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LTE Challenge Antenna and Display

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700MHz to 2700MHz Frequency Range

Table 4. Frequency bands supported in LTE (TS 36.101 V8.1.0 Table 5.2-1)

E-UTRA band	Uplink (UL) UE transmit eNB receive	Downlink (DL) eNB transmit UE receive	UL-DL band separation	Duplex mode
	$F_{UL\_low} - F_{UL\_high}$	$F_{DL\_low} - F_{DL\_high}$	$F_{DL\_low} - F_{UL\_high}$	
1	1920 – 1980 MHz	2110 – 2170 MHz	130 MHz	FDD
2	1850 – 1910 MHz	1930 – 1990 MHz	20 MHz	FDD
3	1710 – 1785 MHz	1805 – 1880 MHz	20 MHz	FDD
4	1710 – 1755 MHz	2110 – 2155 MHz	355 MHz	FDD
5	824 – 849 MHz	869 – 894MHz	20 MHz	FDD
6	830 – 840 MHz	875 – 885 MHz	35 MHz	FDD
7	2500 – 2570 MHz	2620 – 2690 MHz	50 MHz	FDD
8	880 – 915 MHz	925 – 960 MHz	10 MHz	FDD
9	1749.9 – 1784.9 MHz	1844.9 – 1879.9 MHz	60 MHz	FDD
10	1710 – 1770 MHz	2110 – 2170 MHz	340 MHz	FDD
11	1427.9 – 1452.9 MHz	1475.9 – 1500.9 MHz	23 MHz	FDD
.....				
13	777 - 787 MHz	746 - 756 MHz	21 MHz	FDD
14	788 - 798 MHz	758 - 768 MHz	20 MHz	FDD
.....				
33	1900 – 1920 MHz	1900 – 1920 MHz	N/A	TDD
34	2010 – 2025 MHz	2010 – 2025 MHz	N/A	TDD
35	1850 – 1910 MHz	1850 – 1910 MHz	N/A	TDD
36	1930 – 1990 MHz	1930 – 1990 MHz	N/A	TDD
37	1910 – 1930 MHz	1910 – 1930 MHz	N/A	TDD
38	2570 – 2620 MHz	2570 – 2620 MHz	N/A	TDD
39	1880 – 1920 MHz	1880 – 1920 MHz	N/A	TDD
40	2300 – 2400 MHz	2300 – 2400 MHz	N/A	TDD

Antenna Design

- Frequency Bands:

  Five Bands increase to Seven Bands
- Broader Bandwidth:

  With the availability of the 700-MHz analog TV spectrum, LTE will be deployed at lower frequencies than GSM or WCDMA, resulting in much broader bandwidths: 20 MHz/700 MHz = 2.8%, compared with 5 MHz/2100 MHz = 0.24% for typical WCDMA devices
- Antenna Isolation for Coexistence close to 2.4GHz ISM
- Gain Imbalance <3dB
- 2 x 2 MiMo Antenna Correlation <0.5

Platform Noise & Antenna Design

- Open Loop Transmit Diversity Imbalance:

  SNR =24dB, 4dB imbalance, Throughput losses 0%

  SNR= 0 dB, 4 dB imbalance, Throughput losses 20%

  SNR = -6dB, 4dB imbalance, Throughput losses 35%

- Closed-Loop Spatial Multiplexing Imbalance:

  SNR =24dB, 4dB imbalance, Throughput losses 5%

  SNR =0dB, 4dB imbalance, Throughput losses 17%

  SNR =-6dB, 4dB imbalance, Throughput losses 27%

- Closed-Loop Spatial Multiplexing Correlation:

  SNR =24dB, Correlation = 0.8, Throughput losses 20%

  SNR =0dB, Correlation =0.8 Throughput losses 5%

LTE MiMo Envelop Correlation Coefficient

- ## Intel: 802.11n Antennas

The acceptable limits of envelop correlation for antenna s to be less than or equal to 0.7, This level of de-correlation is difficult to achieve among closely spaced antennas in the 800Mhz frequency range. The antennas mounted in notebooks above 2400Mhz and many of antennas correlation factor are smaller than 0.3.

$$\rho_e = \frac{\left|S_{11}^* S_{12} + S_{21}^* S_{22}\right|^2}{\left(1 - \left(\left|S_{11}\right|^2 + \left|S_{21}\right|^2\right)\right)\left(1 - \left(\left|S_{22}\right|^2 + \left|S_{12}\right|^2\right)\right)}$$

- ## Qualcomm: Techniques that are not Recommended

2.2.8.1 : S parameter formulation

2.2.8.2 : Radiated test using channel model

2.2.8.3 : Reverberation Chamber

$$R_{12} = \sum_{j=1}^{N\phi} \sum_{i=1}^{N\theta} \left(XPR \cdot E\theta 1_{i,j} \cdot E\theta 2^*_{i,j} \cdot P\theta + E\phi 1_{i,j} \cdot E\phi 2^*_{i,j} \cdot P\phi \right) \cdot \sin\theta \cdot \Delta\theta \cdot \Delta\phi$$

$$\sigma 1 = \sum_{j=1}^{N\phi} \sum_{i=1}^{N\theta} \left(XPR \cdot E\theta 1_{i,j} \cdot E\theta 1^*_{i,j} \cdot P\theta + E\phi 1_{i,j} \cdot E\phi 1^*_{i,j} \cdot P\phi \right) \cdot \sin\theta \cdot \Delta\theta \cdot \Delta\phi$$

$$\sigma 2 = \sum_{j=1}^{N\phi} \sum_{i=1}^{N\theta} \left(XPR \cdot E\theta 2_{i,j} \cdot E\theta 2^*_{i,j} \cdot P\theta + E\phi 2_{i,j} \cdot E\phi 2^*_{i,j} \cdot P\phi \right) \cdot \sin\theta \cdot \Delta\theta \cdot \Delta\phi$$

- ## Verizon : LTE OTA

The complex antenna voltage E voltage is related to the RSSI value and the I-Q values of the reference symbols : E voltage = Ei + j Eq

