RADIO FREQUENCY EMISSIONS AND IMMUNITY

TEM Cells

to

Anechoic Chambers

Presented By Joseph Heins

SCHAFFNER

Overview of Presentation

- Conducted and Radiated Emissions
  - Test Methods
  - Test Equipment and Test Environments
- Conducted and Radiated Immunity
  - Test Methods
  - Test Equipment and Test Environments
- Compliance vs Pre-Compliance
- Summary

CONDUCTED AND RADIATED EMISSIONS

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Conducted Emissions

Generally measured between

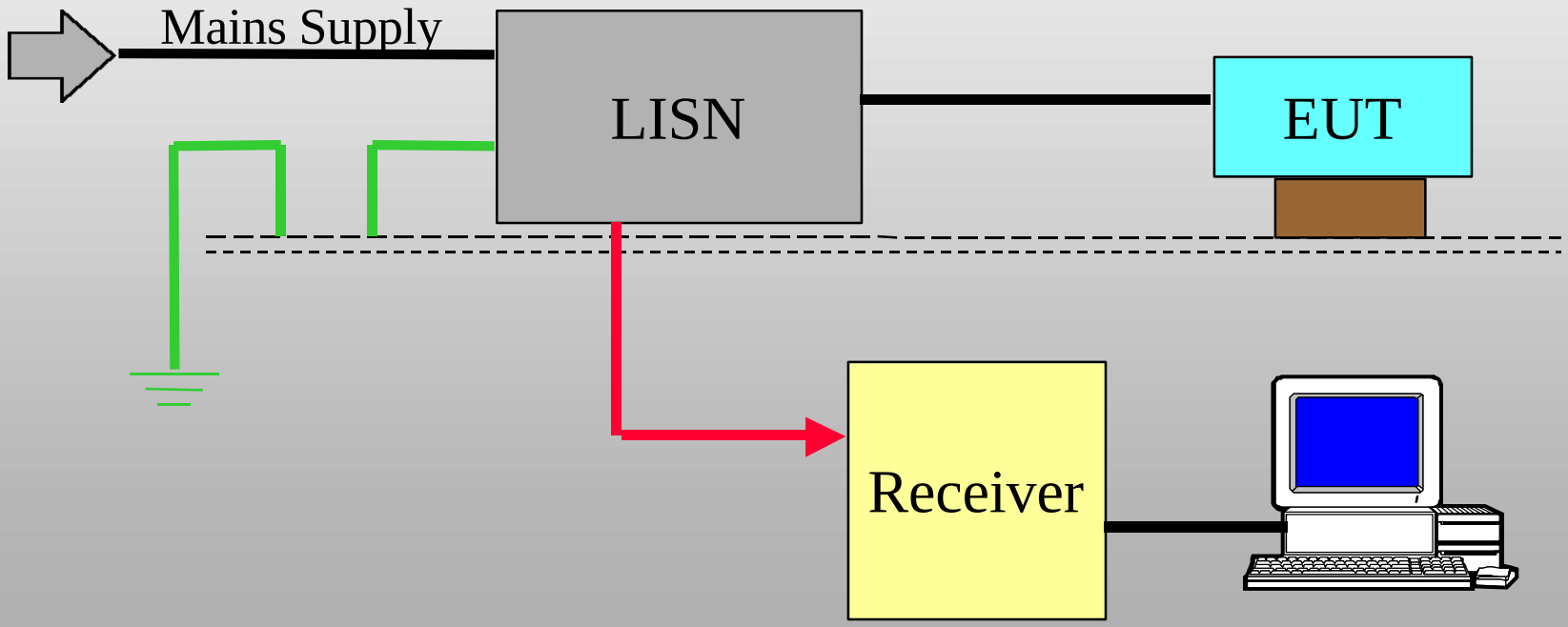
-150 kHz and 30 MHz

-(Some standards start at 9 kHz)

Equipment Required

- LISN
- Receiver or Spectrum Analyzer
- Software

Conducted System Layout



Radiated Emissions

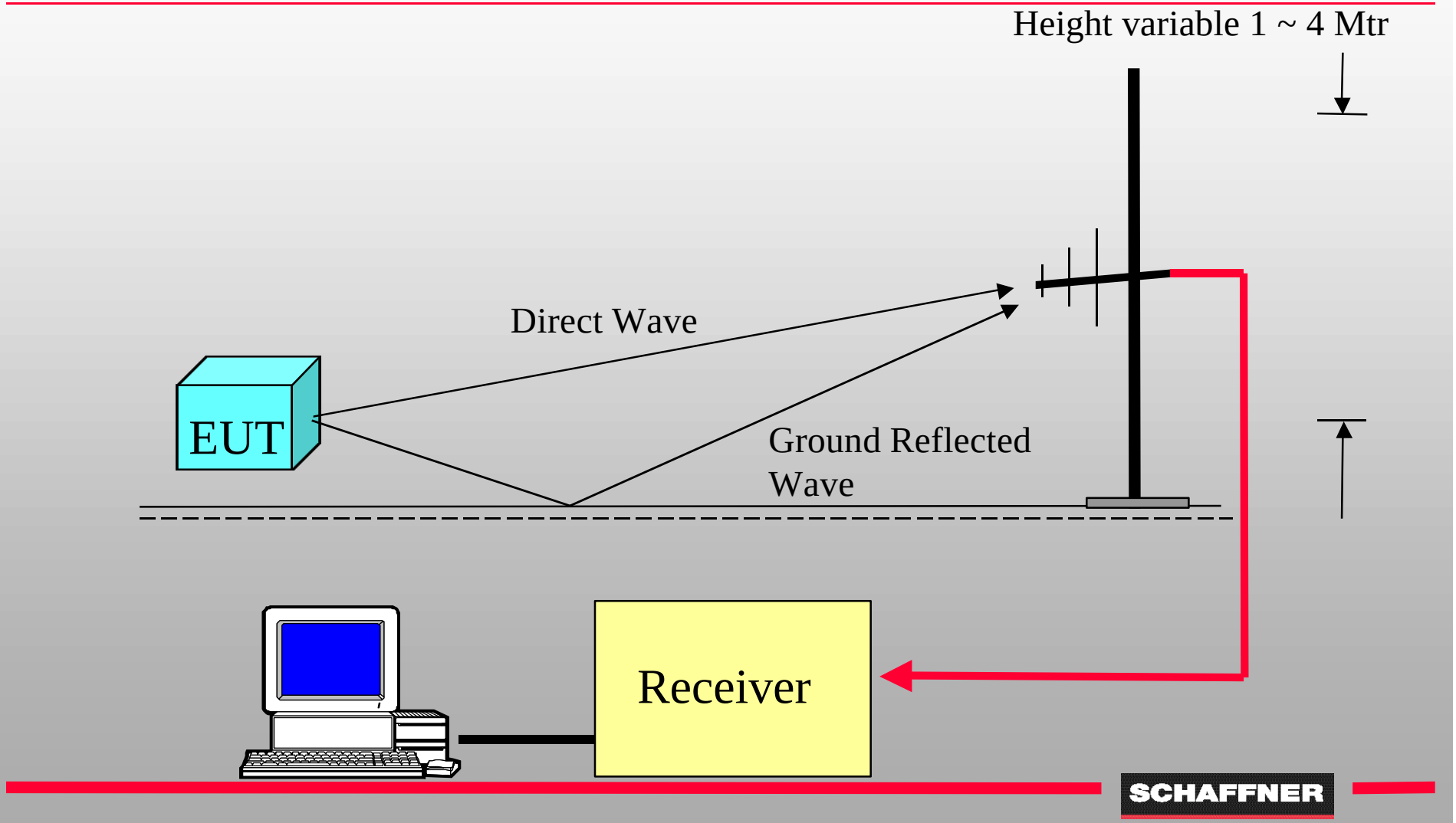
Generally measured between

- 30 MHz to 1 GHz or 10th harmonic
- (Standards are beginning to extend to 2 GHz)

