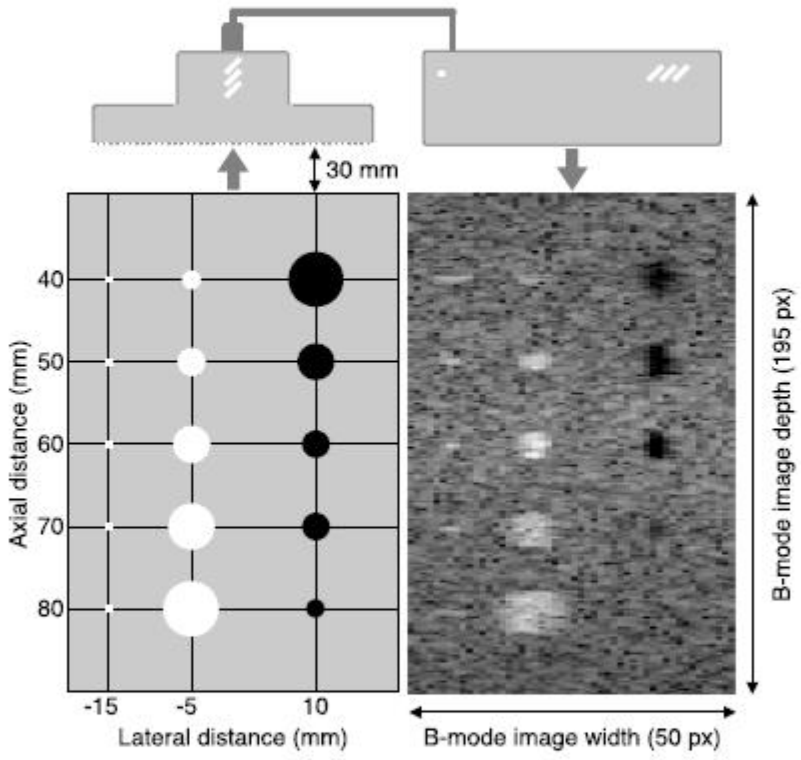


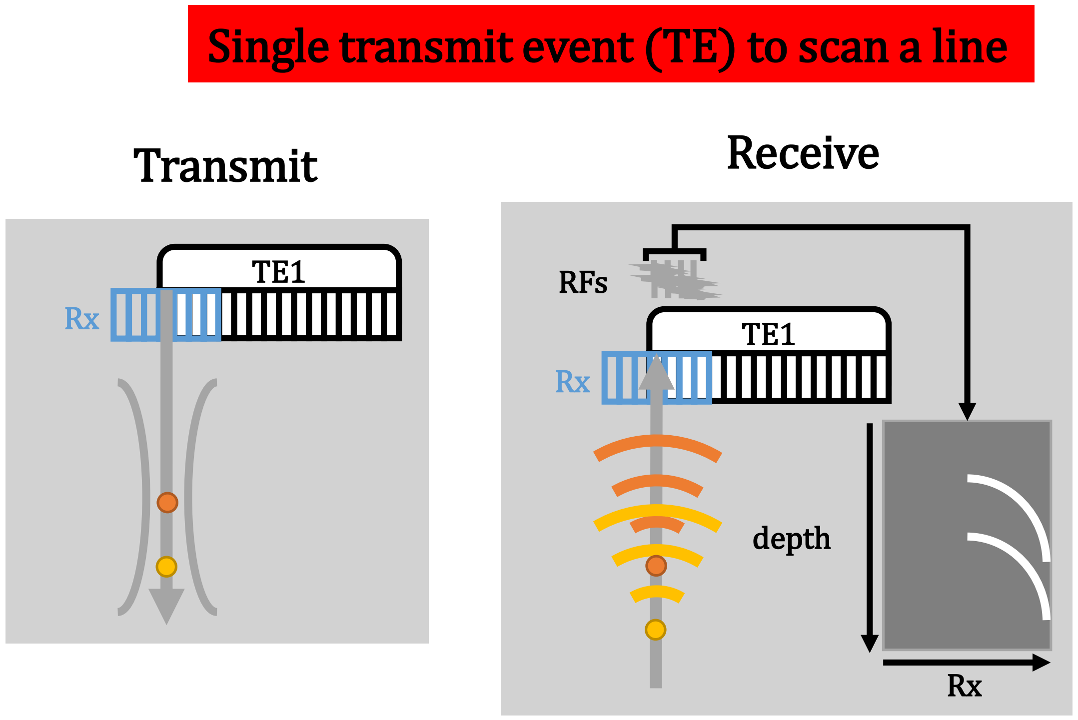
1. In focused B-mode imaging the return echoes from individual scan-line are recorded by the receiver channels.
2. Since, received measurements from multiple channels are not in phase, therefore a delay-and-sum beam-former applies the time delay to the channel measurement and combines them to form image at each scan-line.
3. In conventional DAS beamforming pipeline, time-delayed signals are additively combined followed by the Hilbert transformation, envelope detection and log compression steps.