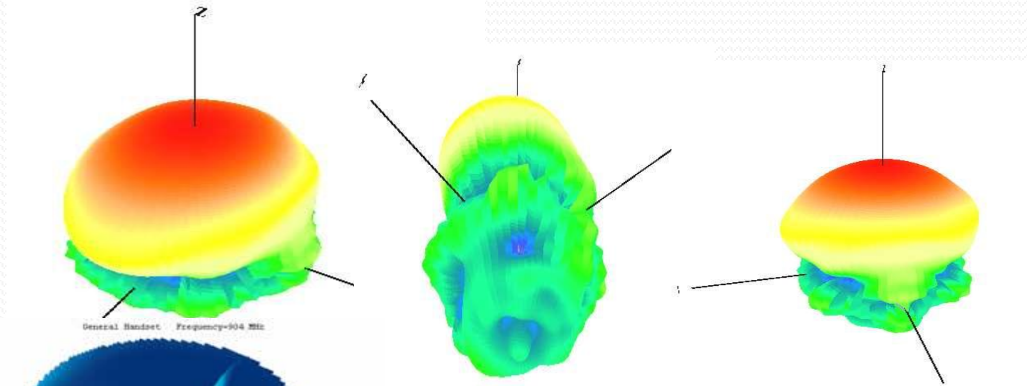
Antenna Near Field and Far Field

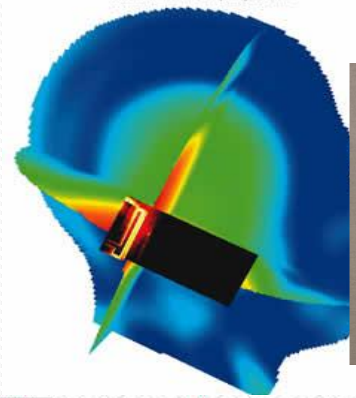
Far Field

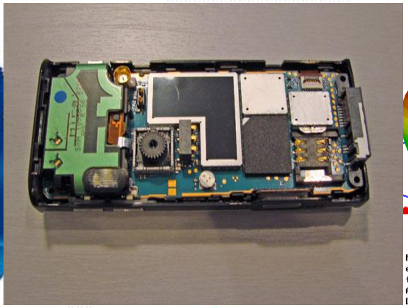
Polarization, Phase and Gain

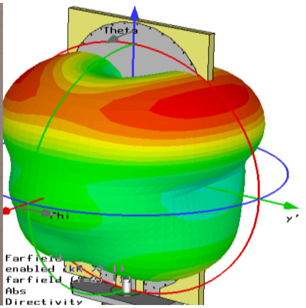
Correlation Coefficient

Gain Imbalance









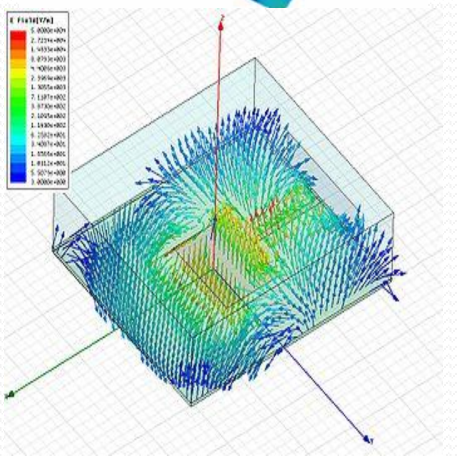
Near Field

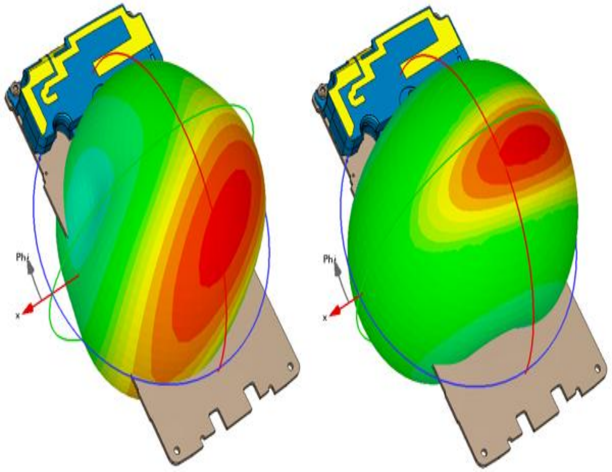
Specify Absorbing Rate: SAR

EMS source to sensitive Parts

Platform Noise Coupling

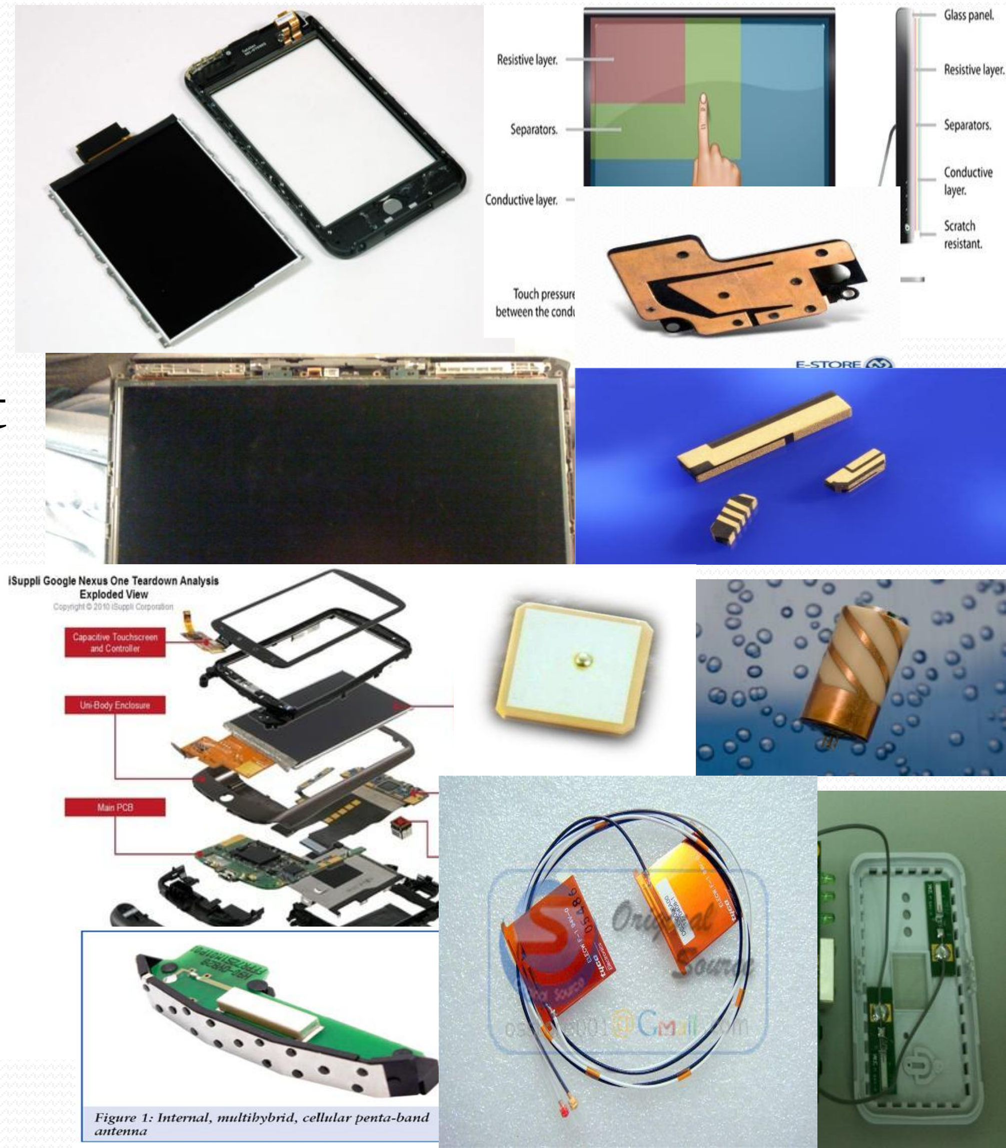
Affected By Hand and Body



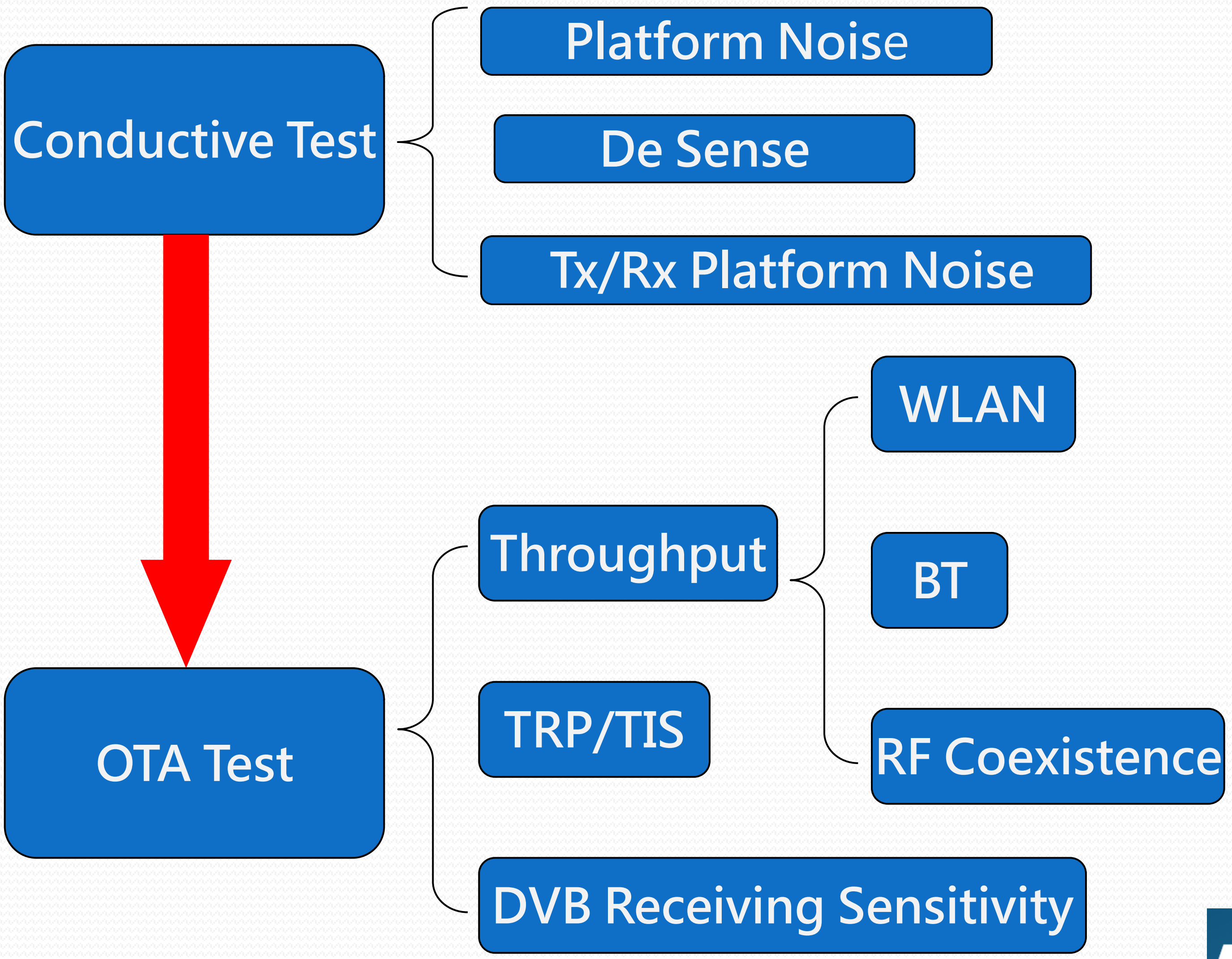


Display and Antenna NF EMC

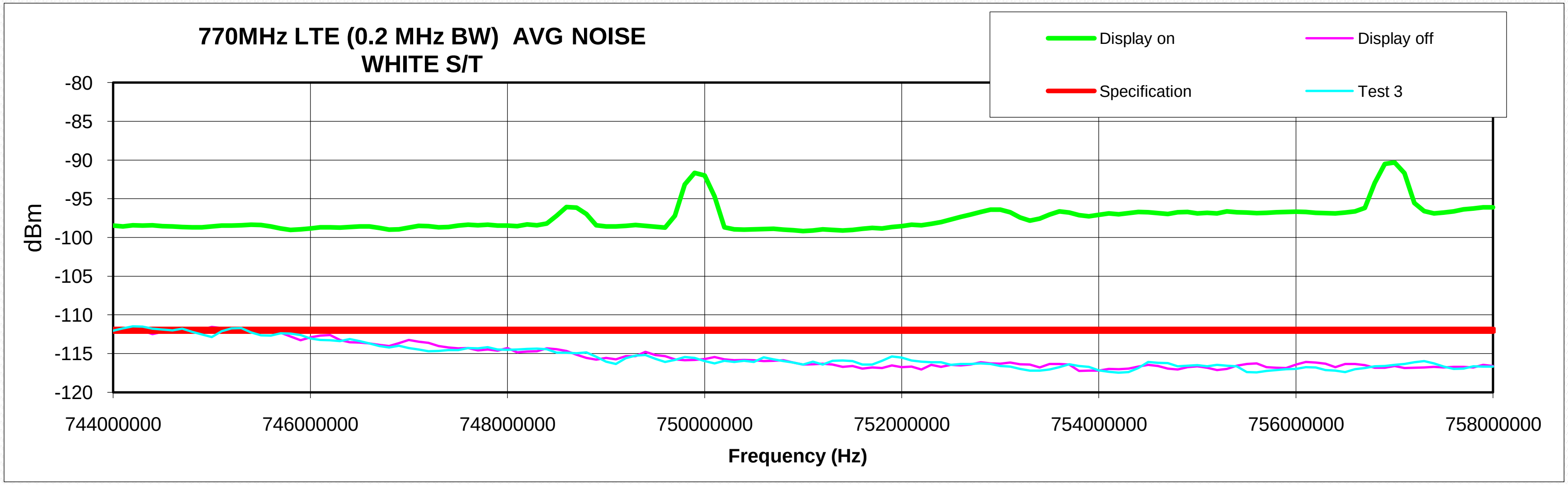
- Display is the largest component in wireless device.
- All the antennas are very close to Display.
- Most components in the wireless device by shielded but not for the Display.
