Test Resource Management Center (TRMC)

National Spectrum Consortium (NSC) / Spectrum Access R&D Program

Application of Massive MIMO to CRTM

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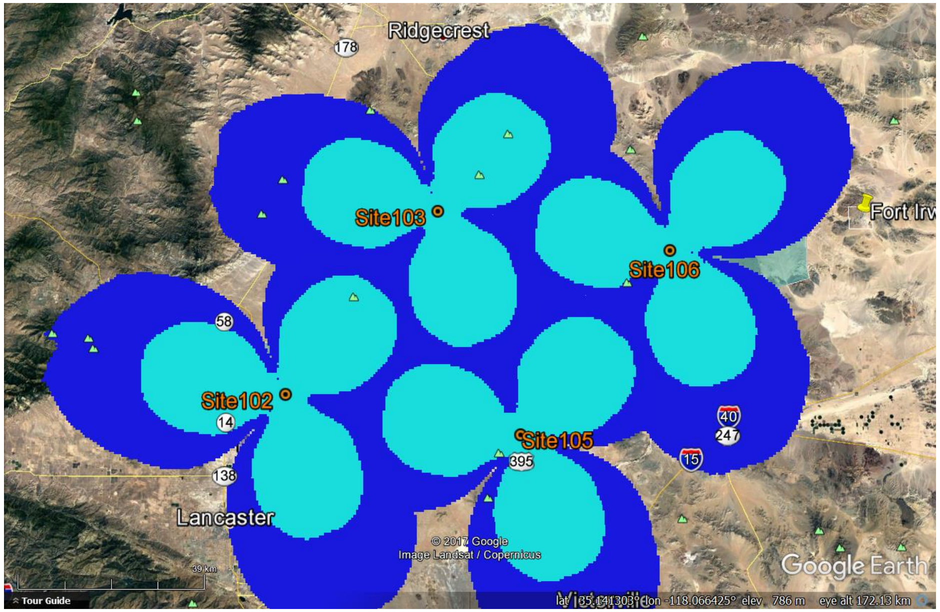
Cellular Range Telemetry (CRTM) concept

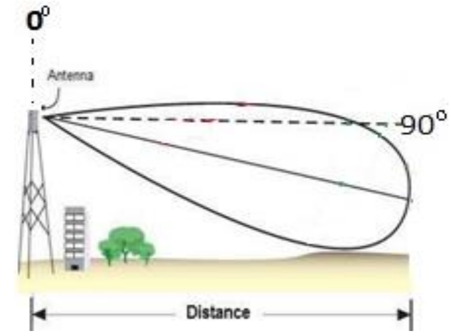
A “cellular” approach to RF coverage

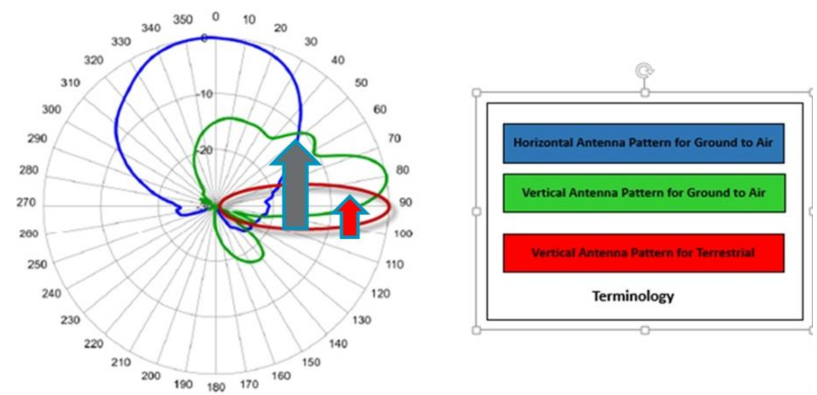
- RF coverage is attained using three “sectors” of coverage around a single site
- Each sector is driven by an antenna and Remote Radio Head (RRH) with all RRHs at a site connected to a single LTE baseband unit
- Sites are placed so as to provide continuous coverage over the desired test space
- Each sector contains 1 or more LTE carriers (“cells” in 3GPP speak). The number of carriers within a sector depends on the data throughput required within that sector
- Typically all sectors contain the same number of carriers, and each carrier can be thought of as part of a single-frequency layer that extends across the system. This allows the capacity of a single LTE carrier to be re-used many times across the system
- An airborne test article is “handed over” as it passes from one coverage area to the next and can also be handed over from one frequency layer to another



