Designing for Success:
An Engineer's Guide to Practical FCC Compliance Pre-Scans

Meet Your Presenter:

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Senior RF Engineer

Questions? Please use the chat window to ask questions! Questions will be answered via email following the webinar.

Today's Agenda

1. Strategy - ***What should be tested in a FCC pre-scan?***
2. Execution – ***Practical advice to maximize pre-scan value.***
3. Results – ***How to evaluate the pre-scan results.***

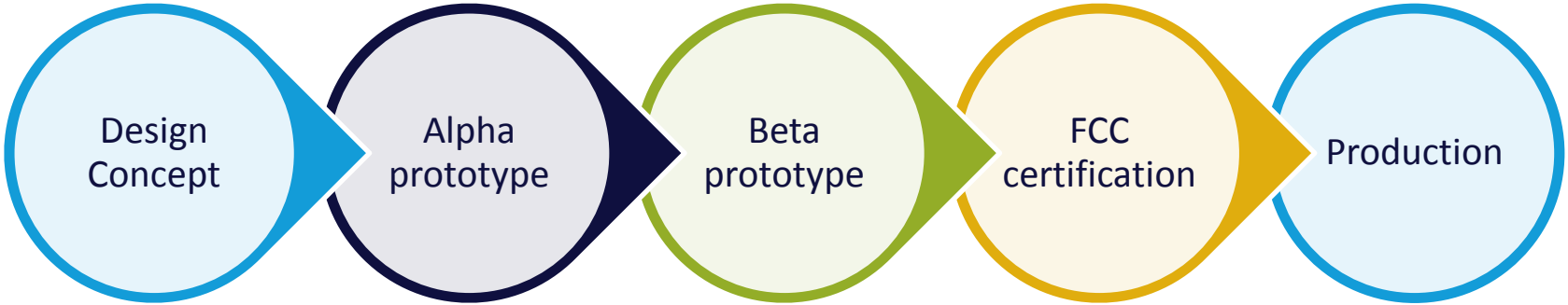
Webinar Scope & Emphasis

- **Scope**
  - An introductory understanding of FCC certifications.
    - Examples: coexistence, radiated fields, intentional radiator
  - Familiar with basic RF terminology
    - Examples: dB, bandwidth, frequency band (ISM)
- **Content Emphasis**
  - Detailed discussion of the FCC standards is not in the scope of the webinar.
  - Strong emphasis on pre-scanning products with radios.
    - Examples: WiFi, Bluetooth, LoRa
  - Higher Risk: Products with radios are more likely to exceed FCC limits.

Pre-Scan Strategy

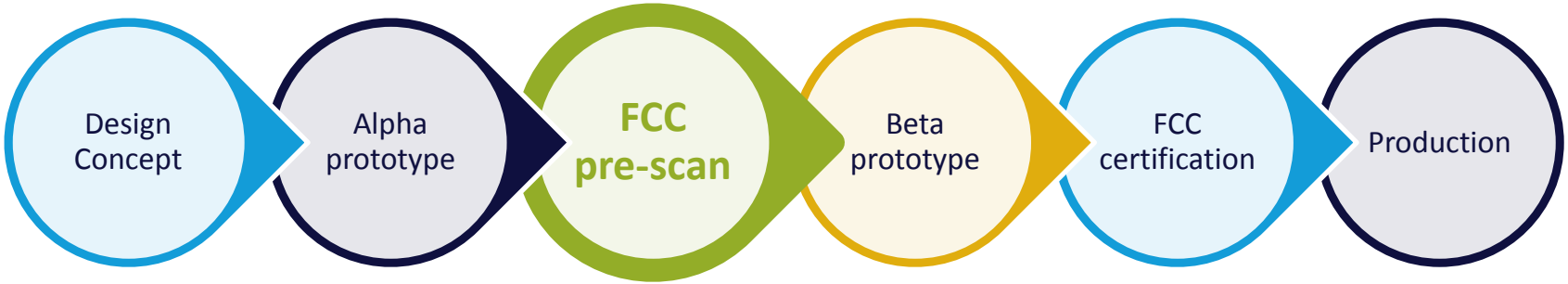
What should be tested in a FCC pre-scan?

Cheapest *(Risky)* FCC Strategy



- **RISK:** This strategy assumes that the product is fully compliant with ***ALL*** of the FCC requirements!
- FCC failures impact the design schedule and budget.
  - Likely require hardware changes/re-design - **$$**
  - Schedule delay to market - **$$**
  - Repeat FCC testing - **$$**

LSR's FCC Strategy



- LSR's development process includes FCC pre-scans – early in the prototype phase.
- Pre-scans are like an insurance policy: *"A small investment early on can pay dividends later – by avoiding expensive redesigns."*
- Pre-scans are a project benchmark – similar to other standard engineering tests.

Recommended Pre-Scans

The following tests are recommended for any FCC pre-scan with a wireless radio.

