Professional grade probes, calibration, measurement and reporting by APREL make EMC Engineering easier

EM-ISight Advantage

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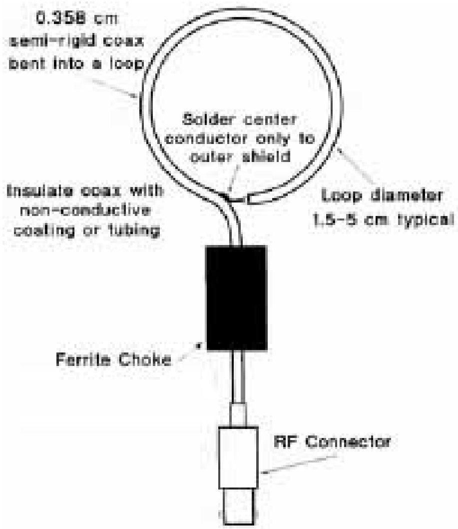
Key Point overview

- This presentation will highlight the EM-ISight probe, probe calibration and applications
- Presentation Outline
  - Intro to common near-field measurement techniques (sniffer probes)
  - EM-ISight Advantage
  - EM-ISight technology overview
  - EM-ISight real world test cases

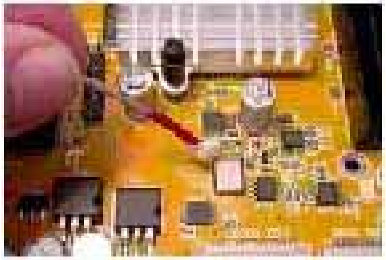
Common EMC Engineering tools

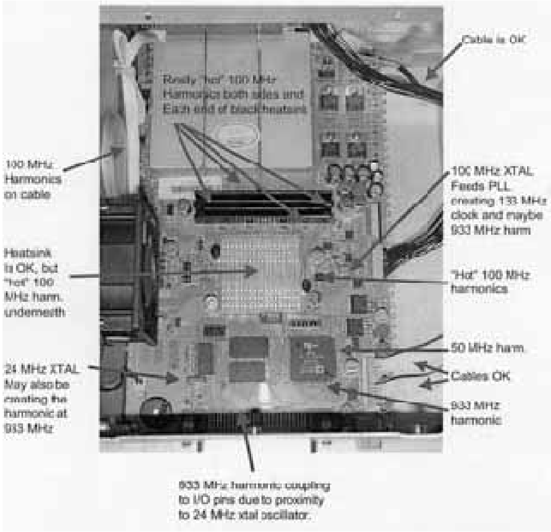


- A typical EMC project requires a lot of iteration (change something + validate)
- Make their own “sniffer” loops -> a lot of work for a little bit of progress

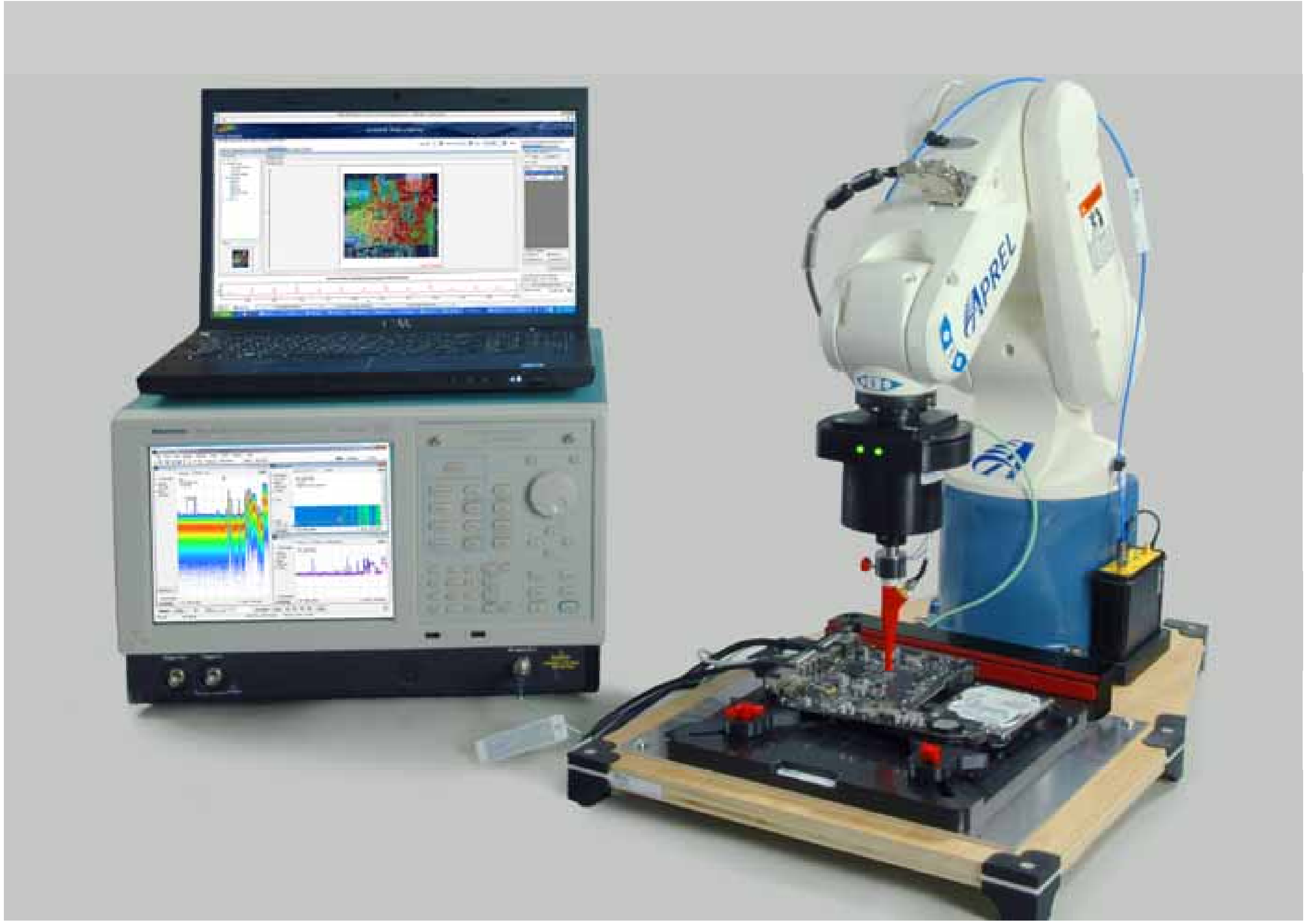
Limitations of traditional EMC methods – A lot of effort for a little information

- Component package size have gotten a lot smaller in the last 10 years. Some smaller than 1 mm.
- Large loop sizes = low spatial resolution, cannot differentiate between small components (< 1mm)
- Hand made loops are typically narrow band, you'll need to "sniff" your device many times with different probes to get an idea of what frequencies and harmonics are causing trouble
- Positioning and measurement repeatability not accurate (waste days trying to get accurate setup, then work is destroyed when someone moves something), cannot be used to qualify vendors
- Probe manufacturing defects could lead you astray (discrimination issues could cause you to see false hotspots or no hotspots)
- Manual reporting of results can take days, must redo report for each iteration





EM-ISight Advantage - A little bit of effort for a large amount of information



EM-ISight advantage - A little bit of effort for a large amount of information

- The EM-ISight system is designed to overcome common challenges in EMC debugging measurement
- Loop size chosen to balance spatial resolution and sensitivity
  - Loop size is small enough to differentiate small components (< 1mm)
  - Probe Sensitivity for smaller loop is compensated by a broad band LNA
- Probe coupling loss not strong enough to significantly influence the measured field (-35 dB or lower)
- Automatic touch feature ensures precise probe positioning over each point and component measured

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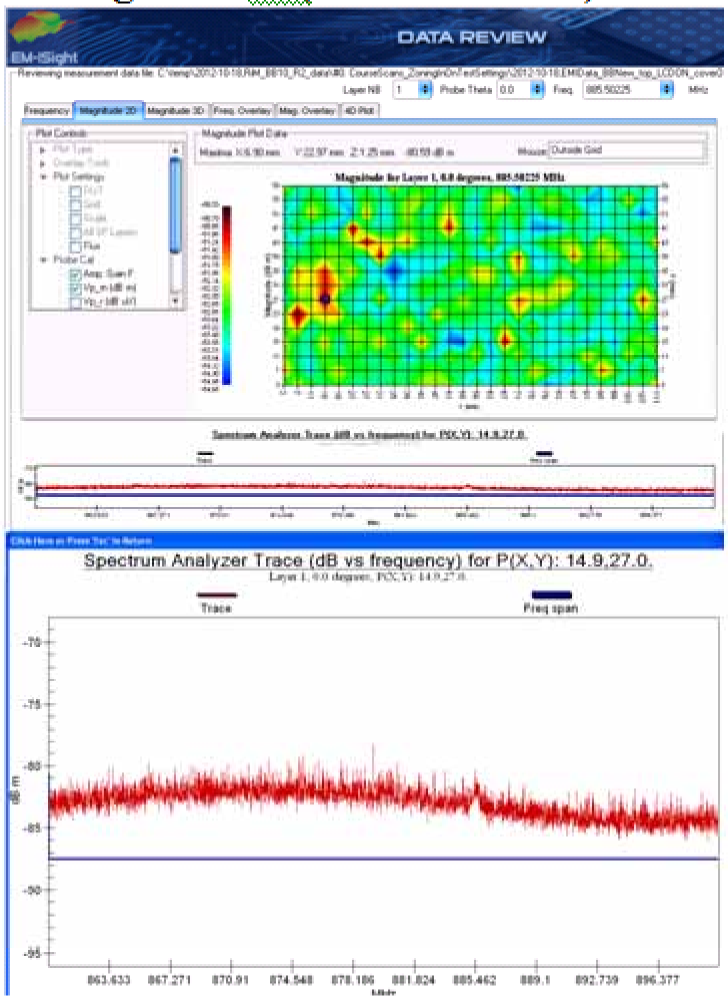
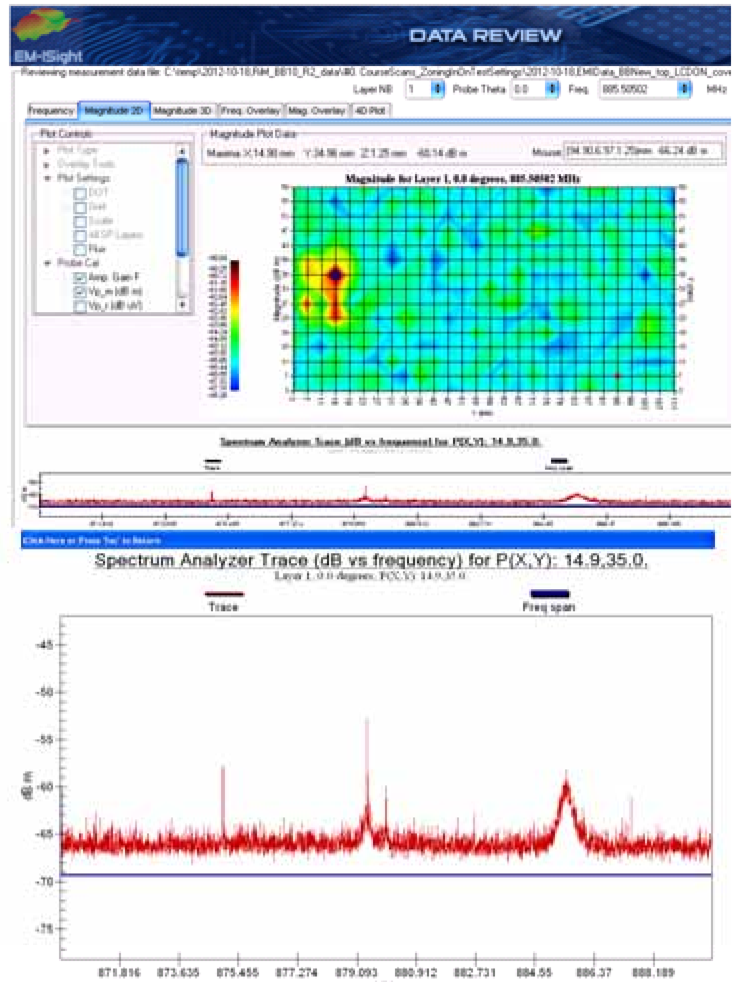
No LNA versus LNA

LNA gain = 0 (LNA not used)

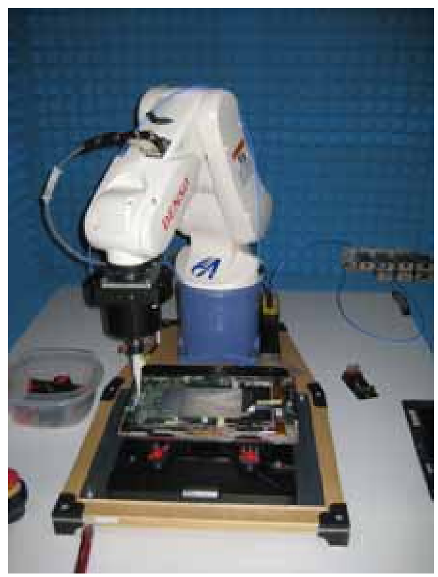


LNA gain = 26dB



Advantages - continued

- EM-ISight system hardware is designed to not alter the field of the DUT (ground plane option available but disabled by default), competitor system users need absorber block to prevent coupling with measurement system.
- Measurement repeatability – EM-ISight probes are batch manufactured and individually characterized. EM-ISight software will automatically compensate for the characterization values. Meaning all measurements are normalized to a standard.
- Automatic Measurement positioning – DENSO automotive manufacturing grade robot, Device constraint to hold device in repeatable position aligned to robot axis.

