EM-ISight
Test Applications Using an Automated Near Field Detection System

18/11/2011

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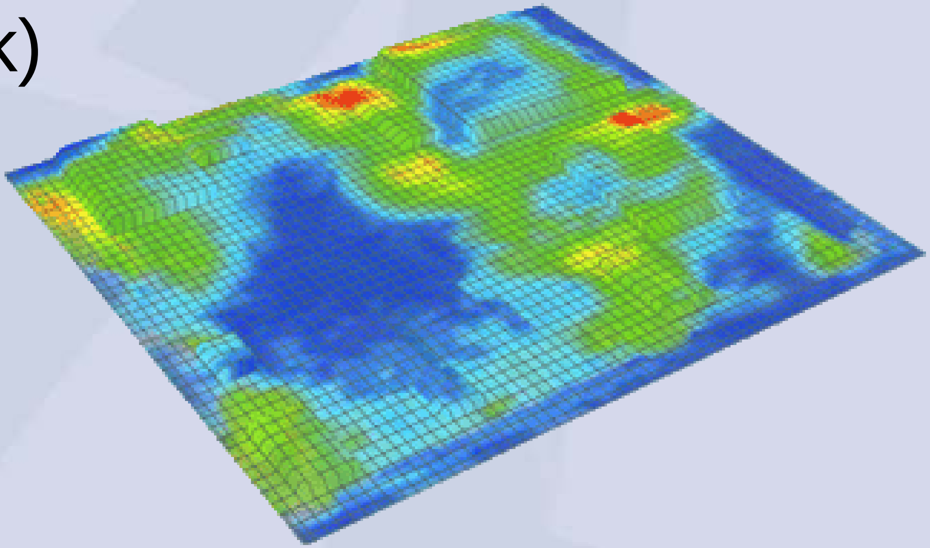
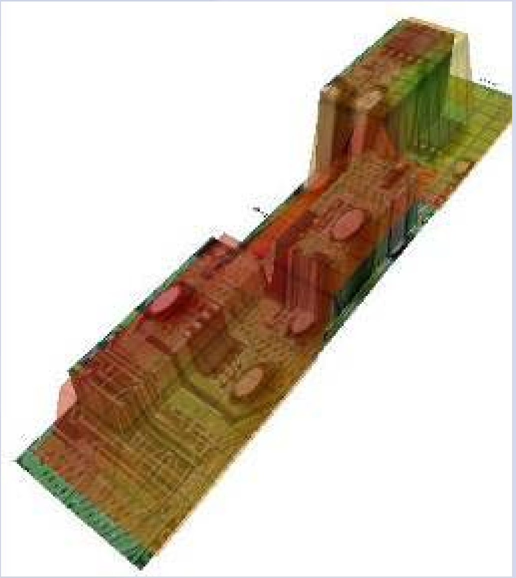


Introduction

Introduction (background)

Wireless technologies are extending into a variety of markets/applications, including industrial, process automation and personal mobile connectivity. Wireless communication generates electromagnetic fields that might be health hazardous or cause problems for technologies located near to or in the same package. Where multiple transmitters exist there is always a need to solve EMC problems relating to noise from IC design, location of components, PCB layout, radio/antenna location or digital devices. This presentation discusses how an automated near field scanning system helped solve such EMC problems.



Technology Overview

- Fully automated system
- 5 or 6 axis Denso robotic control using advanced kinematics
- Positioning uncertainty of less than 0.02mm
- Bench top system for easy location and integration into laboratory
- 120 or 220V operation
- Dynamic touch detection system incorporating “easy scan”
- H-Field antenna probes with 0.035mm substrate thickness (E-Field Probe available)
- Working envelope up to 1200mm X & Y and 1100mm Z
- True 3D kinematics for more complex device analysis
- 2D, 3D and 4D graphical interface and data output
- Fully customizable test reports implementing user “click and select” for data importation into MS Word report
- Remote access to system
- Noise floor measured at better than -145dBm (dependent on spectrum analyzer)
- Pre compliance tool / correlate data to traditional methods (OATS, 10m etc)

Case Study 1 Netbook

- Netbook designed to be fully wireless
- Wireless communication devices include WWAN, Bluetooth, WiFi and WiMAX
- Multiple antennas to be located within small package
- Multiple digital devices within system including camera, video chipset, SIM module, SD card interface and HDMI
- GPS module for tracking
- Multiple USB ports
- Device needs government certification
- Device has to pass carrier certification for WWAN

Case Study (approval)

North America
FCC/IC

Europe EC

PC Netbook
(WiFi-WiMAX)

North America
FCC/IC
PTCRB

Europe EC
GCF

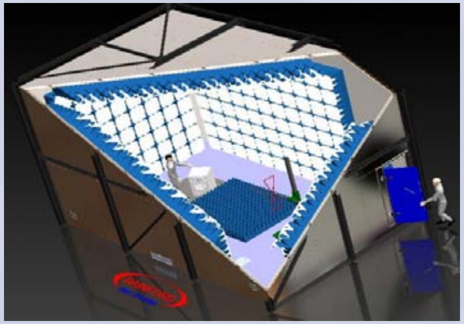
Mini-PCI Radio
(WWAN)

Integrate Mini-PCI WWAN into PC re-certify class 2 etc

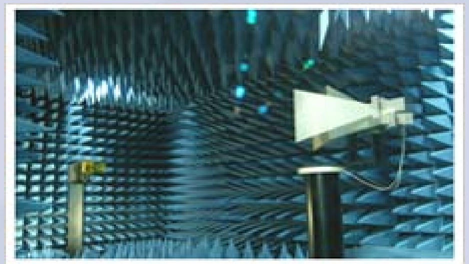
North America
FCC/IC
PTCRB
Updated to include
WWAN radio

Case Study

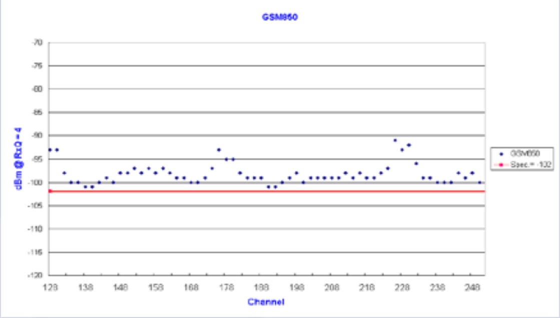
Device Under Test

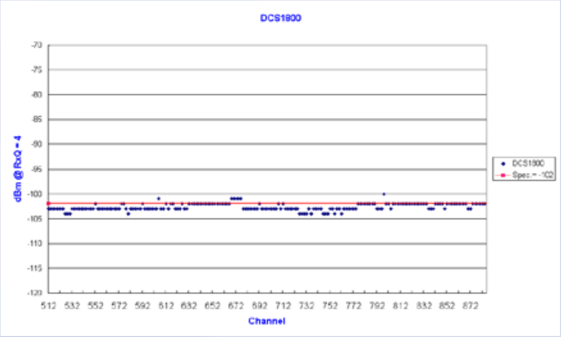


10 Meter Chamber



OTA Chamber

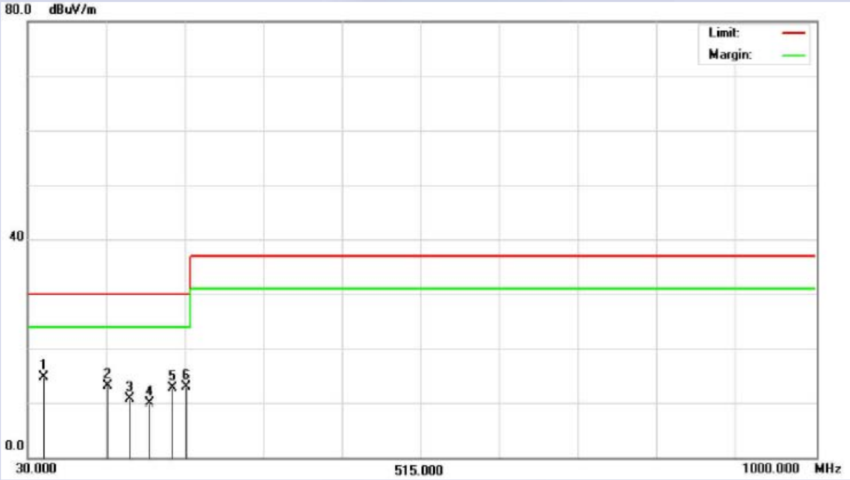




Failed Results

Pre-compliance assessment of device in OTA total isotropic sensitivity failed.

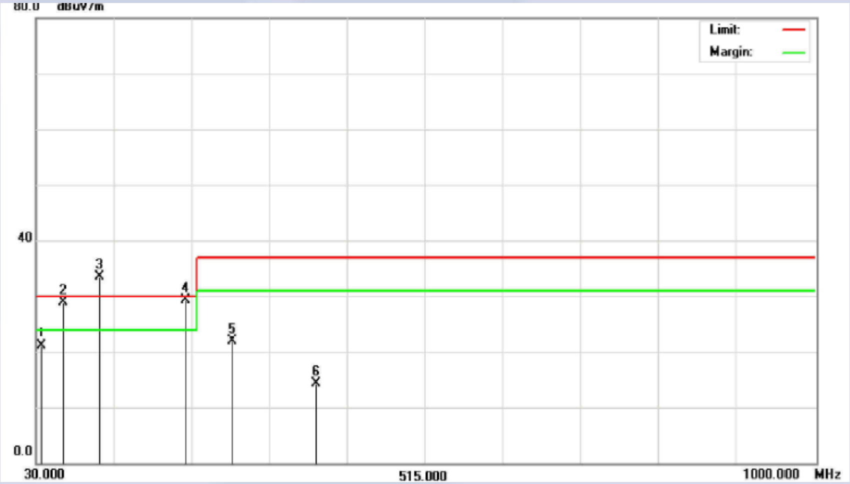
Radiated Spurious Emissions



- Typically don't bother to look further when results do not highlight any problems
- The “no problem here” approach can have a significant effect on other areas of a radio/system design
- Problems can hide way below the normative noise floor of an RSE/Intentional emission measurement

Radiated Spurious Emissions

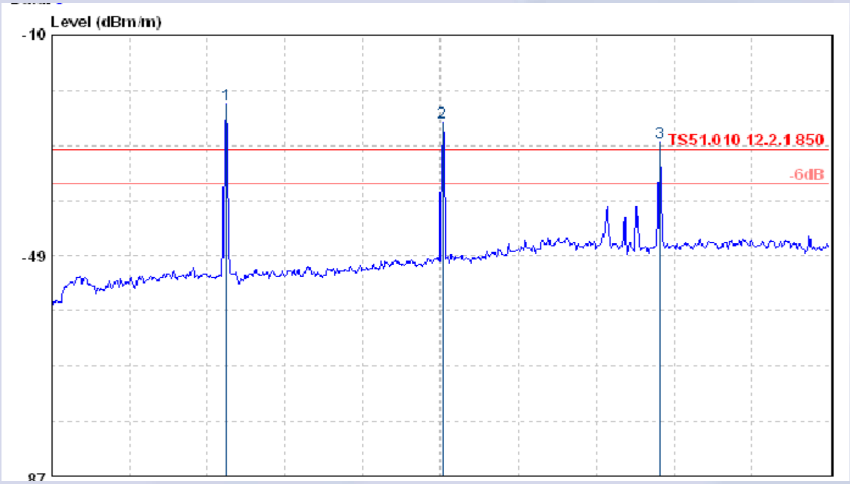
- When we observe measurements that fail then we need to “find the source”
- In these situations where a problem has been observed it can help us when we look further up the frequency spectrum for sources that can effect a receiver sensitivity
- The dynamic range of the measurement then becomes important when problems may be observed at -100dBm or lower

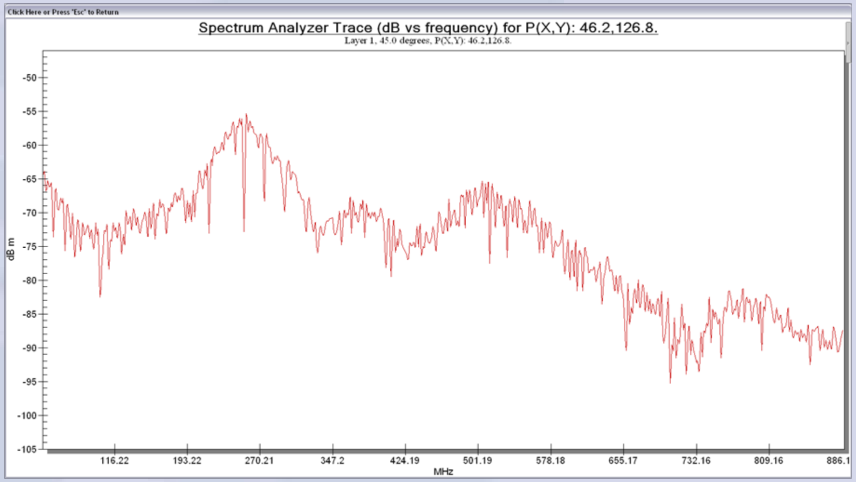


Internal Susceptibility

- For de-sense testing we need to be in the near field
- In some cases designs implemented to reduce RSE can mask problems at very low power levels
- In the EMC field the noise floor can be as much as a factor of 2 greater than that which can effect a radio's operation (receiver sensitivity)
- Can we assume RSE or Intentional measurement methods along with their results can help us find the source of problems for receiver sensitivity? "Only if they were observed earlier in the design phase"
- Most problems on a de-sense test are well below the noise floor of results taken for RSE/Intentional
- When the design is "final" and RSE is controlled these can hide problems that cause susceptibility issues to a radio receiver

Noise Floor





Factor of 2 Higher

Factor of 2 Lower

Typical measurements for spurious have a significantly higher noise floor than those which we use to find a noise source that will effect a receivers sensitivity.

For this type of analysis we would not use an Open Area Test site.

Even some 10M chambers have a noise floor greater than what is required.

