ECE 278C **IMAGING SYSTEMS** **Winter 2021**

ASSIGNMENT 4: Multi-Frequency Backward Propagation

Due: Tuesday, February 16

Name: ______________________________

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 especially in the *range direction*.

The system configuration is the same as that in Assignment 2. The *receiver aperture* is a centered linear receiver array with a span of $60\lambda_0$ (from $x = -30\lambda_0$ to $x = +30\lambda_0$). This receiver array is located at the *plane* $y = y_o = -60\lambda_0$, with quarter-wavelength spacing ($\lambda_0/4$) 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 into the multi-frequency operating mode, we collect wavefield samples over a wide range of spectrum corresponding to 40 different wavelengths, in the form

$$\lambda_n = 40\lambda_0/(n+20) \qquad\qquad n = 1, 2, \dots 40$$

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 bandwidth of $(1/\lambda_0)$. This is to perform coherent image formation procedure *40* times with different operating wavelengths, with the same receiver array configuration. This process produces 40 coherent sub-images, $\hat{s}_n(x, y)$, for $n = 1, 2, \dots. 40$. (It should be noted that the locations of the source distribution and receivers are independent of the change of operating wavelength.)

The goal is to perform multi-frequency image reconstruction of the $60\lambda_0 \times 60\lambda_0$ 2D source region with the *40* 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.

(A) By repeating the coherent backward propagation image formation procedure, produce the 40 coherent sub-images.

(B) Observe the characteristics of the sub-images and compare to the results from Assignment 2.

(C) Superimpose the 40 coherent sub-images *sequentially* and observe the convergence to the overall image,

$$\hat{S}_n(x, y) = \sum_{k=1}^{n} \hat{s}_k(x, y) \qquad\qquad n = 1, 2, \ldots. 40.$$

(D) Plot the magnitude distribution of the 4 images $\hat{S}_{10}(x, y)$, $\hat{S}_{20}(x, y)$, $\hat{S}_{30}(x, y)$, and $\hat{S}_{40}(x, y)$.

(E) Compile a 40-frame video of the image sequence $\hat{S}_n(x, y)$, $n = 1, 2, \ldots. 40.$

(F) Compile a 40-frame video of the spectra of the image sequence $\hat{S}_n(x, y)$.

Report format:

1. Cover page.
2. Magnitude distribution of the final images from Part (D).
3. Video sequences from Parts (E) and (F).
4. Summary: (comments based on your observations)
5. Appendix: (computer code)