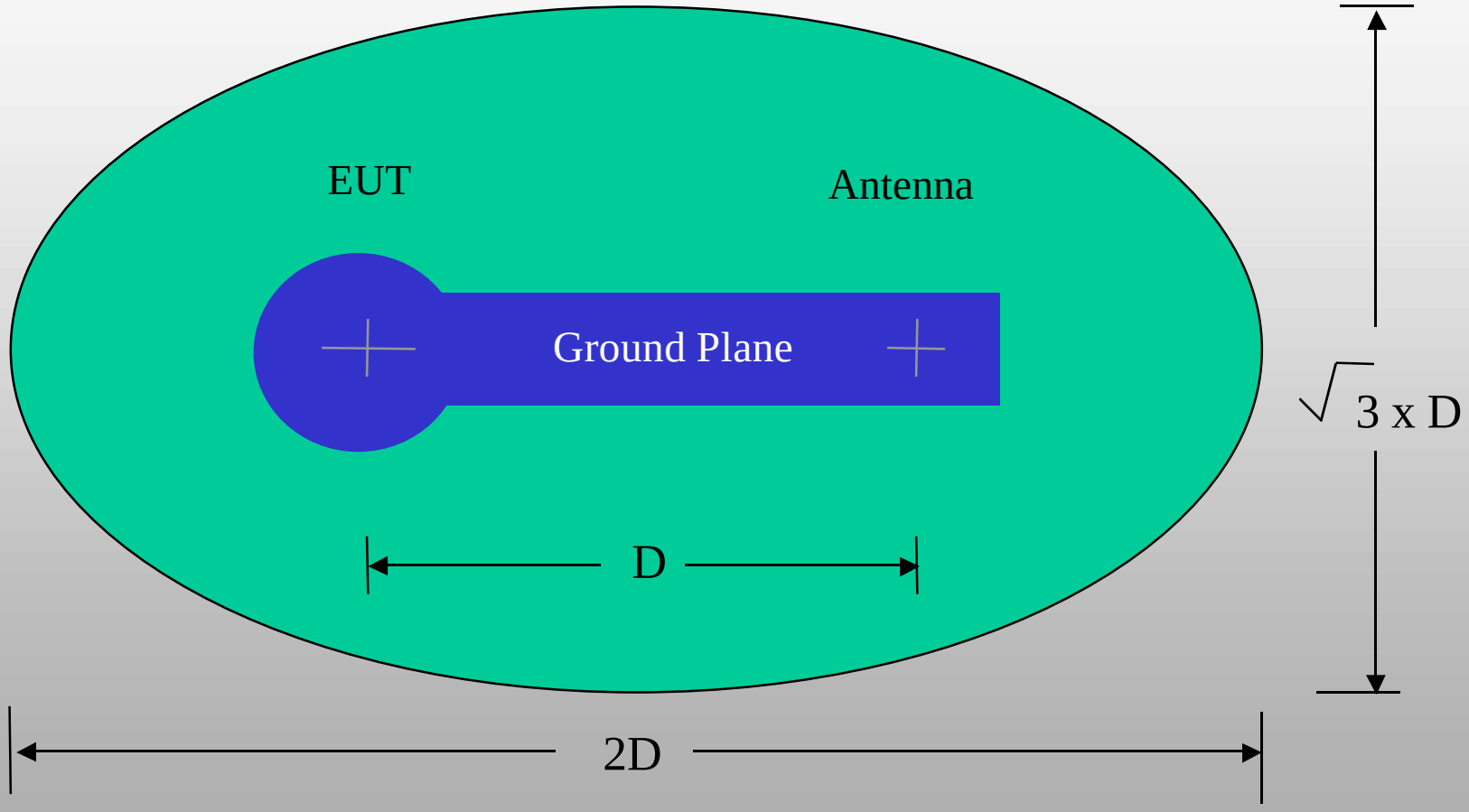
Equipment Required

- Antenna, Mast, Turn-table
- Receiver or Spectrum Analyzer
- Software

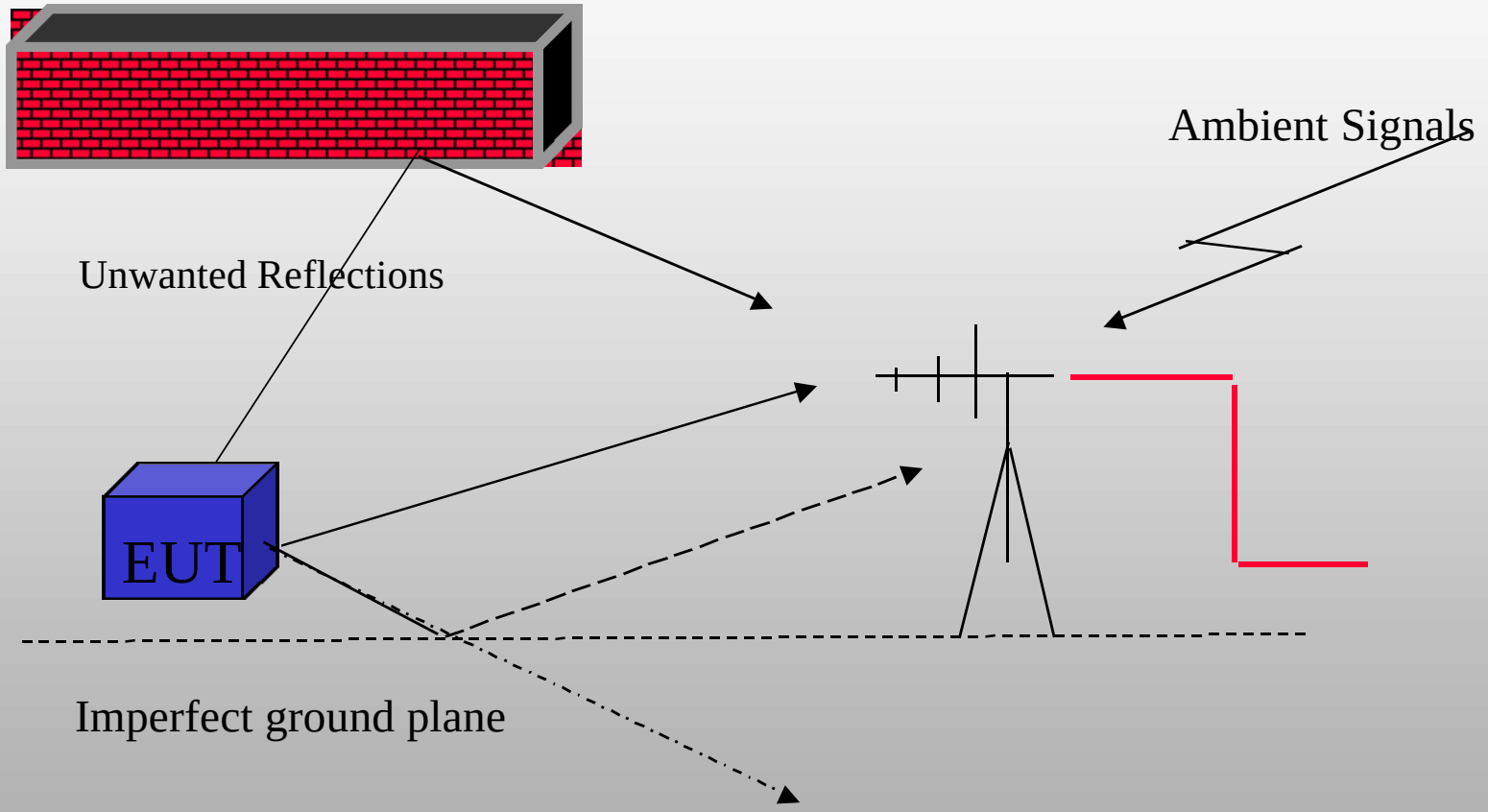
Radiated System Layout



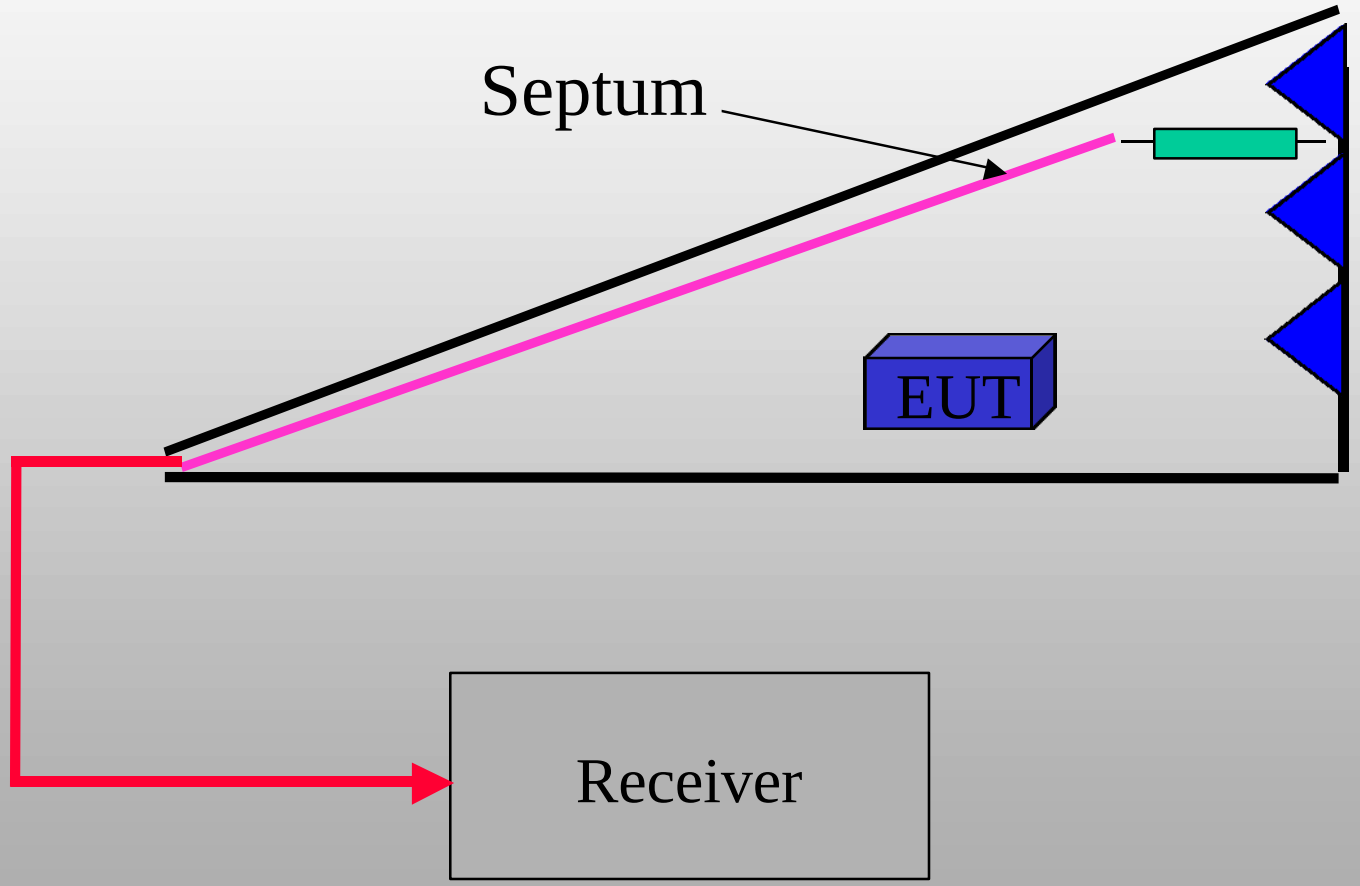
The Open Area Test Site



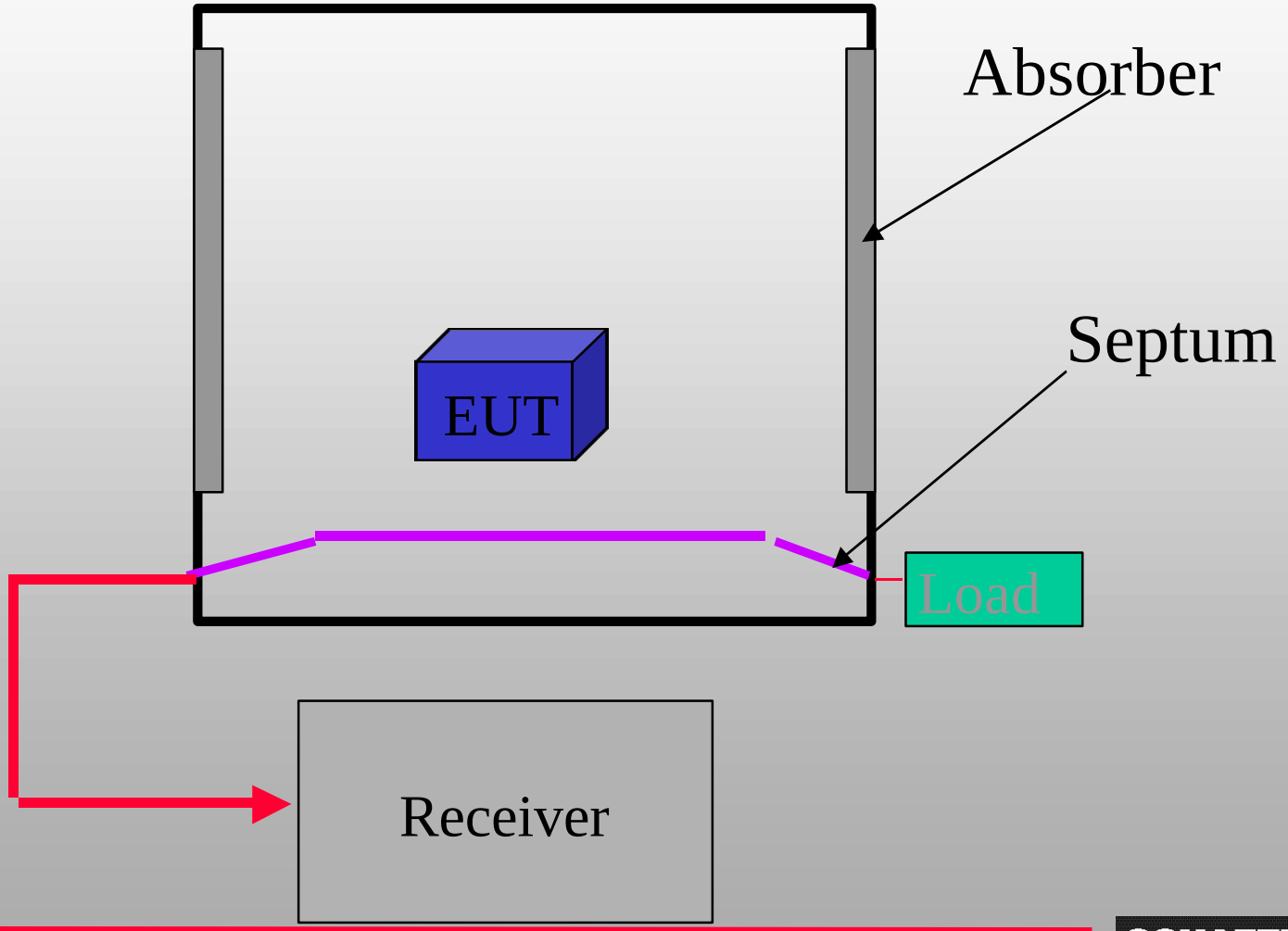
Problems of the Test Site



The GTEM



The TEM Cell (EmCell)



What Kind of Signal?

- RF emissions can take many forms depending on the source.
- System clocks produce harmonics to many times the fundamental frequency.
- Local oscillators may produce a very narrow emission without significant harmonics
- Electric motors produce low repetition pulses of very broadband noise
- Any switching device such as a thyristor produces large numbers of harmonics of the power frequency.

Any Kind of Signal

- Almost any kind of signal or combination of signals can be present.
- Most importantly the user will not know what kind of signal to expect.

CISPR 16

- CISPR 16 defines the performance of instruments used for regulatory standards.
- CISPR 16-1 defines the performance of RF measuring receivers.

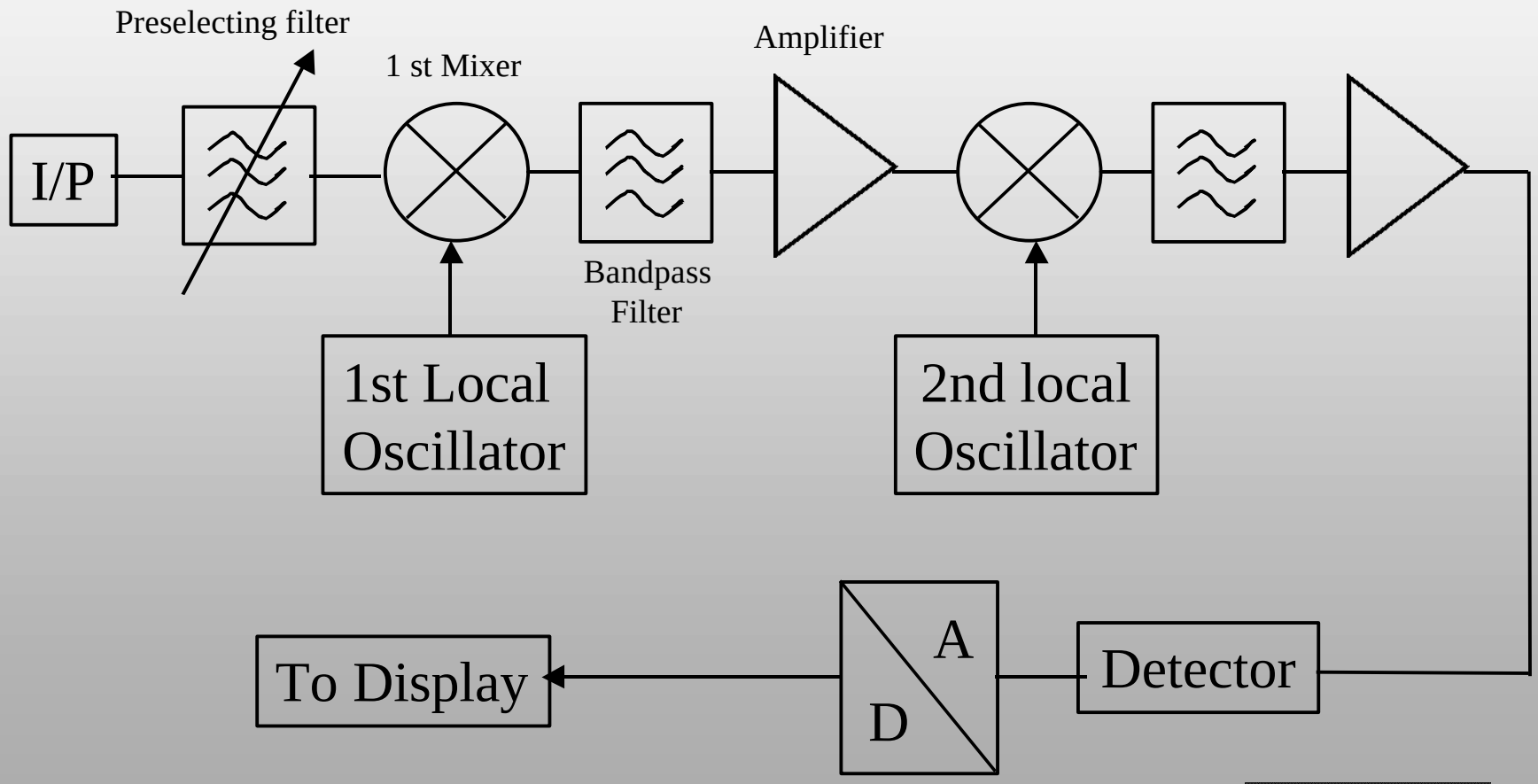
Performance

- CISPR 16-1 does not describe how to build a receiver but defines various performance criteria.
- Any receiver meeting these criteria is compliant.
- Compliant receivers should all produce the same result when presented with the same signal.

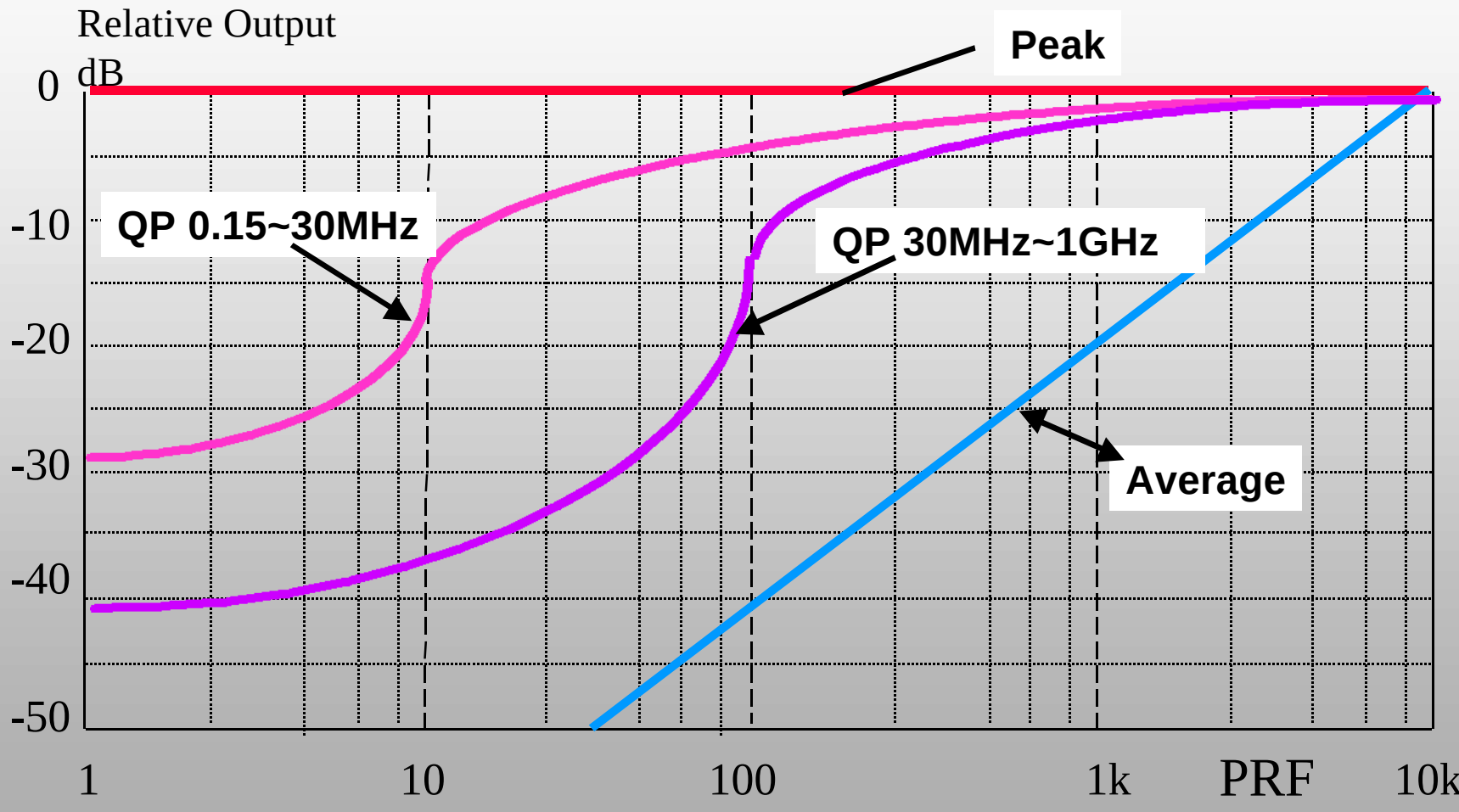
Performance

- Meeting these very stringent criteria is not easy.
- Particular parameters such as low repetition pulse response is particularly difficult and costly.
- Avoiding overload due to broadband or impulsive signals also requires great care.

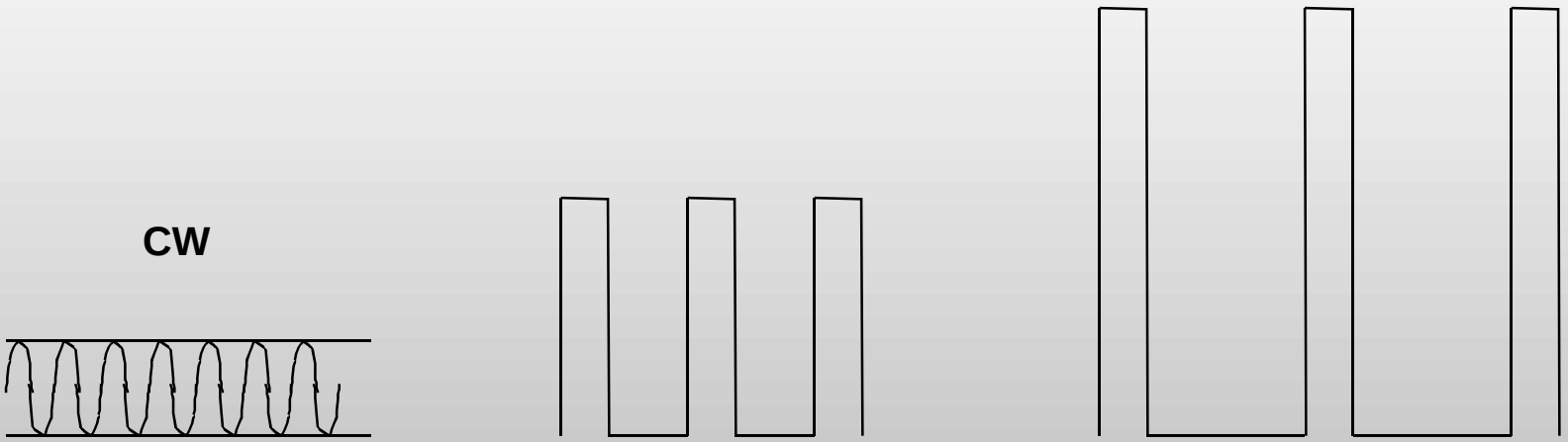
Basic Diagram of Super-Heterodyne Receiver



Detectors


Relative Output
dB
0
-10
-20
-30
-40
-50
Peak
QP 0.15~30MHz
QP 30MHz~1GHz
Average
1
10
100
1k
PRF
10k

Varying Pulse Repetition



All three signals could produce the same result on a CISPR receiver using the QP detector

Noise Floor

- All electronic device produce noise
- In an instrument designed to measure noise this results in a level of noise being displayed when there is no input.
- This level is “The noise floor” of the instrument
- In a receiver this is dependant on the measurement bandwidth.

Effects of Noise Floor

- No measurement of any signal below the level of the noise floor is possible.
- Errors will occur at levels within 6 dB of the noise floor.
- Antenna factor and loss in cables must be added to the noise floor to determine the minimum signal which can be measured.

Antenna Factor

- Antenna factor is the number of dB to be added to a result measured in dBµV on a receiver to determine the field strength in dBµV/m.
- For a high quality antenna (such as the Schaffner-Chase BiLog) this can be as high as 25 dB at the band edges.
- The cable loss can add another 2 dB.

Minimum Measurable Signal

- The lowest signal measurable can therefore be 27 dB above the noise floor of the receiver.
- For accurate measurement this figure can be as high as 33 dB μV/m.
- The QP emission limit for the EN standards are set at 37 dBμV/m.
- Any noise floor above 4dBμV at 1 GHz will result in the minimum measurable signal being in the error band .

Pre Amplifiers

- One method used to improve the low level performance is the pre amplifier.
- An external amplifier can amplify the incoming signal without adding significantly to the noise floor.
- This will however increase the risk of saturation and non linearity.