Case Study

- Assessed the device in 3m EMC chamber
- Assessed the device in OTA (Over the Air) antenna chamber
- The test results show the device would fail TIS (Total Isotropic Sensitivity)
- The noise is found at the cellular 850 and PCS bands
- 3m chamber was used to identify fundamental frequencies

Problem

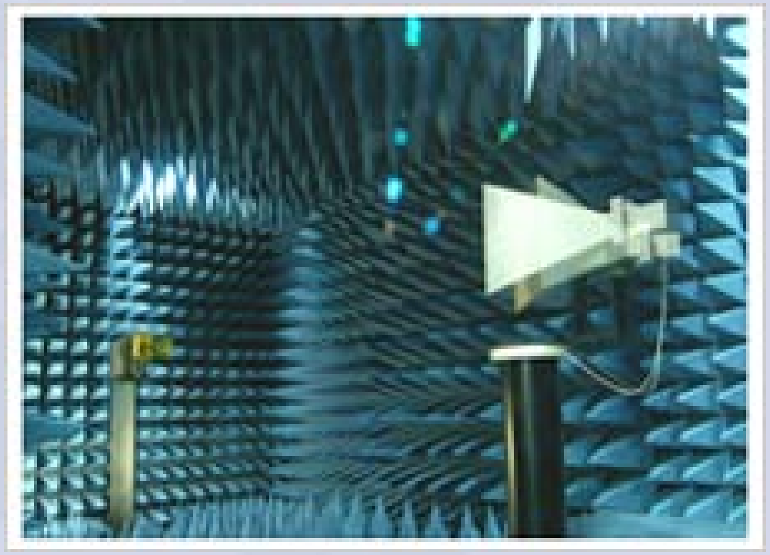
- Multiple factors are contributing to the TIS failure
- OTA chamber very expensive to use for de-bugging availability limited
- It is not possible from the test results in either the OTA chamber nor 3m chamber to show the physical location of the fundamental problem

Solution

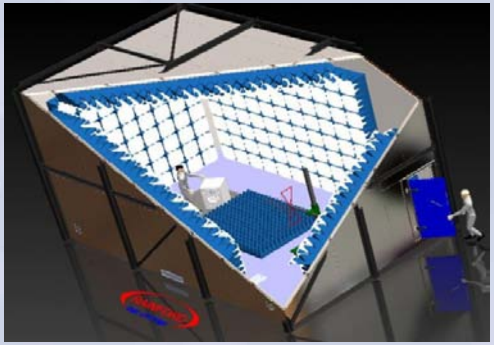
- Use EM-ISight for high resolution scan of the near (reactive) field to identify the physical location of the noise source

Case Study

- Correlate the noise level at source
- TIS limit from carrier to be better than
  -102dBm (target to include 3dB margin)
- Noise limit at source
  -91dBm worst case cellular 850 band
- Assessed delta = 11dBm for the worst case condition
- 11dBm is used for correlation measurements

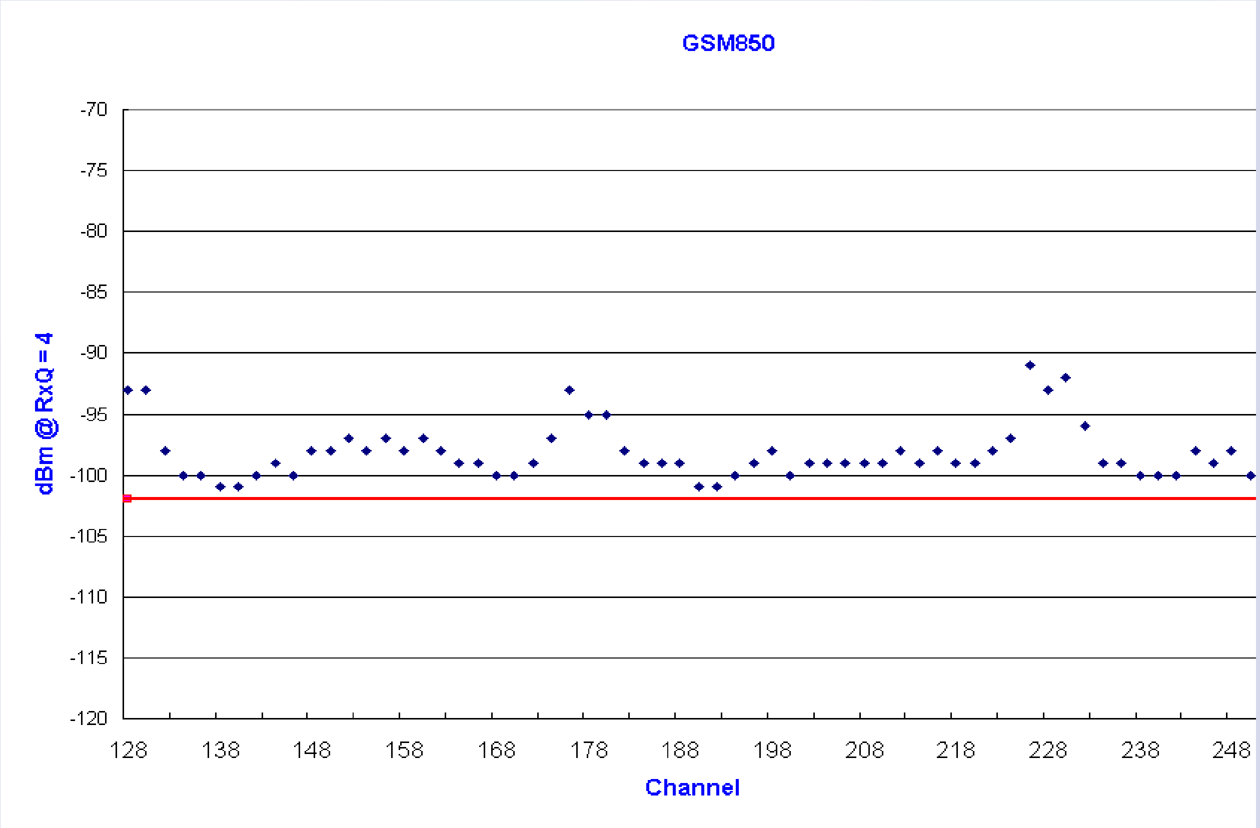


Case Study (analysis)



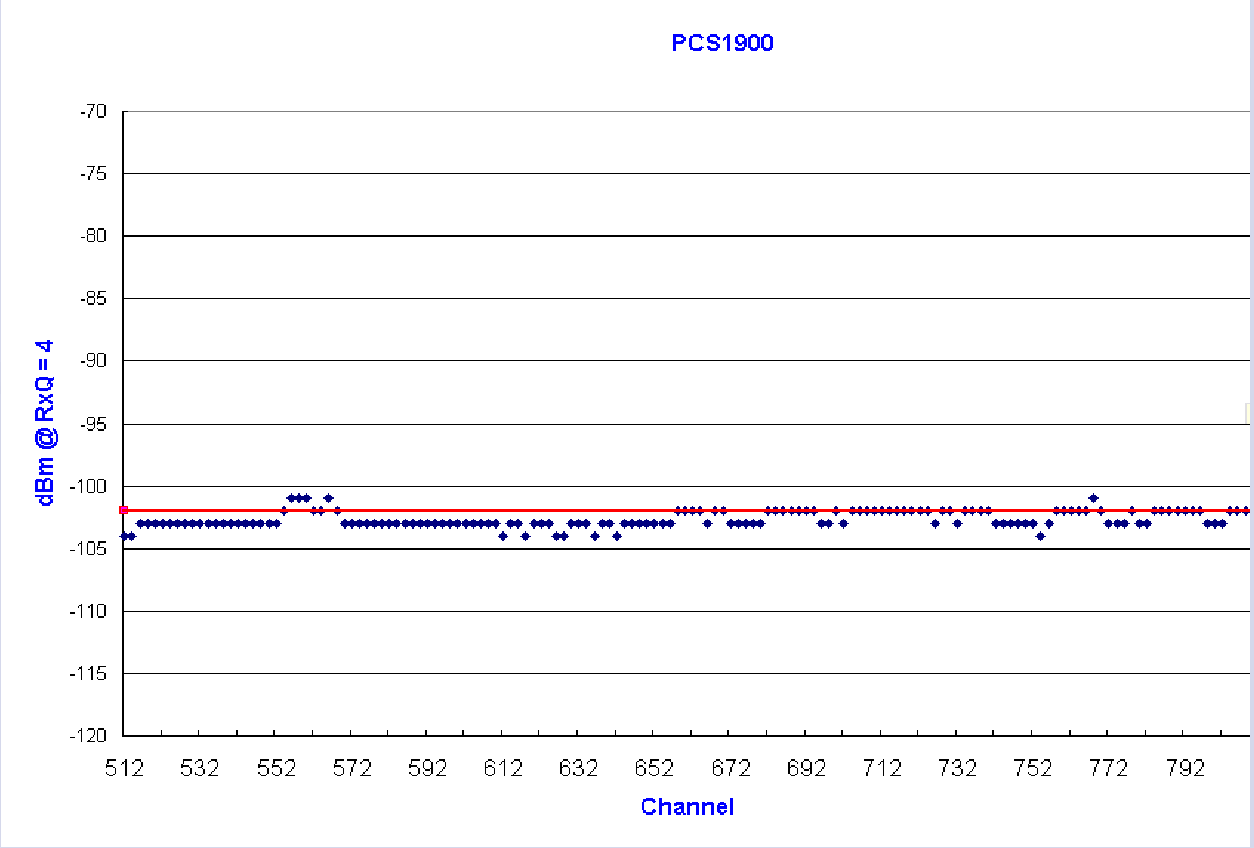
Take the 3m data from the chamber and correlate to measured values on the EM-ISight.
Run area scan across the complete surface of the device and locate physical area(s) which causes the failure.
Use data from 3m site to identify problematic components.

Case Study (Cellular 850 data)



869MHz-894MHz Uplink

Case Study (PCS data)



1930MHz-1990MHz Uplink

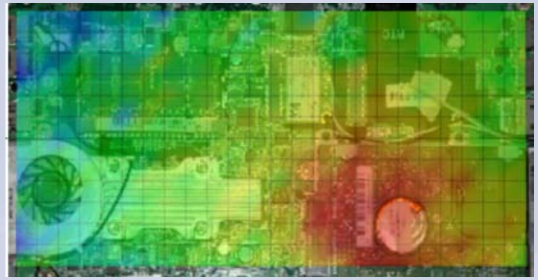
Bands Effected

WWAN Up-Link

Up-Link Band	Frequency (MHz)
Cellular 850	869-894
EGSM	925-960
DCS	1805-1880
PCS	1930-1990
3G/4G AWG	2110-2155

- Cellular 850
- PCS
- The failure means PTCRB for WWAN would not pass TIS (Total Isotropic Sensitivity)
- Further analysis of potential noise source to be initiated
- Determine the fundamental frequencies of noise source

Case Study (analysis)

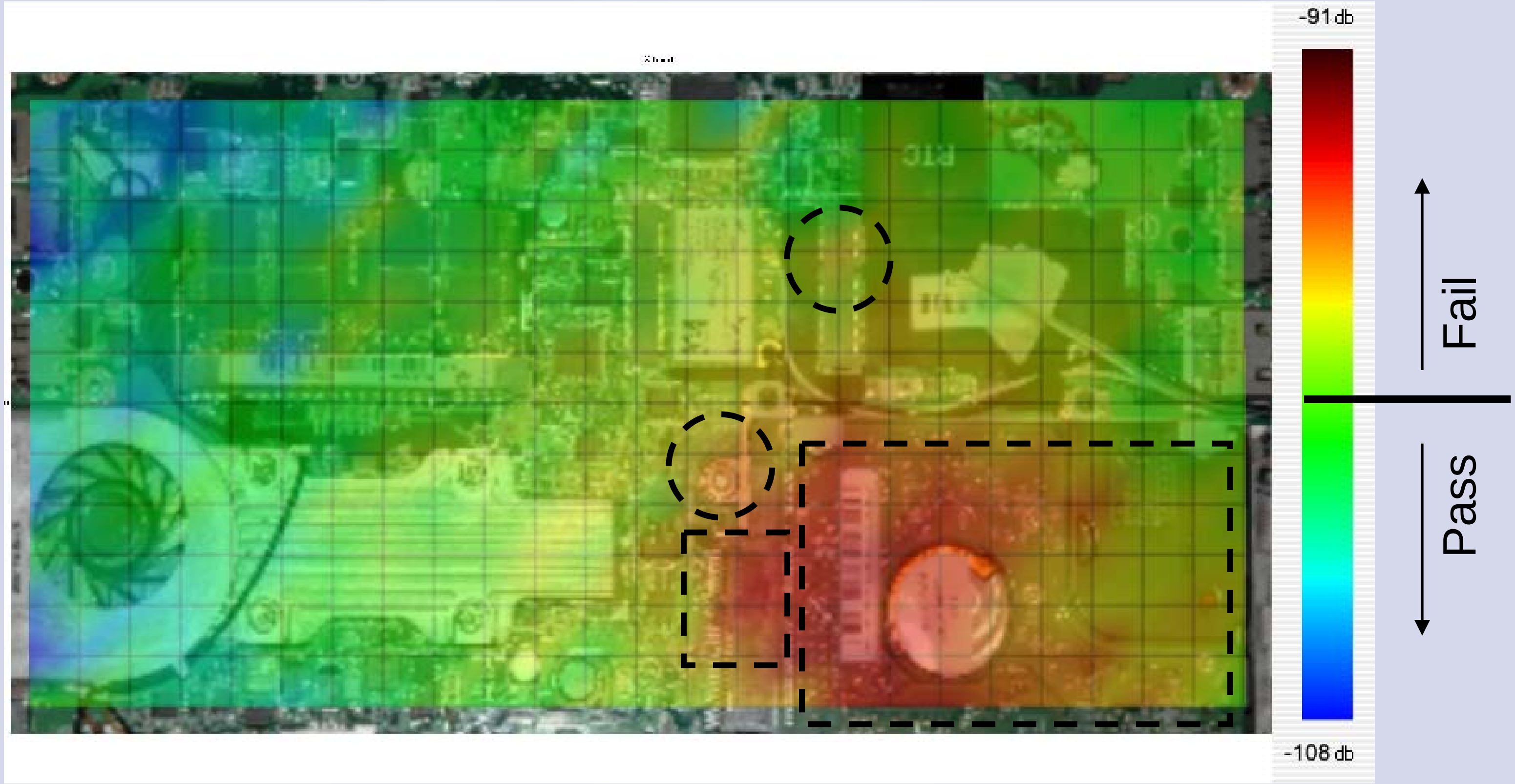


Complete Scan Executed
(Engineer)

Pass Data to Stake Holders (Team Leaders)

- PCB (layout)
- Video
- Storage (HDD)
- Digital (SD, RAM etc)
- Camera

Case Study (area scan)



Problem Areas

Fundamental Analysis

- By identifying some of the key fundamental frequencies we can determine the components that may cause problems
- By understanding the harmonics we can then determine if they can have a negative effect on a communication protocol
- If the fundamental problem is related to a component or IC it may be possible to retrieve data on the emissions (some manufacturers will conduct such measurements)
- If the problem is related to board layout it is more difficult to modify at such an advanced stage

Devices Effecting Receiver

Device	Fundamental Frequency (MHz)	Harmonic	Downlink Frequency Effected (MHz)
DDR2	533	4	2132
DDR3	533	4	2132
DDR3	933	2	1866
DDR3	1066	2	2132
USB 2	480	2	960
AMD	48	20	960
LVDS Clock	71.64	13	931.32
DIMM	133	7	931
Video Memory	390	5	1950
Video Memory	397	5	1985
Video Memory	396	5	1980
GPU	396.18	5	1980.9
Intel Atom FSB N270	533	4	2132
Nvidia Tegra 250 AP20H	300	7	2100
Low Resolution Battery Mode	114.56	16/17	1832.96/1947.52
Actual Low Resolution Battery Mode	114.57	16/17	1832.752/1947.299

850 MHz band WWN Interference	Harmonic	Clock Source	Spread	Note
869 MHz	79 th	11 MHz	No	
875 MHz	35 th	25 MHz	No	
891 MHz	81 th	11 MHz	No	
869 MHz	11 th	79 MHz	YES	LVDS Range
894 MHz	10 th	89.4 MHz	YES	<----------->

Case Study (Identifying the Problem)

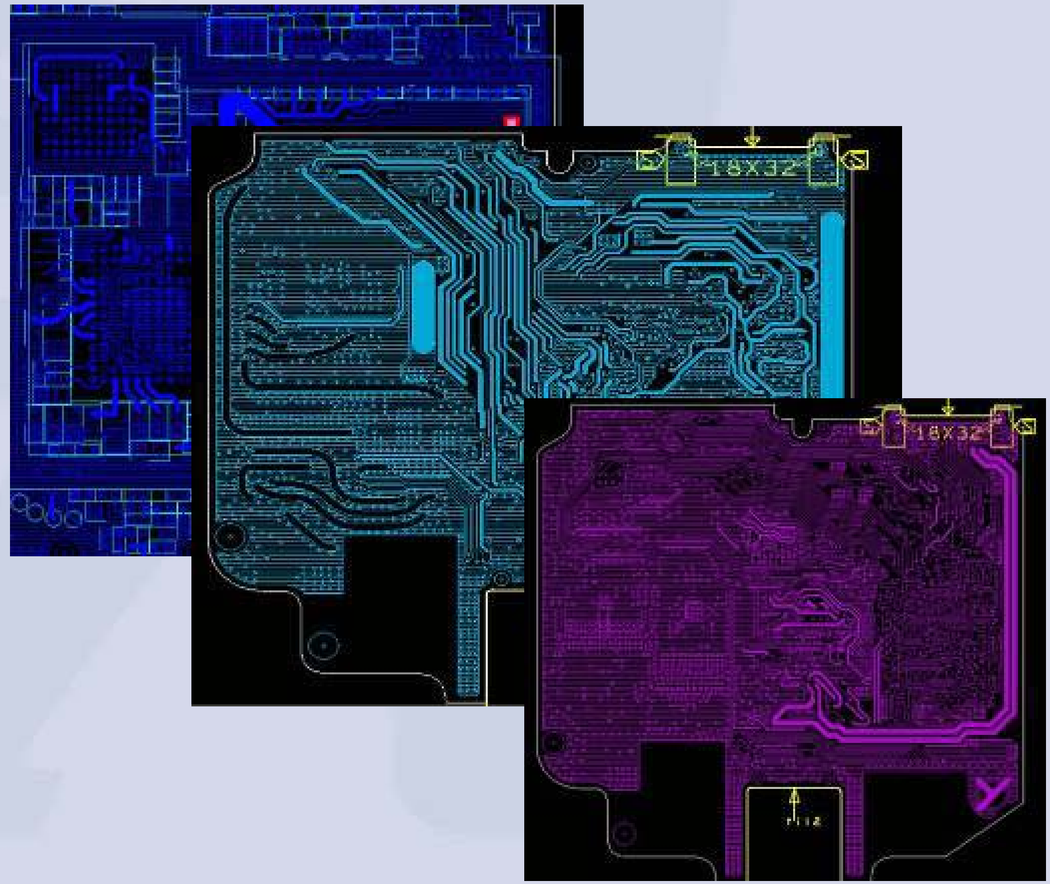
- Problem areas are highlighted through broad band scans from 800MHz through to 2GHz
- Engineer can then identify the location or peripheral device and determine solution
- Engineer can then define the appropriate scan methodology with respect to resolution (probe location X, Y, Z mm and Phi), fundamental frequency, span and number of data points measured by the Spectrum analyzer
- Through high resolution scans the engineer can observe the flux direction, identify the fundamental frequency and level
- The system will allow for gradient fields to be plotted in 2D, 3D and 4D for the use of determining the source of noise, and solving the problem
- The engineer can pull data from the measurement database and analyze in real time so as to monitor progress and manage the project

