Military Radiated Immunity Tests: RS101, RS103

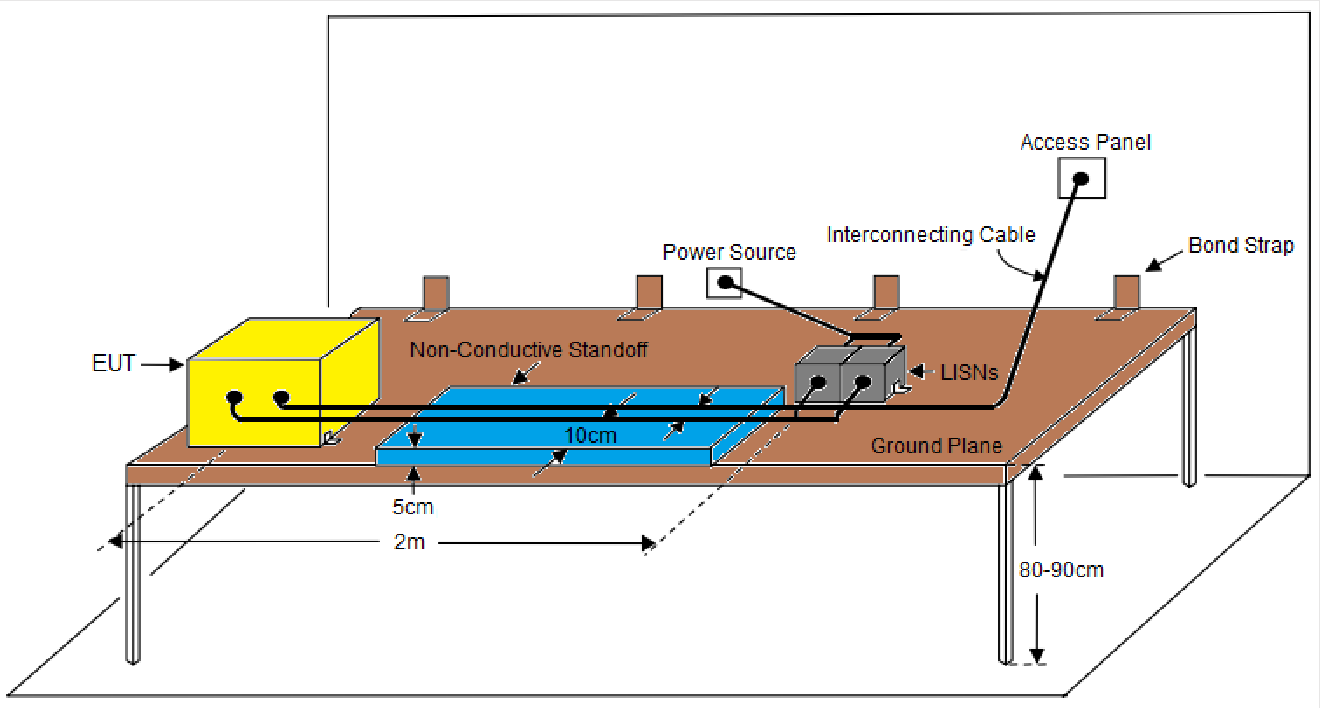
Osman ŞEN

05 September 2019
Barcelona, Spain

MIL STD 461F General Test Setup I

MIL-STD-461 is the standard that defines the test limits, test levels, and test procedure for various electromagnetic phenomena for electronic equipment used for military purpose (Army, Navy, and Air Force on all platforms).

- Unless otherwise specified, the EUT shall be installed on a ground plane that simulates the actual installation.
- If the actual installation is unknown or multiple installation are expected, then a metallic ground plane shall be used.
- When a ground plane is not present in the EUT installation, the EUT shall be placed on a non-conductive table.



The EUT should be tested in all possible operating modes, but at a minimum shall be tested under following conditions.

- Operating modes which are considered most susceptible to EMI shall be chosen for RS and CS tests.

During the susceptibility testing,

- Induces electromagnetic energy into EUT enclosure and interconnecting cable.
- Validates the EUT's ability to operate as intended when exposed to platform related electromagnetic environments and conditions.

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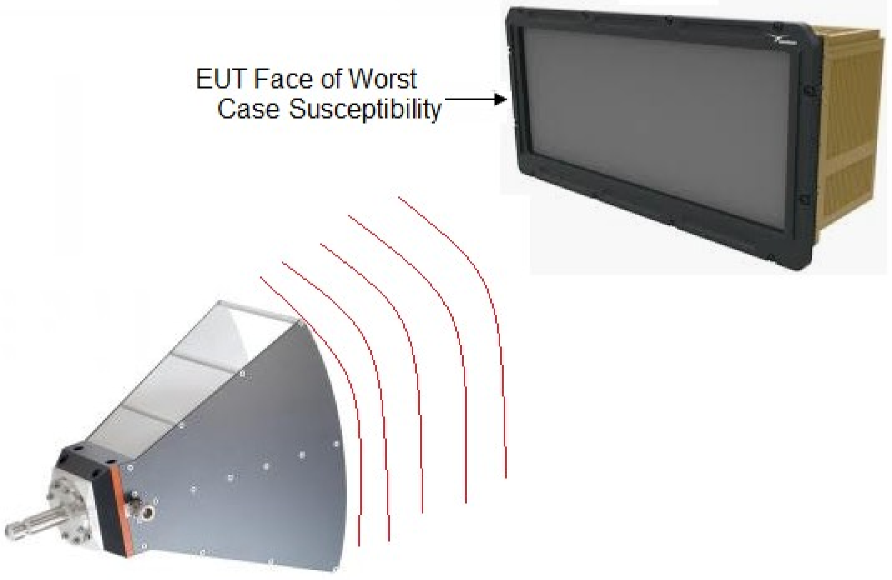
MIL STD 461F General Test Setup II

The EUT orientation shall be such that the maximum coupling of electric field is simulated.

All EUT electrical interfaces shall be terminated with either the actual equipment from the platform installation or representative loads which simulate the electrical properties

A peak detector shall be used for all frequency domain emission and susceptibility measurements.

During RS101 and RS103 testing, the step size shall be chosen as per Table given below. Scan rates and step sizes shall be decreased when necessary to permit observation of a response.



Frequency Range	Analog Scans Maximum Scan Rates	Stepped Scans Maximum Step Size
30 Hz – 1 MHz	$0.00333f_0$/sec	$0.05\ f_0$
1 MHz – 30 MHz	$0.00667f_0$/sec	$0.01\ f_0$
30 MHz – 1 GHz	$0.00333f_0$/sec	$0.005\ f_0$
1 GHz – 40 GHz	$0.00167f_0$/sec	$0.0025\ f_0$

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MIL STD 461F General Test Setup III

Stepped scans shall dwell at each tuned frequency for the greater of 3 seconds or the EUT response time.

During tests, the EUT is exposed to electric&magnetic fields of a specified magnitude to ensure that it does not exhibit any malfunction, degradation of performance, or deviation from specified indications.

When EUT susceptibility is noticed, reduce the signal level till EUT recovers. Then further reduce the level by 6dB. Then increase the signal level till the susceptibility occurs. This is the threshold of susceptibility. Note the frequency (band) & other parameters.

