

Antennas for EMC Testing



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Outline

- EMC Terms and Definitions
- Typical EMC Antennas
- Calibration of EMC Antennas
- Application of EMC Antennas
- Comparing antenna usage in alternative facilities (reverberation chamber/ GTEM/TEM cell/Field generators)



Applications in EMC testing

- Antennas convert time-varying voltages to a **radiated** electromagnetic field.
- Field generators such as
 - TEM cells, parallel plates, and E/H field generators are, strictly speaking, not antennas.
- EMC antennas are mainly used for
 - Radiated Emissions Measurement
 - Radiated Immunity Testing
 - Site qualification test (Normalized site attenuation)
 - Other applications, such as exciting a reverberation chamber



Terminology

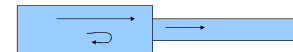
- Gain
- VSWR (return loss)
- Antenna factor
- Radiation (reception) pattern, Beamwidth
- Bandwidth (frequency of operation)
- Phase center
- Polarization
- Near/Far field



- Directivity (gain)
 - Specifies an antenna's ability to concentrate a transmitted signal in a desired direction, or receive a signal from this direction.
 - A passive antenna can not amplify a signal. Directivity is defined by comparing to a theoretically omni-directional antenna with the same input power.
 - In some cases gain is interchangeable with directivity. In most EMC applications, gain also includes the mismatch factor between the antenna and its feed - "realized" gain.
 - By reciprocity, transmit gain is the same as receive gain.



- VSWR (reflection coefficient/return loss)
 - They all describe the same physical phenomenon.
 - VSWR defines how a device is matched to the measuring instrument (normally at 50 ohms).
 - Analogy: water (RF signal) flows through pipes with unequal diameters. Some goes through, and some is reflected.



- A perfect match (everything goes through) is when VSWR=1:1, reflection coefficient is 0, and return loss is infinite.



- Example:

- VSWR=2:1
- Reflection coefficient is 1/3
- Return loss is 9.5 dB
- 11% of the power is reflected, or 89% of the power is delivered to the load.



- Antenna Factor (AF)

- AF is a function of antenna directivity gain, VSWR, and frequency. AF can be converted to/from gain by a simple equation.
- AF is a convenient term for EMC applications, as it provides a receiving antenna the relationship between the incident EM field and the voltage induced on a 50 ohm load (EMC receiver/Spectrum Analyzer) connected to the antenna.
 - $AF=E/V$
- AFs are normally provided by antenna manufacturers or calibration labs. The accuracy/uncertainty of AFs directly affects radiated emission measurements.



- Antenna Radiation Pattern & Beamwidth

- Is the response of an antenna as a function of viewing angle.
- Beamwidth is typically measured when power received has fallen half (3 dB down) of the boresight direction. This is called half-power beamwidth or 3 dB beamwidth.



- Phase Center

- Radiated wavefront has a curvature when in near field (in far field, the curvature is so large that it can be regarded as plane wave). The apparent center of the curvature is the phase center.
- For log periodic antennas, phase center moves with frequency. The measurement distance from antenna to device under test is unclear. It is often chosen at a fixed position as an approximation.



- Polarization

- Linear/circular/elliptical
- It has to do with radiated vector field traced out as a function of time
- Most EMC antennas are linearly polarized, such as log periodic dipole antennas, biconical antennas, and dipoles. Some are circularly polarized, as required by earlier MIL-STD 461, and in some communication applications.



- Bandwidth

- “The range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specific standard” – (Balanis- Antenna Theory)
- The “characteristics” normally include:
 - VSWR
 - Beamwidth
 - Radiation pattern



- Balun

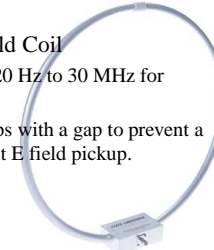
- *Balanced-to-Unbalanced* transformer.
- Provides low impedance to differential current, and high impedance to common mode current.
- Coaxial cables are unbalanced, because they are unsymmetrical with respect to ground plane
- Unbalanced antennas have different responses depending on which side is up when vertically polarized. This causes large measurement uncertainties.
- Some baluns also transform impedances, for better matching to system, i.e. 50 ohms.



Typical EMC Antennas

- Loop & Magnetic Field Coil

- Low frequency from 20 Hz to 30 MHz for measuring H field.
- Most are shielded loops with a gap to prevent a shorting turn, and limit E field pickup.



- Dipole

- Tuned to a specific frequency, approximate between 30 MHz to a few GHz. Narrow band.
- Often used as reference antenna because performance can be theoretically calculated. Note: balun impedance has an effect on AF. Antenna performance can only be calculated if the balun is known.
- Seldom used in everyday measurement, due to the need for individual tuning at each frequency.



- Biconical Antenna

- Typical 20 MHz to 300 MHz
- All biconical elements on market have similar sizes and shapes, because they are based on MIL-461 spec from the 1960s.
- Due to high VSWR (more than 5:1) at <50 MHz, balun performance is important for bicons.
- Common mode current can be induced on the feed cable. Ferrite beads are often used to suppress it. Cable should be extended out from the antenna before dropping.



- Log Periodic Dipole Arrays

- Typical 80 MHz to a few GHz
- Phase center of a log antenna moves from the back of the antenna boom to the front as frequencies go up.
- For emissions measurement, center of the boom is typically used to measure distance to an EUT as an approximation
- For immunity measurement, the front of the boom is typically used to measure distance.
- Gain is typically around 5 dB, which provides a good compromise between beamwidth and sensitivity (or power requirement).



