MATLAB EXPO

레이더 및 무선 통신 공존 모델링

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MathWorks®

Airports with Low-Visibility Landings in 5G Deployment

Federal Aviation Administration

Aircraft Category - % Approved to Land

Green - Greater than 90% of Aircraft Models Available to Land — 78%

Yellow - 50%-89% of Aircraft Models Available to Land — 22%

Approved Airport Count by Aircraft Model

No Airport Filter Applied - Select Point on Map to Apply Filter

Make	Model
	ATR 42-300
	ATR 42-320
	ATR 42-500
	ATR 72-100
	ATR 72-200
	ATR 72-210
	ATR 72-212A

% of Airports Accessible (0% — 50% — 100%)

State	Green - Greater than 90% of Aircraft Models Available to Land	Yellow - 50%-89% of Aircraft Models Available to Land
AL	1	1
AR	1	
AZ	1	2
CA	11	5
CT	1	
DE	1	
FL	12	1
IL	3	
IN	4	

|		
ALBANY INTL	01/19	95%
	10/28	81%
ATLANTIC CITY INTL	04/22	100%
	13/31	81%
AUSTIN-BERGSTROM INTL	18L/36R	95%
	18R/36L	95%
BALTIMORE/WASHINGTON INTL THURGOOD MARSHALL	10/28	100%
	15L/33R	100%
	15R/33L	100%
BATON ROUGE METRO, RYAN FLD	04L/22R	100%
	04R/22L	100%
	13/31	100%

Source: FAA
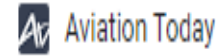
Aviation Today

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

... interference issues facing aircraft radar altimeter systems two weeks ahead of the planned launch of new 5G C-Band wireless networks.

Source: Aviation Today

NPR
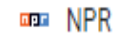
Boeing and Airbus urge a delay in 5G wireless service over

...

The companies have expressed concern that 5G, which operates on a frequency close to that used by aircraft systems such as radio altimeters,...
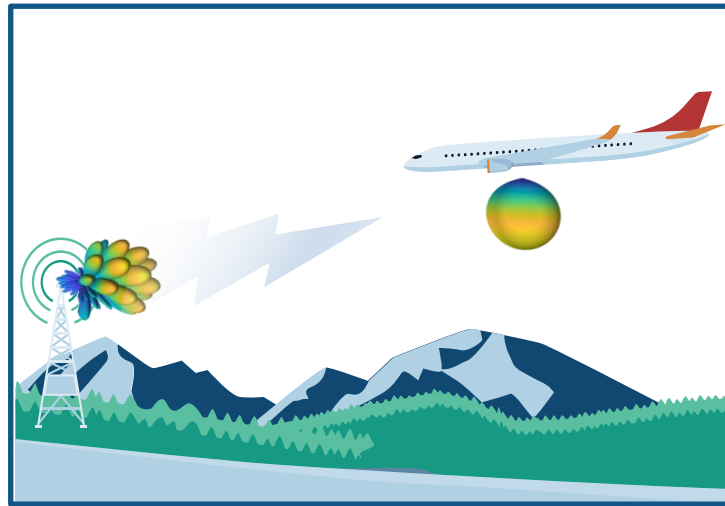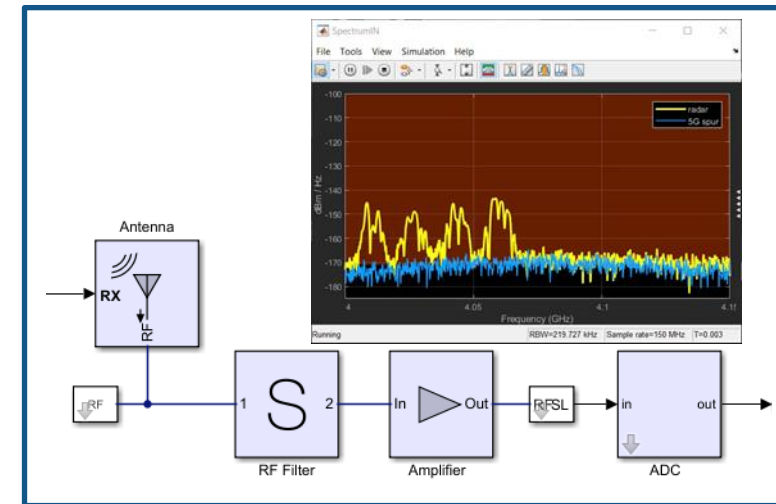
Source: NPR

Use modeling and simulation to analyze the effects of interference between radar and wireless communications systems

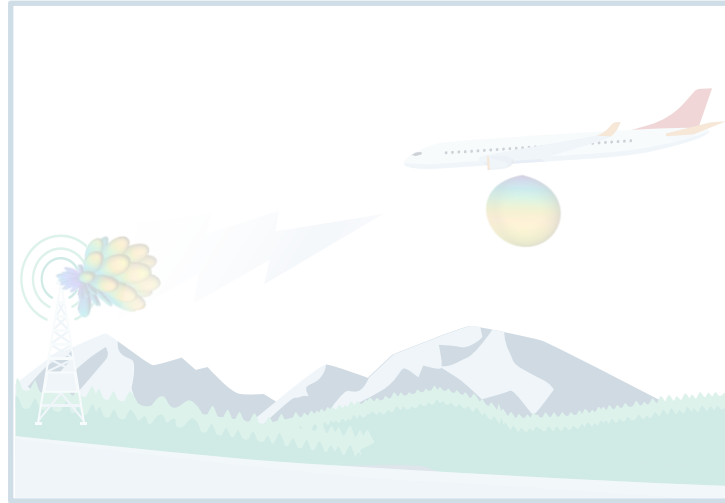Increasing Congestion in the
RF Spectrum
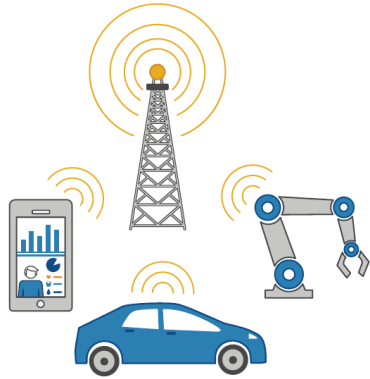

Scenario Modeling for Radar
and Wireless Coexistence

Analyze and Simulate
in the RF Domain

Increasing Congestion in the RF Spectrum

5G applications drive demanding data rate & efficiency requirements

New Applications

4K and 8K 360° Video

Virtual Reality

Connected Vehicles

Internet of Things

Technical Solutions

Increased bandwidth

Better spectral efficiency

Flexible air interface

Densification

Higher Frequency Bands

PEAK RATE 1 Gbps

PEAK RATE 50 Gbps

18 28 38 60 GHz

FREQUENCY BAND

LEGACY BANDS

NEW BANDS

5G Requirements / Use Cases

Enhanced mobile broadband (>10 Gbps)

Ultra low latency (<1 ms)

Massive machine-type communication (>1e5 devices)
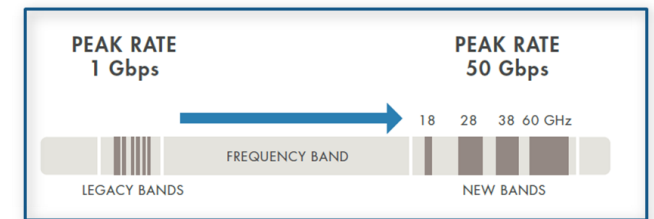
Higher frequency operations result in propagation challenges
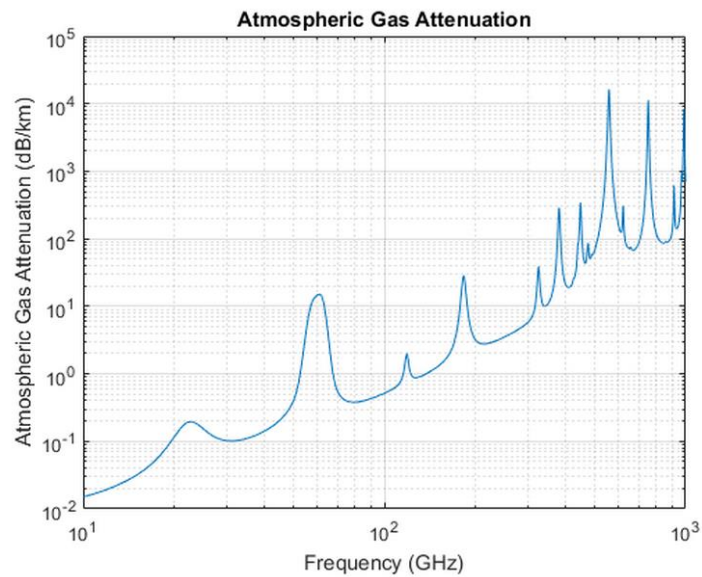
Signal Attenuation
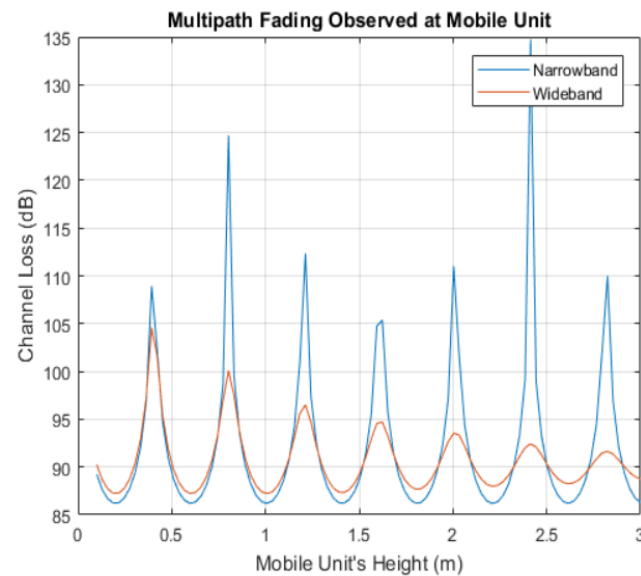
Wideband performance
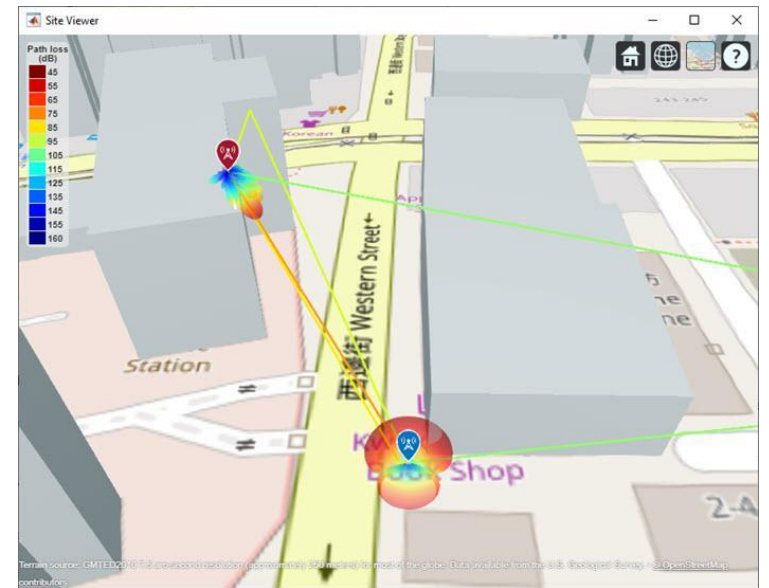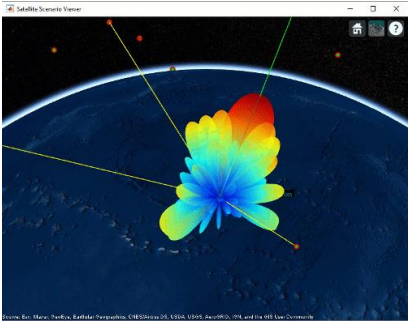
Scatterer-rich propagation

