MATLAB EXPO

Modeling Radar and Wireless Coexistence

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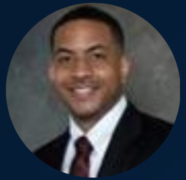

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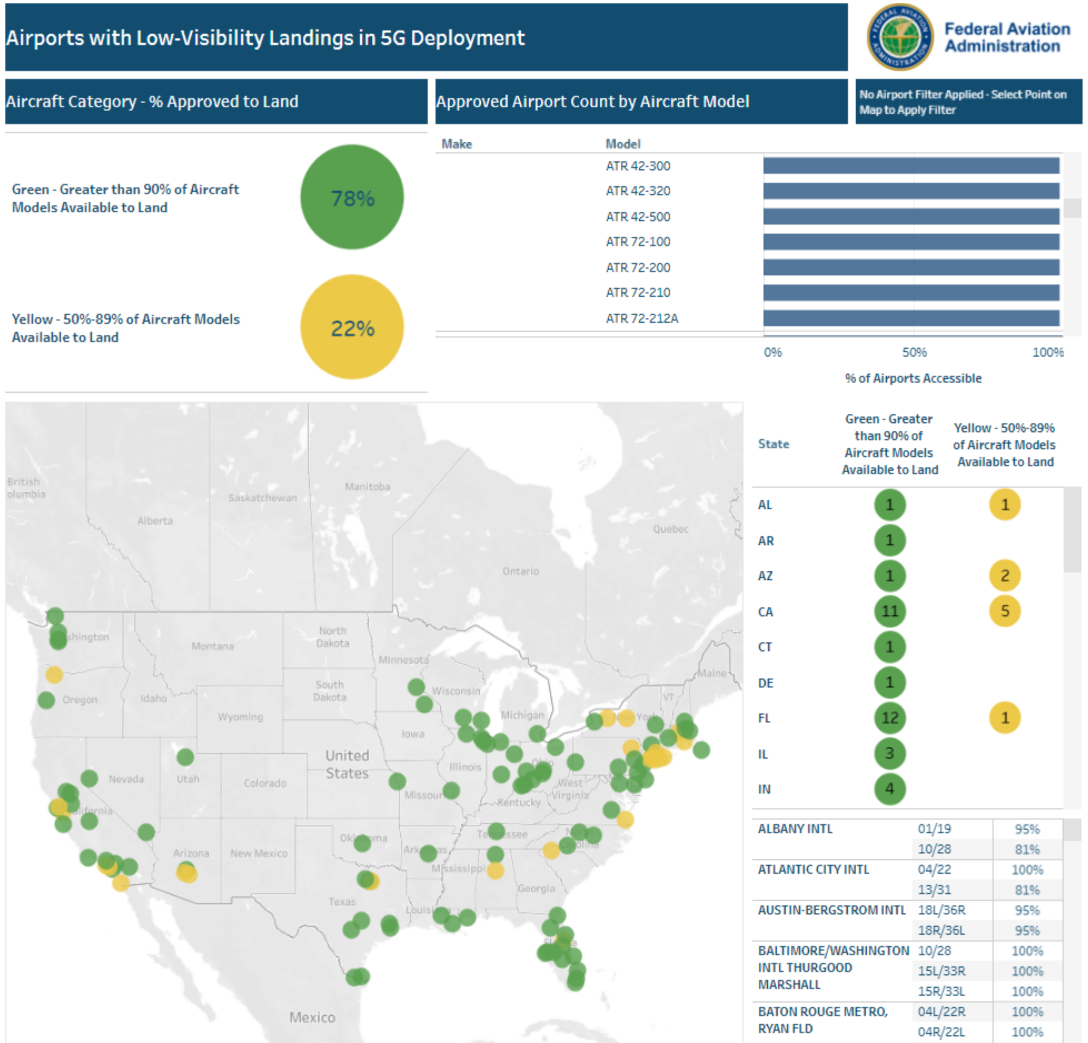


Source: [FAA]

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

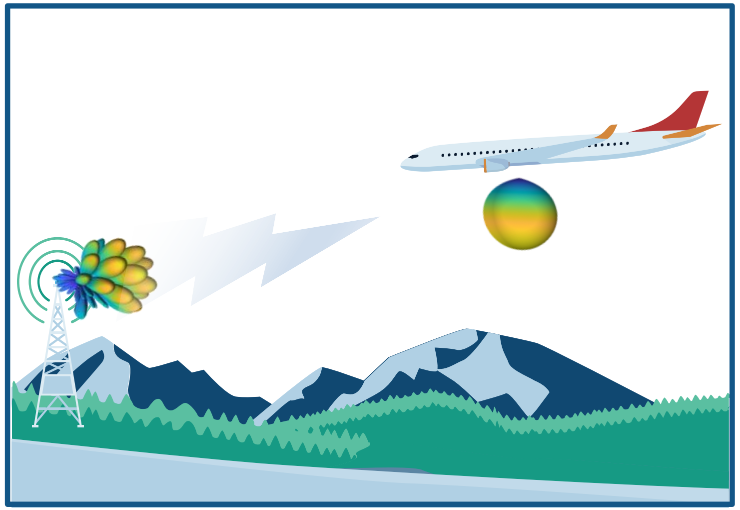
Boeing and Airbus urge a delay in 5G wireless service over ...

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

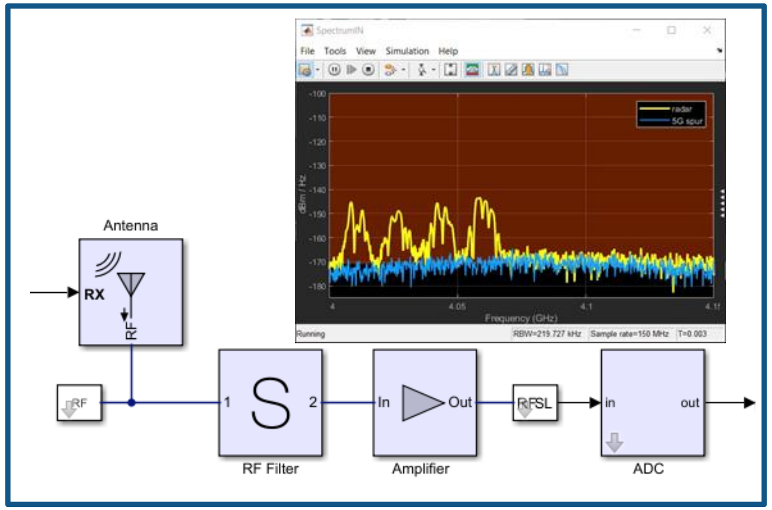
Source: [NPR]

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

Increasing Congestion in the RF Spectrum



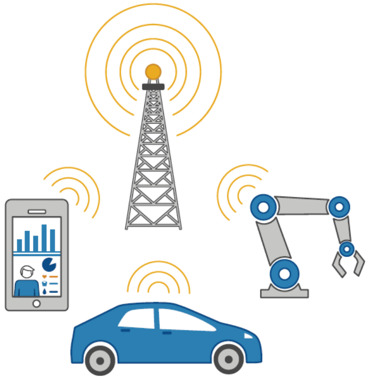
Scenario Modeling for Radar and Wireless Coexistence



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

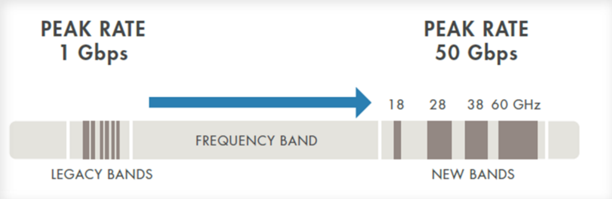
5G Requirements / Use Cases

- Enhanced mobile broadband (>10 Gbps)
- Ultra low latency (<1 ms)
- Massive machine-type communication (>1e5 devices)

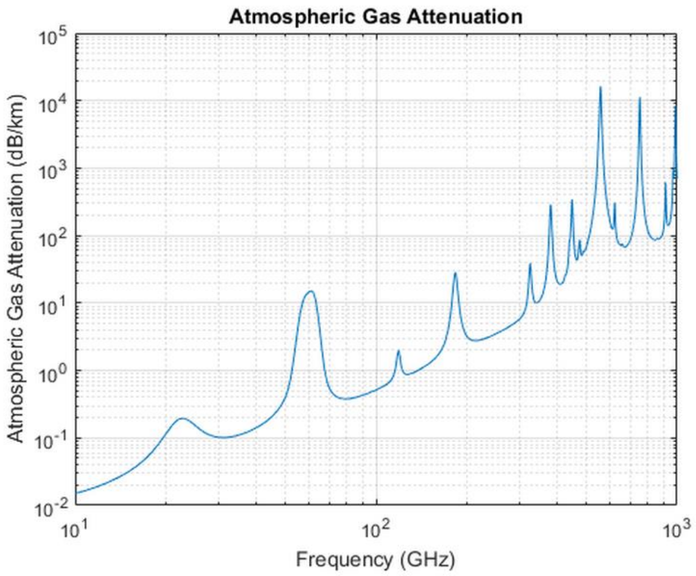
Technical Solutions

- Increased bandwidth
- Better spectral efficiency
- Flexible air interface
- Densification

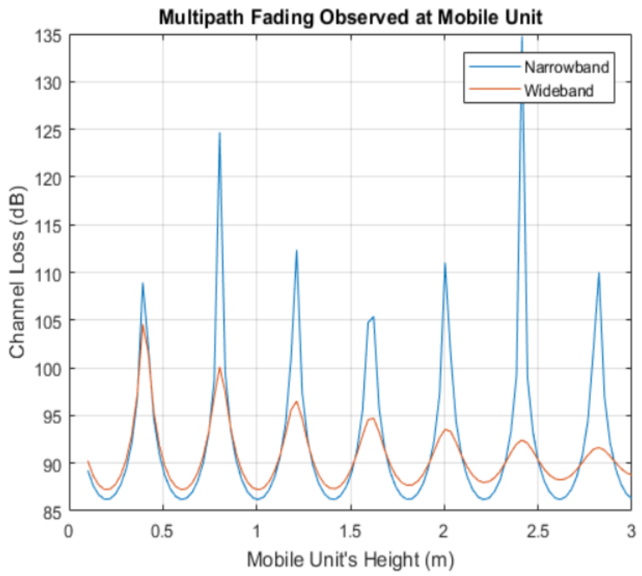
Higher Frequency Bands



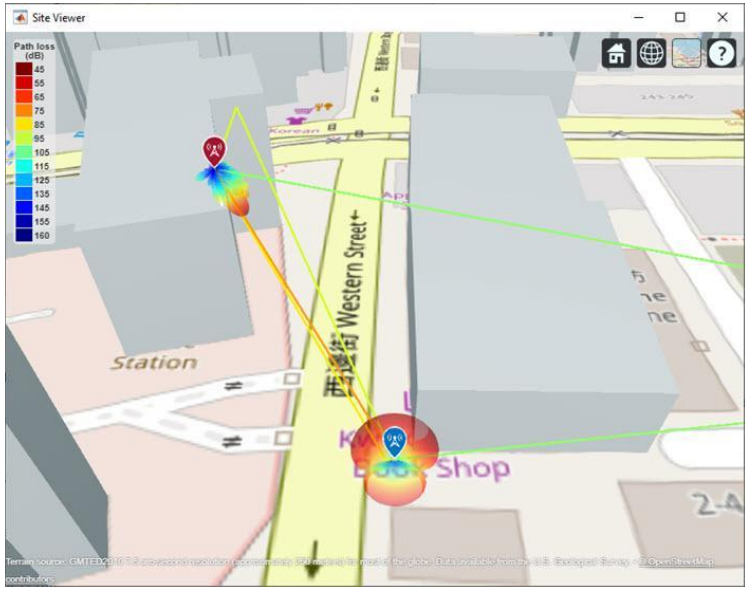
Higher frequency operations result in propagation challenges