Pre-compliance Testing

A Definition

A Pre-Compliance Test
Is a test applied to a product
prior to a visit to a test house
to reduce the risk of a costly failure
at the test house.

In House Testing

Although it is possible
to perform fully compliant testing
“In House”

It is more common that
“In House”
equipment will
be defined as
pre-compliant.

Reasons for In House Testing

- Development Testing
- Component Selection
- Engineering Changes
- Pre-compliance Testing
- Diagnostic Testing
- Production Testing
- Self Certification ??????
- Technical Construction File Testing

Turnkey System Solution

- Complete system
- Options for special applications
- Simple to use PC software
- Upgradable
- Flexible
- Operates to 2GHz
- Cost equivalent to about ten test house visits

CONDUCTED AND RADIATED IMMUNITY

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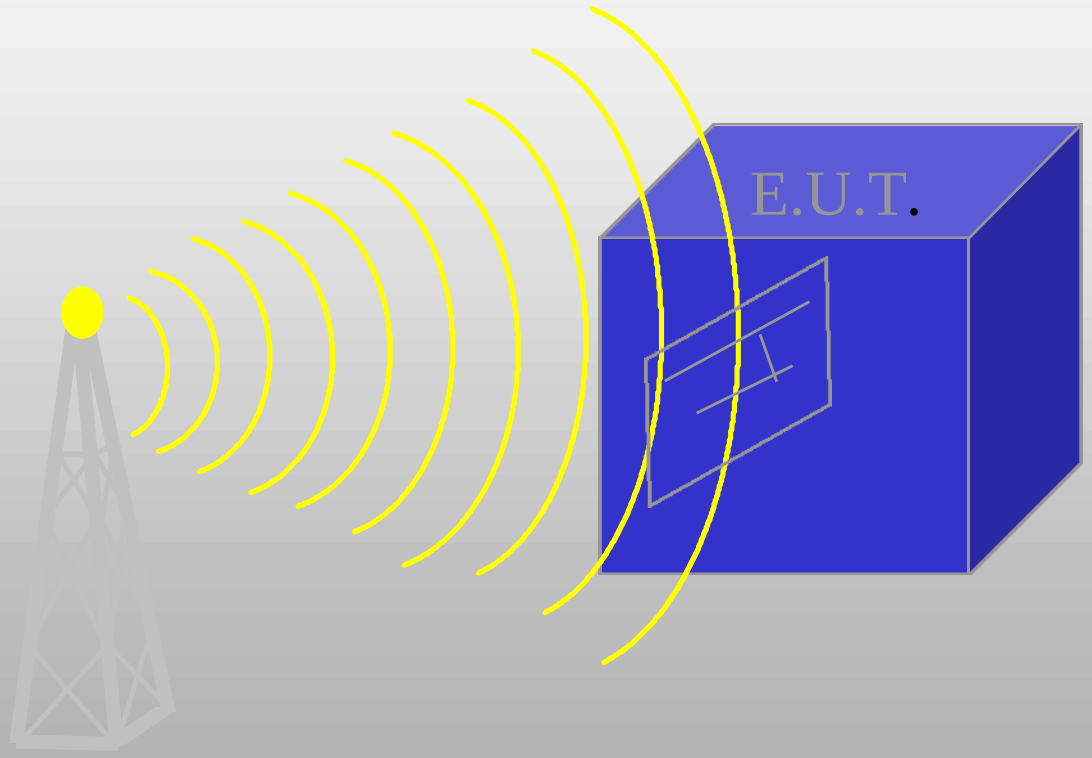
IMMUNITY

- A measure of how immune (or Susceptible) a product is to RF signals coming from the environment.
- IEC 1000-4-3 is applicable to the immunity of electrical and electronic equipment to radiated electromagnetic energy. It establishes test levels and the required test procedures.
- The test methods defined in the standard are structured for the primary objective of establishing adequate repeatability of results at various test facilities for qualitative analysis of effects.

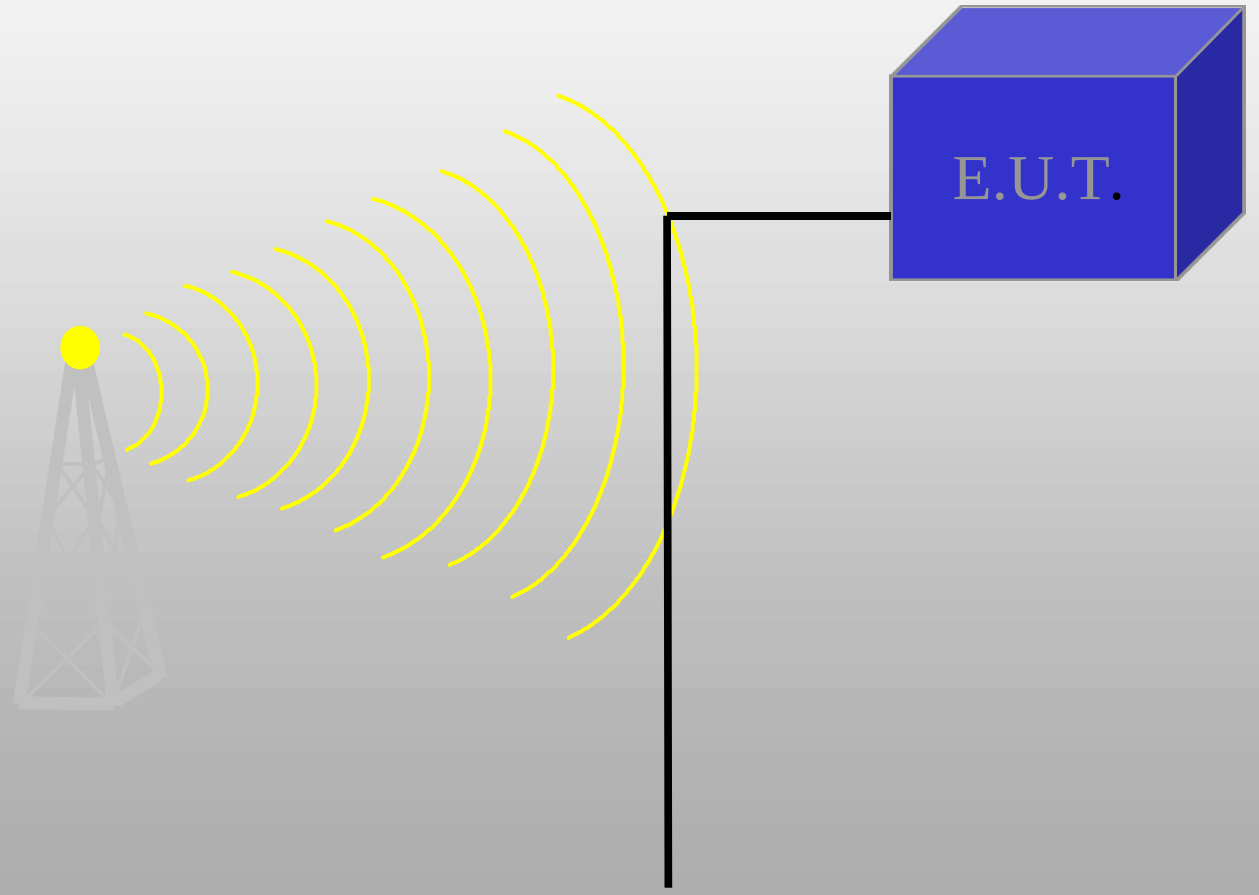
How do real signals get into a piece of equipment ?

- Direct radiation
- Radiation onto cables
- Conducted from a source through connected cables

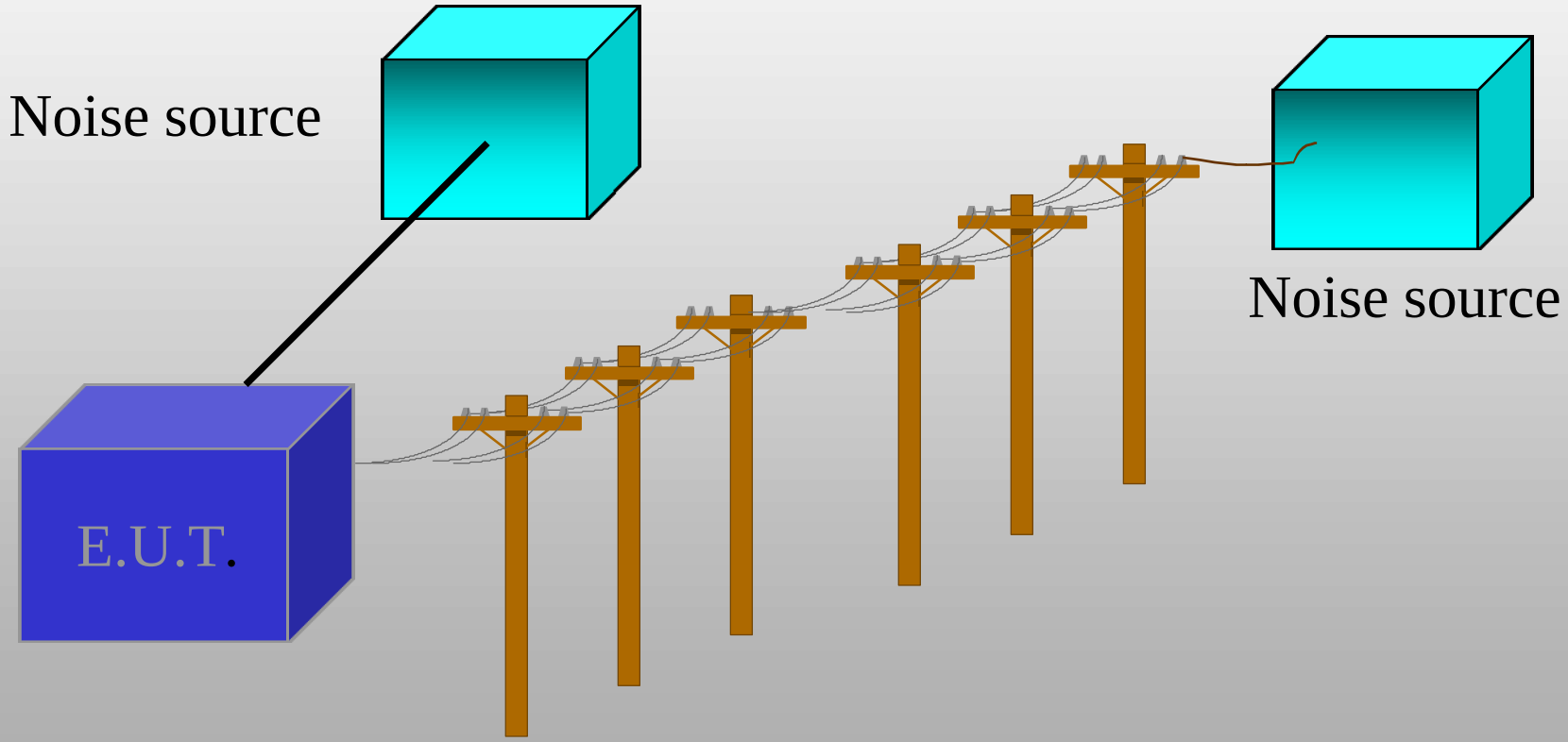
Direct Radiation



Radiation onto cables



Through the power supply or other cables



IEC 801-3 vs IEC 1000-4-3

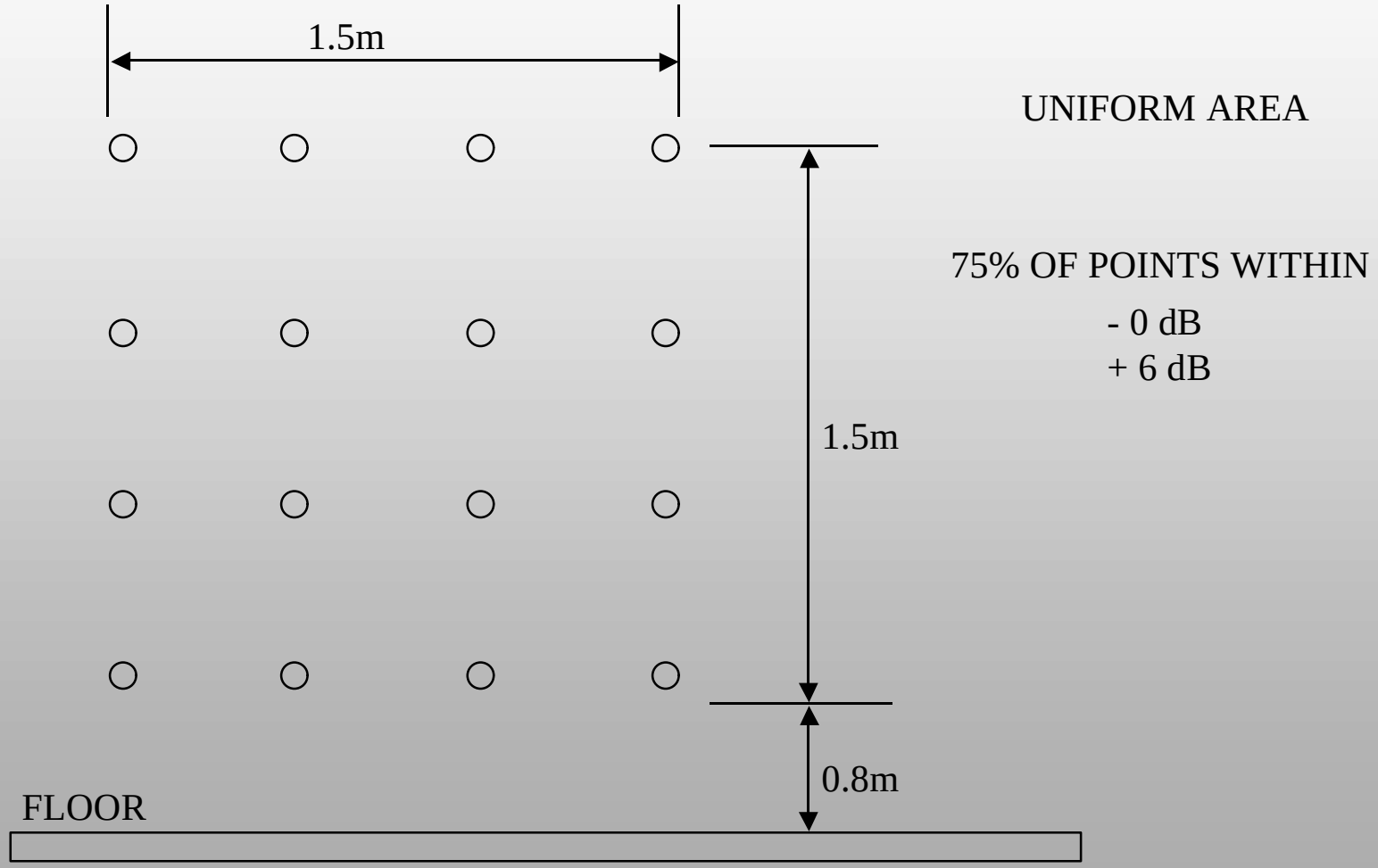
IEC 801-3, 1984

- 27-500MHz
- Active Leveling with EUT in Field
- Multiple Field Probes
- No Modulation
- 1 meter Tx Distance
- “Hot Spots”
- Field Varies with Probe Placement

IEC 1000-4-3, 1995

- 80-1000MHz
- Field Uniformity Calibration, -0/+6dB
- Single Field Probe
- 80% AM w/1kHz sine
- 3 meter Tx Distance
- Reduced “Hot Spots”
- Field Tolerances Consistent

Field Uniformity



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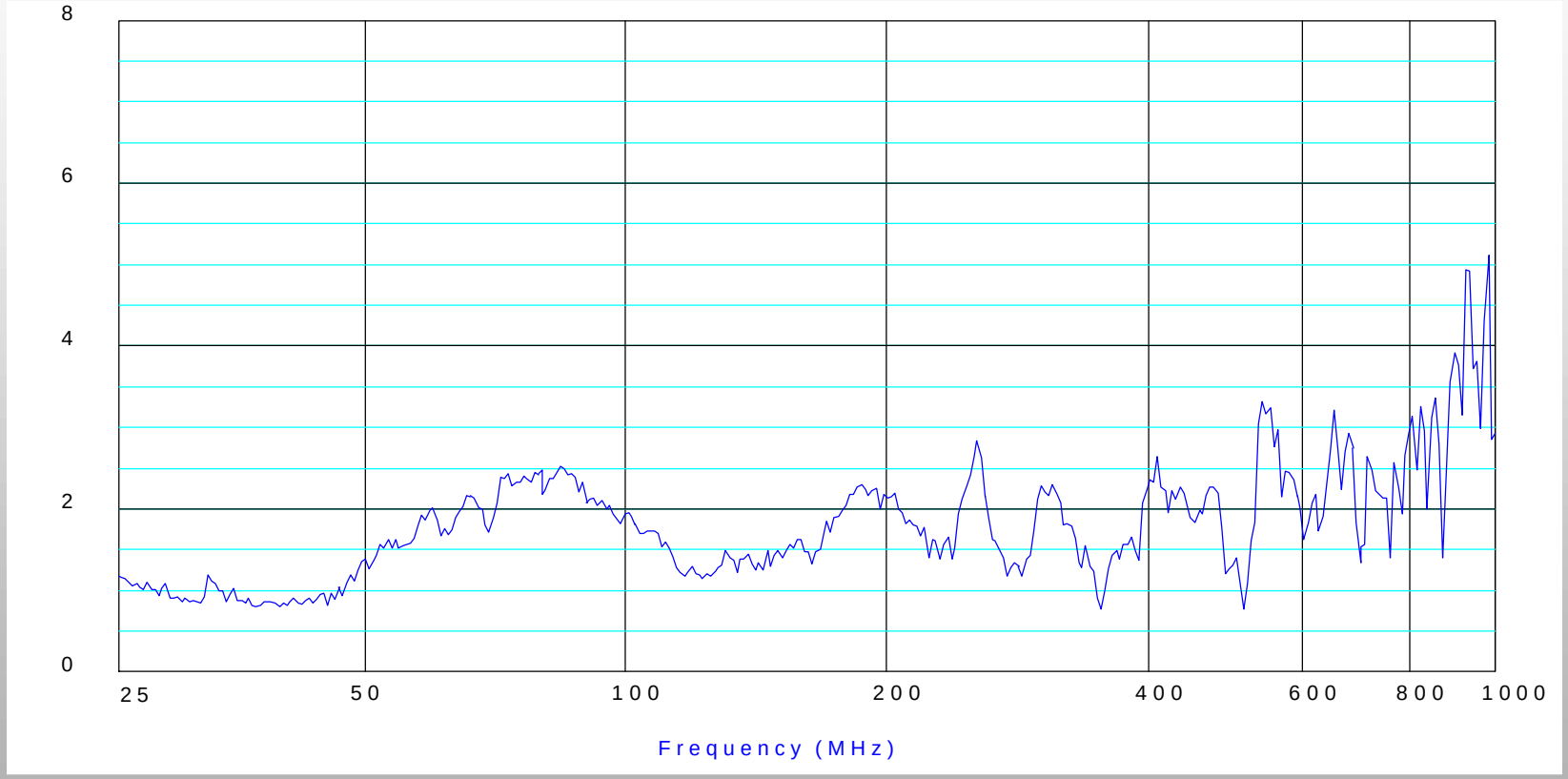
FIELD UNIFORMITY



