EMC Testing per CISPR 12 and ISO 11451-2:

CISPR 12, ISO 11451-2 and Equivalent Standards

Outline

- The Standards
- CISPR 12 site and chamber requirements
- Antenna requirements for CISPR 12
- ISO 11451-1 and –2: Chamber requirements
- Recommended antennas and Amplifier Power
- Other Full Vehicle testing Standards
- Conclusions

Standards

- Automotive Standards for full vehicle are mainly those from CISPR, SAE and ISO.
- OEMs have also their own internal standards.
- The following is a list of most of the Full Vehicle Standards.

CISPR Standards (full vehicle)

Spec	Title	Typ	Equivalent	Test set up	Chamber needed
CISPR 12	**Vehicles, boats, and internal combustion engine driven devices - radio disturbance characteristics - limits and methods of measurement**	**RE**	SAE J 551-2	a monopole is used for the range 150KHz to 30MHz only vertical polarization measurements are made, for 30MHz to 200MHz a biconical antenna is used, the log periodic is used for the range 200MHz-1000MHz or tunned dipoles can be used for the entire range. for 10m testing the antenna is located 3m over ground and it is not scanned, the antenna is 10meters from outer skin of vehicle and in line with engine mid point. Both sides of vehicle are tested. For 3m testing antenna is placed at 1.8m both polarizations are measured.	Chamber must be correlated to OATS, an NSA measurement showing a small deviation should demonstrate that.
CISPR25	**Limits and methods of measurement of radio disturbance characteristics for the protection of receivers used on board vehicles**	**RI/ RE**	SAE J 551-4 and SAE J 1113-41	for the chamber testing procedure a monopole is used for the range 150KHz to 30MHz, for 30MHz to 200MHz a biconical antenna is used, the log periodic is used for the range 200MHz-1000MHz. For equipment testing a TEM cell can be used. Whole vehicle testing is trying to see how the radio or radios in the car are affected by the different systems in the vehicle, that is how the radio is affected by windshield wipers, to put an example	when an absorber lined chamber is used the absorption of the material has to be better than 6dB for the range 70MHz and up.

SAE Standards (full vehicle) I

SAE J551-	Title	Typ	Equivalent	Test set up	Chamber needed
-1	Performance levels and Methods of measurement of EMC of vehicles and devices (60Hz-18GHz)		Definitions	Definitions	
-2	Test limits and methods of measurement of radio disturbance characteristics of vehicles, Motorboats, and spark-ignited Engine Driven Devices	RE	CISPR12	See CISPR 12	See CISPR 12
-4	Test limits and methods of measurement of radio disturbance characteristics of vehicles and devices, broadband and narrowband, 150KHz to 1000MHz	RE RI	CISPR 25	See CISPR 25	See CISPR 25
-5	Performance levels and methods of measurement of magnetic and electric field strength from electric vehicles, 9kHz to 30MHz			Specifies limits for electric vehicles	

SAE Standards (full vehicle) II

SAE J551-	Title	Typ	Equivalent	Test set up	Chamber needed
-11	Vehicle Electromagnetic immunity-Off vehicle source	**RI**	ISO 11451-2	No absorbent material between antenna and EUT. Antenna is to be place at least 2m from the vehicle engine's center point the uniformity plane is HORIZONTAL and it is a 1.5 diameter circle where the field for frequencies above 200MHz is between +-3dB for 80% of the frequencies	shielded anechoic chamber.
-12	Vehicle Electromagnetic Immunity-On board transmitter simulation	**Self RI**	ISO 11451-3		a shielded room that will meet the SAE j551-1 and -2 will do
-13	Vehicle Electromagnetic Immunity-Bulk Current injection	**CI**	ISO 11451-4	a shielded room will do, no absorber is necessary but test can be performed in a shielded enclosure with absorber	
-15	Vehicle Electromagnetic Immunity-Electrostatic Discharge	**ESD**	ISO-10605	**Shielded room**	
-17	Vehicle Electromagnetic Immunity-Power line magnetic fields	**RI**		**Large area for vehicle and field generating coils**	**Shielded enclosure recomended**

ISO Standards (full vehicle)

ISO 11451	Title	Typ	Equivalent	Test set up	Chamber needed
-1	Road vehicles - vehicle test methods for electrical disturbances by arrowband radiated electromagnetic energy: part 1: General and Definitions		SAE J551-1	definitions	
-2	Road vehicles - vehicle test methods for electrical disturbances by narrowband radiated electromagnetic energy part 2: off vehicle radiation source	RI	SAE J 551-11	No absorbent material between antenna and EUT. Antenna is to be place at least 2m from the vehicle engine's center point the uniformity plane is HORIZONTAL and it is a 1.5 diameter circle where the field for frequencies above 200MHz is between +-3dB for 80% of the frequencies	shielded anechoic chamber.
-3	Road vehicles - vehicle test methods for electrical disturbances by narrowband radiated electromagnetic energy part 3: On board transmitter simulation	Self RI	SAE J551-12		a shielded room that will meet the SAE j551-1 and -2 will do
-4	Road vehicles - vehicle test methods for electrical disturbances by narrowband radiated electromagnetic energy part 4: bulk current injection	CI	SAE J551-13	a shielded room will do, no absorber is necessary but test can be performed in a shielded enclosure with absorber	

2004/144 EC Standard (full vehicle)

2004/144 EC	Title	Typ	Equivalent	Test set up	Chamber needed
Annex I **Annex II A** **Annex II B**	Requirements met by vehicles and electrical/electronic sub-assemblies fitted to a vehicle		SAE J551-1	definitions	
Annex IV	Method of measurement of radiated broadband emissions from vehicles	**RE**	**CISPR 12**	a monopole is used for the range 150KHz to 30MHz only vertical polarization measurements are made, for 30MHz to 200MHz a biconical antenna is used, the log periodic is used for the range 200MHz-1000MHz or tunned dipoles can be used for the entire range. for 10m testing the antenna is located 3m over ground and it is not scanned, the antenna is 10meters from outer skin of vehicle and in line with engine mid point. Both sides of vehicle are tested. For 3m testing antenna is placed at 1.8m both polarizations are measured.	Chamber must be correlated to OATS, an NSA measurement showing a small deviation should demonstrate that.
Annex V	Method of measurement of radiated narrowband emissions from vehicles				
Annex VI	Method of testing for immunity of vehicles to electromagnetic radiation	**RI**		antenna is placed no less than 1.5m above the ground and no less than 2 meters from the center of the engine field uniformity requirement is that points on a horizontal line of 1m in length perpendicular to the antenna line of sight must be within 6dB	**Absorber lined chamber**

Regarding Standards

- As mentioned before there are a lot of Standard Documents that were not on the above list. However, a lot of the documents that are not mentioned are based on international documents. Of these international standards CISPR 12 and ISO 11451 are the critical ones.

CISPR 12

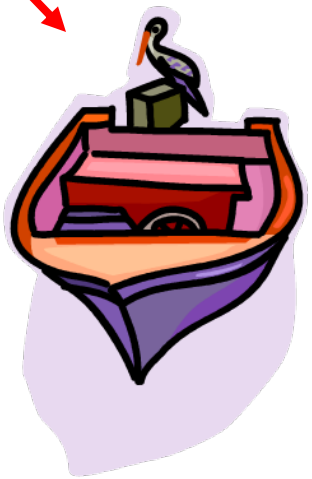
Vehicles, boats, and internal combustion engine driven devices –

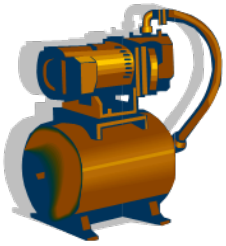
Radio disturbance characteristics –

Limits and methods of measurement for the protection of receivers except those installed in the vehicle/boat/device itself or in adjacent vehicles/boats/devices

CISPR 12

Radio disturbance characteristics for the protection of receivers used from emissions from vehicles, boats, and on devices ...





CISPR 12

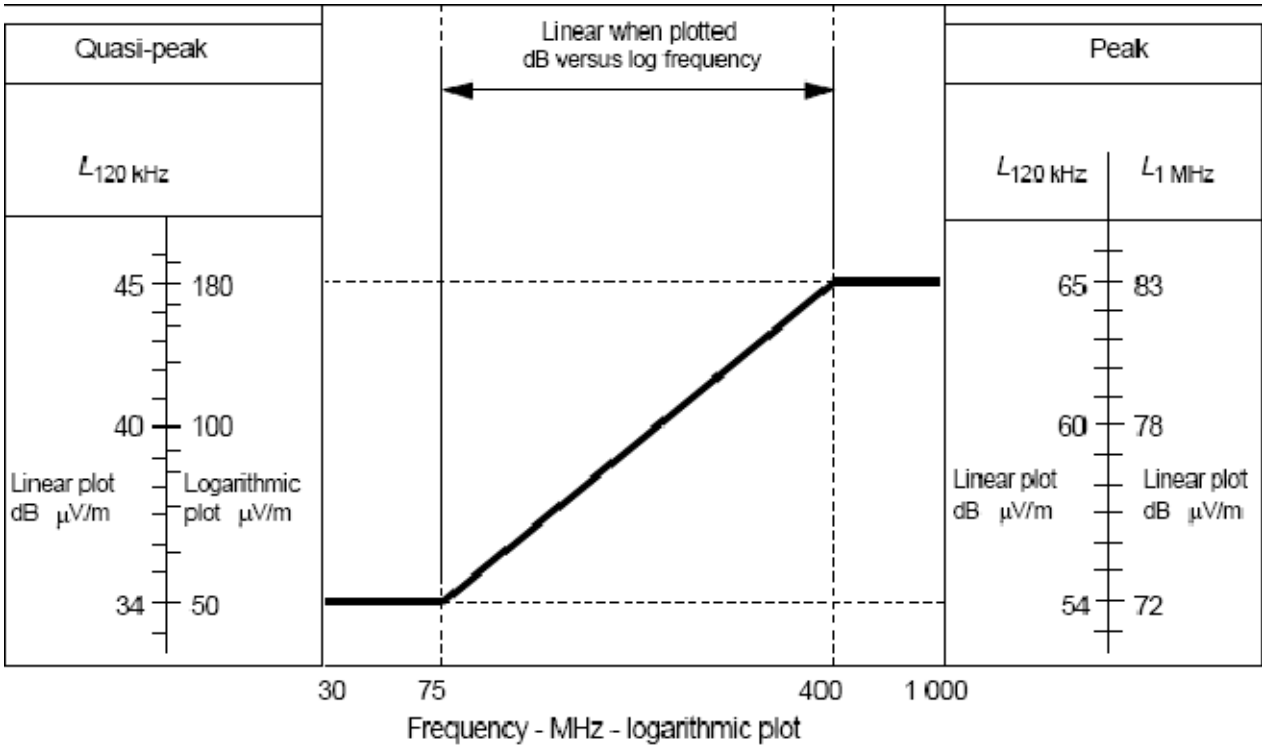
- So CISPR 12 deals with how much do electric and electronic systems affect outside receivers from emissions from systems aboard:
  - Automobiles powered by internal combustion engines or electric motors
  - Boats (up to 15m) powered by internal combustion engines or electric motors
  - Devices powered by internal combustion engines but not for the transport of people.(I.e. compressors, chainsaws, garden maintenance equipment, etc)

CISPR 12

- As with any other emissions standard we look at measurements at 10m (3m being allowed and limits being raised by 10dB)
- There are limits for Broadband noise and narrowband noise

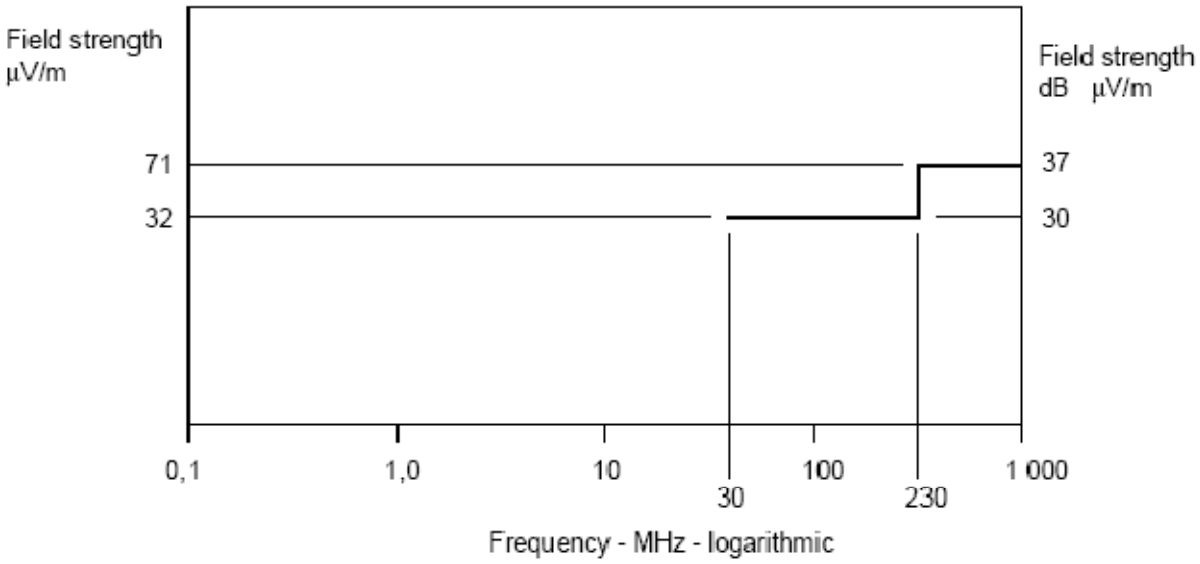
CISPR 12

- Limits for broadband emissions.
- Background noise should be 6dB below the limits (more on that later) and for 3m levels should be 10dB higher