- Display emit the noise and pick up by the Antenna. Display is the noise source.
- PCB noise couple to Antenna via Display, Display is a coupling path.
- When antenna radiated the power then Display is victim.

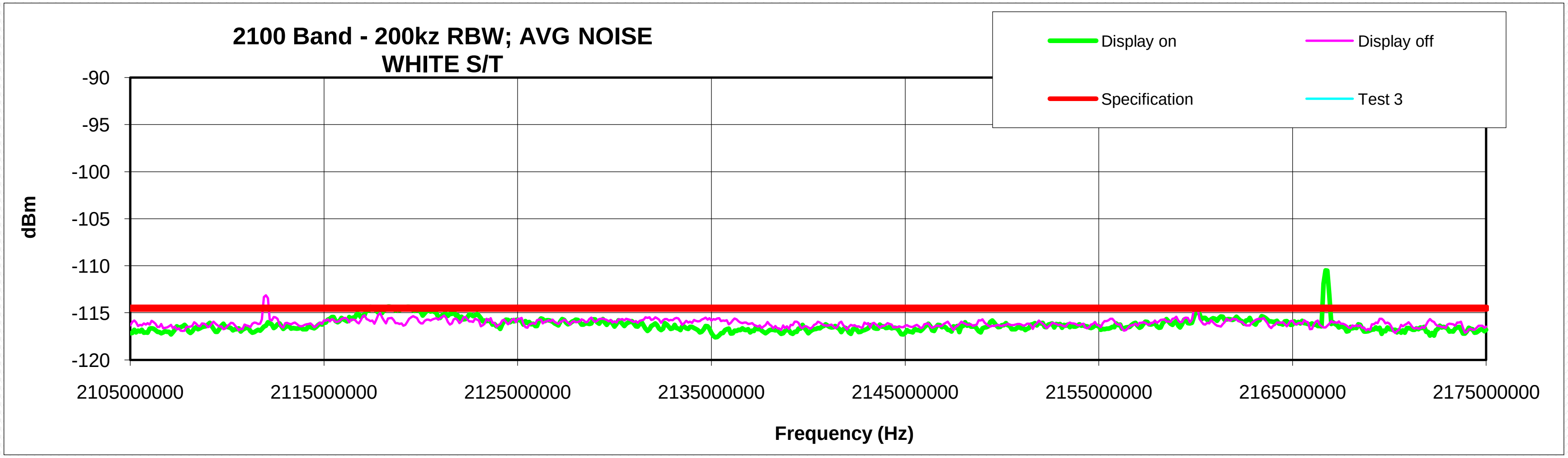


Wireless Performance Test Sequence

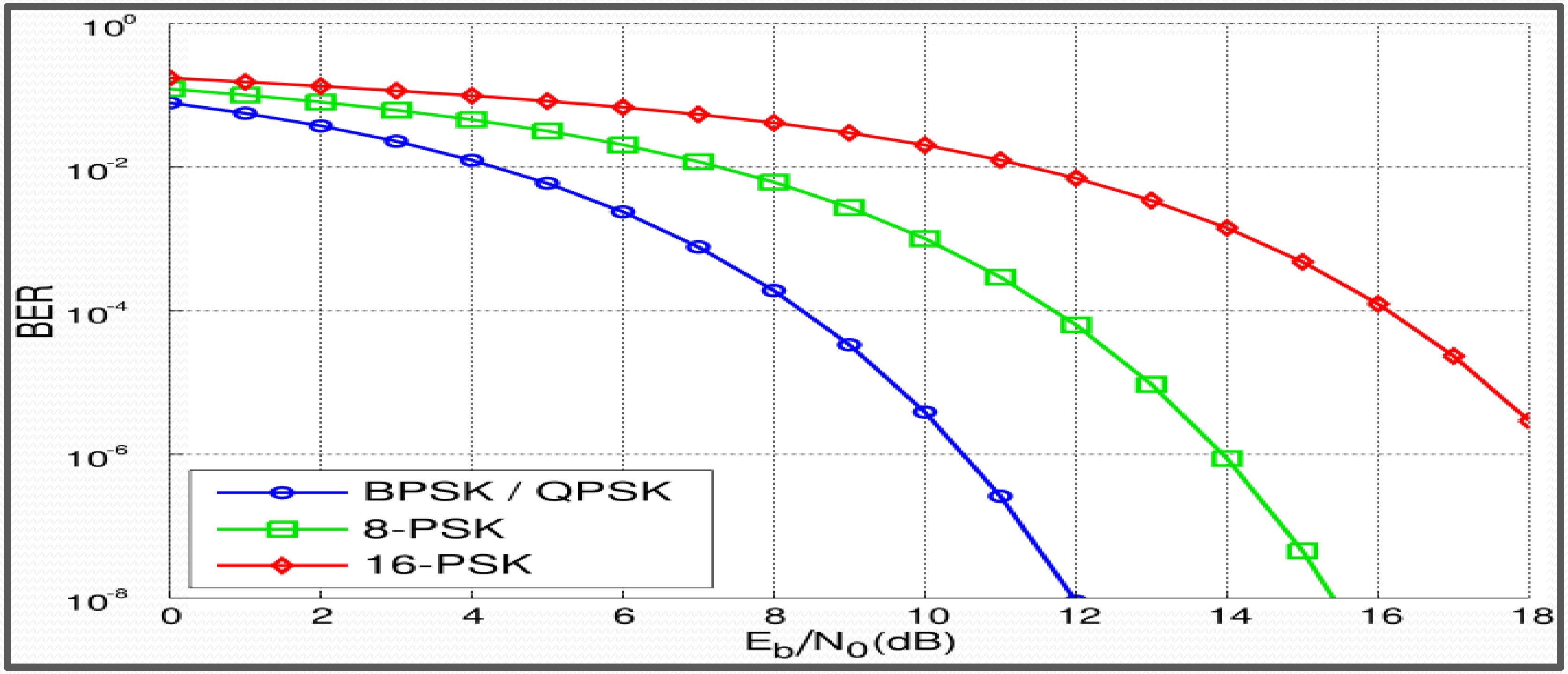


LTE System Noise Band 13 : 746~756MHz





Minimum Eb/Nt



Minimum Eb/Nt is required by maximum BER, BLER, FER or Through put, SINAD (acoustic), DVB image, ...Nt include interference in addition to noise. The Maximum allowable power

Pn = EIS + Gant – Eb/Nt + Gp (Processing Gain for GPS, 802.11b, CDMA, WCDMA,.....), Eb/Nt baseband signal to noise ratio.

LTE System Noise level (dBegnp)

ITU/BDT Arab Regional Workshop on "4G Wireless Systems" - Tunisia 2010

CERT

Layer 1 Peak Bit Rates – Cont.