1. Unintentional Radiator – FCC Part 15, Subpart B
2. Conducted Emissions – AC
3. Intentional Radiator – Harmonics
4. Intentional Radiator – Band Edge

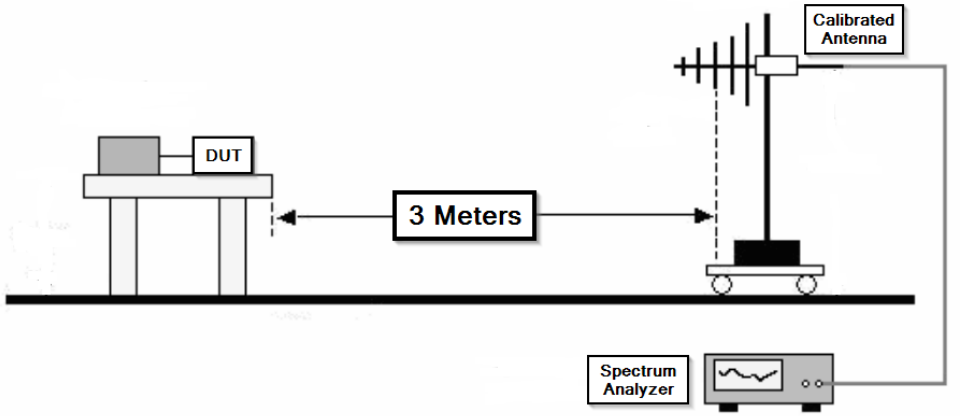
DISCLAIMER: This list is not a complete list for all products. Please work with your EMC lab to make final pre-scan selections. ***Custom products need customized pre-scans!***

1. Unintentional Radiator

- FCC Part 15, Subpart B – commonly called the ‘unintentional radiator’ scan.
- Any digital device that operates at or above 9 kHz. *(clocks & signals)*
- This test verifies that the product will coexistence with other wireless communications.
  - Emergency Radio
  - Cell Phones
  - GPS

FCC General Emissions Limit – 3 Meters

FREQUENCY (MHz)	uV/m	EIRP (dBm)	nW
30-88	100	-55.23	2.99
88-216	150	-51.73	6.71
216-960	200	-49.23	11.93
960-40,000	500	-41.23	75.33



1. Unintentional Radiator

There are many ways to exceed unintentional radiator limits!

Common Offenders

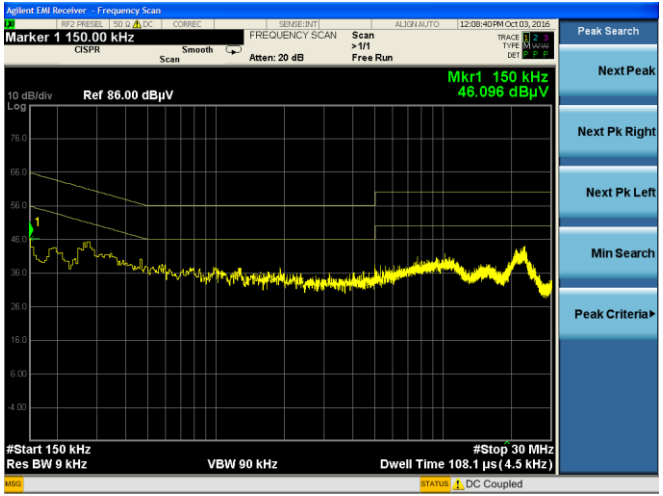
- LCDs
- High Speed Digital *(DDR Memory)*
- Switch Mode Power Supplies

Less Obvious Failures

- Cabling *(Power, USB, Audio)*
- Radio Specific - RX Local Oscillator *(Typically 2x the carrier frequency)*

2. AC Conducted Emissions

- Pre-scan recommended for products connected to AC mains.
- This test measures ‘low frequencies’: 0.15 MHz – 30 MHz.
- Resolving conducted emissions usually requires physically large filters.
- Can present mechanical integration challenges if discovered too late *(schedule + budget impact).*



2. AC Conducted Emissions

Low frequency radios can create conducted emission failures!

Common Offenders

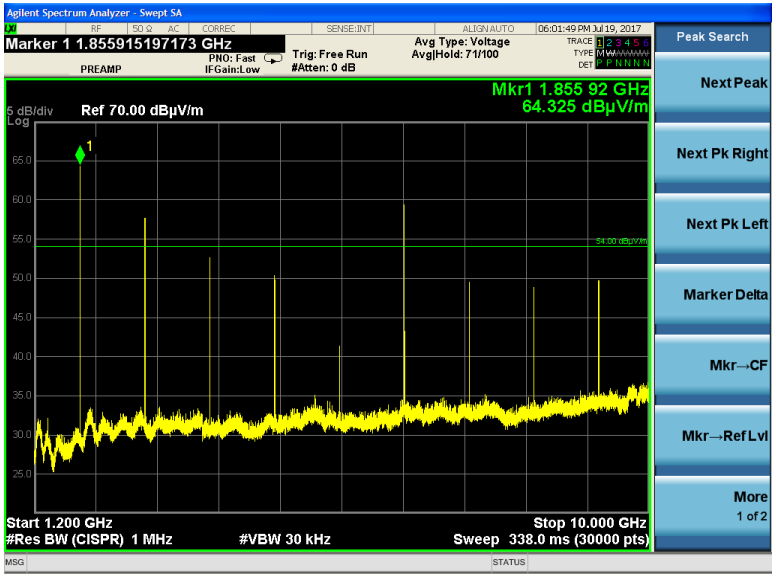
- AC/DC Power Supplies
- DC-DC Switch-Mode Power Supplies
- Motors

Less Obvious Failures

- Near Field Communication (NFC) Radios *(13.56 MHz)*
- RFID *(13.56 MHz)*
- Low frequency radios are more likely to fail conducted emissions than radiated

3. RF Harmonics

- Harmonics are integer multiples of the radio's fundamental.
  - Fundamental = 2.4 GHz
  - 2nd Harmonic = 4.8 GHz
  - 3rd Harmonic = 7.2 GHz etc…
- Harmonics are a result of nonlinearities within a radio.
- Harmonics are universal for all radios – recommended to pre-scan.