Signal Attenuation



Wideband performance



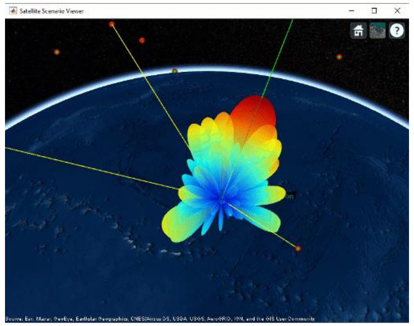
Scatterer-rich propagation

Shared spectrum operations present interference challenges

LTE

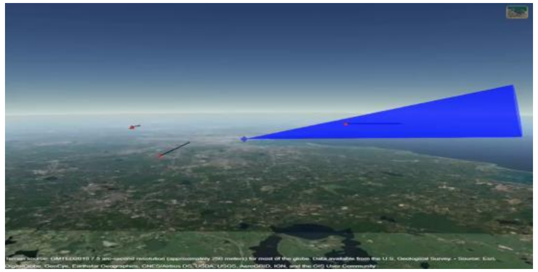
Custom

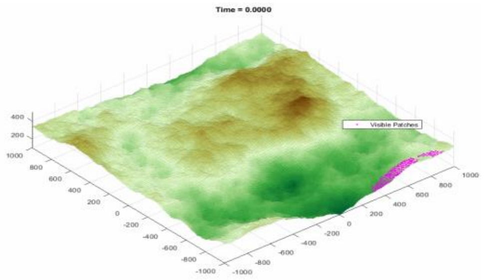
5G



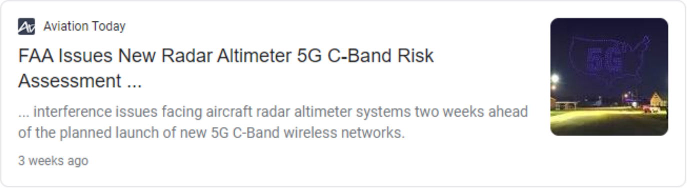
Satellite

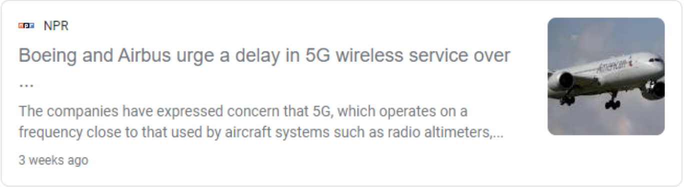
Communications





Radar


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.
3 weeks ago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Boeing and Airbus urge a delay in 5G wireless service over ...
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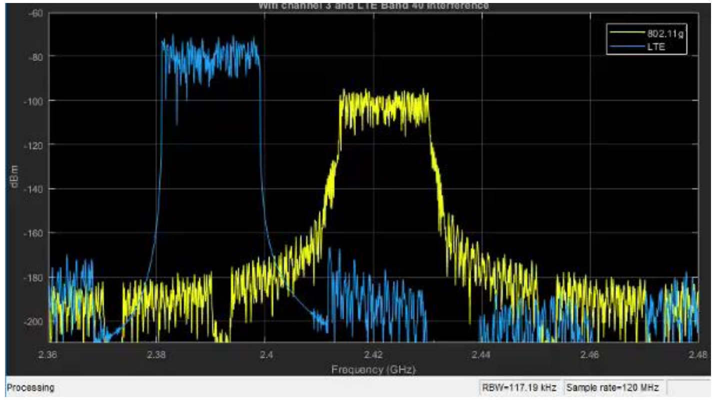
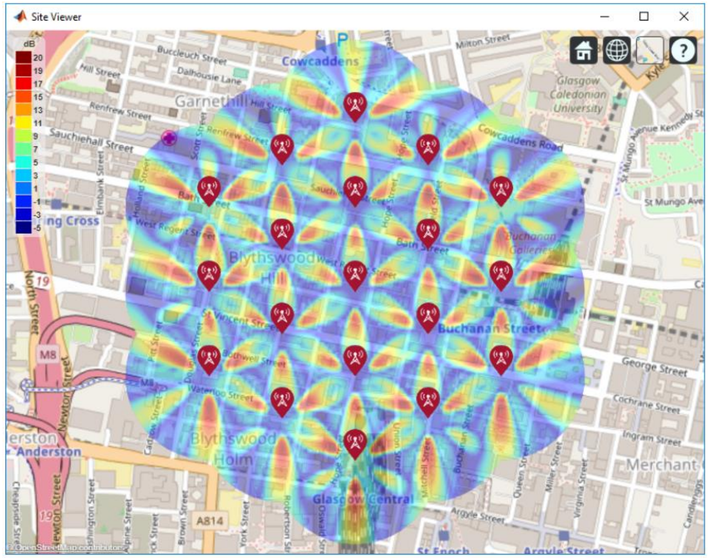
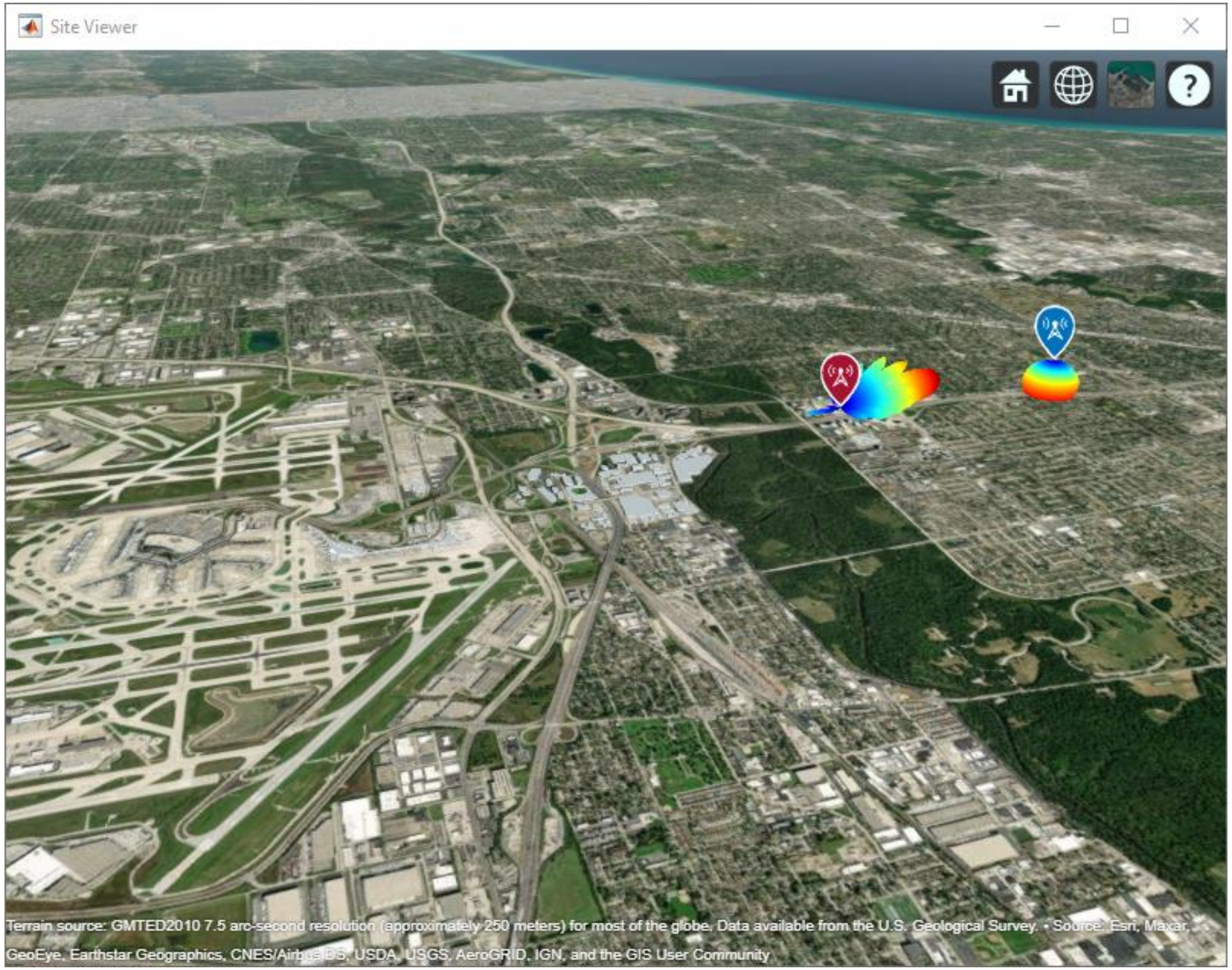
3 weeks ago

Interference

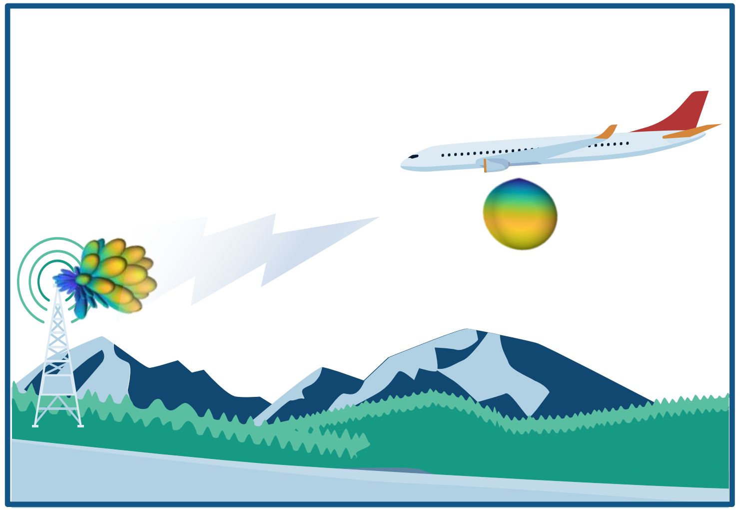
Signal-level and power-level analysis can help with planning