Shared spectrum operations present interference challenges

Communications

Radar

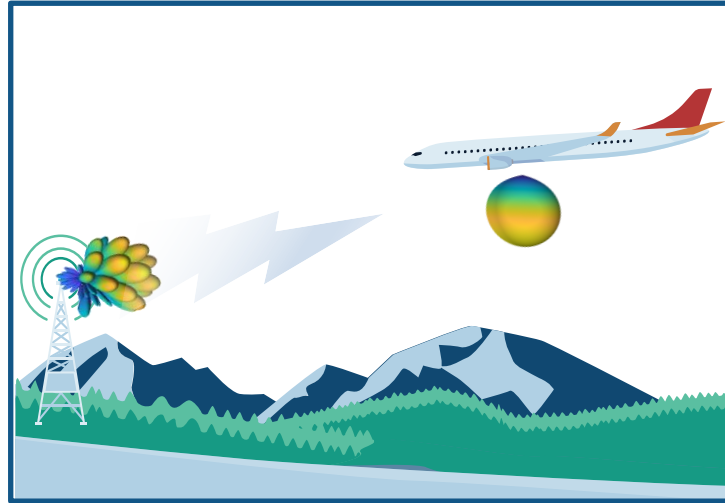https://www.5gtechnologyworld.com/

Interference

Signal-level and power-level analysis can help with planning
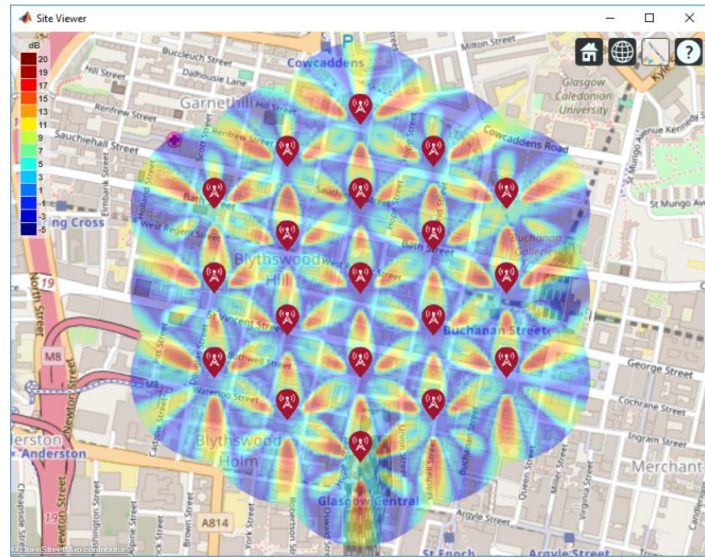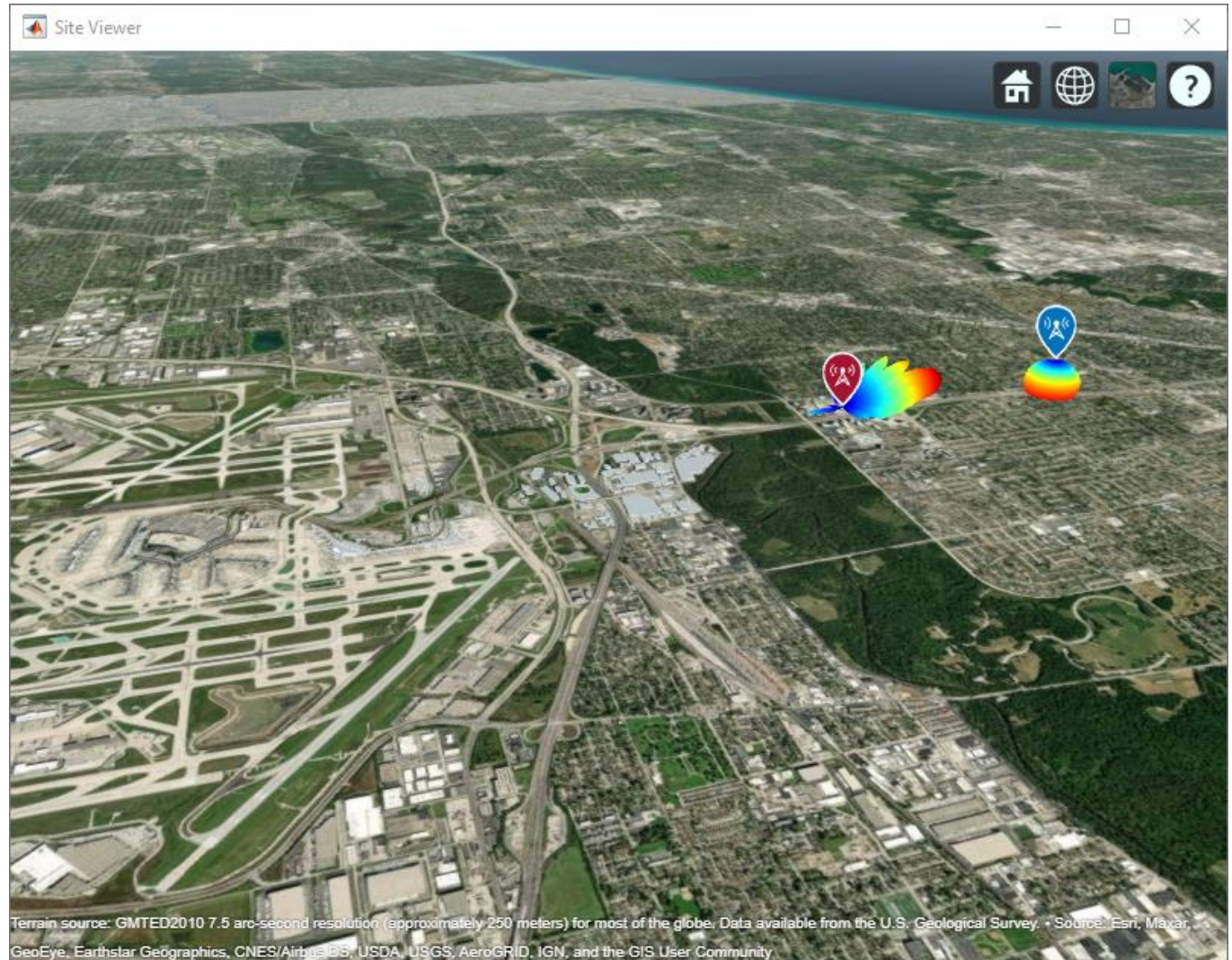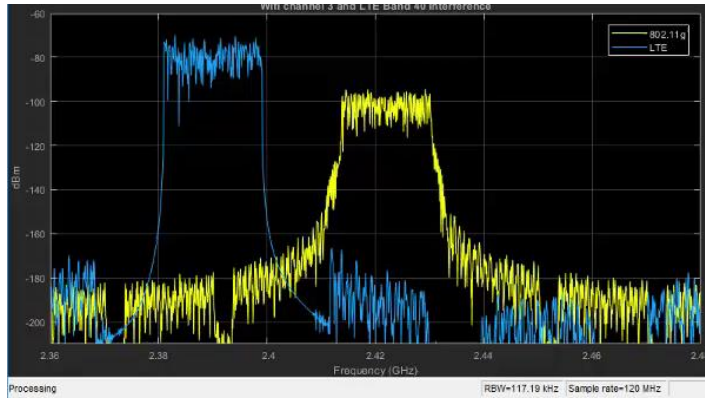
Scenario Modeling for Radar and Wireless Coexistence

