EMC Introduction and solution

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Outlines

1. EMC basic concepts
2. EMI test method and test equipment
3. Basic techniques of EMI suppression
4. EMC debugging tool

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1. EMC basic concepts
2. EMI test method and test equipment
3. Basic techniques of EMI suppression
4. EMC debugging tool

EMC = EMI+EMS

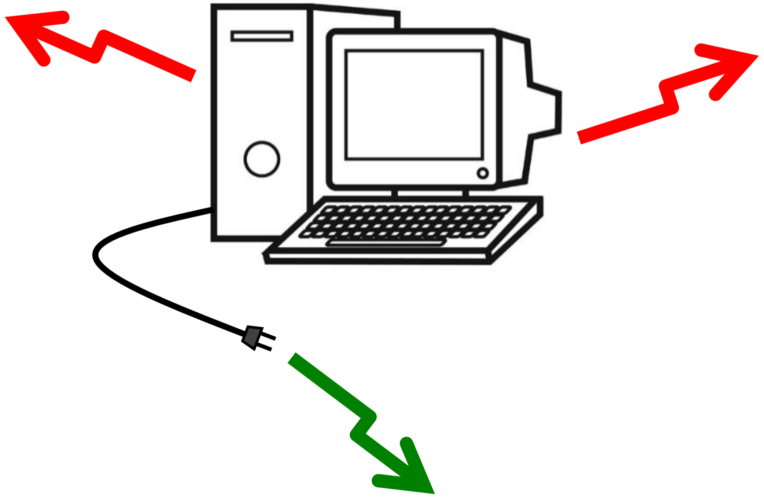
EMC:
Electromagnetic Compatibility

EMI: Emissions
Electromagnetic Interference

+

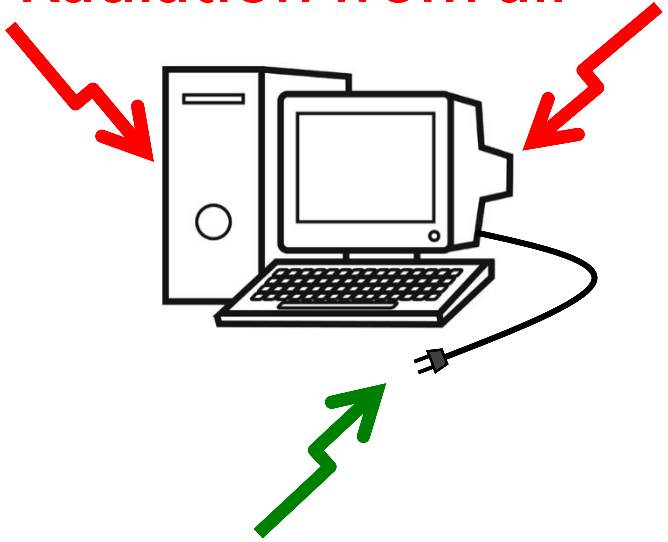
EMS: Immunity
Electromagnetic Susceptibility

Radiation to air



Conduction to power net

Radiation from air



Conduction from power net

EMC pretest and certification steps:

1. Confirm adopted EMI regulations.
2. Conduct pretest item by item.
3. Send products to certified labs for tests.
4. If the tests pass, Lab will prepare test reports and documents.
5. If the tests fail, retune and repeat procedure 2~4.

EMI regulations

FCC	CISPR	EN's	Description
18	11	EN 50011	Industrial, scientific and medical equipment
--	12	--	Automotive
15	13	EN 55013	Broadcast receivers
	14	EN 55014	Household appliances/tools
	15	EN 55015	Fluorescent lights/luminaries
15	22	EN 55022	Information technology equipment
	--	EN61000-6-3, 4	Generic emissions standards
	16	--	Measurement apparatus/methods
	16	EN 55025	Automotive component test

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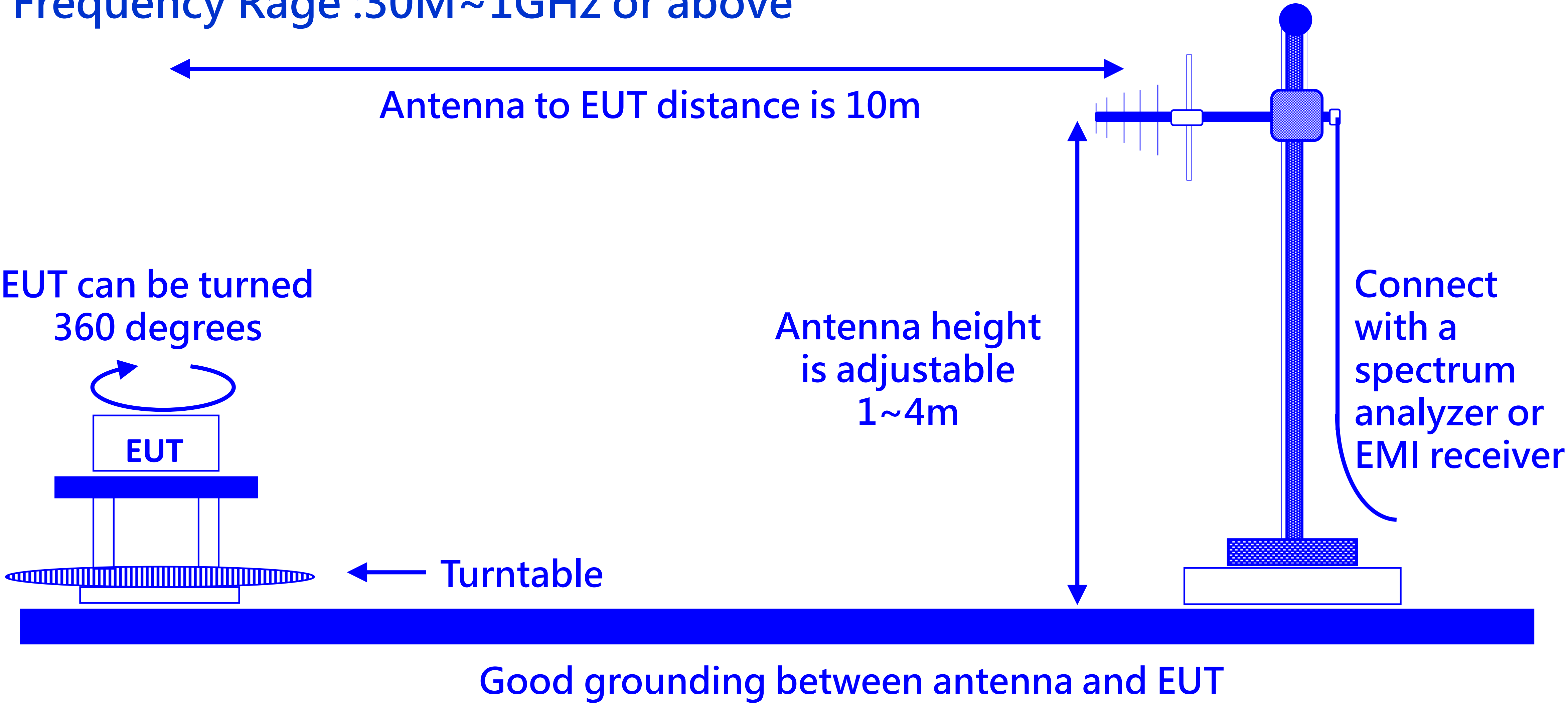
1. EMC basic concepts
2. **EMI test method and test equipment**
3. Basic techniques of EMI suppression
4. EMC debugging tool

EMI radiation test at Open Area Test Site

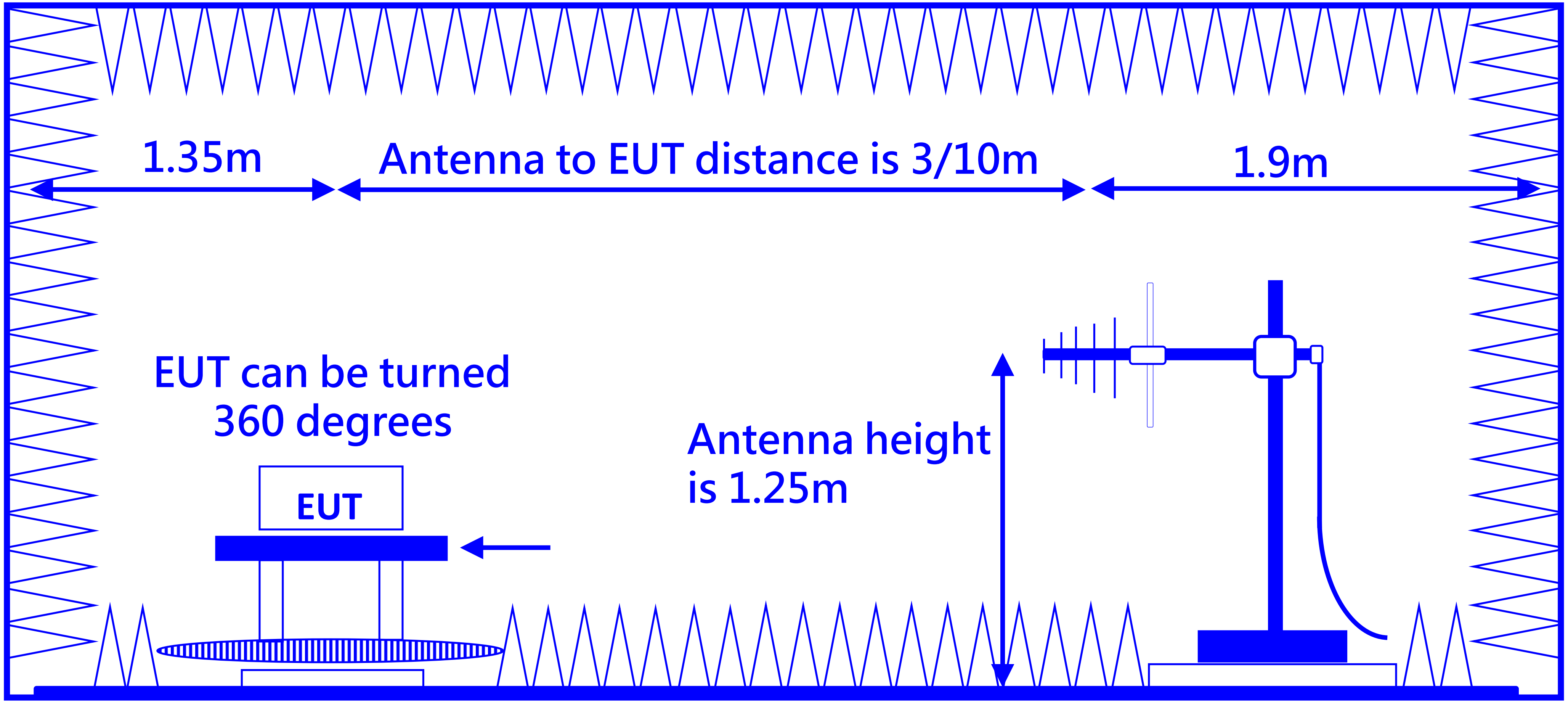
Frequency Rage :30M~1GHz or above



10m EMI open area test site

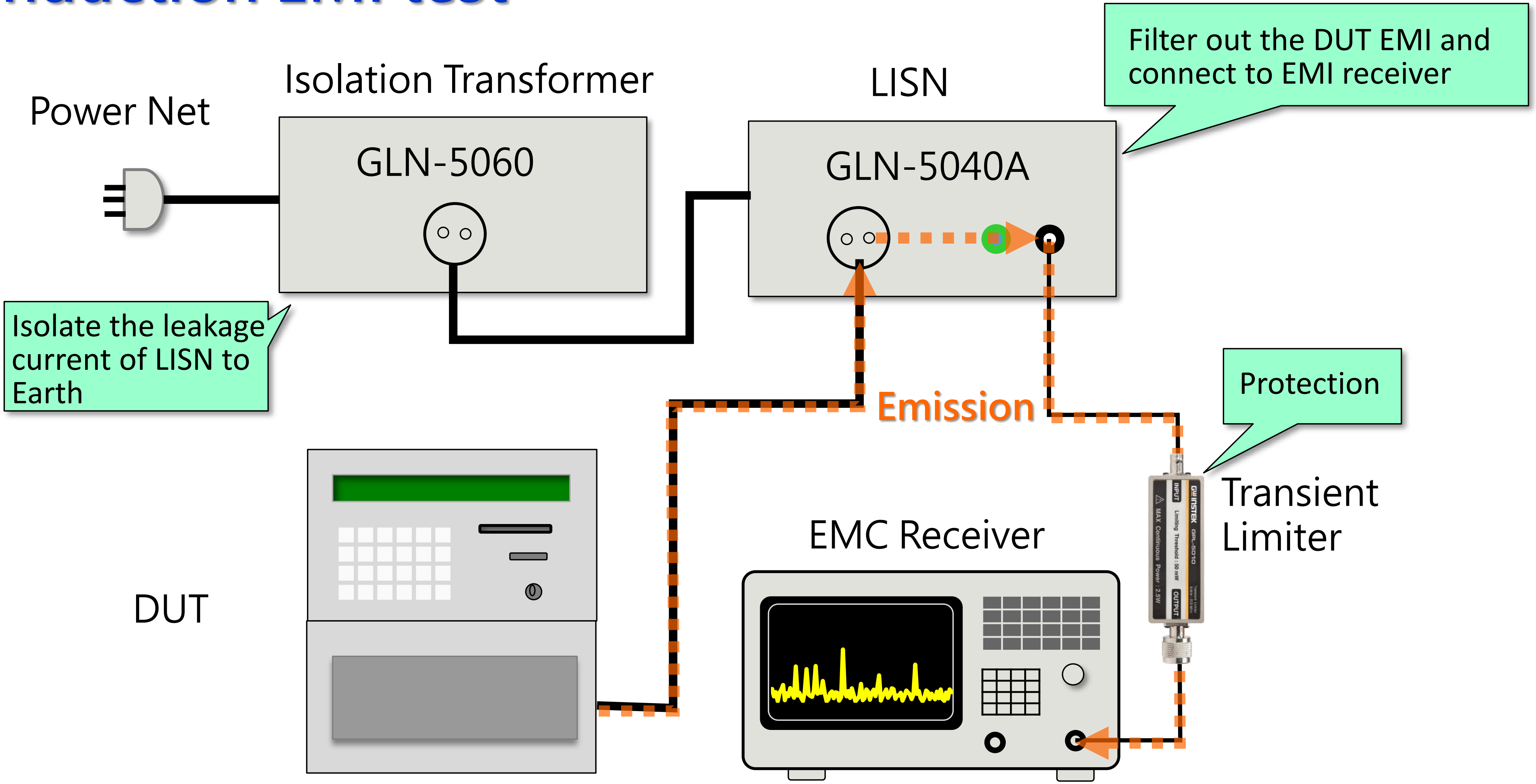
EMI radiation test in Anechoic Chamber

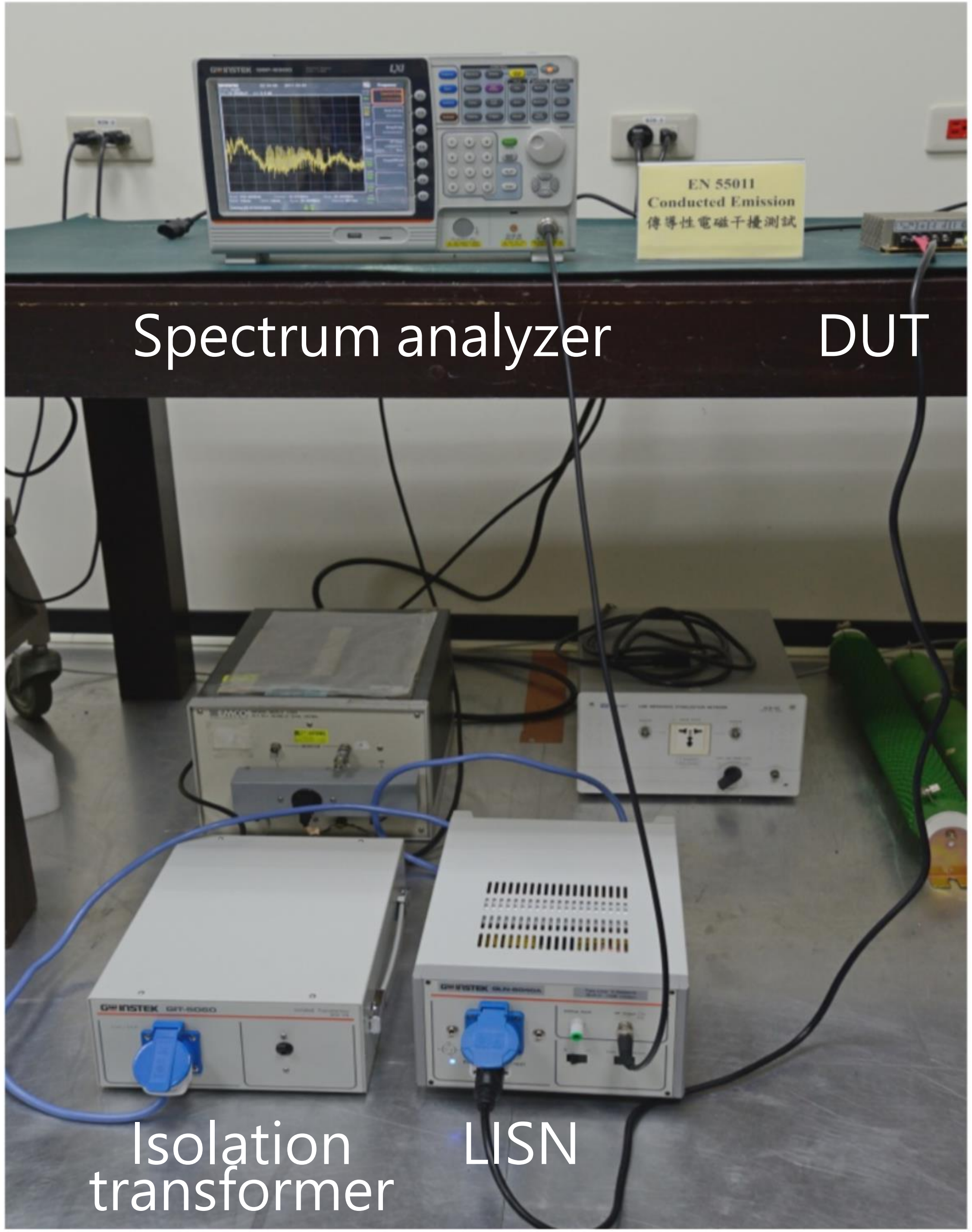
Frequency Rage :30M~1GHz or above

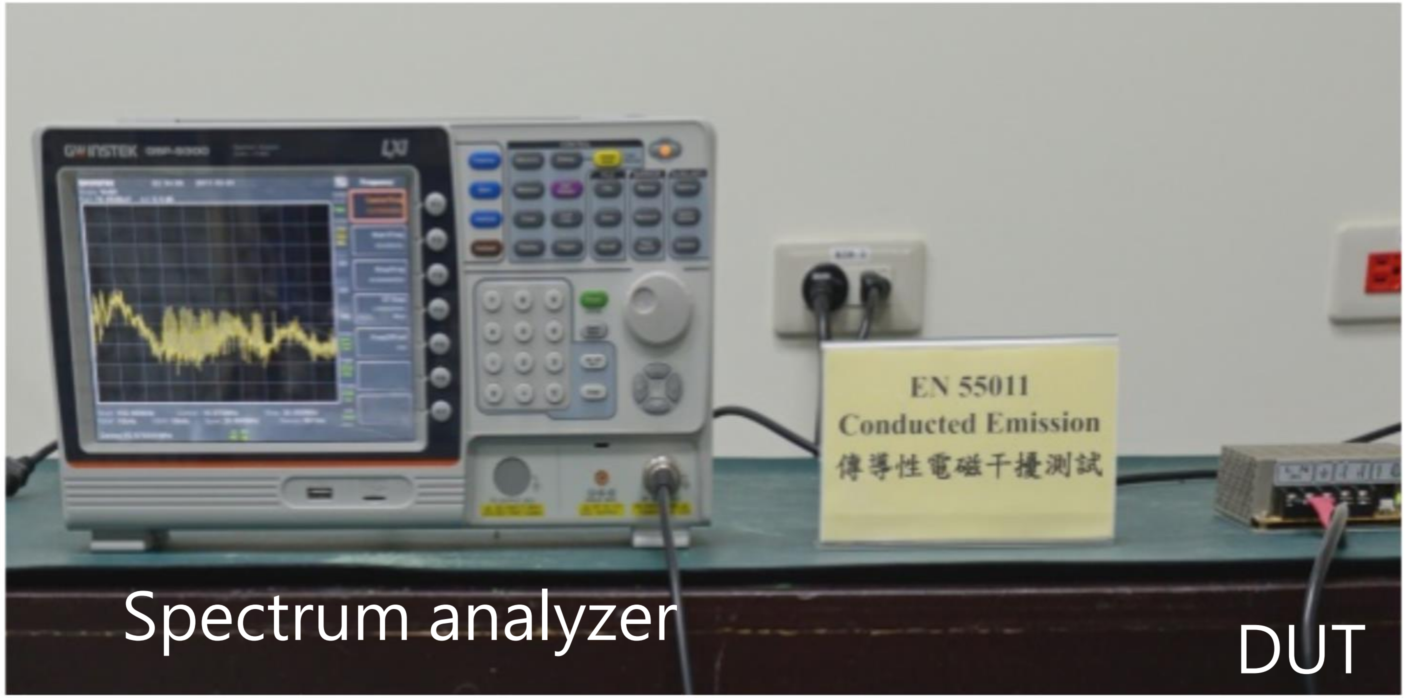


EMI test site: anechoic chamber

Conduction EMI test




EN 55011
Conducted Emission
傳導性電磁干擾測試
Spectrum analyzer
DUT
Isolation
transformer
LISN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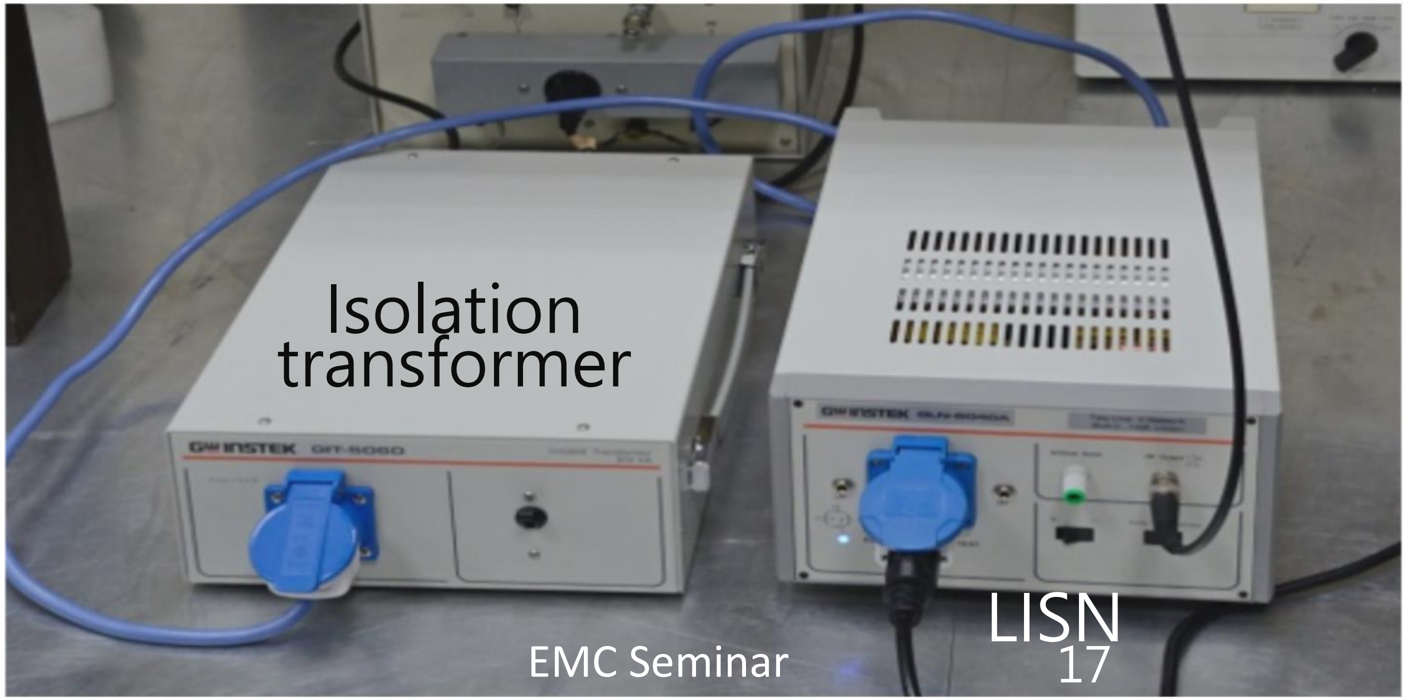

Isolation
transformer
LISN

Detectors in EMI test (ex: CISPR 22)

Limits for conducted disturbance at the mains ports of Class A ITE		
Frequency range MHz	Limits dB(μV)	
	Quasi-peak	Average
0.15 to 0.50	79	66
0.5 to 30	73	60
Note – The lower limit shall apply at the transition frequency		

Limits for conducted disturbance at the mains ports of Class B ITE		
Frequency range MHz	Limits dB(μV)	
	Quasi - peak	Average
0.15 to 0.5	66 to 56	56 to 46
0.5 to 5	56	46
5 to 30	60	50

Notes
1. The lower limit shall apply at the transition frequencies
2. The limit decreases linearly with the logarithm of the frequency in the range 0.15 MHz to 0.50 MHz

Conduction EMI

Limits for radiated disturbance of Class A ITE at a measuring of 10 m	
Frequency range MHz	Quasi – peak limits dB(μV/m)
30 to 230	40
230 to 1000	47

Notes
1. The lower limit shall apply at the transition frequency
2. Additional provisions may be required for cases where interference occurs

Limits for radiated disturbance of Class B ITE at a measuring of 10 m	
Frequency range MHz	Quasi – peak limits dB(μV/m)
30 to 230	30
230 to 1000	37

Notes
1. The lower limit shall apply at the transition frequency
2. Additional provisions may be required for cases where interference occurs

