Electromagnetic Compatibility (*EMC*)

Introduction EMC Testing

Agenda

- *System Radiated Interference Test*
- System Conducted Interference Test

System Radiated Interference Test

- *Open-Area Test Site (OATS)*
  - RE、RS measurement
  - Test Antennas
  - Measurement Precautions(預防措施)
  - Open-Area Test Site
- Measurement in a Laboratory(實驗室)
  - Microwave Anechoic(無反射) Chamber(房間)
  - Transverse(橫向) Electromagnetic (TEM) Cell
  - Reverberating(反射) Chamber
  - G-TEM Cell

Open-Area Test Site

- Why use “Open-Area Test Site”
  - IF RE、RS measurement are done in a room, or an enclosed area, it is possible that reflections or scattered(散射的) signals from walls, floor and ceiling(天花板) will be present.
  - It is necessary if the measurements yield a true representation of the characteristic being measured, and lead to repeatable results.
- Defect
  - No Immunity test procedures are allowed on this type of EMC facilities due to governmental regulations.

Open-Area Test Site

RE、RS measurement

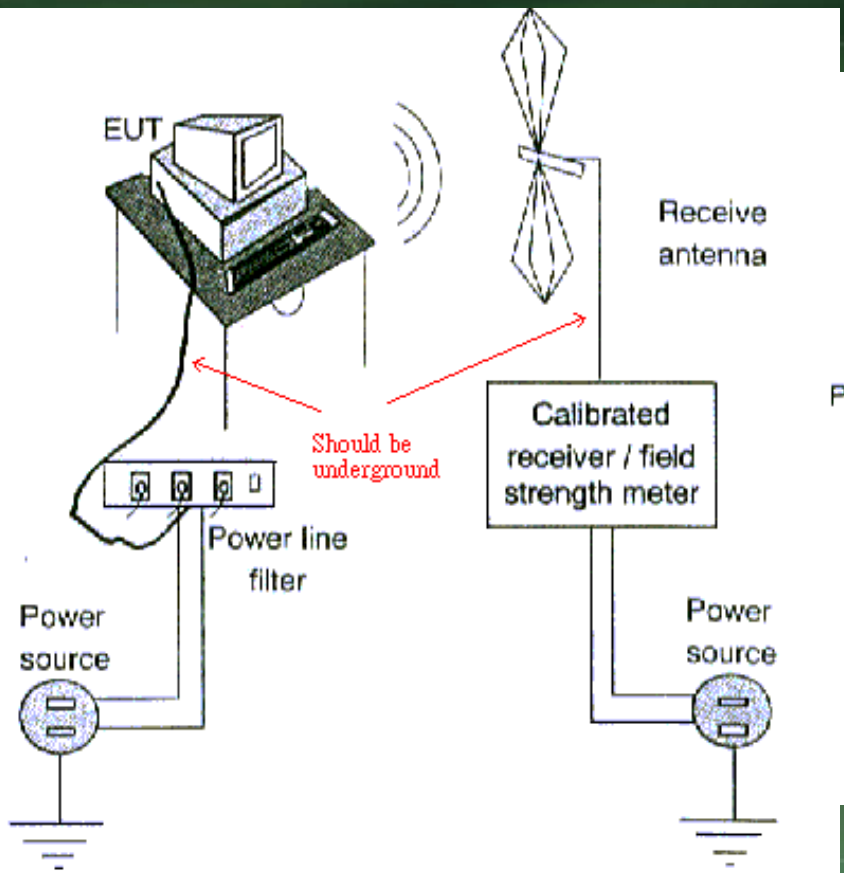


Figure 5-1 Principle of measurement of radiated emissions

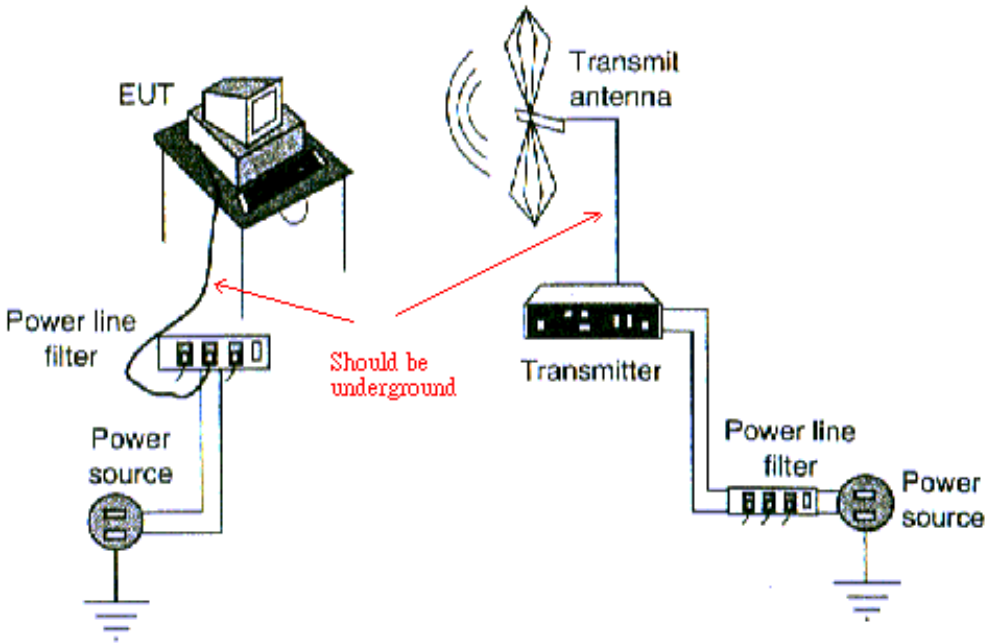


Figure 5-2 Schematic for measurement of radiation susceptibility

Open-Area Test Site

Test Antennas

- A convenient approach to illuminate an equipment under test with known field strengths is to use exact half wavelength long dipoles at fixed frequency.
- Test antenna depends on the frequency of operation.

Antenna Type	Frequency, MHz
Rod antenna	.01 ~ 30
Loop antenna	.01 ~ 30
Biconical antenna	30 ~ 220
Log periodic antenna	200 ~ 1000
Dipole antenna **(Broad-Band antenna)**	30 ~ 1000
Conical log spiral	200 ~ 10,000
Double ridged waveguide	1000 ~ 18,000
Waveguide horn	Above 1000

Open-Area Test Site

Test Antennas -- Example

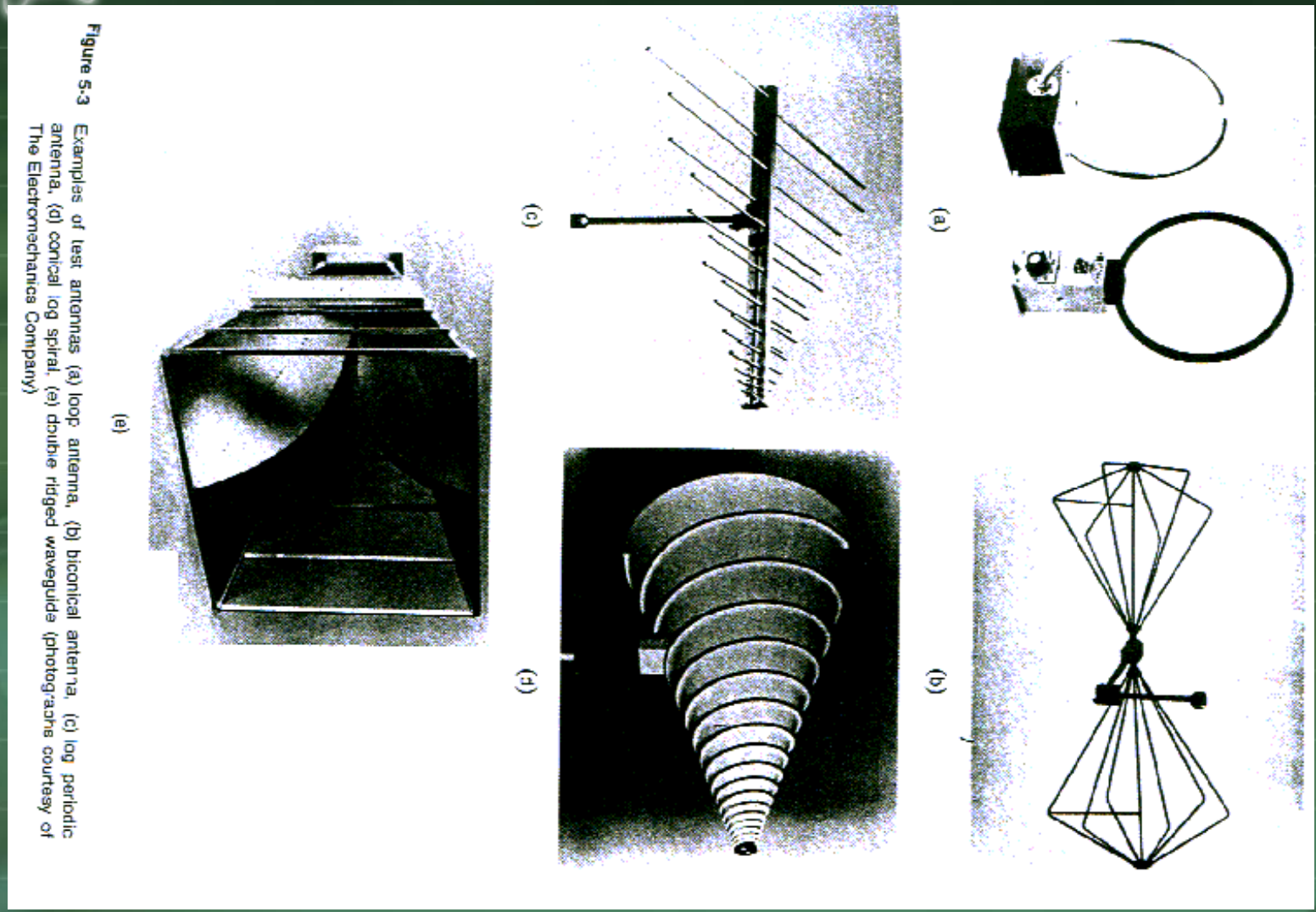


Figure 5-3 Examples of test antennas (a) loop antenna, (b) biconical antenna, (c) log periodic antenna, (d) conical log spiral, (e) double ridged waveguide (photographs courtesy of The Electromechanics Company)

Open-Area Test Site

Measurement Precautions

- Measurement Precautions(預防措施)
  - Electromagnetic environment of the open area test site will be relatively quite (at least 6dB below) and free from strong signals.
  - The open area test site will be free from electromagnetic scatters.(散射源)
  - Underground cables and pipelines also lead to electromagnetic scattering, if not buried deep enough.

