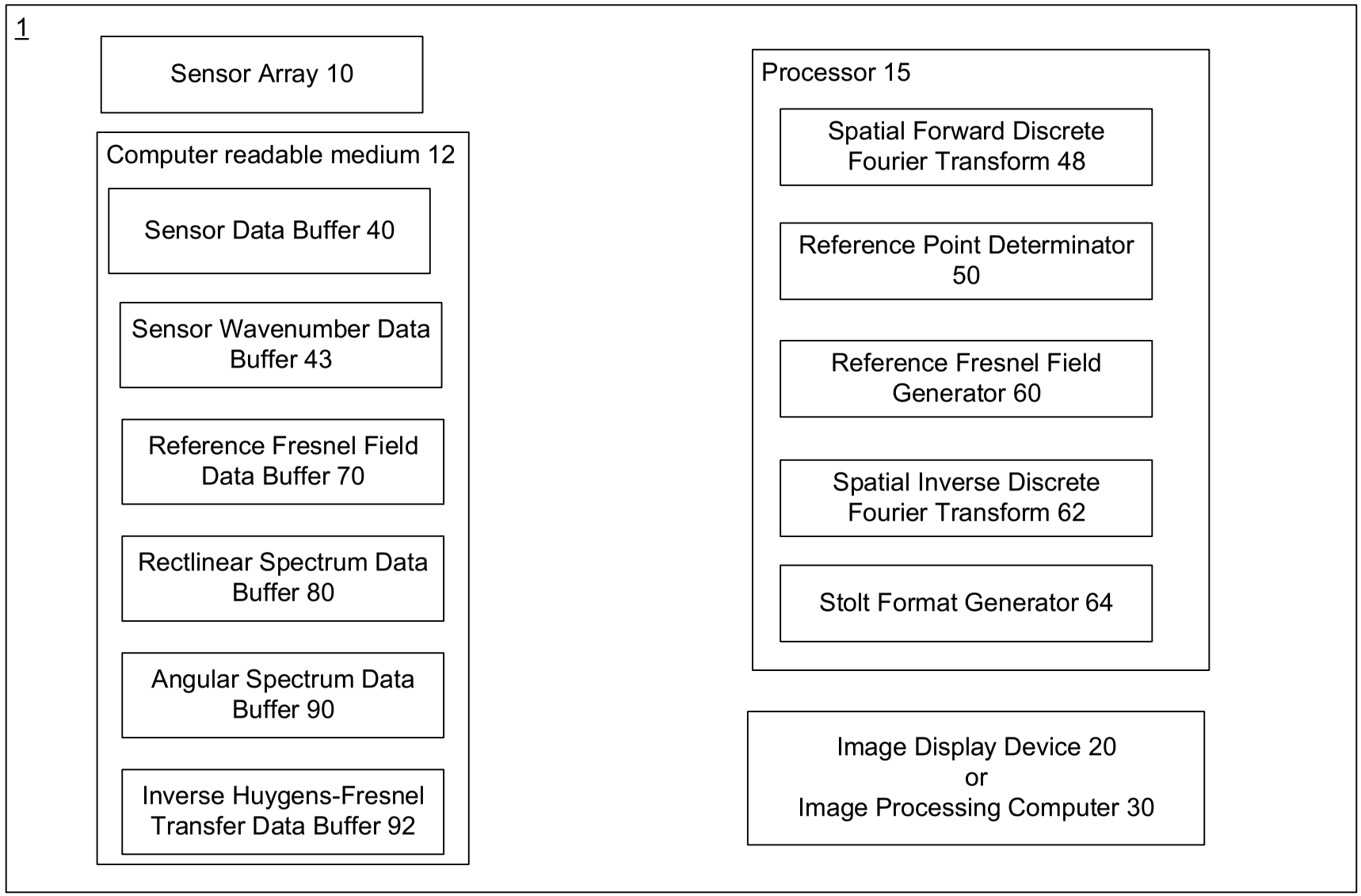

1
Sensor Array 10
Computer readable medium 12
Sensor Data Buffer 40
Sensor Wavenumber Data Buffer 43
Reference Fresnel Field Data Buffer 70
Rectlinear Spectrum Data Buffer 80
Angular Spectrum Data Buffer 90
Inverse Huygens-Fresnel Transfer Data Buffer 92
Processor 15
Spatial Forward Discrete Fourier Transform 48
Reference Point Determinator 50
Reference Fresnel Field Generator 60
Spatial Inverse Discrete Fourier Transform 62
Stolt Format Generator 64
Image Display Device 20
or
Image Processing Computer 30

FIG. 1A

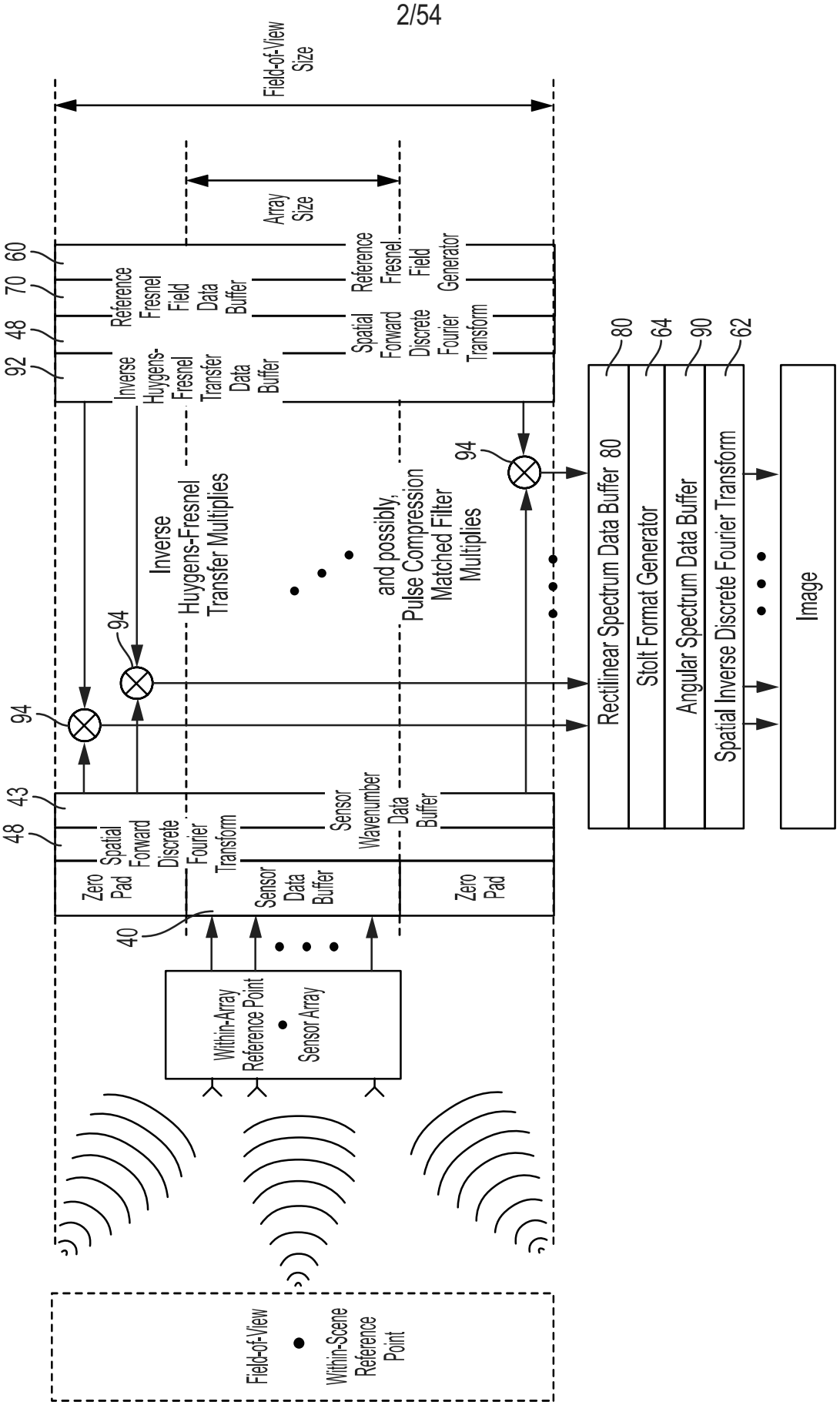

Field-of-View Size
Array Size
60
70
48
92
Reference Fresnel Field Generator
Reference Fresnel Field Data Buffer
Spatial Forward Discrete Fourier Transform
Inverse Huygens-Fresnel Transfer Data Buffer
Inverse Huygens-Fresnel Transfer Multiplies
and possibly, Pulse Compression Matched Filter Multiplies
94
80
64
90
62
Rectilinear Spectrum Data Buffer 80
Stolt Format Generator
Angular Spectrum Data Buffer
Spatial Inverse Discrete Fourier Transform
Image
43
48
Sensor Wavenumber Data Buffer
Spatial Forward Discrete Fourier Transform
Zero Pad
Sensor Data Buffer
Zero Pad
40
Within-Array Reference Point
Sensor Array
Field-of-View
Within-Scene Reference Point

FIG. 1B

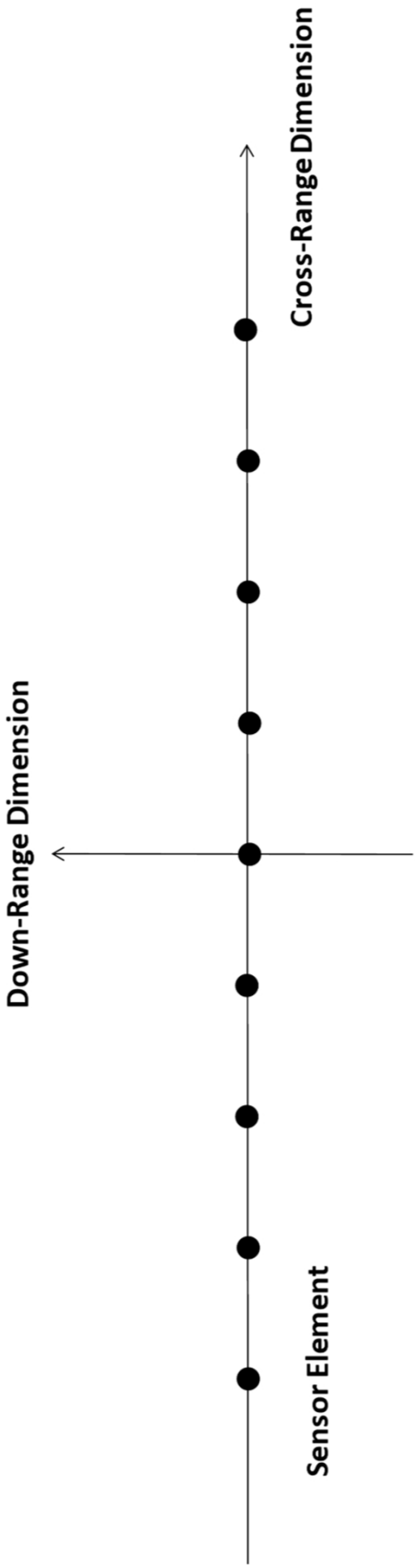

Cross-Range Dimension
Down-Range Dimension
Sensor Element

FIG. 1C

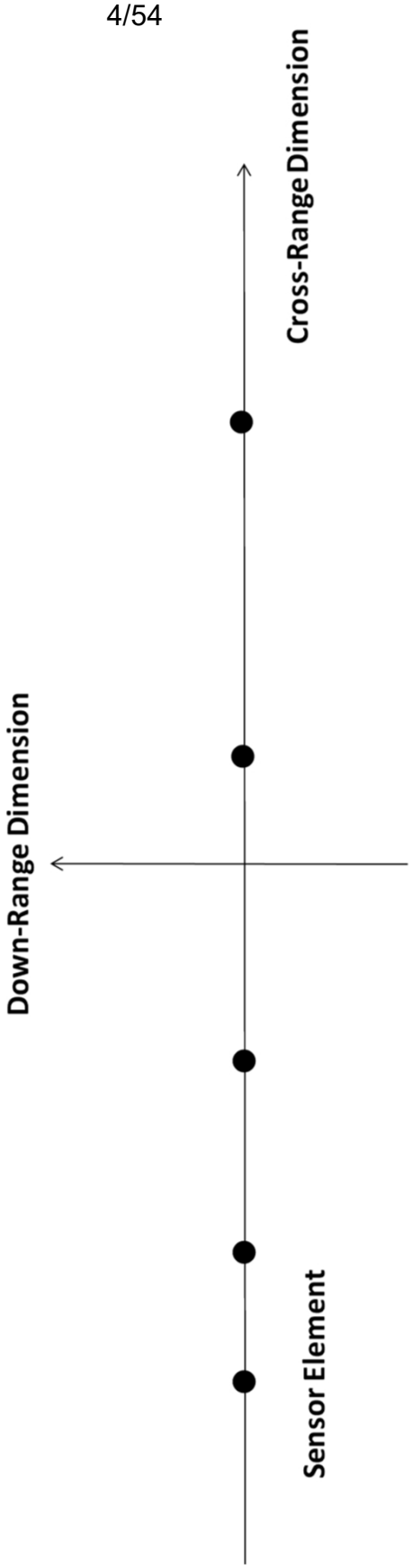

Cross-Range Dimension
Down-Range Dimension
Sensor Element

FIG. 1D

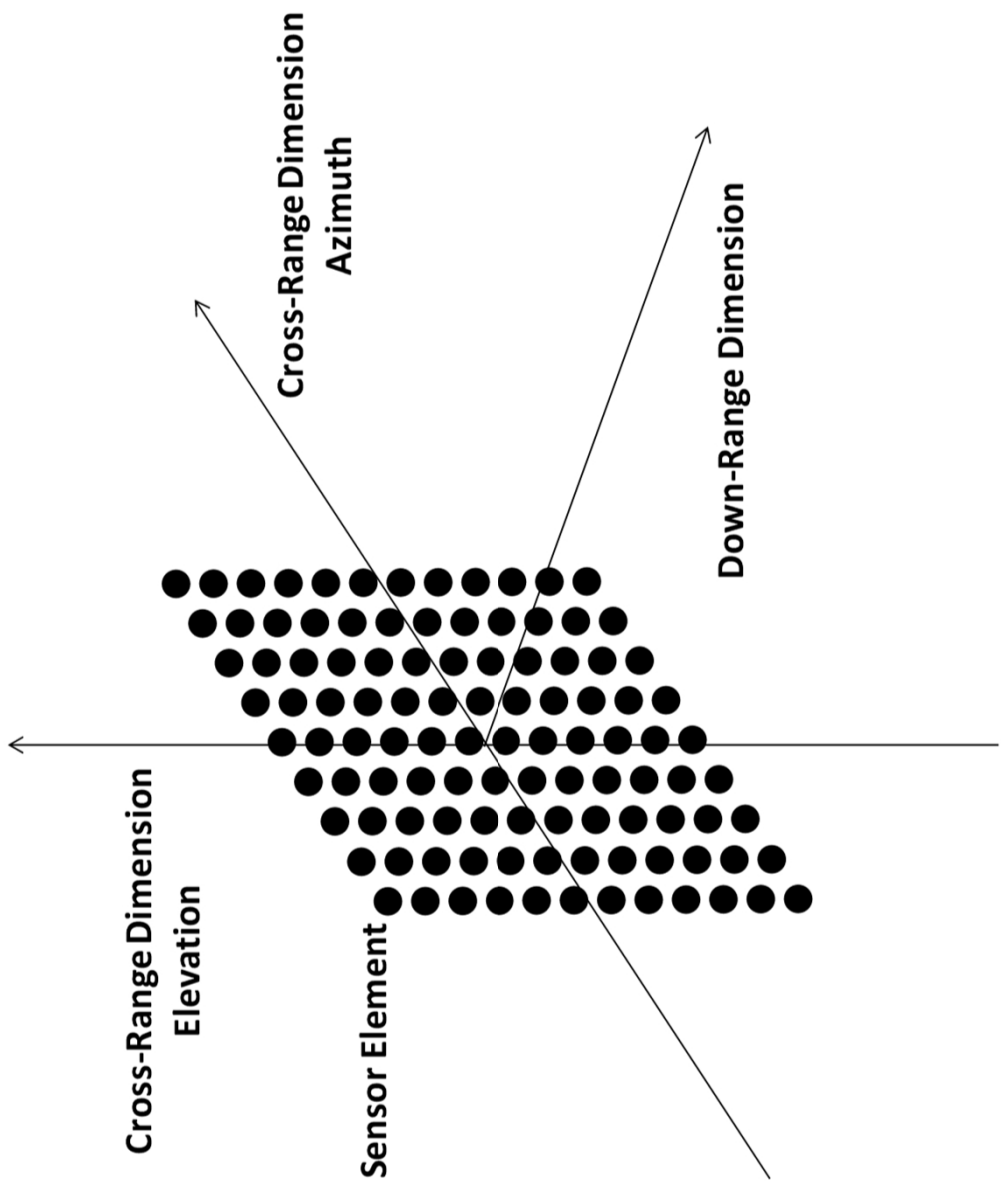

Cross-Range Dimension
Azimuth
Down-Range Dimension
Cross-Range Dimension
Elevation
Sensor Element

FIG. 1E

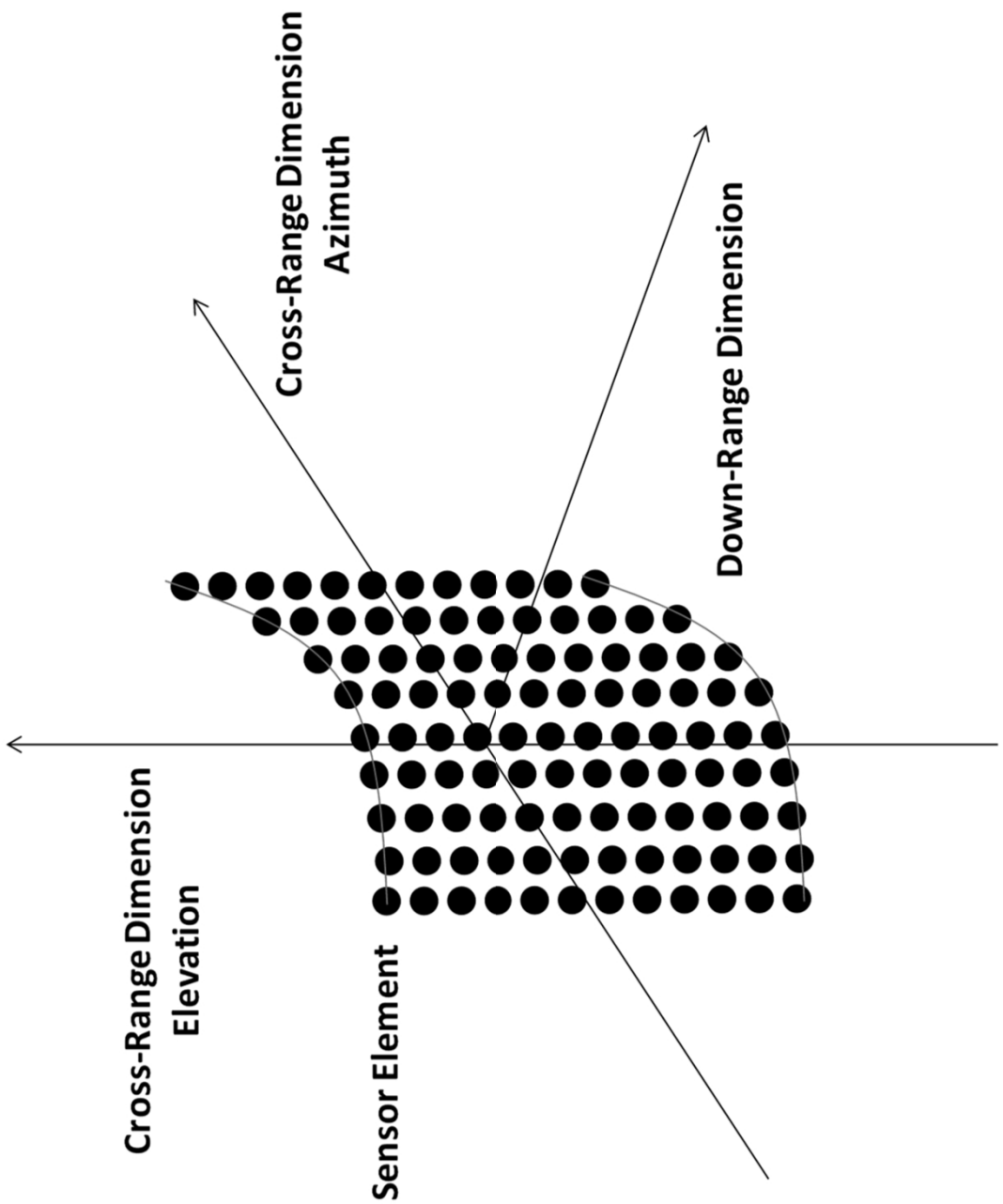

Cross-Range Dimension
Azimuth
Down-Range Dimension
Cross-Range Dimension
Elevation
Sensor Element

FIG. 1F

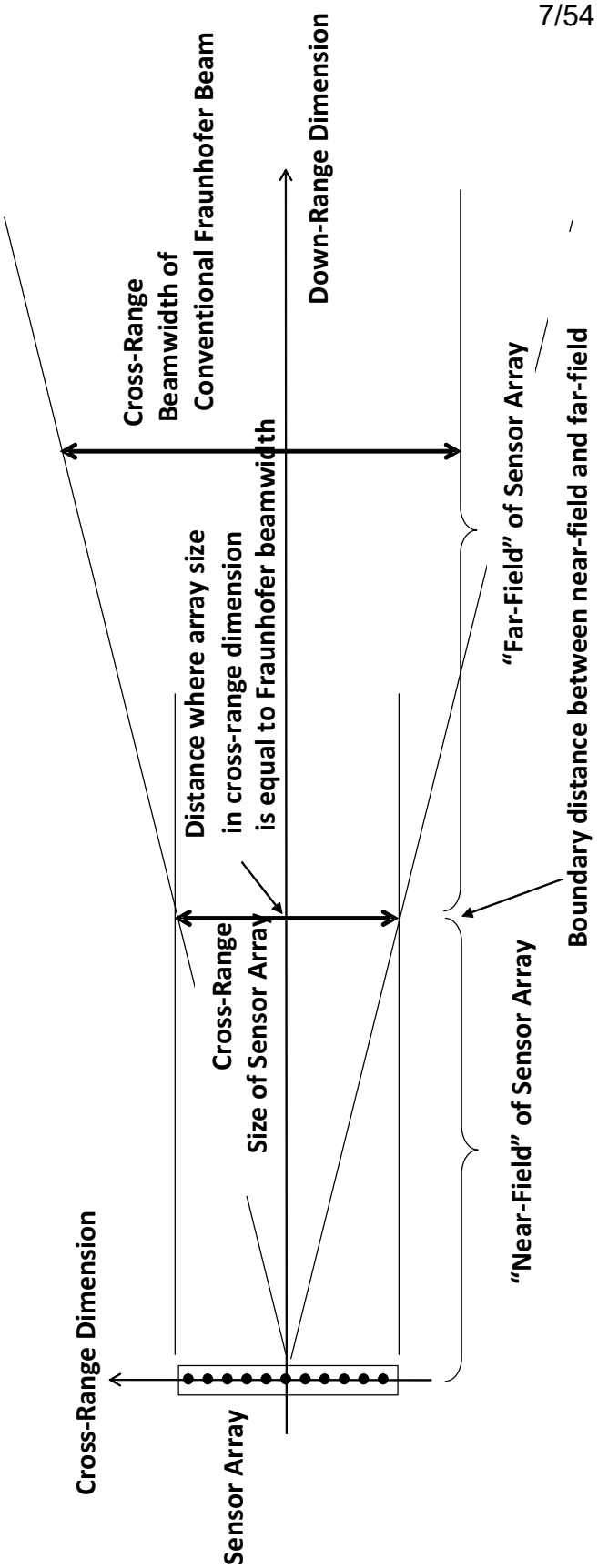

Cross-Range Dimension
Sensor Array
Cross-Range
Size of Sensor Array
Distance where array size
in cross-range dimension
is equal to Fraunhofer beamwidth
Down-Range Dimension
Cross-Range
Beamwidth of
Conventional Fraunhofer Beam
"Near-Field" of Sensor Array
"Far-Field" of Sensor Array
Boundary distance between near-field and far-field

FIG. 1G

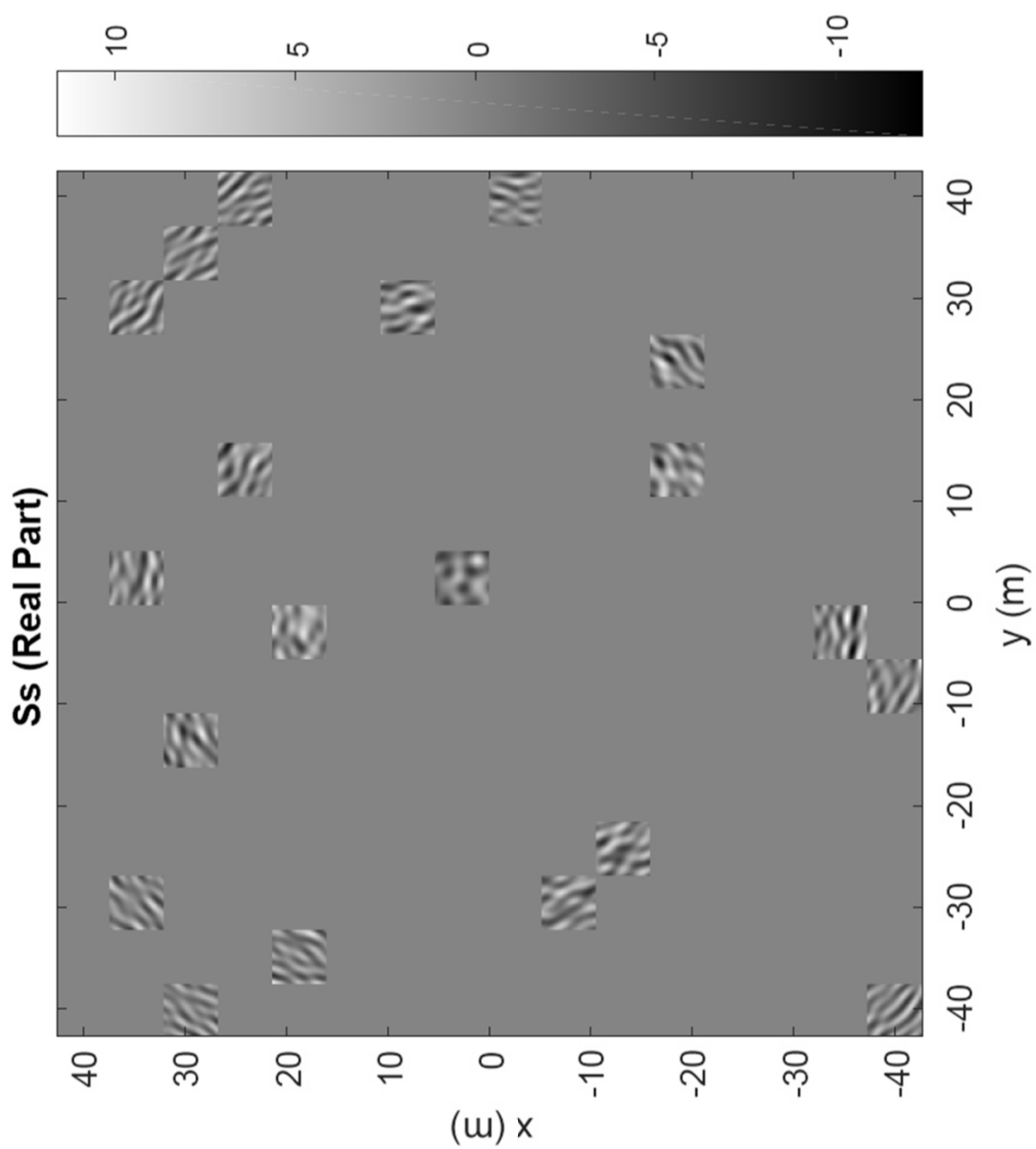

Ss (Real Part)
10
5
0
-5
-10
x (m)
40
30
20
10
0
-10
-20
-30
-40
y (m)
40
30
20
10
0
-10
-20
-30
-40