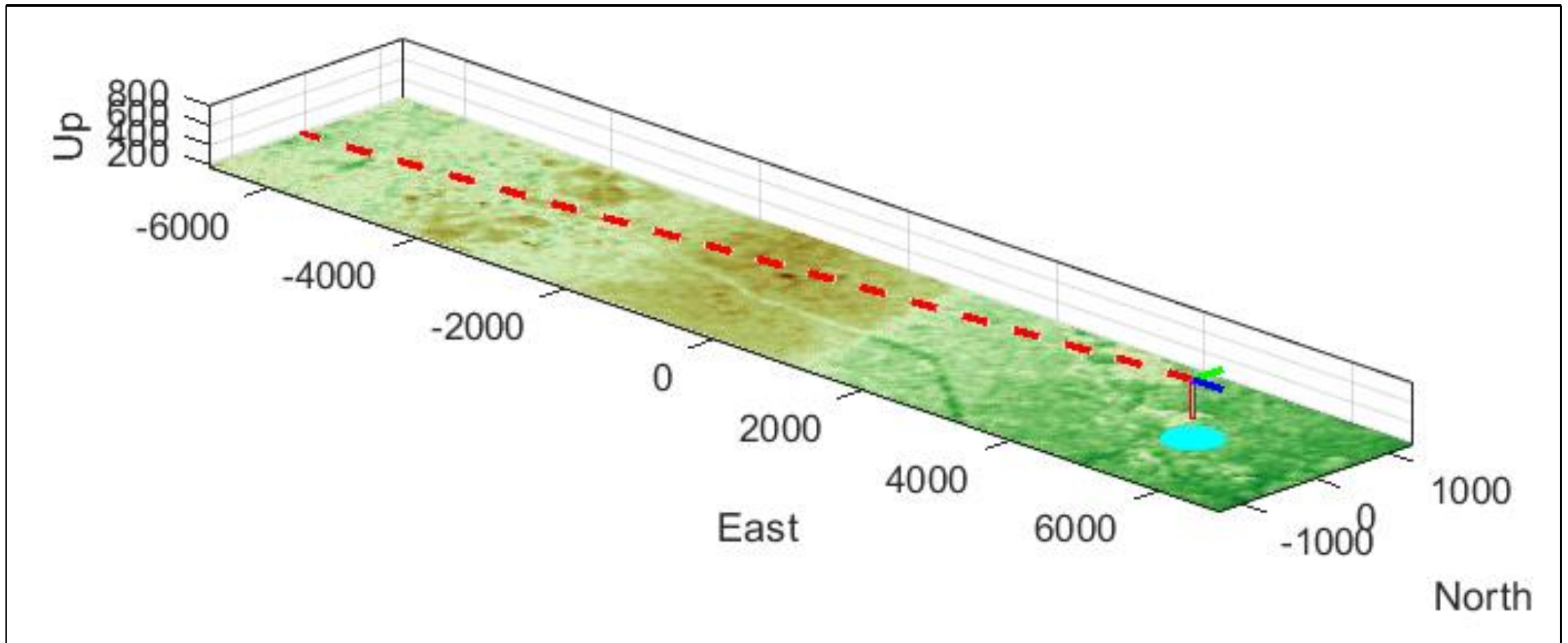# Typical radar scenario modeling workflow

| Model Platforms and Targets | Model Surfaces and Clutter | Model Trajectories | Model Sensors | Simulate Scenarios |

Model the radar altimeter sensor

Parameter	Value
Center Frequency	4.3 GHz
PRF	143 Hz
Chirp Bandwidth	150 MHz

Source of radar altimeter specifications: Recommendation ITU-R M.2059-0

```matlab
RadarAltWaveform = phased.FMCWWaveform( ...
            'SweepBandwidth',RadarAlt.ChirpBW, ...
            'SampleRate', RadarAlt.fs, ...
            'SweepTime',RadarAlt.SweepTime, ...
            'OutputFormat','Sweeps');


RadarAltTransmitter = phased.Transmitter('PeakPower', ...
            RadarAlt.TransmitterPower);


cp = Beamwidth2CosiePower(RadarAlt.AntennaBeamWidth,RadarAlt.fc);
AntennaElement = phased.CosineAntennaElement("CosinePower",cp);
RadarAltAntenna = phased.ConformalArray('Element',AntennaElement);
RadarAltRadiator = phased.Radiator('OperatingFrequency',RadarAlt.fc, ...
            'Sensor',RadarAltAntenna);


RadarAltCollector = phased.Collector('OperatingFrequency',RadarAlt.fc, ...
            'Sensor',RadarAltAntenna);


RadarAltReceiver = phased.ReceiverPreamp( 'SampleRate', RadarAlt.fs, ...
            'NoiseFigure', RadarAlt.NF);


RadarAltSensor = radarTransceiver('Waveform',RadarAltWaveform,...
            'Transmitter',RadarAltTransmitter, ...
            'TransmitAntenna',RadarAltRadiator, ...
            'ReceiveAntenna',RadarAltCollector, ...
            'Receiver',RadarAltReceiver, 'MountingAngles', [0 -90 0], ...
            'NumRepetitions', RadarAlt.numSweep);
```

Simulate the scenario and generate IQ signal
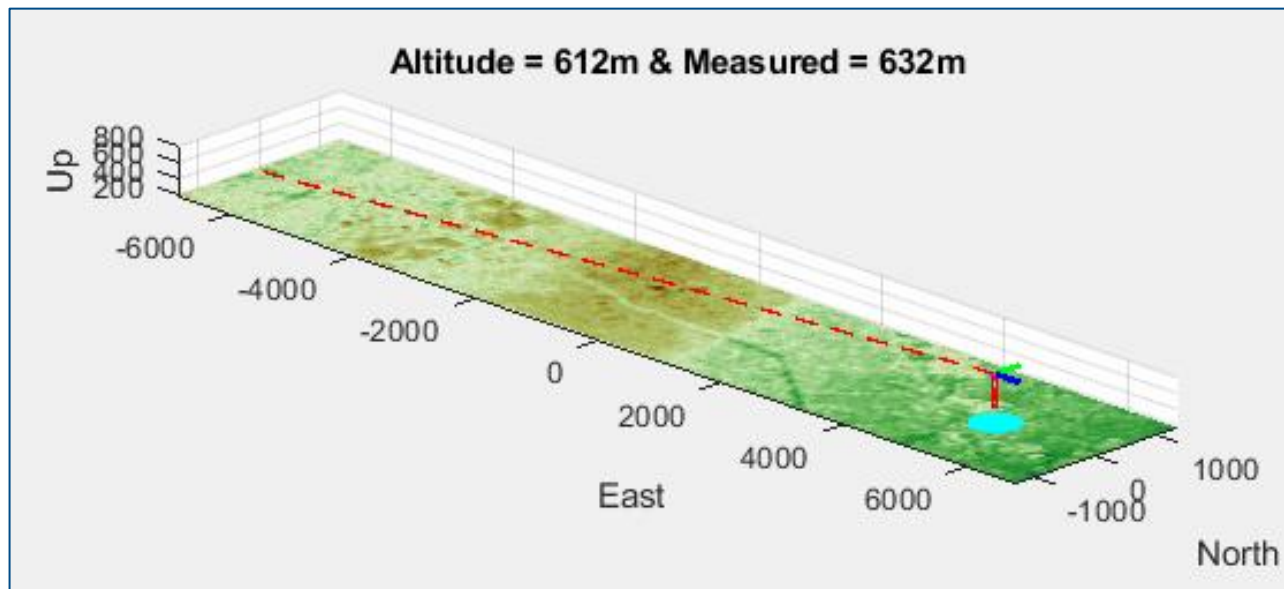
```
while advance(scene)
    iqsig = receive(scene);

    xr = dechirp(iqsig{:},refSig);

    xr = pulsint(xr,'coherent');

    fb_rng = rootmusic(xr,1,RadarAlt.fs);

    MeasuredAltitude = beat2range(fb_rng, ...
        RadarAlt.SweepSlope,c);
end
```
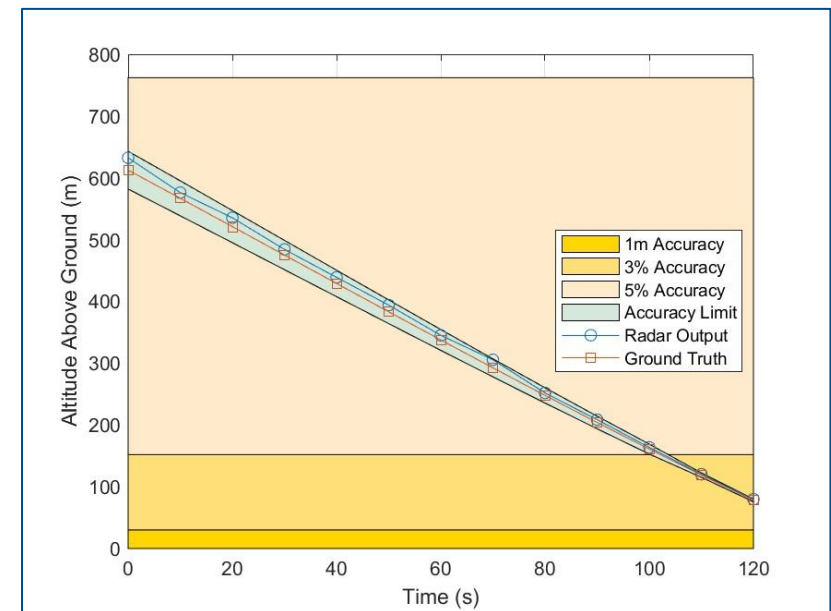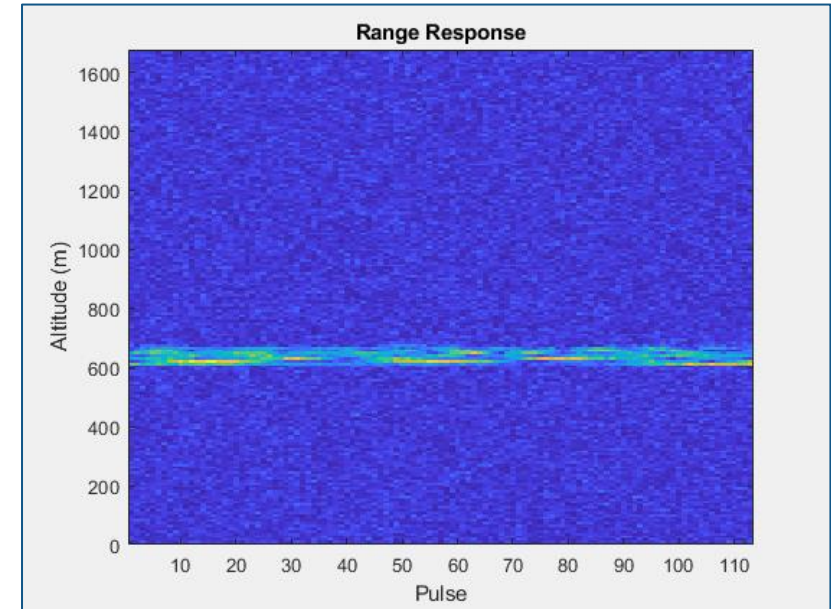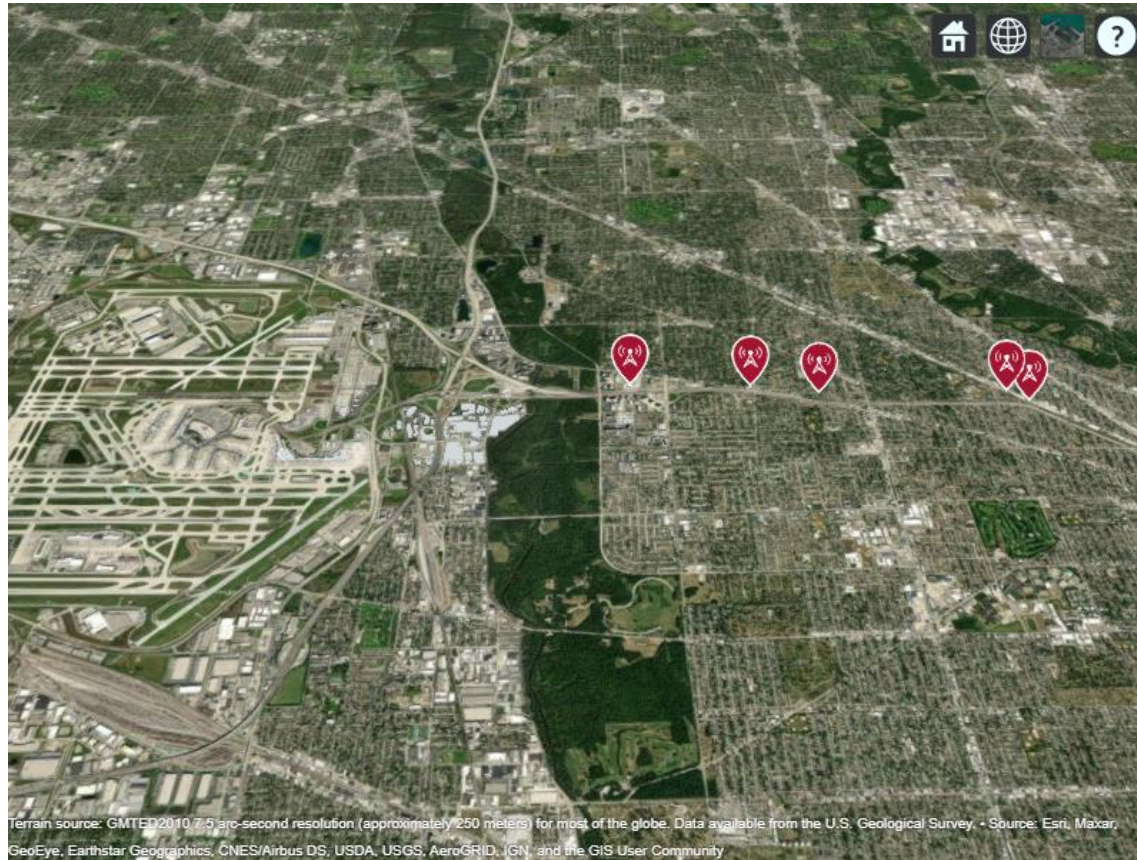

