Measurement Results for Radar and Wireless System Coexistence at 3.5 GHz

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Sponsored by NSWC Dahlgren Division
Overview

• Preliminary 3.5 GHz Radar-Communications Compatibility Tests
• Cognitive Navy Radars and 3.5 GHz Spectrum Sharing
PRELIMINARY 3.5 GHZ RADAR-COMMUNICATIONS COMPATIBILITY TESTS
Overview of Tests

• LTE communication at 3550-3650 MHz in presence of Naval radar
• Location: Eastern Shore of VA
• Emphasis on proof-of-concept (existence proof)
Equipment Used

- Rhode & Schwarz CMW500 as eNodeB
- Commercial LTE User Equipment
  - UE in shielded enclosure
  - Dipole affixed to UE as coupler
- Custom frequency translators
  - 700 MHz to/from 3550 MHz
- Broad-beam directional antennas
  - C-band TVRO feed horns
  - adjustable linear polarization
Hardware Configuration

- Power limiters added to protect translator
- Interference was within filter passband
- Step attenuator used on downlink
Downlink*

*representative path loss shown
Uplink*

*representative path loss shown

*Nominal uncompressed gain.
** Estimated due to amplifier compression.
Measurement Locations

Beam width about 90 degrees, visitor's center had radar perpendicular to LTE path, on Beech radar was in the antenna 3dB BW and eNB pointed away from radar.
# Test Conditions

<table>
<thead>
<tr>
<th>File numbers</th>
<th>Location</th>
<th>LTE Path Distance</th>
<th>Path Loss est.</th>
<th>DL Resource Blocks</th>
<th>DL Mod.</th>
<th>UL Resource Blocks</th>
<th>UL Mod.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-91</td>
<td>Visitors Center</td>
<td>25m</td>
<td>72 dB</td>
<td>16</td>
<td>QPSK</td>
<td>16</td>
<td>QPSK</td>
</tr>
<tr>
<td>92</td>
<td>Beach</td>
<td>45m</td>
<td>77 dB</td>
<td>16</td>
<td>QPSK</td>
<td>16</td>
<td>QPSK</td>
</tr>
<tr>
<td>93-172</td>
<td>Beach</td>
<td>45m</td>
<td>77 dB</td>
<td>50</td>
<td>64 QAM</td>
<td>16</td>
<td>16 QAM</td>
</tr>
</tbody>
</table>
LTE and Radar Spectra

Peak and instantaneous power displaced.

LTE downlink (L)
LTE uplink (R)

Navy Radar
LTE Statistics Collected

- **ACKs**: packet acknowledgments
- **NACKs**: negative acknowledgments
- **DTX**: discontinuous transmit, UE did not recognize that a packet was sent
- **BLER**: Block Error Rate
- **CQI**: Channel quality indication
- **UE Status**: e.g., Attached, Connected
- **Throughput**
CMW500 Downlink Screen
Downlink Throughput at Visitor Center (BPSK, Radar Active)
Downlink BLER at Visitor Center
(BPSK, Radar Active)
Downlink Throughput at Beach
(64 QAM, Radar Active)
Downlink BLER at Beach
(64 QAM, Radar Active)
Conclusion

• Communication is possible in the presence of operating Naval radars under certain operating conditions
• Power for the LTE system can overcome the radar
• Additional work is needed to provide a detailed feasibility assessment for LTE communication in the 3550-3650 MHz band
Future Work

• Bench-top testing using pulse interference with various PRF and pulse width combinations
• Receiver improvements, e.g., band-reject filters
• Field measurements with longer transmit-receive paths
Future Work

- Use of omnidirectional antennas
- Experimentation with DSA to increase robustness of low-SNR links
- Tests with additional radars that operate in or near the 3500 MHz band
- Use stop band filters
- Study of implications for use of the band further from coast / radar locations
Acknowledgments

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T. Charles Clancy, PhD

COGNITIVE NAVY RADARS AND 3.5 GHZ SPECTRUM SHARING
Cognitive Radar Project

Add intelligence to a legacy radar to reduce its impact on WiMAX and LTE infrastructure operating in the 3550 to 3650 MHz frequency band

Goal: Fall 2014 field trial demonstrating closed-loop control of Naval radar system to demonstrate reduced impact on WiMAX base stations
Cognitive Radar Project

High-Level Integration Strategy

Diagram:
- User Interface
- Phased Array
- RF Analog Systems
- Omni Spectrum Sensor
- Real Time Scheduler
- Array Control
- Transmit/Receive Signal Processing
- Sensor Signal Processing
- Clutter Map
- Radar Control Subsystem
- System Strategy Reasoner
- Radio Environment Map

Connections:
- Doctrine Messages Ethernet
- Digitized IF Tap
- High-Gain Directional Sensing
- Low-Gain Omni Sensing
Broad Areas of Research
Radar Spectral Mask

MATLAB-based waveform model based on measurements from Navy radars collected in partnership with NSWC Dahlgren
Impact on 3.5 GHz Exclusion Zones

275km Exclusion Zone  
NTIA/CSMAC Value

65km Exclusion Zone  
Radio Horizon  
LTE (100m) → Radar (30m)

65km Exclusion Zone  
Radio Horizon for Specific Ship Locations

Exclusion Zone  
Known Tower, Propagation, & Ship Location

Observations

① LTE does not significantly interfere with OOB 3.5 GHz Navy Radars: out of band; if in-band, power less than clutter return within radio horizon

② Navy Radars can interfere with LTE: 5% radar duty cycle can be addressed through waveform mitigation and cognitive radar