The Vectors of 5G

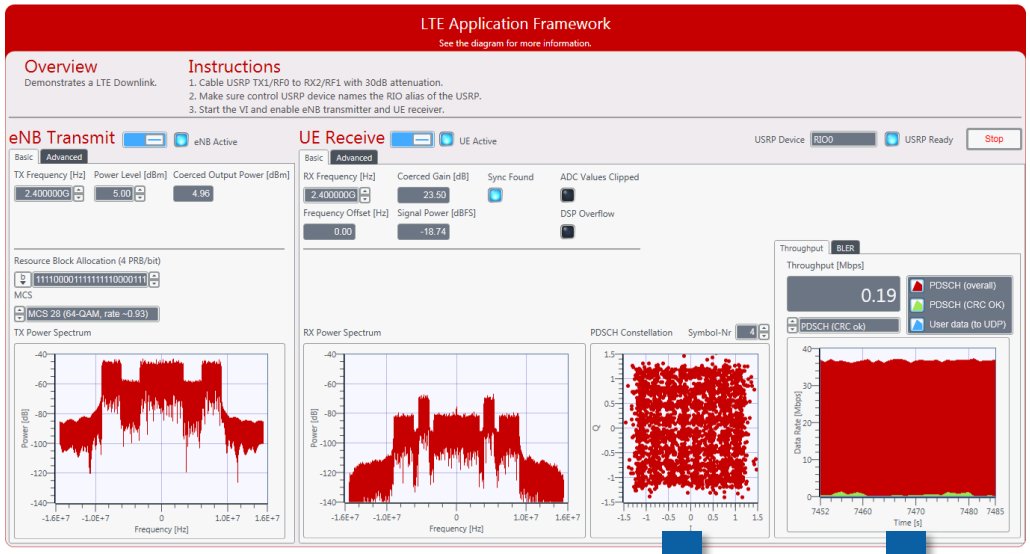
National Instruments' 5G Vision

- 5G will be a combination of various technologies that together will revolutionize how humans and machines can be connected
  - Much higher network capacity (1000x)
  - Much lower latency (10x)
  - Much more ubiquitous coverage
  - Much higher reliability
  - Much lower cost (for the developing world)
- 4 Major Vectors of 5G Innovation
  - Physical layer enhancements
  - Massive MIMO
  - New Network Architectures
  - mmWave access

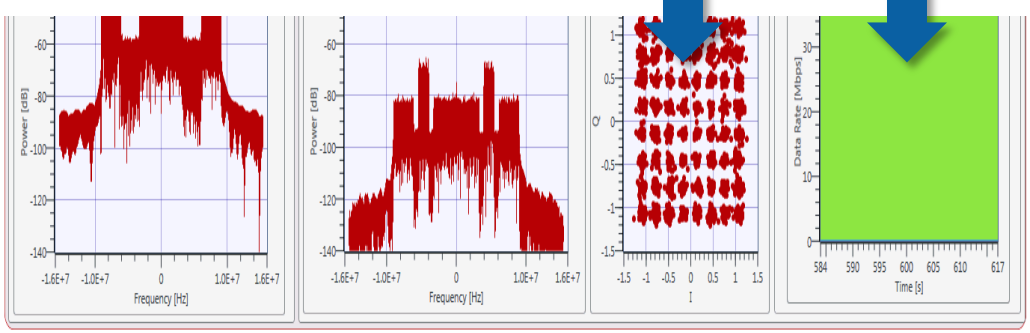
Physical Layer Enhancements

- New flexible 5G waveforms for broad range of scenarios
  - Spectrum agility – opportunistic/flexible/efficient use of available spectrum
  - Low-latency - 1ms or less RTT
  - Ultra-low power machine-type communication
  - Multi-RAT capability – Aggregation of multi-RAT or seamless mmwave HO
- Full-duplex
  - Simultaneous DL/UL over same time-frequency
  - Early promising results on sufficient TX/RX isolation
  - Flexibility to accommodate diverse network scenarios, e.g. D2D, Relays
- Improved Multiple Access
  - Multiuser Superposition Transmission - NOMA

