412th Test Wing

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U.S. AIR FORCE

JT3

Initial Approaches to Mitigating the Impacts of the AWS-3 Auction (1755-1780 MHz)

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Overview

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- Transition Plan Ground Rules
- Transition Plan Summary
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Background

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Telemetry Spectrum Summary

- **Lower L-Band: (1435-1525 MHz)**
  - Heavily used by F35. Also used for weapons re-rad.
- **Upper L-Band: (1755-1850 MHz)**
  - Shared band - many uses
  - Losing 1755-1780 MHz in 5-10 years
  - Previously lost 1710-1755 MHz
- **Lower S-Band: (2200-2290 MHz)**
- **Upper S-Band: (2360-2395 MHz)**
  - Previously lost 2310-2360 MHz; gained 2390-95 MHz
- **Lower C-Band: (4400-4940 MHz)**
  - Shared Band
  - Will be used for iNET Developmental Flight Test at Edwards and Pax
- **Middle C-Band: (5091-5150 MHz)**

Background (con't)

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Frequency Bands Under Investigation For Potential Repurposing Under the Presidents National Broadband Initiative

Goal is to repurpose 500 MHz from the following bands

Frequency Band (MHz)	Amount (MHz)	Current allocation/usage
406.1-420	13.9	Federal
1300-1390 (Being Studied)	90	Federal
1675-1710 (Studied) (1695-1710 Auctioned)	35	Federal/non-federal shared
1755-1850 (Studied) (1755-1780 Auctioned)	95	Federal
2700-2900	200	Federal
2900-3100	200	Federal/non-federal shared
3100-3500	400	Federal/non-federal shared
3500-3650 (Studied) (3550-3650 To Be Auctioned)	150	Federal
4200-4400	200	Federal/non-federal shared
5350-5470	120	Federal/non-federal shared
5850-5925	75	Federal/non-federal shared
Total	1578.9	

Background (con't)

1755-1780 MHz Repurposing

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- The first of several frequency bands to be auctioned under the Presidents National Broadband Initiative
  - **FCC auction completed in Jan 15, netted ~$45B**
- Proceeds go to the Spectrum Reallocation Fund (SRF) to pay for modifications needed to Government systems impacted by the loss of spectrum
  - 1755-1850 MHz is a Government band used by many systems (AMT, ACTS, SUAS, SATCOM, Microwave Links, Robotics, etc.)
  - AMT must move out of the lower 25 MHz of the band and compress into the remaining portion of the band
    - More crowding and increased scheduling challenges
  - AMT must live with the new occupants of the adjacent band which is expected to be 4G LTE-Advanced services
    - More potential for RF interference from commercial services
    - Band will be paired and auctioned with the 2155-2180 MHz band resulting in potential S-Band interference as well

Background (con't)

1755-1780 MHz Transition Plan

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- DoD (and other Departments) asked to provide NTIA and FCC with a Transition Plan for each service (i.e. AMT) impacted by the loss of 1755-1780 MHz
  - DoD Plan submitted to NTIA on 15 Jan 2014
- USAF 1755-1780 MHz Working Group formed to create TP for AMT
  - AMT Transition Plan for USAF Ranges completed, submitted, and accepted by AFSMO, AFSPC, SAF, DoD CIO, OMB, NTIA, FCC
  - Addresses Edwards, Eglin, UTTR, NTTR, and Vandenberg
  - Coordinated with the Navy for consistency

Transition Plan Summary

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- Ground Rules and Assumptions
  - If Ranges have the capability to support AMT in this band they must retain that capability
    - Just because you aren't using the band now doesn't mean you aren't impacted
  - Current TM Quality of Service, Test mission scheduling opportunities and test mission execution rates must not be impacted
  - There are many unknowns when it comes to the interference potential of new 4G LTE-A services
    - Develop conservative case scenarios when estimating
    - Cannot request more money later if team under estimated or overlooked something important; Can give money back to the SRF.