CISPR 12

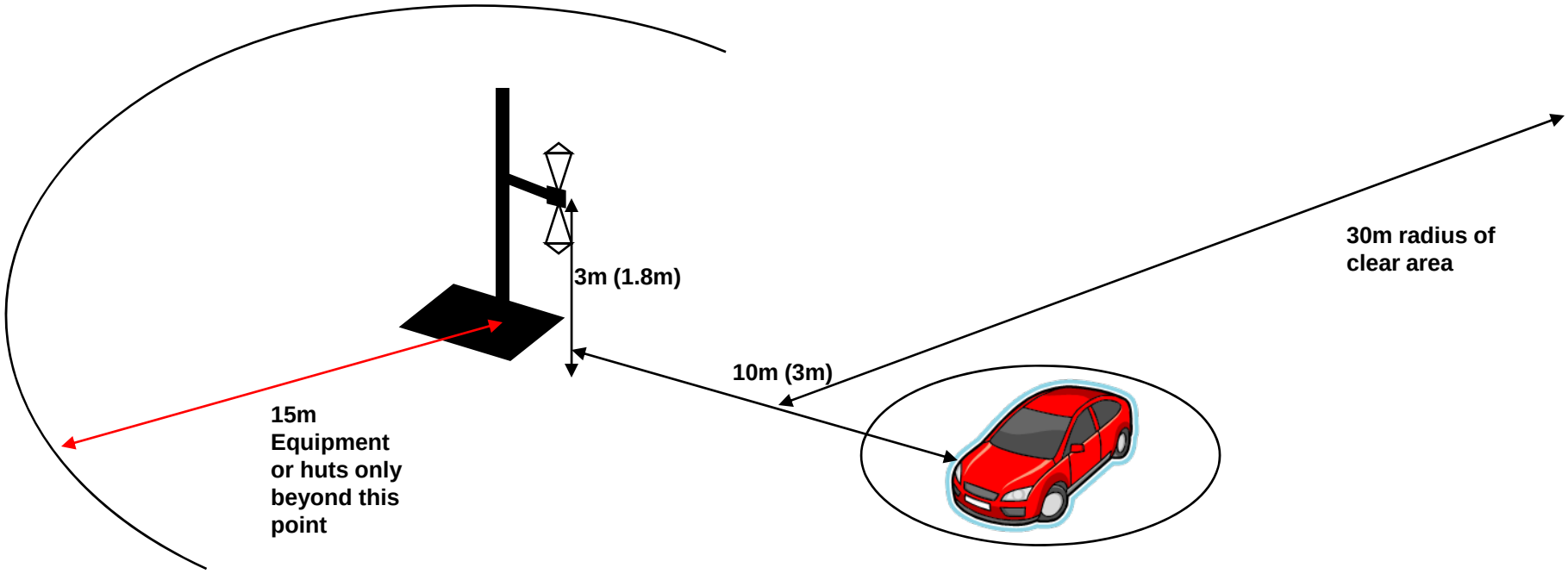
- Limits for narrow band emissions.
- Background noise should be 6dB below the limits (more on that later) and for 3m levels should be 10dB higher



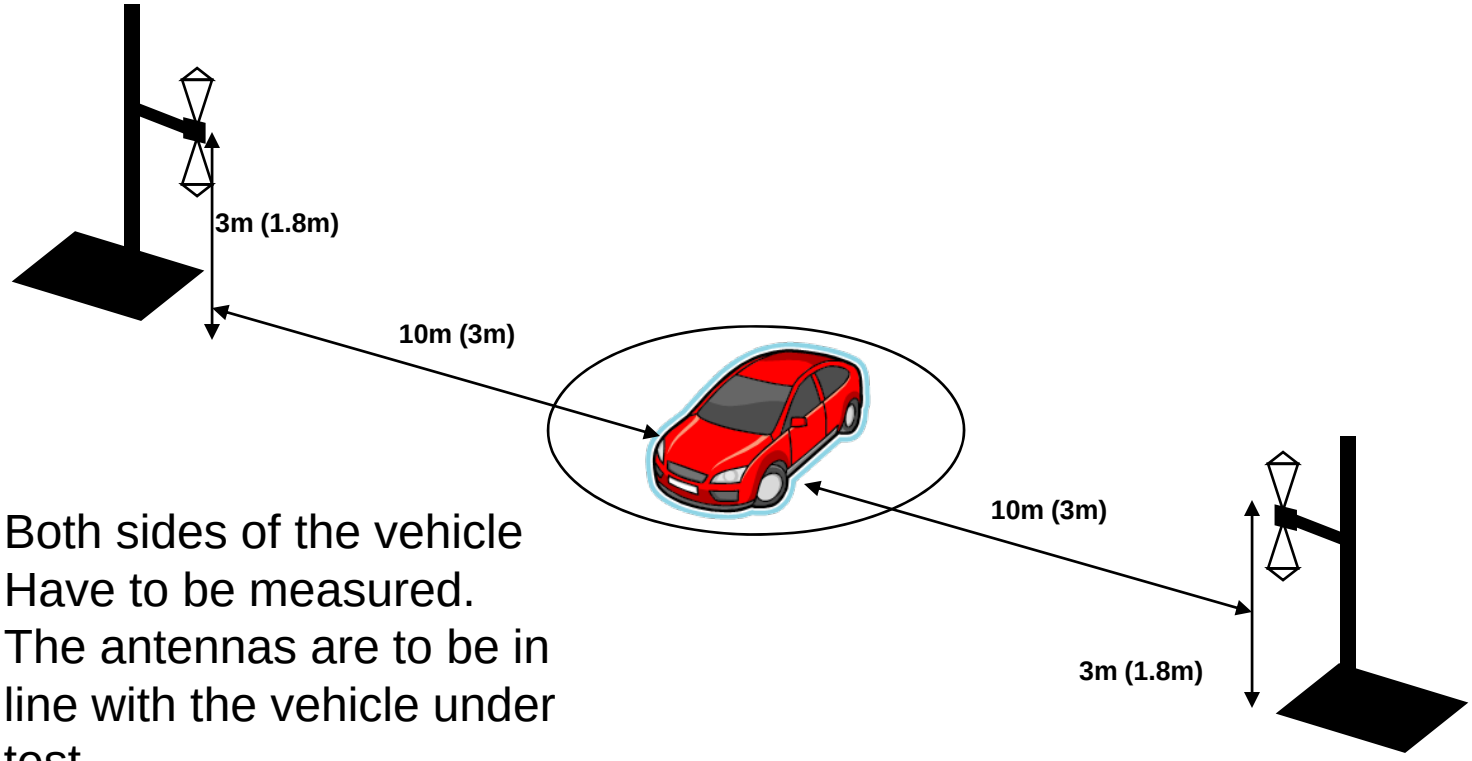
CISPR 12

- Regarding the test site, the CISPR 12 Standard defines the oats as the recommended site.
- The OATS must follow the requisites stated in CISPR 16

OATS layout


3m (1.8m)
30m radius of clear area
10m (3m)
15m Equipment or huts only beyond this point

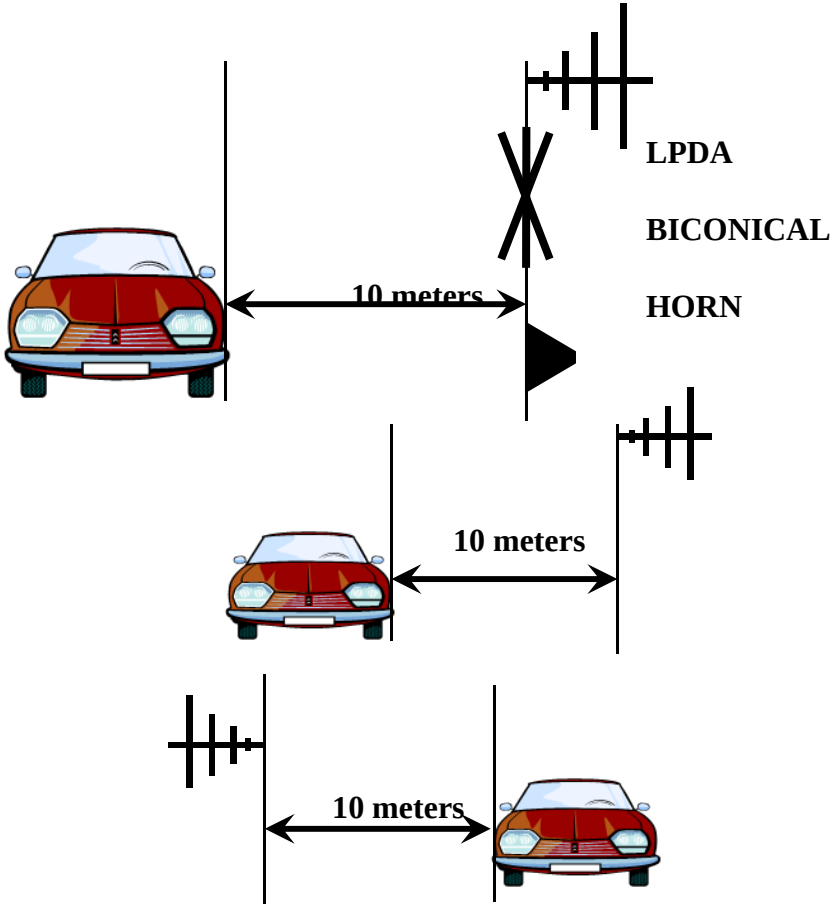
measurement layout



Both sides of the vehicle Have to be measured.
The antennas are to be in line with the vehicle under test.

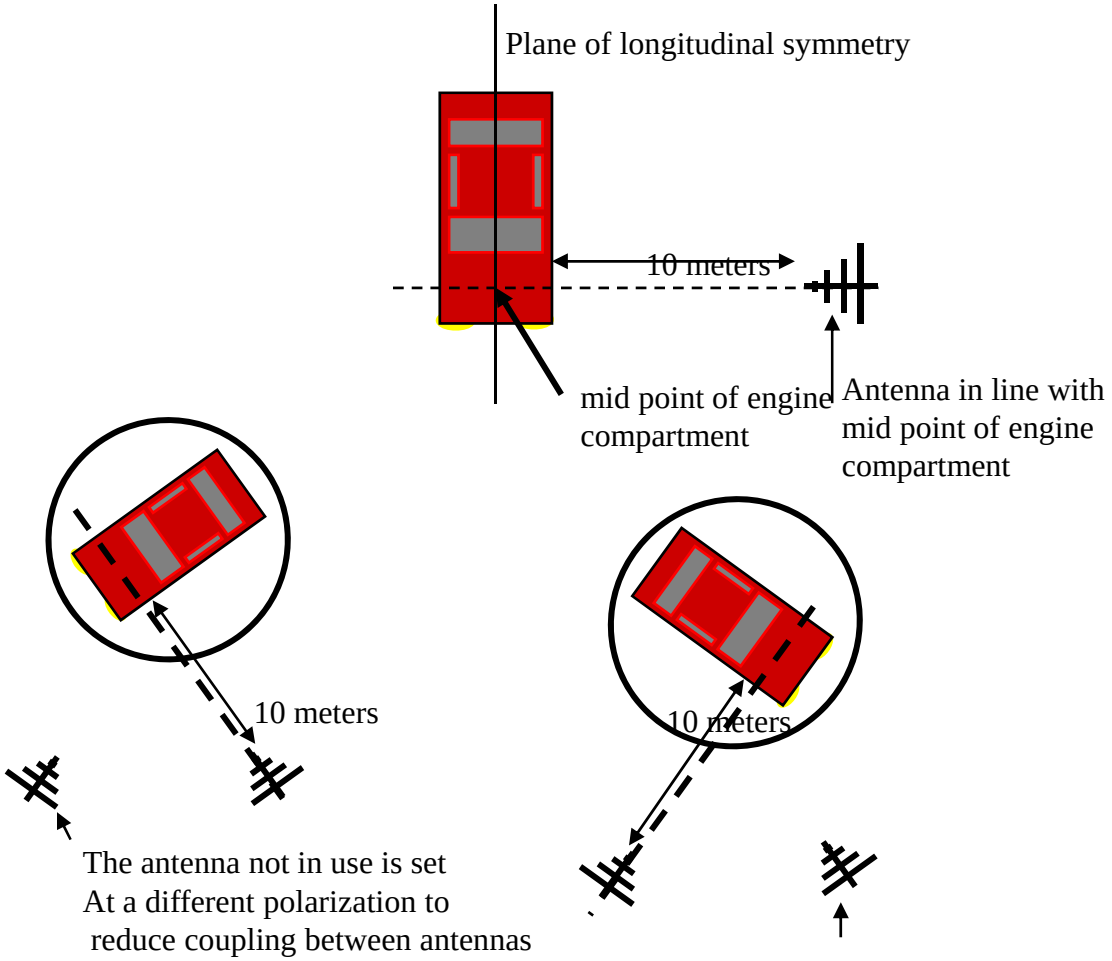
Measurement Layout

- The 10m emission testing locates the antenna 10m from the outer shell of the vehicle
- The antenna is not scan but located at 3m height. (For 3m testing the antenna is located at 1.8meters.
- Both sides of the vehicle and both polarizations are tested