Open-Area Test Site

Measurement Precautions

- A well-defined test environment
- The metallic ground plane and absence of reflecting objects ensure That the measurements will be quite repeatable.

Open-Area Test Site

Stationary EUT

- Sc, Sd：scattered signals
  - Sc ≤ Sd - 6dB
- D’ ≥ 1.5D

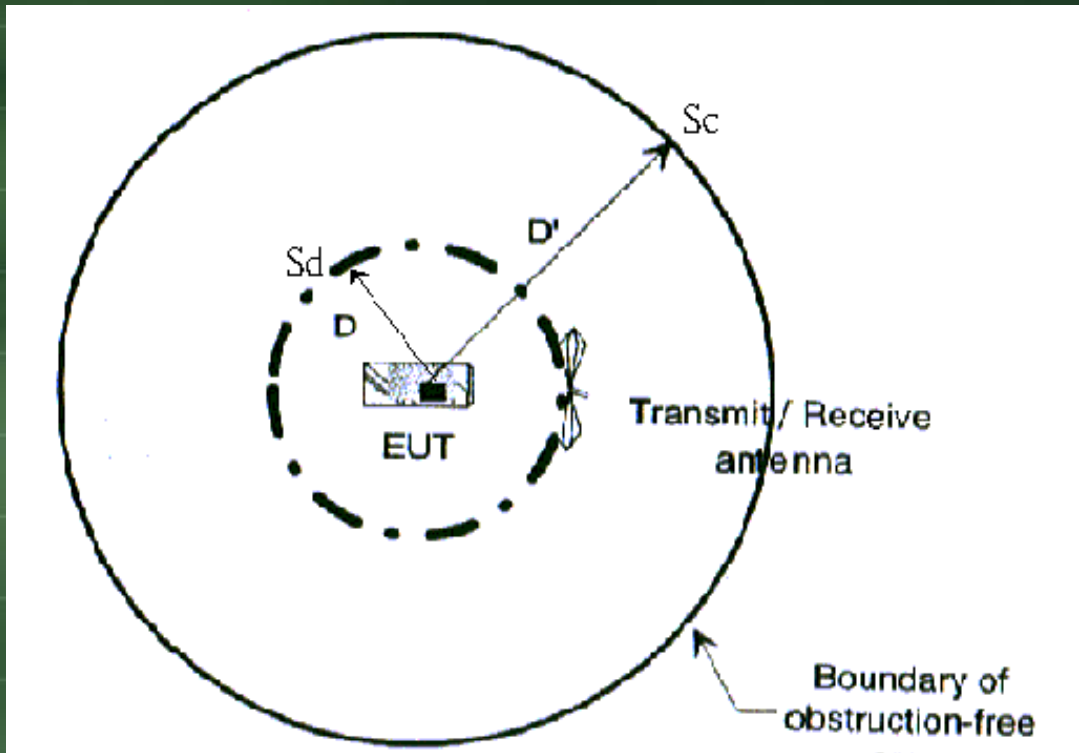


Figure 5-4 Obstruction-free area of OATS with stationary EUT

Open-Area Test Site

Stationary Antenna

- $M_D=2D$
- $Md=\sqrt{3}\,D$

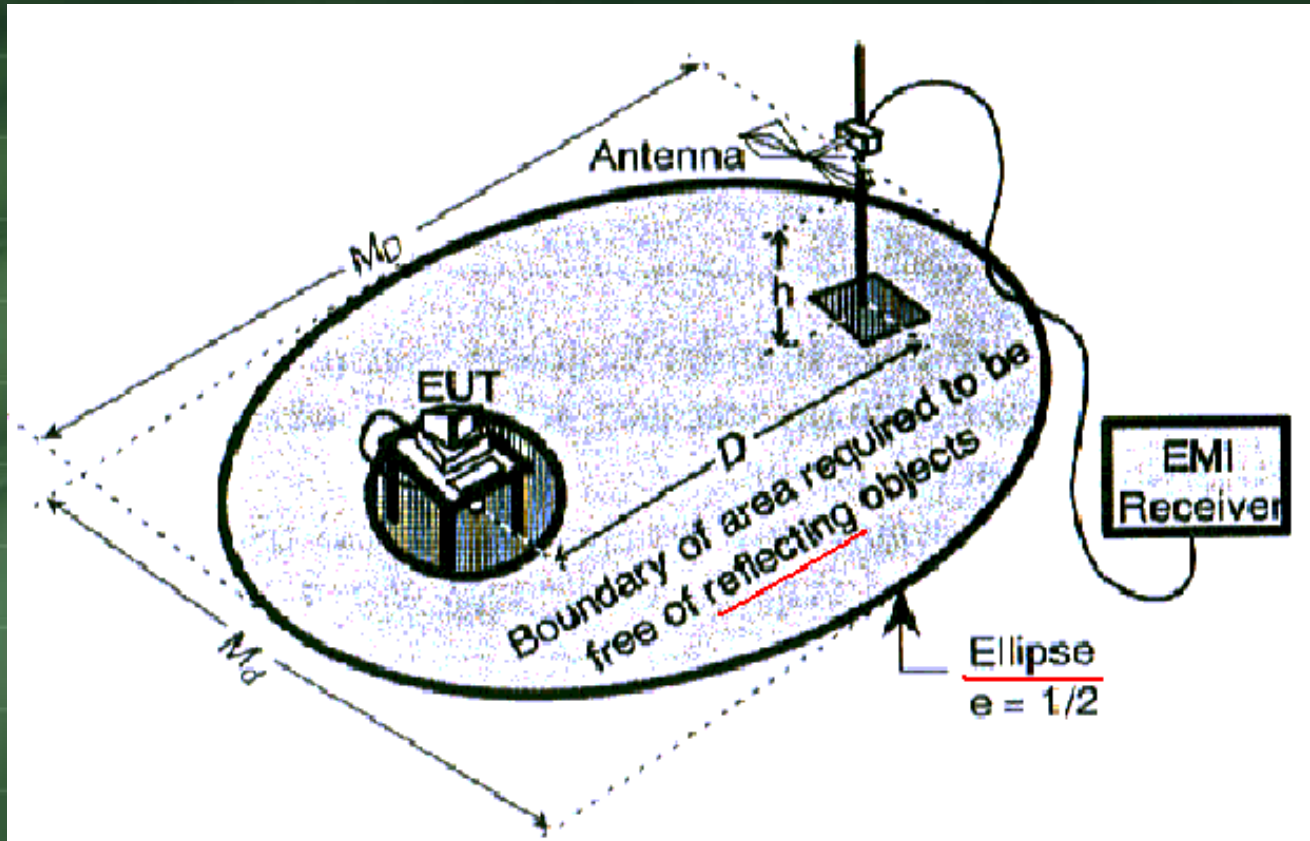
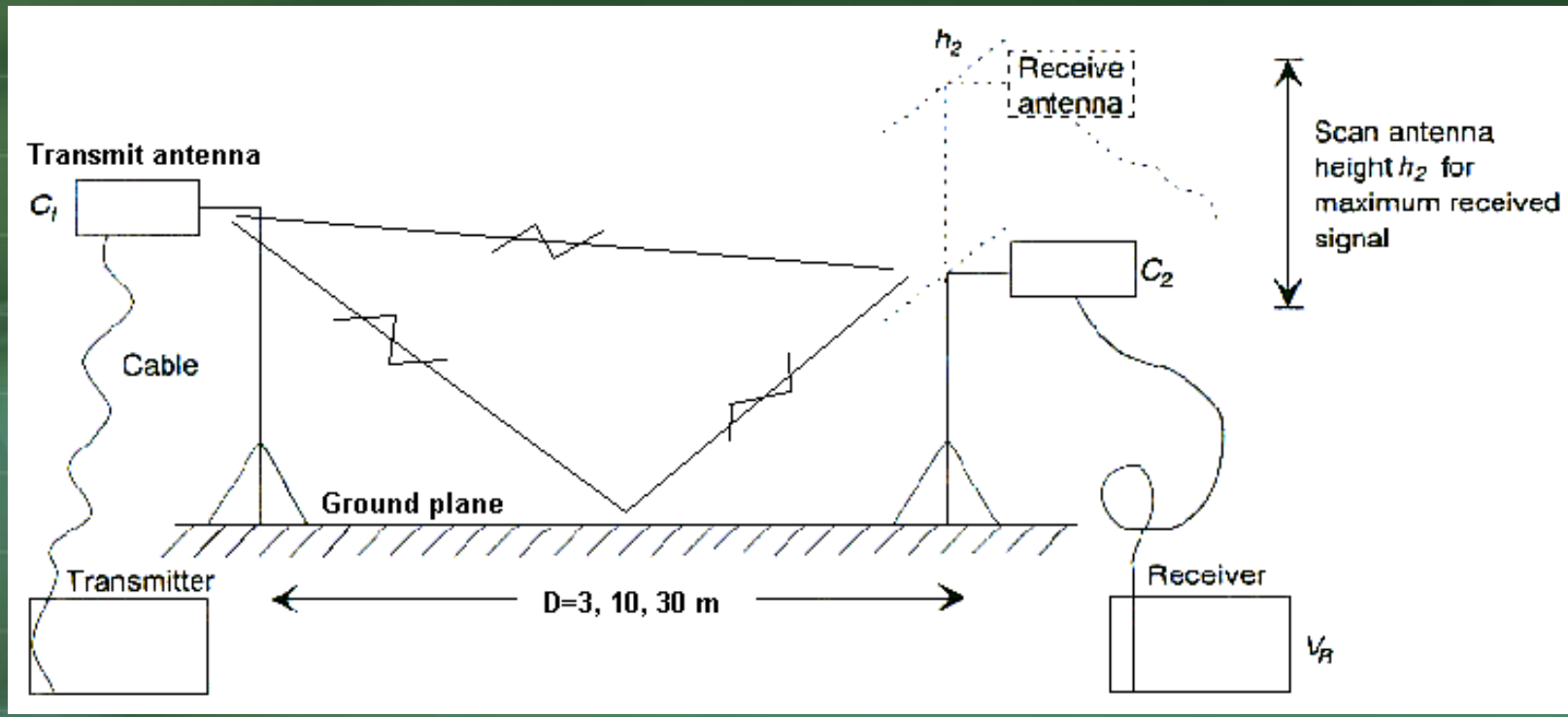