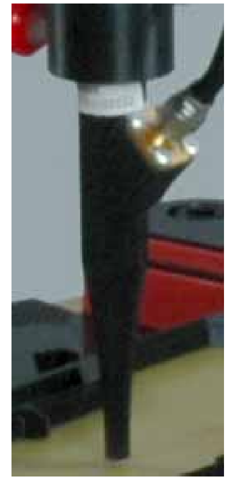


Advantages Continued

- System validation process with strip-line (standard) that also validates conversion from dBm to dBuA/m
- Coupling Loss Normalization feature will give you power in dBm @ the surface of the device
- Probe Characterization and traceability to NIST will facilitate team work between different EM-ISight systems as the data will be comparable

Advantages – EM-ISight Probe

- APREL probes are wide-band. You can get the snap-shot of what's happening with a single measurement
- APREL Probe types
  - Hxy 10KHz to 6GHz
  - Hxy 10KHz to 20GHz
  - Hz 10KHz to 6 GHz
  - Hz 10KHz to 20 GHz
  - Ez 10KHz to 6 GHz
  - Ez 10KHz to 20 GHz
  - Exy 10KHz to 6GHz
  - Exy 10KHz to 20GHz



APREL

E-Field and H-Field

- E-field hotspots and H-Field hotspots form at different parts of the source
- E-field and H-Field waves propagate on different planes

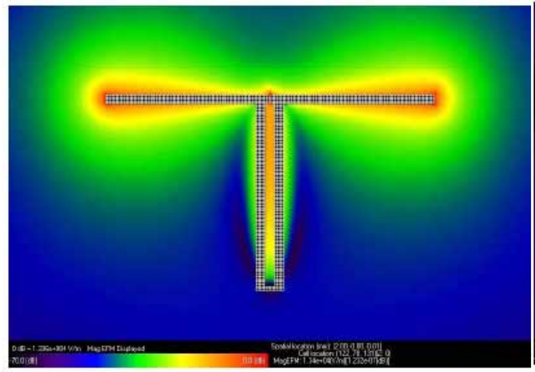


Figure D.5—E-field distribution around λ/2 dipole

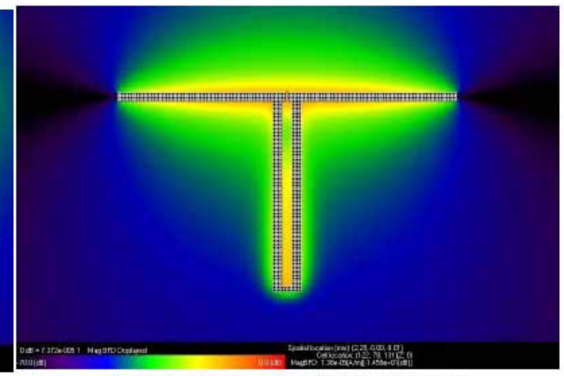


Figure D.6—Magnetic field distribution around λ/2 dipole

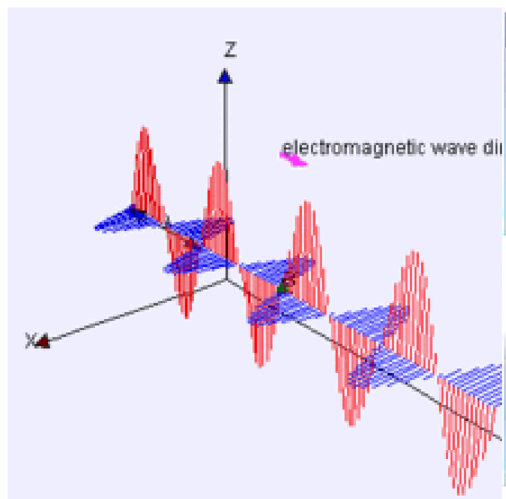


Figure.4 Total Magnetic Fields

Figure.5 Hy Component

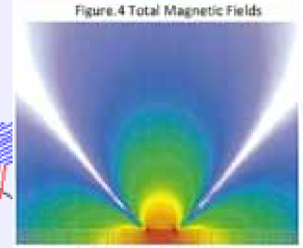


Figure.6 Hx Component

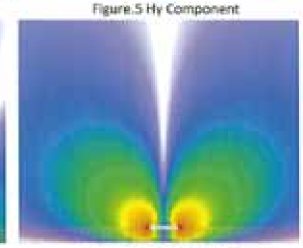
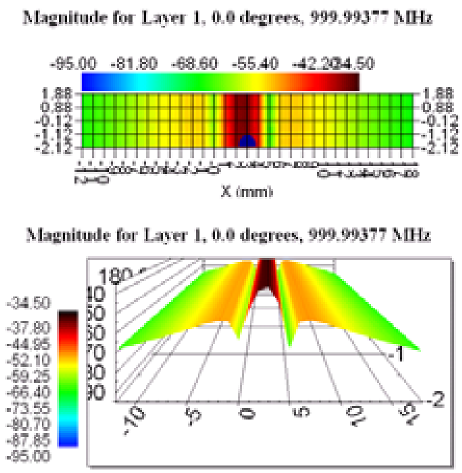


Figure.7 Hz Component

Advantages - probe

- APREL probes have good discrimination, meaning they can isolate the field components

Hxy Probe 0 Degree
(Hx Component)



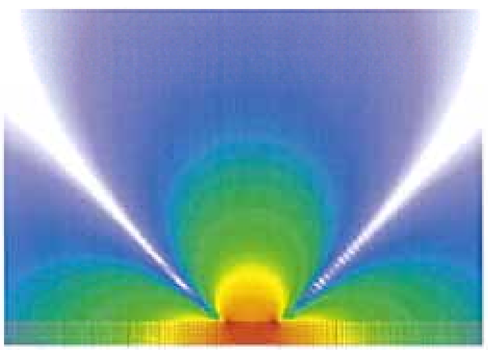
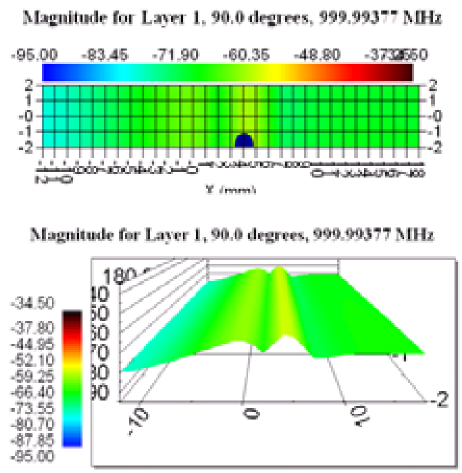


Figure.6 Hx Component

Hxy Probe 90 Degree
(Hy component)



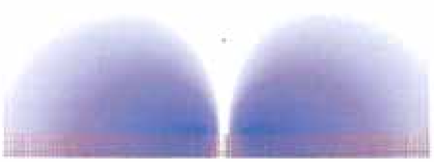
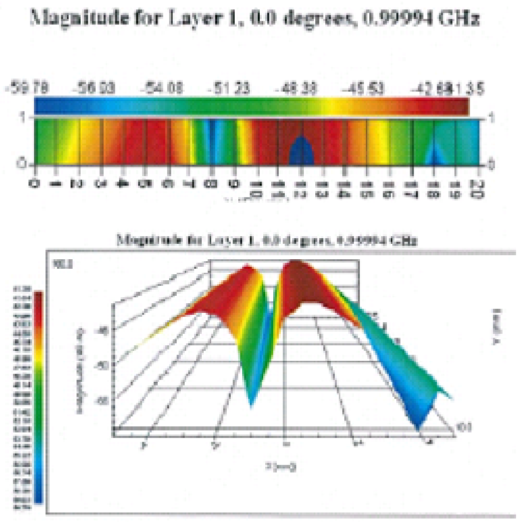


Figure.5 Hy Component

Hz Probe (Hz Component)



Peak Magnitude: -41.43

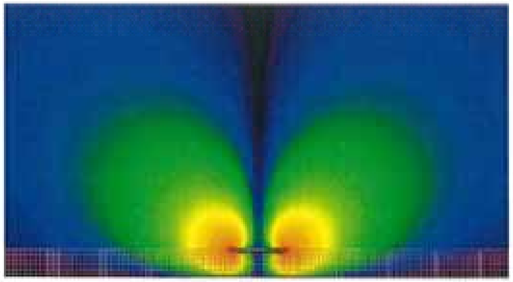
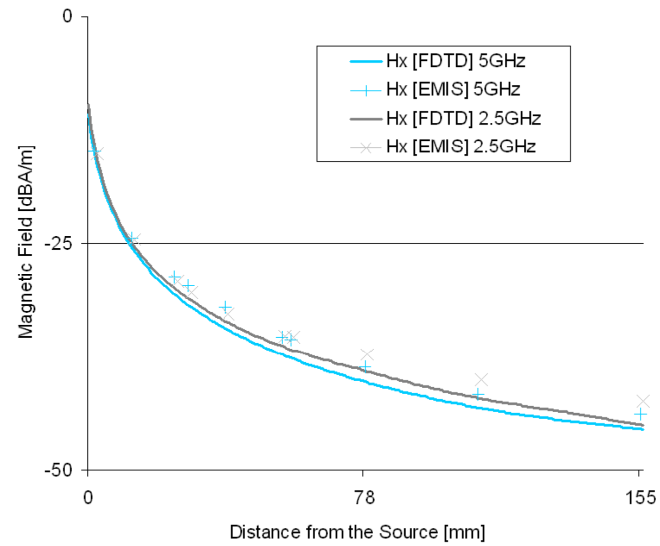
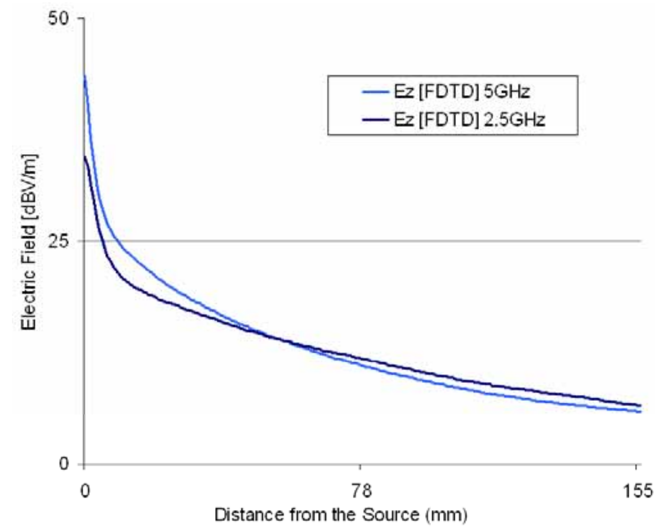


Figure.7 Hz Component

What are probe applications?