Case Study (digital)

- Scan was run on the assembly while running video file
- Scan was run on the assembly while in standby mode
- Scan was run on the hard drive while performing a read right test routine
- Scan looked at the cellular 850 and PCS bands for downlink

Case Study (layers)

L01 - Components & Signals
L02 - Signals
L03 - Signals
L04 - Ground
L05 - Signals
L06 - Signals.
L07 - Ground
L08 - Signals
L09 - Ground
L10 - Signals
L11 - Signals
L12 - Components & Signals

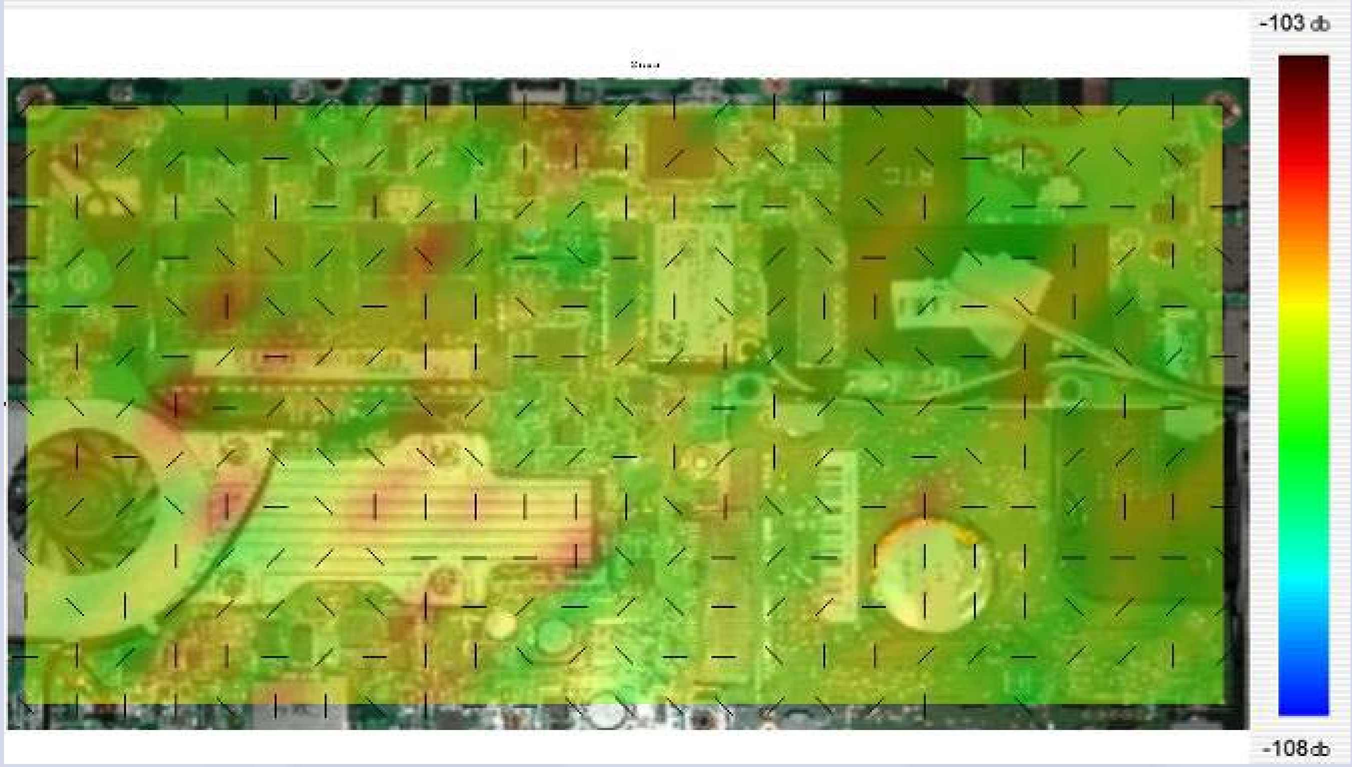


Case Study (resolution)

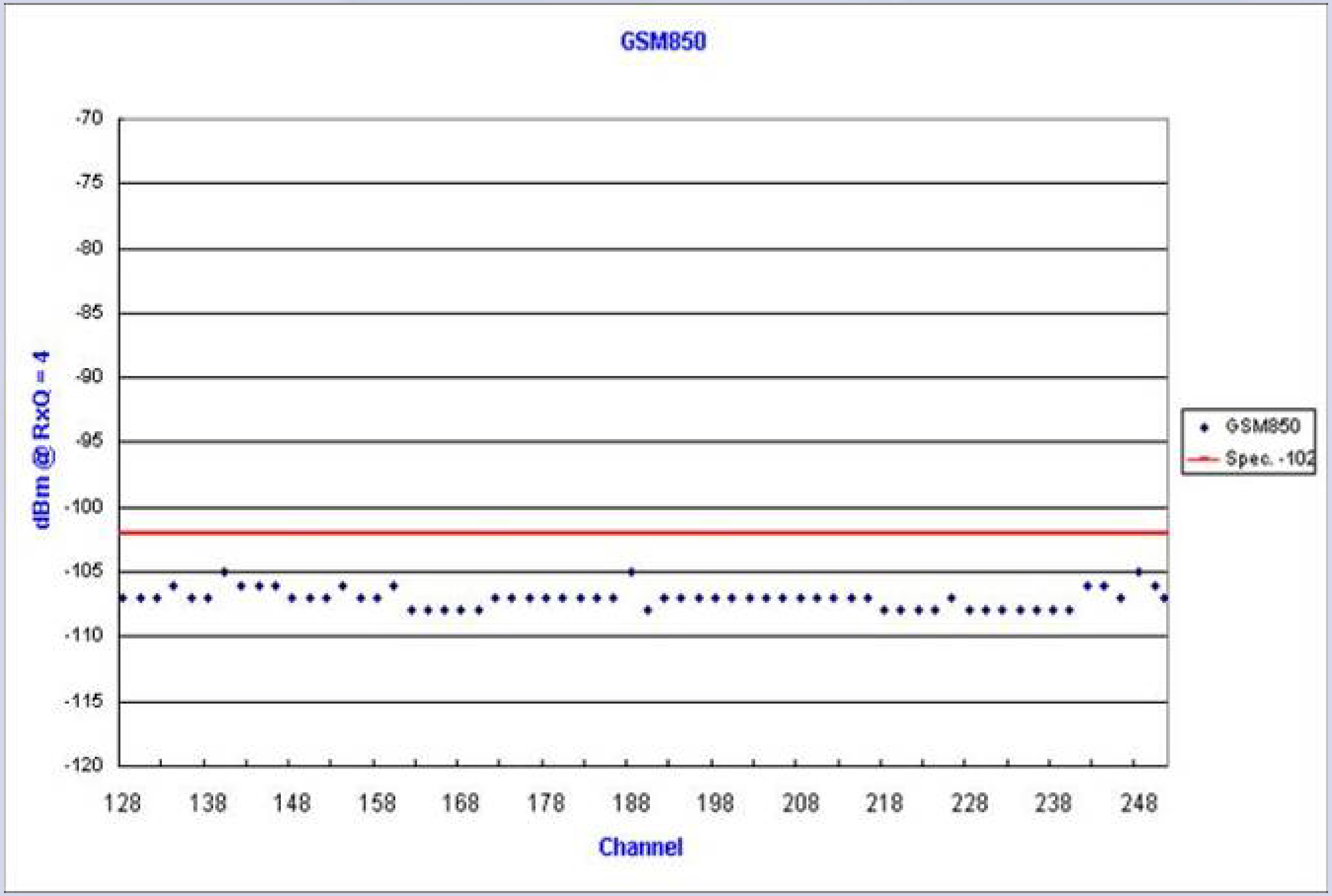
Main issue is the device design is final only small changes can be made

- Poor connector at the HDD (SATA)
- Poor connector at the MPCI
- Identification of noise source allowed for vendor change (connectors)
- Using tape and gaskets allowed the WWAN module to be isolated better
- Nominal changes to shielding were done
- Better selection of components (higher quality)
- Retest and show compliance

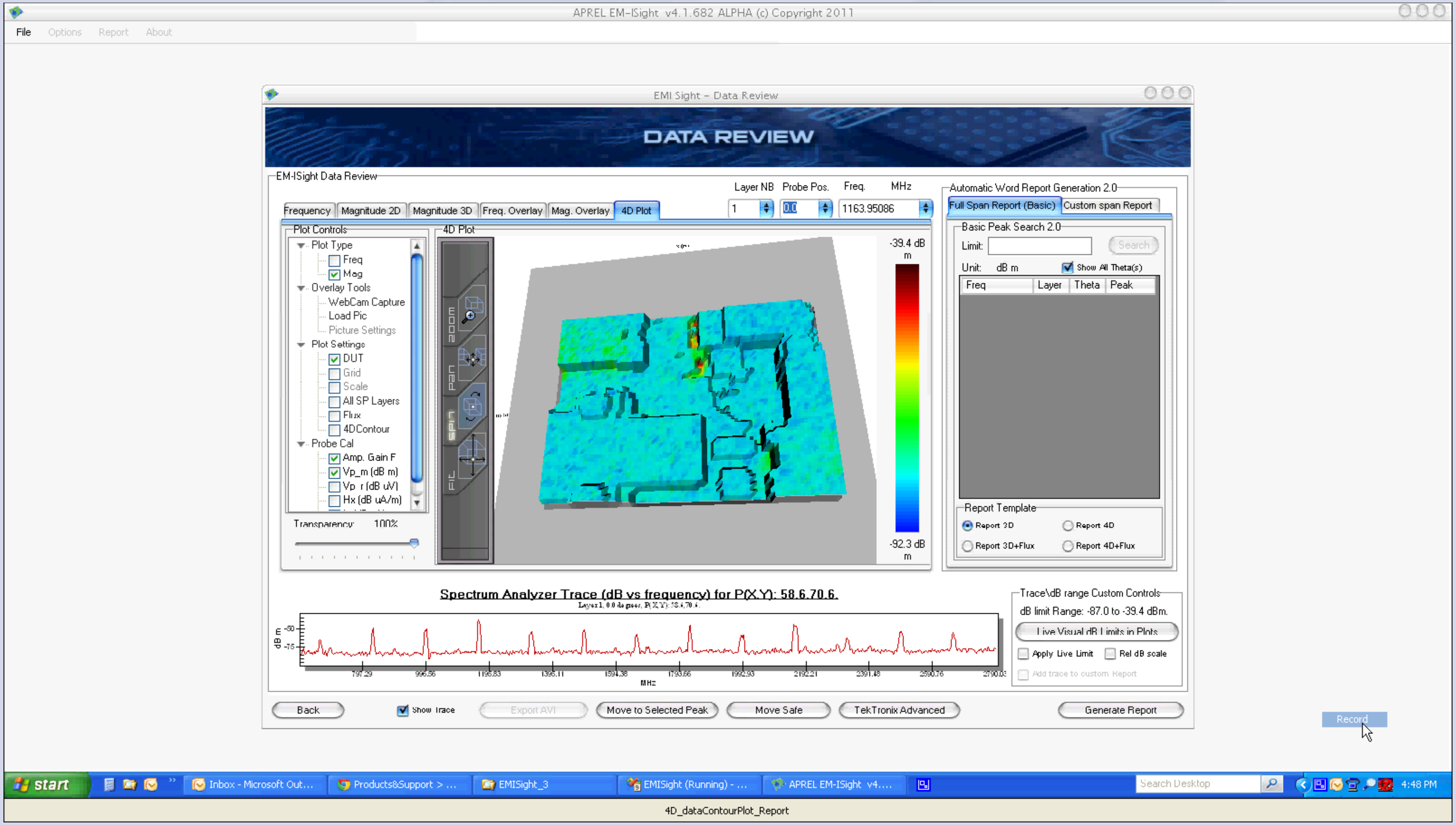
Case Study (results)



Case Study (results)



Case Study (local area scan)



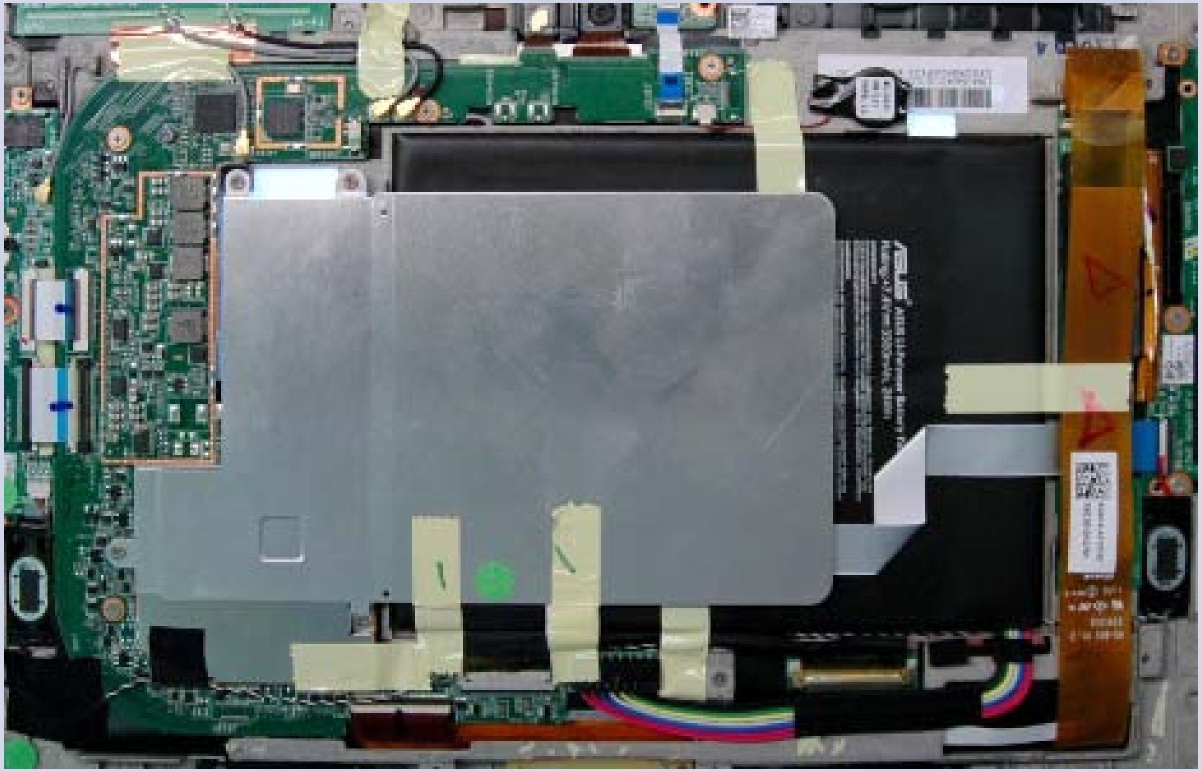
Correlation

- Correlation of near-field to far-field distances is accomplished by using a 50ohm micro-strip line calibration reference fixture to obtain a known current versus frequency for a set level of input power.
- The far-field radiation field strength can then be calculated by substituting the known current within a conductor into equation (9.6) as referenced in Testing for Compliance Approaches and Techniques by Mark I. Montrose and Edward M. Nakauchi as published by the IEEE Press
- Including equations (11.1-2) as referenced in Noise Reduction Techniques in Electronic Systems by Henry W. Ott as published by Wiley-Interscience.

