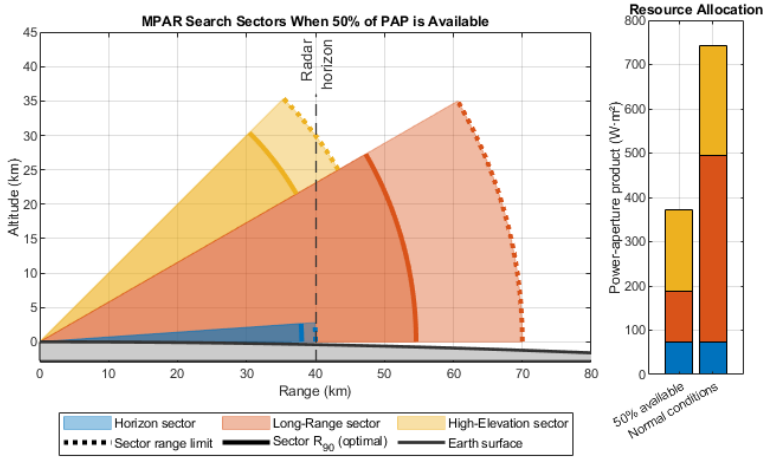
MATLAB EXPO

在MATLAB中优化雷达和天线系统的设计和运行

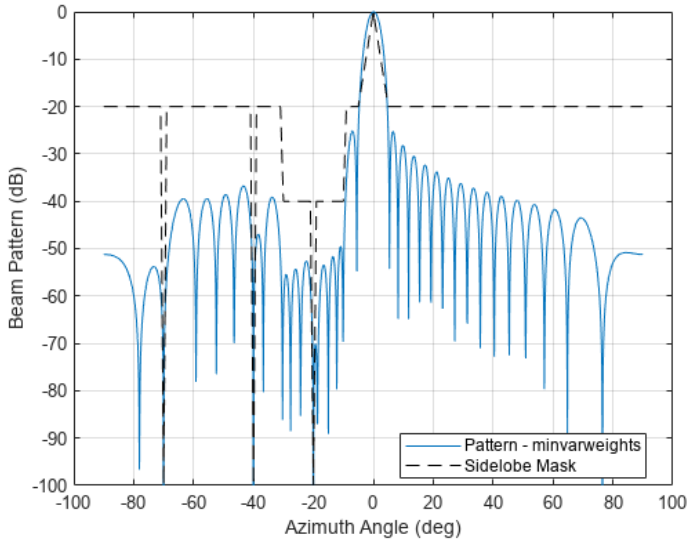
陈晓挺, MathWorks

MathWorks

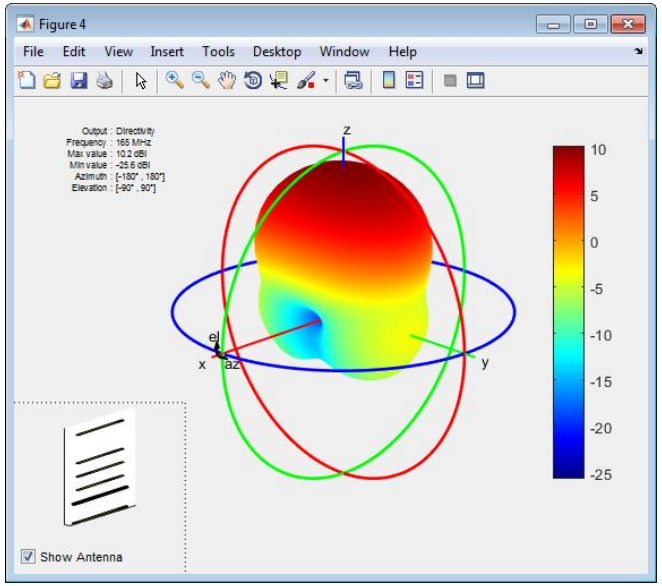
将设计优化应用于关键的雷达和天线设计挑战



雷达资源管理

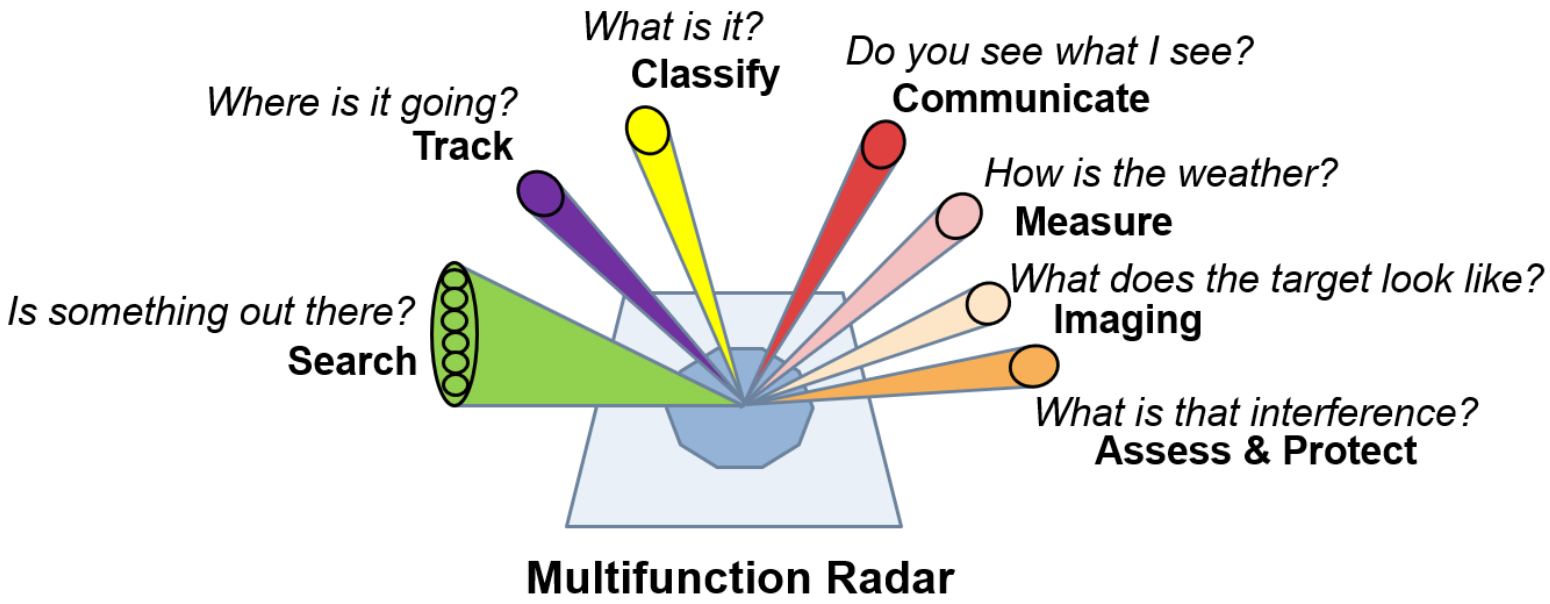


阵列方向图合成



天线设计

多功能相控阵雷达(MPAR)



能力

- 电子控制相控阵可实现**灵活的**波束和动态的时间/能量资源分配
- 控制参数几乎可以**瞬时改变**
- 支持**不同功能**的**多任务**可以在时间和角度上多路复用

资源限制

- 传输能量/时间预算
- 带宽
- 计算量
- 减少泄露

更高运行频率增加了干扰挑战

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...