Figure 5-5 Open-field test site with EUT rotatable 360° in the azimuth

Open-Area Test Site

Height of Antenna

- D=3 or 10m,h_2 scans from 1 to 4m
- D=30m, h_2 scans from 2 to 6m
- Antenna scans vertically and horizontally



Open-Area Test Site

Advantage

- No multiple reflections
- Full Compliance Emission
- Cheap investment
- Easy to construct

Disadvantage

- Weather influence
- Environmental influence
- Regular maintenance
- Needs quiet environment
- No Immunity test is allowed
- Dimensions: 6 x 20 m
- Space needed: 20 x 40 m

Open-Area Test Site

System Radiated Interference Test

- Open-Area Test Site (OATS)
  - RE、RS measurement
  - Test Antennas
  - Measurement Precautions(預防措施)
  - Open-Area Test Site
- *Measurement in a Laboratory(實驗室)*
  - *Microwave Anechoic(無反射) Chamber(房間)*
  - Transverse(横向) Electromagnetic (TEM) Cell
  - Reverberating(反射) Chamber
  - G-TEM Cell

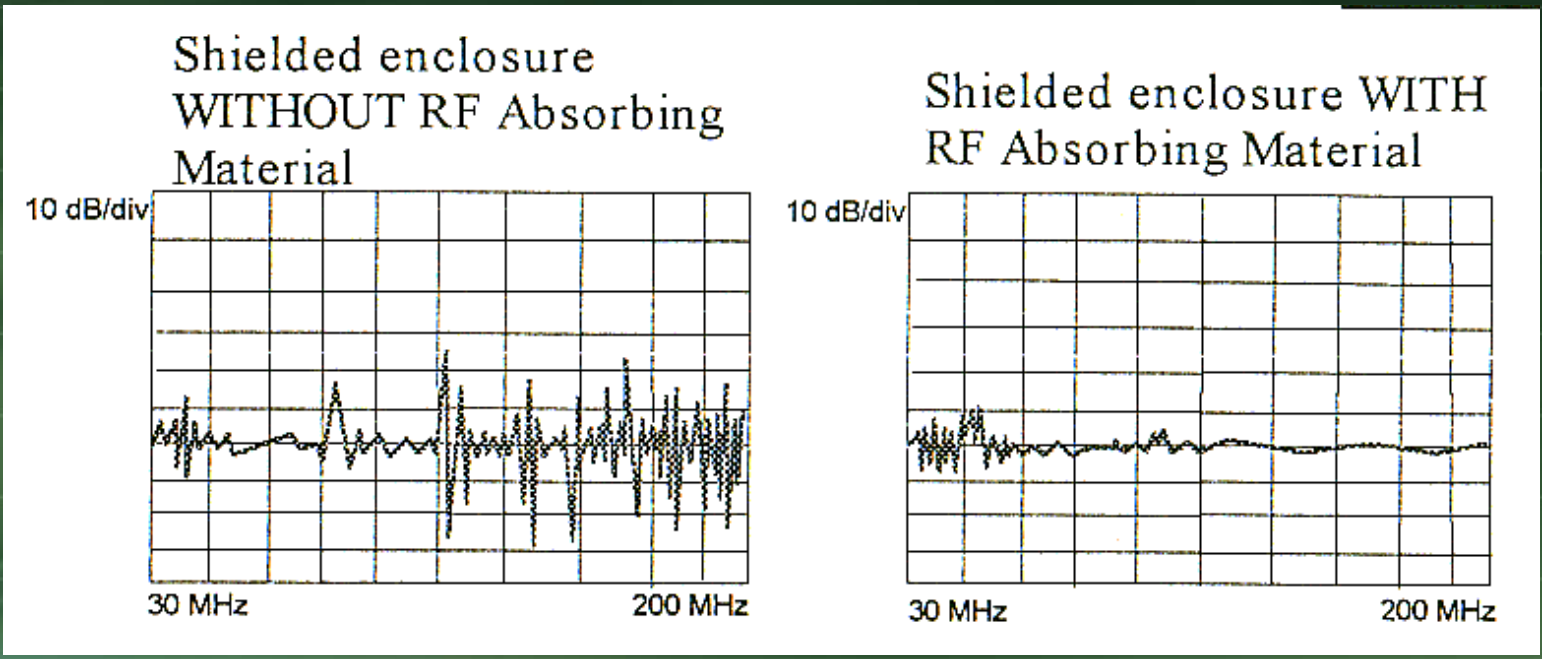
Measurement in a Laboratory

Semi-Anechoic Chamber

- A Semi-Anechoic Chamber is constructed as a shielded room, with absorbing materials on all walls and ceiling, thus *simulating an OATS*.
- On the floor, *a full reflecting groundplane* is installed.
- With some additions, these chambers can be used for Full Compliance Immunity testing as well.

Measurement in a Laboratory

Semi-Anechoic Chamber



- Some reflections still exist in the 30-80 MHz range, this is because the chamber size limited the size of the absorbing cones.(錐形體)
- FCC allows use of 3m semi-anechoic rooms, if it results correlative to open site.

Measurement in a Laboratory

Semi-Anechoic Chamber

Advantage

- *Full Compliance Emission*
- *Full Compliance Immunity*
  - using add. Floor absorber
- No weather influence
- Ambient-free
- Operator friendly work condition

Disadvantage

- Need internal office space
- Capital investment
- Dimensions: 9x6x6(h) m
  - 3m S.A. chamber
- Dimensions: 20x12x8(h) m
  - 10m S.A. chamber

Measurement in a Laboratory

Semi-Anechoic Chamber

Broad-Band Antenna

Measurement in a Laboratory

Full Anechoic Chamber

- The Full Anechoic Chamber, CFAC, is constructed as a shielded room, covered with absorber materials on all walls, ceiling and floor.
- Its application is for Full compliance Immunity testing.
- It can be used for Pre-compliance emission testing.
- Standards are in preparation to accept Emission testing in this type of chambers

Measurement in a Laboratory

Full Anechoic Chamber

- A most common laboratory approach
- High isolation from external electromagnetic environment, so it is suitable for highly sensitive measurements involving very low signal levels
- Cost of a microwave anechoic chamber increases very rapidly with its size
  - Typical 10.8x7.2x5.2m
- Available test zone is limited to 200MHz
  - Because the properties of this absorbing materials(泡棉/瓷磚); they provide higher absorption capabilities at higher frequencies.
- Used for EMI and EMS test

Measurement in a Laboratory

Full Anechoic Chamber

Advantage

- Full Compliance Immunity
- Correlation with OATS EMI measurements
- Needs little office space
- Quick scan EMI testing
- Economical investment
- No weather influence
- Ambient-free
- Operator friendly work condition
- Dimensions: 7x3x3(h) m

Disadvantage

- Pre-Compliance Emission

Measurement in a Laboratory

Full Anechoic Chamber

Measurement in a Laboratory

Full Anechoic Chamber

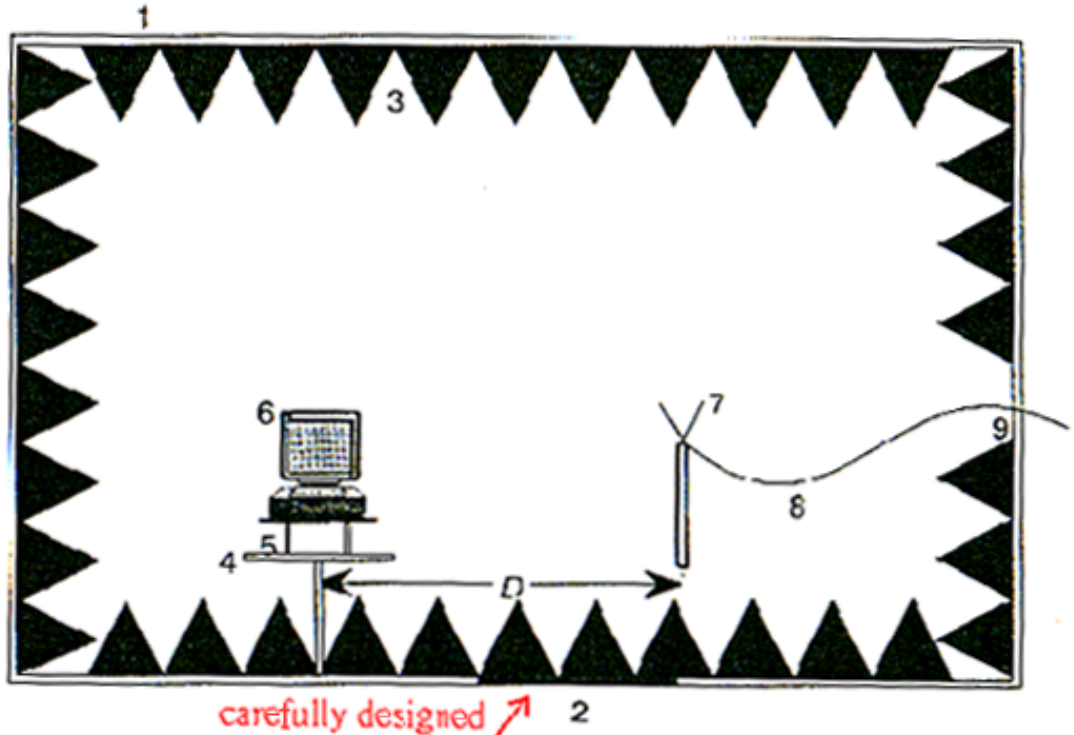


Figure 6-1 Details of microwave anechoic chamber (1) metallic wall, (2) door, (3) microwave absorbing materials, (4) turntable for azimuth rotation, (5) wooden table (optional for height increase), (6) equipment under test, (7) antenna, (8) cable connection for instrumentation, (9) special panel for connectors