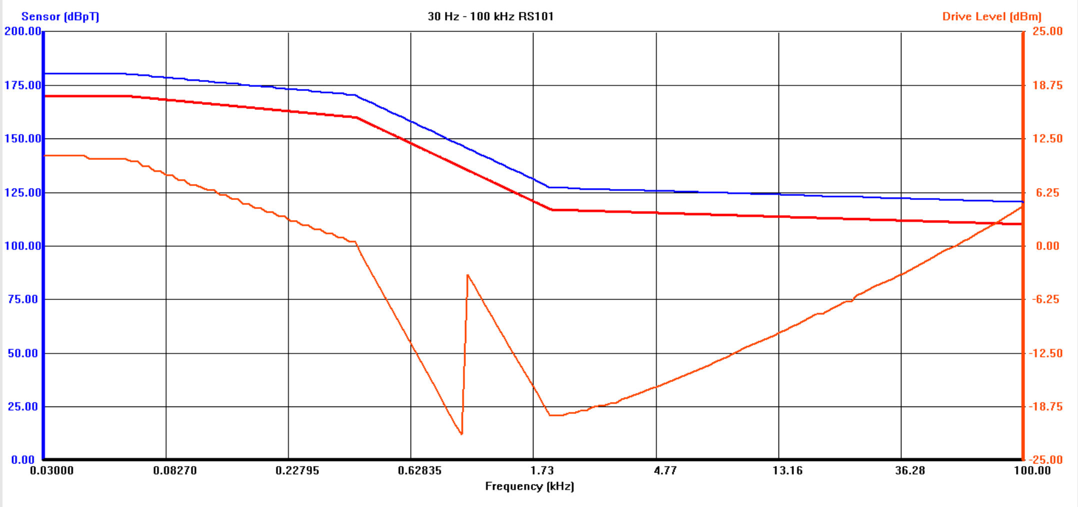
Test Result: Pass

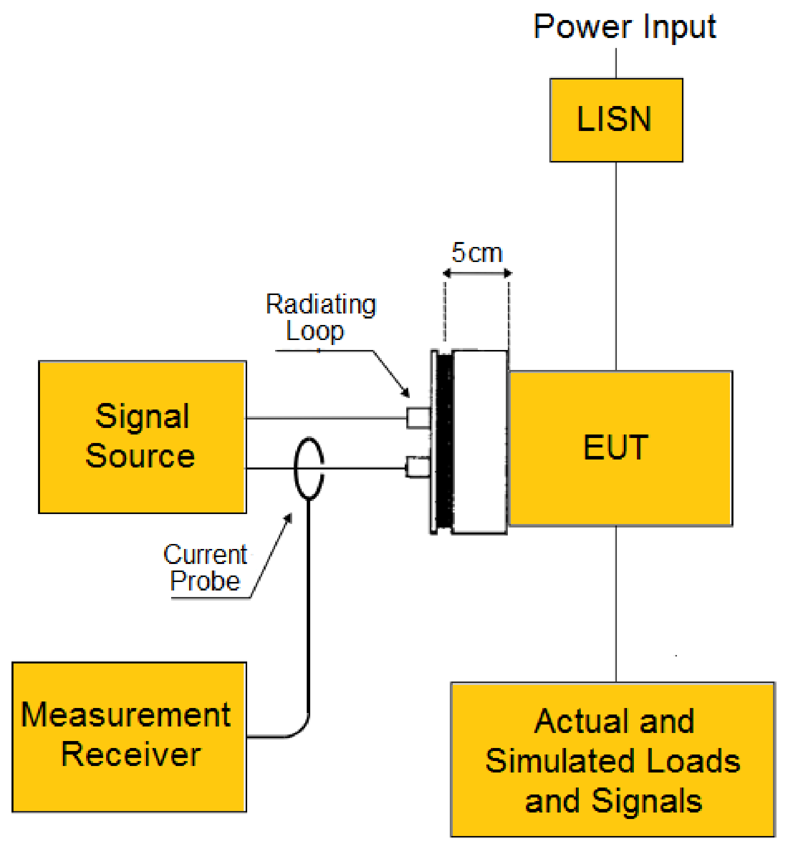
Test Result: Fail

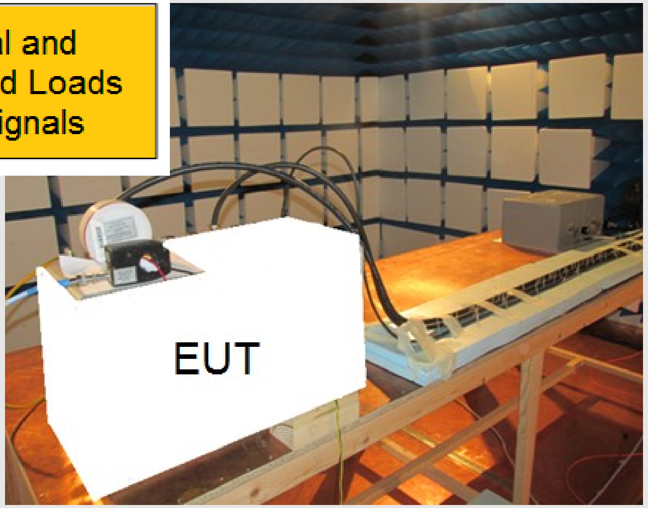
RS101 Test Method

The RS101 test verifies the susceptibility of equipment installed in close proximity to large radiated magnetic fields, and their ability to withstand them in the frequency range 30 Hz–100 kHz.

- The transmit loop is placed 5 cm from the EUT surface and the electrical interface connector.
- The transmit loop is positioned every 30 cm x 30 cm area over each face including each connector interface.
- The transmit loop is supplied with sufficient current to produce magnetic field strengths at least 10 dB greater than the applicable limit, but not exceeding 15 amps (183 dBpT) in order to quickly detect potential susceptibility issues.





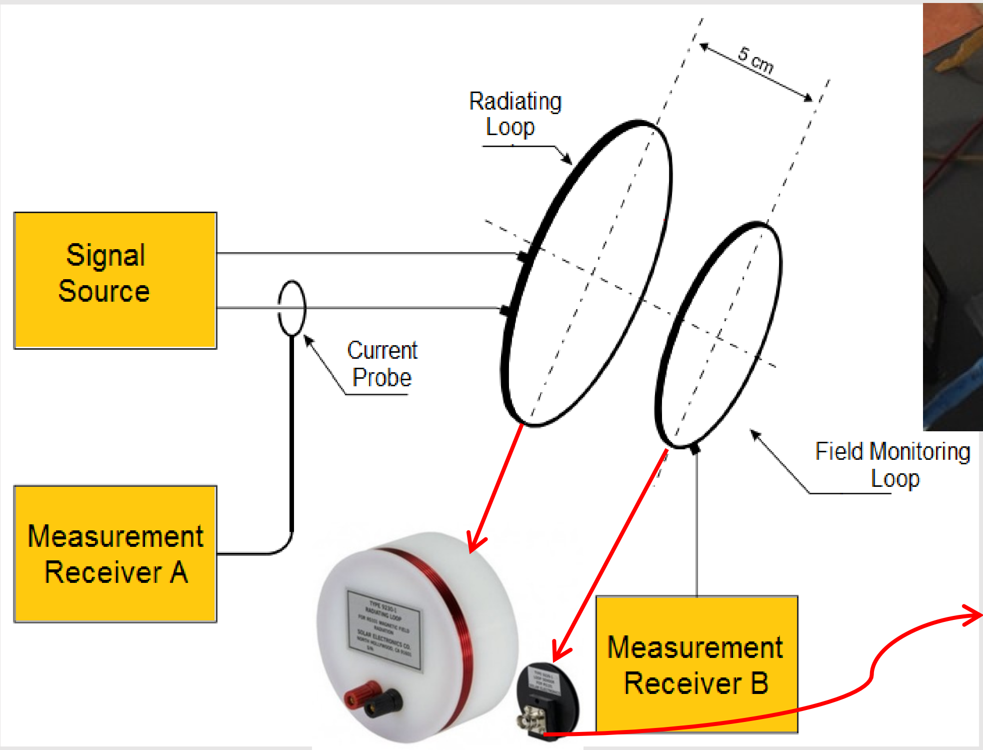


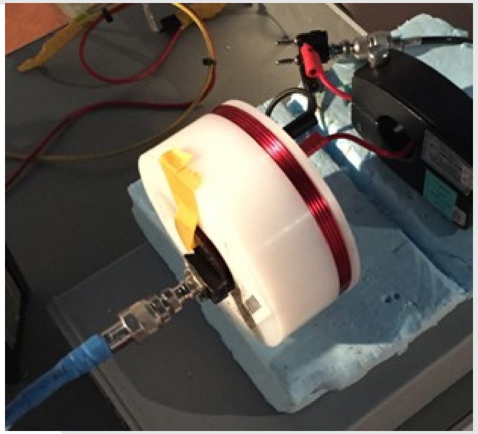
Verification of RS101 Test System

Before RS101 testing, test laboratory must perform verifications to ensure the quality and precision of test results by means of verification as the verification can detect errors beforehand in the test setup and prevent wrong testing.

