# Military Radiated Emission Tests: RE101, RE102

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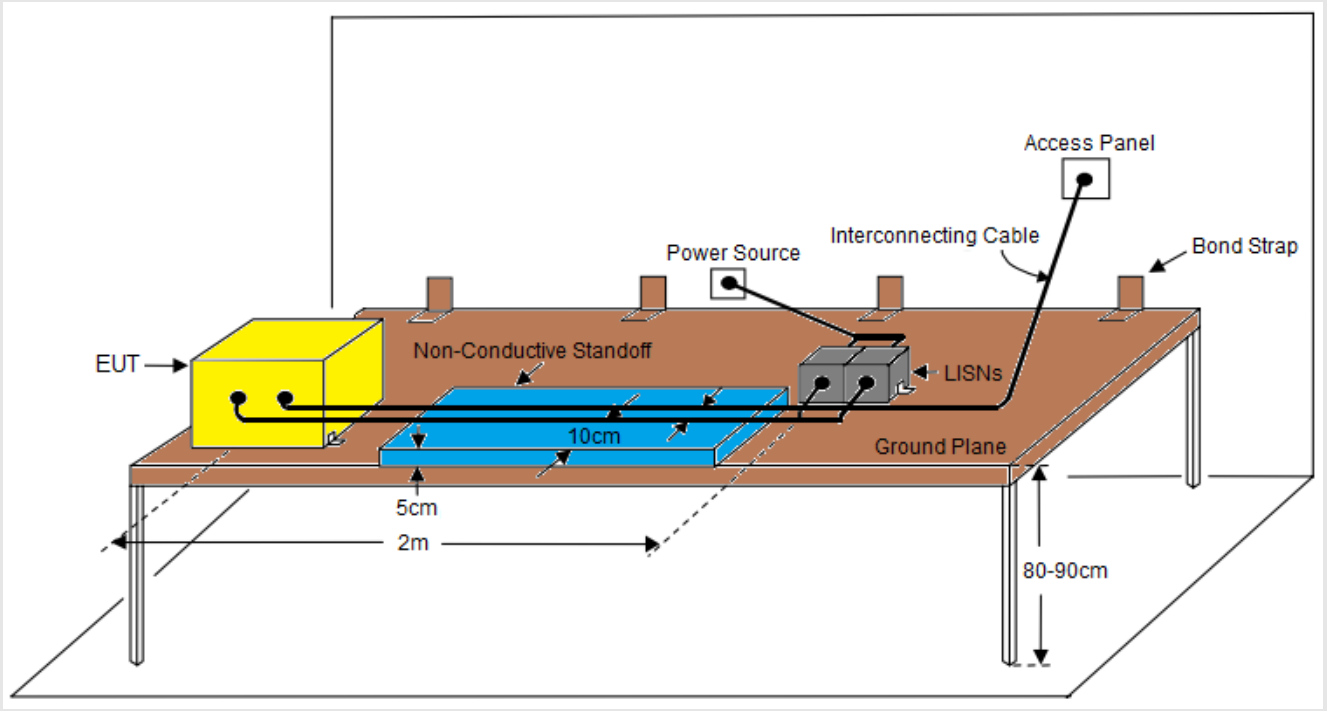
Barcelona, Spain

# 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 will produce maximum emissions shall be chosen for RE and CE tests.

During the emission testing,

- Measures the electromagnetic energy emitted from the EUT enclosure and interconnecting cabling.
- Validates that the EUT will not cause operational problems in other subsystems or equipment while performing its intended functions.

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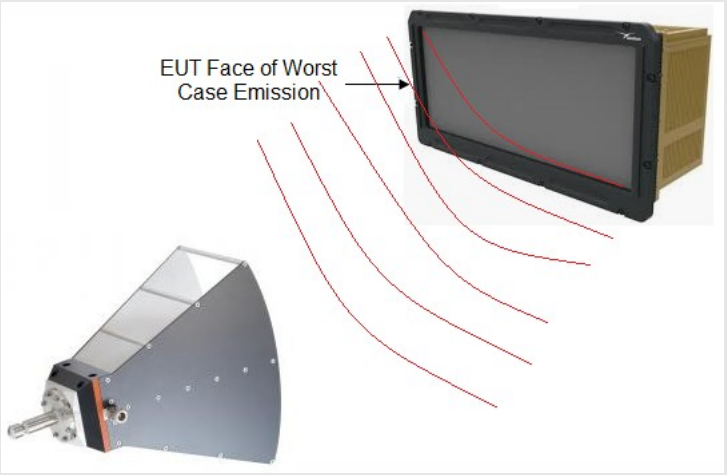
# MIL STD 461F General Test Setup II

EUTs shall be oriented such that surfaces which produce maximum radiated emissions and/or respond most readily to radiated signals face the measurement antennas (large apertures, ventilation ducts, connector panels, video displays, etc…).

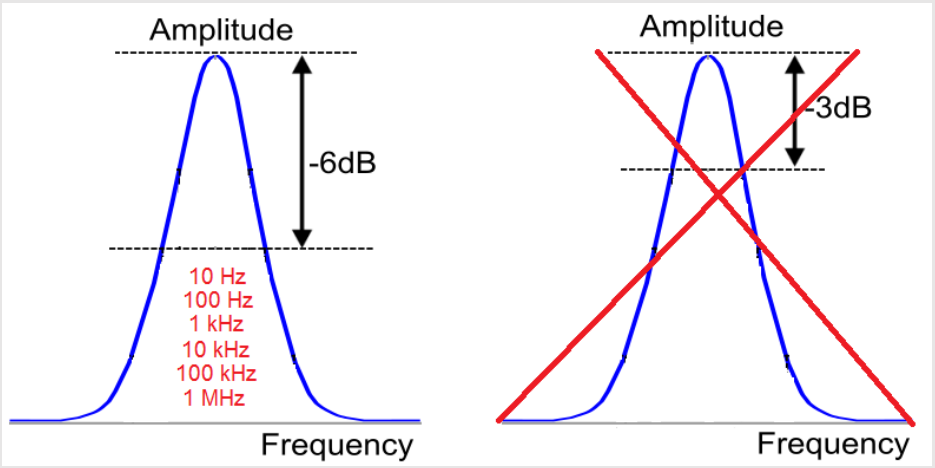
All EUT electrical interfaces shall be terminated with either the actual equipment from the platform installation or representative loads which simulate the electrical properties




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

The measurement receiver bandwidths listed in Table given below shall be used for emission testing. These bandwidths are specified at the 6 dB down points for the overall selectivity curve of the receivers. Video filtering shall not be used to bandwidth limit the receiver response.

| Frequency Range | 6 dB Bandwidth | Dwell Time | Minimum Measurement Time Analog Measurement Receiver |
|---|---|---|---|
| 30 Hz – 1 kHz | 10 Hz | 0.15 sec | 0.015 sec/Hz |
| 1 kHz – 10 kHz | 100 Hz | 0.015 sec | 0.15 sec/kHz |
| 10 kHz – 150 kHz | 1 kHz | 0.015 sec | 0.015 sec/kHz |
| 150 kHz – 30 MHz | 10 kHz | 0.015 sec | 1.5 sec/MHz |
| 30 MHz – 1 GHz | 100 kHz | 0.015 sec | 0.15 sec/MHz |
| 1 GHz – 18 GHz | 1 MHz | 0.015 sec | 15 sec/GHz |

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# RE101 Test Method

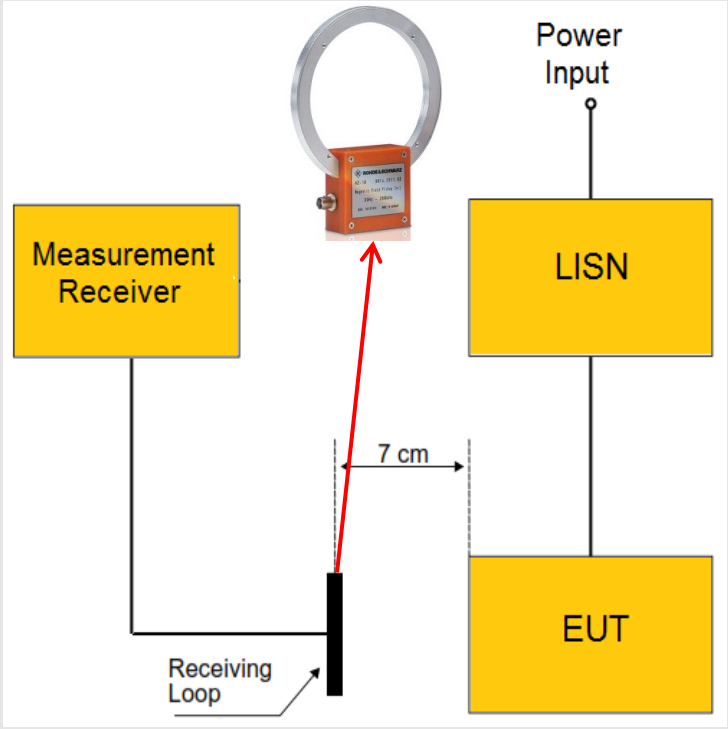
RE101 testing is performed to verify that magnetic field emissions from the EUT with and its associated electrical interfaces do not exceed specified requirements.

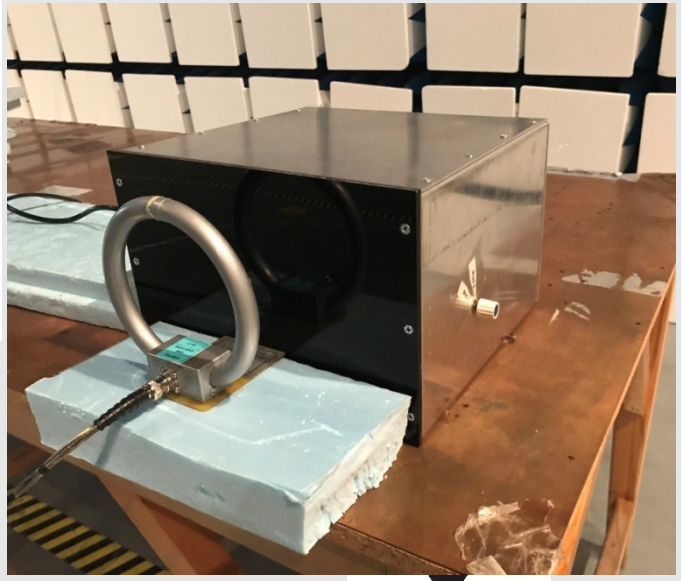
This test is applicable in the frequency range 30 Hz – 100 kHz.