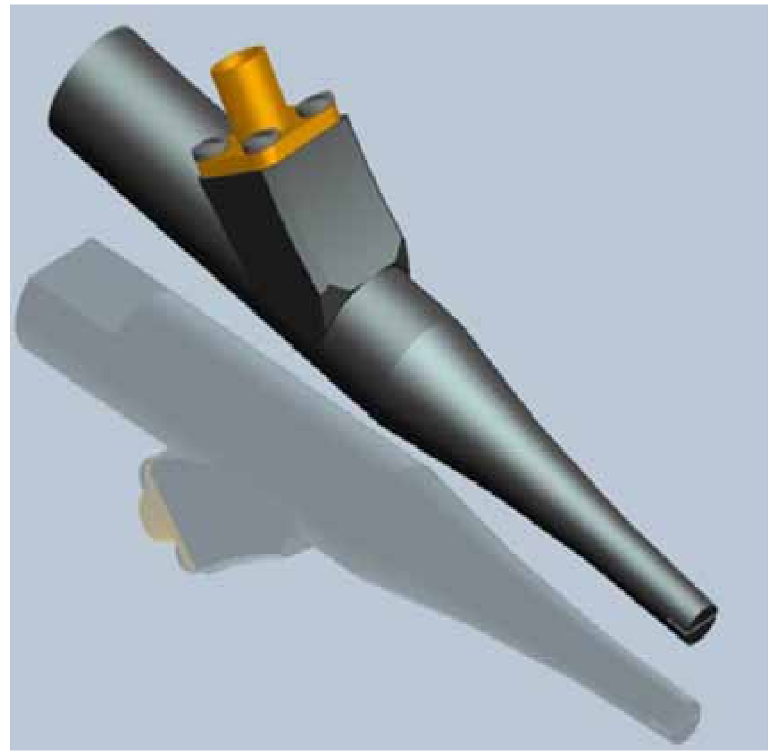
- Majority of EMI EMC issues are rooted in the flow of current at the board level
- H-Field is the direct result of current and very reliably measured in the near-field.
- E-Field measurements in the near-field are not as stable and can change sporadically based on probe positioning.
- APREL H-Field probes are great for:
  - Locating emission sources
  - Locating emission leaks
  - Shielding effectiveness testing
  - Component or vendor qualification
  - Receiver sensitivity or radio performance debugging
  - Current loop evaluation
  - Etc.
- APREL E-Field probes are great for
  - LCD touch screen qualification
  - Stylus performance qualification
  - Etc.





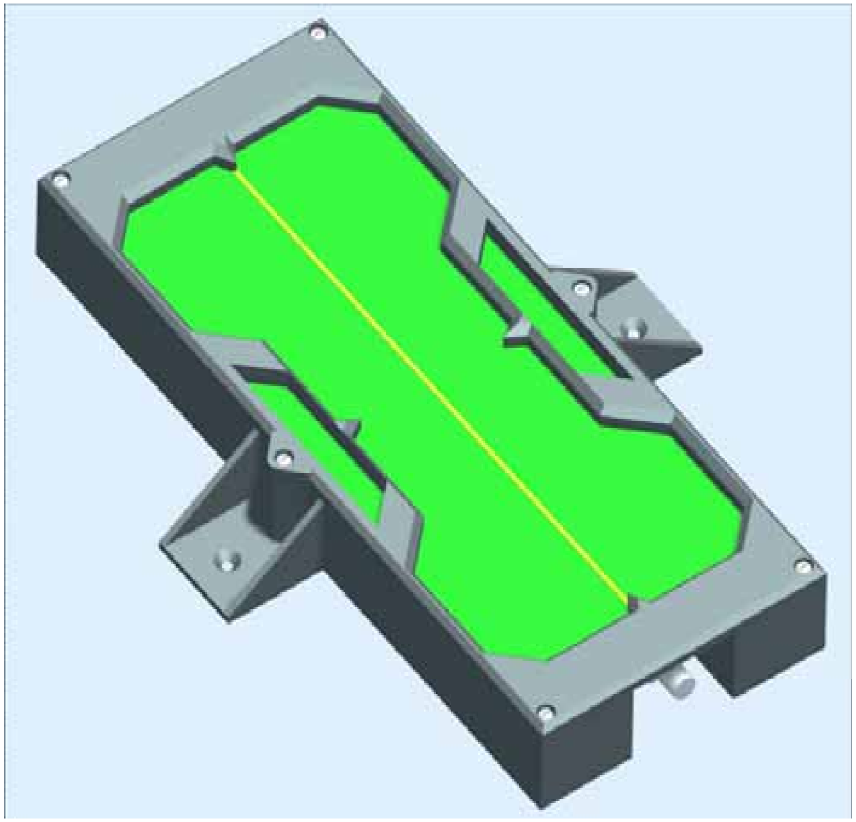
Technology Overview: H-Field Probe

- Based on the details in IEC-61967 Pt 1&6
- IEC has Limitations to the frequency response
- IEC has Limitations to the probe sensitivity
- A new probe design was implemented
- All the design ideas were validated in simulation and then experimentally validated



CAD Model used in Simulation

Technology overview: Strip-line Design

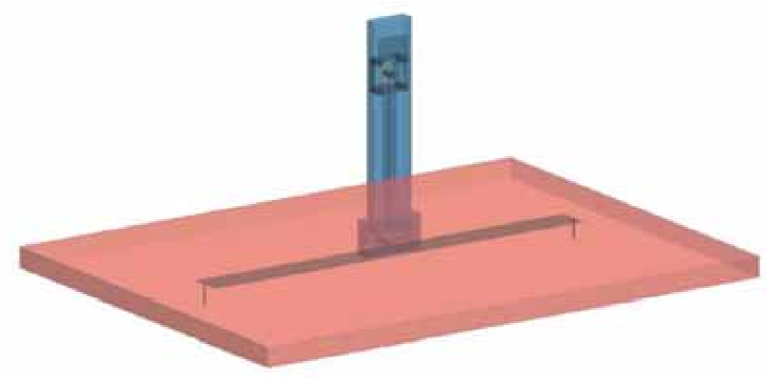


CAD Model used in Simulation

- Strip-line based on IEC 61967 Pt 1&2
- Modified and improved design to extend the frequency from 10kHz to 6GHz
- Integrated key features to use as a calibration source
- The design was simulated and then validated experimentally

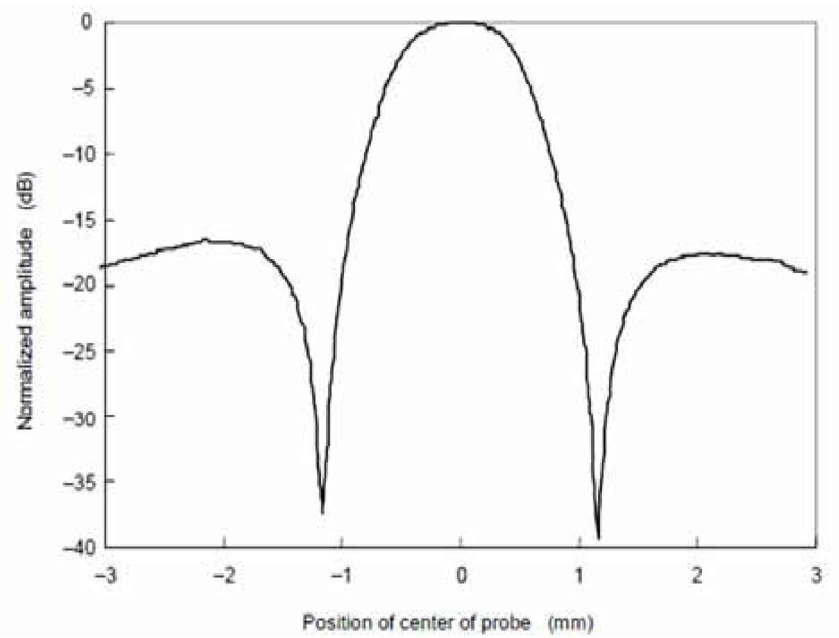
Technology Overview: Characterization

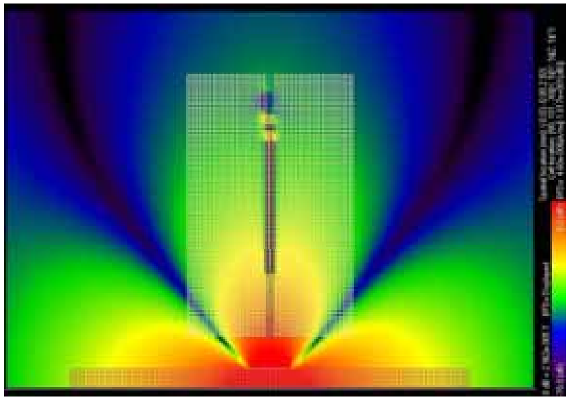
- The probe and strip-line simulations were conducted to allow for frequency extension
- By simulating both the probe and strip-line we were able to optimize and improve the design of the probe and strip-line
- Identified key elements based on sound scientific design principles
- Complete characterization of the probe and strip-line from 10kHz to 20GHz



Simulation

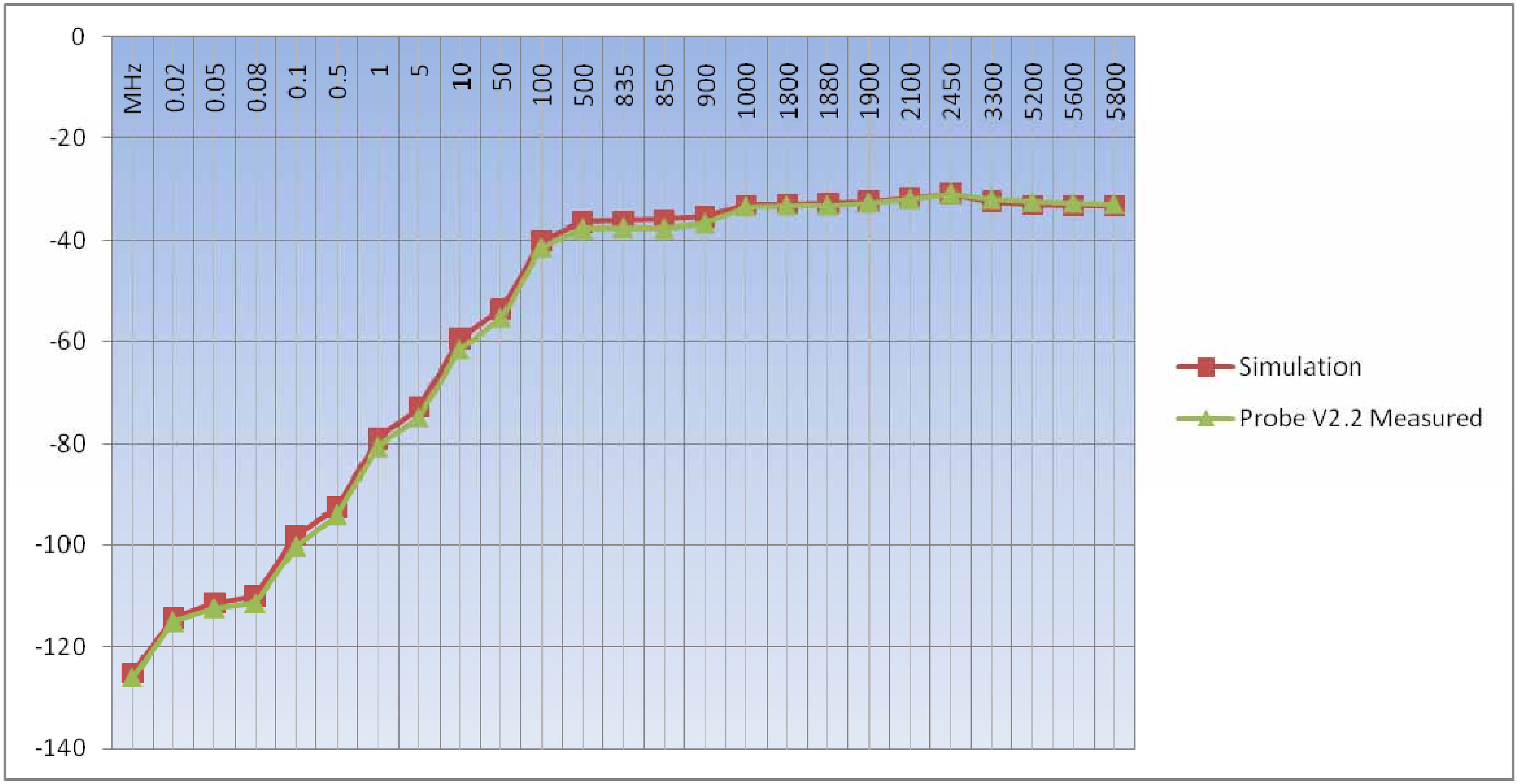
Technology Overview: Probe strip-line validation correlation between IEC 61967, Simulation, EM-ISight for Hx orientation