Example of a Radiated Harmonic Scan

3. RF Harmonics

- Majority of radio harmonics fall in the FCC's restricted bands of operation!
- Restricted bands are limited to the general limits – *think nano-watts*.

900 MHz ISM BAND	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
2.4 GHz ISM BAND	2nd	3rd	4th	5th	6th	7th	8th	9th	10th

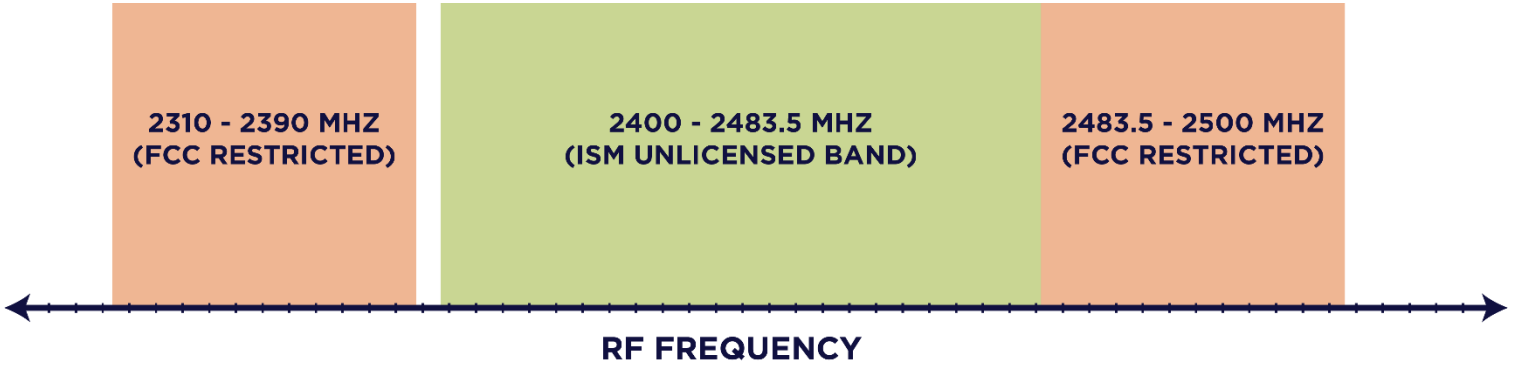
LEGEND:

RED = Harmonic **IS** in a FCC Restricted Band

GREEN = Harmonic **IS NOT** in a FCC Restricted Band

4. Band Edge

ISM bands can be close to restricted bands!



- Band edge measurement verifies that the radio only transmits within its intended frequency band.
- Recall: Restricted bands use the general emission limit – *think nano-watts*.

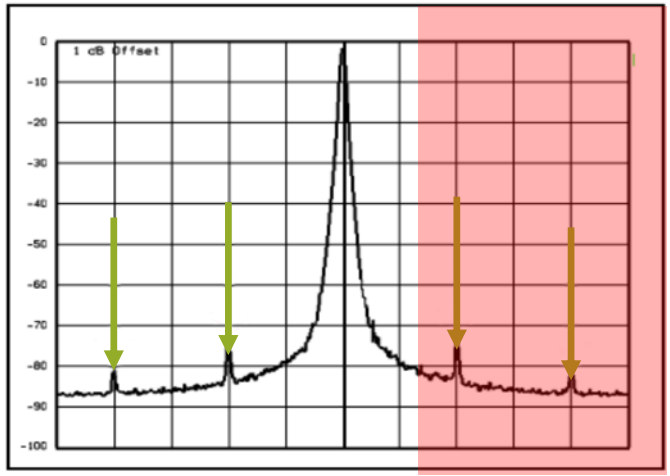
Example: Wi-Fi/Bluetooth

- Operates in '2.4GHz Band' = 2400 to 2483.5MHz

4. Band Edge

Common Offenders

- Example Failure Modes:
  - Poor RF Power Amplifier Linearity
  - Poor Antenna Impedance Matching
  - Spurious Noise Offsets
  - Output Power is Too High
    - Example: Many Wi-Fi radios reduce output power on channel 1 & 13 to meet band edge requirements.