Range Response

Altitude = 612m & Measured = 632m

Model the base stations close to the flight path

Waveform → Antenna Array → Propagation Channel

Generate 5G signal with the wireless waveform generator App
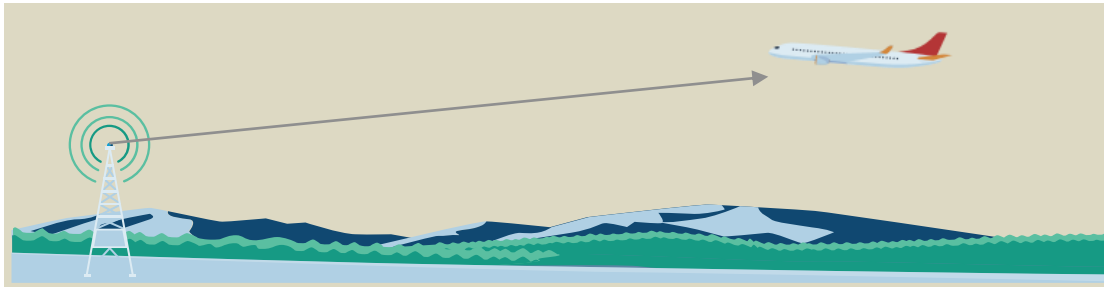
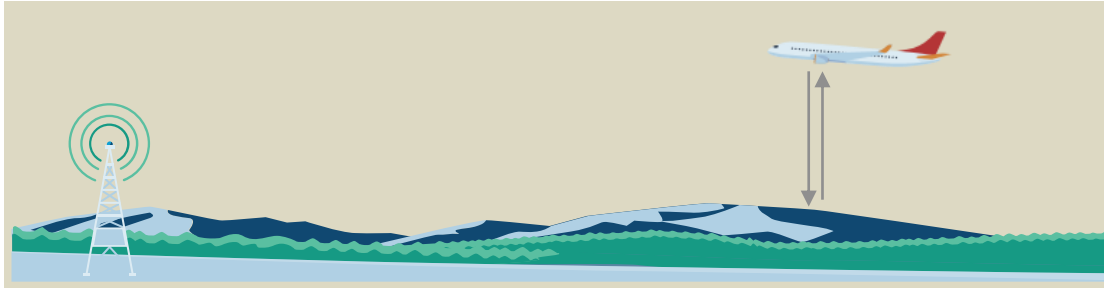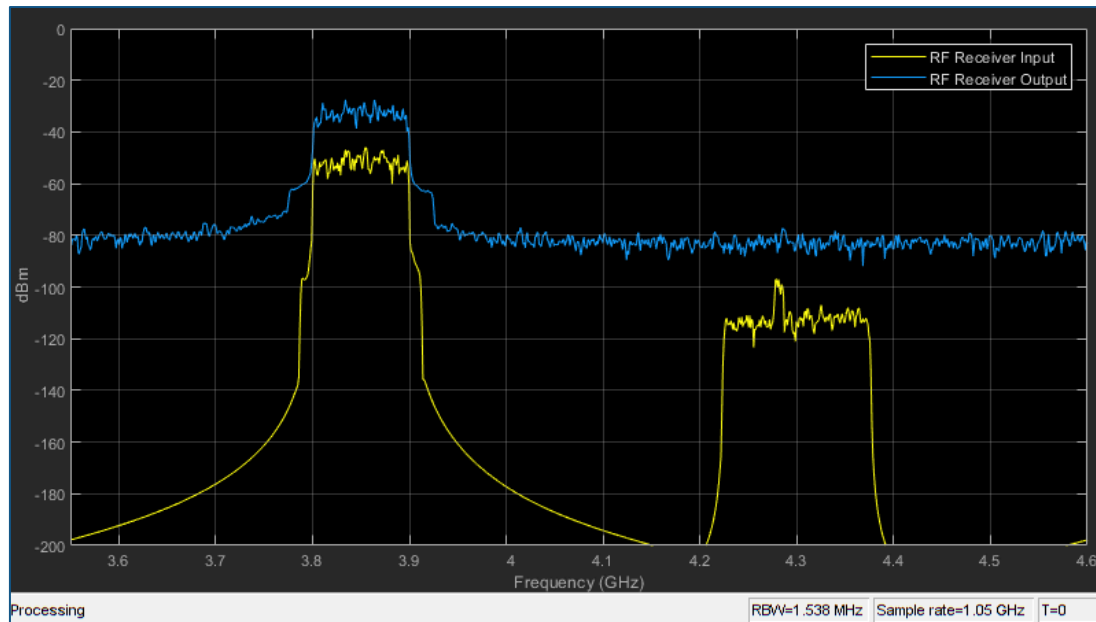# Model base station antenna with NR rectangular panel array
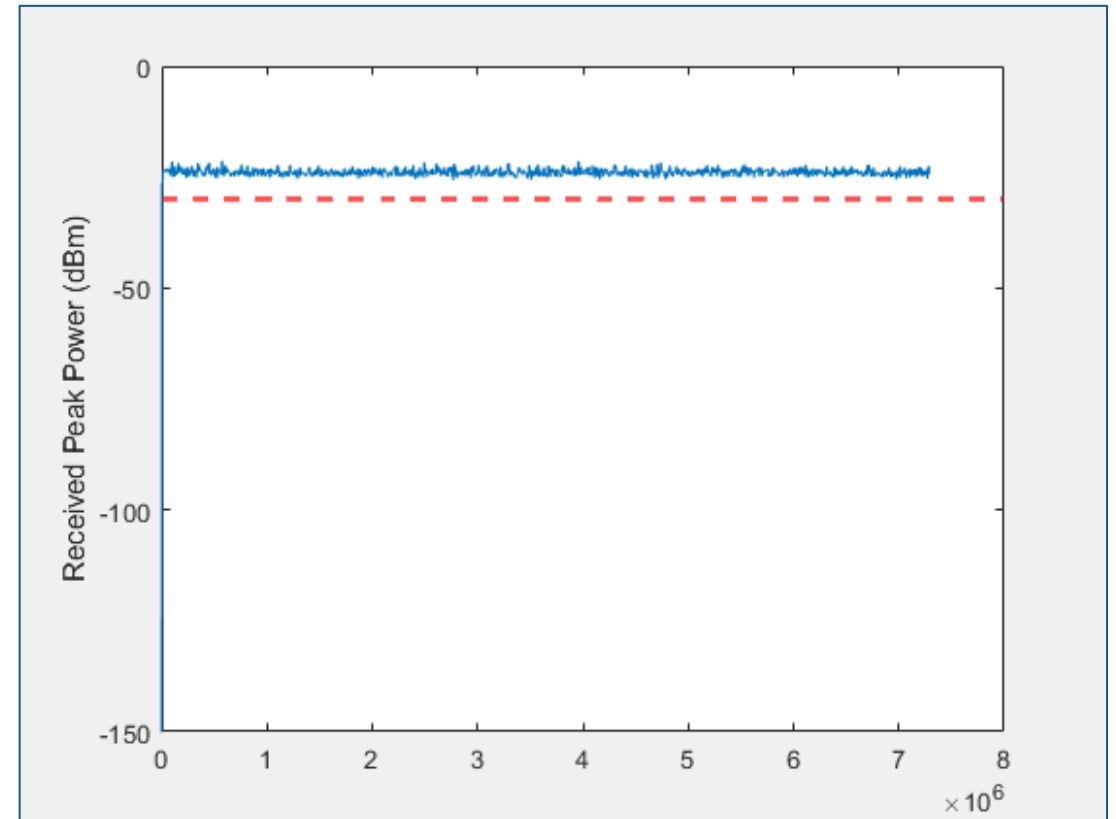
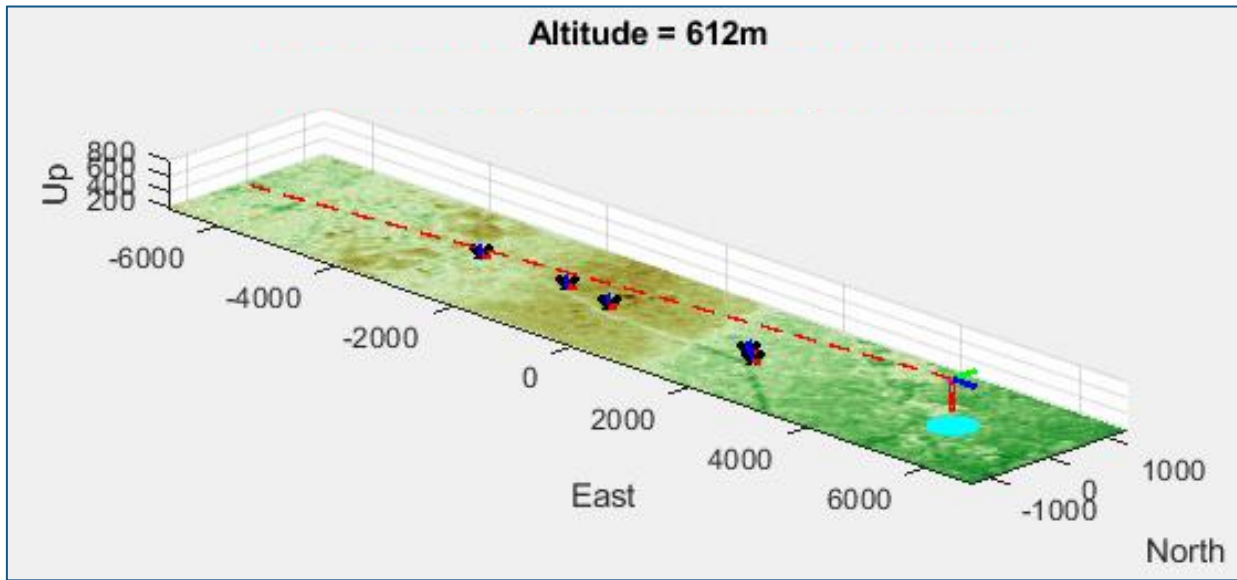5G Antenna Array