Example results of GFDM versus OFDM



OFDM interference



GFDM interference

- Demonstrated that GFDM has superior performance to OFDM with respect to
  - PAPR
  - side-lobe suppression
  - Flexible waveform parameters to accommodate a wide variety of scenarios
- Other waveforms are also under investigation, and achieve similar superiority over OFDM but with various tradeoffs

* Work in collaboration with TU Dresden

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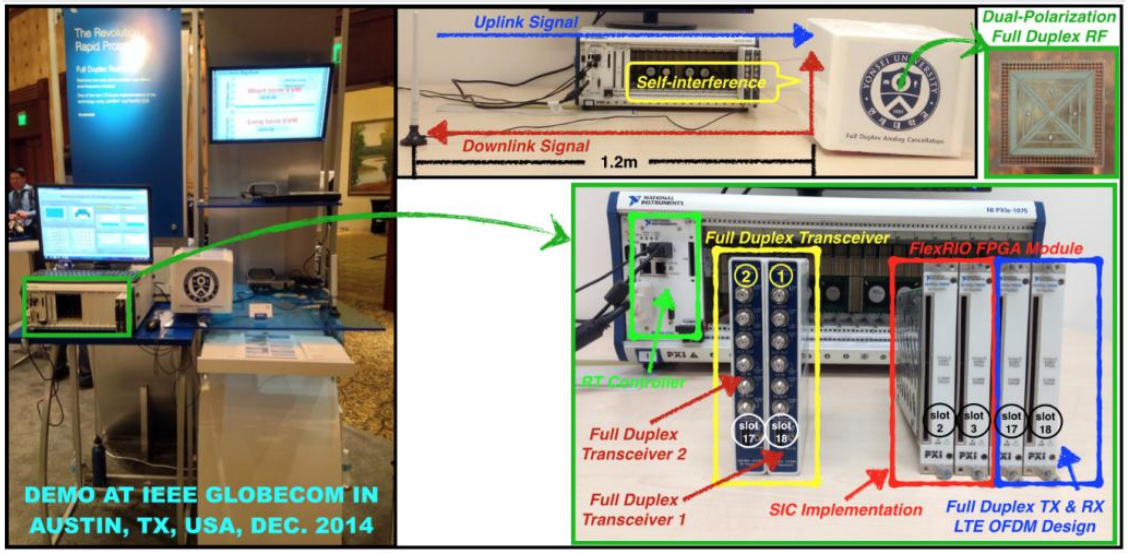
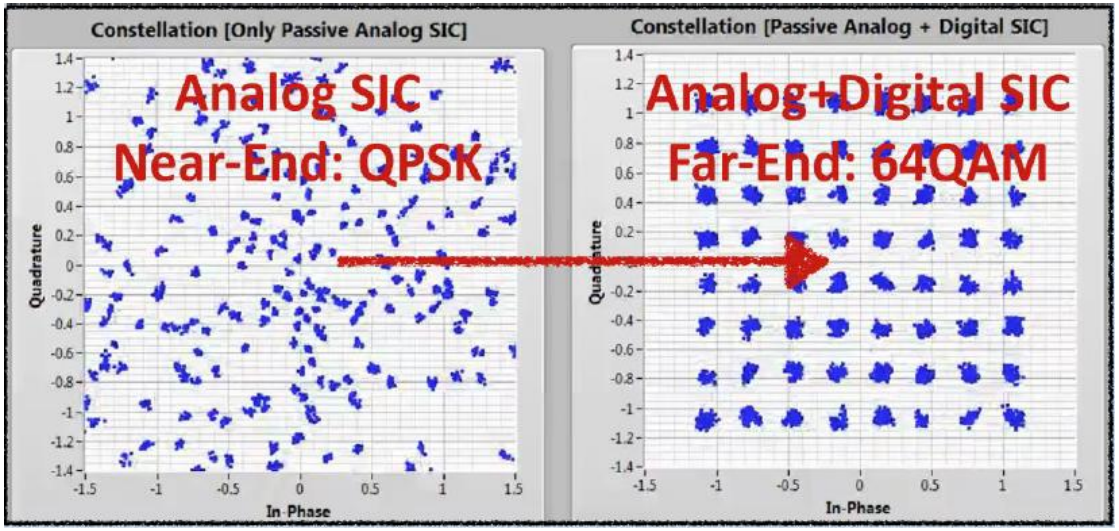
Example Results for Full Duplex LTE