Transition Plan Summary (con't)

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- Proposed Mitigation Courses of Action
  - Telemetry receivers will be replaced or modified to be capable of supporting more bandwidth efficient modulation methods
    - Required to deal with compression and the need to be more spectrally efficient
    - Other capabilities will be considered to maintain TM data quality
  - Telemetry antenna systems will be modified to desensitize them to commercial operations in the 1755-1780 MHz and 2155-2180 MHz bands
    - Better filters and LNA's
    - Or TBD Technologies identified in upcoming studies
  - Telemetry antenna systems will be modified to provide bi-directional capability to control Test Article AMT transmitters
    - Feed modifications, new rotary joints, C&C transceiver integration, etc.
    - Control TM transmitter frequency, power, modulation, coding…

Transition Plan Summary (con't)

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- Mitigation Courses of Action Cont…
  - Test Articles (aircraft) will require modifications
    - Multi-Band Multi-Mode transmitters to improve frequency agility and implement bandwidth efficient modulation methods
    - Transceivers to facilitate control of AMT transmitter parameters
  - Other upgrades and modifications propose include
    - Improved frequency monitoring capabilities
    - New AMT Noise and Interference monitoring capabilities
    - Improved frequency scheduling and de-confliction tools
    - AMT transmitter command and control software
    - Upgraded support equipment to test systems using new modulations methods
    - Technical studies of various types
- Transition Plan cost estimates
  - Hardware, software, systems engineering, labor, and limited O&M for initial standup and testing,FY15-FY24
- USAF estimates were accepted and will be funded
  - Accommodates some risk and uncertainty factors

Transition Plan Execution

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- SRF Funds Expected in very late FY 2015
  - Studies, Specification/Requirements Development/System Engineering up front.
  - Major buys in the FY18-FY22 timeframe

- AF Project Office's Being Stood Up
  - Separate Edwards AFB & Eglin AFB project offices
    - Air Force Test Center purview overall
  - Edwards project office will oversee all AF Ranges in the South West (Edwards, UTTR, NTTR, Vandenberg)
  - Liaison with Navy Ranges in the South West through RCC and South West Range Alliance Connections

Technical Challenges

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- AMT Acquisition and Support System Modification:
  - Purchase/Install Bandwidth Efficient, Higher Performance Receivers
    - Determine enhanced performance feature candidates required to maintain TM data quality
    - Maintain interoperability/Implement Improved Antenna System Filtering/ACI&OOBE noise rejection
      - Market research and or development of high dynamic range LNAs, and maximally “square” filters
      - Market research and or development of adaptive noise cancelling
    - Translate candidates into hard technical specifications
  - Implement Antenna System Transmit Modifications (Enable Uplink)
    - COTS available
  - Develop Additional Transportable Ground Stations (Provide Geographic Diversity)
    - Develop candidate site list for R-2508
    - Refine CONOPS to determine site support system requirements
  - Perform Support Equipment Mods/Updates
    - COTS available

Technical Challenges (con't)

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- Enhance AMT Resource Management Capability:
  - Build TM Acquisition System Remote Control Room/GUI/Software
  - Develop/field Noise and Interference Monitoring Systems (NIMS)
    - Develop Mobile/Transportable NIMS stations
    - Survey candidate locations; select sites; implement
  - Develop/field Upgraded Frequency Monitoring Systems
    - Develop Mobile/Transportable Frequency Monitoring stations
    - Survey candidate locations; select sites; implement
  - Develop AMT Transmitter Command and Control Capability/GUI/Software
- Field Transmission and Support System Modifications

Technical Challenges (con't)

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- Test Article Tasks
  - Technology assessment/solution analysis of alternatives
  - Design Modifications
    - Multi-Band Transmitters
    - Multi-Band Aircraft Splitters
    - Multi-Band Aircraft Antennas
    - Uplink/C&C Transceivers
  - Perform Aircraft Modifications
  - Perform Aircraft Ground Support Unit Modifications