Measurement in a Laboratory

Full Anechoic Chamber

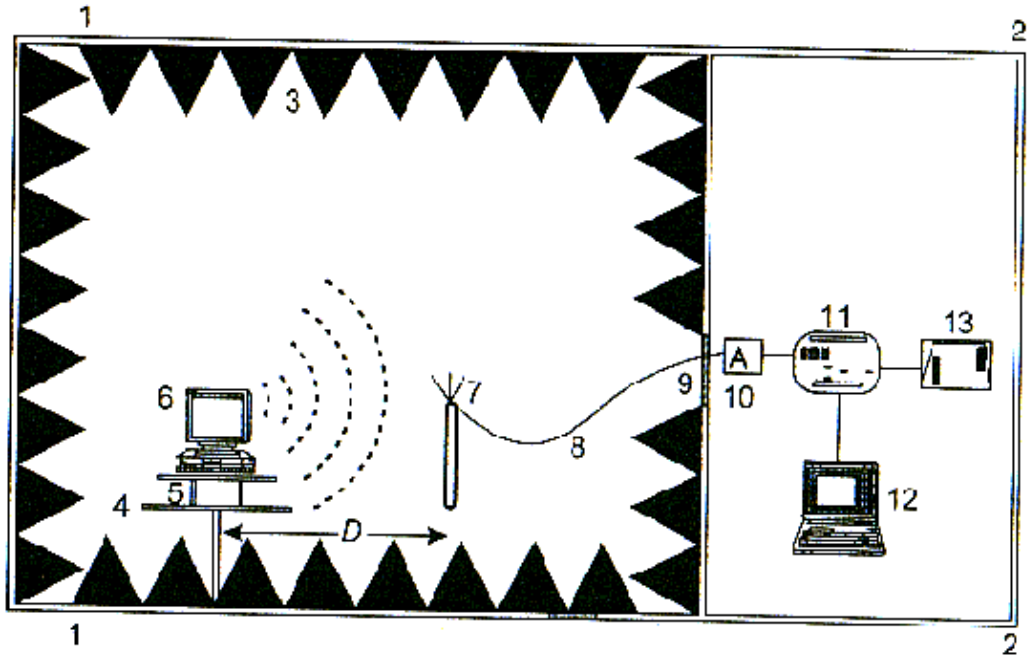


Figure 6-4 Schematic for measurement of raciated emissions from the equipment under test (1) shielded anechoic chamber, (2) anteroom for test instrumentation, (3) EM Energy absorbing materials, (4) turntable for azimuth coverage, (5) wooden table (optiona.), (6) equipment Under Test (EUT), (7) EMI receiving antenna, (8) calibrated RF cable, (9) special panel for connectors, (10) amplifier for higher dynamic range, (11) EMI meter, (12) Instrument controller for EMI meter and plotter, (13) plotter

Measurement in a Laboratory

Full Anechoic Chamber

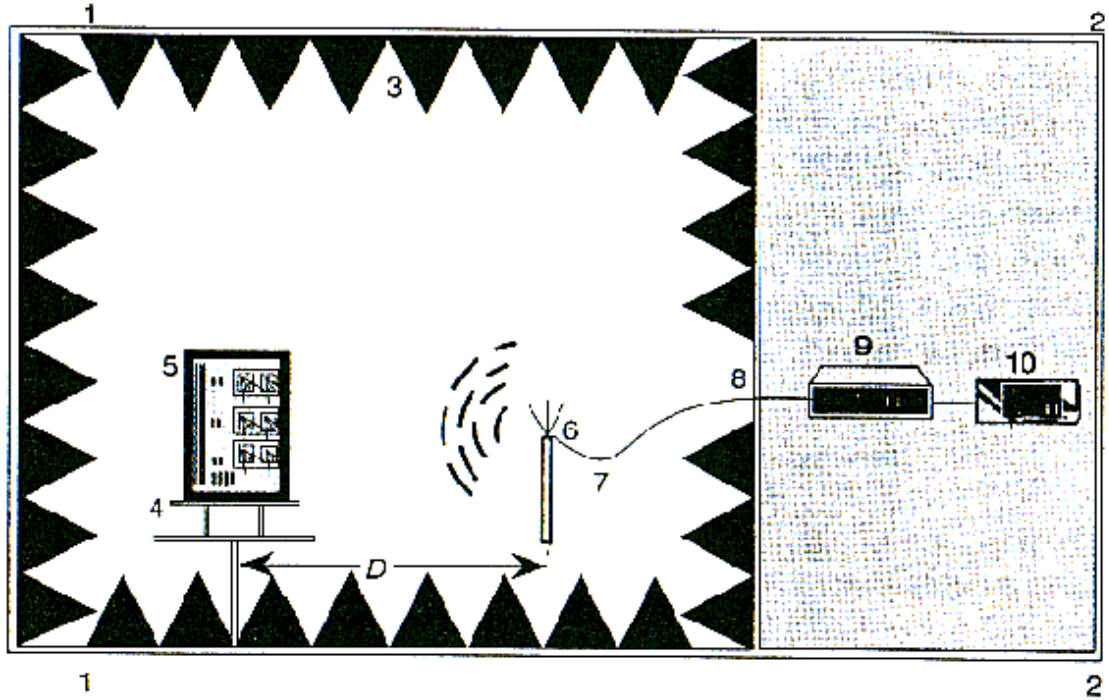


Figure 6-6 Schematic for evaluation of radiation susceptibility of an equipment under test (1) shielded anechoic chamber, (2) anteroom for test instrumentation, (3) EM Energy absorbing materials, (4) turntable for azimuth coverage, (5) equipment under test, (6) radio frequency (RF) transmitting antenna, (7) calibrated RF cable, (8) special panel for connectors, (9) RF power amplifier, (10) RF signal generator

System Radiated Interference Test

- Open-Area Test Site (OATS)
  - RE、RS measurement
  - Test Antennas
  - Measurement Precautions(預防措施)
  - Open-Area Test Site
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  - *Transverse(橫向) Electromagnetic (TEM) Cell*
  - Reverberating(反射) Chamber
  - G-TEM Cell

Transverse Electromagnetic (TEM) Cell

Using a TEM cell (commonly approach)

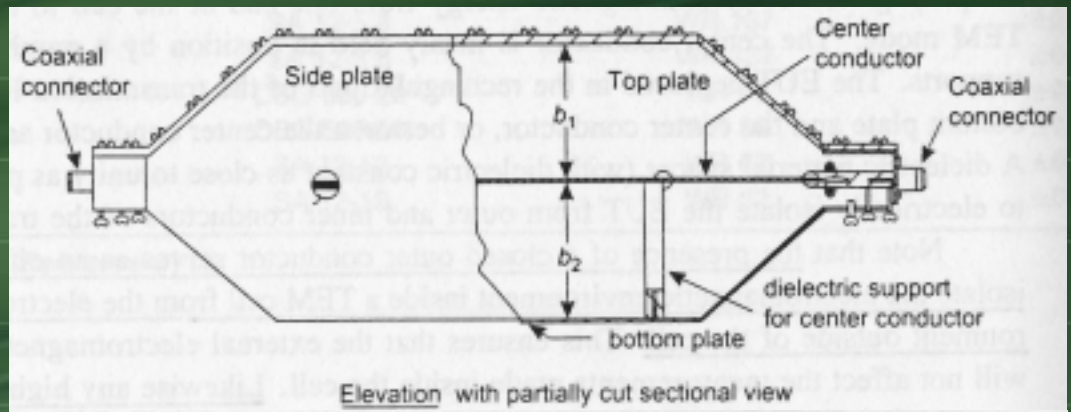
- Advantages
  - Less expensive, broadband without different antennas
- *Limitations：size*
  - The size of a TEM cell is limited by the upper frequency, up to which it can be used.
    - Possible cell size smaller at higher frequencies
  - The maximum size of an EUT inside a TEM is limited by the requirement that any change in TEM cell characteristic impedance resulting from an EUT placement should be minimum.

Transverse Electromagnetic Cell

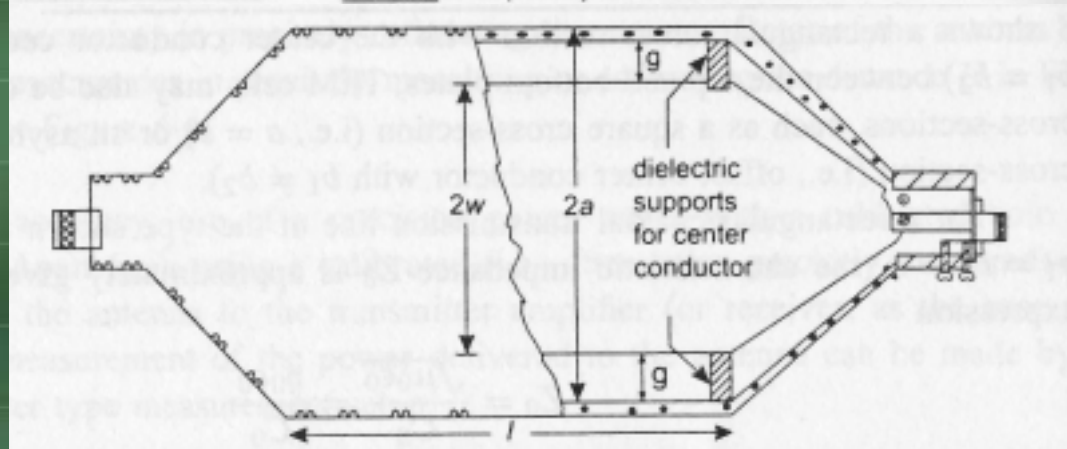
- TEM cell is *a rectangular coaxial transmission line.*
  - The rectangular section is tapered at both ends and matched to a 50Ω coaxial transmission line.
  - EUT is placed in the rectangular part of the transmission line between the bottom plate and the center conductor, or between the center conductor and the top plate.
- Center conductor and outer conductor facilitate (促進) the propagation of electromagnetic energy from one end of the cell to the other end in TEM.
  - The center conductor is held in position by several dielectric supports. Another dielectric material is used to isolate the EUT from outer or inner conductor of TEM, when
  - *The closed outer conductor serves as an effective shield to isolate the electromagnetic environment.*

Transverse Electromagnetic Cell

- The characteristic impedance Zo of a TEM cell is relative to a, b and g [2] Ch 6-3



Elevation with partially cut sectional view



Plan (with partially cut top plate)