- Bicon/Log Hybrid

- Sometimes called biconilog/bilog etc.
- Combines the frequency range of a bicon and a log antenna (typically ~20 MHz to a few GHz)
- At 30 MHz, $\lambda/2=5$ m. Hybrid antennas are electrically short. Some antennas use loading techniques to compensate for the size. These antennas should typically only be used for immunities test. (Z. Chen "Understanding the measurement uncertainties of the bicon/log hybrid antenna", ITEM 1999)





- Broadband ridged waveguide horn
 - 700 MHz to 18 GHz
 - Versatile and broadband. Make sure beamwidth meets your measurement requirement.



- Standard Gain Horn antenna
 - A few hundred MHz to GHz
 - Gains can be calculated based on physical dimensions of the horn.
 - Many horns are needed to cover a broad frequency range.



Antenna Calibration

- Standard Site Method:
 - For “dipole-like” antennas, such as dipole, bicon, log antennas, and bicon/log hybrid, ANSI C63.5 specifies the method based on Normalized Site Attenuation (NSA).
 - Site Attenuation (SA): basically is the insertion loss between transmit and receive antenna
 - $NSA \text{ (in dB)} = SA - AF1 - AF2$



- Basic setups for standard site method:
 - Conducting ground plane
 - One antenna is at a fixed height (2 m)
 - The other antenna is 10m away, and scanned from 1 to 4 m in height
 - Minimum SAs are recorded (or maximum response).
 - Calculations are then performed to derive the antenna factors.
 - Although ground plane is used, the aim of the calibration is to obtain free space AF by theoretically removing the ground plane effect.



- Some assumptions made in the standard site method
 - Antennas have radiation patterns of a point dipole (i.e. Uniform in H-plane, and $\sin(\theta)$ in the E-plane): donut shape.
 - No mutual couplings among transmit, receive antennas and ground plane.
 - Physical size of the antenna does not affect the AF (i.e. Antennas are immersed in a uniform field)



- These simple assumptions are not always acceptable for all NSA geometries. The error for a single bicon antenna factor can be as large as 2 dB. Antenna calibrations should be limited to “near-free-space” geometry only (horizontal/10m/2m)
- New ANSI C63.5-2004 provides correction factors for bicons. The correction factors are based on numerical simulation, and perfect 50 ohm or 200 ohm baluns.
- Another way is to use a calculable bicon, which does not make any assumptions in the balun.



- For log antennas, there is currently no correction table provided. These major factors contribute to errors:
 - Non-stationary phase center with respect to frequency
 - Non-dipole-like pattern. Log antennas have approximately 5 dBi gains.
- Research is in progress to develop a new method based on a complex fit NSA scheme. (Z. Chen, M. Foegelle “An improved method for determining normalized site attenuation using log periodic dipole arrays”, IEEE symposium 2000)



- Calibrations for High frequency Antennas (Horn antennas)
 - Horns typically have high gains (10 dBi or more), thus have narrow beamwidth.
 - Antennas do not see ground plane at close distances. Calibration is in free-space condition.



Use of Antennas for Radiated Emission Testing

- Test setup per ANSI C63.4/ or equivalent EN standards.
- Metal ground plane
- Use free-space antenna factors. Although emissions tests are not performed in free space, FSAF is deemed a good average AF in different geometries. Standard site method in the near FS setup (horizontal, $d=10m$, $h_1=2m$) yields free space AFs

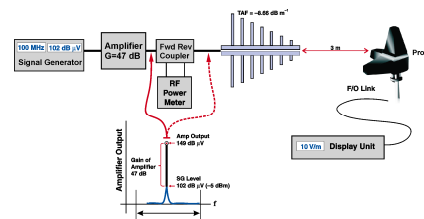


Use of Antennas for Radiated Immunity testing

- No US requirements for commercial EMC. Most tests are performed per EN 61000-4-3.
- Requires the establishment of a uniform field plane where is EUT would be. Absorbing materials are likely necessary between the antenna and the uniform plane to neutralize the ground reflection.



Typical Immunity Test setup



Idealized Immunity Test System Equipment Function according EN 61000-4-3

- **Signal Generator** - Source of test signal, amplitude and frequency, 80 - 1000 MHz, 80% AM
- **Amplifier** - Increases level of test signal to achieve desired test field values
- **Forward/Reverse power Coupler** - Samples forward and reflected power to radiating device
- **Power Meter** - Reads power values in forward and reverse channels, allows calculation of forward power to antenna
- **Antenna** - Generates test field at 3 m
- **Field Meter** - Reads generated field levels, provides feedback loop



Use of Antennas for Site Validation Testing

- Reverse of antenna calibration process. Requirement is within +/- 4 dB.
- What AFs to use
 - FSAFs for the antenna pair and Geometry Specific Correction Factors
 - Geometry Specific Correction Factors (GSCF)
 - Available in C63.5 for bicon antennas
 - For other antennas, a measurement approach is provided in C63.5 to obtain GSCFs. A reference site is needed, and a pair of antennas are measured multiple times at multiple locations on the reference site to derive the GSCFs.



C63.5 vs. CISPR 16 Approach

- Measurement GSCF method boils down to comparing the users site to the reference site. Note that there are physical requirements and electric requirements on the reference site, and also multiple locations are used on the reference site to reduce uncertainties.
- In CISPR 16, AFs are bypassed in favor of a direct site to site comparison method. The reference site is validated by using calculable dipoles.



Discussion

