MATLAB EXPO

Optimizing the Design and Operation of Radar and Antenna Systems in MATLAB

Sumit Garg, MathWorks

Chris Lee, MathWorks

MathWorks

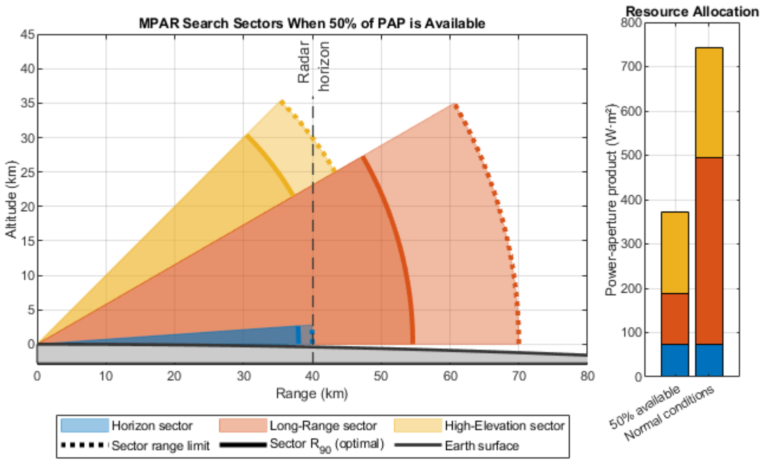
MathWorks
@MathWorks

Share the EXPO experience
#MATLABEXPO

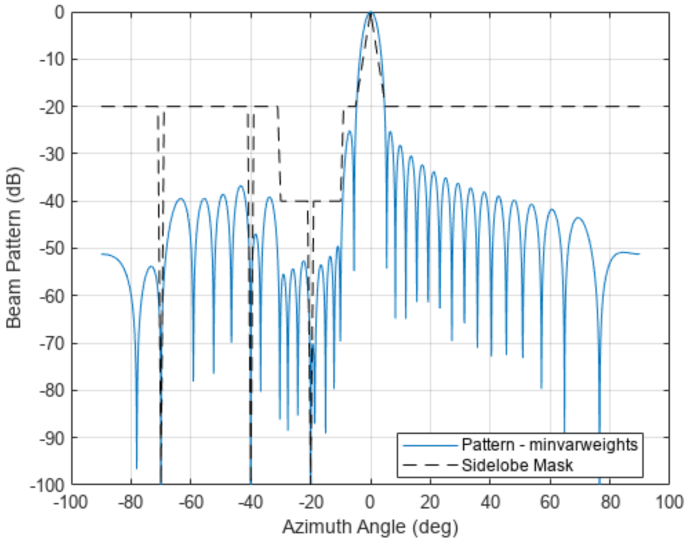
linkedin.com/in/
sumit-garg-689bb916

linkedin.com/in/
chrisstlee

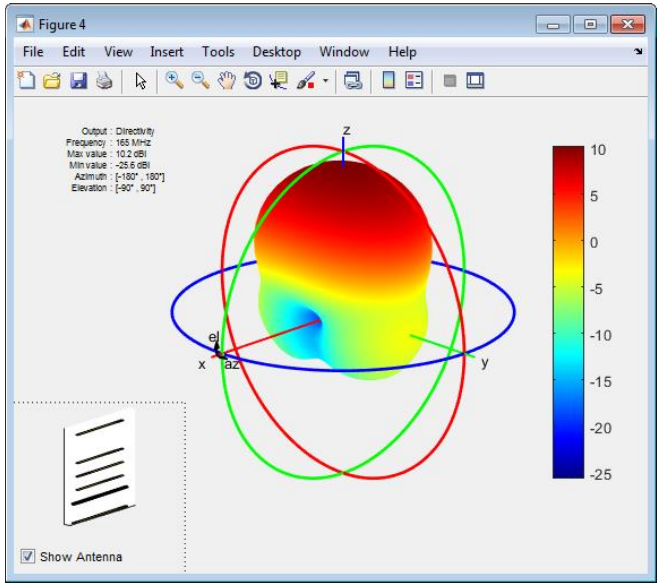
Apply design optimization to key radar and antenna design challenges



Radar resource management

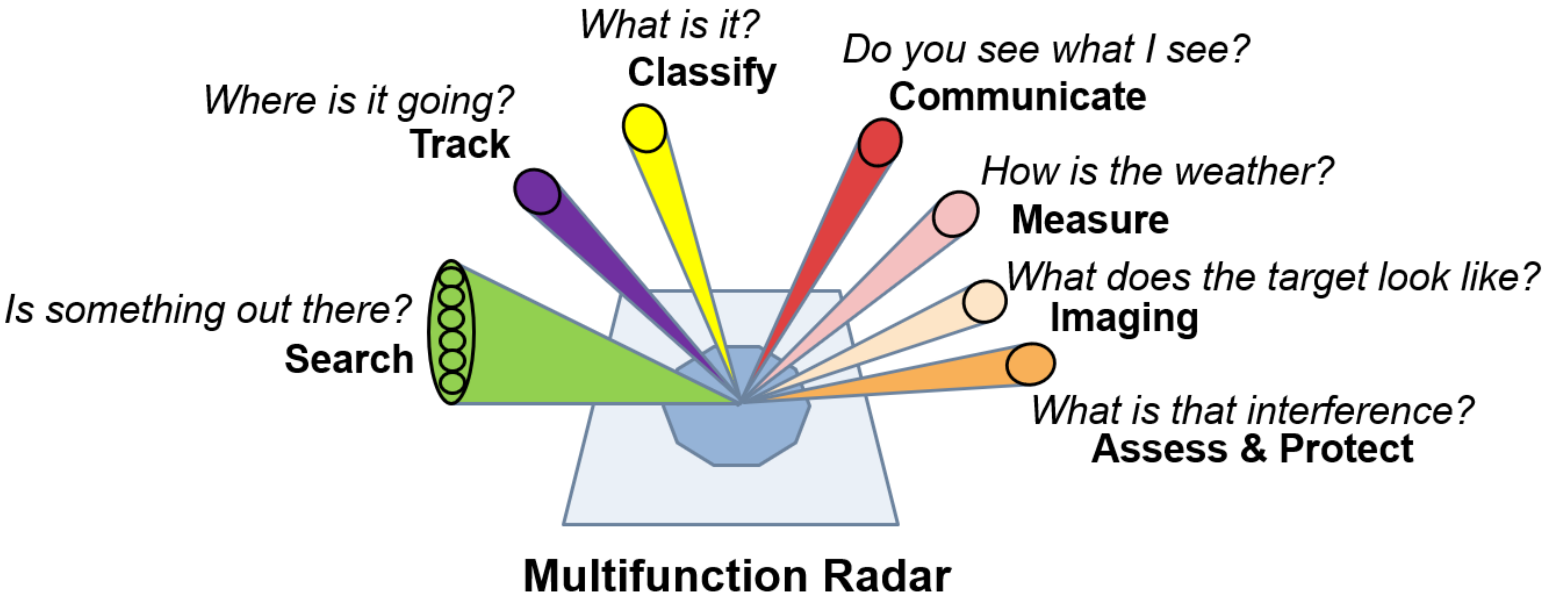


Array pattern synthesis



Antenna design

Multifunction Phased Array Radar (MPAR)



Capabilities

- Electronically steered phased array enables an ***agile*** beam and dynamic time/energy resource allocation
- Control parameters can be ***varied*** nearly ***instantaneously***
- ***Many tasks*** supporting ***different functions*** can be multiplexed in time and angle

Resource constraints

- Transmit energy/time budget
- Bandwidth
- Computation
- Emission reduction

Higher frequency operation increases the interference challenges

Aviation Today

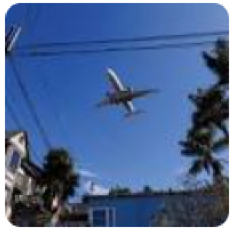
FAA Issues New Radar Altimeter 5G C-Band Risk Assessment ...

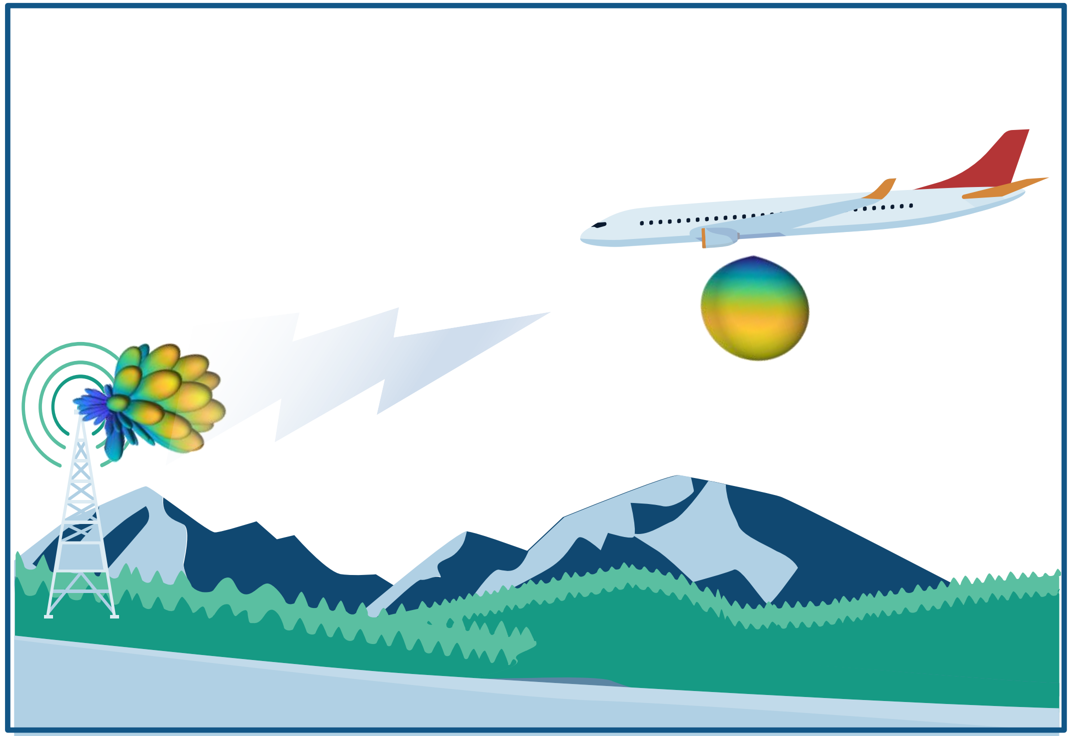
As the FAA indicated in its Dec. 7 AD, while it has heard concerns from airlines, the FAA, and aircraft OEMs over the potential interference...