- The signal source is set to a frequency of 1 kHz.
- The output is adjusted to provide a magnetic flux density of 110 dB above one picotesla, as determined by the reading obtained on measurement receiver A, as well as the relationship given in Magnetic Flux Density.
- The voltage output from the loop sensor is measured using measurement receiver B.
- It is verified that the output on measurement receiver B is within ± 3 dB of the expected value based on the antenna factor. This value is recorded.

If the measured signal levels deviate by more than ± 3 dB, the test is not continued and the error must be rectified in the test system.



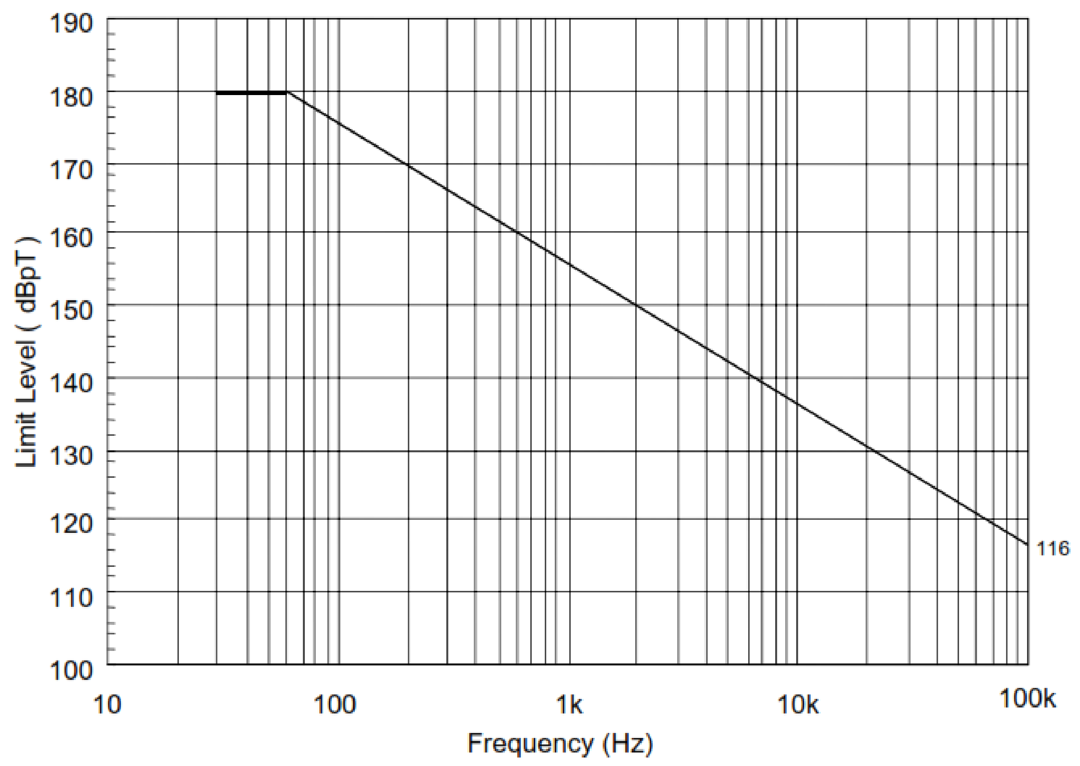


The receiving loop antenna shall be calibrated in accordance with SAE ARP958.

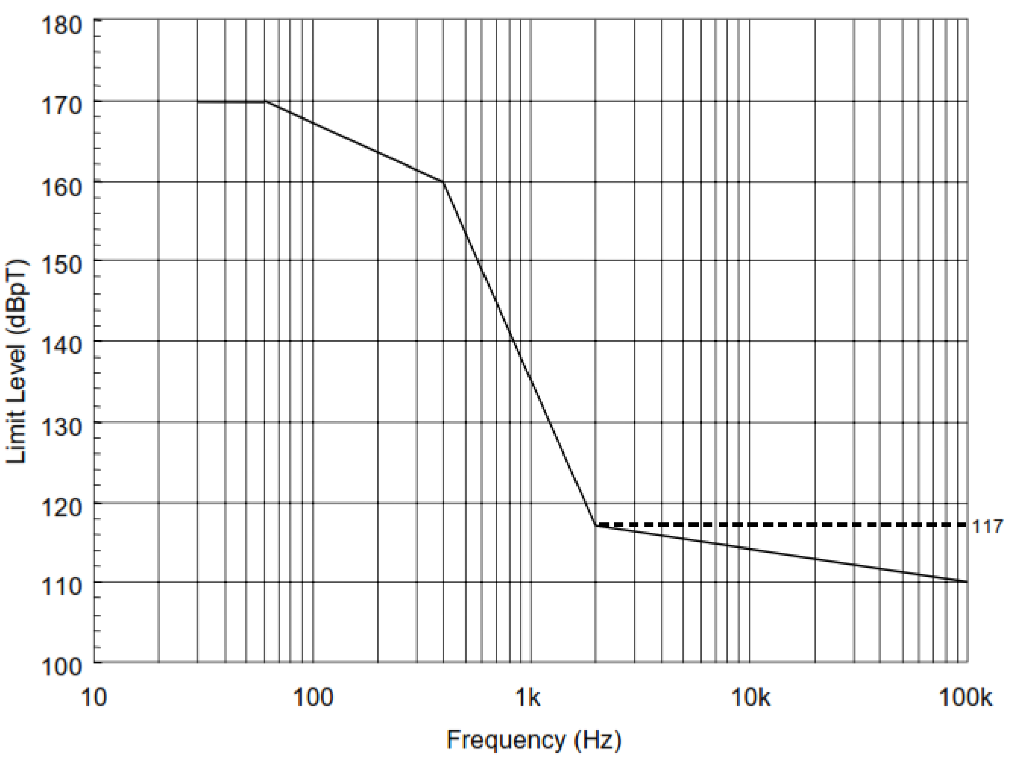
Frequency	Target Value (dBpT)	Receiving Loop AF (dB(pT/µV))	Reading Value from EMI Receiver (dBµV)	Measured Value (dBpT), (AF + EMI)	Margin (dB)	Tolerance (dB)	Result
30 Hz	110	99.2	10.5	109.7	0.3	± 3	✓
1 kHz	110	71.2	37.9	109.1	0.9	± 3	✓
100 kHz	110	39.3	71.1	110.4	-0.4	± 3	✓