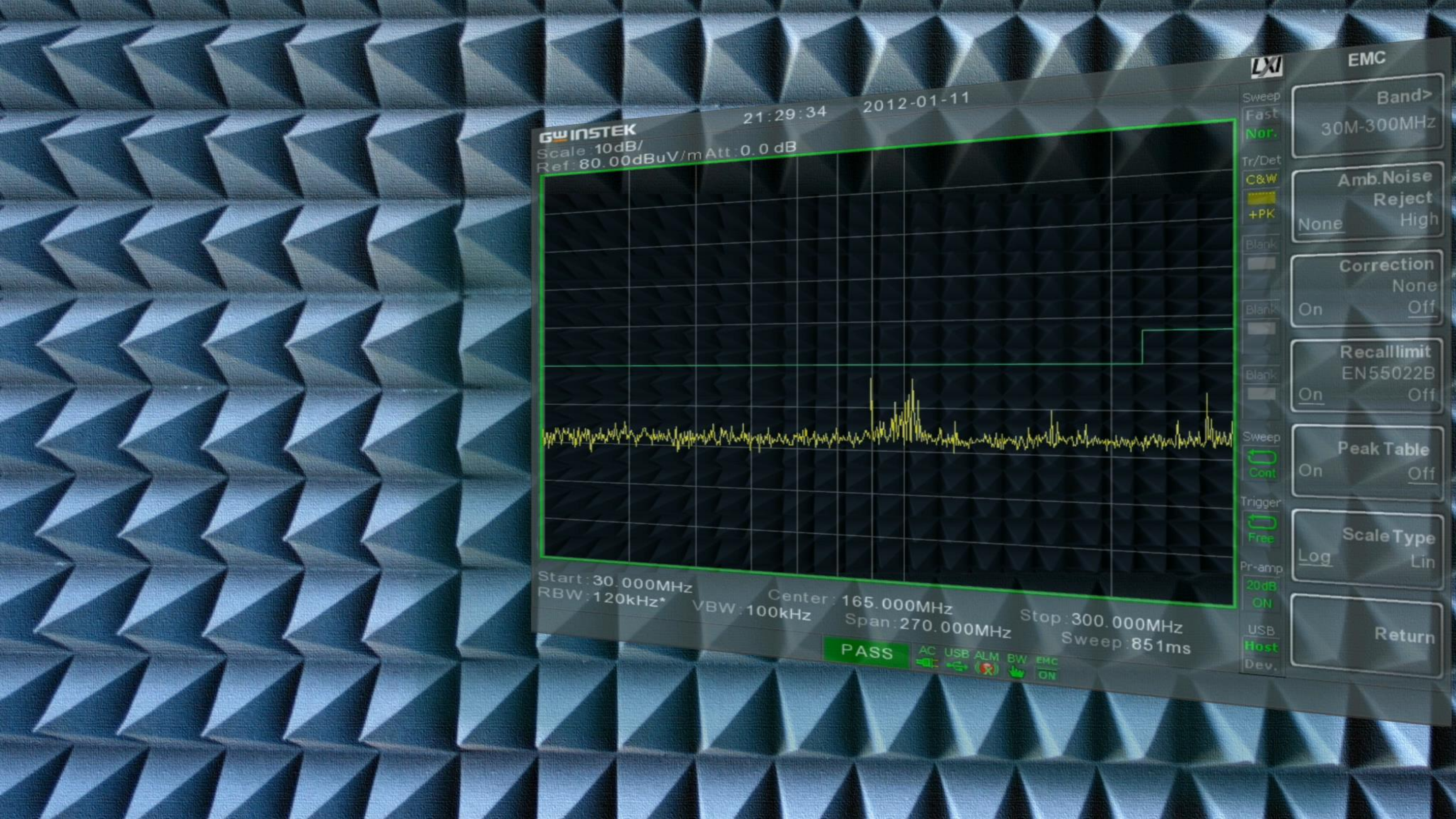
Radiation EMI

Peak, Quasi-Peak and Average detectors

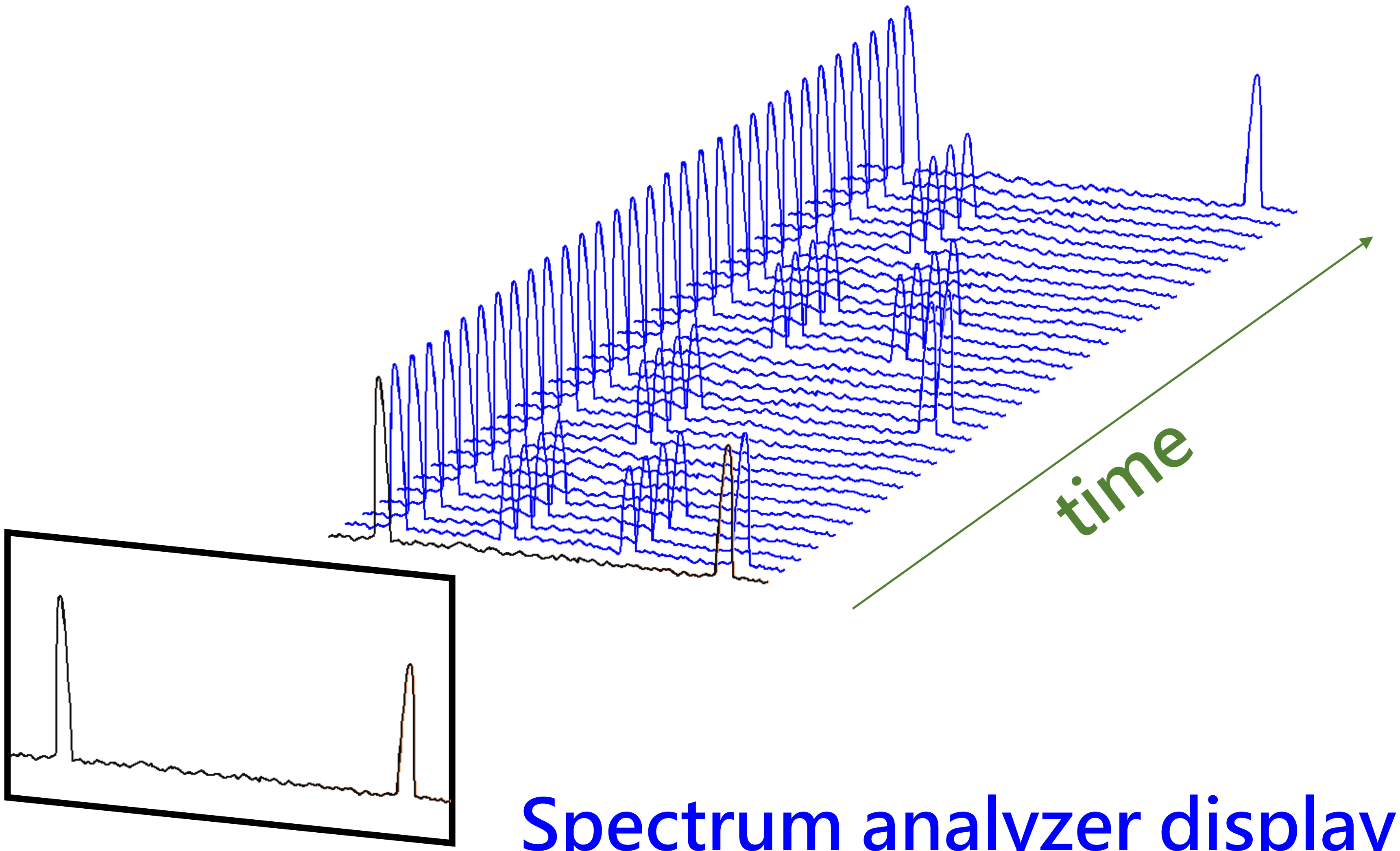
EMI signals can be divided into the following categories:

- CW, Continuous wave: appear continuously without pause.
- Repetitive: periodically appear.
- Random: appear irregularly.

In order to accurately measure different EMI signals, the regulations require using Peak, QP (Quasi-Peak) and Average detectors to conduct measurements to determine if the results meet the regulations.

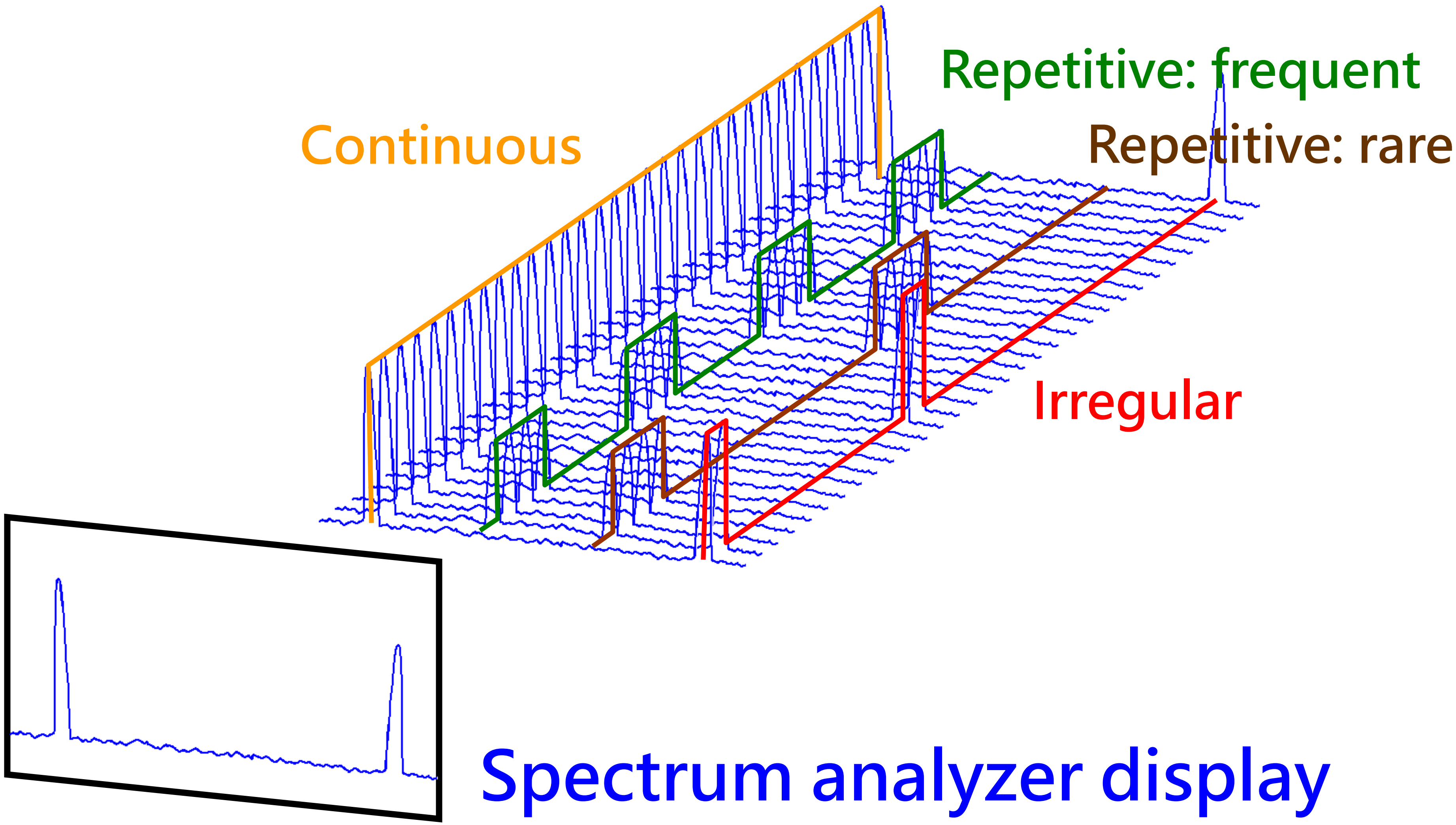

EMC
GW INSTEK
21:29:34
2012-01-11
Scale:10dB/
Ref:80.00dBuV/m
Att:0.0 dB
Sweep
Fast
Nor.
Tr/Det
C&W
+PK
Blank
Cont
Trigger
Free
Pr-amp
20dB
ON
USB
Host
Dev.
Band>
30M-300MHz
Amb.Noise
Reject
None
High
Correction
None
On
Off
Recalllimit
EN55022B
On
Off
Peak Table
On
Off
Scale Type
Log
Lin
Return
Start:30.000MHz
RBW:120kHz*
VBW:100kHz
Center:165.000MHz
Span:270.000MHz
Stop:300.000MHz
Sweep:851ms
PASS
AC
USB
ALM
BW
EMC
ON

Various EMI signals on time domain

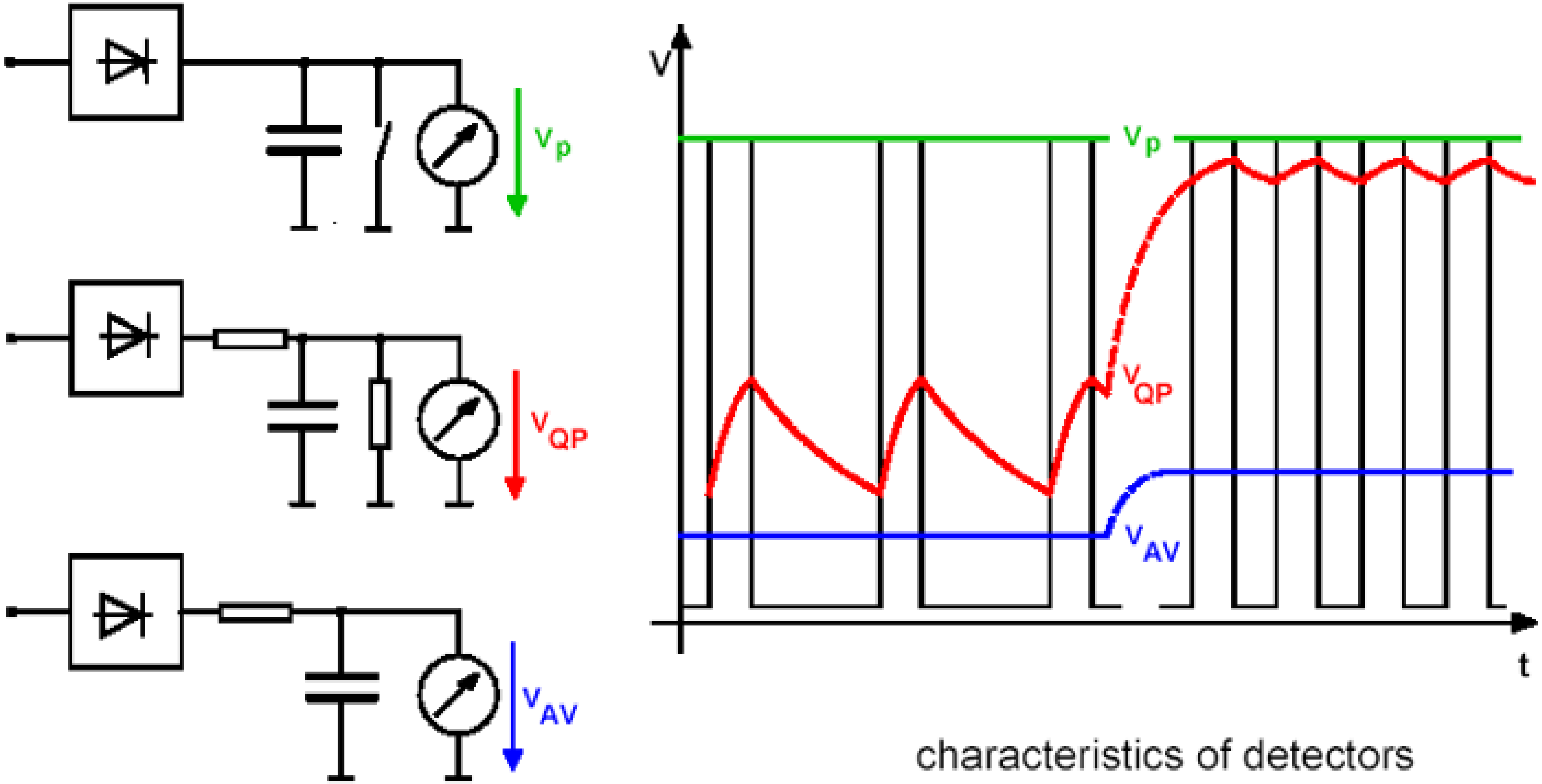


Spectrum analyzer display

Various EMI signals on time domain



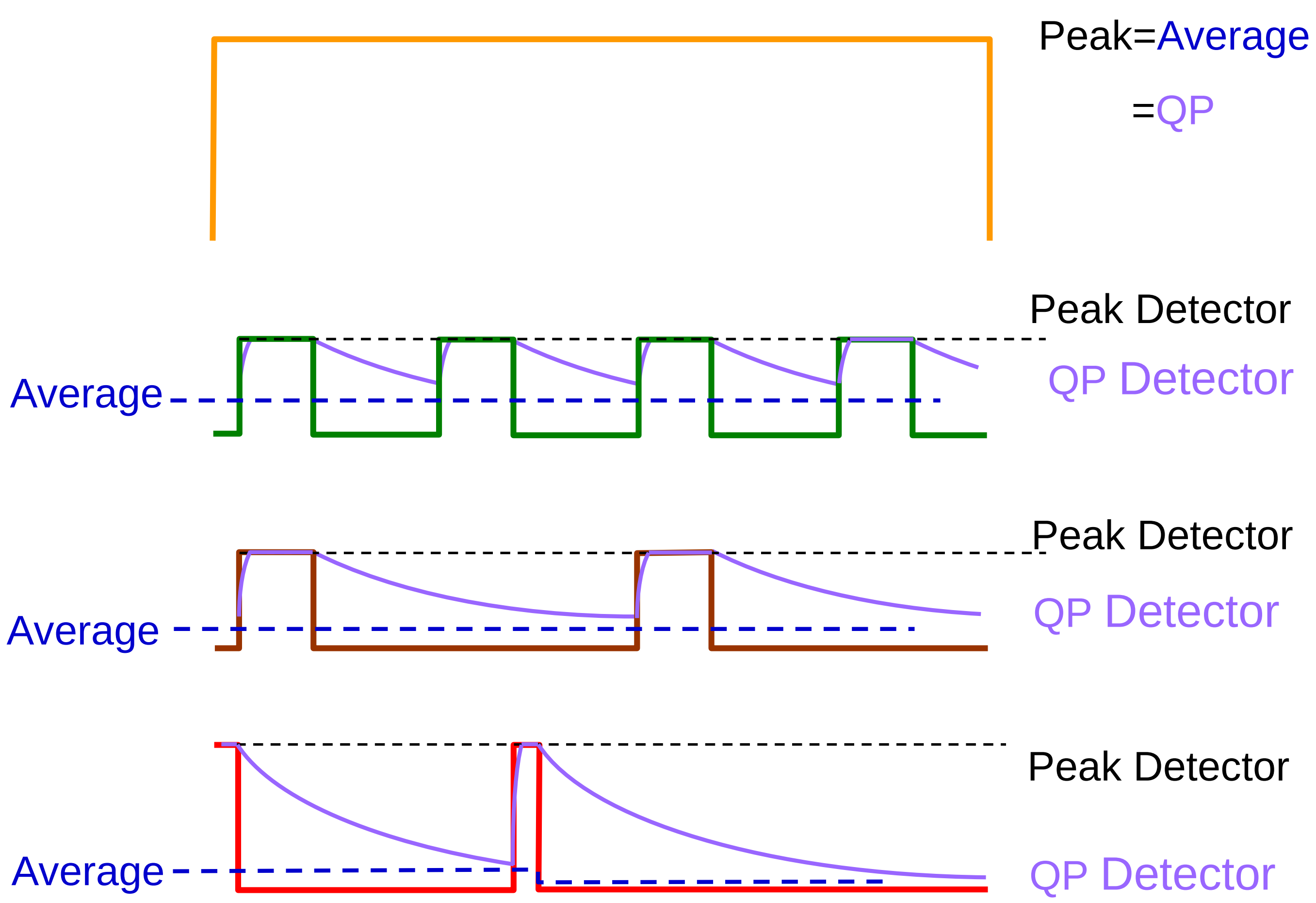
Conclusion: Peak ≥ QP ≥ Average



characteristics of detectors

Fundamental characteristics of QP receivers

Characteristics	Frequency		
	Band A 9kHz to 150kHz	Band B 150kHz to 30MHz	Band C and D 30MHz to 1000MHz
Bandwidth at the -6dB points, in kHz	0.2	9	120
Detector electronical charge time constant, in ms	45	1	1
Detector electronical discharge time constant, in ms	500	160	550
Mechanical time constant of critically damped indicating instrument, in ms	160	160	100
Total time constant, ms	**705**	**321**	**651**
Note 1: Not all characteristics are presented. Note 2: In the electronic instrument, the mechanical time constant may be simulated by a circuit.			



Peak=Average
=QP
Peak Detector
Average
QP Detector
Peak Detector
Average
QP Detector
Peak Detector
Average
QP Detector

Conclusion: Peak ≥ QP ≥ Average

Peak Detector:

- Use this mode to start testing.
- Test speed is faster than that of QP and Average.
- If the Peak mode passes, other modes can also be passed. There is no need to conduct other tests.

Conclusion: Peak ≥ QP ≥ Average

QP detector :

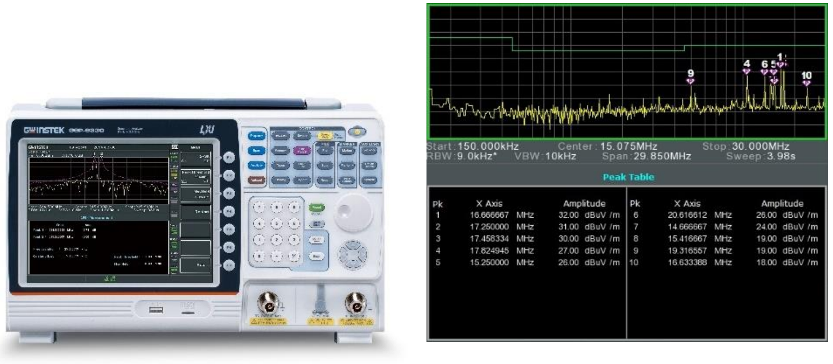
- For continuous wave: QP=Peak.
- Compared with Peak, Quasi-Peak tests are very slow since the tests require long circuit discharge.
- Considering more frequency points, QP test time is much longer.

Average detector:

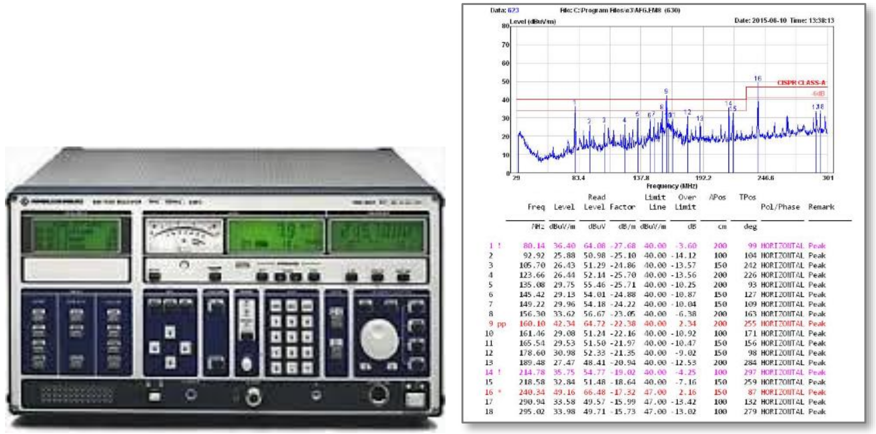
- Radiation interference signals exceed 1GHz will use this mode.

How is EMI tested in Lab?

- Use Spectrum analyzer to scan the entire band with Peak Detector to find the potential noises.
- Use EMI Receiver to test the potential noises one by one with QP Detector.
- Obtain and record the readings of each test point for report.

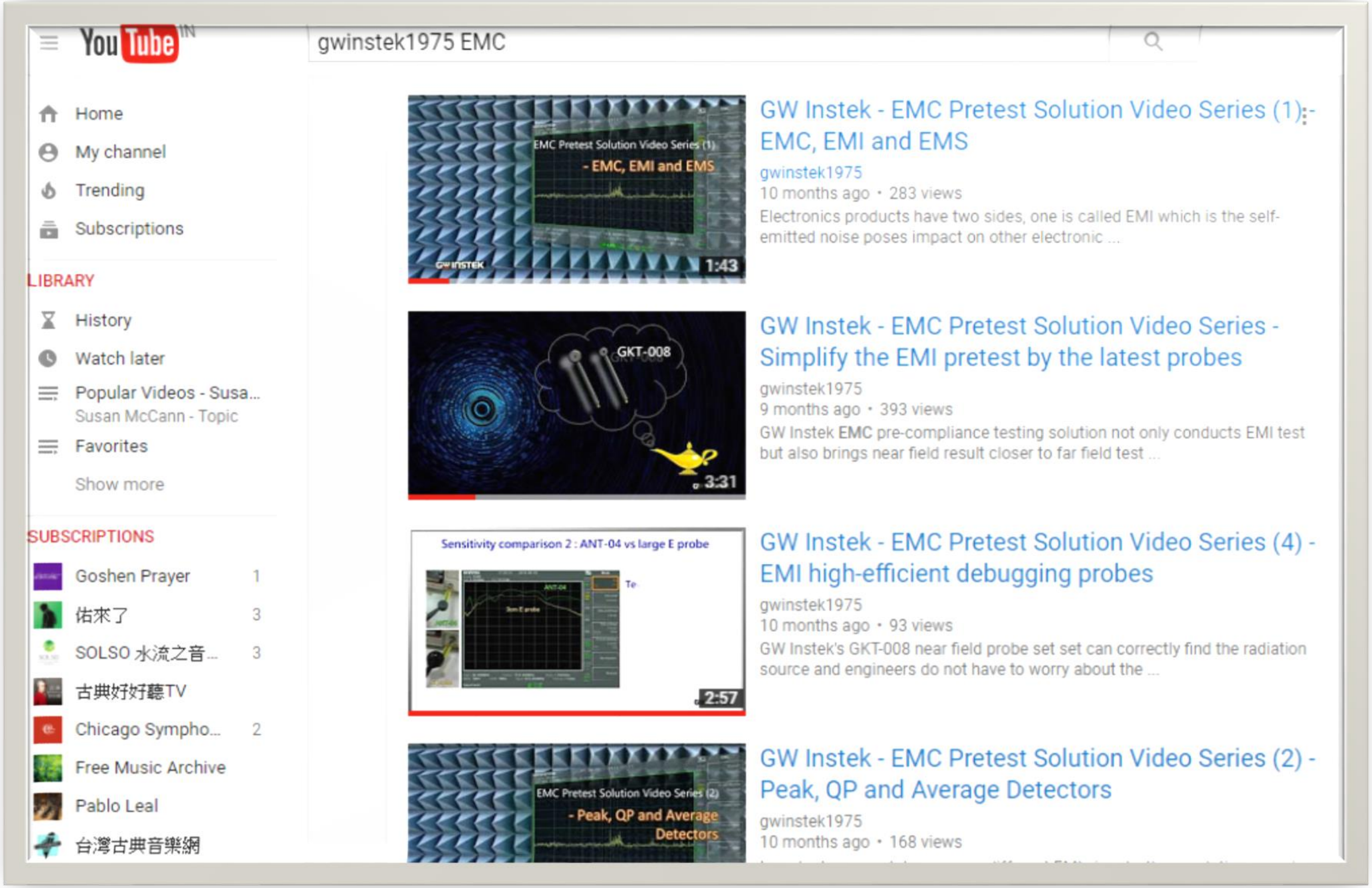


Spectrum Analyzer



EMI Receiver

Complete videos about EMC can be found at YouTube

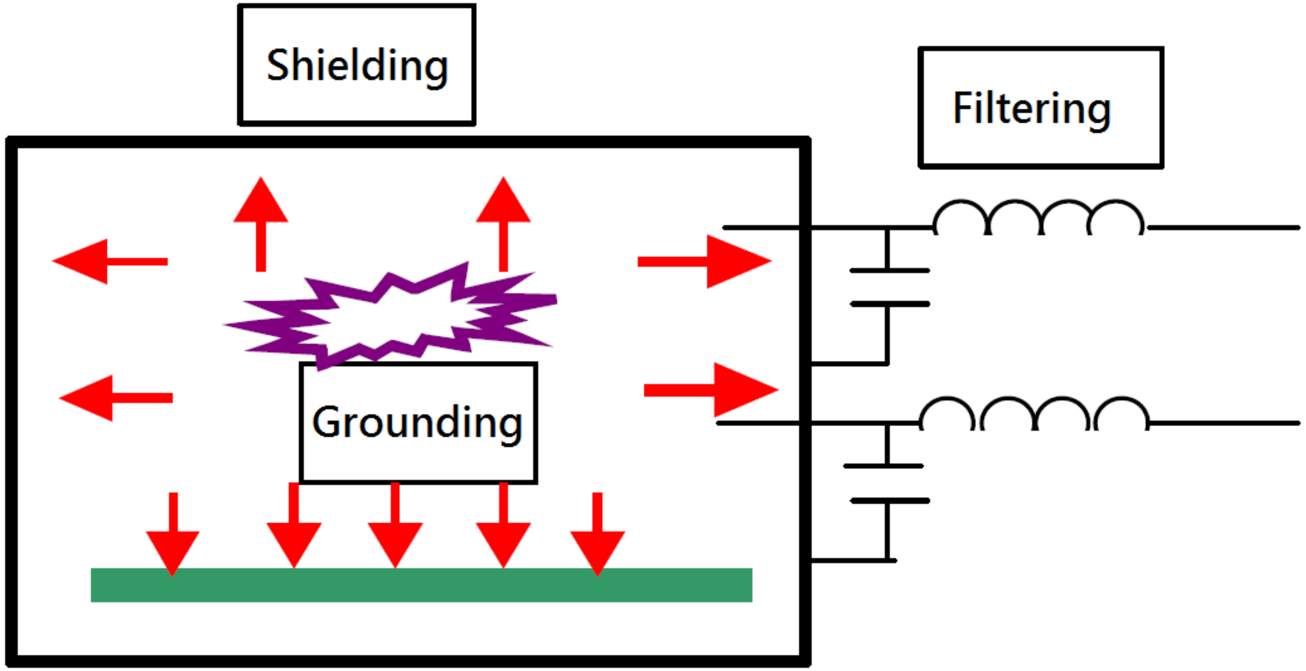


Outlines

1. EMC basic concepts
2. EMI test method and test equipment
3. **Basic techniques of EMI suppression**
4. EMC debugging tool