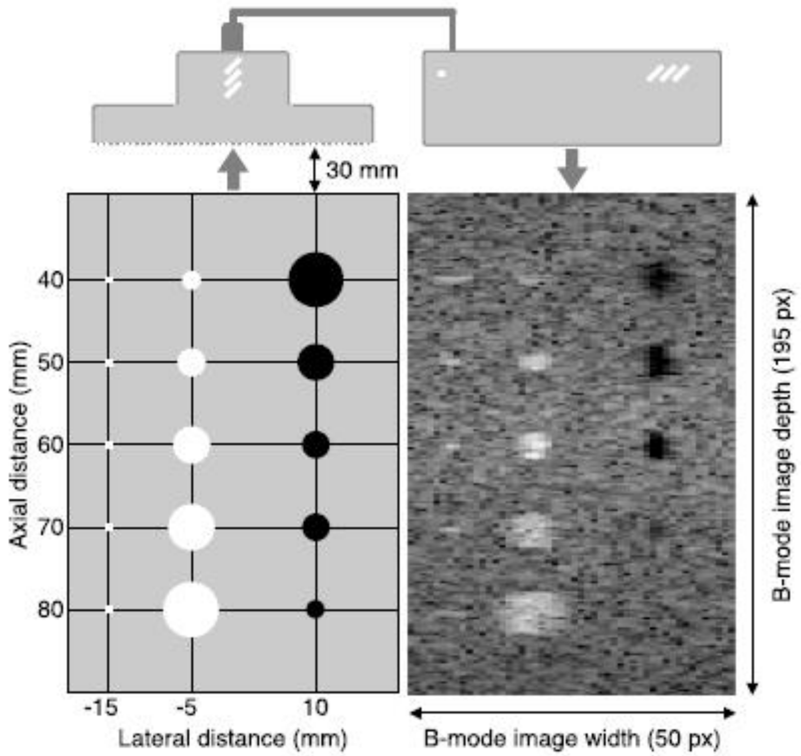
delay-and-sum (DAS) beamforming pipeline