RS101 Test Limits

Limit for all Navy Applications



Limit for all Army Applications



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RS103 Test Method

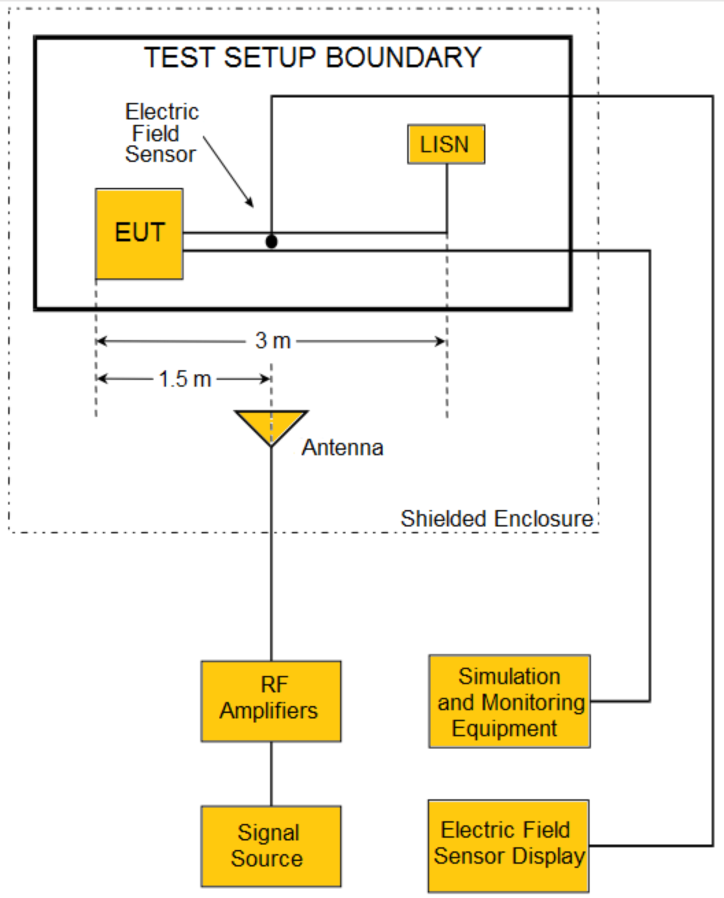
RS103 testing is used to verify the ability of the EUT enclosures and associated cabling to withstand external electric field, generated by antenna transmissions.

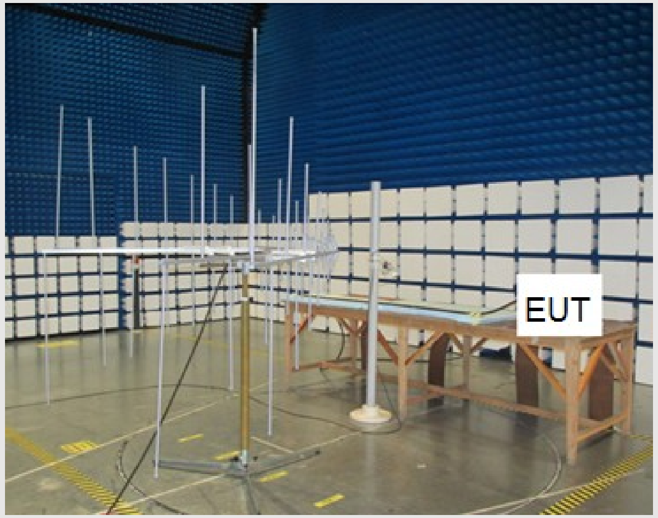
This test is applicable in the frequency range 2 MHz – 18 GHz (18 GHz to 40 GHz is optional).

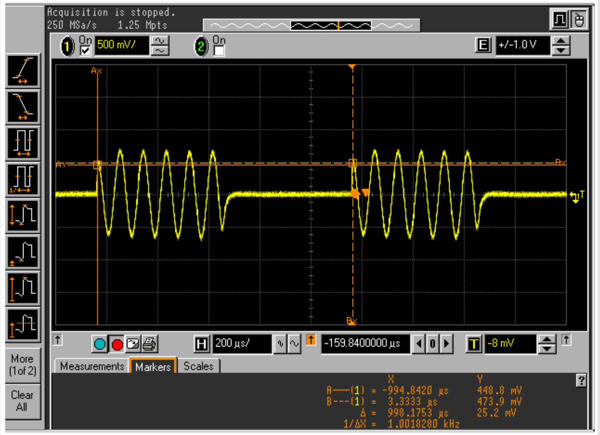
Up to 30 MHz, the requirement shall be met for vertically polarized fields. Above 30 MHz, the requirement shall be met for both horizontally and vertically polarized fields. Circular polarized fields are not acceptable.

The test limits for EUT are based on levels expected to be encountered during the service life of the EUT.

Susceptibility test signals for RS103 shall be pulse modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle.





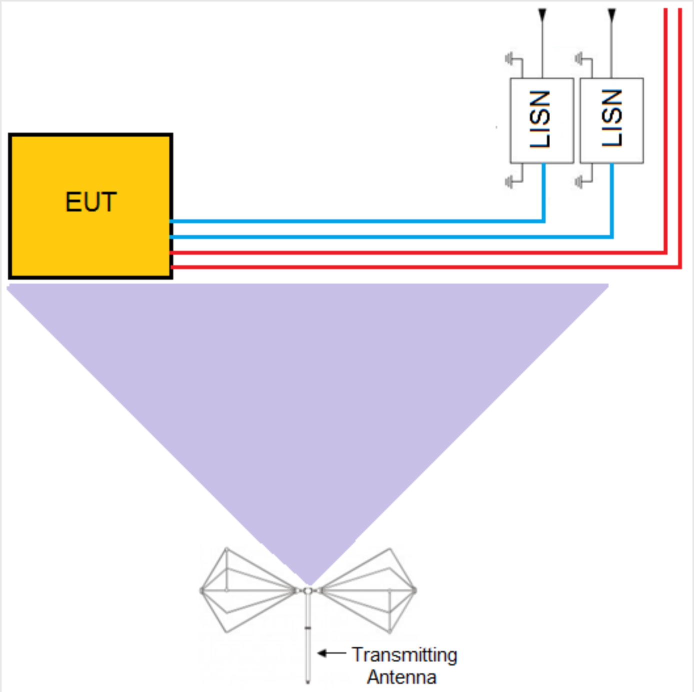


PULSE MODULATION SHAPE FOR RS103 AND CS114 TESTS

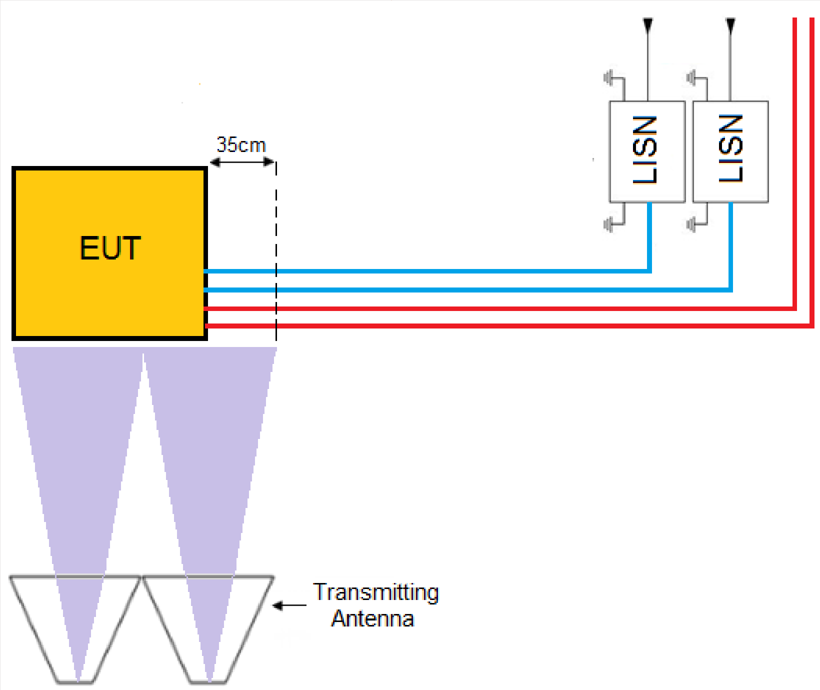
RS103 Antenna Position

For testing below 200 MHz, use the following criteria to determine the individual antenna positions.