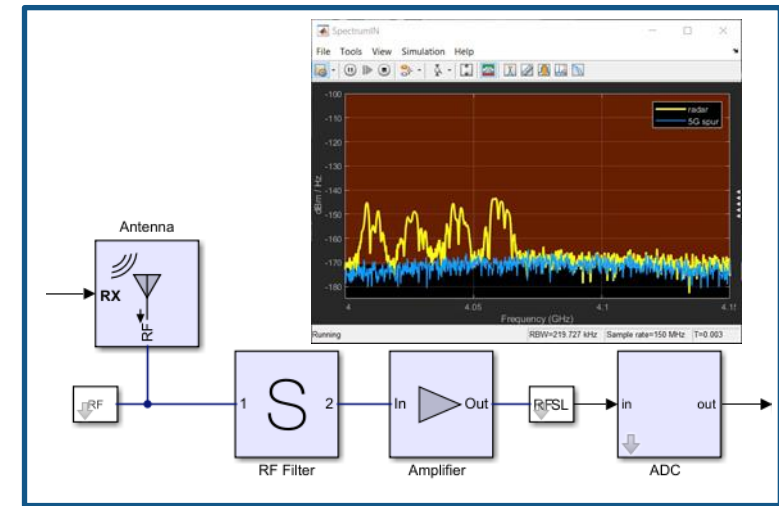(3GPP TR 38.901)
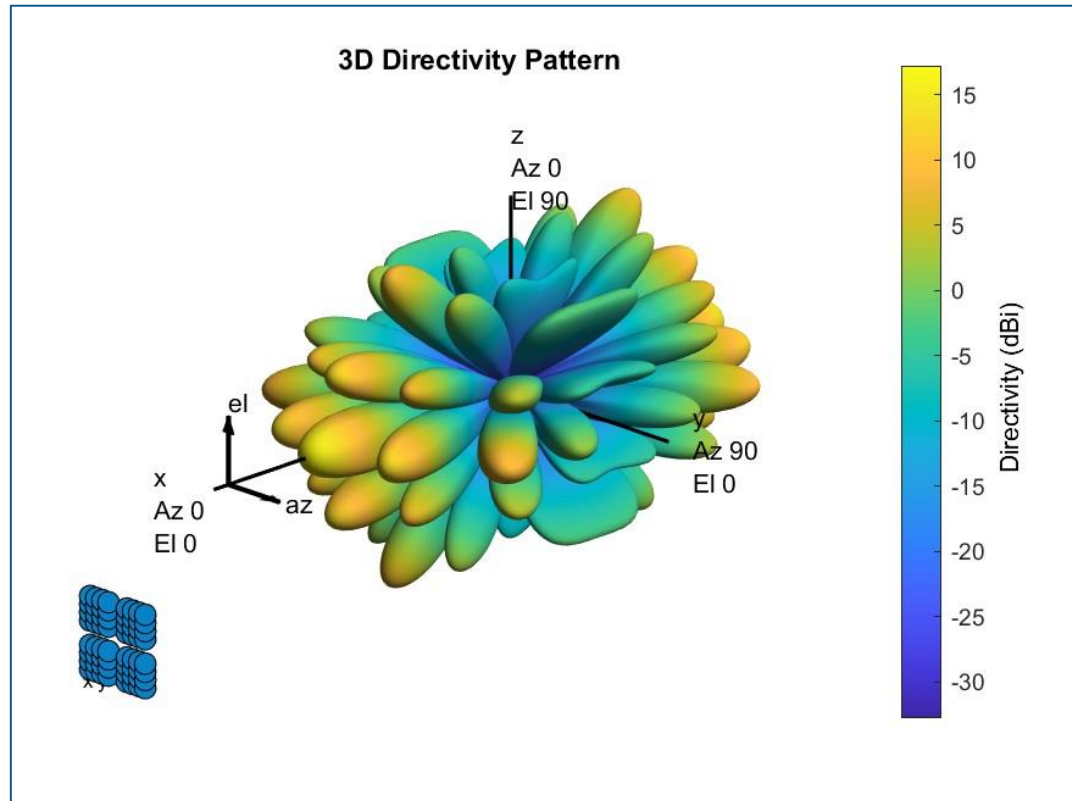
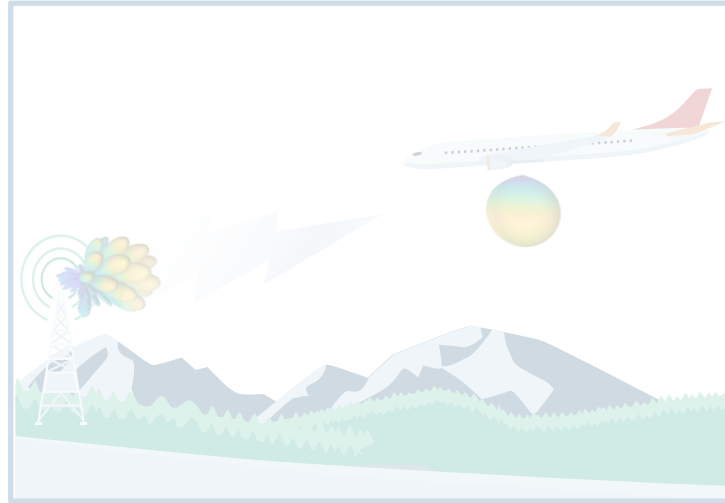Maximize directivity for
worst case scenario
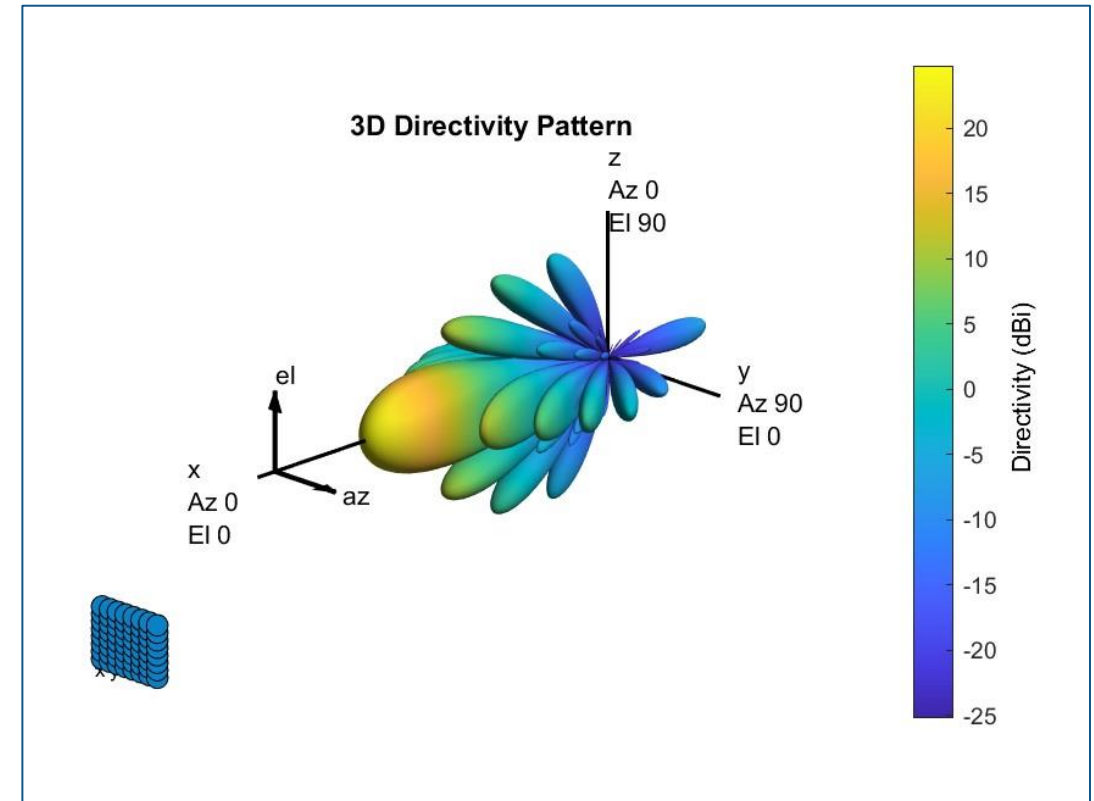
Simulate radar and interference signal propagation
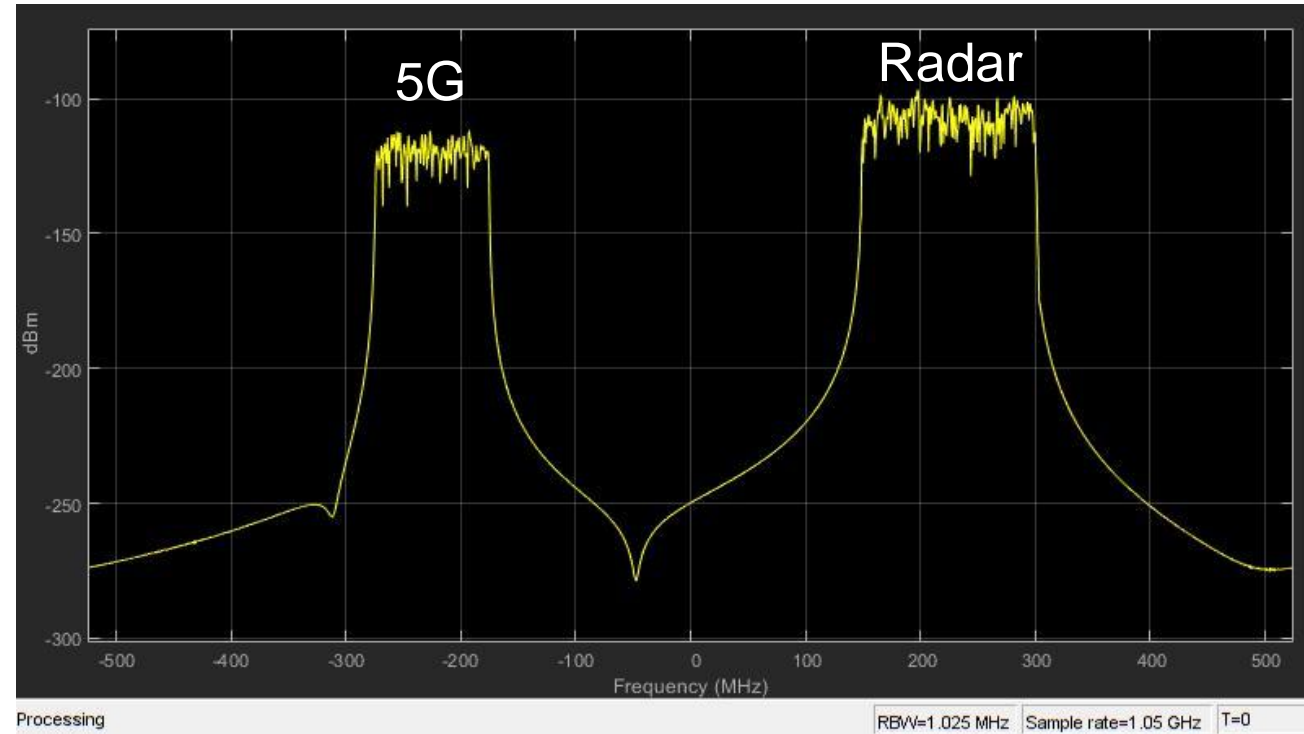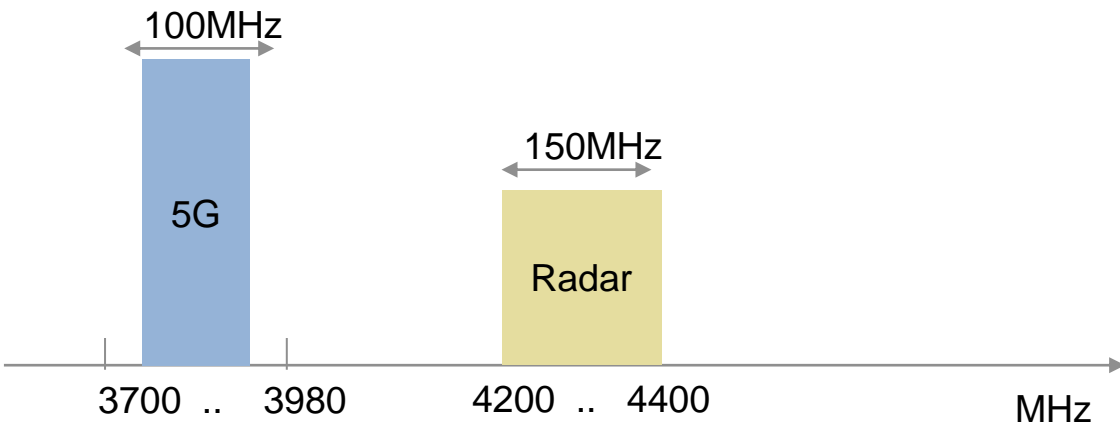
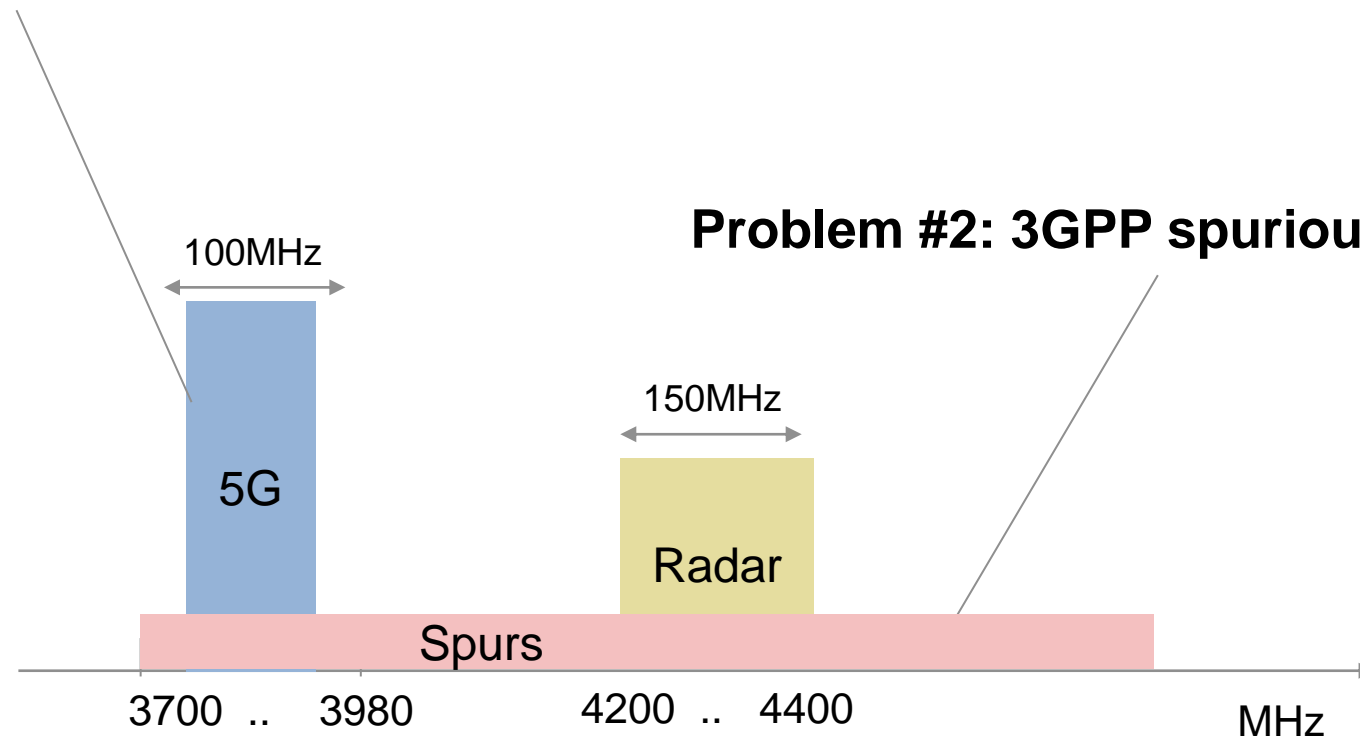# Simulate the interference from fundamental emissions of 5G