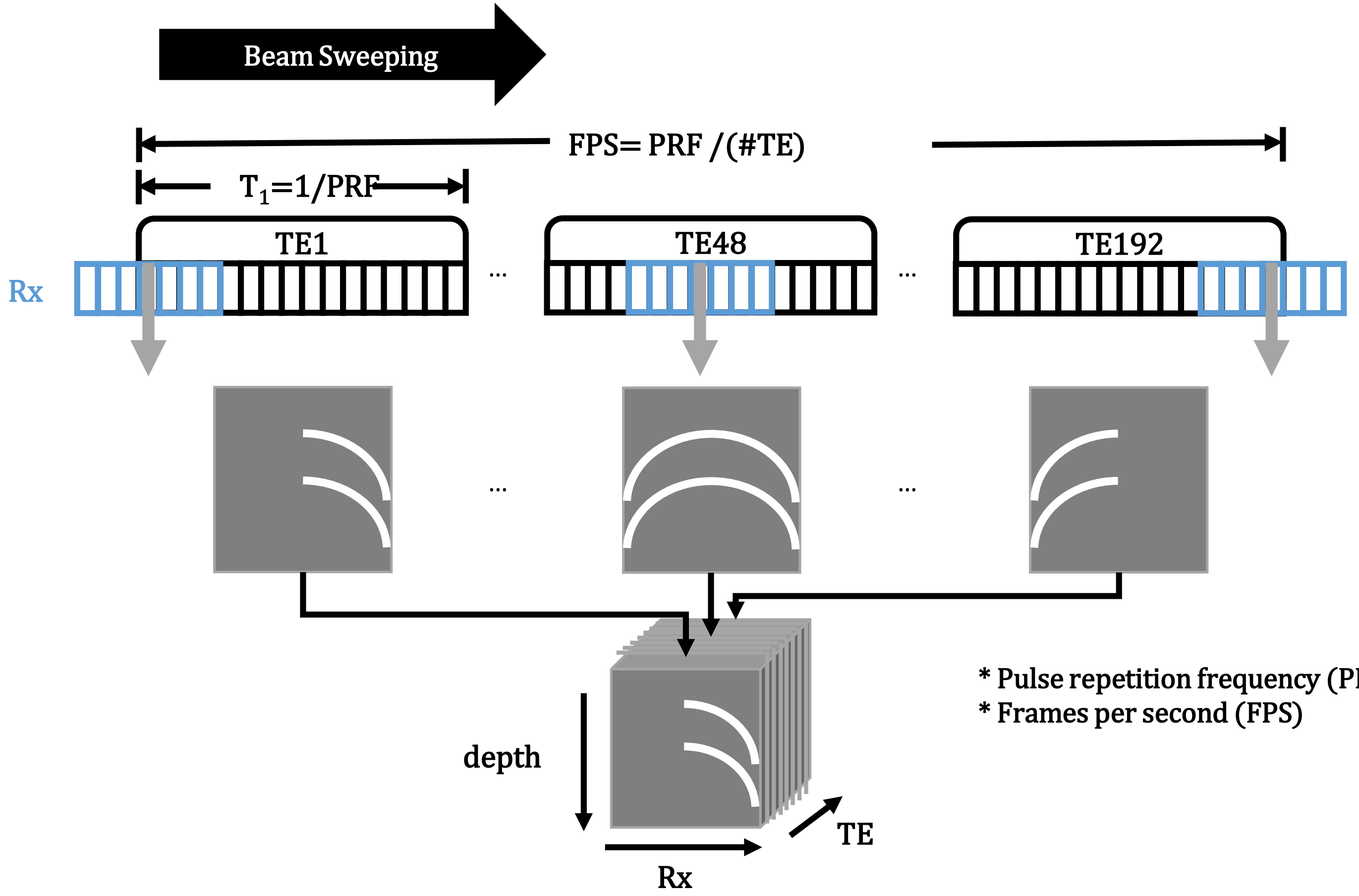
Focused B-Mode Imaging





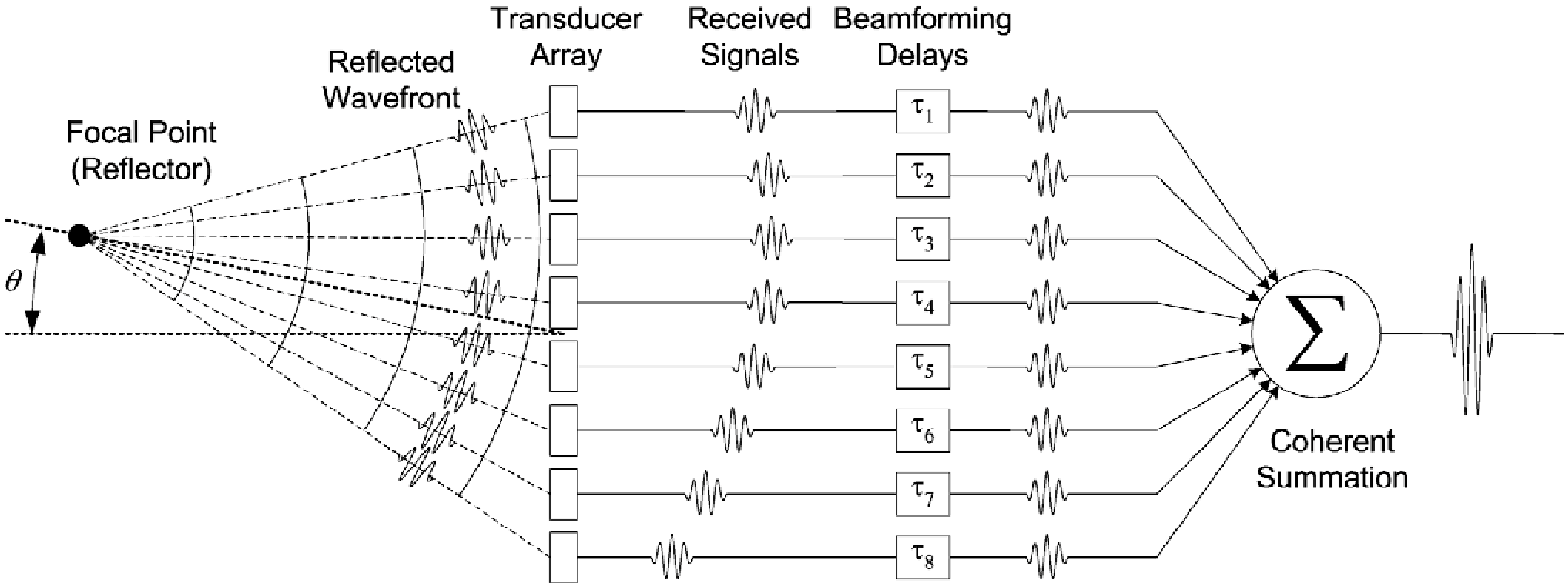
Focused B-Mode Imaging





* Pulse repetition frequency (PRF)
* Frames per second (FPS)