Antenna approaches

- Antennas for terrestrial systems are designed for optimal ground coverage from elevated towers using antenna downtilt
  - Vertical beamwidth typically narrow ~10°
  - Narrow vertical beamwidth allows larger azimuthal gain
- Antennas with greater vertical coverage required for test range applications
  - An antenna designed and deployed for the European Aviation Network (EAN) operating at S-band frequencies has increased vertical coverage when used in conjunction with antenna uptilt
  - For the CRTM project, a C-band version of that antenna is being designed
- Shortcomings of the current approach
  - Initial RF coverage simulations are optimistic for high altitude coverage or for lower altitude coverage, but not for both simultaneously.
  - Antenna gain may limit the ability to reach high SINR (UL throughput) over high percentage of the range
  - Insufficient gain to support larger distances for inter-range and over water coverage

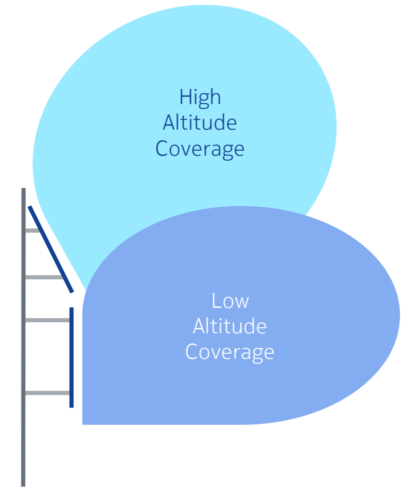


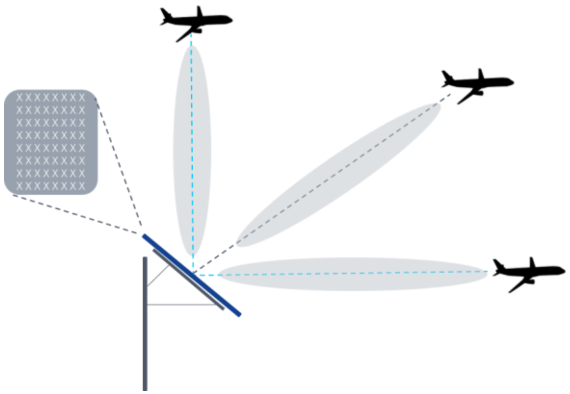


Forward looking CRTM antenna ideas

- Additional antennas
  - Add a second antenna / radio in each sector focused on lower altitude coverage
  - Creates a six sector site with increased capacity
  - Configuration requires no new LTE capability
- Panel arrays with beamforming
  - Allows the ground station to form a narrow beam antenna pattern aimed at a user - reduces interference from airborne transceivers on other test articles
  - Wide antenna aperture allows wider range of altitude coverage
  - Focused beams provide higher gain
  - Allow larger inter-cell distances (fewer sites required) and/or provide higher average throughput over a larger portion of a range
  - Support inter-range coverage and possibly over-water coverage

Lowering the required interference margin and adding antenna gain should result in a significant improvement in coverage area.