LEGEND:

Arrows: Spurious Noise Offsets

Shaded Region: FCC Restricted Band

Pre-Scan Strategy Summary:

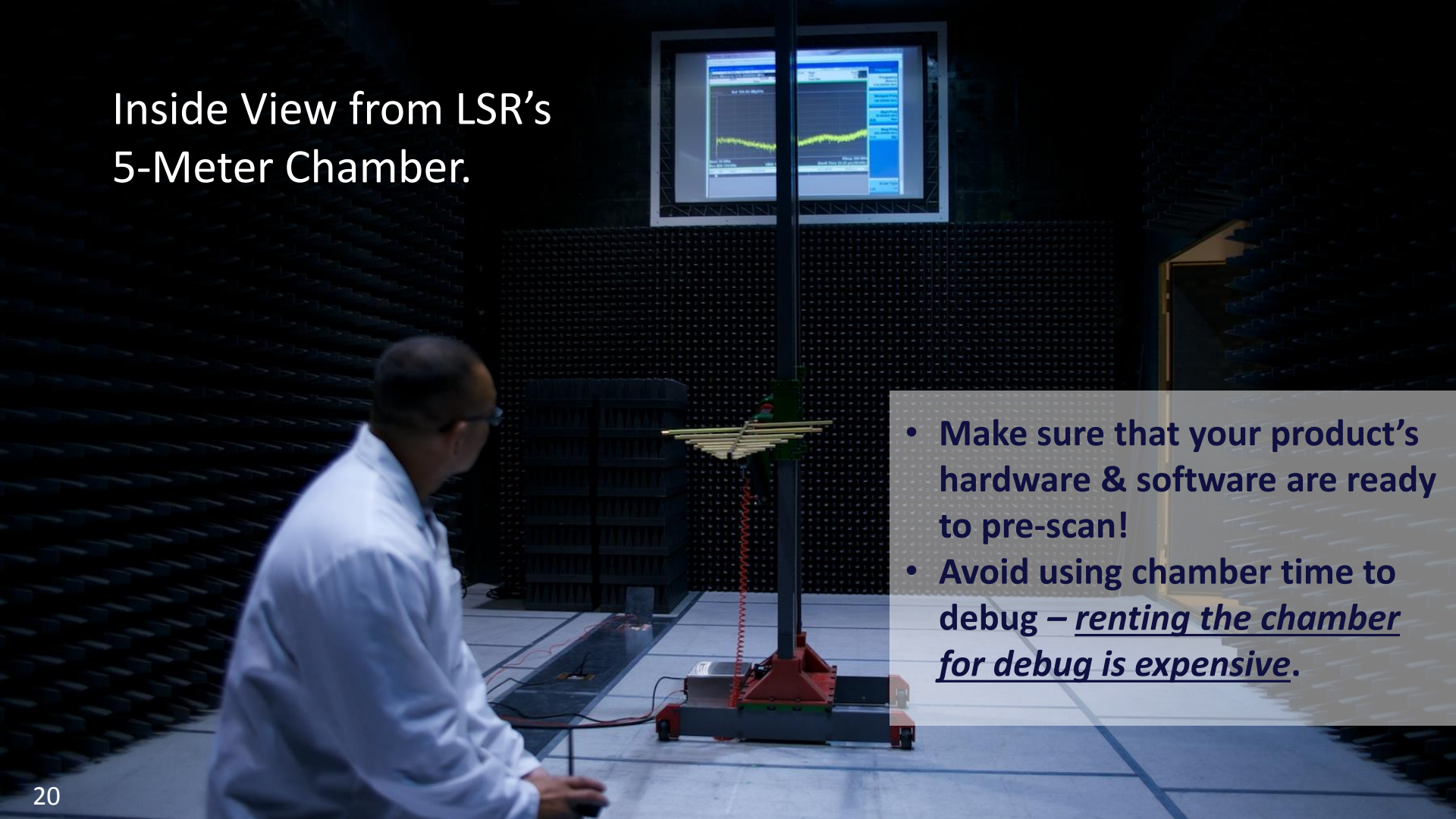
- Custom products require customized pre-scans.
- Work with your EMC Lab to select the appropriate pre-scans.
- *“Find all of the issues, so you can fix all of the issues.“*

Tip: For pre-scans, make sure the compliance engineer knows to continue testing to discover all failures. They are trained to **STOP** testing at the first failure.

Pre-Scan Execution

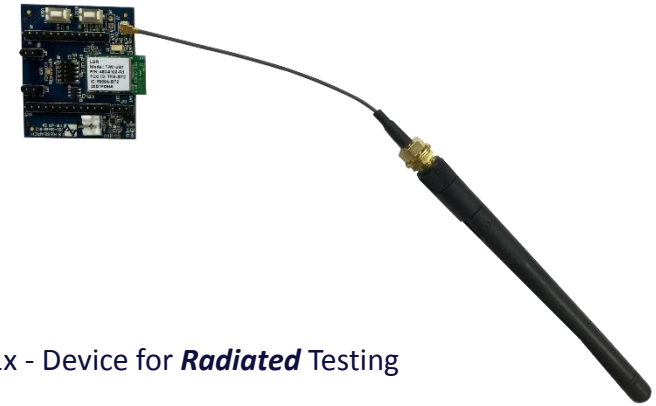
Practical advice to maximize pre-scan value.

Inside View from LSR's 5-Meter Chamber.