FIG. 1H

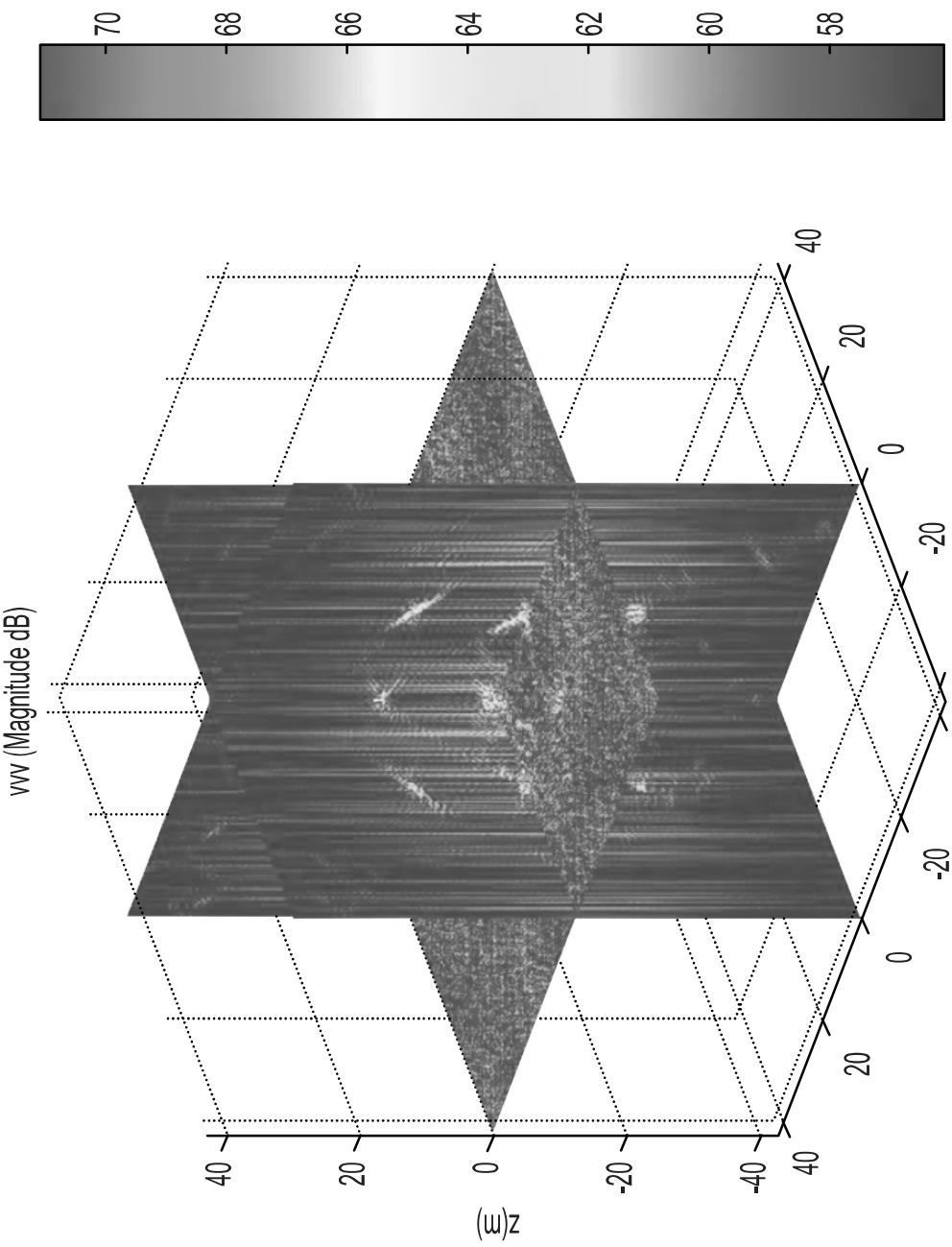


FIG. 1I

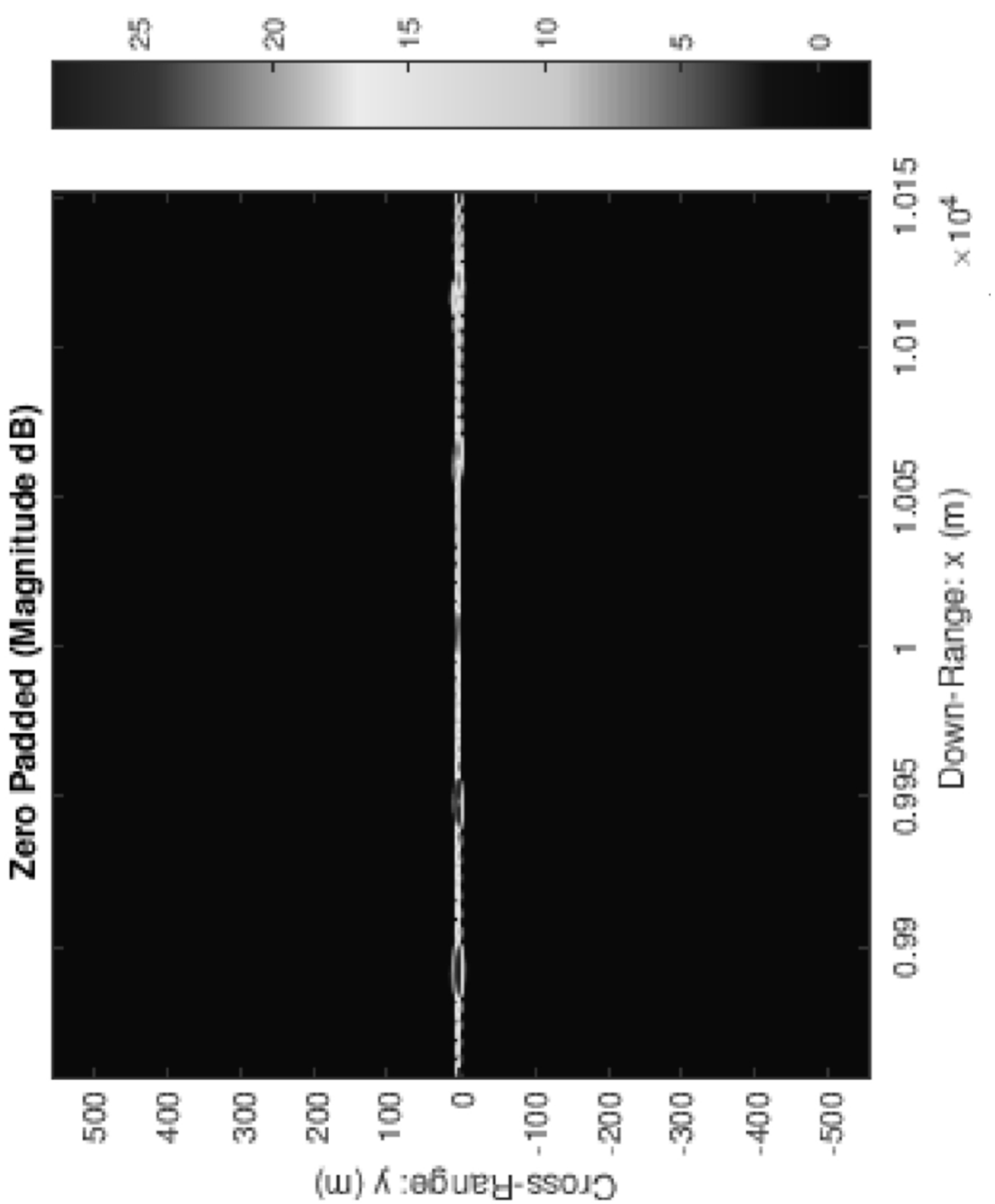


FIG. 2 (PRIOR ART)

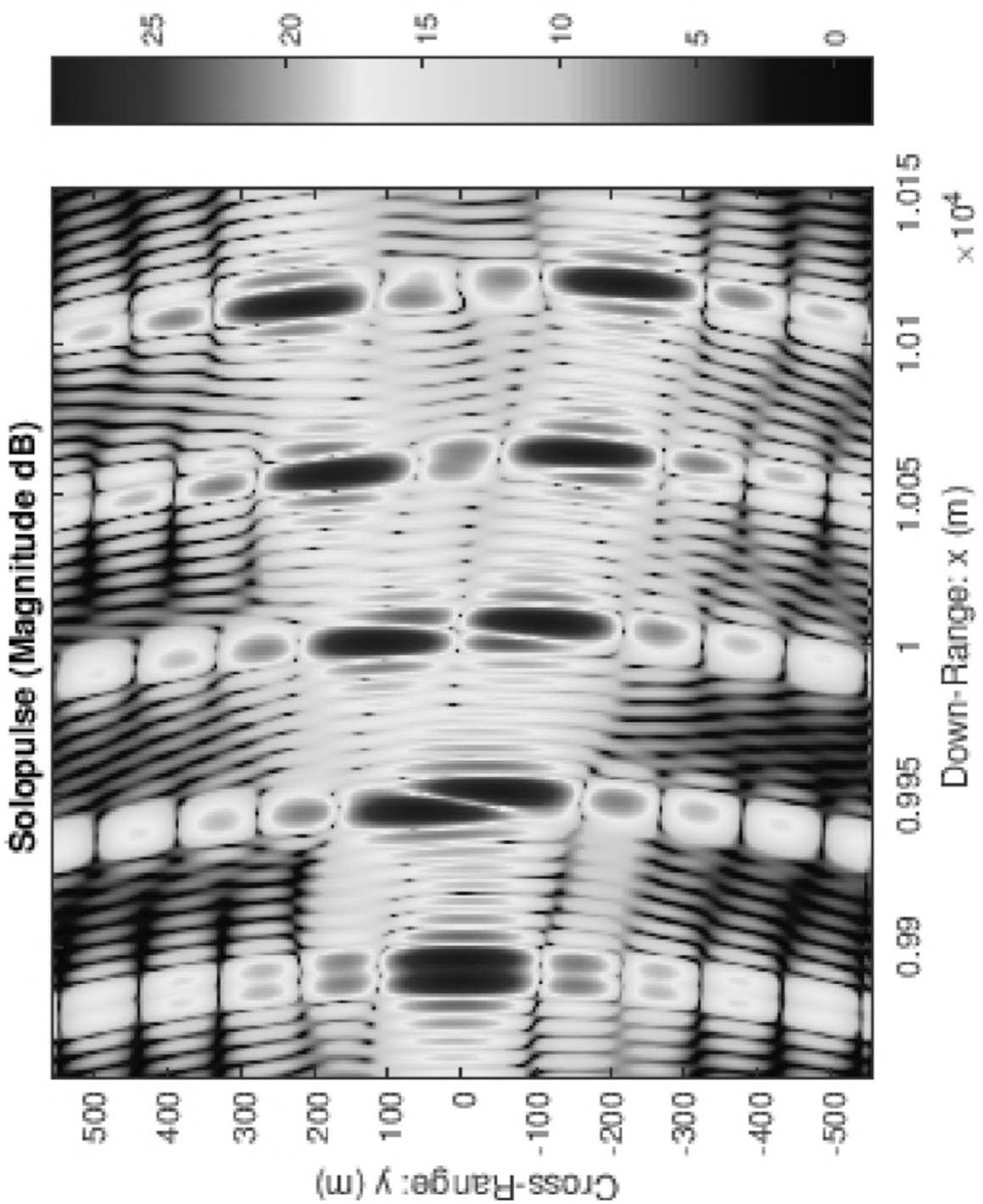

Solopulse (Magnitude dB)
25
20
15
10
5
0
500
400
300
200
100
0
-100
-200
-300
-400
-500
Cross-Range: y (m)
0.99
0.995
1
1.005
1.01
1.015
Down-Range: x (m)
×10^4

FIG. 3

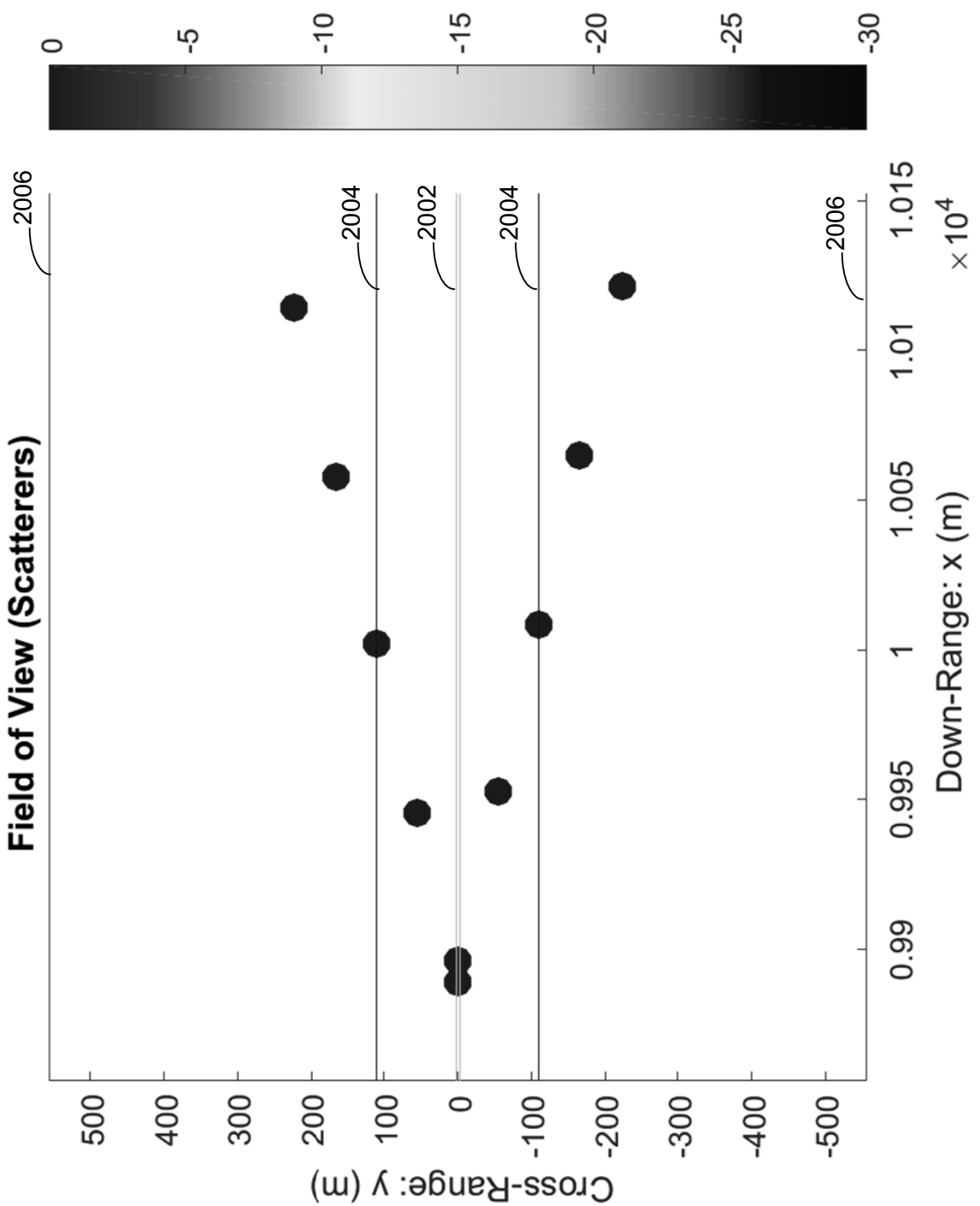

Field of View (Scatterers)
2006
2004
2002
2004
2006
0
-5
-10
-15
-20
-25
-30
500
400
300
200
100
0
-100
-200
-300
-400
-500
Cross-Range: y (m)
0.99
0.995
1
1.005
1.01
1.015
Down-Range: x (m)
×10^4

FIG. 4

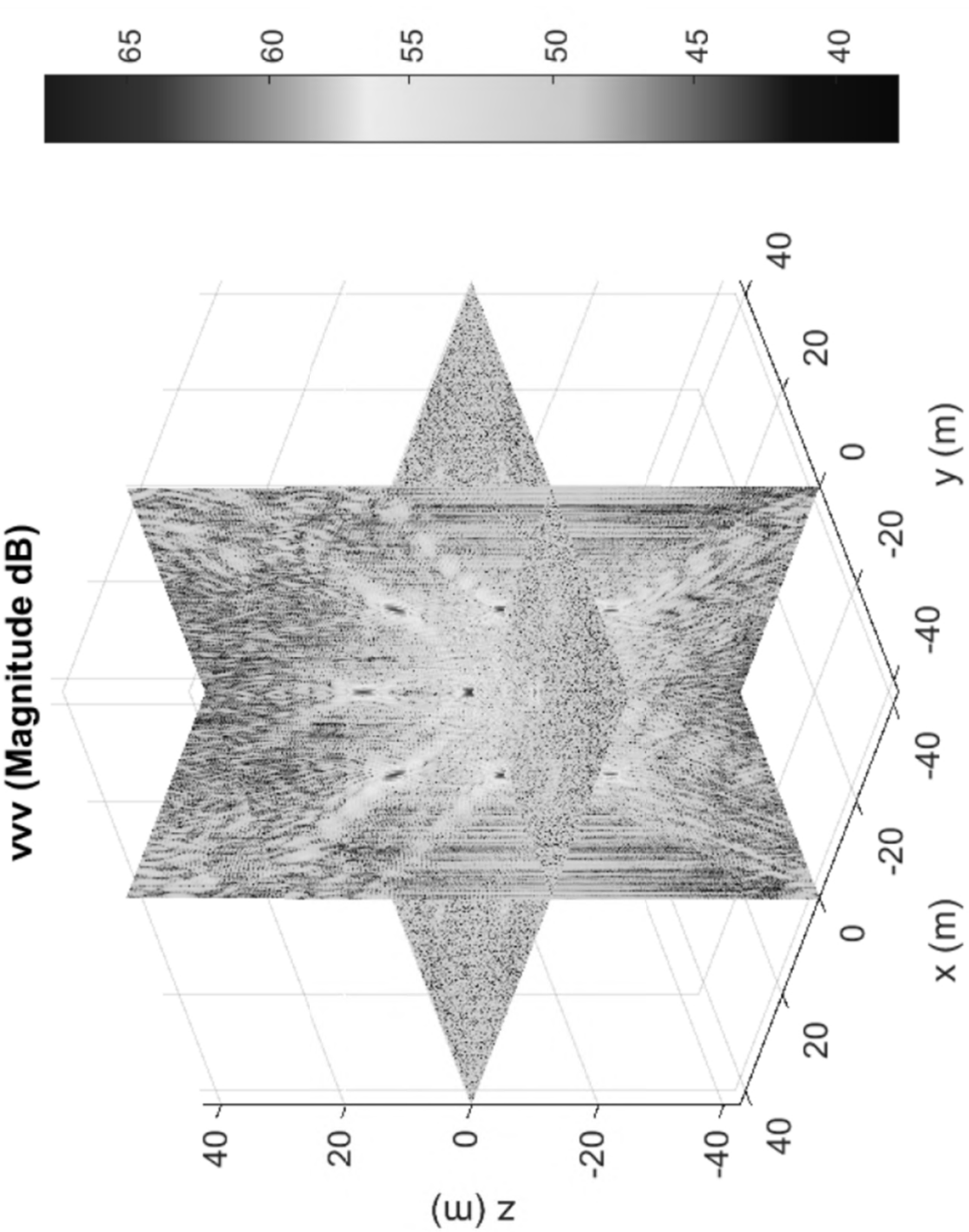

vvv (Magnitude dB)
65
60
55
50
45
40
z (m)
40
20
0
-20
-40
x (m)
40
20
0
-20
-40
y (m)
40
20
0
-20
-40

FIG. 5

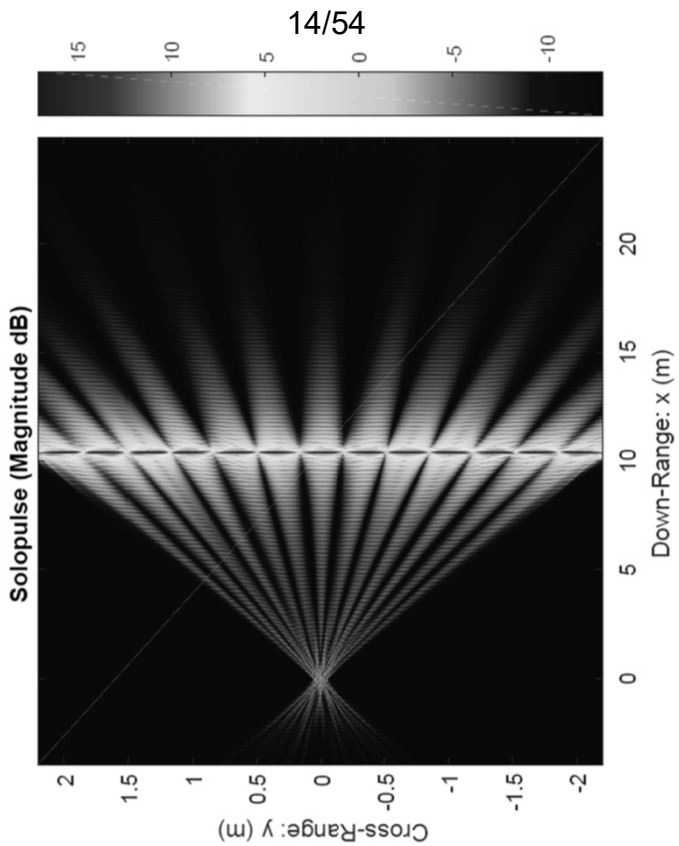

Solopulse (Magnitude dB)
Cross-Range: y (m)
Down-Range: x (m)

FIG. 6B

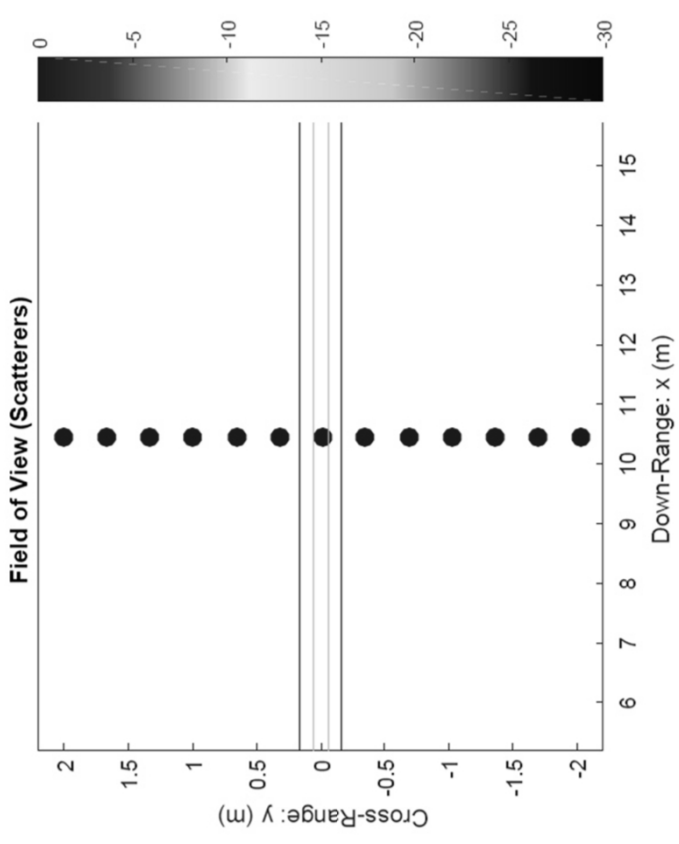

Field of View (Scatterers)
Cross-Range: y (m)
Down-Range: x (m)