RE101 testing is a low frequency near field radiated magnetic field emission measurement test. The emission levels are determined by measuring the magnetic fields 7 cm from all faces of the EUT and connectors. The limits are based on according to the platform where the EUT is used.

If the specified emissions limits are exceeded, the measurement distance is increased until the emissions fall within the limit.

The Pass/Fail ciriterion depends on for the EUT.



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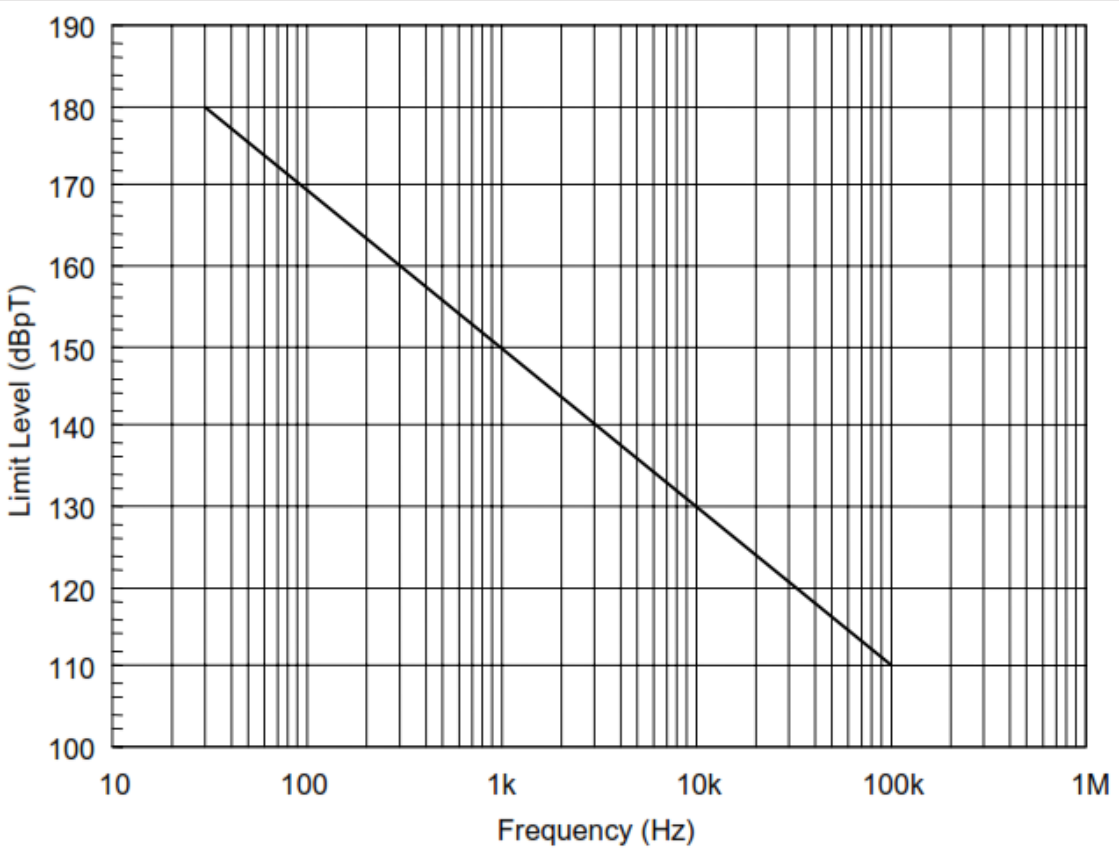
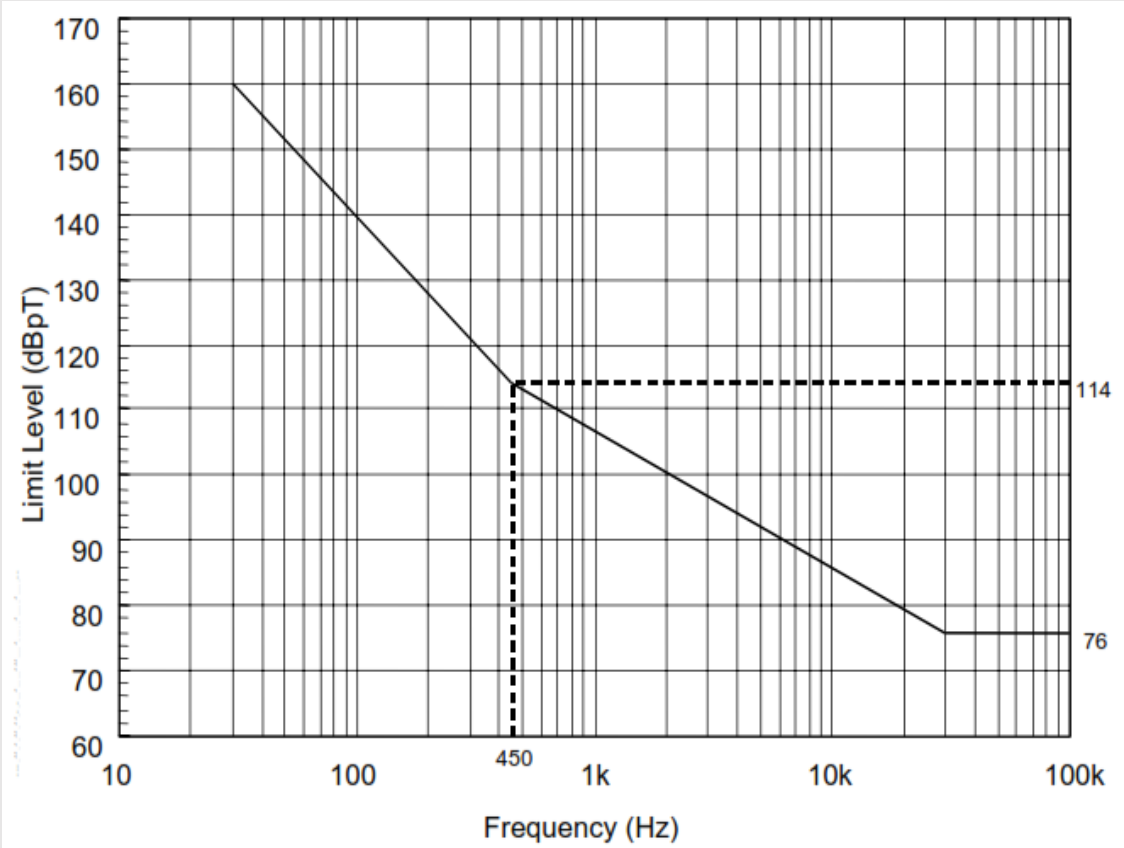
# RE101 Test Limits

Limit for all Army Applications




Limit for all Navy Applications

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# Verification of RE101 Test System

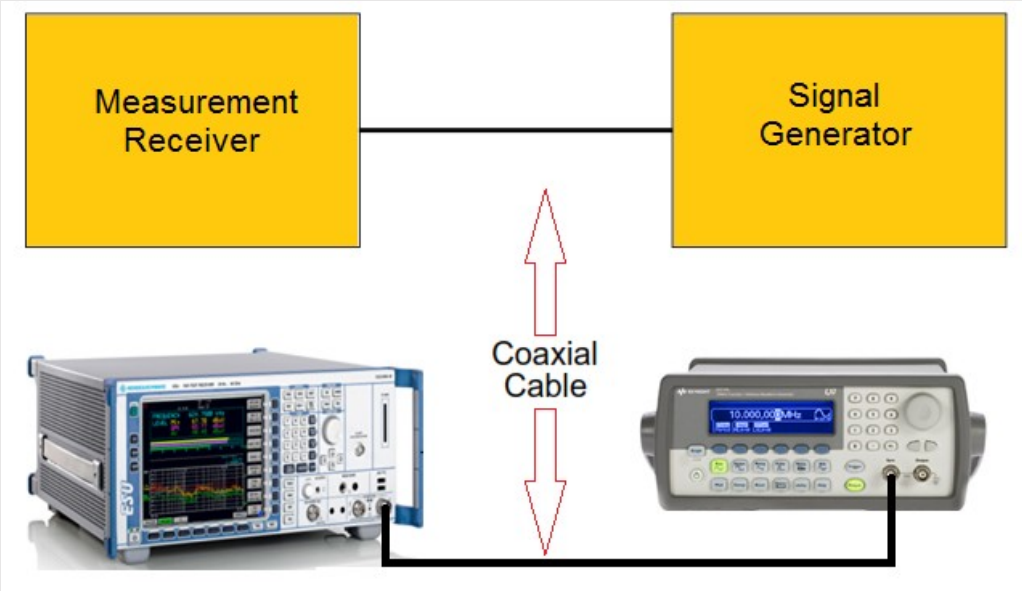
Before RE101 testing, test laboratory must perform verifications to ensure the quality and precision of test results by means of verification as the verification can detect errors beforehand in the test setup and prevent wrong testing.

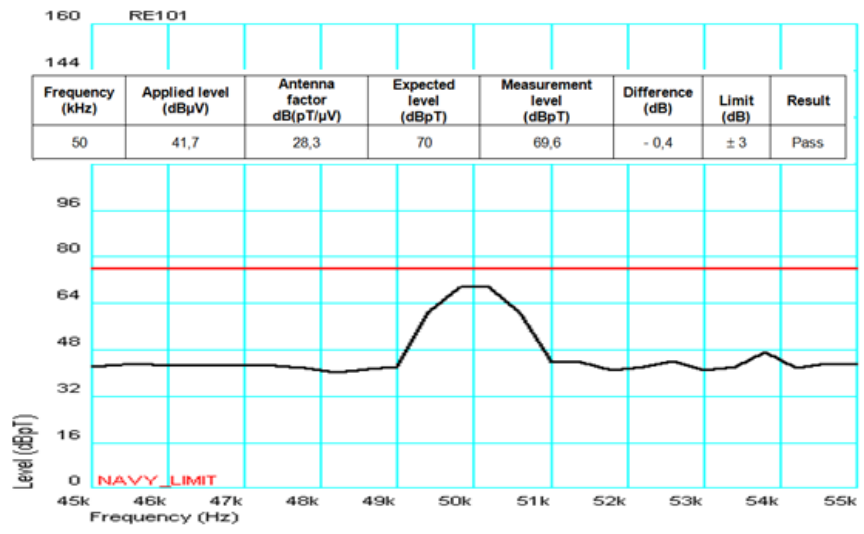
Apply a calibrated signal level, which is at least 6 dB below the limit (limit minus the loop antenna factor), to the coaxial cable to be connected  the receiving loop antenna at a frequency of 50 kHz.

