Future In Radiated Immunity Testing

Flynn Lawrence
Flynn Lawrence is an Applications Engineer for AR RF/Microwave Instrumentation. At AR, Flynn is actively engaged in new application and product development and testing, worldwide sales and customer support, as well as hardware demonstrations and training. Prior to joining AR, Flynn was an EMC Systems and Test engineer, working in requirements maintenance, test planning and test execution on military space components and systems.
Agenda: Future In Radiated Immunity Testing

• What Is Radiated Immunity Testing?
  – Why Is It Needed
  – What Is The Value In Future Products
  – Defining Susceptibility Thresholds
  – Defining Test Criteria

• What Are The Standards That Are Applicable For RI Testing
  – IEC61000-4-3, Auto, Military, Aviation

• Traditional Radiated Immunity Testing
  – Equipment Requirements
  – Summary Of Test Procedures And Sample Setup

• Future Radiated Immunity Testing
  – Testing With Multiple Tones
  – Benefits

• Compare Traditional To Future Radiated Immunity Testing
  – Equipment Requirements
  – Calibration
  – Testing
  – Reporting

• Summary Of Future Electronic Trends And The Need For Simultaneous Multiple Tone Radiated Immunity Testing

• Questions And Answers
What Do The Following Items Have In Common?

They All Require Radiated Immunity Testing.
Why Is Radiated Immunity Testing Needed

Everywhere You Turn, Electronic Devices Are Being Designed To Make Our Lives Easier, Healthier, Faster, Etc…

The Radio Frequency (RF) Spectrum Is Becoming More And More Congested

All Of These Devices Need To Work And Co-exist With Radio Transmitters Of Many Kinds
  • Products And Systems Must Be Able To Operate In Their Electromagnetic Environment
  • They Must Not Introduce Intolerable Electromagnetic Disturbances Back Into The Environment Or Produce Harmonics That Interfere With Other Devices

Manufacturers Must Anticipate The Most Likely Environment That Their Product Will Be Used In

That’s Where Radiated Immunity Testing Comes In
Examples Of Electronic Products Co-existing

Car Driving Next To Airport

Power Wind Mill With Radar System In Proximity

Medical Instrument With A Cell Phone Next To It

Microwave Oven With A Cell Phone
What Happens When You Have RF Interference

Critical Electronic Devices Might Fail
What Is The Value Of Radiated Immunity Testing Today And Tomorrow - Priceless!
What Is Radiated Immunity Testing

• Before a product or system hits the marketplace, it must be tested for RF immunity and emissions.

• Immunity (also called susceptibility) is a measure of the ability of electronic products to tolerate the influence of electrical energy (radiated or conducted) from other electronic products and electromagnetic phenomena.

• The test methods are divided into application of stress by conducted coupling, and by radiated field coupling.
Characteristics That Influence Immunity Testing

- Timing
- Amplitude
- Related Positions
- Frequency
Characteristics That Influence Immunity Testing

Frequency

Out-Of-Band

Culprit

RF Current

Victim

In-Band

Culprit

Victim
Defining Radiated Immunity Test Criteria

To Perform An Immunity Test, The Manufacturer Defines Performance Criteria Against Which A Product Will Be Assessed. These Are Commonly Divided Into Three Categories During An Immunity Test:

• The Product Continues To Operate As Intended
• Degradation Of The Product Performance Occurs, But Normal Operation Resumes At The End Of The Test With No Data Loss
• The Product Either Stops Functioning Or Its Performance Degrades And Does Not Recover After The Test Without Intervention

Whenever Performing Immunity Testing, It Is Very Important That:

• The Performance Criteria And The Monitoring Method Be Clearly Defined
• The Product Is Operating In A Fully Exercised Mode, Allowing For The Easy Observance Of Failures
• An **Objective** Set Of Metrics Is Used (Such As Bit Error Rate, SINAD) **Rather Than A Subjective** Metric (Watch For The LED To Stop Flashing, Observe Monitor Screen For Distortion, Etc.)

