Constant Envelope Transceivers in Millimetre-Wave Massive MIMO: EVM and Link Budget Considerations

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INTRODUCTION

- RF 30 GHz ray-tracing simulation,
  - M-MIMO - Urban canyon propagating environment
- Constant Envelope (CE) and Variable Envelope (VE) RF signals evaluated in two models
- Multiple mobile terminals employing single carrier PSK modulation

Why?

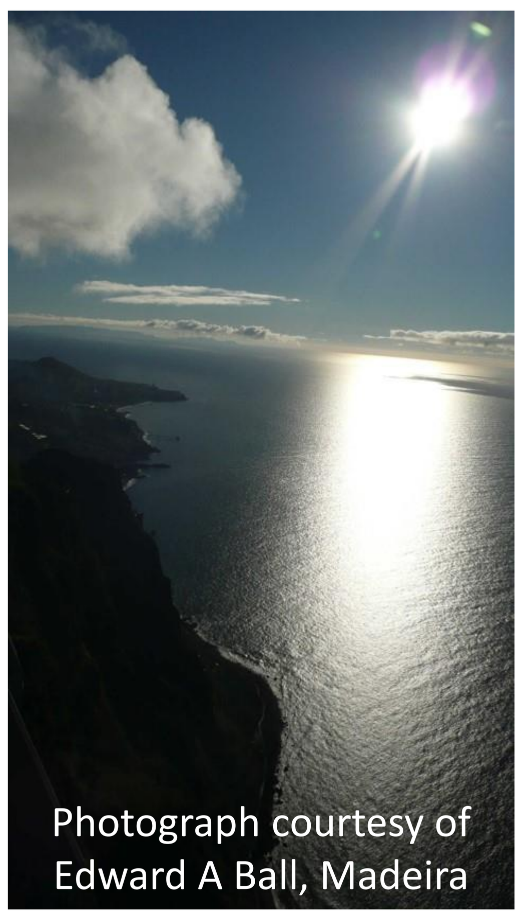
- Need a simple analytical model that approximates real environment
- Understand the effect of the real environment on the M-MIMO TX and RX design.
- Propose simplified TX and RX design architectures.

Glistening Zone Model

The two models

Reflection source	*Ray Rich*	*Ray Sparse*
Road reflections	13 rays	4 rays
Single wall reflections	8 rays	2 rays
Double wall reflections	10 rays	2 rays
Total reflective rays	31	10

Each BS M-MIMO antenna element could potentially provoke production of these ray sets – leading to a propagation channel model



Photograph courtesy of Edward A Ball, Madeira

Physical Model

- Obtain surface reflection coefficients for medium:

$$|\Gamma| = \left|\frac{Z_2 - Z_1}{Z_2 + Z_1}\right|$$

- Z_2 & Z_1 perpendicular or parallel impedances:

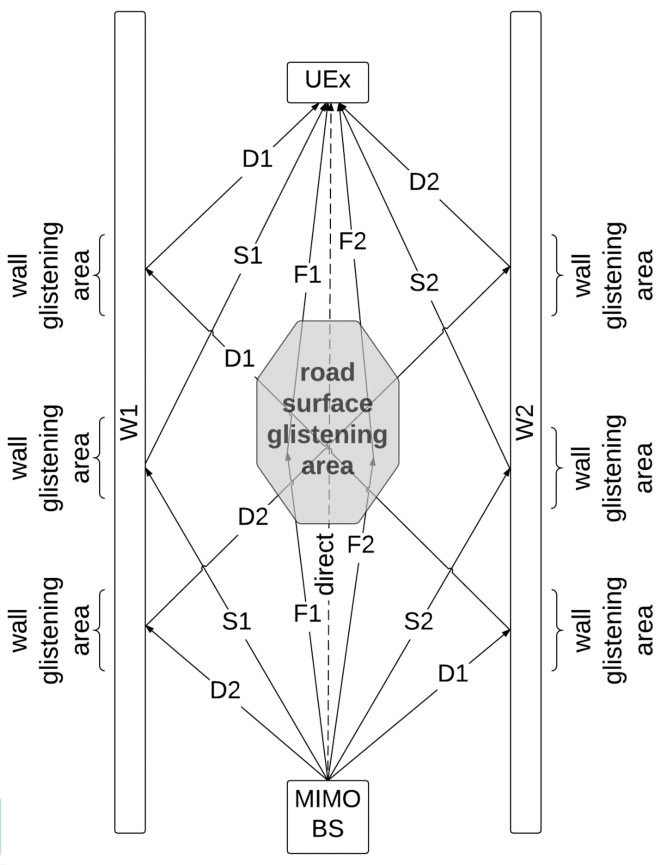
Air: $\eta_1 = 120\pi$

Lossy media: $\eta_2 = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\varepsilon}}$