Ferrite Lined Compact Anechoic Chamber

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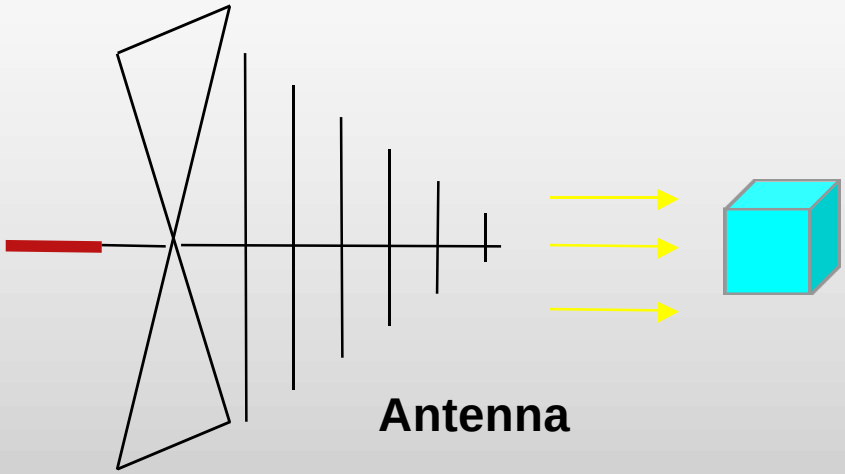
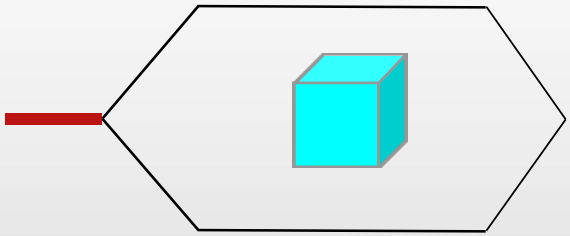
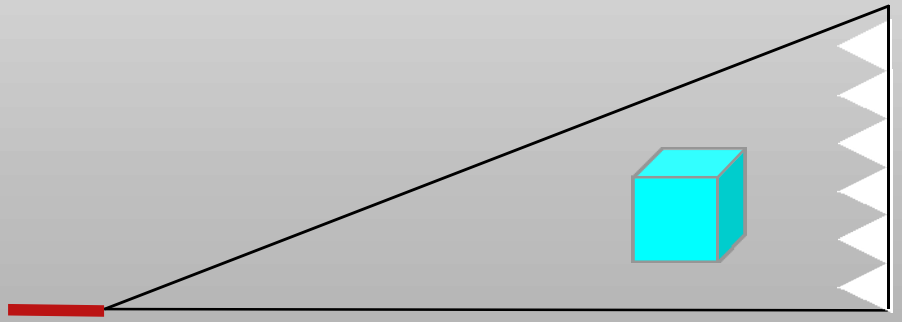
How do we get the signal in ?



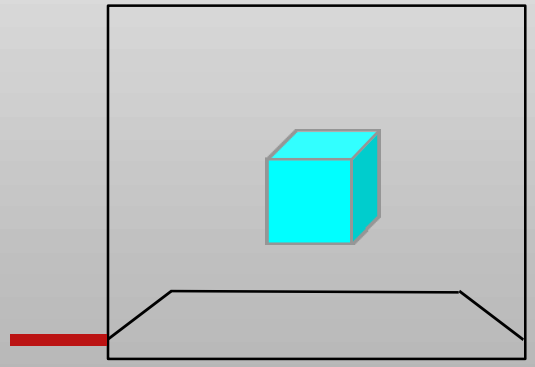
Antenna



Strip Line or TEM cell

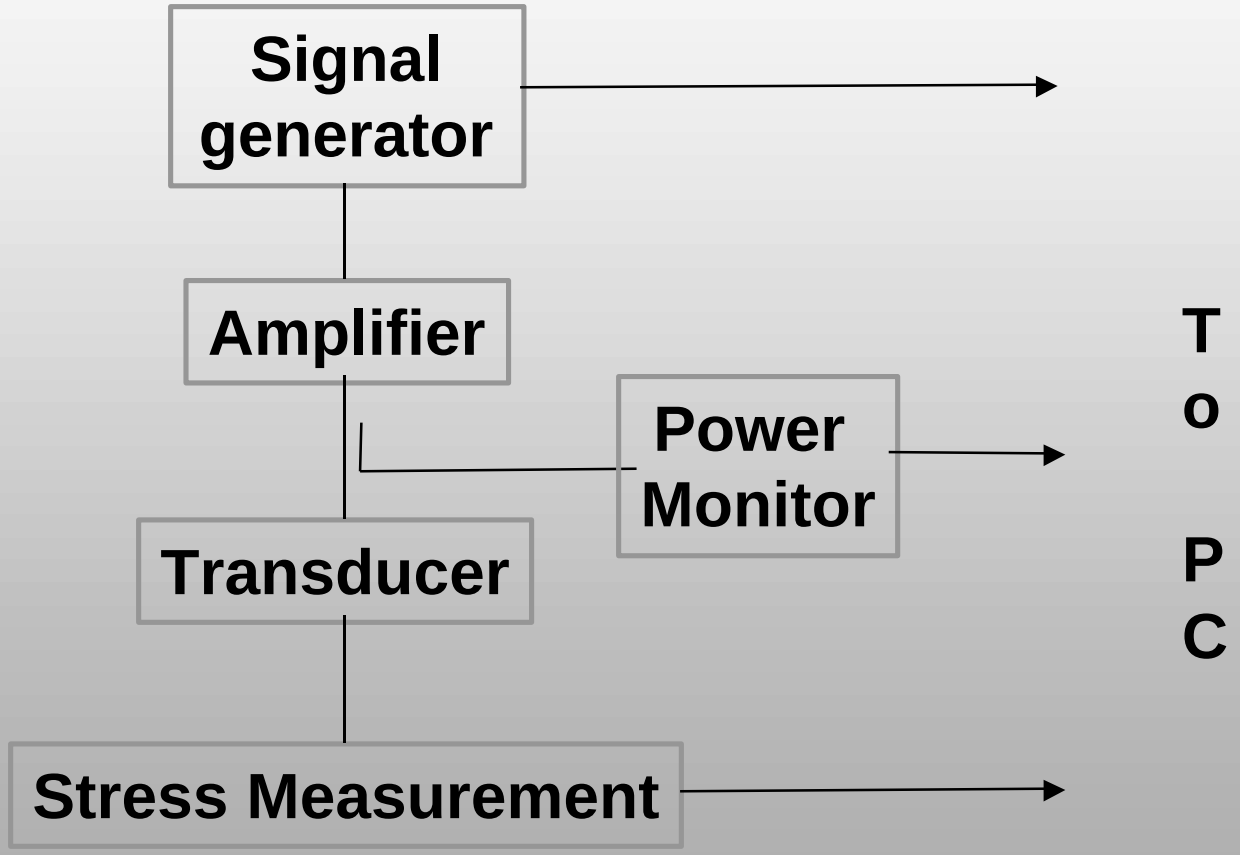


G-TEM Cell



EmCell

The Complete System



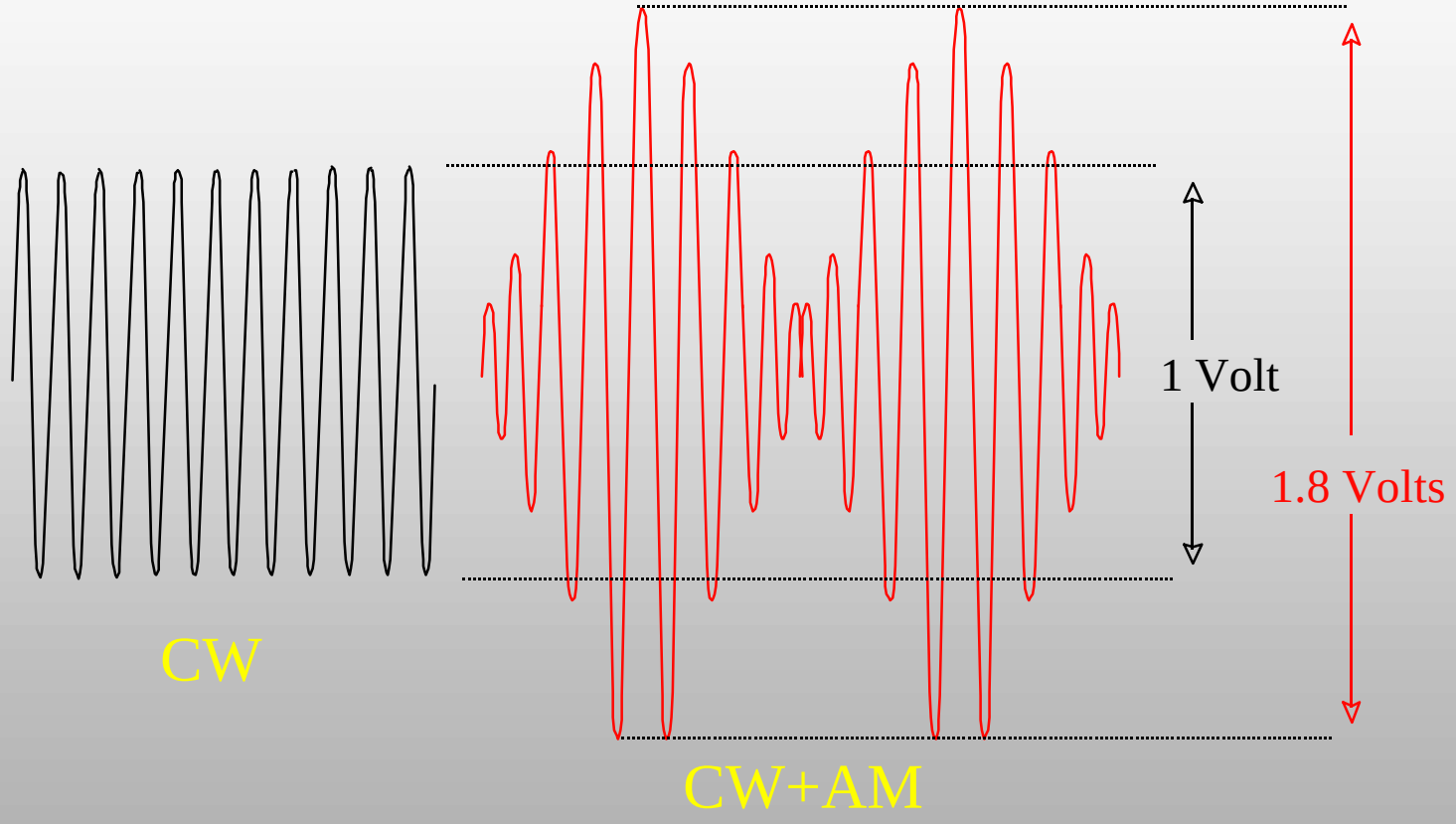
What is Important in a Signal Generator

- Must Cover the Frequency Range
- Must Cover the Amplitude Range
- Must Have Modulation capability
- Must Not Create Transients When Sweeping or On/Off Modulation Modes
- Must Have Good Frequency and Level Stability and Repeatability

What is Important in an Amplifier

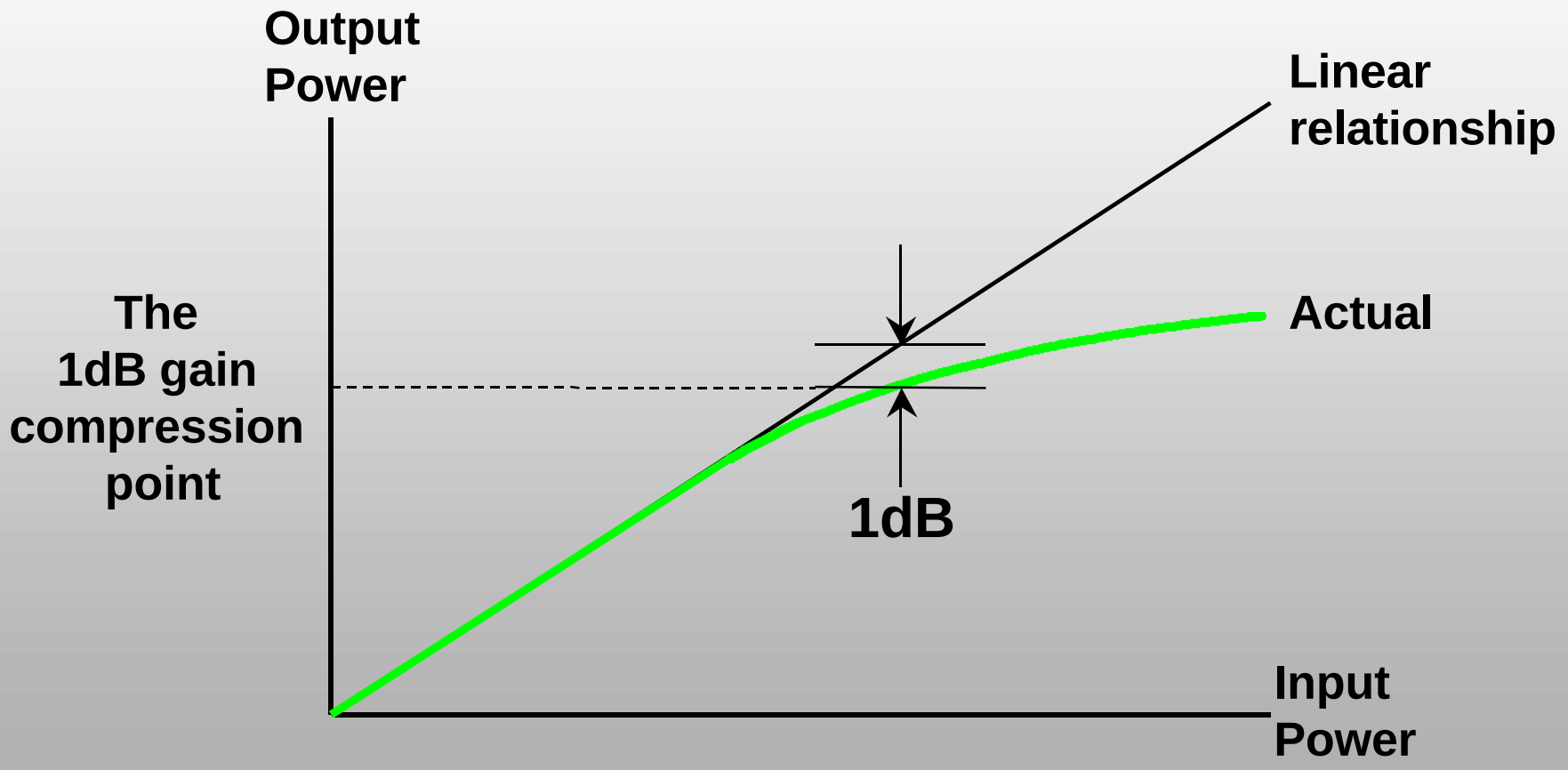
- Must Cover the Frequency Range
- Class A Type
- Must Deliver Necessary Power Without Harmonic Distortion
- Must Be Able To Withstand 100% Reflected Power