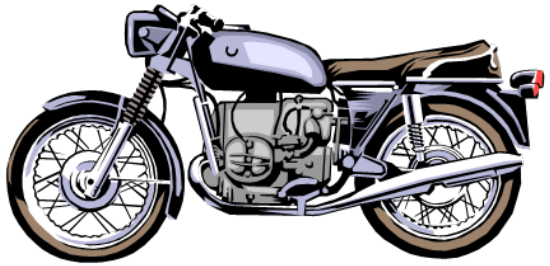
Automotive Testing: A Short Introduction

- The antenna is to be in line with the middle point of the engine compartment.
- A two antenna position site and the addition of a turntable makes the test much easier
- There is no need to reposition the vehicle to test the other side.



CISPR 12 EUT req.

- Internal combustion engine:
  - Engine Idle:
    - 2500RPM 1cyl
    - 1500RPM 2 or more cyl
- Electric Propulsion motors
  - Vehicle running:
    - 40km/h or max vehicle speed if less.



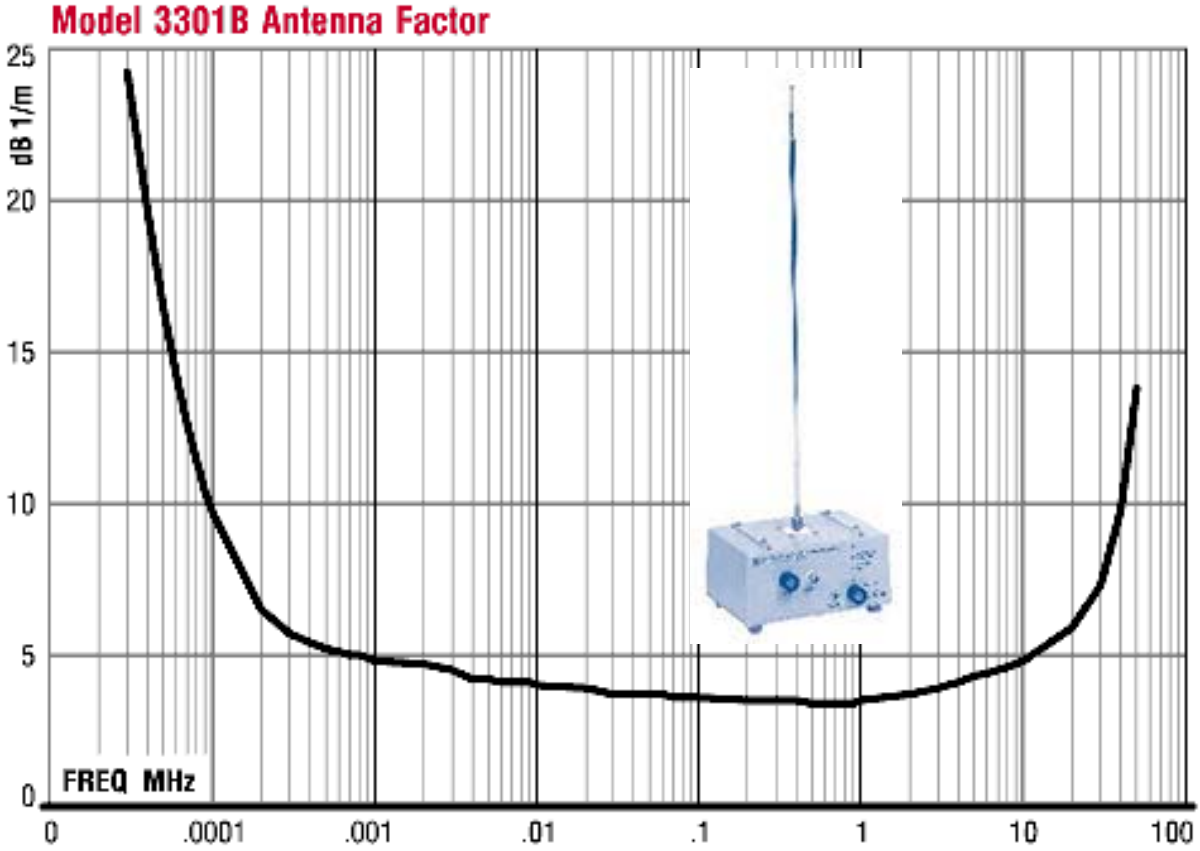
CISPR12: Antennas

- **Antennas are a key requirement in CISPR 12. The standard bases its choice of antennas on the CISPR 16 Standard**

Frequency range	Type
30Hz-50MHz	Active monopole rod
30-300MHz	Biconical
200-2000MHz	Log periodic
1GHz-18 GHz	Dual ridge guide horns

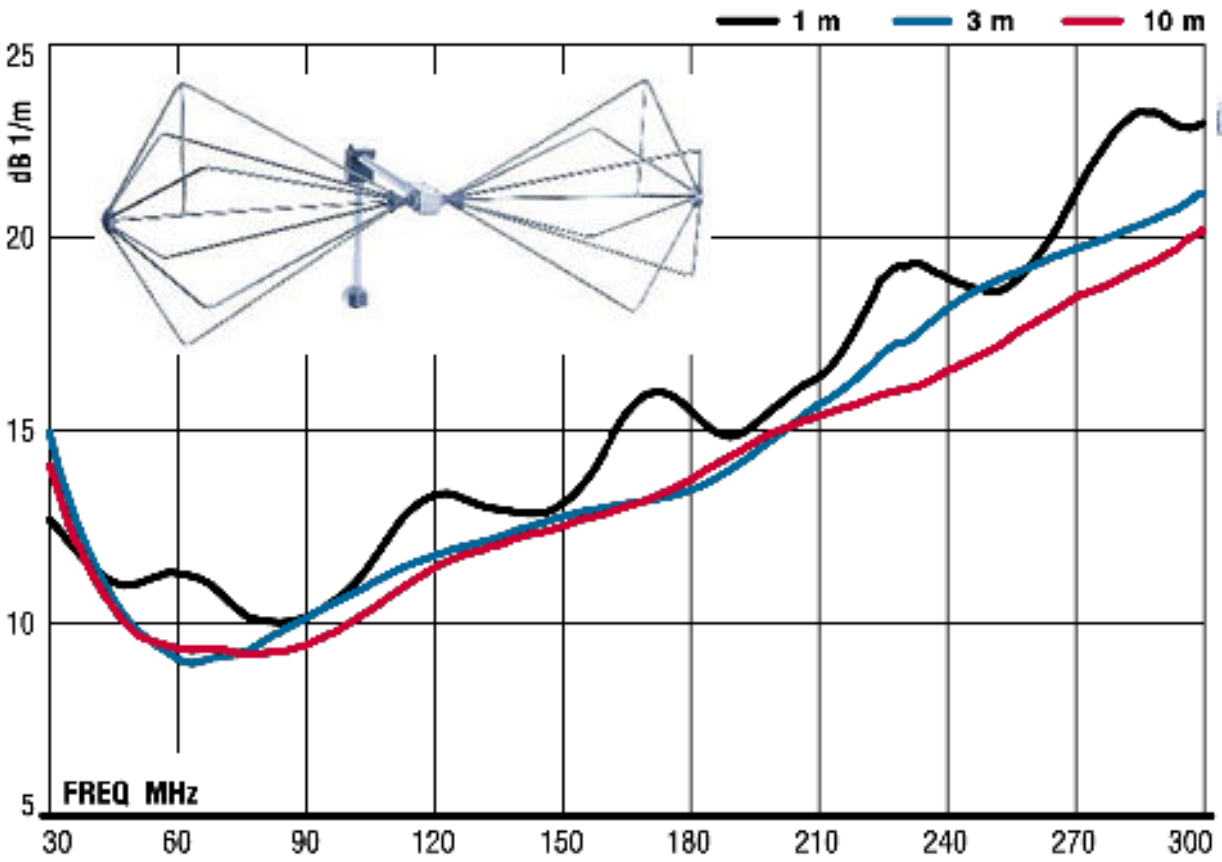
150kHz to 30MHz Active Rods

Monopole Rod antennas.
These antennas have been used in EMC for testing at very low frequencies and are the recommended antennas in a lot of standards
The typical rod has a very poor performance since they are an electrically short antenna. To improve the performance “active” rods have a preamplifier at the base. Usually they are used with a small ground plane on top of the pre-amplifier.



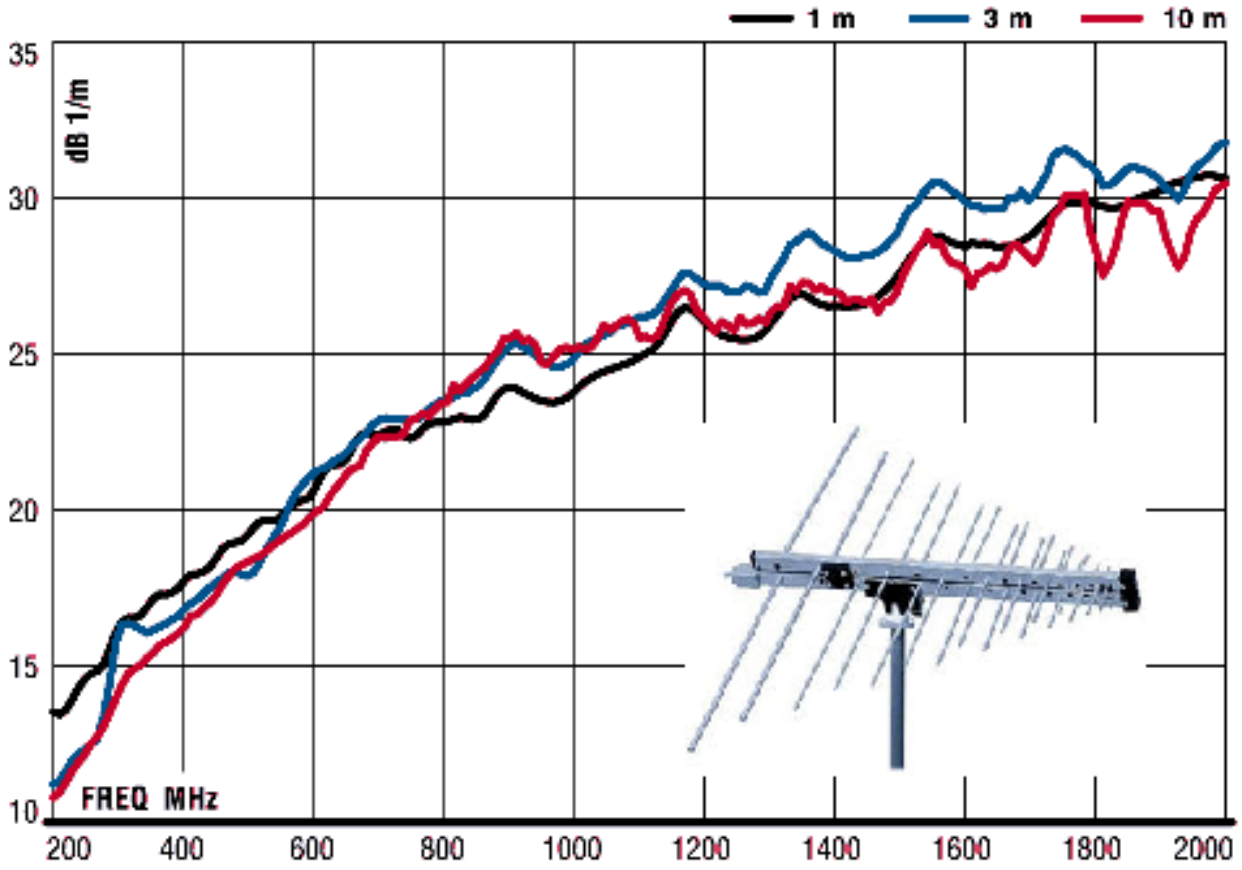
30MHz to 200MHz biconicals

Biconical Antennas.
These antennas have been used in EMC for testing at low frequencies and are the recommended antennas in a lot of standards
The typical biconical antenna usually has a range of 20 to 300MHz, However, it is recommended that they are used from 30MHz to 200Mhz where they offer their best performance compared with other antennas.