- Demonstrated up to 90dB of analog+digital self-interference cancellation using only linear algorithms

* Work in collaboration with Yonsei University

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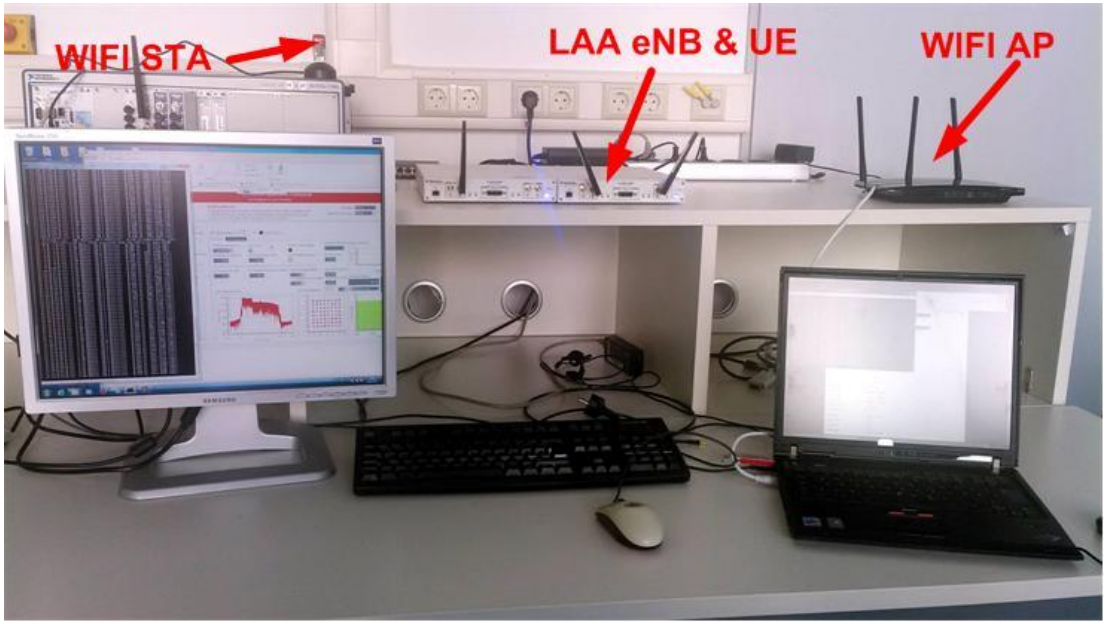
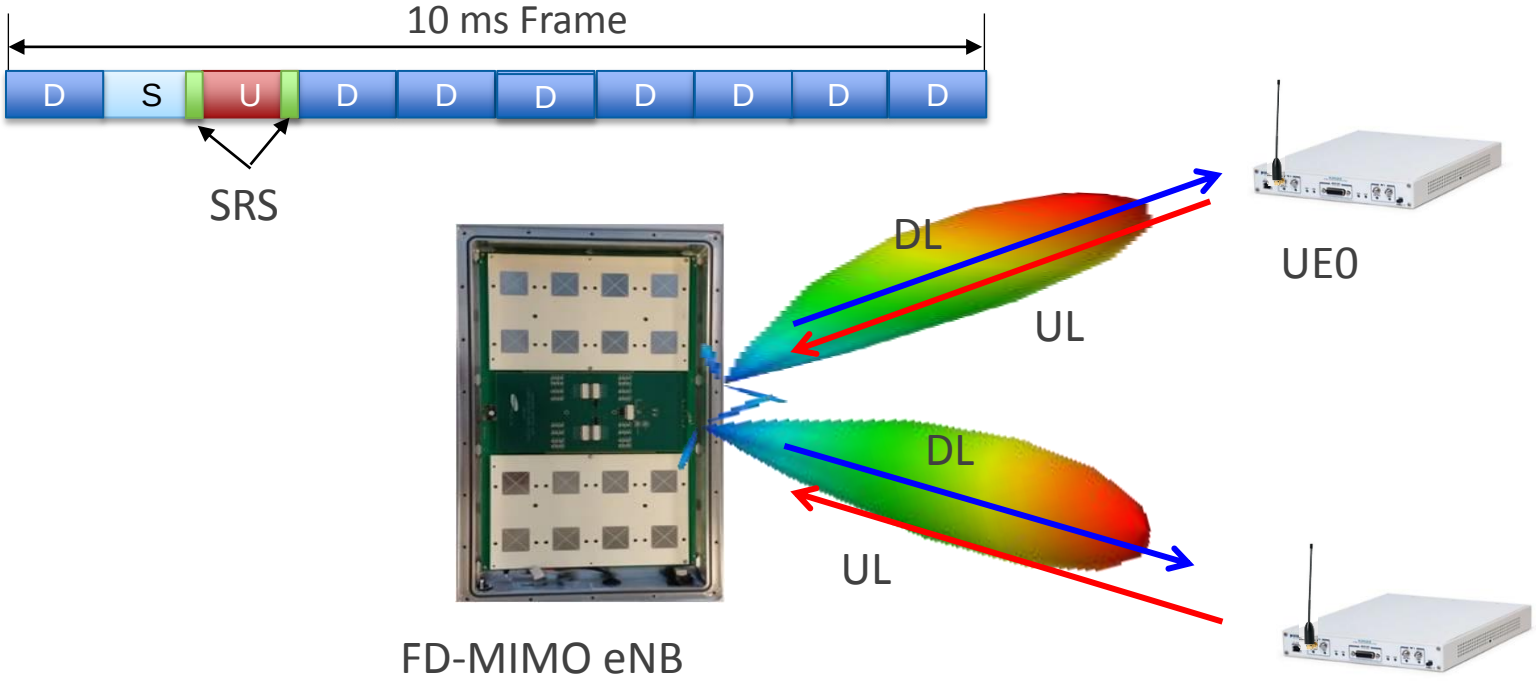
LAA