Time-of-Flight Correction



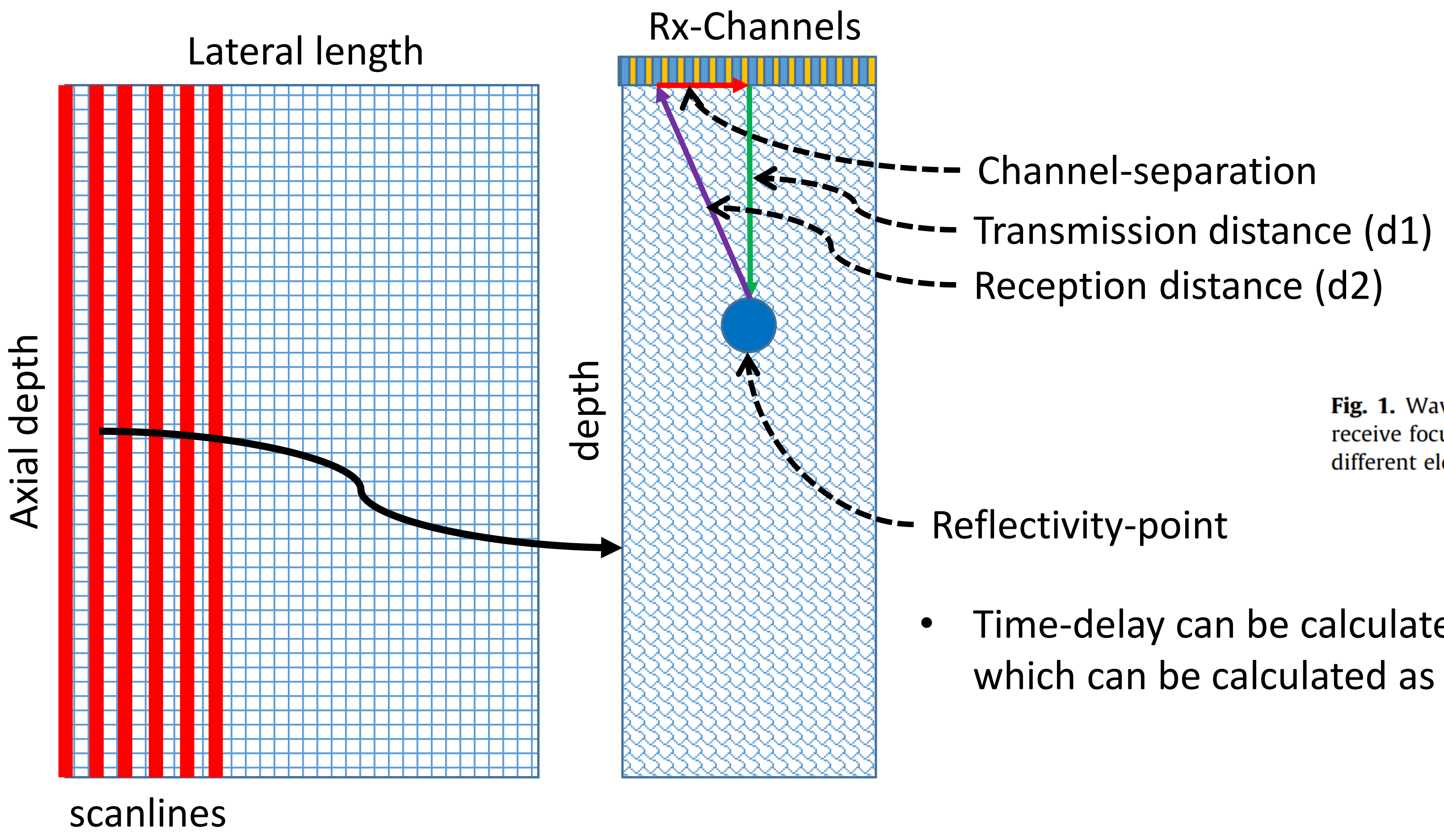
Project Description

- The objective of this project is to implement DAS and DAS+CF beamformer for ultrasound (US) imaging.
- There are total five tasks, first four tasks are related to the implement *delay-and-sum* (DAS) beam-former. And for last task you will use Mallart-Fink Coherence Factor (CF) method with DAS.
- For this project we will provide a real ultrasound dataset, obtained from a tissue mimicking Phantom. The dimensions of the US data are as follows
