Emission Test Procedures For 802.11 Transmitters — Working Session

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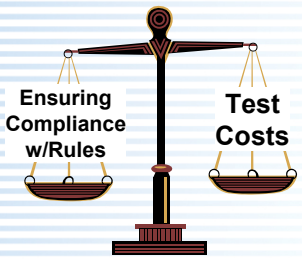
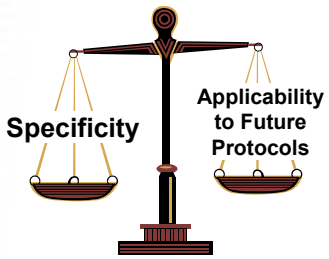
Objective

- **Develop Emission Test and Review Procedures for 802.11 Equipment**
  - 802.11-Specific Addenda for Existing Procedures
  - Equipment Authorization Guidance





Status

- **Existing Measurement Procedures**
  - **UNII**: Public Notice DA 02-2138, "*Measurement Procedure Updated for Peak Transmit Power in the Unlicensed Information Infrastructure (U-NII) Bands*" - http://hraunfoss.fcc.gov/edocs_public/attachmatch/DA-02-2138A1.pdf
  - **15.247 DTS**: Knowledge Database Pub # 558074, *"New Guidance on Measurements for Digital Transmission Systems in Section 15.247"* http://gullfoss2.fcc.gov/prod/oet/cf/kdb/forms/FTSSearchResultPage.cfm?id=21124&switch=P
  - **15.247 Freq. Hopping**: Public Notice DA 00-705, *"Filing and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems"* http://www.fcc.gov/Bureaus/Engineering_Technology/Public_Notices/2000/da000705.txt
- **802.11-Specific Expansions**
  - Thought process has just begun
  - Plan to test some samples to identify test issues
    - Awaiting receipt of requested samples
  - *Seeking input from TCBC regarding test issues that we should consider for equipment authorization*

Overview

- **Which Communication Modes to Test**
- **Which Channels to Test**
- **Test Software and Fixtures**
- **New Transmit Power Rules & Procedures**
- **Smart Antenna Rules**

Goal is to seek your inputs

Session Format

This is an interactive working session

Please interrupt me!

Specific questions are in blue italics

Issue: Which Communication Modes Should Be Tested?

Example: 802.11g

	Mode	Rates (Mbps)	Modulation	Clock (MHz)	# of Carriers
11b	**ERP-DSSS**	1, 2	BPSK [1], QPSK [2]	11	1
11b	**ERP-CCK**	5.5, 11	QPSK	11	1
11b	**ERP-PBCC** (opt)	5.5, 11, 22, 33	QPSK 8-PSK 8-PSK	11 11 ***16.5***	1 1 1
11g	**ERP-OFDM**	6, 9, 12, 18, 24, 36, 48, 54	OFDM: BPSK OFDM: QPSK OFDM: 16-QAM OFDM: 64-QAM	~0.25	52
11g	**DSSS-OFDM** (opt)	6,9,12,18,24, 36,48,54	As above, but w/DSSS preamble/hdr	~0.25	52
Non-Standard	**Turbo/Proprietary**	?	?	?	?

Modes to Test

- *b + g + turbo (3)?*
- *Each "mode" (5)?*
- *Each mod & clock in b, g, & turbo (9)?*
- *Each rate in each mode (17)?*

?

For Which Tests?

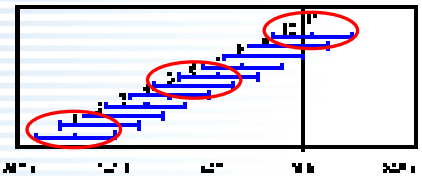
- **Conducted Tx Power, PSD, & Emission Bandwidth**
- **Out-of-band Emissions**
- **Line Conducted Emissions**

Issue: Which Channels Should Be Tested?

802.11b/g

L, M, H

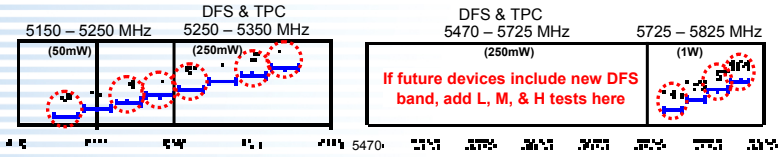
- Chan 1
- Chan 6
- Chan 11



802.11a

L, M, H in each band?

(9 channels)



Note that rqts for in-band power, out-of band emissions, DFS & TPC differ between adjacent bands

For Which Tests?