Case Study 2 (tablet)

- Why is there a limited number of tablets running 3/4G
- What are the benefits of having a greater number of peripherals located inside one package
- Is noise a major problem within some tablet devices
- Is there a noise source that would effect 3G/4G or GPS

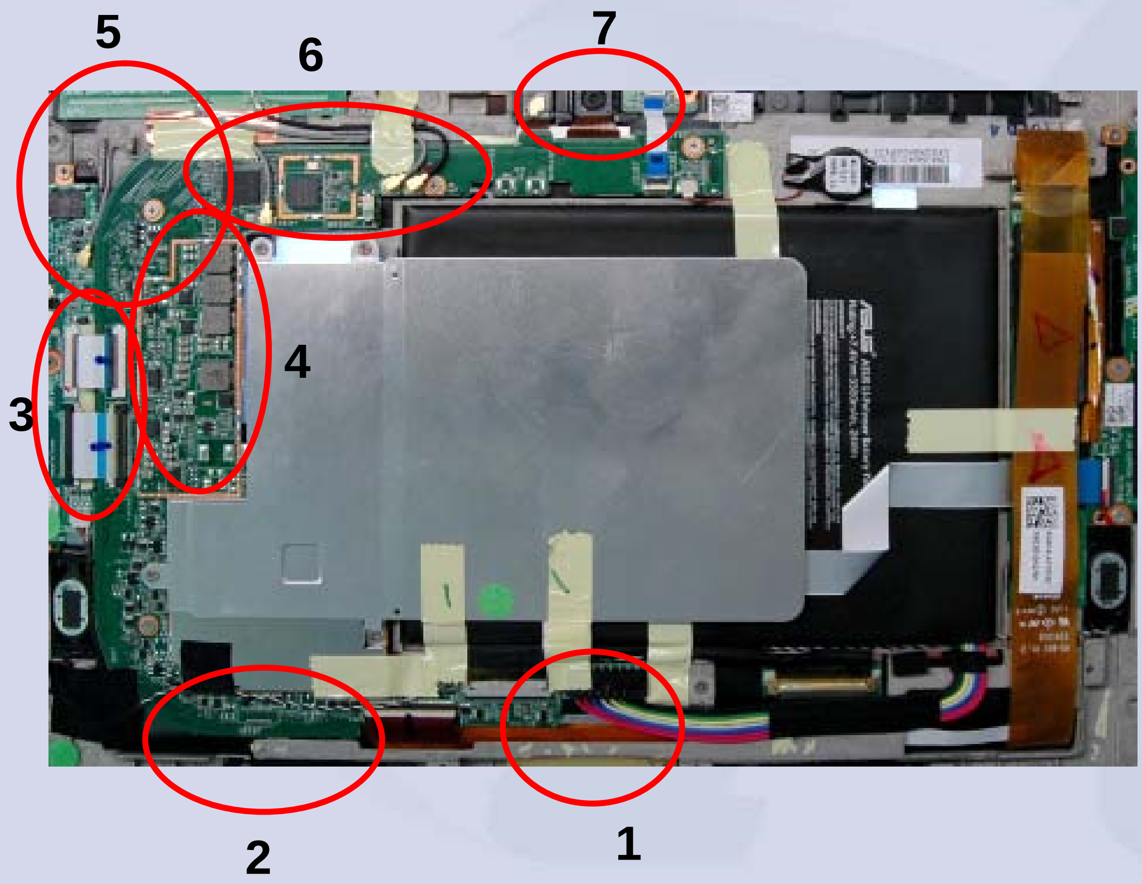
Underneath the Hood



Method of Analysis

- Planer scans were executed to see what dominant fundamentals/spurs could be found
- Based on the analysis of these spurs we could then decide what locations we wanted to conduct high resolution scans
- We identified 7 key areas of interest
- These areas and fundamental frequencies were then assessed to see what could be effected

Areas of Interest



1. Power and docking port
2. Keyboard docking latch
3. Dual flex connector
4. Power circuit
5. Micro-coax lead
6. GPS
7. Back facing camera

Potential Sources of Noise 3G

Device	Fundamental Frequency (MHz)	Harmonic	Downlink Frequency Effected (MHz)
NAND	33.33	26/28/55/56/58/59/64/65	Multiple
USB 2	480	2	960
LVDS Clock	71.64	13/26/27/30	Multiple
Video Memory	390	5	1950
Video Memory	397	5	1985
Video Memory	396	5	1980
GPU	396.18	5	1980.9
Nvidia Tegra 250 AP20H	300	7	2100
HDMI	350	6	2100

Up-Link Band	Frequency (MHz)
Cellular 850	869-894
EGSM	925-960
DCS	1805-1880
PCS	1930-1990
3G/4G AWG	2110-2155

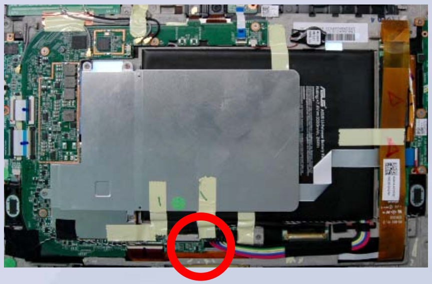
Potential Sources of Noise GPS

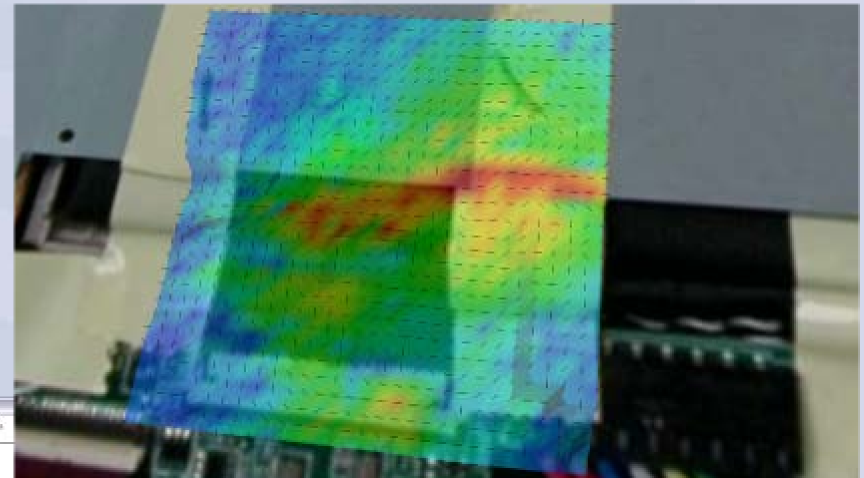
Device	Fundamental Frequency (MHz)	Harmonic	Downlink Frequency Effected (MHz)
NAND	33.33	47	1566.651
1394 Serial Bus	24.576	64	1572.86
LVD (Low Voltage Differential) Signaling	71.64	22	1576.08
LVD (Low Voltage Differential) Signaling	72	22	1584
PCI (Docking)	33.3333	47	1566.67
Video Memory	396	4	1584
GPU (Performance Mode)	396.18	4	1584.72

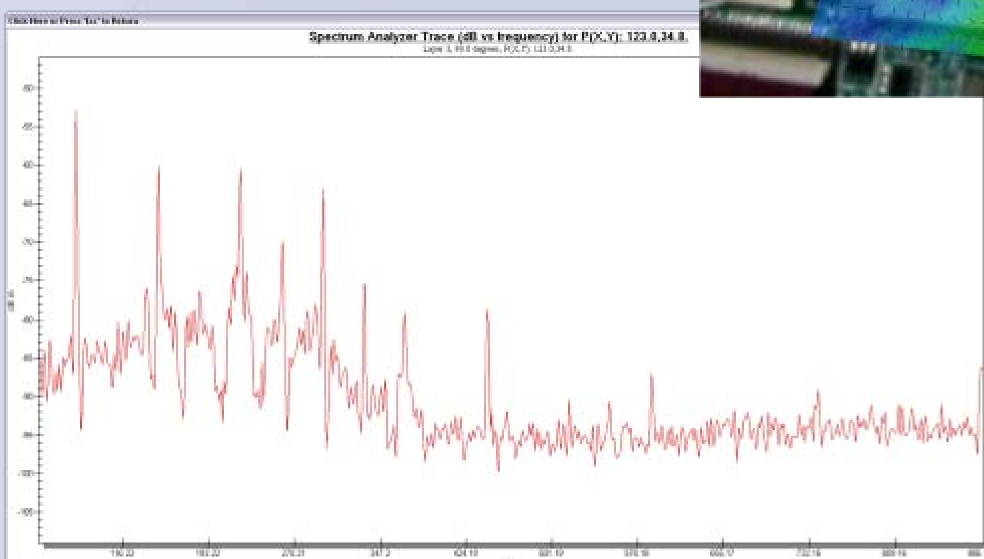
GPS RECEIVE BAND: 1565-1585MHz (with guard band)

Type of bus interface is not known until analysis is performed by EM-ISight

Power and Docking Port (1)

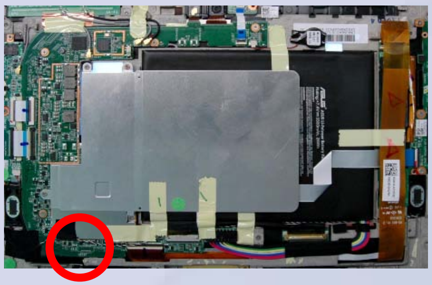


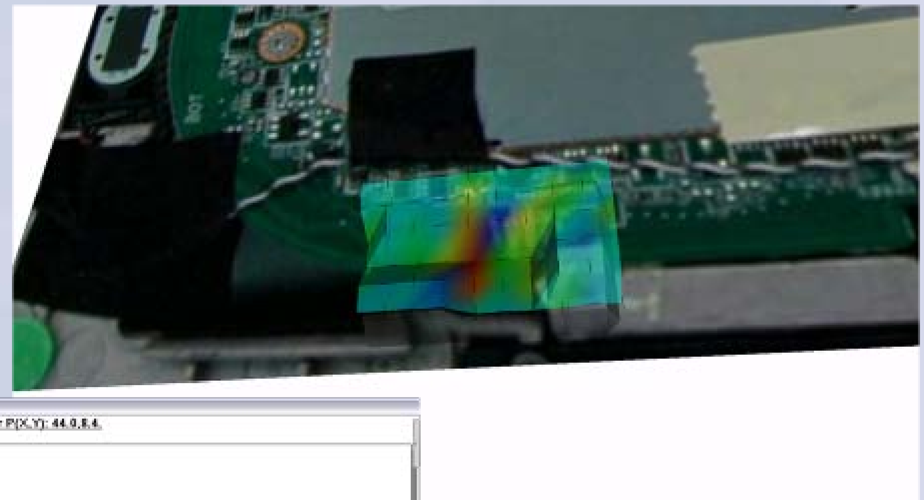


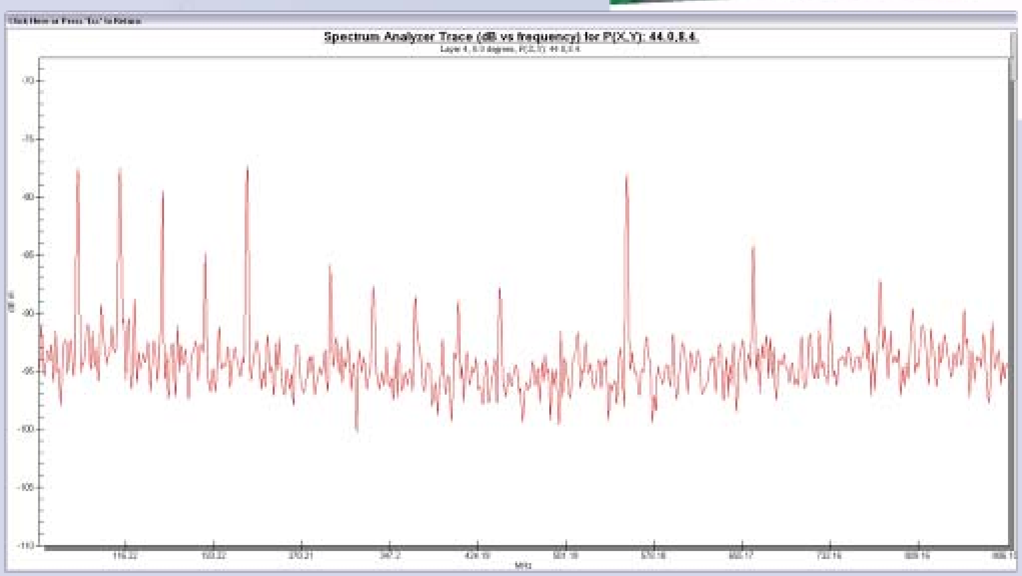


Fundamental 73.5MHz
Measured = -88dBm
Could be LVD

Keyboard Docking Latch (2)

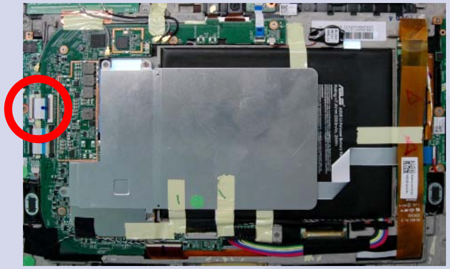


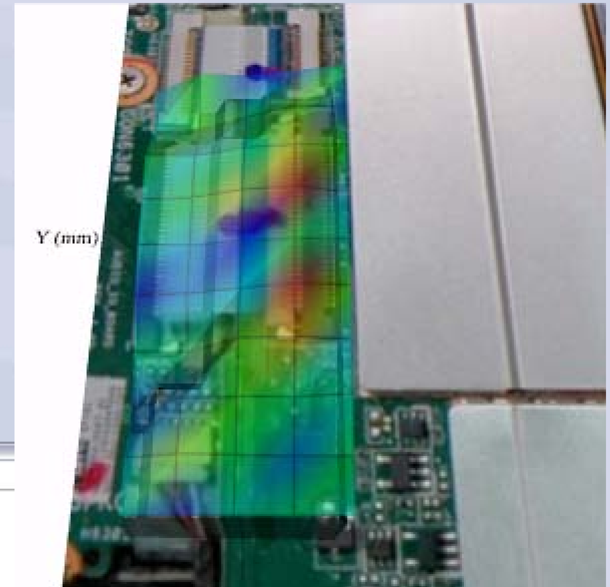


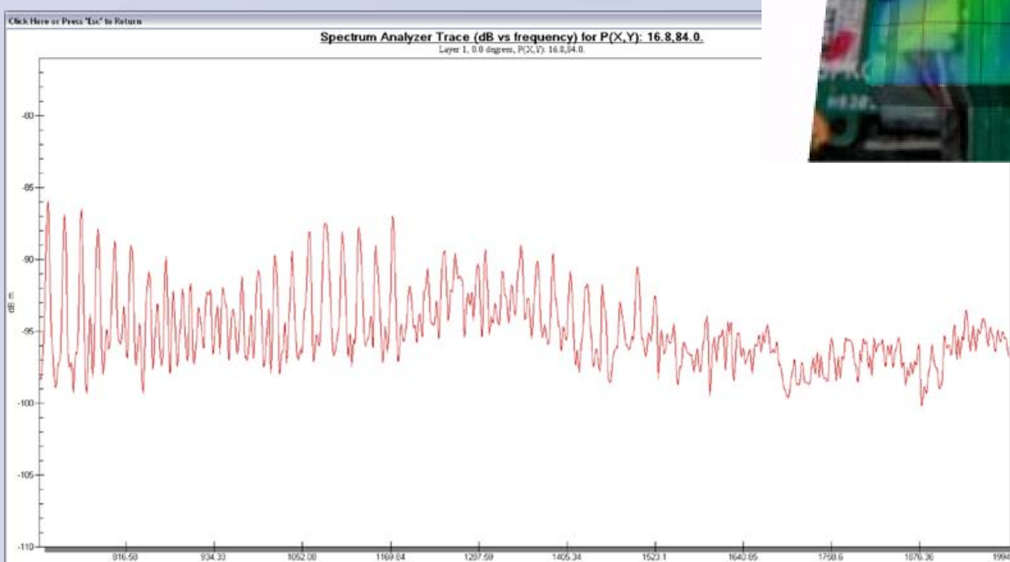


1st Fundamental 73.5MHz
Measured = -113dBm
2nd Fundamental 110MHz
Measured = -112dBm
Continues up spectrum
Dominates the Cellular 850 band

