Optimizing RF Signal Performance to Improve LTE Coverage and Capacity

Tim Keller
Presentation Abstract

• With the dramatic growth of data traffic, service providers are increasingly turning to 4G LTE to provide the capacity their subscribers demand. Cell site optimization and improving the RF signal performance of LTE networks has become critical. Tower mounted amplifiers (TMAs) are a cost-effective solution that can be used to expand a cell site’s coverage area (including VoLTE rollouts) and improve the signal-to-noise ratio for the uplink path. This presentation will discuss how TMAs help service providers by optimizing the receive sensitivity of a site’s antenna system, expanding the site’s coverage area and providing higher uplink data throughput.
Agenda

• Market Trends
• Problems and challenges
• Options and solutions
• Benefits of uplink improvements
• Conclusion
• Q&A
Market Trends
Market Trends - Mobile Data Growth 2013-2019

- Mobile data grows at CAGR of 45% from 2013 to 2019
- Driven by the widespread adoption of Smartphones
  - Users of newer Smartphones use more data
    - Models from 2013 consumed 7.2 times more data than 2009 models
    - Larger screen sizes and more processing power → more data usage
    - Data growth dominates voice growth
    - Even in mature markets with high Smartphone usage data growth is significant
- Faster growth on the uplink than on the downlink
  - In 2013, downlink data grew at 100% while uplink grew 141%
    - Indicates growth in video sharing, video conferencing, social networking

Source: Ericsson Mobility Report, June 2014
Market Trends - Mobile Providers Turn to LTE

• Operators have committed to 500 networks
  – 49 Networks in North America

• LTE connections are forecast to surpass 2.3 billion by 2020
  – 125.8 million connection in North America

• 10 radio spectrum bands used for LTE today ranging from 700 MHz to 2.6 GHz

• LTE-Advanced deployments beginning
  – AT&T launched LTE-Advanced in March 2014
Problems and Challenges
Problems and Challenges

• Data hungry consumers with tight budgets
  – Large or unlimited data plans are becoming more common

  **Verizon undercuts AT&T with $60 plan for unlimited talk, text and 2 GB for individuals**
  August 18, 2014 | By Phil Goldstein

  **Sprint drops unlimited everything plan to $60, undercuts T-Mobile by $20**
  August 21, 2014 | By Mike Dano

  **T-Mobile cuts prices on family plans with 7-10 lines, launches $10/month tablet plan**
  August 26, 2014 | By Phil Goldstein

• Net result → ARPU is falling and the average revenue per megabyte of data is falling dramatically.
Problems and Challenges

• Introduction of VoLTE
  – In order to satisfy customers demand for data, operators need to move voice services from 2G and 3G networks to LTE and eventually re-commission the freed up spectrum for LTE

• Key issues for VoLTE deployment
  – Handset availability
    • Two handsets made available by Verizon in their VoLTE rollout
  – Coverage, coverage, coverage
    • Coverage holes mean CSFB is required → can’t decommission 2G/3G
Options and Solutions
Options and Solutions

• Goal – Overcome large link budget imbalance of LTE

• Options
  – Increase transmit power of mobile devices
    • Not practical
  – Build more macro cell sites
    • Expensive, time-consuming
  – Bring RF point of presence closer to the user
    • DAS, Small Cells
      • Attractive options that will continue to grow for the foreseeable future
        » Still RF challenged areas will exist
  – Use Tower Mounted Amplifiers to boost uplink
TMA Overview

- Cost effective tool for optimizing cell site RF signal performance
- Band specific, dual-duplexed, tuned cavity filter with a low noise amplifier (LNA) for the uplink signal
- Typically mounted on the top of a cell tower close to the antenna and before the long lossy cable run to the eNodeB
- What does a TMA do?
  - Filters and amplifies the uplink signal
  - Filters the downlink signal
  - Provides auto-bypass in case of failure
    - Sector stays up but with slight degradation
Benefits of Uplink Improvement
TMA Specs – Gain and Noise Figure

• Two important specifications of a TMA
  – Noise figure
  – Gain

• TMA Gain and Noise figure are used to calculate the overall system noise figure using the Friis Equation

\[ F_{System} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1G_2} + \ldots + \frac{F_n - 1}{G_1G_2\ldots G_{n-1}} \]
Cascaded NF Calculation – Baseline

![Diagram showing cascaded NF calculation](image)

\[ F_{\text{System}} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \cdots + \frac{F_n - 1}{G_1 G_2 \cdots G_{n-1}} \]