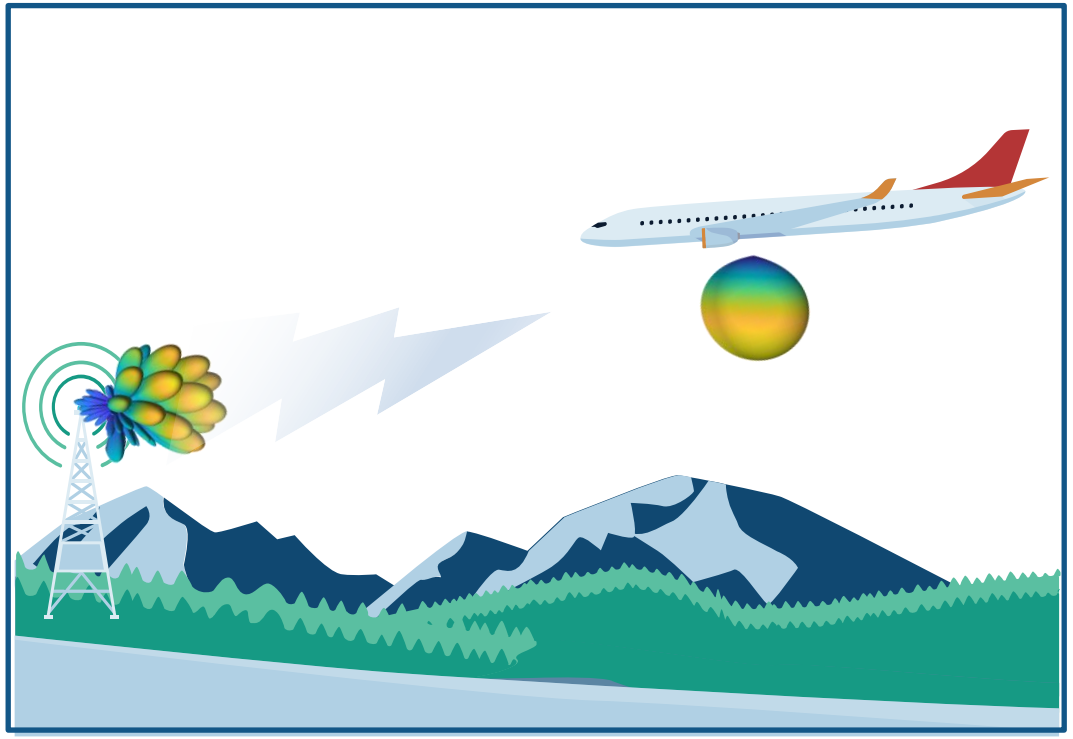
联邦航空局发布新的高度计雷达 5G C波段风险评估

Reuters

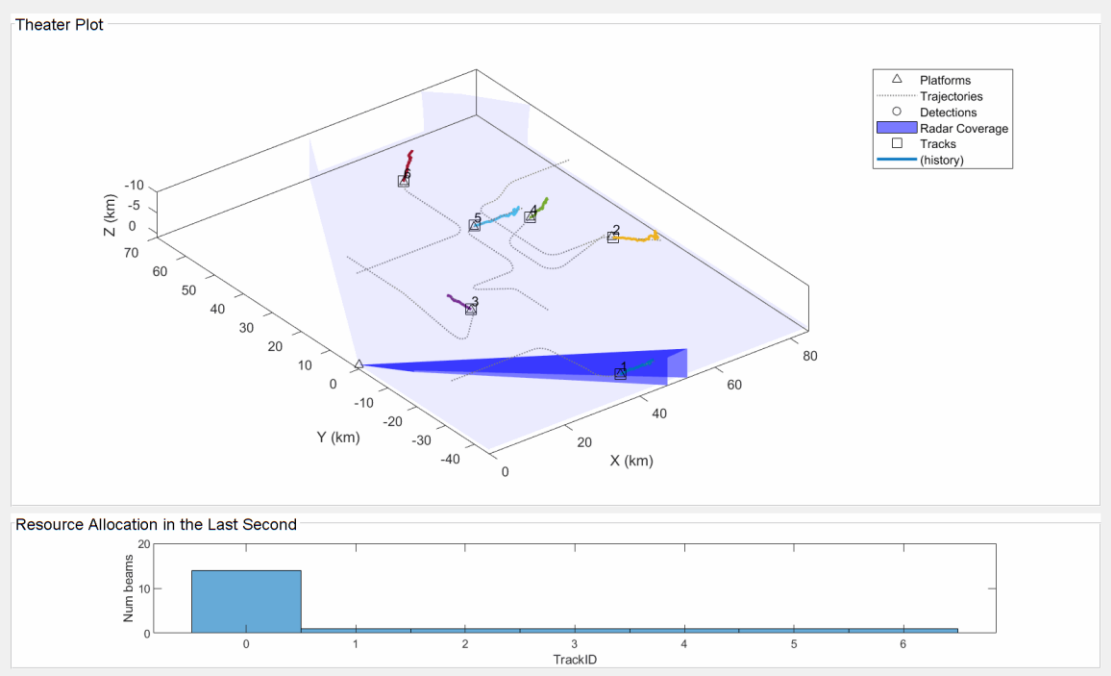
FAA wants U.S. airlines to retrofit, replace radio altimeters

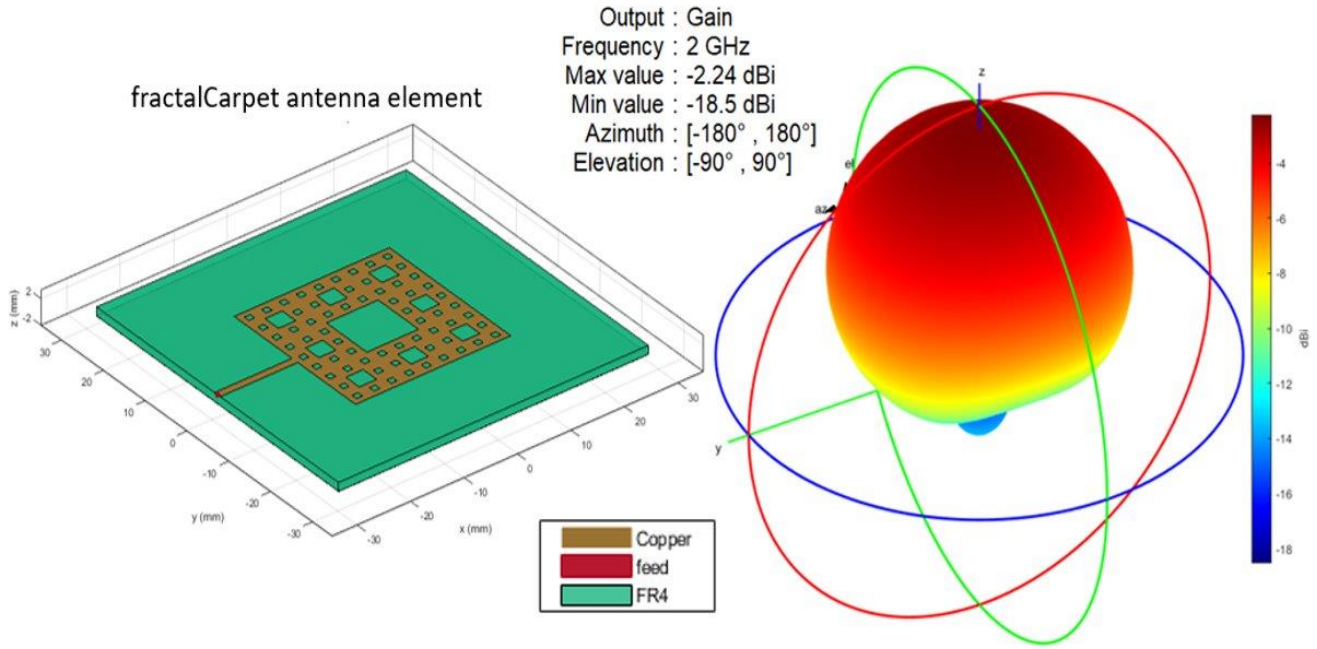
... a push to retrofit and ultimately replace some airplane radio altimeters that could face interference from C-Band 5G wireless service.

联邦航空局希望美国航空公司改造，取代高度计无线电

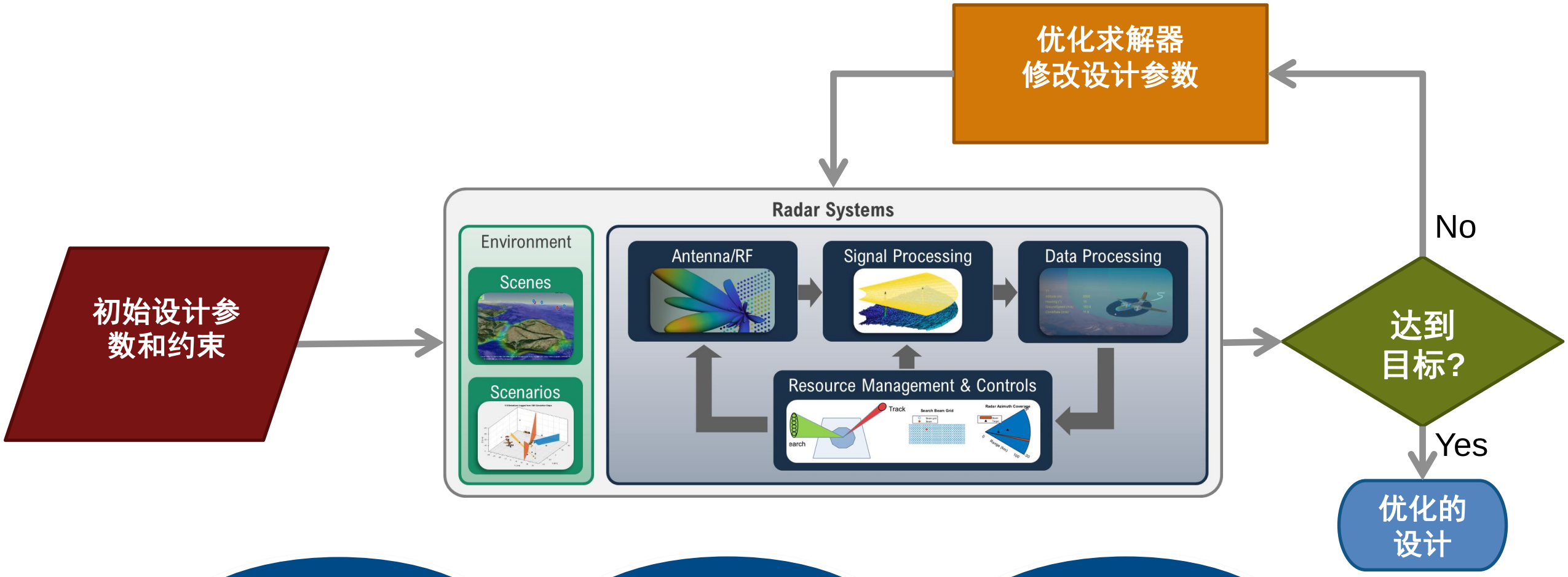


业务和物理资源有限


Theater Plot
Platforms
Trajectories
Detections
Radar Coverage
Tracks
(history)
Z (km)
Y (km)
X (km)
Resource Allocation in the Last Second
Num beams
TrackID


fractalCarpet antenna element
Output : Gain
Frequency : 2 GHz
Max value : -2.24 dBi
Min value : -18.5 dBi
Azimuth : [-180° , 180°]
Elevation : [-90° , 90°]
Copper
feed
FR4
dBi