Transverse Electromagnetic Cell

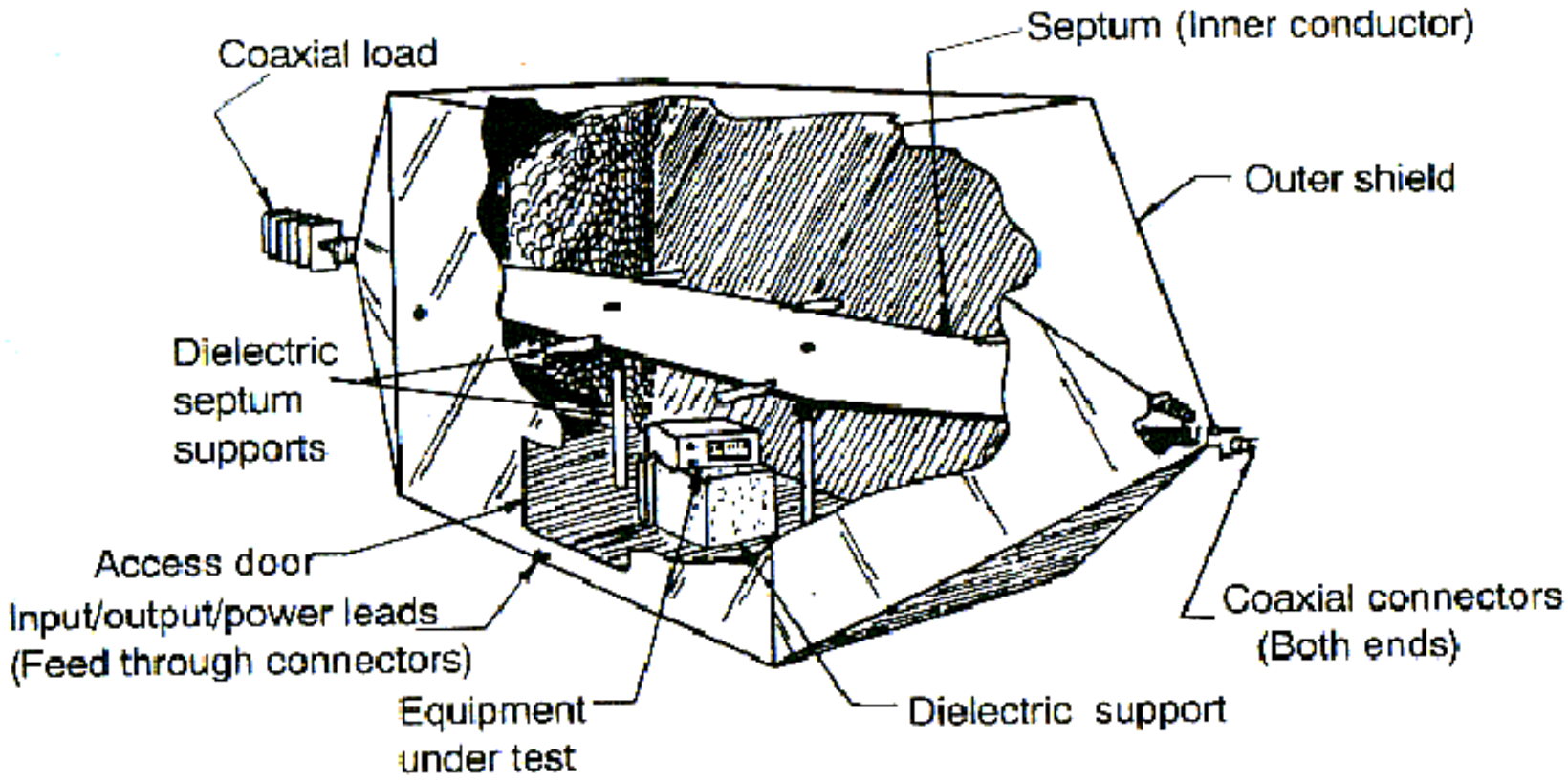
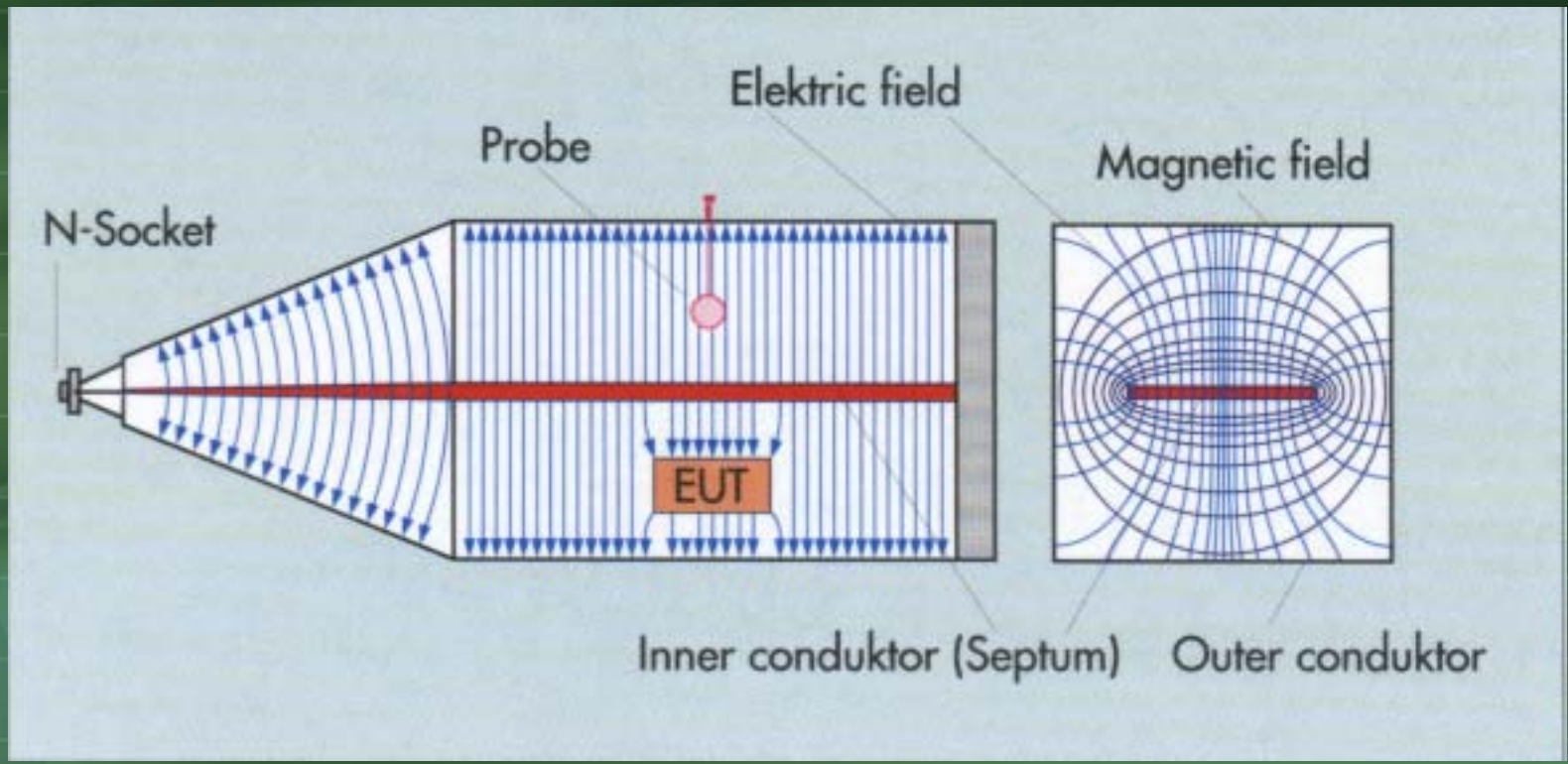


Figure 6-11 TEM cell with the EUT placed inside

Transverse Electromagnetic Cell

- External dimensions：(LxDxH) 3,020mmx1008mmx1900mm
- Test volume：(LxDxH) 750mmx450mmx300mm
- Frequency rangy：DC~2GHz with ferrite absorber