Scan the measurement receiver for 50 kHz in the same manner as a normal data scan. Verify that the data recording device (test software) must indicate a level within ±3 dB of the injected level.

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.

Using an ohmmeter, verify that the resistance of the loop sensor winding is 5 – 10 ohms.

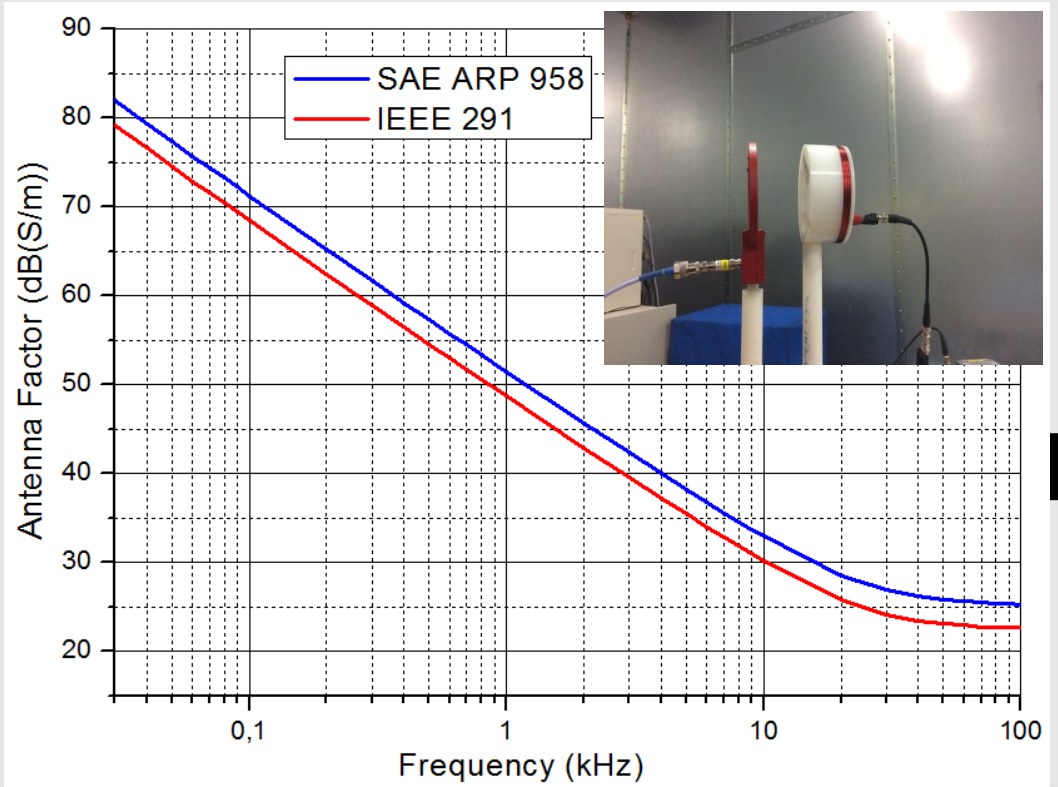


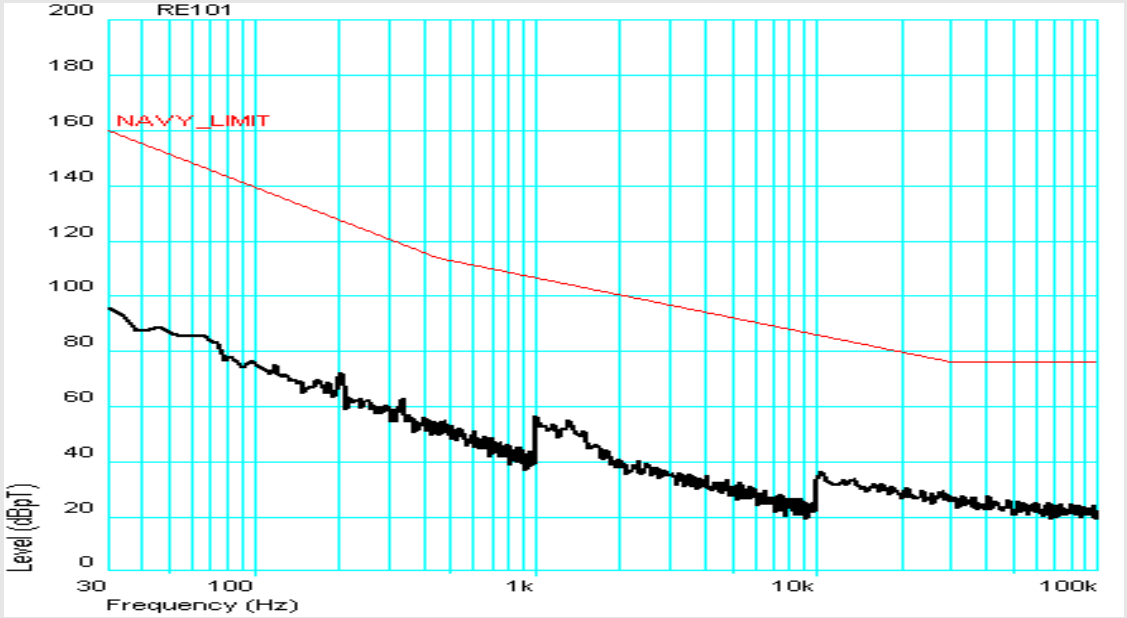




| Frequency (kHz) | Applied level (dBµV) | Antenna factor dB(pT/µV) | Expected level (dBpT) | Measurement level (dBpT) | Difference (dB) | Limit (dB) | Result |
|---|---|---|---|---|---|---|---|
| 50 | 41,7 | 28,3 | 70 | 69,6 | - 0,4 | ± 3 | Pass |

# BN Measurement for RE101 Testing and Antenna Factor

Before the RE101 testing, the background noise level measured with the EUT de-energized and all auxiliary equipment turned on shall be at least 6 dB below the allowable specified limits when the test is performed in a shielded enclosure.




As per MIL STD 461F/G, the factors for test antennas shall be determined in accordance with SAE ARP958.

TÜBİTAK UME

*Sen, O., Cakir, S. "Loop Antenna Calibrations with Inclusion of Vector Network Analyser and Comparison Between Calibration Methods", International Symposium and Exhibition on Electromagnetic Compatibility (EMC Europe 2017), Angers (04-08/09/2017) : 5 p.*

# RE102 Test Method

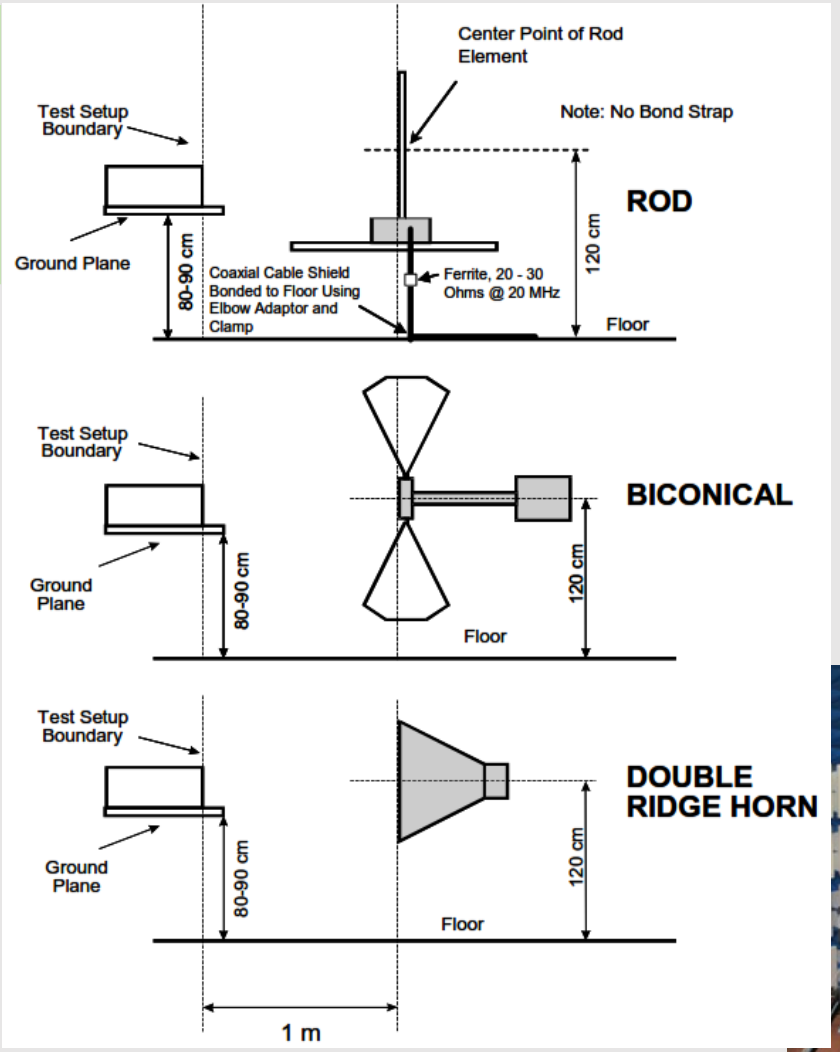
RE102 testing is performed to verify that electric field emissions from the equipment and subsystem enclosures, all interconnecting cables, and antennas designed to be permanently mounted to EUTs (receivers and transmitters in standby mode) do not exceed specified requirements.

This test is applicable in the frequency range 10 kHz – 18 GHz.

The levels of the electric field emitted from the EUT are determined by using different types of with linearly polarized receiving antennas. The receiving antenna is placed 1 meter from the test setup boundary and 120 cm above the floor ground plane.

This test shall be carried out on the EUT face with maximum emissions.

The limits are based on the platform where the EUT is used. The Pass/Fail ciriterion depends on EUT.