Analyze and Simulate in the RF Domain

Two Problems to Analyze and Simulate in the RF Domain
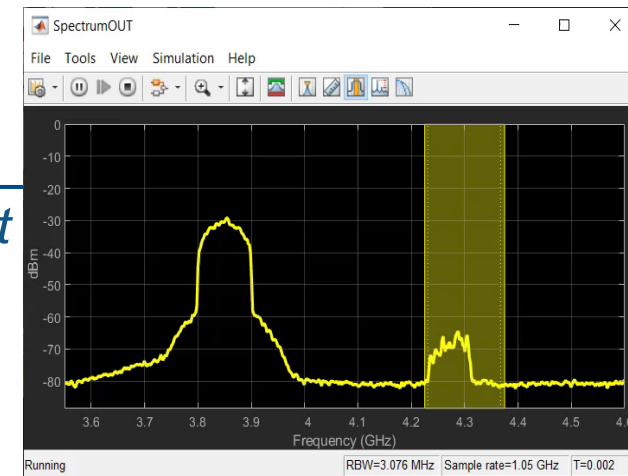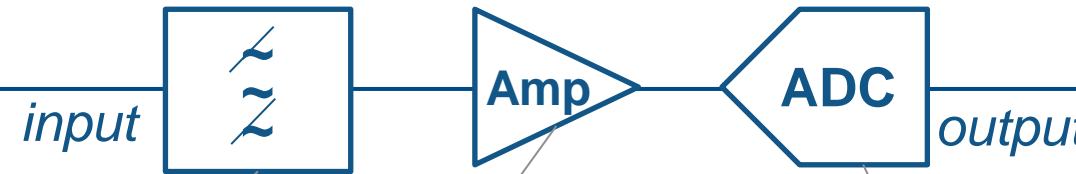
Problem #1: 3GPP fundamental emissions

