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INTRODUCTION

• RF 30 GHz ray-tracing simulation,
  o 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

<table>
<thead>
<tr>
<th>Reflection source</th>
<th>Ray Rich</th>
<th>Ray Sparse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road reflections</td>
<td>13 rays</td>
<td>4 rays</td>
</tr>
<tr>
<td>Single wall reflections</td>
<td>8 rays</td>
<td>2 rays</td>
</tr>
<tr>
<td>Double wall reflections</td>
<td>10 rays</td>
<td>2 rays</td>
</tr>
<tr>
<td>Total reflective rays</td>
<td>31</td>
<td>10</td>
</tr>
</tbody>
</table>

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

MIMO Channel Model

Complex amplitudes of received symbols, after TX Conjugate Precoding

\[ R_{VE1,2,3} = \sum_{\mathbf{x}, \mathbf{y}} H_{UE1,2,3}[\mathbf{x}, \mathbf{y}] T_{\text{composite}}[\mathbf{x}, \mathbf{y}] \]

\[ R_{CE1,2,3} = \sum_{\mathbf{x}, \mathbf{y}} H_{UE1,2,3}[\mathbf{x}, \mathbf{y}] T_{\text{CE}}[\mathbf{x}, \mathbf{y}] \]

Evaluate symbol EVM and link budget!

What is EVM?

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

Physical Model

• Obtain surface reflection coefficients for medium:

\[ |\Gamma| = \frac{|Z_2 - Z_1|}{|Z_2 + Z_1|} \]

\[ Z_2 \text{ and } Z_1 \text{, perpendicular or parallel impedances:} \]

Air: \( \eta_1 = 120\pi \)

Lossy media: \( \eta_2 = \frac{\sqrt{\mu\sigma - j\omega \sigma e}}{\sigma + j\omega \sigma} \)

• Use Snell’s law to relate angle of incidence & transmission from surface of medium:

\[ \sin(\theta_i) = \frac{Z_2}{Z_1} \sin(\theta_t), \quad \eta_{12} = \frac{\omega}{\eta_1 \eta_2} \]

Hence |\(\Gamma|\) can be predicted.

Effects due to TX nonlinearity

EVM as function of array length N (UE 1 at 20 m, UE 2 at 30 m, UE 3 at 30 m)

Ray-rich model

Ray-sparse model

TX Nonlinearity & Link Budget

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

<table>
<thead>
<tr>
<th>BS URA array size</th>
<th>UE1 EVM VE/CE (%)</th>
<th>UE2 EVM VE/CE (%)</th>
<th>UE3 EVM VE/CE (%)</th>
<th>UE1 RX level (dBm)</th>
<th>UE2 RX level (dBm)</th>
<th>UE3 RX level (dBm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>54x64</td>
<td>1.4/1.6</td>
<td>1.3/1.5</td>
<td>1.2/1.4</td>
<td>-51</td>
<td>-58</td>
<td>-68</td>
</tr>
<tr>
<td>31x31</td>
<td>1.4/1.7</td>
<td>2/2</td>
<td>1.9/2.2</td>
<td>-59</td>
<td>-66</td>
<td>-75</td>
</tr>
<tr>
<td>12x32</td>
<td>2/2.4</td>
<td>3/4.3</td>
<td>3/3.2</td>
<td>-75</td>
<td>-82</td>
<td>-92</td>
</tr>
<tr>
<td>16x16</td>
<td>3/4.6</td>
<td>4/1.5</td>
<td>4/3.9</td>
<td>-99</td>
<td>-106</td>
<td>-116</td>
</tr>
<tr>
<td>8x8</td>
<td>12/16</td>
<td>10/12</td>
<td>10/14</td>
<td>-123</td>
<td>-130</td>
<td>-140</td>
</tr>
</tbody>
</table>

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
   o Low DC power
   o Cost-effective hardware solutions
   o Simple baseband implementations
5. Reconfigurable BS enables trade-off between
   o Numbers of UEs supported
   o Service range
   o DC power