Determine If The Interference Occurs Continuously, Periodic Or Randomly
Applicable Radiated Immunity Standards

- IEC 61000-4-3 and Associated Standards
- Substitution Method DO-160
- Automotive Substitution Method (ISO 11452 Or 11451)
- Medical Equipment IEC 60601-1-2
- These Only Apply To Multiple Tones There Are More Radiated Immunity Specs
Traditional Radiated Immunity Testing – Equipment Requirements

- Power Amplifiers
- RF Signal Generators
- Directional Coupler
- RF Power Meter
- Isotropic Field Probe And Monitor
- EMI Filters
- Horn And Log-periodic Antennas
- Anechoic Chamber
Traditional Radiated Immunity Testing – Summary Of Set-Up And Procedures

Calibration
Test
Report
Radiated Immunity Calibration Set-up

- Isotropic field probe
- Uniform field area
- Chamber wall
- Field generation antenna
- Optional anechoic material in case of semi-anechoic chamber to reduce floor reflections
- Fibre optic or filtered signal link
- 3 m distance
- 0.8 m distance
Radiated Immunity Calibration Procedure

UFA (Uniformity Field Area)
- Constant Field
- Constant Power

Amplifier Not In Saturation
- Linearity
- Intermod And Harmonics
Constant Field Method - Data Collection

Start 1st Grid Point

Set Initial Frequency

While monitoring field strength, adjust forward power until desired field strength is obtained

Record Forward Power

Measure & Record Forward Power

Select Another Grid Point

All Grid Points Completed

All Frequency steps complete

Set Next Frequency

Yes

No

Yes

No

Yes

No

A
Constant Field Method
Determine Forward Power to be Used for Each Frequency Point

1. Set Freq To initial Value
2. Sort each grid point Forward Power in descending order
3. Find highest Forward Power
4. Subtract 6 dB
5. Determine how Many grid points are within 6 dB
6. Are 75% of the grid Pts Within 6 dB
   - Yes: Record this Forward Power For this Frequency
   - No: Find next Highest Forward Power
7. If all frequencies completed: Constant Field Strength Calibration Completed
8. Next Frequency
### Example Of How Field Uniformity Is Calculated Using Constant Field Method and a 16-point Grid

**Table #1**

<table>
<thead>
<tr>
<th>Grid Point (Px)</th>
<th>Forward Power (dBm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27</td>
</tr>
<tr>
<td>2</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>23</td>
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<td>4</td>
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<td>34</td>
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<td>6</td>
<td>40</td>
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<td>8</td>
<td>24</td>
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<td>9</td>
<td>30</td>
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<td>28</td>
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<td>11</td>
<td>35</td>
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<td>12</td>
<td>37</td>
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<td>13</td>
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<td>14</td>
<td>32</td>
</tr>
<tr>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>16</td>
<td>31</td>
</tr>
</tbody>
</table>

**Measured Forward Power @ 10 V/m @ 80 MHz**

**Table #2**

<table>
<thead>
<tr>
<th>Grid Point (Px)</th>
<th>Forward Power (dBm)</th>
<th>Range 1 (dBm)</th>
<th>Range 2 (dBm)</th>
<th>Range 3 (dBm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>40</td>
<td>40</td>
<td>37</td>
<td>35</td>
</tr>
<tr>
<td>12</td>
<td>37</td>
<td>37</td>
<td>37</td>
<td>35</td>
</tr>
<tr>
<td>11</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
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<tr>
<td>5</td>
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<td>34</td>
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<tr>
<td>7</td>
<td>34</td>
<td>34</td>
<td>34</td>
<td>34</td>
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<td>2</td>
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<td>14</td>
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<td>9</td>
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<td>16</td>
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<td>4</td>
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<td>13</td>
<td>29</td>
<td>29</td>
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<td>29</td>
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<tr>
<td>3</td>
<td>23</td>
<td>23</td>
<td>23</td>
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</tr>
<tr>
<td>15</td>
<td>22</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
</tbody>
</table>

**Range 1: 40 to 34 (dBm)**

**Range 2: 37 to 31 (dBm)**

**Range 3: 35 to 29 (dBm)**

**Points within 6 dB in %**

- **31.25%** (5 out of 16)
- **50%** (8 out of 16)
- **75%** (12 out of 16)

Highlighted cells show grid points within 6 dB window.