Effect of 80% Modulation upon Peak Power

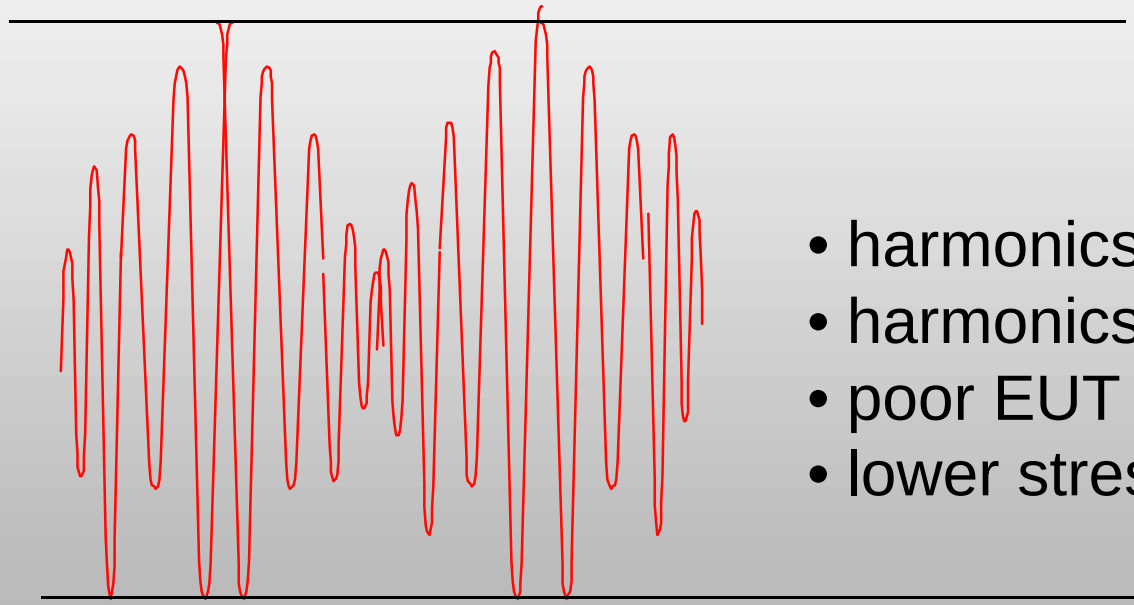


$P \propto V^2$ therefore peak power is 3.24 times greater

Gain Compression



Effects of Distortion



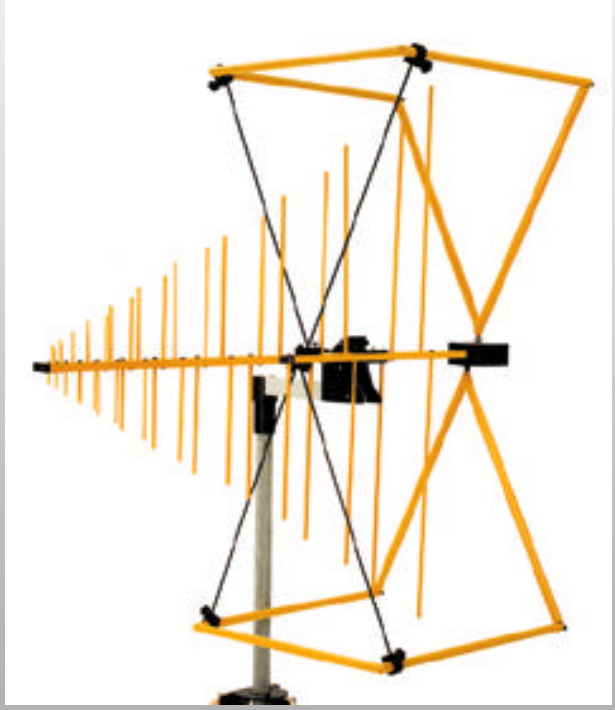
- harmonics of modulation frequency
- harmonics of carrier frequency
- poor EUT failure repeatability
- lower stress at intended frequency

What is Important in an Antenna

- Size
- Antenna Factor
- VSWR
- Polarization
- Balance and Symmetry

Typical Broadband Antennas

26MHz to 2GHz



80MHz to 2GHz

VSWR

- Critical parameter when applying power to antenna.
- Most antennas have poor VSWR at low frequencies.
- A VSWR of 30:1 (not uncommon at 30MHz) means that 87.5% of the power will be reflected!
- For emission measurements the same VSWR will increase uncertainty by ± 1.75dB

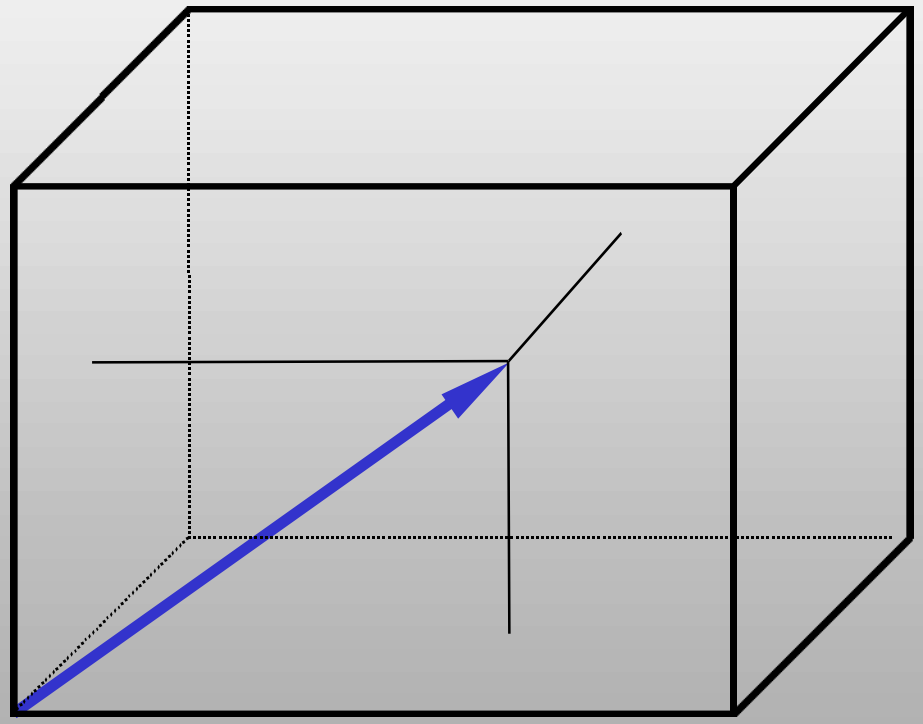
Balance

- The difference between the antenna factors when the antenna is rotated through 180^{o}
- Antennas should to be better than 1dB, some antennas are 0.3dB.
- Mainly a characteristic of Balun - matching network

What is Important in an Isotropic Field Probe

- It must be Isotropic
- It must cover the Frequency Range
- It must cover the Level Range (preferably in one range)
- It must have good Resolution over the entire range

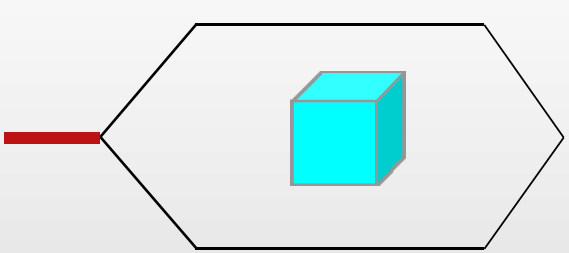
What does Isotropic mean



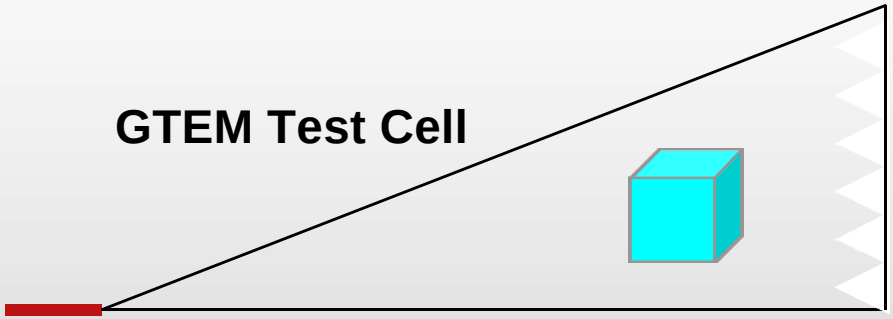
Immunity Software Features

- Log Linear or Table Sweeps
- Edit Display Facility
- Multi-Vendor Hardware Capability
- Cal. File Leveling
- Active Leveling Alternative
- Save/ Load Results and Report
- Calibration Routine
- EUT Failure Entry
- Radiated and Conducted Tests
- Runs on Windows 98 and NT 4.0

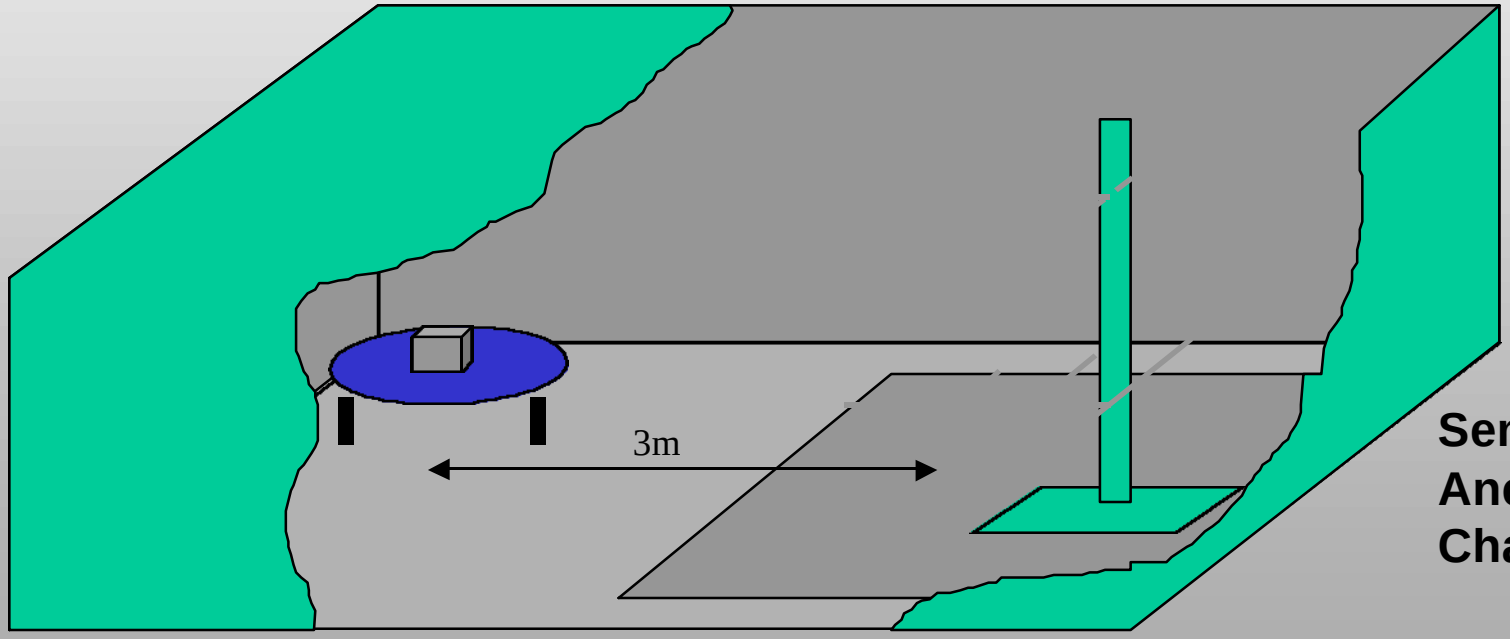
Test Environments



Strip Line or TEM cell



GTEM Test Cell



Semi-Anechoic Chamber

TEM Cell

Definition

An Enclosed Transmission Line System, often a rectangular coaxial line, in which a wave is propagated in the transverse electromagnetic mode to produce a specified field for testing purposes.

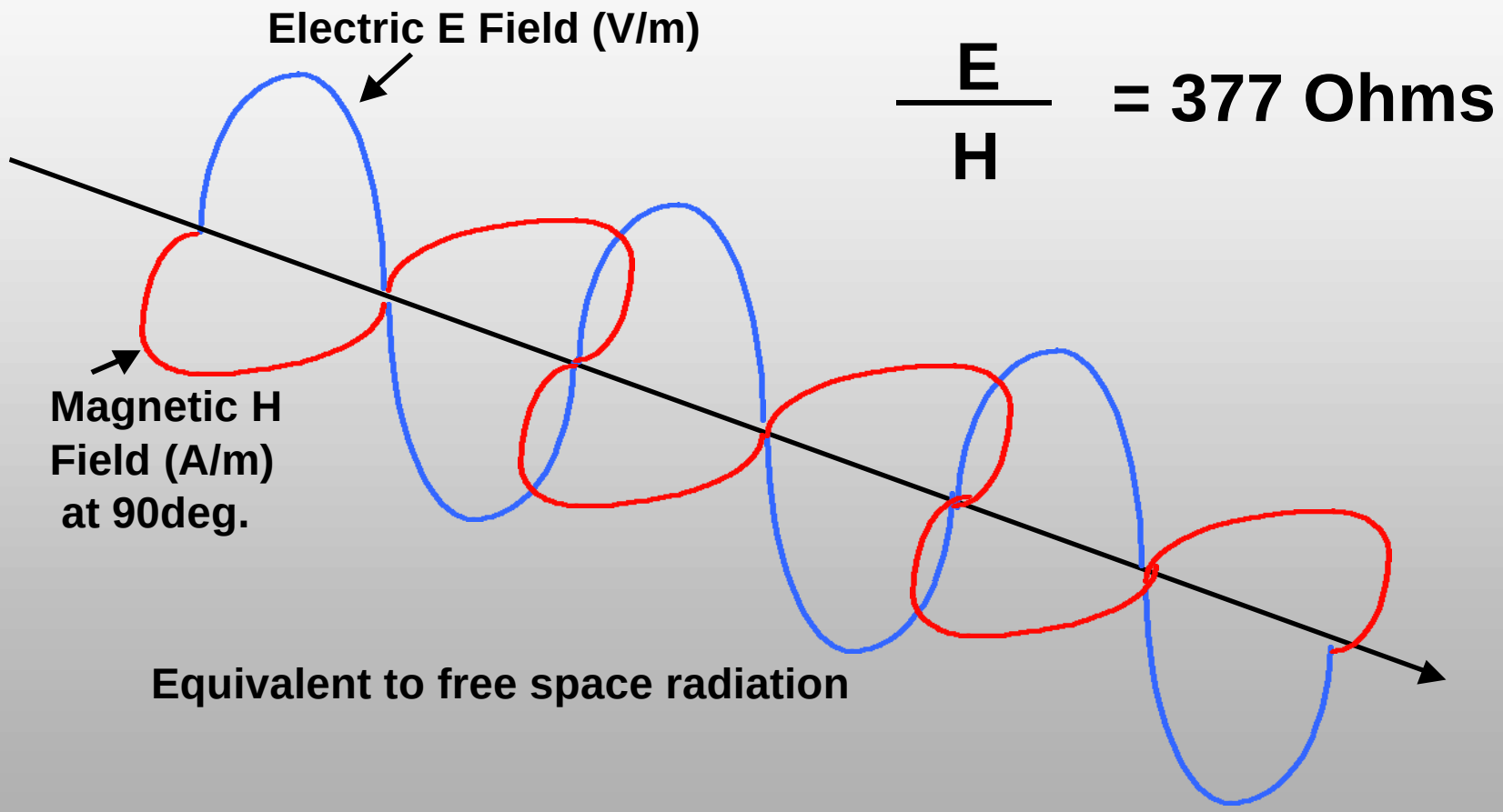
TEM Mode

Transverse Electromagnetic (TEM) Mode:

In TEM mode both the electric and magnetic field are entirely transverse to the direction of propagation. There is no component of either the E or H in the direction of transmission.

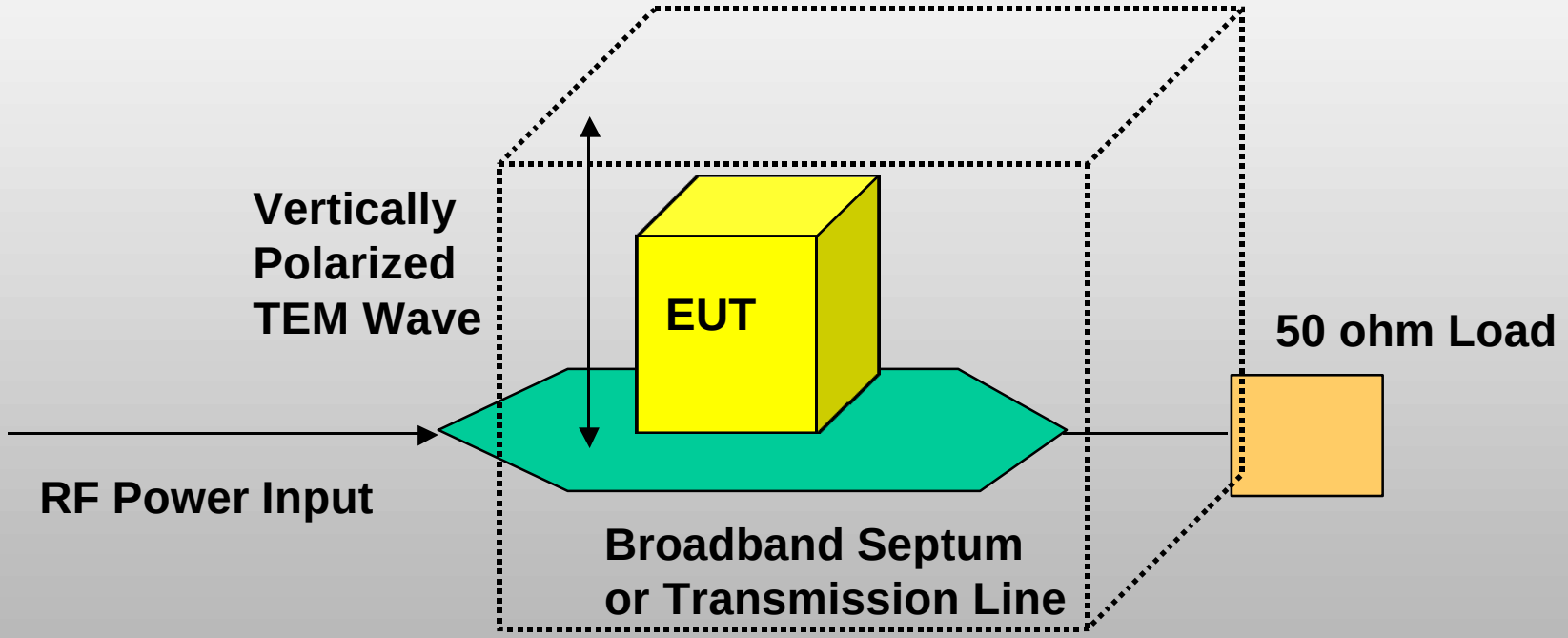
The TEM Mode is equivalent to an incident plane wave for the purpose of immunity testing.