通过优化工作流程应对设计挑战

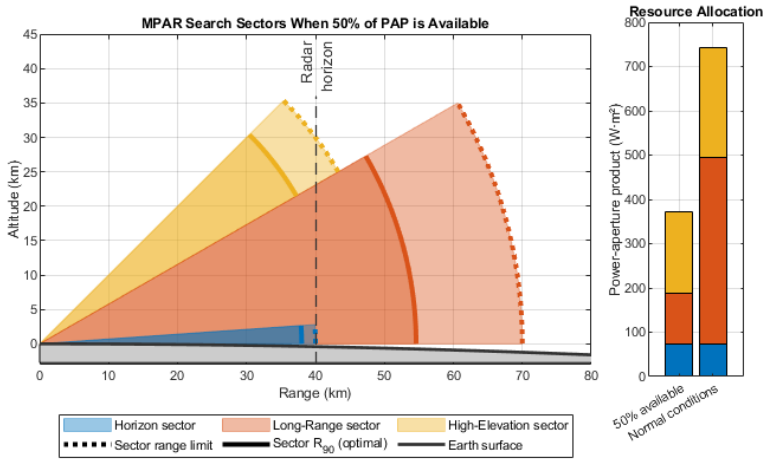


在满足要求的同时找到最佳设计

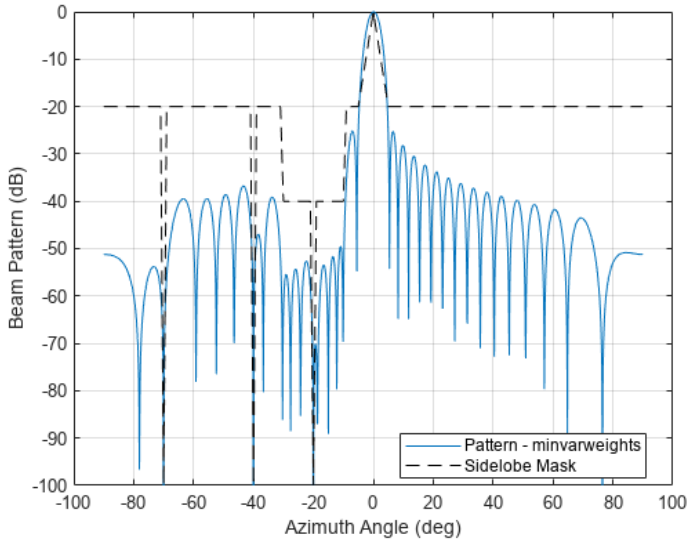
减少设计迭代时间

自动化运行决策

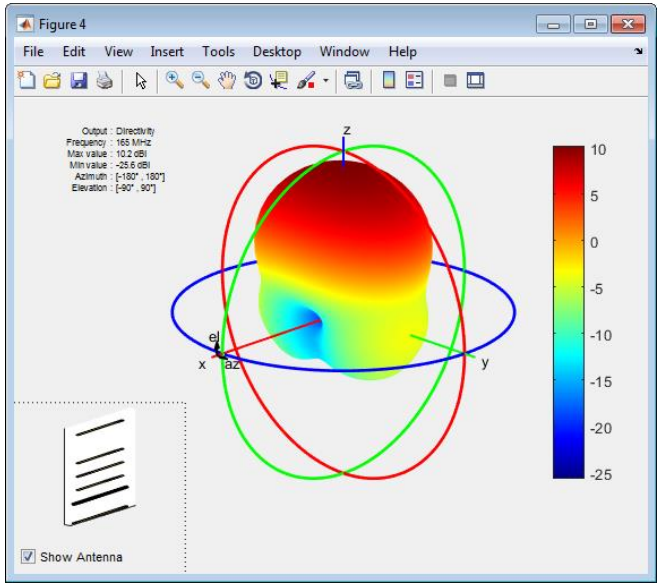
将设计优化应用于关键的雷达和天线设计挑战



雷达资源管理



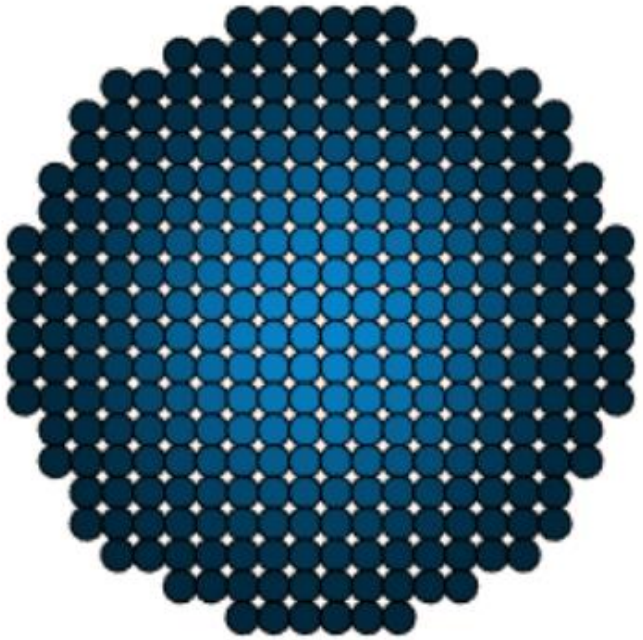
阵列方向图合成



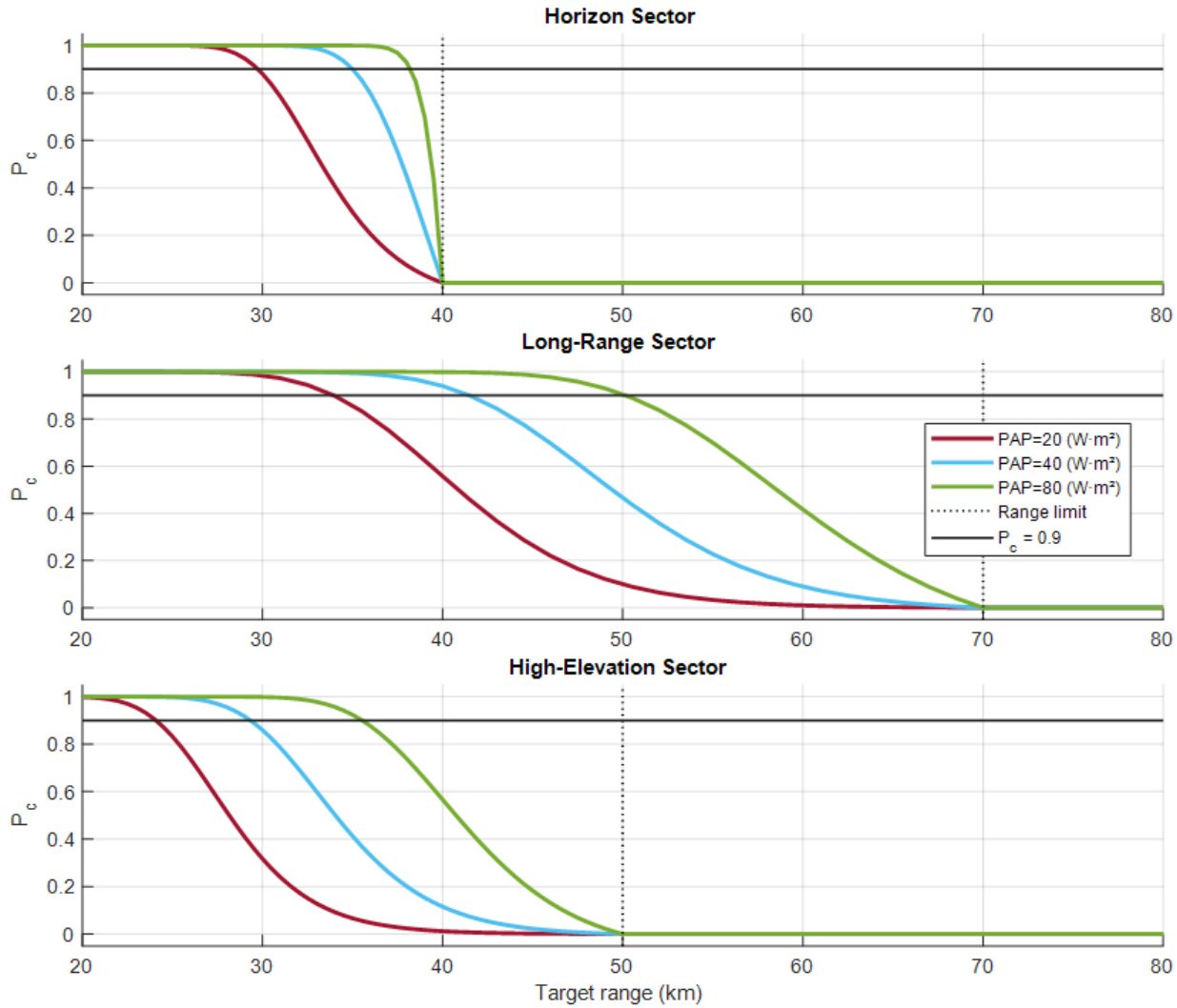
天线设计

搜索任务的成功完成取决于功率孔径积(power aperture product)