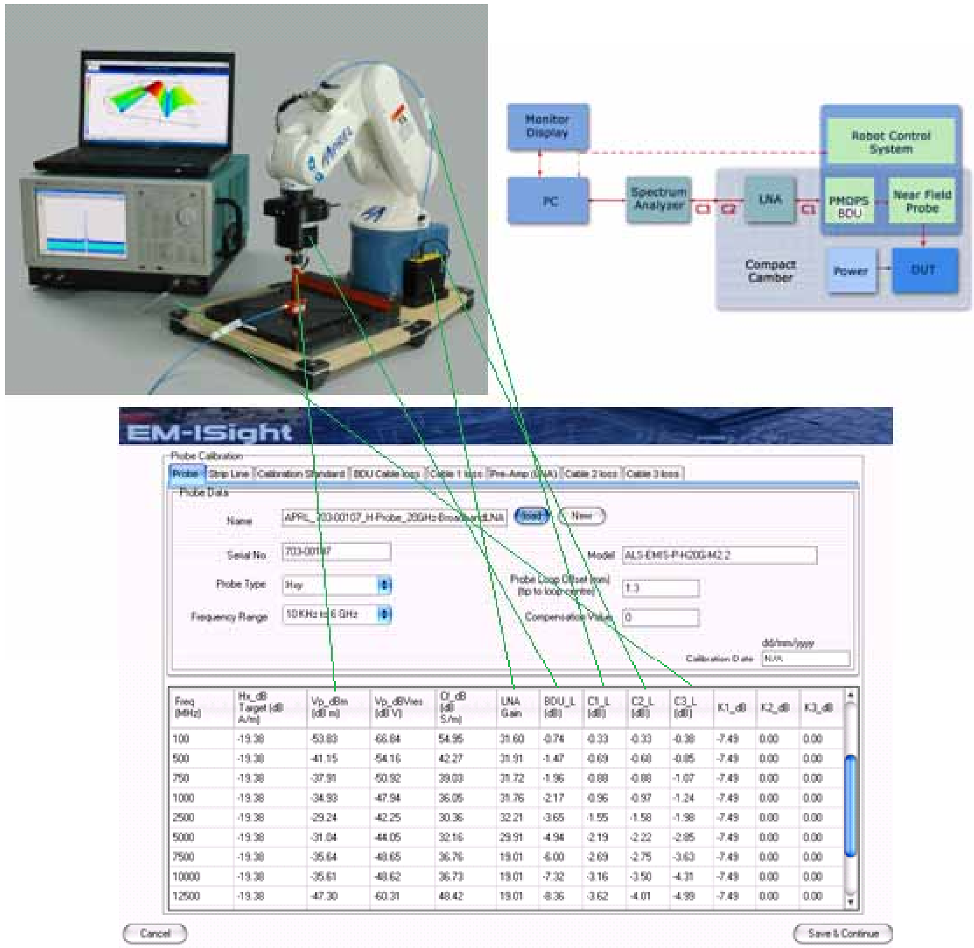
IEC-61967 Part 6

Technology Overview: Correlation between EM-ISight measurements and Simulation



Comprehensive characterization of the H-Field probe
Simulation versus Experimental

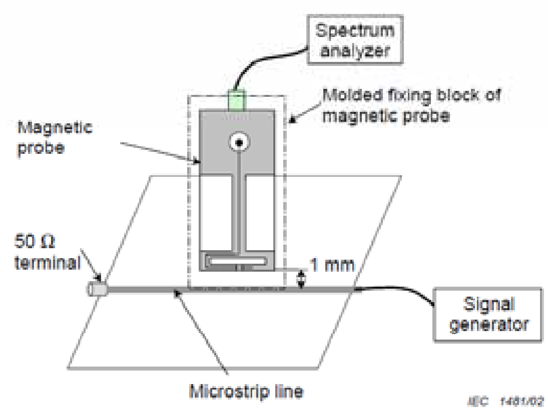
Technology Overview: Signal path component characterization factors in EM-ISight software



Freq (MHz)	Hx_dB Target (dB A/m)	Vp_dBm (dB m)	Vp_dBVies (dB V)	Cf_dB (dB S/m)	LNA Gain	BDU_L (dB)	C1_L (dB)	C2_L (dB)	C3_L (dB)	K1_dB	K2_dB	K3_dB
100	-19.38	-53.83	-66.84	54.95	31.60	-0.74	-0.33	-0.33	-0.38	-7.49	0.00	0.00
500	-19.38	-41.15	-54.16	42.27	31.91	-1.47	-0.69	-0.60	-0.85	-7.49	0.00	0.00
750	-19.38	-37.91	-50.92	39.03	31.72	-1.96	-0.88	-0.88	-1.07	-7.49	0.00	0.00
1000	-19.38	-34.93	-47.94	36.05	31.76	-2.17	-0.96	-0.97	-1.24	-7.49	0.00	0.00
2500	-19.38	-29.24	-42.25	30.36	32.21	-3.65	-1.55	-1.58	-1.98	-7.49	0.00	0.00
5000	-19.38	-31.04	-44.05	32.16	29.91	-4.94	-2.19	-2.22	-2.85	-7.49	0.00	0.00
7500	-19.38	-35.64	-48.65	36.76	19.01	-6.00	-2.69	-2.75	-3.63	-7.49	0.00	0.00
10000	-19.38	-35.61	-48.62	36.73	19.01	-7.32	-3.16	-3.50	-4.31	-7.49	0.00	0.00
12500	-19.38	-47.30	-60.31	48.42	19.01	-8.36	-3.62	-4.01	-4.99	-7.49	0.00	0.00

Technology Overview – probe calibration math from IEC 61967 part 6, 2002

- The probe is positioned above a strip-line, and a calibrated VNA is used as signal generator and spectrum analyzer to measure the coupling loss at each frequency
- The probe (antennae) calibration factor is calculated as per IEC 61967 with each variable as in input to the EM-ISight software, resulting in a factor with units dB S/m



NOTE A transmission loss of the microstrip line should be half the overall loss when the magnetic probe is placed in the centre of the microstrip line.

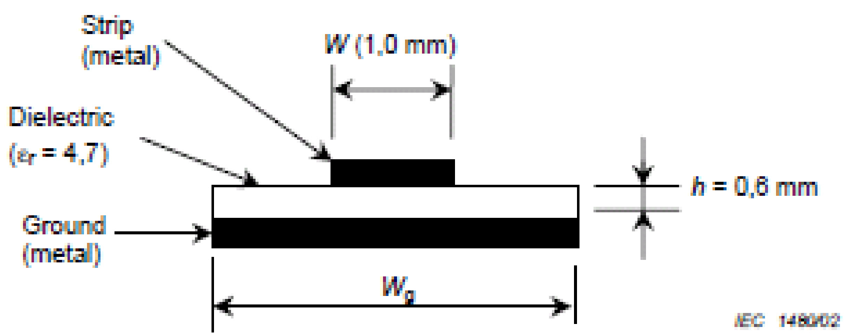
Technology Overview – probe calibration math from IEC 61967 part 6, 2002

Use a microstrip line structure shown in figure A.1. The insulator thickness (*h*) of the microstrip board used shall be 0,6 mm, and the characteristic impedance shall be 50 Ω ± 5 Ω.

In the case of dielectric constant ε_r = 4,7, the strip conductor width (*W*) is 1,0 mm. The ground plane width (W_g) of the microstrip line should be at least 50 mm. The microstrip line should be long enough (for example, 101,6 mm) and should have a sufficiently high frequency performance.

In order to check the characteristic impedance, RF measurement equipment such as a network analyzer or a TDR oscilloscope should be used.

NOTE Power required to obtain a sufficient signal to noise (S/N) ratio may be determined in advance over frequency range of interest.

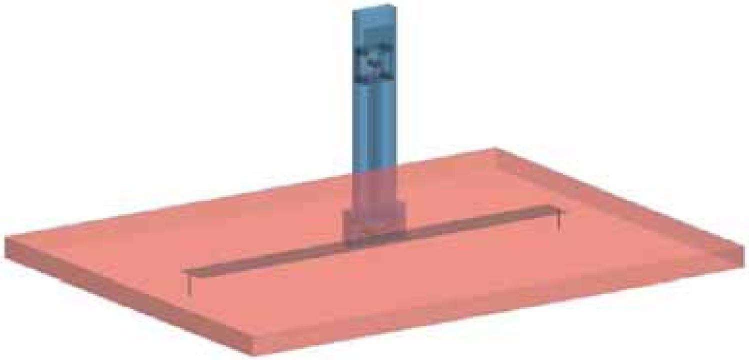


Technology Overview – probe calibration math from IEC 61967 part 6, 2002

$$C_{f\_dB} = 20 \log \left[\frac{h}{\pi Y (Y + 2h)} \right] - V_{p\_dB} + V_{s\_dB} - 30 \qquad \text{(dB S/m)} \qquad \text{(A.1)}$$

where

- C_{f_dB} is the calibration factor for the magnetic field (dB S/m),
- Y is the distance (m) between the strip conductor and the centre of the loop of the magnetic probe,
- h is the insulator thickness (m) of the microstrip board used for calibration,
- V_{p_dB} is the output voltage of the magnetic probe (dB V),
- V_{s_dB} is the output voltage of the signal generator (dB V).



Technology Overview: unit conversions within EM-ISight

C_f is the calibration factor for the magnetic field (S/m);

V_p is the voltage across the impedance (V).

In the logarithmic expression, the magnetic field (H_{x_dB}) is given by the following equation (B.12):

$$H_{x\_dB} = C_{f\_dB} + V_{p\_dB} \quad \text{(dB A/m)} \qquad \text{(B.12)}$$

The calibration factor (C_{f_dB}), which is a measured value and is obtained by the calibration method in annex A for the magnetic probe specified in this standard, is shown in figure B.3.

Substituting equation (B.12) into equation (B.10) yields the following equation (B.13):

$$I_{\_dB} = V_{p\_dB} + C_{f\_dB} - C_{h\_dB} \quad \text{(dB A)}$$

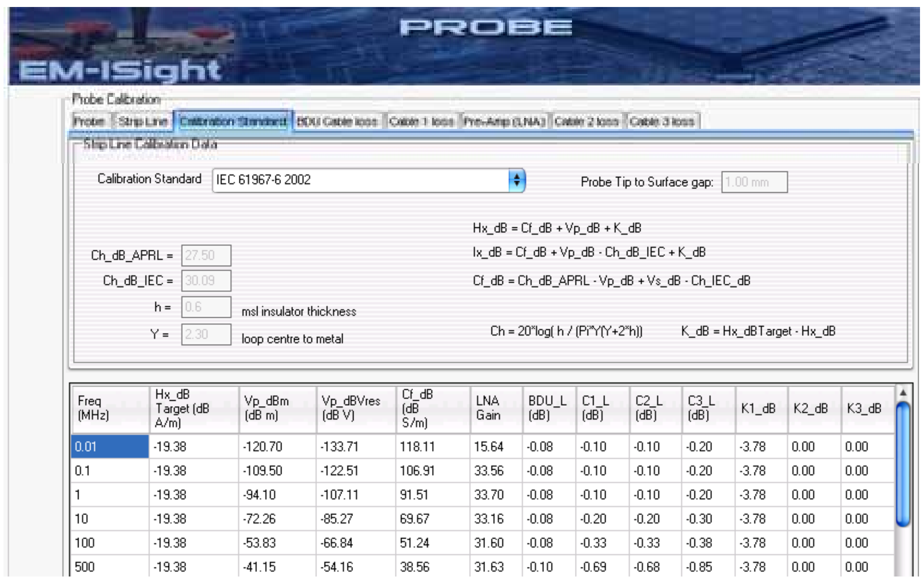
where

V_{p_dB} = V_p value in dB (dB V);

C_{f_dB} = C_f value in dB (dB S/m);

C_{h_dB} = C_h value in dB (dB 1/m).