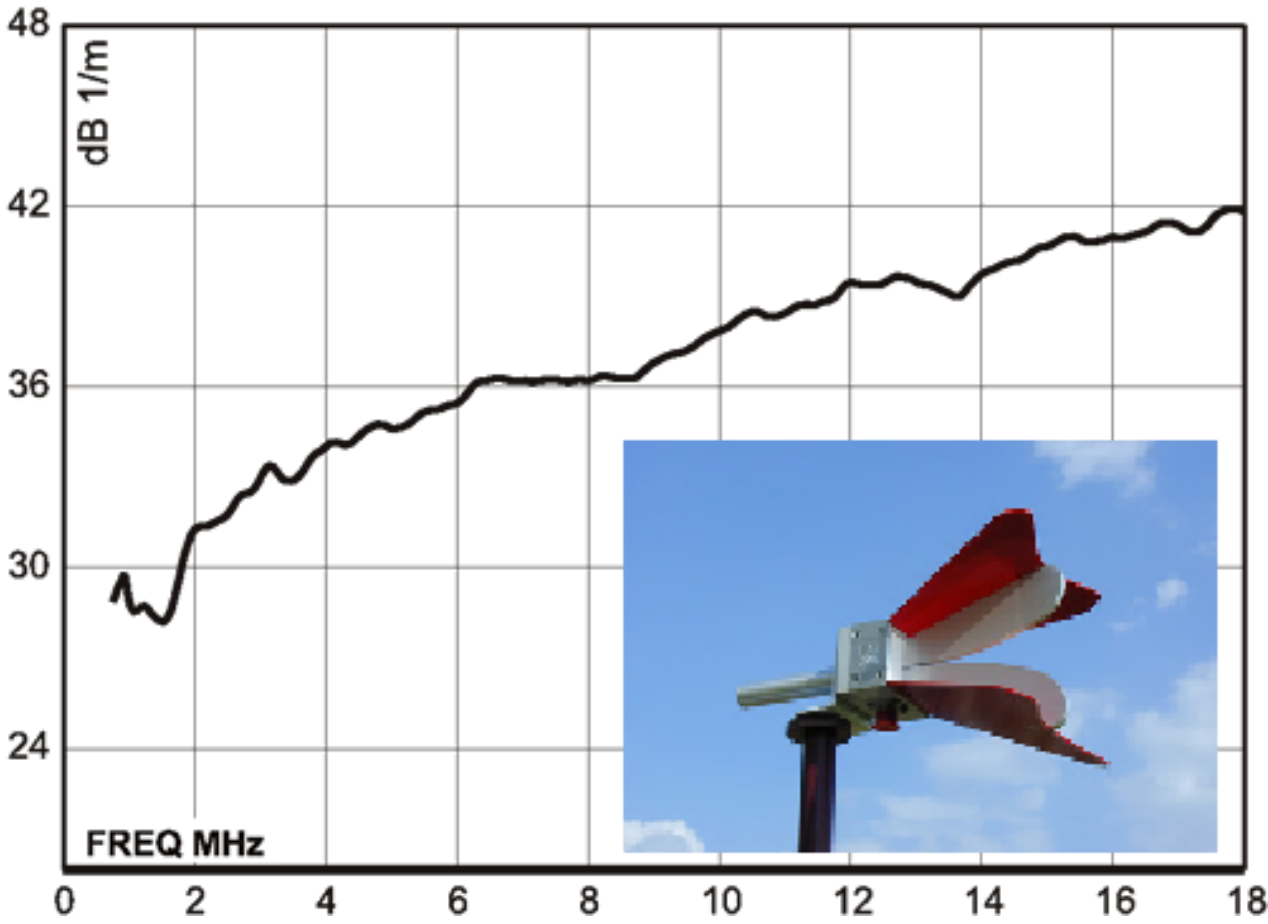
200MHz to 2000MHz log periodics

Log Periodic antennas.
200MHz to 1GHz it is recommended that a log periodic antenna be used. Log periodic antennas have a typical range of 200 to 2000MHz or 3000MHz depending on the manufacturer.



Ridge horns 1GHz to 18GHz

Dual Ridge Horns.
There are however, newer models in the market that correct the pattern problems of the traditional dual ridge horns. The new dual ridge horns are antennas with improved pattern behavior above 10GHz. This translates in to a more constant antenna factor and gain.

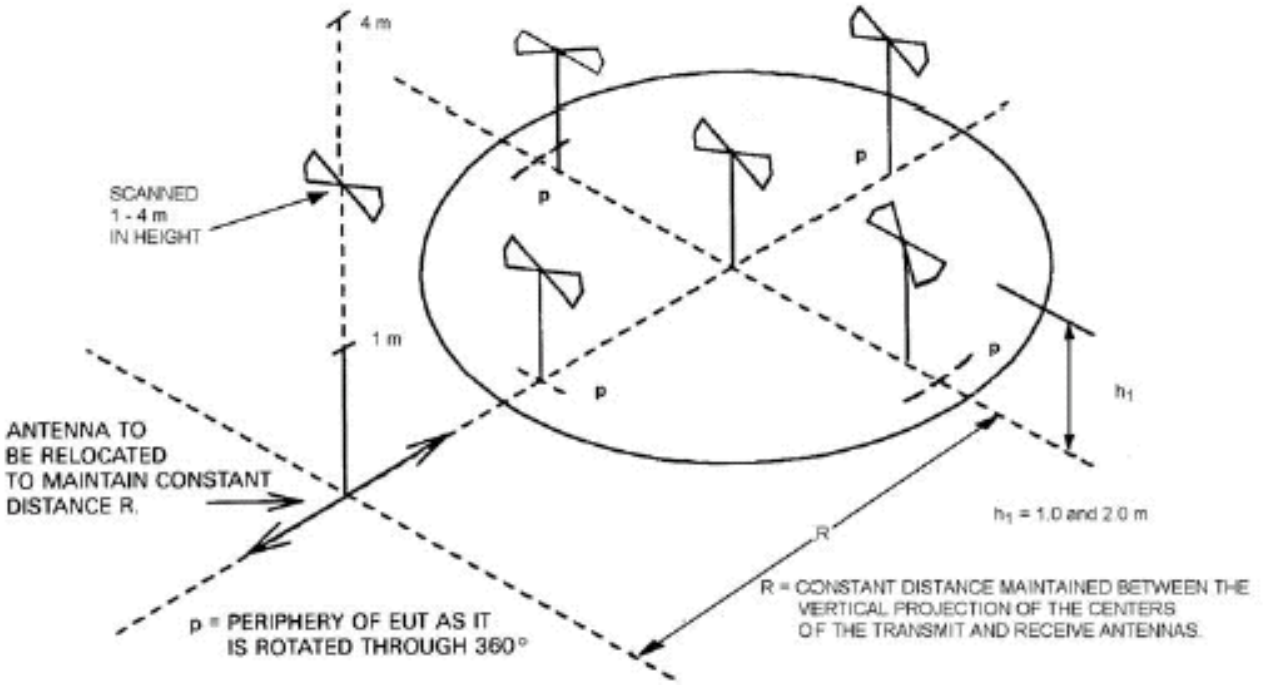


Alternative Sites

- Anechoic Chamber:
  - A shielded absorber lined enclosure can be used provided that correlation with OATS can be shown
  - In my view, doing the NSA measurement of the Chamber if the results fall within the limits of the CISPR 16 requirements the Chamber is good for CISPR 12 testing

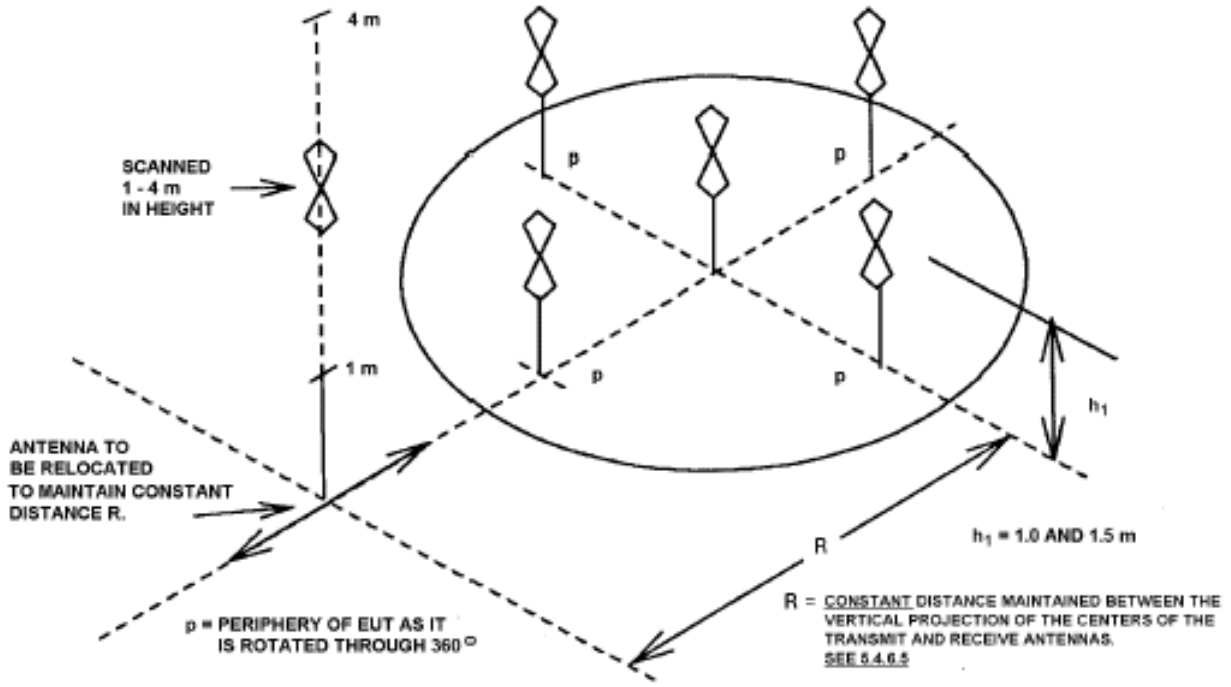
Site Quality Verification
(NSA – Normalized Site Attenuation)

- Horizontal Polarization



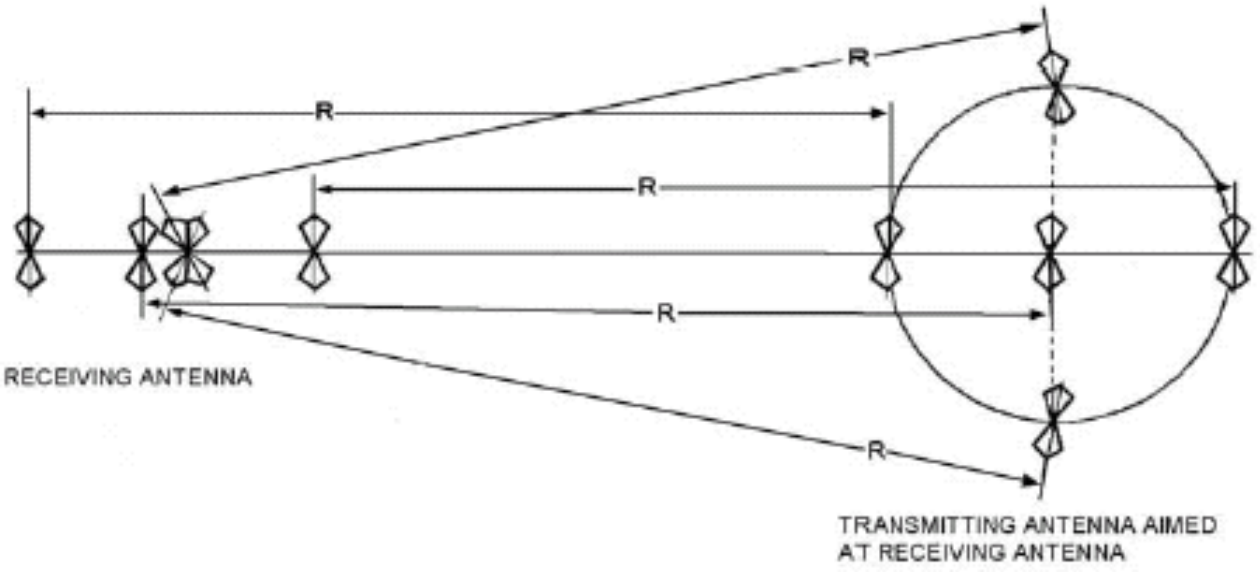
Site Quality Verification
(NSA – Normalized Site Attenuation)

- Vertical Polarization



Site Quality Verification
(NSA – Normalized Site Attenuation)

- Typical measurement positions.