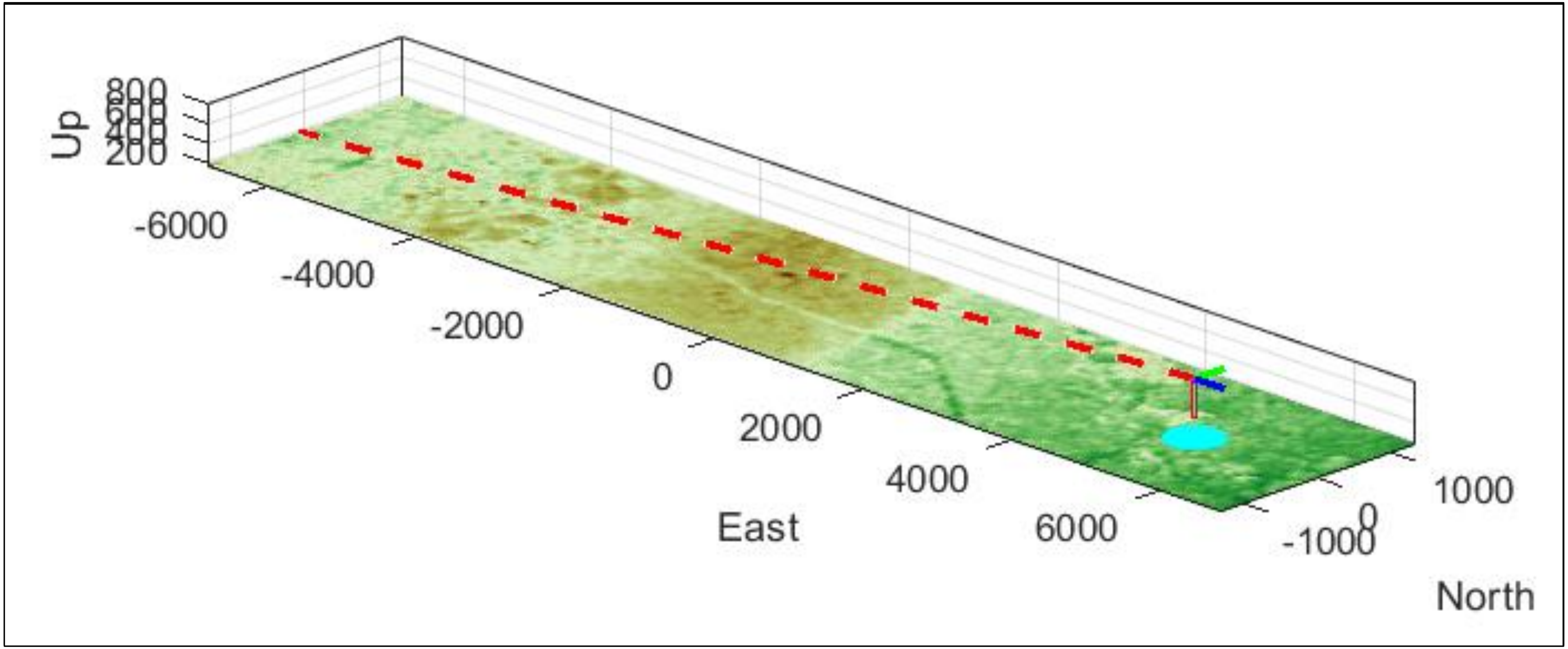


Scenario Modeling for Radar and Wireless Coexistence



Typical radar scenario modeling workflow

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



Model the radar altimeter sensor

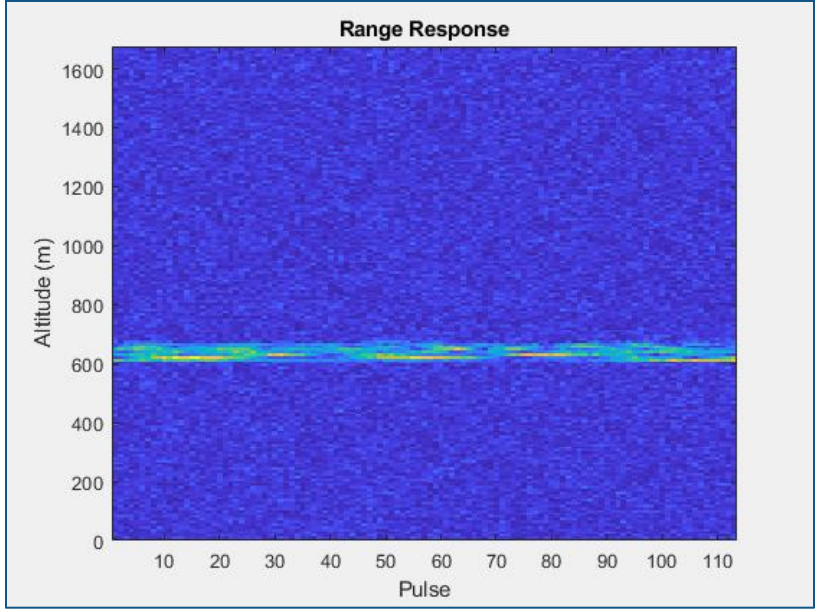
Parameter	Value
Center Frequency	4.3 GHz
PRF	143 Hz
Chirp Bandwidth	150 MHz

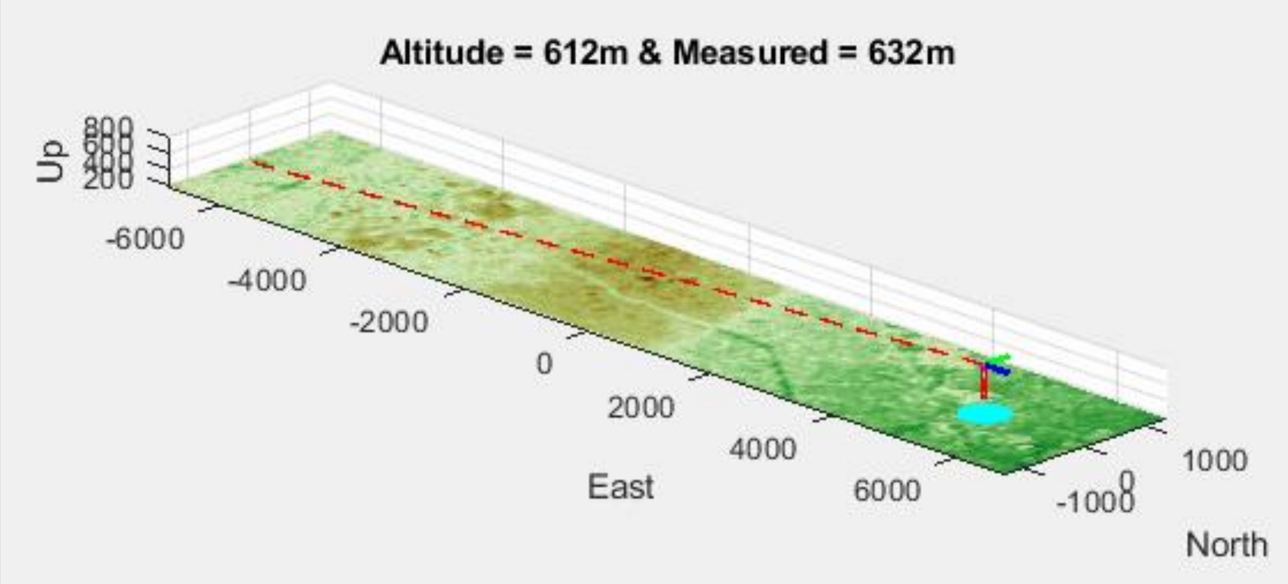
```
RadarAltWaveform = phased.FMCWWaveform( ...
                'SweepBandwidth',RadarAlt.ChirpBW, ...
                'SampleRate', RadarAlt.fs, ...
                'SweepTime',RadarAlt.SweepTime, ...
                'OutputFormat','Sweeps');

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);
```

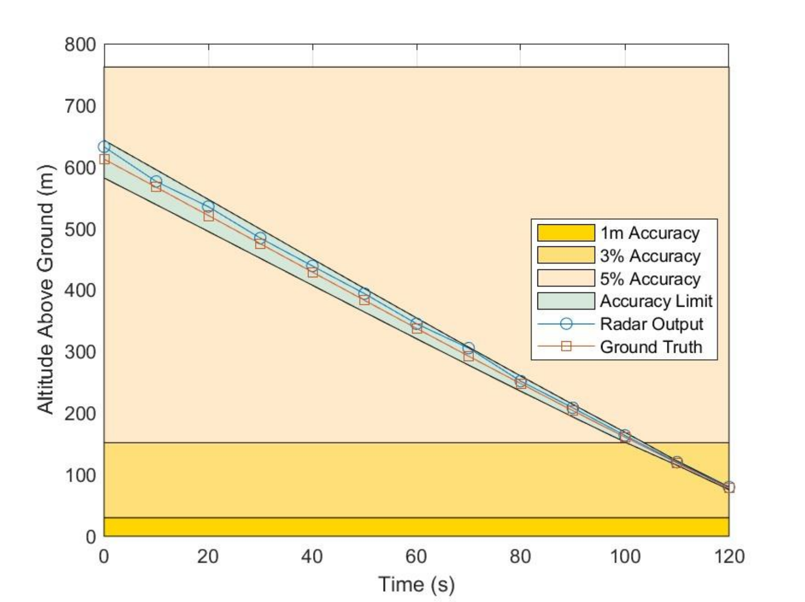
Source of radar altimeter specifications: [Recommendation ITU-R M.2059-0]