FIG. 6A

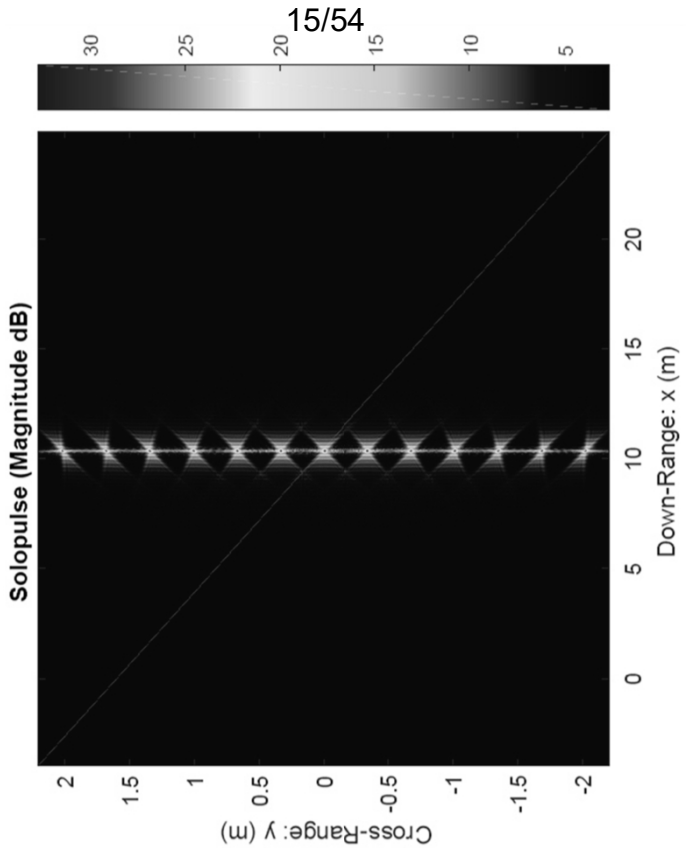

Solopulse (Magnitude dB)
Cross-Range: y (m)
Down-Range: x (m)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
5
10
15
20
30
25
20
15
10
5

FIG. 7B

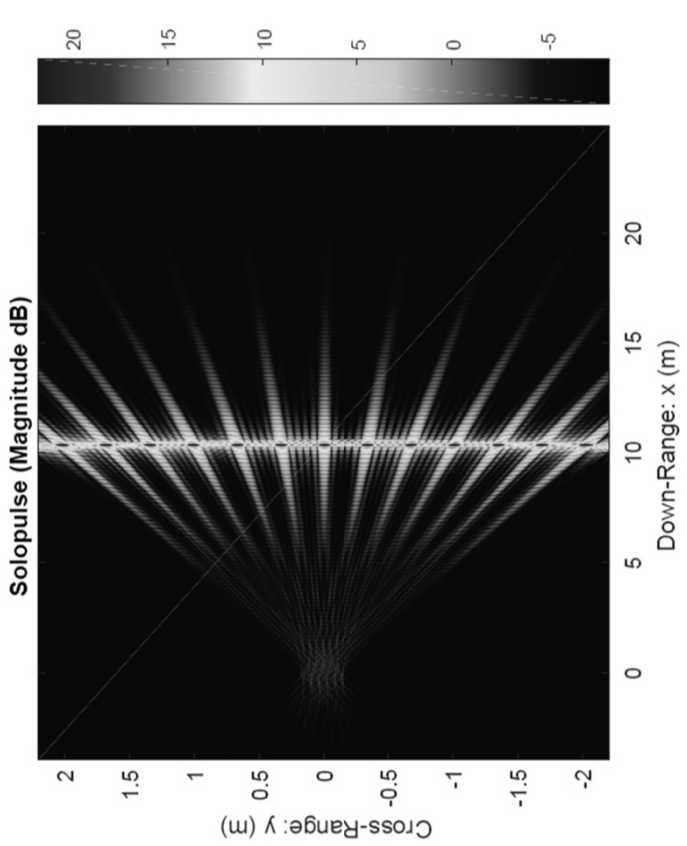

Solopulse (Magnitude dB)
Cross-Range: y (m)
Down-Range: x (m)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
5
10
15
20
20
15
10
5
0
-5

FIG. 7A

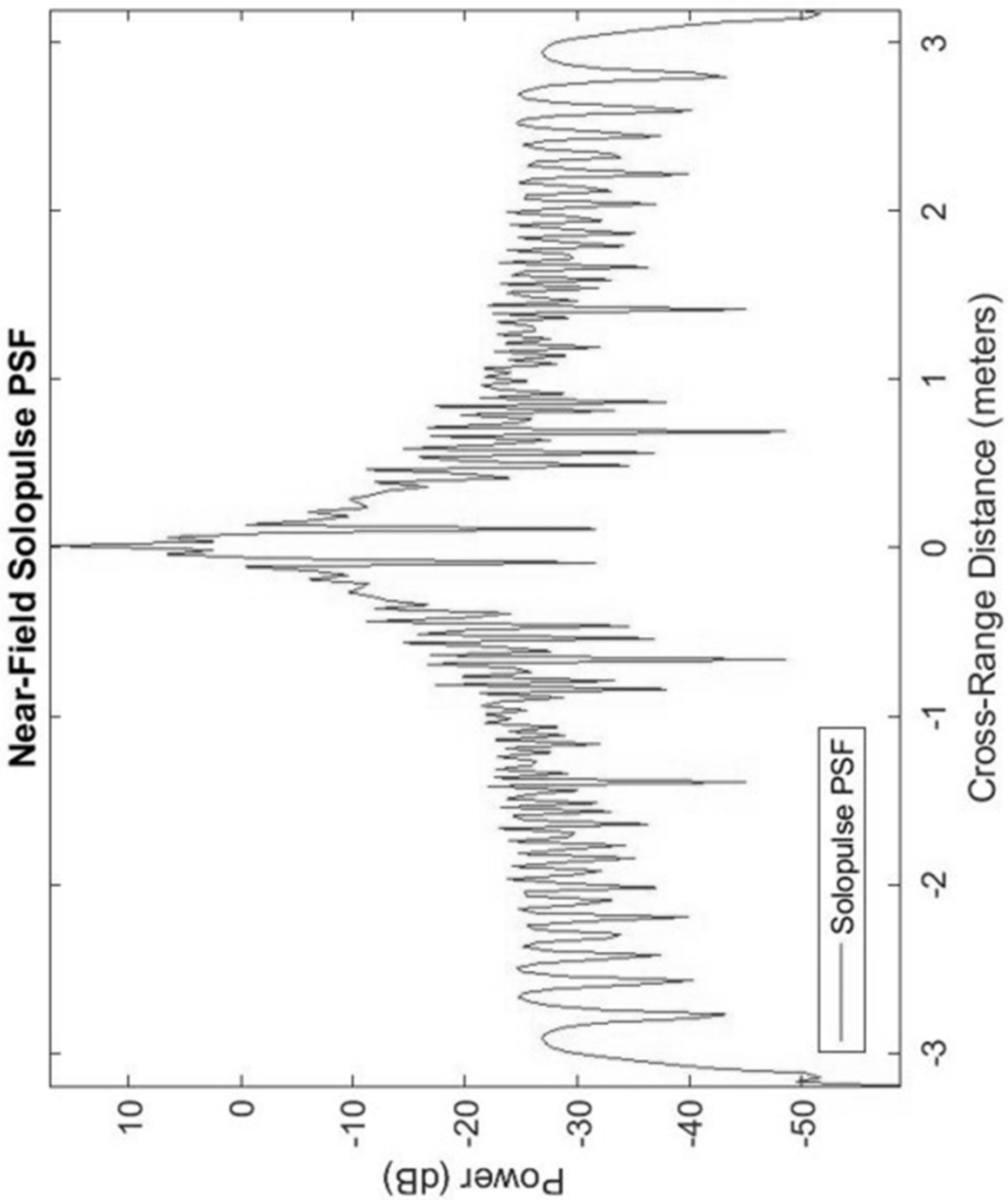

Near-Field Solopulse PSF
Power (dB)
10
0
-10
-20
-30
-40
-50
-3
-2
-1
0
1
2
3
Cross-Range Distance (meters)
Solopulse PSF

FIG. 8

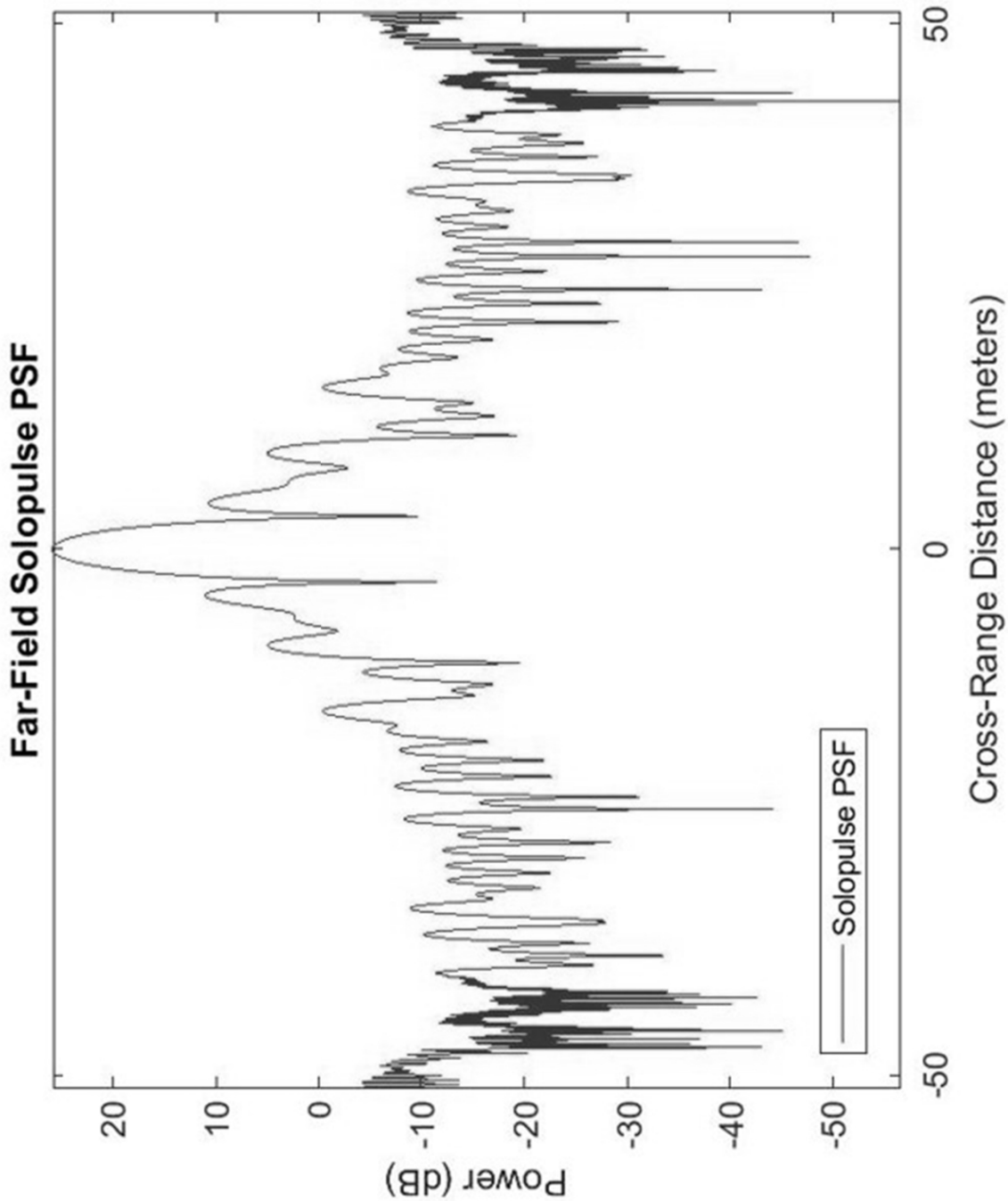

Far-Field Solopulse PSF
Power (dB)
20
10
0
-10
-20
-30
-40
-50
-50
0
50
Cross-Range Distance (meters)
Solopulse PSF

FIG. 9

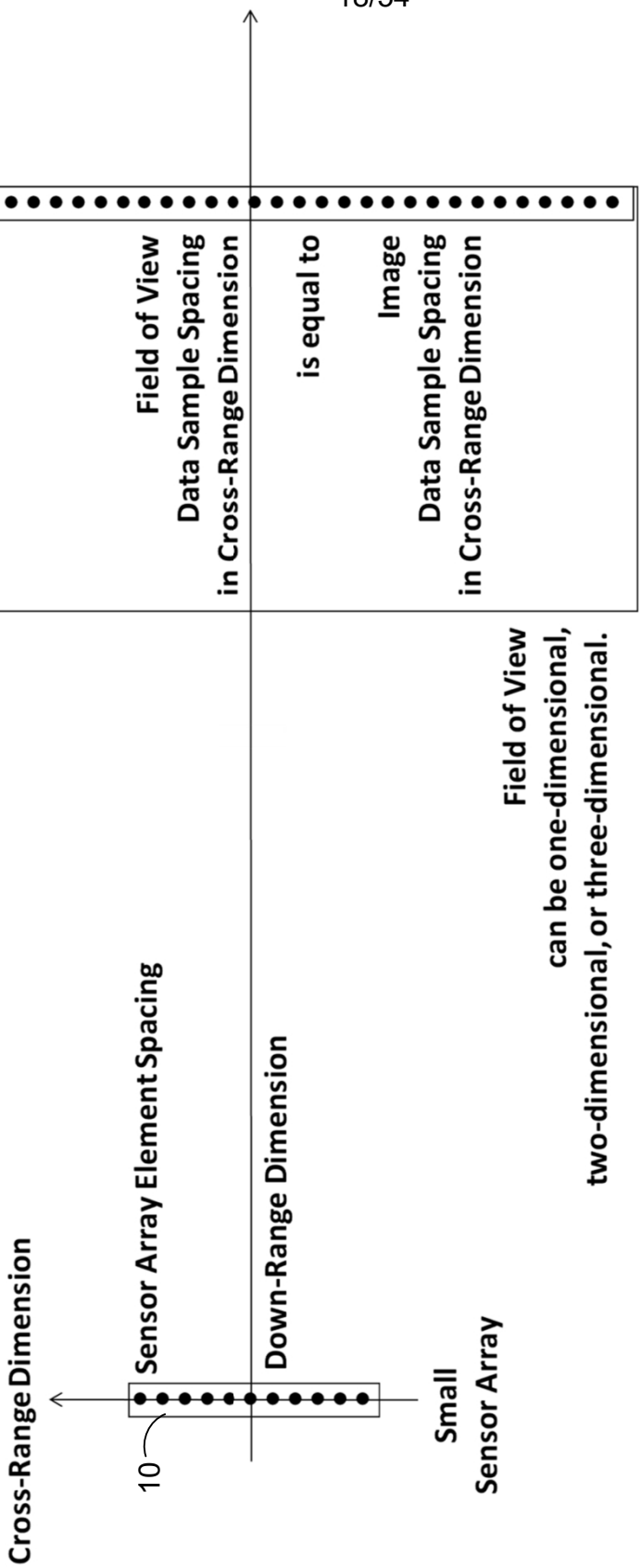

Large
Field of View
Field of View
Data Sample Spacing
in Cross-Range Dimension
is equal to
Image
Data Sample Spacing
in Cross-Range Dimension
Field of View
can be one-dimensional,
two-dimensional, or three-dimensional.
Cross-Range Dimension
Sensor Array Element Spacing
Down-Range Dimension
10
Small
Sensor Array

FIG. 10

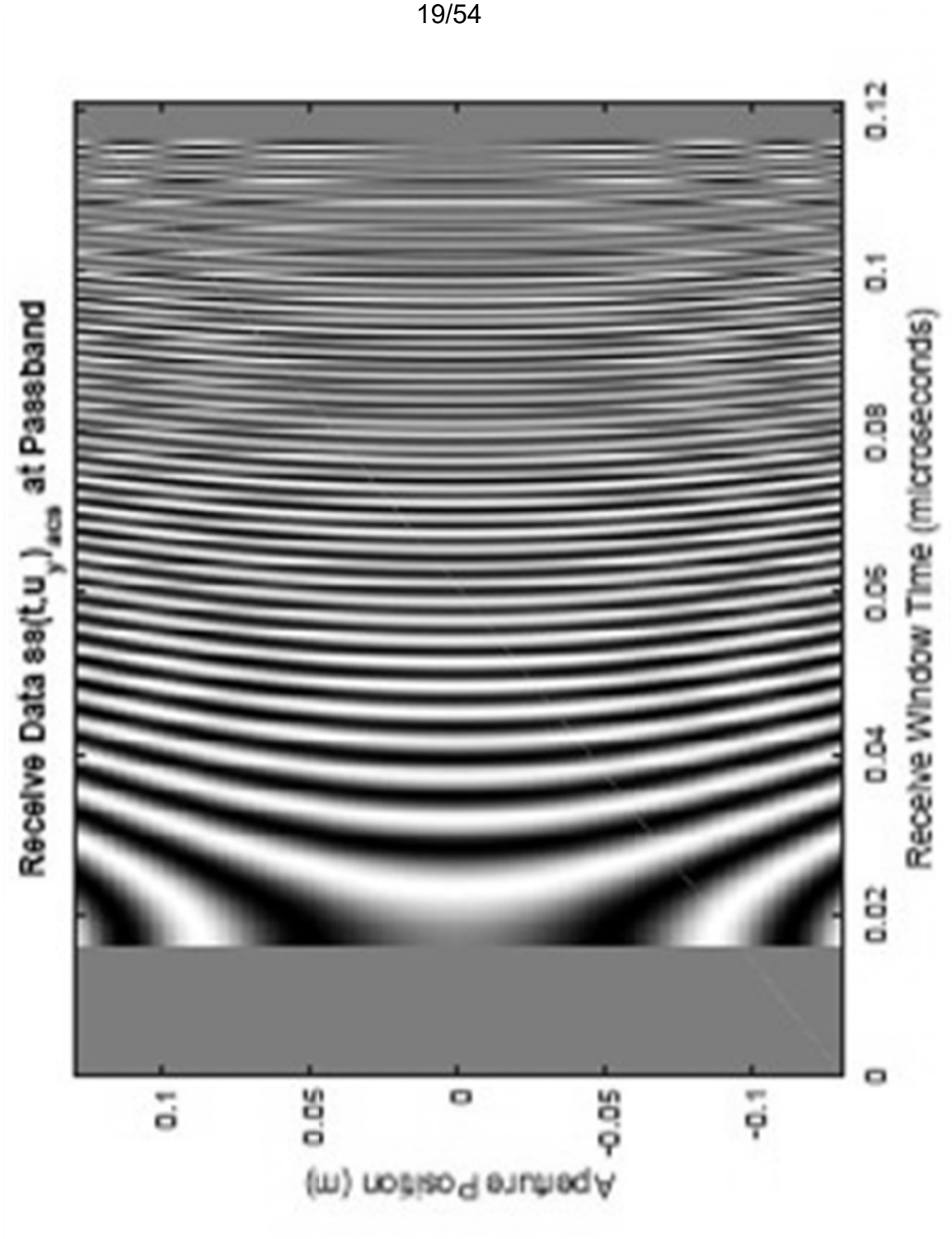

Receive Data $s_R(t,u_y)_{ACS}$ at Passband
Aperture Position (m)
0.1
0.05
0
-0.05
-0.1
0
0.02
0.04
0.06
0.08
0.1
0.12
Receive Window Time (microseconds)

FIG. 11A

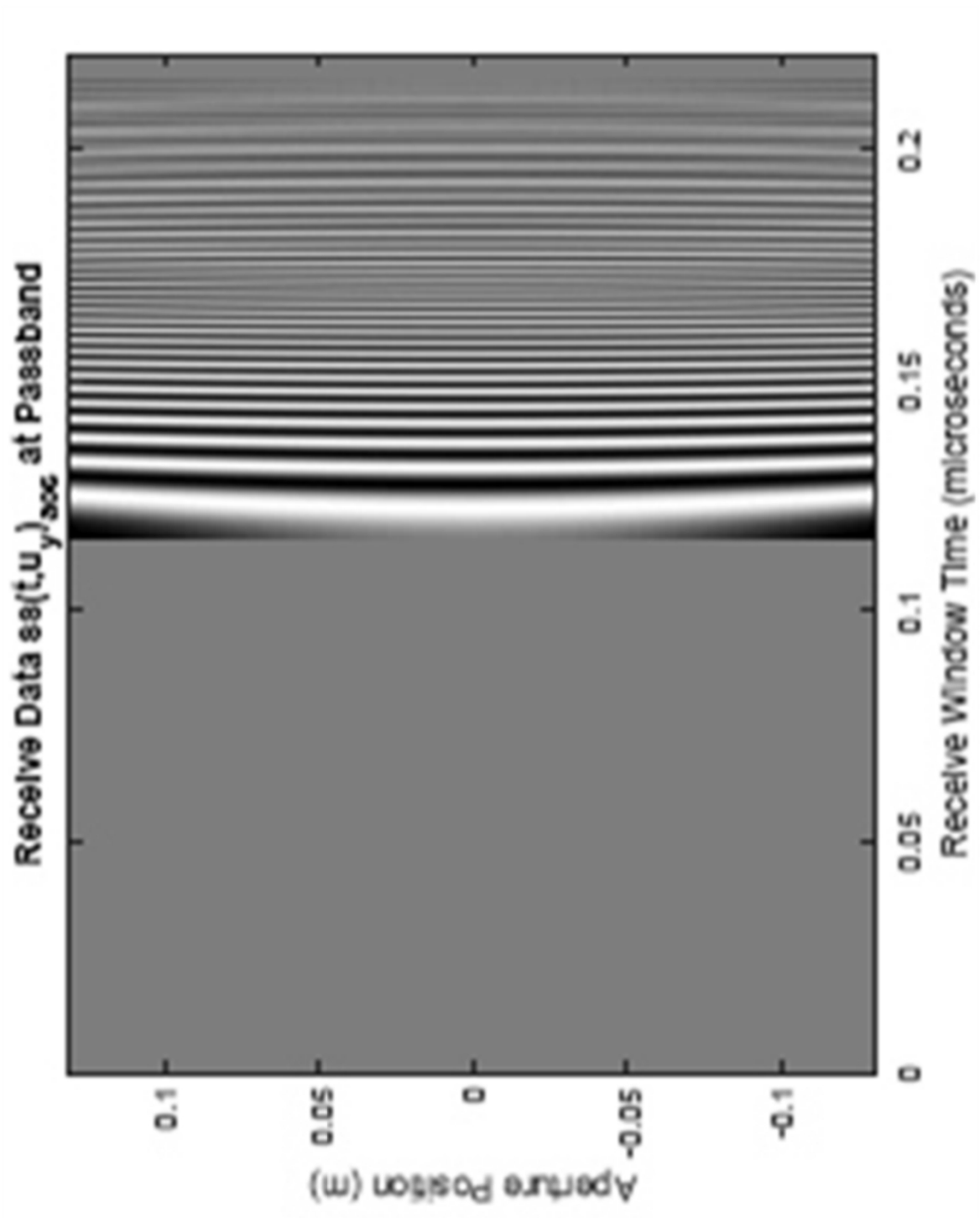

Receive Data $s_R(t,u_{y'})_{SAC}$ at Passband
Aperture Position (m)
0.1
0.05
0
-0.05
-0.1
0
0.05
0.1
0.15
0.2
Receive Window Time (microseconds)

FIG. 11B

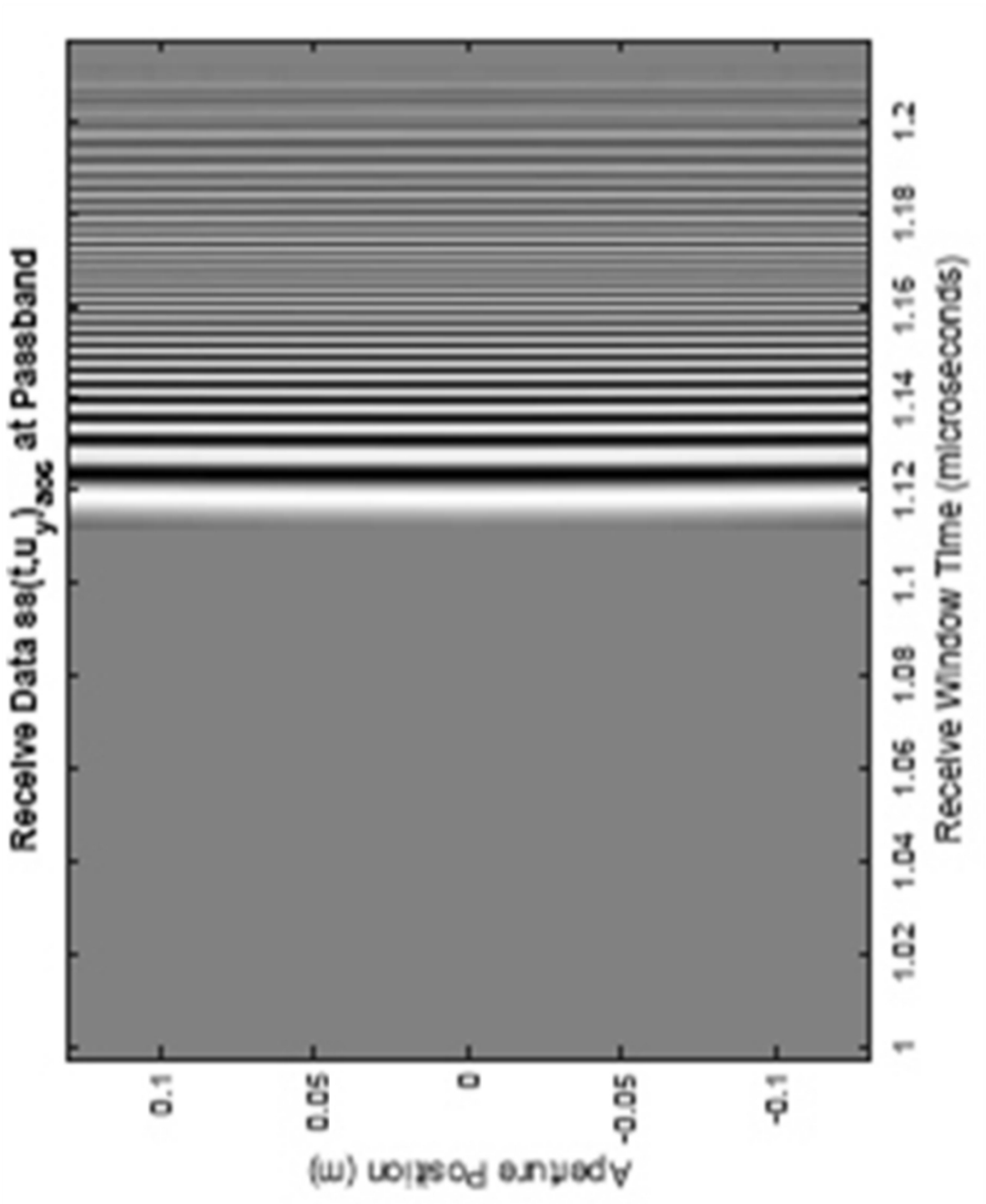

Receive Data $s_R(t,u_{y'})_{SAC}$ at Passband
Aperture Position (m)
0.1
0.05
0
-0.05
-0.1
1
1.02
1.04
1.06
1.08
1.1
1.12
1.14
1.16
1.18
1.2
Receive Window Time (microseconds)