Modulation and coding	Bits/ symbol	MIMO usage	BW RB/Sub-carriers 1.4 MHz 6/72	3.0 MHz 15/180	5.0 MHz 25/300	10 MHz 50/600	15 MHz 75/900	20 MHz 100/1200
QPSK 1/2	1	Single stream	0.9	2.2	3.6	7.2	10.8	14.4
16QAM 1/2	2	Single stream	1.7	4.3	7.2	14.4	21.6	28.8
16QAM 3/4	3	Single stream	2.6	6.5	10.8	21.6	32.4	43.2
64QAM 3/4	4.5	Single stream	3.9	9.7	16.2	32.4	48.6	64.8
64QAM 1/1	6	Single stream	5.2	13.0	21.6	43.2	64.8	86.4
64QAM 3/4	9	2 × 2 MIMO	7.8	19.4	32.4	64.8	97.2	129.6
64QAM 1/1	12	2 × 2 MIMO	10.4	25.9	43.2	86.4	129.6	172.8
64QAM 1/1	24	4 × 4 MIMO	20.7	51.8	86.4	172.8	259.2	345.6

Downlink peak bit rates (Mbps)

ETSI TS 136101 7.3.1 Minimum Requirement(QPSK)

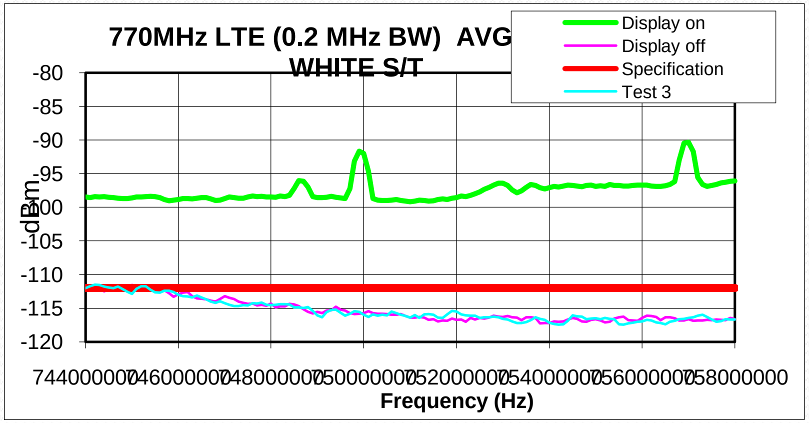
Reference Sensitivity Prefsense: -94dBm Channel Bandwidth : 10MHz at Band12 and Band 13

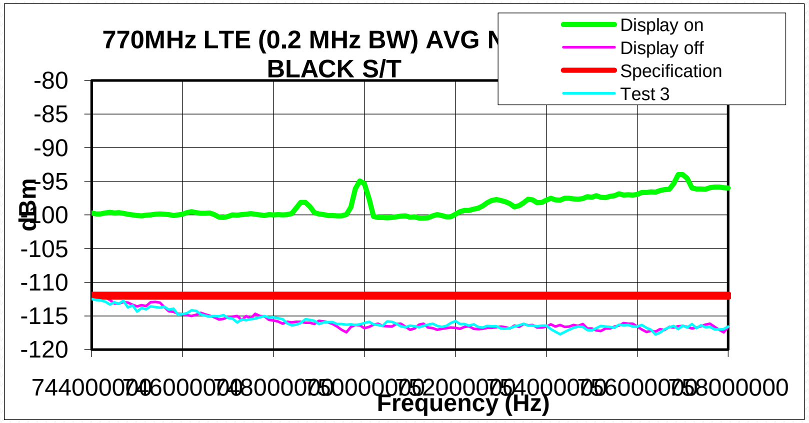
600 sub Carrier at 100% of relative T-put SNR= 0dB

System Noise Limit dBegnp = -94dBm -10log600 = -122 dBm

Antennas Gain Balance Ratio

- With gain imbalance of 3dB or more, the benefit of MIMO is significantly reduced. To have two antennas with equal performance on a given platform, each of the antennas should have a similar counterpoise dimension.
- The Maximum Gain Imbalance of 3dB is base on Noise Free condition or same AWGN power at each antenna.
- It is not diversity antenna, each antenna out put signal (gain balance ratio) must be smaller than 3dB for each subcarrier and the SNR for of each subcarrier also need to within 3 dB . Or increase the signal level have higher SNR than the minimum requirement.
- The theoretical gains from MIMO are a function of the number of transmit and receive antennas, the radio propagation conditions, the ability of the transmitter to adapt to the changing conditions, and the SNR





De-Sense

- Represent the self – interference (noise or unwanted rf power degradation and the limitation of Noise Budget.
  EIS = Ps (dBm) – Antenna Gain + Desense

  Gain Imbalance & Envelop Correlation Coefficient must be meet the minimum requirement
- EUT Configuration(Include operation mode H&H):

  (1)Same WWAN module in different Platform
- (2)Same Platform for different WWAN module
- Conductive Sensitivity:

  Reference Sensitivity & Test Mode
- OTA: Intermediate Channel
- Coexistence

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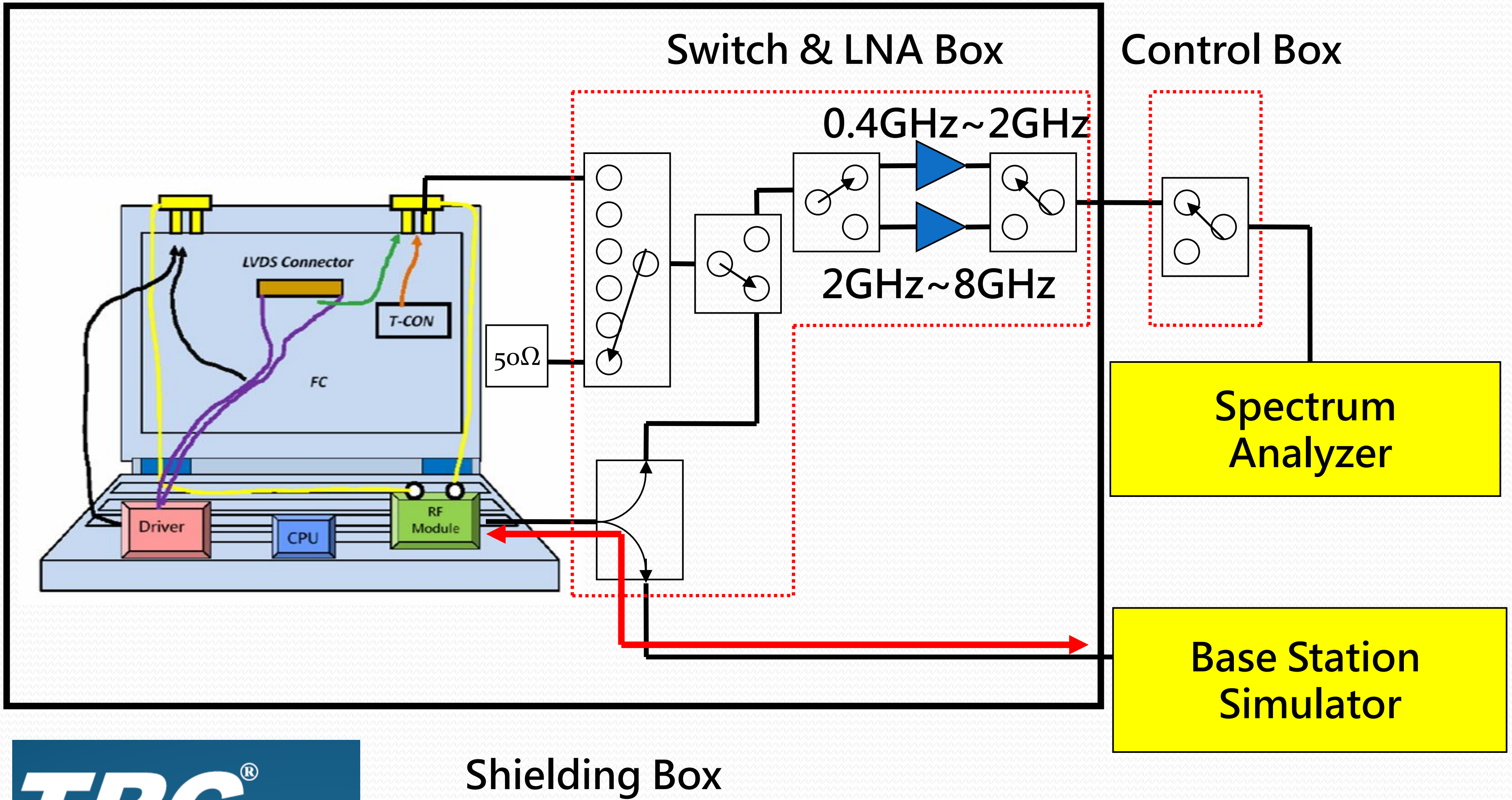
Conductive Sensitivity Test