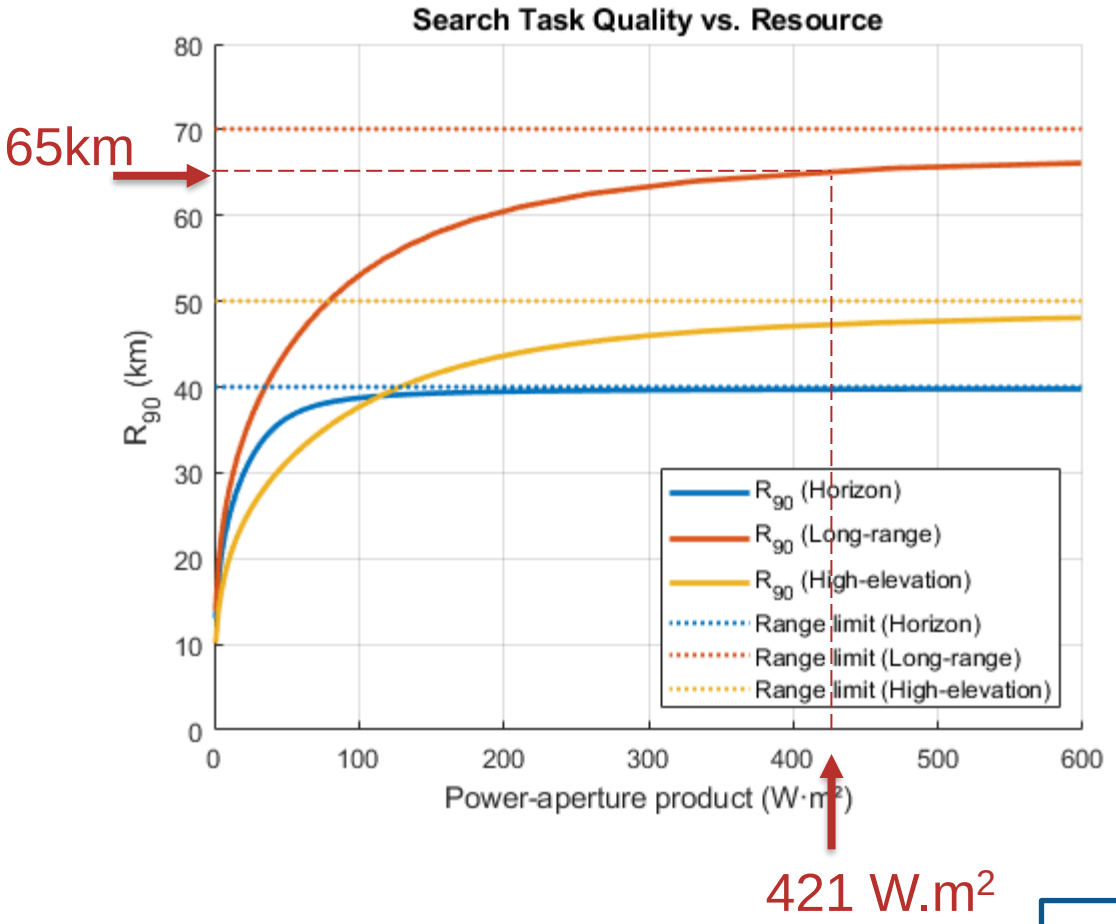
Link to example

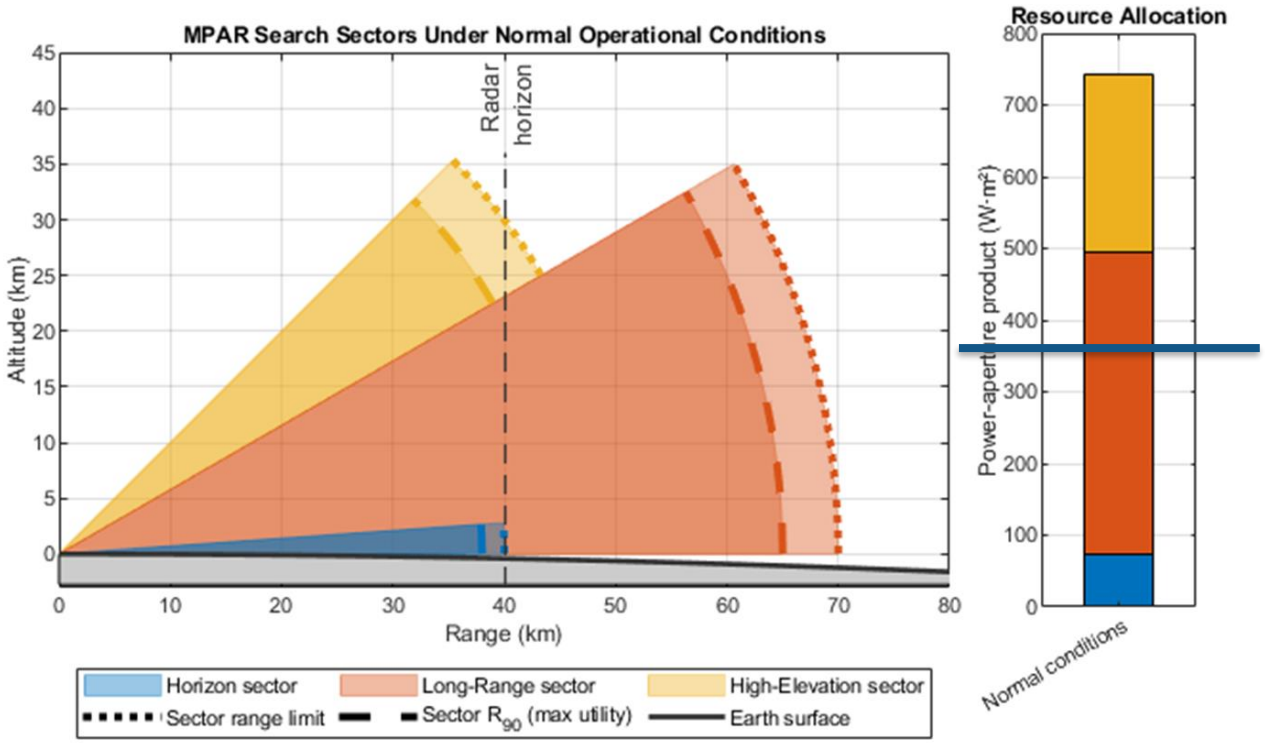


圆形平面阵列



正常运行条件下的资源分配





如果我们只能访问所需 功率孔径积 的一半怎么办？

通过 QoS 优化所有扇区的搜索质量

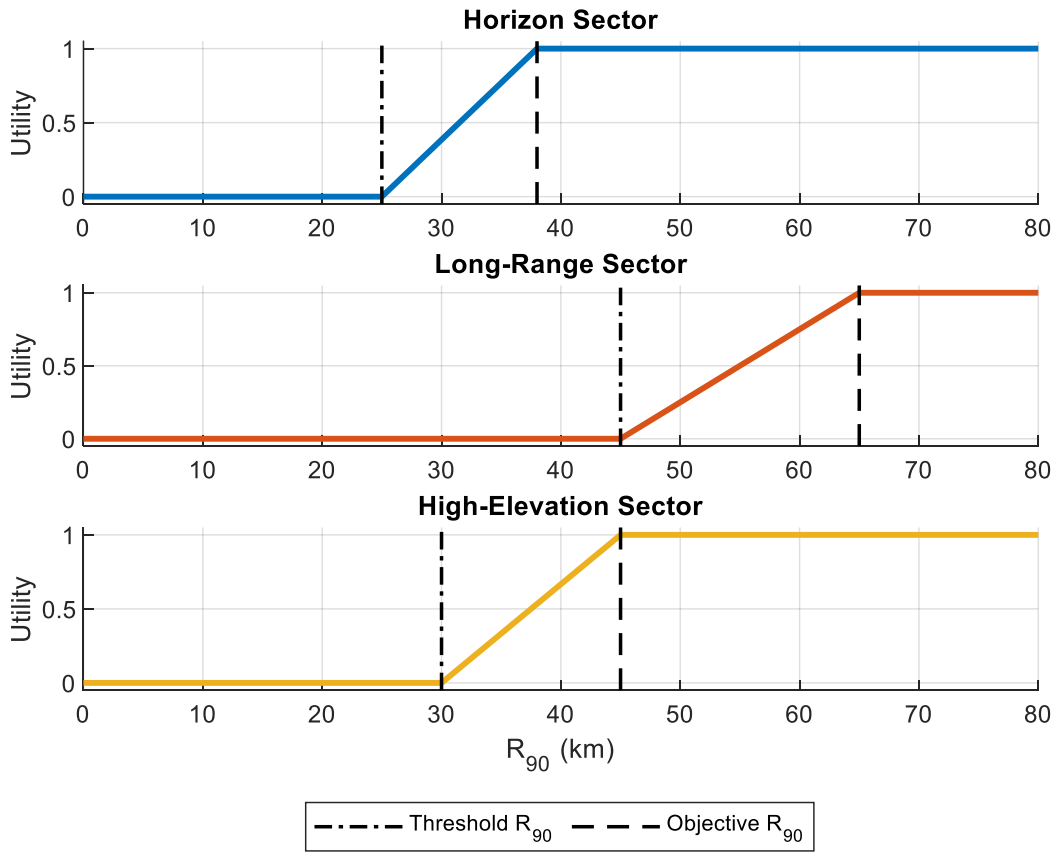
资源

转换为范围

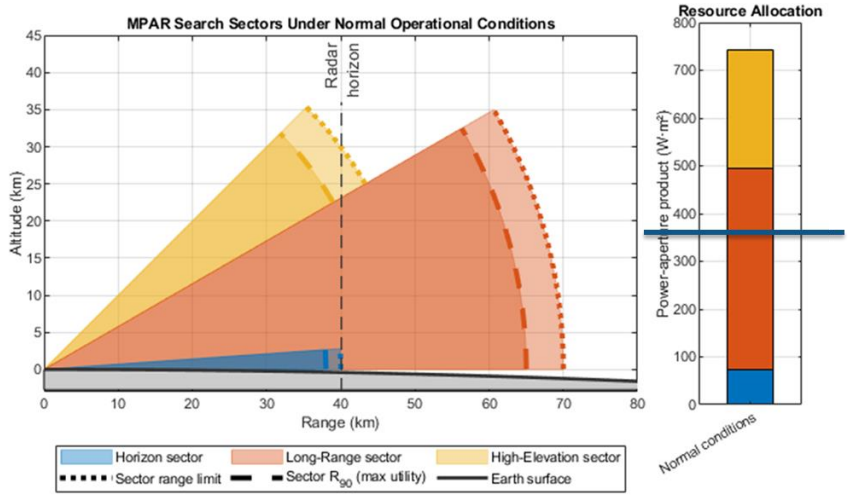
$$\max_{PAP} u(PAP) = \sum_{i=1}^{M} w_i \cdot u_i(q_i(PAP_i;\theta_i))$$