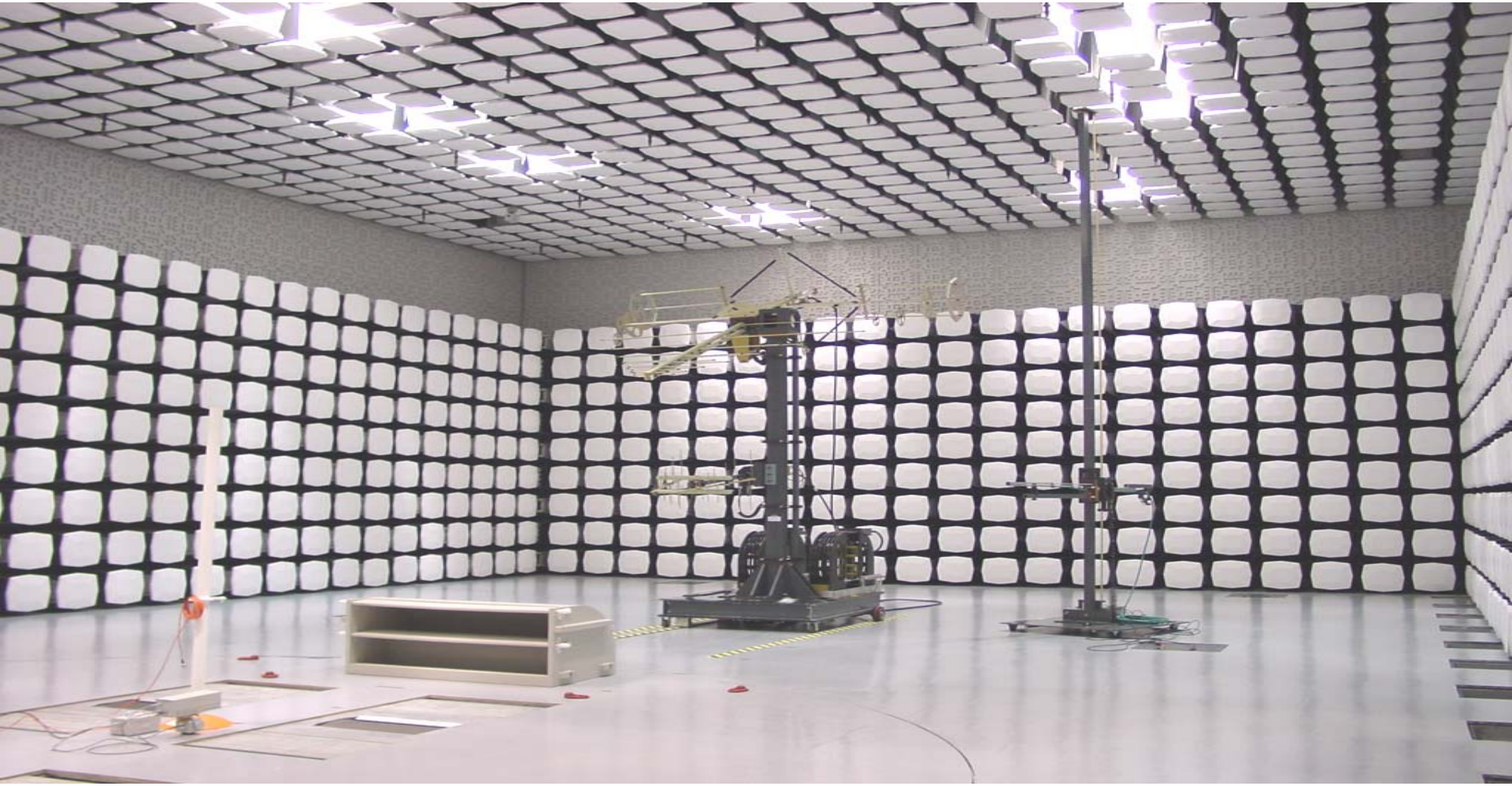


CISPR 12 Absorber

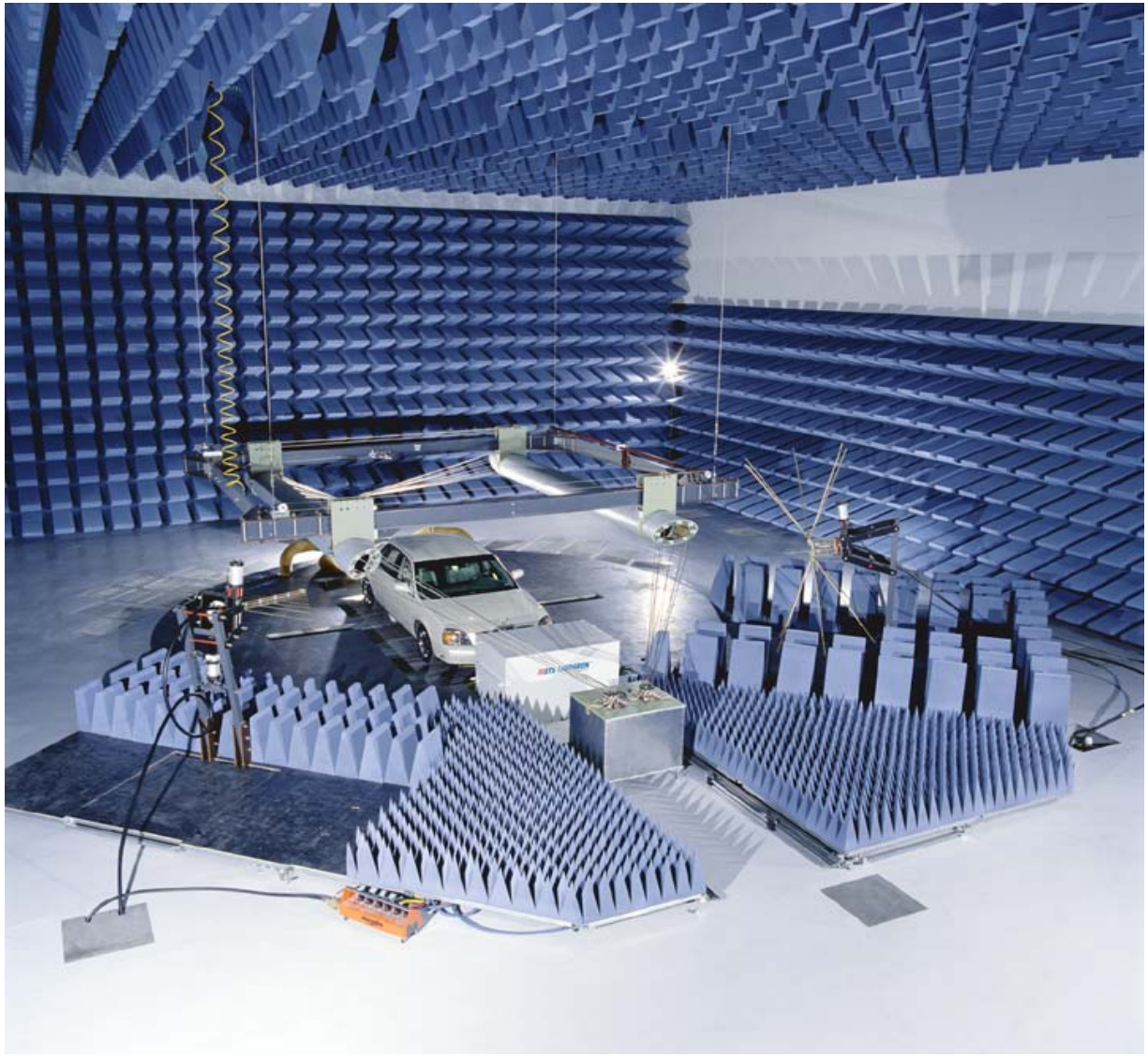
Hybrid Absorber .

Electric and Magnetic Losses

Preferred technology for EMC Applications. foam has to have special formula for good matching with ferrite tile at the bottom. At High frequencies its performance is not as good as MW pyramid of equal size. Flat top causes undesired reflections at MW range. Between 1m and 1.5m in length

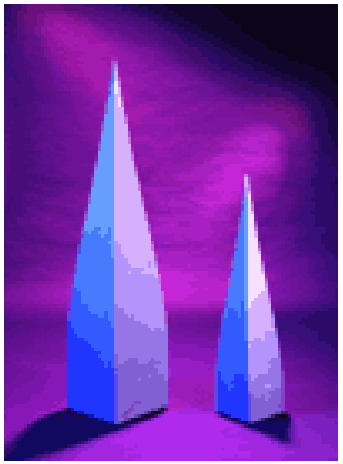


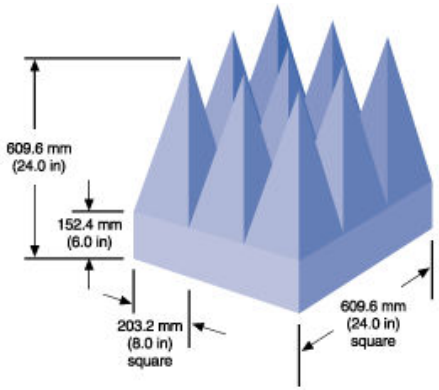
Honda R&D America Raymond, Ohio



GM Proving Grounds Milford, Michigan

CISPR 12





Microwave Pyramidal absorber. EMC and EHP series

Electric Losses

Preferred technology for High frequencies It can be used for low frequencies if size (length) is increased, for CISPR 12 chambers minimum 1.8m and also use of curvilinear pyramids

Commercial EMC/Automotive EMC and Antenna/Satellite Chamber
at LIT/INPE São Jose dos Campos, SP, Brazil