  - US_DATA_SIMPLE: 192x2304x192 → [Scanlines]x[depth]x[elements/channels]

Project Tasks

1. Time of flight correction (delay)
2. Beamforming (sum)
3. Envelope detection using Hilbert transform
4. Log-compression and CR plot for different DRs
5. Use Mallart-Fink Coherence Factor (CF) method with DAS
6. Compare DAS and DAS+CF on different dynamic ranges (DRs) and give remarks on the performance of each method in terms of CR, computational cost and any other factors e.g., image quality.

Time-of-Flight Correction



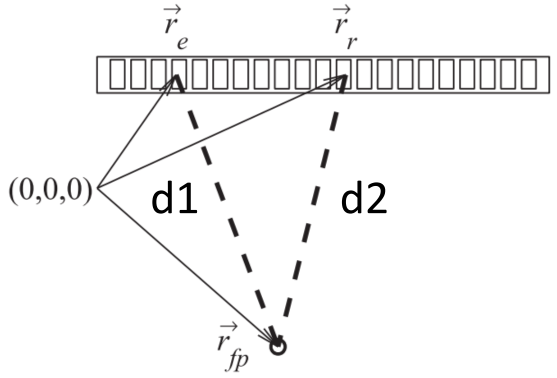
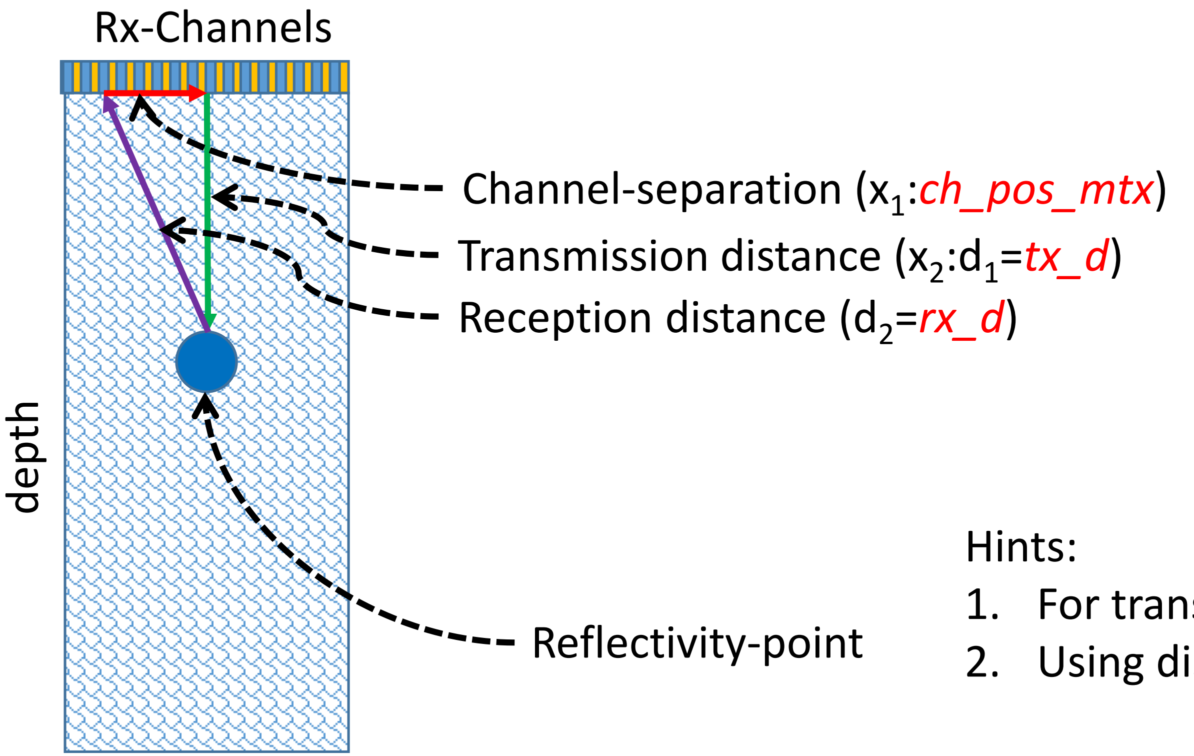