Basic Techniques

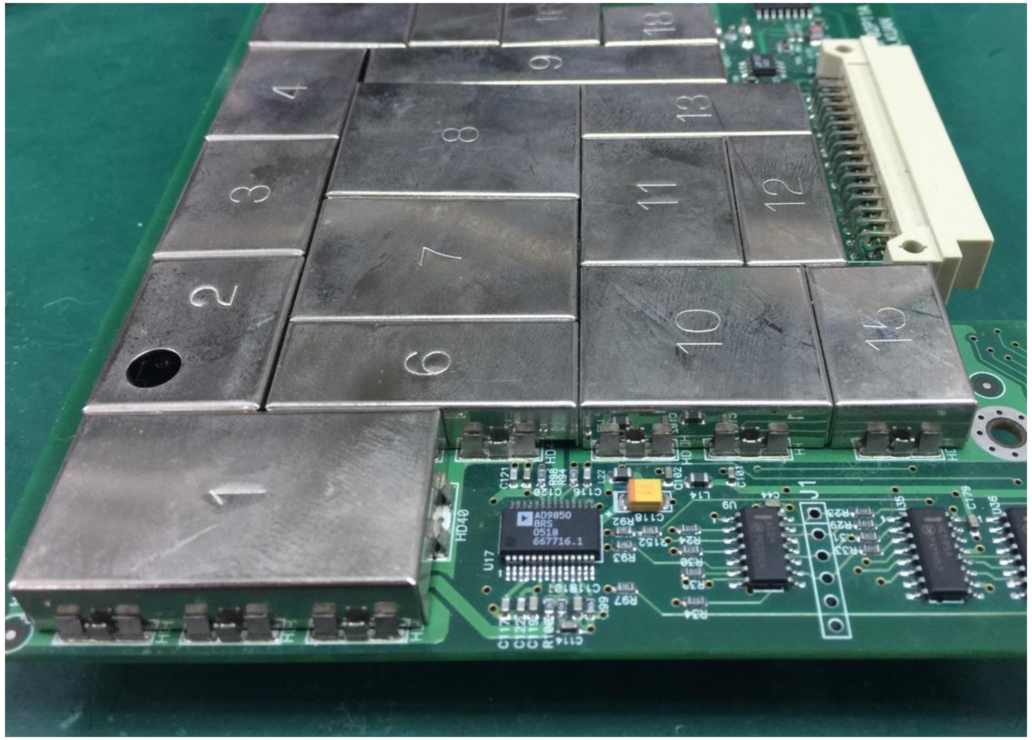
- Shielding - limits the electromagnetic energy to a specific space
- Filtering - causes the electromagnetic wave energy to dissipate
- Grounding - Reduces the generation of electromagnetic waves

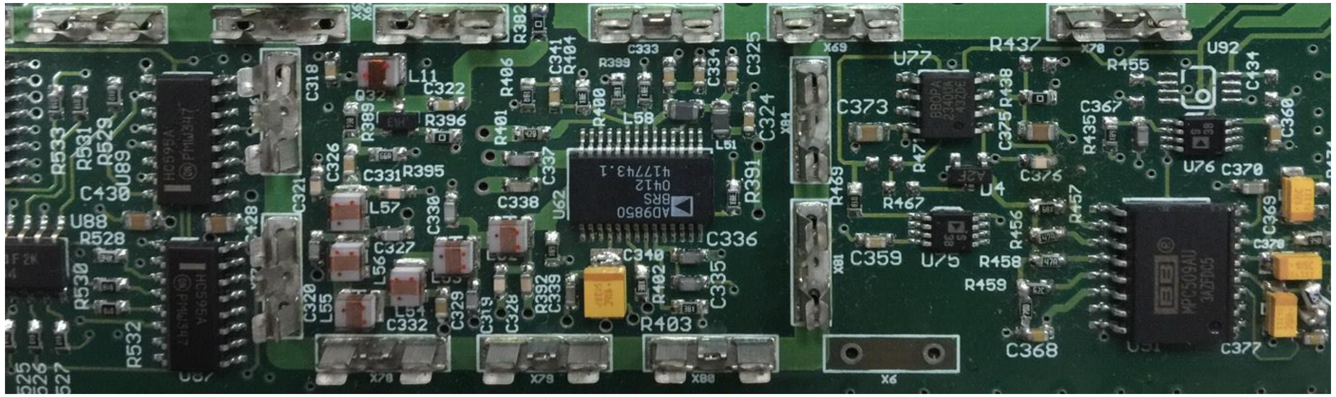


1. Shielding to suppress EMI

Introduction to shielding methods

- Cost is increased
- Must be planned in design phase
- Can effectively constrain the EMI radiation for entire frequency range
- Does not affect the product function

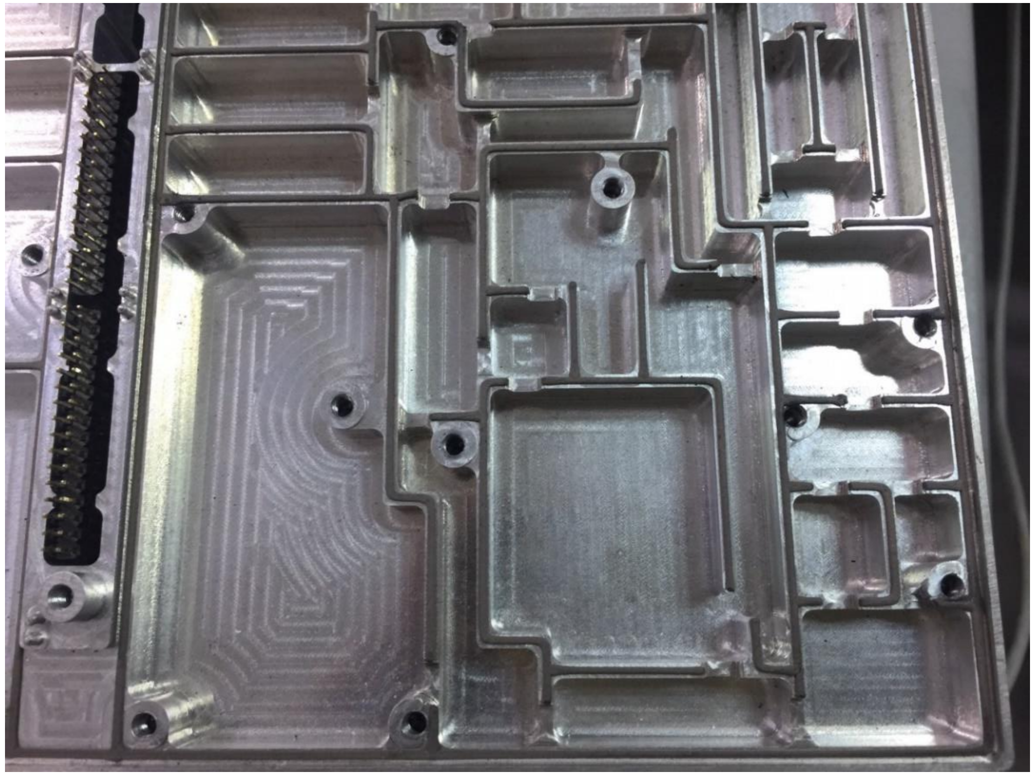




1. Shielding to suppress EMI

Shielding purposes

- Limiting the radiation energy within specific space, or preventing interference from outside radiation.
- Last option
- The Shielding effectiveness is performed by the Absorption and Reflection of the shielding material.



Shield effectiveness, S = A + R (dB)

Absorption of shielding

The incident wave is absorbed by the shielding material. The absorption or penetration loss is obtained by:

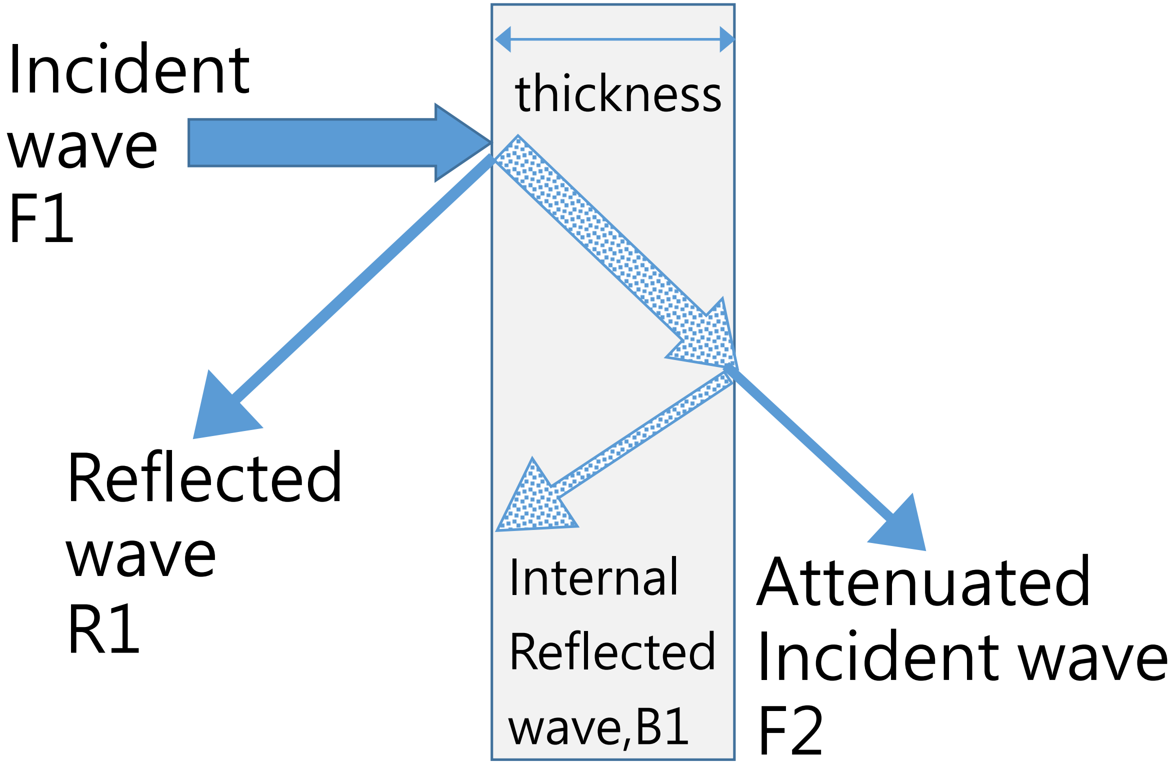
$$A = 1.314 \cdot \sqrt{f \mu_r \sigma_r} d \text{ , } dB$$

f: frequency in Hz,

μ_r : relative permeability

σ_r : relative conductivity

d : shielding thickness in cm



Reflection of shielding

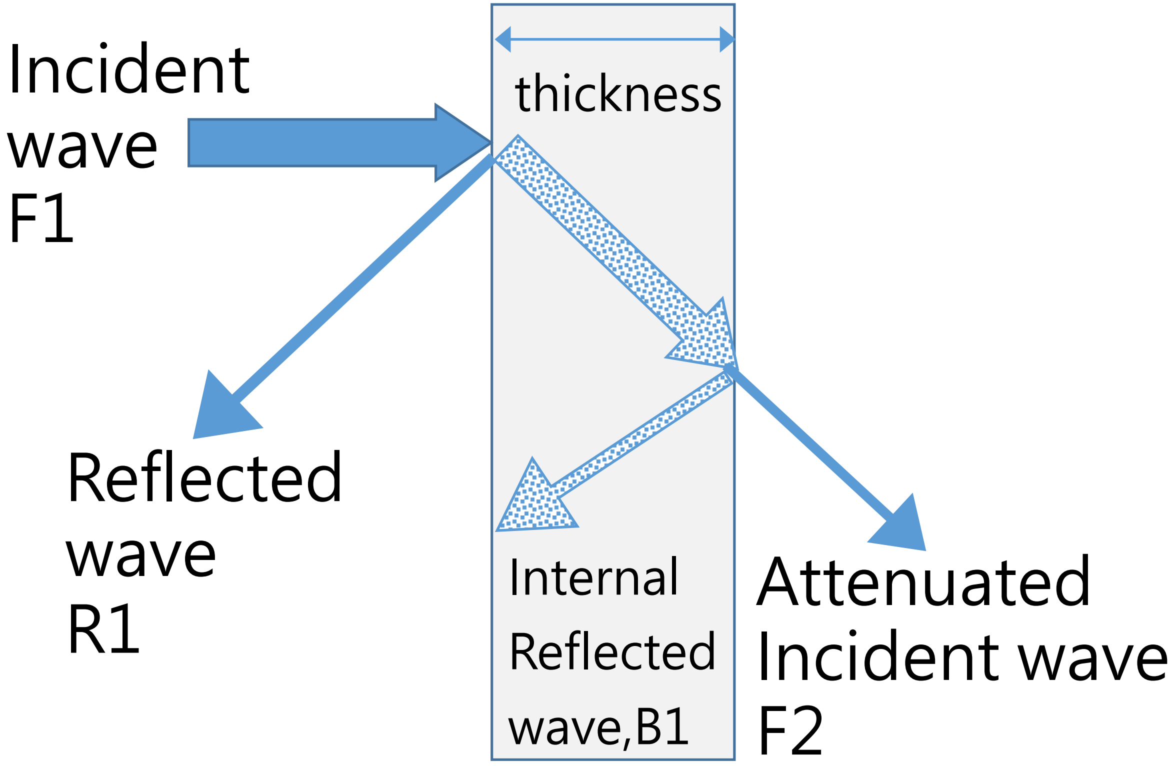
For a planner wave source, the reflection is:

$$R = 168 + 10 \cdot \log\left(f\,\mu_r / \sigma_r\right),\ dB$$

f: frequency in Hz

μ_r : relative permeability

σ_r : relative conductivity



Reflection and absorption of various metal/ alloy

unit : dB

Metal / Alloy	σ_r	μ_r	A, 10kHz	R, 10kHz	A, 30MHz	R, 30MHz	A, 1GHz	R, 1GHz
Permalloy	0.03	80,000	64	144	3,526	179	20,356	194
Mu-metal (nickel, iron alloy)	0.06	80,000	91	147	4,986	182	28,788	197
Steel	0.1	1,000	13	168	720	203	4,155	218
tin	0.15	1	1	200	28	235	161	250
Iron	0.17	1,000	17	170	938	205	5,418	220
Zinc	0.29	1	1	203	39	237	224	253
magnesium	0.38	1	1	204	44	239	256	254
aluminum	0.61	1	1	206	56	241	325	256
gold	0.7	1	1	206	60	241	348	256
copper	1	1	1	208	72	243	416	258
silver	1.05	1	1	208	74	243	426	258

Shielding thickness: 0.1 mm

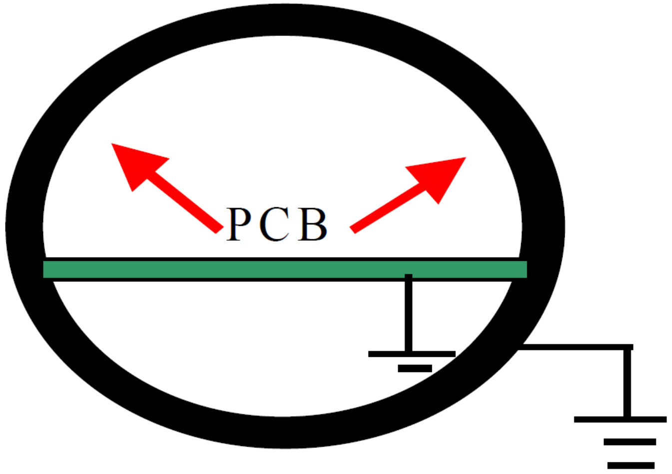
S (= A + R), are good in ideal case!

Practical situation of shielding

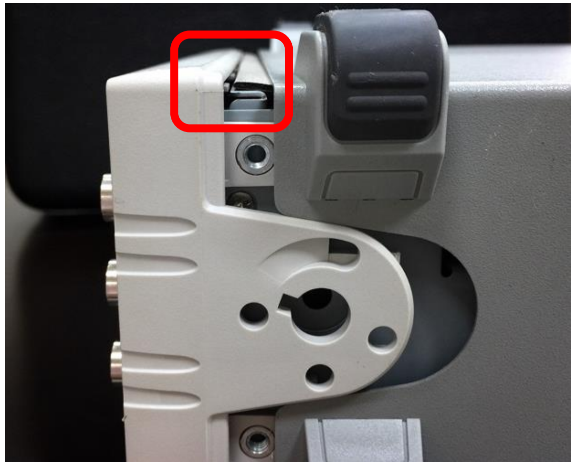
Ideally the perfect shielding of well-sealed-metal-box will not leak any EMI radiation.

The practical situation of shield is destructed by two major factors:

- Apertures – holes or slots in the enclosure.
- The mechanical characteristics and effectiveness of the gaskets used on the enclosure.



Ideal shield, Faraday ball



2. Filtering to suppress EMI

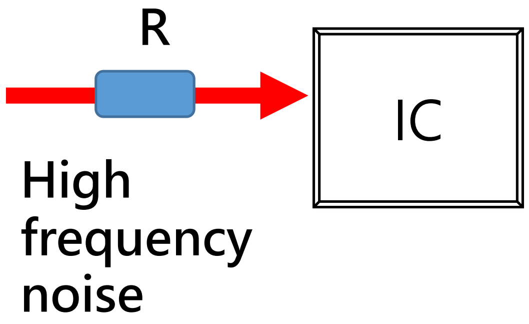
Components used for EMI noise filtering

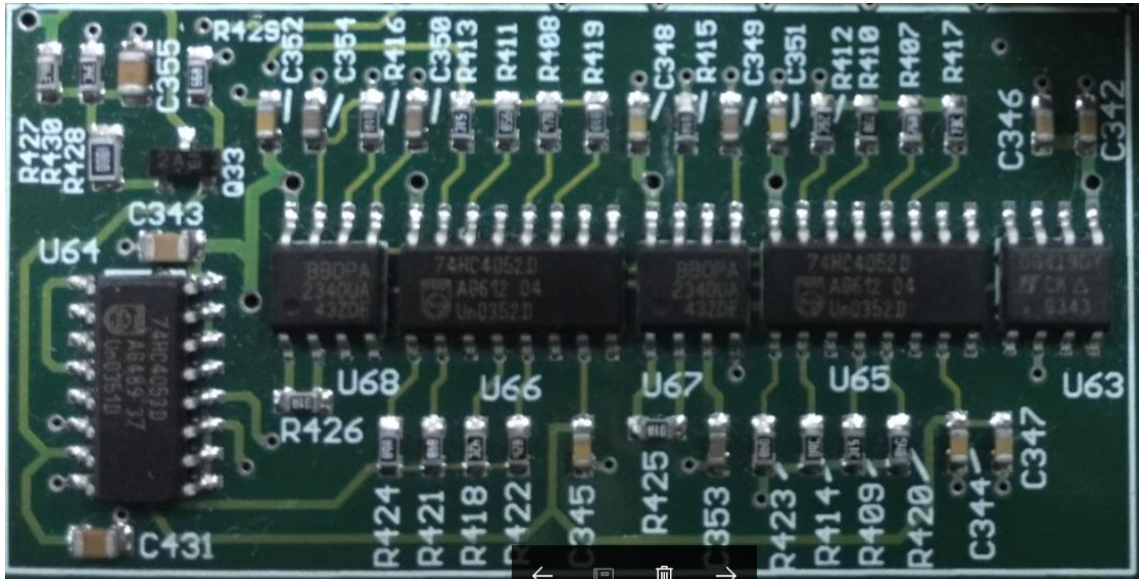
- Resistor
- Capacitor
- Inductor
- Ferrite bead or ferrite choke

Basic ideas of filtering EMI

Blocking

Dissipate the noise energy by a serial resistor

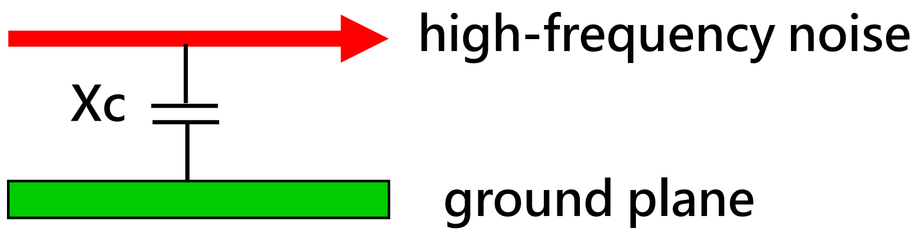


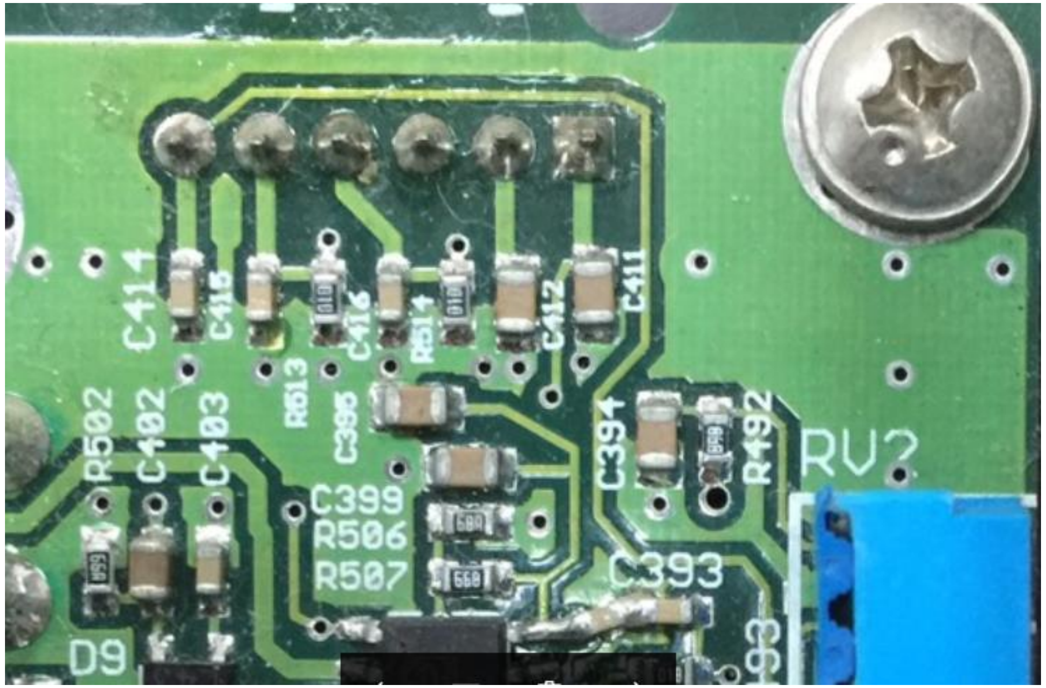


Basic ideas of filtering EMI

Guide EMI to ground

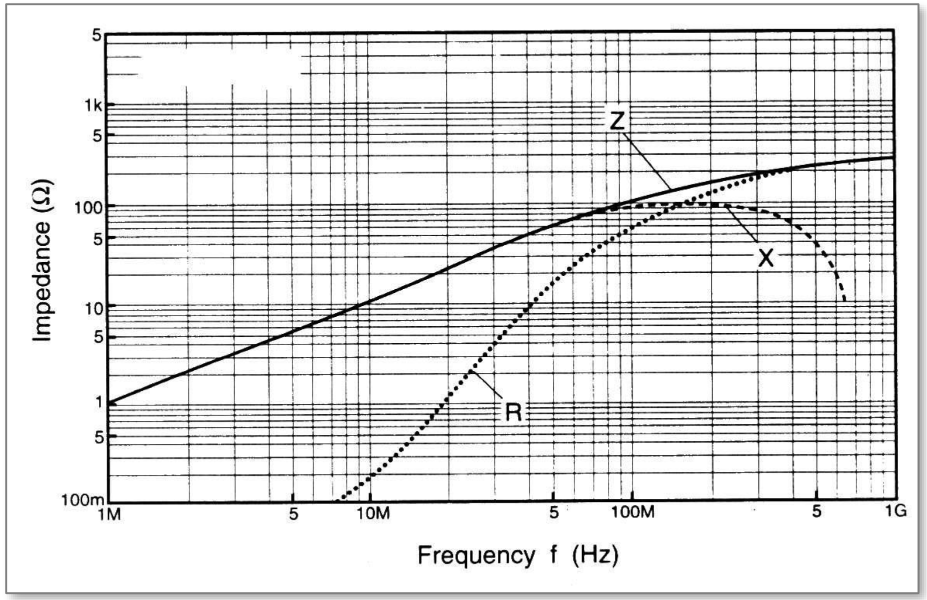
Conduct the high-frequency noise to the ground



