ECE 278C **IMAGING SYSTEMS** **Winter 2024**

ASSIGNMENT 4: Multi-Frequency Backward Propagation

Due: Tuesday, February 20

Objective: The objective of this programming assignment is to experience image formation by multi-frequency backward propagation and to observe the effects on image resolution in the form of spectral coverage.

The system configuration is the same as that in *Assignment 2*, with *3* point sources at the same locations. The *receiver aperture* is a centered linear receiver array with a span of $60\lambda_0$ (from $x = -30\lambda_0$ to $x = +30\lambda_0$), located along $y = y_o = +60\lambda_0$, with quarter-wavelength $(\lambda_0/4)$ spacing. For each coherent frequency, there are *241* wavefield samples in total over the $60\lambda_0$ - long aperture.

In *Assignment 2*, one single wavelength was applied. As we move up to the multi-frequency (wideband) operating mode, we collect wavefield samples over a wide range of spectrum corresponding to *64* different wavelengths, in the form

$$\lambda_n = 64\,\lambda_0/(n+32) \qquad\qquad n = 1, 2, \ldots 64$$

Thus, this imaging modality operates with a sequence of wavelengths, from $0.67\lambda_0$ to $2\lambda_0$, corresponding to the spatial-frequency band from $0.5(1/\lambda_0)$ to $1.5(1/\lambda_0)$ resulting a spatial-frequency bandwidth of $(1/\lambda_0)$.

The complete data set is a *(64 x 241)* array, corresponding to *64* wavelengths and *241* receiver positions.

Superposition of coherent images:

This is to perform coherent image formation procedure *64* times corresponding to 64 different operating wavelengths and the same receiver array configuration. This process produces *64* coherent sub-images, $\hat{s}_n(x, y)$, for $n = 1, 2, \ldots. 64$. For simplicity, the phase-only version of the Green's function is applied to image reconstruction.

The goal is to perform multi-frequency image reconstruction over the $(60\lambda_0 \times 60\lambda_0)$ 2D source region with the *64* sets of coherent wavefield samples. The source region is an area centered at $(0, 0)$ and bounded by $x = \pm 30\lambda_0$ and $y = \pm 30\lambda_0$. For consistency, use quarter-wavelength $(\lambda_0/4)$ spacing as the sample spacing in both directions for the display of the images.

(1) By repeating the coherent backward propagation image formation procedure, produce the *64* coherent sub-images.

(2) Superimpose the *64* coherent complex sub-images *sequentially* and observe the convergence to the overall image,

$$\hat{S}_n(x, y) = \sum_{k=1}^{n} \hat{s}_k(x, y) \qquad\qquad n = 1, 2, \ldots 64.$$

(3) Produce the spectra of the complex image sequence $\hat{S}_n(x, y)$, $n = 1, 2, \ldots 64$.

(4) Compile a *64*-frame video of the image sequence $\hat{S}_n(x, y)$.

(5) Compile a *64*-frame video of the spectra of the image sequence.

Report format:

(A) Cover page.

(B) Video sequences.

(C) Summary: (comments based on your observations)

(D) Appendix: (computer code)