Reuters

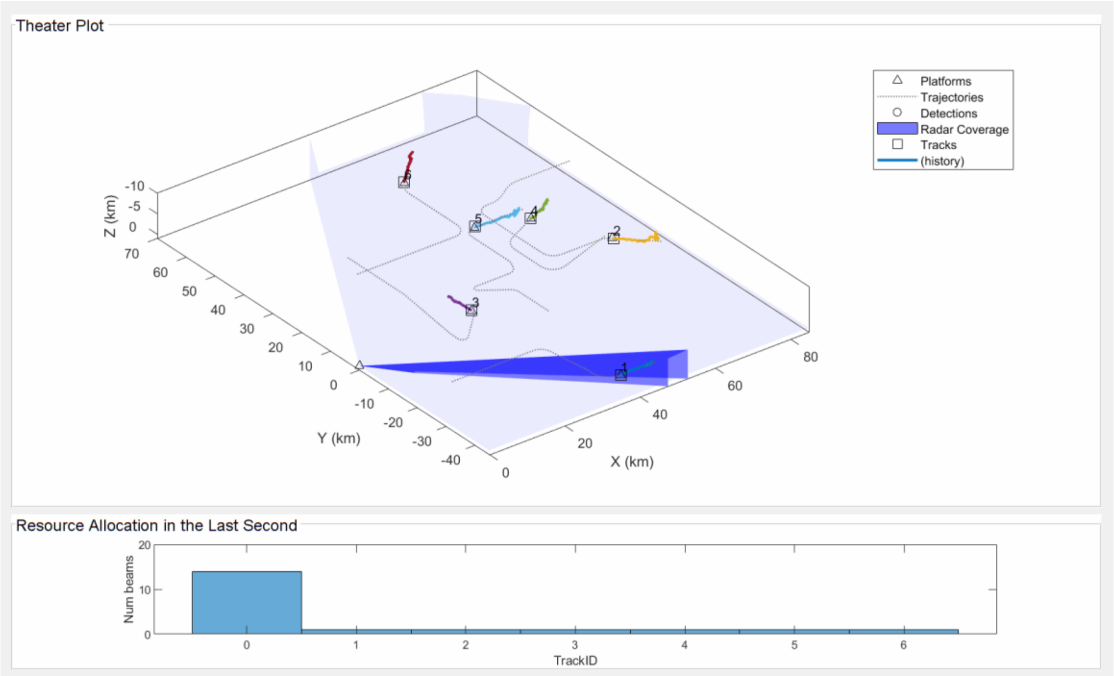
FAA wants U.S. airlines to retrofit, replace radio altimeters

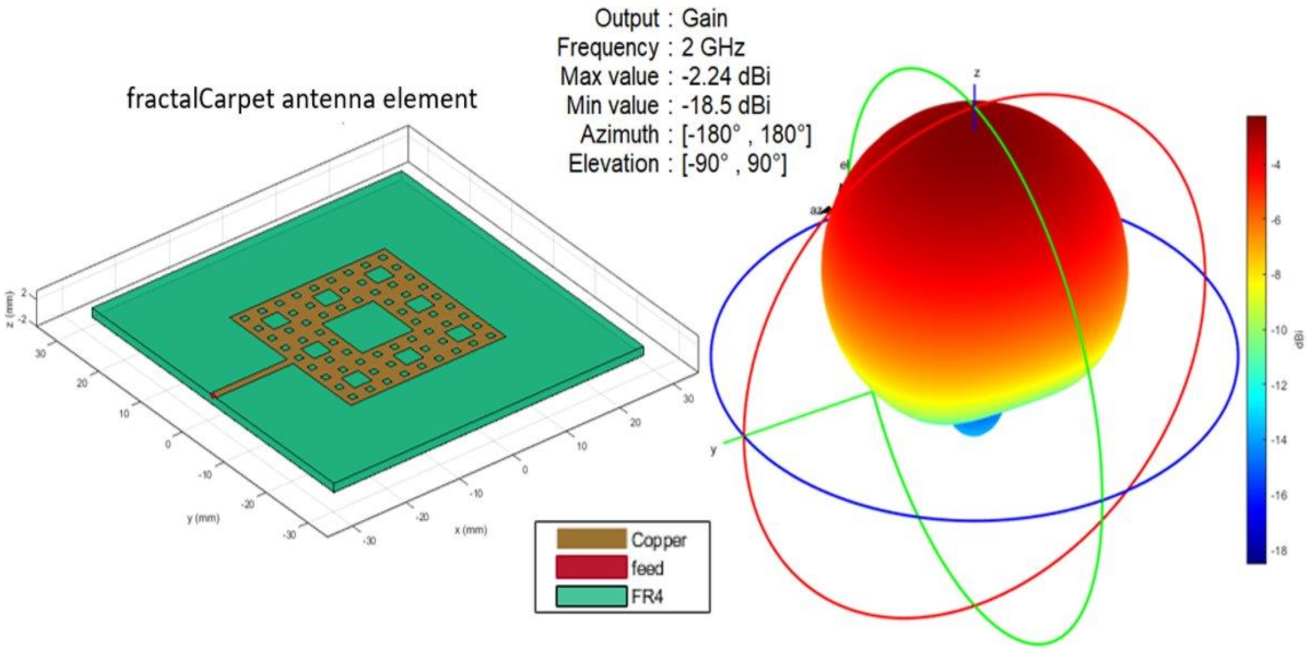
... a push to retrofit and ultimately replace some airplane radio altimeters that could face interference from C-Band 5G wireless service.



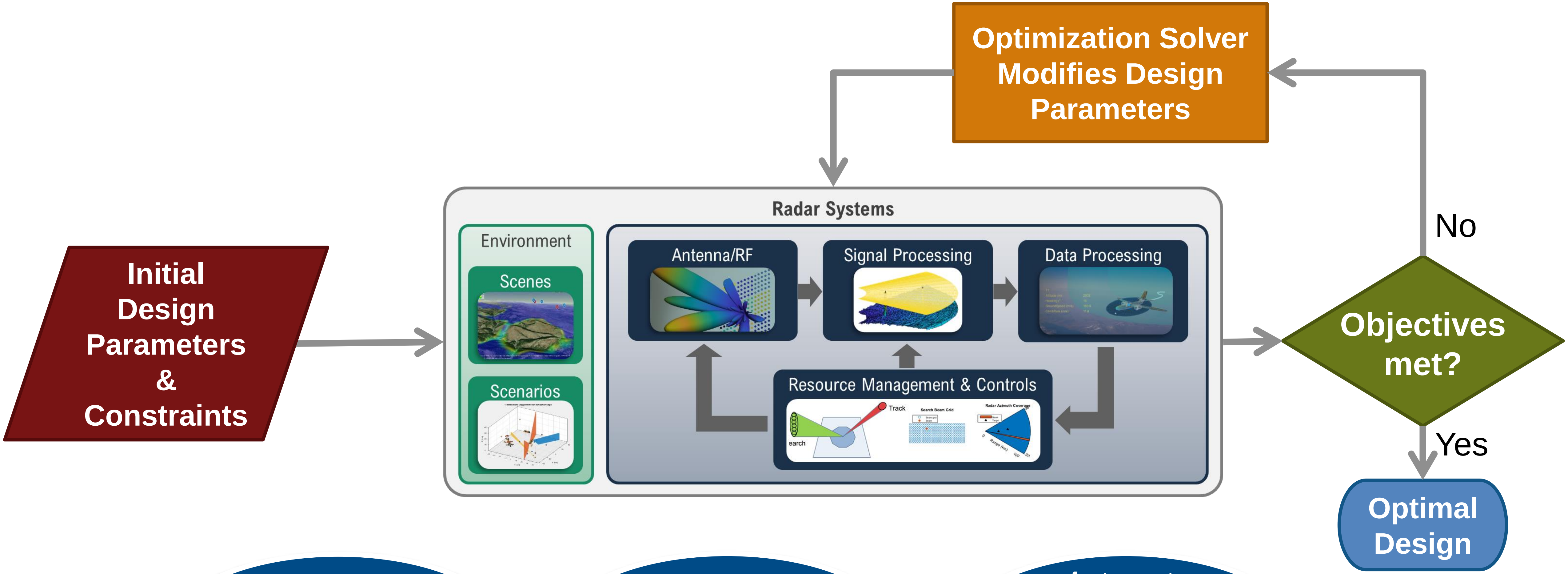


Operational and physical resources are limited





Address the design challenges with optimization workflows

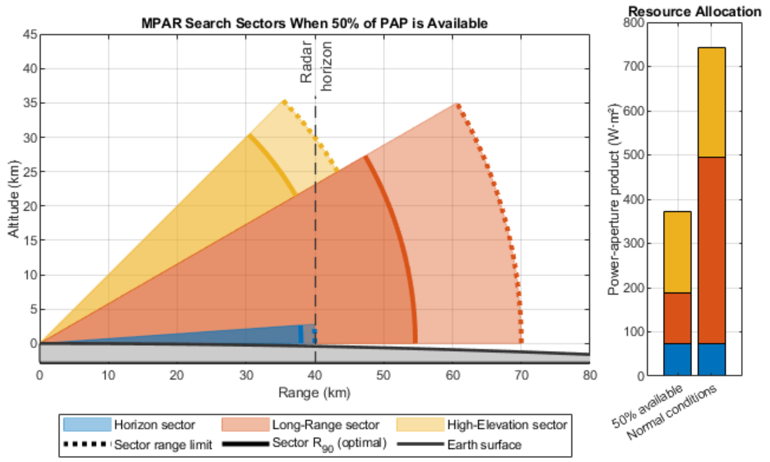


Find optimal designs while satisfying requirements

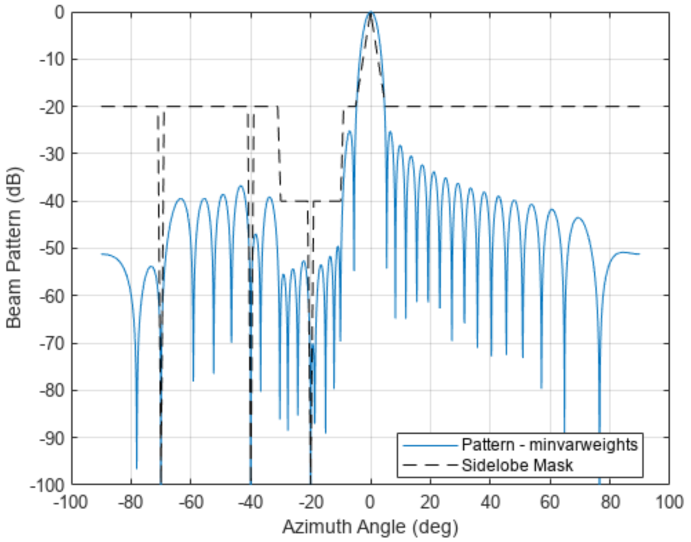
Reduce time of design iterations

Automate operational decision-making

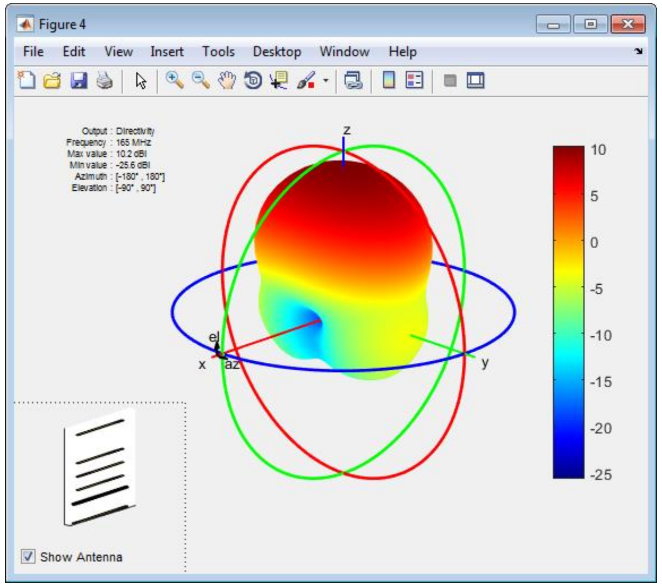
Apply design optimization to key radar and antenna design challenges



