Simulation-Enabled 5G Antenna Design
Agenda

1. 5G Motivation and Challenges
2. Mobile Device Antenna Array Example
3. Huawei MIMO Base Station Demonstrator
5G Motivation and Challenges

- Consumer device bandwidth requirements increasing at rapid rates
- Historical (4,3G) bands below 3 GHz increasingly crowded
- Push for 28+ GHz frequency for 5G
  - subject to relatively high atmospheric attenuation
  - smaller wavelength more susceptible to multipath loss
5G Antenna design

Antenna Requirements

- Efficiency is critical, targeted Gain of 12 dB for mobile device and 25 dB for base stations
- Gain cannot come at the expense of coverage - beam steered arrays ideal solution
- Diversity Gain can also be leveraged - MIMO

Simulation challenges

- High frequency and array topology pose simulation challenges (memory, system complexity)
Diversity / MIMO Antennas

Multiple antennas (antenna diversity) may overcome this problem.

Multi-path signal transmission may lead to destructive signal overlay resulting in local deep dips (called Rayleigh-Fading).

Antenna 1

Antenna 2

„best of“ (diversity gain)
Mobile Antenna Array

Element-> Array design
Device level performance
System level performance
Optimized design

Design Guidelines

- To increase (decrease) the resonant frequency, decrease (increase) the patch length.
- To increase bandwidth, increase the substrate height and/or decrease the substrate permittivity (this will also affect resonant frequency and the impedance).
- The bandwidth may be increased (decreased) by increasing (decreasing) the patch width.
- To increase (decrease) the input impedance decrease (increase) the pin inset.

Note: Antennas on very thin substrates have high copper-losses, while thicker and higher permittivity substrates may lead to performance degradation due to surface waves and feed-pin impedance. The effect of surface waves and substrate size are described in the Magus article: "Planar antennas and surface waves." The maximum impedance that can be realised is governed by the impedance seen at the edge of the patch. The minimum realiseable impedance is zero, at the centre of the patch. However, the practical minimum is governed by the rapid impedance variation as the centre is approached.
Mobile Antenna - Array Synthesis

Synthesize planar array for 8 dB gain from Array Factor @ 28 GHz
Mobile Antenna - Array Synthesis

Distribution Matrix Layout

Isotropic Array Pattern

Synthesised Array Pattern

Choose Element Pattern

Export Distribution Matrix (Wavelength)  Export Distribution Matrix (Physical)
Finite Array Performance

Broadside radiation

Full S-Parameter Matrix
Best Achievable Pattern

Theta = 0 deg
Phi = 0 deg

Theta = 15 deg
Phi = 30 deg
Array coverage

Theta=10

Theta=45

Theta=85

Best achievable pattern

Theta 60->12 dBi
Theta 90-> 4.5 dBi
Mobile Antenna Array

Element -> Array design

Device level performance

System level performance
System Assembly Modelling (SAM)

SAM provides convenient layout assembly to bring in phone and other antenna models.

Several copies of array independently placed and parameterizable.
Layout Modelling

After wiring system, switch to layout view and align antenna arrays.
Layout Modelling

- Lower hemispherical array needs to be flipped to aim ‘downward’
- Rotate on axis for diversity
Simulation Task
Simulation Performance

- 3.5 Minutes simulation time per excitation on dual CPU workstation with NVIDIA Kepler 20 GPU (10% GPU capacity)

- 3.48 GB of system Memory utilized for initial Matrix Calculation
Installed Performance - Coupling

- Both arrays operating (boresight), pattern intact
- In band coupling to WiFi antenna, GPS coupling at 5G operating frequency
Installed Performance - Coupling
Installed Performance - Envelope

- Relatively, low coupling to GPS at 28 GHz, but radiation angles towards GPS antenna are affected
- ‘Best Achievable Pattern’ envelope clearly shows performance degraded
Mobile Antenna Array

Element-> Array design

Device level performance

System level performance
CST Installation Help Files include both static and posable CTIA Hand (+spacer) models
System Assembly Modelling

Add posed hand model to System model and align to spacer in Layout mode.
Simulation Performance

- 15 Minutes simulation time per excitation on dual CPU workstation with nVIDIA Kepler 20 GPU (~35% GPU capacity)
- 8.5 GB of system Memory utilized for initial Matrix Calculation
Effects of Hand Model

- ‘Top’ hemisphere array is largely unaffected
- ‘Bottom’ array highly dependent on finger proximity
MIMO Base Station Array Example

Huawei MIMO Base Station Example

- Novel antenna array concept study for small cell sizes (higher capacity and efficiency), 25% bandwidth at 2GHz
- MIMO Diversity gain central to improved efficiency
- 2 logical ports; Polarization diversity utilized (Eh and Ev received)
- 12 physical ports (spatial diversity)
- Unique 360° azimuth plane beam forming capabilities
- Elevation up and down tilt beam steering capabilities
Horizontal Element

- 4 printed arc-dipoles, centrally fed
- Printed stack up and parasitic tuning elements used to obtain good compromise between size and bandwidth (~27%)
Vertical Element

- ‘Small ground’ monopole
- Planar width increases bandwidth
Obtained Return Loss

Broadband impedance matching obtained, while maintaining compact antenna configuration
Array Design and Considerations

- Spacing between horizontal elements a challenge, 
  grating lobes for array
- Top and bottom ground plates introduce phased
  reflections to mitigate; acts as a small ground for
  vertical monopole elements
Summary

- 5G Antenna Device design will require high efficiency devices at frequencies approaching mm wave.
- Beam steering capability to have omni-directional patterns.
- MIMO to leverage diversity gain.
- Antenna Magus provides Antenna and Array synthesis for rapid design exploration.
- System level simulation increasingly important for antenna performance.