Fig. 1. Wave propagation path (dotted line) for calculating the time-of-flight in receive focusing. The transmit origin, $\vec{r}_e$ and the receive point, $\vec{r}_r$ are illustrated as different elements of an array.

- Time-delay can be calculated using the time of flight information, which can be calculated as

$$t_{tof} = \frac{d}{c} = \frac{|\vec{r}_{fp} - \vec{r}_e| + |\vec{r}_r - \vec{r}_{fp}|}{c}.$$

Tasks # 1: Time of flight correction (delay)



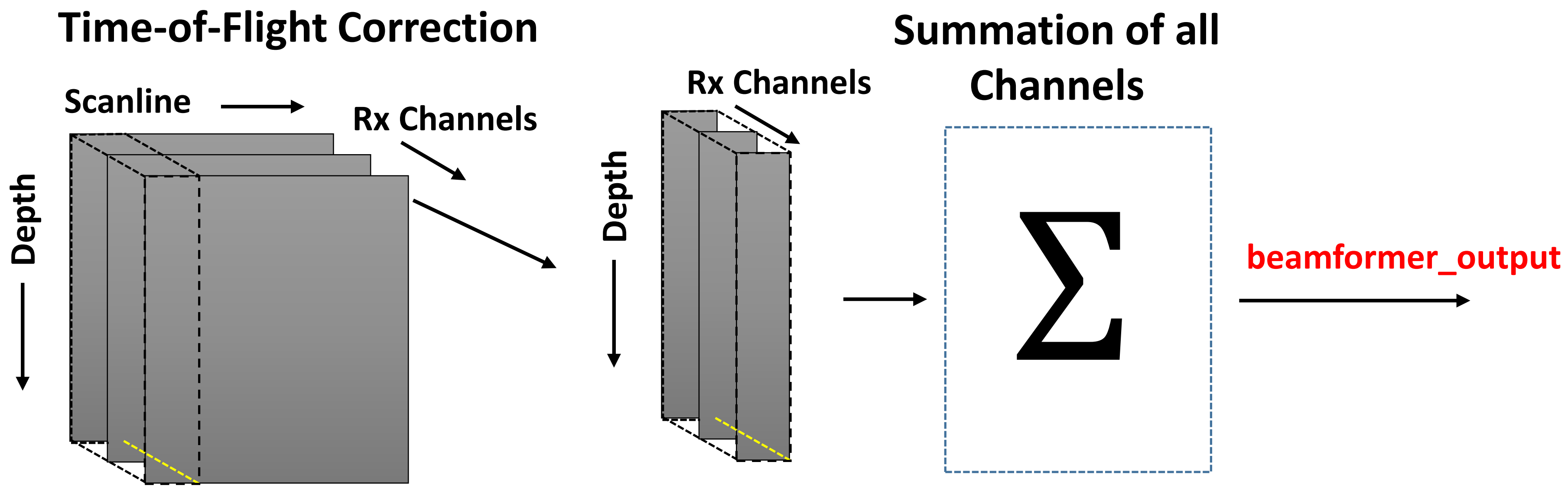
$$d_2 = \sqrt{x_1^2 + x_2^2}$$

$$t = ttx + trx$$

Hints:
1. For transmission distance use depth information matrix (*d_mtx*).
2. Using distance formula calculate (*rx_d*)

