Measurement and Sensing in 5 GHz

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Measurement and Sensing in 5 GHz

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Study Question:

What are the strengths and weaknesses of measurement-based and sensor-based spectrum sharing methods, and how can the weaknesses be overcome? How can this spectrum sensing and spectrum monitoring data be analyzed to identify and address environmental trends pointing towards potential interference situations before harmful interference occurs? Specific bands of interest are U-NII-2B (5350-5470 MHz) and U-NII-4 (5850-5925 MHz).

Systems Spreadsheet
U-NII-2B (5350-5470 MHz)

5350 - 5460	Aeronautical Mobile Telemetry and Telecommand	Current	HP/WB/LF/EL/CO/MO - DOWNLINK Air Force Unmanned Aircraft Systems send telemetry and video signals as well as NASA using radar to track balloons, air craft and launch vehicles	(The following specs are from NASA with the up and downlink included): Control communications bandwidth estimates on the order of 10 to 11.4 MHz for the networked configuration Control communications bandwidth estimates on the order of 3.6 to 4.1 MHz for the nonnetworked ATC voice communications bandwidth estimates on the order of 2.7 to 3.1 MHz, split equally between the uplink and downlink ATC data communications bandwidth estimates on the order of 5.2 to 5.9 MHz - one example power on a UAS of 50 Watt transmitter (assuming at least 3 dBi antenna gain, therefore
5350 - 5460	Radiolocation	Current	HP/WB/LF/EL/IN/FX&MO - military radars, tracking rockets, missiles and other targets. Navy shipborne radars. Additionally meteorological radar systems in this band.	most systems in kilowatts; bandwidths could range 100s of kHz to 10s of MHz or more
5350 - 5460	Earth Exploration-Satellite and Space Research	Current	HP/WB/LF/EL/IN/MO - space based measurements of surface topography and ocean wave height	Sentinal Sea - ice monitoring, glacier/ice sheet motion - 5.405 GHz Radarsat 2 - lake/river ice monitoring, sea ice monitoring, glacier/ice sheet motion 5.405 GHz - (assigned bandwidth 100,540 kHz 11.6 to 100 MHz, peak power 1650 to 2280 Watts) - footprint smallest swath 18km for 1m resolution or upto 500 km swath at 100 m Snow layer thickness obtained using airborne radars operating at 5 GHz with a 6 MHz bandwidth
5460 - 5470	Aeronautical Mobile Telemetry and Telecommand	Current	**HP**/WB/LF/EL/CO/MO - DoD Unmanned Aircraft Systems send telemetry, command and control as well as NASA using radar to track balloons, air craft and launch vehicles	see above
5460 - 5470	Radiolocation	Current	HP/WB/LF/EL/IN/FX&MO - military radars, tracking rockets, missiles and other targets. Navy shipborne radars. Additionally meteorological radar systems in this band.	see above
5460 - 5470	Earth Exploration-Satellite and Space Research	Current	HP/WB/LF/EL/IN/MO - space based measurements of surface topography and ocean wave height	see above

Systems Spreadsheet
U-NII-4 (5850-5925 MHz)

5650 - 5925	Fixed-Satellite	Current	HP/NB/SF/LO/CO/FX - UPLINK DoD operators fixed-satellite service earth stations to connect to commercial satellite systems in support of operations and data transmissions	Commercial Satellite Communication Systems The military agencies lease capacity on commercial satellite systems to satisfy their communication requirements. The satellite terminals transmit an uplink signal in the 5850-6425 MHz
5650 - 5925	Land Mobile	Current	LP/NB/SF/LO/IN/MO - DoD and NASA use hand-held mobile systems for personal communications, video and unit	personal communications <5 watts, < 1 MHz
5650 - 5925	Low Power Devices	Current	LP/NB/SF/LO/IN/FX&MO - Part 15 devices	
5850-5925	Intelligent Transportation System using Dedicated Short Range Communications Service System (DSRCS)	Planned	LP/NB/SF/LO/IN/FX&MO	10 MHz channel similar to 802.11a - Communications-based active safety applications use vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) short-range wireless communications to detect potential hazards in a vehicle's path – even those the driver does not see. The connected vehicle provides enhanced awareness at potentially reduced cost, and offers additional functionality over autonomous sensor systems available on some vehicles today. Communications-based sensor systems could potentially be