- Conducted Tx Power & PSD
- Out-of-band Emissions
- Line Conducted Emissions
- Emission Bandwidth

Issues: Test Software

- ***Does test software provide access to:***
  - *All modes?*
    - *Basic Standard Modes?*
    - *Optional Standard Modes (if included)?*
    - *"Turbo"/Proprietary Modes?*
  - *All rates?*
  - *All channels?*
  - *Smart antenna modes & beam steering directions?*
- ***Does the test software allow continuous transmission (100% duty factor)?***

Issues: Test Fixtures

- **Provisions for conducted measurements of output power**
  - *Does manufacturer provide a modified device to allow connections for conducted output power measurements?*
  - *Are special adapters required for connections?*
  - *Are radiated tests performed using a different, unmodified device?*

Transmit Power — New Rules

- **U-NII:**
  - **"*Maximum Conducted Output Power*"**
    (previous rule specified peak transmit power)

    Intent:
    - Measure conducted Tx power averaged across symbols while at maximum power control level
    - Averaging interval must *not* include transmitter OFF times or periods of reduced power
- **15.247**
  - ***Maximum Peak Conducted Output Power***
  - Alternative for systems using digital modulation:
    Maximum Conducted Output Power (15.247(b)(3))

These changes were adopted by Report & Order released July 12, 2004 (Modification of Parts 2 and 15 of the Commission's Rules for unlicensed devices and equipment approval)

Maximum Conducted Output Power Measurement

From:

--*Public Notice DA 02-2138* (U-NII)

--Knowledge Database: *"New Guidance on Measurements for Digital Transmission Systems in Section 15.247"*

- **Method 1 (Preferred)**
  - EUT operates at 100% duty factor at max power control level
    OR,
    Analyzer sweep is triggered on pulse, and pulse duration > sweep time
  - Trace average in power average mode
- **Method 2 (RBW must be > Emission Bandwidth)**
  - Zero span, trigger on transmit pulse
  - Trace average, then find peak of average trace
- **Method 3**
  - Max hold

Note: Methods 1 & 3 require summing power across Emission Bandwidth (e.g. with channel power function)

Maximum Conducted Output Power Measurement Issues

- **Duty factor**
  - *Does test software allow 100% duty factor?*
  - *If not, …*
    - *What duty factors are achieved?*
    - *Should we specify conditions or adjustments under which slightly less than 100% duty factor is acceptable?*
    - *Is Tx pulse duration longer than analyzer sweep times used for power measurement?*
- **Power Averaging**
  - Trace averaging in Method 1 must be true power average (equiv. to RMS). Video average of log display is not permitted.
- **Power meter**
  - Approved procedures defined only for spectrum analyzer. *Is this a significant issue?*
    - Peak power procedure for 15.247 does allow peak power meter

"Smart Antenna" Rules

- **Intent**
  - Allows some multi-beam systems to use the "point-to-point" (P2P) Tx power limits (1dB/3dB gain reduction w/antenna gain vs 1dB/dB)
  - Simultaneous Tx in up to 6, non-overlapping beams without reducing power in each beam
- **Applicability**
  - Must form *"multiple directional beams…for the purpose of directing signals to individual receivers or groups of receivers"*
  - Different information must be transmitted to each receiver
    - Exception allowed for occasional mgt & control signals

Smart Antenna rules apply only in the 2.4 GHz band

"Smart Antenna" Rules

- **Three limits on Conducted Transmit Power must *all* be satisfied**
  - **Each beam ≤ "P2P" limit**
    - 1 watt or ⅛ watt, less 1 dB per 3 dB of antenna gain above 6 dBi
  - **Reduce power in overlapping beams**
    - *"We will require that the aggregate power transmitted simultaneously on overlapping beams be reduced to ensure that EIRP in the area of overlap does not exceed the limit for a single beam"* - R&O FCC 04-165 paragraph 13
  - **Aggregate of all simultaneous beams ≤ P2P limit + 8 dB**
    - Allows 6 simultaneous, non-overlapping Tx beams—each at P2P limit
    - Per beam power reduction required for > 6 beams

Approval of "Smart-Antenna" and Other Multiple-Tx-Antenna Devices Under 15.247 & 15.407

- **In the near term (perhaps 3 - 6 months)**
  - **FCC Lab**
    - Devices having *multiple transmitter outputs* driving *multiple antennas* for a *single data communication process*
      - E.g., 802.11 and bluetooth, or 802.11g and 802.11a are considered separate data communication processes
    - This is a working definition. Contact FCC Lab for clarification
  - **TCBs**
    - Devices having only *one transmitter output* per data communication process

      Output may
      - connect to a single antenna
      - be switchable between antennas
      - connect to a phased array with a passive steering network. (Total directional gain of the antenna array must be considered in power- and PSD-reduction formulas)
    - Case specific guidance from FCC Lab is required for "smart antenna" devices operating 15.247 or 15.407 (but note that smart antenna rules apply only to 2.4 GHz band)
- **Long term**
  - Goal is to allow TCB certification of all smart antenna systems