Simulate the scenario and generate IQ signal

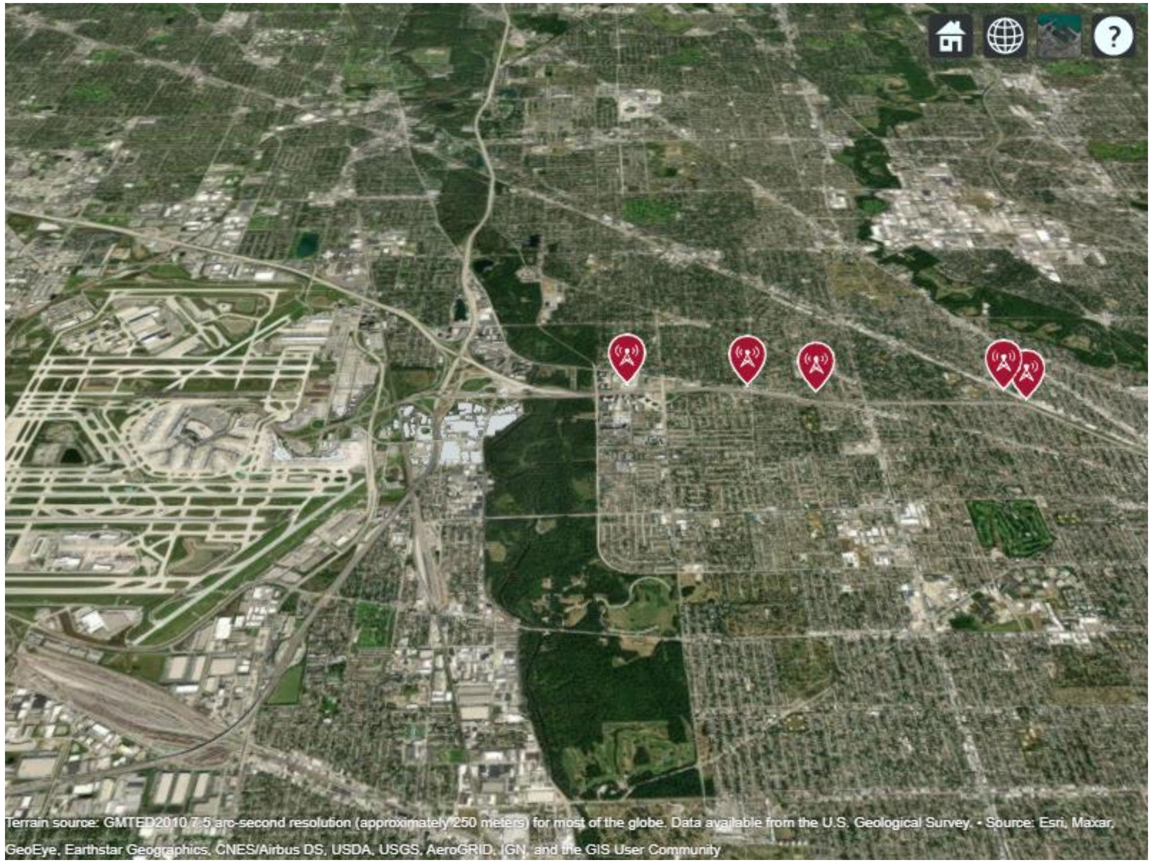
```
while advance(scene)
    iqsig = receive(scene);

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

    xr = pulsint(xr,'coherent');

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

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





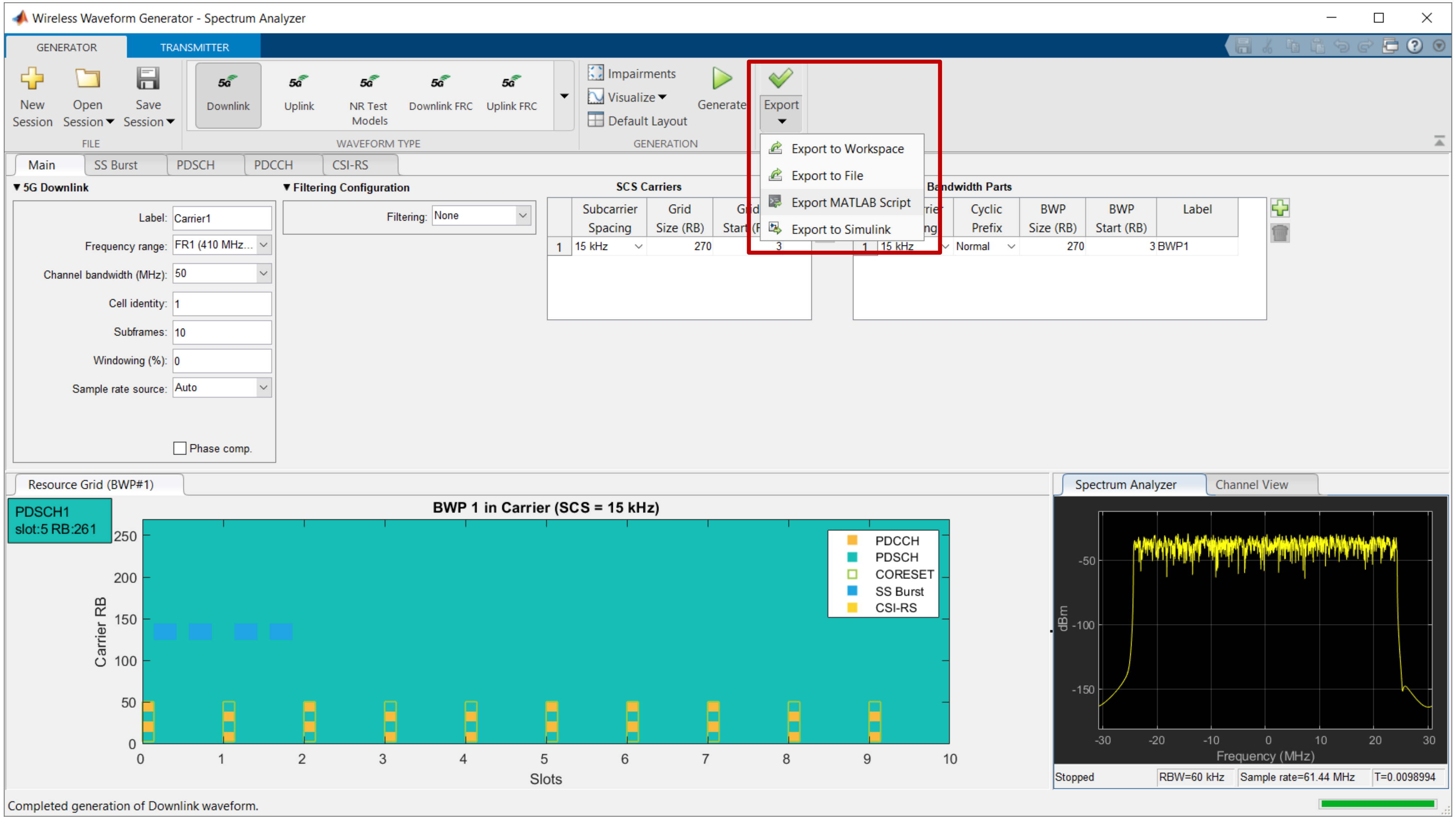


Model the base stations close to the flight path



Waveform → Antenna Array → Propagation Channel

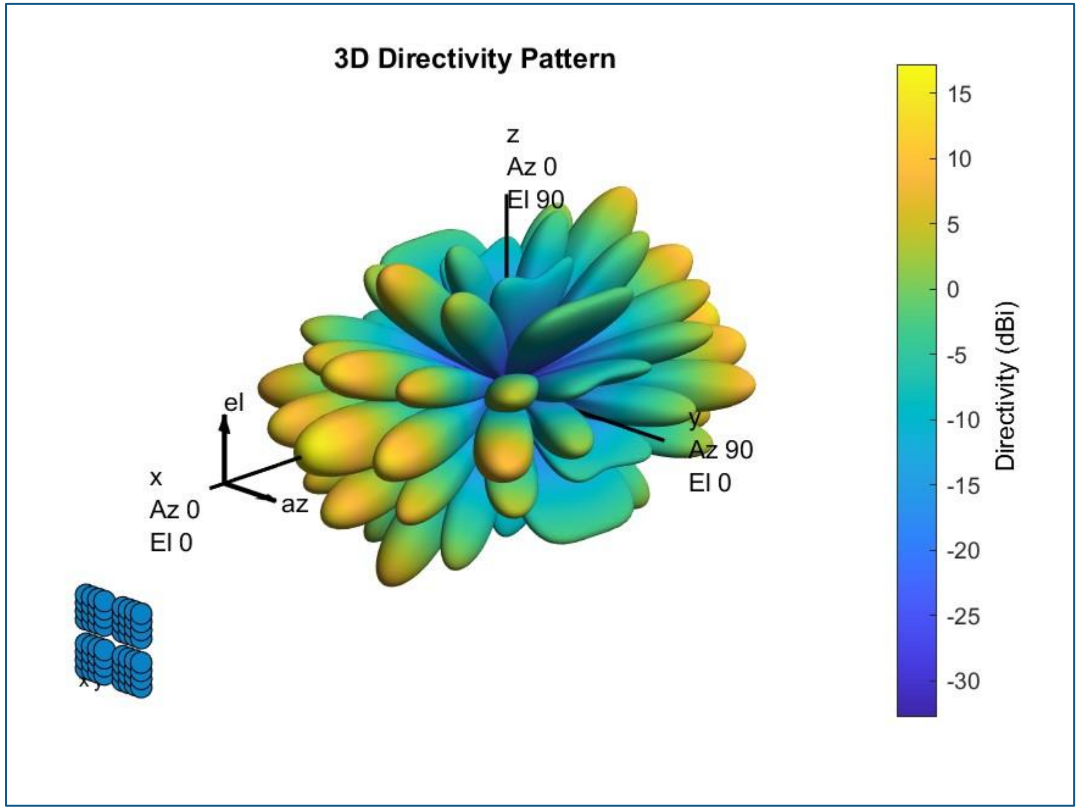
Generate 5G signal with the wireless waveform generator App

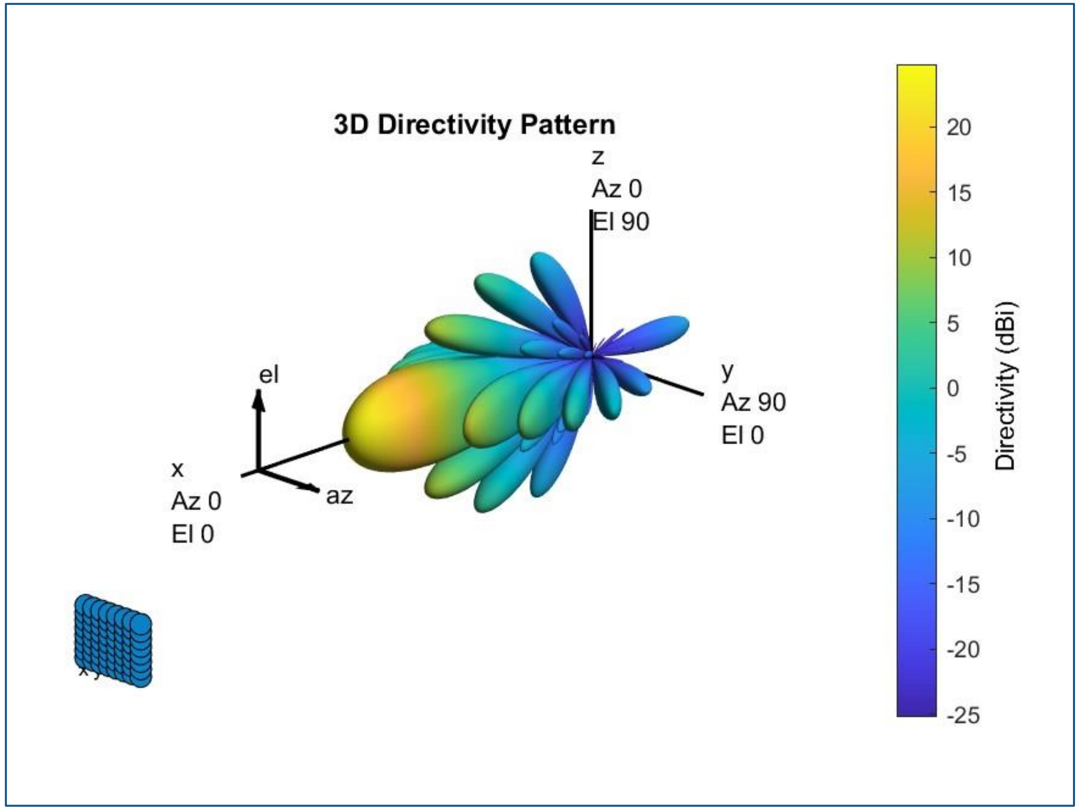


Model base station antenna with NR rectangular panel array

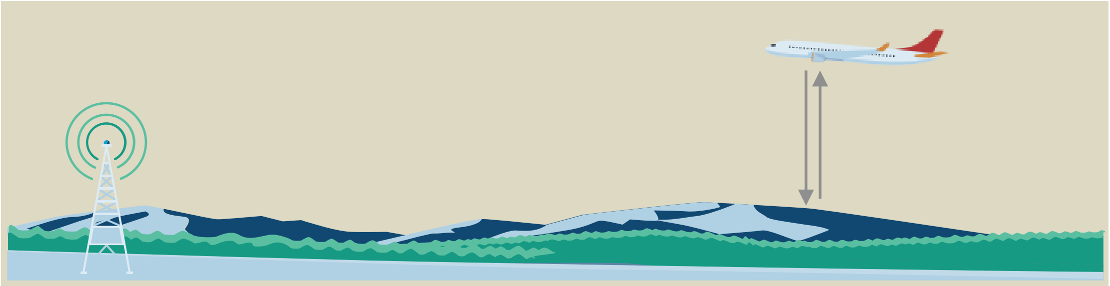
5G Antenna Array
(3GPP TR 38.901)

