P25 C4FM & LSM SIMULCAST TESTING WITHOUT SYSTEM INFRASTRUCTURE
Yosemite National Park

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BACKGROUND AND SYSTEM REQUIREMENTS

• Implementation of a CAD/AVL Data System for Transit, Traffic Monitoring, and Portable Roadside Signs in Yosemite National Park
• Existing VHF Conventional Voice Radio System with Stand-Alone Repeaters
• Microwave Interconnect System Being Implemented Over Next 2 Years
• CAD/AVL System Needs to Send and Receive Data Packets to and from Vehicles Without “Knowing” Vehicle Location
• CAD/AVL System On-Board Equipment Requires IP Interface
• Trunked System Not an Option (Cost & Spectrum Availability)
• Best Option: P25 Multi-Site Simulcast System with Receiver Voting
SIMULCAST SYSTEM REQUIREMENTS

• Non-Capture Overlap Area Signal Power Ratios:
  • 10-15 dB – Analog Simulcast
  • 15-20 dB – C4FM & LSM

• Delay Spread Requirements:
  • <50-60 microseconds – Analog
  • <50-60 microseconds – LSM
  • <30 microseconds – C4FM

• Sites Used for Testing in Yosemite National Park Produced Significant Non-Capture Overlap Areas in the Yosemite Valley; Signals Power Levels Often Within 10 dB

• Yosemite Valley about 8 Miles Long, so Worst-Case Delay Spread Values Were Probably <40 microseconds. Longer delayed echoes would have caused more problems, especially for C4FM
Radio Frequency Environment – Yosemite Valley
Multipath (!!)

Test Parameters & Configuration

- RSSI, Bit Error Rate, and Modulation Fidelity measured from Two Pairs of Sites: Yosemite Village/Turtle Back Dome and Sentinel Dome/Turtle Back Dome
- Both C4FM and Motorola LSM Modulation Tested in Simulcast Mode
- Base Station Test Repeater Sites:
  - Yosemite Village
  - Sentinel Dome
  - Turtle Back Dome
- 3 dBd Gain Omni Antenna with 95’ F5J4-50 ½” Superflex Transmission Line at all three sites + 7 dBd Gain Corner Reflector Directional Antenna at Turtle Back Dome
- Directional Antenna Used to Minimize Non-Capture Overlap Zone Between Sites
- 32 Watts ERP (OMNI) – 83 Watts ERP (DIRECTIONAL)
Test Parameters & Configuration

Base Station Test Equipment Configuration

Mobile Test Antenna Configuration
BER Testing: Signal Quality Color Codes

<table>
<thead>
<tr>
<th>BER</th>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BER&lt;1.0%</td>
<td>Green</td>
<td>Excellent</td>
</tr>
<tr>
<td>BER&lt;2.0%</td>
<td>Orange</td>
<td>Very Good</td>
</tr>
<tr>
<td>BER&lt;3.0%</td>
<td>Yellow</td>
<td>Good</td>
</tr>
<tr>
<td>BER&lt;5.0%</td>
<td>Red</td>
<td>Fair</td>
</tr>
<tr>
<td>BER&gt;5.0%</td>
<td>Red</td>
<td>Poor</td>
</tr>
</tbody>
</table>

These BER/signal quality correlations are for voice transmissions, but should be similar for packet data with small and relatively constant size data messages typical of CAD/AVL systems.

2.0% Corresponds to DAQ 3.4

BER Test Results: Sentinel Dome & Turtle Back Dome Sites - C4FM - OMNI - Sentinel Dome to Yosemite Village to El Portal
BER Test Results: Sentinel Dome & Turtle Back Dome Sites
- LSM - OMNI - Sentinel Dome/Yosemite Village/El Portal

Anomalous High BER Points due to "glitch" in LSM File

BER Test Results: Sentinel Dome Single Site C4FM vs. Sentinel Dome/Turtle Back Dome LSM
Test Results & Conclusions

- P25 Simulcast operation works well (especially with LSM) even in environments with a combination of high levels of multipath and significant non-capture overlap as long as the delay spread values are low enough.
- Worst-case delay spread values for the two site combinations shown above are likely to be on the order of 30-35 µsec (Yosemite Valley is ~8 miles long; TBD-SD site separation = 6.8 miles). Longer delayed echoes may result in higher BER values.
- Turtle Back Dome and Sentinel Dome sites with OMNI antennas and Linear Simulcast Modulation (“LSM”) provide the best overall coverage of Yosemite Valley & Glacier Point Road (DA not needed at TBD, since non-capture overlap area not an issue for C4FM or LSM).
- LSM provides a significant improvement in BER and Modulation Fidelity over C4FM in areas where C4FM coverage and BER are marginal.
- Simulcast BER test methodology works well and allows testing without installing system infrastructure.

Acknowledgements

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