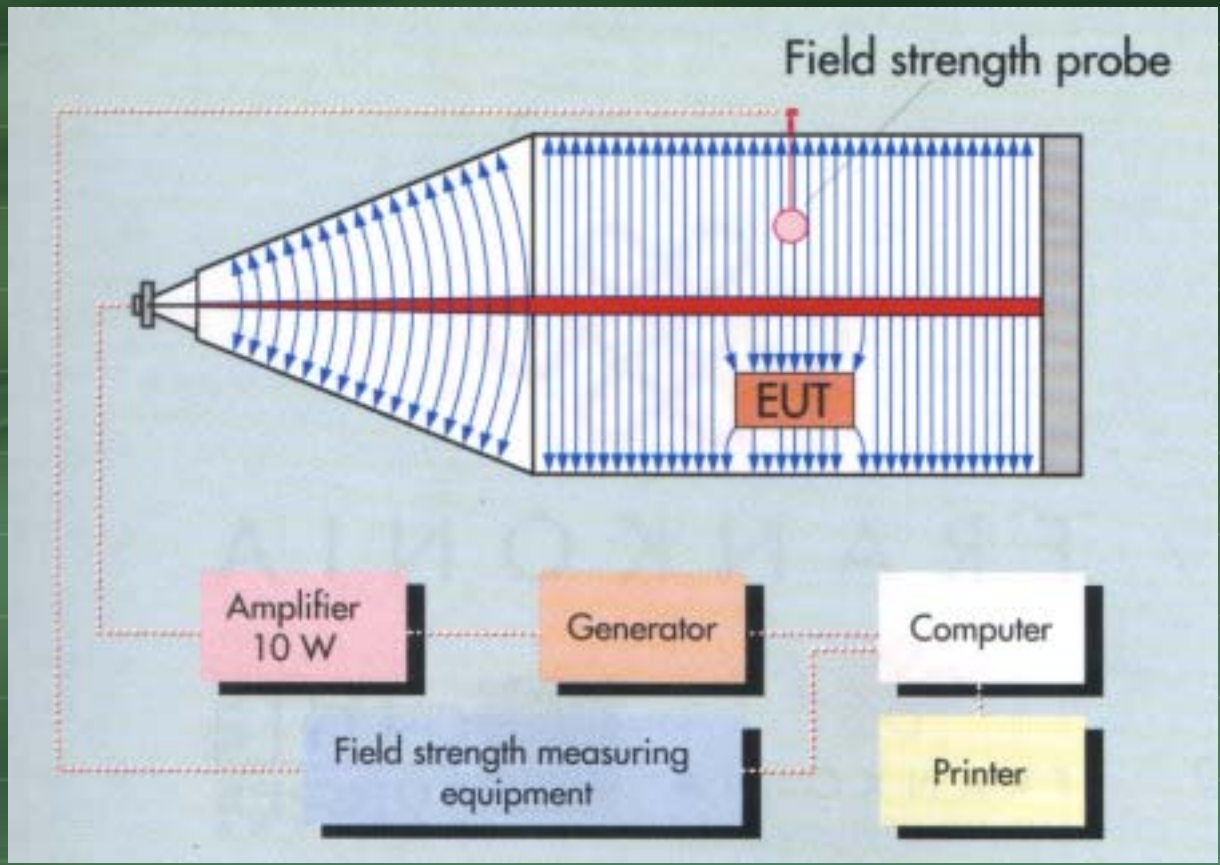
Transverse Electromagnetic Cell



Transverse Electromagnetic Cell

Measurements using TEM Cell

- Radiation Susceptibility Test *(IEC 1000-4-3)*



Transverse Electromagnetic Cell

Measurements using TEM Cell

- Radiation Susceptibility Test Steps
  1. EUT is positioned centrally in the lower half.
     - EUT is placed on the floor, when a grounding of EUT is desired. When EUT casing must be floated electrically, a sheet of insulating (dielectric constant close to unity) is placed between EUT and the bottom of TEM cell.
     - Note the EUT orientation(方向) relative to field polarization
     - *When EUT is not small, it will effectively short out a part of the vertical separation, and result in an increase field level.*
  2. Input/output connections are given to EUT.
     - Setting up EUT, including power, signals…connectors. These connectors must be with appropriate filters to prevent RF leakages into TEM cell, and also to ensure filters themselves don't affect the measured results.
     - Various cables may be placed on the bottom of TEM cell and *covered with a conductive tape to avoid the cross coupling* by an exposure of these to the fields in TEM.

Transverse Electromagnetic Cell

Measurements using TEM Cell

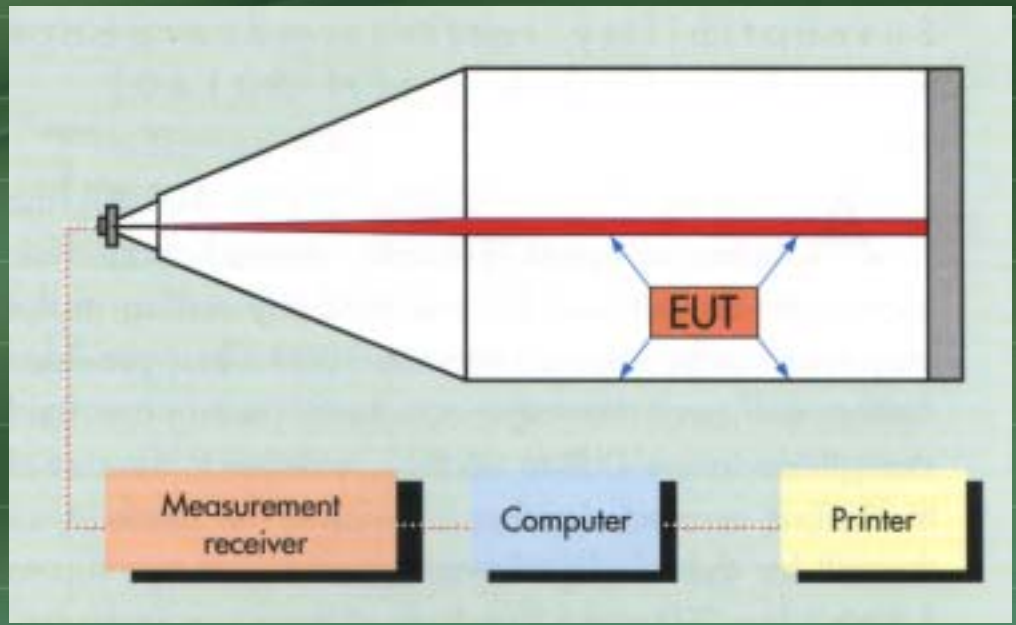
- Radiation Susceptibility Test Steps

3. Measuring apparatus are connected to TEM cell and EUT
   - A RF power source is connected to TEM cell to establish necessary field levels.
   - $E = V_{RF} / b$
4. The radiation susceptibility test is now conducted as per the test schedule and specification.

Transverse Electromagnetic Cell

Measurements using TEM Cell

- Measurement of Radiated Emissions
  - When RF energy is somehow generated and radiated by a source (EUT) located inside TEM cell, it propagates inside the cell and couples to the two ports of the TEM cell.
  - By measuring such energy, one can estimate the radiated emissions from The EUT.



Agenda

- System Radiated Interference Test
- *System Conducted Interference Test*

System Conducted Interference Test

- Line Impedance Stabilization Networks
- Conducted EMI Emission
- Immunity to Conducted EMI

Line Impedance Stabilization Networks (LISN)

- Measurement of conducted EMI requires ambient(周圍) power line noise isolated from that emitted by EUT.
  - Line Impedance Stabilization Networks (LISN)

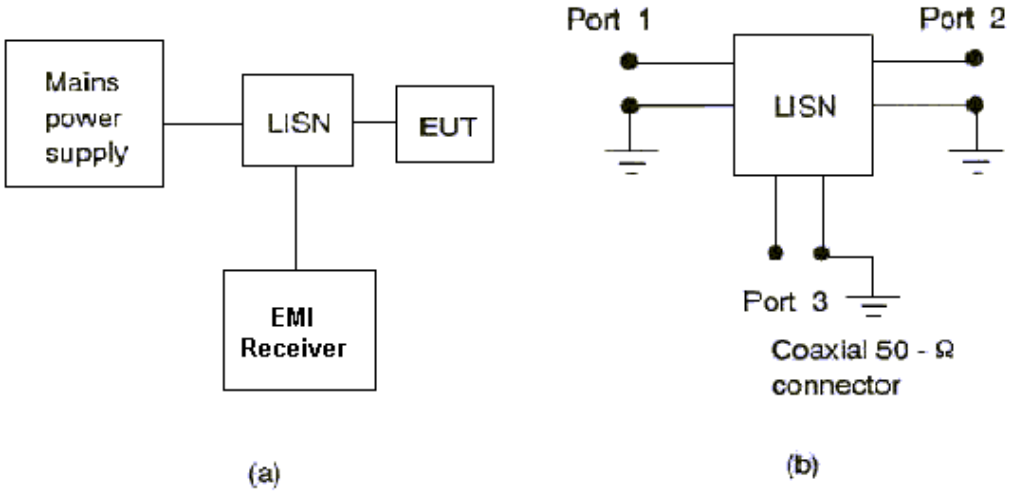


Figure 7-4 (a) Placement of LISN in a measurement set-up (b) The three ports of LISN

Line Impedance Stabilization Networks (LISN)