- **Make sure that your product's hardware & software are ready to pre-scan!**
- **Avoid using chamber time to debug – *renting the chamber for debug is expensive*.**

Hardware Requirements



1x - Device for ***Radiated*** Testing

1x - Device for ***Conducted*** Testing

- It's good practice to provide extra test units (2-3x).
- Provide any cabling that can be used with a product.
  - Cables are part of compliance testing!
  - External Power Supplies
  - USB, Ethernet, Headphones etc.

Conducted Device Tips:

- Verify conducted impedance is 50Ω.
- Provide external power connection.

Software Requirements

All Products

- Configure the product for normal operation.
- Provide the test engineers the ability to use all normal product features.

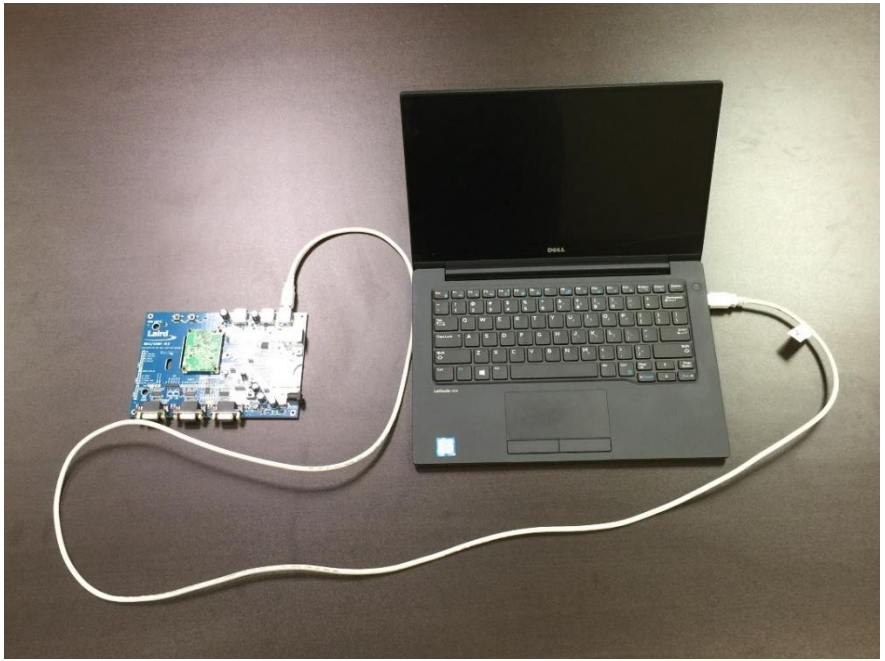
Radio Specific Test Modes

- **Constant Transmit Modes**
  - Modulated *(>98% duty cycle)*
  - Un-Modulated
- **Constant Receive Mode****
- **EMC engineers also need control of:**
  - RF Channel Selection *(for both transmit and receive)*
  - Power Settings *(if adjustable)*
  - Data Rates *(if adjustable)*

** **Tip:** Dedicate a status LED to indicate when the radio is in constant receive mode!

Testing Interface

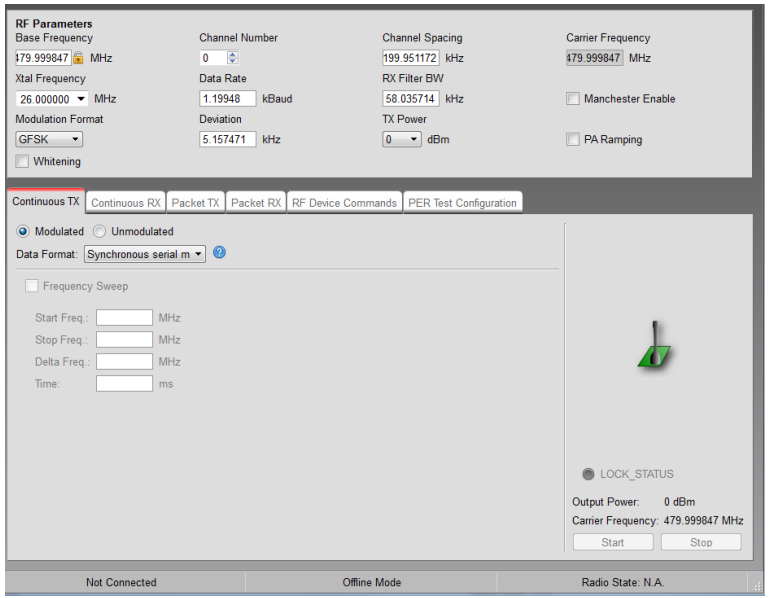
- The lab needs a hardware/software interface to control the product.
- **GOAL:** Provide an intuitive interface so that the EMC engineer can work efficiently in the chamber.
- ***This will directly maximize the pre-scan value.***
- Avoid having dangling cables from the devices ***– remember these can accidently radiate!***



Example of Generic USB Test Interface

Software Interface – Manufacturer Provided

- Software is already created – *no additional development schedule required.*
- The software is tested and proven – *works right out of the box.*
- Typically well supported and intuitive for EMC test engineers.