Dual Flex Connector (3)

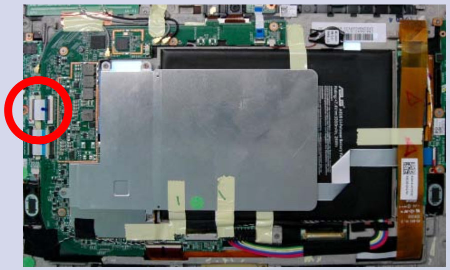


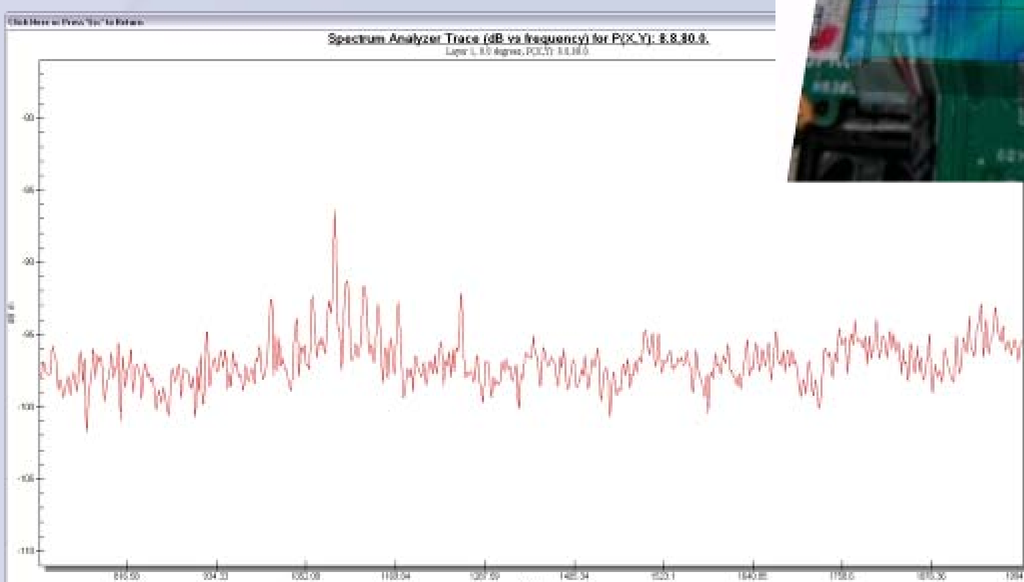


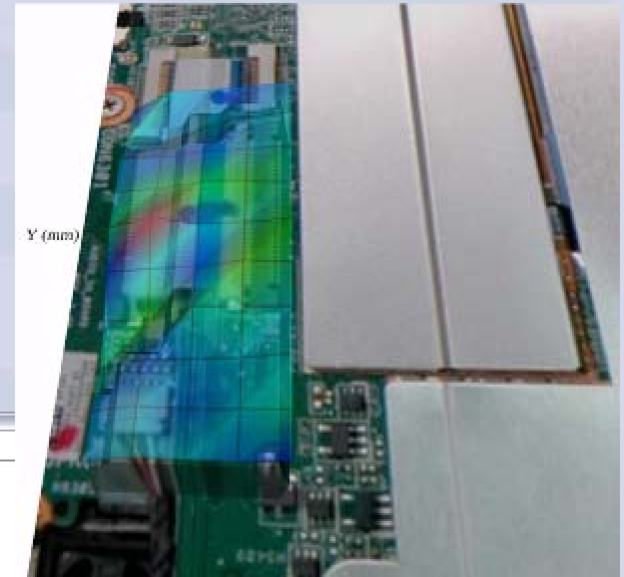


Unintentional 1574MHz
Measured = -129dBm
Could be LVD 22nd Harmonic

Dual Flex Connector (3)

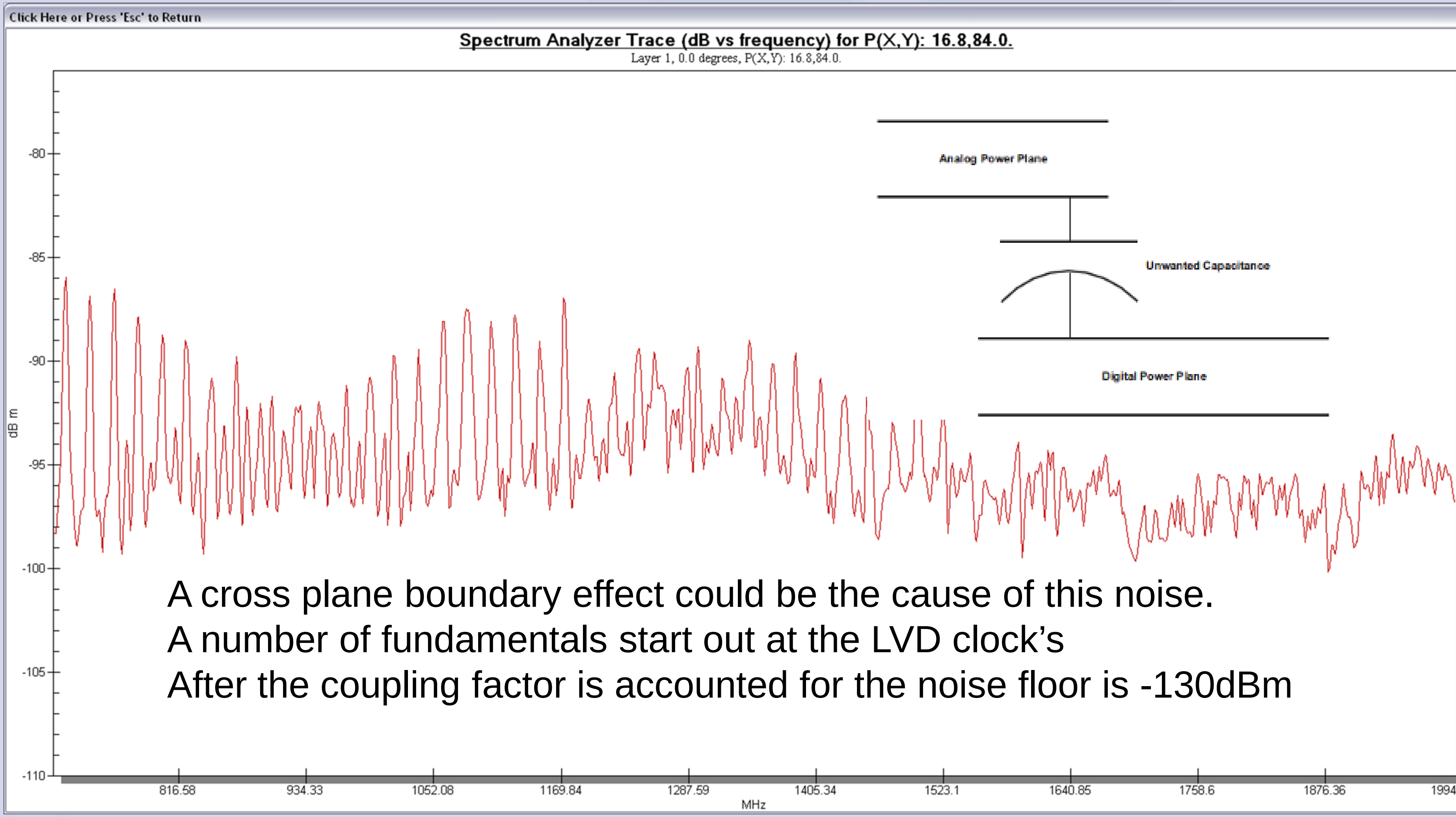






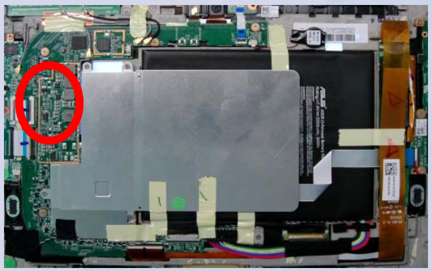
Unintentional Peak 1089MHz
Measured = -121dBm

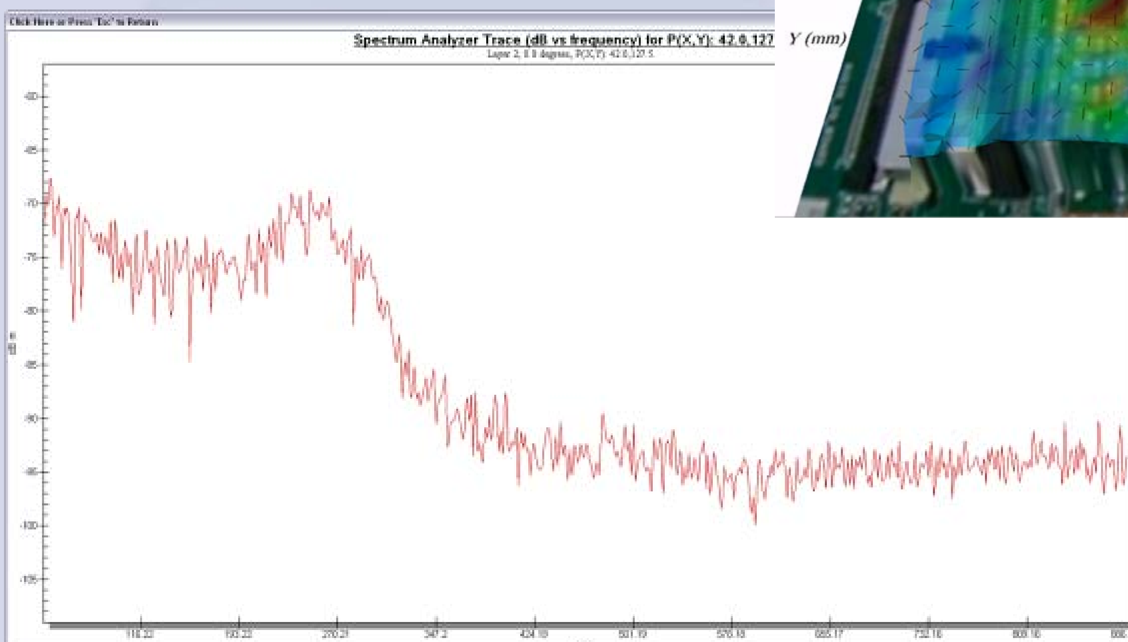
Reason for Noise

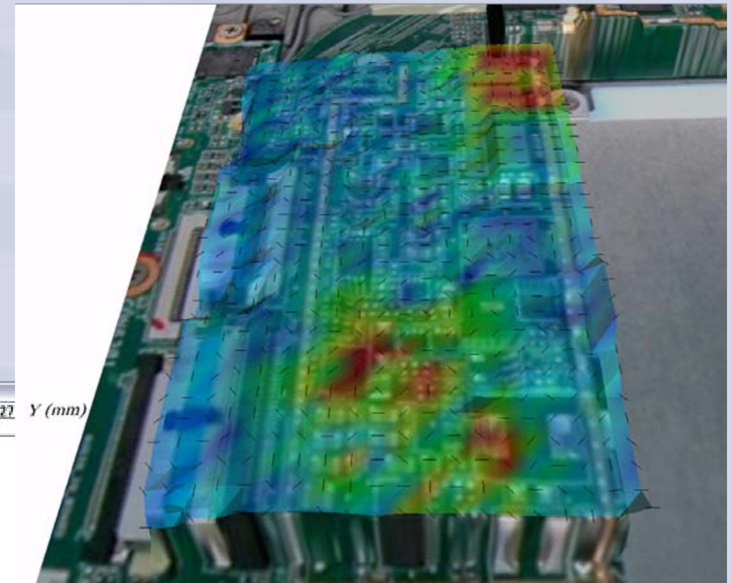


A cross plane boundary effect could be the cause of this noise.
A number of fundamentals start out at the LVD clock's
After the coupling factor is accounted for the noise floor is -130dBm

Power Circuit (4)





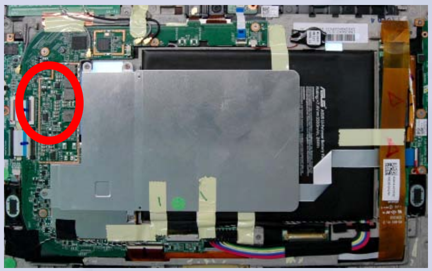


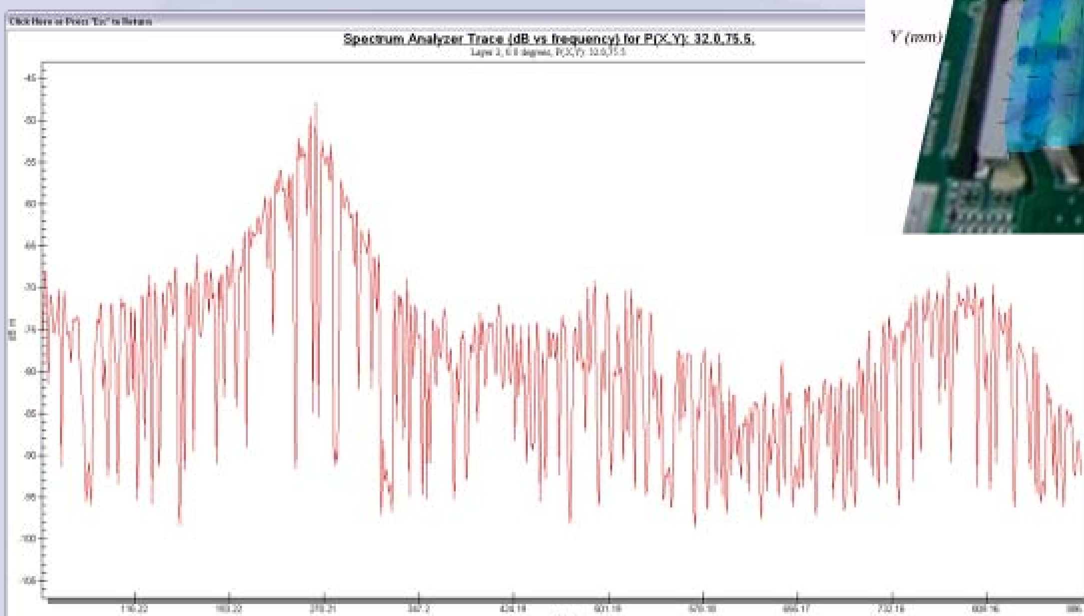
The shielded can was removed as we observed some fields were effecting the GPS.