FIG. 11C

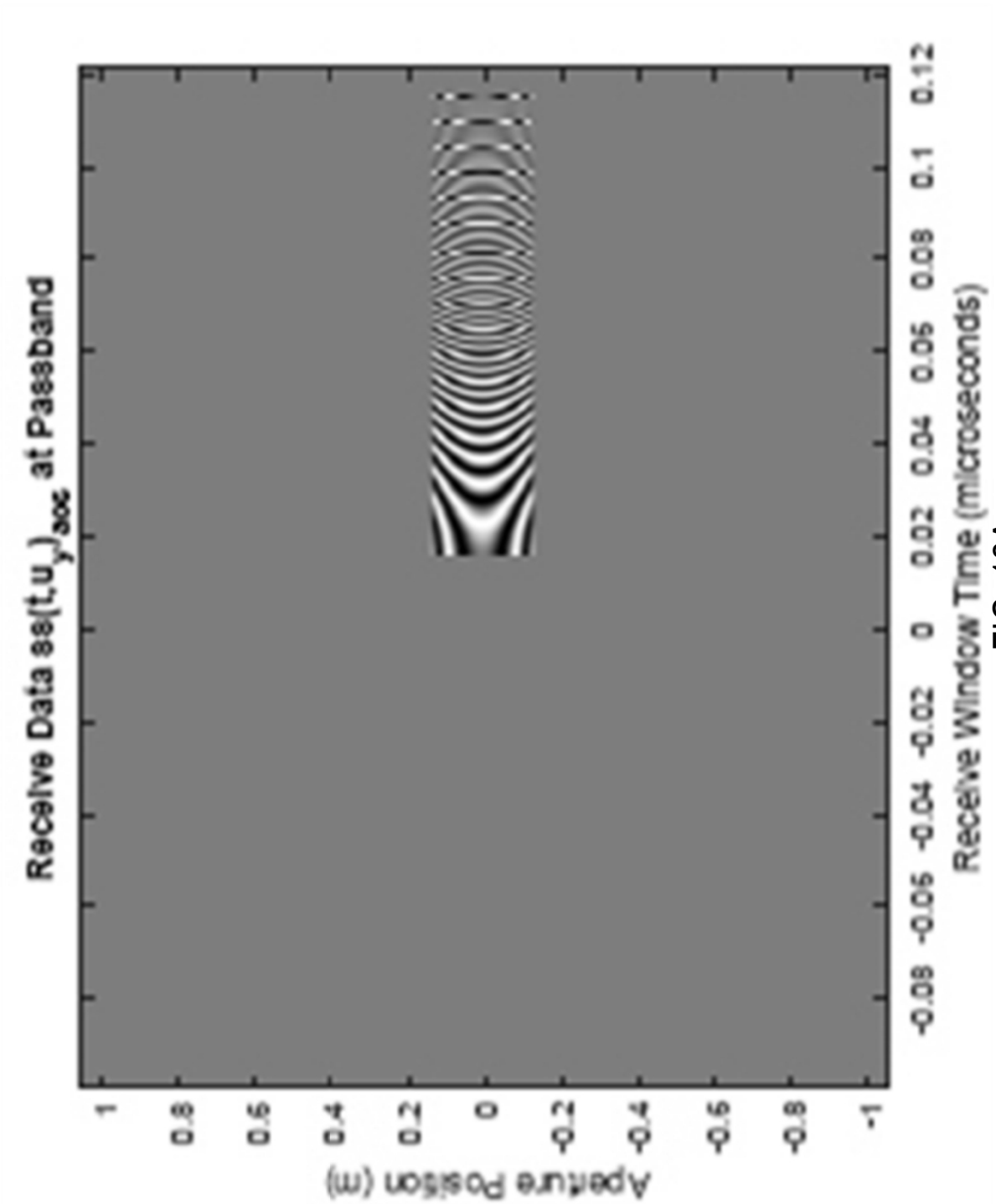

Receive Data $ss(t,u_y)_{soc}$ at Passband
Aperture Position (m)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-0.08 -0.06 -0.04 -0.02 0 0.02 0.04 0.06 0.08 0.1 0.12
Receive Window Time (microseconds)

FIG. 12A

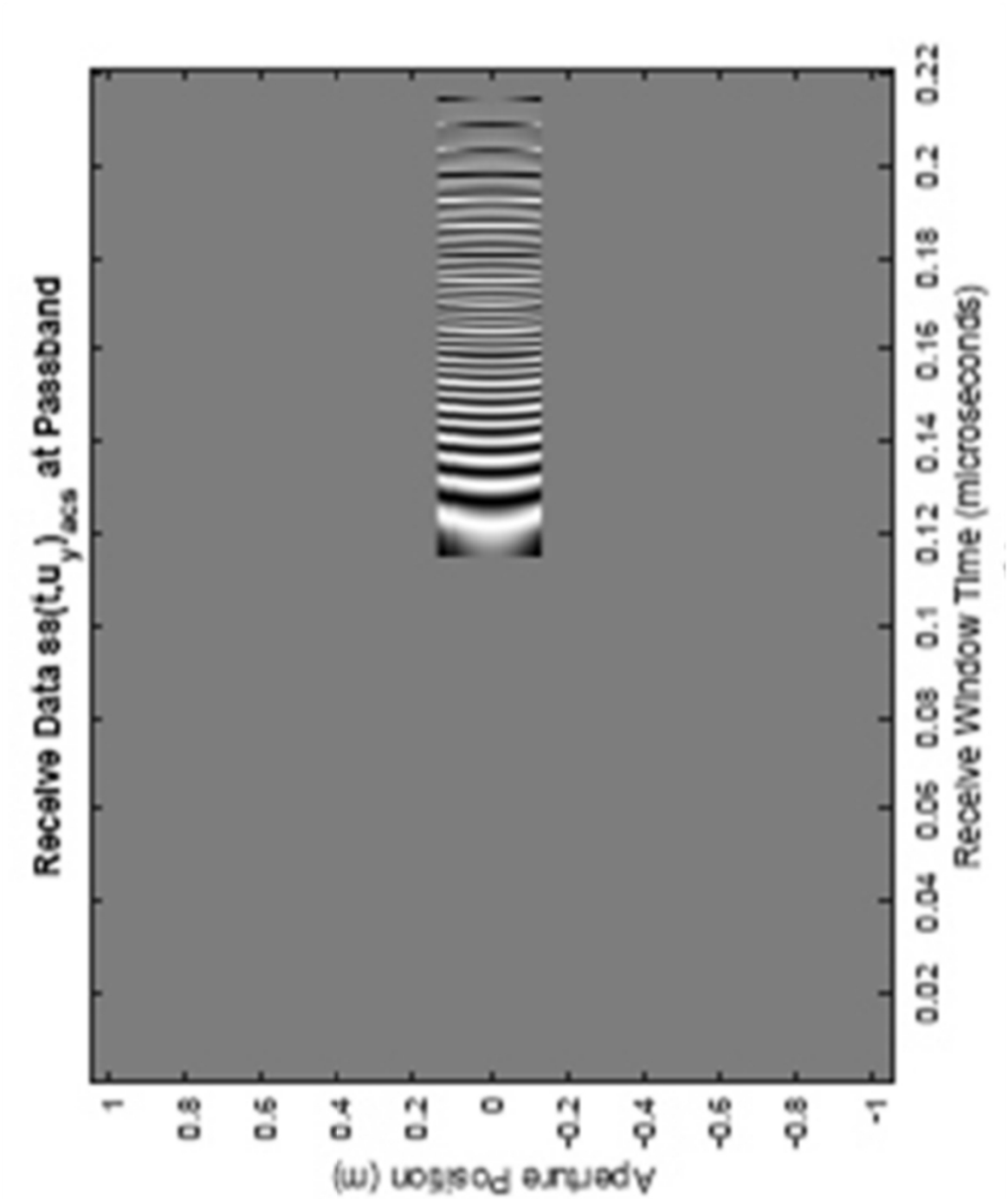

Receive Data $ss(t,u_y)_{acs}$ at Passband
Aperture Position (m)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
Receive Window Time (microseconds)

FIG. 12B

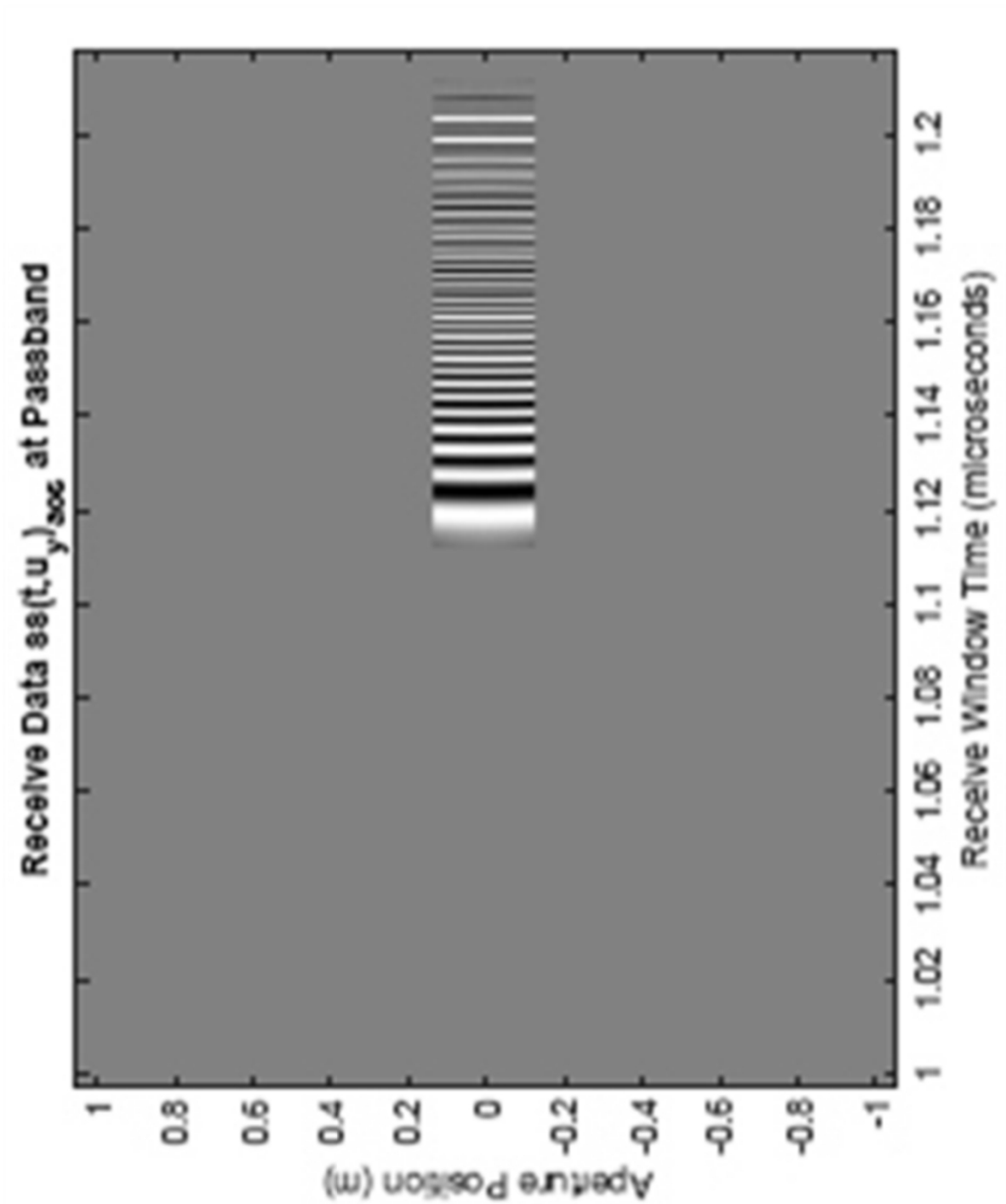

Receive Data $s_R(t,u_{y'})_{SOC}$ at Passband
Aperture Position (m)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
1.02
1.04
1.06
1.08
1.1
1.12
1.14
1.16
1.18
1.2
Receive Window Time (microseconds)

FIG. 12C

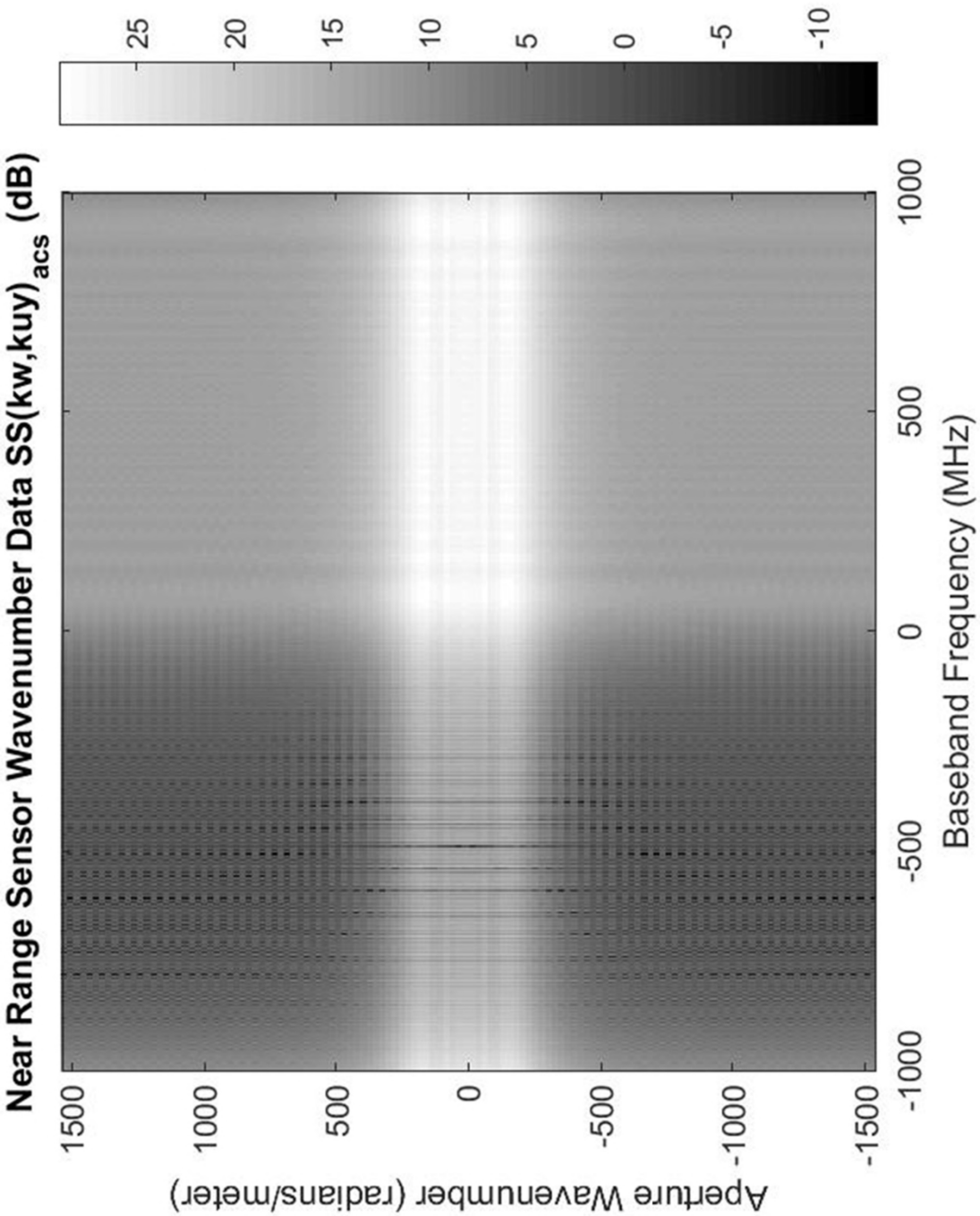

Near Range Sensor Wavenumber Data SS(kw,kuy)acs (dB)
25
20
15
10
5
0
-5
-10
1500
1000
500
0
-500
-1000
-1500
Aperture Wavenumber (radians/meter)
-1000
-500
0
500
1000
Baseband Frequency (MHz)

FIG. 13A

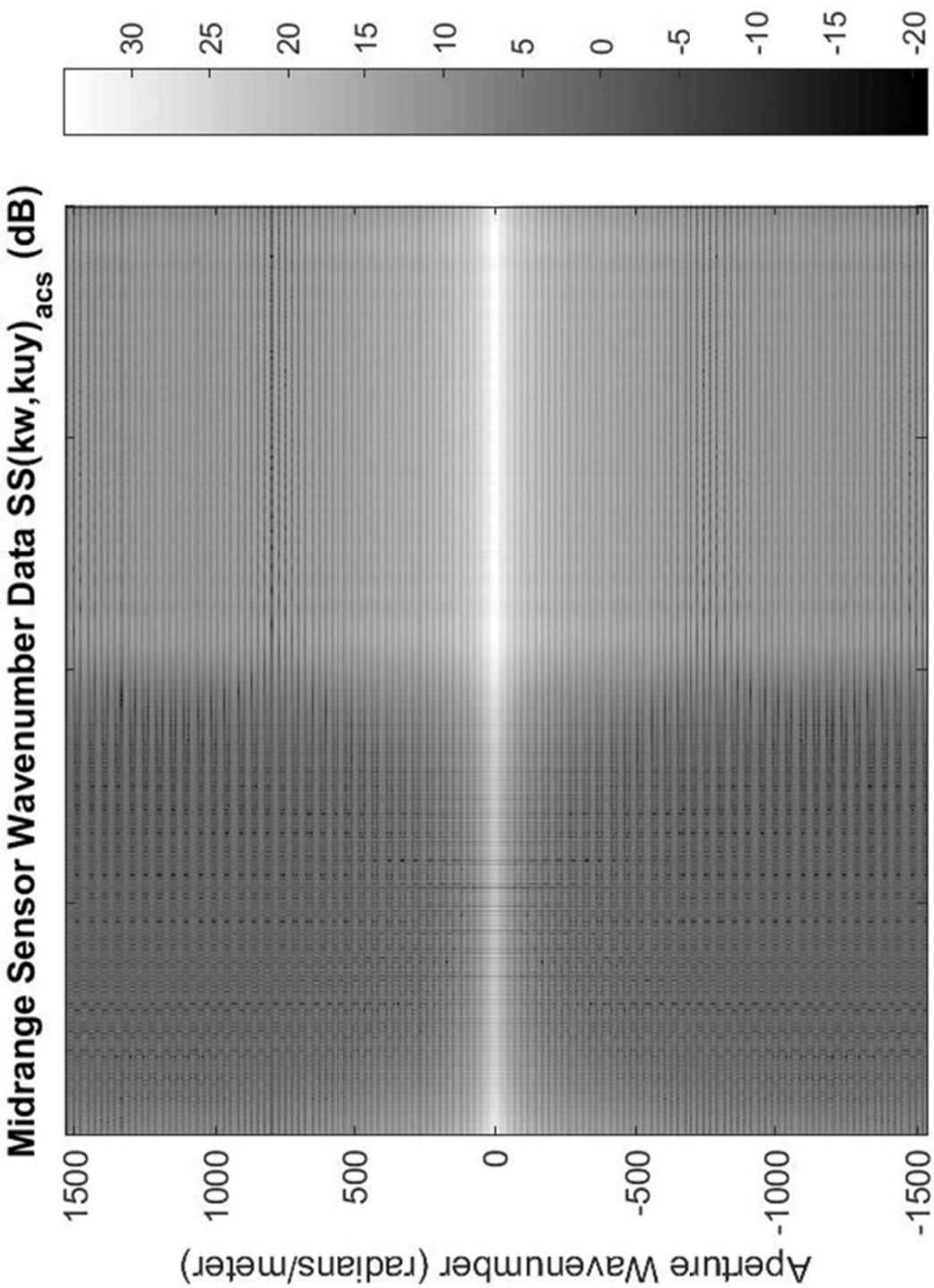

Midrange Sensor Wavenumber Data SS(kw,kuy)acs (dB)
30
25
20
15
10
5
0
-5
-10
-15
-20
1500
1000
500
0
-500
-1000
-1500
Aperture Wavenumber (radians/meter)
-1000
-500
0
500
1000
Baseband Frequency (MHz)

FIG. 13B

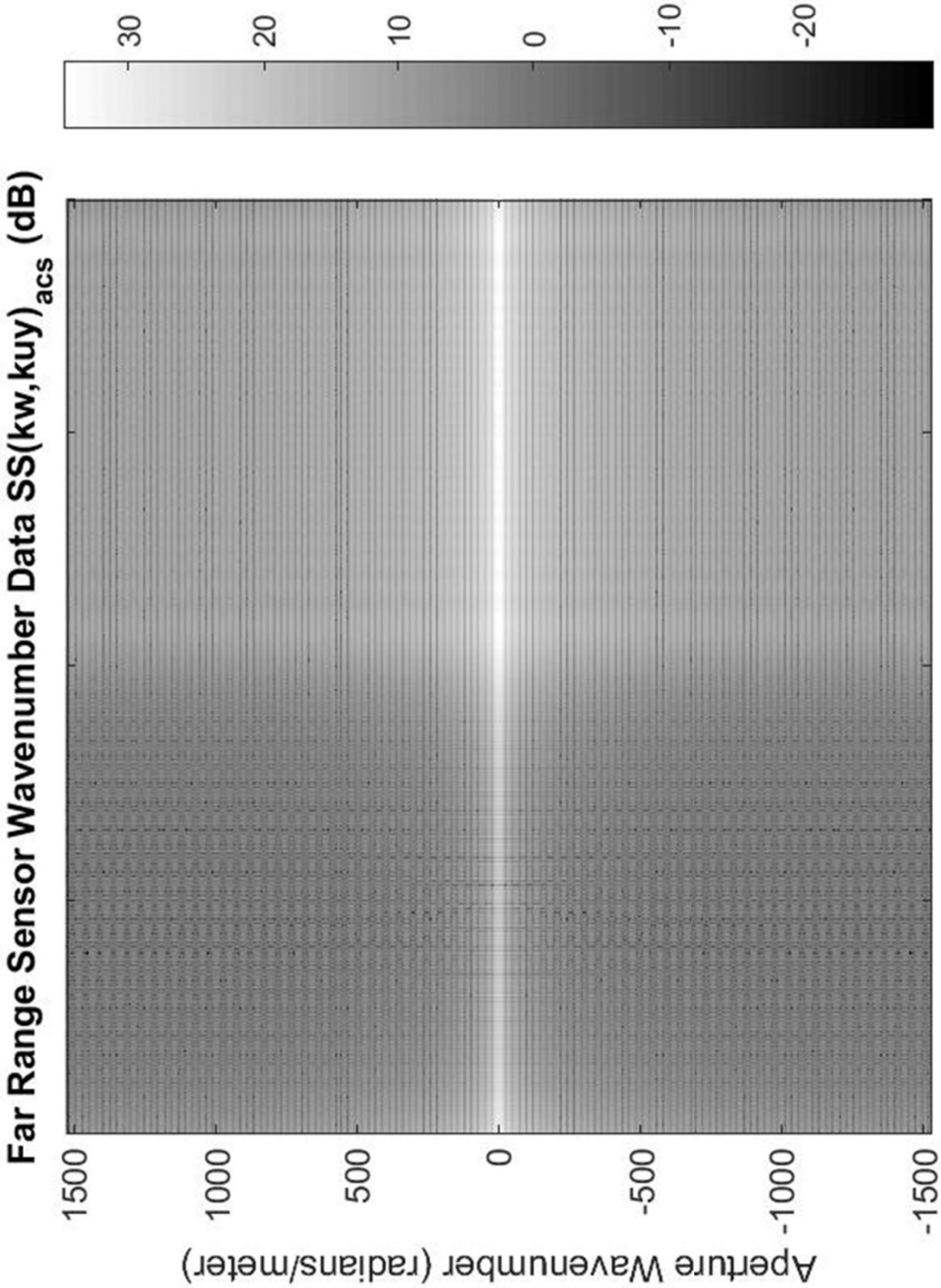

Far Range Sensor Wavenumber Data SS(kw,kuy)acs (dB)
30
20
10
0
-10
-20
1500
1000
500
0
-500
-1000
-1500
Aperture Wavenumber (radians/meter)
-1000
-500
0
500
1000
Baseband Frequency (MHz)