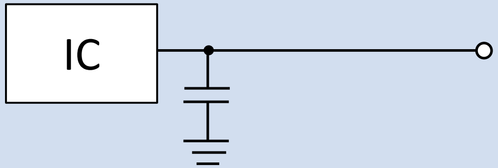
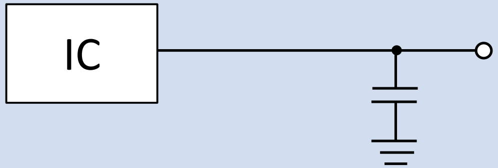
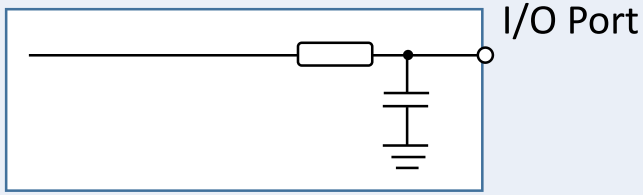
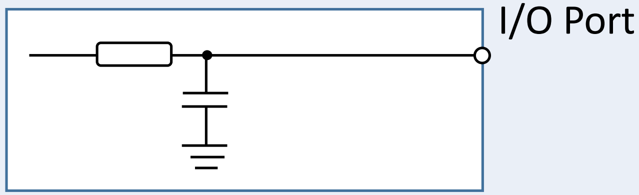
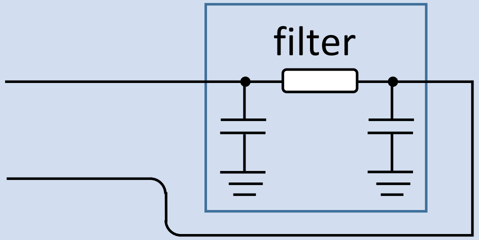
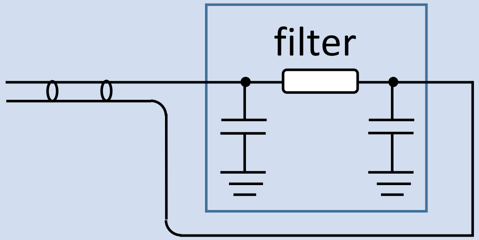


Basic ideas of filtering EMI

- Ferrite bead/choke can absorb and dissipate the radiated energy
- Prevents the cable from acting as an antenna
- Ferrite core impedance characteristics varies with frequency
- No effect for DC or low frequency signal

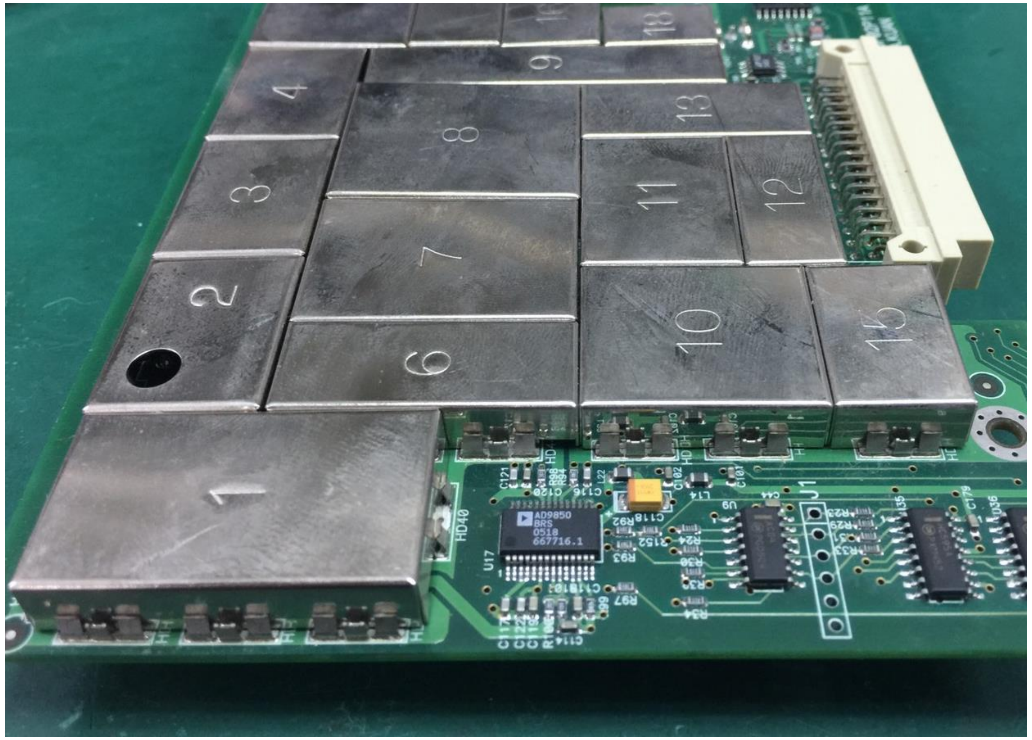


Position of deploying filtering parts

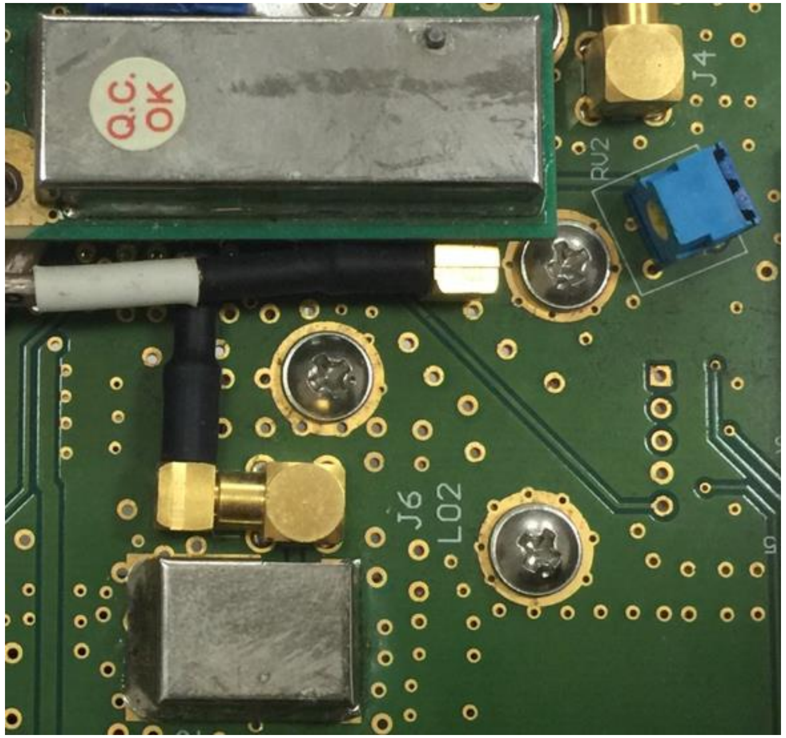
	Good	No Good
Close to noise terminal as much as possible		
Close to I/O port as much as possible		
Preventing two traces from close placement		

Shielding box

Trade-off between productivity and effectiveness



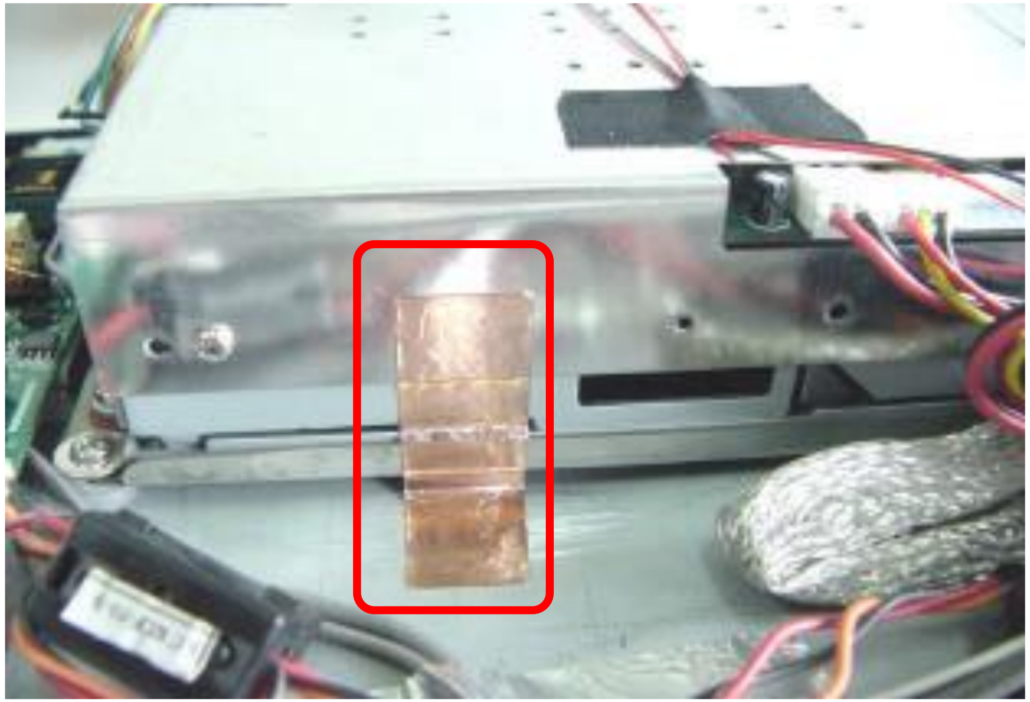
Shielding box is held by metal clips. Flaw exists essentially

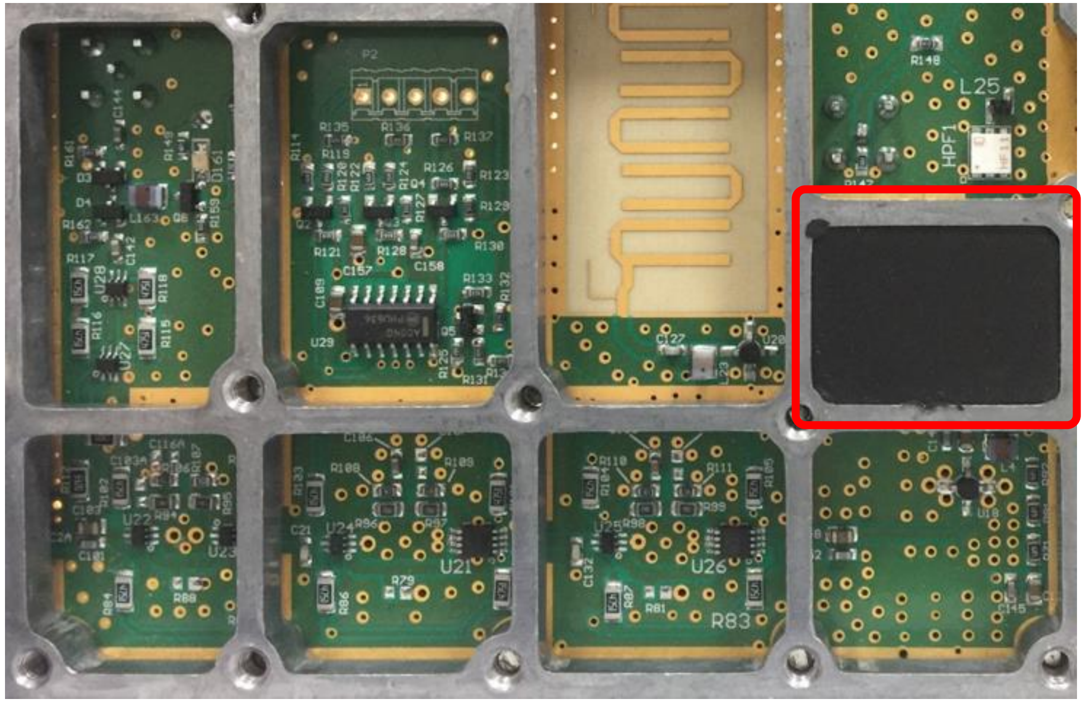


Shielding box is soldered to seal the seam. It makes uncovering very difficult

Foil and rubber EMI absorber

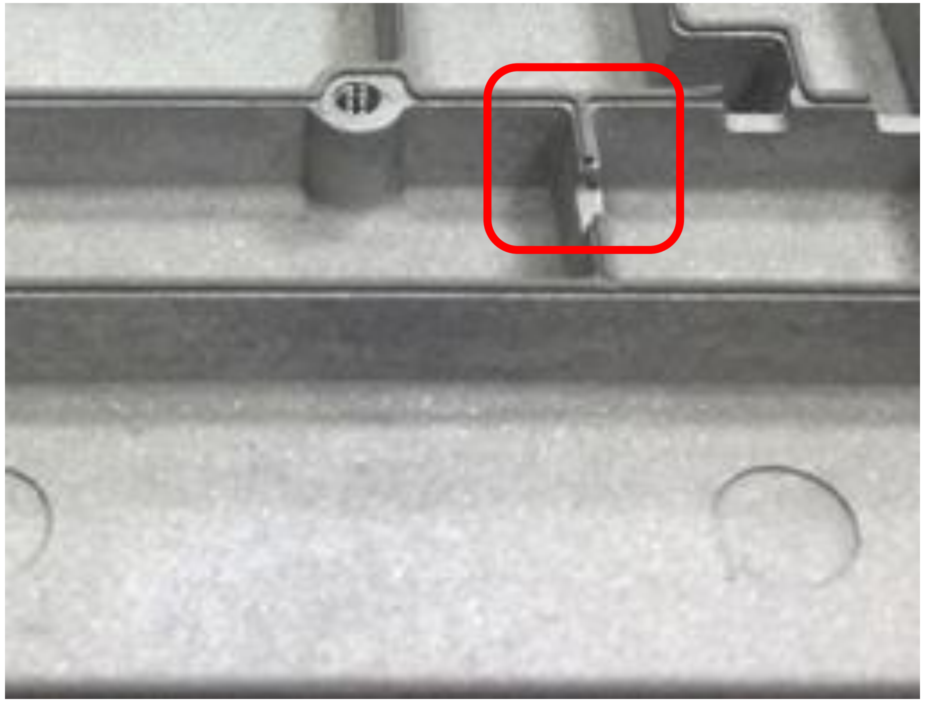
- Foil can be bended to improve the conductivity continuity and seal the hole at the same time.
- Rubber EMI absorber can be easily shaped and fit into the EMI sensitive area.

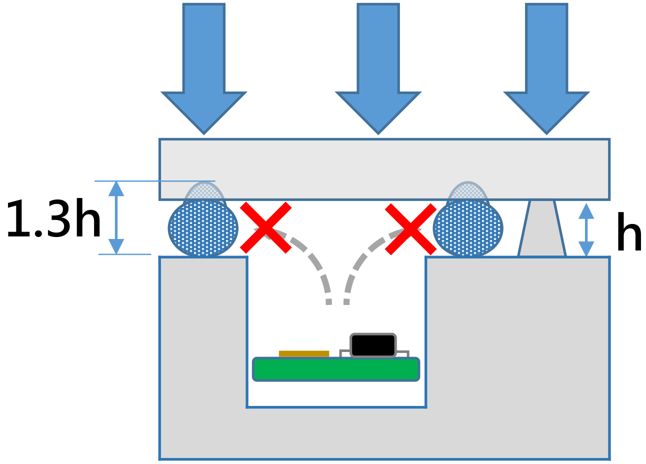




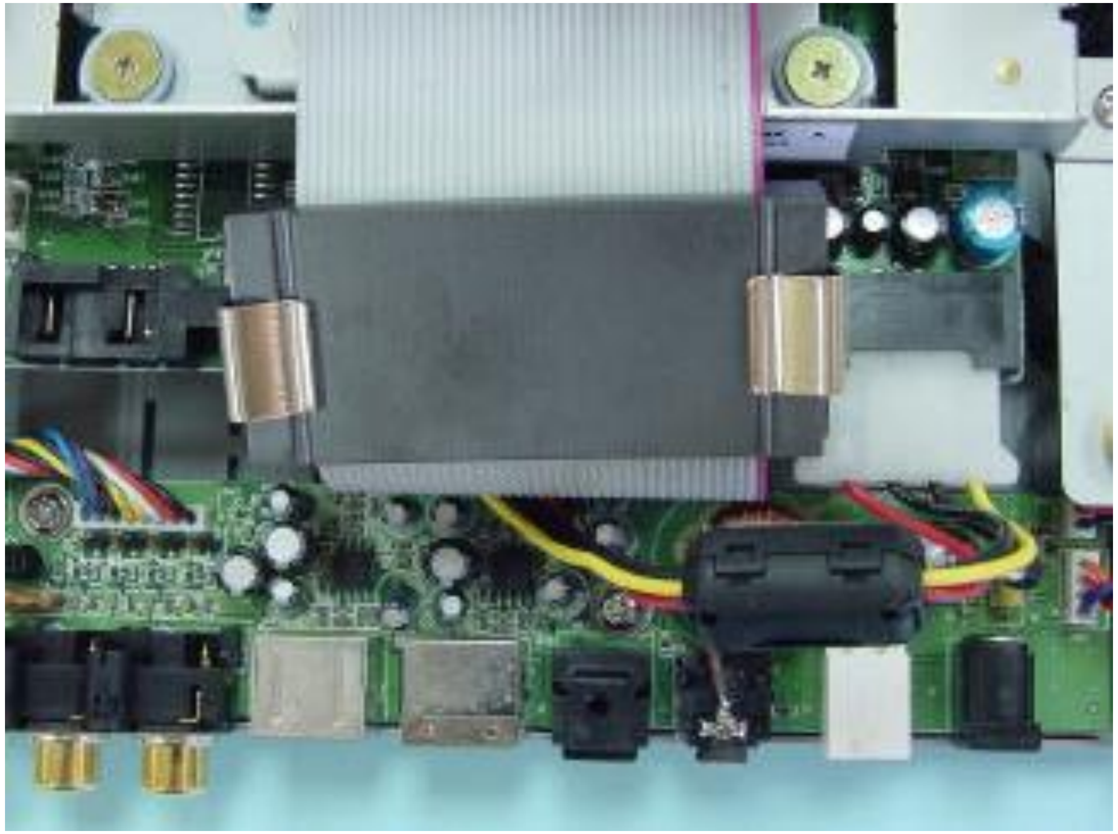
EMI conductive gasket and dispensed gasket

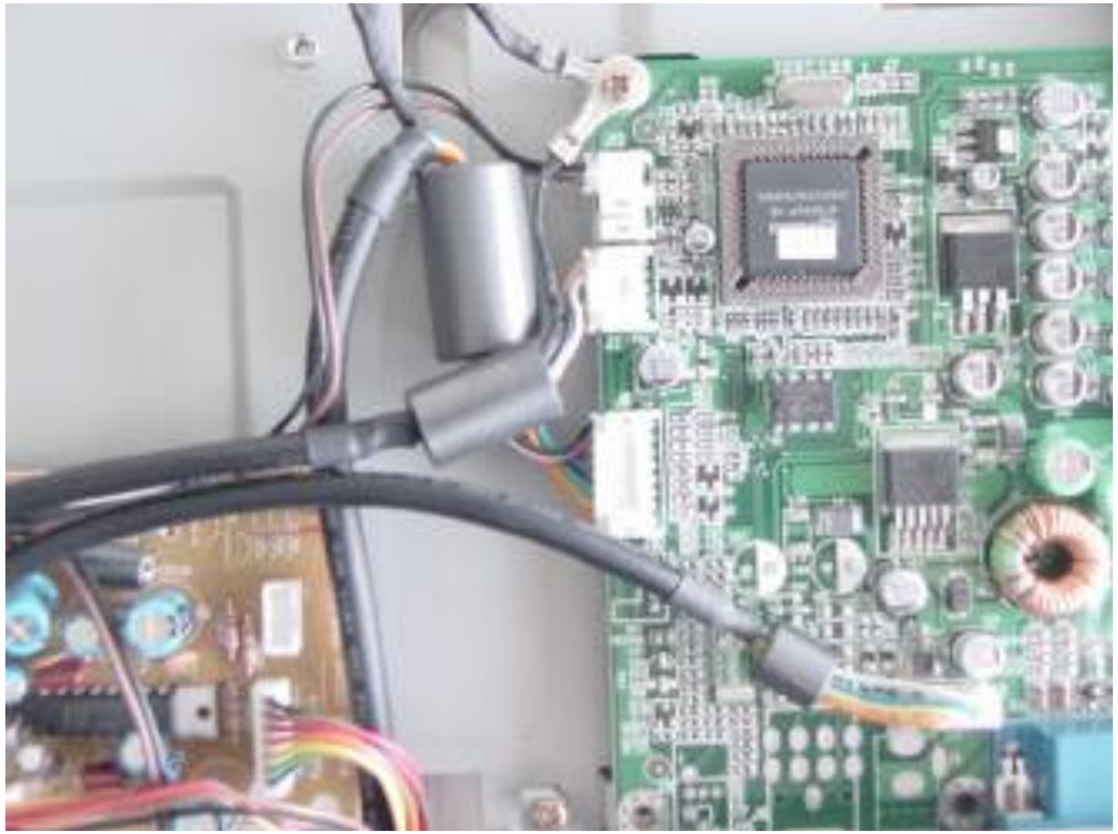
As the conductive foam or dispensed gasket is stuffed into the seam between two metals for conductivity continuity, the gasket height is advised to be 1.3 times of the seam





Ferrite core example





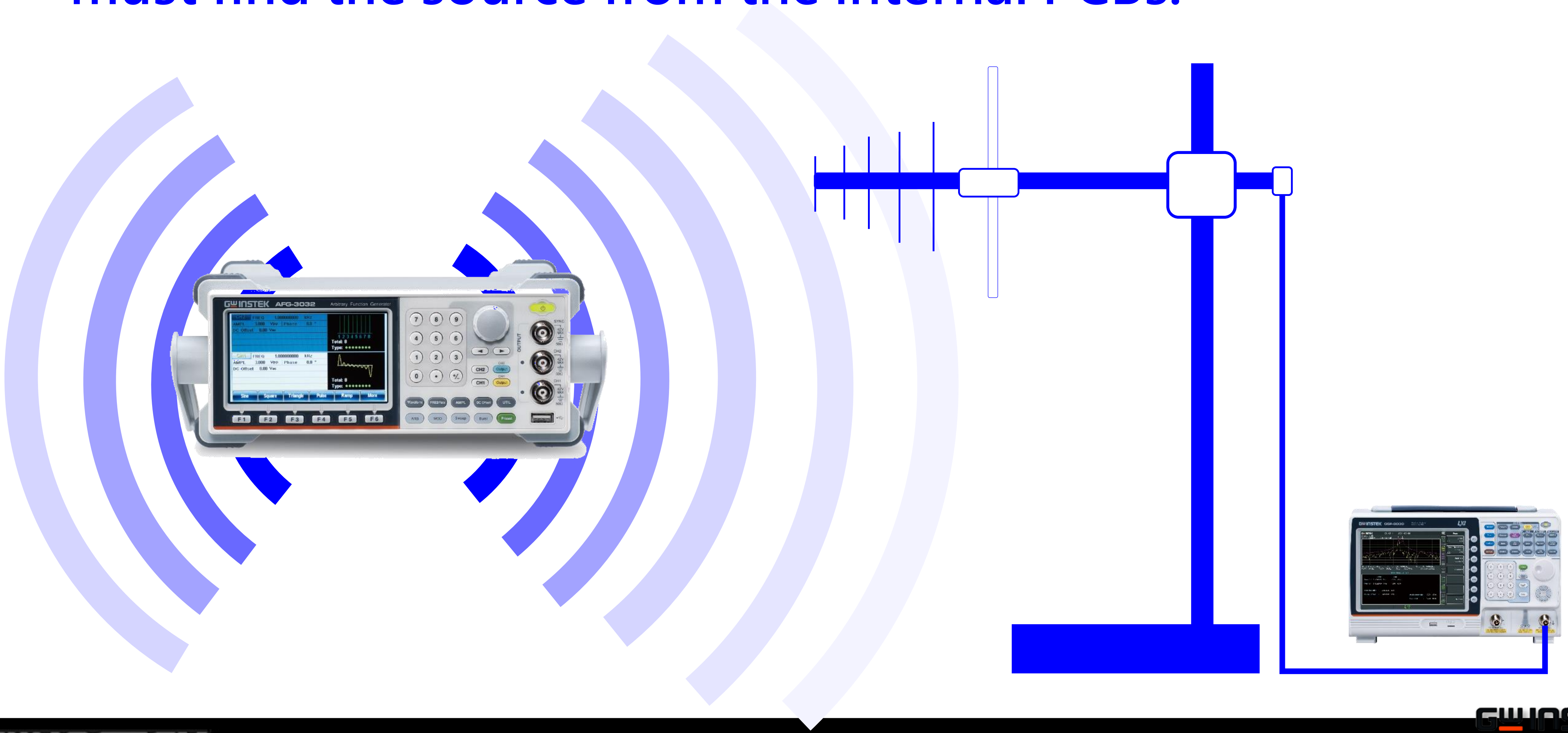
3. Guideline of PCB GND design

- The impedance of common ground of circuits must be as low as possible.
- Keep grounding path as short as possible
- Prevent unnecessary ground loops from becoming antenna.
- Enlarge the ground area as much as possible
- PCB layers, analog/digital circuits, heavy/light current, I/O port and cable ground …

Outlines

1. EMC basic concepts
2. EMI test method and test equipment
3. Basic techniques of EMI suppression
4. **EMC debugging tool**

- EMI measured from the lab is far field signals emitted by EUT.
- The source can not be identified by the results directly, one must find the source from the internal PCBs.