Thus, in practice, the RF current ($I_{\_dB}$) is calculated.



Freq (MHz)	Hx_dB Target (dB A/m)	Vp_dBm (dB m)	Vp_dBVres (dB V)	Cf_dB (dB S/m)	LNA Gain	BDU_L (dB)	C1_L (dB)	C2_L (dB)	C3_L (dB)	K1_dB	K2_dB	K3_dB
0.01	-19.38	-120.70	-133.71	118.11	15.64	-0.08	-0.10	-0.10	-0.20	-3.78	0.00	0.00
0.1	-19.38	-109.50	-122.51	106.91	33.56	-0.08	-0.10	-0.10	-0.20	-3.78	0.00	0.00
1	-19.38	-94.10	-107.11	91.51	33.70	-0.08	-0.10	-0.10	-0.20	-3.78	0.00	0.00
10	-19.38	-72.26	-85.27	69.67	33.16	-0.08	-0.20	-0.20	-0.30	-3.78	0.00	0.00
100	-19.38	-53.83	-66.84	51.24	31.60	-0.08	-0.33	-0.33	-0.38	-3.78	0.00	0.00
500	-19.38	-41.15	-54.16	38.56	31.63	-0.10	-0.69	-0.68	-0.85	-3.78	0.00	0.00

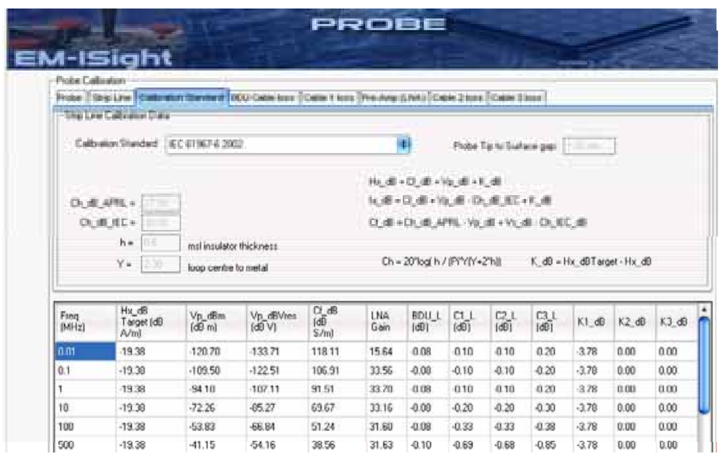
APREL

EM-ISight Unit Conversions

- Vp_dBm = SpecAn - LNAGain + cable_losses
- Vp_dBV = Vp_dBm – 30 + 10*log(50ohm)

  – ***P=V^2/R, convert to dB -> P(w)dB = VdB – RdB***
  – ***Convert P(w) to P(mW) P(w)dB = P(mW)dB – 10log(10^3mW/W)***

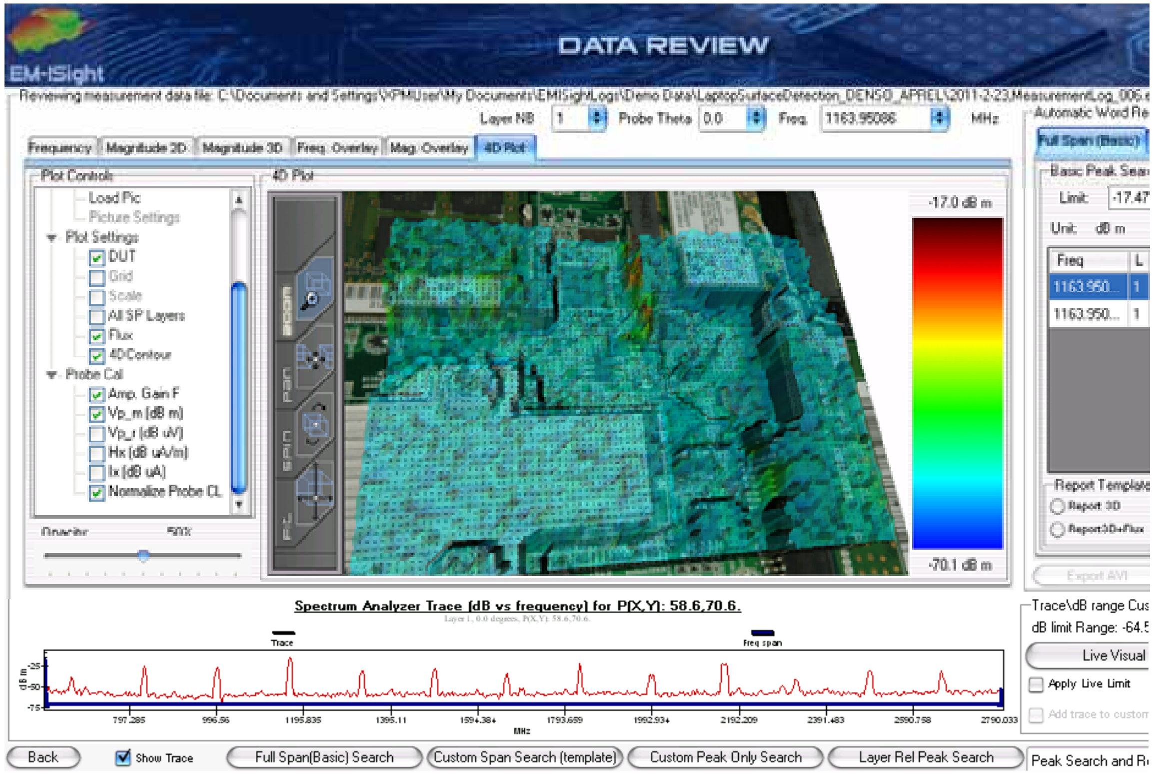
- dBV to dBuV -> dBuV = dBV – 120, where 20log(10^6uV/V) = 120



Freq (MHz)	Hx_dB Target (dB A/m)	Vp_dBm (dB m)	Vp_dBVres (dB V)	Cf_dB (dB S/m)	LNA Gain	BDU_L (dB)	C1_L (dB)	C2_L (dB)	C3_L (dB)	K1_dB	K2_dB	K3_dB
0.01	-19.38	-120.70	-133.71	118.11	15.64	-0.08	-0.10	-0.10	-0.20	-3.78	0.00	0.00
0.1	-19.30	-109.50	-122.51	106.91	33.56	-0.00	-0.10	-0.10	-0.20	-3.70	0.00	0.00
1	-19.38	-94.10	-107.11	91.51	33.70	-0.08	-0.10	-0.10	-0.20	-3.78	0.00	0.00
10	-19.30	-72.26	-85.27	69.67	33.16	-0.00	-0.20	-0.20	-0.30	-3.70	0.00	0.00
100	-19.38	-53.83	-66.84	51.24	31.60	-0.08	-0.33	-0.33	-0.38	-3.78	0.00	0.00
500	-19.38	-41.15	-54.16	38.56	31.63	-0.10	-0.69	-0.68	-0.85	-3.78	0.00	0.00

Software Probe Form

Technology overview: Unit conversion in data review form



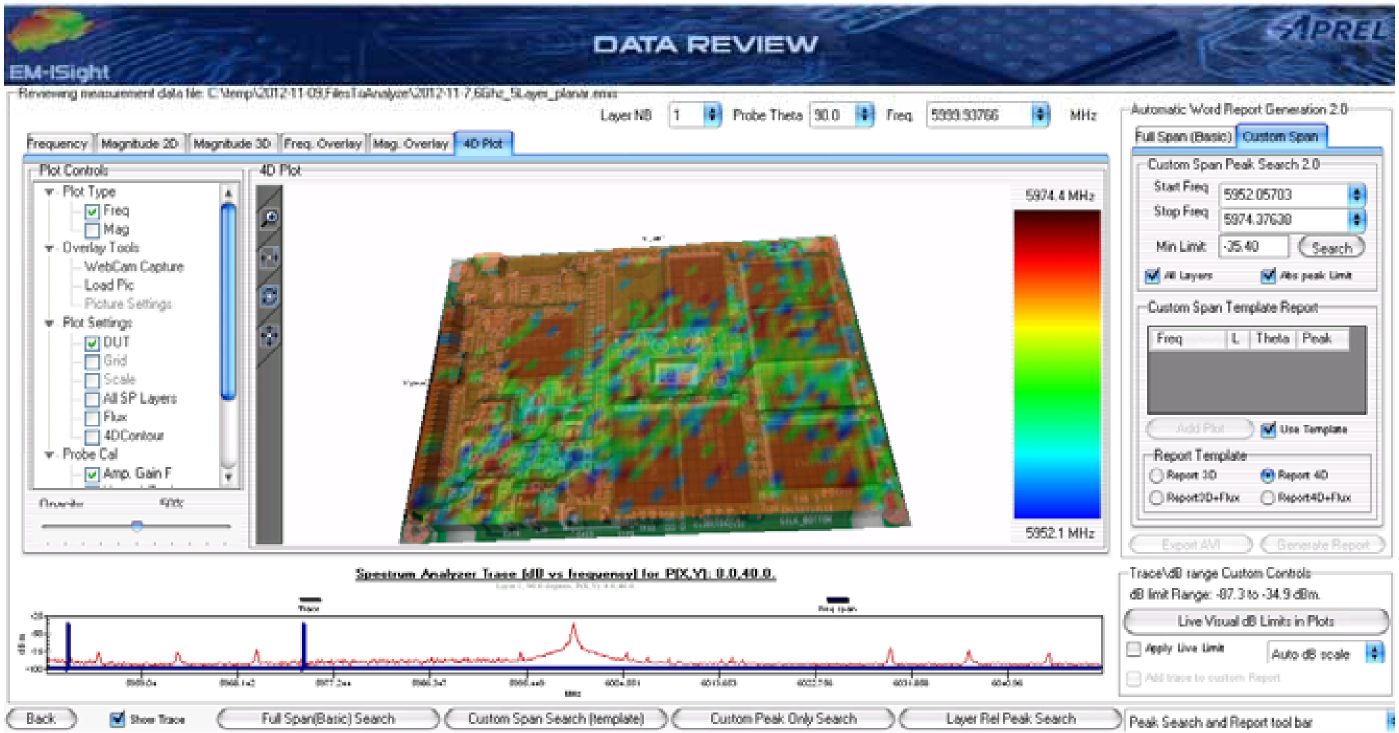
Default mode is normalize Probe CL= Vp_dBm(measured) – Vp_dBm(characterization)

Vp_r(dB_uV) = convertTodBuV(Vp_dBm – ampGain + cableLosses)