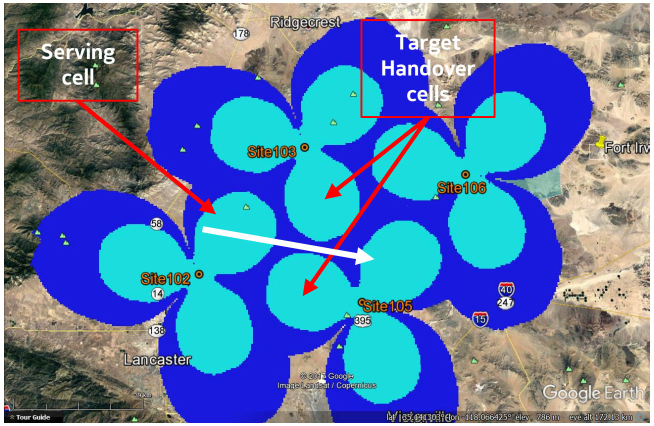
Beamforming approaches

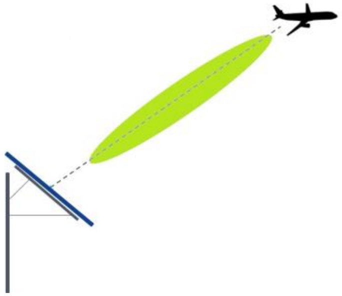
Assumptions

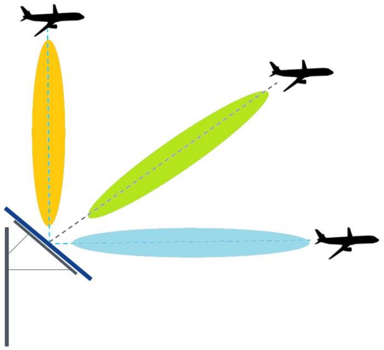
- No beamforming on the test article antenna
  - Keep the implementation of the airborne transceiver simple
- Fixed beam for the downlink transmit signal
  - Airborne terminal needs a broad pattern to be able to determine best serving cell to attach to
- Beamforming implemented on the uplink receive signal at the ground station

Approaches

- One beam (test article) per frequency per sector
  - Simplest approach implementation – beam formed based on maximizing power received in the carrier bandwidth
  - Limits use of carrier to one test article per sector
- Multiple beams (test articles) per frequency per sector
  - Supports multiple test articles per carrier per sector
  - Requires antenna element weights to be calculated simultaneously per test article