权重

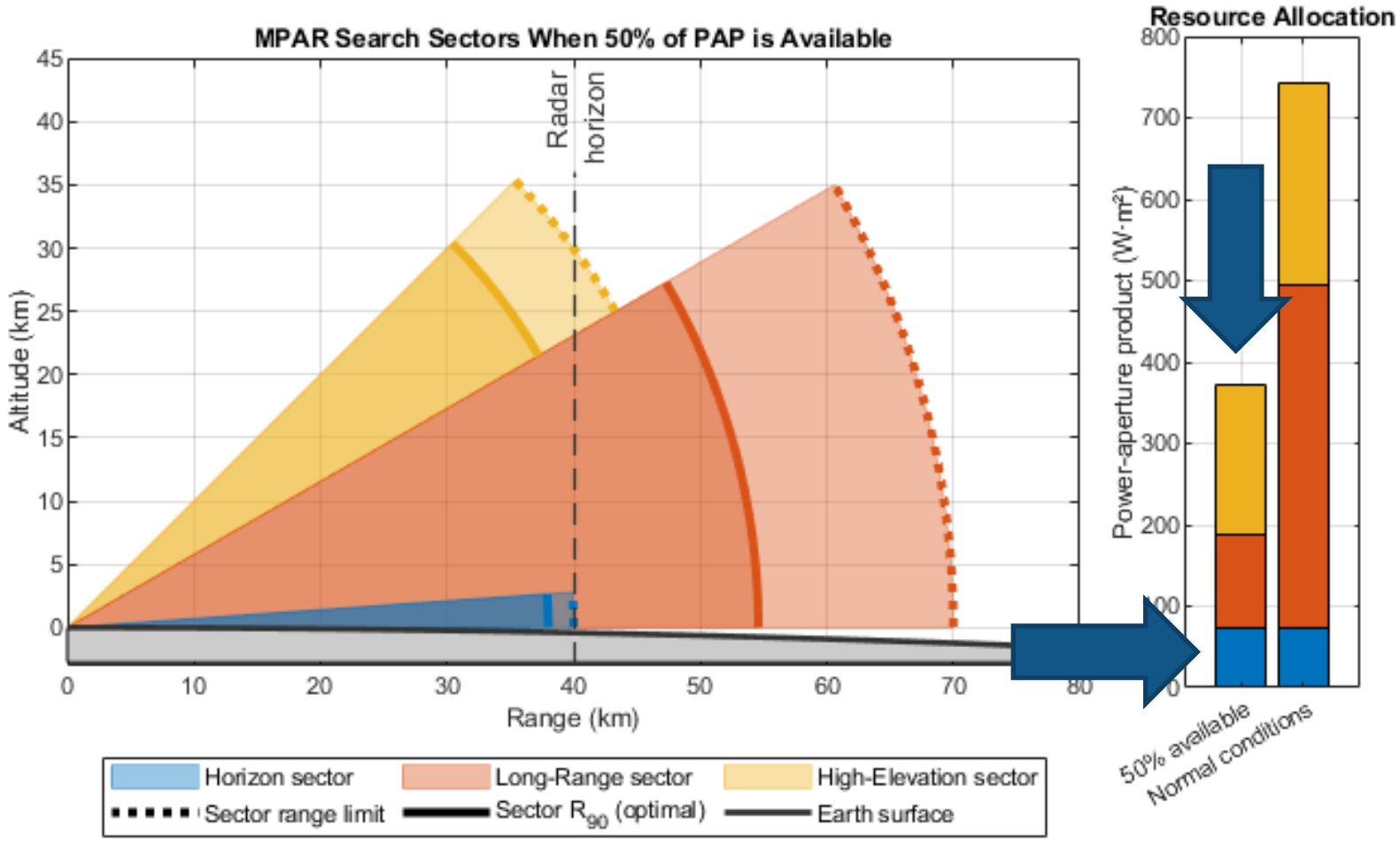
效用函数



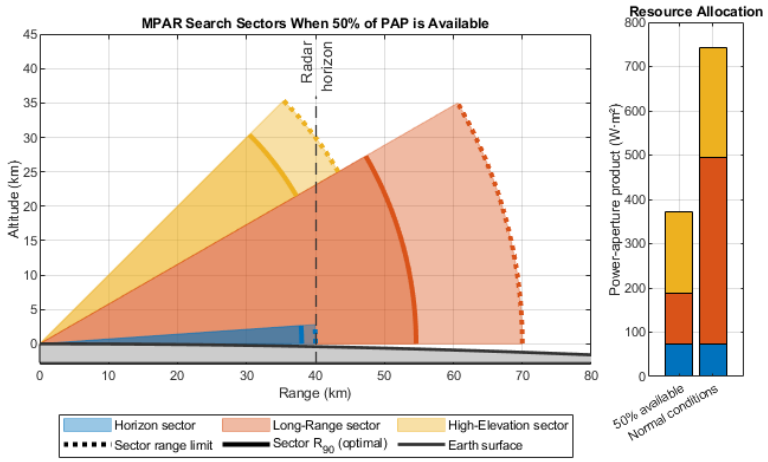
在受限的运行条件下找到最佳资源分配



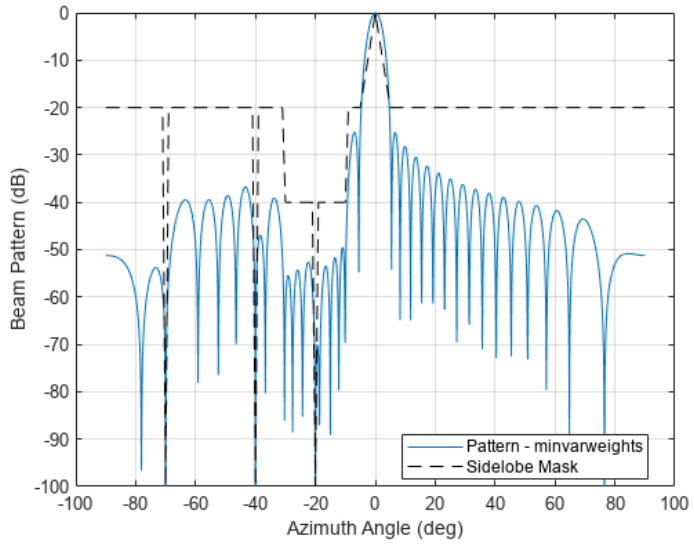
搜索扇区	优先级权重
地平线	0.55
高海拔	0.3
远距离	0.15



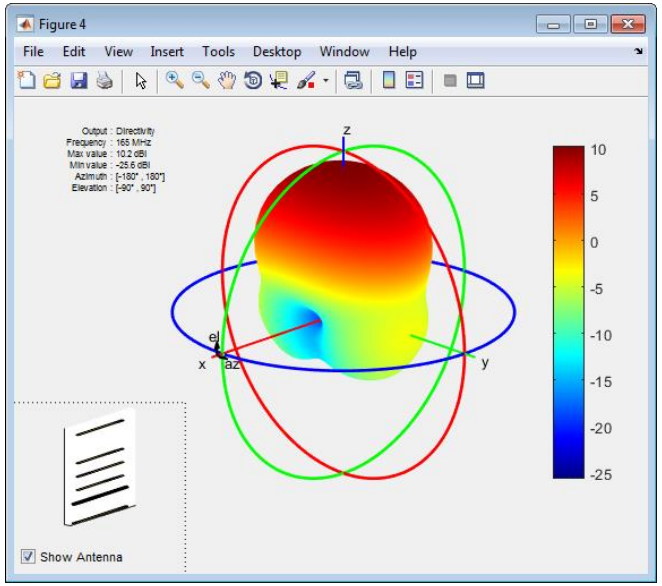
将设计优化应用于关键的雷达和天线设计挑战



雷达资源管理



阵列方向图合成



天线设计

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

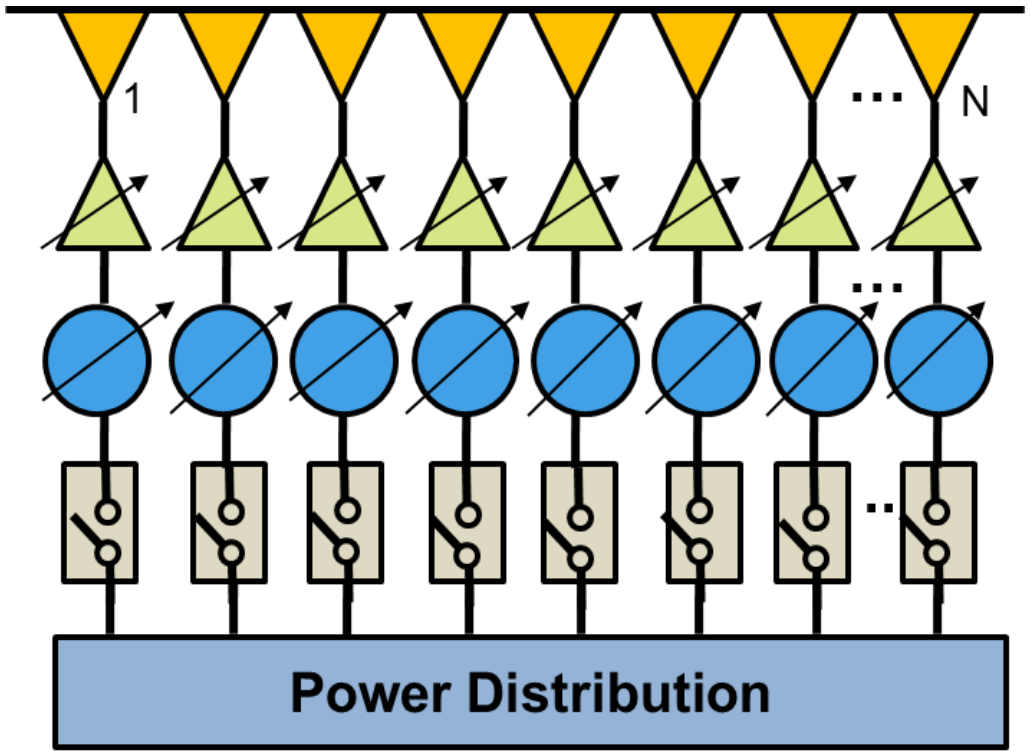
Array Geometry

Array 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

如何获得满足我要求的方向图？

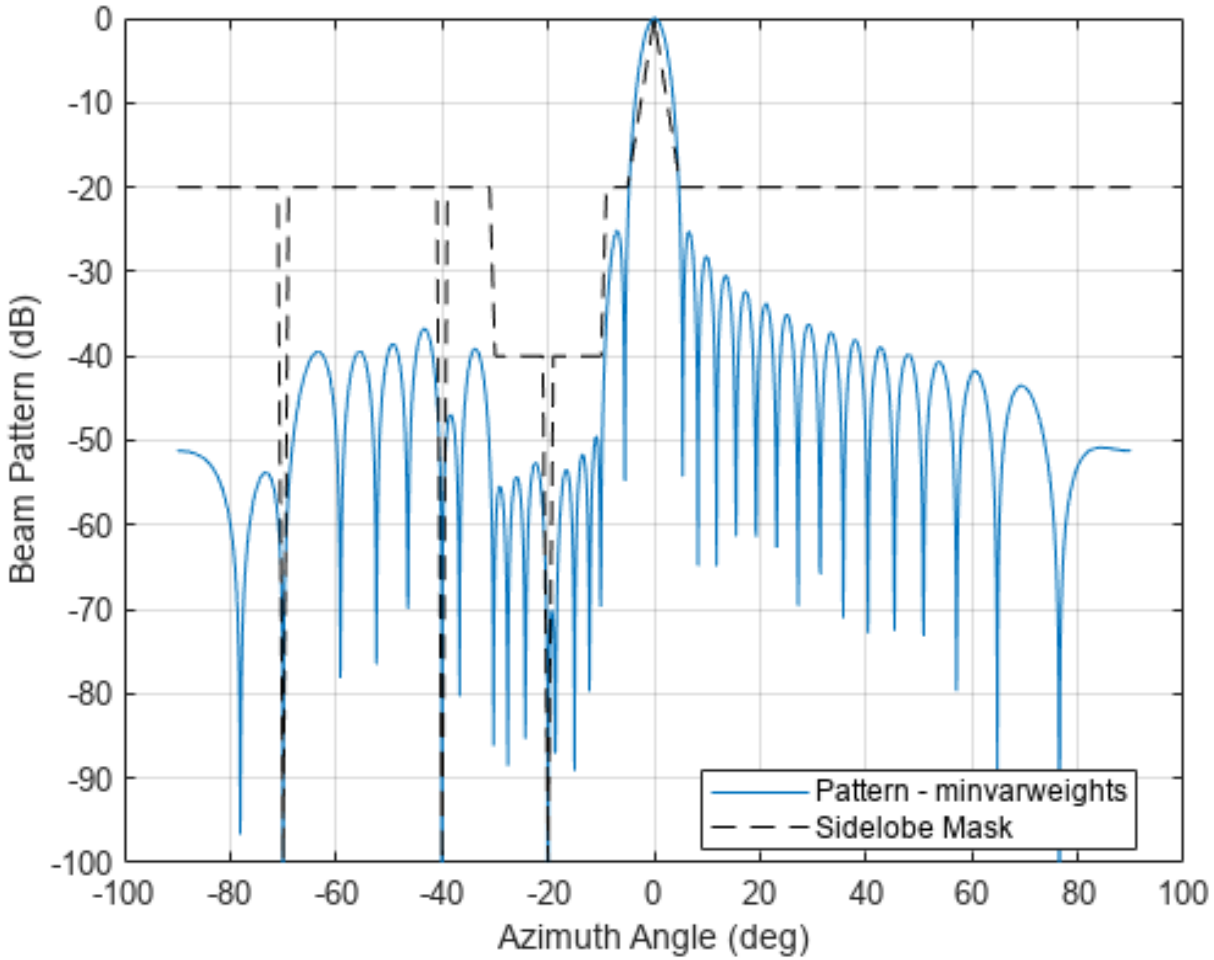
- 传统流程非常繁琐
- 对阵列几何形状、参数、间距、权重等进行反复试验

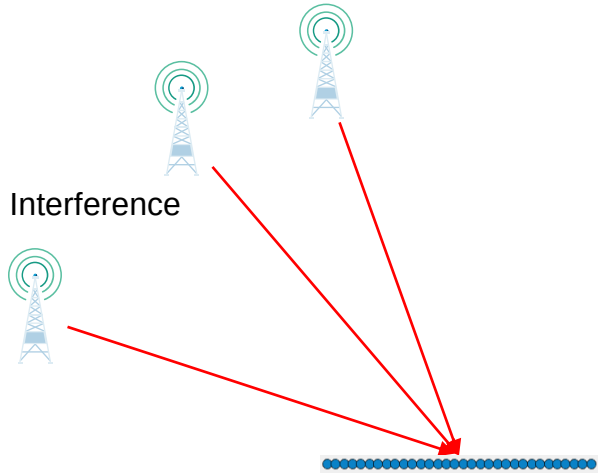


您可以使用优化工具执行阵列合成来驱动方向图属性

示例：最小方差波束成形

Link to example





感兴趣的信号在 0° 方位角
干扰在 -70°, -40°, 和 -20° 方位角