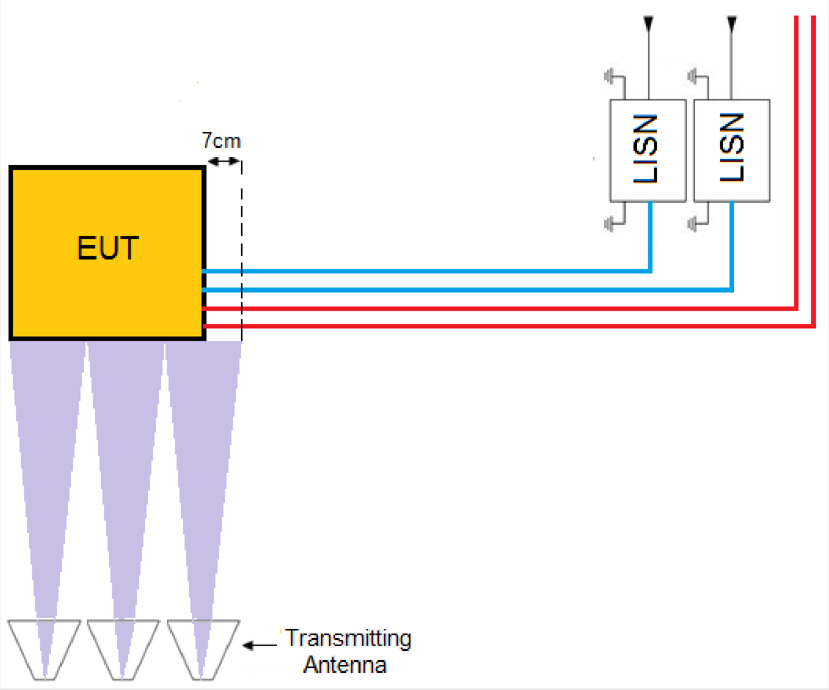
- ➢ For setups with the side edges of the boundary 3 meters or less, one position is required and the antenna shall be centered with respect to the side edges of the boundary.
- ➢ For setups with the side edges of the boundary greater than 3 meters, use multiple antenna positions at spacing.



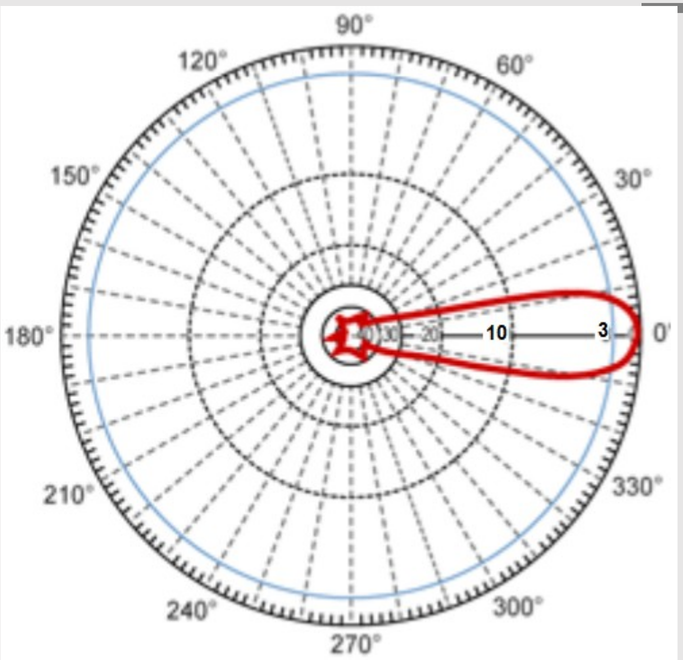
For testing from 200 MHz up to 1 GHz, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.



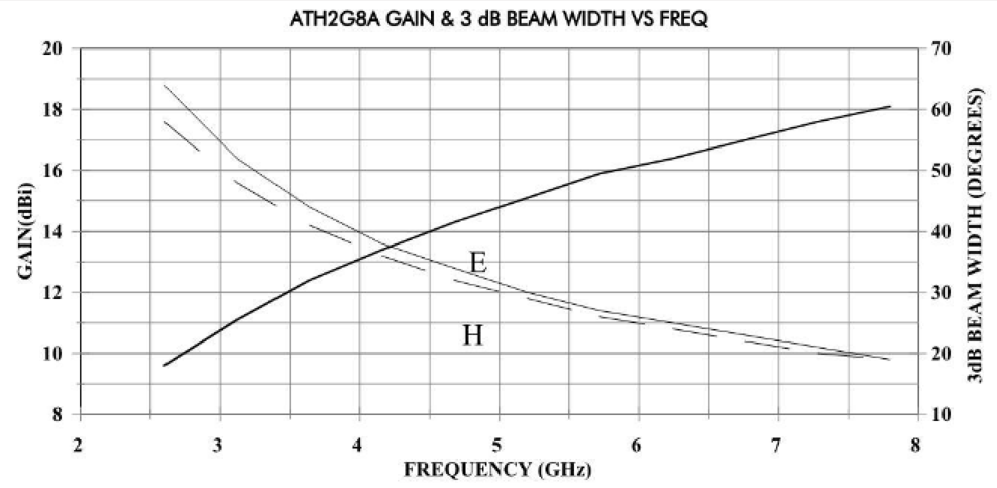
For testing at 1 GHz and above, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

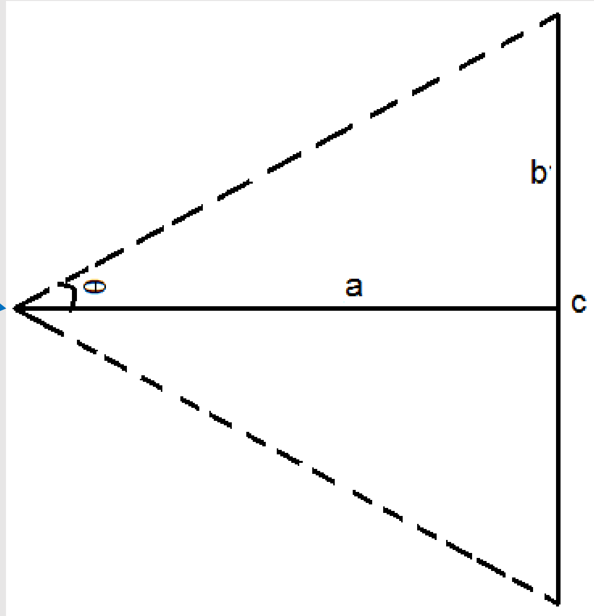


Determination of RS103 Antenna 3 dB Beamwidth



http://www.l-com.com/multimedia/datasheets/DS_HG2414SP-120.PDF





Where;
θ = ½ antenna beam width (as specified by antenna manufacturer.
a = 1 meter (distance to setup boundary)

b = tan (θ) x a

c = 2 x b (total antenna coverage in meters)

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RS103 Test Limits

FREQ. RANGE / PLATFORM		LIMIT LEVEL (VOLTS/METER)							
		AIRCRAFT (EXTERNAL OR SAFETY CRITICAL)	AIRCRAFT INTERNAL	ALL SHIPS (ABOVE DECKS) AND SUBMARINES (EXTERNAL)*	SHIPS (METALLIC) (BELOW DECKS)	SHIPS (NON-METALLIC) (BELOW DECKS) **	SUBMARINES (INTERNAL)	GROUND	SPACE
2 MHz → 30 MHz	A	200	200	200	10	50	5	50	20
	N	200	200	200	10	50	5	10	20
	AF	200	20	-	-	-	-	10	20
30 MHz → 1 GHz	A	200	200	200	10	10	10	50	20
	N	200	200	200	10	10	10	10	20
	AF	200	20	-	-	-	-	10	20
1 GHz → 18 GHz	A	200	200	200	10	10	10	50	20
	N	200	200	200	10	10	10	50	20
	AF	200	60	-	-	-	-	50	20
18 GHz → 40 GHz	A	200	200	200	10	10	10	50	20
	N	200	60	200	10	10	10	50	20
	AF	200	60	-	-	-	-	50	20

KEY: A = Army
N = Navy
AF = Air Force

* For equipment located external to the pressure hull of a submarine but within the superstructure, use SHIPS (METALLIC)(BELOW DECKS)

** Equipment located in the hanger deck of Aircraft Carriers

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Verification of the RS103 Test Systems I

The measurement system check shall be performed according to steps given below prior to RS103 testing.