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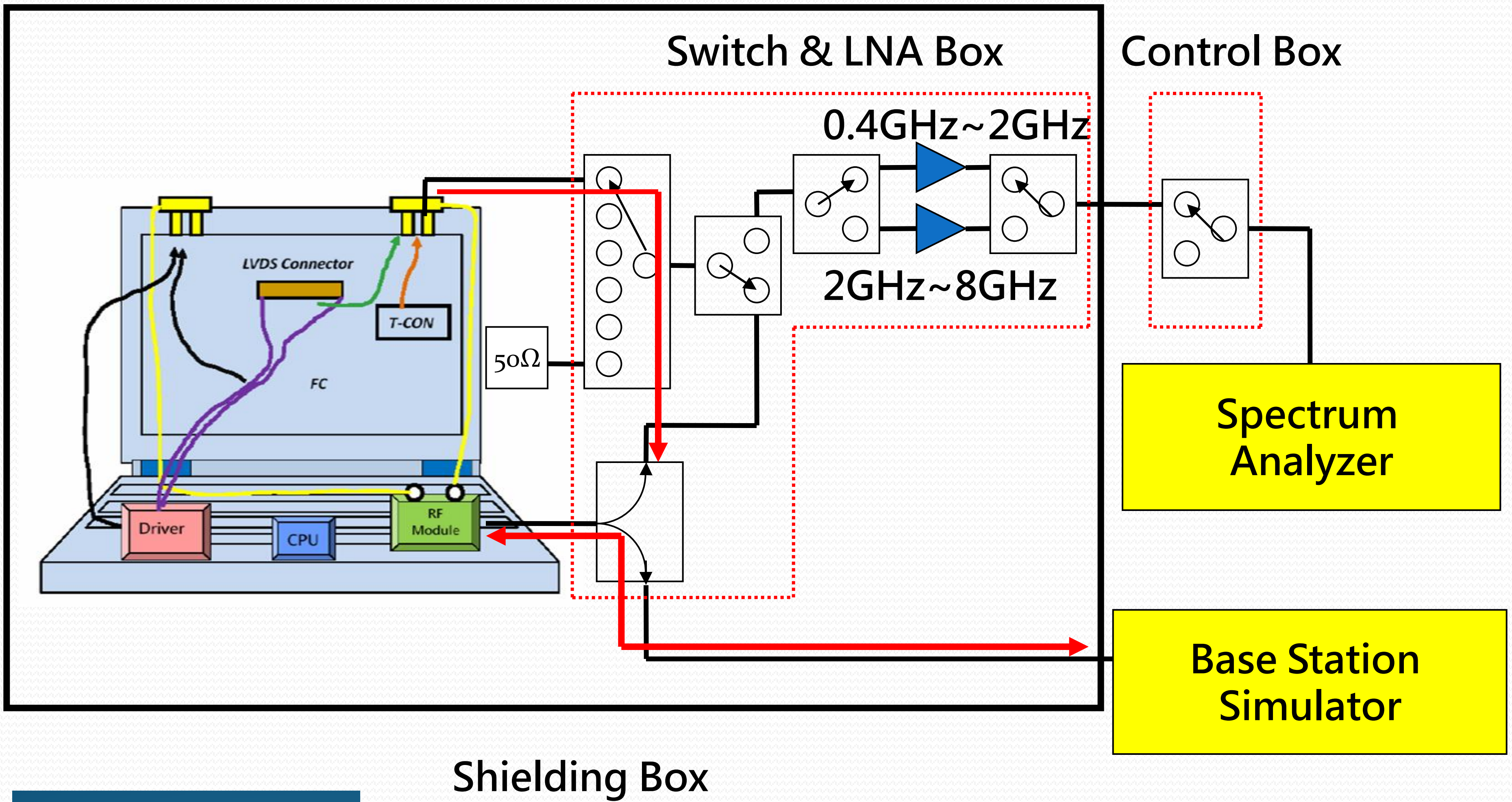
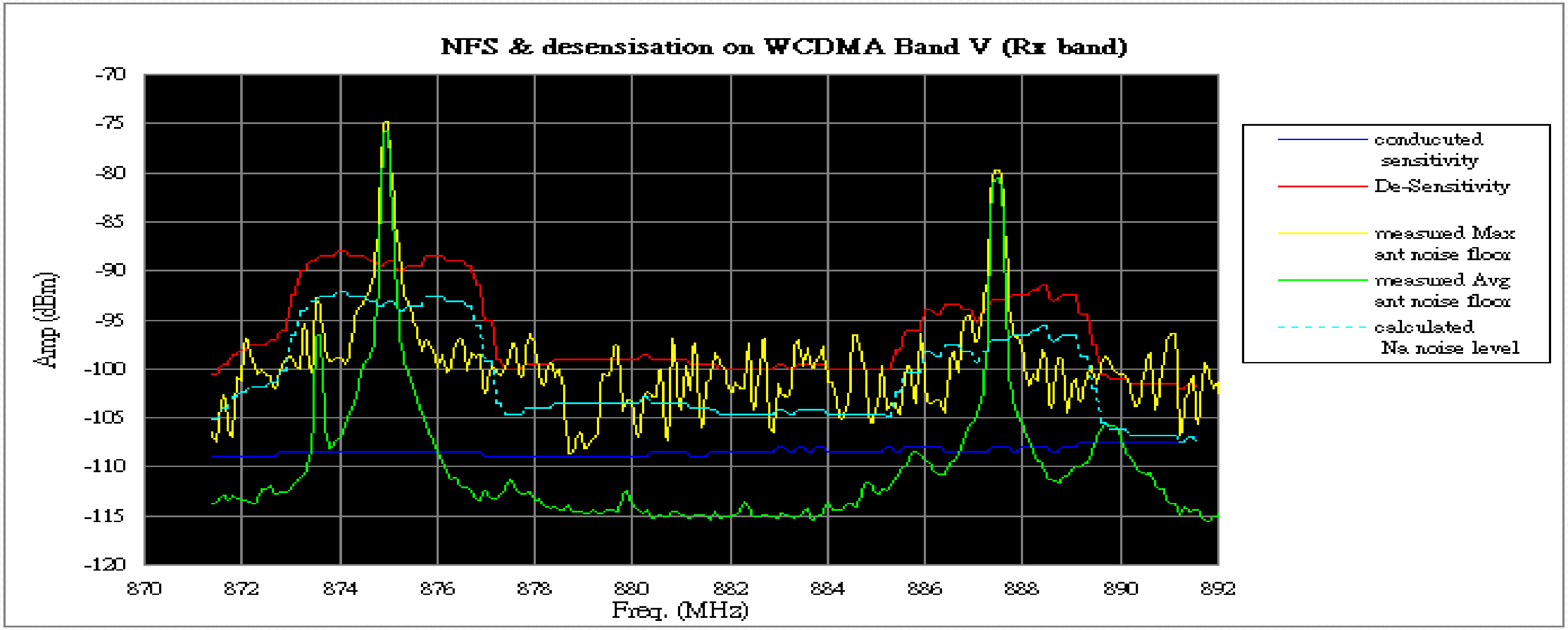
Conductive Sensitivity Test with Ant. Noise



Probability Density Function

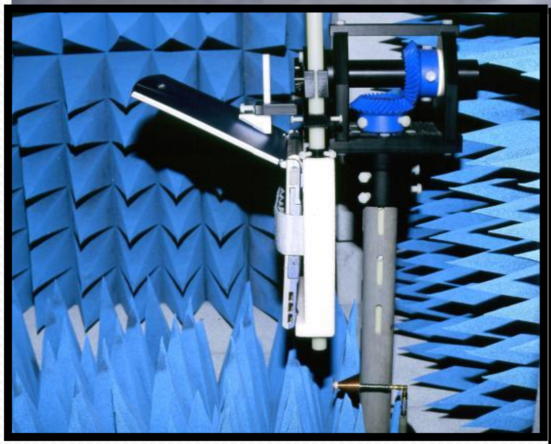


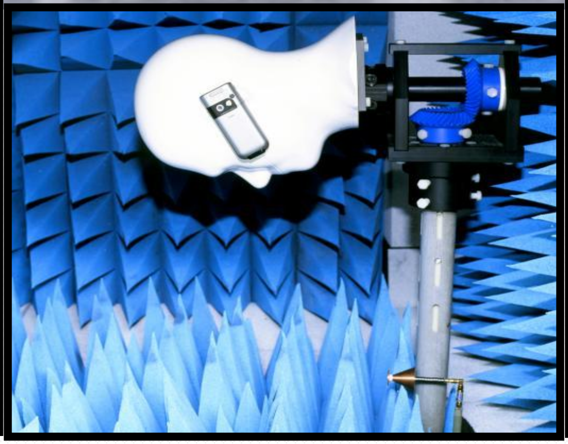
The **Noise Signature** test comprises a peak noise (yellow trace) and an average **Noise Signature** (green trace). In case of Gaussian Noise, the 3 sigma peak/average ratio is about 10dB and also representing as **PDF**(880~884MHz).

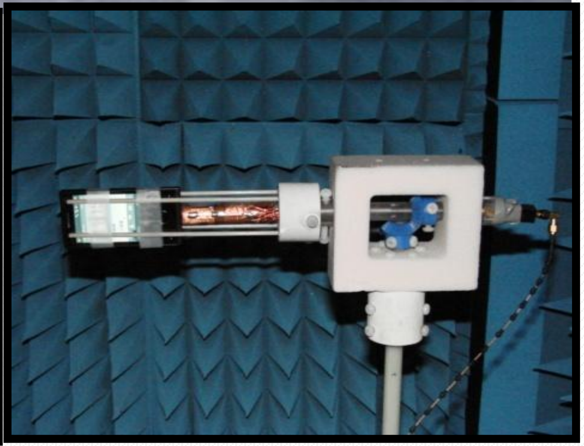
Equivalent Gaussian Noise Power

- Platform Noise degrade the receiver sensitivity define by the noise Probability Density Function.
- Give a number for noise power and unit as dB egnp
- Since different components inside the platform have different PDF, egnp is a uniform unit for different components platform noise power equivalent to Gaussian Noise power at same EVM (Same Sensitivity degradation)
- EGNP is easy to find for all the digital RF Demodulation simulation and Channel Modeling.