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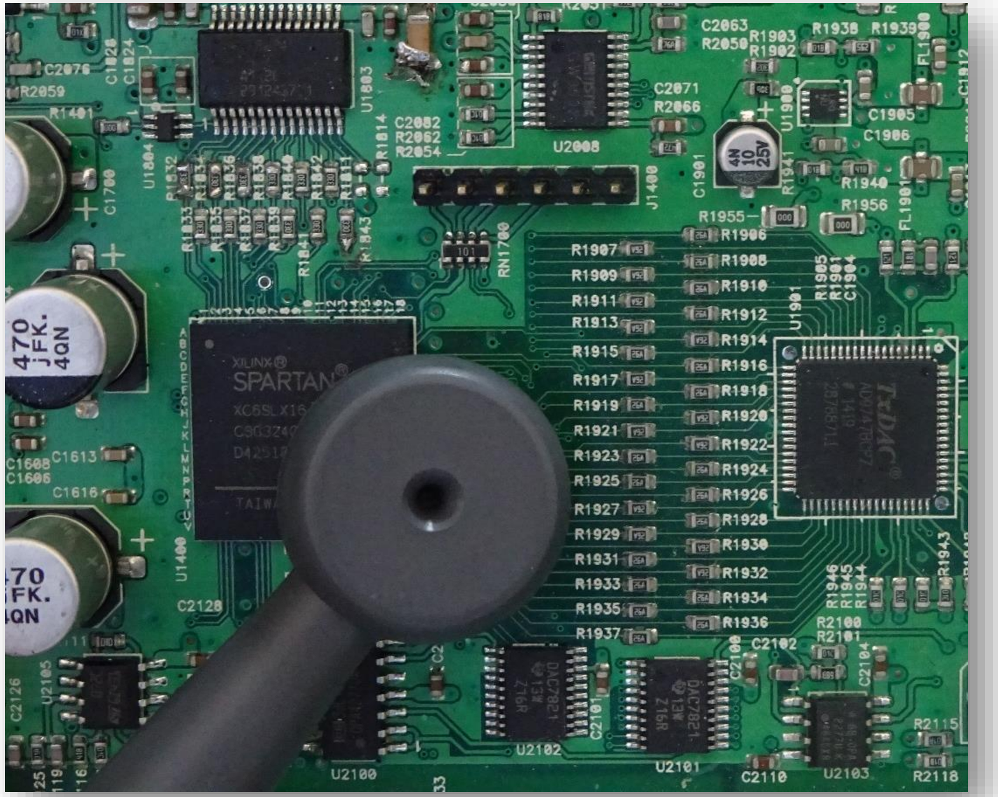
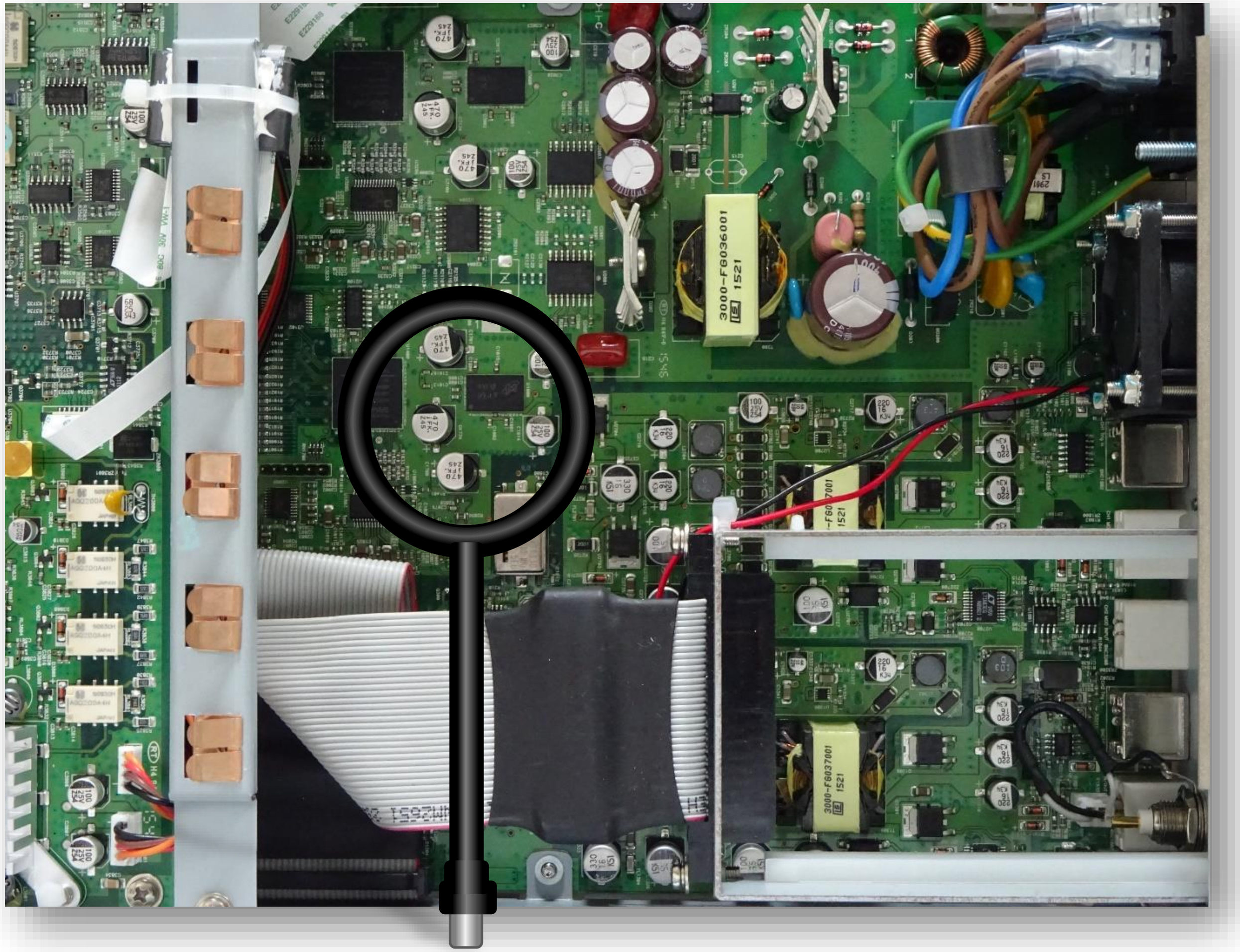
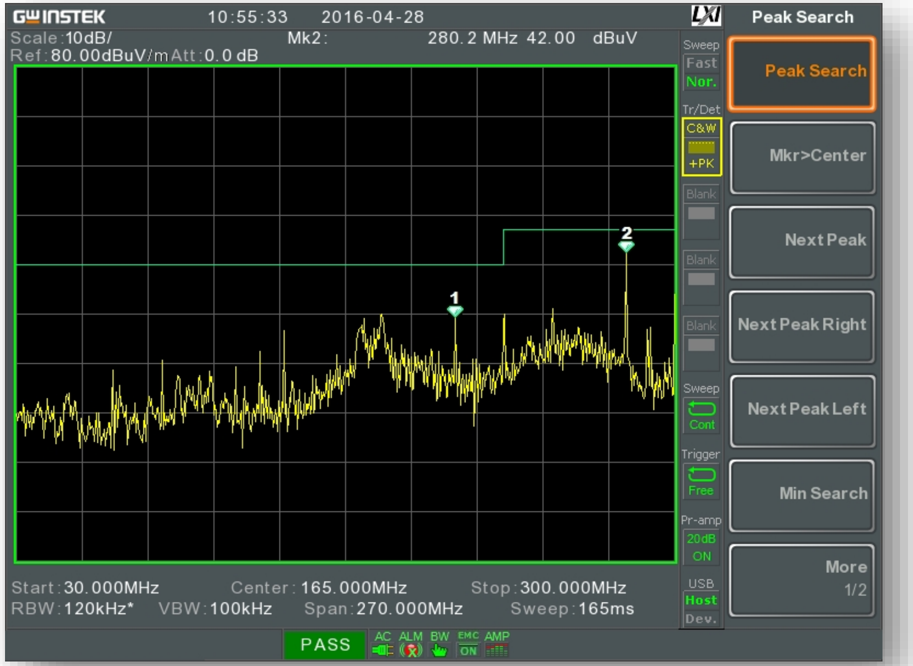
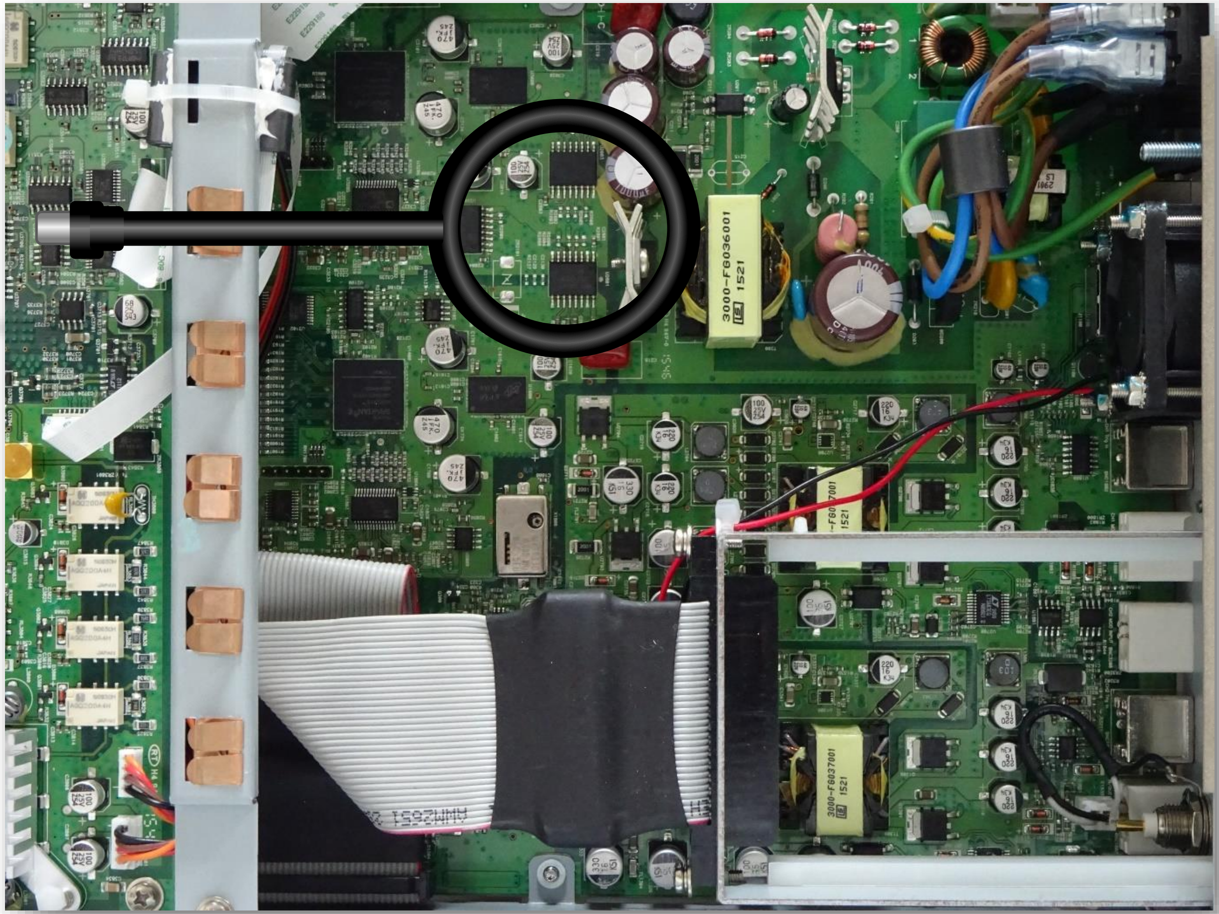


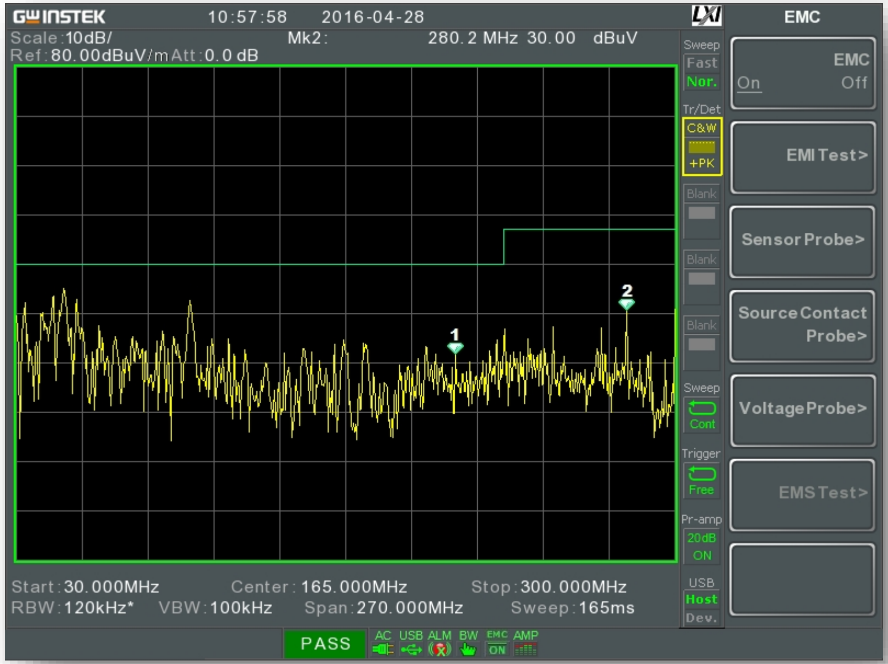
- Near field probes are used to detect the EMI signals by moving around the surface of internal PCBs or modules.



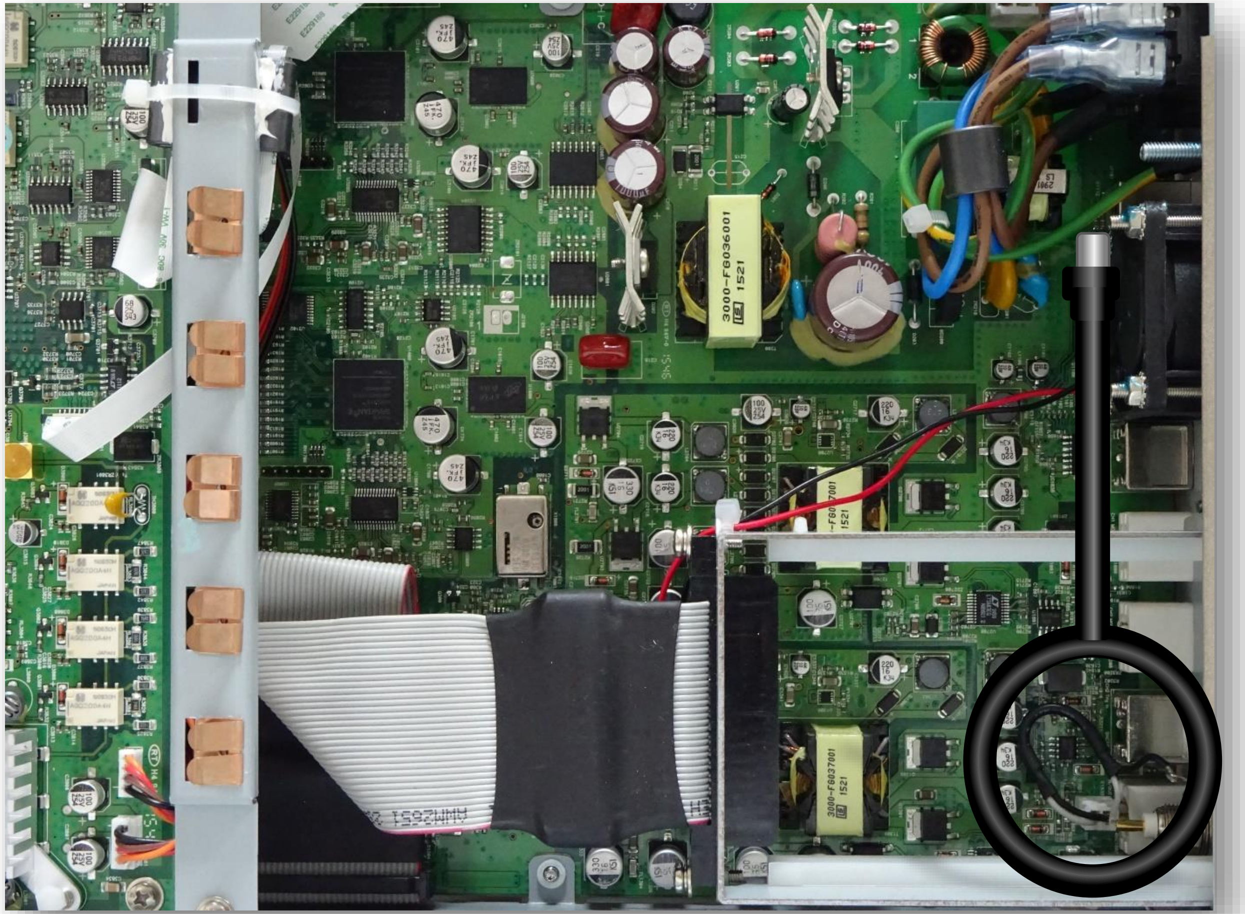


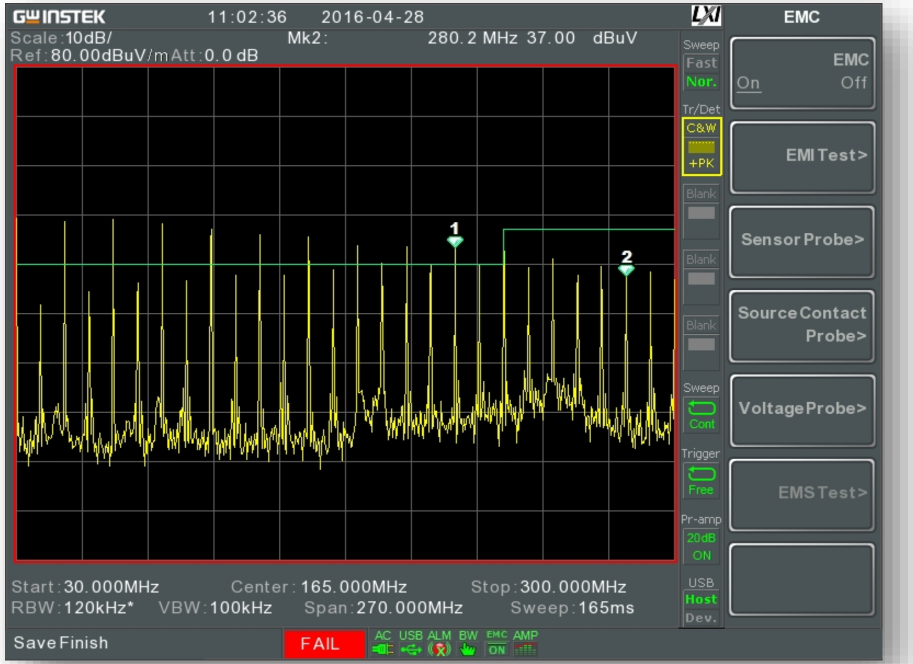
- Near field probes are used to detect the EMI signals by moving around the surface of internal PCBs or modules.



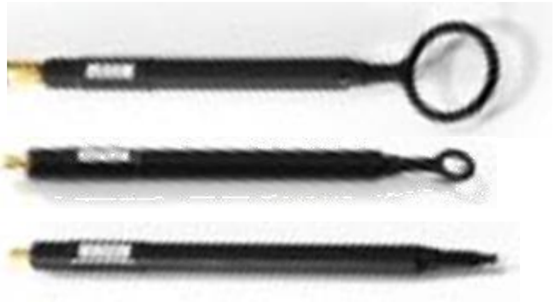


- Near field probes are used to detect the EMI signals by moving around the surface of internal PCBs or modules.



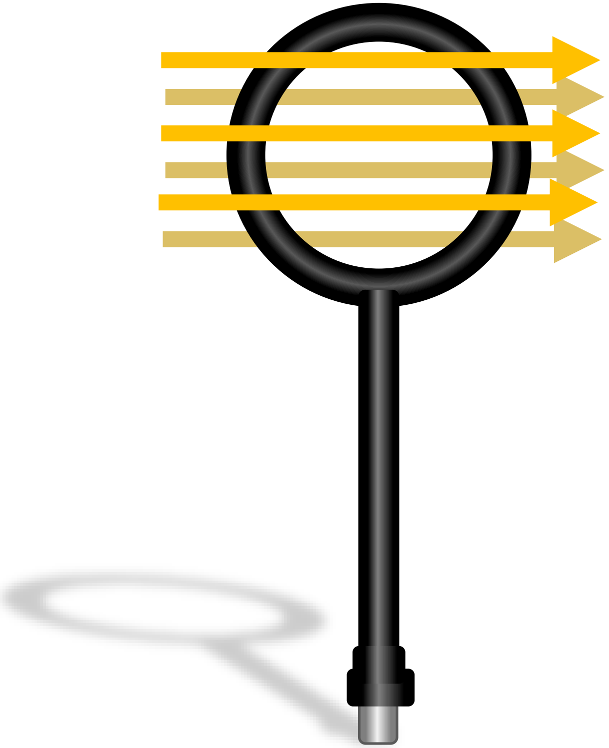


- EMI probe set provided by Keysight and R&S are as below.

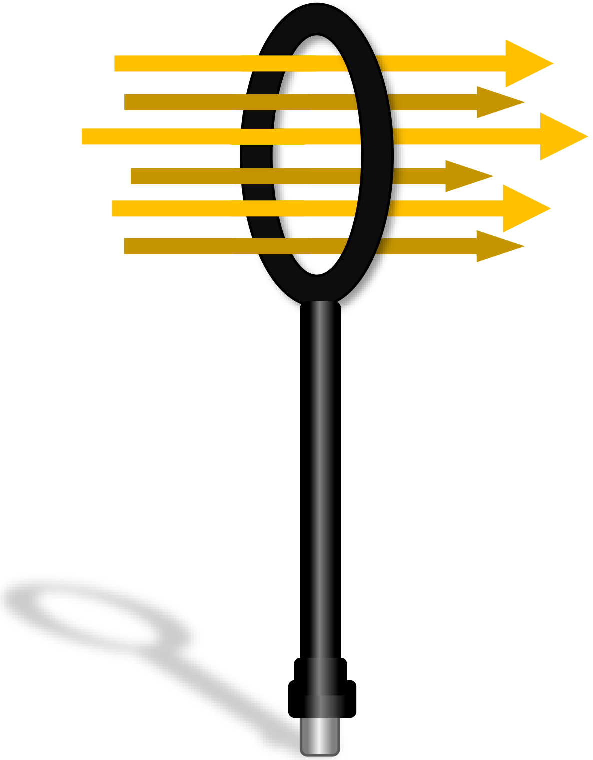
Brand	Keysight N9311X-100b Close Field Probe Set	R&S HZ-15 Probe Set
H (magnetic field) probe		
E (electrical field) probe		

Principle of H probes (loop antenna structure):

- More magnetic field passing through loop, the stronger signal is received.



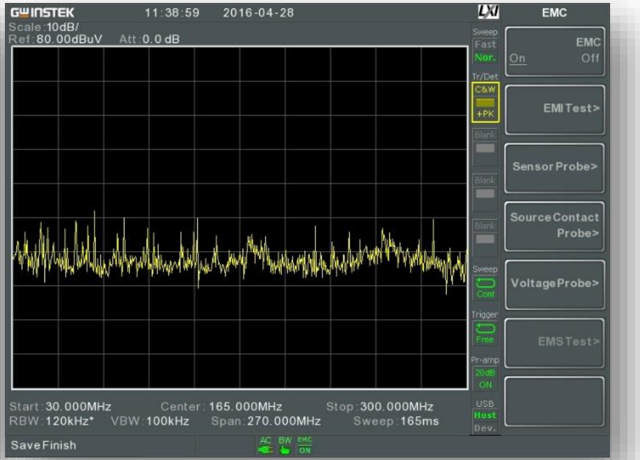
Less signals picked



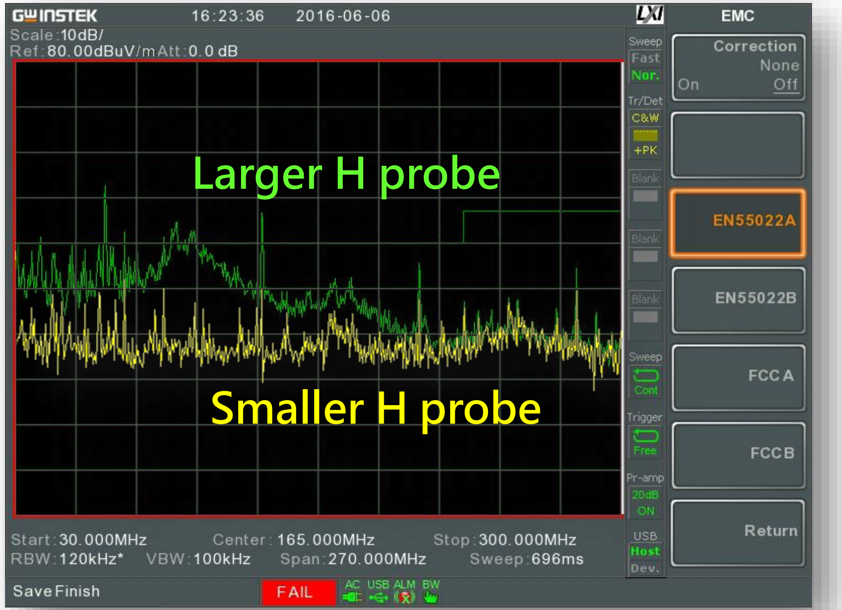
More signals picked

• Accurately identification vs Sensitivity.

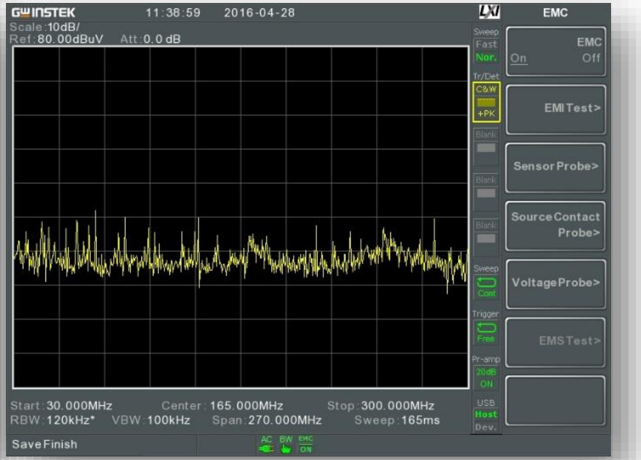

6cm H probe

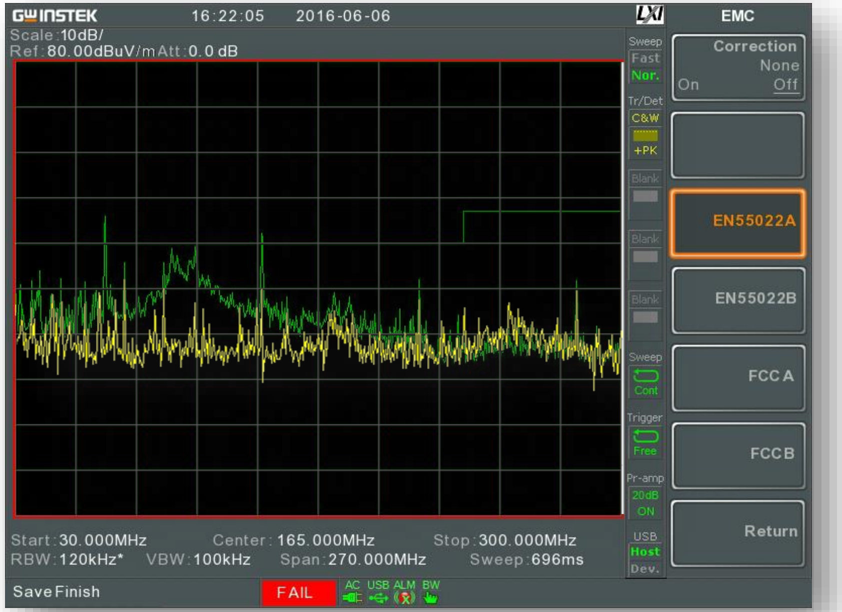
3cm H probe



- # Measurement results are different between different angles.