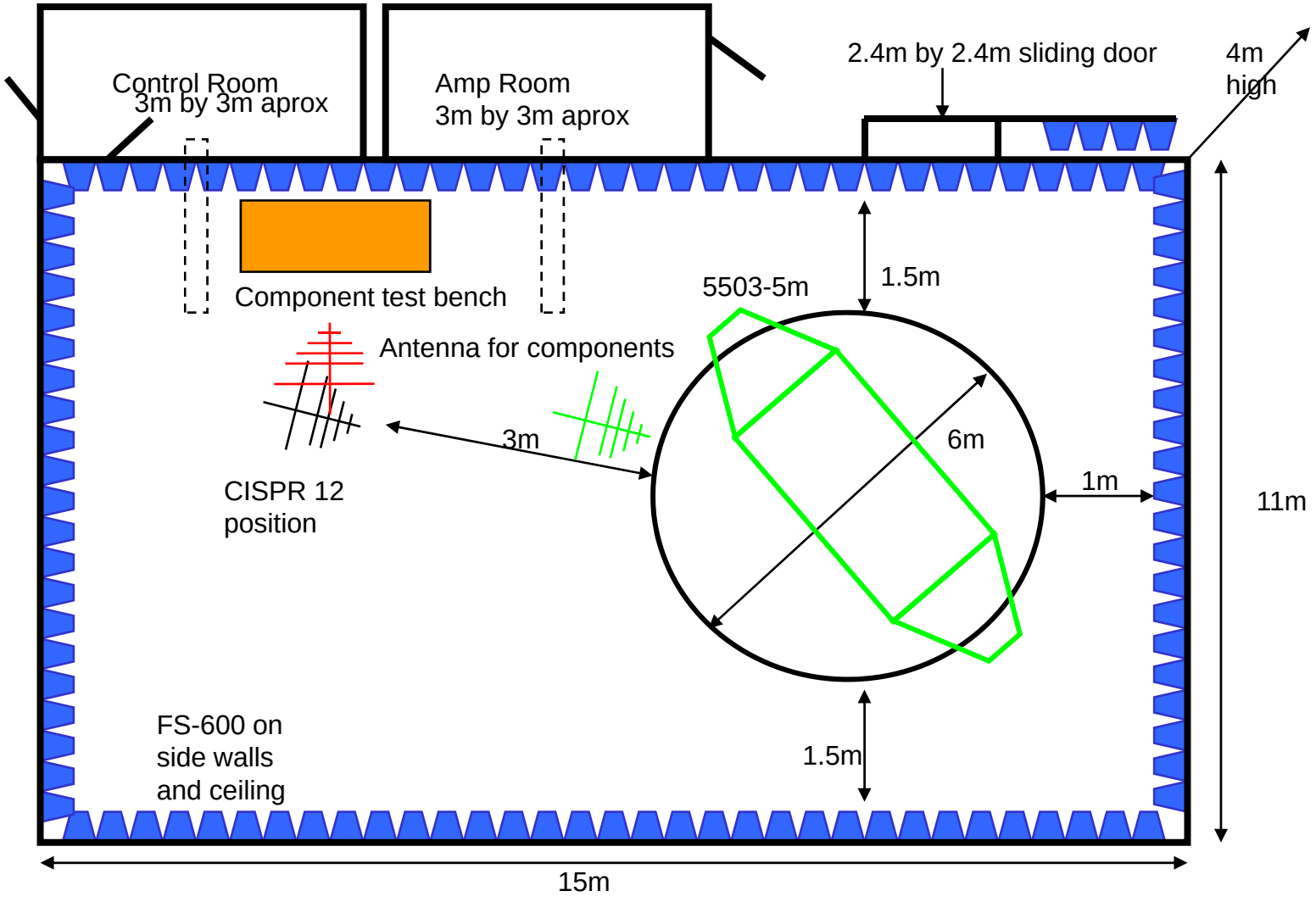
Typical EMC 10m range Chambers

model	Size Ft (m)	absorber	NSA	FU
FACT 10 –3.0 Std	59,30,22 (18,9.2,6.6)	PS-1250 all walls and ceiling, RI patch of PS 600	±4.0dB	0 to +6dB 75%
FACT 10 – 3.0 Std +	63,38,28 (19,11.5,8.5)	PS-1250 9 rows walls, ceiling, RI patch of PS 600	±3.5dB	0 to +6dB 75%
FACT 10 –3.0 premium	63,38,28 (19,11.5,8.5)	FS-1500 9 rows on walls, ceiling, RI patch FS-400	±3.0dB	0 to +6dB 75%
FACT 10 –4.0 Std	65,36,22 (20,11,6.6)	PS-1250 all walls and ceiling, RI patch of PS 600	±4.0dB	0 to +6dB 75%
FACT 10 – 4.0 Std +	65,40,28 (20, 12, 8.5)	PS-1250 9 rows walls, ceiling, RI patch of PS 600	±3.5dB	0 to +6dB 75%
FACT 10 –4.0 premium	65,40,28 (20,12,8.5)	FS-1500 9 rows on walls, ceiling, RI patch FS-400	±3.0dB	0 to +6dB 75%
FACT 10-6.0 Std +	71,43,28 (22,13,8.5)	PS-1250 9 rows walls, ceiling, RI patch of PS 600	±3.5dB	0 to +6dB 75%

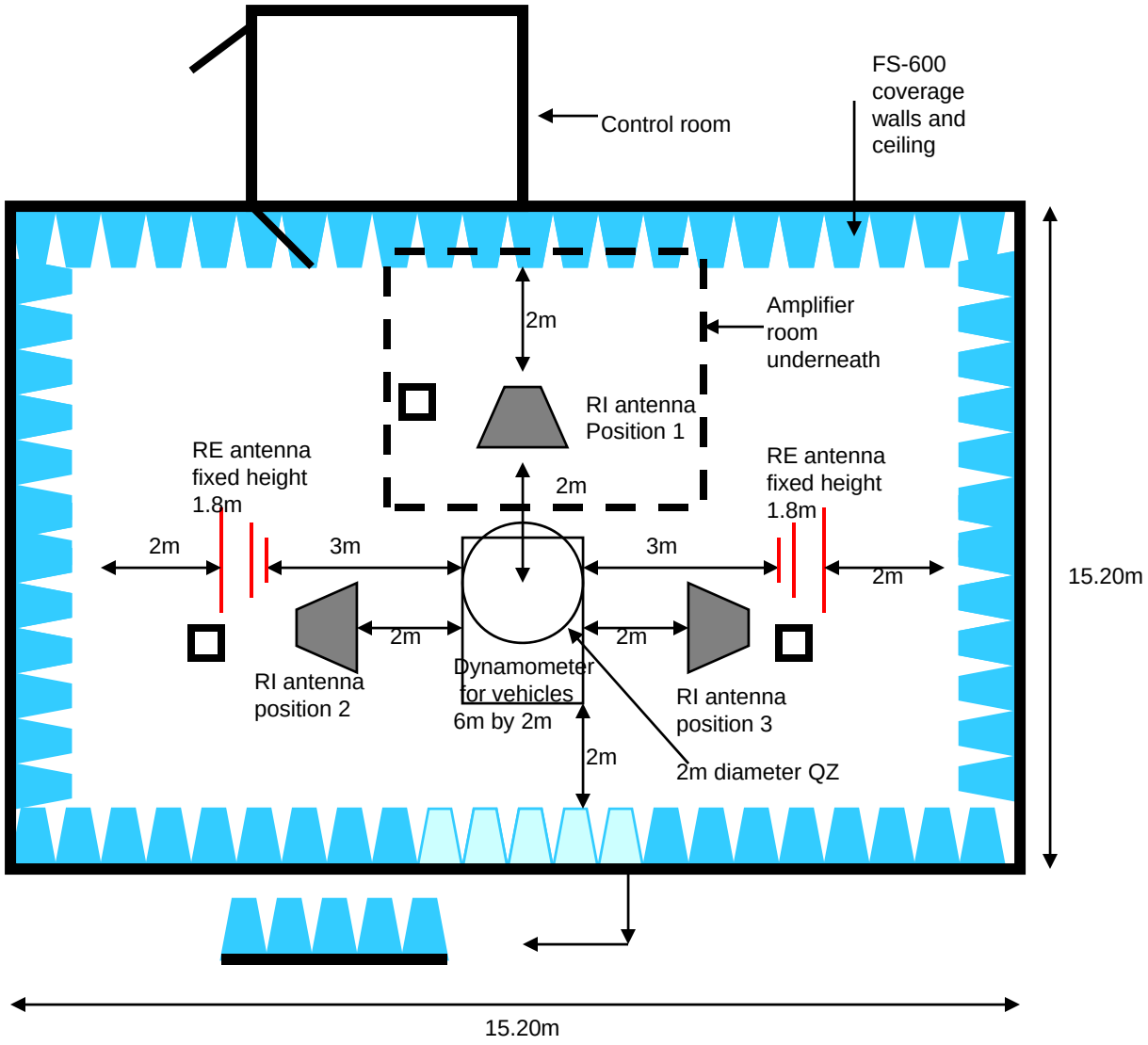
Special features for automotive

- Dynamometer Turn Table. Although for emissions the vehicle just needs to idle.
- Exhaust system
- Fire Protection systems
- QZ may be as large as 9m making chamber larger
- Chamber supported EH generators
- Large level entry door

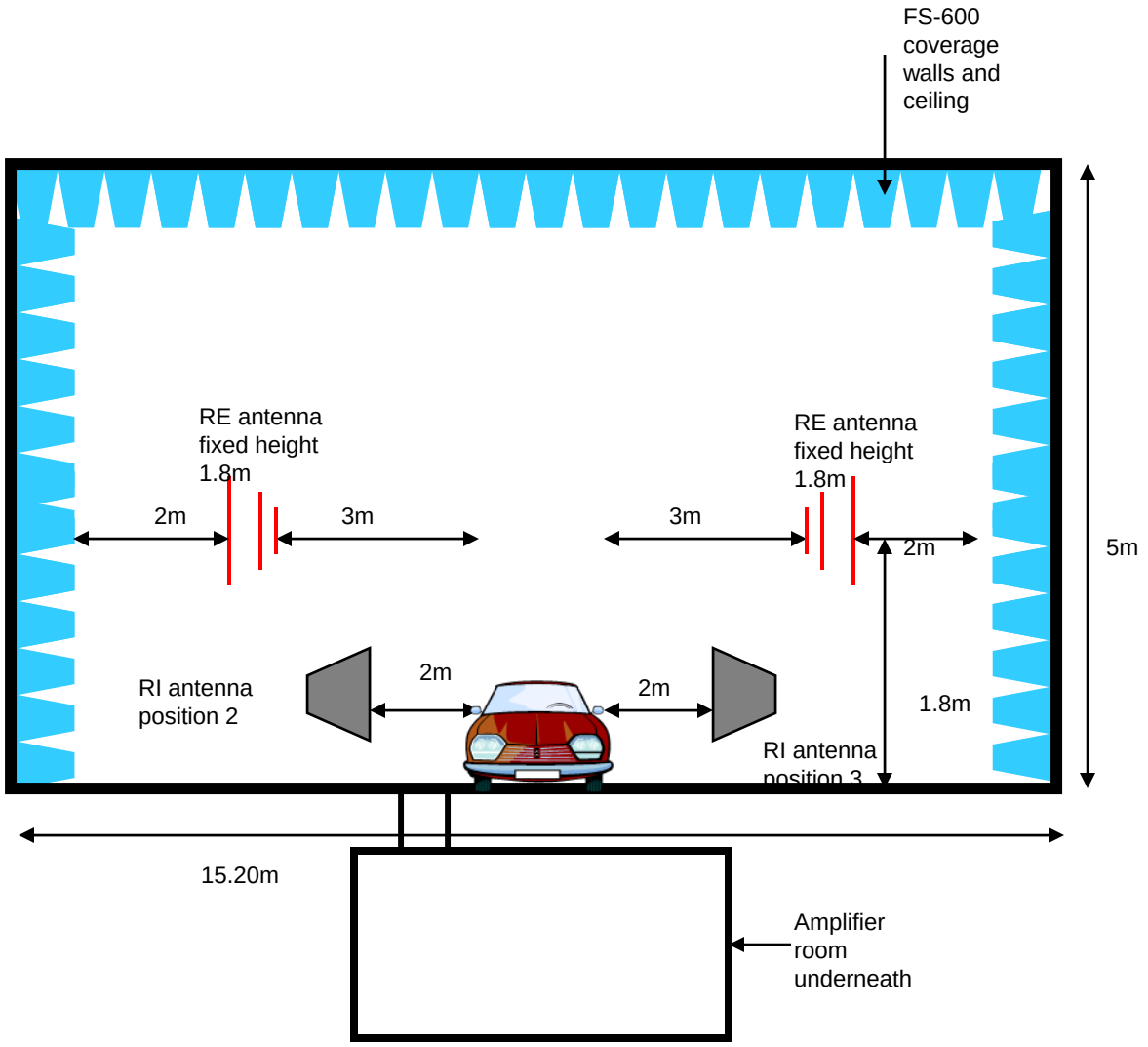
Turntable no Dynamometer (3m testing)



Dynamometer no Turntable (3m testing)



Turntable no Dynamometer (3m testing)



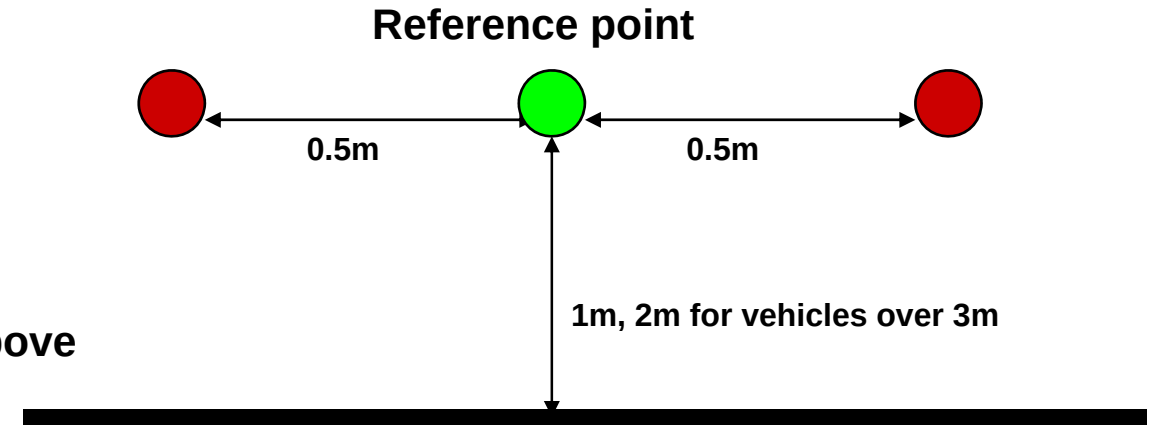
Vehicle immunity

Automotive Immunity testing

The main Standards that this solution addresses are the following:
ISO 11451-2
SAE J551-11
95/54 EC Annex VI
The SAE and the ISO are virtual copies of each other and they both require a highest severity level of 100V/m. ISO contemplates an additional level of severity to be agreed between the test house and the manufacturer..
Field uniformity requirements are (for SAE and ISO) that the field level be generated at a reference point located 1m above the ground on to which the vehicle rests (2m for vehicles higher than 3m) and at two points 75cm on either side of the reference point. At these points the field level should be within 3dB of the reference point level. For 95/54 EC the points are 50cm on either side and the highest level of severity is 24V/m with 80% AM modulation.