Example of Manufacturer Provided Test Software

Software Interface – Custom CLI

- This approach uses a CLI to send custom messages from a computer to the product in the test chamber.
- The CLI sets the product into the proper test modes.
- ***Keep it simple!*** A complex CLI leaves room for errors or inefficiencies during compliance testing.

```
test transmit dut_101_plt stop_tx
test transmit dut_101_plt set_channel 1 0 1
test transmit dut_101_plt config_tx_power 4000 1 0 1
test transmit dut_101_plt tx_enable 500 3 300 1 00:11:22:33:44:55
```

Example of a Complex CLI Command Set

- Testing complexity can increase if each command requires a long CLI string!

Software Interface – Custom CLI

- ***Keep it simple!*** To avoid a complex CLI – instead consider leveraging CLI scripting software
- Example: Docklight (https://docklight.de/)
- Software is designed to convert typed-CLI commands into a simple, intuitive push-button interface.

```
test transmit dut_101_plt stop_tx
test transmit dut_101_plt set_channel 1 0 1
test transmit dut_101_plt config_tx_power 4000 1 0 1
test transmit dut_101_plt tx_enable 500 3 300 1 00:11:22:33:44:55
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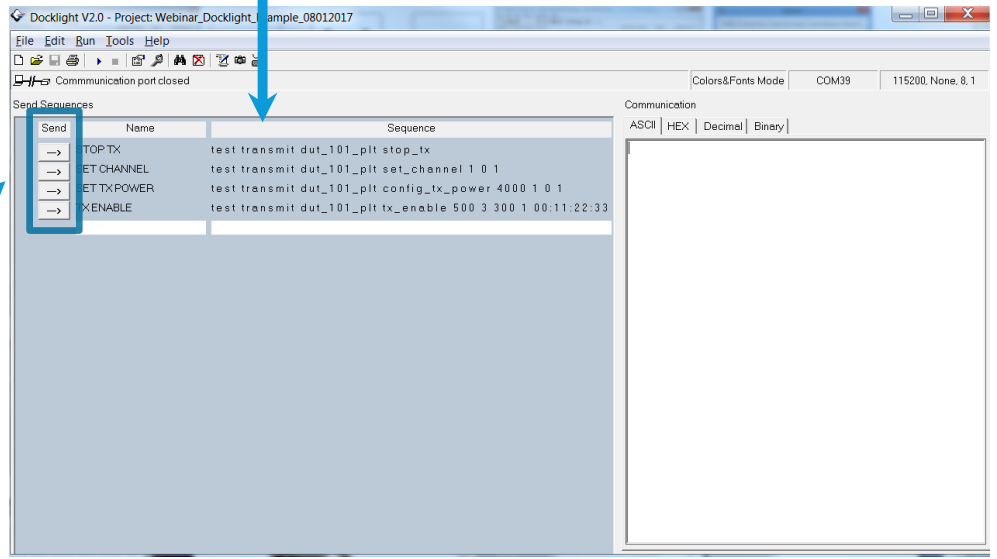
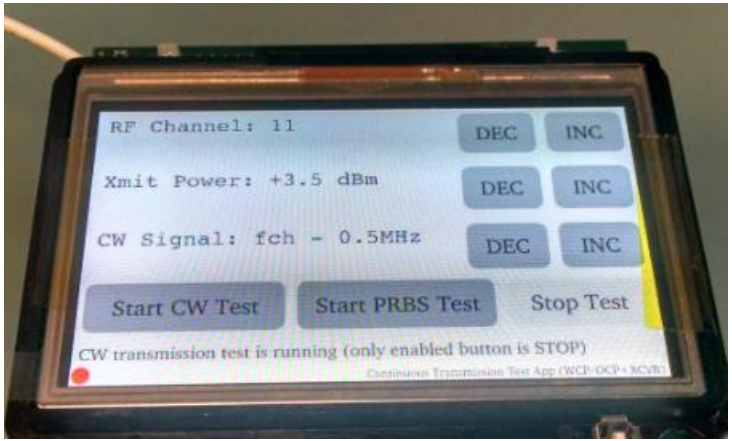


Simple, Push Button Interface

Software Interface – Custom

- One product re-purposed the product's touch screen to control the FCC pre-scan test software.
- Clear, intuitive, no test wires required.



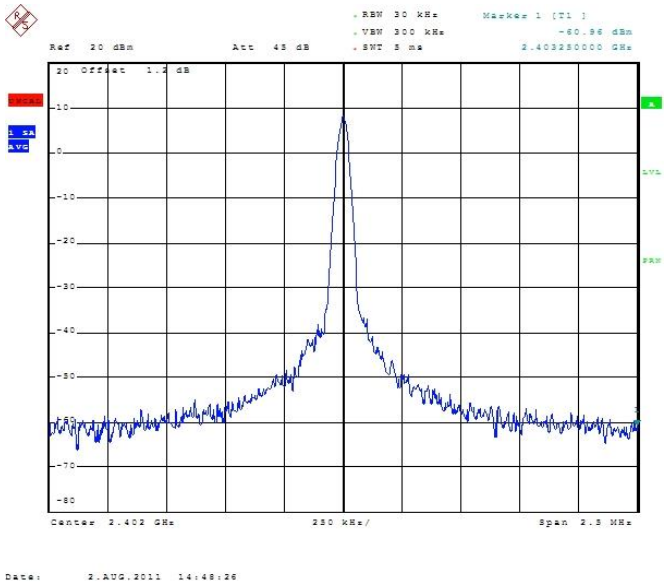
Example of a Custom Touch Screen Test Interface

Verify Your Software

It is much cheaper to verify & debug the test software on the bench that in the test chamber!