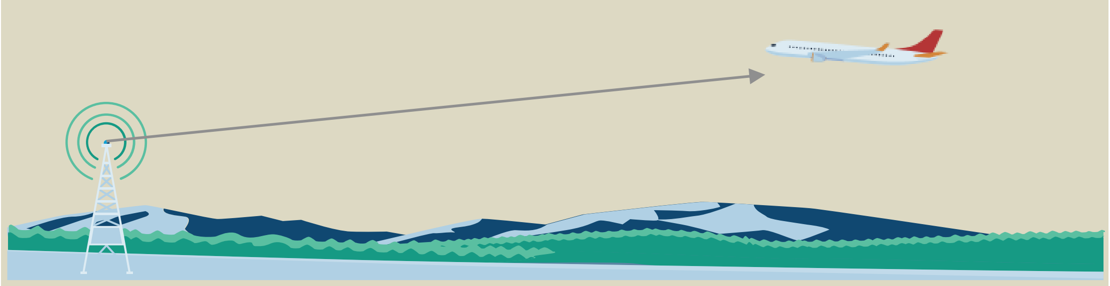
Maximize directivity for
worst case scenario

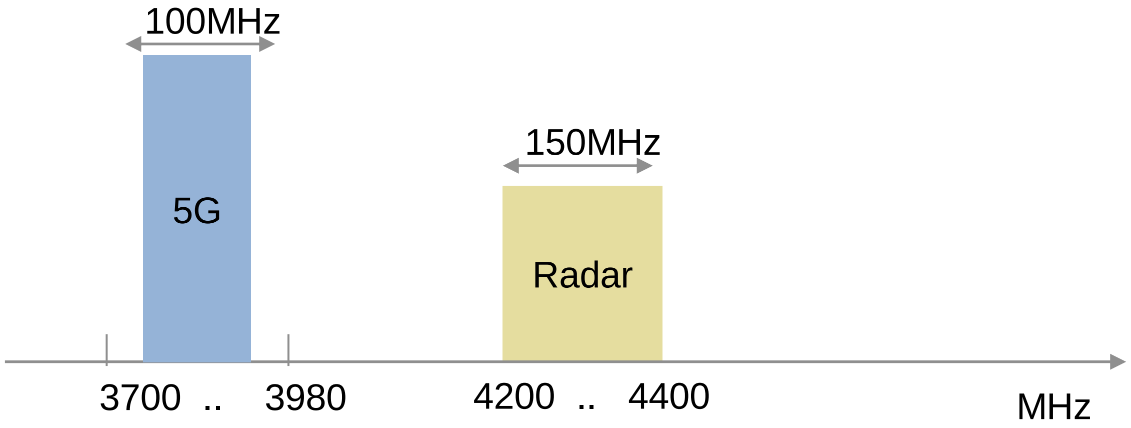


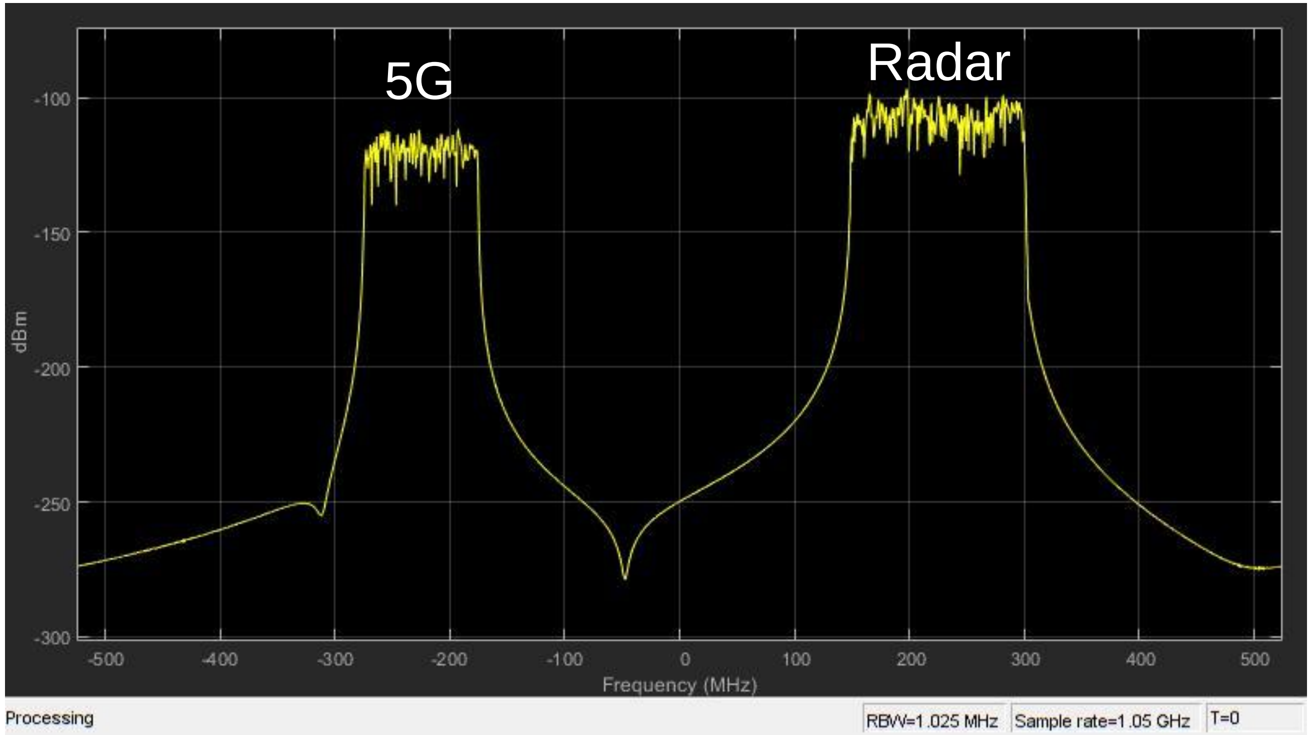


Simulate radar and interference signal propagation

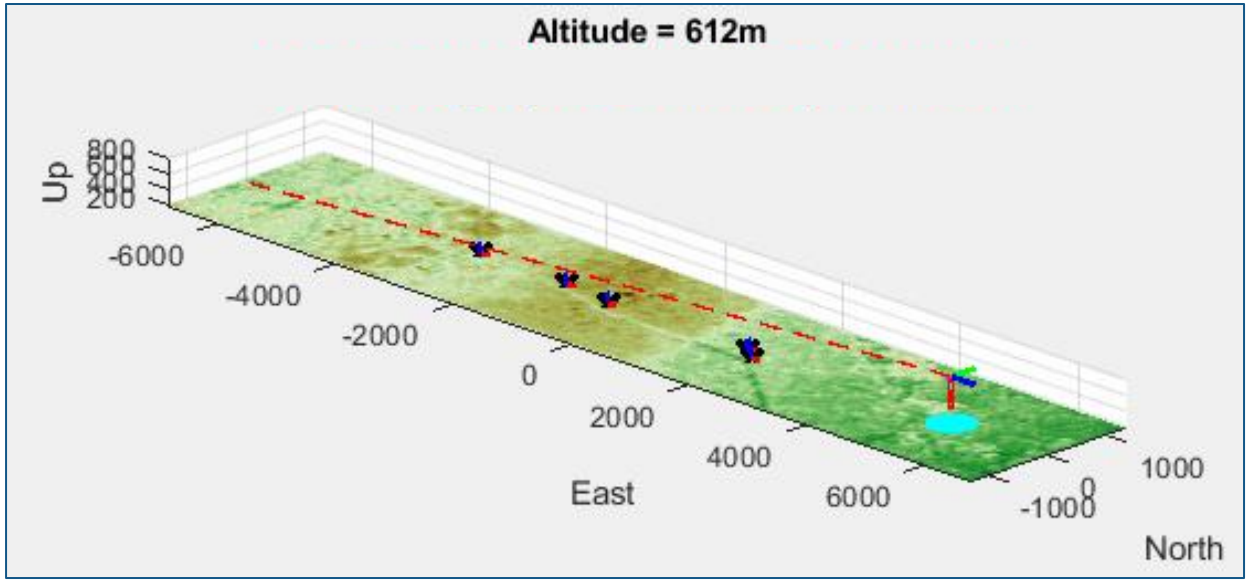


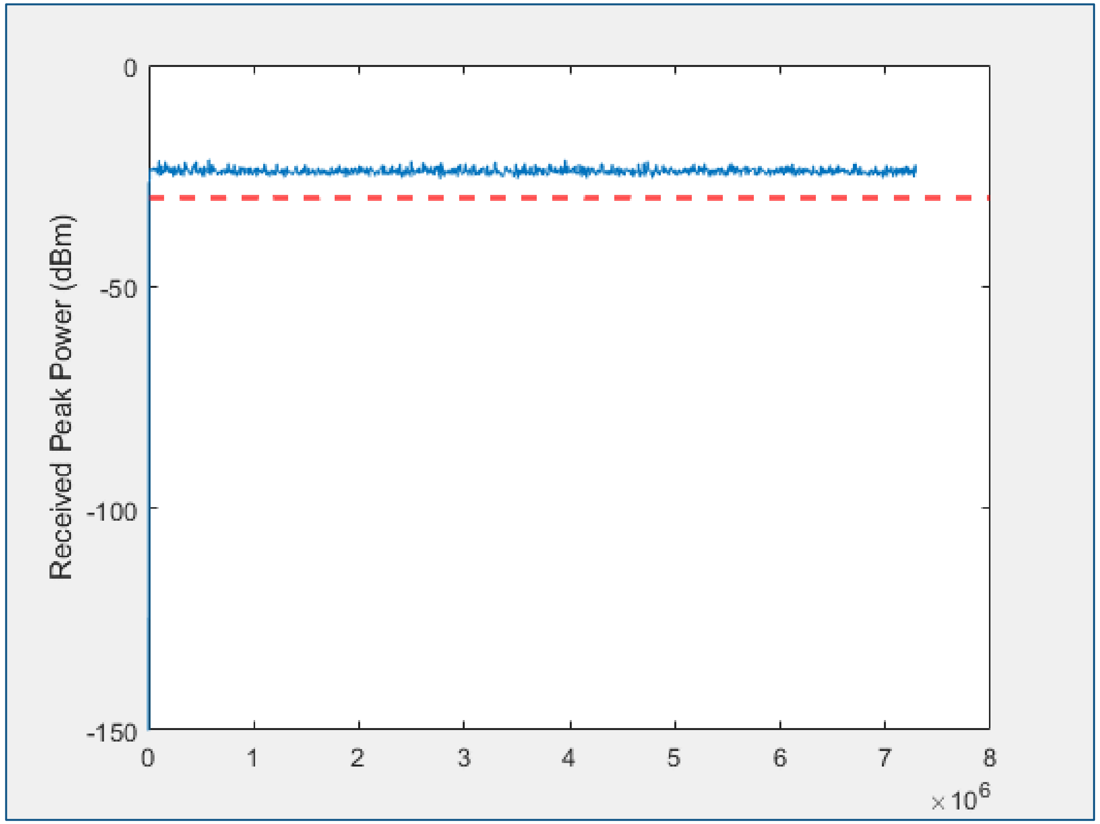


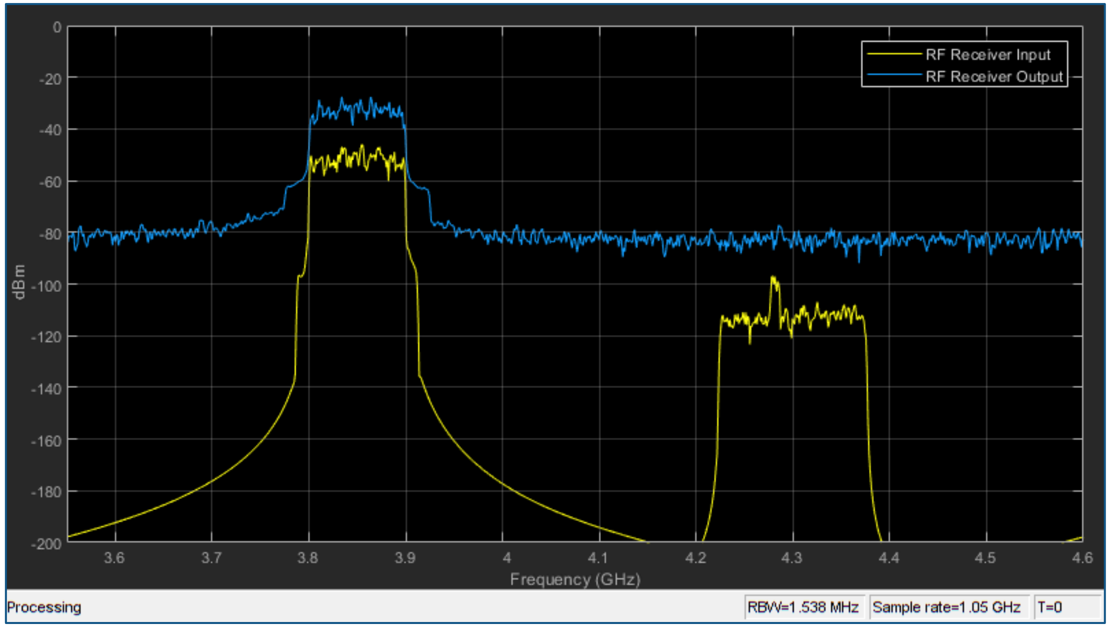




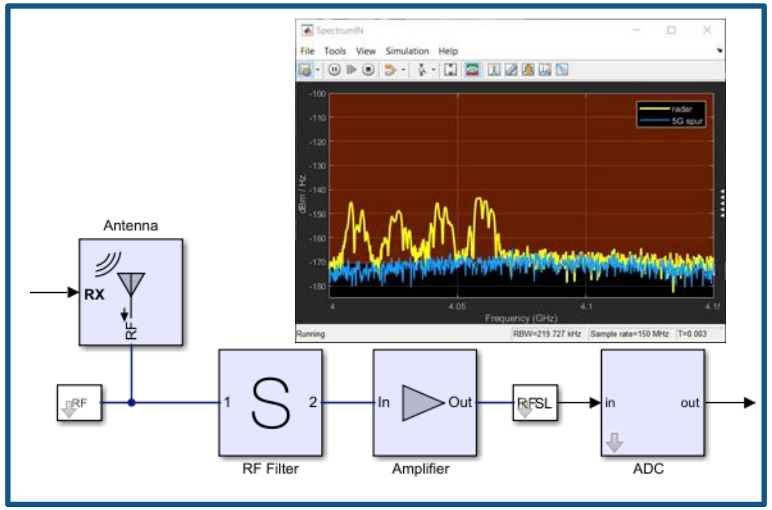
Simulate the interference from fundamental emissions of 5G



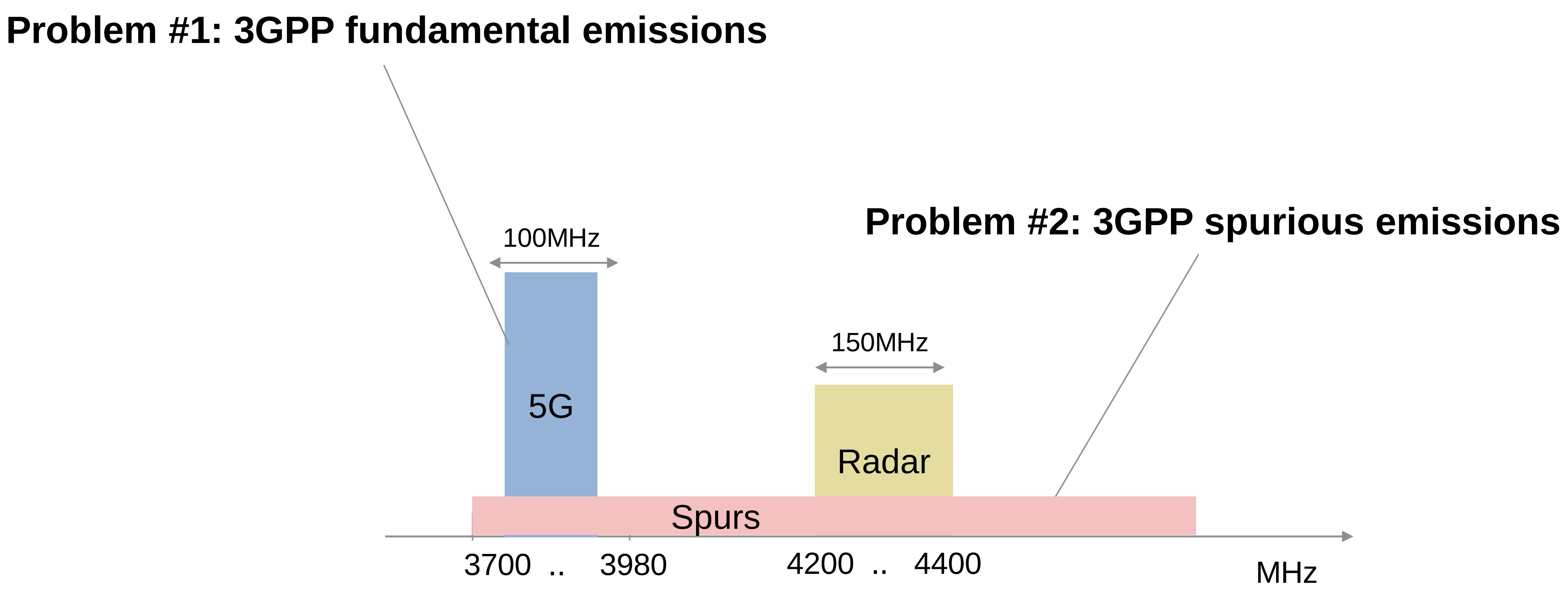




Analyze and Simulate in the RF Domain



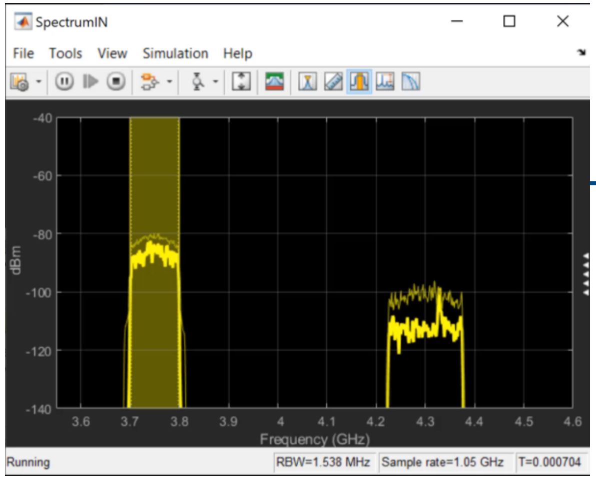
Two Problems to Analyze and Simulate in the RF Domain

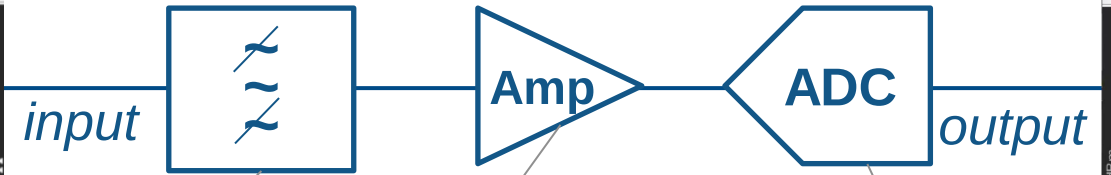


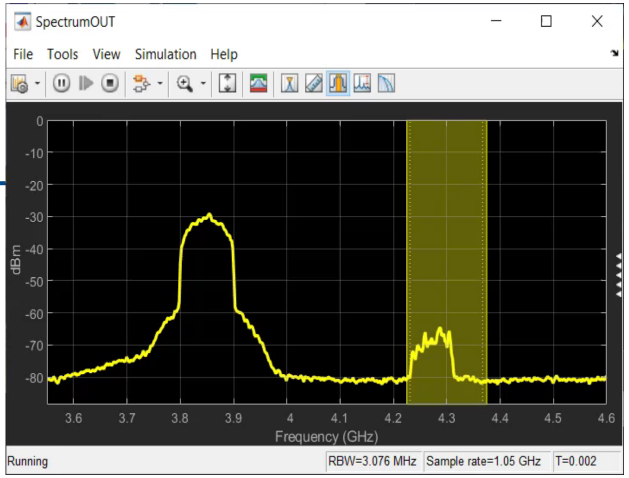
Problem #1: 3GPP Fundamental Emissions

Saturation and spectral regrowth