FIG. 13C

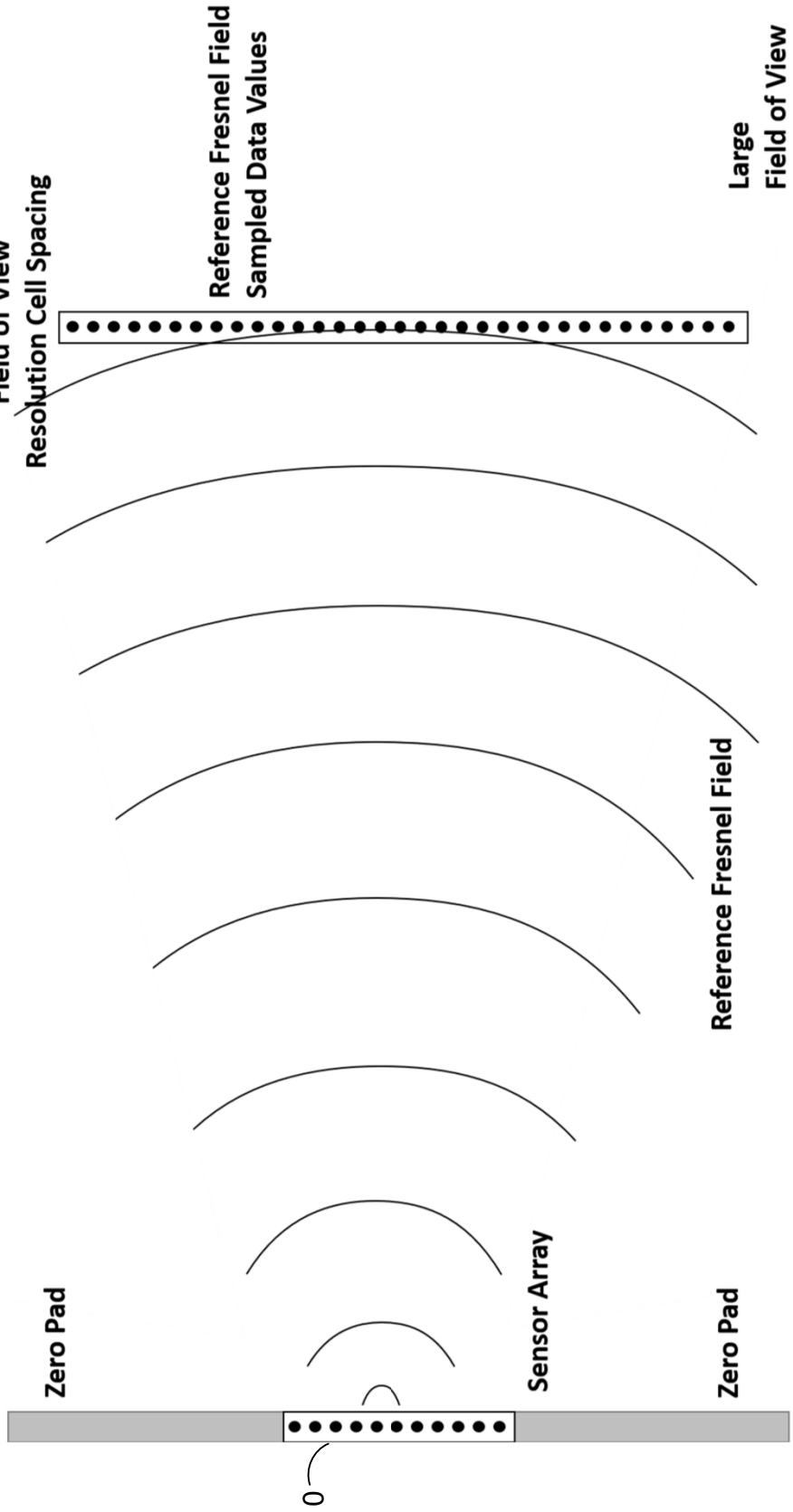

Field of View
Resolution Cell Spacing
Reference Fresnel Field
Sampled Data Values
Large
Field of View
Reference Fresnel Field
Zero Pad
Sensor Array
Zero Pad
10

FIG. 14

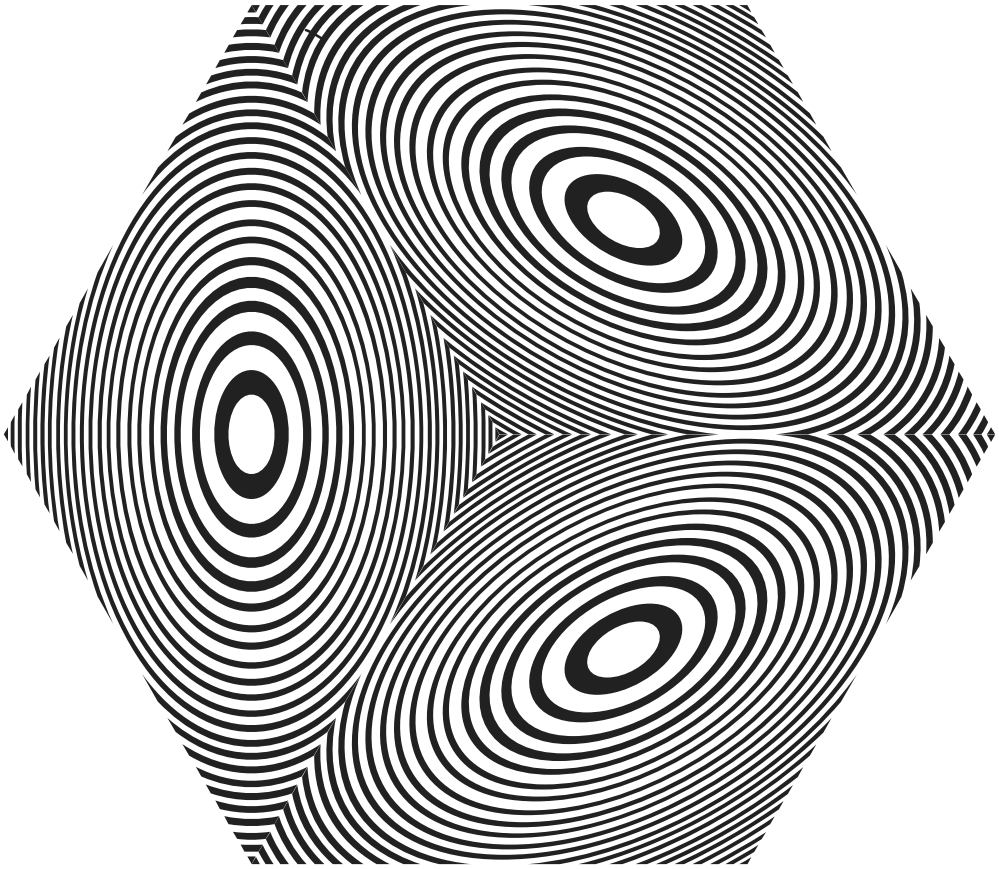


FIG. 15B

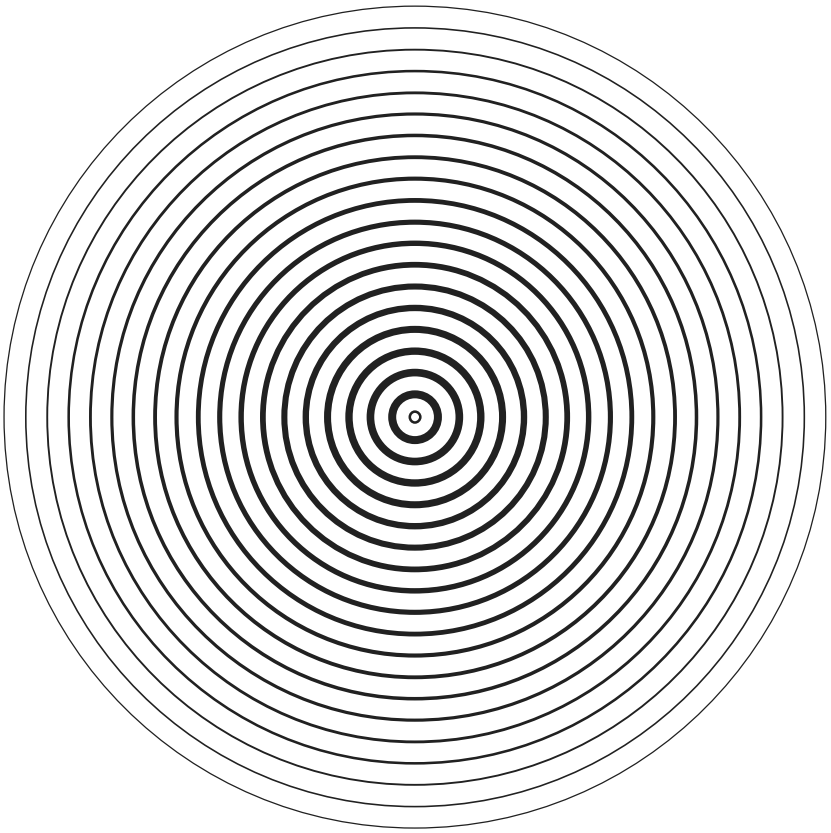


FIG. 15A

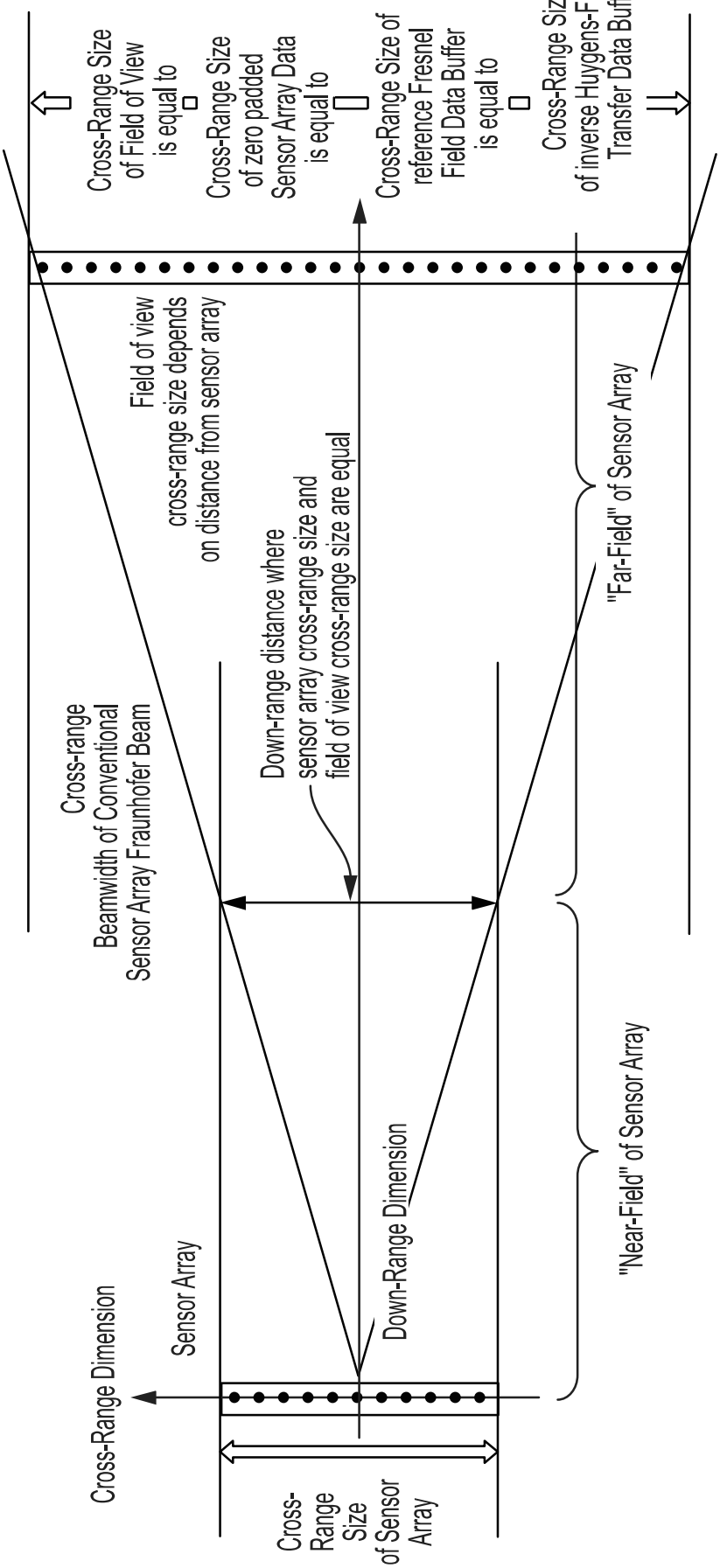

Cross-Range Size of Field of View is equal to
Cross-Range Size of zero padded Sensor Array Data is equal to
Cross-Range Size of reference Fresnel Field Data Buffer is equal to
Cross-Range Size of inverse Huygens-Fresnel Transfer Data Buffer
Field of view cross-range size depends on distance from sensor array
Down-range distance where sensor array cross-range size and field of view cross-range size are equal
Cross-range Beamwidth of Conventional Sensor Array Fraunhofer Beam
"Far-Field" of Sensor Array
"Near-Field" of Sensor Array
Cross-Range Dimension
Sensor Array
Down-Range Dimension
Cross-Range Size of Sensor Array

FIG. 16

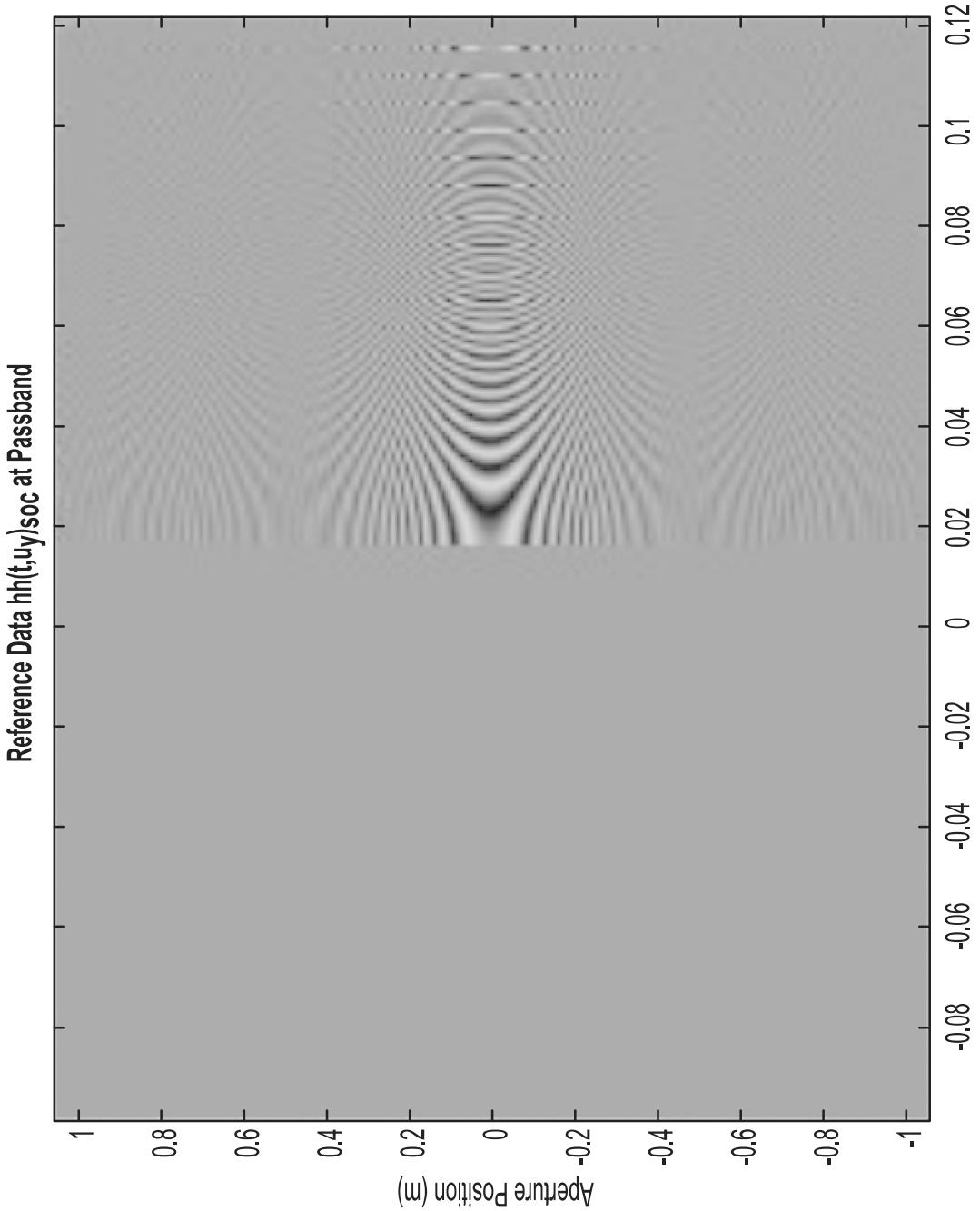

Reference Data hh(t,uy)soc at Passband
Aperture Position (m)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-0.08
-0.06
-0.04
-0.02
0
0.02
0.04
0.06
0.08
0.1
0.12
Receive Window Time (microseconds)

FIG. 17A

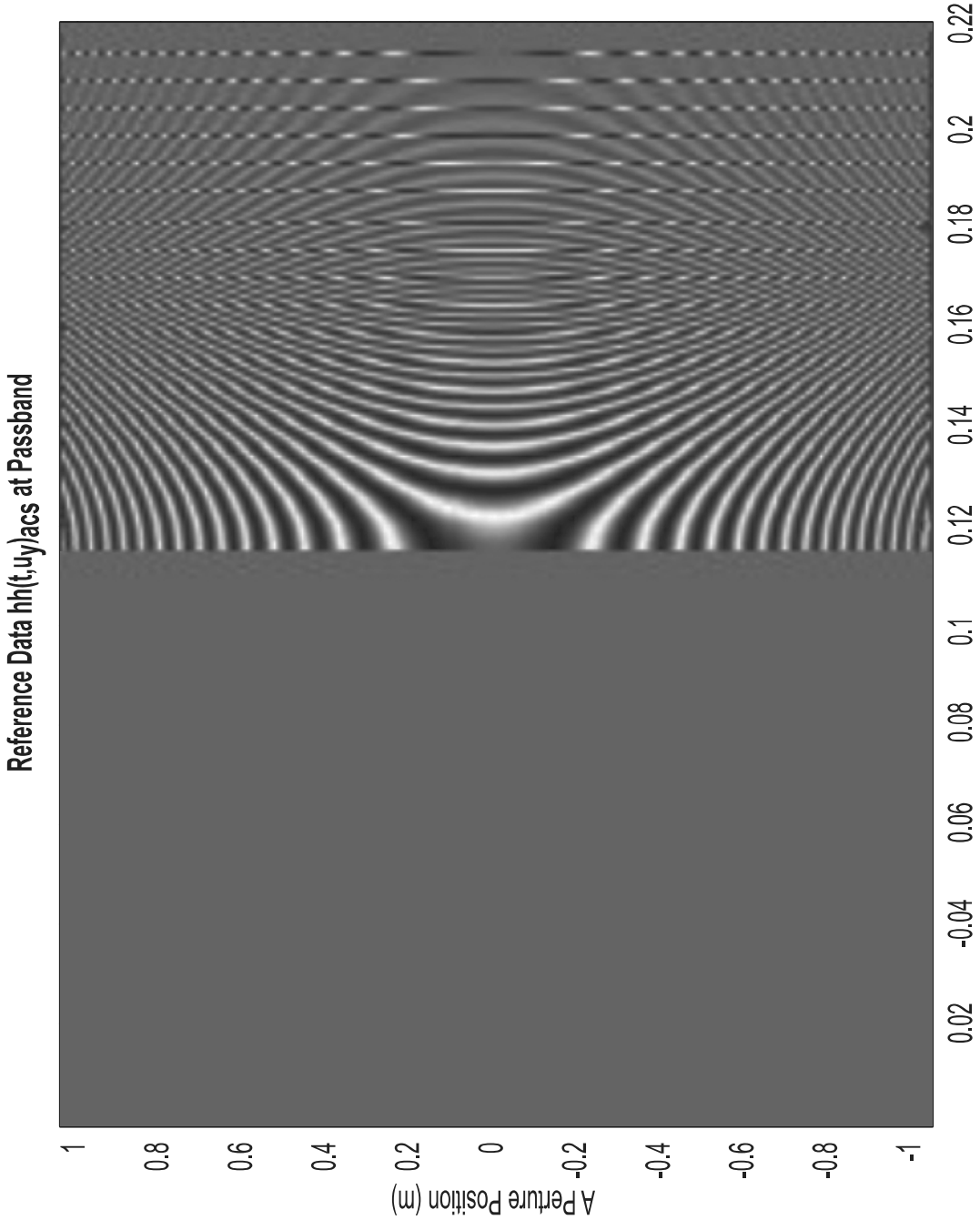

Reference Data hh(t,uy)acs at Passband
A Perture Position (m)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0.02
-0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
0.22
Receive Window Time (microseconds)

FIG. 17B

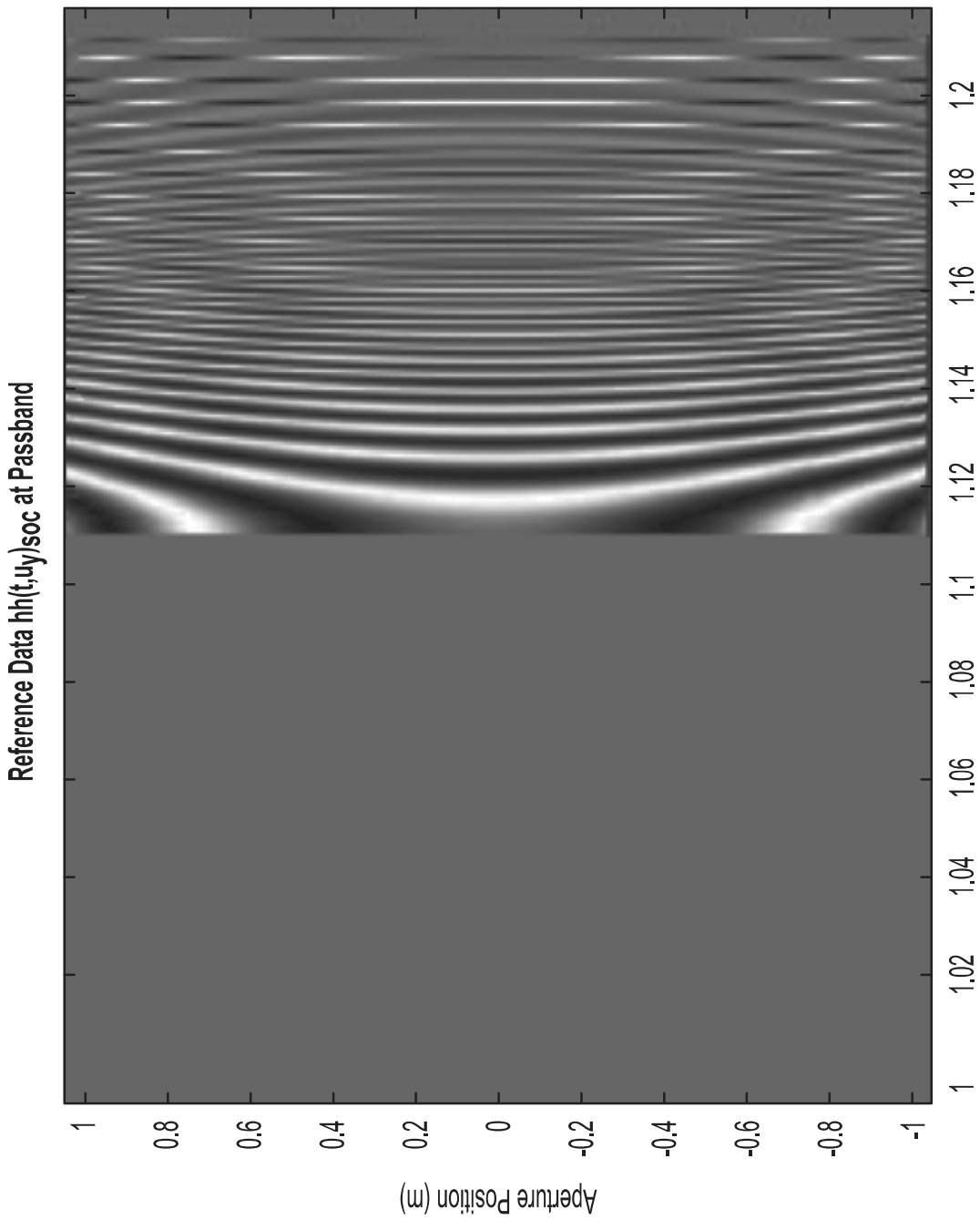

Reference Data hh(t,uy)soc at Passband
Aperture Position (m)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
1
1.02
1.04
1.06
1.08
1.1
1.12
1.14
1.16
1.18
1.2
Receive Window Time (microseconds)