Radar resource management



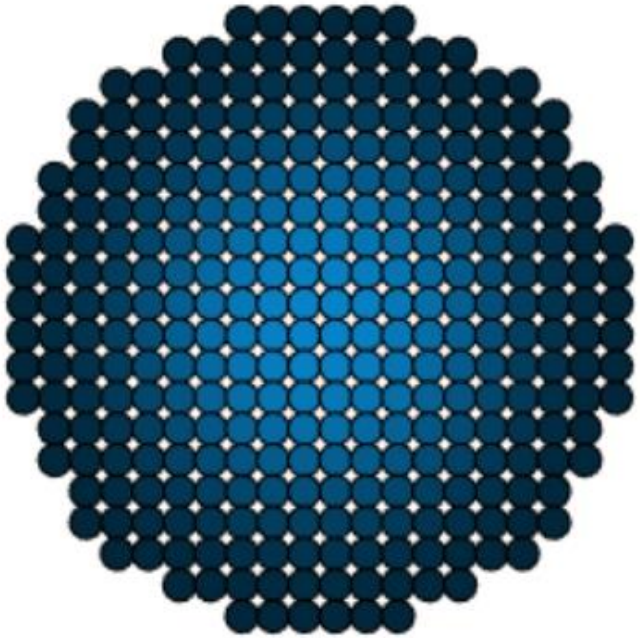
Array pattern synthesis



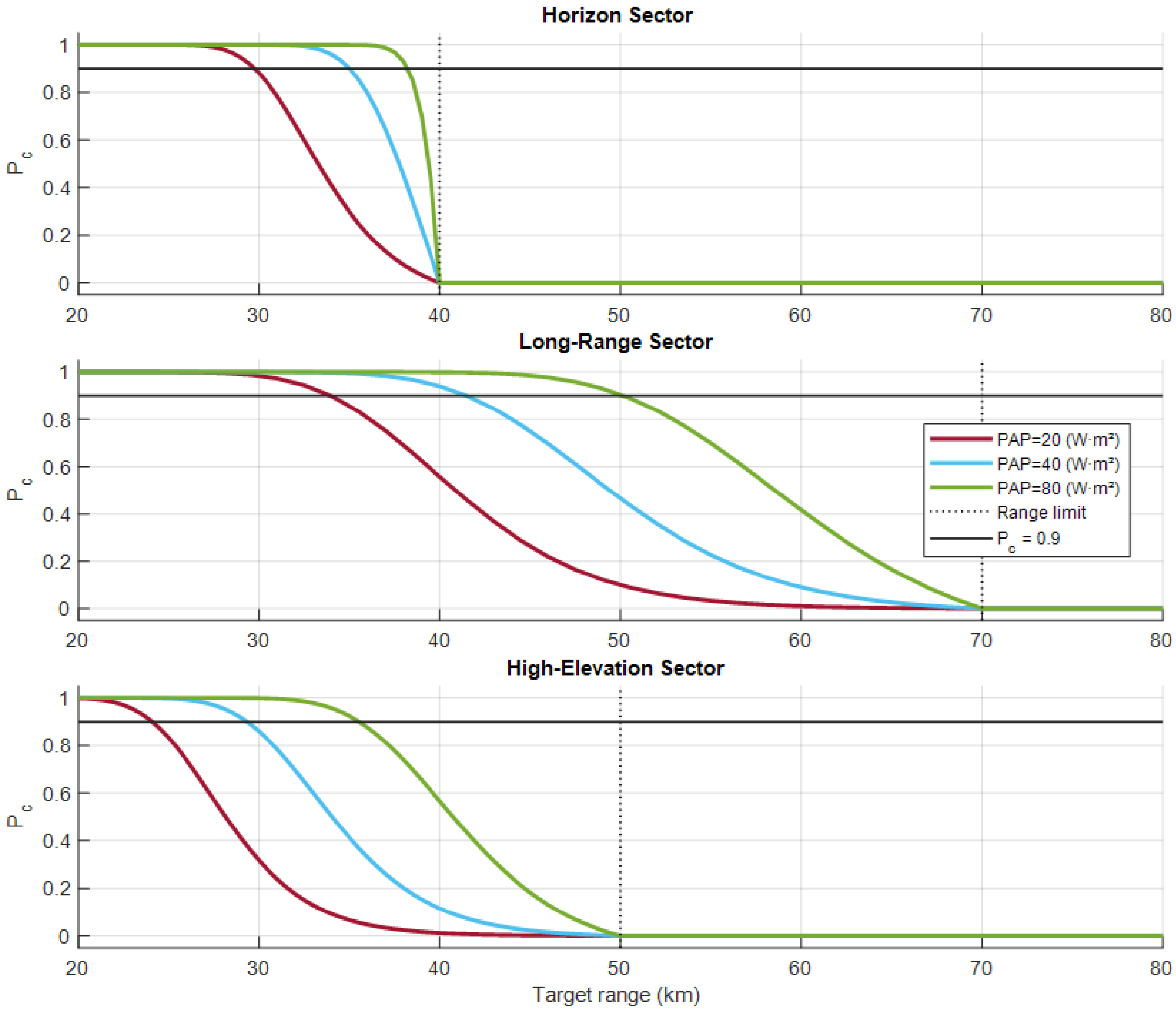
Antenna design

Successful completion of a search task depends on power aperture product (PAP)

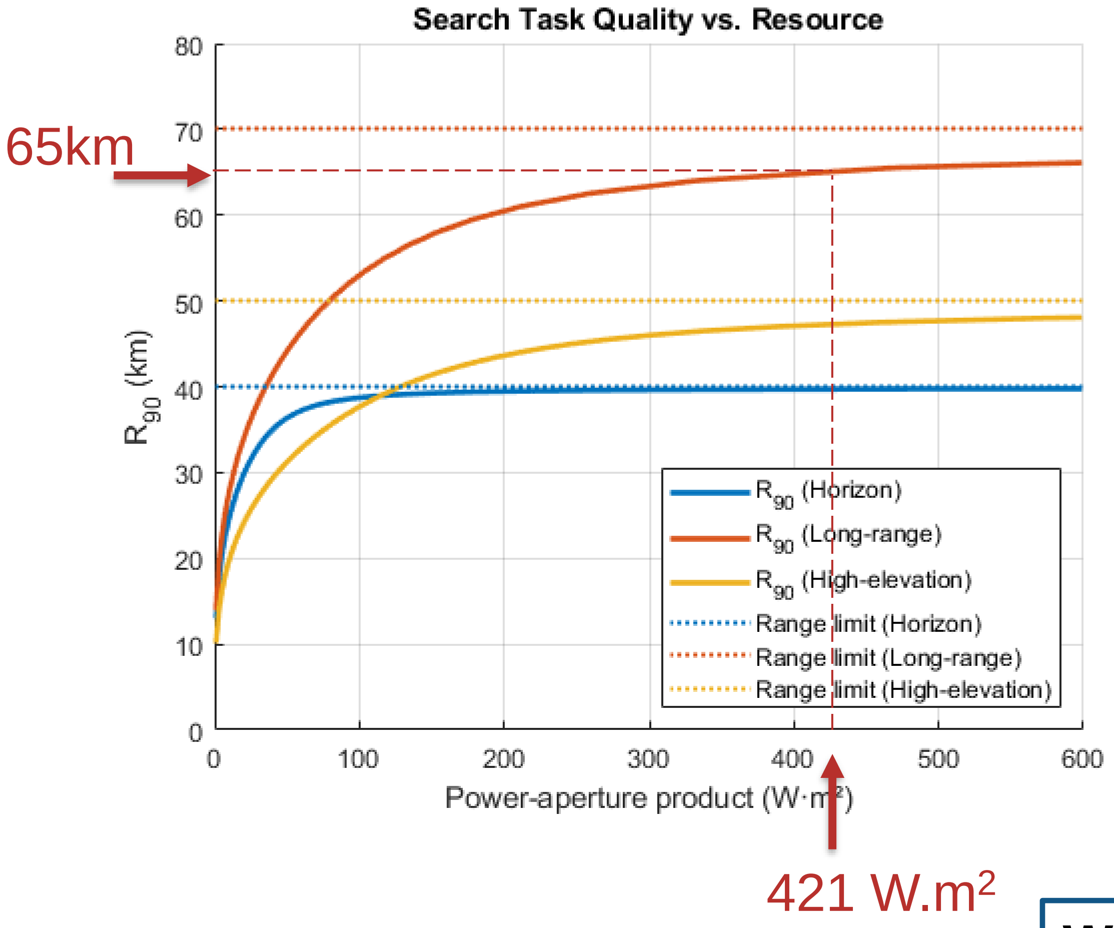
Link to example

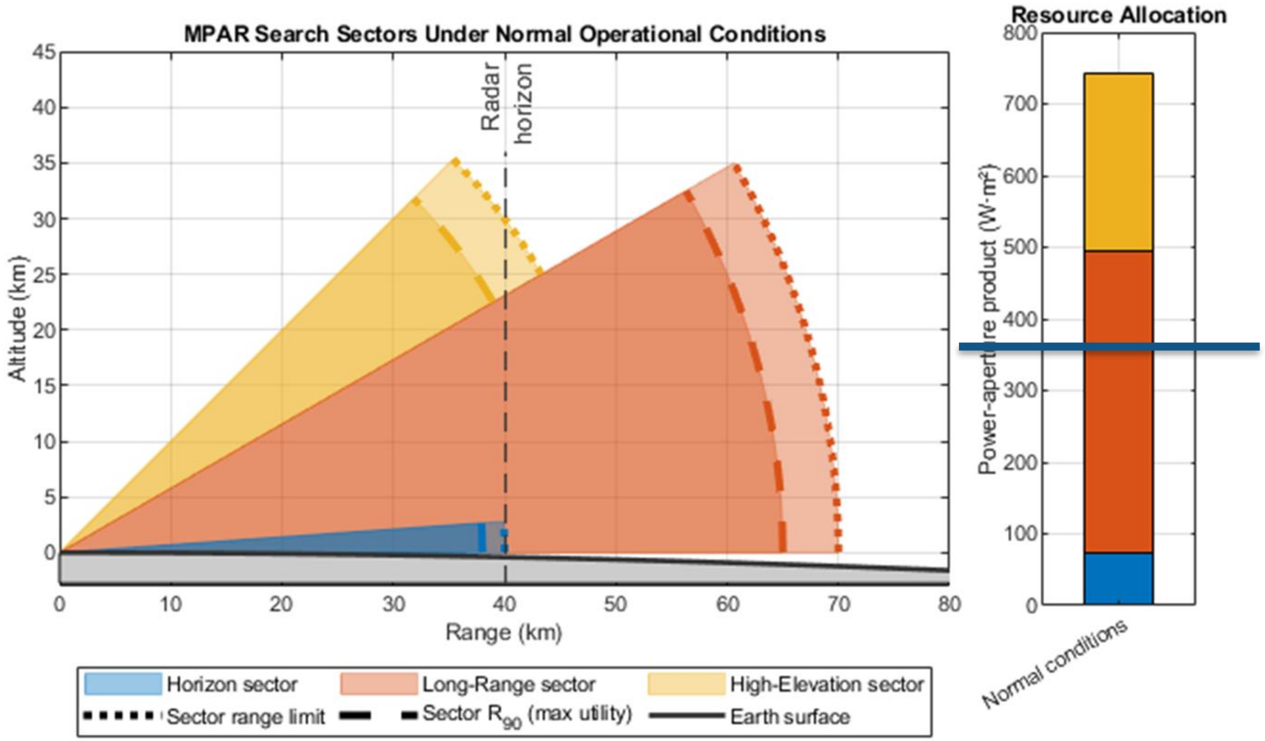


Circular Planar Array



Resource allocation under normal operational conditions





What if we only have access to half of the required PAP?