TRC 3D Test System-Vertical Cell







LTE Over The Air Radiated Performance

- ## Total Radiated Power (TRP)

Modulation :QPSK, 12RB, RBstart=0,20, 38
UE's primary connector conducted power.
Spherical effective isotropic radiated power.
Calculate the TRP using the EIRP pattern

- ## Total Isotropic Sensitivity (TIS)

Primary & Secondary adjust the down link level until 95% of maximum throughput.
Downlink signal -52dBm @ 10M channel
Amplitude and Phase store on local device.

- ## Envelop Correlation Coefficient

Rho shall be generated from the complex pattern data with an assumed model for the incident field and power angular density is assumed to be uniform in azimuth and Gaussian in elevation.

Test	Mod.	RB All.	Mod.	RB All.
1	QPSK	50	QPSK	15 start = 0
2	QPSK	6 start = 0	QPSK	6start = 0
3	QPSK	6 start = 22	QPSK	6 start = 0
4	QPSK	6 start = 44	QPSK	6 start = 0

Test	Maximum T-Put Averaged Over 1 Frame(Kbps)
Test 1	3952.8
Test2	453.6
Test3	428.8
Test4	453.6

Large and Small Display

- Large display :

  1. Antenna at the knowing location and with knowing antenna type.

  2.Measure the noise power as Equivalent Gaussian Noise Power.

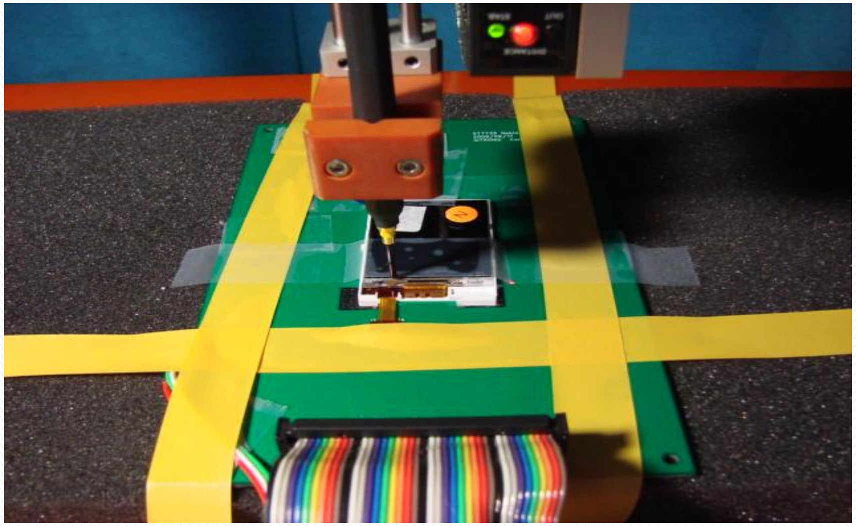
  3. Base on minimum S/N required by the throughput.

- Small display:

  1. Antenna can be anywhere and any type.

  2. Scan at 1mm per step for 30MHz 3GHz

  3.Measure data calibrated to microstrip Line.



Noise Budget for small form factor device

- Subjective:

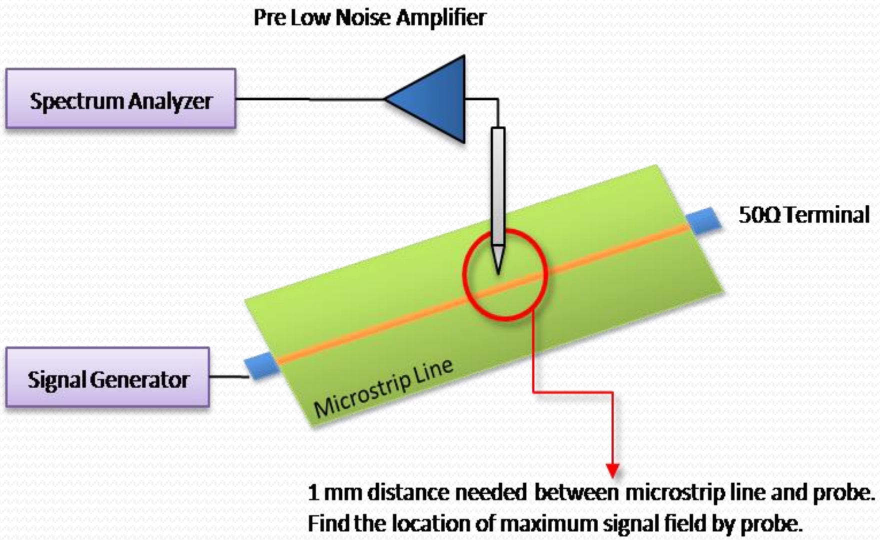
  The component like camera, Display module, touch screen module, FFC, FPC,……will apply this noise budget testing methodology for the hand held device.

- Substitution Method:

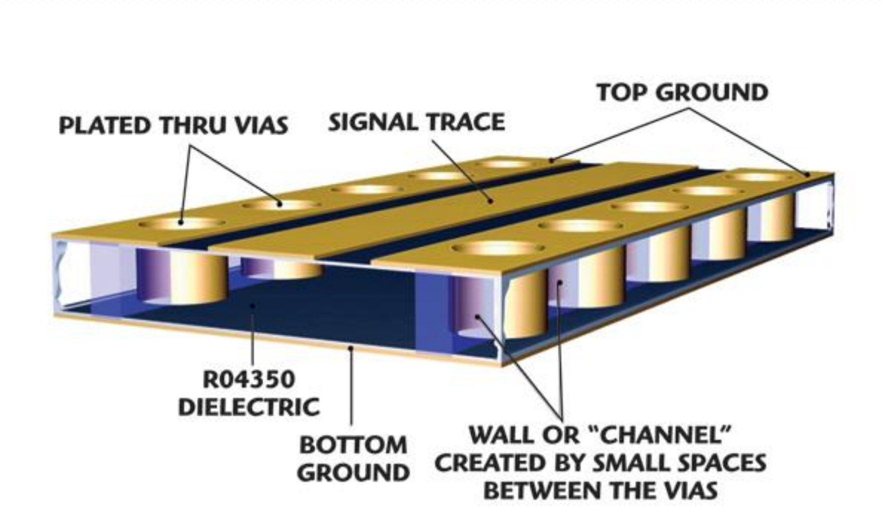
  The EUT Substituted by a micro strip line for correction the near field emission level.

- Noise Budget:

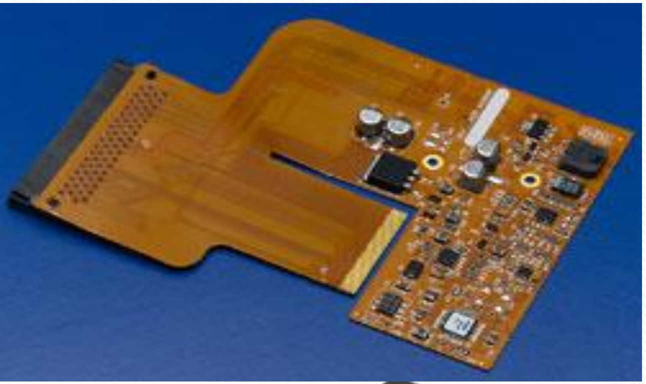
  The different limitation for in Band (DVB, WWAN, GPS, WLAN,…) and out band near field emission level.