TEM = Transverse Electromagnetic Wave



$$\frac{E}{H} = 377 \text{ Ohms}$$

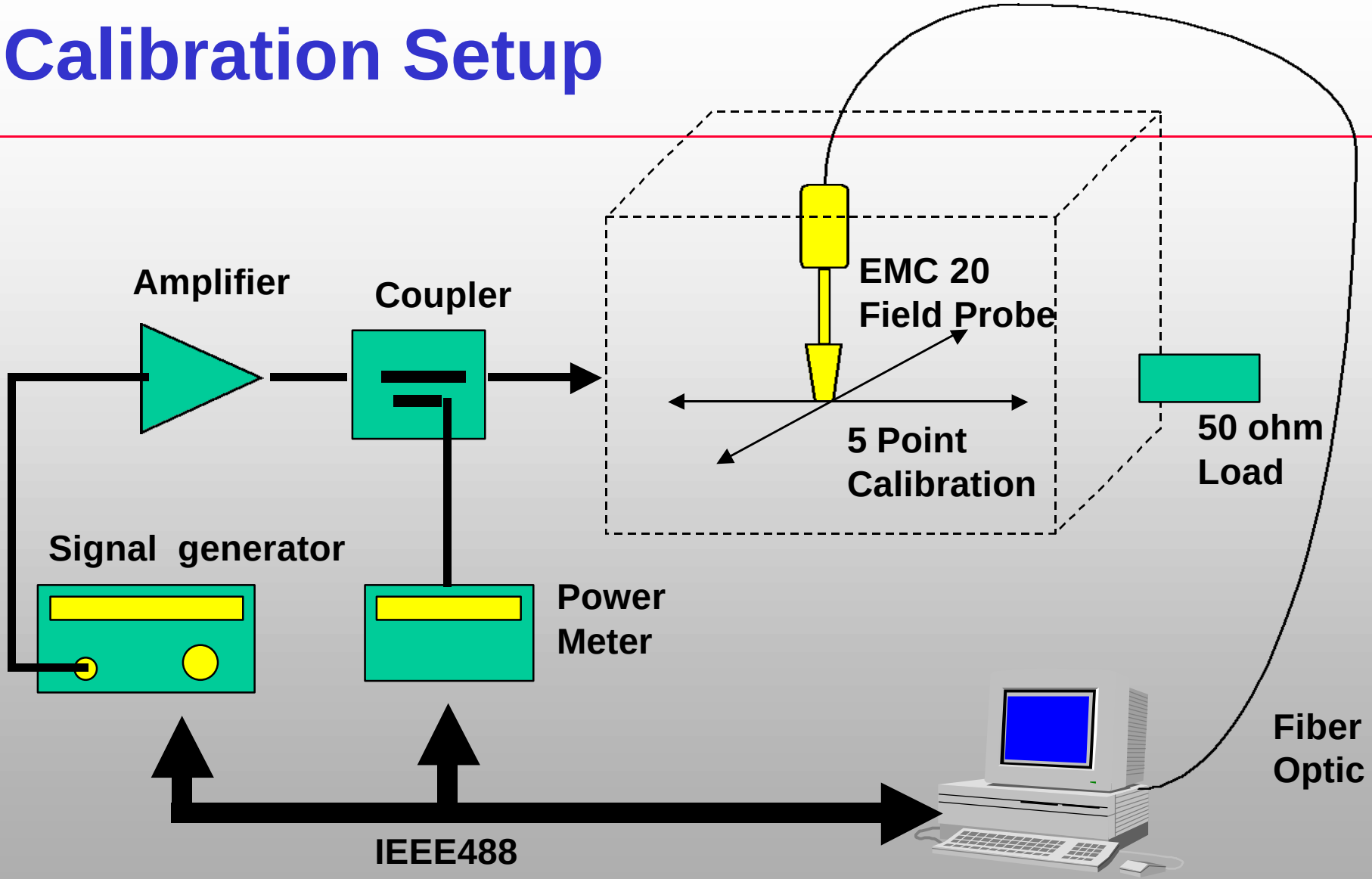
TEM Cell: How It Works



TEM Cell Characteristics

- 100kHz to 200MHz (2GHz)
- Extended frequency range with enhanced septum design/absorber.
- Low Cost - $ 30,000 complete system, 10V/m.
- Requires lower power amplifiers when compared to a chamber.
- Considered Pre-Compliant: Due to field uniformity and higher order modes.
- Small EUT's with minimal cabling, 20" cube.
- Uniform area is typically 1/3 the separation of the outer and inner conductor.
- Septum or center conductor acts as the broadband transmitting antenna.

Calibration Setup



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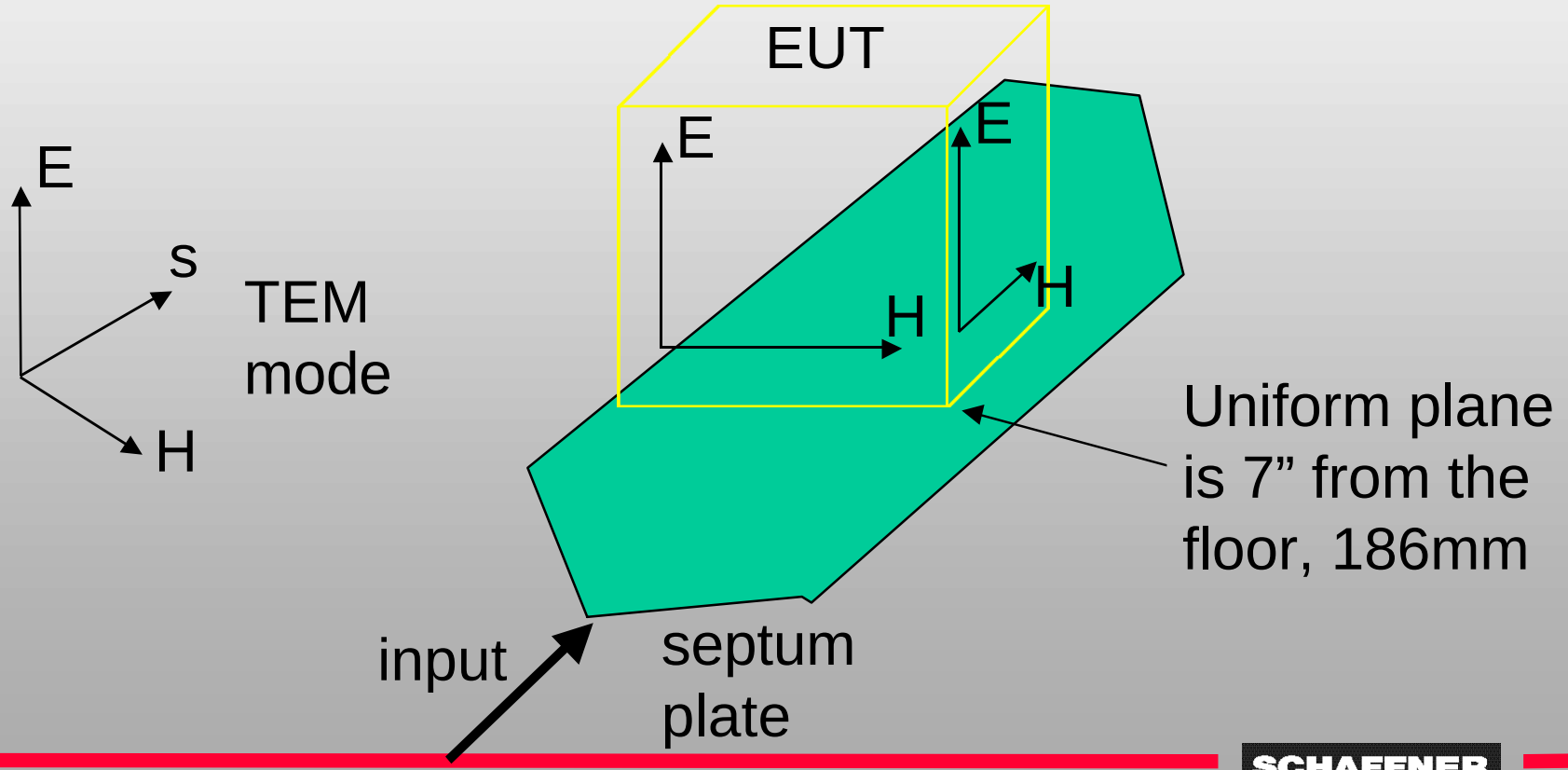
Arrangement of EUT Wiring

- Wiring is left exposed to the electromagnetic field and is routed above the floor, at either EUT level or along a diagonal, to the exit point in the cell. Routing cable along a conducting wall shall be avoided.
- We recommend that the cables be non-inductively looped and bound together (as per the Conducted emissions part of EN 55022, for example) in 0.5 x 0.5 meter lengths.
- Rotate Cables with EUT.

Test Method

Rotate the EUT until all faces have been exposed in both polarization's, note: rotate cables also



What can manufacturers do with acceptable results?

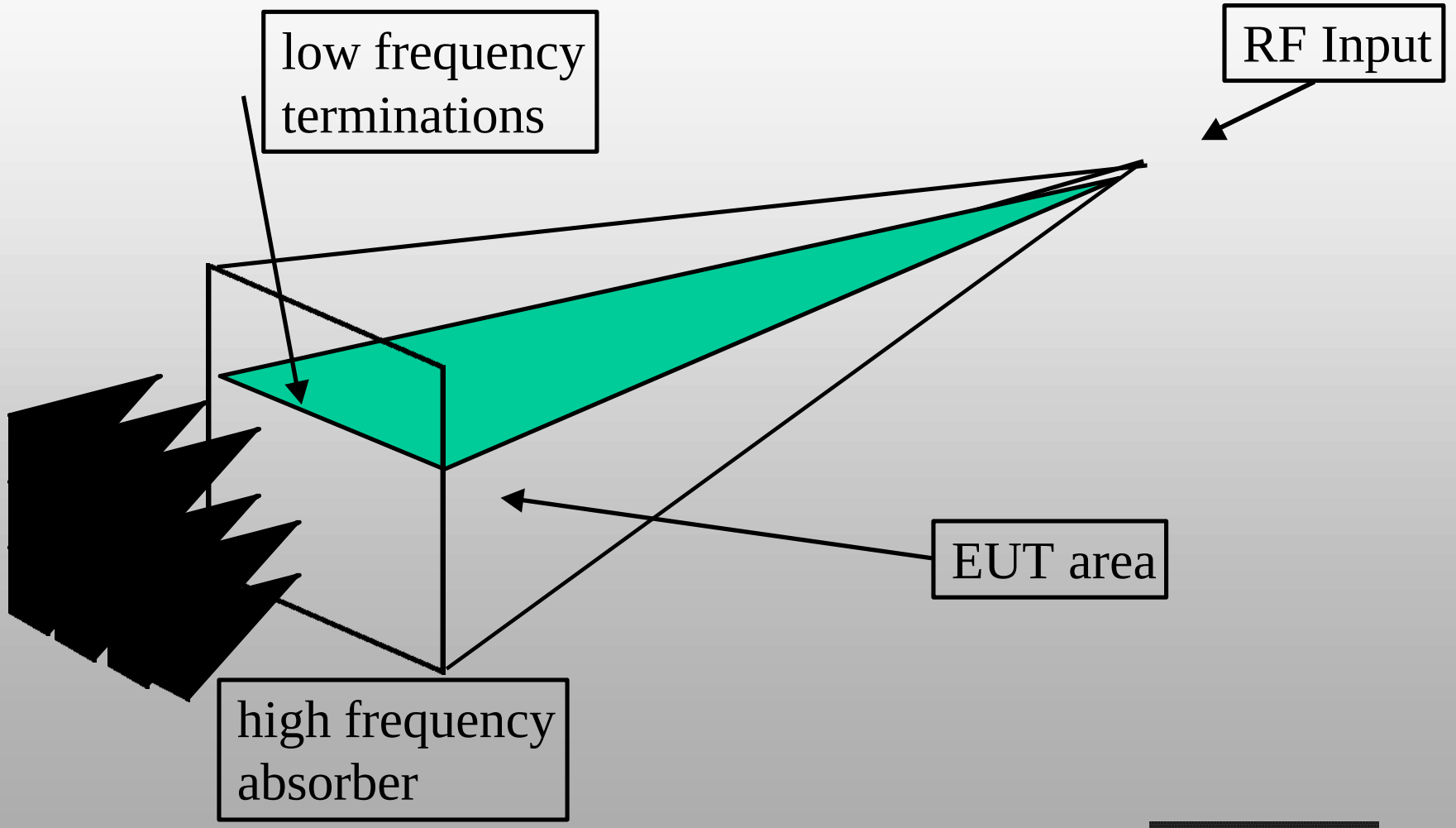
- Use the results as a confidence check before approaching an independent test house for compliance testing.
- Self Certify
- Insert results into a technical construction file [TCF] for 3rd party assessment.

G-TEM™ Cell

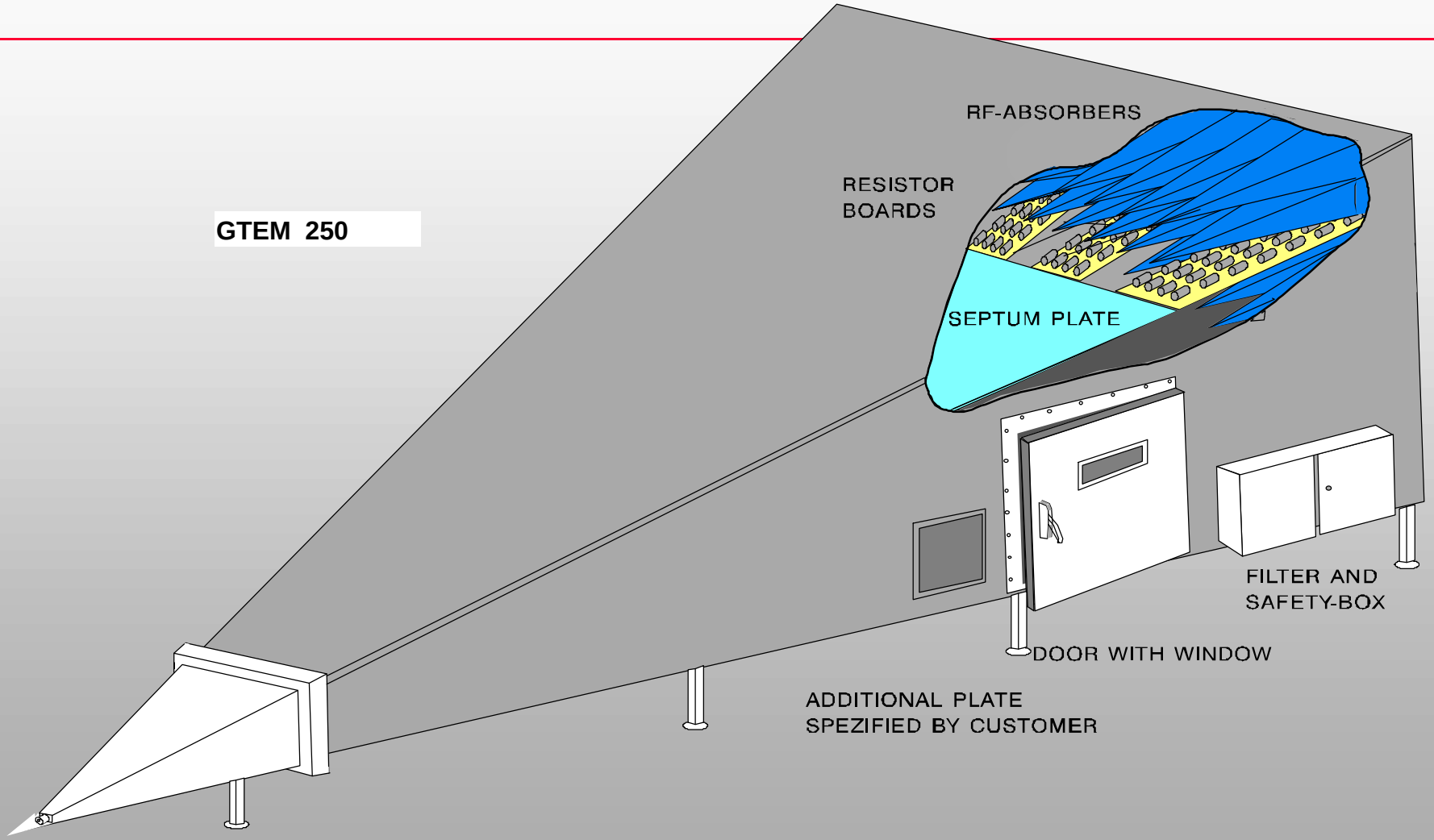
Description:The G-TEM is a pyramidal tapered, doubly terminated section of 50Ω transmission line. At the input, a normal 50Ω coaxial line is physically transformed to a rectangular cross section.

Proven Technology: On the market since 1988, License ABB, 4 licensee, more then 400 operating installations world wide, more then 100 scientific publications.