旁瓣< −40 dB 在 −30 到 −10 度
旁瓣< −20 dB 主瓣外的任何地方

波束成型权重 → wts

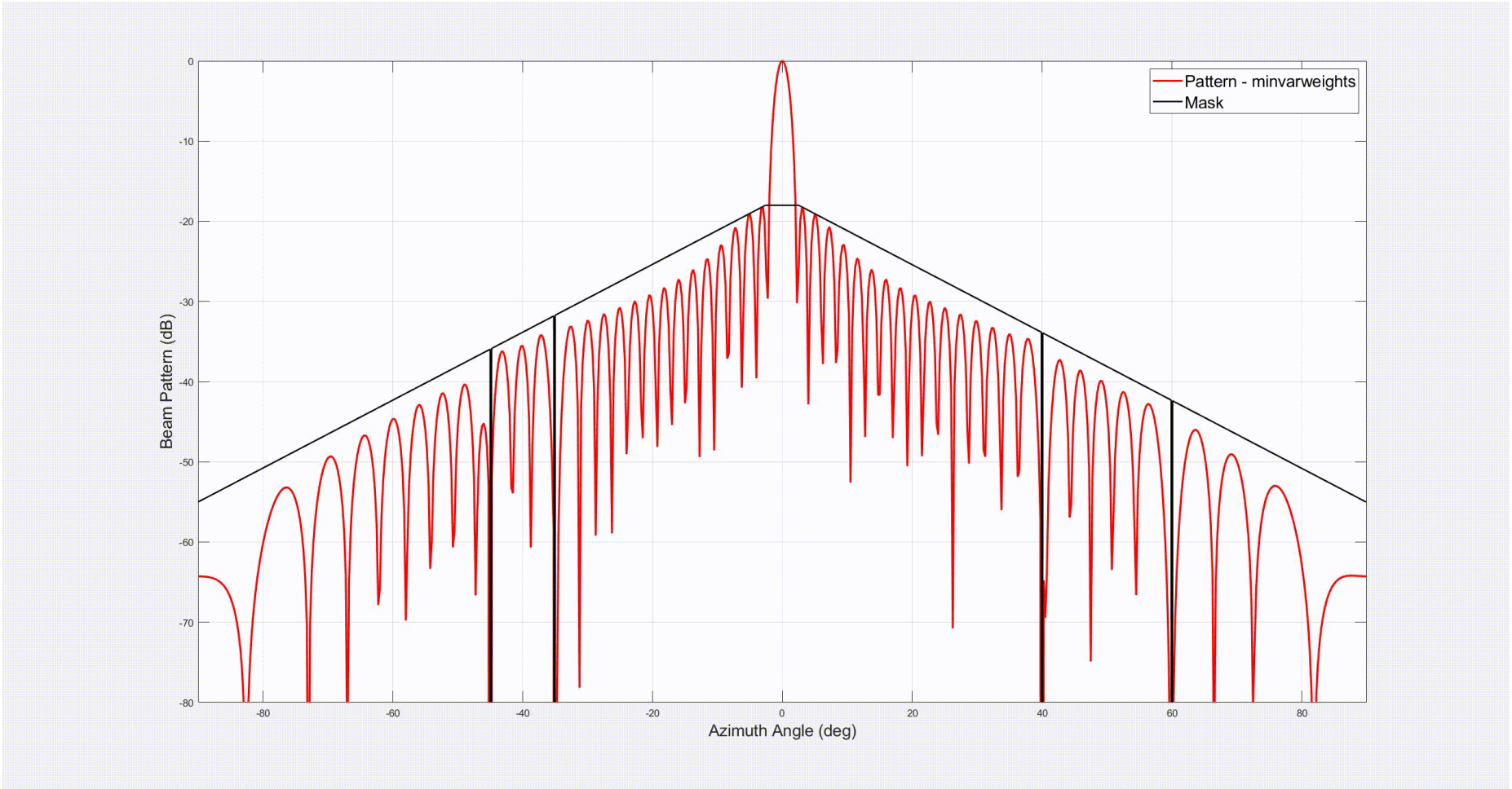
波束成形方向 → ang

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

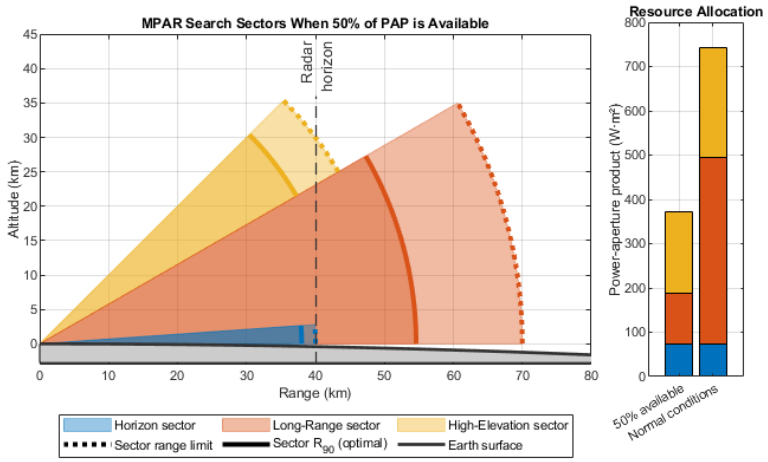
阵元位置 → pos

示例：最小方差波束成形

锥形旁瓣模板从 -18 dB 线性降低到 -55 dB
-45、-35、40 和 60 度方位角处的零陷
扫描波束从 -35 到 35 度



将设计优化应用于关键的雷达和天线设计挑战



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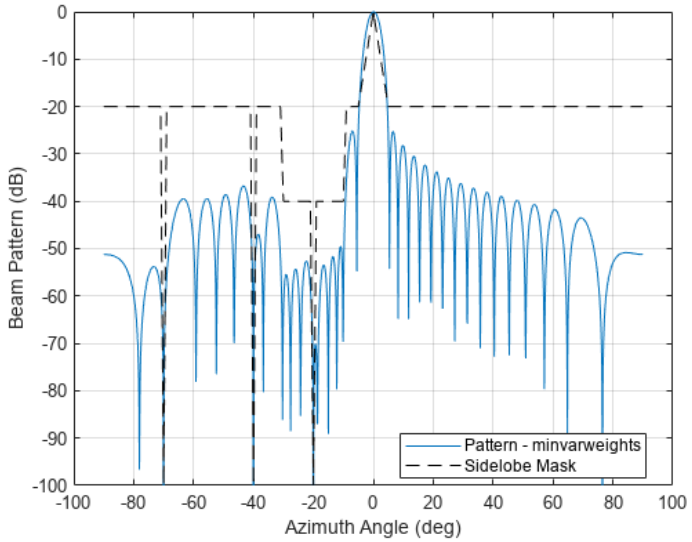

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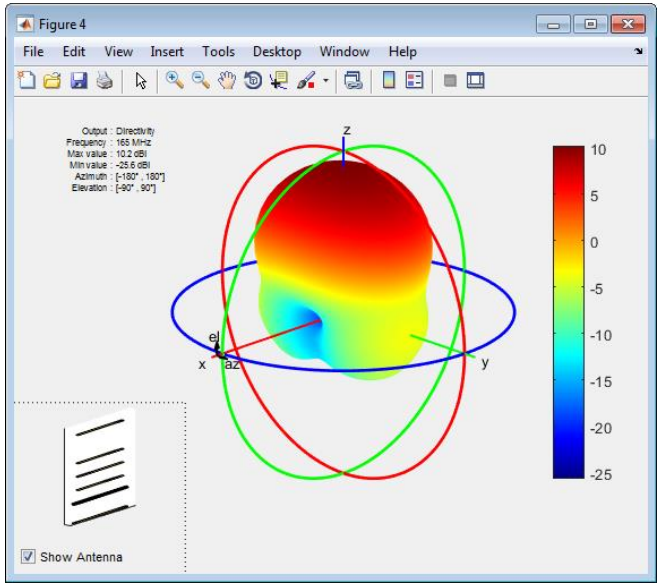


天线设计

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

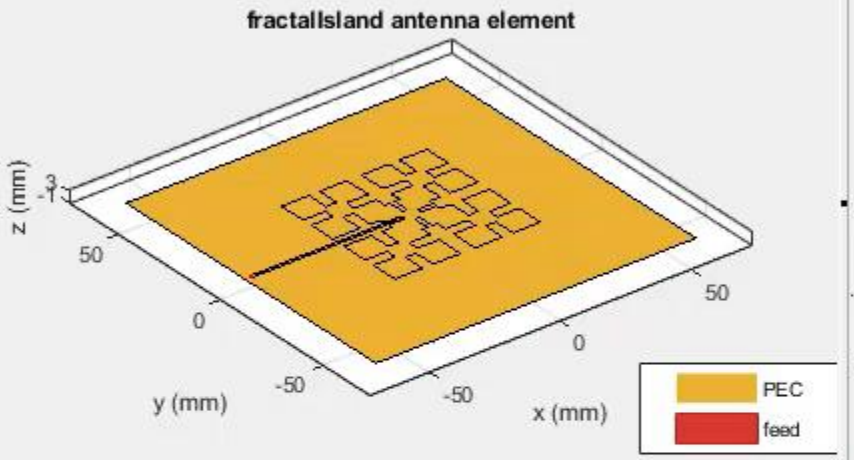
▼ fractalIsland

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]

