



5G Air Interface Waveforms

3GPP RAN workshop on 5G

Phoenix, USA, September 17-18, 2015

Supported by  **TELSTRA**

Diverse 5G Requirements

- Mobile Broadband
 - Peak user data rates 5 - 10 Gbps
 - Massive capacity (750 Gbps/sq.km)
 - High mobility (500 km/hr)
- Machine Type Communications
 - Massive numbers of devices (150,000/sq.km)
 - Extended link budget (> 20 dB)
 - Low power / low complexity

5G waveforms will be fundamental to satisfying these diverse and stringent requirements

5G Waveform Requirements

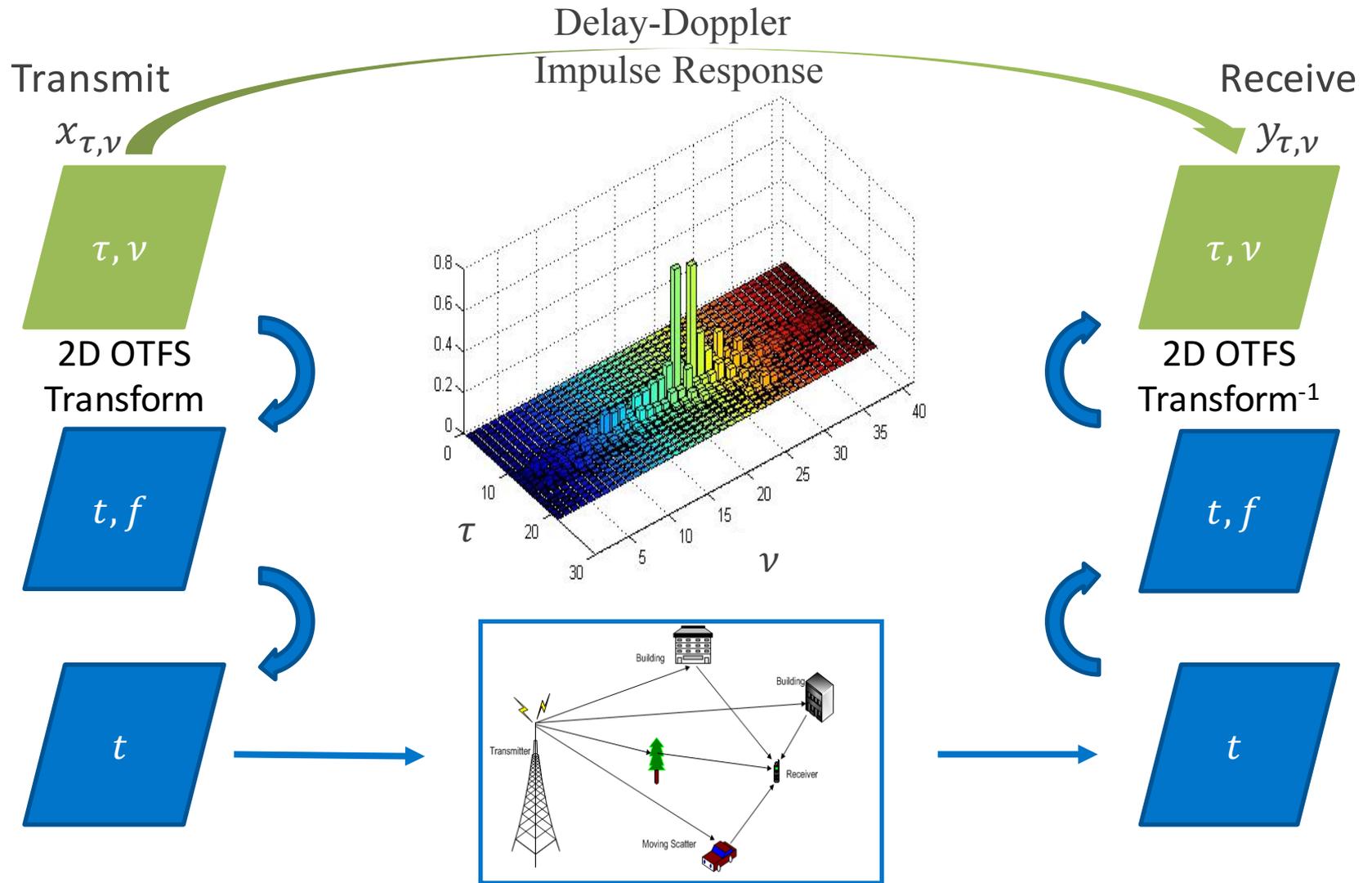
- Further improve spectral efficiency – under all transmission schemes, traffic types & environments
 - MIMO, massive MIMO
 - Multi-point schemes (CoMP)
 - High Doppler
 - Dense deployments (high interference)
- Highly efficient support of connectivity
 - Classic mobile broadband
 - Massive MTC (including deep in-building)
- Low cost transport
 - Robust NLOS wireless backhaul