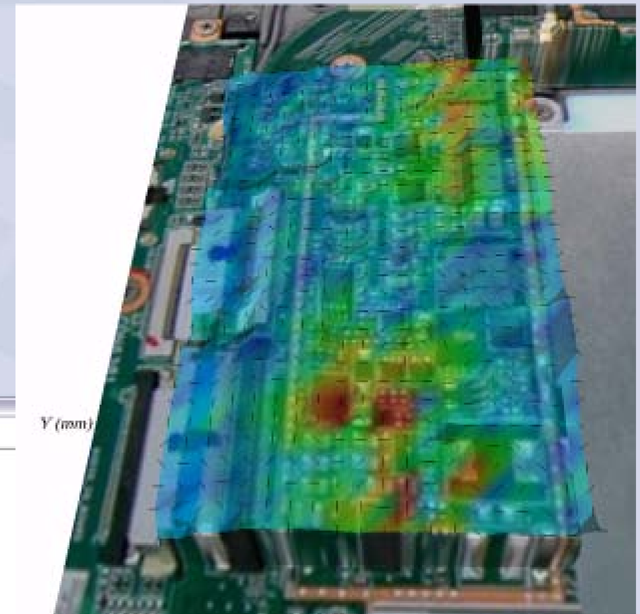
Measured = -103dBm

Strong influence from 40MHz to 380MHz

Power Circuit (4)

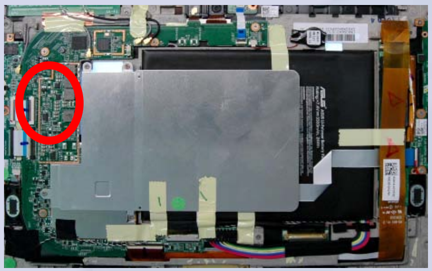


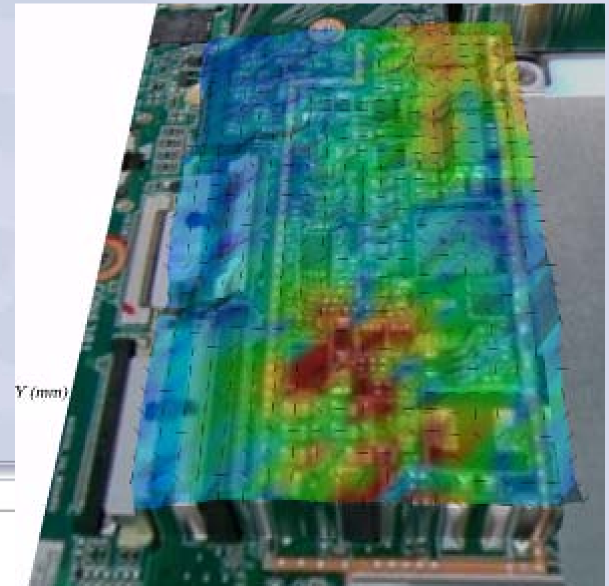


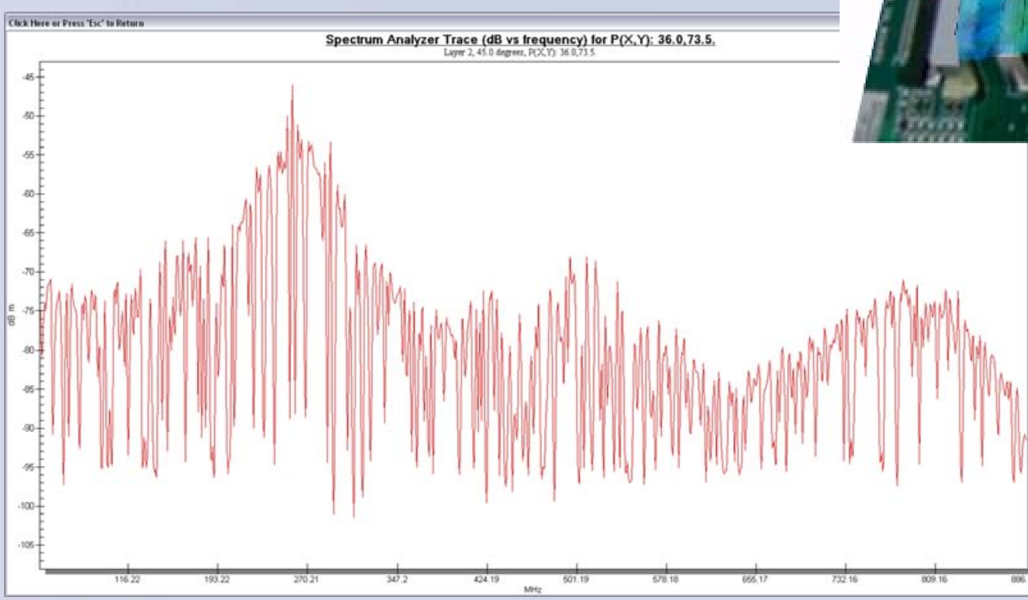


Measured = -83dBm
First Harmonic 260MHz
Second = 23dBm down
Next = 18dBm from first

Power Circuit (4)

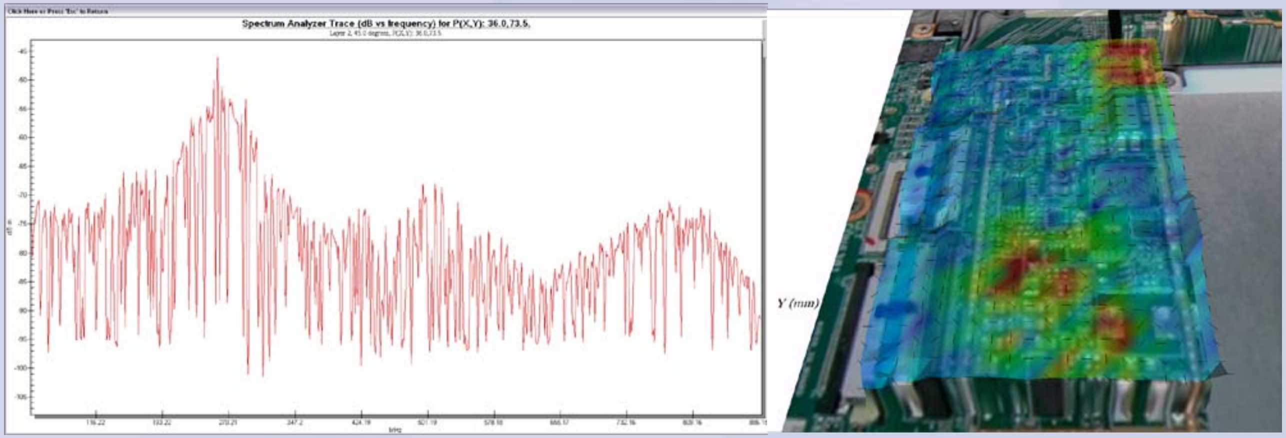




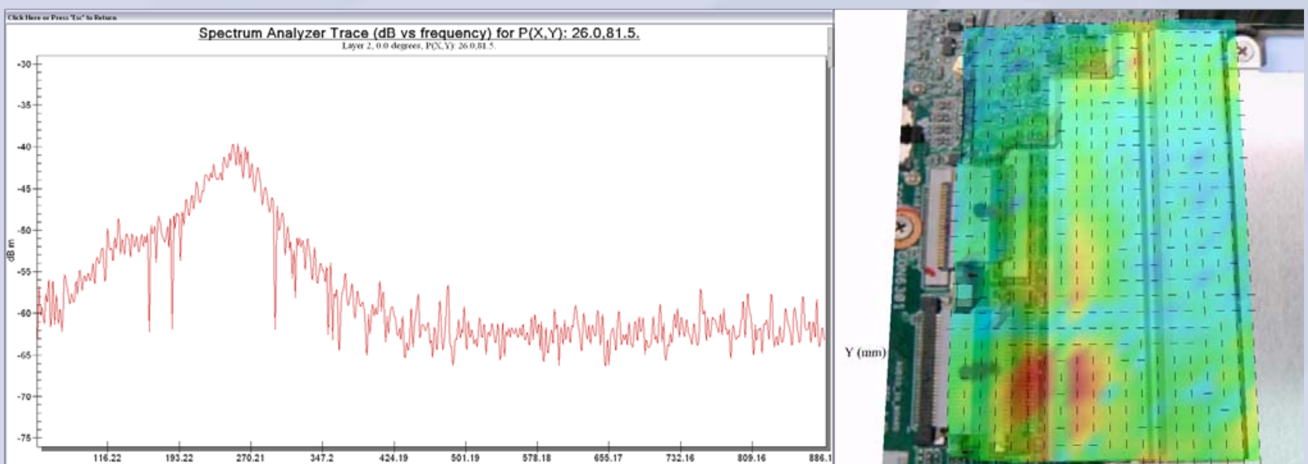


Measured = -46dBm
First Harmonic 260MHz
Second = 22.5dBm down
Third = 4dBm from 2nd

Adding a Shield



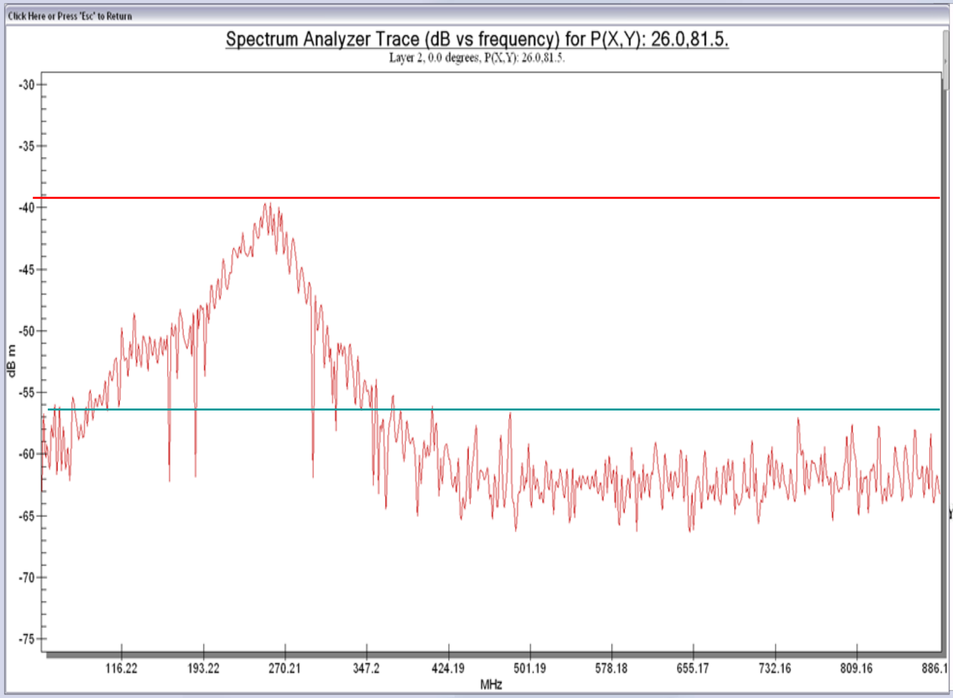
No Shield

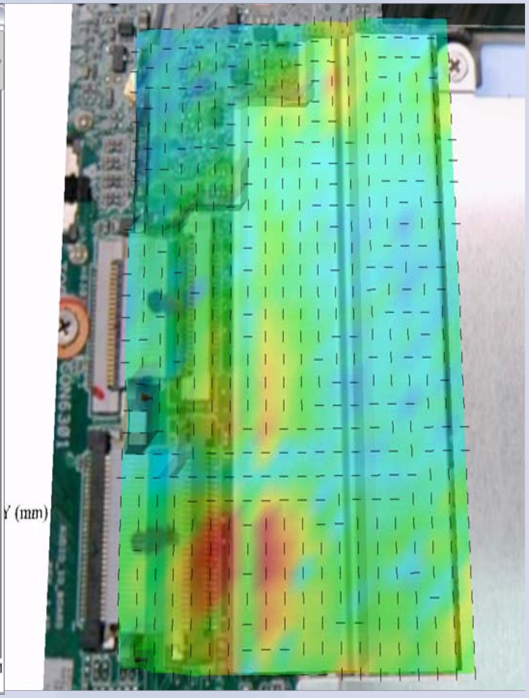


With Shield

APREL

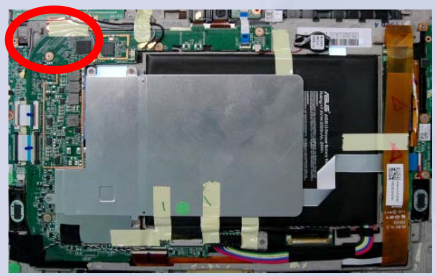
Shield Effect

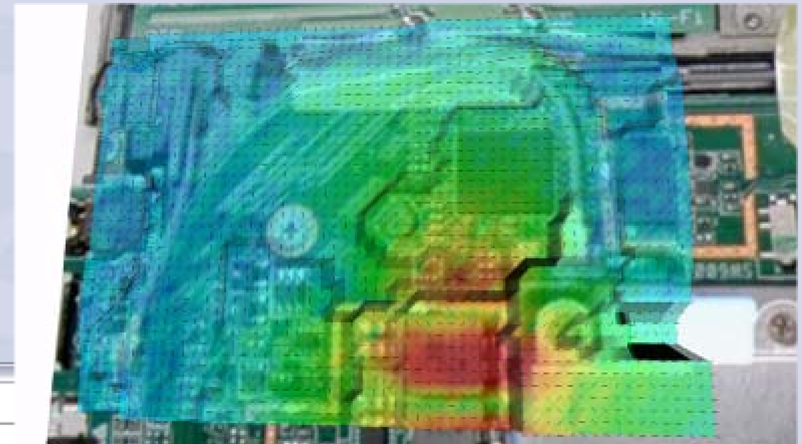


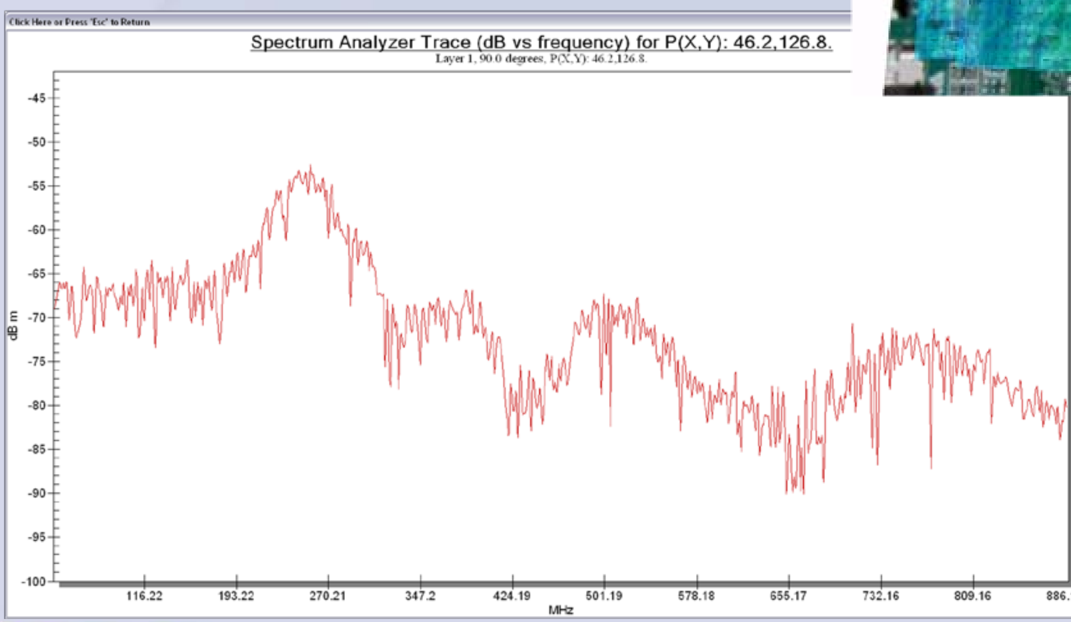


Dropped the second and third harmonics by 22dBm
Shifted the fields away from the GPS/Wireless location

Micro-Coax Lead Radio (5)