Automotive EMC Immunity

- 100V/m highest severity level (200v/m contemplated in the ISO standard
- Field Uniformity Requirements

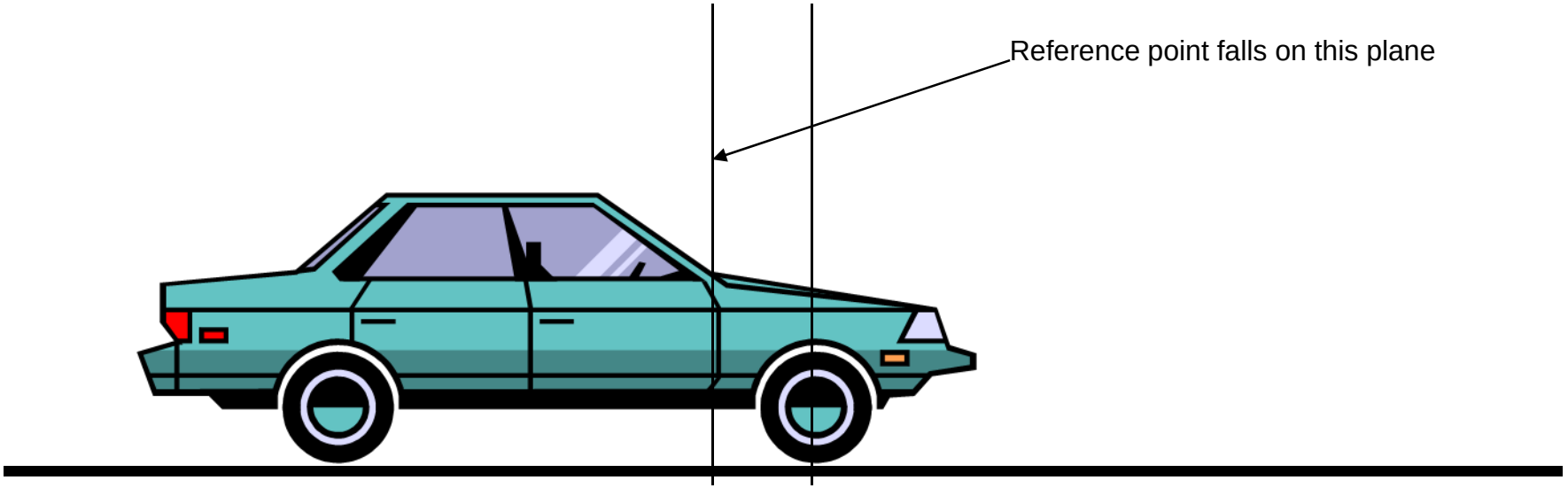


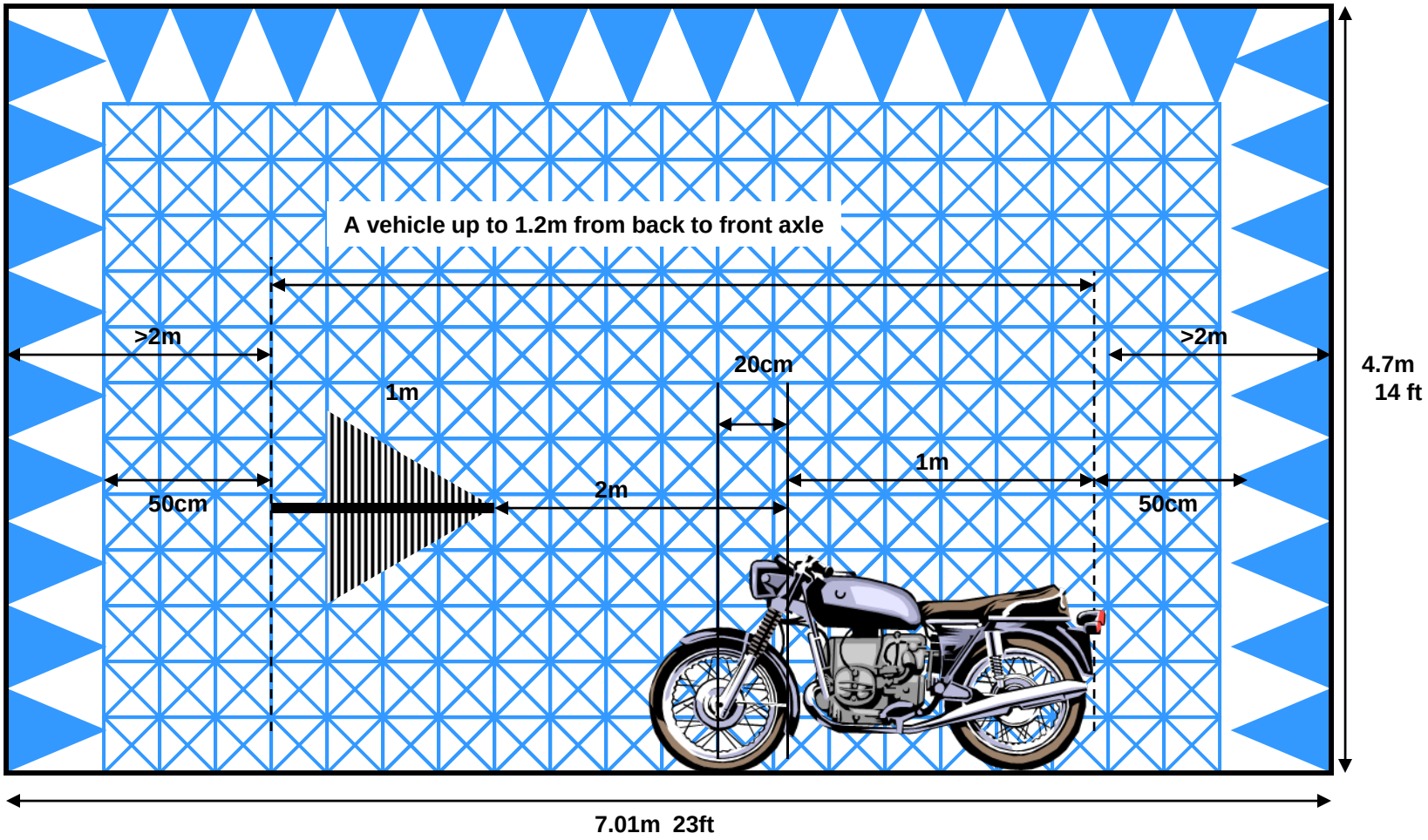
SAEJ551-11
ISO 11451-2
200MHz and above

Automotive EMC Immunity

The reference point position on the vehicle corresponds to the point where the windshield and the hood of the car meet. Or the front axel, which ever is farther away from the antenna.

For rear-engined vehicles the vehicle will be tested with the rear facing the antenna and the reference point at the rear axel.




A vehicle up to 1.2m from back to front axle
>2m
1m
50cm
2m
20cm
1m
50cm
>2m
4.7m
14 ft
7.01m 23ft

Field Generation

The key to automotive immunity is the generation of high fields. The proper selection of the antenna is key to lowering the amplifier requirements.

The next Slides deal with recommendations of the most suitable antennas for ISO 11451-2 and equivalent standards.

Recommended Antennas

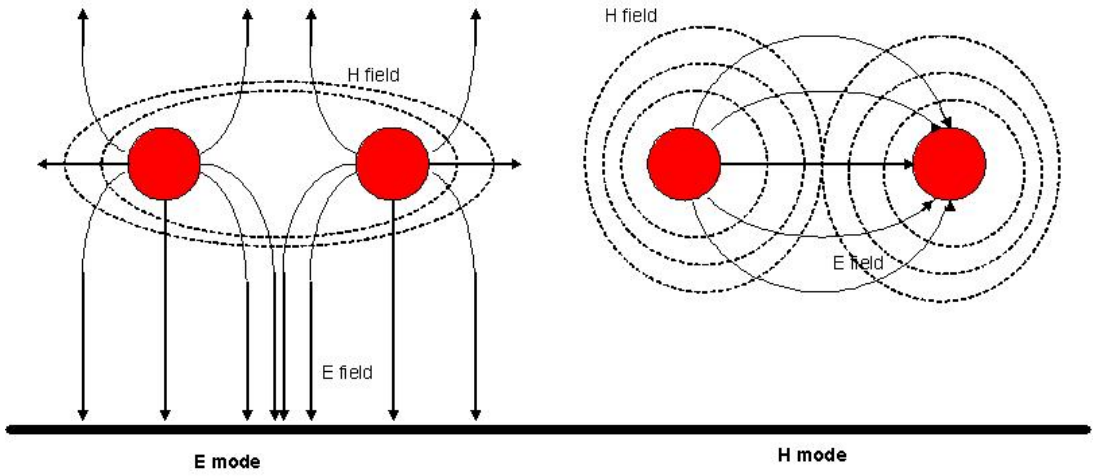
- 100kHz to 30MHz E-H generator
- 30MHz to 100MHz Biconical
- 100MHz to 1000MHz Dual Ridge Horn
- 1000MHz to 18000MHz Octave Gain horns

E-H Field Generators

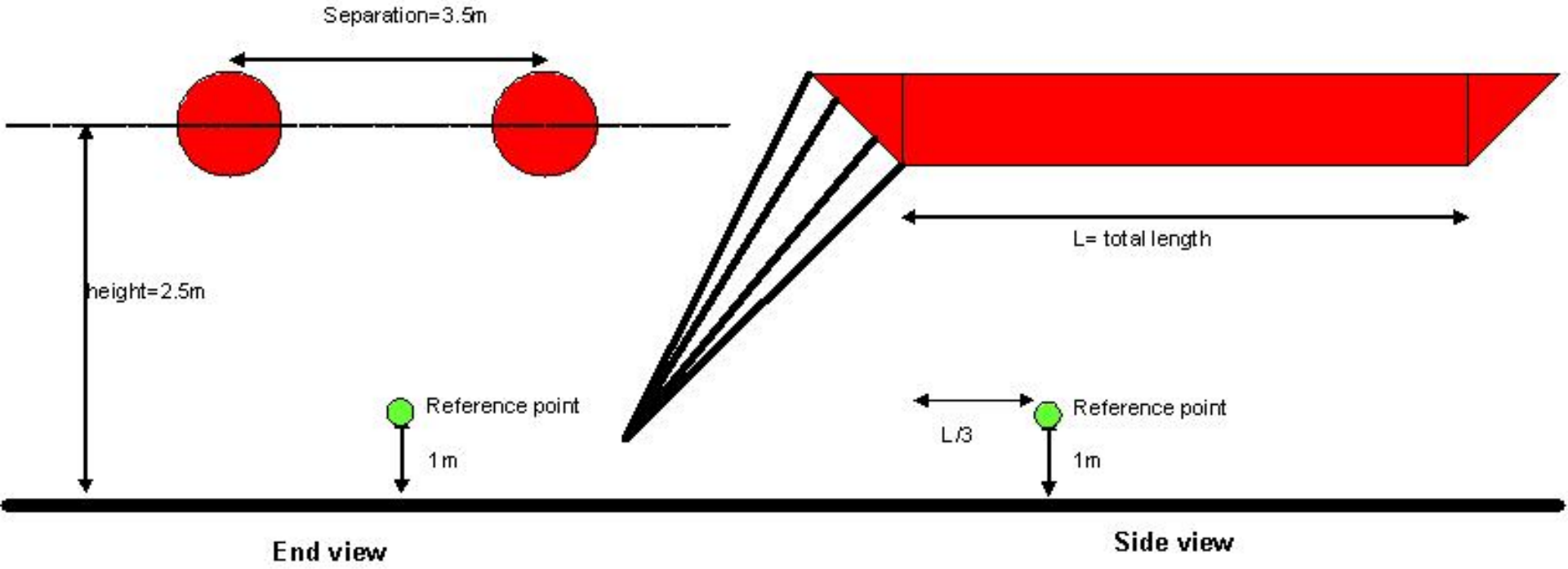
- Transverse Electromagnetic Mode Transmission lines.
- Field concentrated between elements and ground.
- No radiation into the chamber unless separation between the elements is more than ½ a wavelength

E-H Field Generators

- Two elements
- Both can be driven together against ground (E Mode)
- One can be driven against the other isolated from ground (H Mode)