# RE102 Test Antennas

- Below 30 MHz, the measurements with the 104 cm rod are performed only for vertical polarization.
- Above 30 MHz, the measurements shall be performed to measure both horizontal and vertical components of the radiated field.
- The following types of antennas shall be used to scan the entire frequency range.

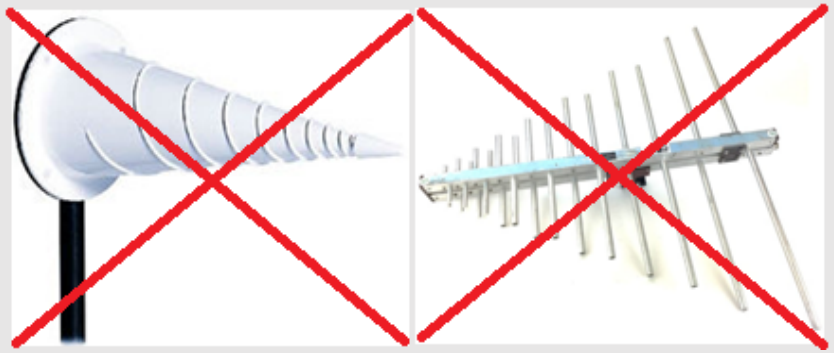
**Active Rod Antenna**: 104 cm with impedance matching network, preamplifier, and square counterpoise measuring 60cm on a side (10 kHz–30 MHz)

**Biconical Antenna**: 137 cm tip to tip (30 MHz–200 MHz)

**Large Double Ridged Horn Antenna**: 69 x 94.5 cm opening (200 MHz–1 GHz)

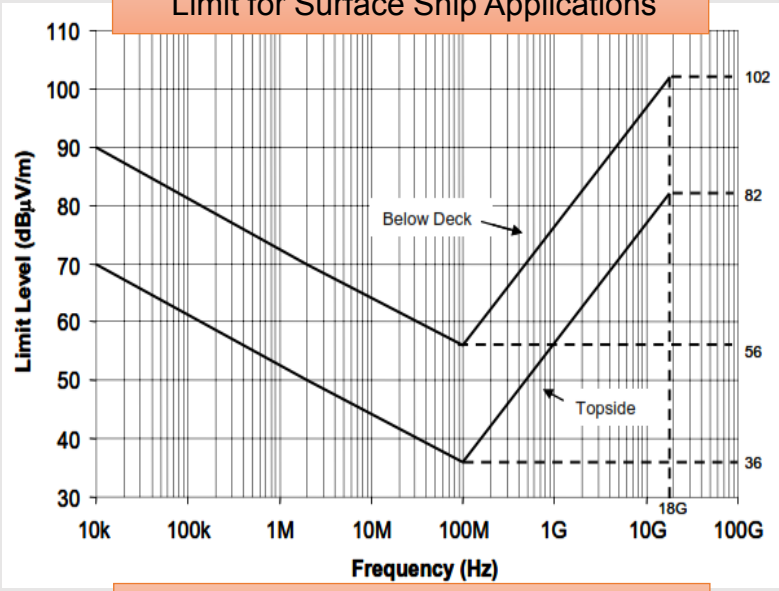
**Small Double Ridged Horn Antenna**: 24.2 x 13.6 cm opening (1 GHz–18 GHz)

**Log spiral antennas, Bilog antennas and Log periodic antennas are not permitted.**

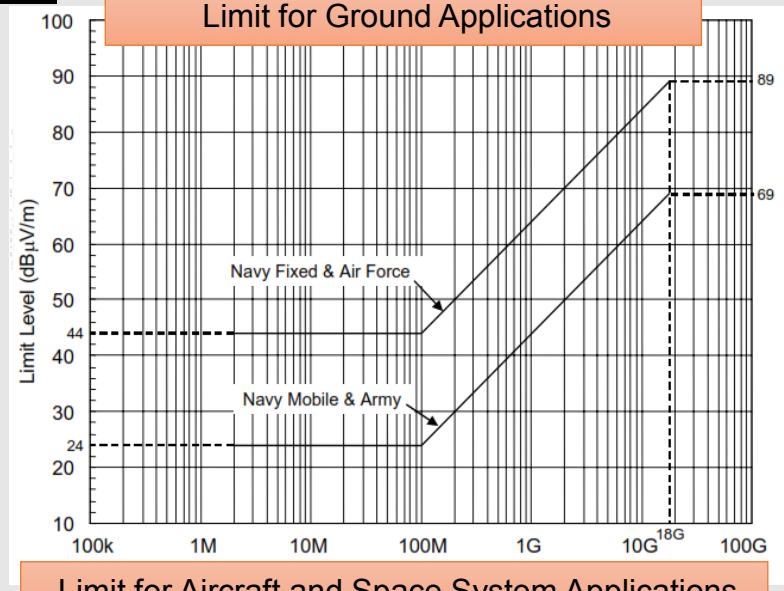


# RE102 Test Limits

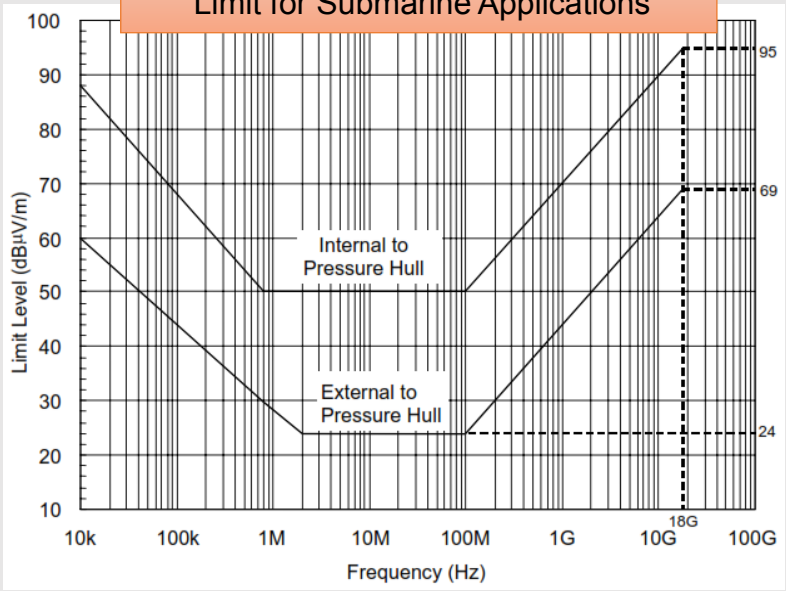
## Limit for Surface Ship Applications



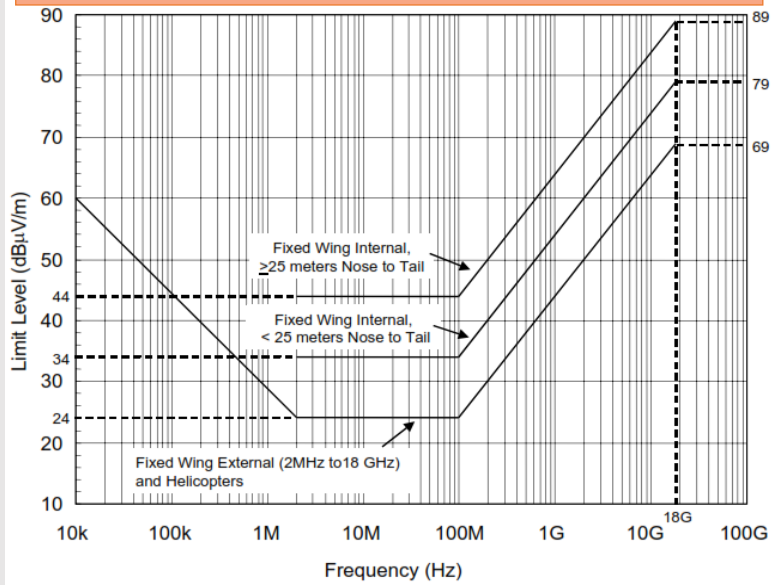

## Limit for Ground Applications




## Limit for Submarine Applications




## Limit for Aircraft and Space System Applications



# Verification of RE102 Test System

Before RE102 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.

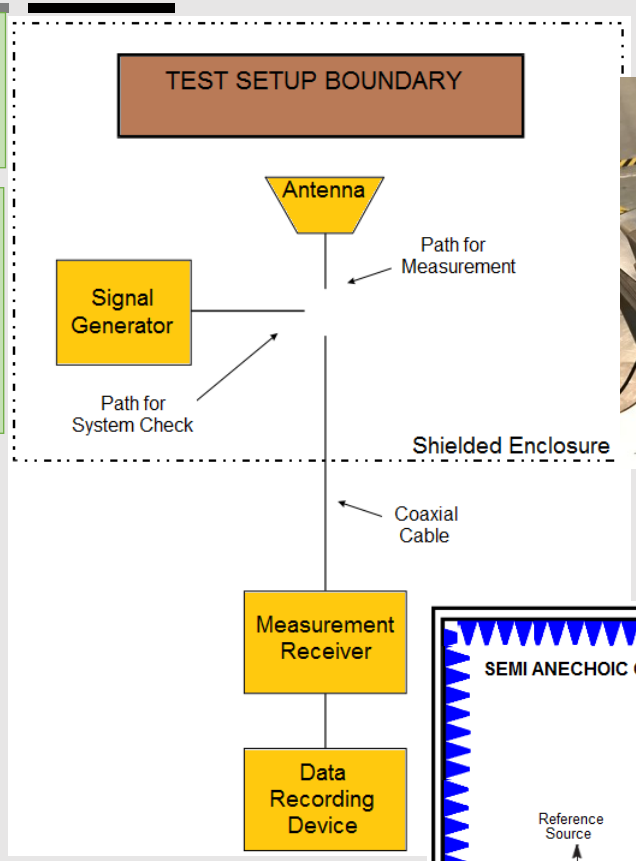
The evaluation shall be performed on the overall measurement system from each antenna to the data output device at the highest measurement frequency of the antenna. For the active rod antenna, the evaluation shall be performed at the lowest frequency of test, at a mid-band frequency, and at its highest measurement frequency.