- Use Snell's law to relate angle of incidence & transmission from surface of medium:

$$\sin(\theta_t) = \frac{\gamma_1}{\gamma_2}\sin(\theta_i),\ \gamma_{1,2} = \frac{-\omega\mu}{j\eta_{1,2}}$$

Hence |Γ| can be predicted



MIMO Channel Model

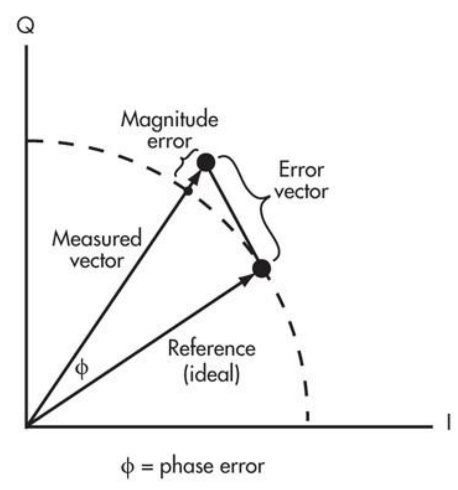
Complex amplitudes of received symbols, after TX **Conjugate Precoding**

$$R_{VE1,2,3} = \sum_x \sum_y H_{UE1,2,3}[x,y] T_{composite}[x,y]$$

$$R_{CE1,2,3} = \sum_x \sum_y H_{UE1,2,3}[x,y] T_{CE}[x,y]$$

$T_{composite}$: VE model $\quad T_{CE}$: CE model

$H_{UE1,2,3}$: Channel transfer function, path of each MIMO BS TX to UE



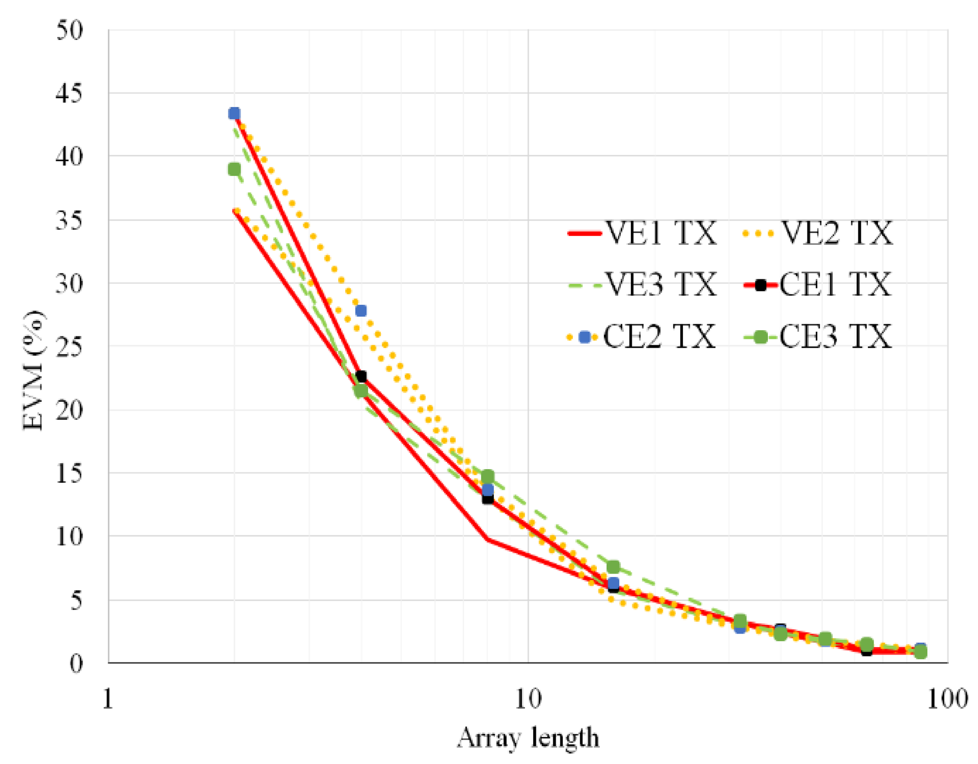
Evaluate symbol EVM and link budget!