- LAA/LTE-U testbed to assist in LTE/Wi-Fi coexistence studies in unlicensed bands
- NI 3GPP contribution on LAA Cat 2 LBT algorithm (Aug '15)
  - Showed LAA duty cycle affects Wi-Fi throughput significantly
  - For a given duty cycle, LTE load (resource block allocation) does not impact Wi-Fi throughput
- Currently adding LAA Cat 4 LBT algorithm to test bed



FD-MIMO

- Thoroughly characterized small-cell proof-of-concept system with 3~5 times Rel. 10 capacity target



Adaptive 3D beamforming @ ~100 times per second

Uplink sounding reference signal (SRS)
Downlink shared channel (PDSCH)

* Work in collaboration with Samsung

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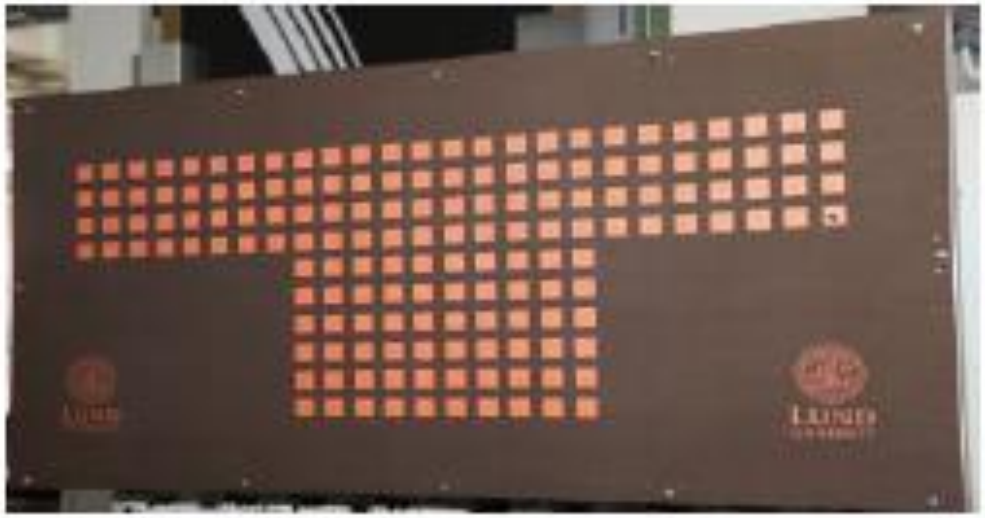
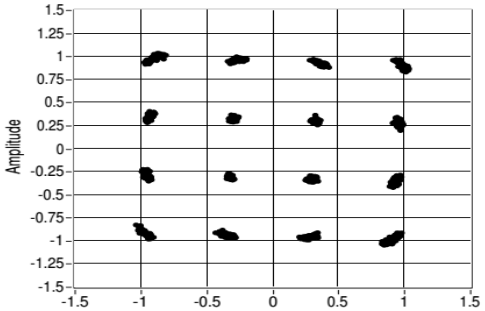
Massive MIMO