5G TX power







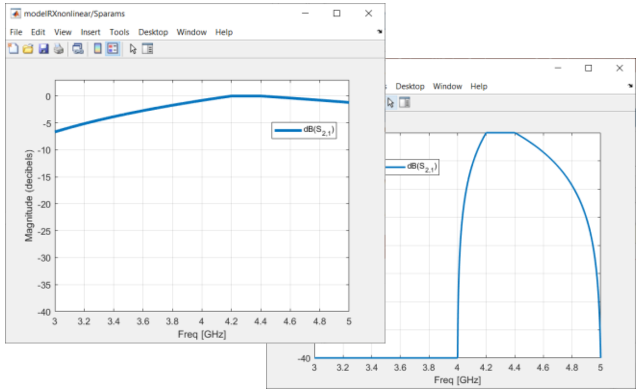
Noise floor

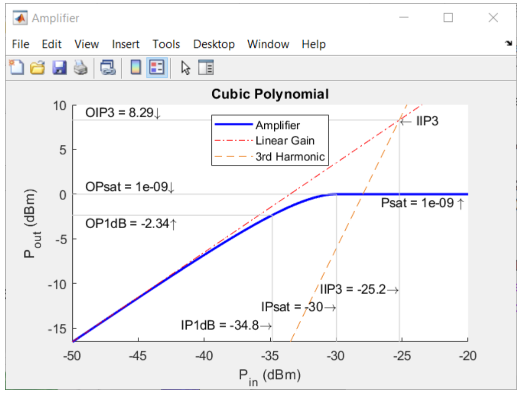
5G center frequency

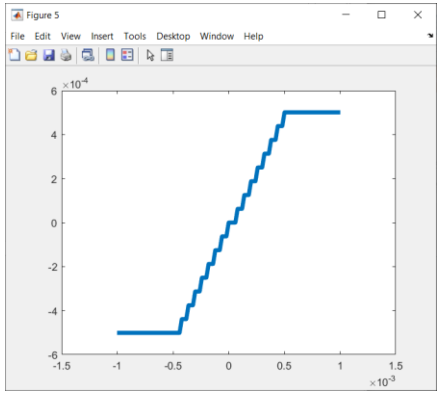
Amplifier
- Gain
- Noise figure
- Non-linearity (IP3)
- **Saturation (P1dB/Psat)**

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

Input filter
- **S-parameters selectivity**



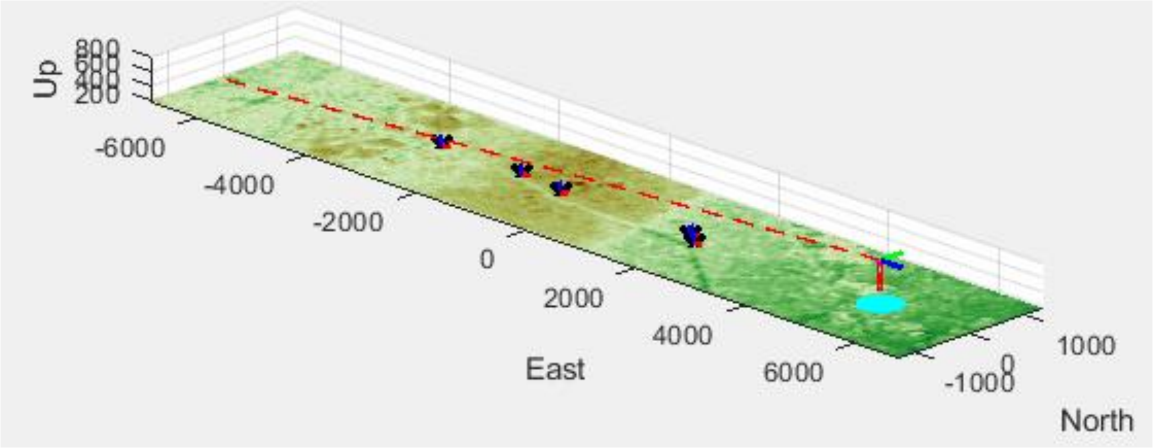




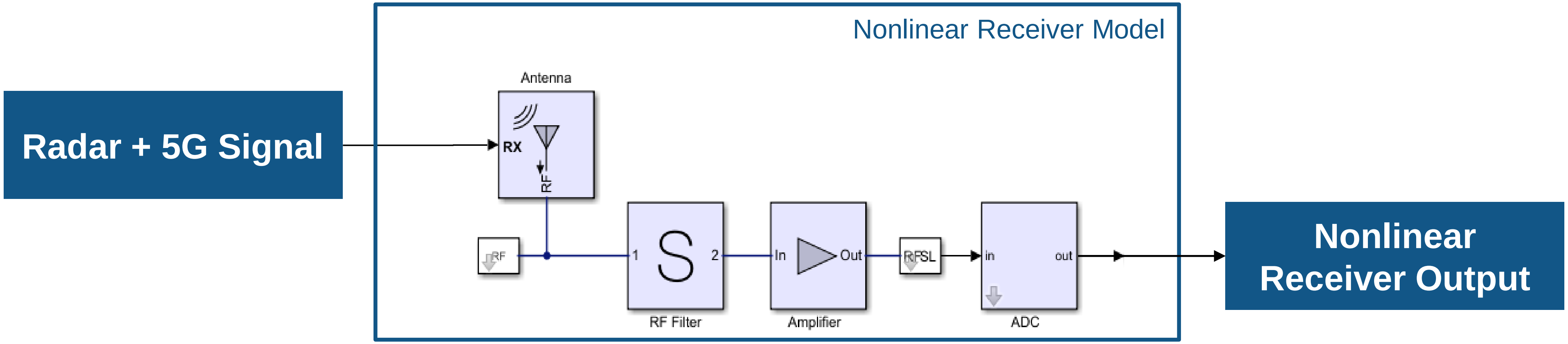
Can 3GPP Fundamental Emissions Cause Front-End Overload?

It depends …

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



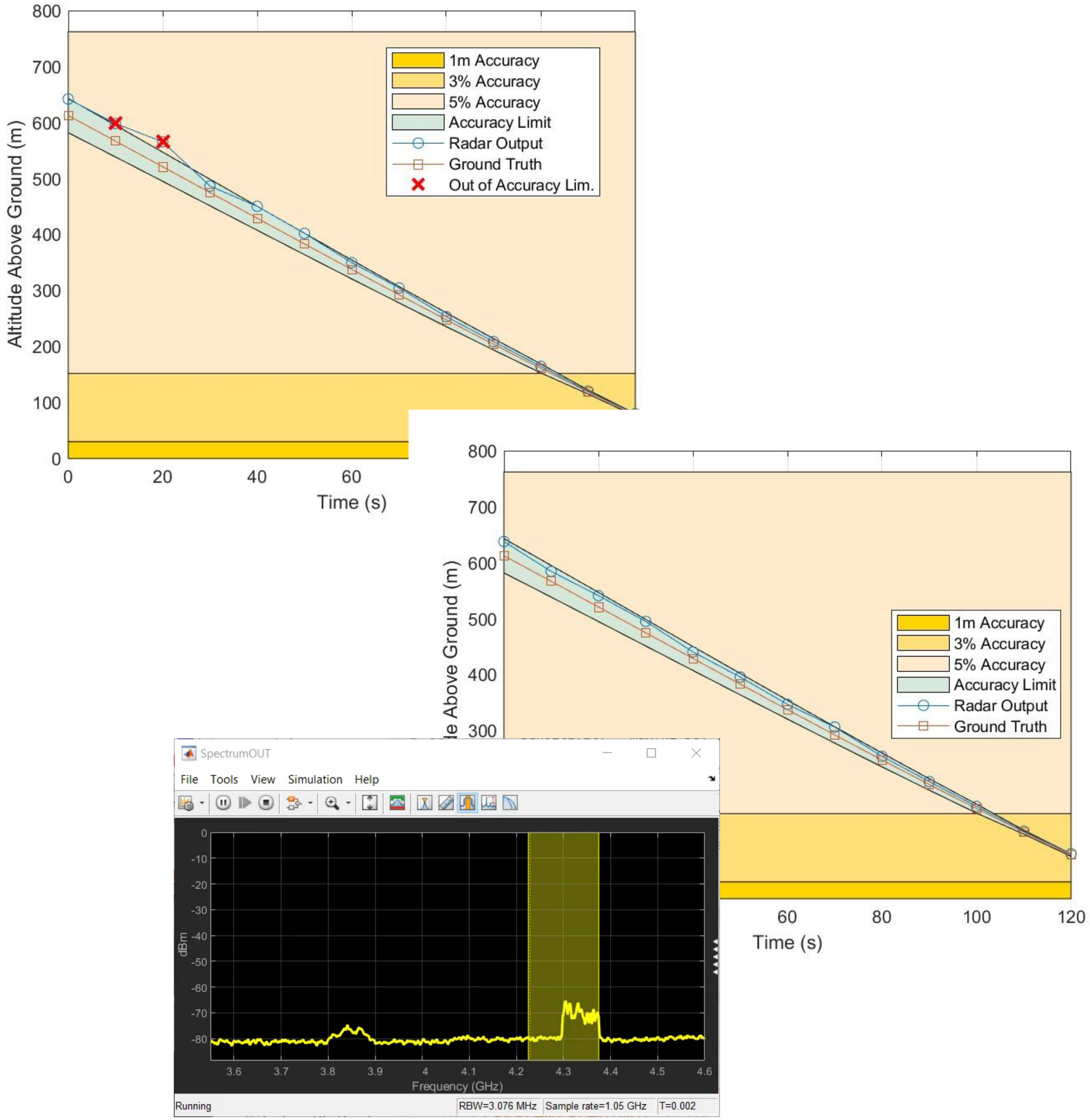
Simulate the (worst-case) scenario and verify the altitude reading!



Simulation of Worst-Case Scenario: Erroneous Altitude Reading

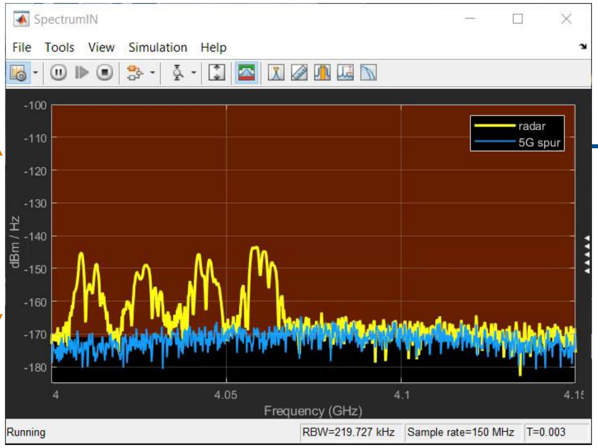