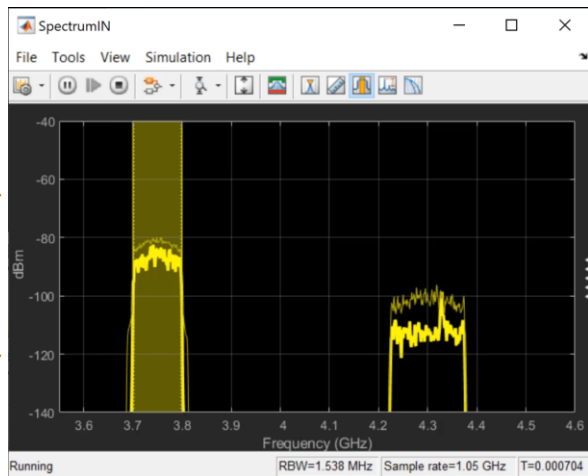**Problem #2: 3GPP spurious emissions**

Problem #1: 3GPP Fundamental Emissions

Saturation and
spectral regrowth

5G TX power

Noise floor

5G center frequency
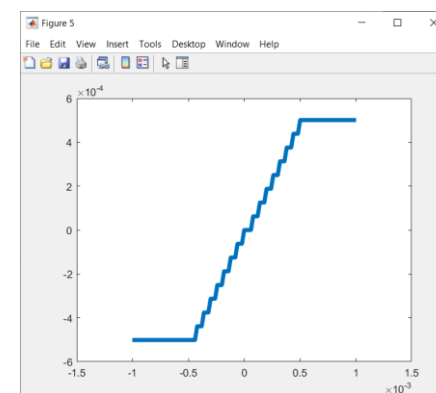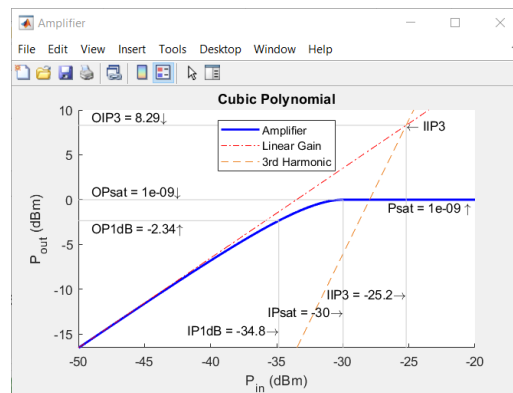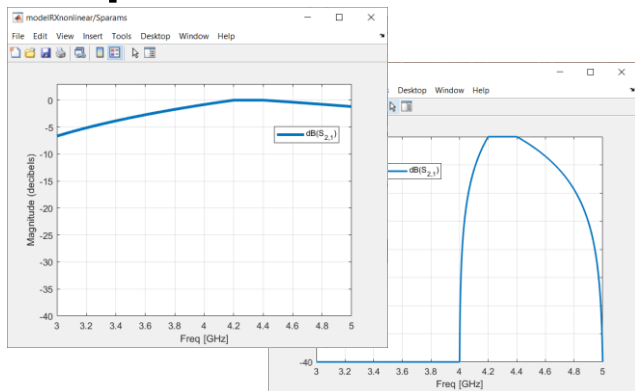
Input filter
• **S-parameters selectivity**

Amplifier
• Gain
• Noise figure
• Non-linearity (IP3)
• **Saturation (P1dB/Psat)**

ADC
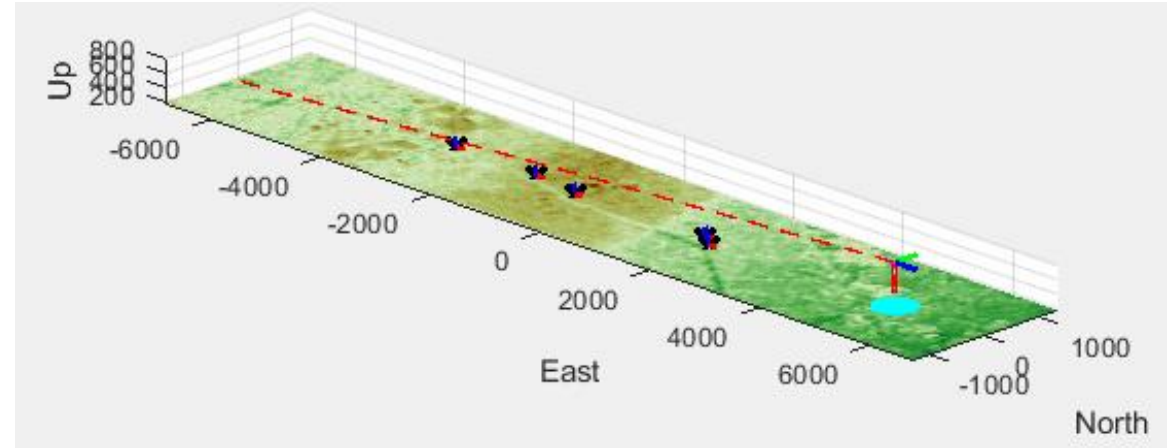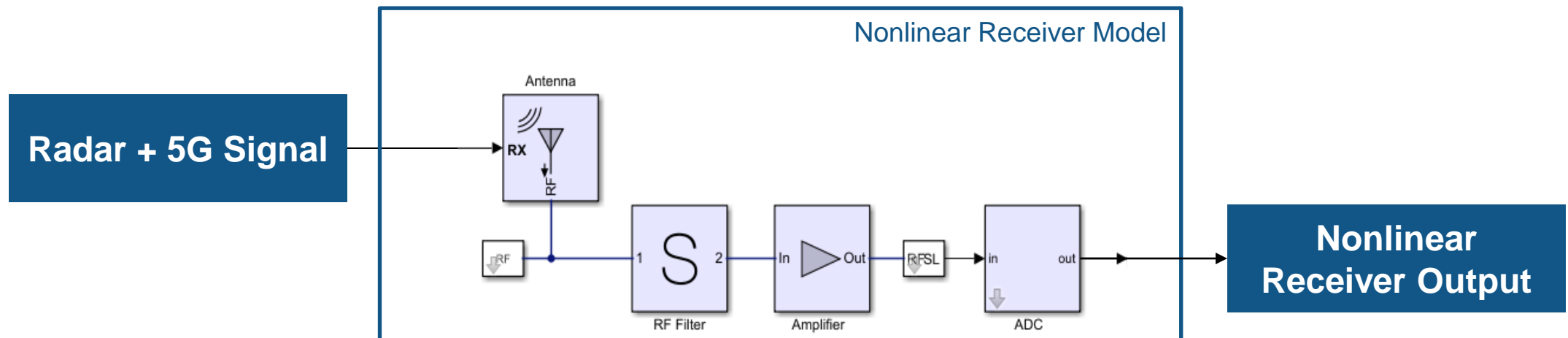• Quantization noise
• **Saturation**
• **Dynamic range**

Can 3GPP Fundamental Emissions Cause Front-End Overload?

It depends …

- Location of the base station and flight path
- 5G beam direction and transmitted power
- Receiver filter selectivity and saturation power

Simulate the (worst-case) scenario and verify the altitude reading!


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Simulation of Worst-Case Scenario: Erroneous Altitude Reading

- 5G Base station
  - TX power = 67.5dBm
  - Antenna steered towards airport
- Altimeter receiver
  - RF filter attenuation ~3dB
  - Input referred saturation power ~ -30dBm

- Possible mitigation strategies
  - Increase RF filter attenuation: ~ -40dB
  - Increase receiver saturation: -10dBm
  - Change signal processing algorithm
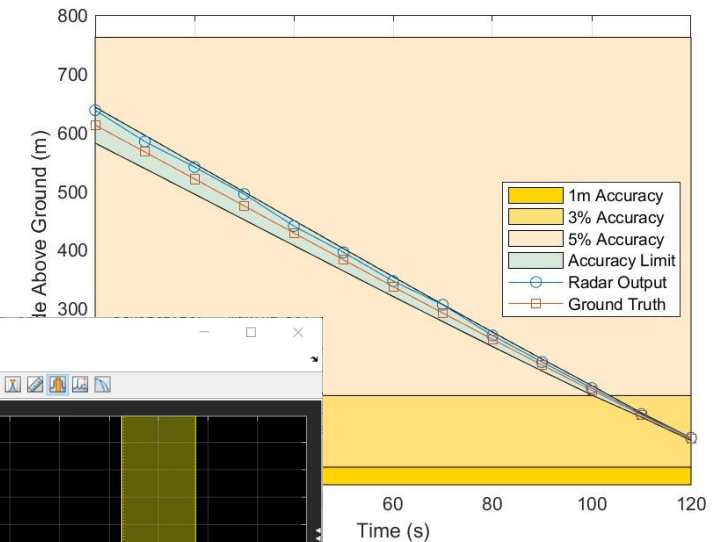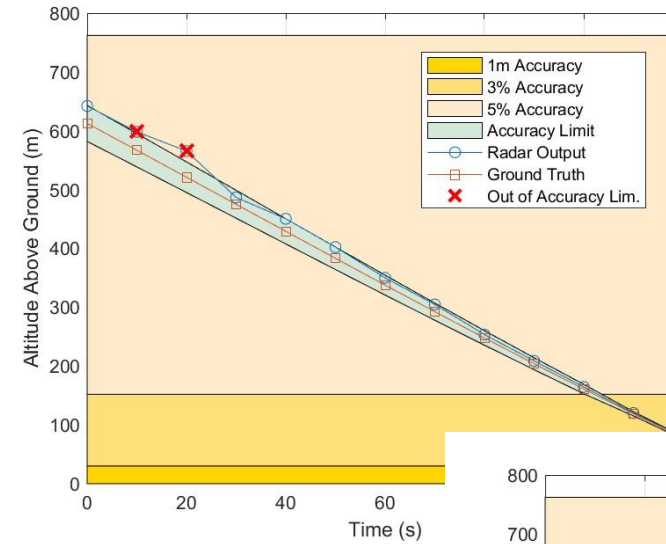
Problem #2: 3GPP Spur Emissions
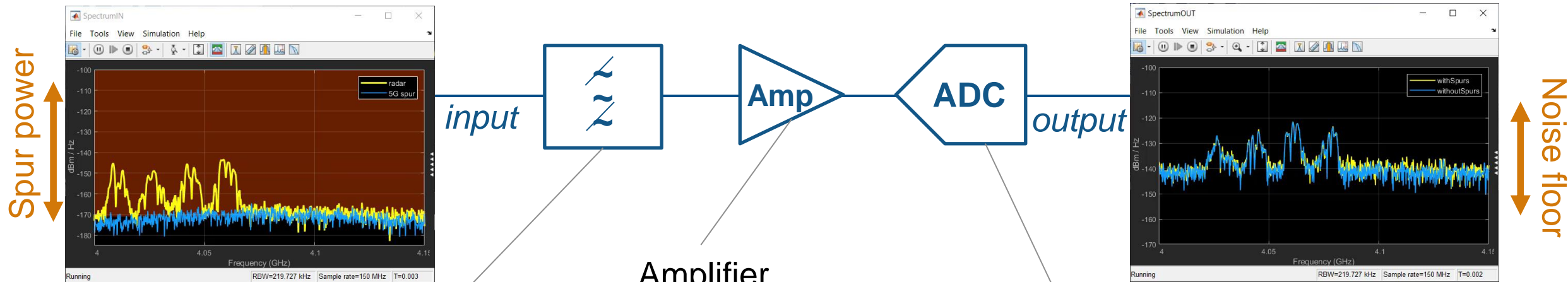
Spur power