- The electric field sensor is positioned 1 m from the test setup and directly opposite, the transmit antenna at a minimum of 30 cm above the ground plane below 1 GHz. Above 1 GHz, the electric field sensor is placed at height corresponding to the area of the EUT being illuminated.
- The electric field sensor is not placed directly at the corners or edges of the EUT components.
- The amplitude shown on the electric field sensor display unit due to EUT ambient noise or RF/TWT amplifier ambient noise is recorded.
- If the ambient noise is coming from EUT, the electric field sensor repositioned until this level is < 10% of the applicable field strength used for testing.
- If the ambient noise is produced by the RF/TWT amplifier, the test laboratory shall use appropriate attenuator or cables in order to reduce the ambient noise until this level is < 10% of the applicable field level or the target field level should be increased (as long as the EUT passes at the RS103 test).

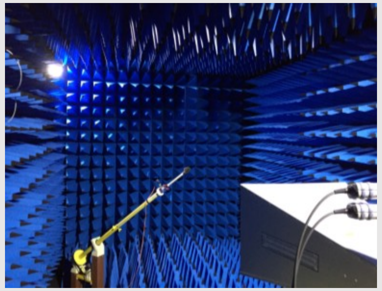
Frequency Range	Background Noise (V/m)	Target Electric Field Level (V/m)	Applied Electric Field Level (V/m)
2 MHz – 30 MHz	1,3	10	20
30 MHz – 100 MHz	1,3	10	20
100 MHz – 1 GHz	1,9	10	30
1 GHz – 4 GHz	1,7	10	30
4 GHz – 8 GHz	1,7	10	30
8 GHz – 18 GHz	2,1	10	30
18 GHz – 26,5 GHz	3,2	10	50
26,5 GHz – 40 GHz	4,3	10	50

According to the customer instructions, the target electric field level is determined as 10 V/m. However, to meet the requirement of “the background noise shall be less than 10% of the test level” of the standard, the test level is increased accordingly when required.

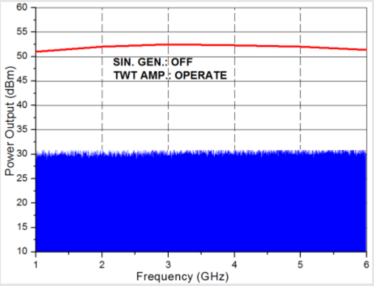
Field Level	Ambient Level	2.6 to 4.3 GHz Setup	4.3 to 7.8 GHz Setup	7.8 to 12 GHz Setup	12 to 18 GHz Setup
200	20	6.5 V/m with original cable	11.5 V/m with original cable	13 V/m with original cable	16.3 V/m with original cable
100	10	6.5 V/m with original cable	6 V/m with original cable + 9 meter cable	5.6 V/m with original cable + 9 meter cable	6 V/m with original cable + 9 meter cable
50	5	3.5 V/m with original cable + 9 meter cable	4 V/m with original cable + 9 meter cable + 6dB attenuator	2.2 V/m with original cable + 9 meter cable + 6dB attenuator	2.3 V/m with original cable + 9 meter cable + 6dB attenuator
10	2	3.5 V/m with original cable + 9 meter cable + 6dB attenuator	1.2 V/m with original cable + 9 meter cable + 16dB attenuator	1.7 V/m with original cable + 9 meter cable + 10dB attenuator	1.7 V/m with original cable + 9 meter cable + 10dB attenuator

Verification of the RS103 Test System II

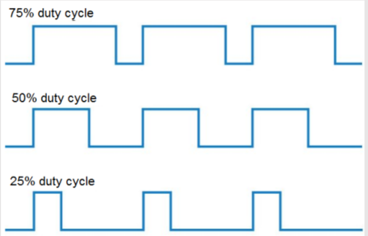
➢ The calibration of electric field probe shall be performed according to IEEE 1309 (frequency response, linearity, isotropy) by an accredited calibration laboratory and the calibration factors shall be entered into the test software.



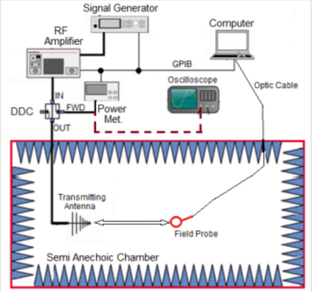
➢ If the TWT Amplifier is used at the test, the internal noise of the TWT Amplifier should be considered.

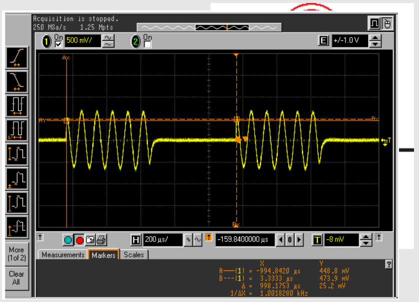


➢ The calibration of the signal generator shall be performed by an accredited calibration laboratory according to the modulation types to be used in the RS103 test.



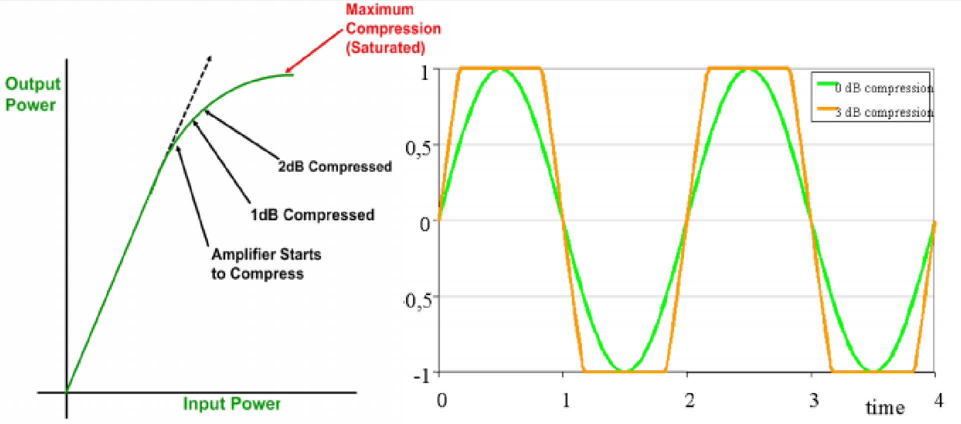
➢ The correctness of PM modulation which is applied in the RS103 test and generated by the software shall be checked with an oscilloscope.





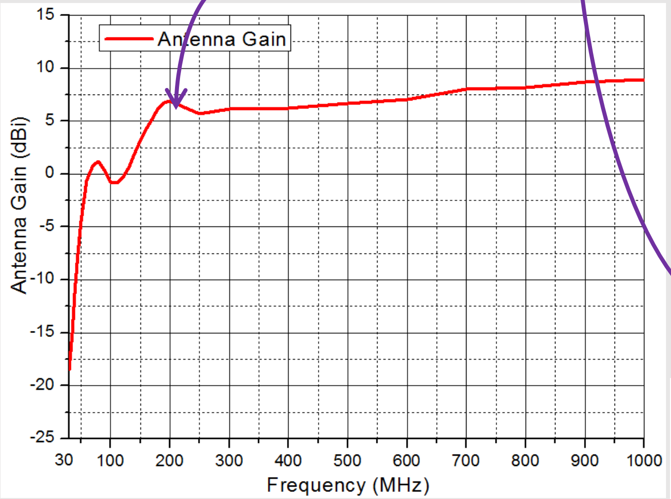
Harmonic Mesurements for RS103 Test System I