What is EVM?

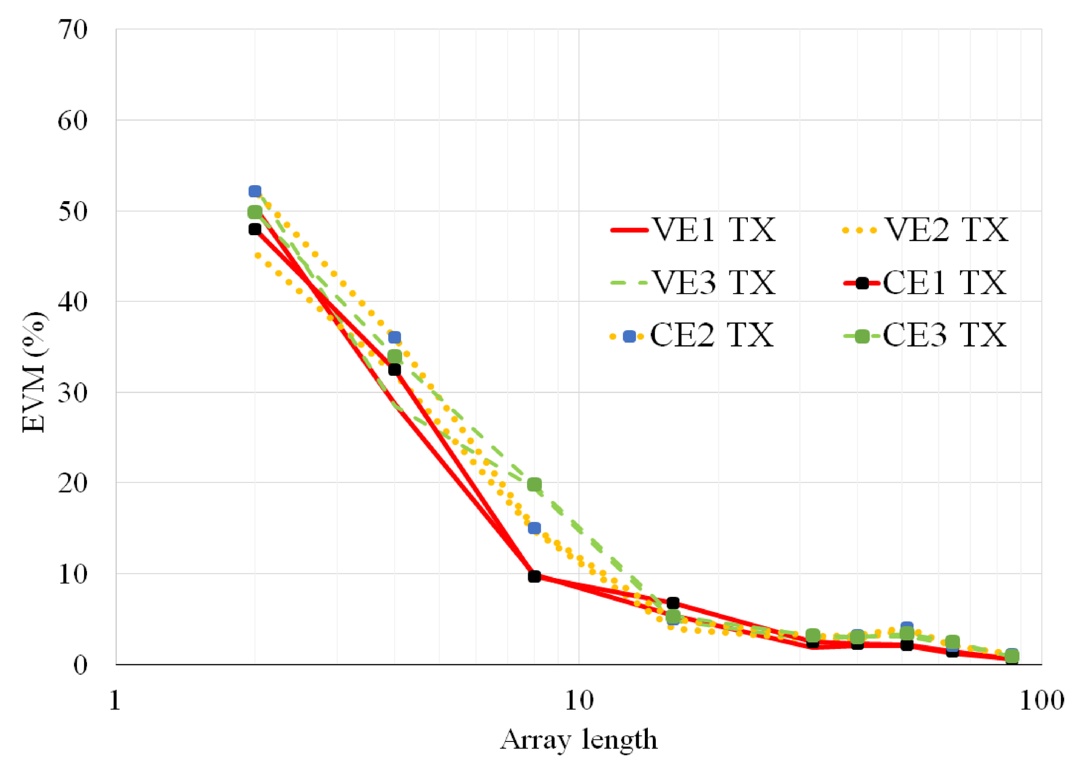
Error Vector Magnitude (EVM) is the vector distance between ideal and measured IQ symbols.

Effects due to TX nonlinearity

EVM as function of array length N (UE 1 at 20 m, UE2 at 30 m, UE3 at 30 m)