SPECTRUM MEASUREMENT ARCHITECTURES - Strengths and Weaknesses vs. Applications

	HP/WB/LF/EL/CO/FX			HP/WB/LF/EL/CO/MO			HP/WB/LF/EL/IN/FX			HP/WB/LF/EL/IN/MO			HP/WB/LF/LO/CO/FX			HP/WB/LF/LO/CO/MO			HP/WB/LF/LO/CO/NO		
	5470-5570, 5570-5650 - Meteorological Radars - Current						5350-5460, 5460-5470 - Radiolocation - Current									5570-5650 - Tactical Radars - Current					
Examples => Red Print = U-NII 2B or 4 Yellow Highlights are challenging Applications to Observe Green Highlights should be realtively easy to view with the right equipment				5255-5350 - Aeronautical Telemetry (Air Force UAVs), 5350-5460 - Downlink, 5460-5470, 5470-5570, 5570-5650, 5650-5925 GHz - DoD UAS CMD & Control and NASA / DoD telemetry and video, Radar (EESS) - Current						4940-4990 - Wideband Data Link - Current, 5250-5255, 5255-5350, 5350-5460, 5460-5470 - Earth Exploration Satellit & Space Research - Current, 5470-5570, 5570-5650, 5650-5925 GHz - military & special purpose radars - Current			5470-5570, 5570-5650 - Meteorological Radars - Current, 5650-5925 - Tactical Radars - Current								
	PRE	OPN	POST	PRE	OPN	POST	PRE	OPN	POST	PRE	OPN	POST	PRE	OPN	POST	PRE	OPN	POST	PRE	OPN	POST
Architecture																					
Fixed Site (~30 meters)																					
- Low Density (> 250 km^2)																					
- Narrowband (=> fast sweep)	Y	Y	Y	Y	Y	Y	Y	Y	Y	R	R	R	Y	Y	Y	R	R	R	R	R	R
- Wideband (=> slow sweep)	G	G	G	G	G	G	G	G	G	G	Y	G	Y	Y	Y	R	R	R	Y	Y	Y
- High Density (</= 250 km^2)																					
- Narrowband	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	R	R	R	R	R	R
- Wideband	G	G	G	Y	Y	Y	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G
Nomadic Site (~6 meters)																					
- Terrestrial																					
- Narrowband	Y	Y	Y	Y	Y	Y	Y	Y	Y	R	R	R	Y	Y	Y	R	R	R	R	R	R
- Wideband	G	G	G	G	G	G	G	G	G	Y	Y	Y	G	G	G	Y	Y	Y	Y	Y	Y
- Aerostat																					
- Narrowband	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	R	R	R	R	R	R	R	R	R
- Wideband	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	Y	Y	Y	G	G	G

Strengths and Weakness of Spectrum Measurement Systems

Strengths:

- Requires minimal legacy system operator participation,
- Indirectly measures propagation losses and thus enables the largest amount of potential spectrum sharing, and
- Some measurement architectures require no extra equipment and could be lower in cost (e.g. dynamic frequency selection-DFS).

Weaknesses:

- Measurement system needs to be designed for specific band systems,
- Some measurement architectures require deployed monitors and related infrastructure, which is expensive,
- System potentially determines sensitive legacy system information (i.e. potential security issues), and
- Measurements made co-existent with entrant (new) system have the potential to block detection of harmful interference problems

Recommendations 1 – Measurement Techniques:

- *It is recommended that NTIA use different measurement technologies in different bands in order to determine the viability of spectrum sharing for the U-NII-2B (5350-5470 MHz) and U-NII-4 (5850-5925 MHz) bands*.
  - The lower band (U-NII-2B) can employ high gain antennas over long periods of time with clear line-of-sight to airport and space assets in order to determine spectral use.
  - The upper band (U-NII-4) will be more challenging due to the distributed transmission characteristics and will require either distributed spatial measurements use of some form of signal augmentation techniques.

Recommendations 2 – Trend Information and Databases:

- *It is recommended that NTIA use different measurement technologies in order to enable spectrum sharing for the U-NII-2B (5350-5470 MHz) and U-NII-4 (5850-5925 MHz) bands.*
  - The lower band (U-NII-2B) can use database techniques for protecting satellite systems, dynamically updated database techniques or sparsely-distributed fixed elevated sites for protection of airborne telemetry systems.
  - The upper band (U-NII-4), due specifically to the use for DSRC, should employ signal augmentation/beaconing or a geo-registered database for protection of potentially deployed systems. Due to the lack of interoperability analysis that has been done between the DSRC systems and possible sharing waveforms, it is difficult to determine the sensitivity of the measurement systems that are needed to insure protection of the DSRC systems.