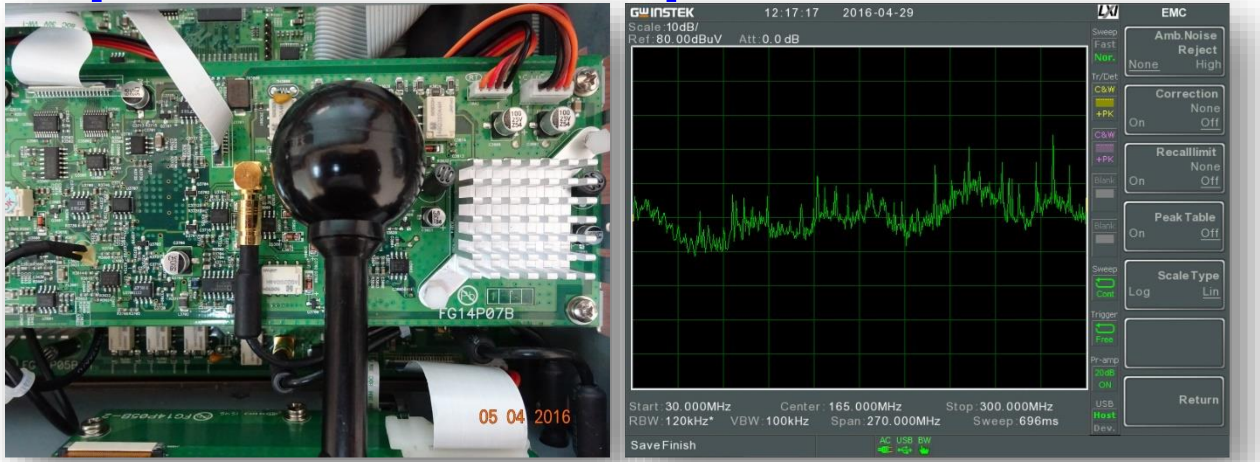


Different magnetic field probe placement angles…

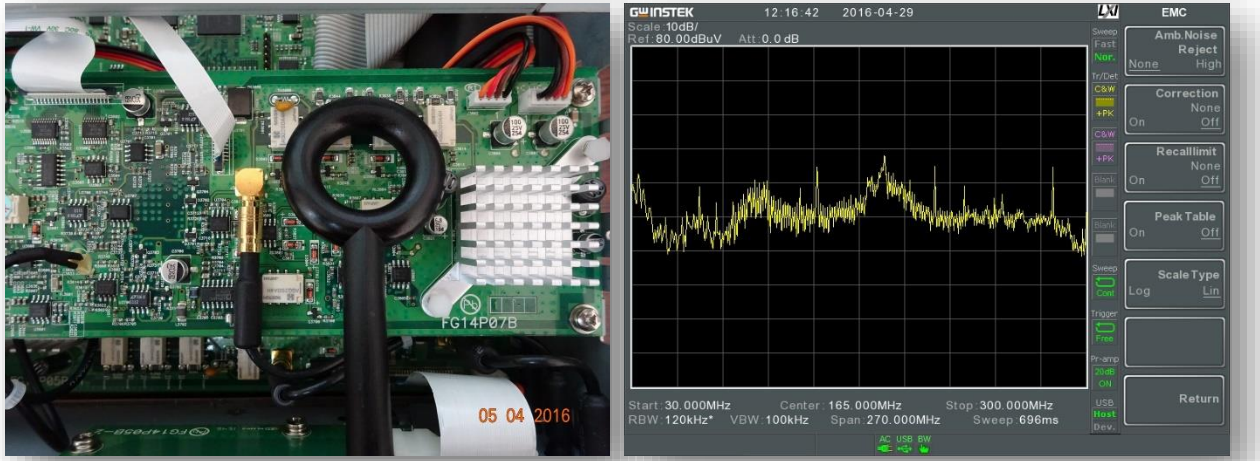


…result in different measurement results

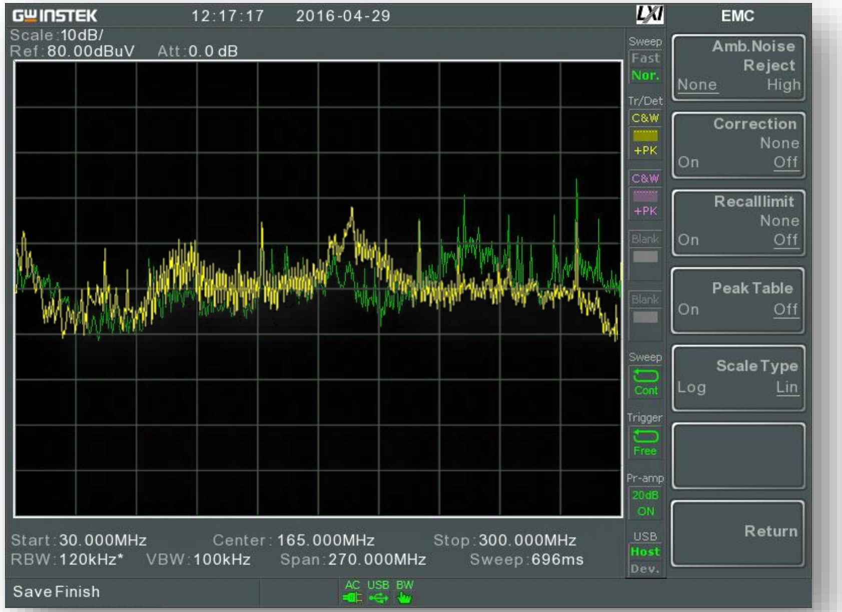
- There are different measurement results between E probes and H probes.



Measurement results of E probe



Measurement results of H probe



The distinct difference from E probe measurement

The advantages of GKT-008 near field probes

In GKT-008, two near field probes, ANT-04 and ANT-05, provide the following key advantages.

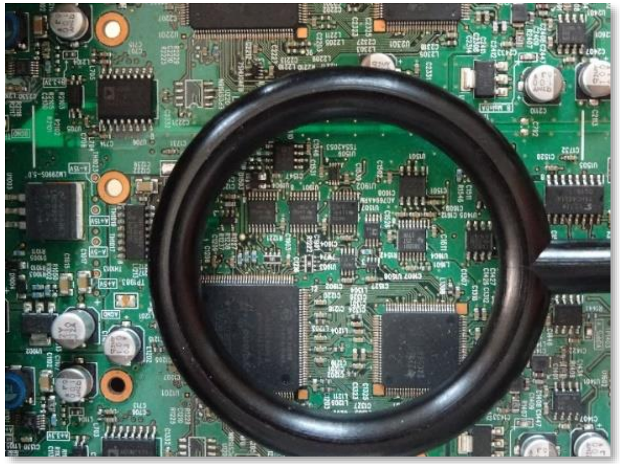
1. Small size, they can accurately identify the radiation source.
2. High sensitivity, they can directly sense EM (electromagnetic) wave's energy instead of conducting separate E-field and H-field tests .
3. Do not have to concern about placement angle issue like H probes having.

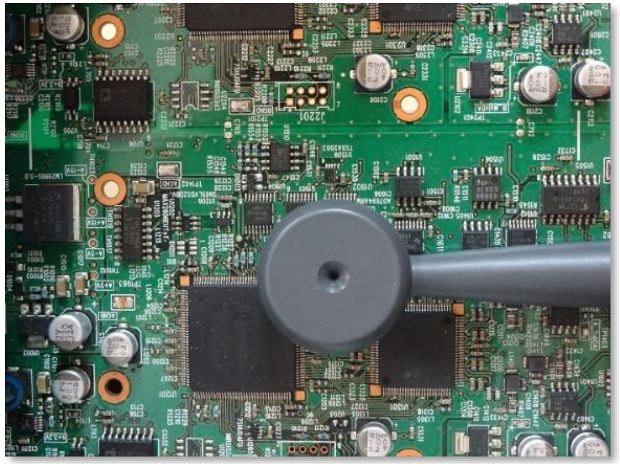
ANT-04 ANT-05

Small size can accurately identify the radiation source

The general larger near field probes are used to sense EM wave but they can not identify radiation source. GW Instek's ANT-04 and ANT-05 are small in size and have high identification resolution

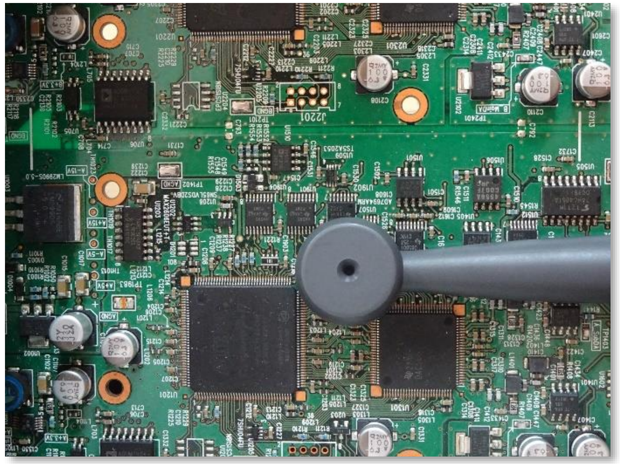
6.8cm loop H probe





ANT-04, 2.6cm

3cm metal ball E probe



ANT-05, 1.8cm

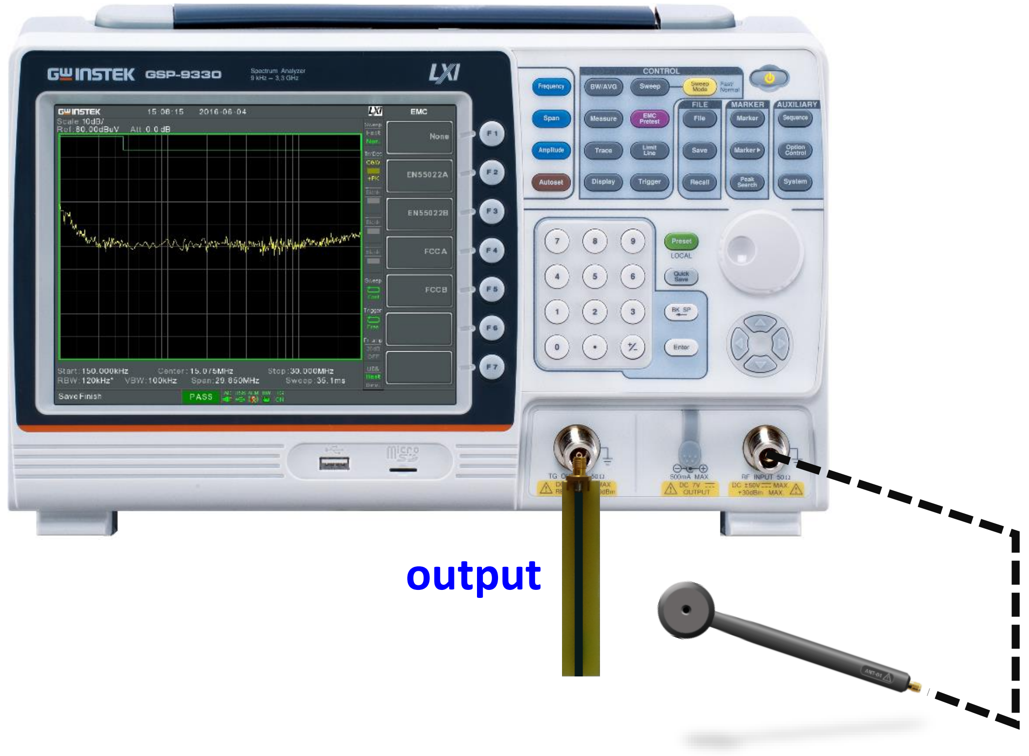
Probe comparison test

The method of comparison test

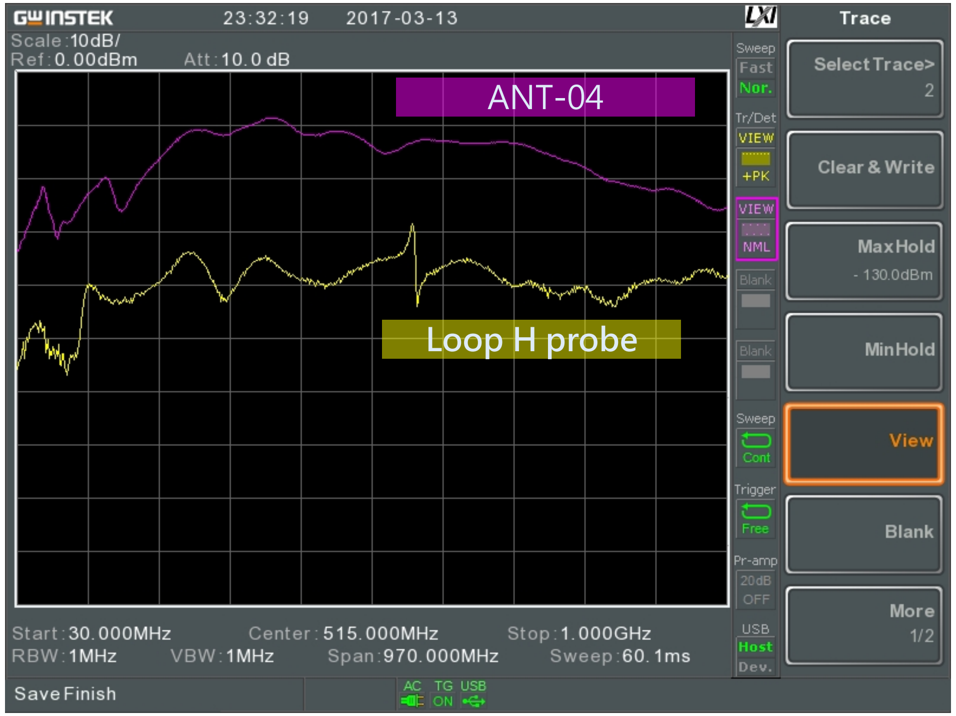
1. Use GSP-9330's TG to produce signals of 30M ~ 1GHz, 0dBm.
2. Connect TG with a PCB monopole antenna to simulate EMI signals produced by PCB layout.
3. Connect probes with SA input terminal, compare characteristics of (1)sensitivity, (2)directionality

vs

Spectrum Analyzer



Sensitivity comparison 1 : ANT-04 vs large H probe



Test results of ANT-04:

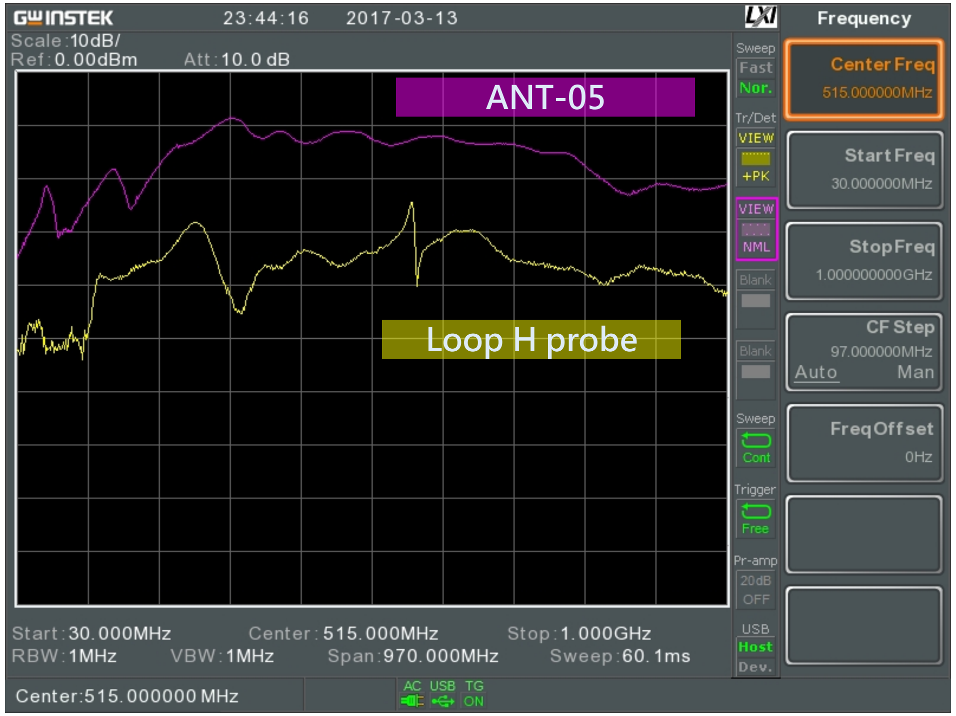
1. Smaller size
2. Better sensitivity
3. Better frequency response

Sensitivity comparison 2 : ANT-04 vs large E probe

Test results of ANT-04:

1. Smaller size
2. Better sensitivity in high frequency range
3. Better frequency response

Sensitivity comparison 3 : ANT-05 vs large H probe



Test results of ANT-05:

1. Even smaller size
2. Better sensitivity in high frequency range
3. Better frequency response

Sensitivity comparison 4 : ANT-05 vs large E probe

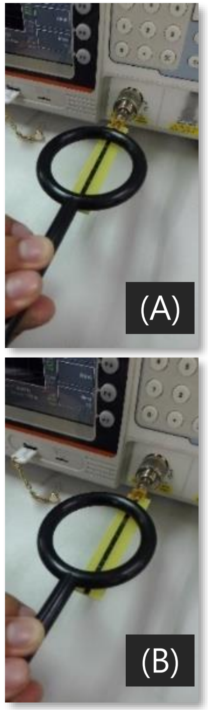
Test results of ANT-05:

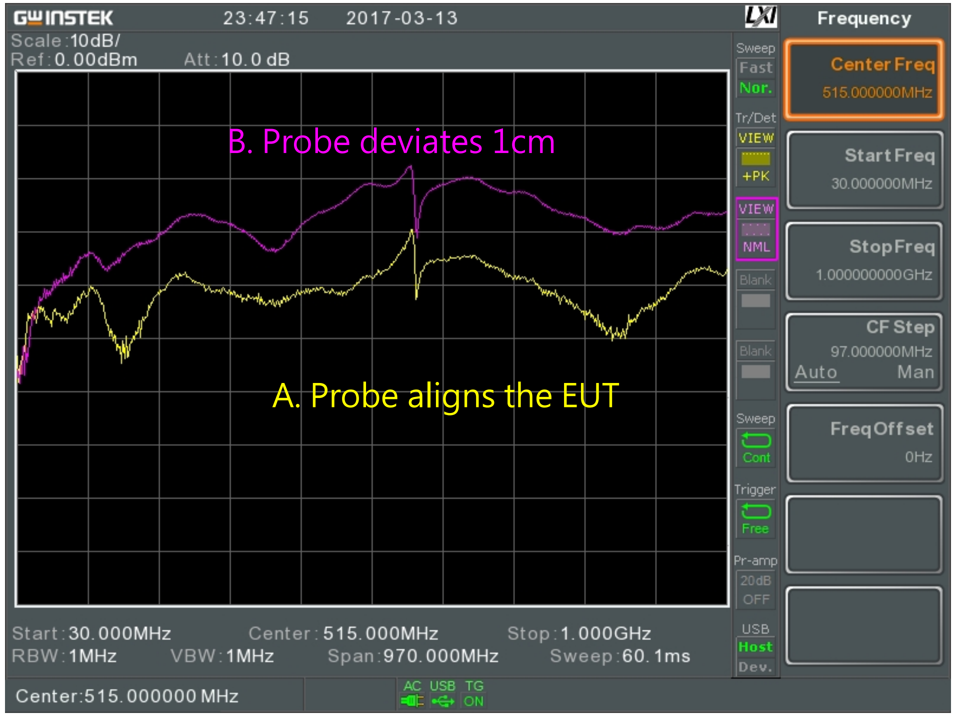
1. Even smaller size
2. Better sensitivity in high frequency range
3. Better frequency response

Directivity comparison-1 Horizontal shift: loop H probe

Test results:

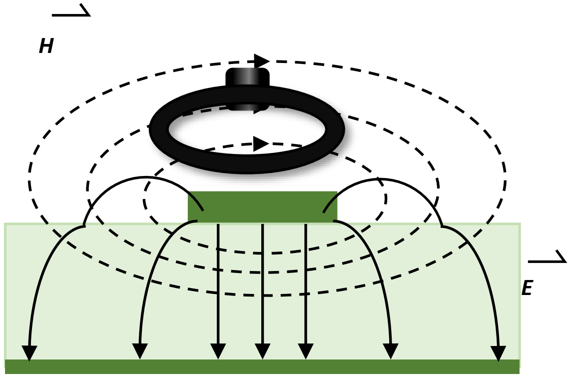
1. Loop probe has a better sensitivity while deviating 1cm (B).
2. This phenomena will cause misjudgment for electronics products with high density design.



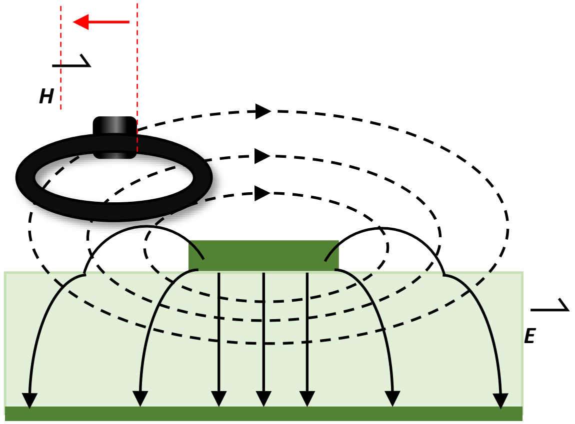


A probe aiming at the center of PCB layout can not guarantee the maximum H field be sensed.

- Diagram a shows the probe is placed directly above PCB trace can not sense maximum signals.
- In diagram b, more magnetic field passes through and stronger signals can be obtained if deviating a distance.



a. A Probe placed directly above the PCB

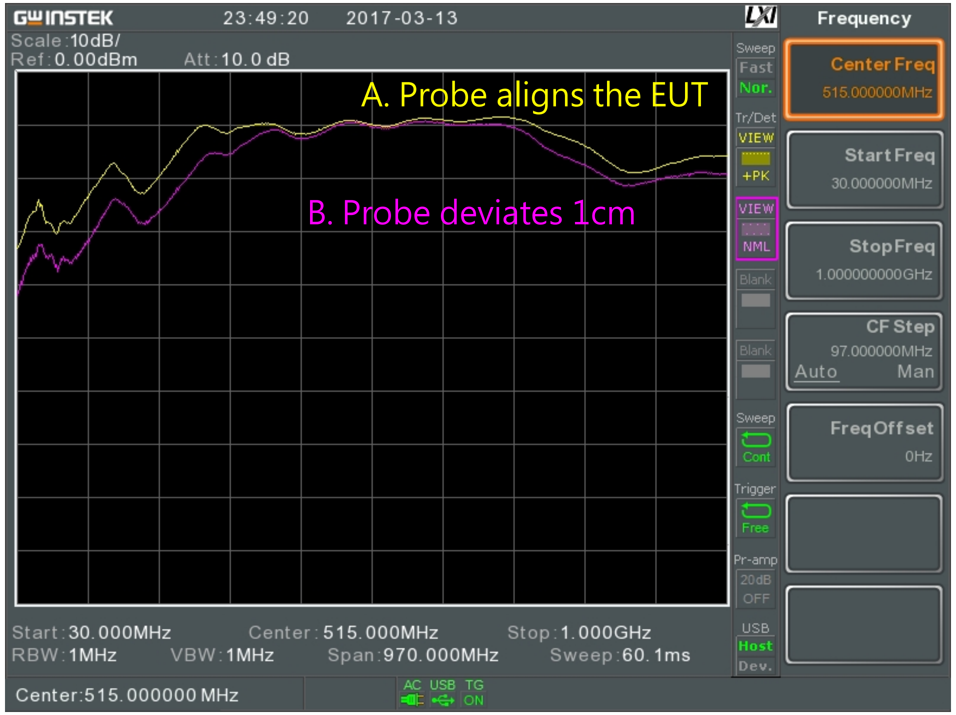


b. A slight distance deviation from the center

Directivity comparison-2 Horizontal shift : ANT-04

Test results:

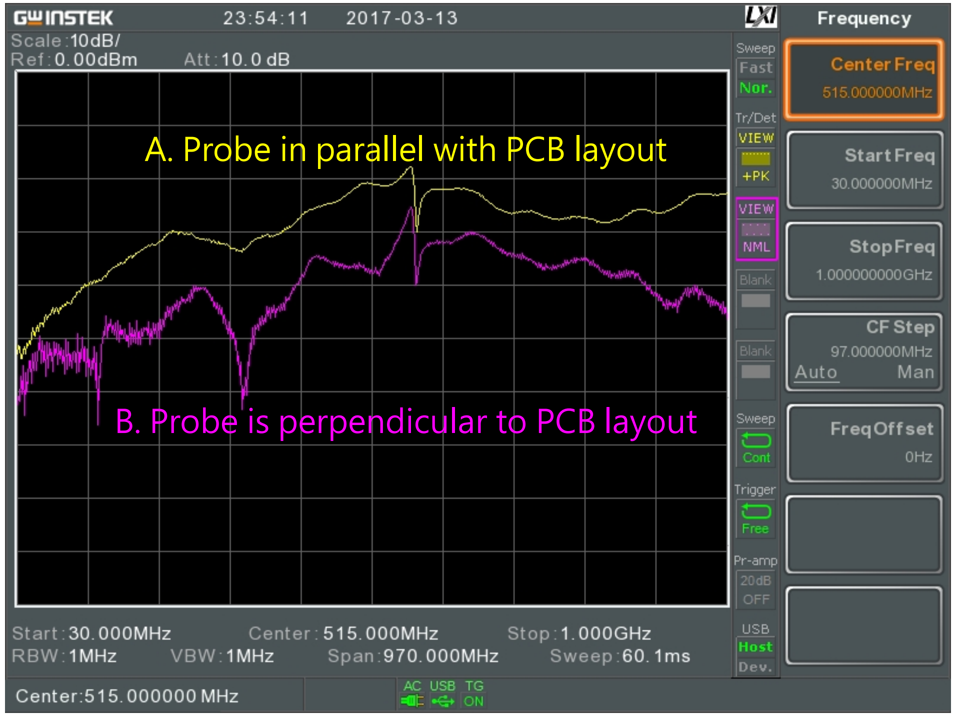
1. ANT-04 obtains more signals when aiming at the center of EUT (A)
2. 1cm deviation resulted in weaker signals. This phenomena will not cause misjudgment



Directivity comparison-3 Different angles: loop H probe

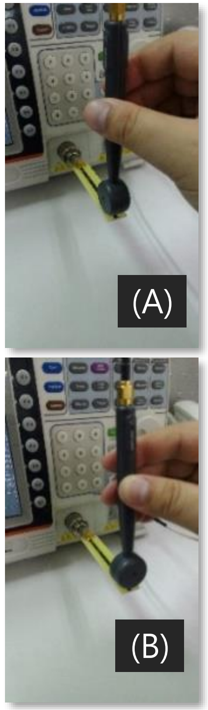
Test results:

1. More signals obtained when a loop H probe is in parallel with PCB layout (A)
2. Less signals obtained when a loop probe is perpendicular to PCB layout (B) 。



Directionality comparison-4 Different angles: ANT-04

Test result:
ANT-04 has almost identical and stable measurement results when it is in parallel and perpendicular to PCB layout