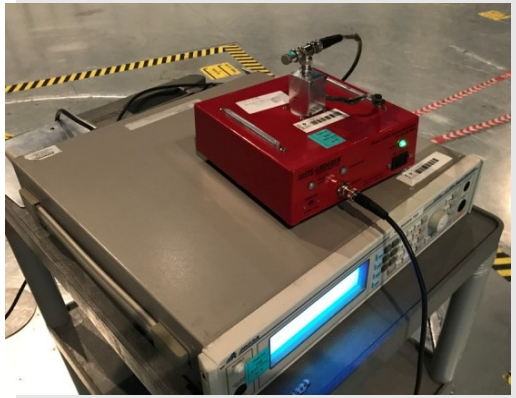
A signal generator shall be connected to the coaxial cable in place of the measurement antenna. For the rod antenna, a 10 pF capacitor shall be used in place of the rod element and the signal shall be injected through in the rod antenna using the 10 pF capacitor .

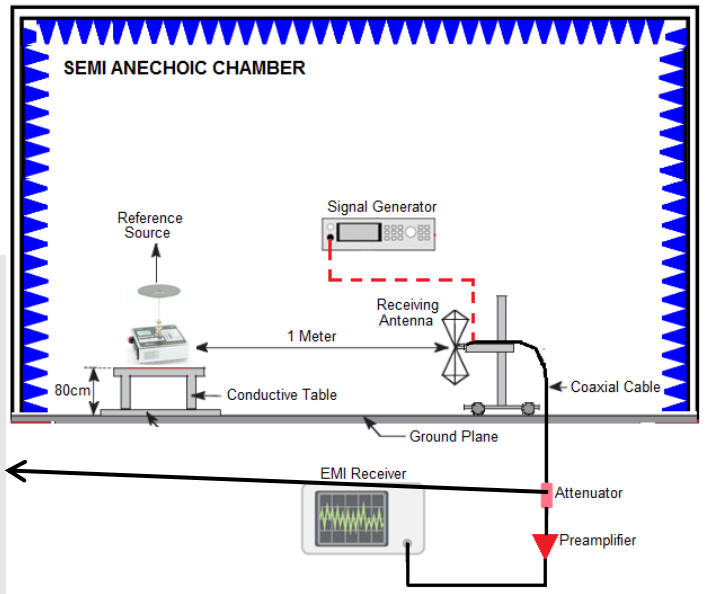
A known signal that is 6 dB below the limit (limit minus antenna factor except rod antenna) to the input of the each receiving antenna at the specified frequency. Thereafter, the measurement receiver is scanned for each frequency in the same manner as a test scan and it is expected that the test software must indicate a level within ± 3 dB of the injected level.

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.

Moreover, the reference source shall be utilized before RE102 testing in order to check all the test system including the test chamber and the receiving antenna.



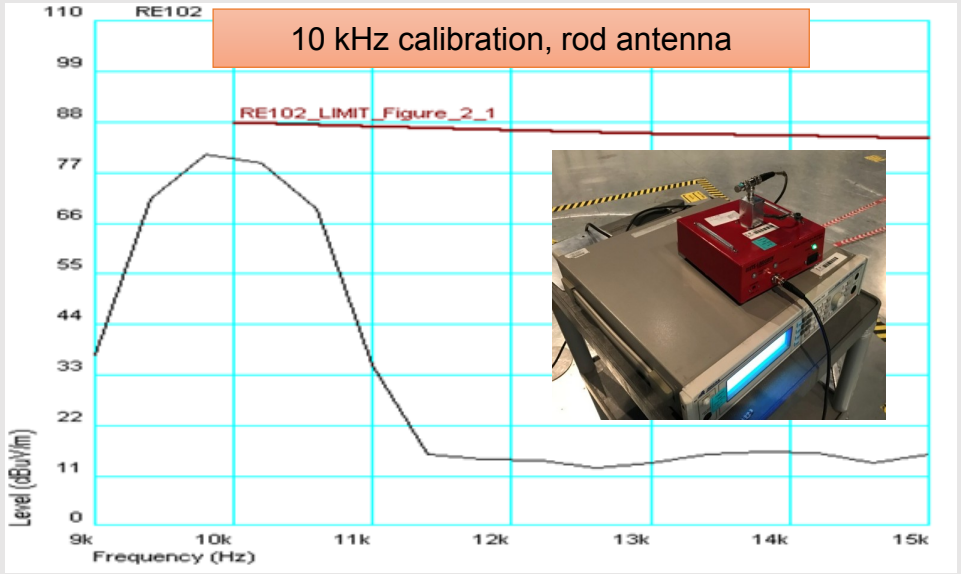





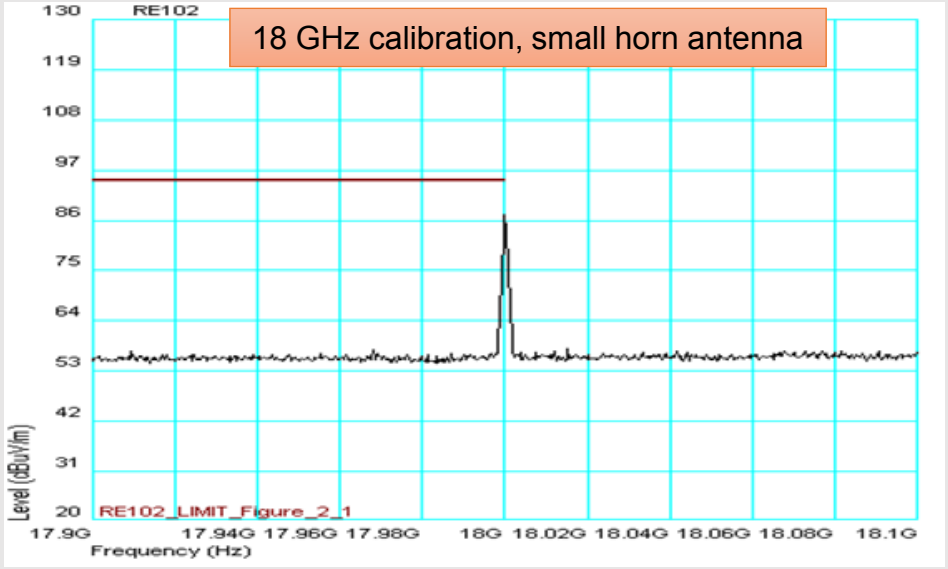

The attenuator (at least 6 dB) shall be used between the output of receiving antenna and the input of the preamplifier in order to minimize the mismatch of impedance.

# Verification of RE102 Test System

10 kHz calibration, rod antenna



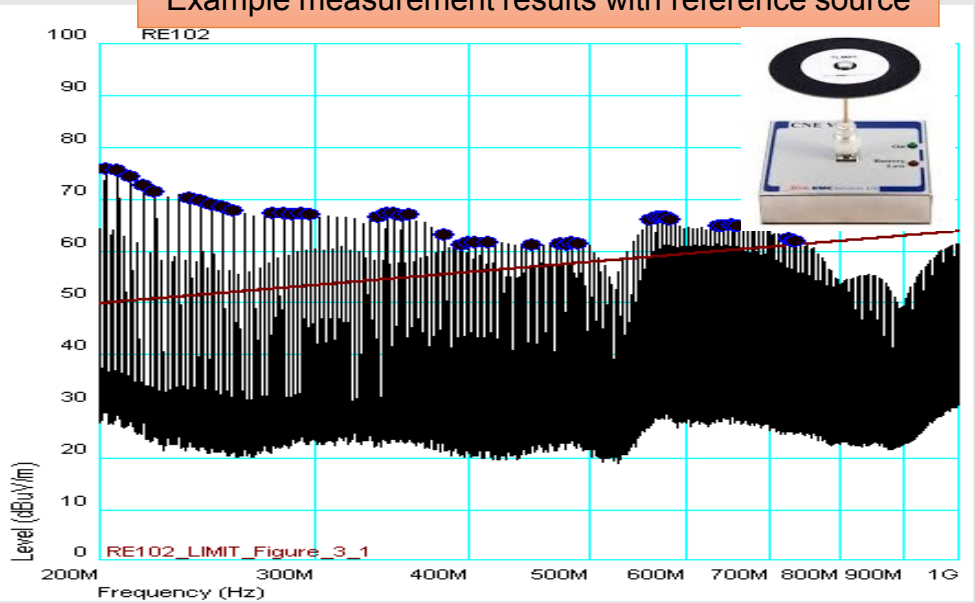

18 GHz calibration, small horn antenna




Example RE102 calibration results

| Frequency (MHz) | Antenna type | Antenna factor (dB/m) | Applied value (dBµV) | Expected value (dBµV/m) | Measured value (dBµV/m) | Margin (dB) | Tolerance (dB) | Result |
|---|---|---|---|---|---|---|---|---|
| 0,01 | Rod | -1,4 | 76,0 | 82,0 | 80,8 | -1,2 | ± 3 | ✓ |
| 2 | Rod | -1,4 | 38,0 | 44,0 | 44,4 | 0,4 | ± 3 | ✓ |
| 30 | Rod | 0,8 | 38,0 | 44,0 | 42,1 | -1,9 | ± 3 | ✓ |
| 200 | Biconical | 14,0 | 36 | 50,0 | 50,2 | 0,2 | ± 3 | ✓ |
| 1000 | Horn | 23,2 | 40,8 | 64,0 | 64,6 | 0,6 | ± 3 | ✓ |
| 18000 | Horn | 46,0 | 43,0 | 89,0 | 87,4 | -1,6 | ± 3 | ✓ |

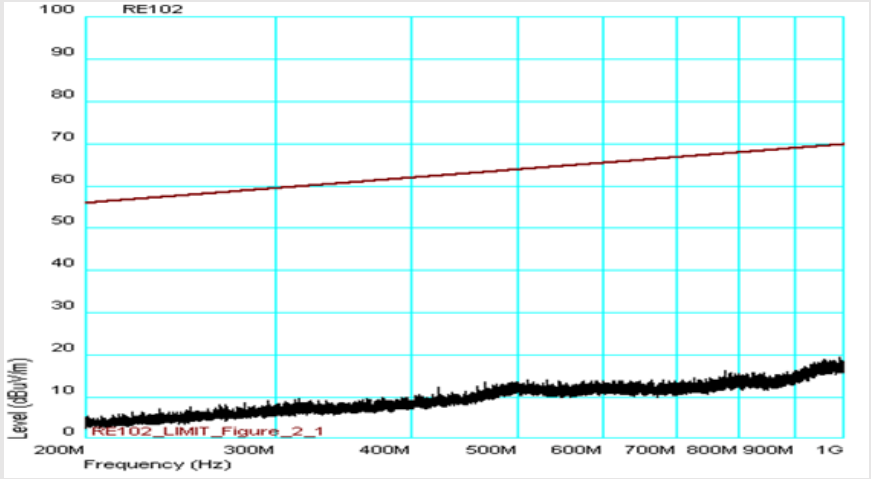
Example measurement results with reference source



# BN Measurement for RE102 Testing

Before the RE102 testing, the background noise level measured with the EUT de-energized and all auxiliary equipment turned on shall be at least 6 dB below the allowable specified limits when the test is performed in a shielded enclosure.