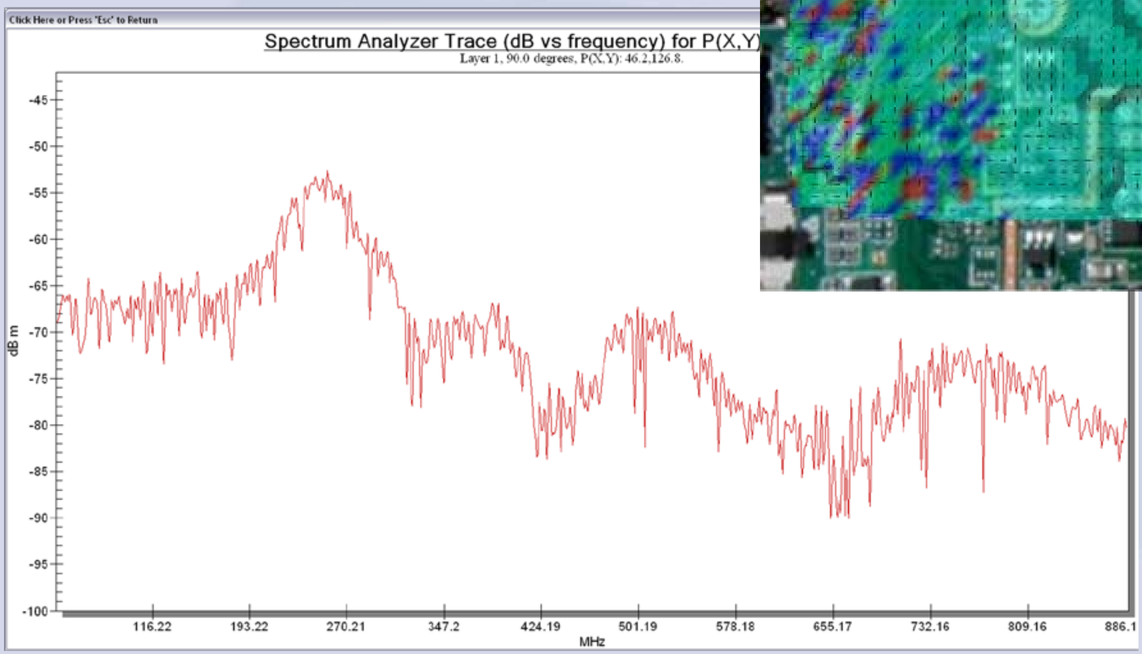


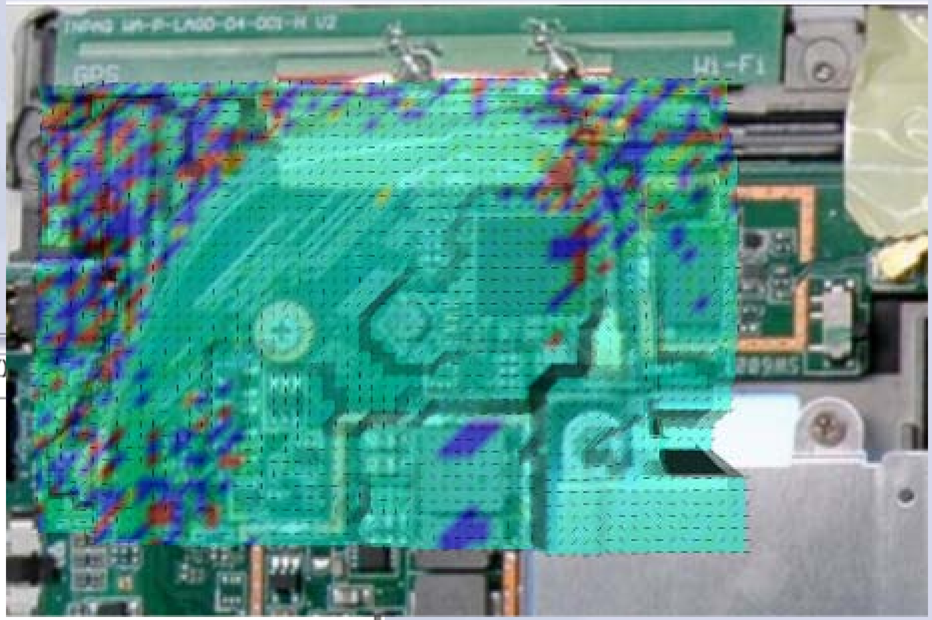


Fundamental = 260MHz
Peak = -89dBm
Second Harmonic = -103dBm
Third Harmonic = -109dBm

Micro-Coax Lead Radio (5)

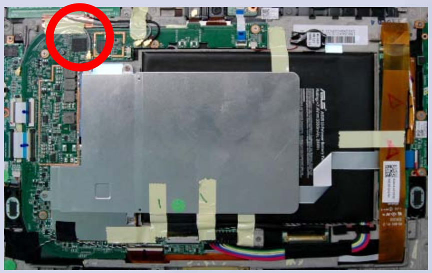
Frequency Spread.
Green = 40MHz
Blue = 254MHz
Red = 887MHz

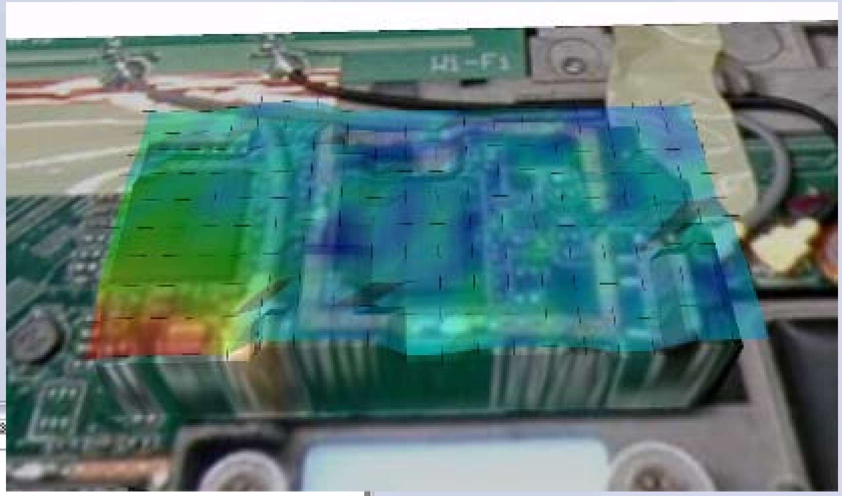


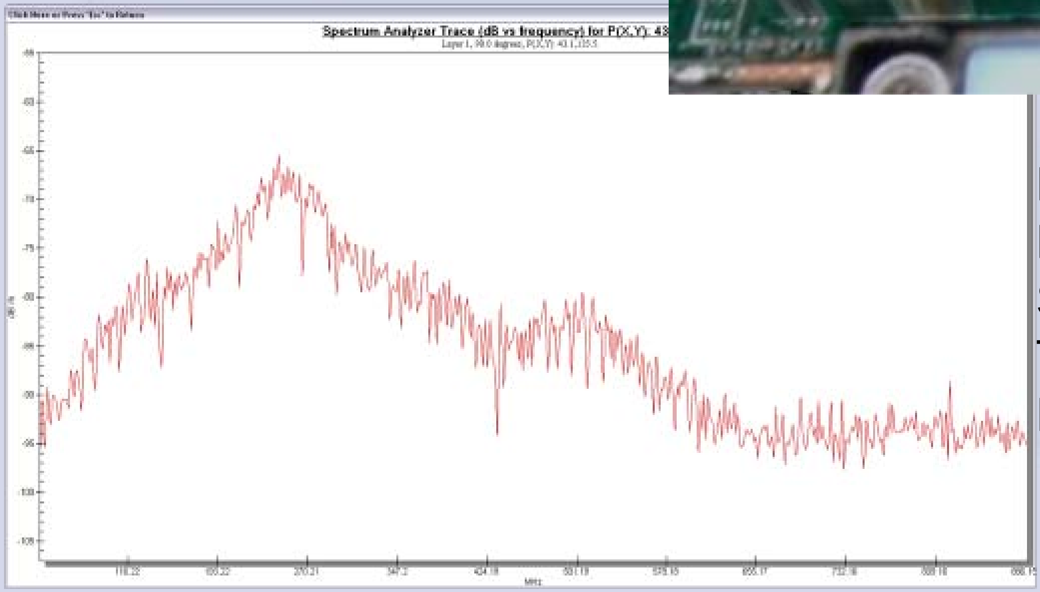


This scan shows fringing due to the board shape. Cellular 850 RX & GPS are effected by this.

GPS Circuit (6)

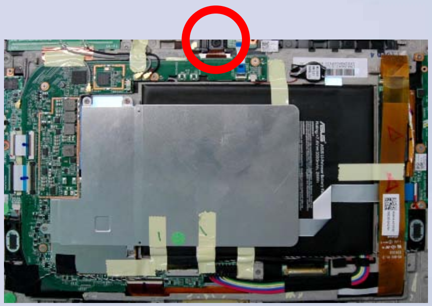


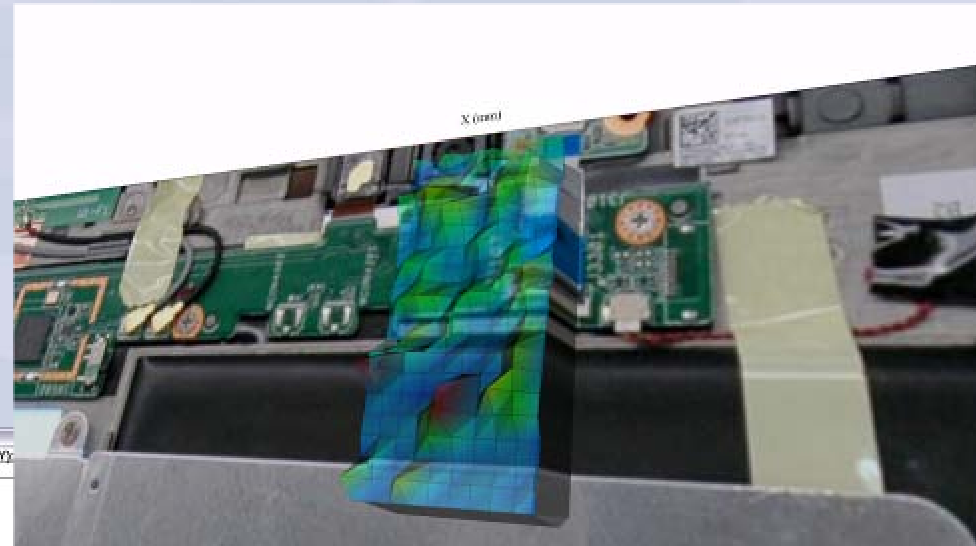


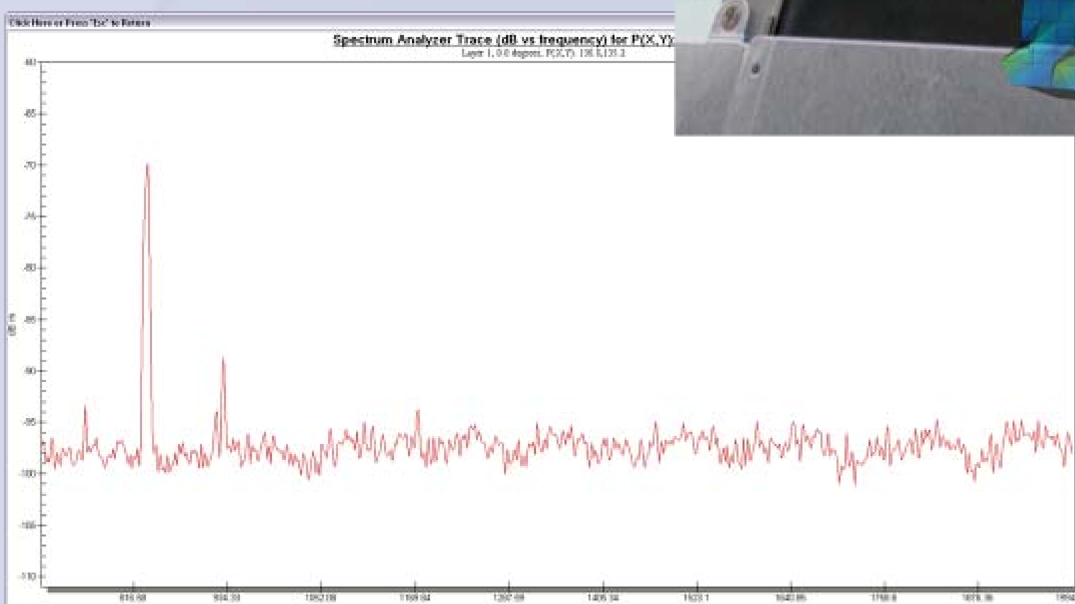


Fundamental = 260MHz
Peak = -100dBm
Second Harmonic = -115dBm
Third Harmonic = -125dBm
Noise Floor = -135dBm

Back Facing Camera (7)







Fundamental = 830MHz
Peak = -105dBm
No overall effect on RX path

Observations

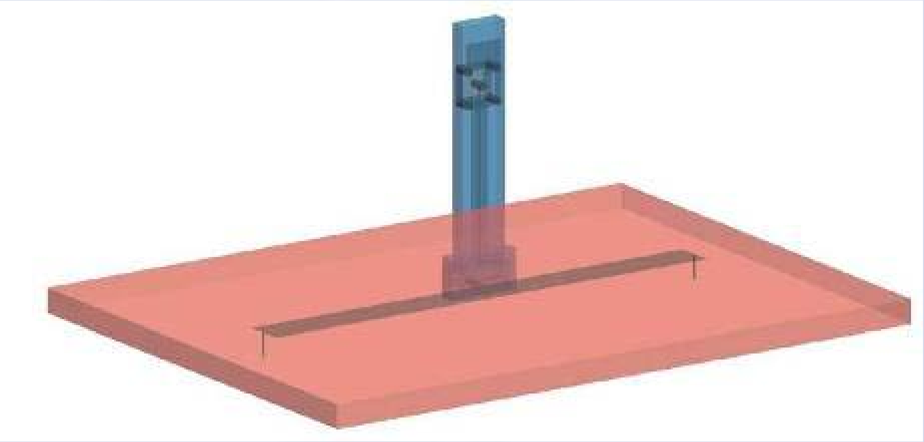
- Without a BoM or schematics it was difficult to see how superficial changes could improve the design
- Very high noise floor when you consider the deployment of a GPS radio
- Multiple PCB’s assembled within one package
- Non contiguous board layout at power stage
- Shielding not tied to appropriate grounding schemes
- Ground loops causing harmonics
- EMI rules not being followed
- Unusual PCB shapes causing RF harmonics

Possible Causes

- Cross plane boundary effect means that LVD clocks were resonating
- NAND clock and digital lines had poor spacing
- Digital and analog circuits not adequately separated
- Clock routings too close to power circuits which caused resonances into other areas of the board stack
- Routing over slots in the image plane causing too many loops
- Design of the RF board had too many traces running in a symmetrical plane
- Fringing on the radio board cased multiple harmonics which would swamp the antennas
- Poor grounding of the RF coax transmission lines mean the unit was susceptible to external RF influences

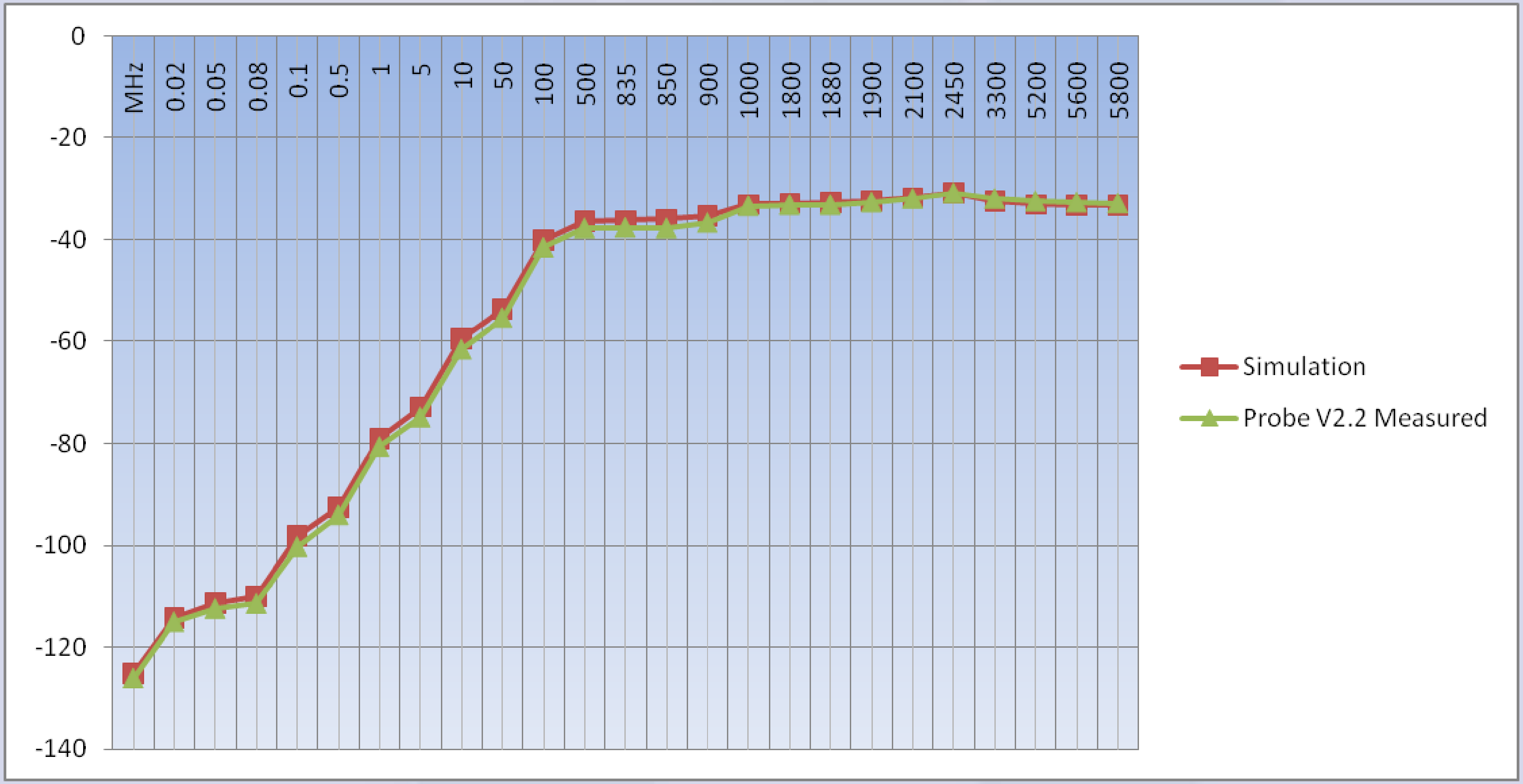
Characterization

- The probe and stripline simulations were conducted to allow for frequency extension
- By simulating both the probe and stripline we were able to optimize and improve the design of the probe and stripline
- Identified key elements based on sound scientific design principles
- Complete characterization of the probe and stripline from 10kHz to 6GHz