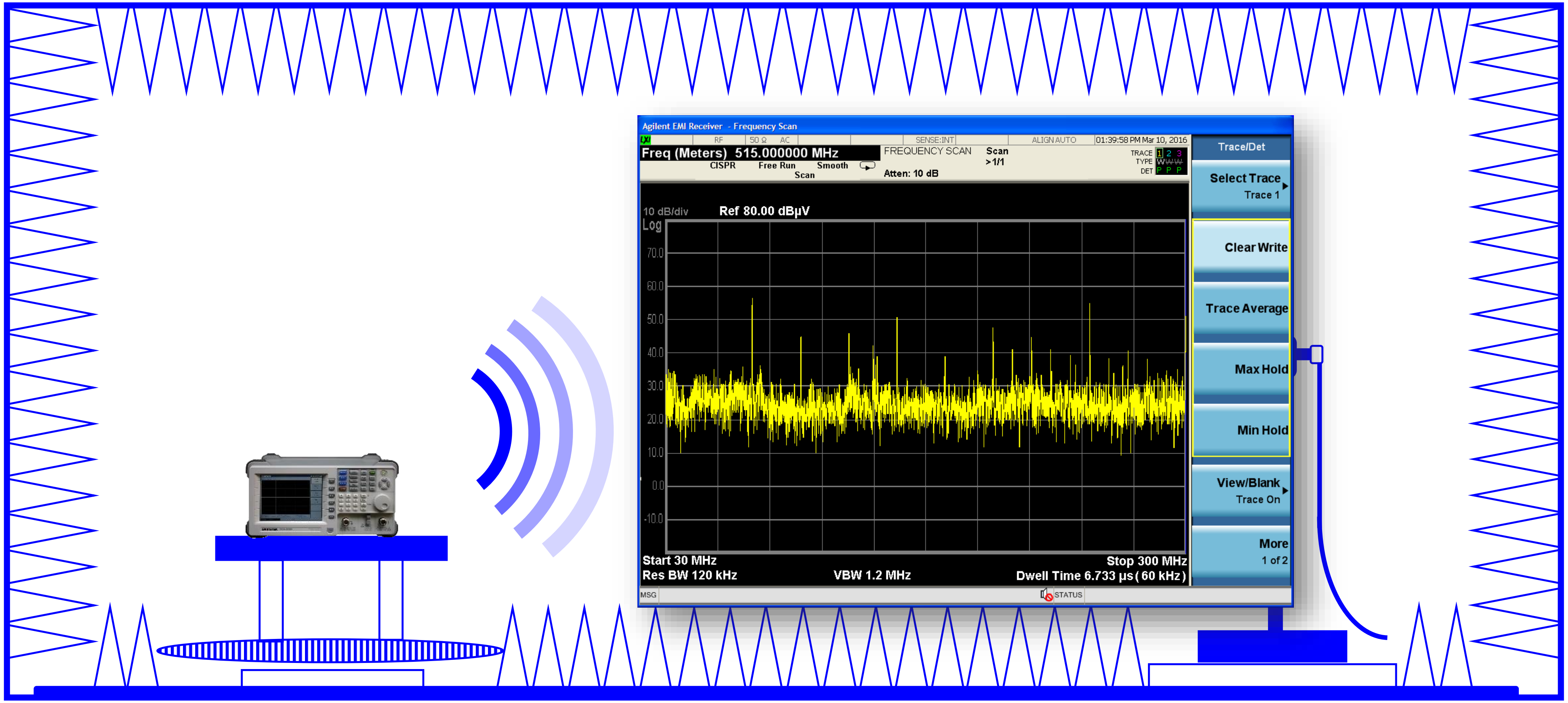
The EMI test result comparisons to anechoic chamber

H, E probes

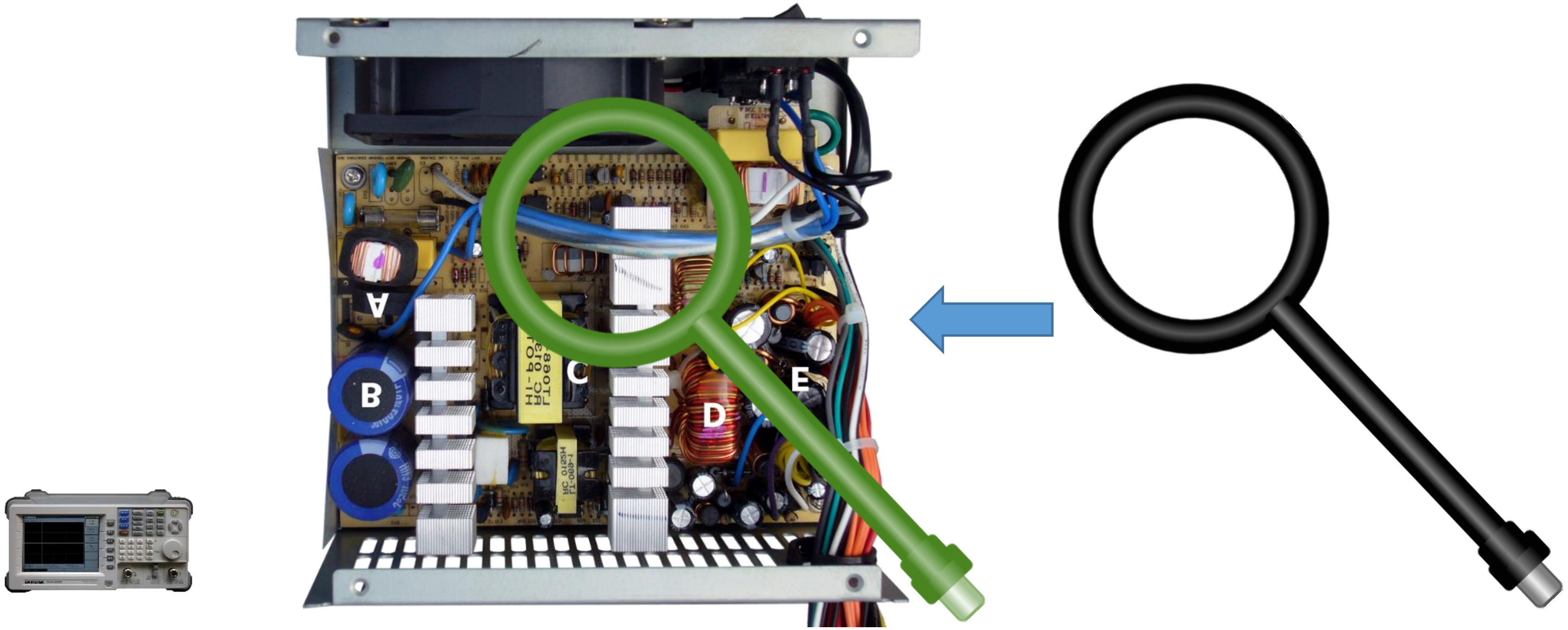
vs

ANT-04

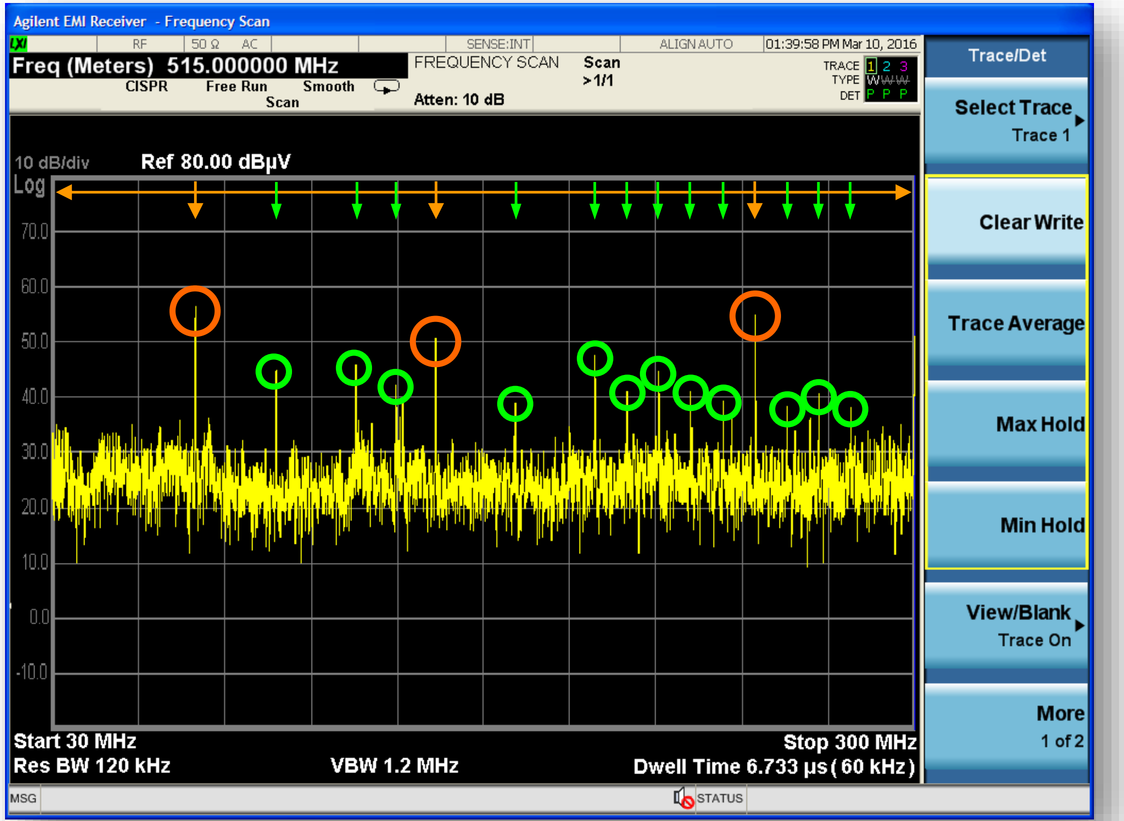
The EUT is tested in anechoic chamber. The EMI spectrum distribution is as below.



Open the box, the internal switching power board is considered as the source. First, use H probe to measure the switching power supply module.



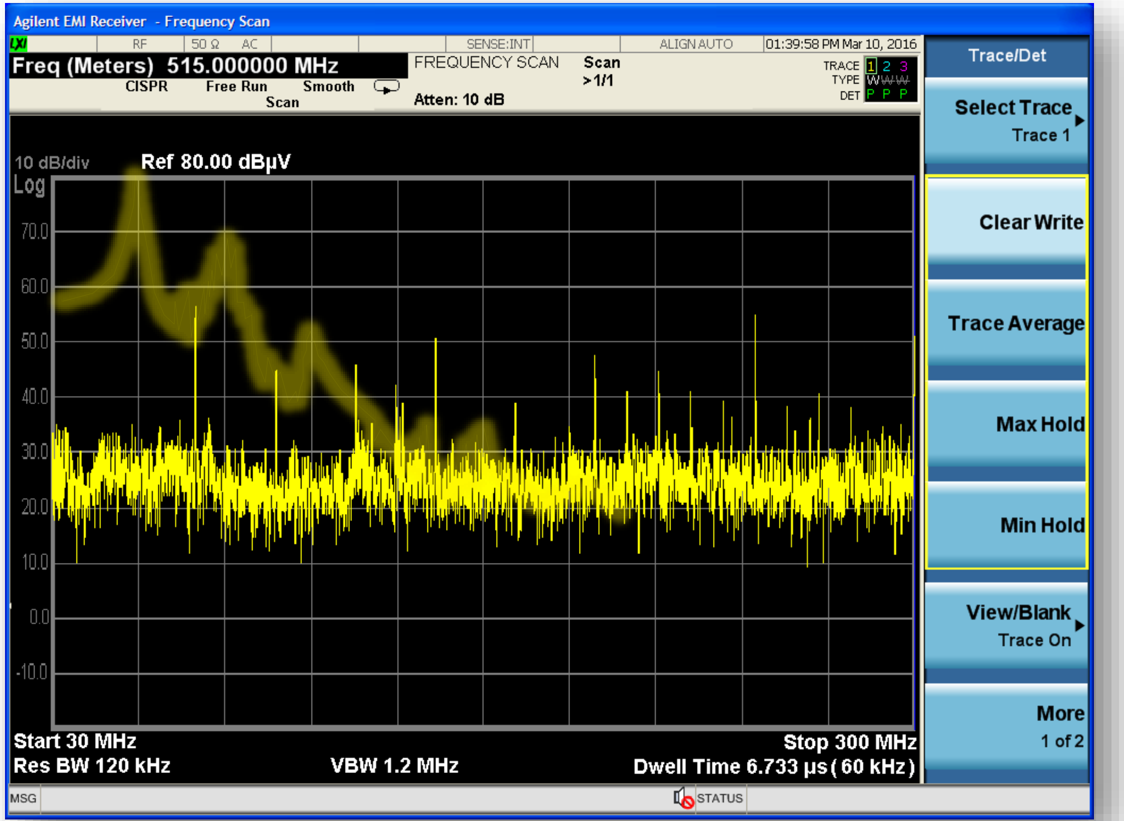
The result of H probe are very different from chamber's result.



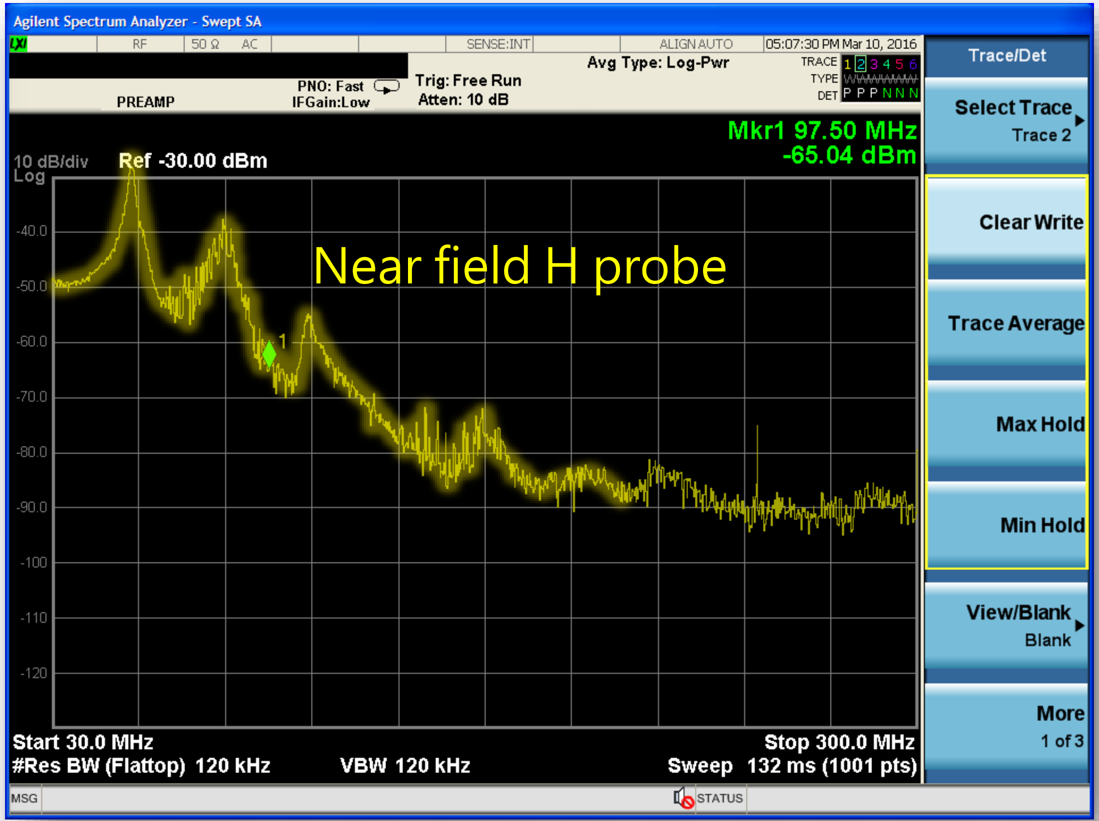
The test result of 3m anechoic chamber

Power supply module's EMI test result

The loop H probe obtained a high composition at low frequency bandwidth but it does not necessarily radiate and become an EMI.

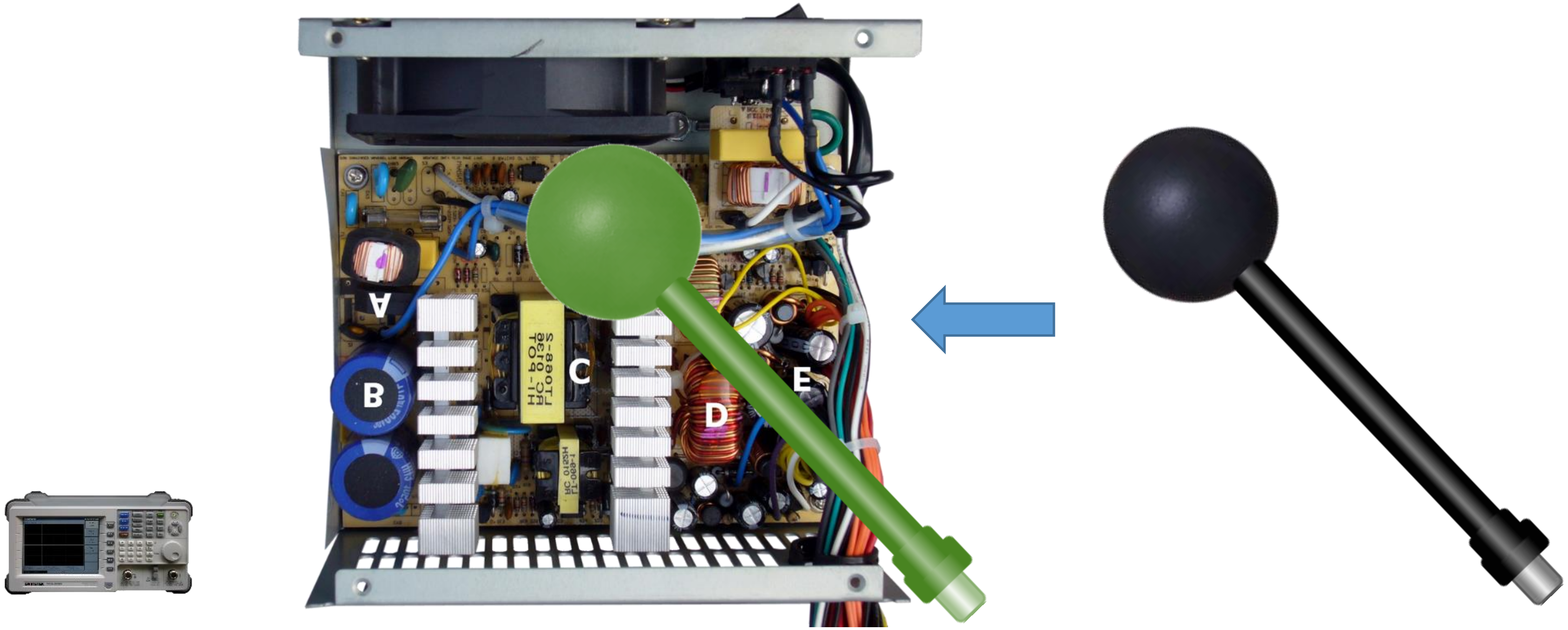


The test result of 3m anechoic chamber

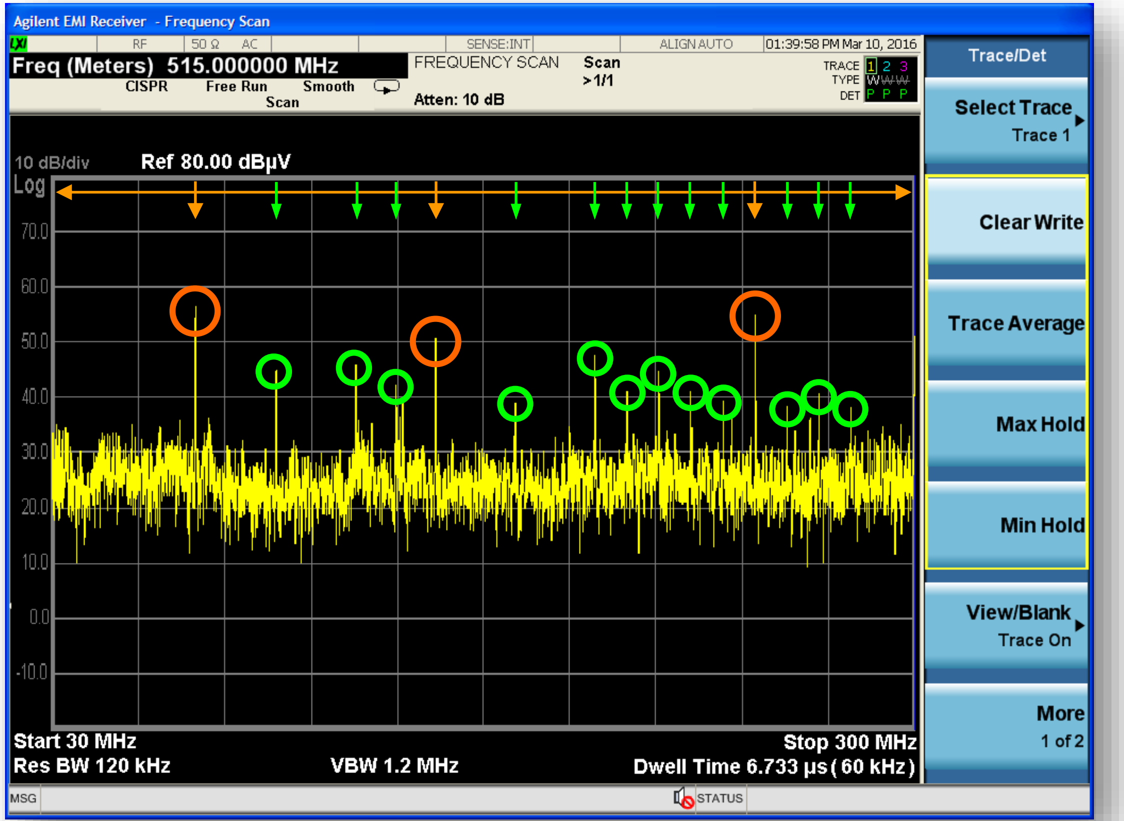


Measurement results of various near field probes

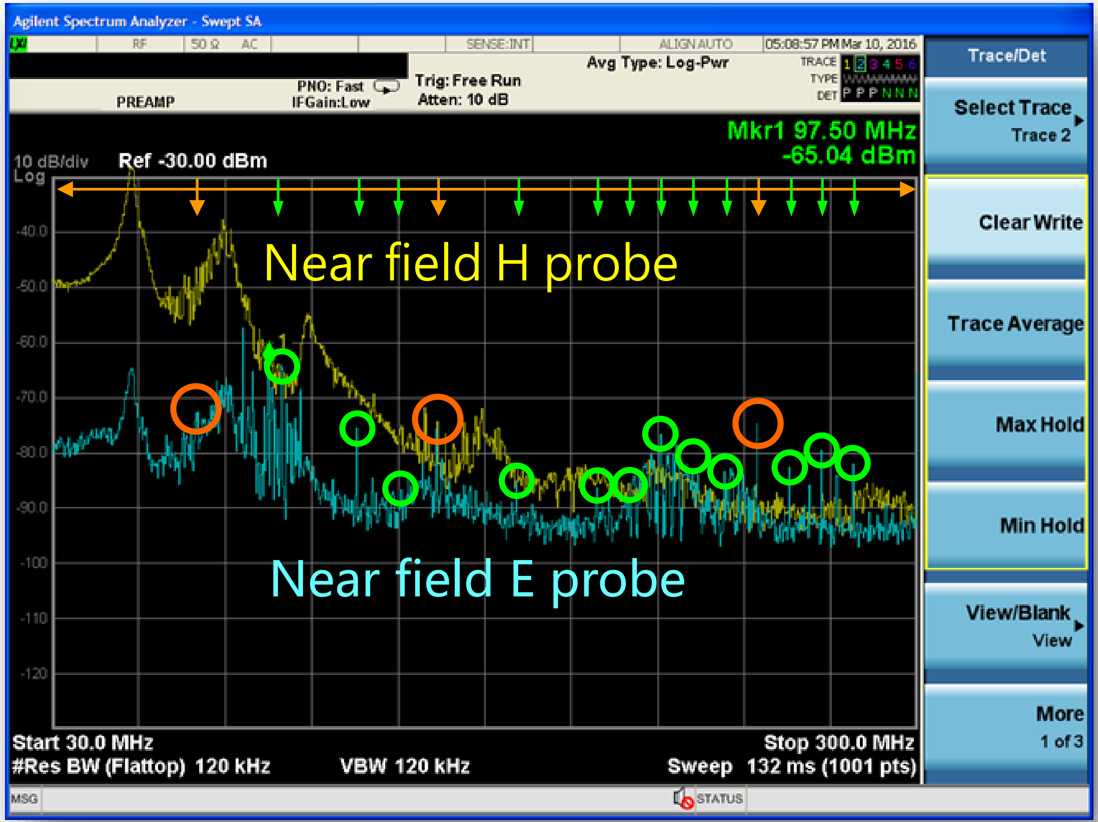
Next, use an E probe.



Next, use an E probe. The result shows EMI is low, especially the difference is greater for low frequency bandwidth.