Inexpensive spectrum analyzers can be used to verify basic radio functionality (output power, frequency, general emissions).

USB Spectrum Analyzer Option: **Tektronix RSA-306** for pre-compliance sanity checks.



General Spectrum Analyzer Screen Capture

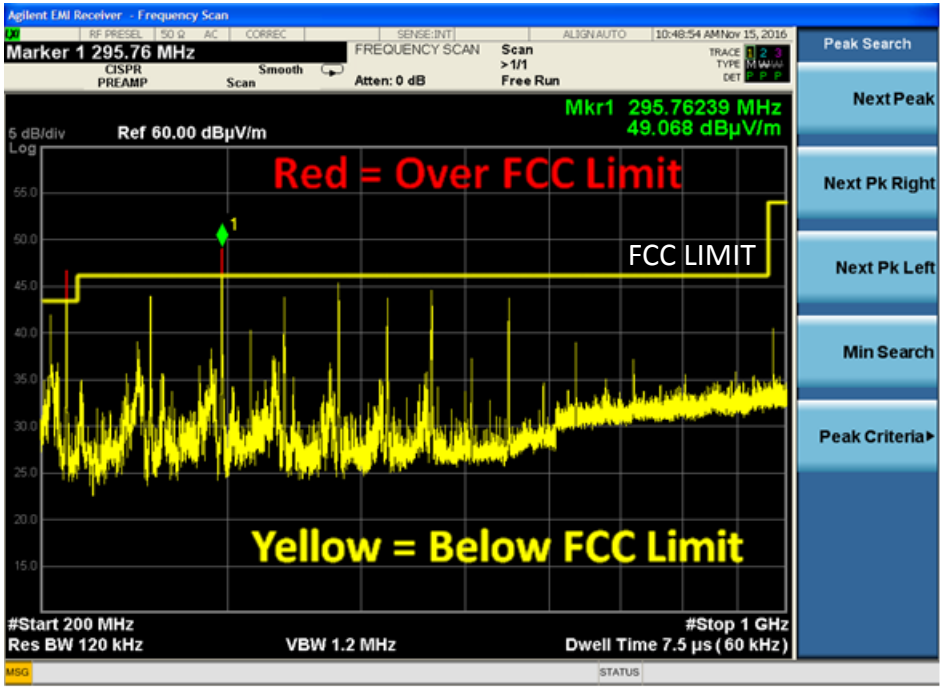
Pre-Scan Results

How to evaluate and interpret pre-scans results.

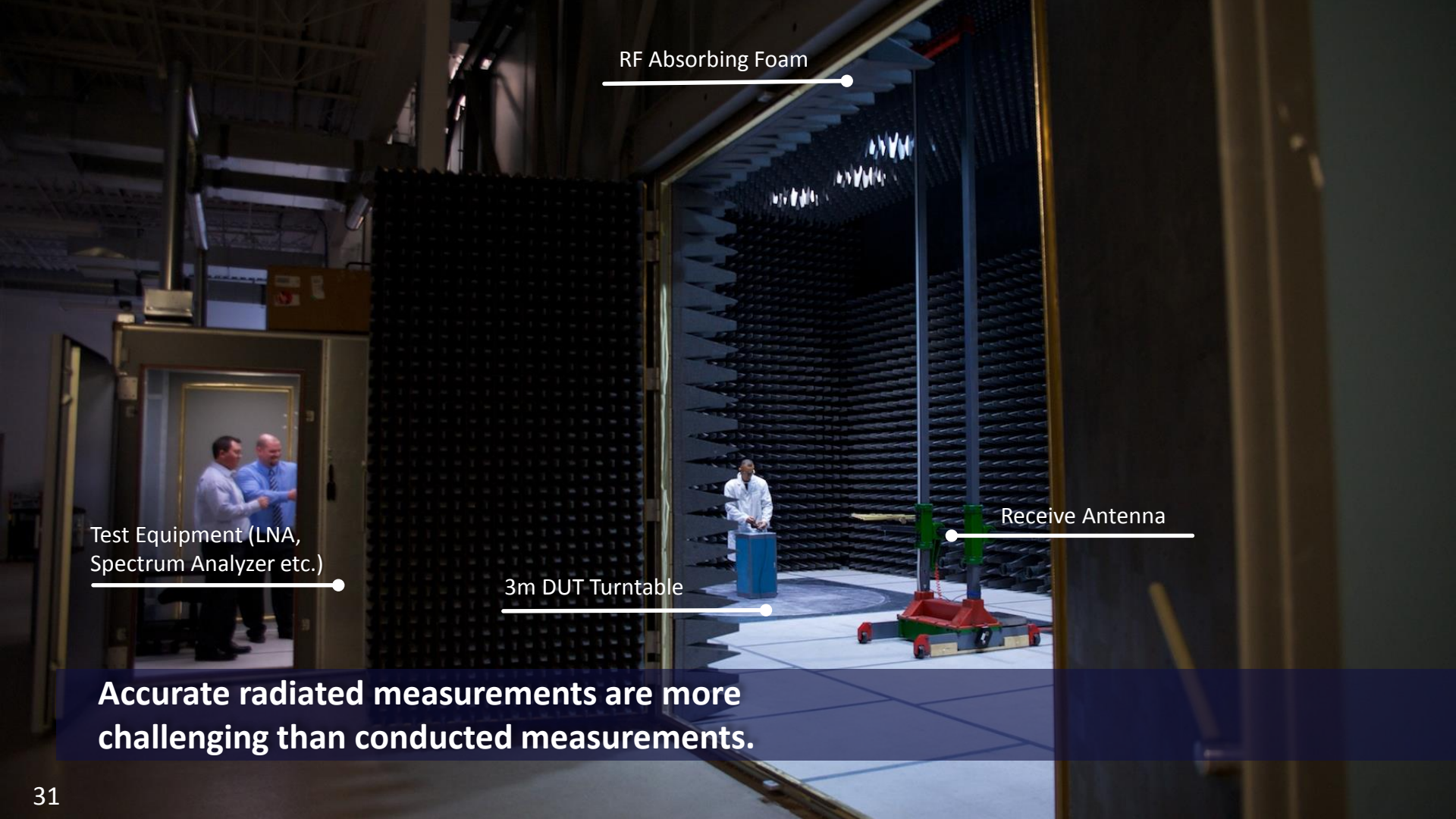
Data Packet

The data packet is the pre-scan deliverable.

- Data packet will include a series of measurement screen captures and tables.
- Find and fix any emissions above the limit.
- Consider investigating any emissions close to the limit.



Example of a Unintentional Radiated Emission Scan



Accurate radiated measurements are more challenging than conducted measurements.

Measurement Uncertainty

Don't overlook measurement uncertainty!

- Even with top of the line equipment and extensive calibration procedures, radiated measurements include significant measurement uncertainty to be aware of.

Measurement Type	Configuration	Uncertainty ±
Radiated Emissions	**Biconical Antenna**	**5.0 dB**
Radiated Emissions	**Log Periodic Antenna**	**5.3 dB**
Radiated Emissions	**Horn Antenna**	**4.7 dB**
AC Line Conducted Emissions	Artificial Mains Network	3.4 dB
Telecom Conducted Emissions	Asymmetric Artificial Network	4.9 dB
Disturbance Power Emissions	Absorbing Clamp	4.1 dB
Radiated Immunity	3 Volts/meter	2.2 dB
Conducted Immunity	CDN/EM/BCI	2.4/3.5/3.4 dB
EFT Burst/Surge	Peak pulse voltage	164 volts
ESD Immunity	15 kV level	1377 Volts

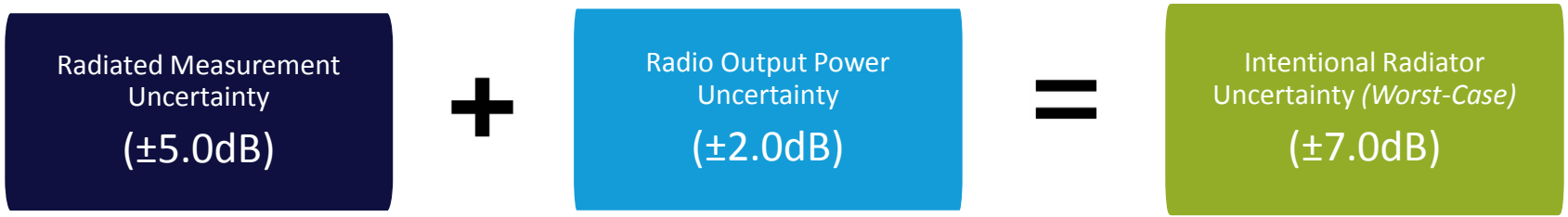