GTEM - How It Works



CLASSIC GTEM TEST CELL



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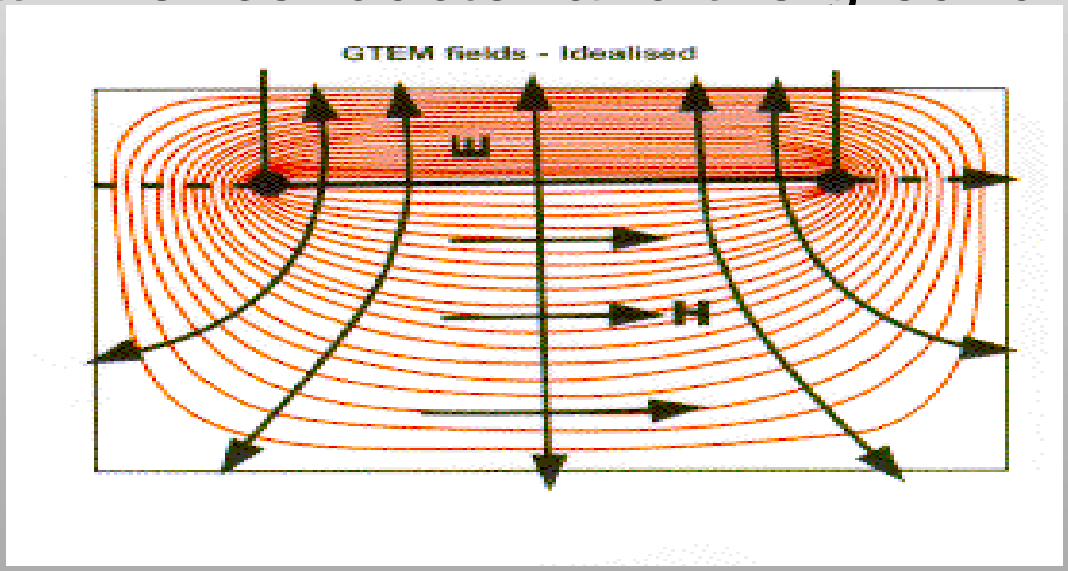
Field generation

- When RF-signals are input, TEM-waves will propagate around the septum
- The intensity of the EM-field is proportional to the applied voltage and the distance between the flat inner conductor and the ground



G-TEM Cell Characteristics

- **100kHz to 5GHz, (18GHz).**
- **Dual Termination: Resistive to match the currents flowing in the septum and RF absorbers for electromagnetic propagation within the cell.**
- **Medium Cost - Dependent on EUT size**
- **Requires lower power amplifiers when compared to a chamber environment.**
- **Considered a compliant solution.**
- **EUT's up to 1.2 meter cube -See Table**
- **Uniform area typically exceeds the 1/3 separation of the outer and inner conductor.**
- **Septum is the broadband transmitting antenna.**

Arrangement of EUT Wiring

- **Wiring is left exposed to the electromagnetic field and is routed above the floor, at either EUT level or along a diagonal, to the exit point in the cell. Routing cable along a conducting wall shall be avoided.**
- **We recommend that the cables be non-inductively looped and bound together" (as per the Conducted emissions part of EN 55022, for example) in 0.5 x 0.5 meter lengths.**
- **Rotate Cables with EUT.**

Test Method

- Rotate the EUT until all faces have been exposed in both polarization's
- Rotate cables with EUT
- The electric field is polarized in a single direction, typically vertical, therefore the EUT should be rotated about the longitudinal axis to simulate vertical and horizontal exposure.

G-TEM Size and Price

Test Volume	µ Price
250mm: 15cm x 15cm x 8cm	$ 10,000
500mm: 30cm x 30cm x 15cm	$ 32,000
750mm: 45cm x 45cm x 22cm	$ 48,000
1000mm: 60cm x 60cm x 30cm	$ 64,000
1250mm: 70cm x 70cm x 40cm	$ 87,000
1500mm: 85cm x 85cm x 45cm	$ 105,000
1750mm: 1m x 1m x 50cm	$ 125,000
2000mm: 1.15m x 1.15m x 60cm	$ 160,000

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What can manufacturers do with acceptable results?

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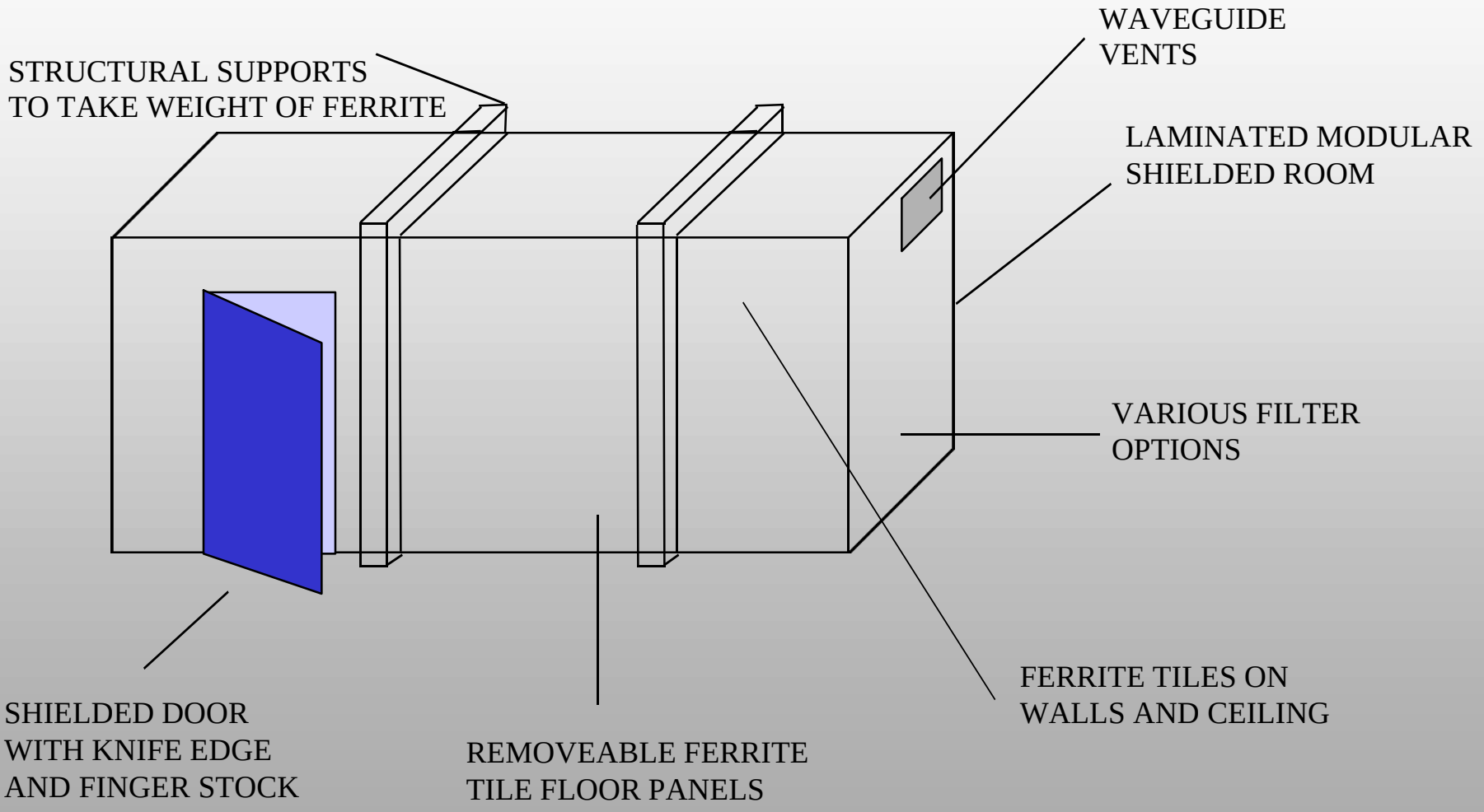
Chamber Components



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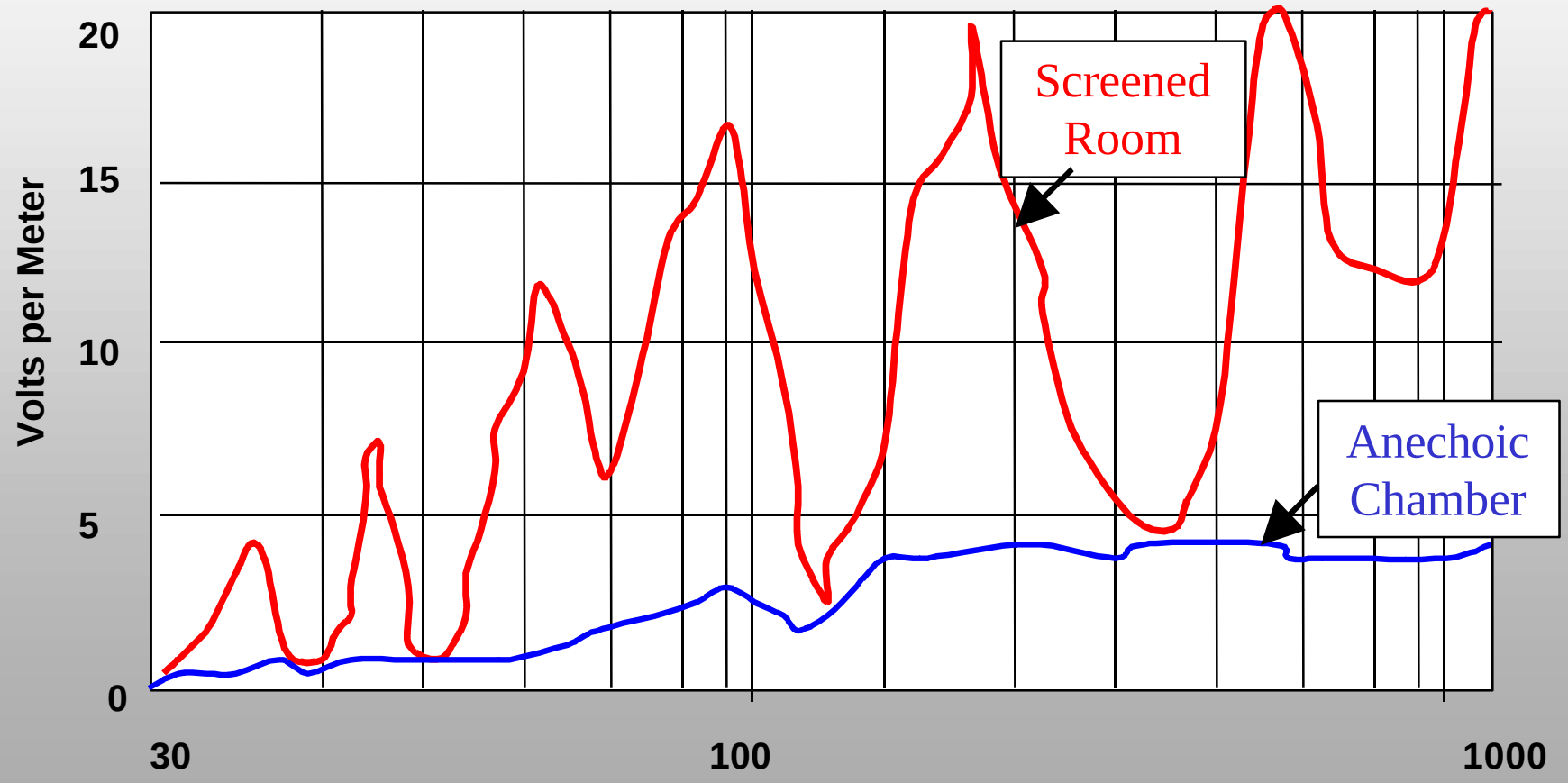
Typical field Strength available from a 10 Watt Amplifier



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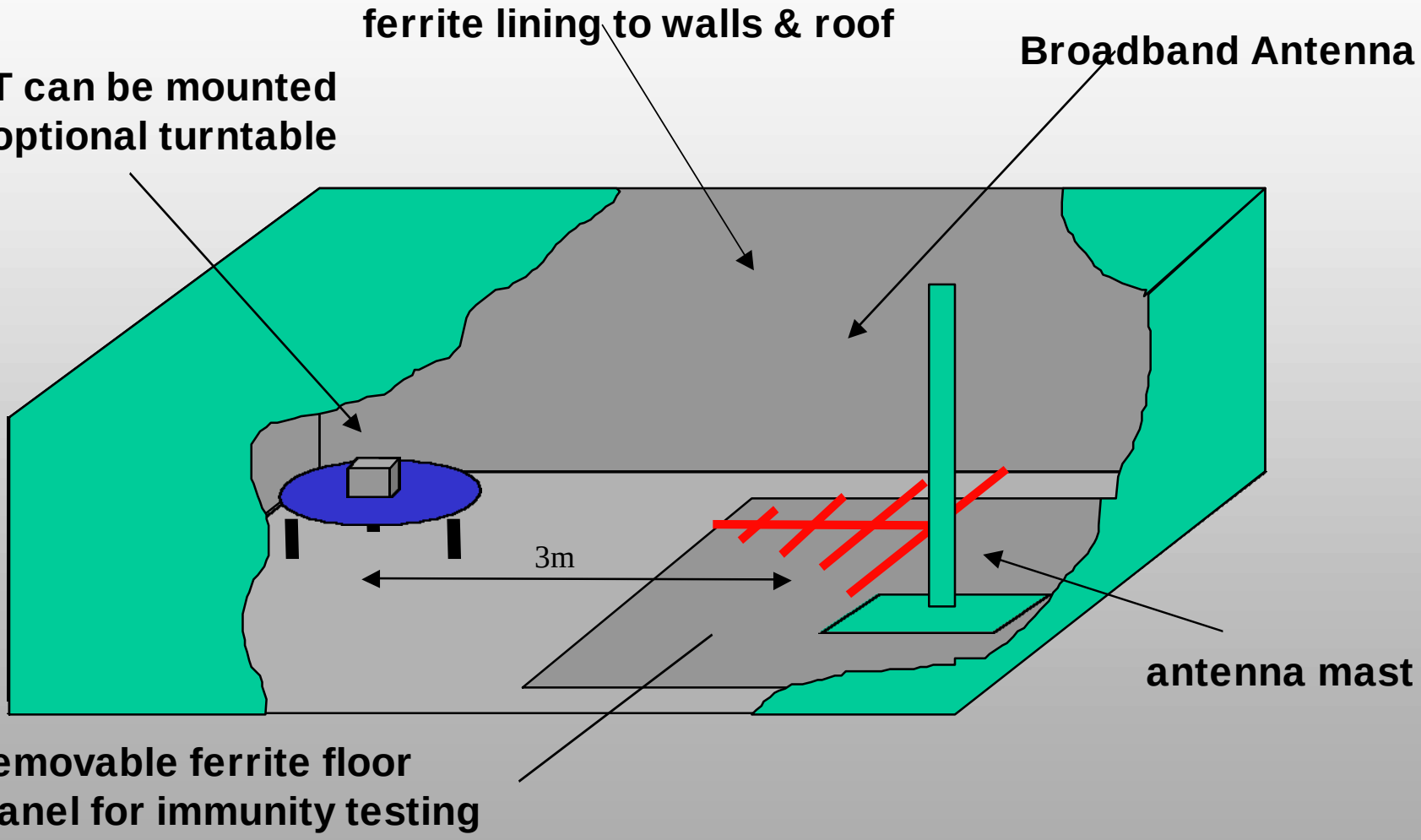
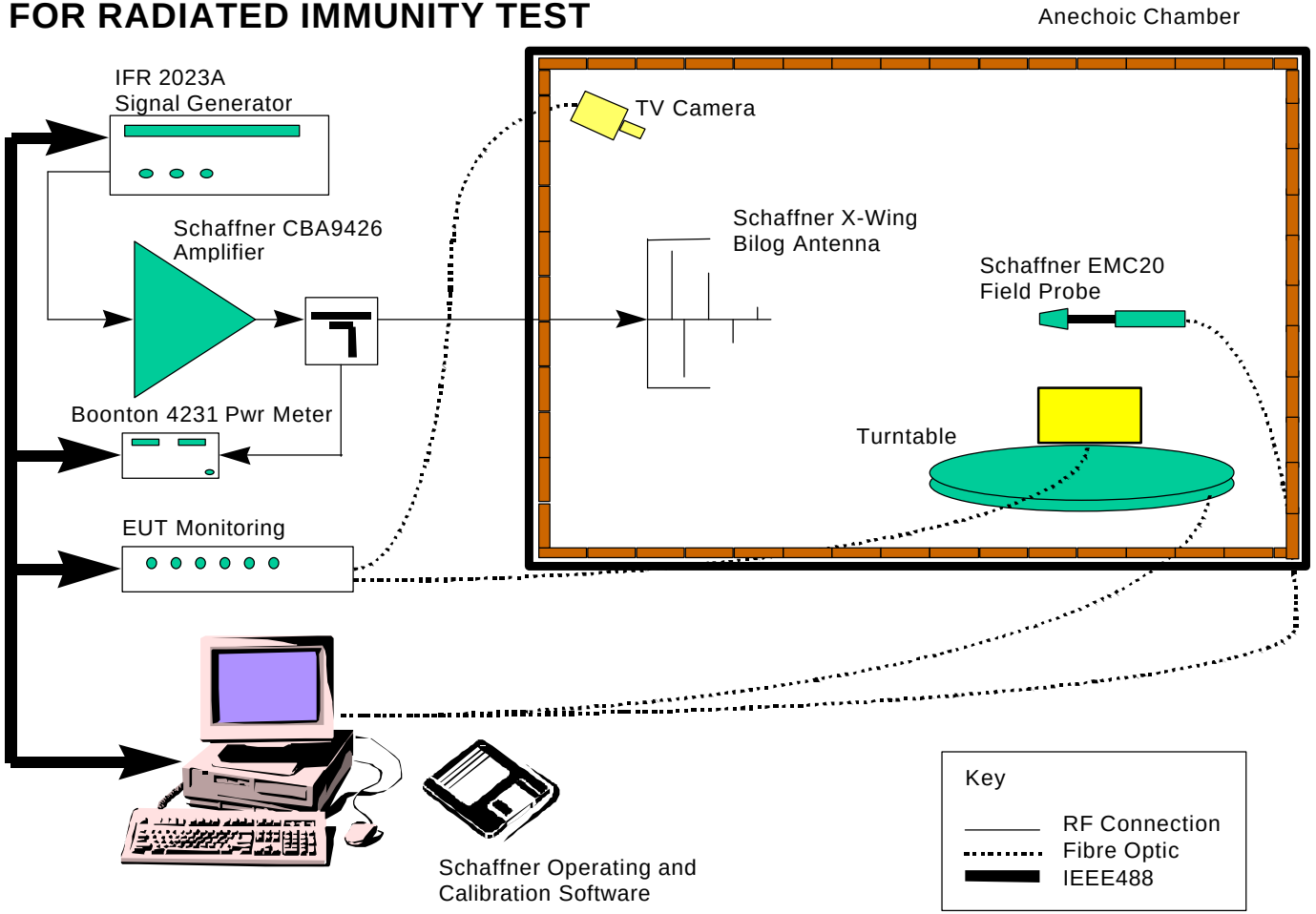
Typical Internal layout



Chamber Immunity System

DIAGRAM SHOWING MEASURMENT SETUP FOR RADIATED IMMUNITY TEST



Chamber Characteristics

- **80MHz (26MHz) to 18GHz**
- **Incorporates High Performance RF absorbers to dampen the reflections.**
- **Considered the bench mark - Preferred Method.**
- **Floor Standing and Tabletop EUT's -1.5 meter.**
- **Uniform area is typically 1.5 m x 1.5 m.**
- **Broadband antenna - 26MHz to 2GHz.**
- **Requires higher power amplifiers when compared to a TEM or G-TEM Cell due to antenna losses.**

Arrangement of EUT Wiring

- **Wiring is left exposed to the electromagnetic field for a minimum distance of 1 meter from the EUT.**
- **EUT consisting of several components, cables between EUT's should route directly off the rear of the tabletop and hang no closer than 25cm to GRP.**
- **EUT cabling to AE should be routed such that a vertical and horizontal component of the cable is exposed to the EMF.**
- **Cables greater than 3 meters shall be inductively decoupled at 3 meters and routed along the GRP to the AE.**
- **Floor standing EUT, cables should be elevated 10cm GRP.**

Test Method

- The EUT is initially placed with one of the faces coincident with the calibration plane.
- Rotate the EUT until all four sides have been exposed in both polarization's.
- Rotate cables with EUT.
- If an EUT consists of several components, it is necessary to modify the position of each component within the EUT while illuminating it from different sides.
- Test time: Four sides approximately 4 hours if maintaining 1.5×10^{-3} d/s.

