Measurement and Sensing in 5 GHz

Subcommittee Recommendations
CSMAC Meeting
June 8, 2016

SAS/Spectrum Database International Extension

Co-chairs:

- Paul Kolodzy
- Dennis Roberson

NTIA Liaison:

- Ed Drocella

Members:

- Mike Chartier
- Mark Gibson
- Dale Hatfield
- Mark McHenry
- Janice Obuchowski
- Rick Reaser
- Kurt Schaubach
- Steve Sharkey
- Mariam Sorond

Work Plan

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).

Approach

Three topic areas:

- Strengths/Weaknesses of Measurement Architectures
- Characterization of the systems and the measurements to be made
- Policy implications and work-arounds for measurement weaknesses from the regulator's perspective

Measurement tasks to be addressed:

- Prior to sharing (opportunity evaluation)
- Measurements to enable sharing (operational support),
- Measurements after sharing is allowed (trending)

Recommendations (1)

- **Recommendation 1 – Measurement Techniques:** It is recommended that NTIA use different measurement techniques 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 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 will be more challenging due to the distributed transmission characteristics and will require either distributed spatial measurements or employing some form of signal augmentation techniques.
- **Recommendation 2 – Trend Information and Databases:** It is recommended that NTIA use different measurement techniques in order to **enable spectrum sharing** for the U-NII-2B (5350-5470 MHz) and U-NII-4 (5850-5925 MHz) bands. It is understood that these measurement technologies will need to be capable of providing trending information for each of the two bands. The lower band, U-NII-2B can use database techniques for protecting the satellite system, dynamically updated database techniques or sparsely distributed fixed elevated sites for production of airborne telemetry systems. The upper band, U-NII-4, should consider employing signal augmentation / beaconing or a geo-registered database for protection of the potentially deployed DSRC systems. Due to the limited 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 (2)

- **Recommendation 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 different applications (prior to sharing, during sharing, and trends analysis post sharing). The focus should be to develop technical criteria (sensor to emitter distances, spectrum scanning revisit rate, detector sensitivity, etc.) so that the measurements have a high detection probability. This report should also describe potential measurement pitfalls and validation tests that should be applied. The goal is to insure that the lack of detecting a signal infers that the signal is not present (within the sensor to emitter distances) and not that the measurement approach is defective.
- **Recommendation 4 – Measurement Architecture Spreadsheet:** It is recommended that NTIA complete the investigation of different measurement architectures and their utility for various spectrum sharing functions (sharing potential, operationally employed during sharing, post sharing trending analysis and potentially enforcement) and federal services. This 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.

	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			HP/WB/LF/LO/IN/FX			HP/WB/LF/LO/IN/MO			HP/WB/SF/EL/CO/FX		
	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, 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	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				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							R	R	R
- 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							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							R	R	R
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									
Mobile (~2 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	Y	Y	Y	Y	Y	Y	R	R	R	Y	Y	Y	Y	Y	Y	Y	Y	Y									
- Aviation																														
- Narrowband	Y	Y	Y	Y	Y	Y	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R									
- Wideband	G	G	G	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y									
- Crowd Sourcing																														
- Narrowband	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y									
- Wideband	G	G	G	Y	Y	Y	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G									

Key: R = RED = Poor Capabilities	HP = High Power (> 100 W EIRP)	LF = Large Footprint (>2.5 km^2)	CO = Continuous Trasmission	PRE = Pre-Implementation
Y = Marginal Capabilities	LP = Low Power (</=100 W EIRP)	SF = Small Footprint (</= 2.5 km^2)	IN = Intermittent Transmission (> 5 min.)	OPN = Operation support for Sharing
G = Strong Capabilities	WB = Wideband (>/=10 MHz)	EL = Elevated Transmitter (>15 meters)	FX = Fixed Transmitter	POST = Post Implementation Trend Observation
	NB = Narrowband (<10 MHz)	LO = Near Ground Transmitter (</= 15 m)	MO = Mobile Transmitter	
			NO = Nomadic Transmitter	

Recommendations (3)

- **Recommendation 5 – Detection Augmentation Techniques: a)** It is recommended that NTIA 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. Examples of such technologies would include beaconing or identification of the specific waveforms that are being used. (**b)** It is further recommended that NTIA reach out to the FCC to investigate techniques to augment the detectability and mitigation of transmissions from users and services that share federal spectrum. These critical investigations will need to address both security and privacy issues.
- **Recommendation 6 – Coordinated Sensing:** It is recommended that the NTIA investigate 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 relative to the resulting implementation complexity.