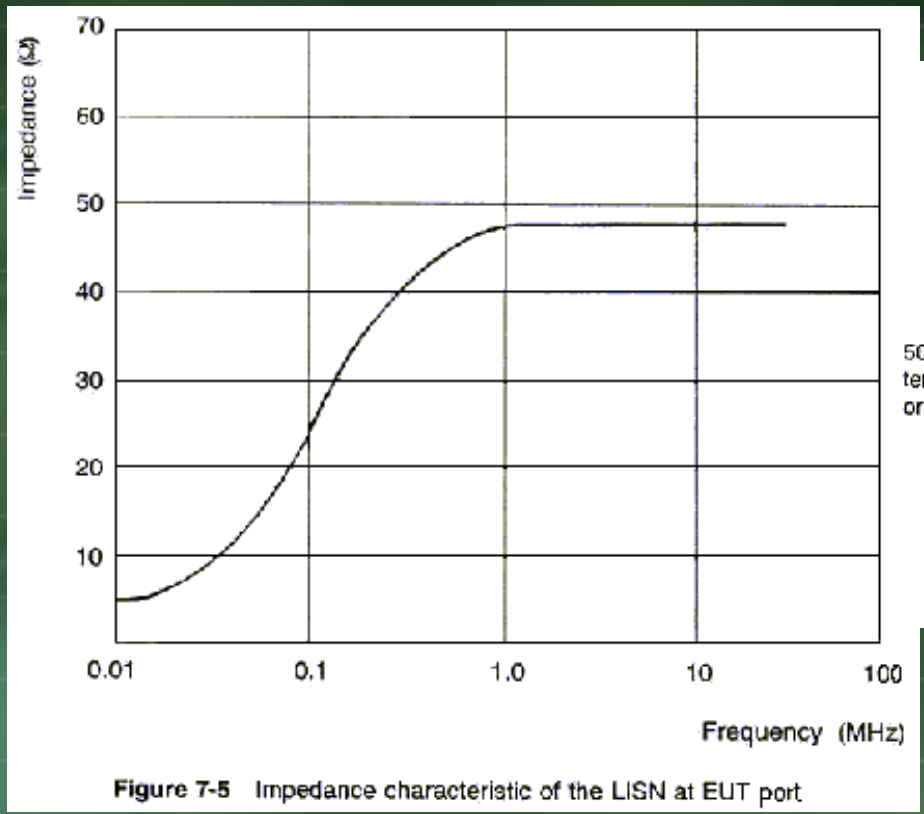


Figure 7-5 Impedance characteristic of the LISN at EUT port

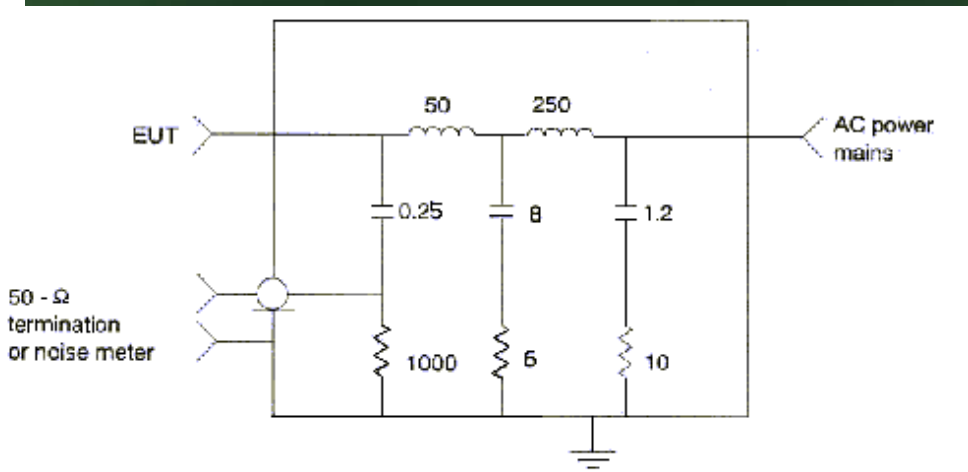
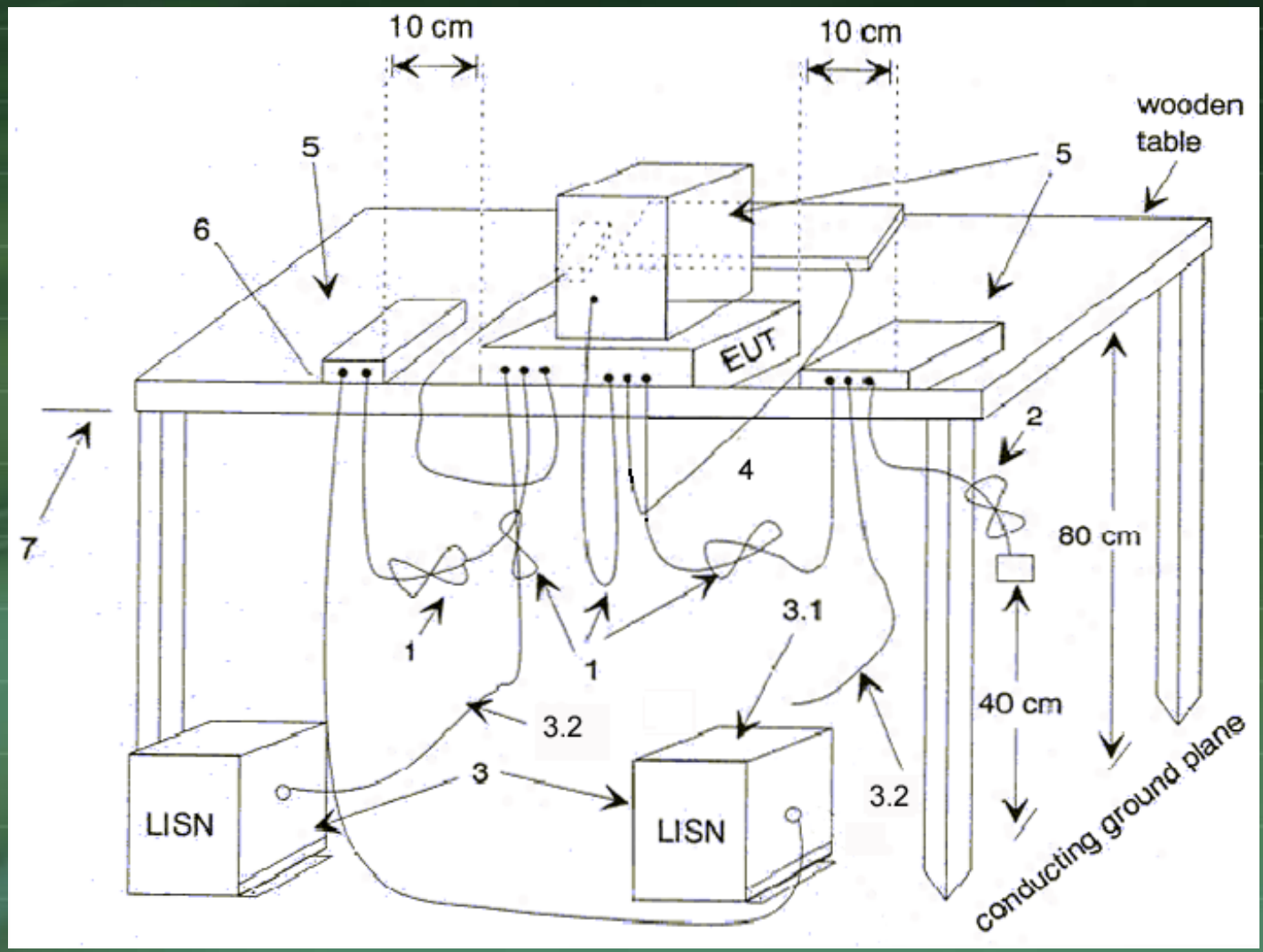


Figure 7-6 Example of a LISN Circuit (Values of the inductances are in μ H, capacitances in μ F, and resisiances in Ω)