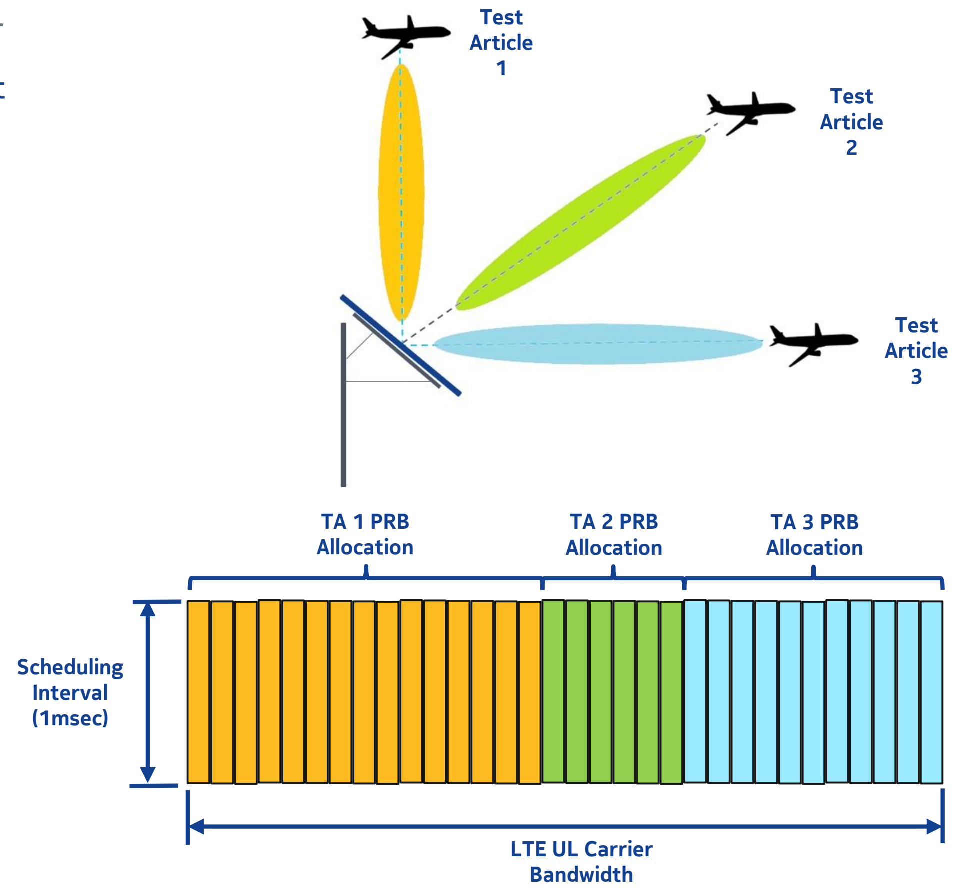






Beamforming implementations

- One beam (test article) per frequency per sector
  - Calculation of antenna element weights can be done at antenna without signal decoding
  - Simple integration with a standard 1Tx / 1 Rx LTE base station configuration
- Multiple beams (test articles) per frequency per sector
  - Antenna element weights calculated for each test article transmission in each scheduling interval
  - Requires knowledge of PRB allocation and decode parameters for each test article – allocations can change every 1msec



Massive MIMO for terrestrial LTE systems

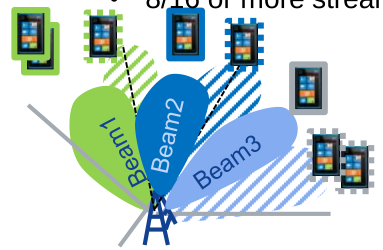
Massive MIMO is the extension of traditional MIMO technology to antenna arrays having a large number (>>8) of controllable antennas

Transmission signals from the antennas are adaptable by the physical layer via gain or phase control

TDD can utilize reciprocal channel with Release 9 (TM8) devices. FDD uses Release 10 (TM9) or Release 13/14 (TM10) devices for feedback.

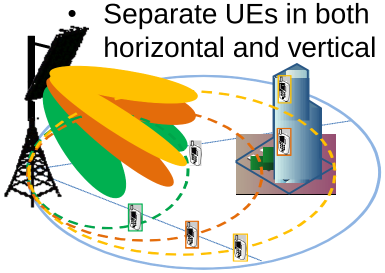
Spectrum Efficiency improvement

- MU-MIMO
- 8/16 or more streams



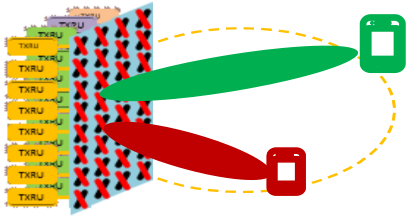
3D coverage

- Separate UEs in both horizontal and vertical



Better User Experience

- Reduce inter-cell interference
- Better UL performance



Capabilities of massive MIMO

Practical at high bands >1.7…3 GHz	Antenna size becomes smaller as operating frequency increases
Works better in TDD than in FDD	TDD can use reciprocal channel with Release 9 (TM8) devices since uplink and downlink use the same frequency. In FDD, mMIMO UL capacity gain is the same as in TDD. FDD provides excellent coverage as there is no time based multiplexing. With slow adaptation and Rel10 (TM9) / Rel13/14 (TM10) UEs DL can work well as well *TDD Works with currently existing UEs*
	Beamforming is integral part of 5G from Day 1
Capacity & coverage solution	Beamforming is a capacity solution in LTE however can also improve coverage
Active antenna	Beamforming requires use of active antennas. Integration of radio helps increase efficiency and realize compact site solutions