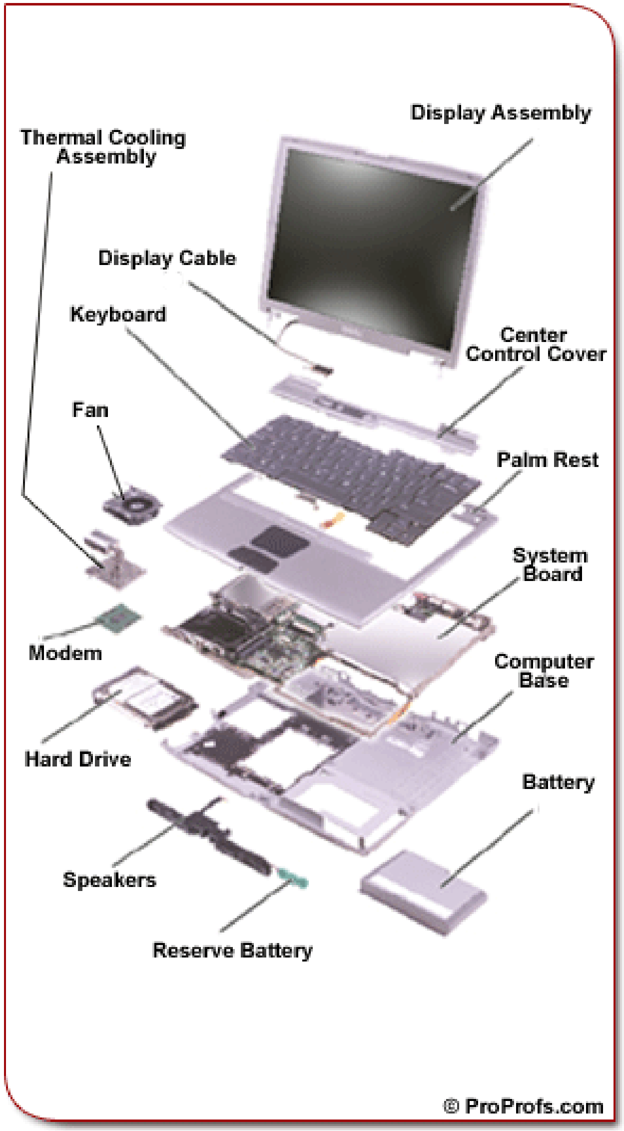


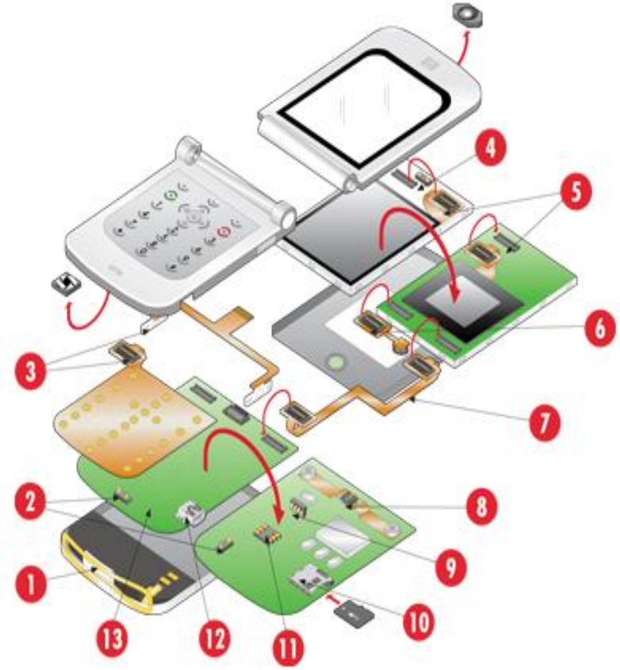
CAL Factor = Signal generator – Spectrum analyzer – Microstrip line loss



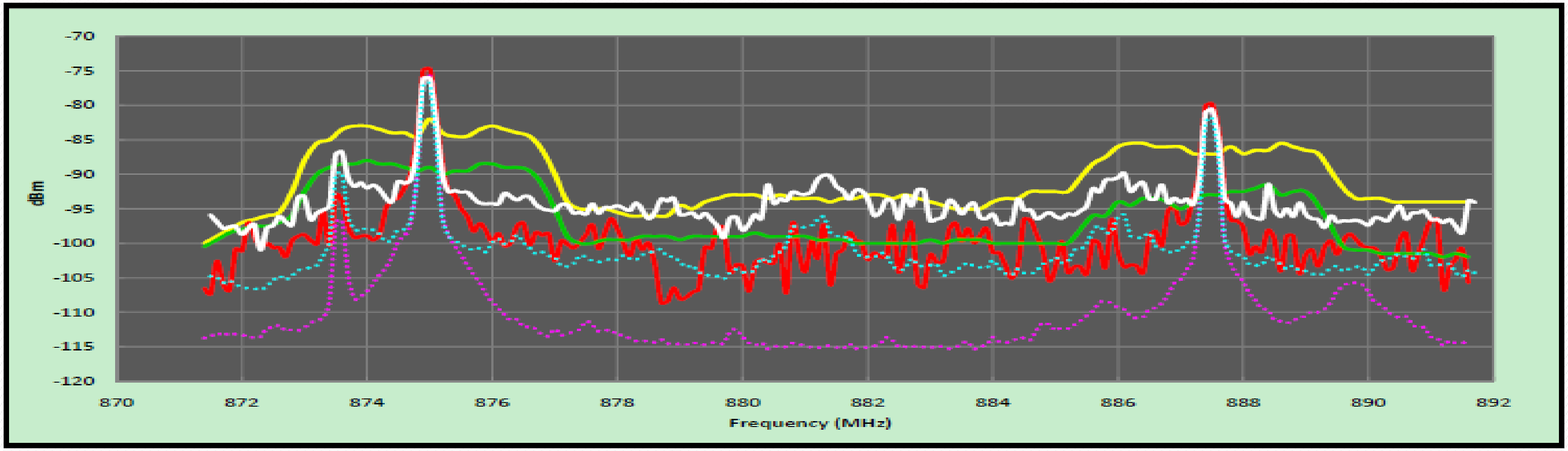
Product Construction
Near field Coupling Path Loss

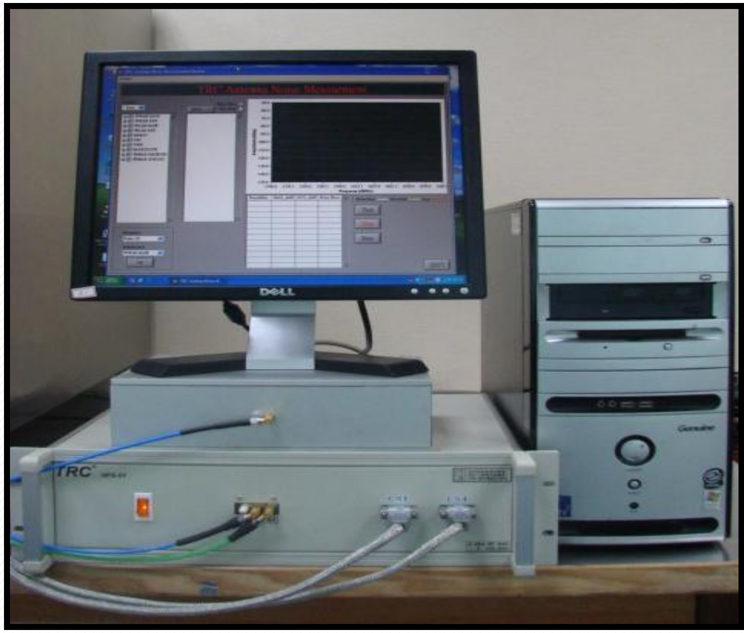


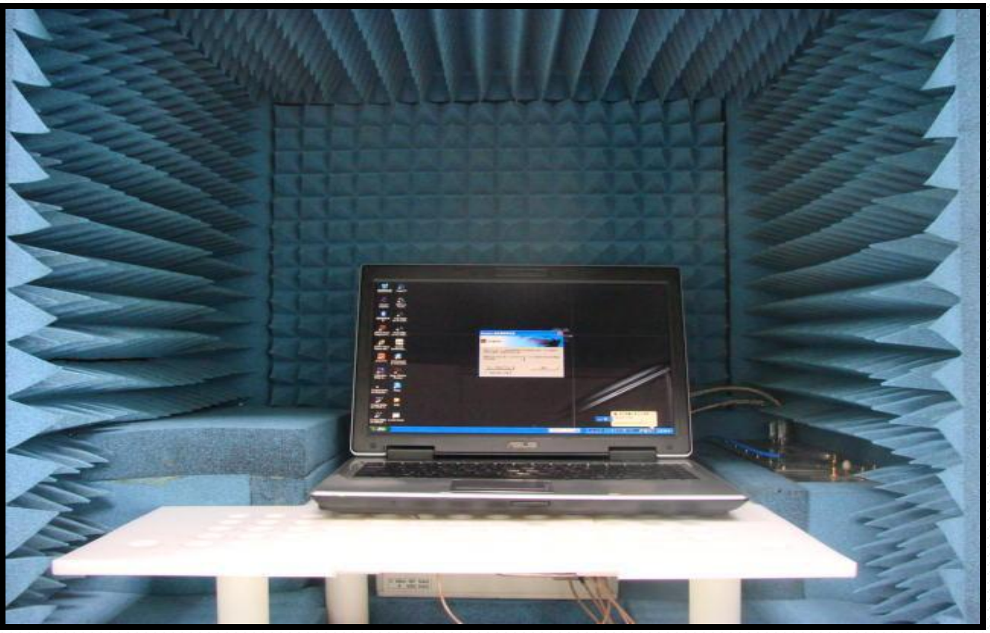




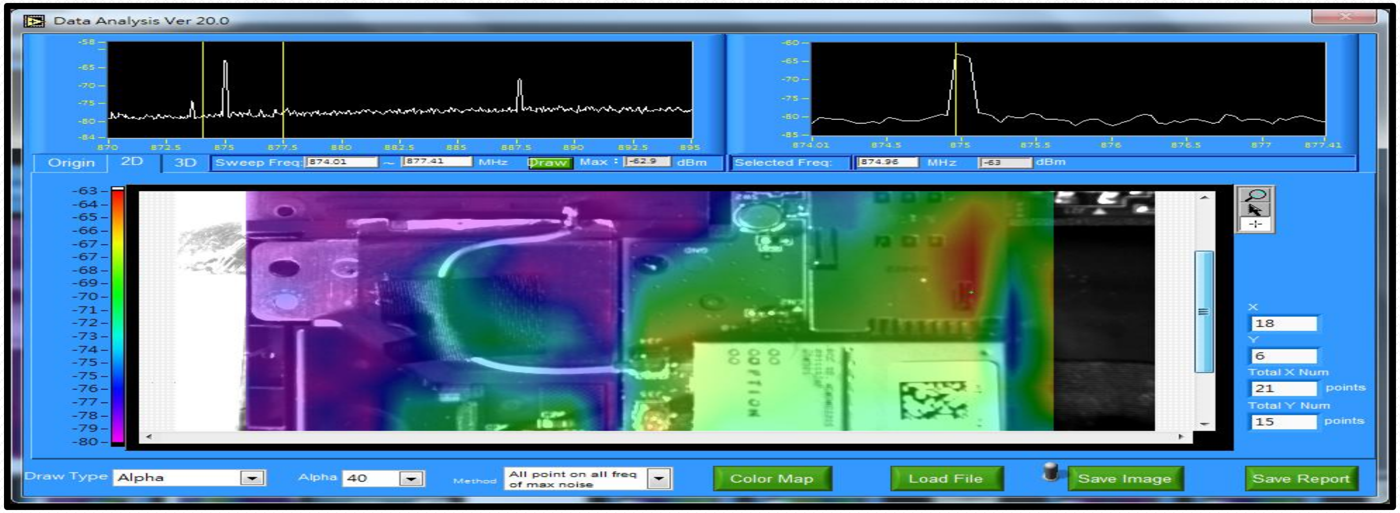
SNA


-70
-75
-80
-85
-90
-95
-100
-105
-110
-115
-120
dBm
870
872
874
876
878
880
882
884
886
888
890
892
Frequency (MHz)