Optimize search quality across all sectors with QoS

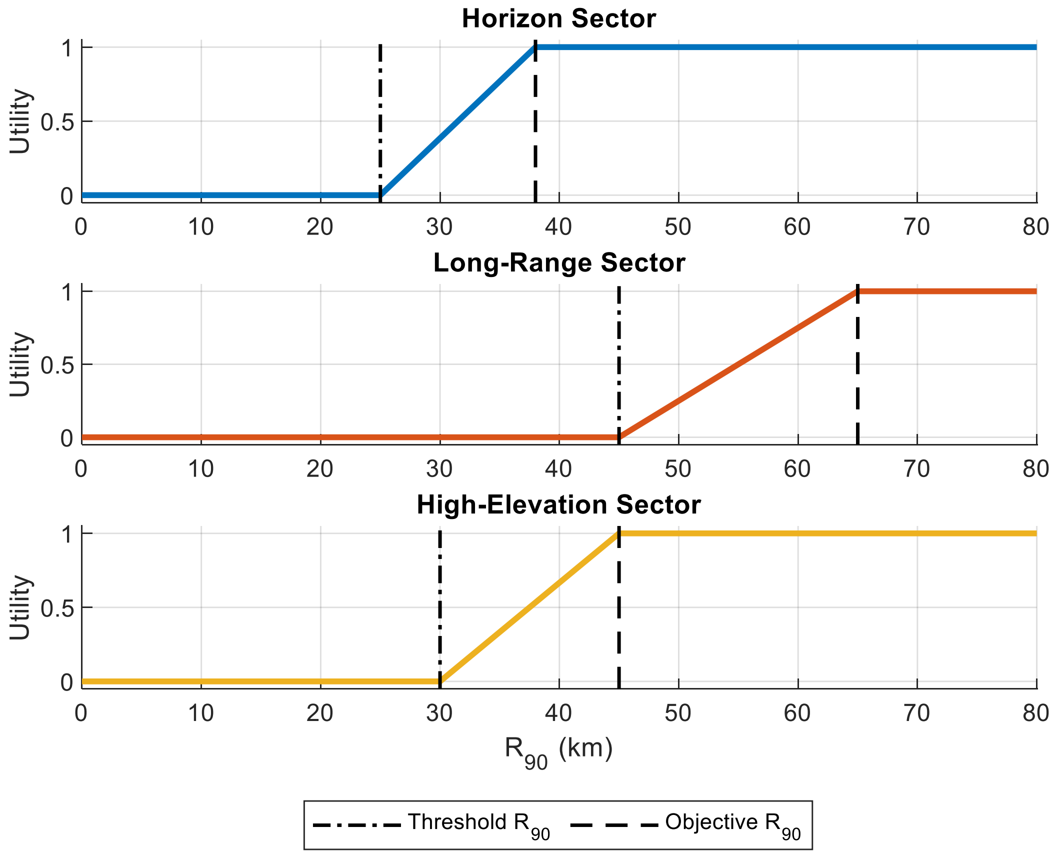
Resource

Translate to range

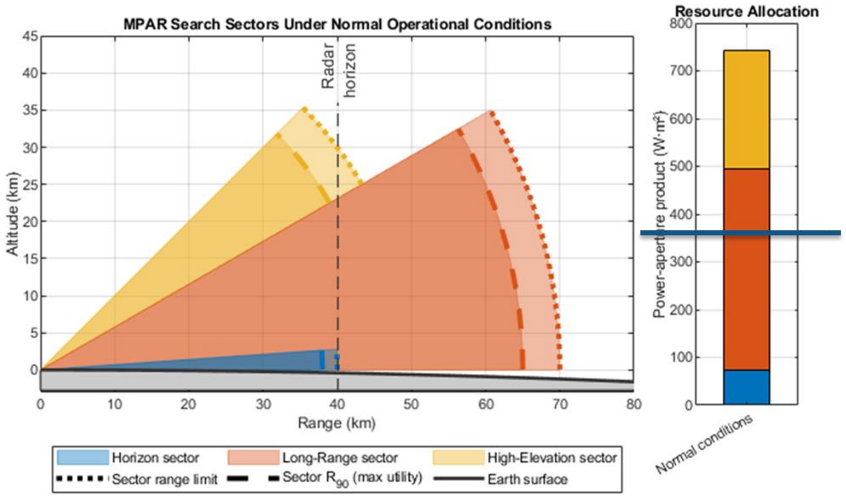
$$\max_{PAP} u(PAP) = \sum_{i=1}^{M} w_i \cdot u_i(q_i(PAP_i; \theta_i))$$

Weights

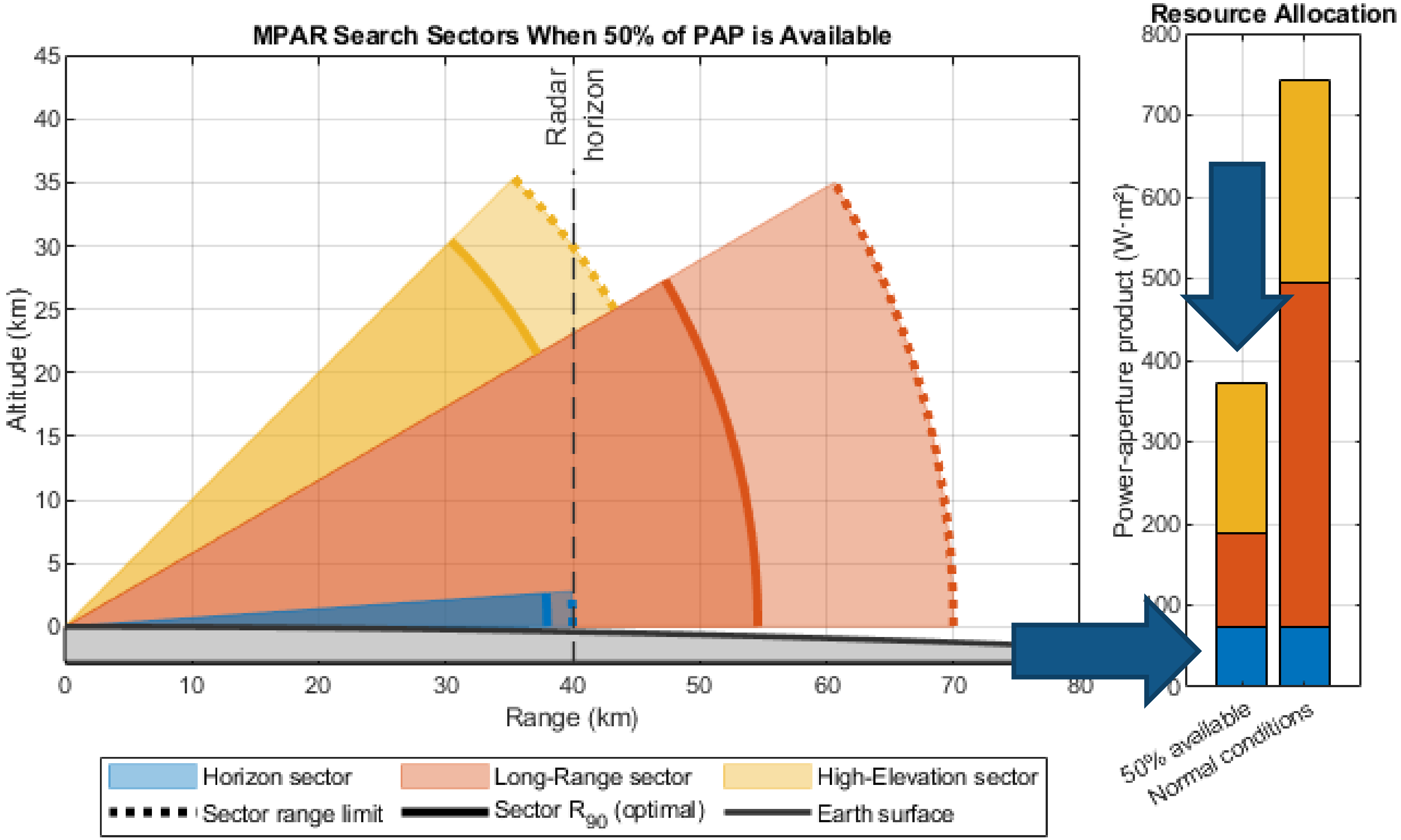
Utility function



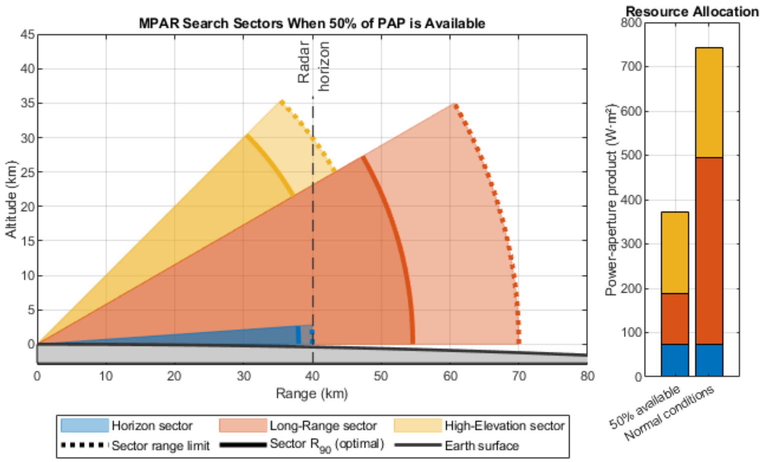
Find optimal resource allocation under constrained operating conditions



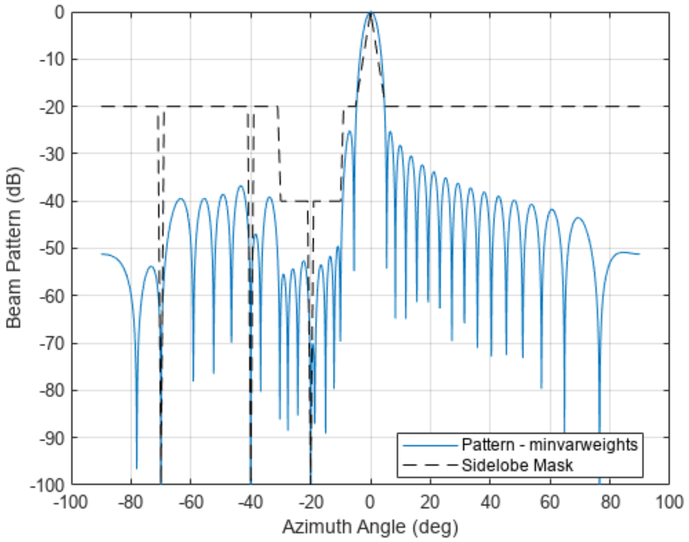
Search Sector	Priority Weights
Horizon	0.55
High Elevation	0.3
Long Range	0.15



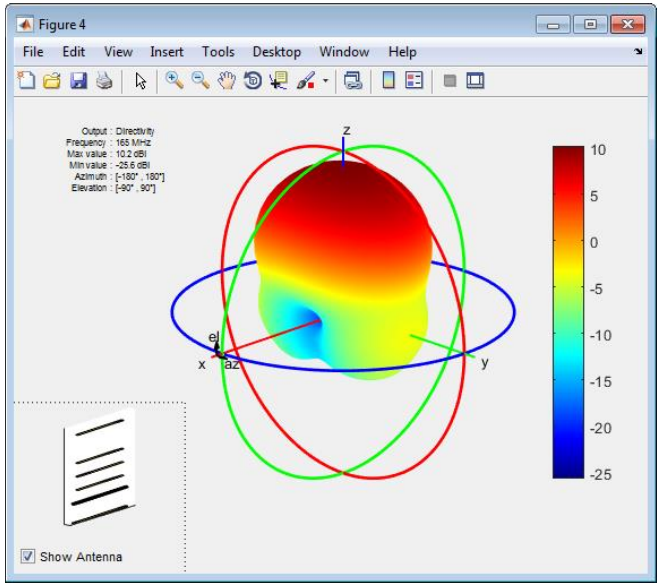
Apply design optimization to key radar and antenna design challenges