Technical Challenges (con't)

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- Studies:
  - LTE UE Characterization
  - Infrastructure Study – Where to put new TM acq sites
  - Others TBD
- Flight Test Verification of New Systems
- Test and Calibration Lab Modifications to Support New Hardware and Systems

Technical Challenges

A More Detailed Example

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Modification of AMT Receiving Sites
for
Interference Protection

AMT Receiving Site Concerns

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- Adjacent Channel Interference (ACI) from LTE-A User Equipment (UE)
  - UE's in 1755-1780 MHz band affecting AMT in adjacent 1780-1850 MHz band
- Out of Band Emissions (OOBE) from UE's into AMT bands
- Aggregation of UE's
  - Noise floor impacts from many UE's in AMT antenna field of view
- AMT Receiving System Saturation from Base Stations
  - LTE-A Base Stations have a high EIRP and operate from 2155-2180 MHz
- Base Station OOBE
  - Into Upper L-Band (1780-1850 MHz)
  - Into S-Band (2200-2395 MHz)

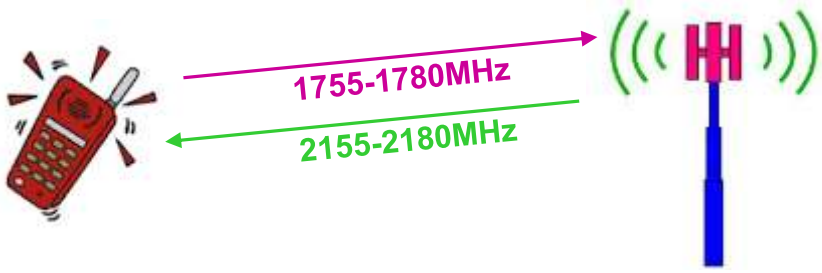
AWS-3 Spectrum

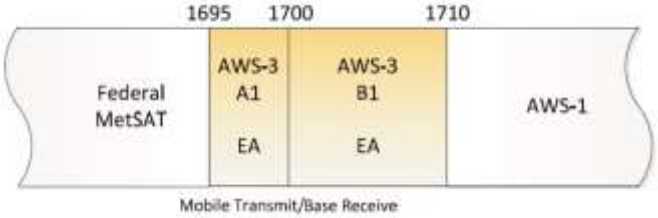
What is it?

- AWS-3 Bands: 1695-1710 MHz, 1755-1780 MHz, and 2155-2180 MHz
- 65MHz Total was auctioned
  - Block A1: 1695-1700 MHz (5 MHz)
  - Block B1: 1700-1710 MHz (10 MHz)
  - Block G: 1755-1760/2155-2160 MHz (10 MHz)
  - Block H: 1760-1765/2160-2165 MHz (10 MHz)
  - Block I: 1765-1770/2165-2170 MHz (10 MHz)
  - Block J: 1770-1780/2170-2180 MHz (20MHz)

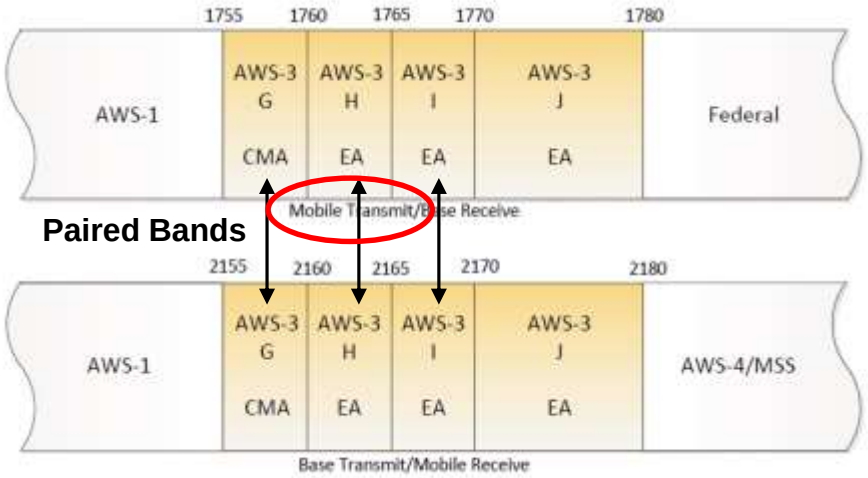
➢ Uplink is in AMT's current "Upper L-Band"