- 5G Base station
  - TX power = 67.5dBm
  - Antenna steered towards airport
- Altimeter receiver
  - RF filter attenuation ~3dB
  - Input referred saturation power ~ -30dBm

- Possible mitigation strategies
  - Increase RF filter attenuation: ~ -40dB
  - Increase receiver saturation: -10dBm
  - Change signal processing algorithm

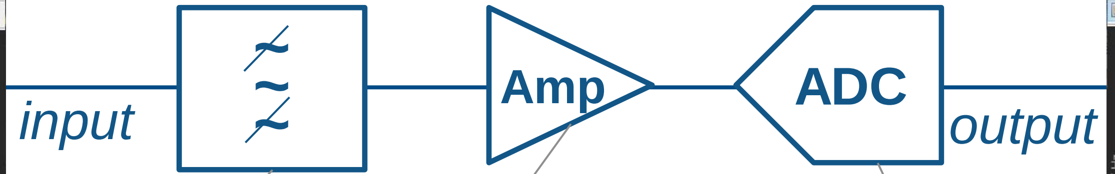


Problem #2: 3GPP Spur Emissions

Spur power



In-band spurs

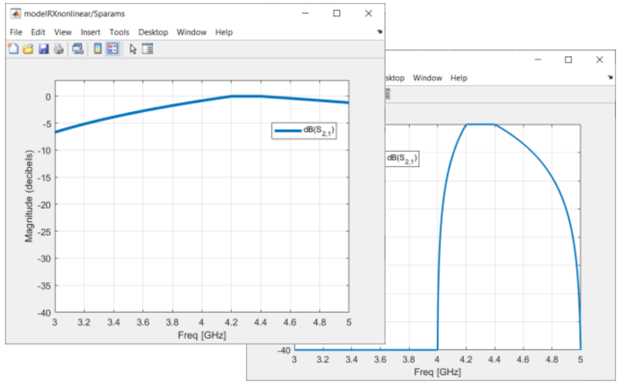


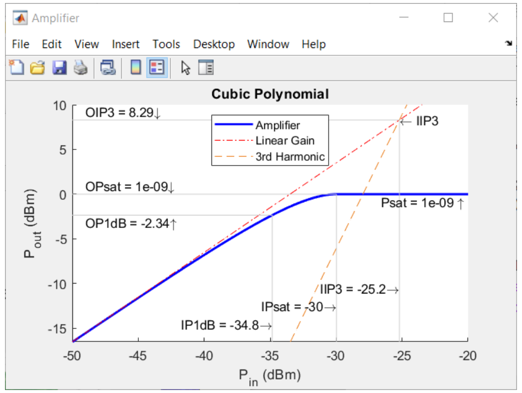
Noise floor

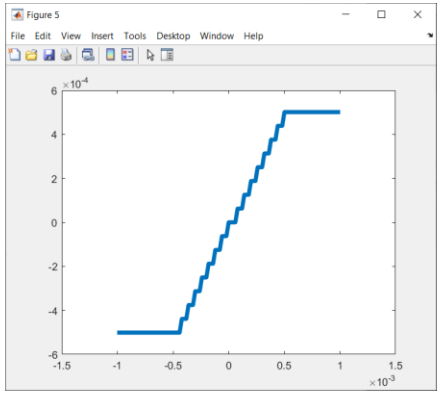
Amplifier
- Gain
- **Noise figure**
- Non-linearity (IP3)
- Saturation

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

Input filter
- S-parameters selectivity





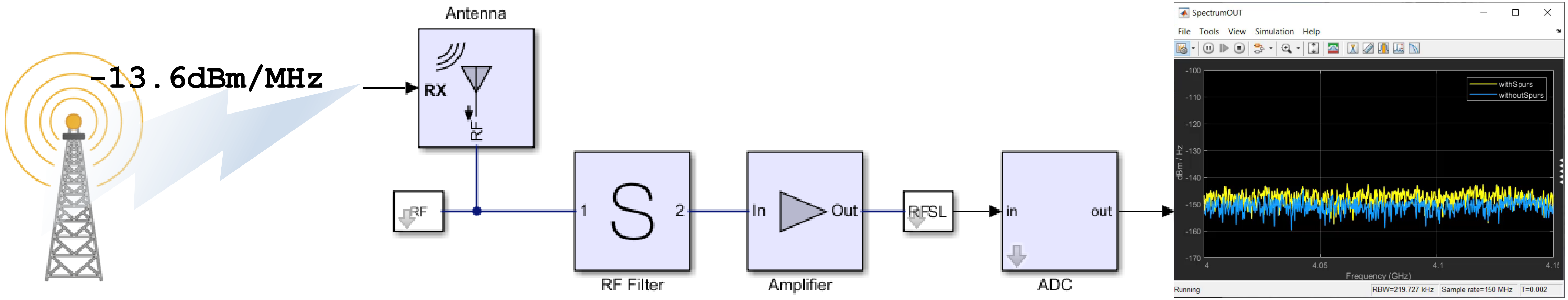