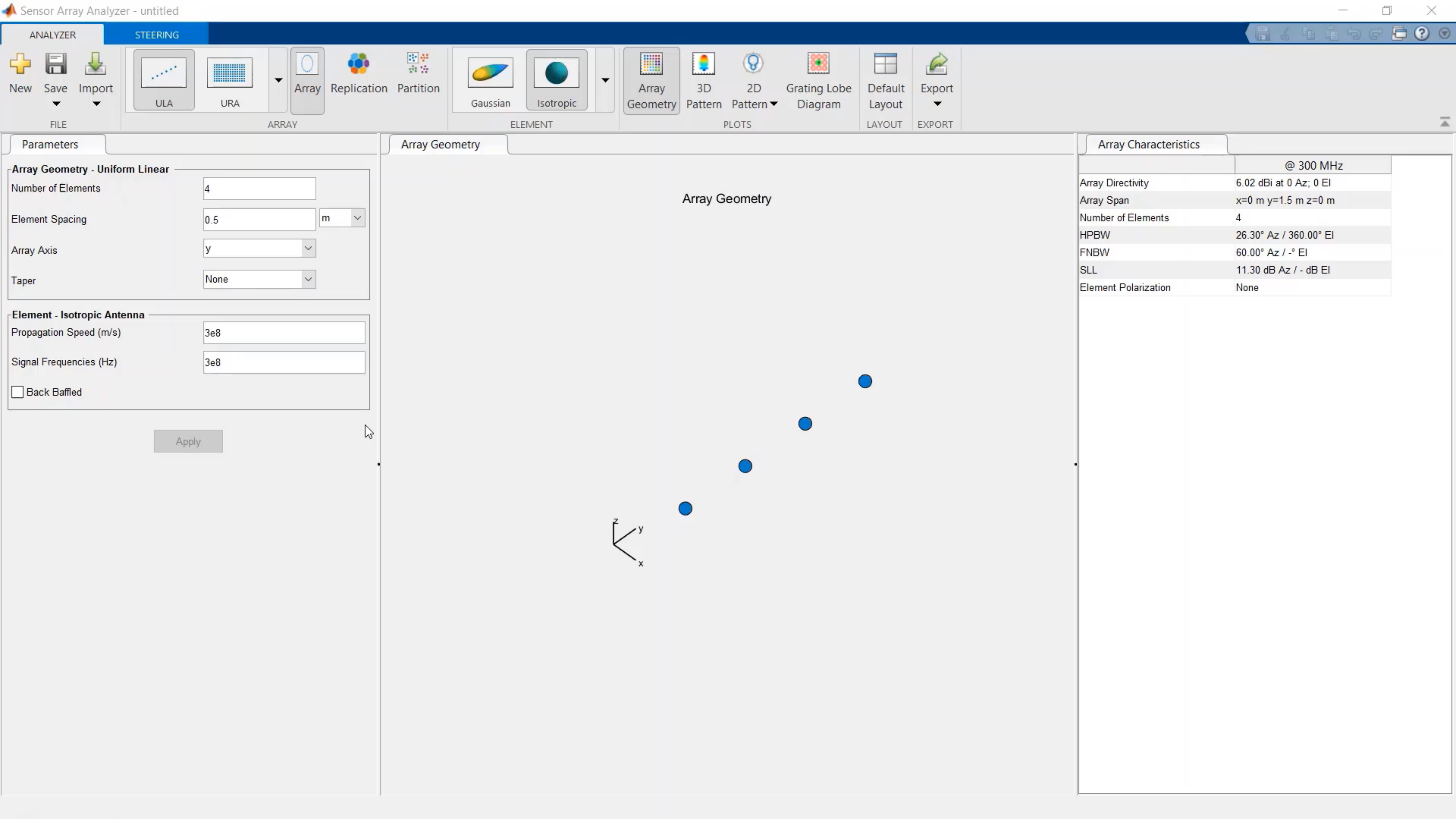
Radar resource management



Array pattern synthesis

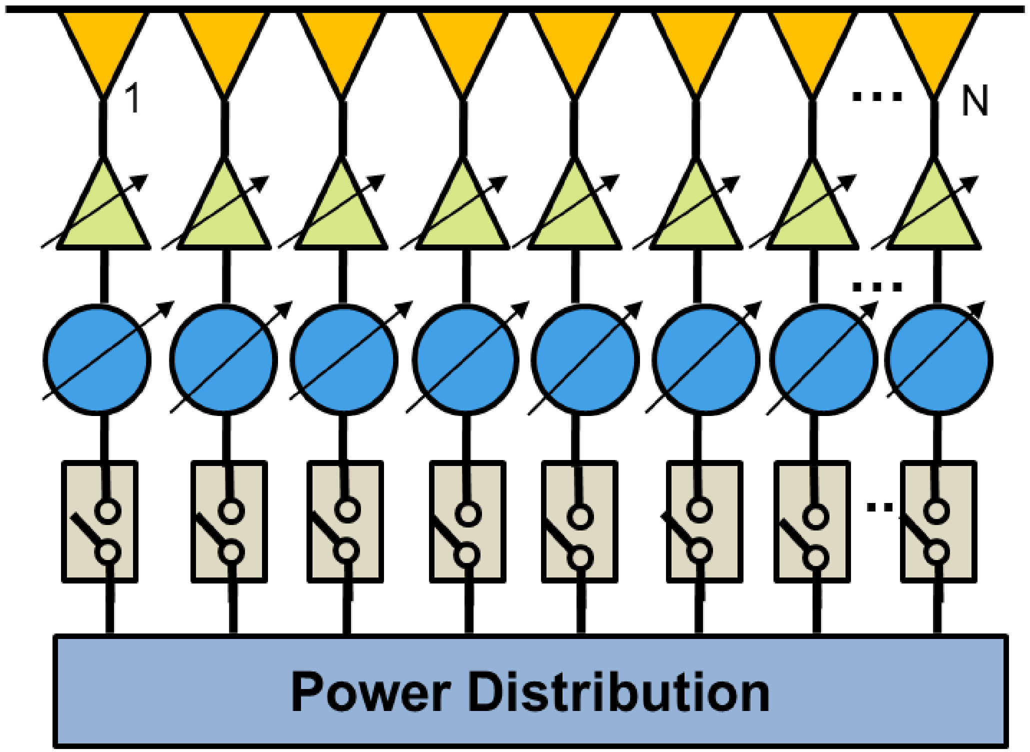


Antenna design

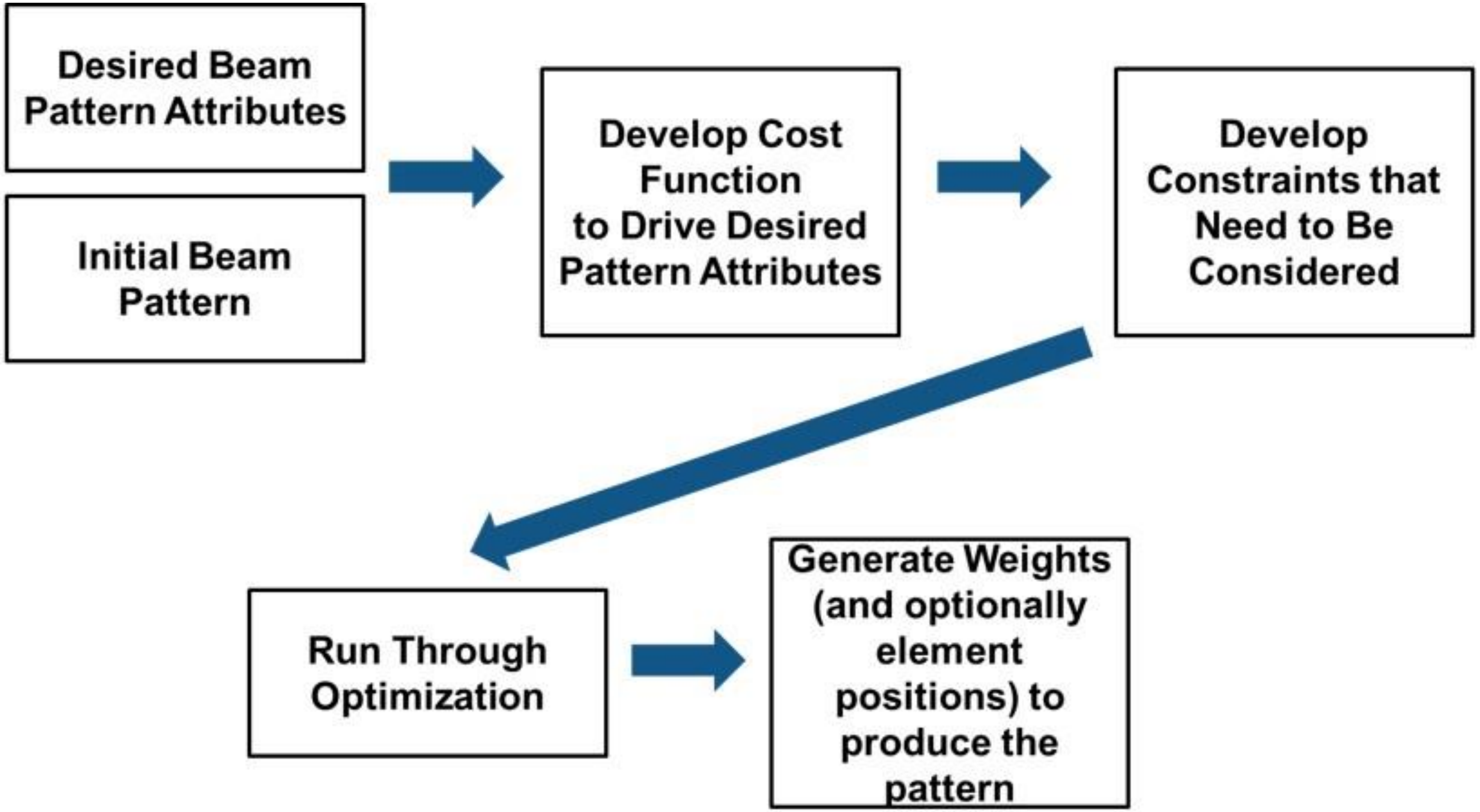

Sensor Array Analyzer - untitled
ANALYZER
STEERING
New
Save
Import
FILE
ULA
URA
Array
Replication
Partition
ARRAY
Gaussian
Isotropic
ELEMENT
Array Geometry
3D Pattern
2D Pattern
Grating Lobe Diagram
PLOTS
Default Layout
LAYOUT
Export
EXPORT
Parameters
Array Geometry - Uniform Linear
Number of Elements
4
Element Spacing
0.5
m
Array Axis
y
Taper
None
Element - Isotropic Antenna
Propagation Speed (m/s)
3e8
Signal Frequencies (Hz)
3e8
Back Baffled
Apply
Array Geometry
Array Geometry
z
y
x
Array Characteristics
@ 300 MHz
Array Directivity
6.02 dBi at 0 Az; 0 El
Array Span
x=0 m y=1.5 m z=0 m
Number of Elements
4
HPBW
26.30° Az / 360.00° El
FNBW
60.00° Az / -° El
SLL
11.30 dB Az / - dB El
Element Polarization
None

How can I obtain a pattern that meets my requirements?

- Traditional process very tedious
- Trial and error with array geometry, parameters, spacing, weighting, etc.

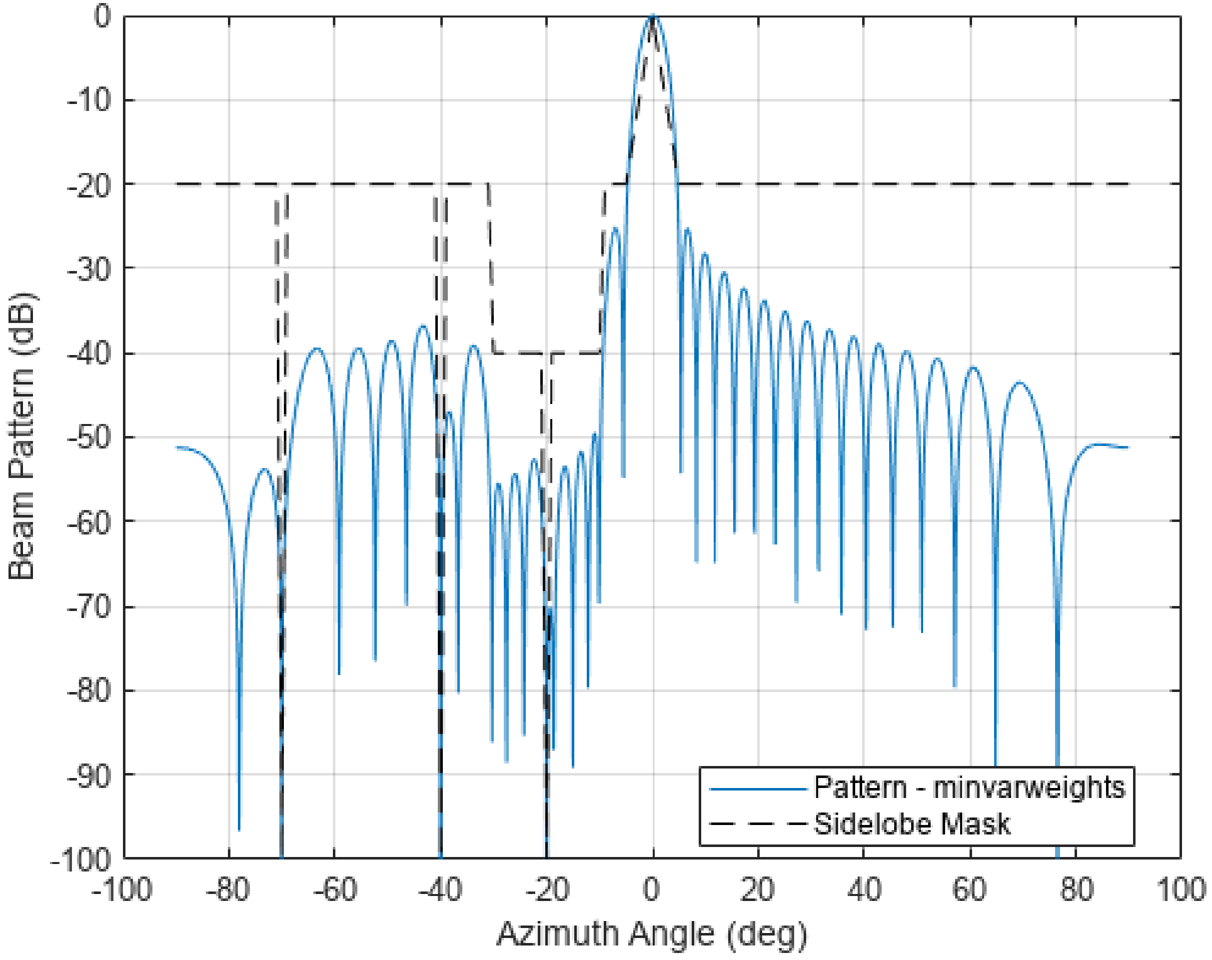


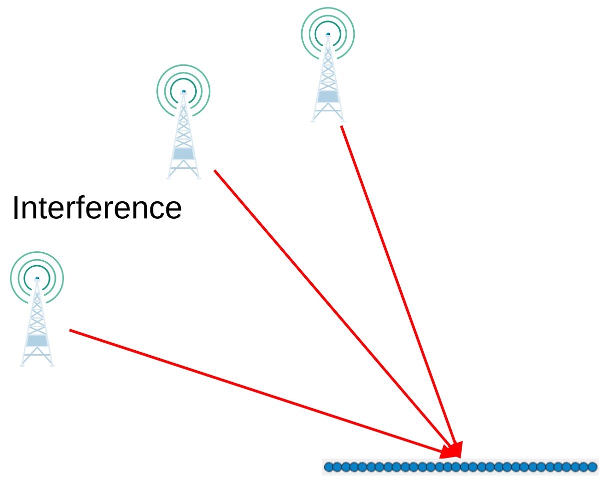
You can perform array synthesis using optimization to drive pattern attributes