Hx(dBuA\m) = Vp_r + Cf + Kfactors

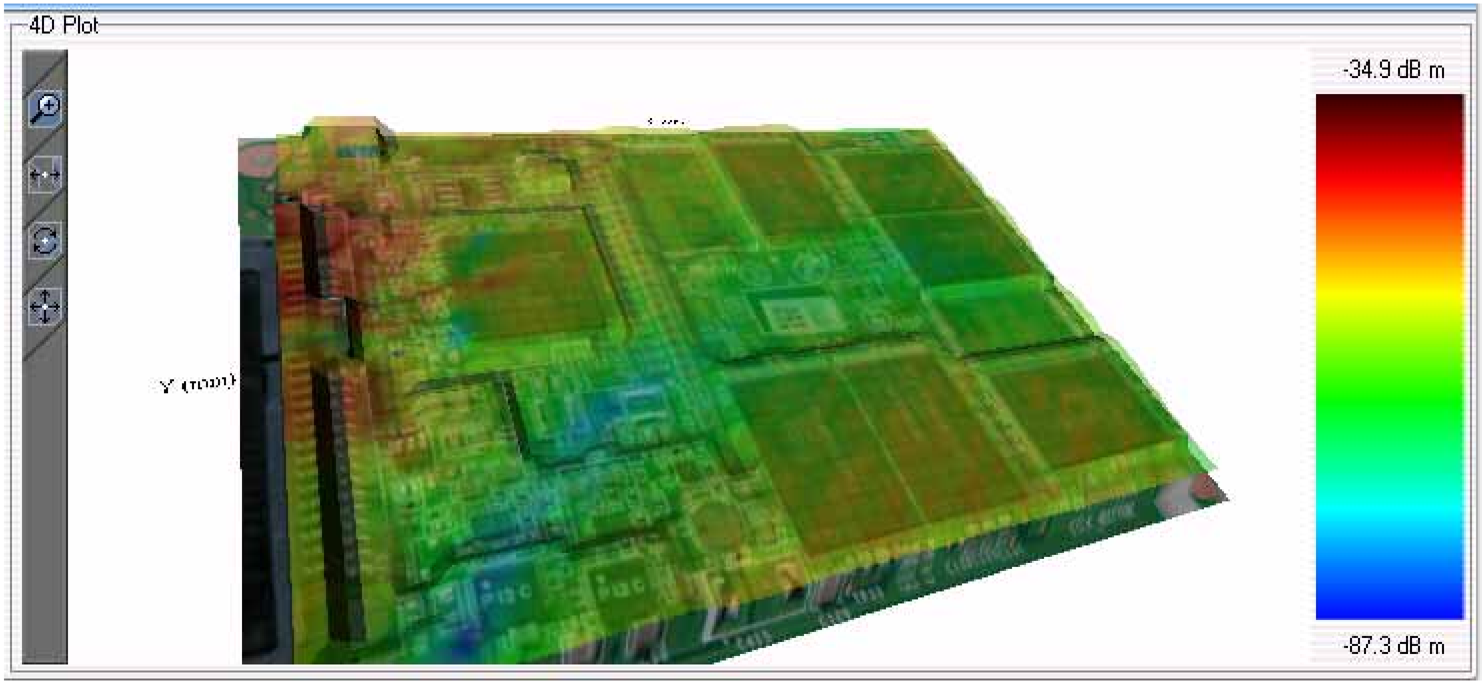
NOTE: above equations applied to each frequency, and all points in plot

Frequency Signature



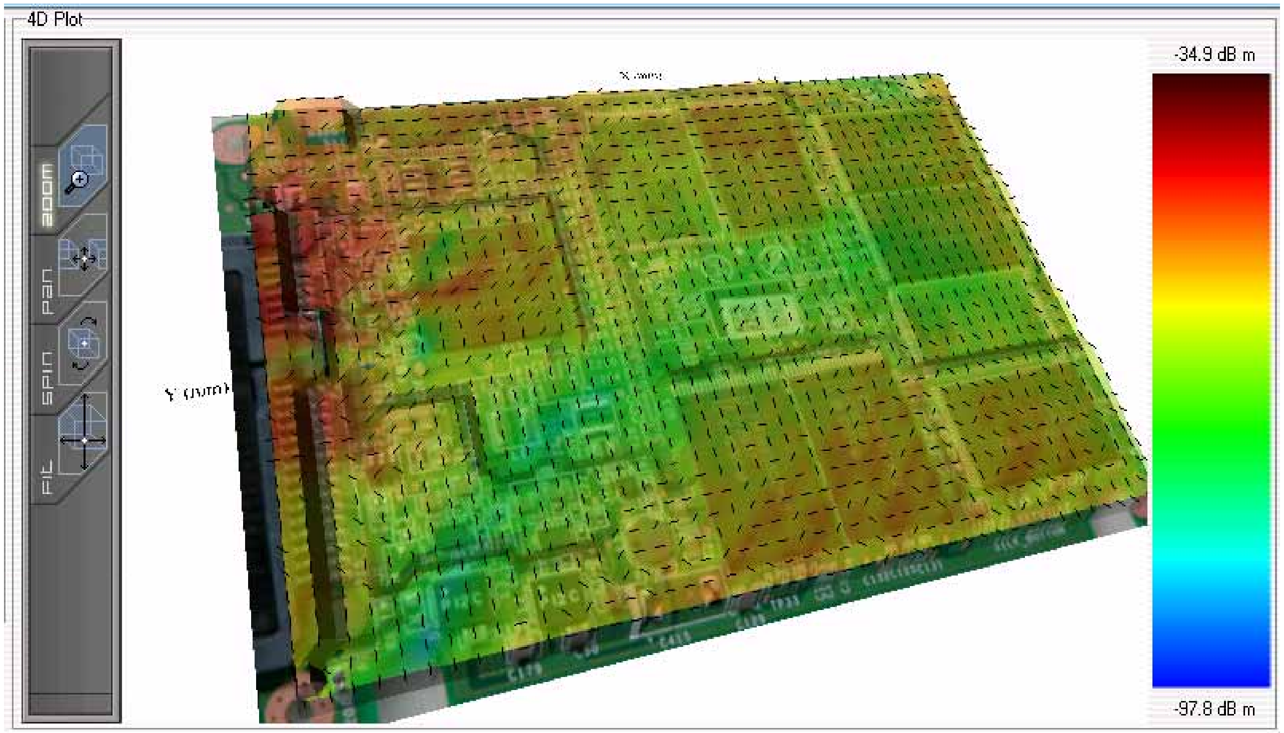
- Visually highlights the dominant frequency for each point
- User can click on point to select frequency to view the hotspots in the magnitude plot overlay or 4D plot picture overlay

4D plot picture overlay



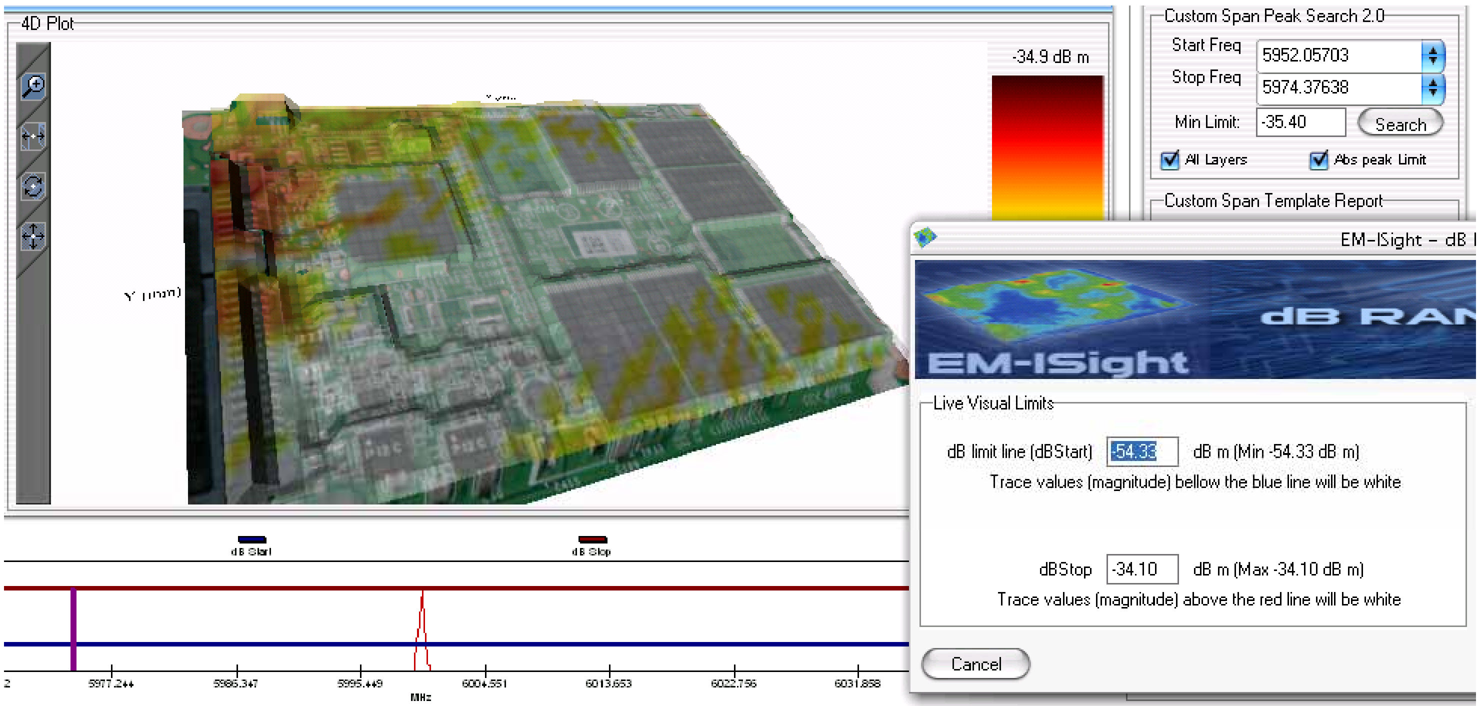
- At each point, the EMISight system performs an automatic touch detection, then the X,Y,Z coordinates for each point and the trace are saved to file on hard drive
- EMISight software will process the data and render it into a 3D scene

Current vector (Flux direction)



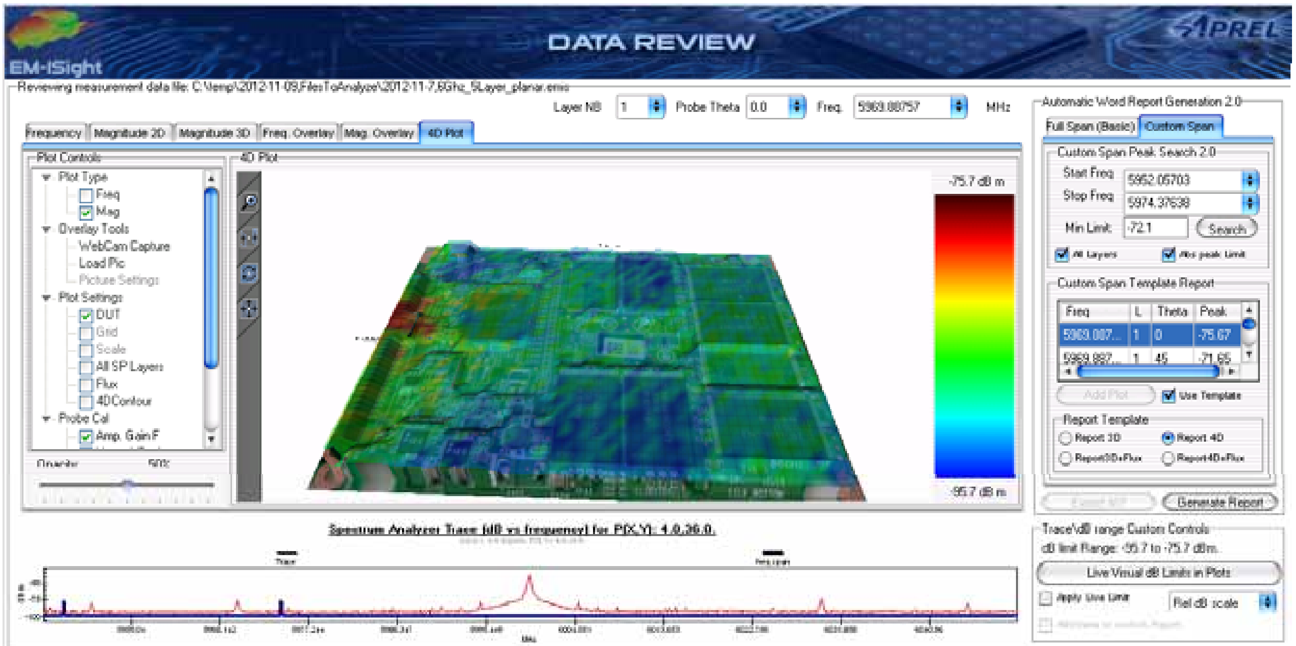
- For the selected frequency, at each measured point a line in the direction of the maximum probe orientation is drawn on the overlay plot. This line represents the current vector as current must be going in this direction for the probe to have a maximum voltage.