**Conclusion:** Use Forward Power of 35 dBm from position 11.
Constant Power Method Part 1 of 2
Measure and Record Field Strength

Determine forward power of reference grid point per freq

- Start 1st Grid Point
- Set Initial Frequency
- While monitoring field strength, adjust forward power until desired field strength is obtained
- Record Forward Power and Field Strength

All Frequency steps complete
- Yes
  - Set Next Frequency
- No
  - Record Field Strength

All Grid Points Complete
- Yes
  - B
- No
  - Set Next Frequency

Set Forward Power to Reference Grid Point Frequency Level
Set Initial Frequency
Select Another Grid Point
All Frequency Steps Complete
- Yes
  - Record Field Strength
- No
  - Set Next Frequency
Constant Power Method Part 2 of 2
Determine Forward Power for Each Frequency Point

- Set Freq To Initial Value
- Sort Each Grid Point Field Strength From Lowest to Highest
- Select the lowest Field Strength as Reference
- Add 6 dB to Field Strength
- Determine How Many Grid Points Are within 6 dB Window
- Are 75% of the Grid Points Within 6 dB
  - Yes
    - Add 6 dB to this reference Forward Power & record
  - No
    - Find Next Highest Field strength
    - Determine How Many Grid Points Are within 6 dB
    - Are all frequencies completed
      - Yes
        - Constant Power Calibration Completed
      - No
        - Next Frequency
Example Of How Field Uniformity Is Calculated
Using Constant Power Method Using A 16 Point Grid

Table #1
Measured Field Strength Based on 10 V/m @ 80 MHz

<table>
<thead>
<tr>
<th>Grid Point (Px)</th>
<th>Forward Power (dBm)</th>
<th>Field Strength V/m</th>
<th>Field Strength Related to position 1 (V/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>29</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>29</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>9</td>
<td>-1</td>
</tr>
<tr>
<td>4</td>
<td>29</td>
<td>9</td>
<td>-1</td>
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<td>5</td>
<td>29</td>
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<td>0</td>
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<td>6</td>
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<td>8</td>
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<tr>
<td>7</td>
<td>29</td>
<td>7</td>
<td>-3</td>
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<tr>
<td>8</td>
<td>29</td>
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<td>9</td>
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<tr>
<td>12</td>
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<td>13</td>
<td>29</td>
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<tr>
<td>14</td>
<td>29</td>
<td>5</td>
<td>-5</td>
</tr>
<tr>
<td>15</td>
<td>29</td>
<td>2</td>
<td>-8</td>
</tr>
<tr>
<td>16</td>
<td>29</td>
<td>2</td>
<td>-8</td>
</tr>
</tbody>
</table>

Table #2
Field Strength in ascending order
To determine 75 % points within -6 dB

<table>
<thead>
<tr>
<th>Grid Point (Px)</th>
<th>Forward Power (dBm)</th>
<th>Field Strength V/m</th>
<th>Field Strength Related to position 1 Range 1 -8 to -2 (V/m)</th>
<th>Field Strength Related to position 1 Range 2 -7 to -1 (V/m)</th>
<th>Field Strength Related to position 1 Range 3 -6 to 0 (V/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>29</td>
<td>2</td>
<td>-8</td>
<td>-8</td>
<td>-8</td>
</tr>
<tr>
<td>16</td>
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<td>11</td>
<td>29</td>
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<td>-4</td>
<td>-4</td>
<td>-4</td>
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<td>12</td>
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<td>8</td>
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<td>4</td>
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<td>-1</td>
<td>-1</td>
<td>-1</td>
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<tr>
<td>2</td>
<td>29</td>
<td>14</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