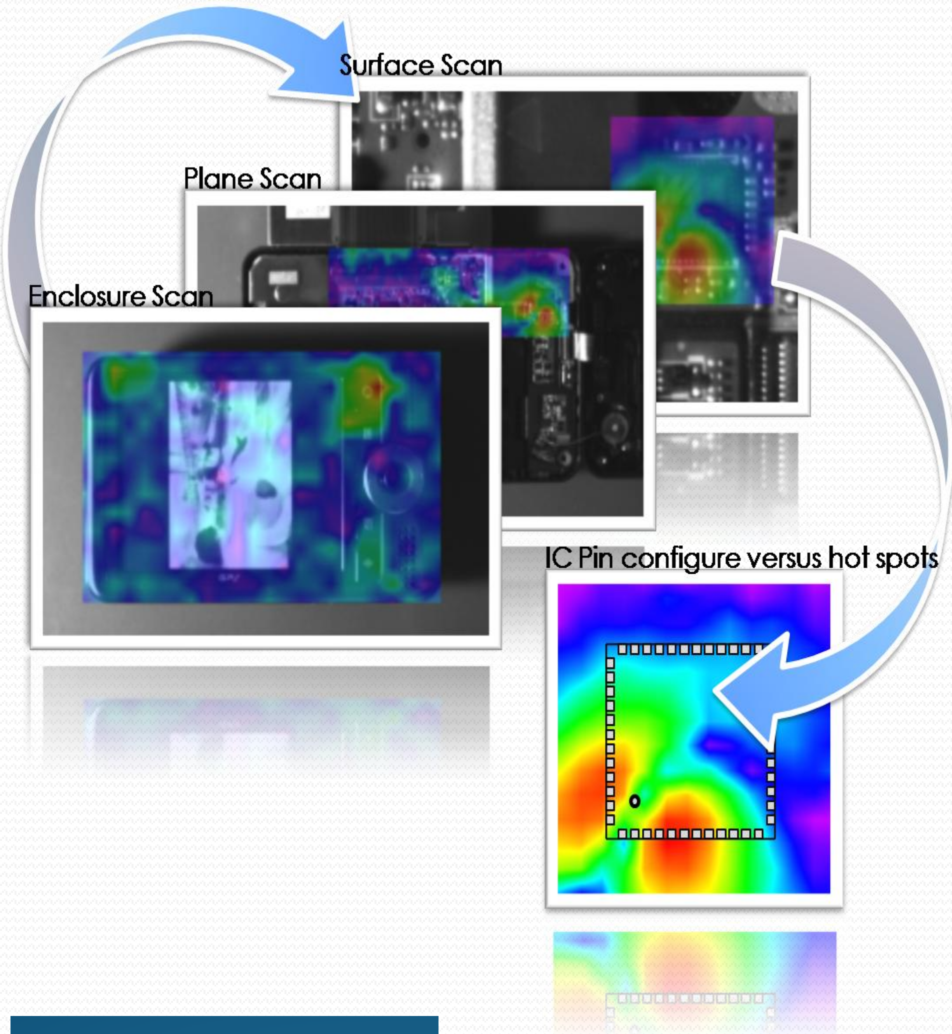




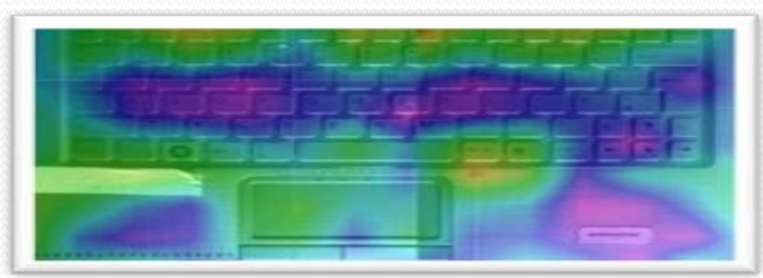
Platform Noise Scanner



Search the Noise Source



With different aperture size of near field probe provide the different sensitivity and space resolution for PNS measurement application. From NB Keyboard size to an IC all can measured by PNS.



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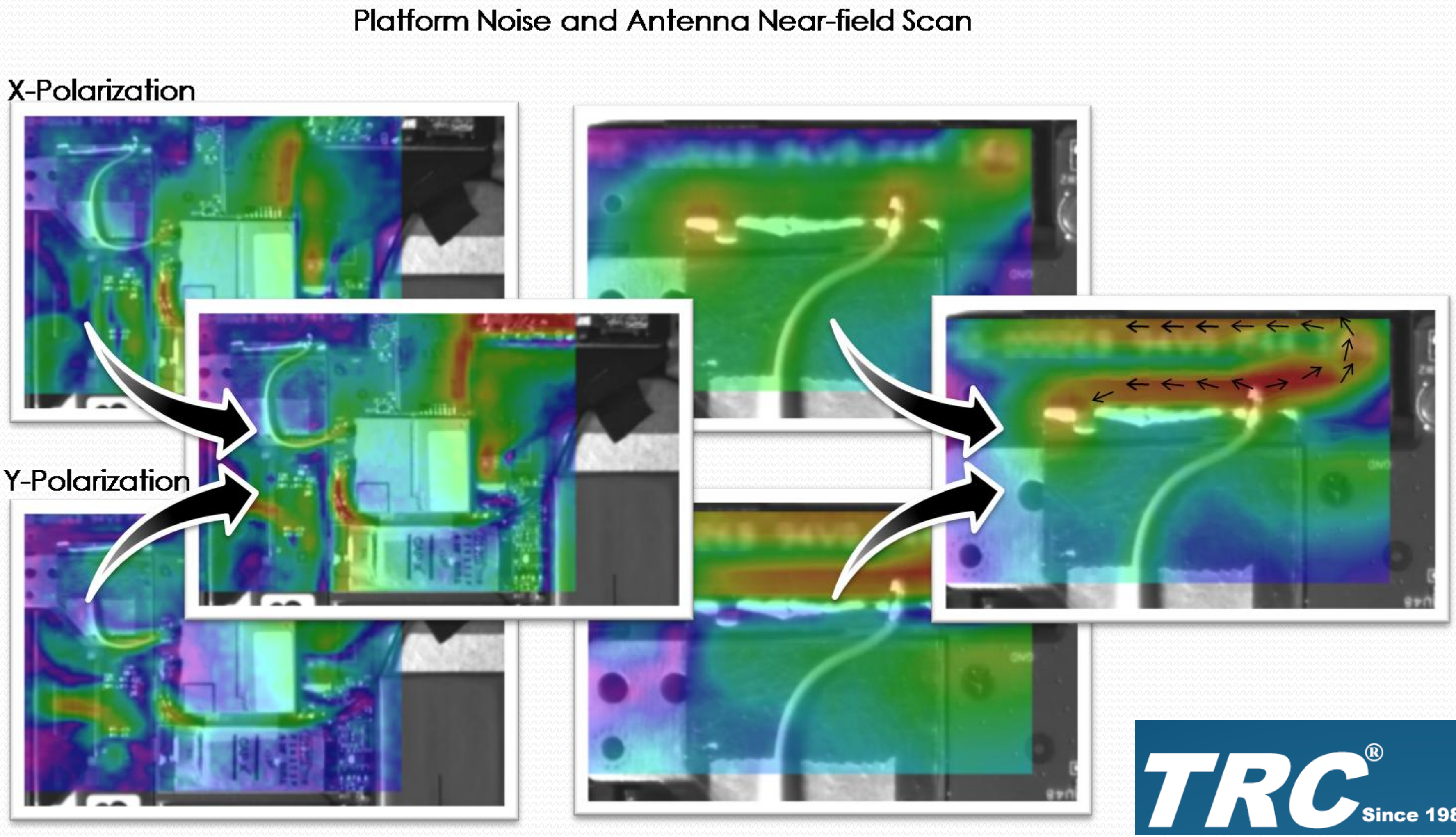
Current and Polarization



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