Can 3GPP Spur Emissions Cause Receiver Desensitization?

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

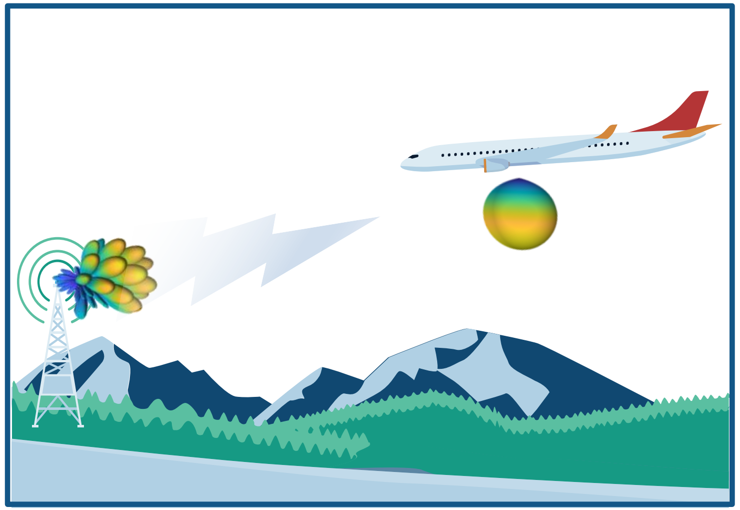
- Model the base station worst-case scenario and compare with regulations
  - TX power = -13.6dBm/MHz
  - Antenna steered towards airport
- Simulate spurious signals and measure noise floor / SNR!

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

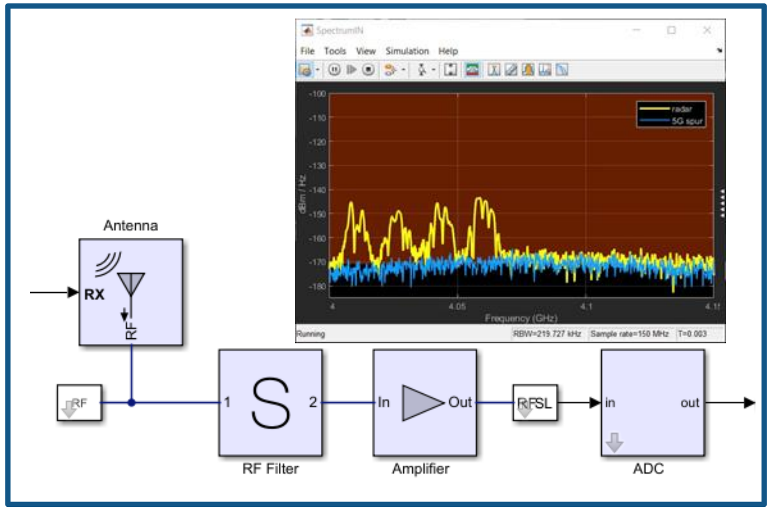


In summary, you can analyze the effects of interference between radar and wireless systems with modeling and simulation

Increasing Congestion in the RF Spectrum



Scenario Modeling for Radar and Wireless Coexistence



Analyze and Simulate in the RF Domain

Thank you

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