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**

- **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**

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**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*

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**Issue: Which Communication Modes Should Be Tested?**

**Example: 802.11g**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Rates (Mbps)</th>
<th>Modulation</th>
<th>Clock (MHz)</th>
<th># of Carriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERP-DSSS</td>
<td>1, 2</td>
<td>BPSK [1], QPSK [2]</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>ERP-CCK</td>
<td>5.5, 11</td>
<td>QPSK</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>ERP-PBCC (opt)</td>
<td>5.5, 11, 22, 33</td>
<td>QPSK, 8-PSK</td>
<td>11</td>
<td>1</td>
</tr>
<tr>
<td>ERP-OFDM</td>
<td>6, 9, 12, 18, 24</td>
<td>OFDM: BPSK, QPSK, 16-QAM, 64-QAM</td>
<td>0.25</td>
<td>52</td>
</tr>
<tr>
<td>DSSS-OFDM (opt)</td>
<td>6, 9, 12, 18, 24</td>
<td>As above, w/DSSS preamble/pkt</td>
<td>0.25</td>
<td>52</td>
</tr>
<tr>
<td>Turbo/Proprietary</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>

**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)

For Which Tests?
- Conducted Tx Power & PSD
- Out-of-band Emissions
- Line Conducted Emissions
- Emission Bandwidth

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

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)

- Method 1 (Preferred)
  - EUT operates at 100% duty factor at max power control level
  - 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

Three limits on Conducted Transmit Power must all be satisfied

- Each beam ≤ “P2P” limit
  - 1 watt or ¼ 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

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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*
  - **Spatial-Multiplexing MIMO** ➔ *Increased data rate by exploiting multipath*

  *May have multiple transmitters*
  *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

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

### 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.)
    - 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?
      - Possible solution: also require test with signal combiner

- **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
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