Example: Minimum Variance Beamforming

Link to example





Signal of interest at 0° azimuth
Interference at -70°, -40°, and -20° degrees azimuth

Sidelobes < −40 dB between −30 and −10 degrees
Sidelobes < −20 dB everywhere outside mainlobe

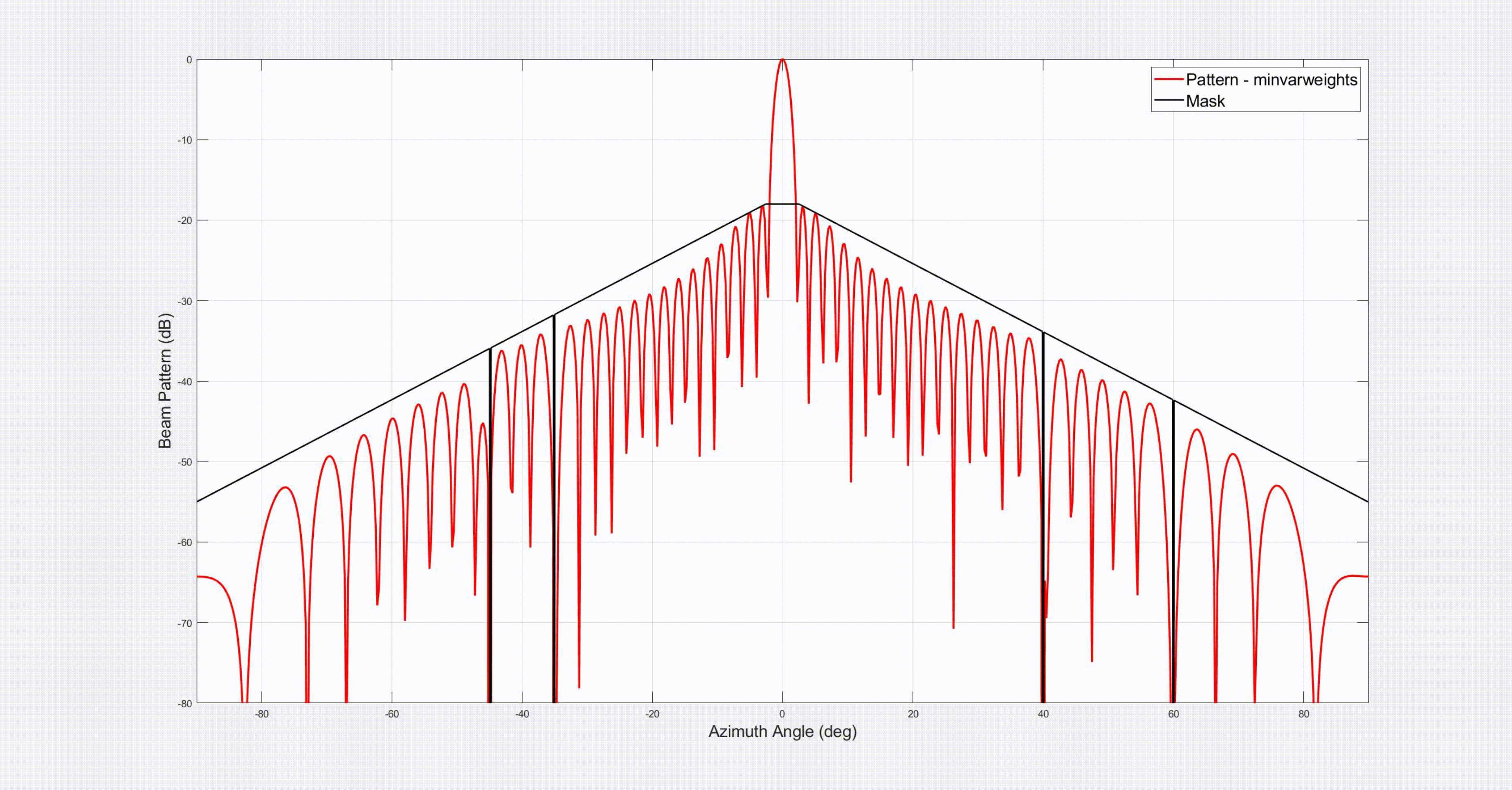
Beamformer weights | Beamforming directions

```
wts = minvarweights(pos,ang)
```

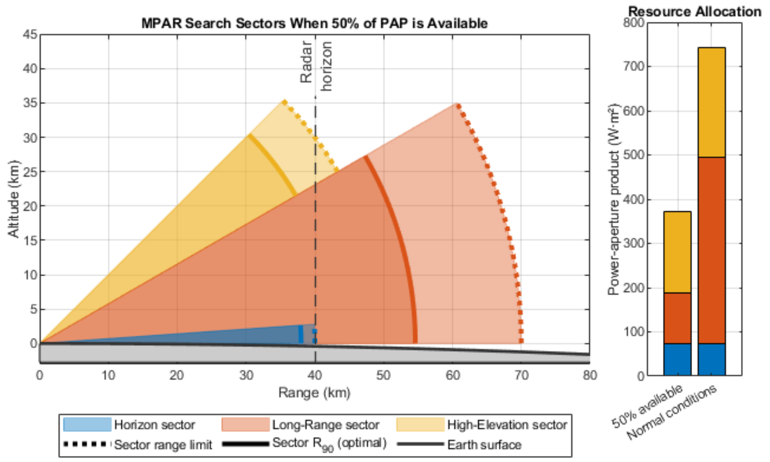
Element positions

Example: Minimum Variance Beamforming

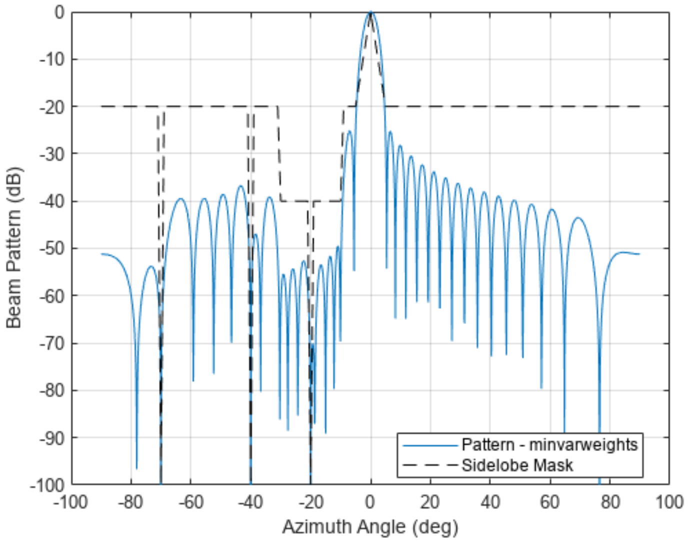
Tapered sidelobe mask decreasing linearly from -18 dB to -55 dB
Nulls at -45, -35, 40, and 60 degrees azimuth
Sweep beam from -35 to 35 degrees



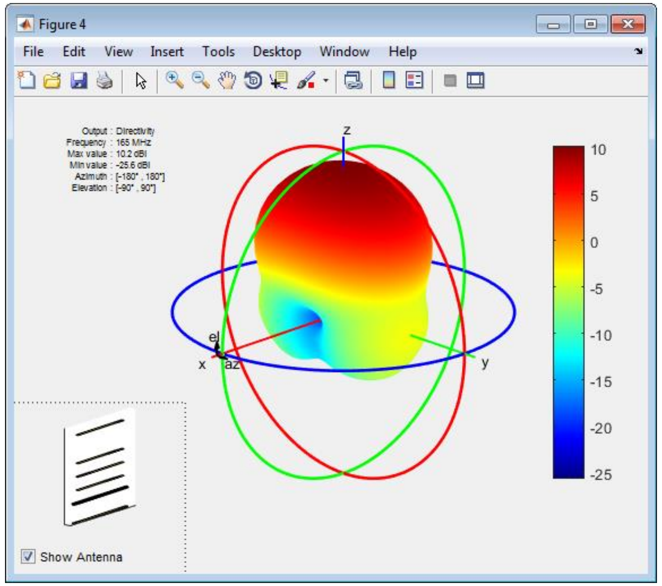
Apply design optimization to key radar and antenna design challenges