Recommendations 3 – Measurement Systems Requirements:

- *It is recommended that NTIA create a report that defines the measurement system requirements and architectures needed to successfully measure signals for various applications (prior to sharing, during sharing, and trends analysis post sharing). The focus should be to develop technical criteria so that the measurements have a high detection probability*.
  - This report should also define the required RF front-end characteristics needed for the spectrum bands and locations so that cost-effective equipment can be deployed with confidence that useful measurements can be obtained.
  - This report should also describe potential measurement pitfalls and validation tests that should be applied so that imperfect data could be "quality rated" by the investigators and still be used by third parties as appropriate. The goal is to insure that the lack of signal detection infers that the signal is not present (within the sensor to emitter distances) and not that the measurement approach is defective.

Recommendations 4 – Measurement Architecture Spreadsheet:

- *It is recommended that NTIA complete the investigation of the provided 5 GHz Band Survey and Categorization spreadsheet (see Appendix A) and the different measurement architectures (see Appendix B). The measurement architectures should include evaluation of their utility for various spectrum sharing functions (sharing potential, operationally employed during sharing, post sharing trending analysis and potentially enforcement) and federal services.*
  - This investigation by NTIA should include the remaining 5 GHz bands and their services not specifically addressed by this subcommittee and other federal services utilizing spectrum under 7 GHz in the extension to the Band Survey and Categorization spreadsheet.

Recommendations 5 – Detection Augmentation Techniques:

- *It is recommended that NTIA*
  - *a) further investigate techniques that can be employed for federal spectrum users to augment the detectability of their users and the impacts of spectrum sharing on their users; and*
  - *b) reach out to work with the FCC to investigate techniques to augment the detectability and mitigation of transmissions from users and services that share federal spectrum.*

Recommendations 6 – Coordinated Sensing:

- *It is recommended that the NTIA adopt the use of coordinated sensing periods in network spectrum sharing systems.*
  - The NTIA should conduct simulation studies to determine the value of coordinated sensing periods within adjacent networks including assessment of this approach's impact on implementation complexity.

Context for Prioritization of Recommendations

- **Greatest Impact.** In general, unless there are timing or logic considerations, recommendations that provide the greater impact should have a higher priority.
- **Logical Order.** Some recommendations may need to be completed or at least underway before another can commence or be completed. More directly, pursuing recommendations in the wrong order could lessen the impact of the effort or even elicit the wrong outcome.
- **Implementation Cost.** Given resource limitations, an otherwise high priority recommendation may have to be de-prioritized because it is unaffordable in terms of the available funding and/or staffing needs.
- **Temporal Circumstance.** In some cases, the opportunity to accomplish a recommendation may be diminished or lost altogether if it is not undertaken at a particular time. Circumstances may dictate action at a particular moment or necessitate delayed action on a recommendation.
- **Implementation timeline.** If a recommendation has dependencies and takes a long time to implement, its initiation may be prioritized over projects that otherwise would be of higher priority.
- **Ease of Implementatio**n. A recommendation may warrant a higher priority if it is easy to implement, especially if it does not require substantial resources, does not take long, and has a reasonable pay back.

Prioritization of Recommendations

- Underlying many of the subcommittee's recommendations is the need for an accurate "spectrum dashboard" for the 5GHz Band other bands.
  - The subcommittee understands that NTIA and FCC are already working on an enhanced "spectrum dashboard" and updates/extensions to the NTIA Federal Spectrum Compendium. A tool such as this should greatly assist in setting recommendation priorities in the long run and spectrum sharing in general.
- Recommendations 2 and 6 request gathering more information. That additional information is essential to determine whether to implement or not implement a specific recommendation.

Suggested New / Continuing CSMAC Work Items

- [Subcommittee] It is suggested that this sub-committee continue investigating the appropriate measurement architectures for spectrum sharing.
  - Architectures matched to primary and shared services is critical for enabling more intensive and effective sharing.

- [Kolodzy] Develop a work item to address the mechanisms to promote effective spectrum management if quickly developed sensing and electronic attack mechanisms become mission critical.
  - The onset of Counter-UnManned Air System (C-UAS) missions for multiple federal agencies now stress both the development, evaluation, and possible deployment of those technologies.
  - Technology advances are quickly outpacing conventional techniques and current spectrum management processes.
  - Crosses boundaries within federal spectrum management and non-federal spectrum management.