### Baseline - No TMA

<table>
<thead>
<tr>
<th>Receive System Component</th>
<th>Item</th>
<th>dB</th>
<th>Linear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jumper Cable</td>
<td>F1</td>
<td>0.10</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>G1</td>
<td>-0.10</td>
<td>1.0</td>
</tr>
<tr>
<td>Main Feeder Cable</td>
<td>F2</td>
<td>3.00</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td>-3.00</td>
<td>0.5</td>
</tr>
<tr>
<td>Jumper Cable</td>
<td>F3</td>
<td>0.50</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>G3</td>
<td>-0.50</td>
<td>0.9</td>
</tr>
<tr>
<td>eNodeB</td>
<td>F4</td>
<td>3.75</td>
<td>2.4</td>
</tr>
<tr>
<td></td>
<td>G4</td>
<td>0.00</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>SYSTEM</strong></td>
<td>NF</td>
<td>7.35</td>
<td>5.4</td>
</tr>
</tbody>
</table>
Cascaded NF Calculation – Tower Mounted TMA

\[
F_{\text{System}} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \cdots + \frac{F_n - 1}{G_1 G_2 \cdots G_{n-1}}
\]

### TMA Mounted at Tower Top

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<td>1.0</td>
</tr>
<tr>
<td>TMA</td>
<td>F2</td>
<td>1.10</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td>13.00</td>
<td>20.0</td>
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**SYSTEM NF**

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<tbody>
<tr>
<td>SYSTEM</td>
<td>NF</td>
<td>1.88</td>
<td>1.5</td>
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</table>

**Improved Rx Sensitivity**

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<tbody>
<tr>
<td></td>
<td>5.47</td>
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Cascaded NF Calculation – Ground Mounted TMA

![Diagram of cascaded NF calculation]

\[
F_{\text{System}} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \ldots + \frac{F_n - 1}{G_1 G_2 \ldots G_{n-1}}
\]

### TMA Mounted on Ground

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<td>0.00</td>
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</tr>
<tr>
<td>SYSTEM</td>
<td>NF</td>
<td>4.93</td>
<td>3.1</td>
</tr>
</tbody>
</table>

**Improved Rx Sensitivity** | **2.42**
Mobile Internet Performance Driver

Maximum Wireless Data Rate
Shannon Theory: \( C = H \times \log_2 (1+\text{SNR}) \)

Key parameters to optimize data rate:
1) Spectrum bandwidth (H)
2) Wireless standards (Adaptive data rate)
3) Network implementation and optimization (SNR)
Important TMA Characteristics

• Noise figure (NF) and noise factor ($F$)
  – Measures of degradation of the signal-to-noise ratio (SNR) caused by components in a radio frequency signal chain
  – Number used to specify performance of a radio receiver

• Gain
  – Measure in dB of the amplification applied to the uplink signal

• Passive Intermodulation (PIM)
  – Result of two or more frequencies interacting with one another to create separate harmonic that can degrade system performance

• Insertion Loss
  – Loss of signal power as a result of inserting a device in a transmission line

• Return Loss
  – Loss of signal power caused by reflection due to a discontinuity in a transmission system
# TMA Value Proposition - Uplink KPI Improvements

<table>
<thead>
<tr>
<th>Uplink KPI</th>
<th>Rural</th>
<th>Urban</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRC Drops</td>
<td>25-35%</td>
<td>0-10%</td>
</tr>
<tr>
<td>RRC Failures</td>
<td>35-40%</td>
<td>0-10%</td>
</tr>
<tr>
<td>Reduced UE Transmit Power</td>
<td>3-6dB</td>
<td>1-3dB</td>
</tr>
<tr>
<td>Coverage Area Expansion</td>
<td>50-100%</td>
<td>15-50%</td>
</tr>
<tr>
<td>QPSK BLER</td>
<td>5-15%</td>
<td>5-15%</td>
</tr>
<tr>
<td>16QAM BLER</td>
<td>0-5%</td>
<td>0-20%</td>
</tr>
<tr>
<td>HARQ ACK %</td>
<td>2-6%</td>
<td>2-6%</td>
</tr>
<tr>
<td>Average Data Throughput</td>
<td>0-20%</td>
<td>15-50%</td>
</tr>
<tr>
<td>Average Packet Loss</td>
<td>10-50%</td>
<td>20-60%</td>
</tr>
<tr>
<td>SINR</td>
<td>0-2dB</td>
<td>1-3dB</td>
</tr>
<tr>
<td>TTI Occupancy</td>
<td>20-40%</td>
<td>20-40%</td>
</tr>
</tbody>
</table>
Conclusion
TMA Value Proposition

**Expand Coverage Area**
- Balance link budget equation
- Extends range of uplink signal
- Improves in-building coverage
- Critical for VoLTE

**Increase Site Capacity**
- Higher uplink data throughput
- More users due to expanded coverage area
- More users due to in-building coverage

**Improve User Experience**
- Faster uploads
- Fewer dropped calls
- Extended battery life

**Cost Effective and Highly Reliable**
- Reduce need for new site builds
- MTBF of over two million hours
- Automatic LNA bypass ensures site remains up even during failure
Questions?

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For more information visit us at:
www.westell.com