Sample - Band Characterization (5350-5470 MHz)

Designation	Band (MHz)	Application	Current or Future Use	Characterization (Power/Bandwidth/Footprint/Elevation/ Continuous or Intermittent/Fixed or Mobile	Attempt at finding real specifications:
U-NII-2B (5350-5470)	5350 - 5460	Aeronautical Mobile Telemetry and Telecommand	Current	HP/WB/LF/EL/CO/MO - Air Force Unmanned Aircraft Systems send telemetry and video signals as well as NASA using radar to track balloons, air craft and launch vehicles	(From NASA not Air Force 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 EIRP > 100 watt
	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
	5250-5725	LTE-U (Band 253)	Proposed for both LTE-U and Wi-Fi		
	5350-5470	Pt. 15 Low Power	Proposed for both LTE-U and Wi-Fi	LP/NB/SF/LO/IN/FX&MO - Part 15 devices	WiFi (802.11a/n/ac/ax) plus numerous other applications

Special Kudos to Pete Tipton and Rick Reaser for leading the effort to produce this chart.

Sample - Band Characterization (5850-5925 MHz)

Designation		Band (MHz)	Application	Current or Future Use	Characterization (Power/Bandwidth/Footprint/Elevation/ Continuous or Intermittent/Fixed or Mobile	Attempt at finding real specifications:
U-NII-2C (5470-5725)	U-NII-3 (5725-5850)	5650 -5925	Aeronautical Mobile Telemetry and Telecommand	Current	HP/WB/LF/EL/CO/MO - DoD Unmanned Aircraft Systems send telemetry, command and control. Also telemetry used for testing of vehicles	see above
		5650 - 5925	Instrumentation Radars	Current	HP/NB/SF/LO/IN/FX - provide highly accurate position data on space launch vehicles and aeronautical vehicles in test.	for an ideal multiple target tracking ~1 MW, >100 MHz BW
		5650 - 5925	Tactical Radars	Current	HP/WB/LF/LO/CO/MO&FX - Tactical air defense system and Navy shipboard sea and air surveillance radars for ship protection	power ~ 10 kW, vertical coverage (land based) to 100,000 ft detection range to > 100 km, > 100 MHz BW
		5650 - 5925	Special Purpose Radars	Current	HP/WB/LF/EL/IN/MO - airborne synthetic aperture radars for land mapping and imaging	peak > 1 kW, BW >10 MHz depending on resolution
		5650 - 5925	Fixed-Satellite	Current	HP/NB/SF/LO/CO/FX - DoD operators fixed-satellite service earth stations to connect to commercial satellite systems in support of operations and data transmissions	
		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 operations	personal communications <5 watts, < 1 MHz
		5650 - 5925	Low Power Devices	Current	LP/NB/SF/LO/IN/FX&MO - Part 15 devices	
		5725-5850	LTE-U (Band 255)	Current		
U-NII-4 (5850-5925)		5850 - 5925	Dedicated Short Range Communications (DSRC)	Current		FCC Pt. 90.371-90.383 The use of radio techniques to transfer data over short distances between roadside and mobile units, between mobile units, and between portable and obile units to perform operations related to the improvement of traffic flow, traffic safety, and other intelligent transportation service applications in a variety of environments. DSRCS systems may also transmit status and instructional messages related to the units involved.
			Pt. 15 Low Power	Proposed for WiFi	LP/NB/SF/LO/IN/FX&MO - Part 15 devices	WiFi (802.11a/n/ac/ax) plus numerous other applications

Special Kudos to Pete Tipton and Rick Reaser for leading the effort to produce this chart.

Suggested Follow-on Activities

- The 5 GHz measurement sub-committee work should continue on the broader topic of spectrum measurements beyond the 5 GHz band