-8 + 6 dB = -7 + 6 dB = -2 + 6 dB = 0

Conclusion: Use Forward Power of 35 dBm
(29 dBm + 6 dB = 35 dBm)
Radiated Immunity Calibration Procedures
Linearity and Harmonics

NOTE: $f_1 = 5$ MHz,

Fwd Pwr dBm

FREQUENCY – MHZ

10

15

$2f_1$

$3f_1$

$> 6$ dBc
Radiated Immunity Test Set-Up
Table-Top And Control Room

NOTE Anechoic lining material on walls and ceiling has been omitted for clarity.

Figure 2 – Example of suitable test facility
Traditional Radiated Immunity Test Procedure

Test

• Level

• Apply Modulation

• Dwell

• Threshold

• Step To Next Frequency And Repeat

• Repeat For All Sides
Traditional Radiated Immunity Test Reporting

Test Reports Should Contain All The Information Necessary To Reproduce The Test Such As:

- EUT And Test Equipment Identification Including Brand Name, Product Type And Serial Number
- Any Special Environmental Conditions
- Defined Performance Level
- Performance Criterion And Rationale For The Pass/Fail
- Any Observed Disturbances And Their Duration That Affected The EUT During Or After The Test
- A Description Of The Cabling And Equipment Position And Orientation
Multi Tone Radiated Immunity Testing

This Section Will Cover Multi Tone Testing

- How To Implement Multi Tone

- Multi Tone Equipment

- Multi Tone Test Setup

- Multi Tone Procedure

- Benefits Of Multi Tone Testing

- Calibration Of Multi Tone
The Transition From ‘Single Tone’ To ‘Multiple Tone’ Radiated Immunity Testing
Method 1

How Can This Be Implemented?
Start With 2 Or More Complete Setups To Radiate The EUT At One Time
The Transition From ‘Single Tone’ To ‘Multiple Tone’ Radiated Immunity Testing Method 2

How Can This Be Implemented?
- Simplify The Setup
- Use Multiple Signal Sources To Drive One Amplifier And One Antenna
The Transition From ‘Single Tone’ To ‘Multiple Tone’ Radiated Immunity Testing Method 3

How Can This Be Implemented?
- Simplify The Setup
- Use A Vector Signal Generator (VSG) To Generate Multiple Frequencies
Standard “Single-Tone” Test Animation

* the frequency range from 80 - 1000 MHz, there are 492 1% steps
* a test setup with 2 antenna polarities and 4 EUT sides has 3936 total steps

(492 steps x 2 antenna polarities x 4 EUT sides = 3936 steps)

<table>
<thead>
<tr>
<th>Selected Dwell Time</th>
<th>3 sec</th>
<th>5 sec</th>
<th>10 sec</th>
<th>30 sec</th>
<th>1 min</th>
<th>3 min</th>
<th>5 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Time Required</td>
<td>3.28 h</td>
<td>5.47 h</td>
<td>10.9 h</td>
<td>32.8 h</td>
<td>66 h</td>
<td>197 h</td>
<td>328 h</td>
</tr>
</tbody>
</table>
Multiple Tone Test Animation