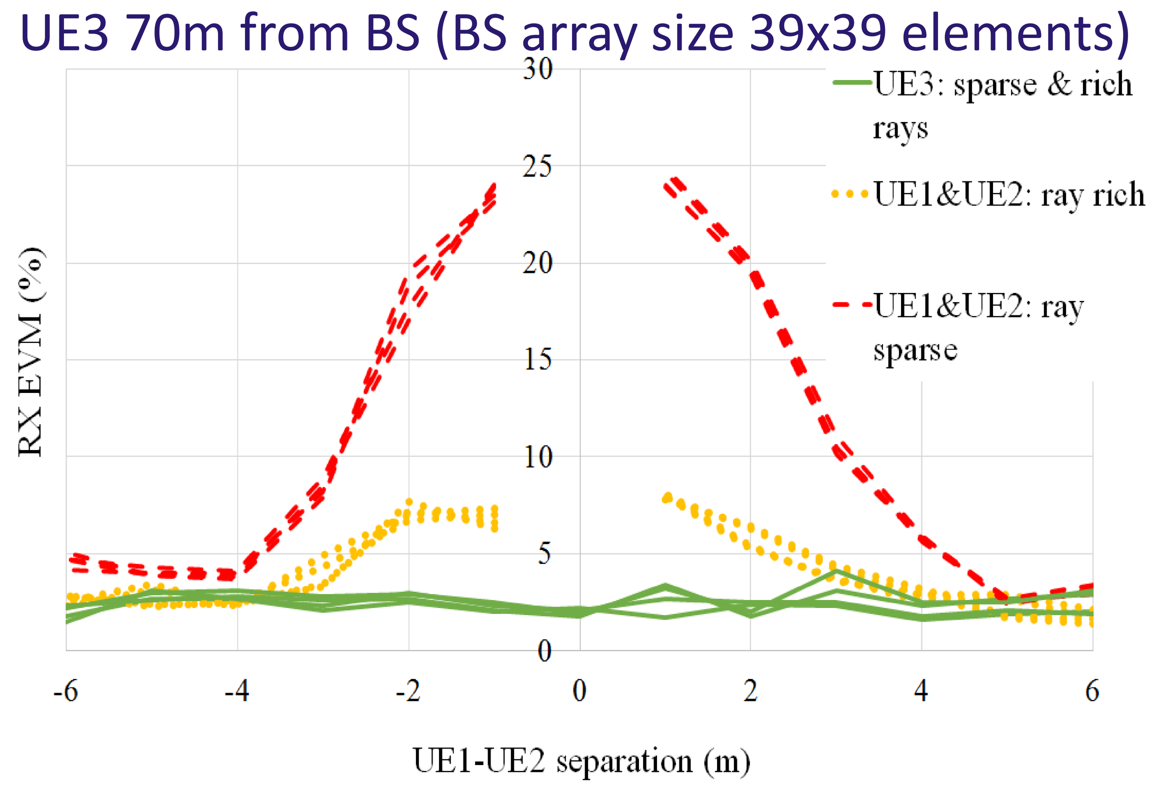
Ray-rich model



Ray-sparse model

EVM as function of UE1-UE2 relative separation (circa 40m from BS)

UE3 70m from BS (BS array size 39x39 elements)



Once UE1 and UE2 are more than 5m apart, EVM is similar to UE3, for both ray models

TX Nonlinearity & Link Budget

EVM & RX powers for UEs (ray-rich channel), UE1 at 50m, UE2 at 100m, UE3 at 200m from BS

BS URA array size	UE1 EVM VE / CE (%)	UE2 EVM VE / CE (%)	UE3 EVM VE / CE (%)	UE1 RX level (dBm)	UE2 RX level (dBm)	UE3 RX level (dBm)
64x64	1.4/1.5	1.3/1.5	1.2/1.4	-51	-58	-68
51x51	1.4/1.7	2/2	1.9/2.2	-59	-66	-75
32x32	2.1/2.4	3.4/3.5	3.3/3.2	-75	-82	-92
16x16	3.8/4.6	4.1/5.2	4.4/3.9	-99	-106	-116
8x8	12/16	10/12	10/14	-123	-130	-140

RX sensitivity was based on maximizing signal BW use of Coherence BW

The resulting RX sensitivities (table) were, UE1: -70dBm, UE2: -67dBm and UE3: -64dBm

The array size required to achieve link budget exceeds array size required for just interference-based low EVM

CONCLUSIONS

1. RX EVM is **not** a strong function of CE TX but a function of relative proximity of UEs BS distance and propagation ray richness
2. Pragmatic mmWave M-MIMO modulation schemes should be adaptive, EVMs of 5 - 30% using low complexity MF conjugate precoding and CE TX chains
3. Explicit forming and pointing of a narrow beam does not appear prerequisite
4. BS hardware architectures should focus on
   - Low DC power
   - Cost-effective hardware solutions
   - Simple baseband implementations
5. Reconfigurable BS enables trade-off between
   - Numbers of UEs supported
   - Service range
   - DC power