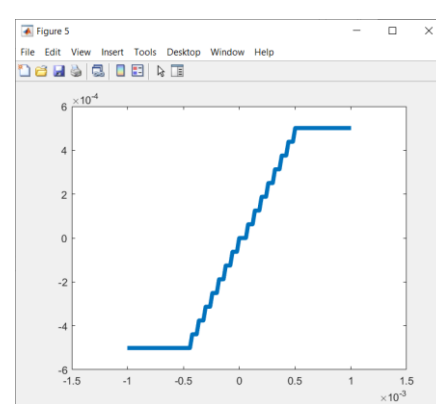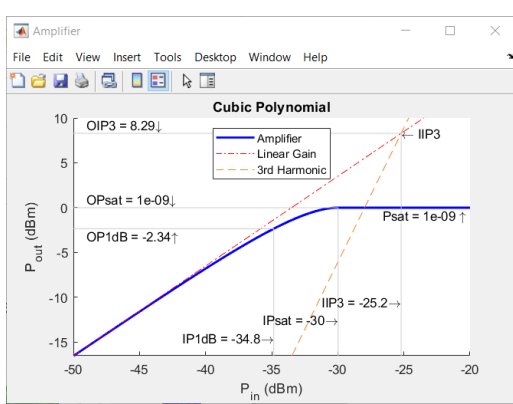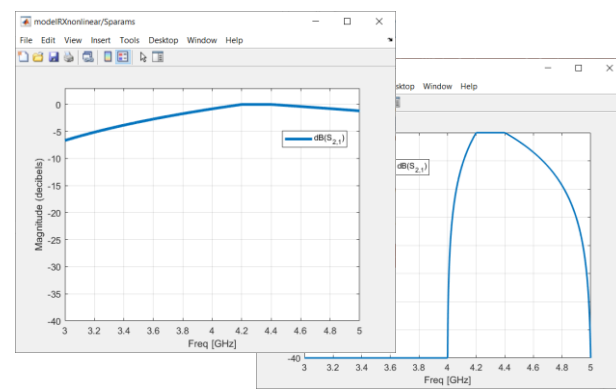Noise floor

In-band spurs

Input filter
- S-parameters selectivity

Amplifier
- Gain
- **Noise figure**
- Non-linearity (IP3)
- Saturation

ADC
- **Quantization noise**
- Saturation
- Dynamic range

# Can 3GPP Spur Emissions Cause Receiver Desensitization?

Desensitization = increase of the receiver noise floor by 1dB due to spur emissions

- Model the base station worst-case scenario and compare with regulations
  - TX power = -13.6dBm/MHz
  - Antenna steered towards airport
- Simulate spurious signals and measure noise floor / SNR!

```
NF = 8dB and BW = 150MHz
Noise floor = -174dBm/Hz+10*log10(BW)+NF
            = -84dBm or -166dBm/Hz
Regulation: Spur < Noise floor - 6dB = -172dBm/Hz
```
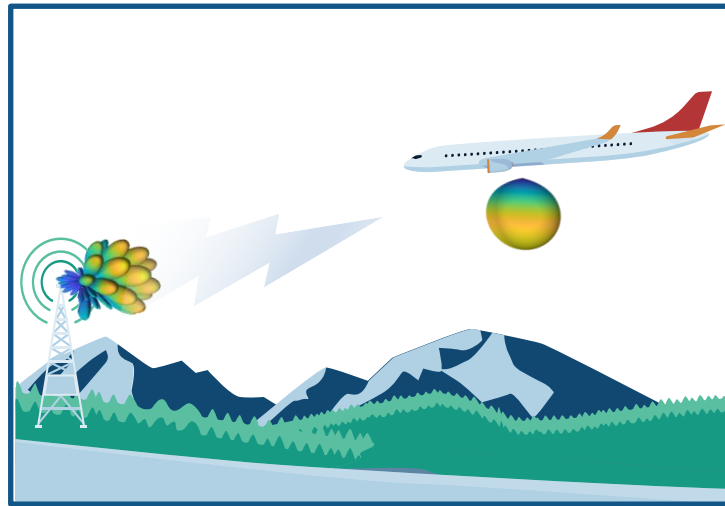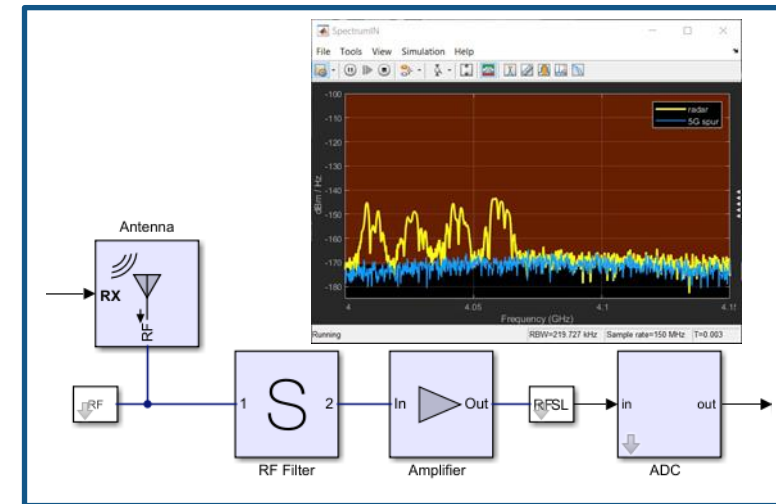

23
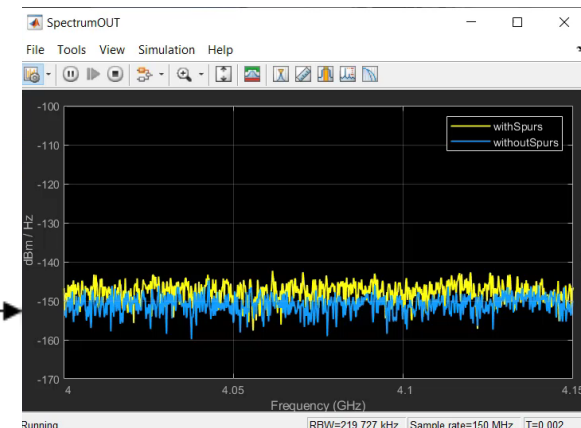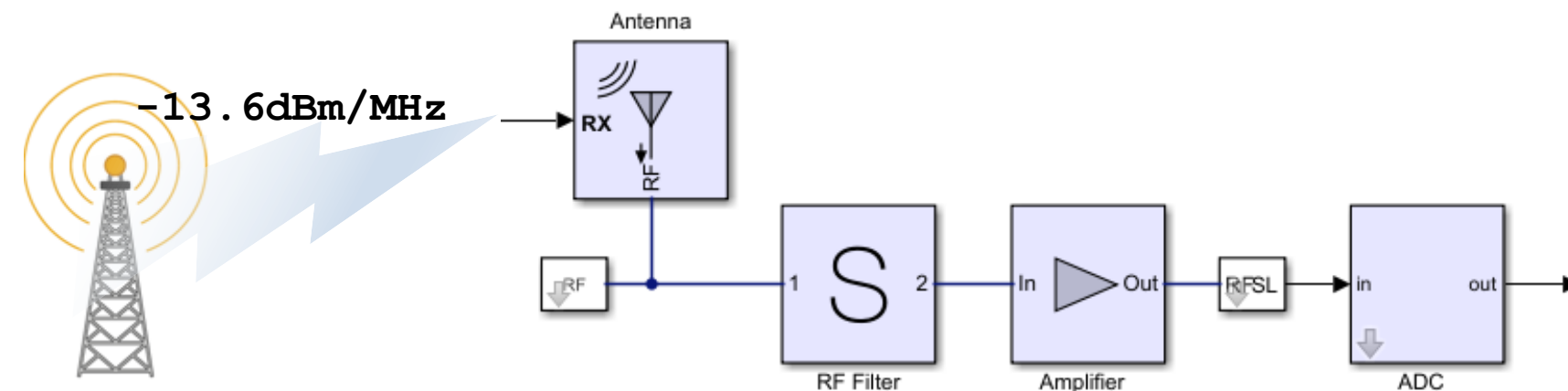
In summary, you can analyze the effects of interference between radar and wireless systems with modeling and simulation

Increasing Congestion in the
RF Spectrum

Scenario Modeling for Radar
and Wireless Coexistence

Analyze and Simulate
in the RF Domain

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Thank you

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