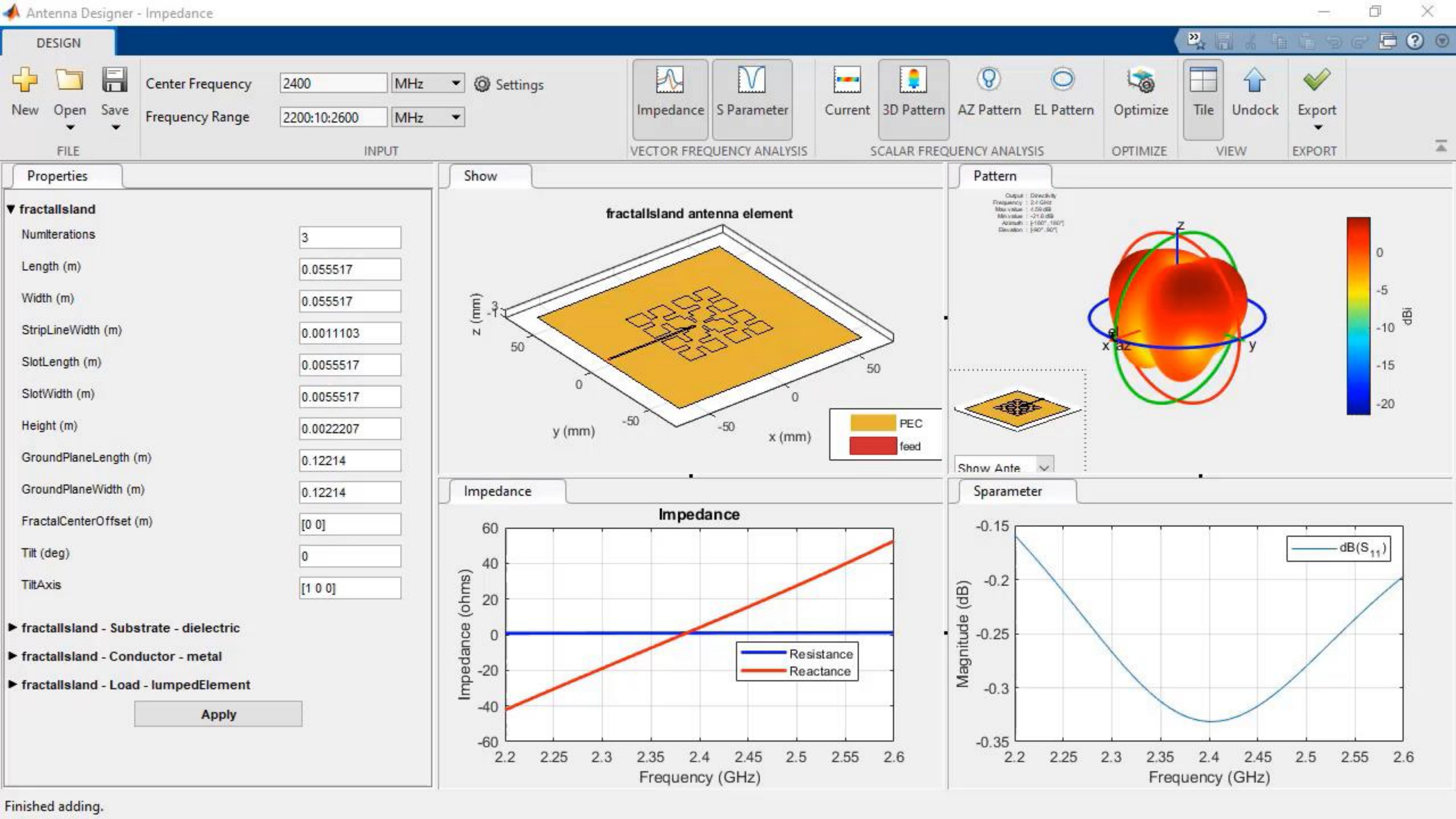
Radar resource management

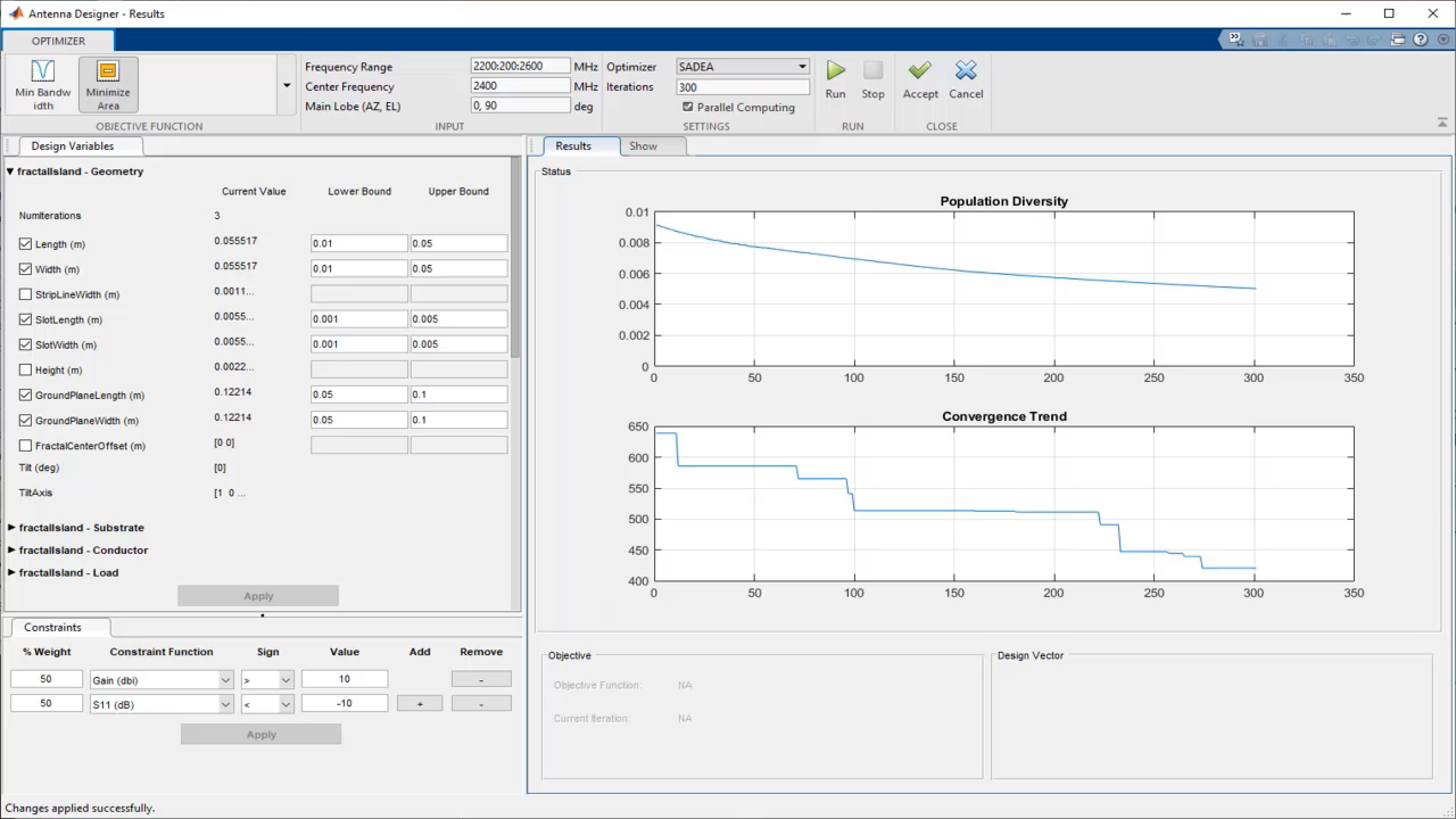


Array pattern synthesis



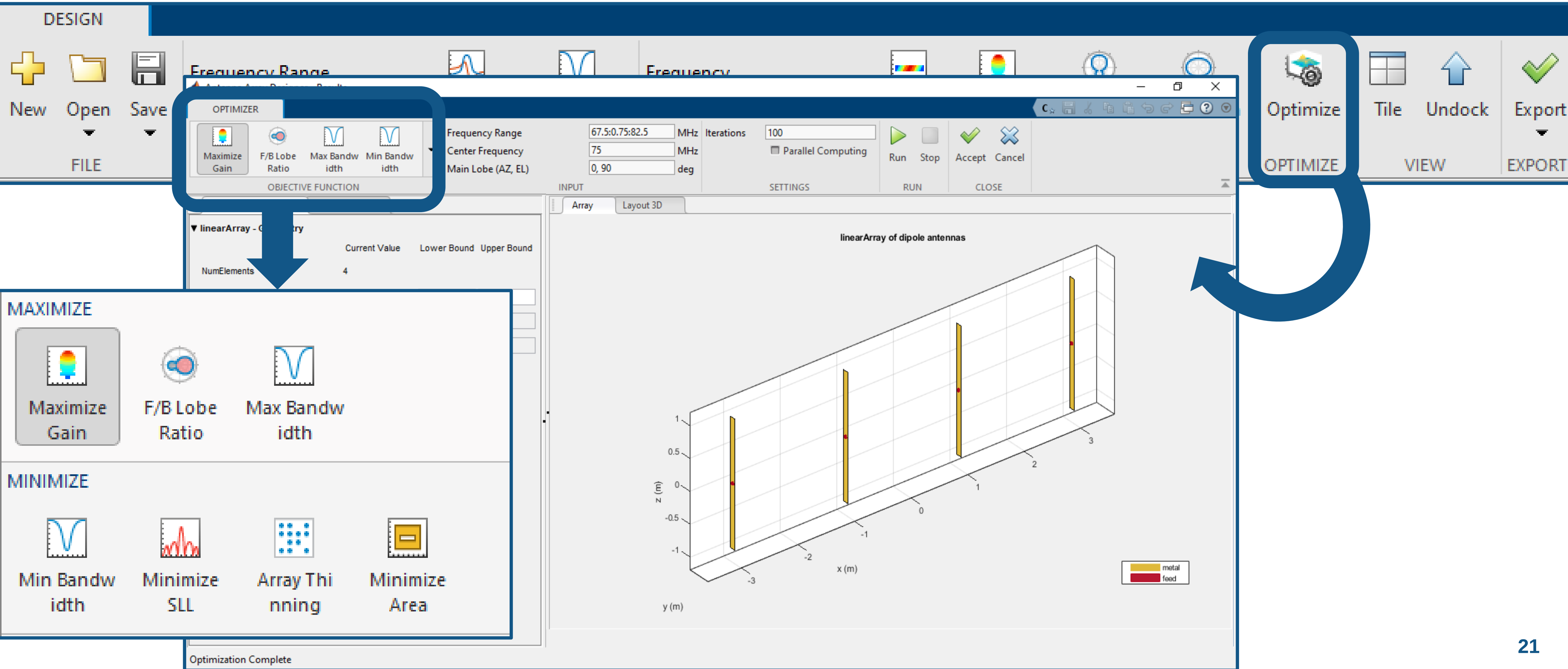
Antenna design


Antenna Designer - Impedance
DESIGN
New
Open
Save
FILE
Center Frequency
2400
MHz
Settings
Frequency Range
2200:10:2600
MHz
INPUT
Impedance
S Parameter
VECTOR FREQUENCY ANALYSIS
Current
3D Pattern
AZ Pattern
EL Pattern
SCALAR FREQUENCY ANALYSIS
Optimize
OPTIMIZE
Tile
Undock
VIEW
Export
EXPORT
Properties
fractalIsland
NumIterations
3
Length (m)
0.055517
Width (m)
0.055517
StripLineWidth (m)
0.0011103
SlotLength (m)
0.0055517
SlotWidth (m)
0.0055517
Height (m)
0.0022207
GroundPlaneLength (m)
0.12214
GroundPlaneWidth (m)
0.12214
FractalCenterOffset (m)
[0 0]
Tilt (deg)
0
TiltAxis
[1 0 0]
fractalIsland - Substrate - dielectric
fractalIsland - Conductor - metal
fractalIsland - Load - lumpedElement
Apply
Show
fractalIsland antenna element
z (mm)
y (mm)
x (mm)
PEC
feed
Pattern
dBi
Show Ante
Impedance
Impedance
Impedance (ohms)
Frequency (GHz)
Resistance
Reactance
Sparameter
dB(S11)
Magnitude (dB)
Frequency (GHz)
Finished adding.


Antenna Designer - Results
OPTIMIZER
Min Bandwidth
Minimize Area
OBJECTIVE FUNCTION
Frequency Range
2200:200:2600
MHz
Center Frequency
2400
MHz
Main Lobe (AZ, EL)
0, 90
deg
INPUT
Optimizer
SADEA
Iterations
300
Parallel Computing
SETTINGS
Run
Stop
RUN
Accept
Cancel
CLOSE
Design Variables
fractalIsland - Geometry
Current Value
Lower Bound
Upper Bound
NumIterations
3
Length (m)
0.055517
0.01
0.05
Width (m)
0.055517
0.01
0.05
StripLineWidth (m)
0.0011...
SlotLength (m)
0.0055...
0.001
0.005
SlotWidth (m)
0.0055...
0.001
0.005
Height (m)
0.0022...
GroundPlaneLength (m)
0.12214
0.05
0.1
GroundPlaneWidth (m)
0.12214
0.05
0.1
FractalCenterOffset (m)
[0 0]
Tilt (deg)
[0]
TiltAxis
[1 0 ...
fractalIsland - Substrate
fractalIsland - Conductor
fractalIsland - Load
Apply
Constraints
% Weight
Constraint Function
Sign
Value
Add
Remove
50
Gain (dbi)
>
10
-
50
S11 (dB)
<
-10
+
-
Apply
Results
Show
Status
Population Diversity
Convergence Trend
Objective
Objective Function:
NA
Current Iteration:
NA
Design Vector
Changes applied successfully.