Chamber Size and Price

	Compact Chamber	FCC 3m Chamber	FCC 10m Chamber
Size	12' x 23' x 10'H	20' x 29' x 18'H	45' x 63' x 28'H
Price	$ 110,000	$ 345,000	1,2000,000
Compliant Emission	NO	YES (FCC)	YES (FCC/EN)
Compliant Immunity	YES	YES	YES

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What can manufacturers do with acceptable results?

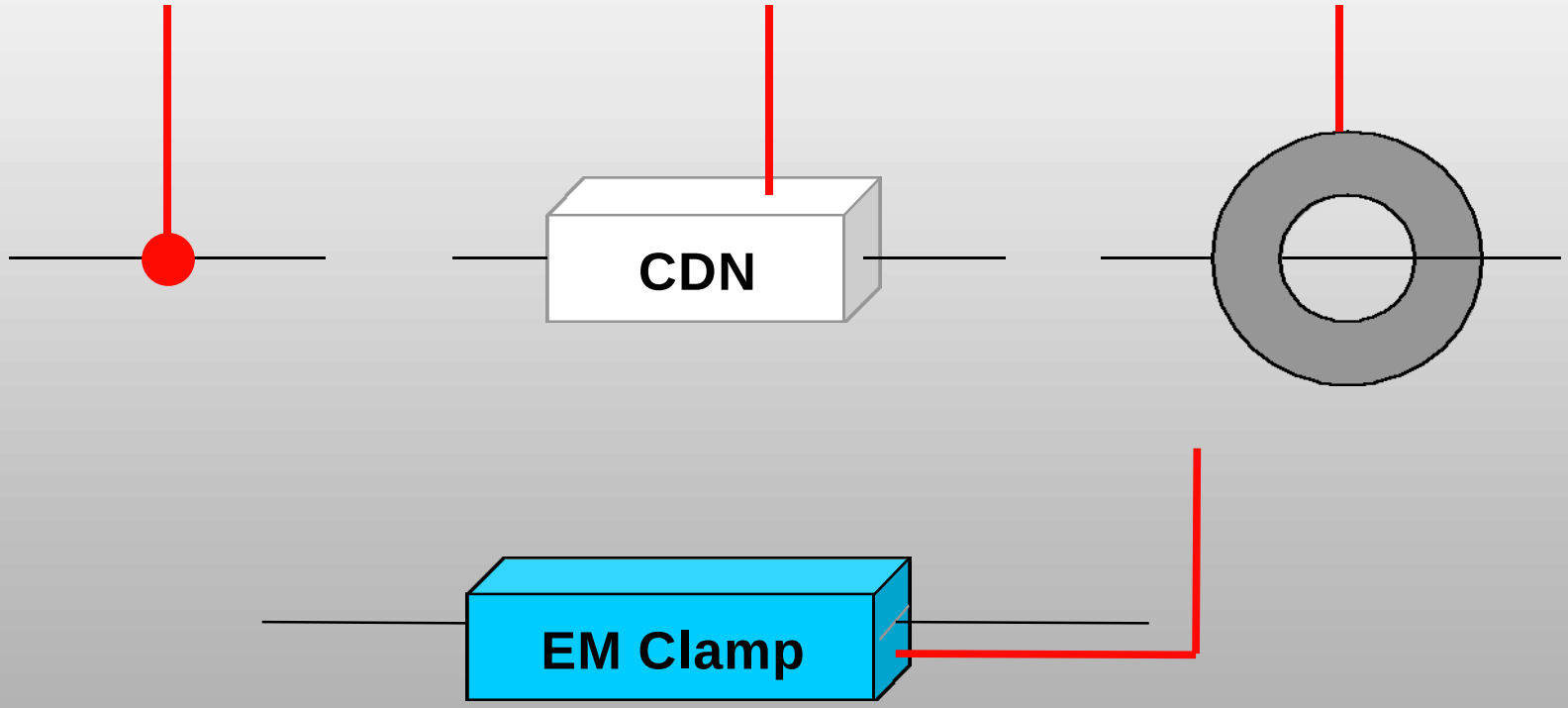
- Self Certify
- Insert results into a technical construction file [TCF] for 3rd party assessment.

Conducted Immunity

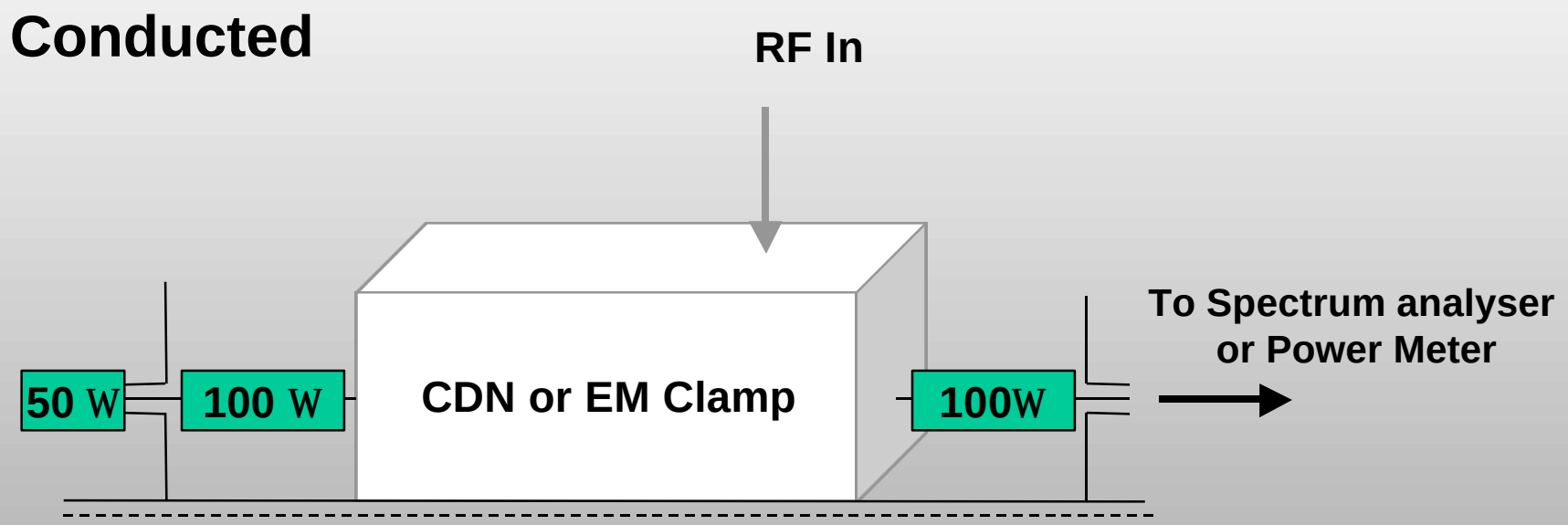
- Lower system cost compared to radiated immunity system.
- Higher degree of repeatability.
- Simulates radiated test by injecting common mode noise onto EUT cables (radiated coupling path)
- 10kHz to 230MHz (1GHz)

How do we get the signal in ?

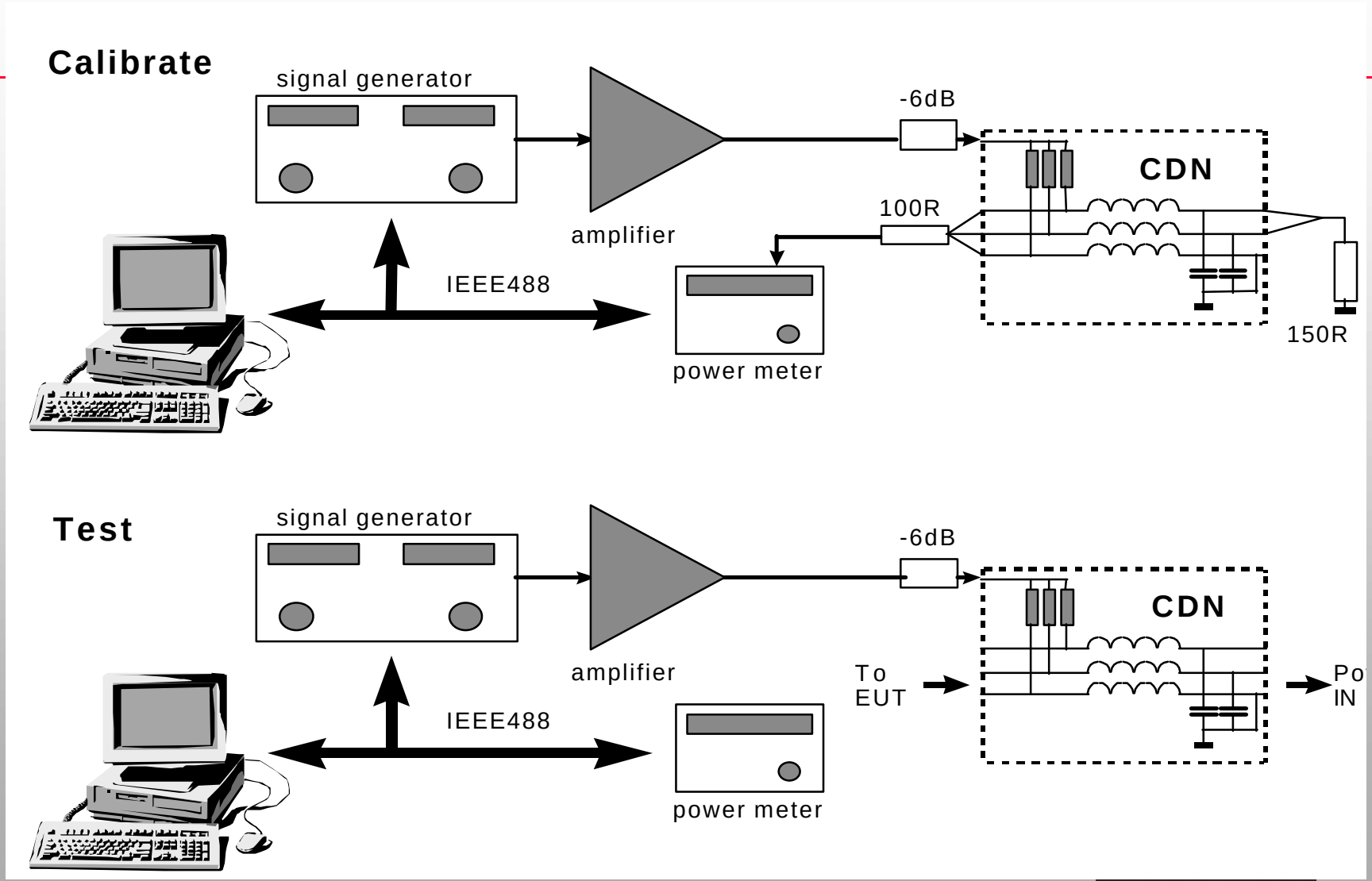
Conducted



How do we measure the Stress

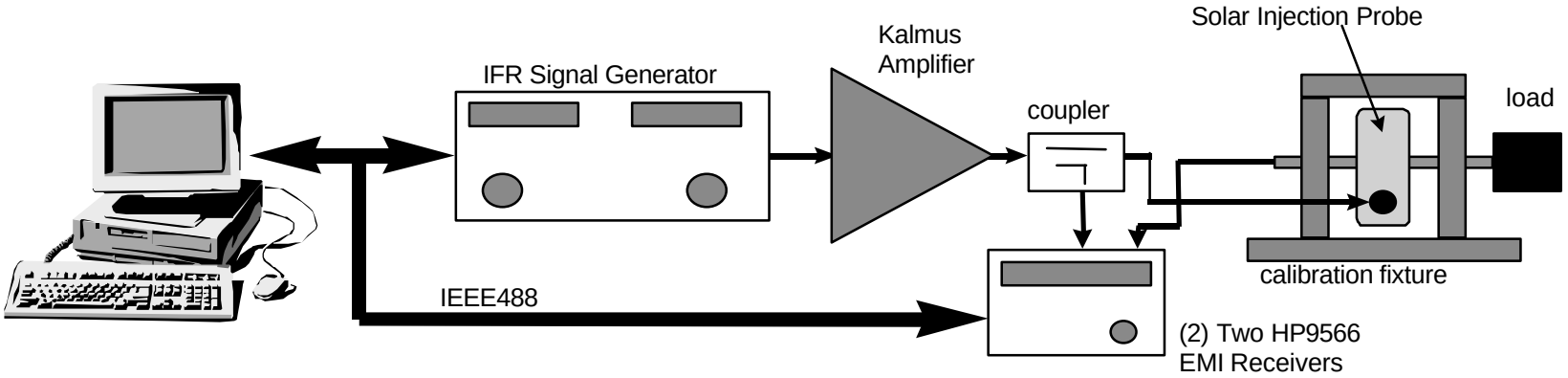


Test System for CDN

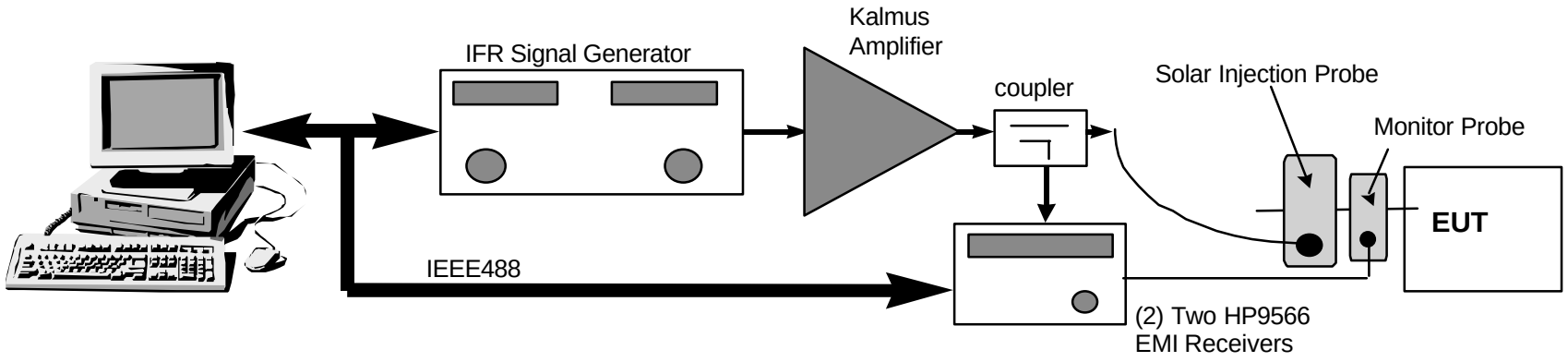


Test System for Clamp and Probe

Calibrate



Test



Summary

- IEC 1000-4-3: Improved repeatability over IEC 801-3.
- Anechoic chamber: Benchmark, Highest cost, High degree of repeatability above 80MHz (3m Tx distance), Compliant emissions (Dependent on Size).
- G-TEM Cell: Widely accepted, low power requirements, compliant emissions, max. EUT size is 1m x 1m x 0.5m.
- TEM Cell: Pre-Compliance, lowest Cost, most effective below 200MHz, max. EUT size is 0.5m x 0.5m x 0.5m.
- Conducted Immunity: Very repeatable, suitable tool for radiated immunity failure analysis - cable coupling.
- System integrators offer Turnkey responsibility.