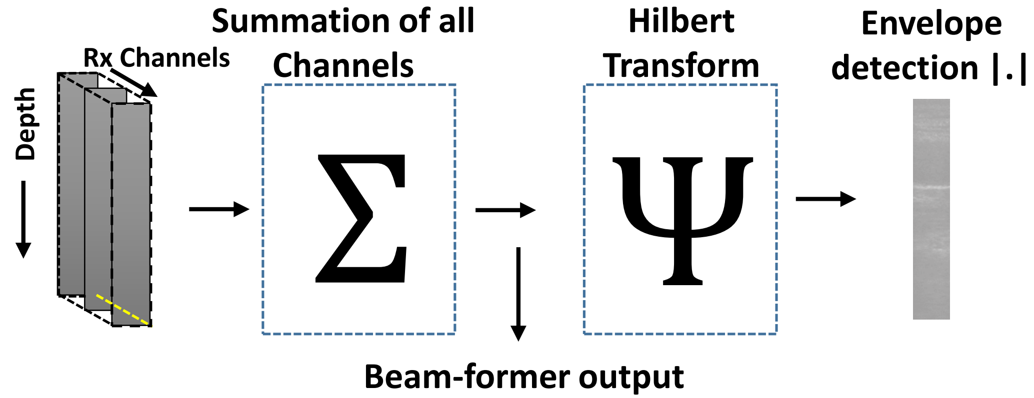
Tasks # 2: Beamforming (sum)

- Add all Rx channels to calculate *'beamformer_output'*



Tasks # 3: Envelope detection

- The envelope detection method involves creating the analytic signal of the beam-former output (‘*beamformer_output*’) using the Hilbert transform. In MATLAB there is a built-in function ‘***hilbert***’

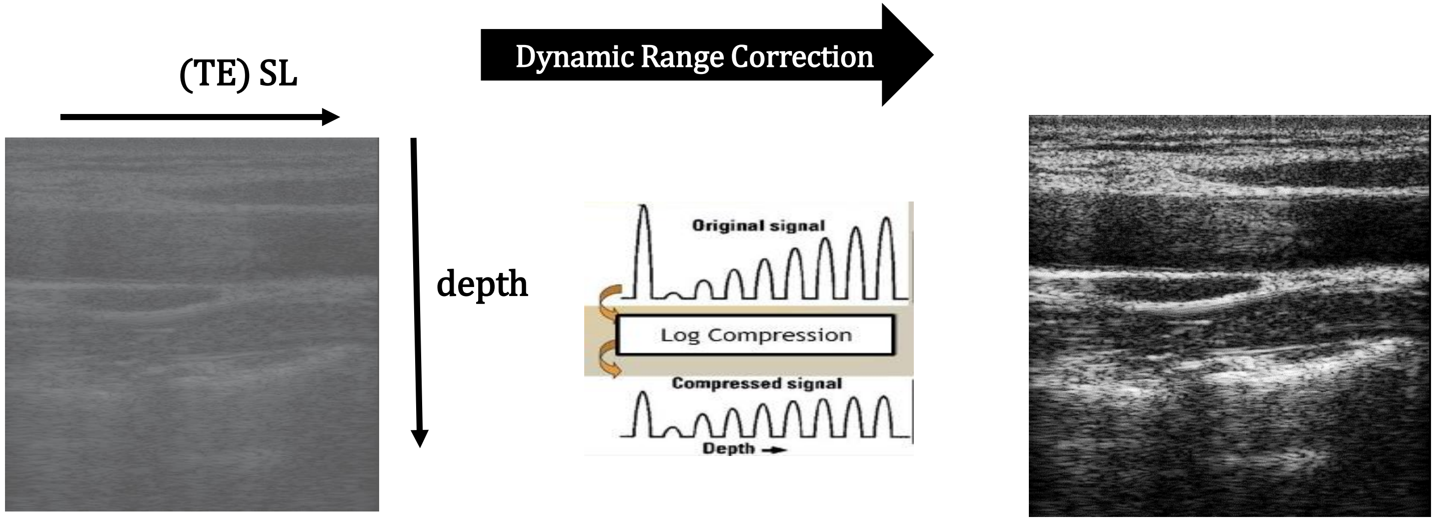


Hints:

1. In MATLAB there is a built-in function ‘***hilbert***’
2. *Envelope can be easily obtain by taking absolute of the ‘analytic_signal’*

Tasks # 4: Log-compression

- Adjust the dynamic range of normalized data *'norm_data'* to 60 dB.