<table>
<thead>
<tr>
<th># of Simultaneous Tones</th>
<th>Selected Dwell Time</th>
<th>3 sec</th>
<th>5 sec</th>
<th>10 sec</th>
<th>30 sec</th>
<th>1 min</th>
<th>3 min</th>
<th>5 min</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total test time required based on number of tones in set</td>
<td>3.28 h</td>
<td>5.47 h</td>
<td>10.9 h</td>
<td>32.8 h</td>
<td>66 h</td>
<td>197 h</td>
<td>328 h</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>0.82 h</td>
<td>1.37 h</td>
<td>2.73 h</td>
<td>8.2 h</td>
<td>16 h</td>
<td>49.2 h</td>
<td>82 h</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>0.41 h</td>
<td>0.68 h</td>
<td>1.36 h</td>
<td>4.1 h</td>
<td>8 h</td>
<td>24.6 h</td>
<td>41 h</td>
</tr>
</tbody>
</table>

* Based on 492 steps, 2 antenna polarity and four sided EUT
Multiple Tone Radiated Immunity Testing – Equipment Requirements

- Higher Power Amplifiers
- Vector Signal Generators
- Directional Couplers
- Vector Signal Analyzer
- Isotropic Field Probe And Monitor
- EMI Filters
- Horn And Log-periodic Antennas
- Anechoic Chamber
Multiple Tone Radiated Immunity Calibration Test Procedure

UFA (Uniformity Field Area) Calibration Is The Same As Traditional Calibration
  – Constant Field
  – Constant Power

Linearity and Harmonics Are Tested To Determine The Grouping Of Tones Used in Each Set
Set fwd pwr for each tone per UFA data

Measure each tone amplitude using peak hold

Reduce the VSG on all tones by 5.1 dB

Measure & record each tone amplitude using peak hold

Check Linearity

Yes

Are there more tones

Reach max tones per set

No

Compare each level to reduce tone level >3.1 dB

Yes

No

Save tone set

Save previous tone set

Test completed

No

Are there more tones

Yes

Get next tone set

Generate multiple tones @ 1% spacing

Add one tone

Are there more tones

Yes

Get 1st tone

Start with one tone
Multiple Tone Radiated Immunity Test Calibration

Flow Chart for Testing Harmonics and Intermods

Start with one tone

- Get 1st tone
  - Generate multiple tones @ 1% spacing
    - Set fwd pwr for each tone per UFA data
    - Add Ant Factor & measure each tone amplitude using peak hold
    - Add Ant Factor & measure intermods around fundamental tone
    - Add Ant Factor & measure intermods around harmonics up to 3rd harmonic
      - Add Ant Factor & measure intermods around harmonics up to 3rd harmonic

- Are there more tones?
  - Yes: Add one tone
    - Check Harmonics and Intermods
      - Set fwd pwr for each tone per UFA data
      - Add Ant Factor & measure each tone amplitude using peak hold
      - Add Ant Factor & measure intermods around fundamental tone
      - Add Ant Factor & measure intermods around harmonics up to 3rd harmonic
      - Compare lowest tone to highest harmonic or intermods > 6dBc
        - Yes: Save tone set
      - No: Reach max tones per set
    - No: Are there more tones?
      - Yes: Generate multiple tones @ 1% spacing
      - No: Test completed

- Are there more tones?
  - Yes: Get next tone set
  - No: Finish testing

Save previous tone set

Test completed

Check Harmonics and Intermods
Multiple Tone Radiated Immunity Calibration
Harmonics And Intermods
(Using Two Tones As An Example)

Fundamental Frequencies And Their Harmonics

Second Order IMD Products

Third Order IMD Products

NOTE: $f_1 = 5$ MHz, $f_2 = 6$ MHz
## Number Of Tones Generated Based On 150 MHz BW

<table>
<thead>
<tr>
<th>Frequency Range (MHz)</th>
<th># Of Steps In Frequency Range Based On 1% steps</th>
<th># Of Tones Generated Simultaneously</th>
</tr>
</thead>
<tbody>
<tr>
<td>80 -1000</td>
<td>492</td>
<td>10+</td>
</tr>
<tr>
<td>1000-2000</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>2000-2500</td>
<td>22</td>
<td>8</td>
</tr>
<tr>
<td>2500-3000</td>
<td>19</td>
<td>6</td>
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<tr>
<td>3000-4000</td>
<td>29</td>
<td>5</td>
</tr>
<tr>
<td>4000-6000</td>
<td>41</td>
<td>4-2</td>
</tr>
</tbody>
</table>
Radiated Immunity Test Set-up
Table-Top And Control Room

NOTE Anechoic lining material on walls and ceiling has been omitted for clarity.