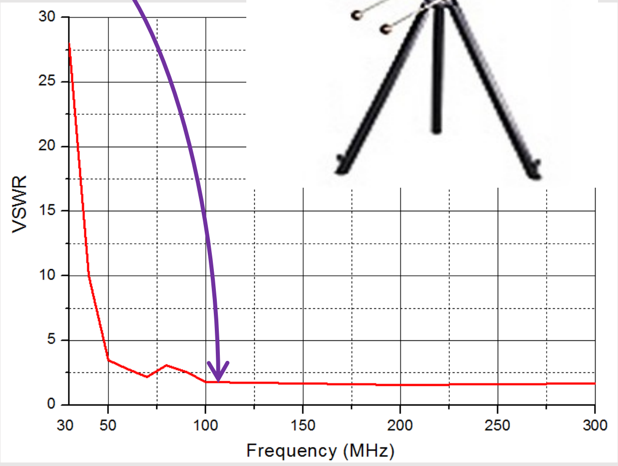
All amplifiers produce the harmonics unwanted frequencies generated by system nonlinearities. The level of these harmonics is dependent on the design and quality of the amplifier and worsens as the amplifier approaches saturation.



https://www.testforce.com/testforce_files/Seminars/SpirentMedicalSeminar2016/SpirentMedicalSystemsMed.pdf

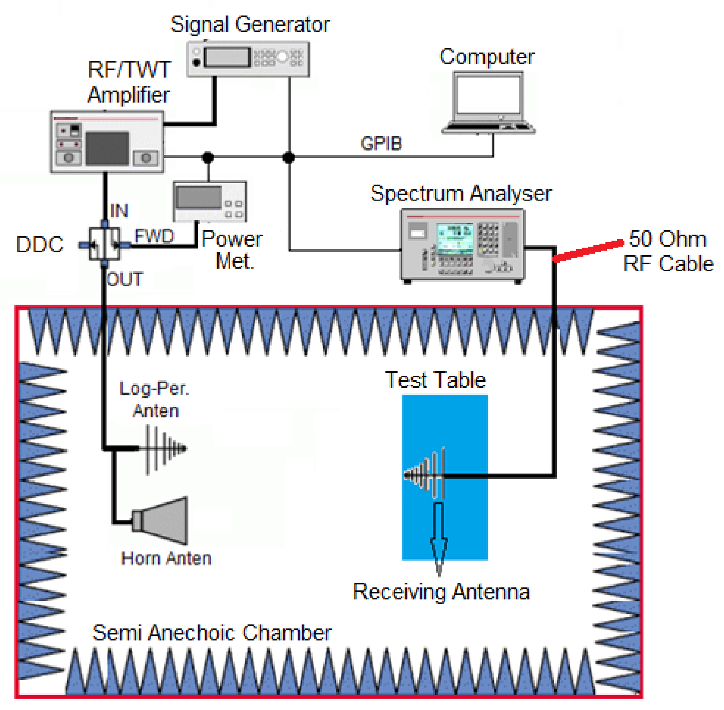
The use of the broadband transmitting antennas also leads to a harmonics problem because the gain of the broadband transmitting antennas usually has better gain and low VSWR at higher frequencies. This can increase the level of the harmonics compared to the fundamental signal.



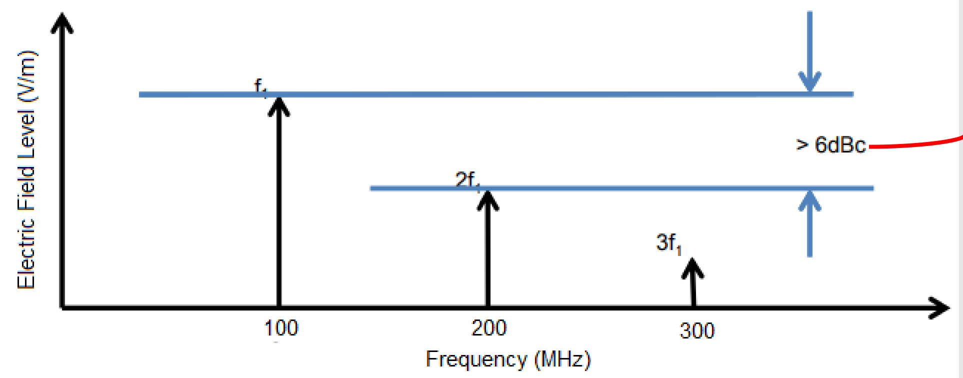


- When using a broadband receiving device at RS103 test such as a field probe, it is not distinguish between different signals (fundamental or harmonic)
- High harmonics can contribute to the readings of the field probe and produce error in the reading.
- This error will cause testing at the intended fundamental frequency to be incorrect.

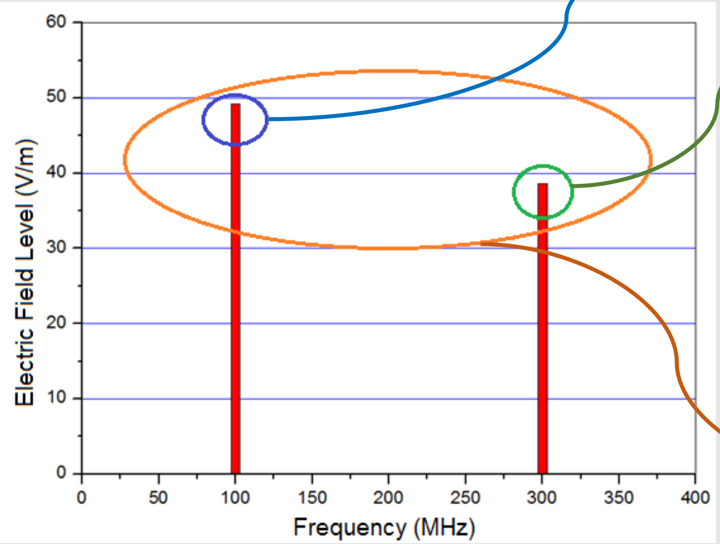
Harmonic Measurements for RS103 Test System II



- The harmonic measurements shall be performed at the highest target electric field level such as 200 V/m.
- The receiving antenna factors and RF cable factors must be taken into account to obtain the 2th&3th harmonic levels of the RF&TWT amplifier.



IEC 61000-4-3 requires that the level of the fundamental signal measured at the test site is 6 dB more than the harmonics. This limit can be used in RS103 test systems.



Measurement (Main) Frequency: **100 MHz**
Measured Field Level with Antenna: **49.2 V/m**

Measurement (Third Harmonic) Frequency: **300 MHz**
Measured Field Level with Antenna: **38.6 V/m**