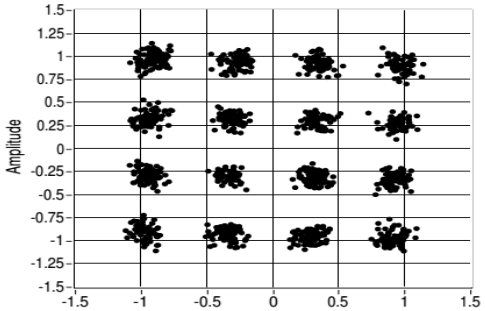
- University research system where 128 antennas @ 20 MHz has been demonstrated
- Distributed processing architecture
- TDD Channel reciprocity needed
- Sub-msec turn-around times demonstrate a step towards high mobility
- Future target of 10x Rel10 capacity



Initial results:
Received signal constellations – LOS & four users 2 m separation



ZF detector

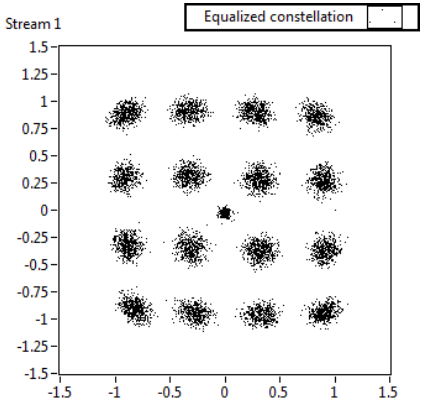


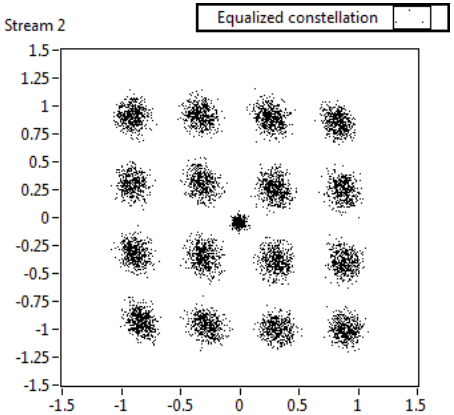
MRC detector

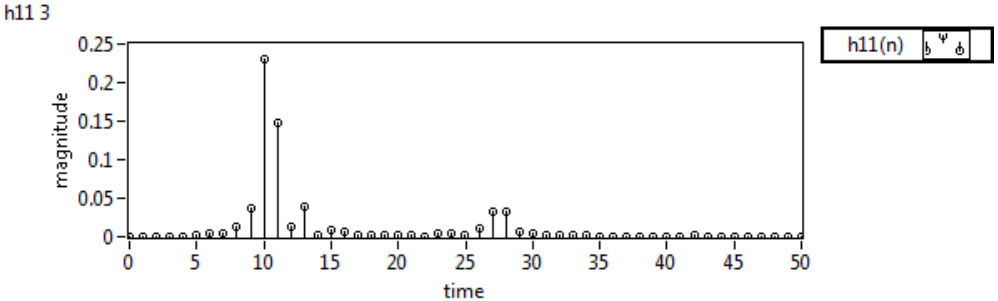
* Work in collaboration with Lund University

mmWave

- New modulation and frame structure needed to exploit the massive bandwidth and the low latency
- Key early results
  - 10Gbps OTA achievable at 72 GHz using Single-carrier Null-CP
  - 200m coverage
  - Beam tracking demonstrated
  - 2-stream MIMO with dual polarization
  - Single carrier numerology achieves PHY latency of <<1ms







* Work in collaboration with Nokia

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