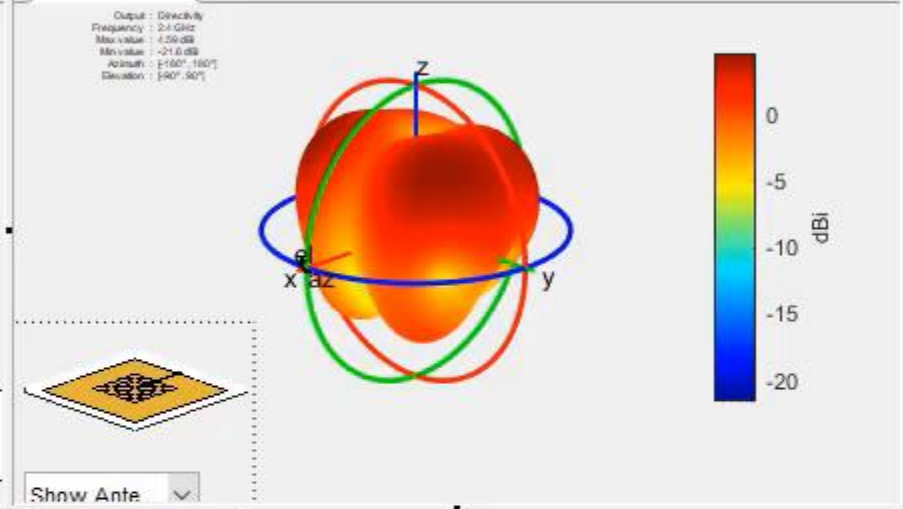
▶ fractalIsland - Substrate - dielectric
▶ fractalIsland - Conductor - metal
▶ fractalIsland - Load - lumpedElement

Apply

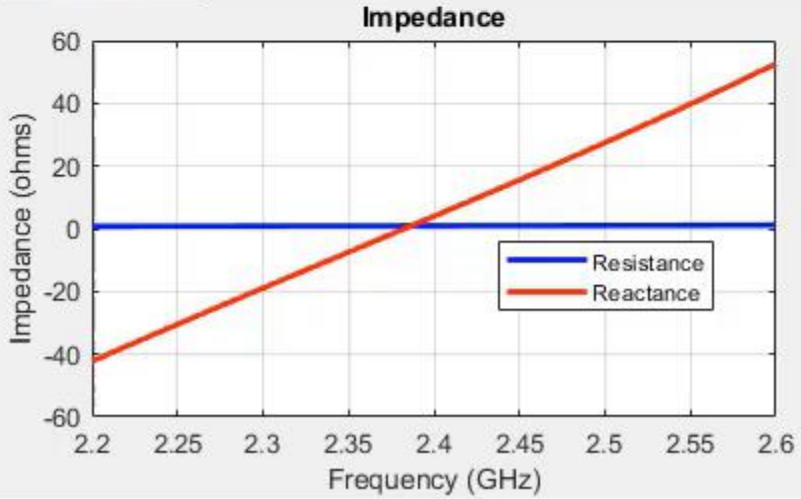
Show



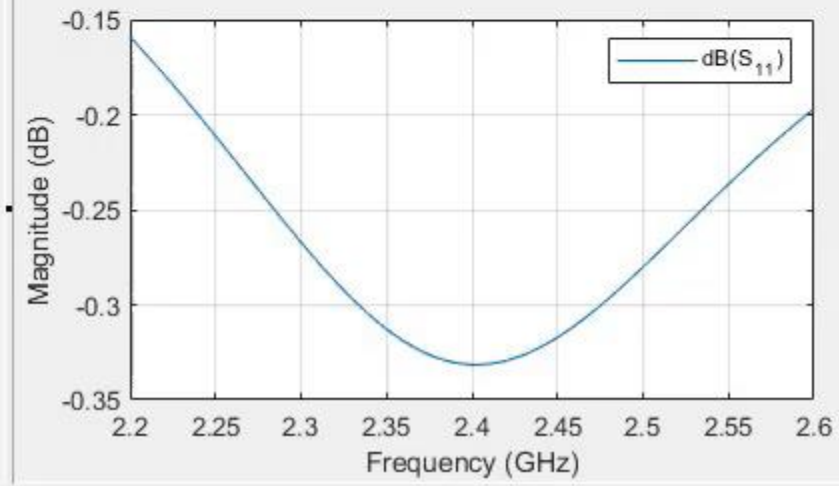
Pattern



Impedance



Sparameter



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

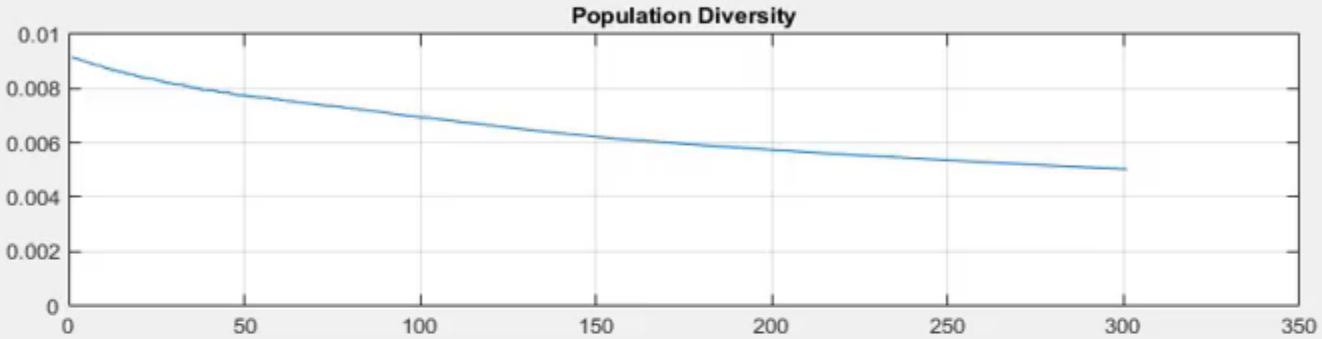
% Weight	Constraint Function	Sign	Value	Add	Remove
50	Gain (dbi)	>	10		-
50	S11 (dB)	<	-10	+	-

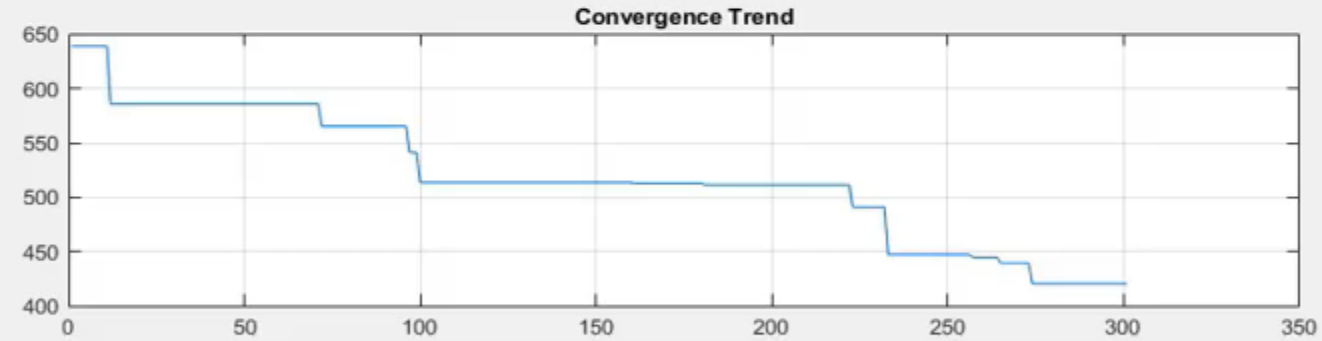
Apply

Changes applied successfully.

