ECE 148: Signal Processing Applications

Weekly review 09

Spring 2025

University of California, Santa Barbara

Range estimation

- Given: *(200 x 128)* data set
- Objective: to produce 2D subsurface profile

Data provided

- Frequency band: *0.976 to 2.0 GHz*
- *128* frequency steps
- *200* receiver positions
- Data array: *200* x *128*
- Target depth: *20 – 30 cm* (40 – 60 cm without scaling)
- Aperture width: 200 x 2.13 cm = *426 cm*
- Permittivity = *6*

1. Propagation speed

$$\varepsilon = 6$$

Speed scaled: $v = 1.225 \times 10^{8}\ m/sec$

2. Time and range resolution

Bandwidth: $B = 1\ GHz$

Time resolution: $\Delta t = 1/B = 10^{-9}\ sec$

Range resolution: $\Delta r = v\,\Delta t\,/2$

$= (1.225 \times 10^{8} \times 10^{-9})/2$

$= 6.125\ cm$

3. Max range distance

Frequency spacing: $\Delta f = (2 - 0.976)/128\ GHz = 8\ MHz$

Max range in time: $T = 1/\Delta f = 125 \times 10^{-9}\ sec$

Max range distance: $v\,T = (1.225 \times 10^{8})\,(125 \times 10^{-9})/2$

$= 7.65\ m = 765\ cm$

4. Range distance for display

Max range/ display range = 765cm/ 24cm = 32 (scaling factor)

128/ 32 = 4 (only the first 4 pixels)

5A. Interpolation for display
(range direction)

Number of frequencies = 128

Display range profile = 1024

Interpolation ratio = 1024/128 = 8

Number of pixels for display = 32

Interpolated pixel size = 6.125/8 = 0.766 cm

5B. Interpolation for display
(range direction)

Number of frequencies = 128

Display range profile = 2048

Interpolation ratio = 2048/128 = 16

Number of pixels for display = 64

Pixel size = 6.125/16 = 0.383 cm

6. Interpolation for display
(horizontal direction)

Number of transceiver positions = 200 (256 with zero padding)

Display image size = 1024 (or 2048)

a. Interpolation ratio = 1024/256 = 4

b. Interpolation ratio = 2048/256 = 8

6A. Interpolation for display
(horizontal)

Interpolation ratio = 1024/256 = 4

Spatial spacing = 2.13 cm /4 = 0.533 cm

6B. Interpolation for display
(horizontal)

Interpolation ratio = 1024/256 = 4

Spatial spacing = 2.13 cm /4 = 0.533 cm

Interpolation ratio = 2048/256 = 8

Spatial spacing = 2.13 cm /8 = 0.266 cm

7. Interpolation for display

(1024 points)

Interpolation ratio (range) = 1024/128 = 8

Spatial spacing = 6.125/8 = 0.766 cm

Interpolation ratio (horizontal) = 1024/256 = 4

Spatial spacing = 2.13 cm /4 = 0.533 cm

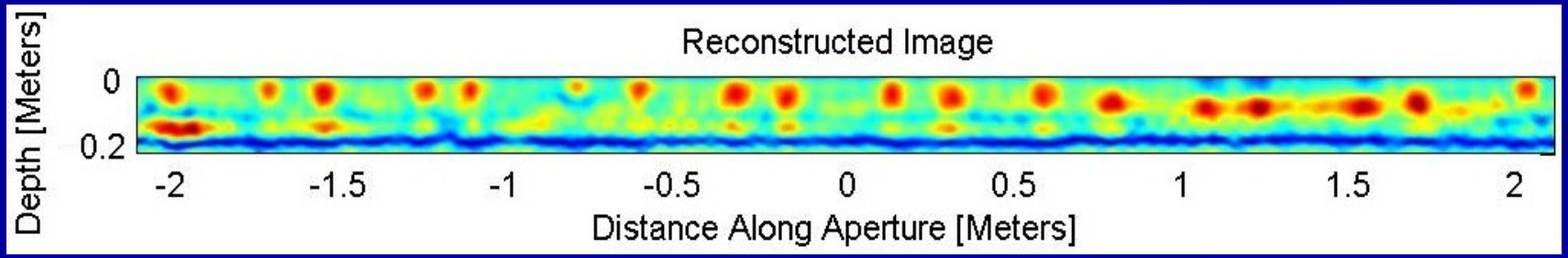
Display ratio = 0.766/0.533 = 1.44

Steps

- A. Range (depth) direction
- 1. Original data matrix *(200 x 128)*
- 2. Zero padding to *(200 x 1024)*
- 3. 1024-point FFT for 200 range profiles *(200 x 1024)*
- 4. Retain the first 32 points *(200 x 32)*
- B. Horizontal direction
- 5. Zero padding to *(256 x 32)*
- 6. 256-point FFT for the 32 sequences *(256 x 32)*
- *7.* Zero padding to *(1024 x 32)*
- 8. Inverse FFT back to space domain *(1024 x 32)*
- 9. Display image *(1024 x 32)*

8. Display

- Original *(200 x 128)* data set
- Range profile: 24cm, *32 pixels*
- Horizontal (cross-range) profile: *545cm, 1024 pixels*
- Array size: *(1024, 32)*
- Dimensions: *(545cm, 24cm)*


Reconstructed Image
Depth [Meters]
0
0.2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Distance Along Aperture [Meters]