➢ Downlink is very close to AMT's "S-Band"





1695-1710 MHz Band Plan



1755-1780 MHz & 2155-2180MHz Band Plans

UE Spurious Emissions Limits

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Transmitter Section

Frequency Bandwidth	Measurement Bandwidth	Minimum requirement	Note
9 kHz ≤ f < 150 kHz	1 kHz	–36 dBm	
150 kHz ≤ f < 30 MHz	10 kHz	–36 dBm	
30 MHz ≤ f < 1 000 MHz	100 kHz	–36 dBm	
1 GHz ≤ f < 12,75 GHz	1 MHz	–30 dBm	
12.75 GHz ≤ f < 5th harmonic of the upper frequency edge of the UL operating band in GHz	1 MHz	–30 dBm	Note 1
NOTE 1: Applies only for Band XXII.			

Receiver Section

Frequency Band	Measurement Bandwidth	Maximum level	Note
30 MHz ≤ f < 1 GHz	100 kHz	-57 dBm	
1 GHz ≤ f ≤ 12,75 GHz	1 MHz	-47 dBm	

Source: 3GPP TS 34.121-1 version 11.2.0 Release 11

Base Station Emission Mask

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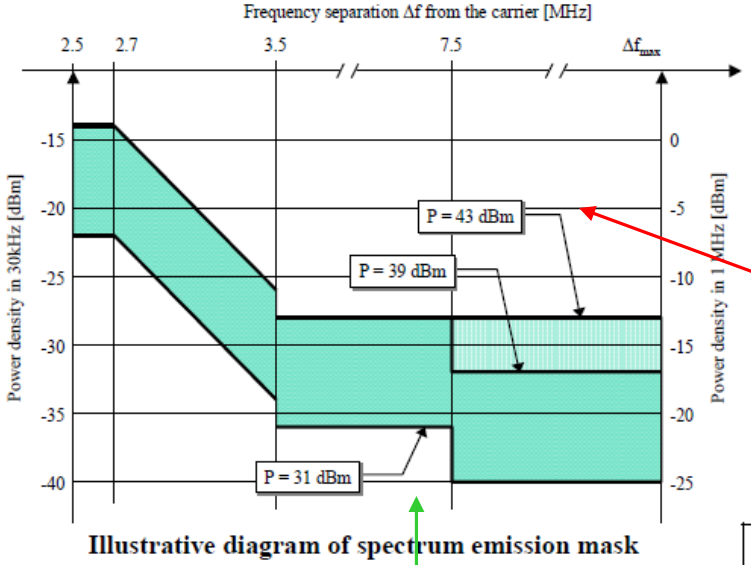


Illustrative diagram of spectrum emission mask

BS class	PRAT
Wide Area BS	- (note)
Medium Range BS	≤ +38 dBm
Local Area BS	≤ + 24 dBm
Home BS	≤ + 20 dBm (without transmit diversity or any MIMO mode) ≤ + 17 dBm (with transmit diversity or MIMO mode) ≤ + 14 dBm (with MIMO mode with four transmit antennas)
NOTE:	There is no upper limit required for the rated output power of the Wide Area Base Station like for the base station for General Purpose application in Release 99, 4, and 5.