Key Enabling Waveform Features

- High quality CSI with low pilot overhead
 - Key to further increasing spectral efficiency
 - Multi-antenna (MIMO) & multi-point (CoMP) schemes
 - High Doppler scenarios
- Fully exploit the diversity offered by the channel
 - Maximize spectral efficiency, increased robustness
 - Both high & low data rates
- Performance invariant to Doppler
 - Doppler inherently captured in the channel characterization
- Allow relaxed synchronization
- Integrated “processing gain” to extend link margin

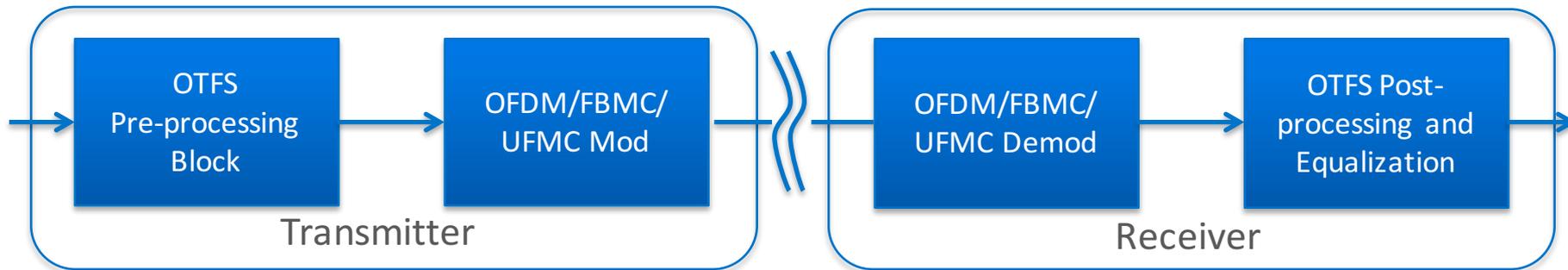
OTFS – The 2D Approach For 5G

Orthogonal Time Frequency Space



OTFS Architecture & Compatibility

QAM Symbols



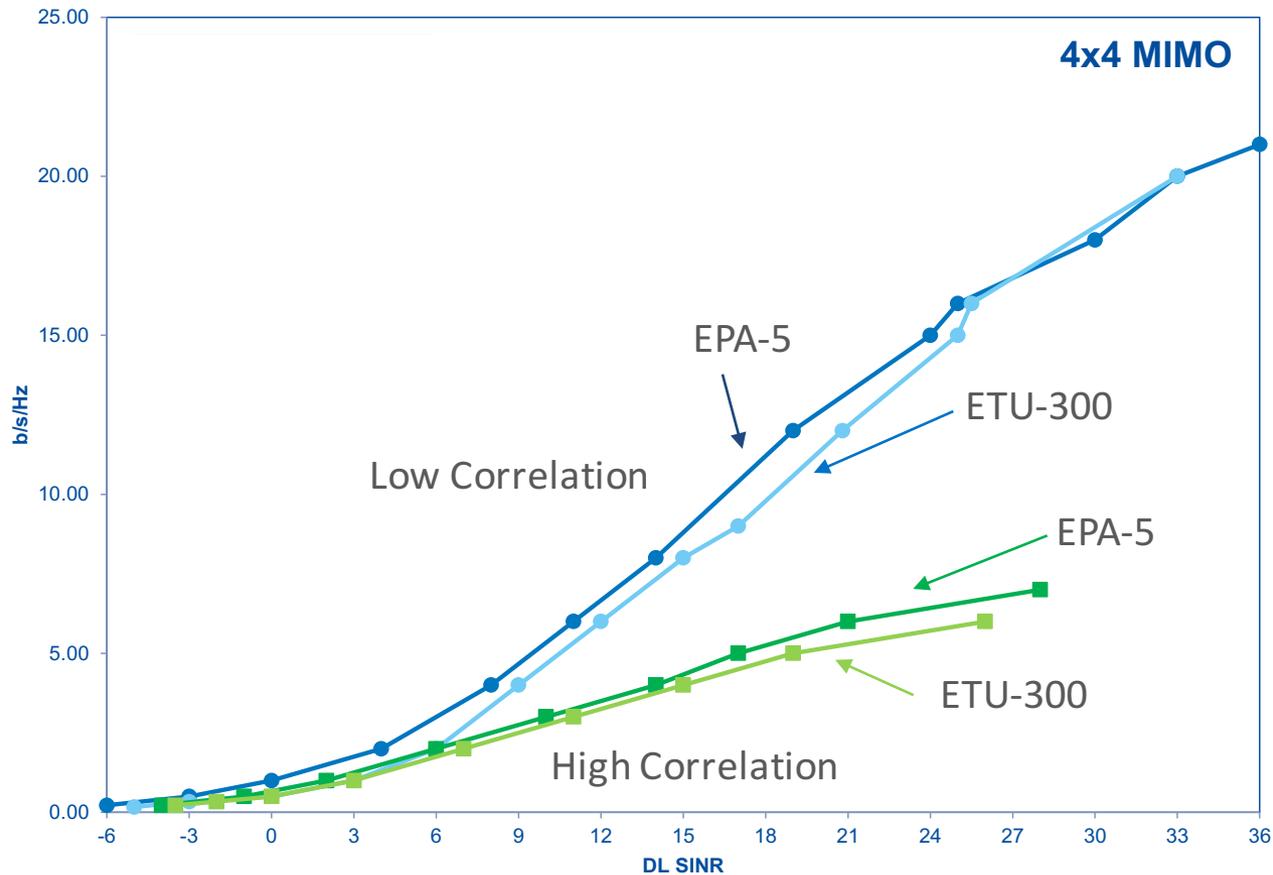
- OTFS is a 2D extension of multicarrier modulations (OFDM, FBMC, UFMC, etc.)
- OTFS can be implemented as an augmentation of multicarrier
 - Incorporate OTFS pre-processing / OTFS post-processing block

Architecturally compatible with LTE

Traditional Multicarrier Limitations

Criteria	Multicarrier	OTFS
Pilot (for CSI and demodulation) overhead	High	Low (<1% per antenna)
Channel estimation quality	Dependent on pilot density and mobility	Exact and independent of mobility
Frequency and time selective fading	QAM symbols experience different SNR	Each QAM symbol experiences exactly the same channel (& SNR)
Performance under high Doppler	Degrades as Doppler increases	Invariant to Doppler
mm-Wave	Impractical to support mobility due to Doppler	Supports mobility / high Doppler from sub 6 GHz to mm-Wave bands

OTFS Measured Spectral Efficiency



OTFS performance is invariant to Doppler

Summary

- OTFS is a new waveform with unique attractive properties, well matched to the requirements of 5G
 - QAM symbols defined in the delay-Doppler domain
 - Very high spectral efficiency in high-Doppler multipath environments
 - Accurate CSI, low pilot overhead, high Doppler tolerance, highly flexible in radio configuration
- Performance does not need to be compromised by mobility
- Properties of OTFS make it suitable for sub-6GHz to mm-Wave bands
- 3GPP should consider waveforms beyond multicarrier variants
 - OTFS should be considered in the mix of technologies for 5G



THANK YOU