Uncertainty for radiated measurements is approximately ***±5dB***.

Measurement Uncertainty

Intentional radiator testing has increased uncertainty.

- Radios also have output power uncertainty - specified in the radio's datasheet!
- **General Rule:** Plan for 1-2dB uncertainty in radio output power.
- Output power uncertainty is additive on top of the general measurement uncertainty - ***often overlooked!***

Intentional Radiator Measurement Uncertainty



Risk of Marginal Passing

Don't forget to consider passing with margin

Pre-Scan Goal

- Measure emissions below FCC limits by greater than the measurement tolerance.

Risk 1:

- Due to radiated measurement tolerances, the final FCC test results may be a few dB higher than previous scans.

Risk 2:

- ***"Every unit a company produces must be FCC compliance"***
- Need testing margin to ensure every product will pass – even if measured in a different chamber.

Bringing It All Together

4 key points to remember about FCC pre-scans

1. **Avoid an unexpected FCC failure by pre-scanning the product early in the design cycle.** Investing in pre-scans will reduce the risk of significant time-to-market delays.

2. **Partner with Laird Compliance Lab to select your optimal pre-scans.** Custom products require customized pre-scans.

3. **Observe the FCC's restricted bands of operation, for products with radios.** These are often overlooked and only allow a small amount of radiated energy.

4. **Resolve any failures on subsequent board designs and strive to pass with margin.** When evaluating the pre-scan results, account for measurement tolerances.

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