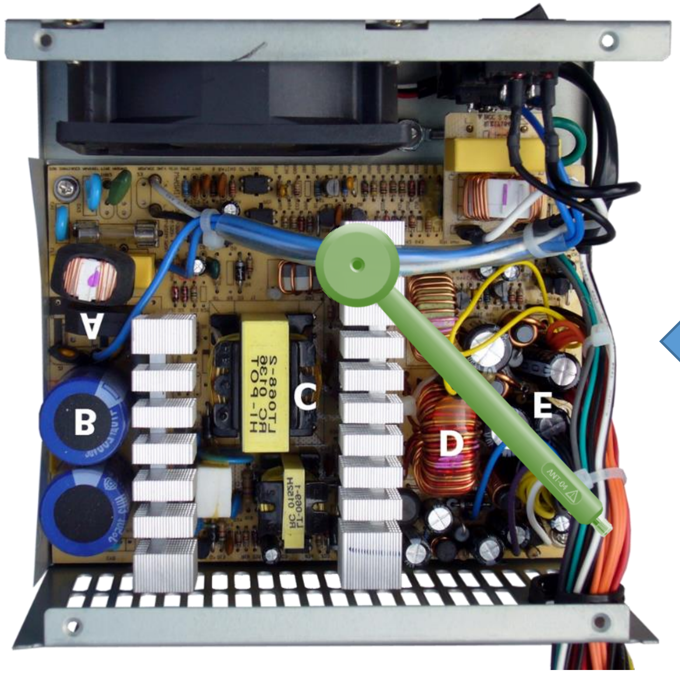


The test result of 3m anechoic chamber

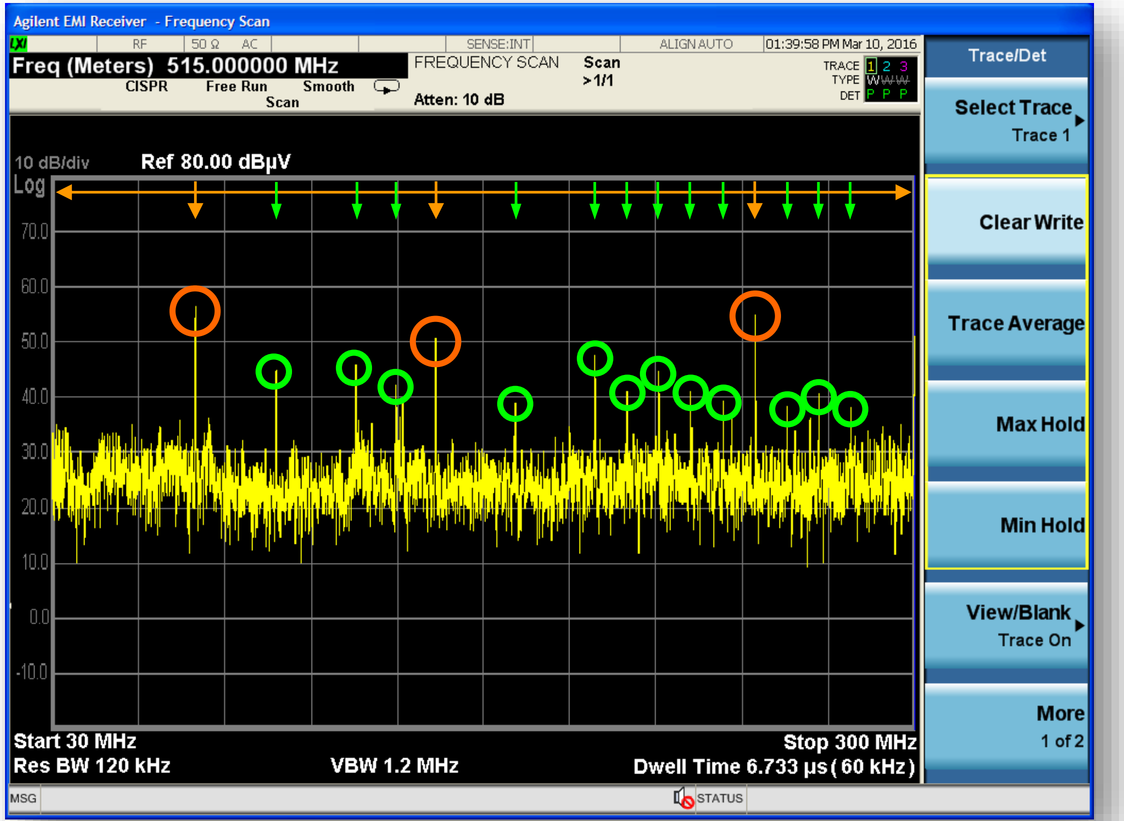


Power supply module's EMI test result

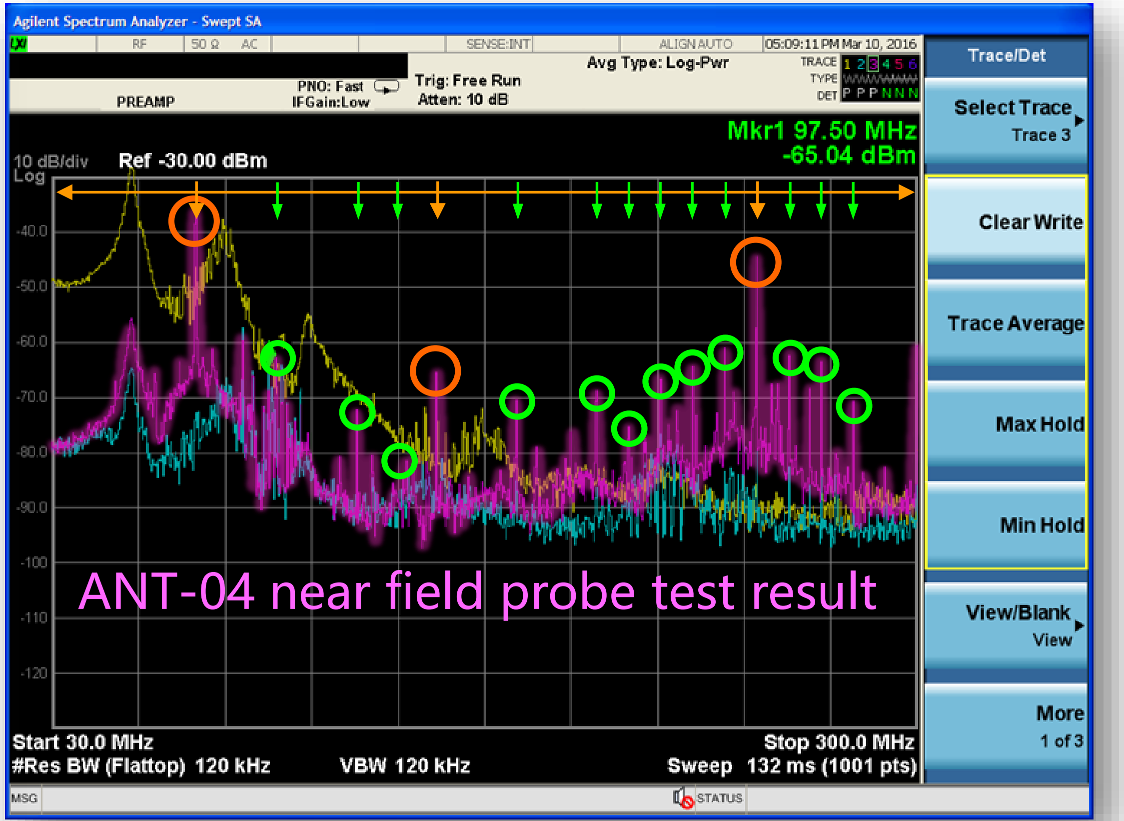
Finally, use an ANT-04 from GKT-008 to conduct measurement on the same location.



Finally, use an ANT-04 from GKT-008 to conduct measurement on the same location. The result is very close to that of anechoic chamber and it is an excellent reference.



The test result of 3m anechoic chamber



ANT-04's measurement result is a better reference

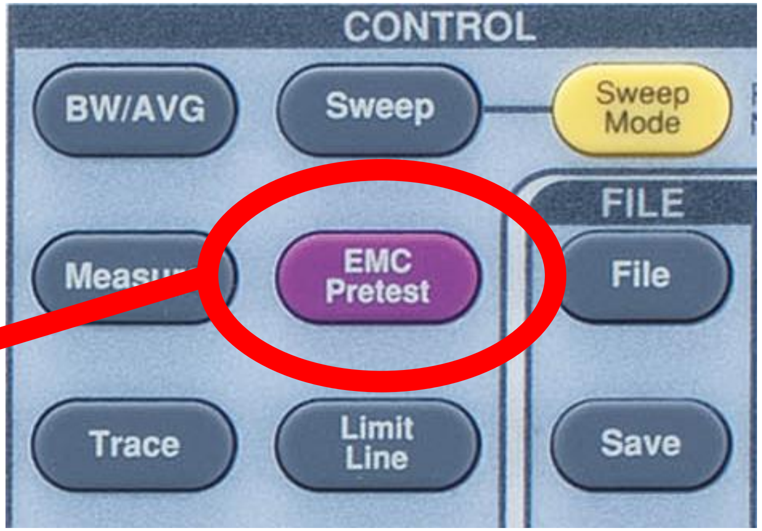
Conclusion: Features of ANT-04, ANT-05

1. Patent design, small size
2. High sensitivity, better frequency response
3. Directly sense near field EM wave's energy without conducting separate E field and H field tests
4. No directivity, no misjudgment of interference source
5. EMI debugging efficiency is greatly enhanced

More about GSP-9330 and GKT-008

- User-friendly interface for EMC test
- The logarithmic scale frequency setting
- Far field estimation
- EMS pre-test by GSP-9330 TG
- Contact probe and PCB Trace and cable EMI estimation
- PR-01 for conducted noise detection
- Battery operational

Built-in Dedicated EMC Pretest Functions

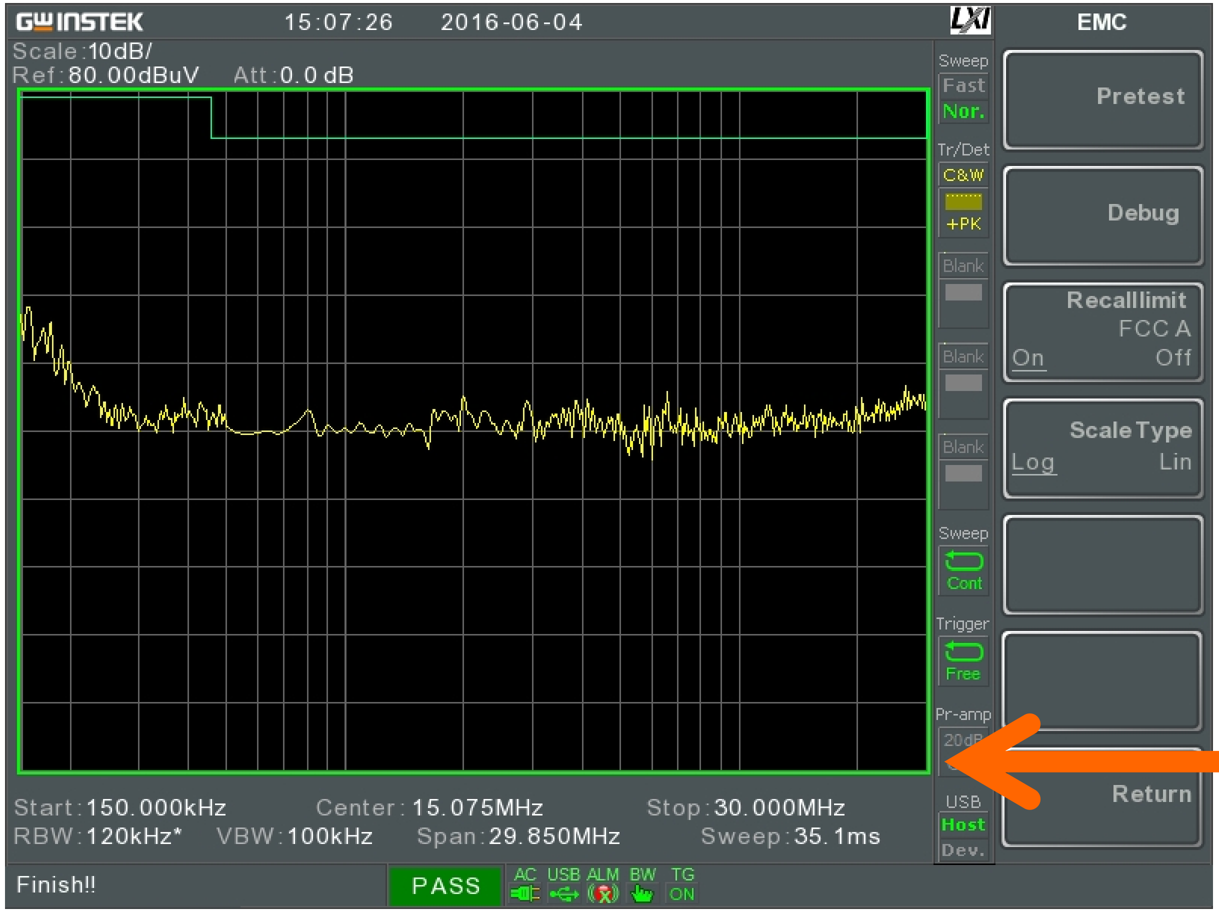


Built-in Dedicated EMC Pretest Functions

- Five Common EMC Functions
- Built-in Standard Frequency Setting
  - ✓ Band A: 9k – 150kHz
  - ✓ Band B: 150k – 30MHz
  - ✓ Band C: 30M – 300MHz
  - ✓ Band D: 300M – 1,000MHz
  - ✓ Band E: above 1GHz
- Ambient Noise Rejection
- Antenna Factor / LISN Correction Factor
- Built-in Limit for ITE Type
  - ✓ EN55022
  - ✓ FCC Part 15

Log scale frequency setting

In conducted test of EMC mode, the frequency can be set log scale which speeds up the product time to market.

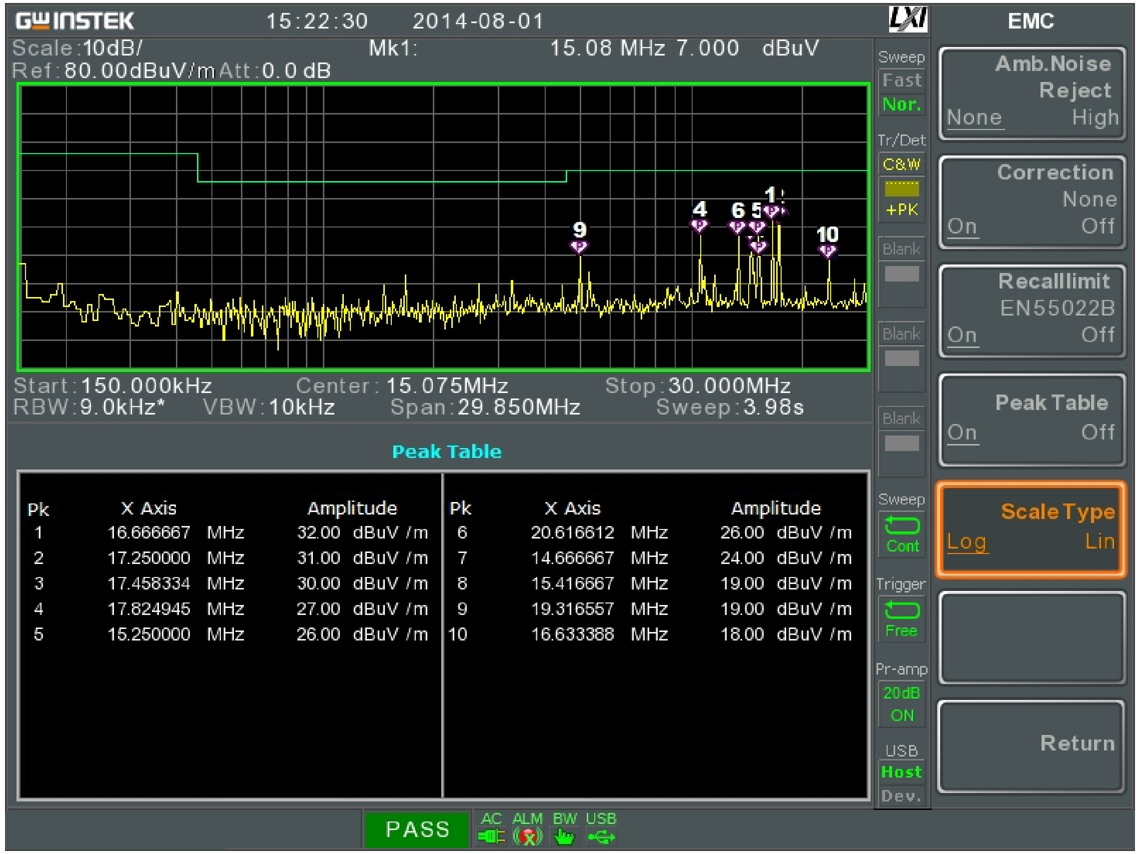


Easy to Inspect

- The status of the test results are represented in a clear-cut manner

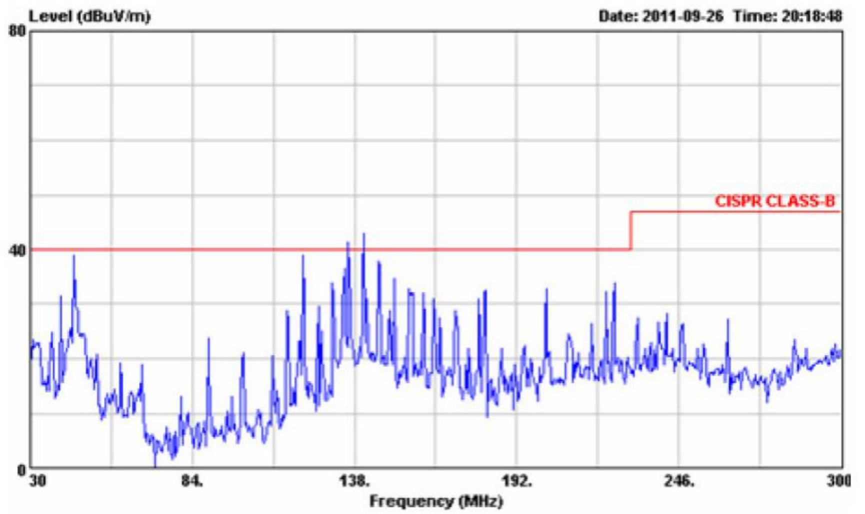
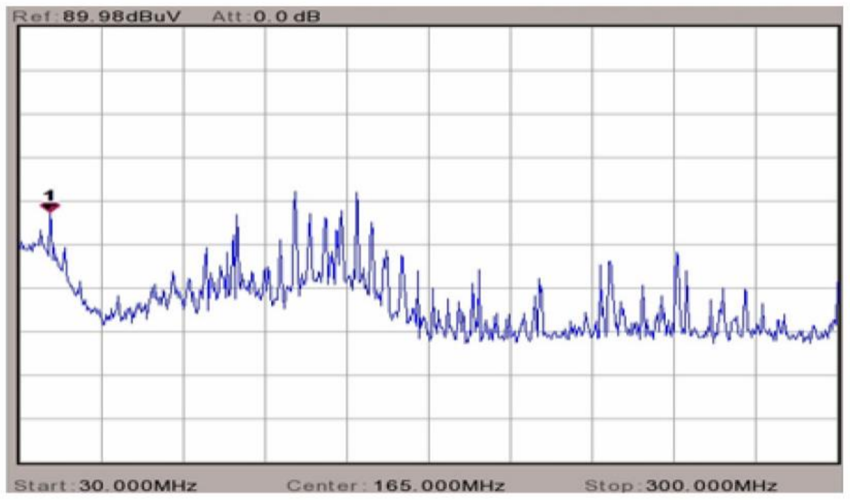
Peak table

- Maximumly 10 peak EMI noise signals can be picked and sowed in the table.



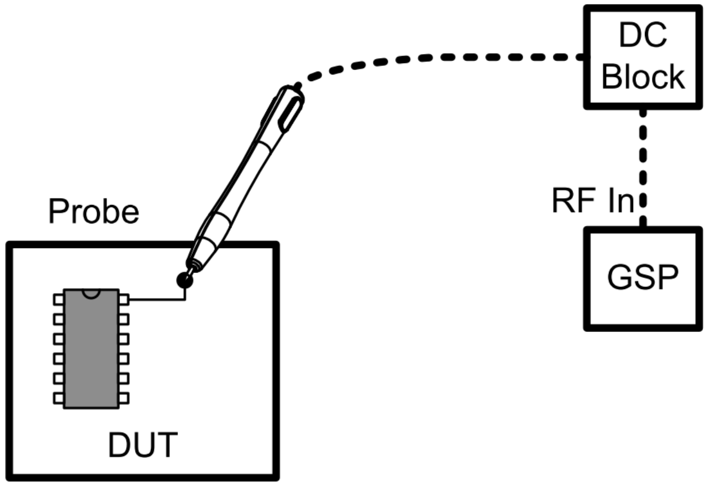
Far-Field Frequency Response Estimation

- Emulate 3/10m test site
  →it needs reference data from real 3/10m test site to compare firstly.

In 3M Far Field	Near Field with 3M Correction
	

Source Contact Probe

- Ground and power noise
- PCB trace noise
- IC pin output noise
- I/O pin output noise
- Confirmation of filter effectiveness

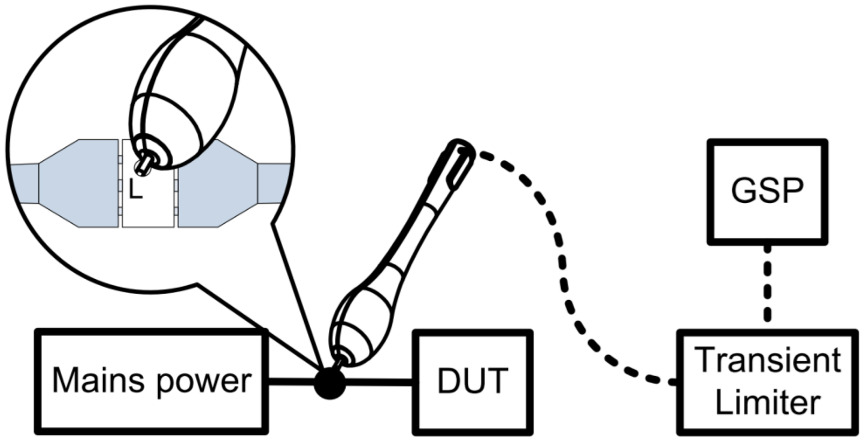


The AC voltage probe PR-01 included in GKT-008 is able to probe the AC circuitry contacts, and display the noise on spectrum analyzer. It is a convenient tool for debugging.

AC voltage probe

Directly touch the AC contact:

- AC conducted noise
- Switching power supply noise and component noise

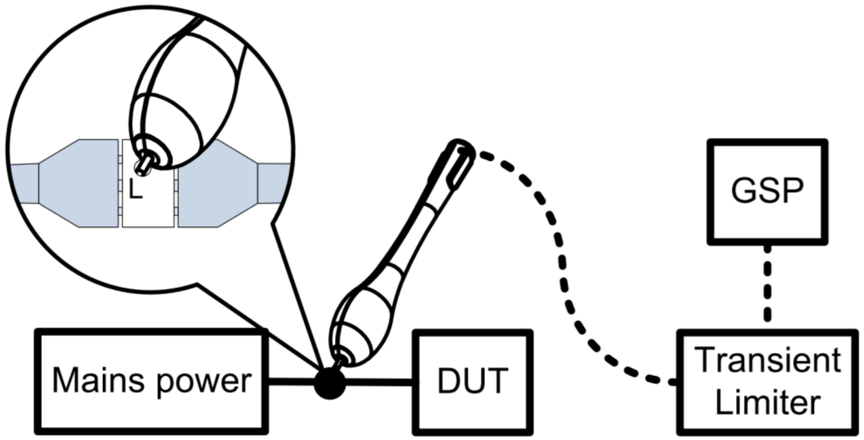


GW INSTEK

AC voltage probe

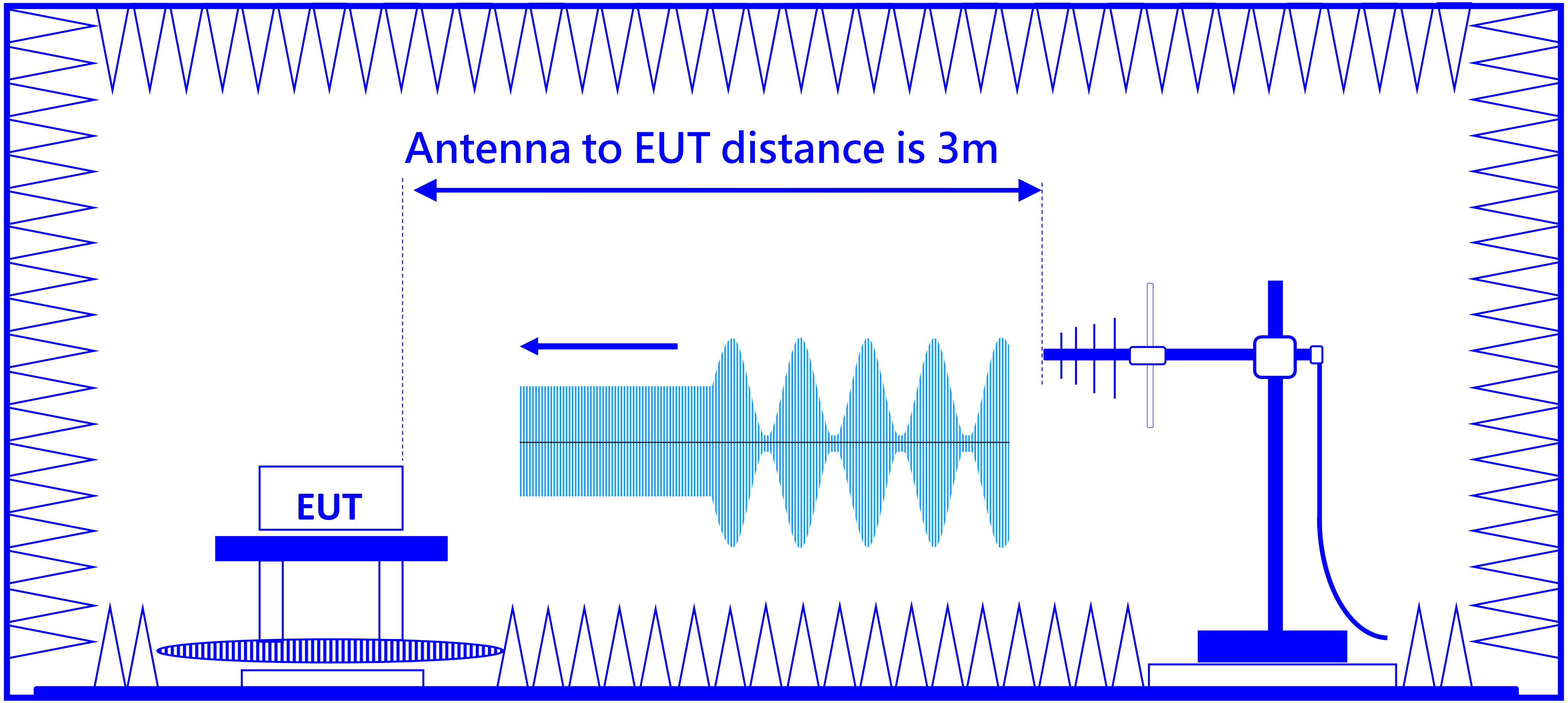
Directly touch the AC contact:

- AC conducted noise
- Switching power supply noise and component noise



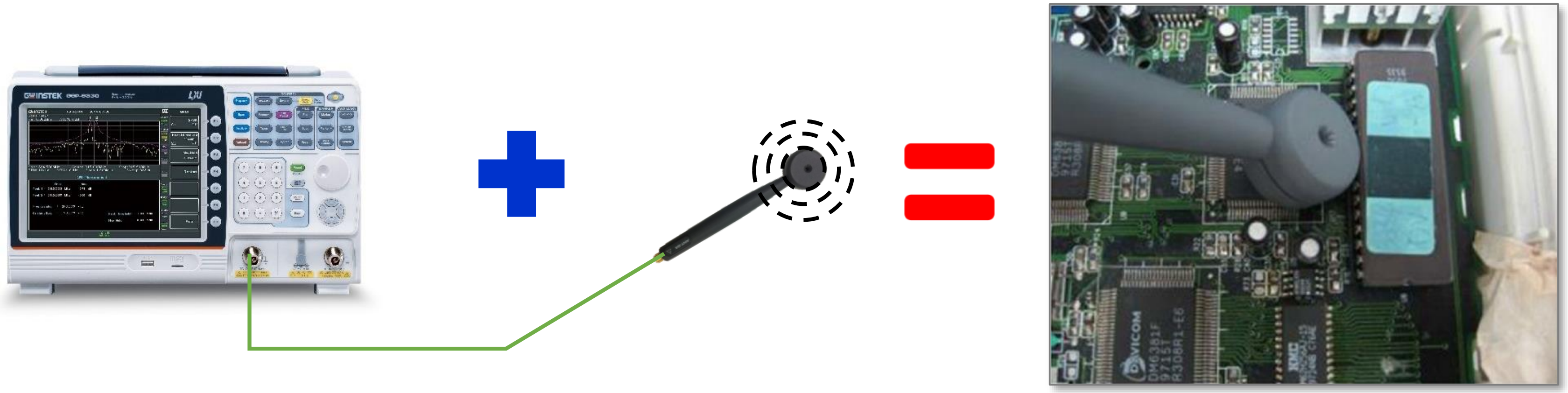
EMS radiation test in Anechoic Chamber

SG generates RF signal as interference to test susceptibility.
RF signal :80M~1GHz, 3V/m, AM 80% 1kHZ sine wave

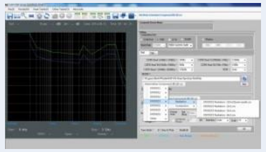


EMS Pretest on Radiation

- GSP-9330 TG connects with ANT-04 and 05 can generate RF signal as noise source to proceed the EMS test.
- Standard EMS source needs to output AM modulation signal for EMS test. Although GSP-9330 TG does not have AM modulation, it can be used as pre-test tool.



GW Instek EMC Pretest Solution

Products	Model
	Spectrum analyzer: GSP9330+TG (optional)
	Near-field Probe/Sensor: GKT-008+adaptor+cable
	Line Impedance Stabilization Network: GLN-5040A
	Isolation Transformer: GIT-5060
 	Pulse Limiter: GPL-5010 Adaptor (SMA-BNC):ADP004
	Freeware for EMI: Spectrum Shot

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for
Listening!

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