FIG. 17C

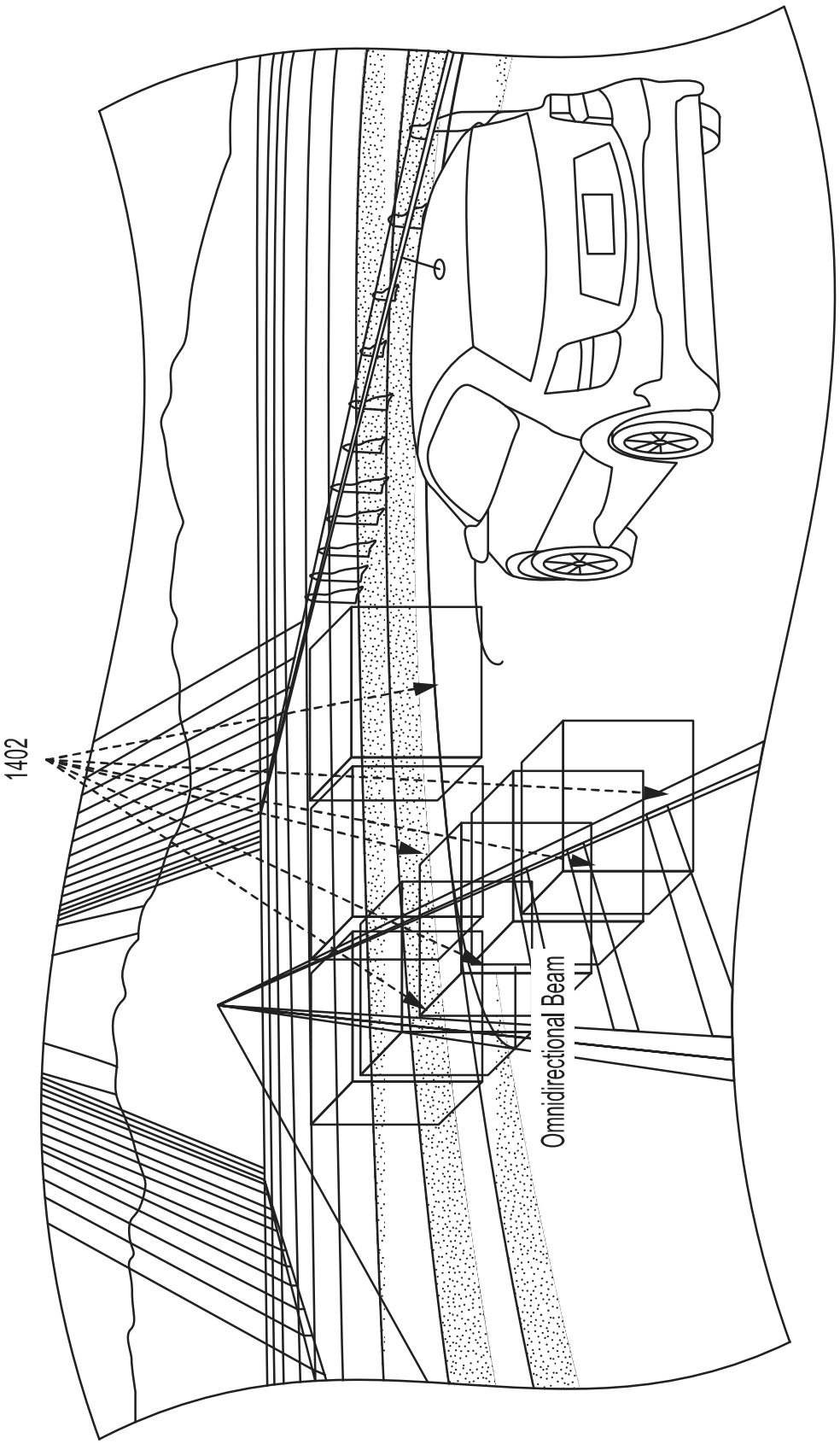


FIG. 18

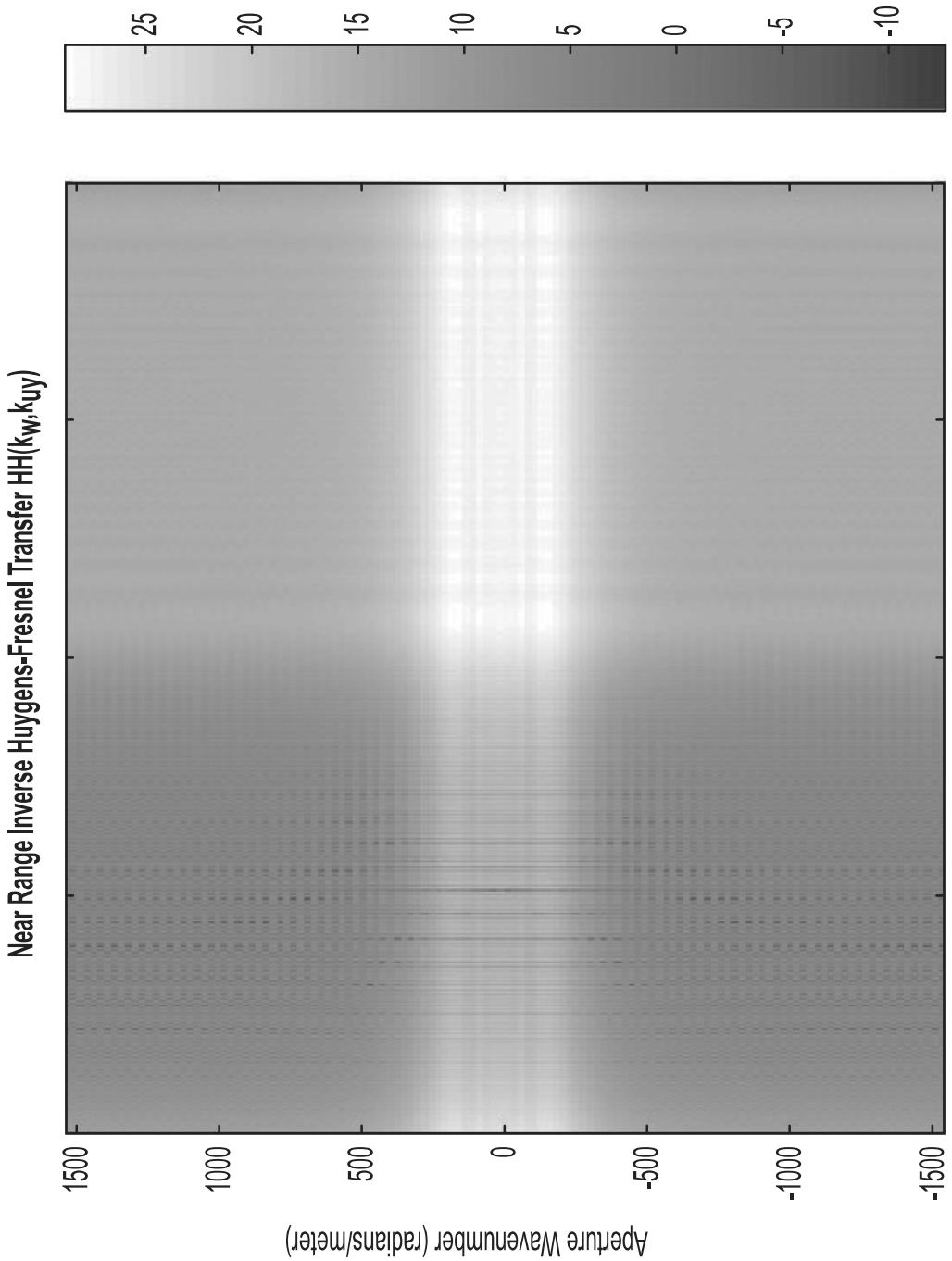

Near Range Inverse Huygens-Fresnel Transfer HH(k_w,k_{uy})
Aperture Wavenumber (radians/meter)
1500
1000
500
0
-500
-1000
-1500
-1000
-500
0
500
1000
Baseband Frequency (MHz)
25
20
15
10
5
0
-5
-10

FIG. 19A

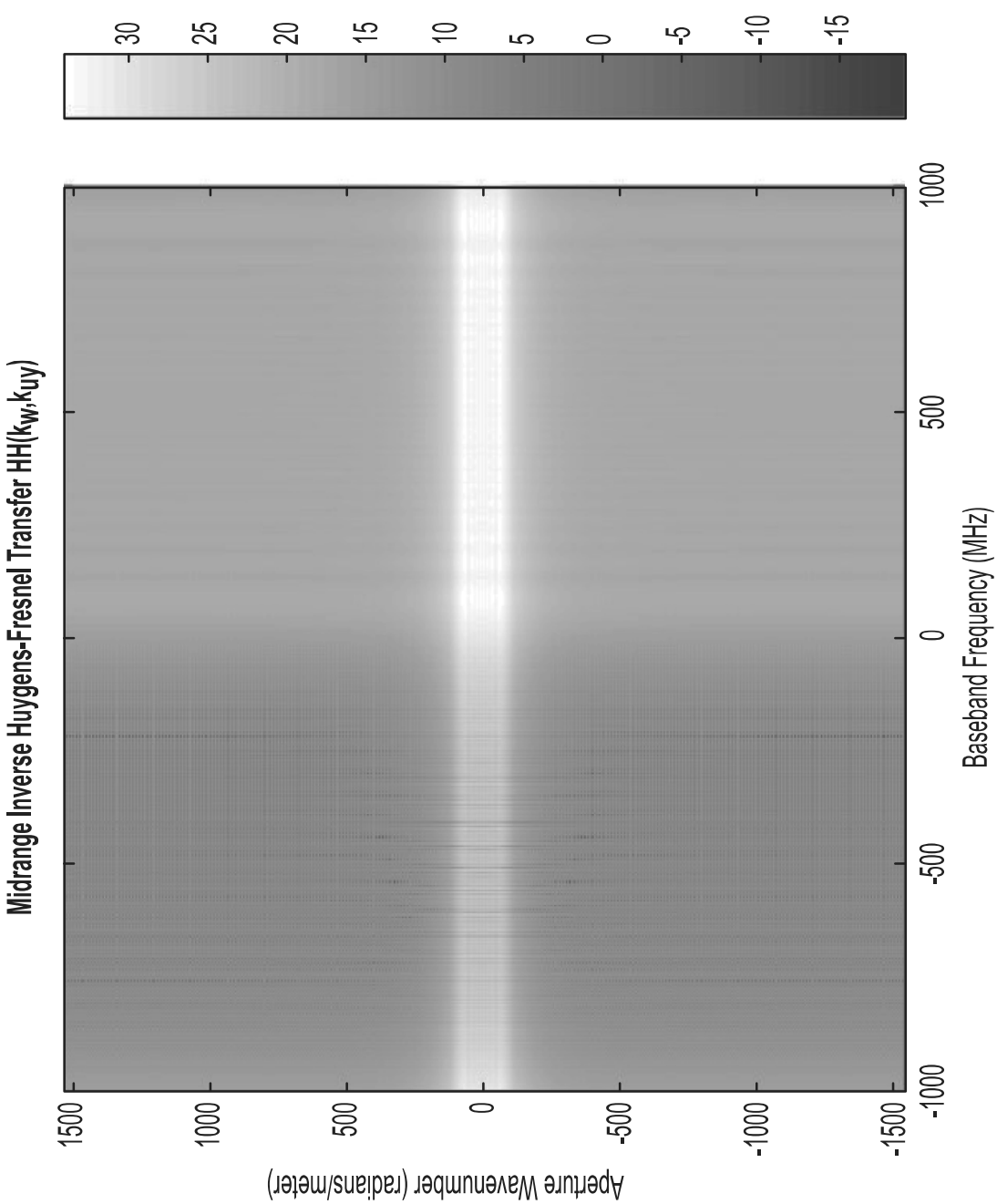

Midrange Inverse Huygens-Fresnel Transfer HH(k_w,k_{uy})
Aperture Wavenumber (radians/meter)
1500
1000
500
0
-500
-1000
-1500
-1000
-500
0
500
1000
Baseband Frequency (MHz)
30
25
20
15
10
5
0
-5
-10
-15

FIG. 19B

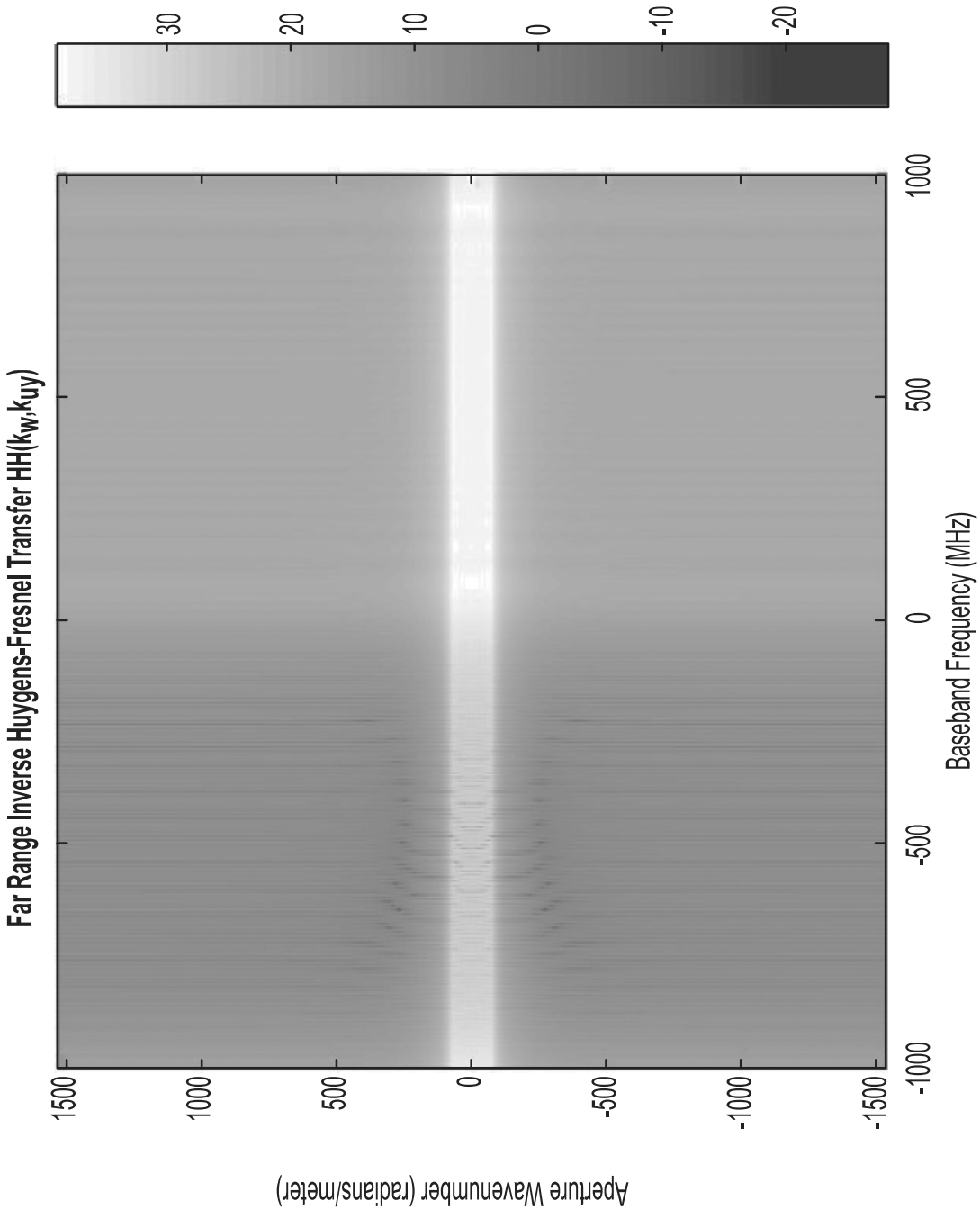

Far Range Inverse Huygens-Fresnel Transfer HH(k_w,k_{uy})
30
20
10
0
-10
-20
1500
1000
500
0
-500
-1000
-1500
Aperture Wavenumber (radians/meter)
-1000
-500
0
500
1000
Baseband Frequency (MHz)

FIG. 19C

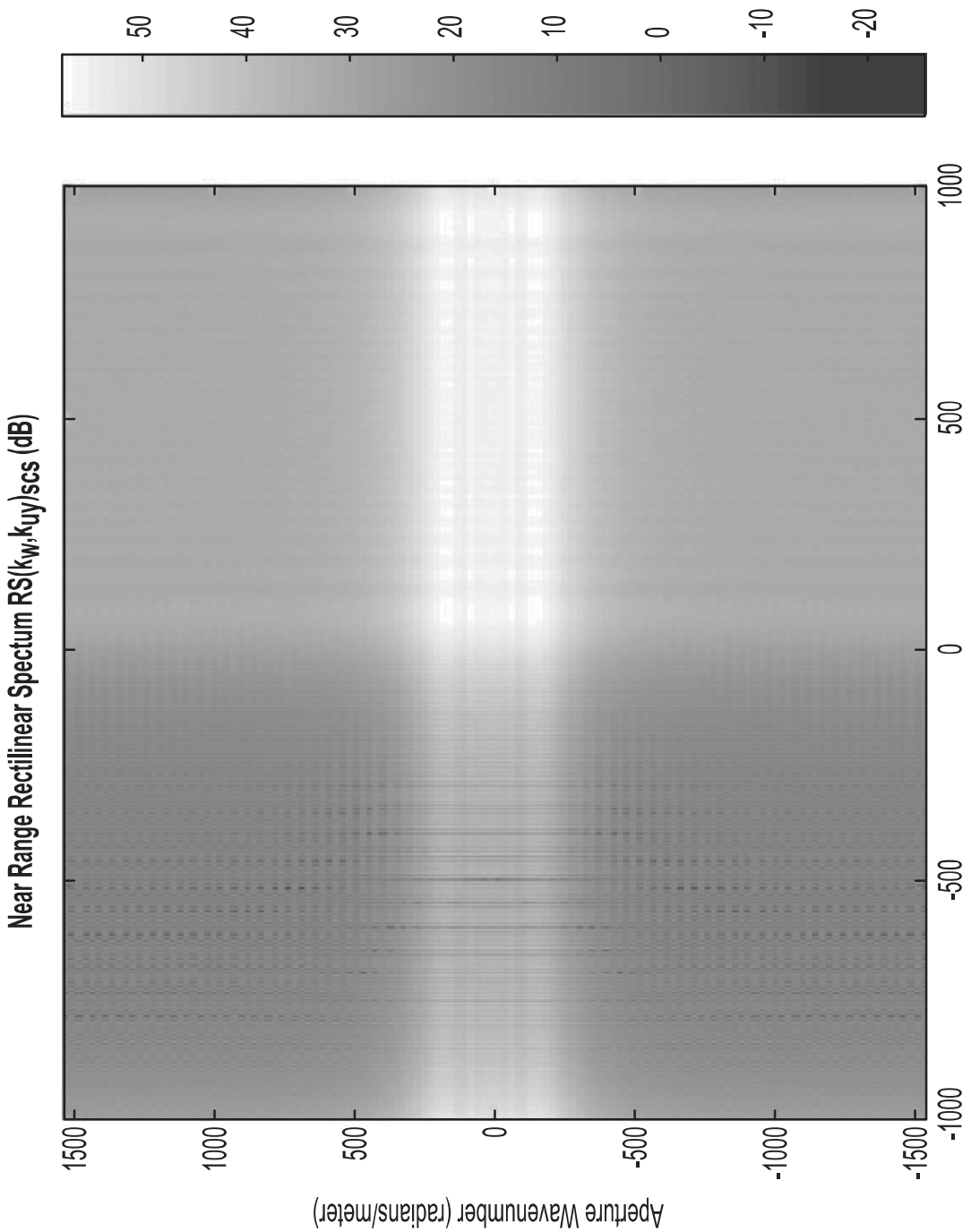

Near Range Rectilinear Spectum RS(k_W,k_{UY})scs (dB)
50
40
30
20
10
0
-10
-20
1500
1000
500
0
-500
-1000
-1500
Aperture Wavenumber (radians/meter)
-1000
-500
0
500
1000
Baseband Frequency (MHz)

FIG. 20A

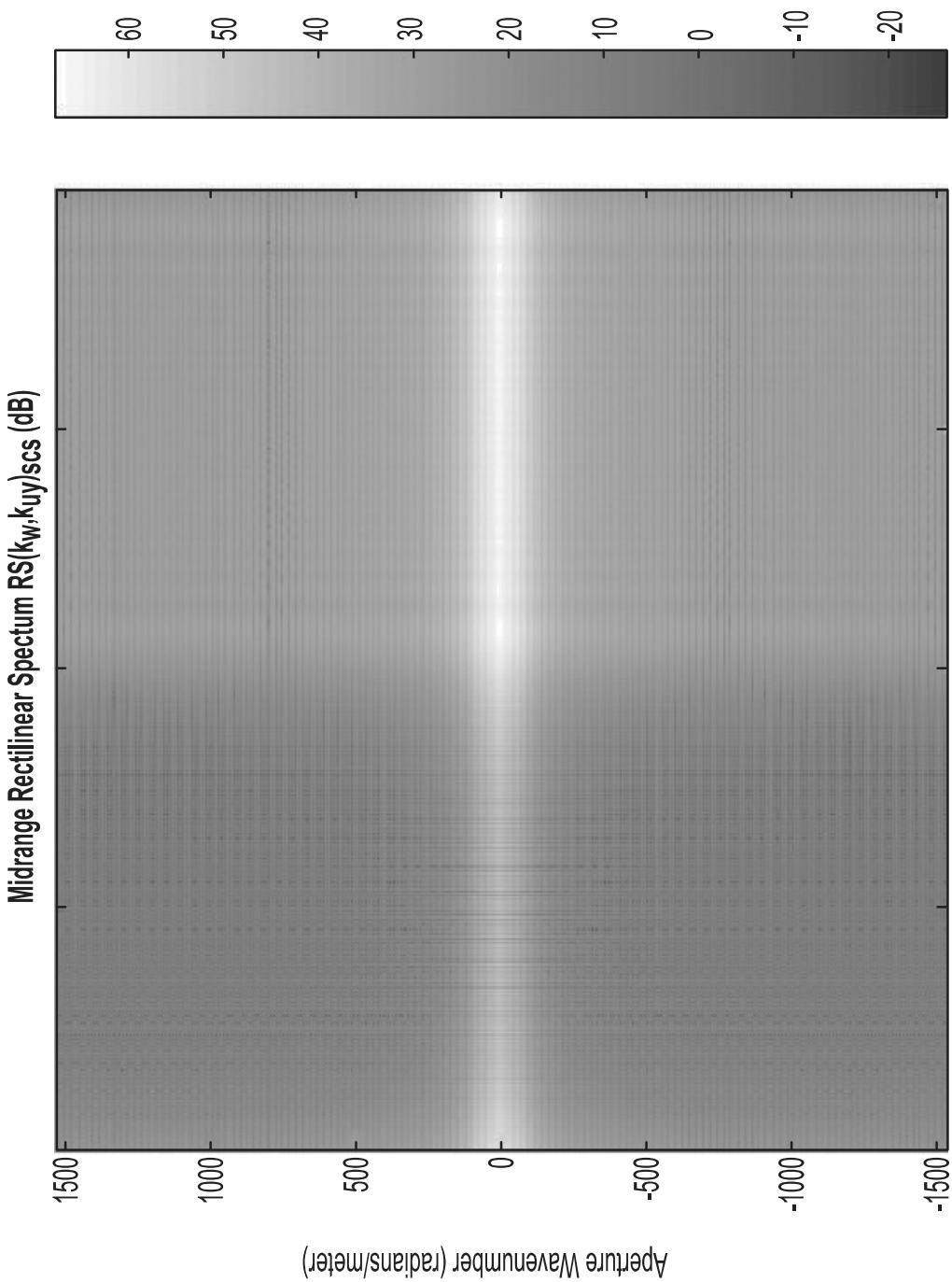

Midrange Rectilinear Spectum RS(kw,kuy)scs (dB)
60
50
40
30
20
10
0
-10
-20
1500
1000
500
0
-500
-1000
-1500
Aperture Wavenumber (radians/meter)
-1000
-500
0
500
1000
Baseband Frequency (MHz)

FIG. 20B

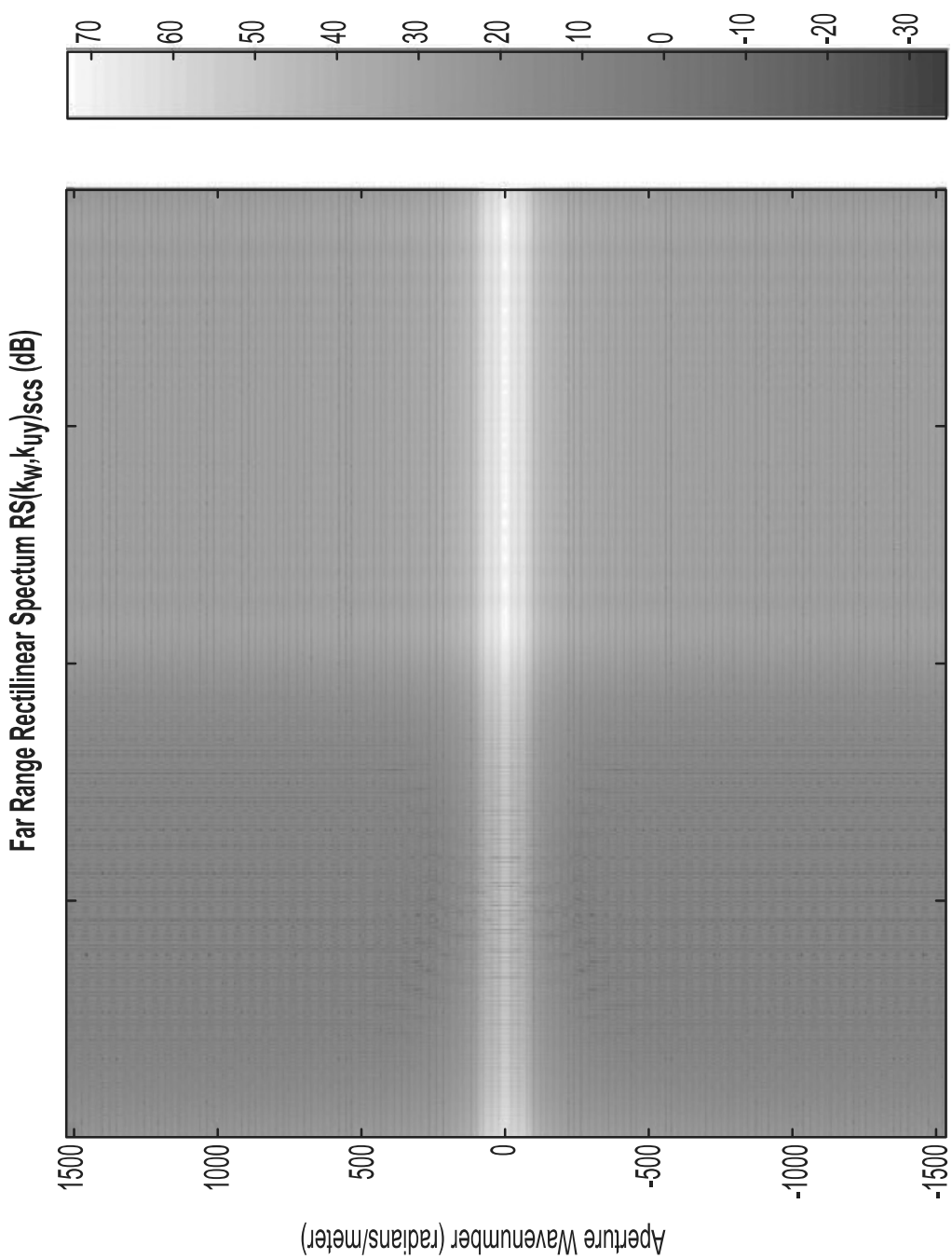

Far Range Rectilinear Spectum RS(kw,kuy)scs (dB)
70
60
50
40
30
20
10
0
-10
-20
-30
1500
1000
500
0
-500
-1000
-1500
Aperture Wavenumber (radians/meter)
-1000
-500
0
500
1000
Baseband Frequency (MHz)