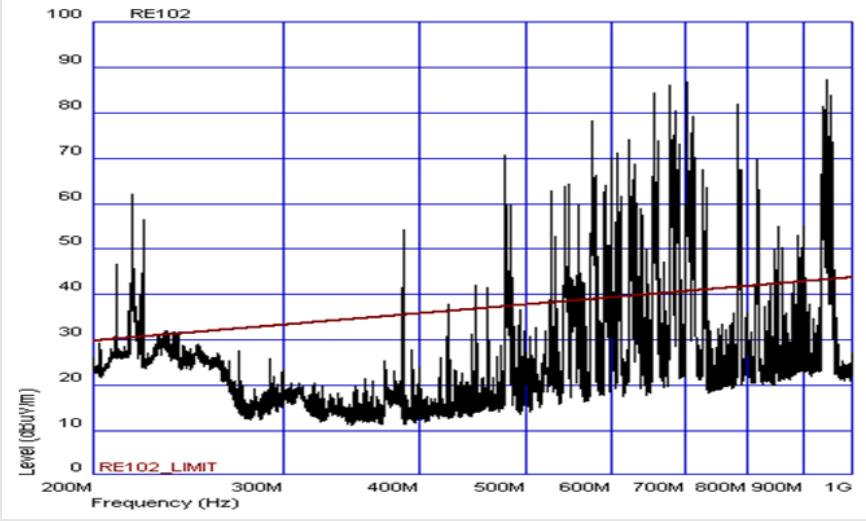
Anechoic chamber background noise measurement results




RE102 testing is normally performed in laboratories in anechoic chambers at 1m in accordance with the MIL STD 461F standard. However, it is not always possible to use laboratories because of some limitations. If the EUT has large dimensions or heavy, it is not possible to use laboratory facilities for tests. As a consequence, on-site radiated emission tests are required for manufacturer.

Due to many RF noise sources such as FM, TV and GSM, in the outdoor environment, the RE102 measurement is not able to be performed properly at OATS for all frequency range.

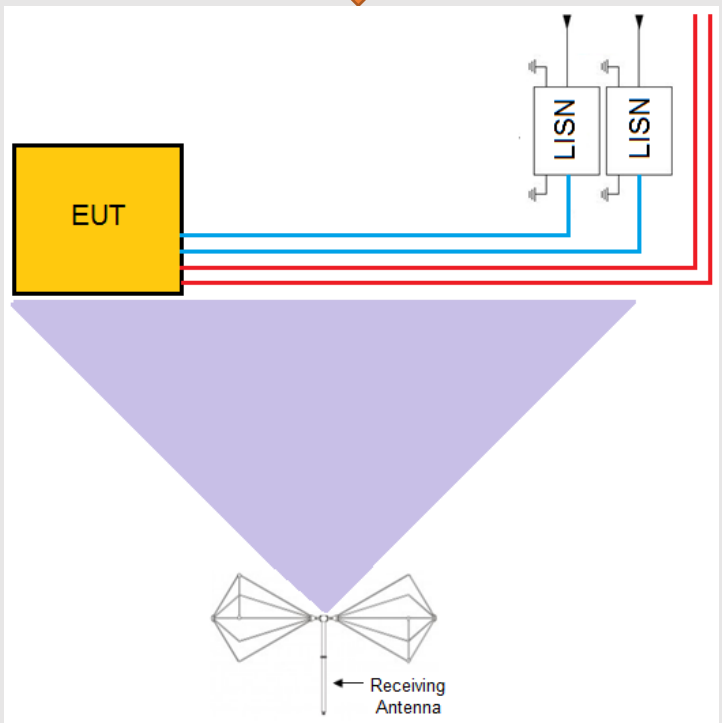
On site background noise measurement results



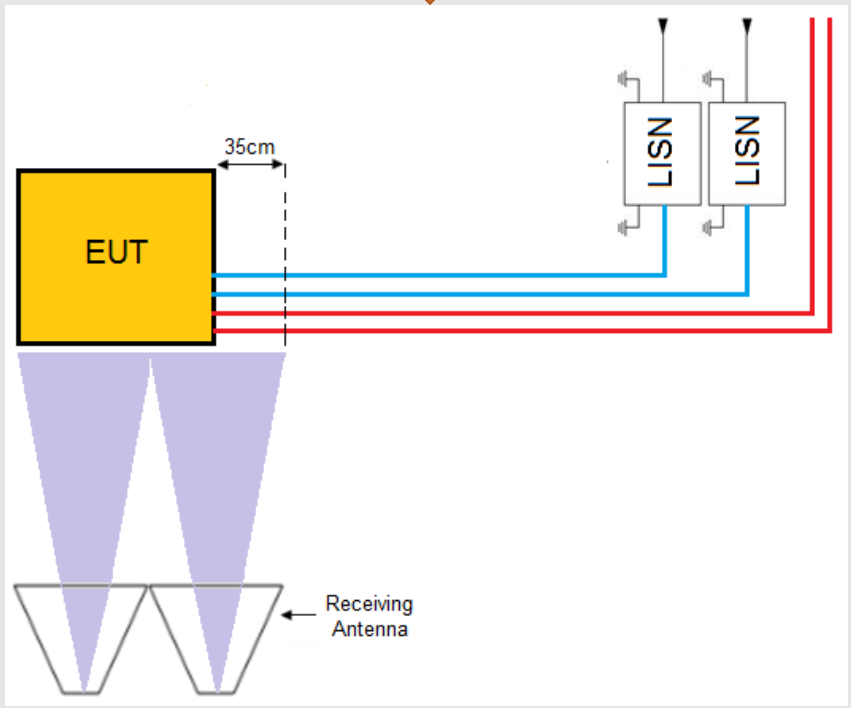
# RE102 Antenna Position

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

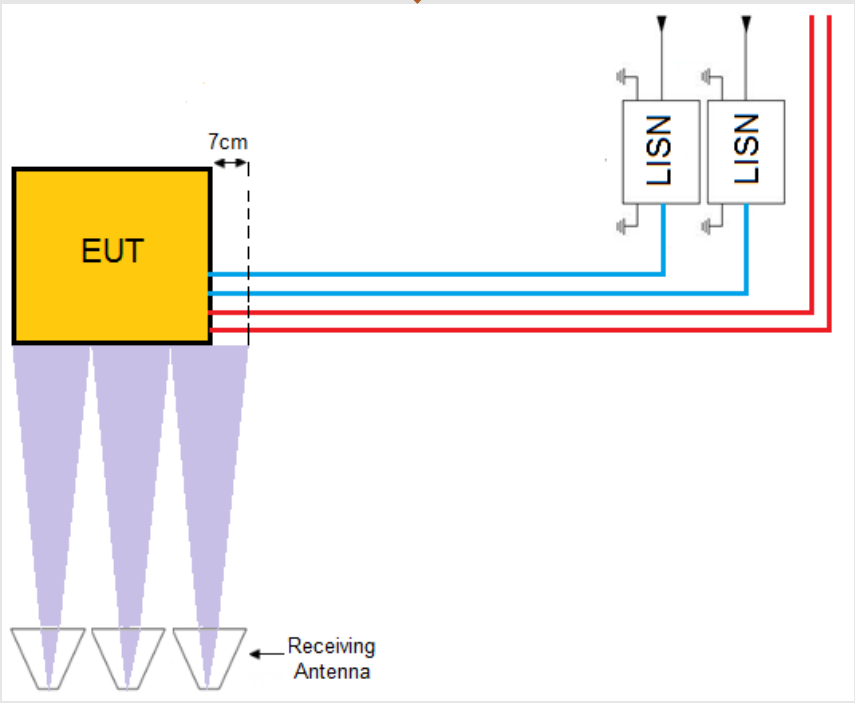
- For setups with the side edges of the boundary 3 meters or less, one position is required and the antenna shall be centered with respect to the side edges of the boundary.
- For setups with the side edges of the boundary greater than 3 meters, use multiple antenna positions at spacing.



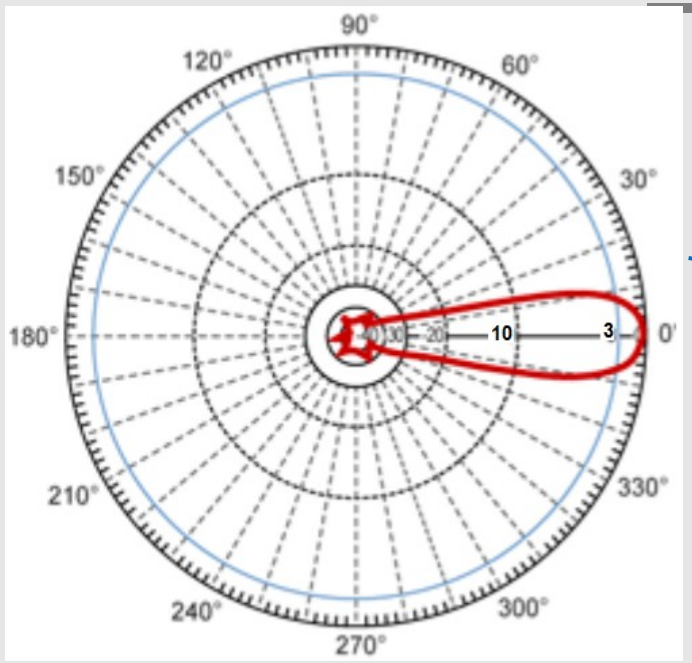

For testing from 200 MHz up to 1 GHz, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.