Figure 2 – Example of suitable test facility
Multiple Tone Time Savings

![Bar Chart]

- IEC 61000-4-3 1% step sizes, taking into account dwell time
Multiple Tone Radiated Immunity Test & Calibration Reporting

Reporting Requirements Will Functionally Be The Same As The Traditional

The Multi-tone Linearity And Harmonic Calibration Test Will Report:
- Linearity For Each Tone
- The Worst Harmonic In Each Set Of Tones

Software Should Provide Necessary Test & Calibration Information To Meet Standard As Well As Document Results In Both Tabular And Graphical Formats.
Radiated Immunity Testing Speed

- Fast Testing
- Estimated EUT Susceptibility Limit
- Range susceptible from multi-tone test and passes single tone test
- Total Energy Present
  - Multi-tone Energy
  - Single Tone Energy

Frequency
Power Required to Generate 10 V/m
Power Required to Generate 10 V/m

IEC 61000-4-3 Vertical 10V/m @ 3 meters Resultant From UFA

- 1 tone: 100 watts
- 2 tones: 50 watts
- 33 watts

Frequency (MHz)

Power (Watts)
Power Required to Generate 10 V/m

IEC 61000-4-3 Vertical 10V/m @ 3 meters Resultant From UFA

- 1 tone: 100 watts
- 2 tones: 99 watts
- 3 tones: 50 watts
- 4 tones: 33 watts
Comparing the Two Radiated Immunity Tests  
Where are the differences

<table>
<thead>
<tr>
<th>Required Equipment</th>
<th>Traditional</th>
<th>Multiple Tones</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amplifier</td>
<td>Larger Amplifier</td>
</tr>
<tr>
<td></td>
<td>RF Signal Generator</td>
<td>Vector Signal Generator</td>
</tr>
<tr>
<td></td>
<td>RF Power Meter</td>
<td>Vector Signal Analyzer</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Calibration Of Linearity, Harmonics And Power Level</th>
<th>Single Tone</th>
<th>Create And Calibrate Tone Groupings/Sets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Savings Is Dependent On Equipment Used. For Example VSG Is Significantly Faster Than GPIB Bus, So Calibration At Group Level Is Faster.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Testing Procedures</th>
<th>Single Tone</th>
<th>Group Of Tones</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performed At</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fault Isolation At</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group Then Via Software Down To Single Tone</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Given Frequency Range</th>
<th>80-1000 MHz, 492 1% Steps, 2 Antenna Polarities, 4 Sided EUT, 3 Second Dwell Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Required</td>
<td>2.9 Hrs.</td>
</tr>
<tr>
<td>Associated Time Savings</td>
<td>0%</td>
</tr>
<tr>
<td></td>
<td>0.43 Hrs.</td>
</tr>
<tr>
<td></td>
<td>85%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reporting</th>
<th>Dependent Upon Software Used, Tabular And Graphical Available</th>
</tr>
</thead>
</table>
Recap of the Future of Radiated Testing

• The Future Holds Exponential Growth in the Number of Electronic Devices Required To Coexist

• Radiated Testing is and will continue to be Increasingly Invaluable

• Testing Should Simulate Threats More Close to the Real World Environment

• With Enhanced Saturation of Frequency Ranges, the Potential Exists for Standards Changing To Reflect the Need For More Steps

• Multiple Tone Testing will be Vital To Meet The Dynamics Demands of these Emerging Market Requirements while Reducing Test Time and Improving Overall Testing Efficiencies.
Questions & Answers