FIG. 20C

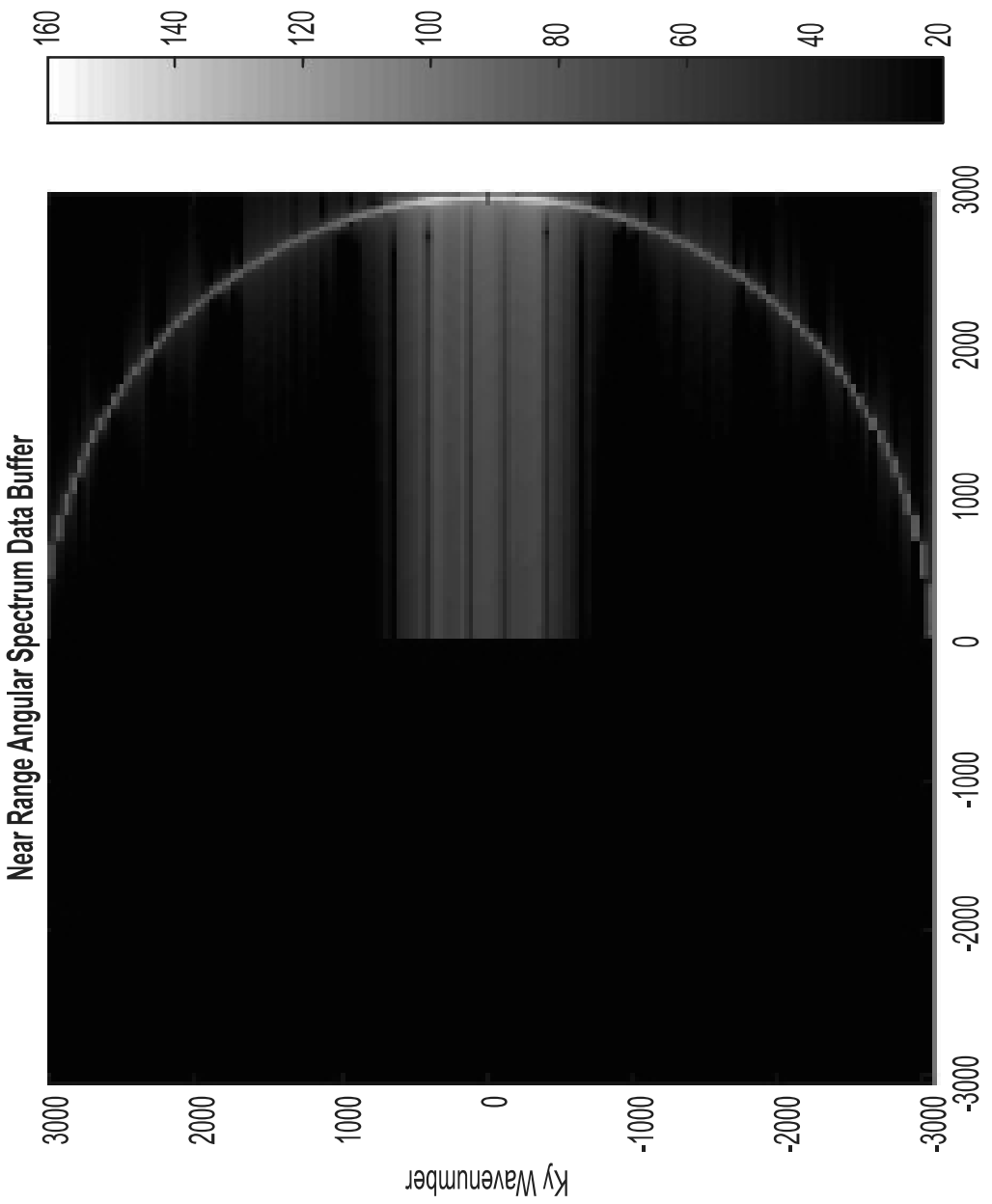

Near Range Angular Spectrum Data Buffer
Ky Wavenumber
Kx Wavenumber
3000
2000
1000
0
-1000
-2000
-3000
160
140
120
100
80
60
40
20

FIG. 21A

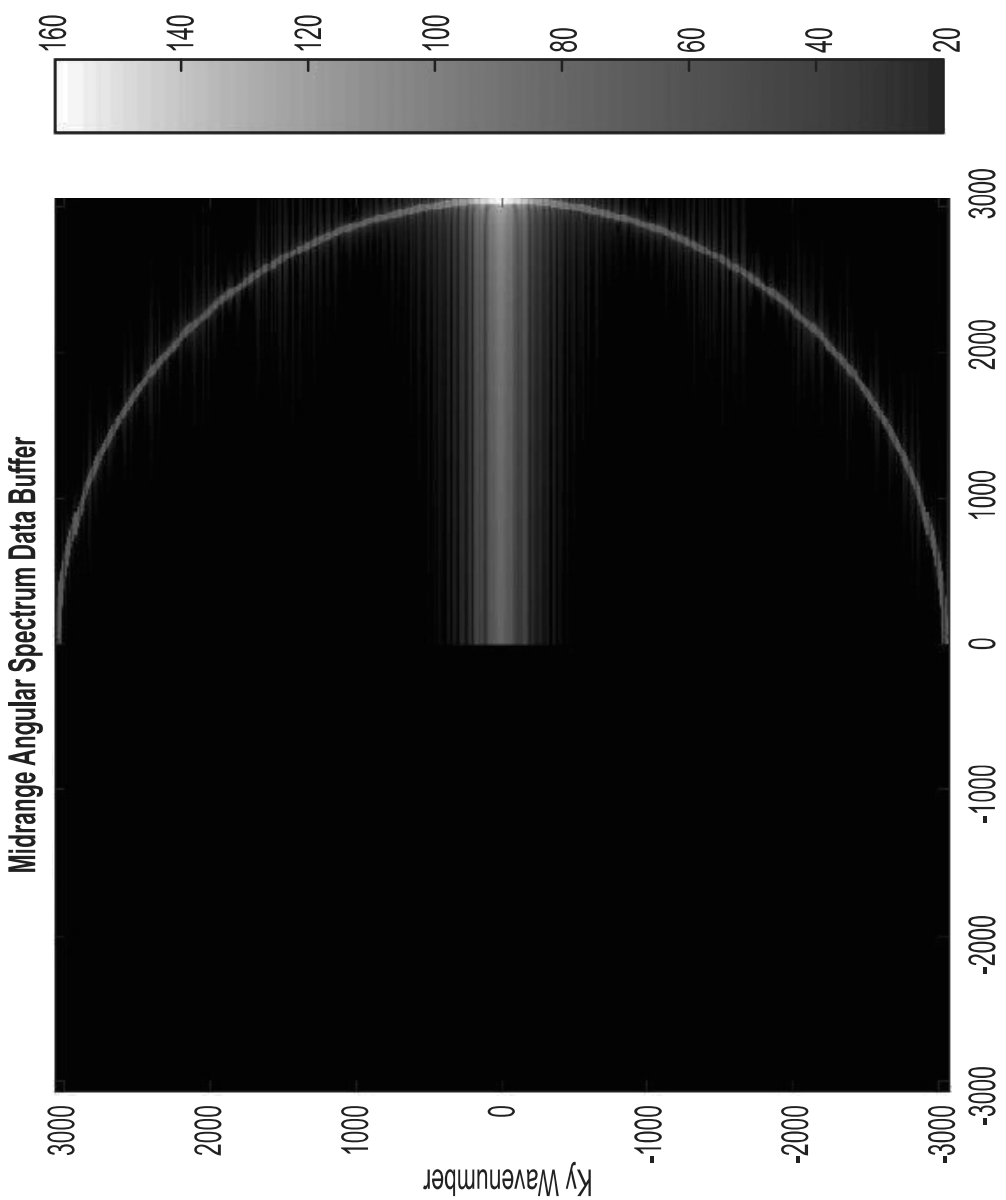

Midrange Angular Spectrum Data Buffer
Ky Wavenumber
Kx Wavenumber
3000
2000
1000
0
-1000
-2000
-3000
160
140
120
100
80
60
40
20

FIG. 21B

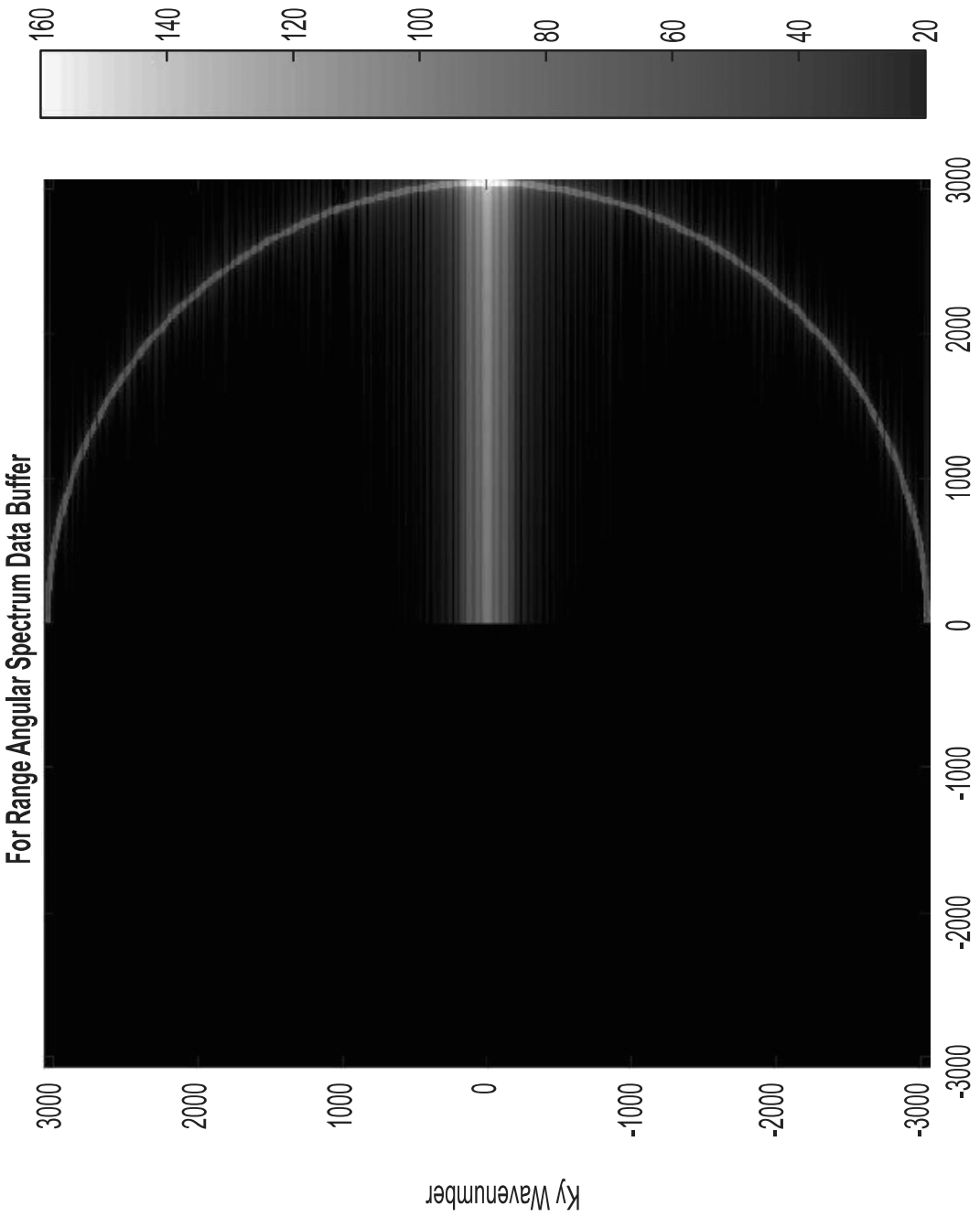

For Range Angular Spectrum Data Buffer
160
140
120
100
80
60
40
20
3000
2000
1000
0
-1000
-2000
-3000
Ky Wavenumber
-3000
-2000
-1000
0
1000
2000
3000
Kx Wavenumber

FIG. 21C

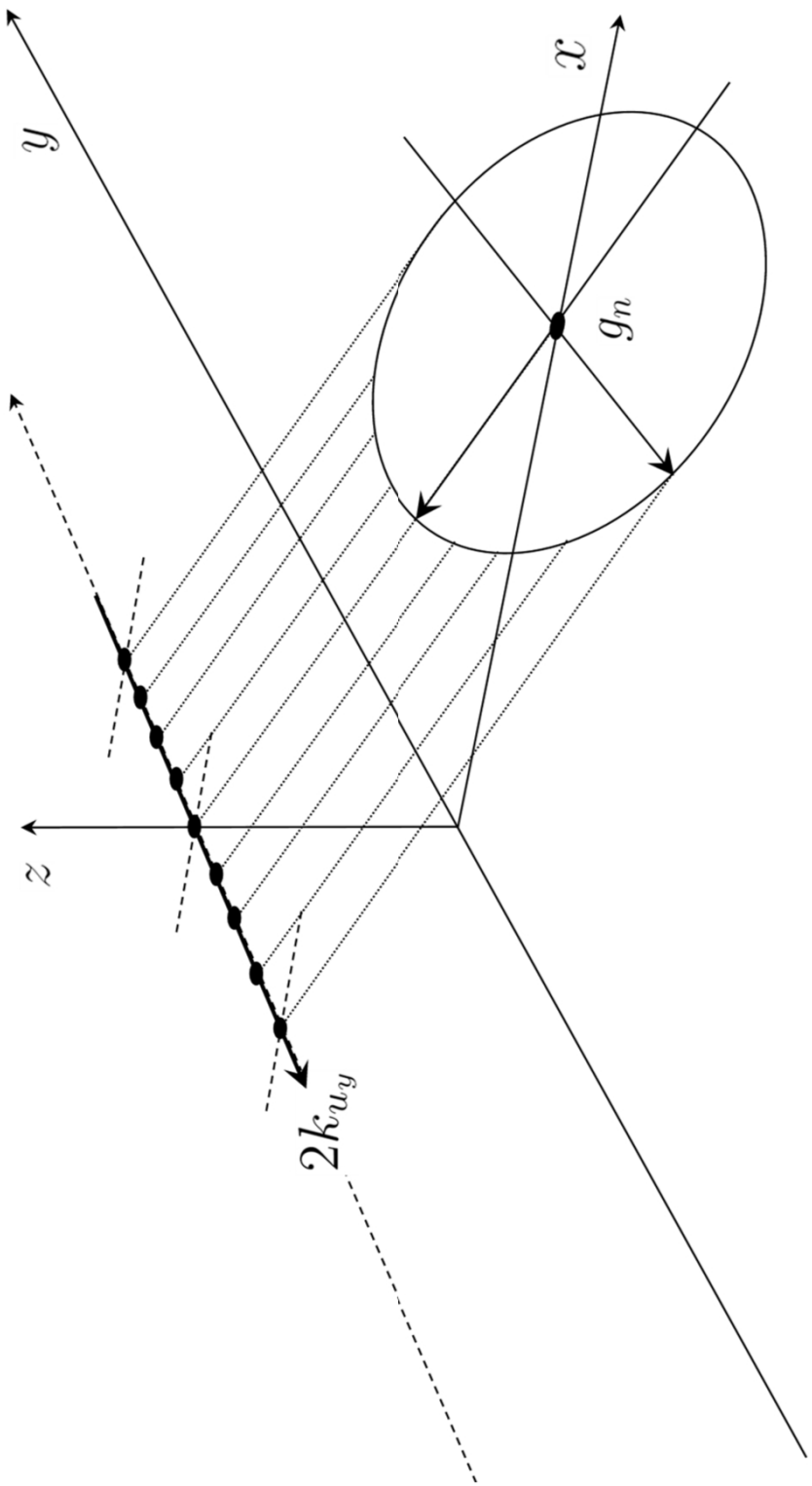


FIG. 22A

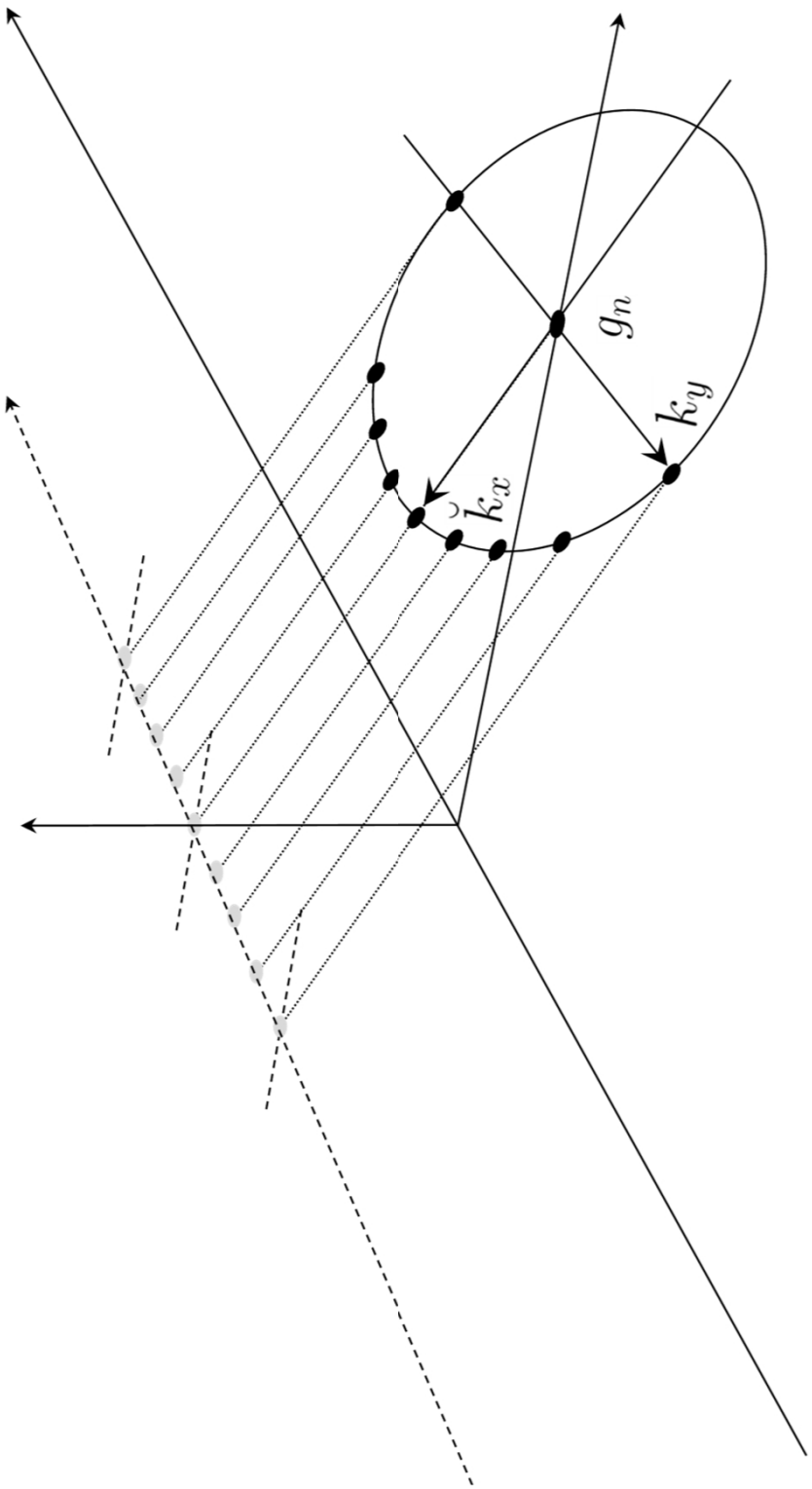


FIG. 22B

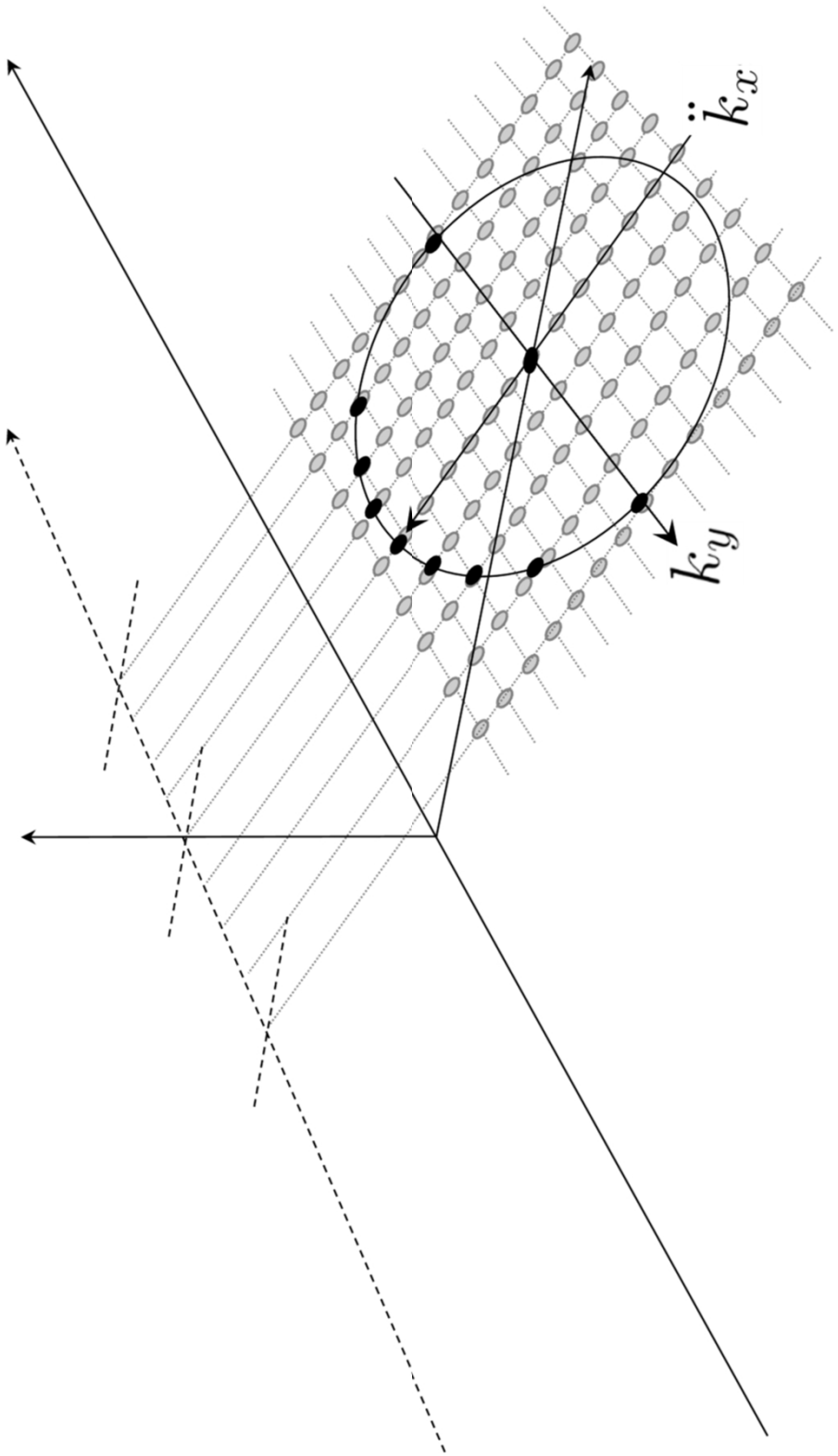


FIG. 22C

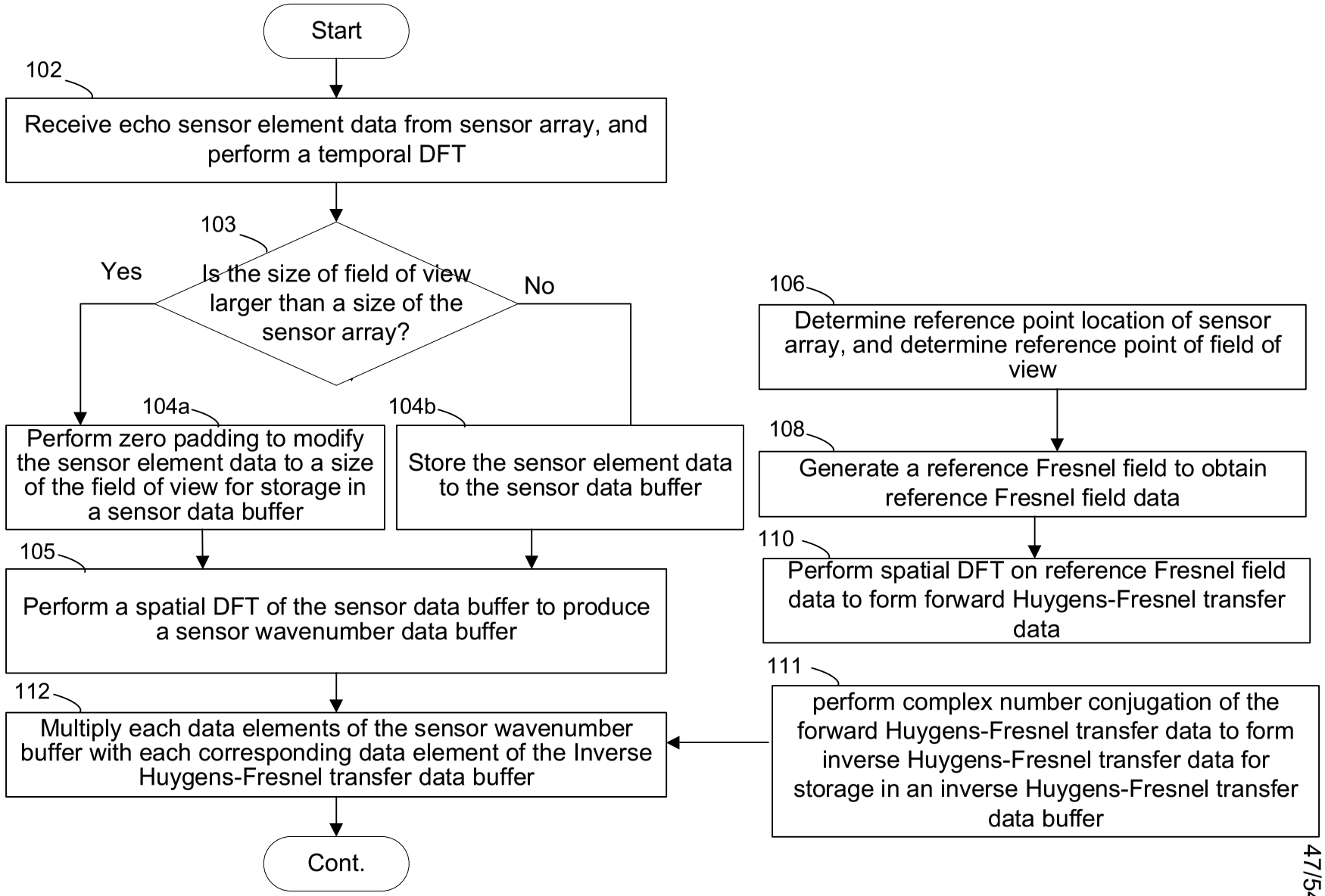

Start
102
Receive echo sensor element data from sensor array, and perform a temporal DFT
103
Is the size of field of view larger than a size of the sensor array?
Yes
No
104a
Perform zero padding to modify the sensor element data to a size of the field of view for storage in a sensor data buffer
104b
Store the sensor element data to the sensor data buffer
105
Perform a spatial DFT of the sensor data buffer to produce a sensor wavenumber data buffer
112
Multiply each data elements of the sensor wavenumber buffer with each corresponding data element of the Inverse Huygens-Fresnel transfer data buffer
Cont.
106
Determine reference point location of sensor array, and determine reference point of field of view
108
Generate a reference Fresnel field to obtain reference Fresnel field data
110
Perform spatial DFT on reference Fresnel field data to form forward Huygens-Fresnel transfer data
111
perform complex number conjugation of the forward Huygens-Fresnel transfer data to form inverse Huygens-Fresnel transfer data for storage in an inverse Huygens-Fresnel transfer data buffer