TOTAL FIELD LEVEL: $((f_1)^2 + (3f_1)^2)^{0.5}$ V/m

TOTAL FIELD LEVEL: $((49.2)^2 + (38.6)^2)^{0.5}$ = **62.5 V/m**

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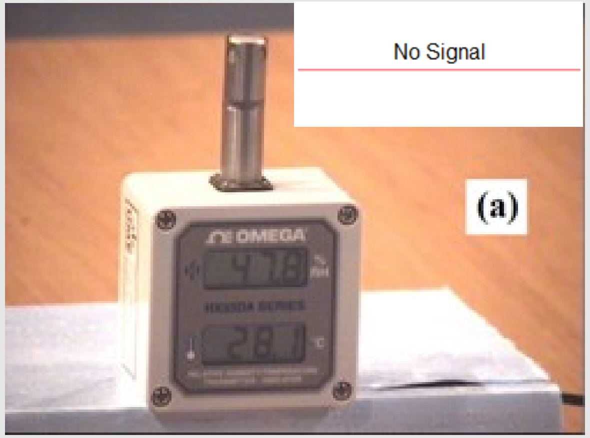
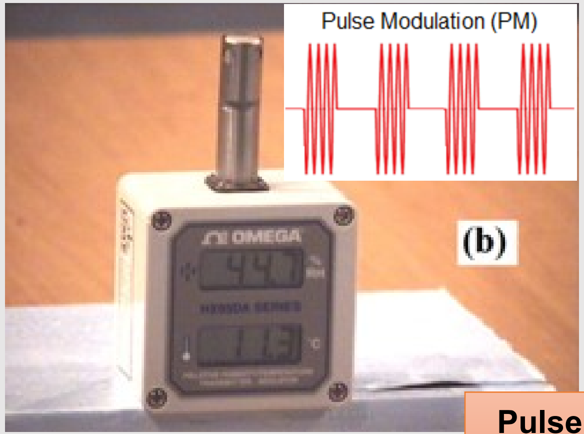
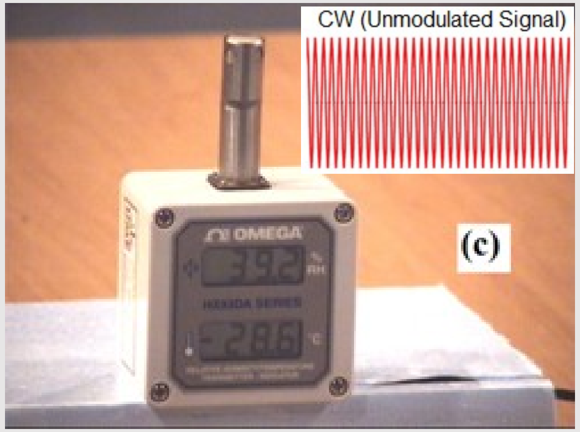
Measurement Frequency: 100 MHz
Measured Field Level with Probe: **60,2 V/m**

Main Issues With RS103 Testing

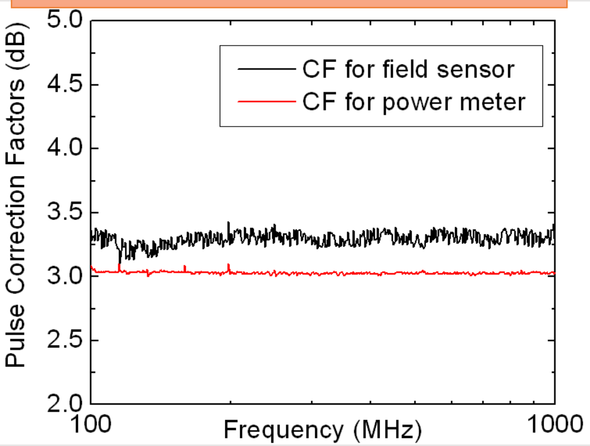
Display photos taken during testing at 100.7 MHz for 50 V/m,
a- reference condition without EM interference in case 1, readings: 28.1 degrees and 47.8%
b- application period with pulse modulation in case 2, readings: 11.3 degrees and 44.7%
c- leveling period with CW in case 3 just before modulation, readings: -28.6 degrees and 39.2%







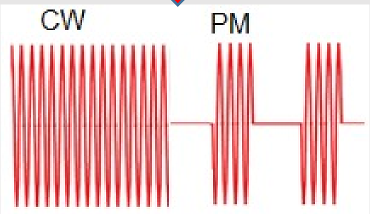
Pulse correction factors for field sensor and powermeter



Method 1 (Leveling Under CW Signal)

Gradually increase the electric field level with CW until it reaches the applicable limit.

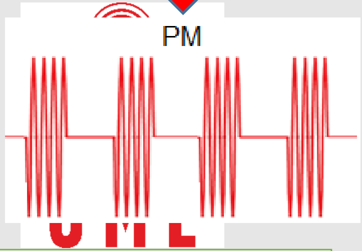
Apply 1 kHz pulse modulation, 50% duty cycle



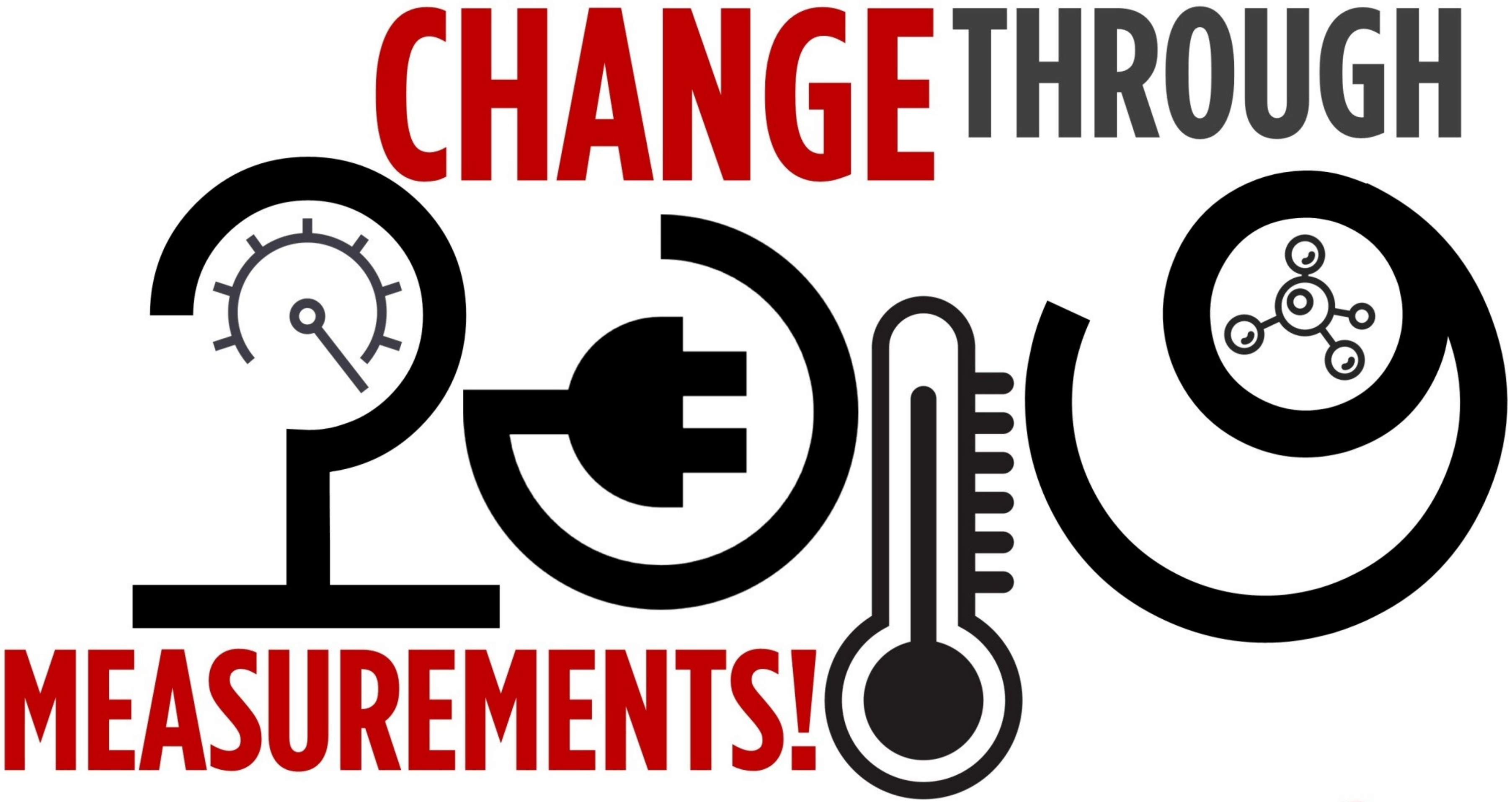
Method 2 (Leveling Under Modulated Signal)

Set the signal source to 1 kHz pulse modulation, 50% duty cycle

Gradually increase the electric field level with PM until it reaches the applicable limit.



Cakir, S., Sen, O., Cinar, M., Cetintas, M. "Investigation of Leveling Methods in Military Susceptibility Testing", 2018 Joint IEEE EMC & APEMC Symposium, Singapore (14-17/05/2018) : 5 p.



TRUE
MEASUREMENT
EXCELLENCE

THANK YOU

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