Visual Limit Overlays



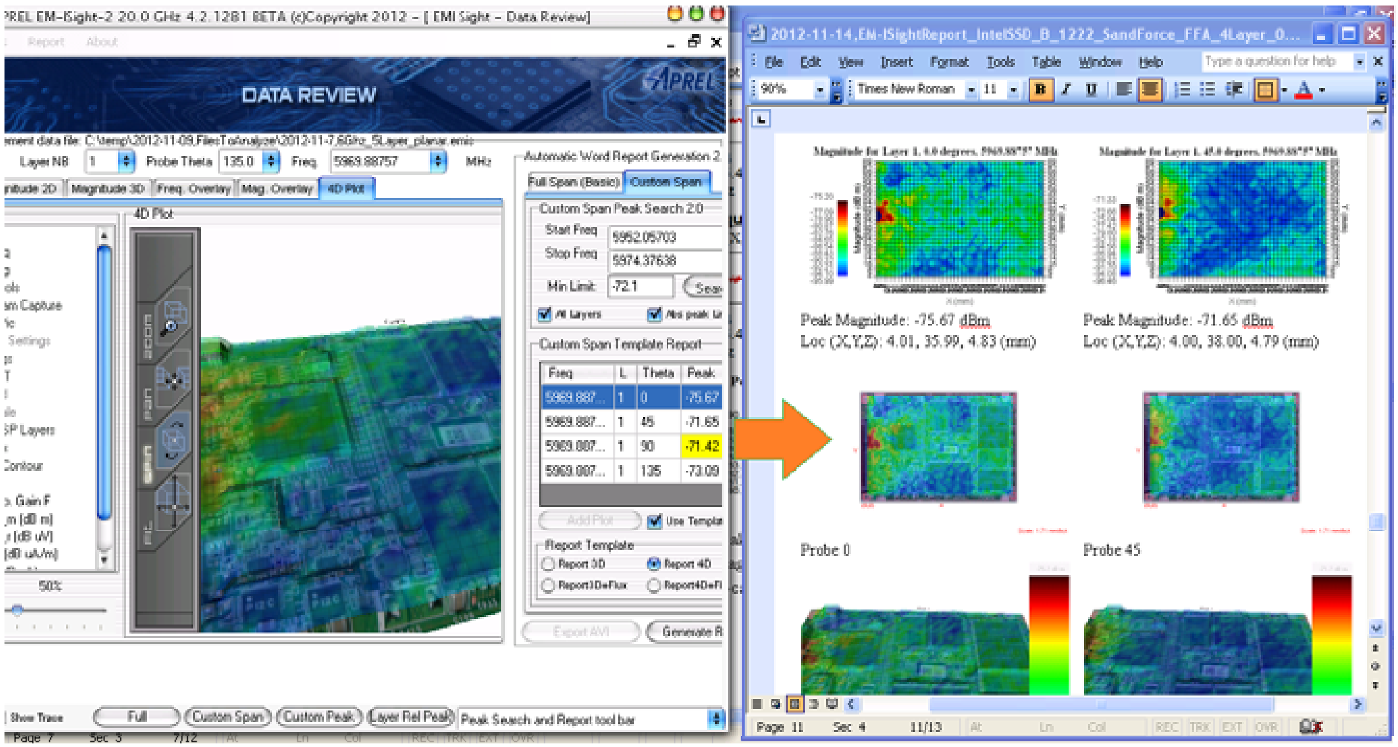
- A maximum and minimum limit will only display hotspots within the limits.
- Highlights hotspots that are over the limit

Automatic peak search and band filtering (start and stop frequency)



- If you have a harmonic rich trace (most cases), you do not need to repeat the scan with a narrow band.
- EM-ISight will only analyze data between a selectable start and stop frequency, (see filter start and stop lines above)
- Harmonics in selected band, and above selected limit will be added to the plot list automatically

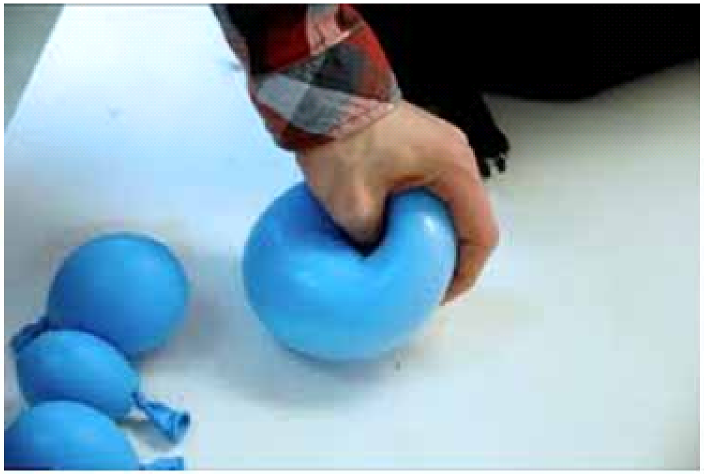
Automatically generated word reports



- All plots in the plot list will be inserted into an automatically generated word report
- Several pre-defined templates can be used
- Custom report templates can also be defined
- Can change company logo and report titles
- Header includes all system variables and data for traceability purposes

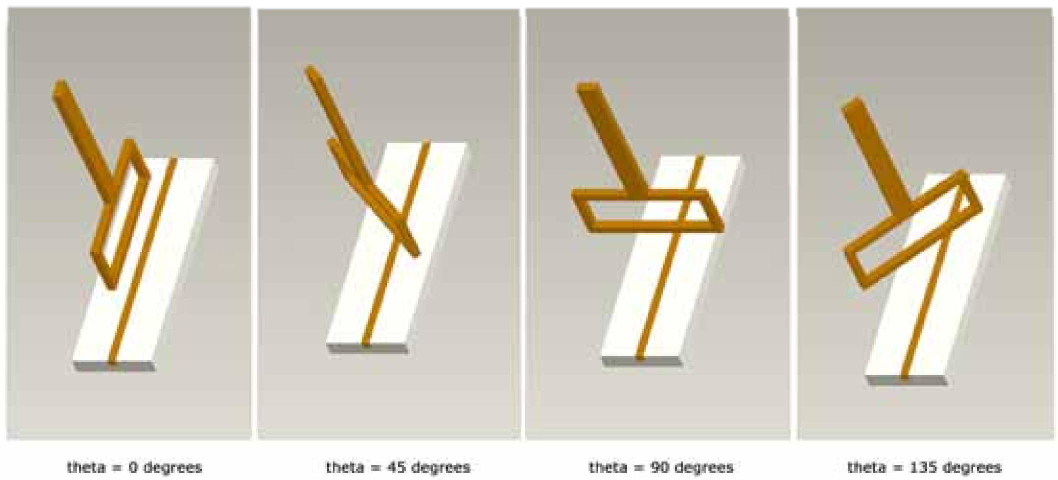
APREL

EM-ISight Application Examples



- EMC prototype qualification is an iterative process. Change a part on the prototype, and then measure the prototype to asses the effect.
- Typical projects require hundreds of iterations, constantly chasing the current around the board and edges (squeeze current out of one area, it pops out in a different area)
- EM-ISight offers a wide range of tools to help the EMC engineer get a better idea of what is actually happening in the prototype (on the board).

Using Probe Magnetic Field Discrimination and automatic probe rotation to solve problems



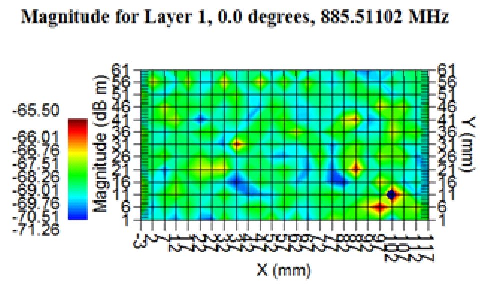
- EM-ISight scans can be configured to rotate the probe to several different probe orientations
- EM-ISight software will post process and display the orientation data in a comprehensive manor to assist with data interpretation.

Mobile phone receiver sensitivity case 1

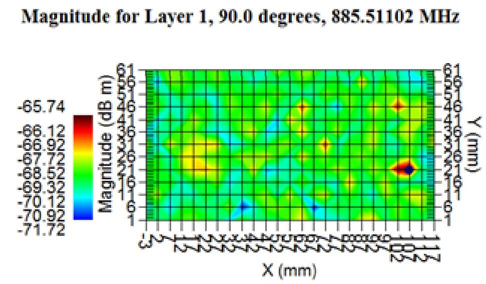
2 dB delta over receiver in NF = 2 dB delta in sensitivity tester

- Mobile phone was scanned with EM-ISight, scan took 5 minutes for two probe orientations, 5 mm grid res.
- Top left showed engineer that an auxiliary antennae was resonating (was supposed to be off), top right showed engineer how that resonation was coupling to the input of his receive antennae that had a different polarization than the auxiliary antennae
- Engineer used his sensitivity tester (Call box) to verify effectiveness of his modifications
- 2 dB change over receiver in near field correlated with 2 dB change with his sensitivity tester

Before Changes to board:

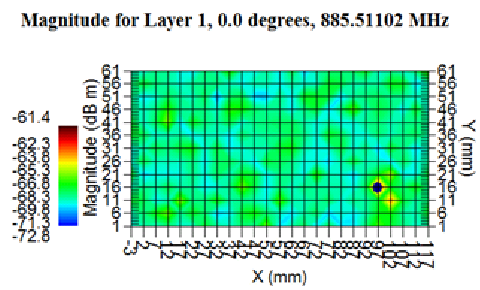


Peak Magnitude: -65.50 dBm
Location (X,Y): 102.30, 11.37 (mm)

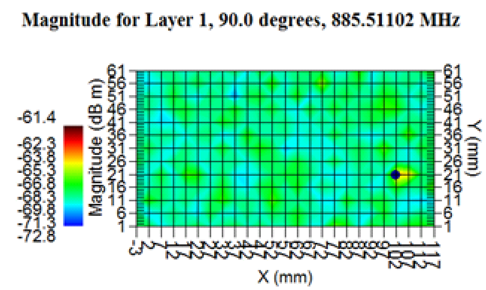


Peak Magnitude: -65.74 dBm
Location (X,Y): 107.30, 21.37 (mm)

After changes to board: removed plastic strip, tightened some board screws that were used as ground post -> result = 2dB worse sensitivity test

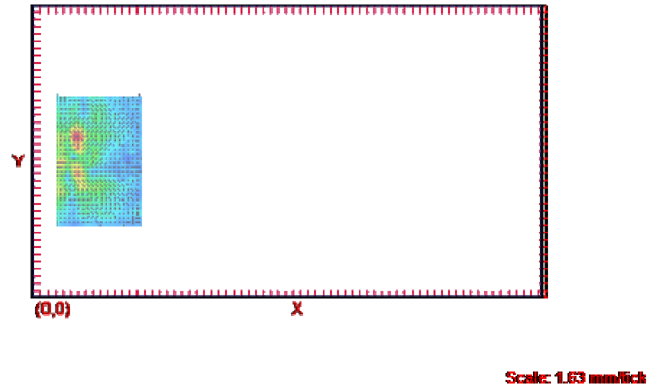


Peak Magnitude: -62.74 dBm
Location (X,Y): 97.30, 16.37 (mm)



Peak Magnitude: -65.05 dBm
Location (X,Y): 102.30, 21.37 (mm)

Mobile phone Test Case 2



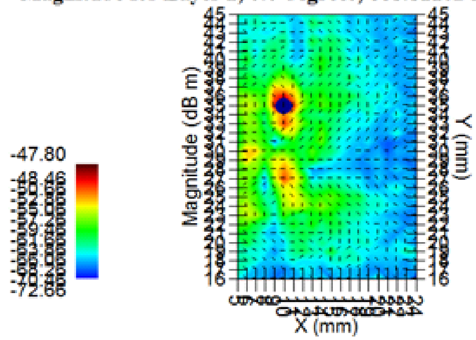
- Touch screen mobile phone
- LCD driver IC is causing receiver sensitivity issues
- EMISight was used to do a 2mm grid resolution with 4 probe orientations, scan time = 20 minutes
- Flux direction lines pointed out grounding issues and lead to a solution with 5 dB performance boost at receive antennae