FIG. 23A

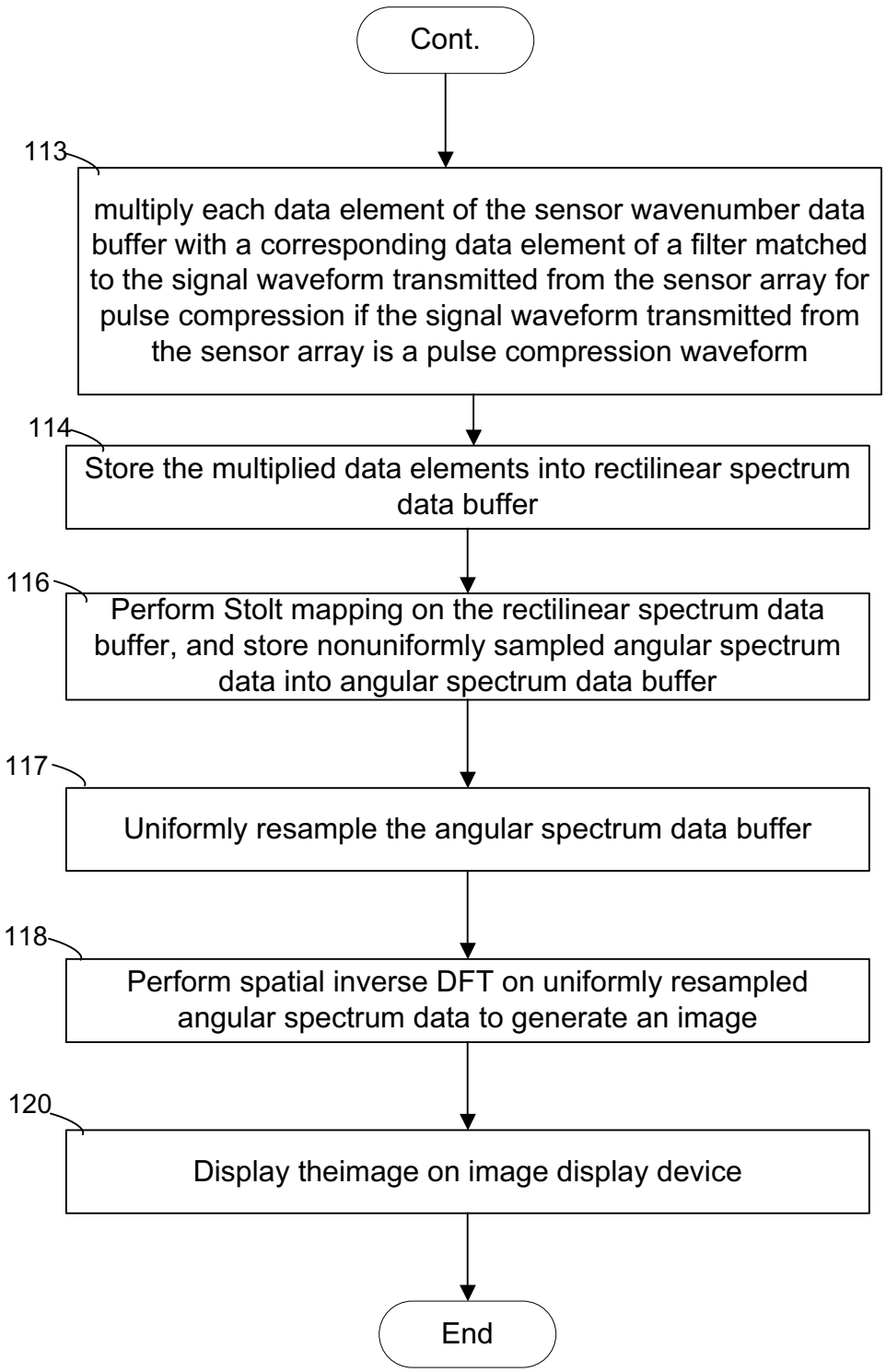

Cont.
113
multiply each data element of the sensor wavenumber data buffer with a corresponding data element of a filter matched to the signal waveform transmitted from the sensor array for pulse compression if the signal waveform transmitted from the sensor array is a pulse compression waveform
114
Store the multiplied data elements into rectilinear spectrum data buffer
116
Perform Stolt mapping on the rectilinear spectrum data buffer, and store nonuniformly sampled angular spectrum data into angular spectrum data buffer
117
Uniformly resample the angular spectrum data buffer
118
Perform spatial inverse DFT on uniformly resampled angular spectrum data to generate an image
120
Display theimage on image display device
End

FIG. 23B

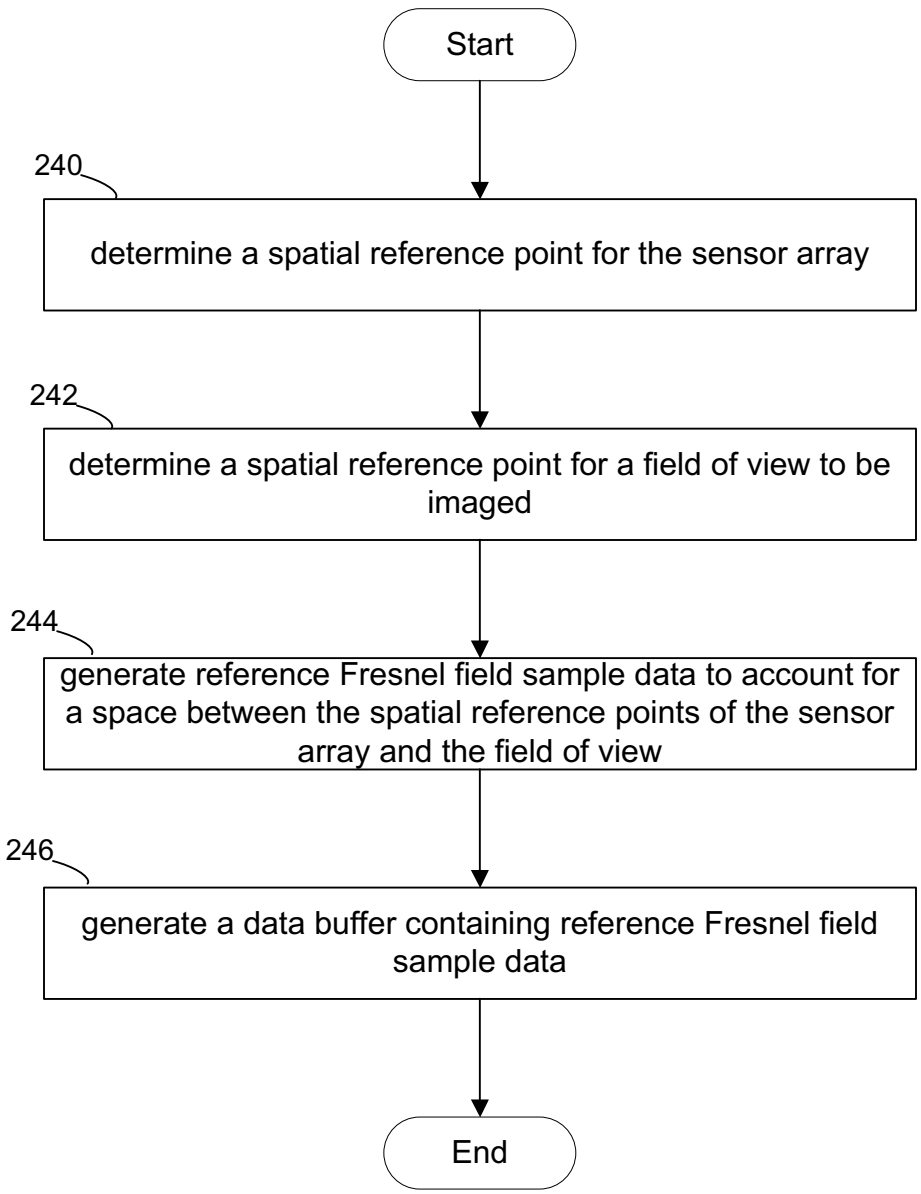

Start
240
determine a spatial reference point for the sensor array
242
determine a spatial reference point for a field of view to be imaged
244
generate reference Fresnel field sample data to account for a space between the spatial reference points of the sensor array and the field of view
246
generate a data buffer containing reference Fresnel field sample data
End

FIG. 24

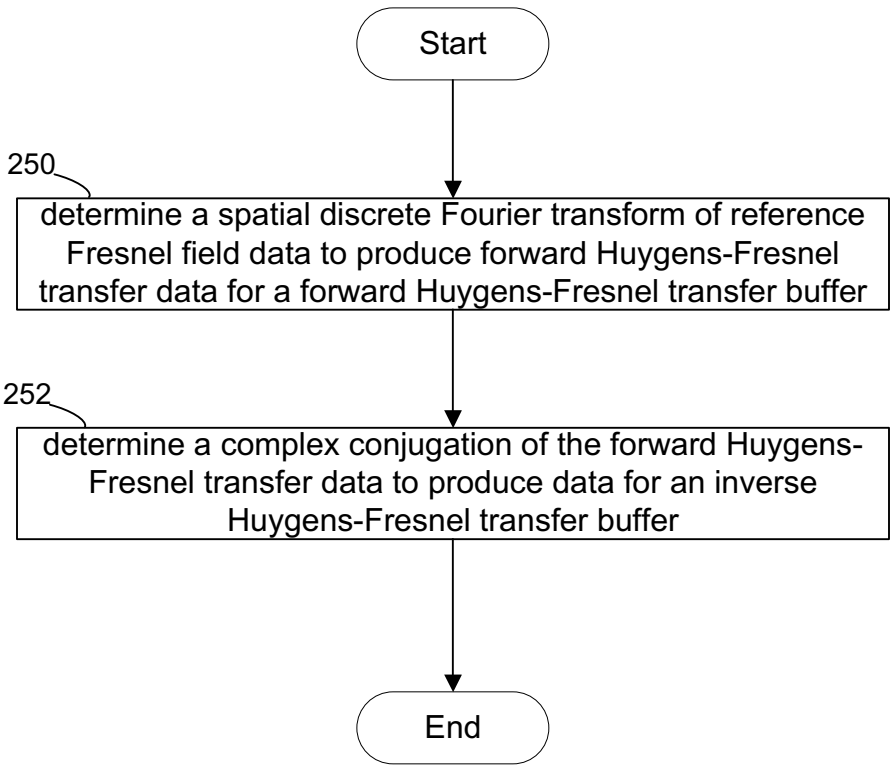

Start
250
determine a spatial discrete Fourier transform of reference Fresnel field data to produce forward Huygens-Fresnel transfer data for a forward Huygens-Fresnel transfer buffer
252
determine a complex conjugation of the forward Huygens-Fresnel transfer data to produce data for an inverse Huygens-Fresnel transfer buffer
End

FIG. 25

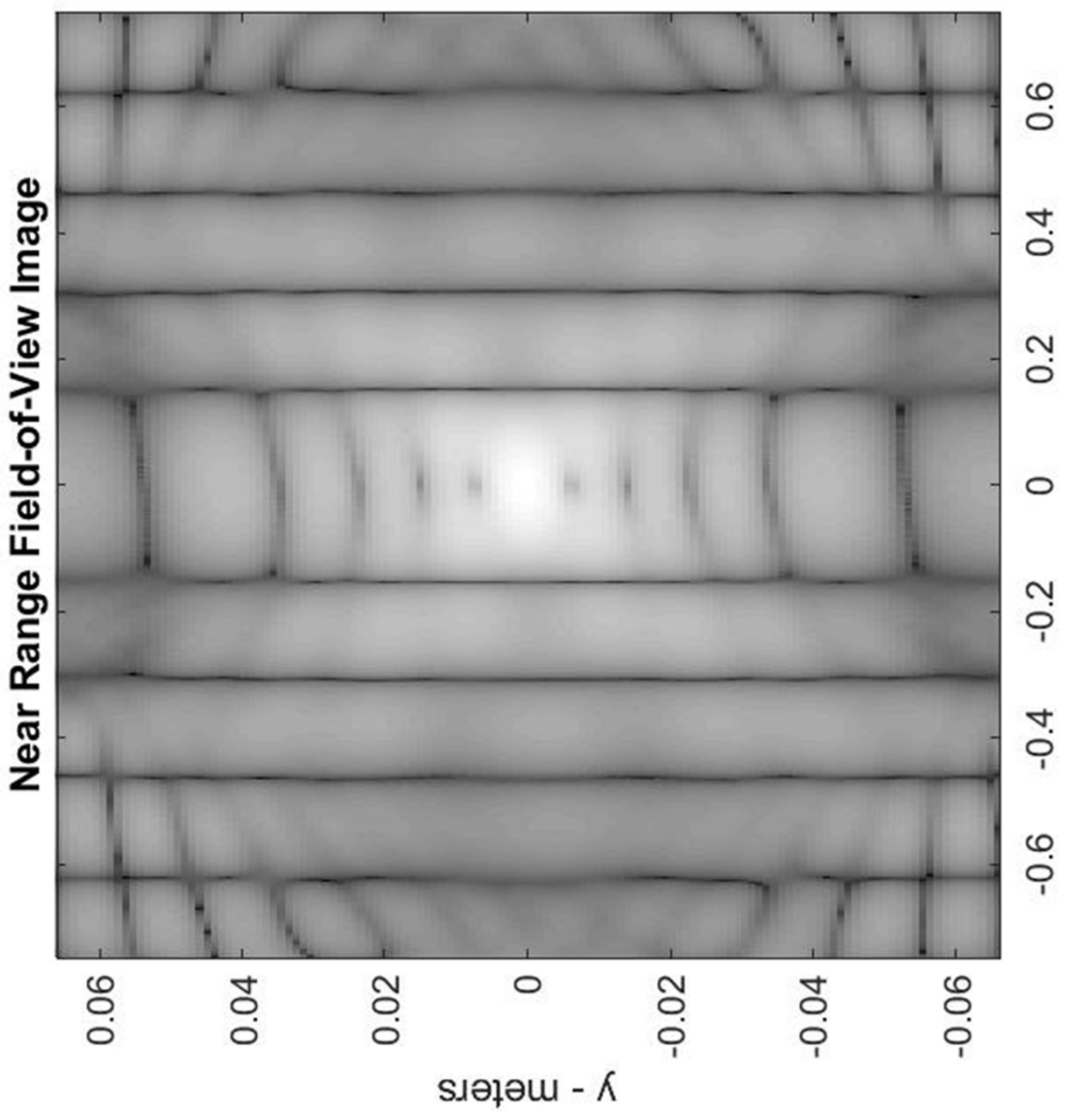

Near Range Field-of-View Image
y - meters
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
x - meters

FIG. 26A

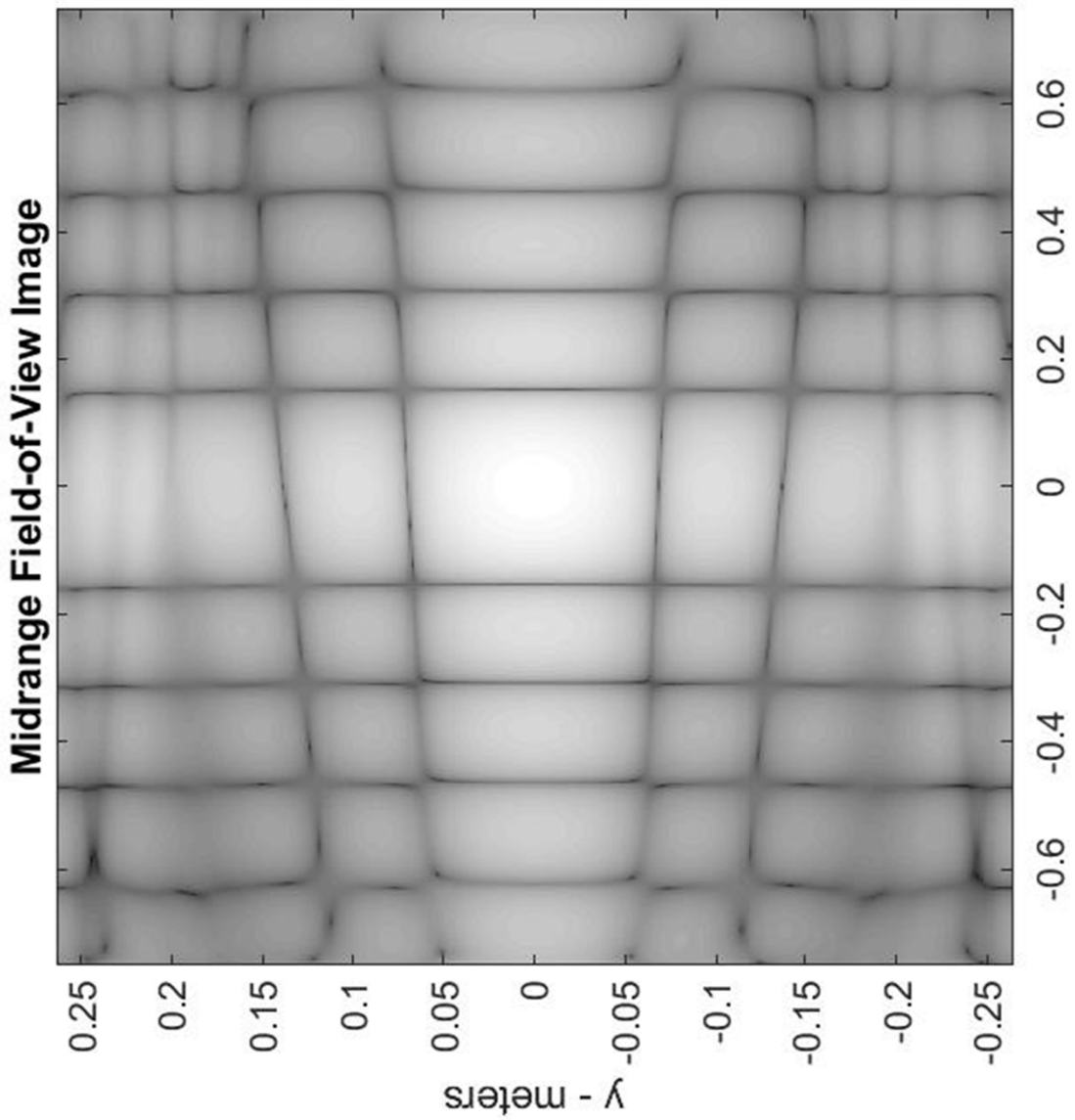

Midrange Field-of-View Image
y - meters
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
x - meters

FIG. 26B

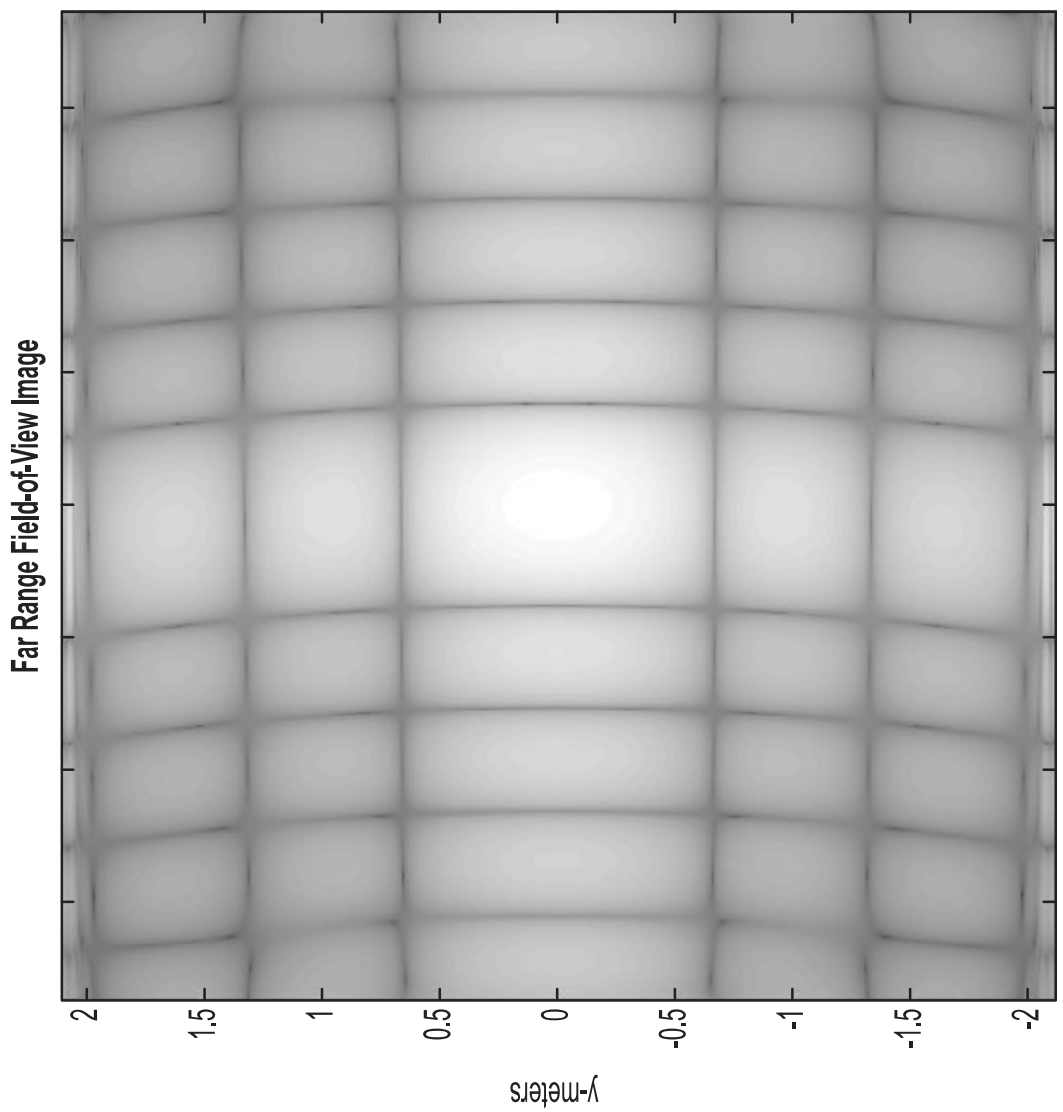

Far Range Field-of-View Image
y-meters
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
x-meters

FIG. 26C

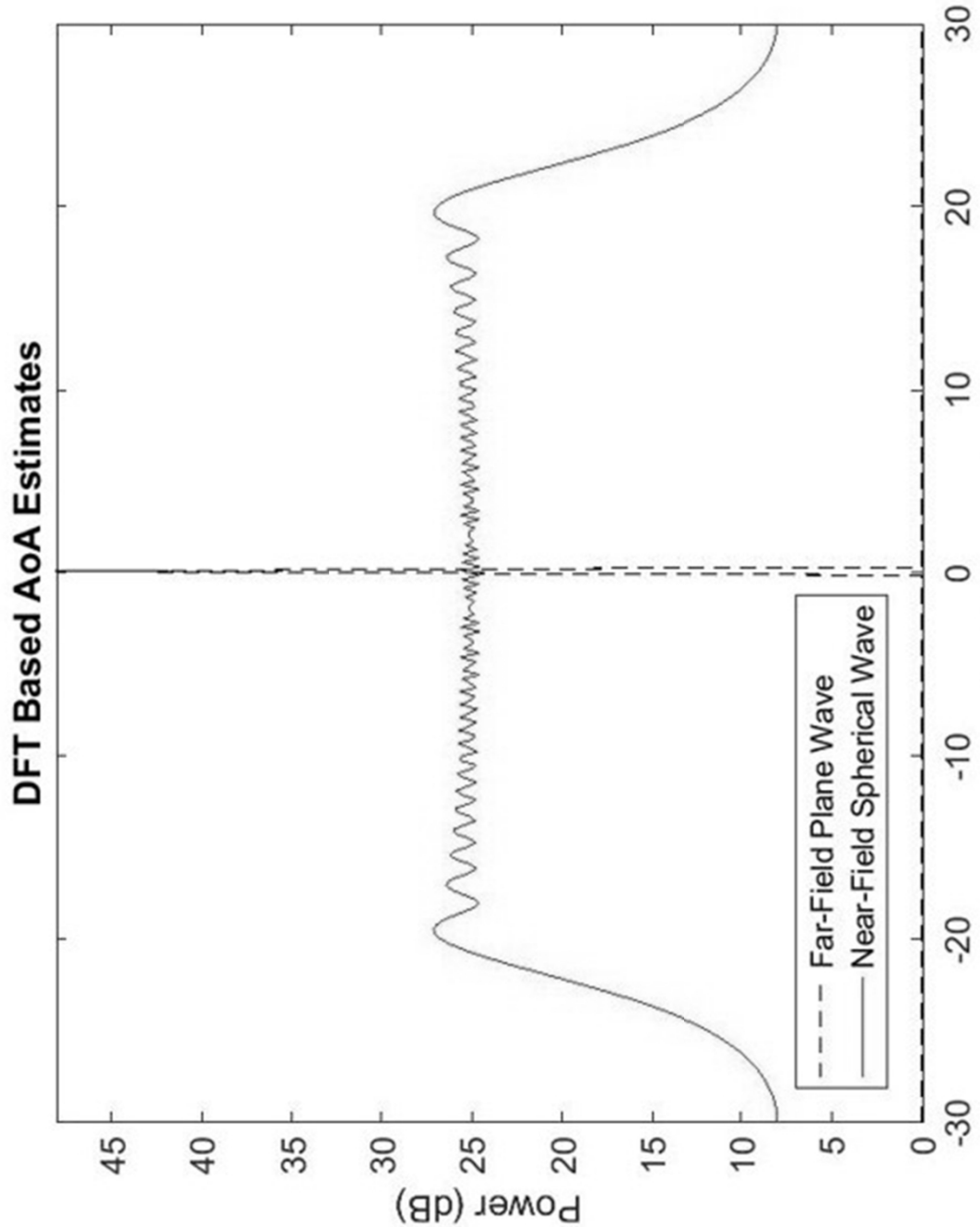


FIG. 27 (PRIOR ART)