RF-SUM DATA

B-mode image

Hints:

1. *use 'min_dB' as a threshold for min value of 'norm_data',*
2. *set minimum value to* ***-dB*** *and adjust all other values to 20log10(x).*

$$log\_data(i,j) = \begin{cases} -dB & if \quad norm\_data(j,i) < min\_dB \\ 20log10(norm\_data(j,i))) & otherwise \end{cases}$$

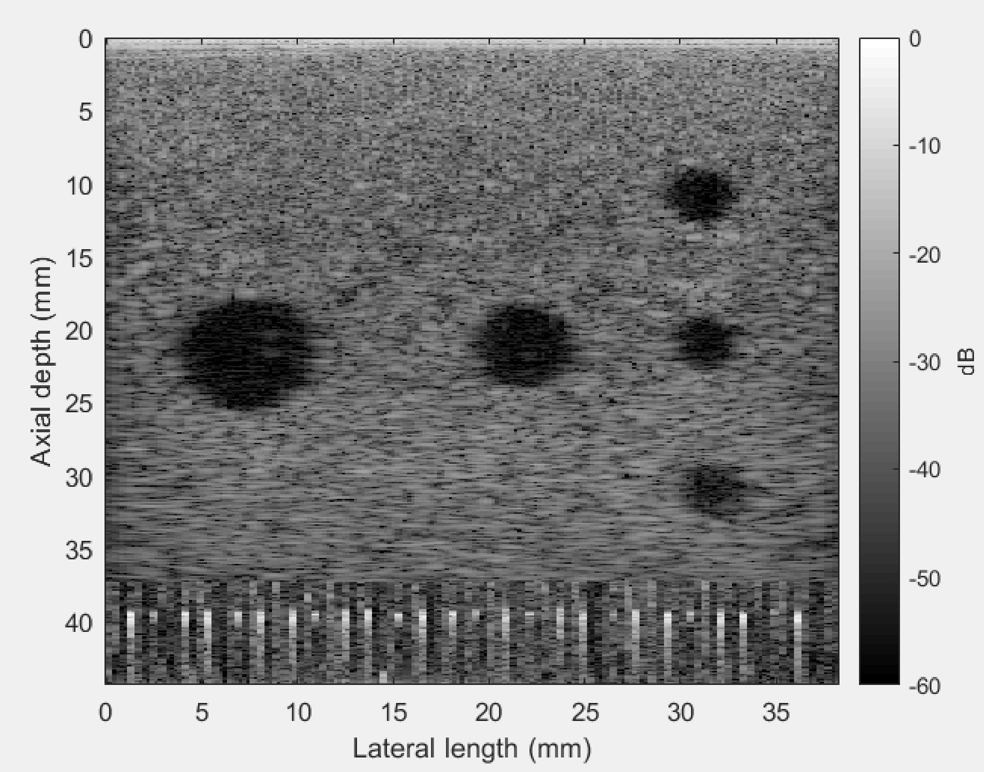
Tasks # 5: Use Mallart-Fink Coherence Factor (CF) method with DAS

- The Coherence Factor (CF), introduced as the Focusing Criterion in [1], is defined as the ratio between the coherent and incoherent energy across the aperture.
- Calculate ***CF*** using Mallart-Fink method defined in Section II B of [1] and modify your DAS code from Task1~4 by changing beamfomer output from DAS to
  cf_beamformer_output = *beamfomer_output_from_DAS x CF*
- For more details see[1].

[1] Rindal, Ole Marius Hoel, Andreas Austeng, Hans Torp, Sverre Holm, and Alfonso Rodriguez-Molares. "The dynamic range of adaptive beamformers." In *2016 IEEE International Ultrasonics Symposium (IUS)*, pp. 1-4. IEEE, 2016.

Expected output (@ 60dB dynamic range)

DAS (CR = 19.3487 dB)



DAS-CF (CR = 18.9277 dB)