Mobile phone Test Case 2

- Top left plot current vectors indicated a grounding problem with ear-piece component
- Bottom plots show how field distribution and current vectors shifted to the left (away from receiver antenna)
- 3^{rd} party antennae sensitivity tester measured a 5 dB performance increase after the change

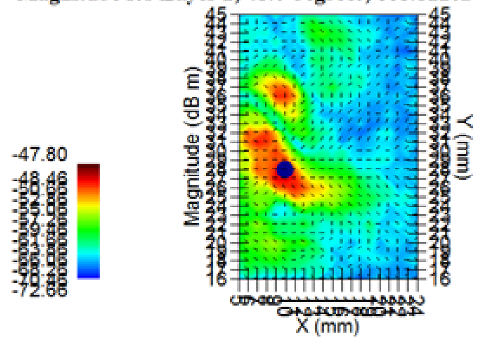
Before change –> receiver sensitivity issue

Magnitude for Layer 1, 0.0 degrees, 885.51102 MHz



Peak Magnitude: -49.84 dBm
Location (X,Y): 9.90, 35.16 (mm)

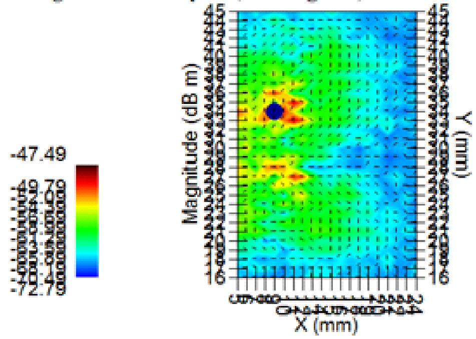
Magnitude for Layer 1, 45.0 degrees, 885.51102 MHz



Peak Magnitude: -49.58 dBm
Location (X,Y): 9.90, 28.17 (mm)

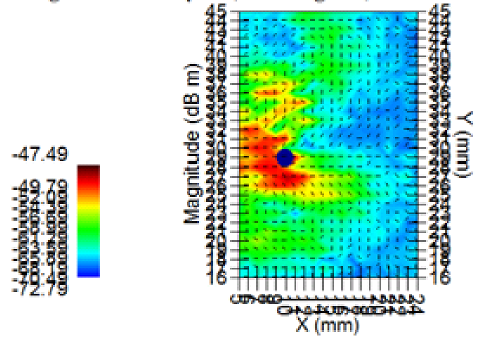
After change -> removed ear-piece and drilled out VIA

Magnitude for Layer 1, 0.0 degrees, 885.51102 MHz



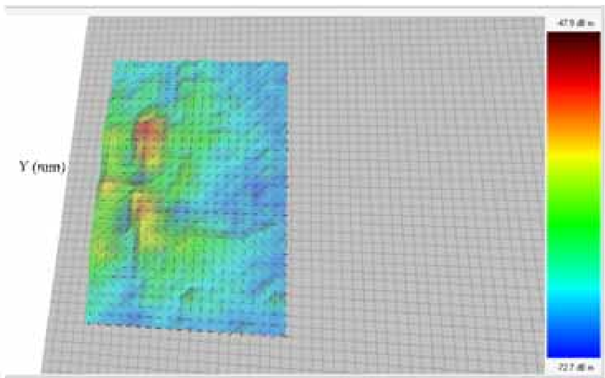
Peak Magnitude: -48.57 dBm
Location (X,Y): 8.90, 34.17 (mm)

Magnitude for Layer 1, 45.0 degrees, 885.51102 MHz

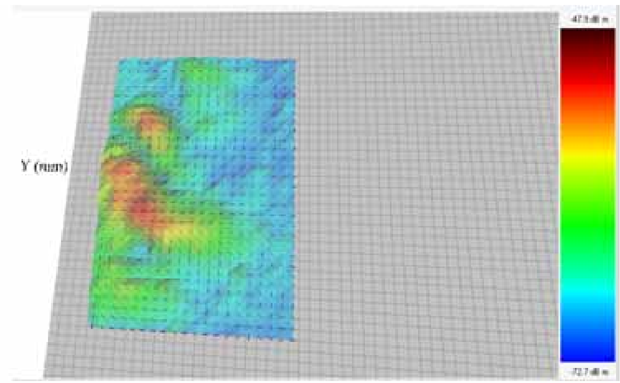


Peak Magnitude: -48.67 dBm
Location (X,Y): 9.90, 29.17 (mm)

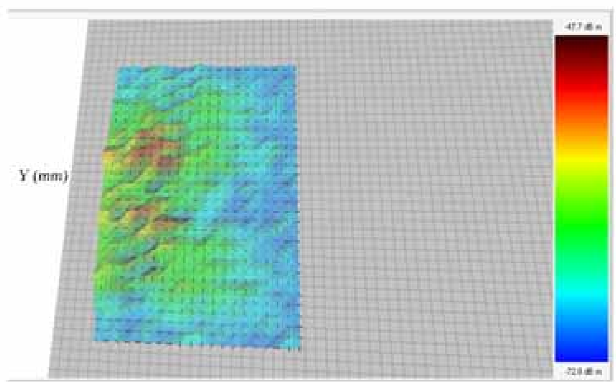
Mobile Phone Test Case 2



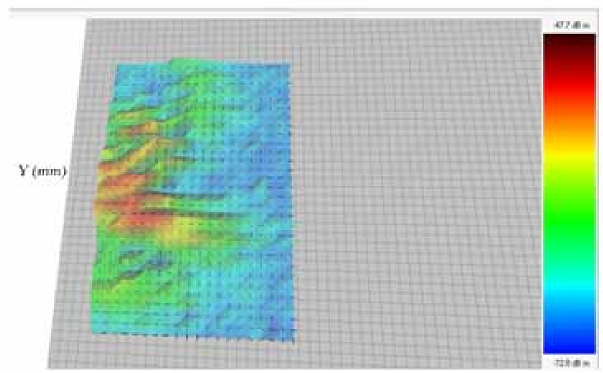
0 degrees before



45 degrees before



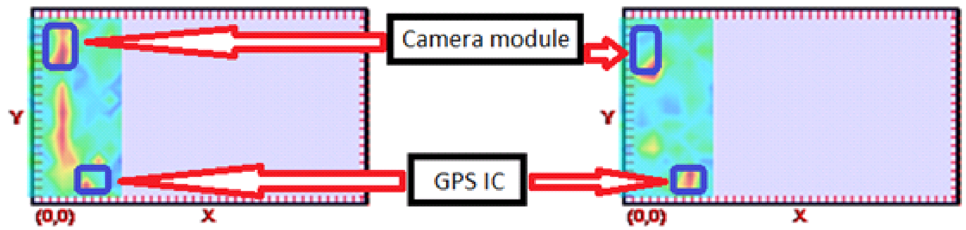
0 degrees after

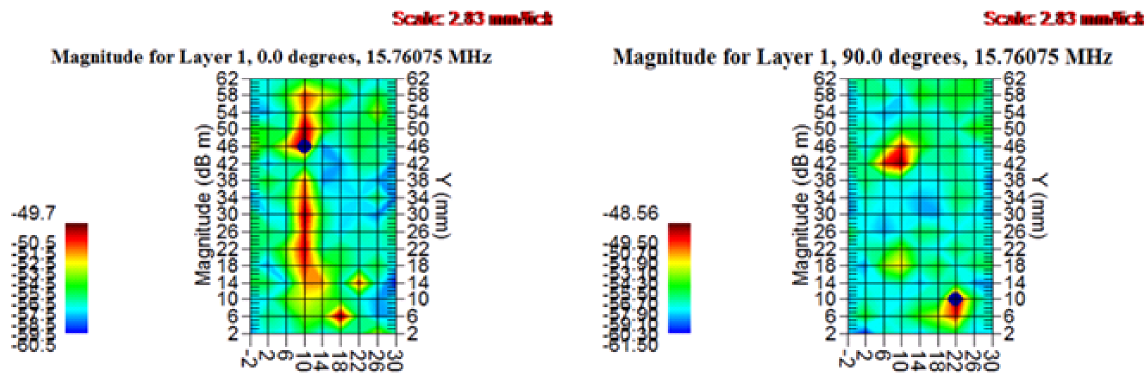


45 degrees after

Test Case 3 detecting GPS issues

- Client had some GPS receiver problems, their current NF scanning solution could not detect any issues in GPS bands
- EM-ISight detected a problem at 15.76 MHz originating at the camera. GPS L1 = 1575.4 MHz -> harmonic of 15.76 MHz





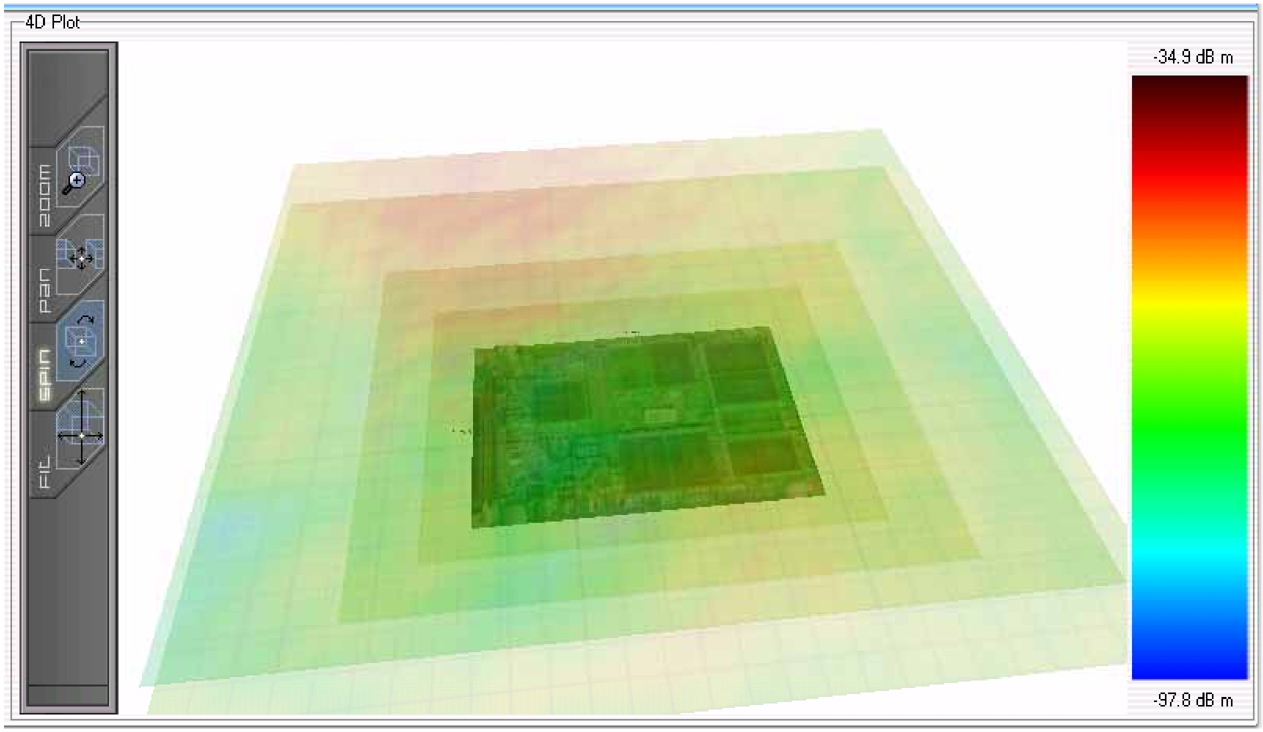
Peak Magnitude: -49.79 dBm
Location (X,Y): 10.10, 46.17 (mm)

Peak Magnitude: -48.56 dBm
Location (X,Y): 22.10, 10.17 (mm)

Summary

- Traditional methods utilize hand held loops, or slow X,Y plotters
- Traditional methods are tedious, and difficult to get repeatable, and traceable measurements
- Very difficult to measure polarization (probe rotation) using traditional or competitor systems
- EM-ISight = professional quality measurement tool to clearly identify potential problem components and report to stake holders in a reasonably short amount of time

APREL Near-Field Volumetric Scan



- Far Field approx preview
- Approximate a single frequency and vector to a point in the far-field
- Approximate release Q1 2013