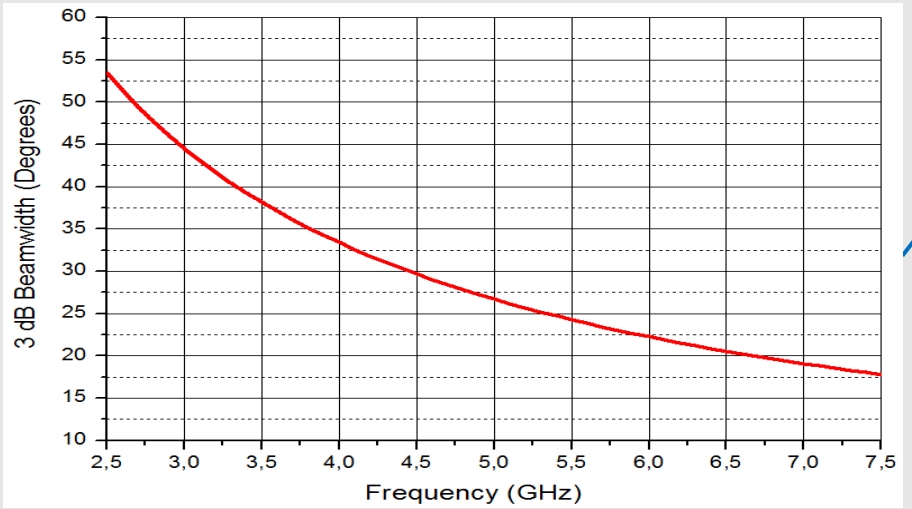

For testing at 1 GHz and above, place the antenna in a sufficient number of positions such that the entire width of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.

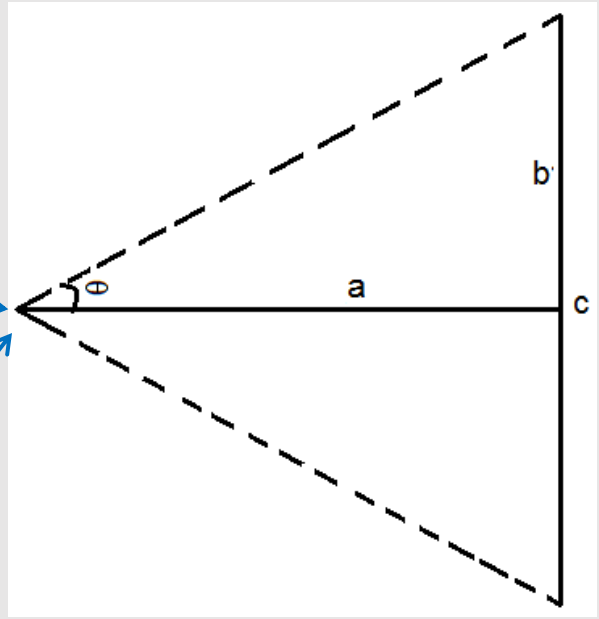


# Determination of RE102 Antenna 3 dB Beamwidth




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)

TÜBİTAK
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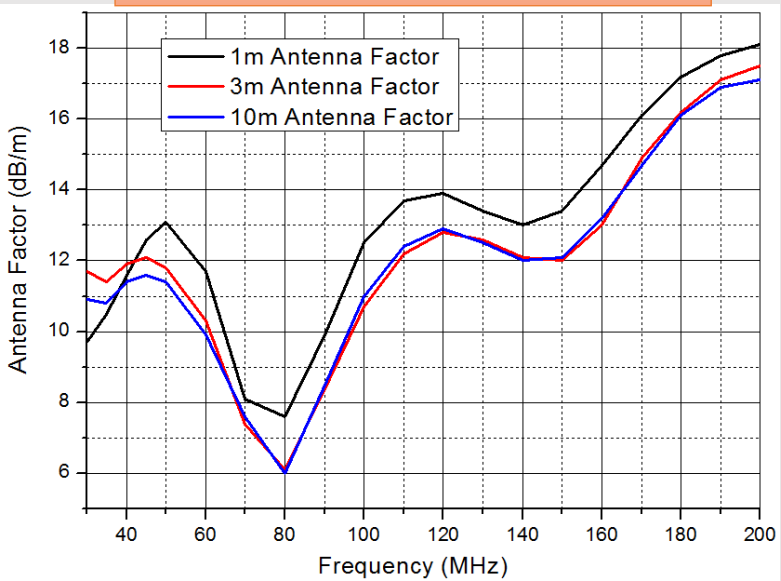
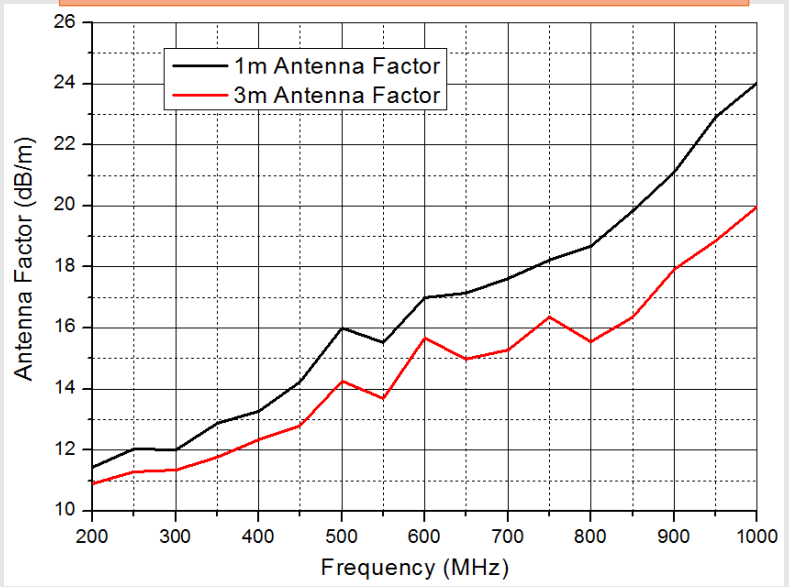
# Effect of Antenna Factors on RE102 Test Results

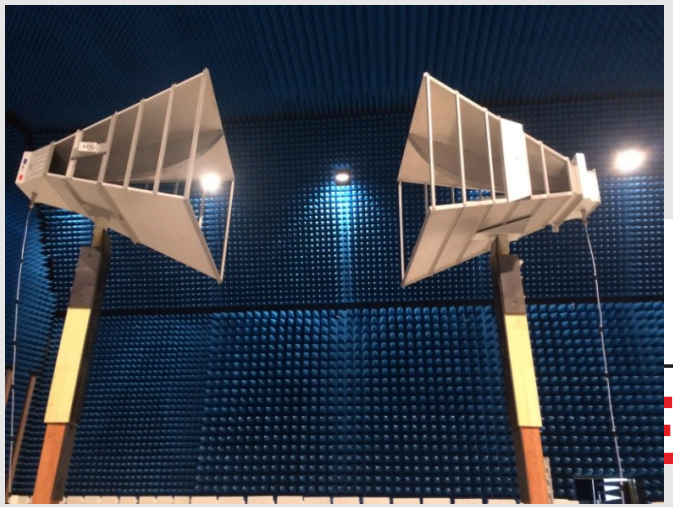
Biconical Antenna Factors




As per MIL STD 461F, the receiving antennas shall be calibrated in accordance with the SAE ARP-958 standard (Distance between antennas 1m) at RE102 testing in order to avoid wrong testing.

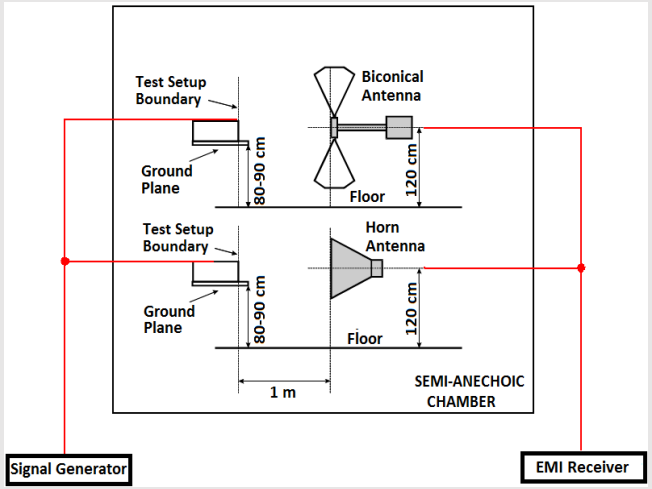
Large Double Ridged Horn Antenna Factors