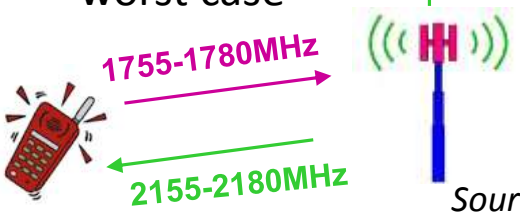
Table 6.3: Spectrum emission mask values, BS maximum output power P ≥ 43 dBm

Frequency offset of measurement filter -3dB point, Δf	Frequency offset of measurement filter centre frequency, f_offset	Minimum requirement (Note 1, 2)	Measurement bandwidth (Note 4)
2.5 MHz ≤ Δf < 2.7 MHz	2.515MHz ≤ f_offset < 2.715MHz	-14 dBm	30 kHz
2.7 MHz ≤ Δf < 3.5 MHz	2.715MHz ≤ f_offset < 3.515MHz	$-14dBm - 15 \cdot \left(\frac{f\_offset}{MHz} - 2.715 \right) dB$	30 kHz
(Note 3)	3.515MHz ≤ f_offset < 4.0MHz	-26 dBm	30 kHz
3.5 MHz ≤ Δf ≤ Δf_{max}	4.0MHz ≤ f_offset < f_offset_{max}	-13 dBm	1 MHz

NOTE 1: For BS supporting non-contiguous spectrum operation within any operating band, the minimum requirement within sub-block gaps is calculated as a cumulative sum of contributions from adjacent sub blocks on each side of the sub block gap. Exception is Δf ≥ 12.5MHz from both adjacent sub blocks on each side of the sub-block gap, where the spurious emission requirements in subclause 6.6.3.1 shall be met.

NOTE 2: For BS supporting multi-band operation with inter RF bandwidth gap < 20MHz the minimum requirement within the inter RF bandwidth gaps is calculated as a cumulative sum of contributions from adjacent sub-blocks on each side of the inter RF bandwidth gap.

- For the Base Station, spectral mask common for Both FDD and TDD
- Base Stations have various output power levels, +43dBm is worst case



Source: 3GPP TS 25.104 version 11.8.0 Release 11, 3GPP TS 25.105 version 11.6.0 Release 11

Mitigation Strategies for AMT Receiving Sites

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- LTE-A User Equipment and eNode-B (Base Station) equipment will be characterized
  - In-band signal characteristics and OOBE will be measured and compared to published data
- Utilizing results obtained from LTE-A equipment characterization and to the extent possible
  - Better quality filters will be employed to mitigate the ACI effects of UE's and eNode-B's
  - High Dynamic Range Low Noise Amplifier's (LNA's) will be employed to deal with saturation issues that may arise from UE clouds and eNode-B's
  - Adaptive Noise Cancellation (ANC) techniques will be explored
- R&D efforts have been proposed to research and prototype advanced filter, LNA and ANC technologies
- AMT receive site geographic diversity
  - Selection of optimum AMT receive site based on measured or anticipated interference conditions may be another solution to mitigate interference

Transition Plan Estimates

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Notional Acquisition Schedules

Transition plan schedules were notional and are in the process of being refined and will be driven by results of technical studies, availability of COTS solutions and prioritization of tasks (courses of action implementations). The bulk of acquisitions are planned in FY17-FY22, however depending on specific AF MRTFB, some acquisitions may take place in FY16 and may extend to FY24.

Equipment	Estimated Qty**
Ground Receivers*	550
Ground Antennas*	80
Ground Support Equipment Mods	40
Test Article Mods	40
Multi-band Antennas	170
Multi-band Splitters	80
Multi-band Transmitters	100
Uplink C&C Transceivers	50
Aircraft Ground Support Unit Mods	20

* Modify or replace

**Will refine in FY16-17

Table 1. AF Test Ranges Notional Equipment/Quantities.

What's Next

- Getting teams up and running
- Performing Studies
- Refining courses of action
  - Soliciting Industry and Academia
  - Leveraging NASCTN, TRMC S&T, SRF R&D Resources
  - Continuing Inter-range technical interchange via Range Commanders Council Telemetry Group (RCC-TG)
- Putting acquisition strategies in place

Points of Contact

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