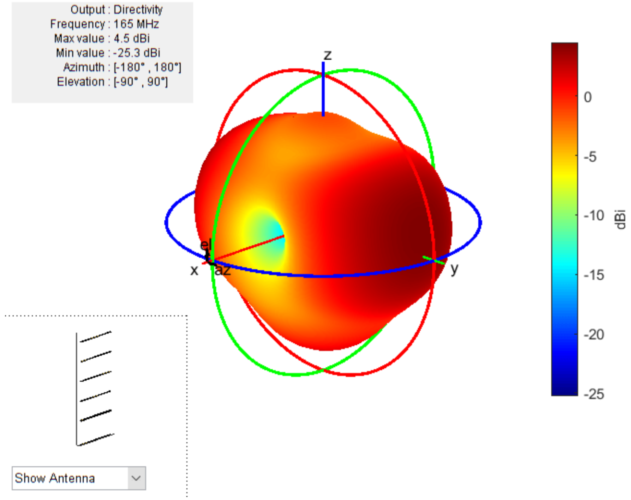
MATLAB EXPO

Also Optimize Arrays and PCB Antennas

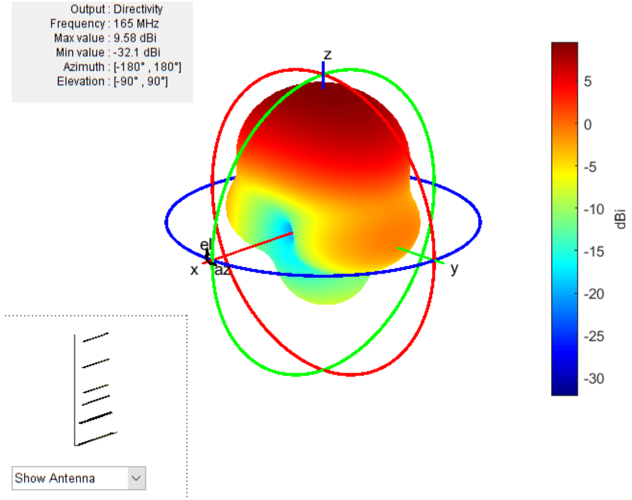


Define Customized Optimization Workflows in MATLAB

- Define the objective and constraint function using MATLAB functions
- Use global or local optimization methods applied to antenna design
- Use parallel computing to speed up computation



Poor directivity



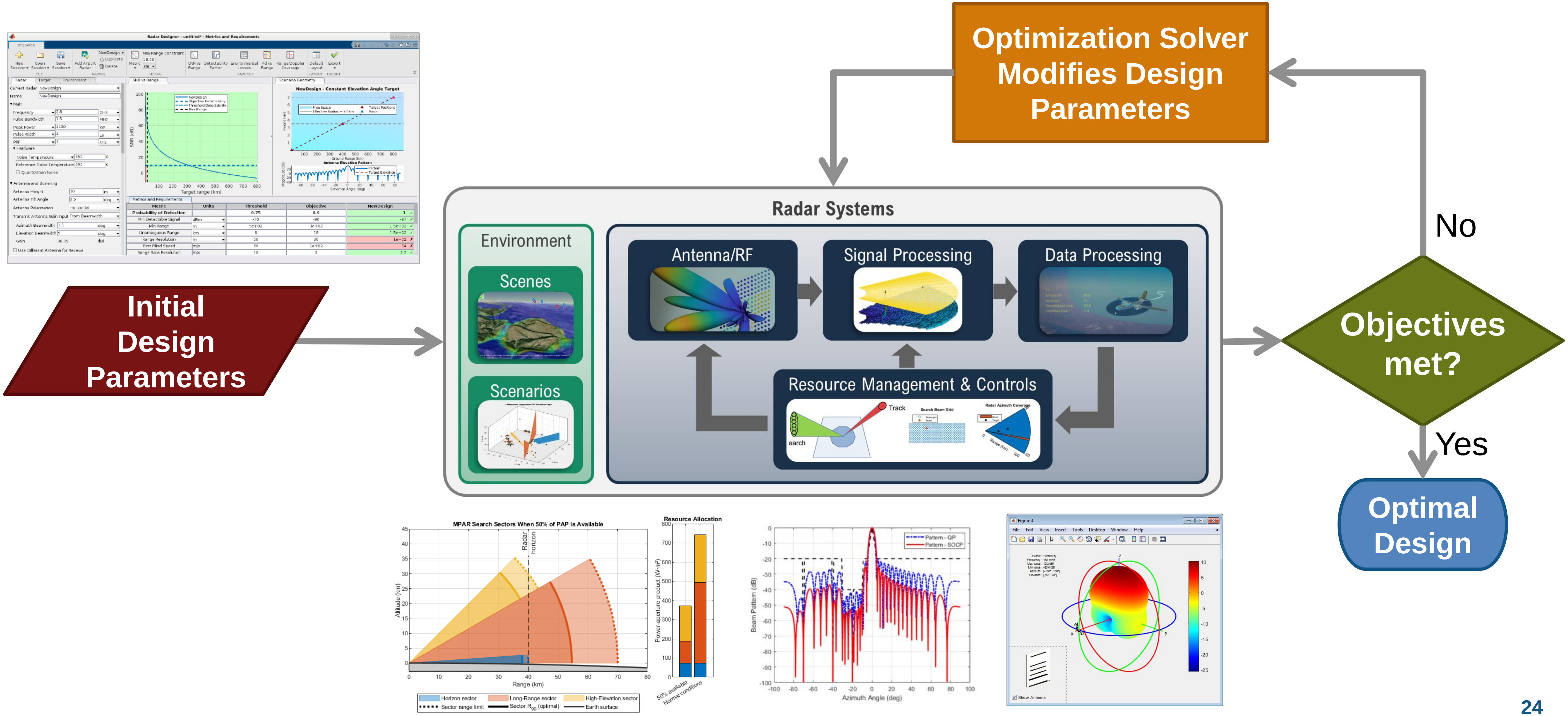
Optimized pattern

```
% Optimizer options
optimizerparams = optimoptions(@patternsearch);
optimizerparams.UseCompletePoll = true;
optimizerparams.PlotFcns = @psplotbestf;
optimizerparams.UseParallel = true;
optimizerparams.Cache = 'on';
optimizerparams.MaxIter = 100;
optimizerparams.FunctionTolerance = 1e-2;

% Antenna design parameters
designparams.Antenna = yagidesign;
designparams.Bounds = parameterBounds;

% Analysis parameters
analysisparams.CenterFrequency = fc;
analysisparams.Bandwidth = BW;
analysisparams.ReferenceImpedance = Z0;
analysisparams.MainLobeDirection = ang(:,1);
analysisparams.BackLobeDirection = ang(:,2);

% Set constraints
constraints.S11min = -10;
constraints.Gmin = 10.5;
constraints.Gdeviation = 0.1;
constraints.FBmin = 15;
constraints.Penalty = 50;
optimdesign = optimizeAntennaDirect(designparams,analysisparams,constraints,optimizerparams);
```

[Example: Design Optimization of Six-Element Yagi-Uda Antenna]

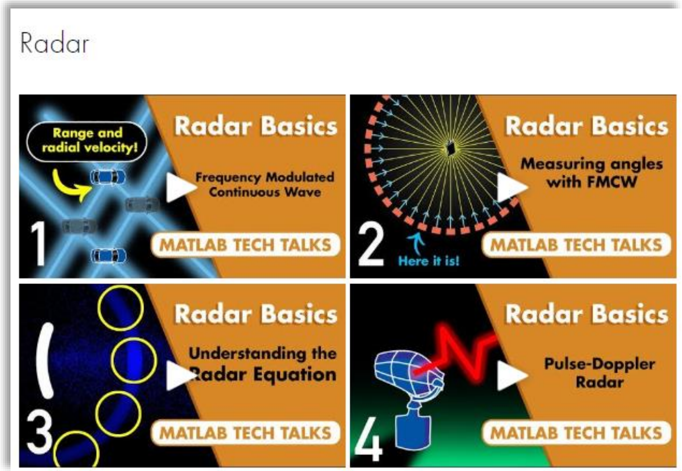
Summary and Resources

Apply design optimization to key radar and antenna design challenges

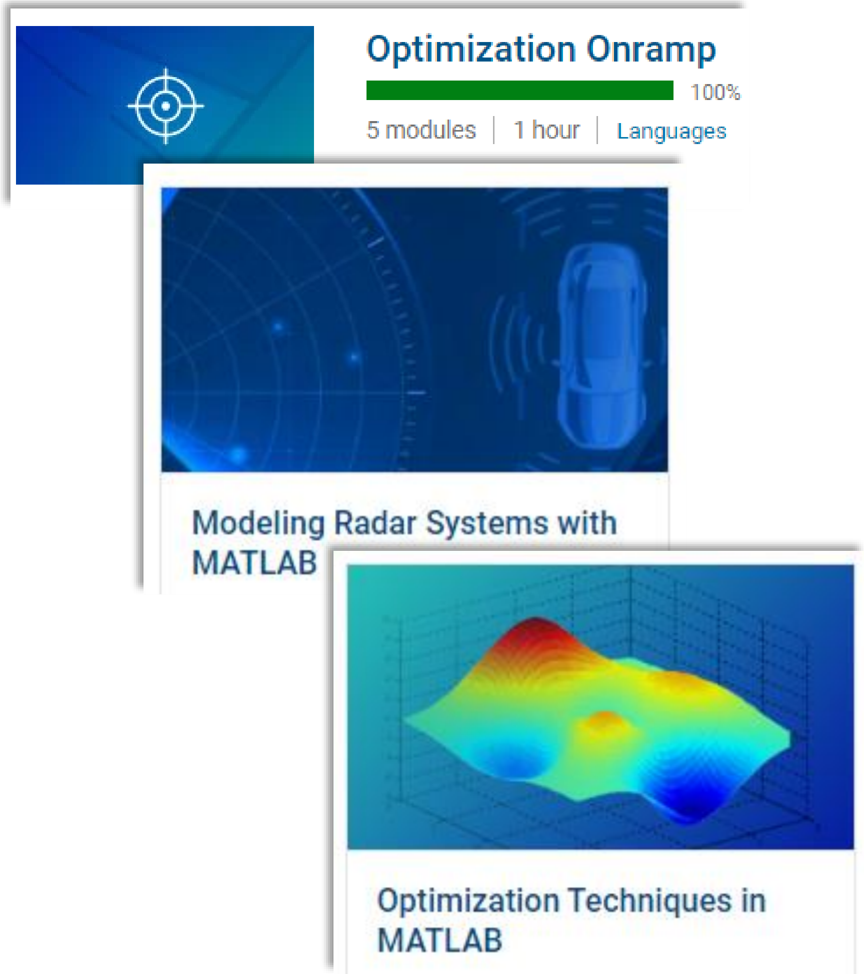


Learn more about designing and optimizing radar and antenna systems in MATLAB

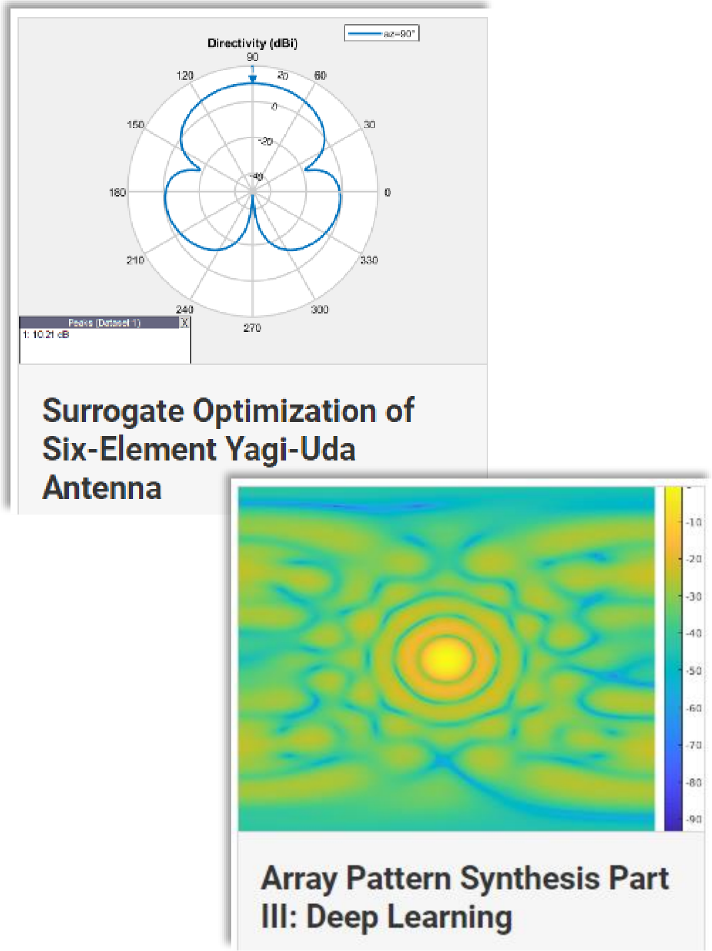
Videos



Training



Examples



MATLAB EXPO

Thank you

MathWorks®