Simulation

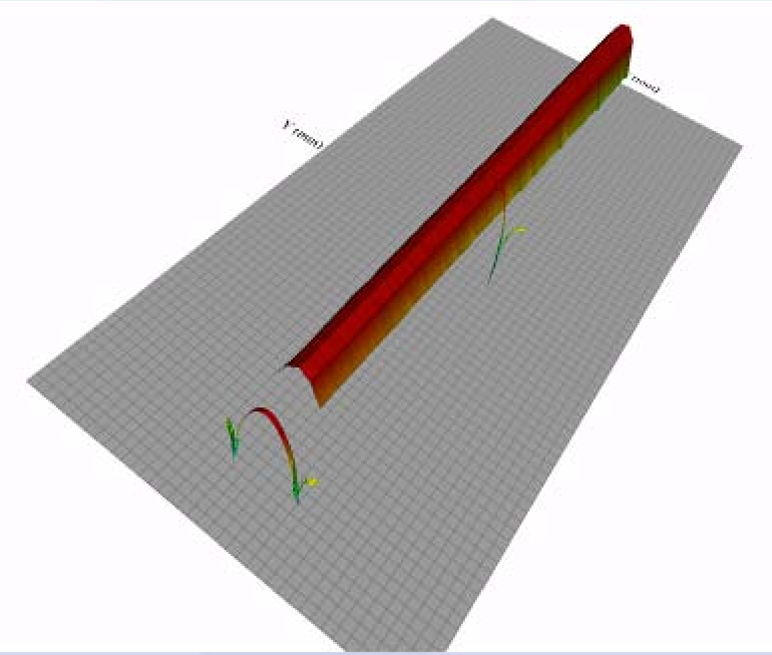
H-Field Probe



Comprehensive characterization of the H-Field probe
Simulation versus Experimental

Probe Characterization Experimental

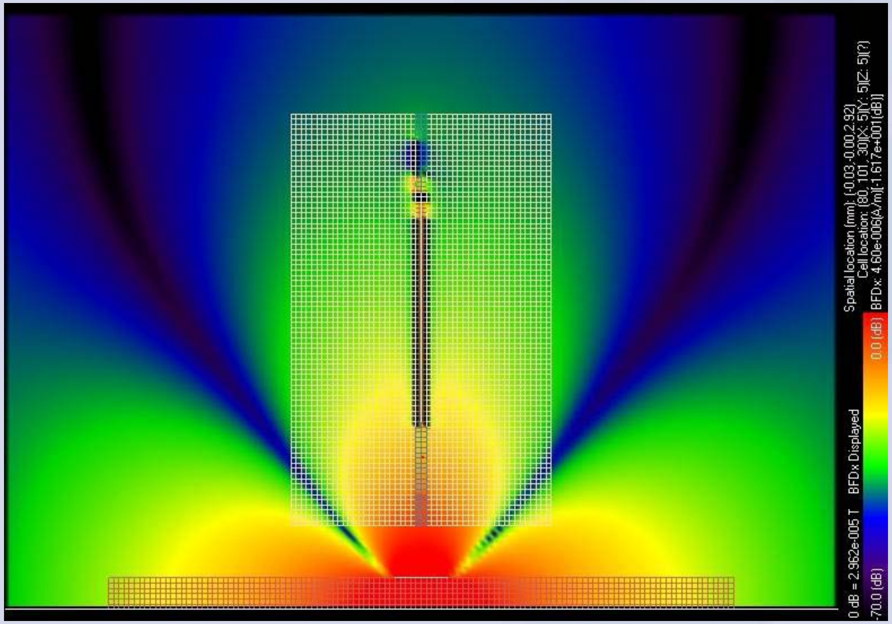
- Stripline calibration method is now well established
- Standing waves on stripline have been eliminated
- Results show extremely good correlation
- All data can be traced back to the IEC 61967 standard
- This method allows for easy ISO/IEC-17025 laboratory certification



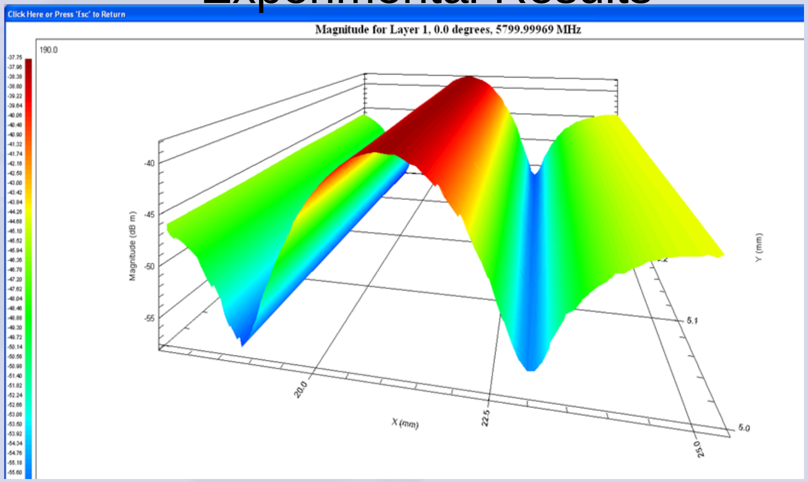
4D Plot of Stripline Taken from EM-ISight

Probe Calibration

Simulation Results

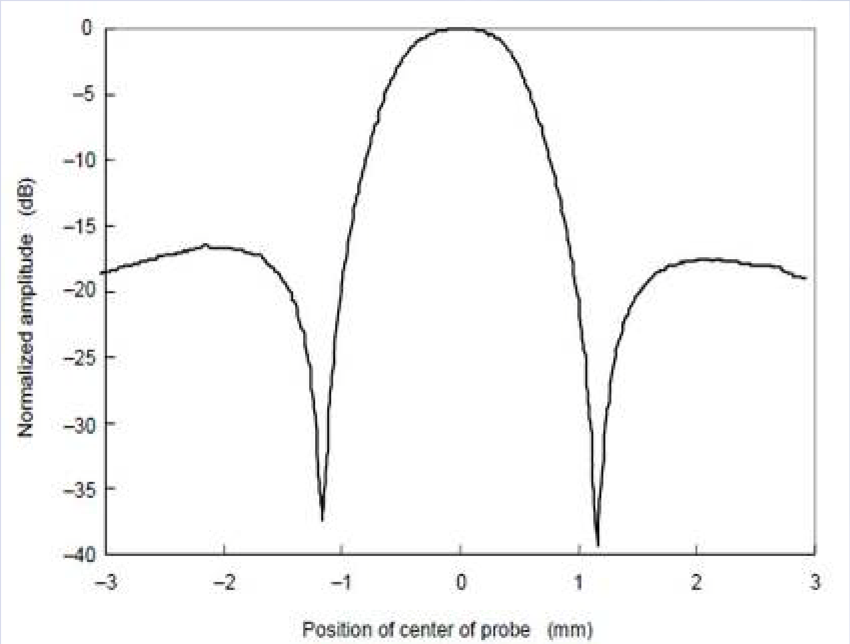


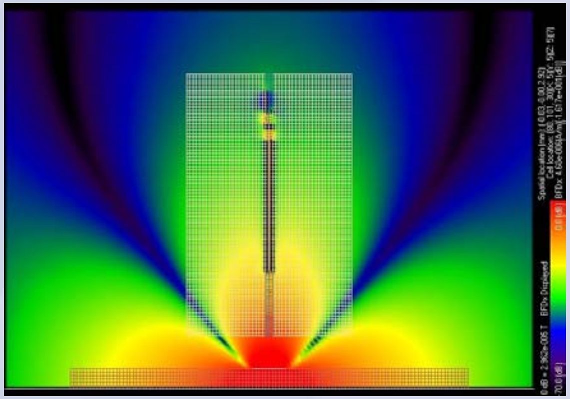
Experimental Results

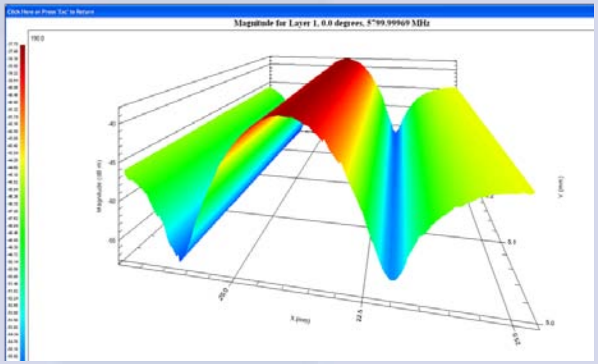


Excellent Correlation

Probe Calibration





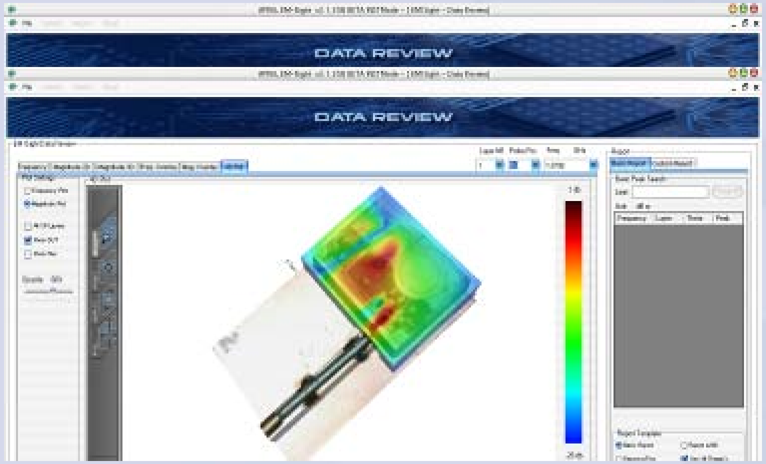


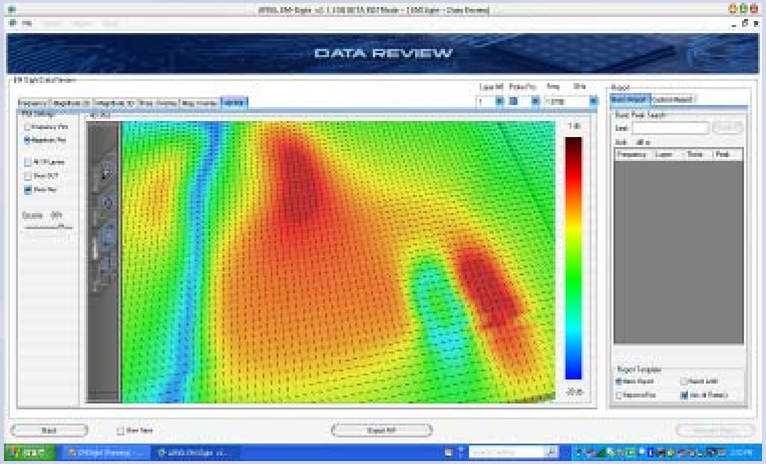
IEC-61967 Part 6

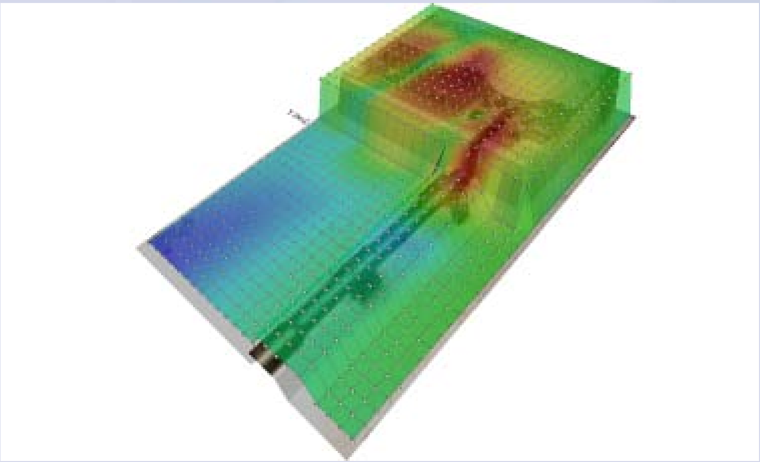
Correlation

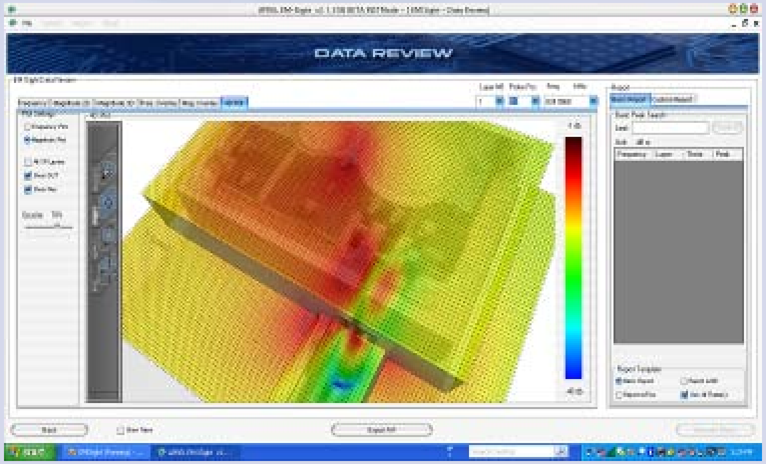
- Correlation of near-field to far-field distances is accomplished by using a 50ohm micro-strip line calibration reference fixture to obtain a known current versus frequency for a set level of input power.
- The far-field radiation field strength can then be calculated by substituting the known current within a conductor into equation (9.6) as referenced in Testing for Compliance Approaches and Techniques by Mark I. Montrose and Edward M. Nakauchi as published by the IEEE Press
- Including equations (11.1-2) as referenced in Noise Reduction Techniques in Electronic Systems by Henry W. Ott as published by Wiley-Interscience.

High Resolution 4D Scans









Benefits

- Low cost
- Fast measurement times
- Easy to integrate into a lab environment
- Multiple access for engineers
- Dynamic frequency selection and limits
- User defined measurement processes
- Dynamic reporting format for information sharing
- Multiple applications not limited to PCB, IC, Modules etc
- Adaptable to the user experience through software module updates
- Easy to maintain and support

Conclusion

- EM-ISight has been used to help identify weakness in a design so that the engineer can solve a number of problems post design
- The De-Sense function of EM-ISight allowed the design engineer to resolve the sensitivity issue of the WWAN receiver
- The EM-ISight allowed the user to correlate far field data to a near field conditions thus allowing a finite analysis for the problem area
- The EM-ISight has multiple functions and test applications where this is only one success story