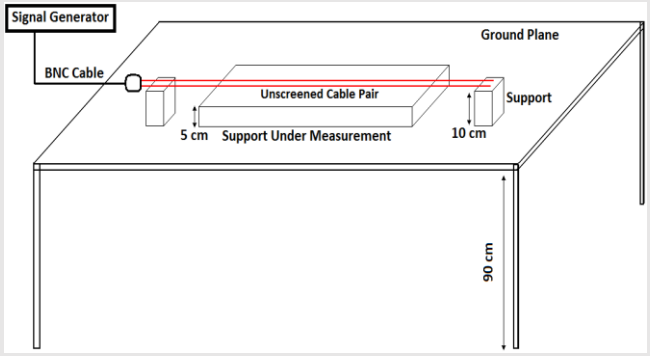


# Support Effect on RE102 Testing

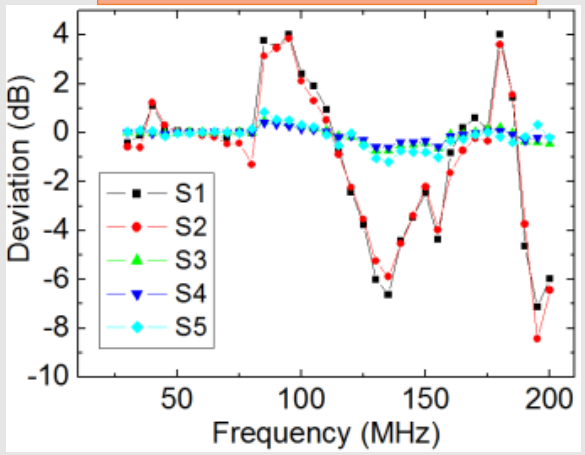
## Measurement Setups



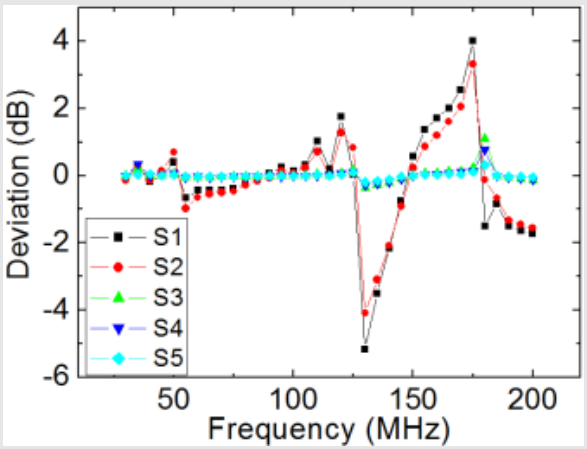




**S1:** Wood,
**S2:** Molding Polyamide,
**S3:** Foam Rubber,
**S4:** Foam-Like Plastic Material
**S5:** Styropor

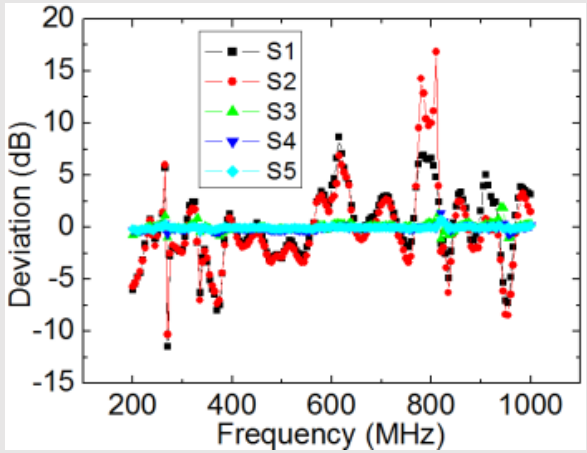
## Vertical Polarization Results



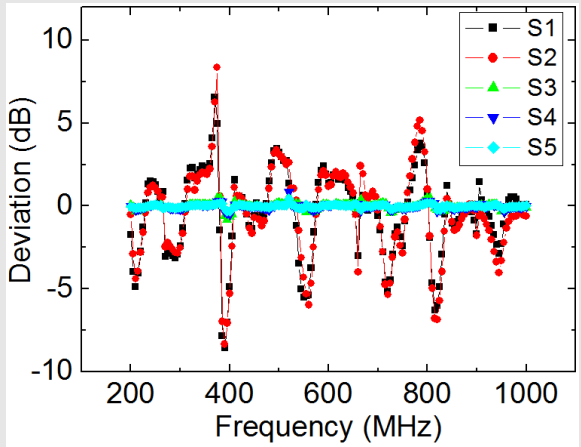

## Horizontal Polarization Results




## Vertical Polarization Results




## Horizontal Polarization Results

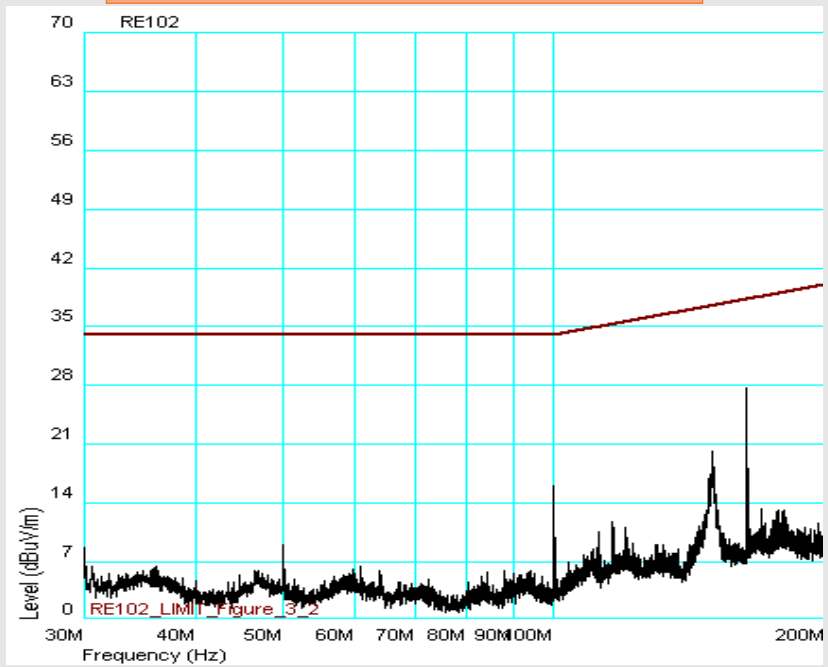



*Sen, O., Cakir, S., Celep, M., Cinar, M., Hamid, R., Cetintas, M. "Influence of Dielectric Support on Military Radiated Emission Tests Above 30 MHz ", 7th Asia Pasific International Symposium on Electromagnetic Compatibility, Shenzhen (18-21/05/2016)*

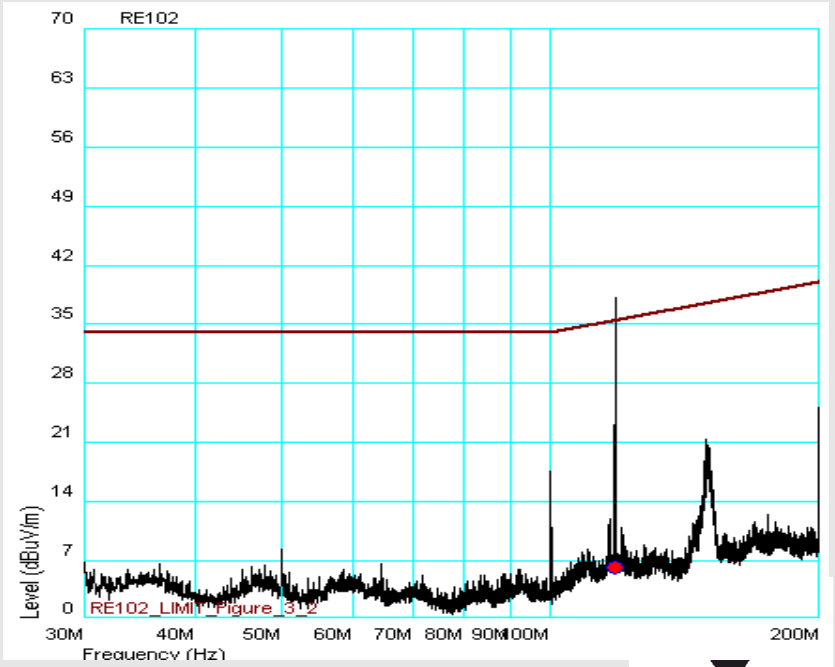
# Time-Varying Signals in RE102 Testing

As per MIL STD 461F, for equipment that operates such that potential emissions are produced at only infrequent intervals, times for frequency scanning shall be increased as necessary to capture any emissions

Measurement Time: 15ms




Measurement Time >15ms

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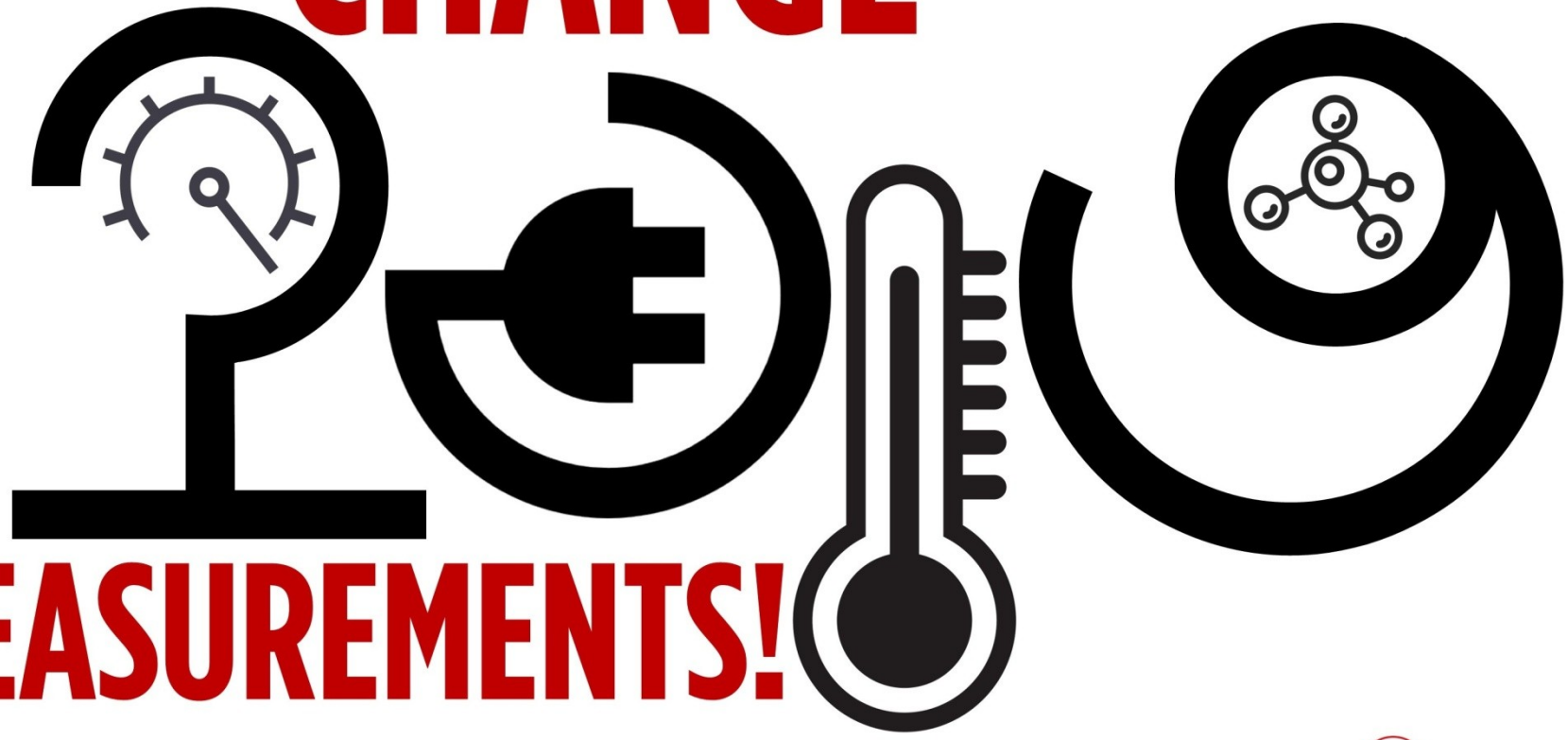
# CHANGE THROUGH



# MEASUREMENTS!

TRUE MEASUREMENT EXCELLENCE

## THANK YOU

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