Results | Show

Status





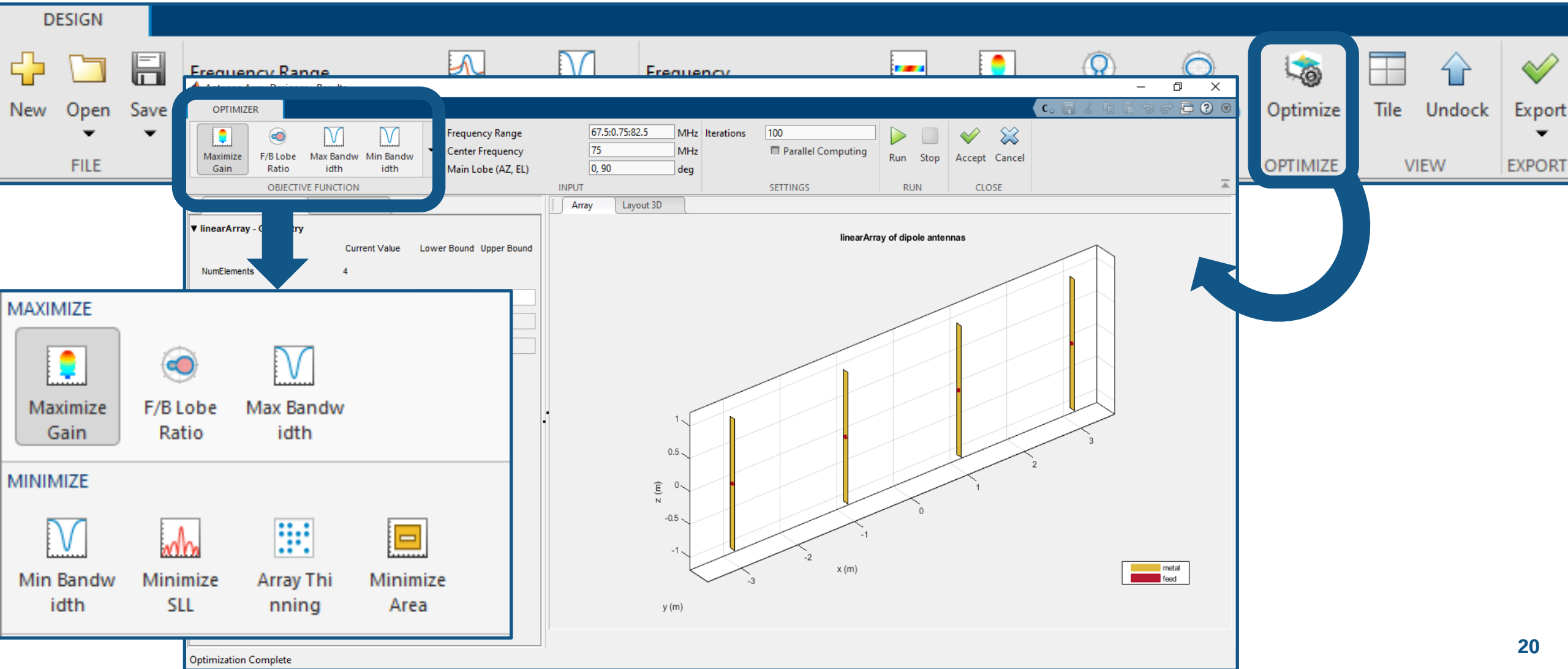
Objective

Objective Function: NA

Current Iteration: NA

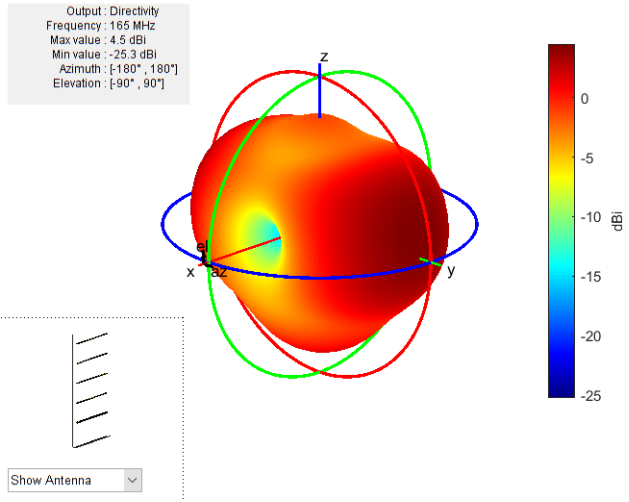
Design Vector

还可以 优化阵列和 PCB 天线

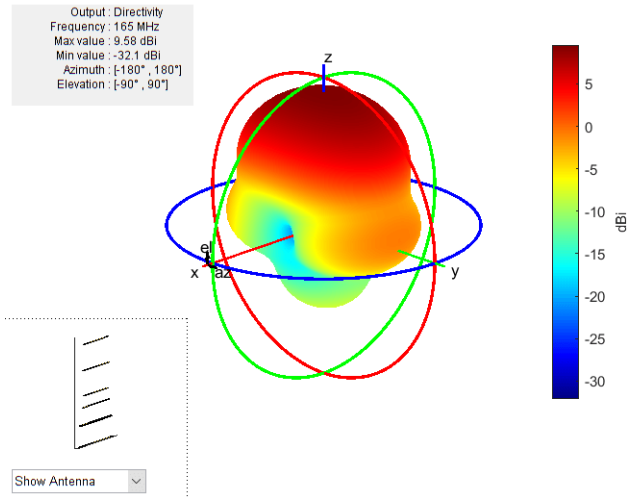


在 MATLAB 中定义自定义优化工作流程

- 使用 MATLAB 函数定义目标和约束函数
- 使用应用于天线设计的全局或局部优化方法
- 使用并行计算加快计算速度



Poor directivity



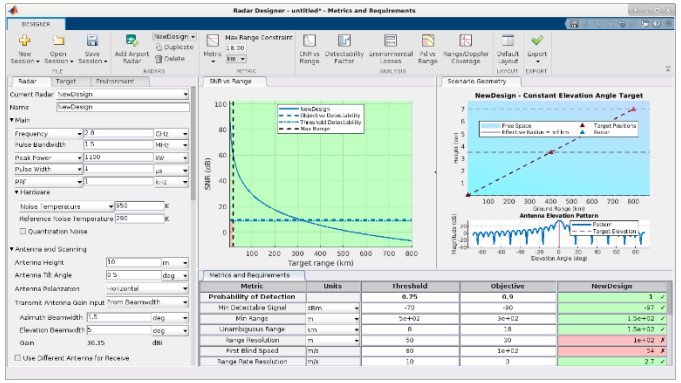
Optimized pattern

```
% 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

小结和资源

将设计优化应用于关键的雷达和天线设计挑战



初始
设计参数

优化求解器
修改设计参数

Radar Systems

Environment

Scenes

Scenarios

Antenna/RF

Signal Processing

Data Processing

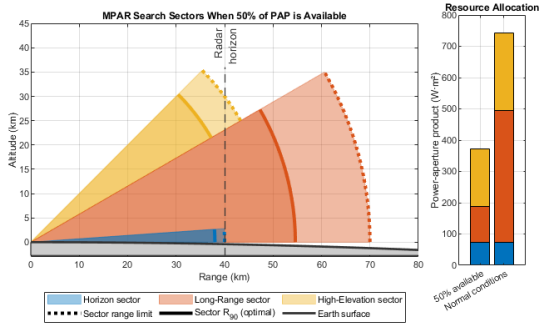
Resource Management & Controls

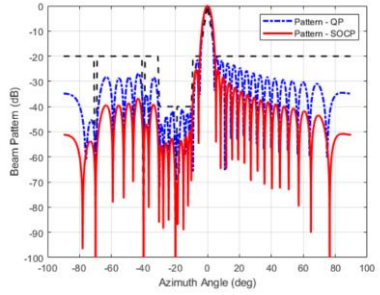
No

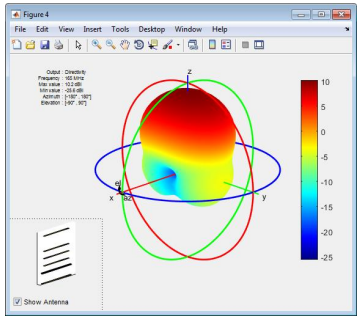
达到
目标?

Yes

优化的
设计

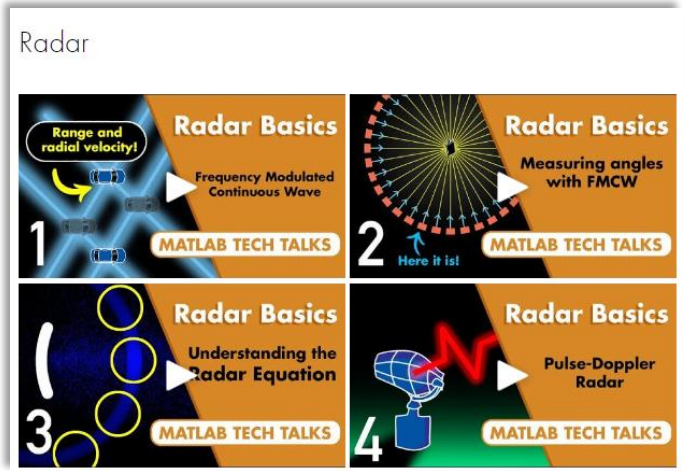




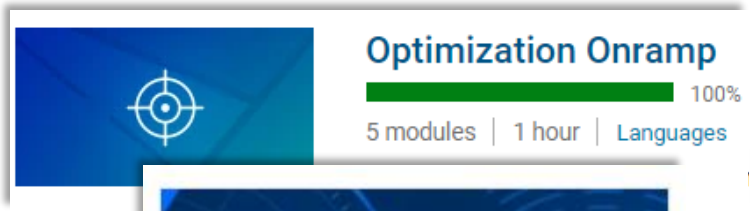


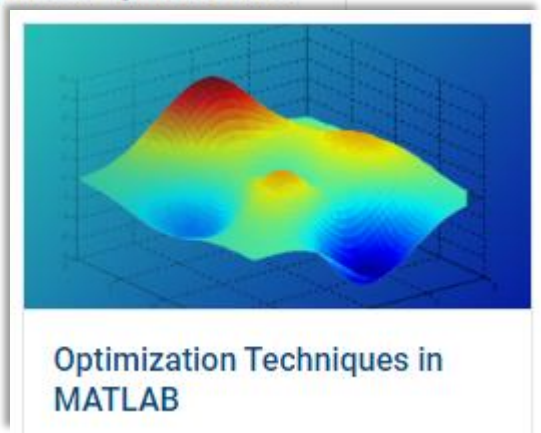
了解有关在 MATLAB 中设计和优化雷达和天线系统的更多信息

视频

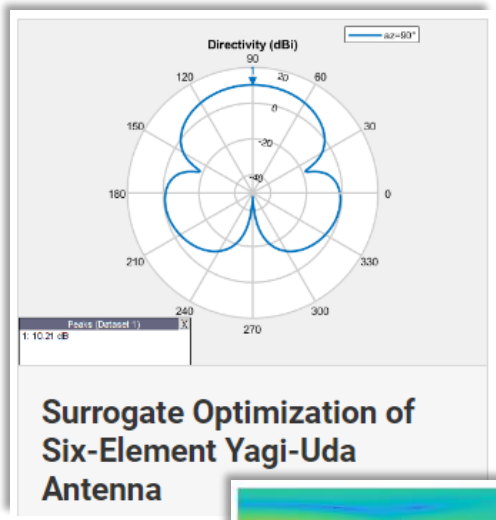


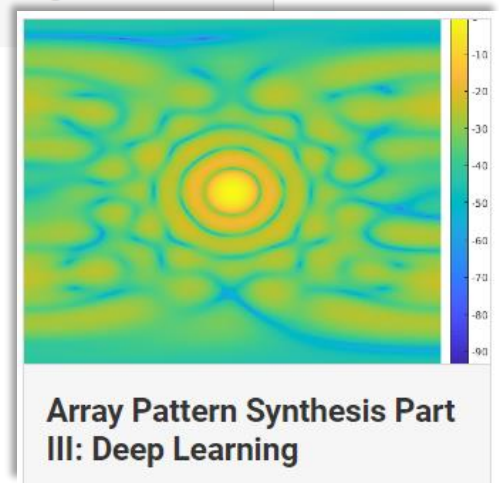
培训





示例



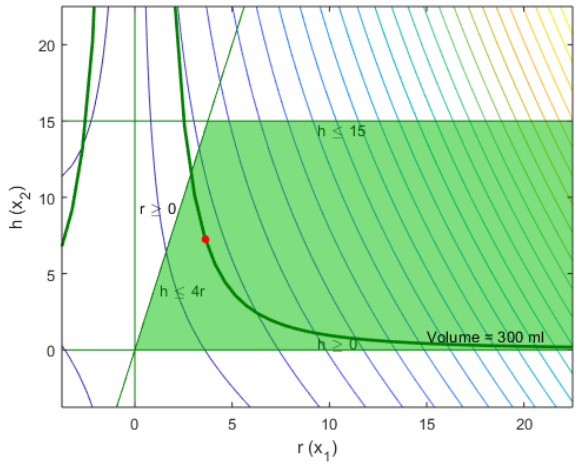


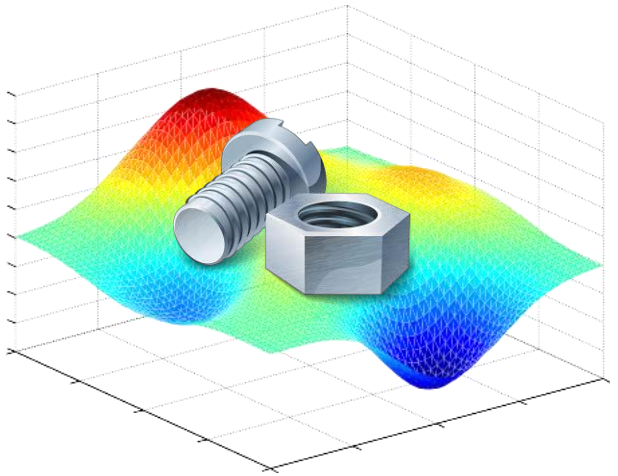
培训课：Optimization Techniques in MATLAB

在这1天的课程之后，您将能够：

- 在 MATLAB 中运行优化问题
- 指定目标函数和约束
- 选择求解器和算法
- 评估结果并提高性能
- 使用全局和多目标优化方法

See detailed course outline





MATLAB EXPO

Thank you