Systems with Multiple Tx Antennas

- **Types of multiple Tx-antenna systems *observed to date* under 15.247 and 15.407**
  - Selectable Tx Antenna → Diversity
  - ***Sectorized Antennas*** → Directional gain
  - ***Phased Arrays*** → Directional (array) gain through beamforming

  } May have multiple transmitters
  - ***Spatial-Multiplexing MIMO*** → Increased data rate by exploiting multipath

  } Requires multiple transmitters

  Other uses of multiple Tx-antennas are possible —e.g., combining array gain and spatial multiplexing MIMO
- **MIMO – Multiple Input, Multiple Output**

  Multiple Tx antennas + multiple Rx antennas can provide any of the following (depending on system design)
  - Array Gain
  - Interference Reduction
  - Diversity Gain
  - Spatial Multiplexing

  } Feature most often associated with MIMO and the only one that requires multiple antennas for both Tx and Rx

Systems with Multiple Tx Antennas

	Sectorized Antennas	Phased Arrays	Spatial Multiplexing MIMO
Antennas	Directional—each pointed in different direction	Omni or directional w/each pointed in same direction	May be omni—sometimes different polarizations
To communicate w/1 receiver,…	Drive one Tx antenna	Drive multiple Tx antennas w/same data—differently phased	Drive multiple Tx antennas with different data
System Strategy	Select the Tx antenna the focuses energy in direction of intended receiver	Select Tx phasing so that received signals are in phase and add coherently at intended receiver (or intended direction)	Reconstruct multiple Tx data streams by using multipath at multiple Rx antennas
Emission pattern	Directional toward intended receiver		May be omnidirectional
Effect of multipath	Degrades performance	Adaptive systems may compensate for multipath	Exploits multipath for increased capacity
Smart Antenna?	Not really	Yes	
Smart Antenna Rule	Can be applicable at 2.4 GHz		Not usually applicable

Systems with Multiple Tx Outputs: Strawman Guidance for In-Band Measurements

- **Directional Antenna Gain**
  (Used to compute limits on output power & PSD)
  - Sectorized systems: Use gain of each antenna
  - Phased Arrays & MIMO:
    Gain of antenna element + 10 log(# of Tx antenna elements)
    - For spatial multiplexing MIMO, if elements are *always* driven incoherently, use only the antenna element gain
- **Conducted Output Power** - ***DO NOT USE A SIGNAL COMBINER!!!***
  - Sectorized systems
    - Single-beam power: Measure power to antenna for that beam
    - Aggregate power: Sum power measurements across Tx outputs (for simultaneous Tx beams)
  - Phased arrays
    - Single Beam: Measure power to each antenna element during Tx in a single beam, then sum the power measurements across elements
    - Aggregate Power: As above, but measure during Tx in multiple beams
  - Spatial Multiplexing MIMO
    - Measure power to each antenna, then sum the powers

Systems with Multiple Tx Outputs: Strawman Guidance for In-Band Measurements

- **In-Band Power Spectral Density**
  - Limit applies to aggregate output of all transmitters. Methods under consideration:
    - Aggregate across transmitters by summing spectral PSDs (in linear power units) at same frequency. (If margin permits, sum of maxima would ensure compliance.)
      Is this too difficult?
    - Possible alternative: Use a signal combiner.
      But how do we avoid signal cancellation for some signal phasings?

Systems with Multiple Tx Outputs: Strawman Guidance for Out-of-Band Measurements

- **Conducted Out-of-Band Emissions**
  (20/30 dB below in-band max for 100 kHz RBW)
  - Requirement must be met individually on each transmitter output
  - *How can we ensure that requirement is met in aggregate for systems with Tx outputs operating simultaneously in different bands?*
    (Combined in-band PSD will be same as individual transmitter, but out-of-band emissions will add)
    - *Possible solution: also require test with signal combiner*
      Comments?
- **Radiated Out-of-Band Emissions**
  - If device can operate in both a single-transmitter mode and a multiple-transmitter mode, measure in both modes
  - If device forms beams, measure a representative sampling of beam positions

Comments & Suggestions?

- ***Any additional comments/suggestions on:***
  - *Communication Modes*
  - *Channels*
  - *Test Software*
  - *Maximum Conducted Output Power*
  - *Smart Antennas*
  - *Other?*
- ***Other guidance that FCC should provide***
  - *E.g., for smart antennas, manufacturer should specify:*
    - *# of beams*
    - *Whether the beams can transmit simultaneously*
    - *How the power reduction requirement for overlapping beams is implemented*