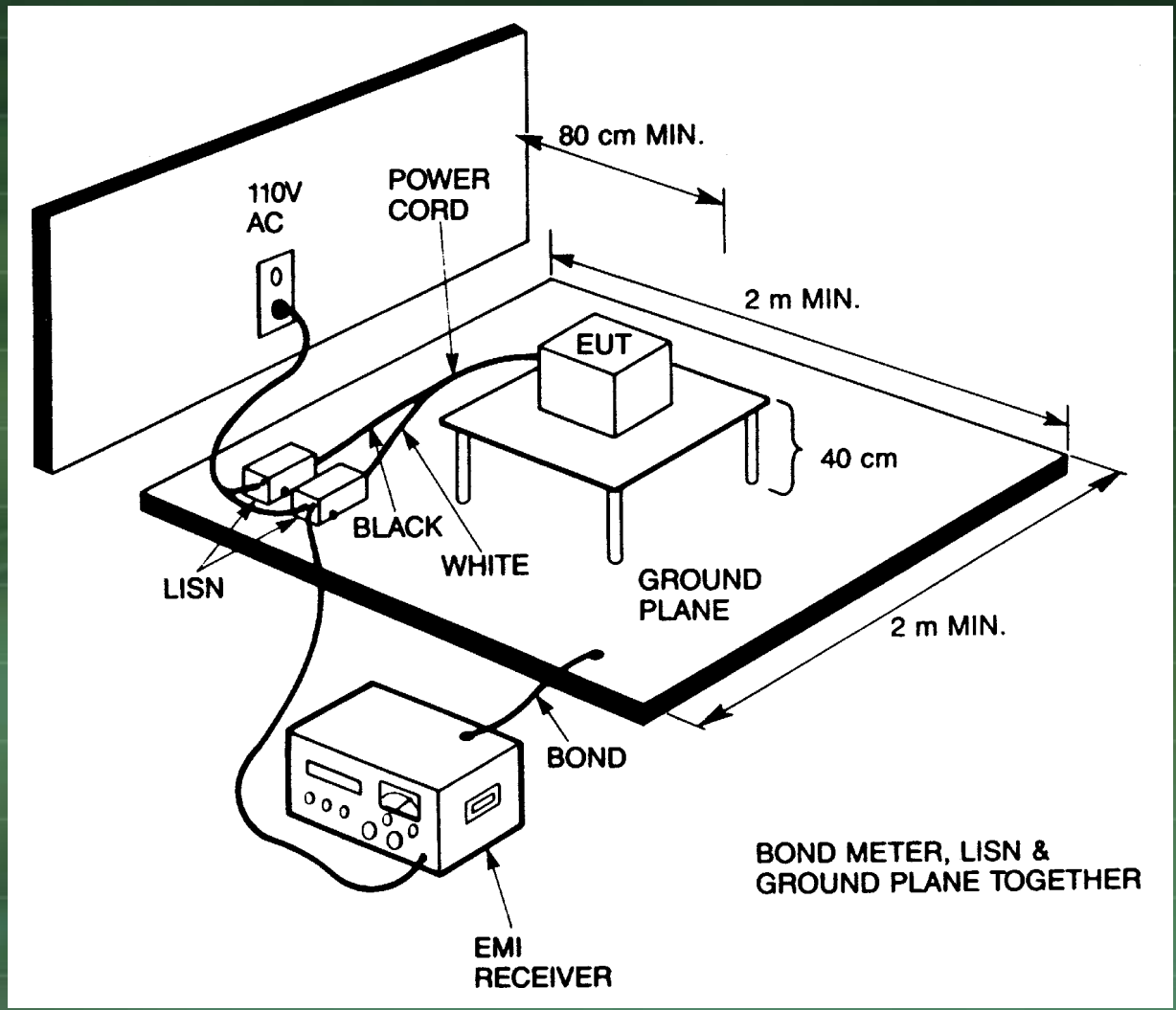
Measurement to Conducted EMI Emission

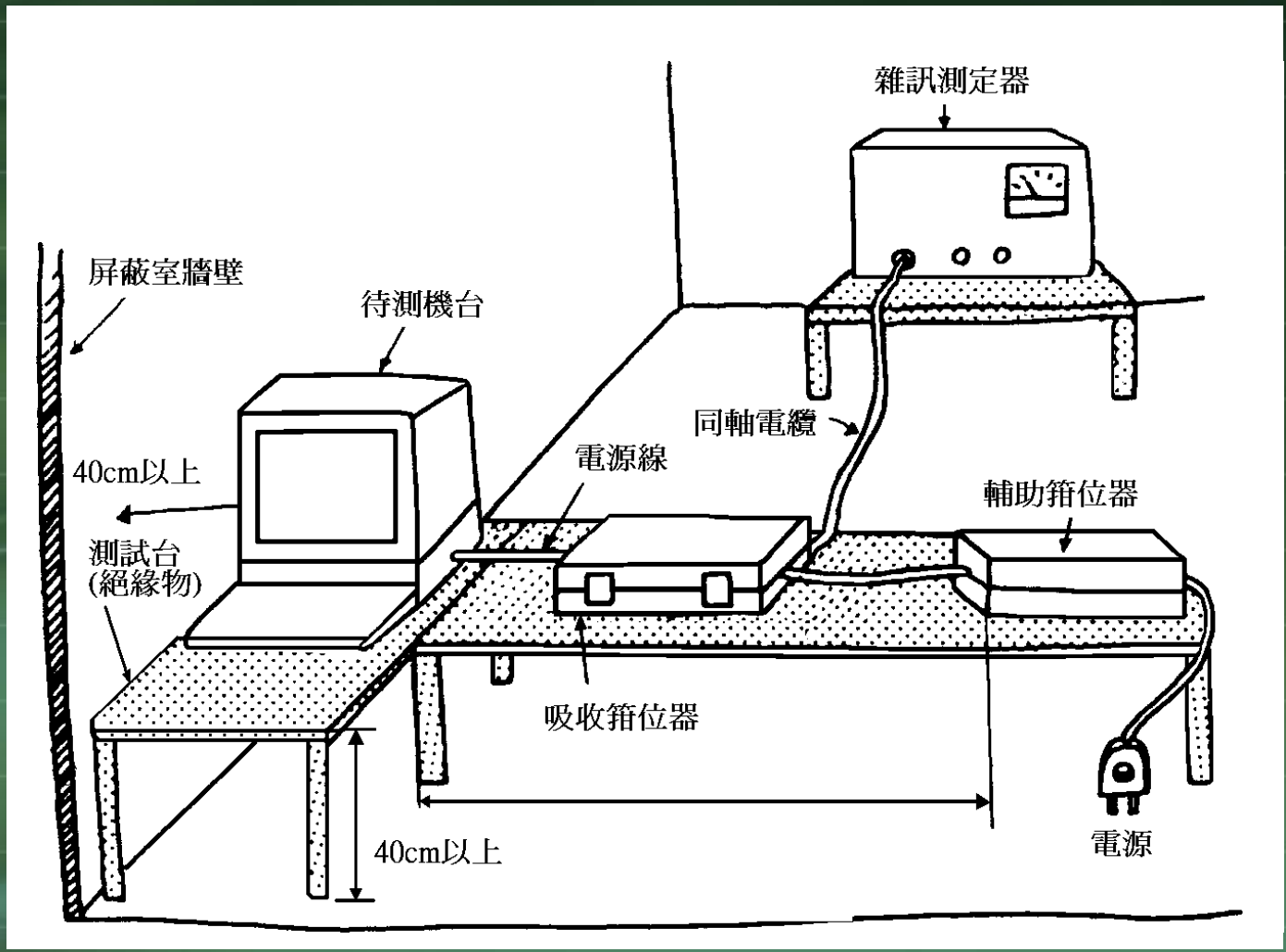


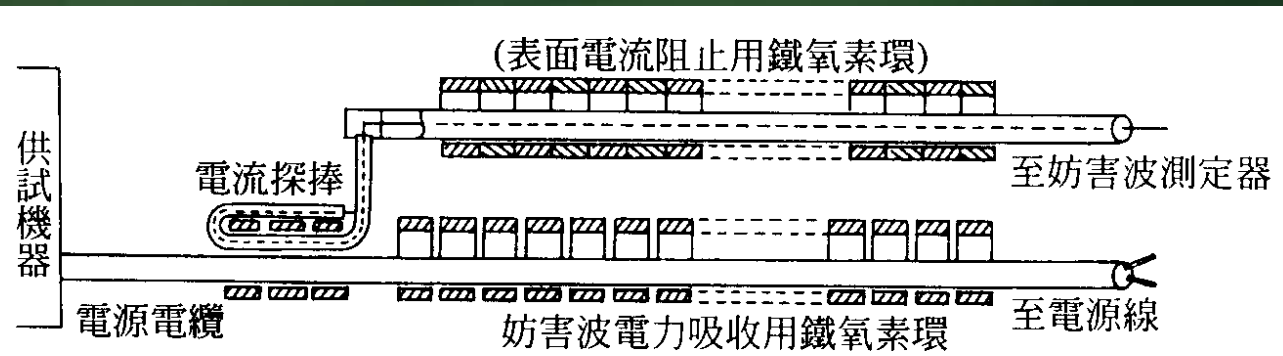
Measurement to Conducted EMI Emission

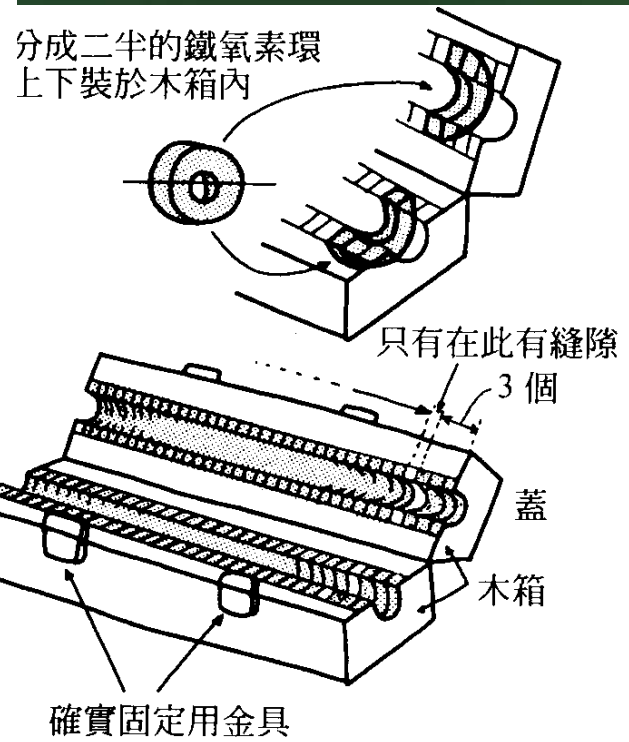
1. Interconnecting cables that hang closer than 40cm to the ground plane shall be folded back and forth forming a bundle 30 to 40 cm long, hanging approximately in the middle between ground plane and table.
2. I/O cables that are connected to a peripheral shall be bundled in center. The end of the cable may be terminated if required using correct terminating impedance. The total length shall not exceed 1m.
3. EUT connected to one LISN. Unused LISN connectors shall be terminated in 50Ω. LISN can be placed on top of, or immediately beneath, ground plane.
   - 3.1 All other equipment powered from second LISN.
   - 3.2 LISN at least 80cm from nearest part of EUT chassis.
4. Cables of hand-operated devices, such as keyboards, mice, have to be placed as close as possible to the host.
5. Non-EUT components being tested.
6. Rear of EUT, including peripherals, shall be all aligned(排好, 對齊) with rear of table top.
7. Rear of table top shall be 40cm removed from a vertical conducting plane that is bonded to the floor ground plane.

FCC Conducted EMI Emission

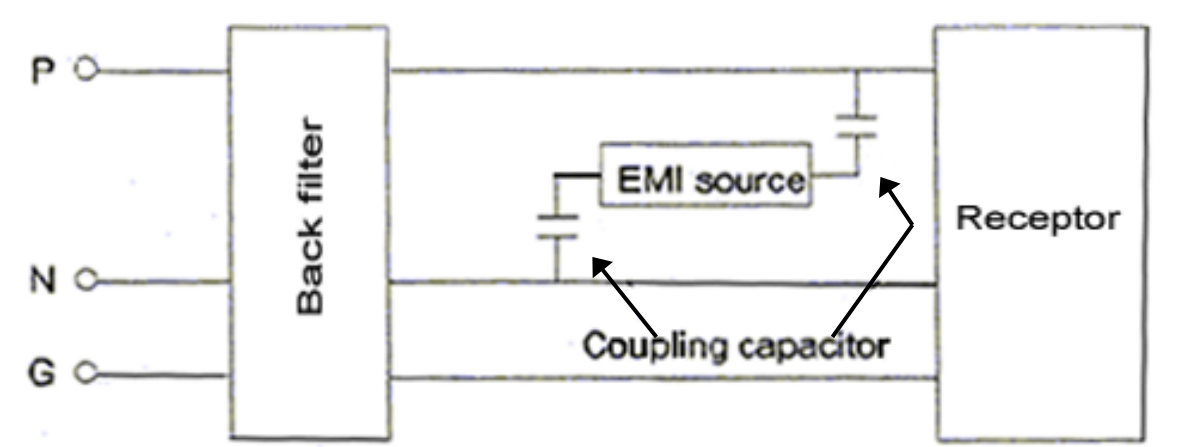



雜訊測定器
屏蔽室牆壁
待測機台
同軸電纜
電源線
40cm以上
輔助箝位器
測試台
(絕緣物)
吸收箝位器
40cm以上
電源

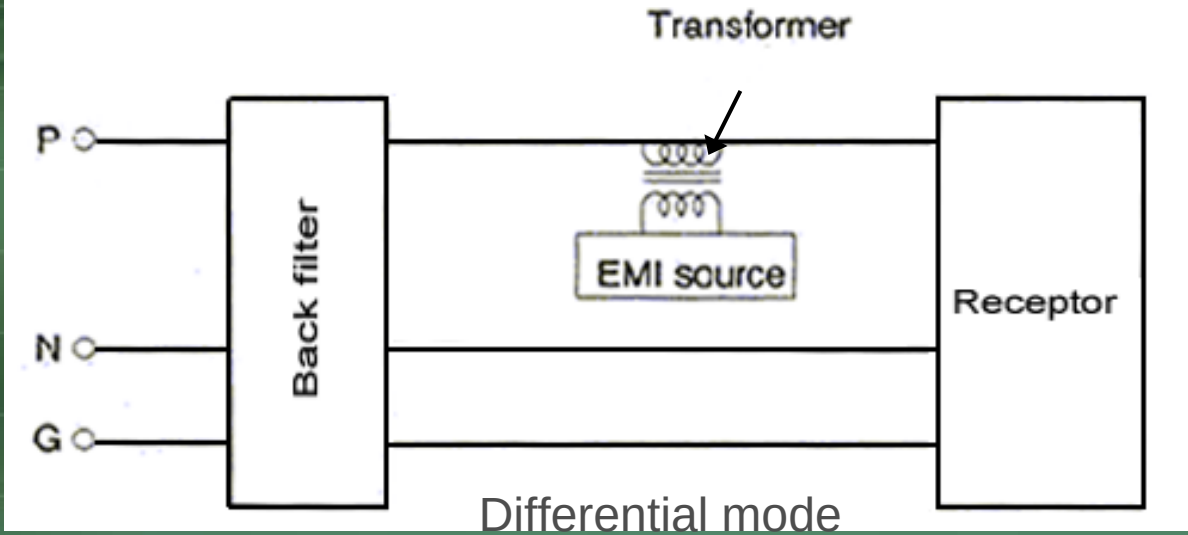

(表面電流阻止用鐵氧素環)
供試機器
電流探捧
至妨害波測定器
電源電纜
妨害波電力吸收用鐵氧素環
至電源線


分成二半的鐵氧素環
上下裝於木箱內
只有在此有縫隙
3 個
蓋
木箱
斷面
確實固定用金具

Immunity to Conducted EMI -- EMS



Common mode



Differential mode

Summary

- Testing result should be repeatable.
- Test environment should be as like as possible to the practical application.
- Open-Area Test Site is the better way to measure EMI performance of a device.
- Antenna for radiated testing and LISN for conducted testing.