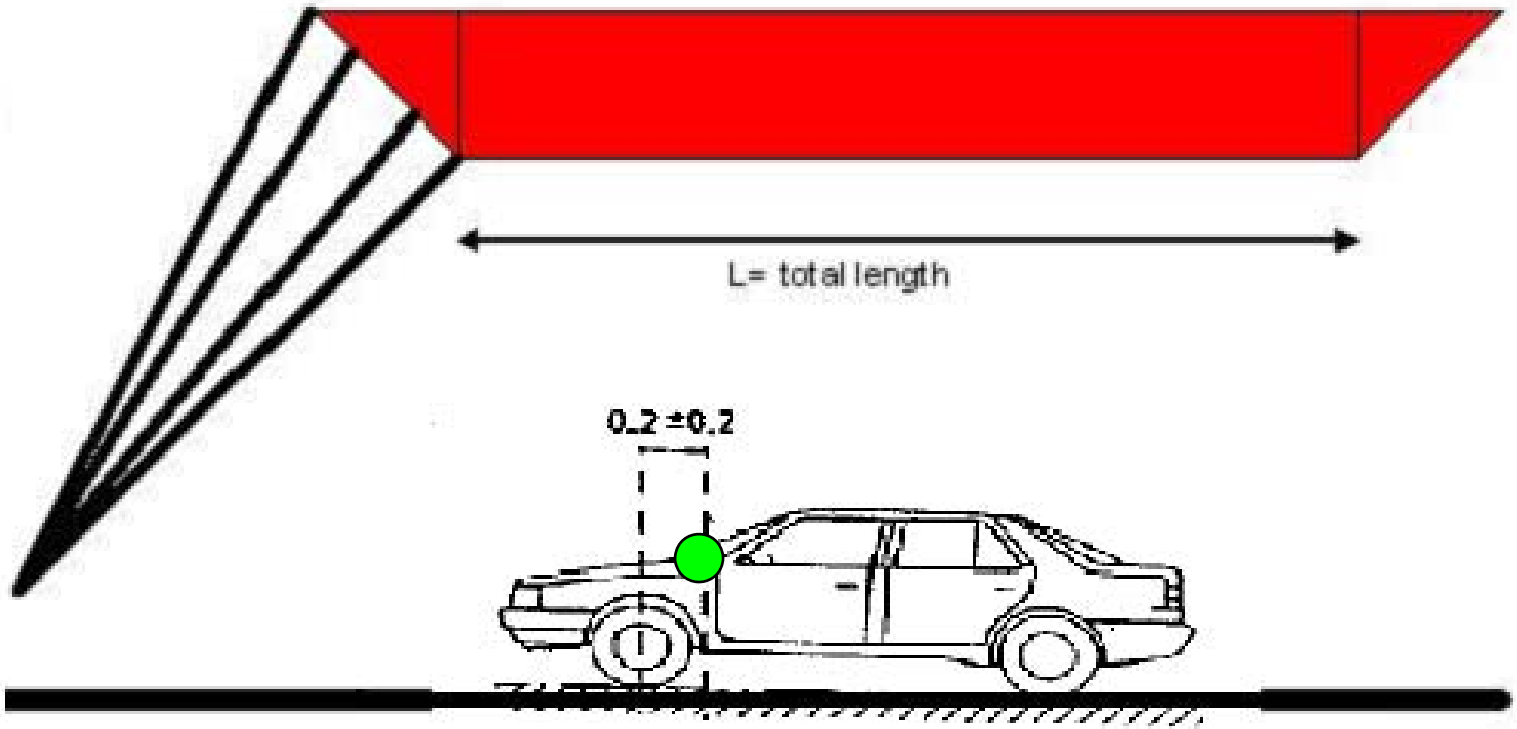


E-H Field Generators



To test the performance the field is measured at one point 1m over the ground and 1/3 the length of the elements from the transition region.
This places the test point roughly at the location of the reference point described on the standards

E-H Field Generators

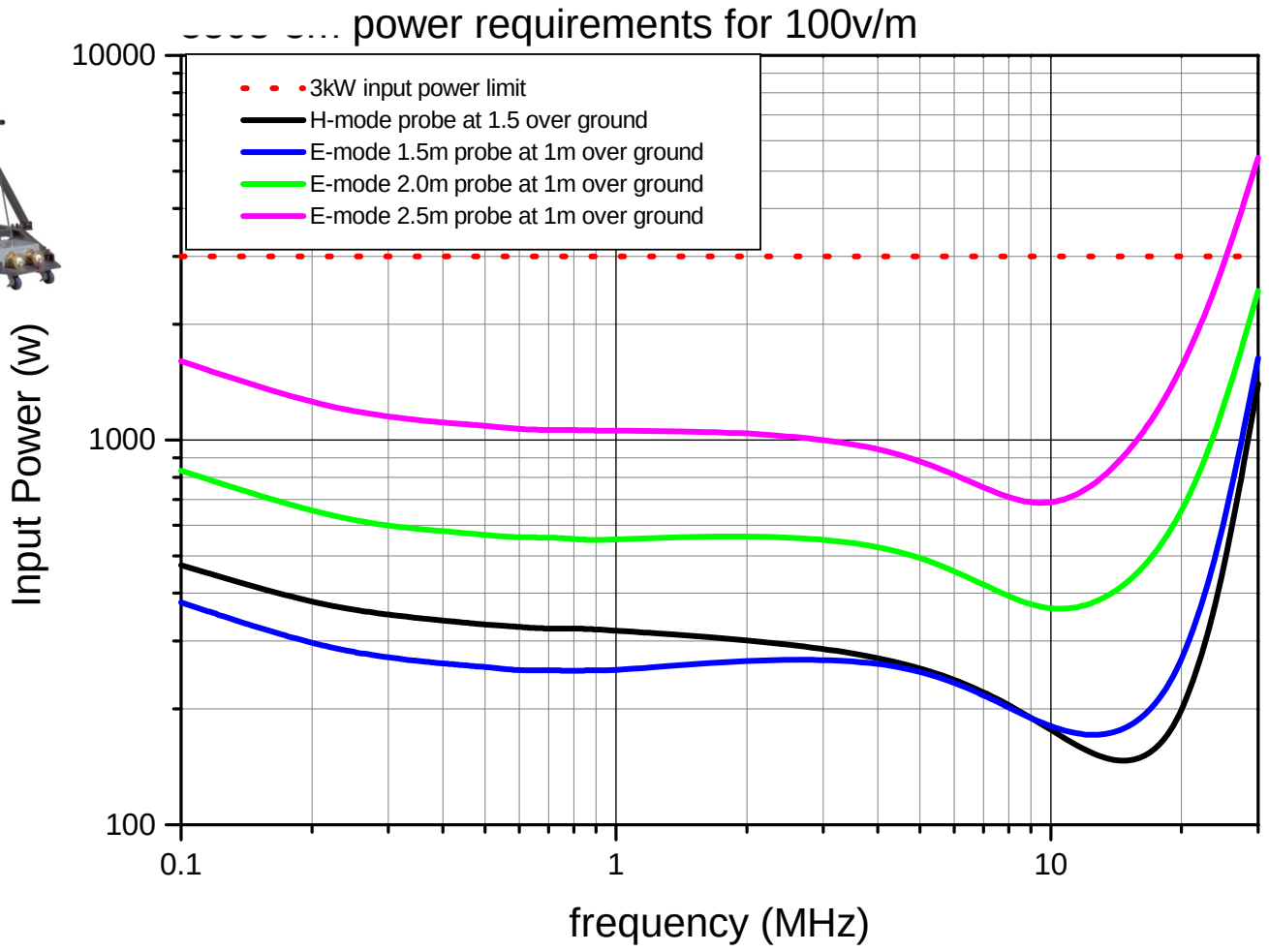


Self Supported Units: Ideal for smaller vehicles

1. 5m element length.
2. 2.5m maximum element height.
3. 2m Maximum element separation for H mode.
4. Manual Operation
5. 3kW maximum input power.

Self supported units

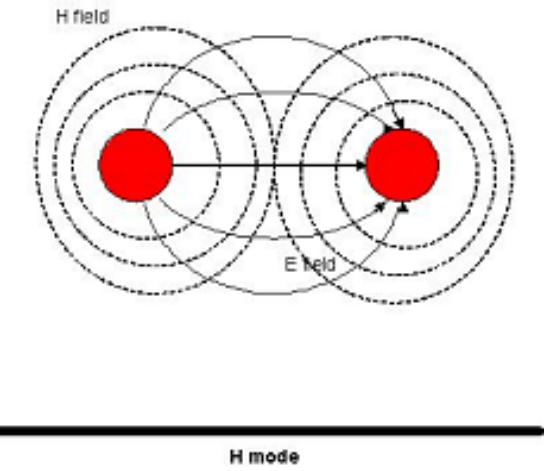
with its limited input power (3kW) can only meet 100v/m requirements. Also it is manually operated and requires at least 4 people to set up. It is intended as a lower cost alternative for small vehicle testing



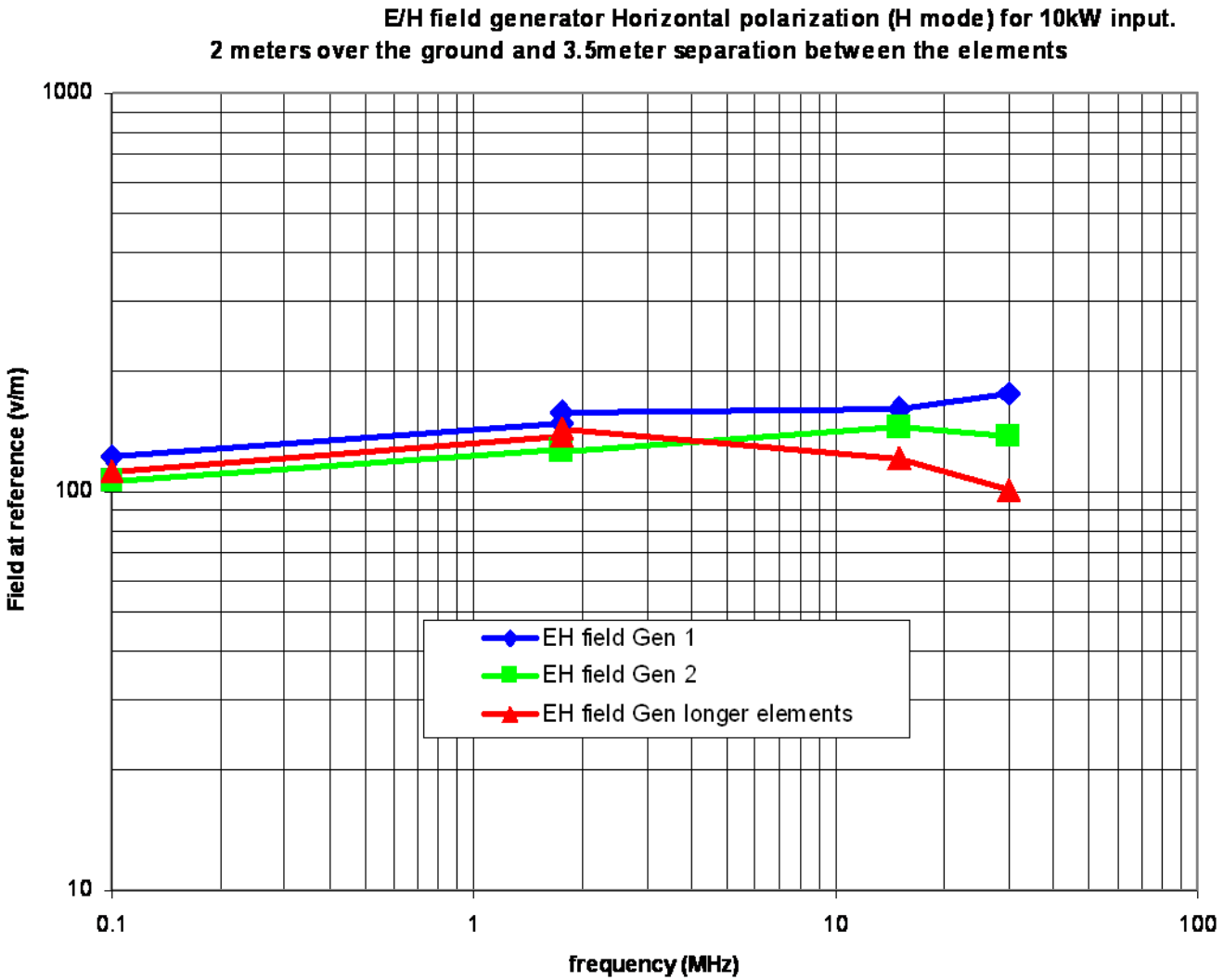
Automated chamber supported Units

1. Variable element length (as customer required)
2. Variable pneumatic element separation for H mode.
3. Variable height motor driven
4. 10kW maximum input power.

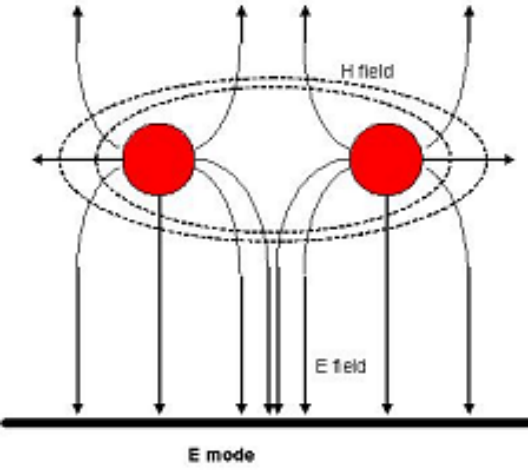
Chamber supported

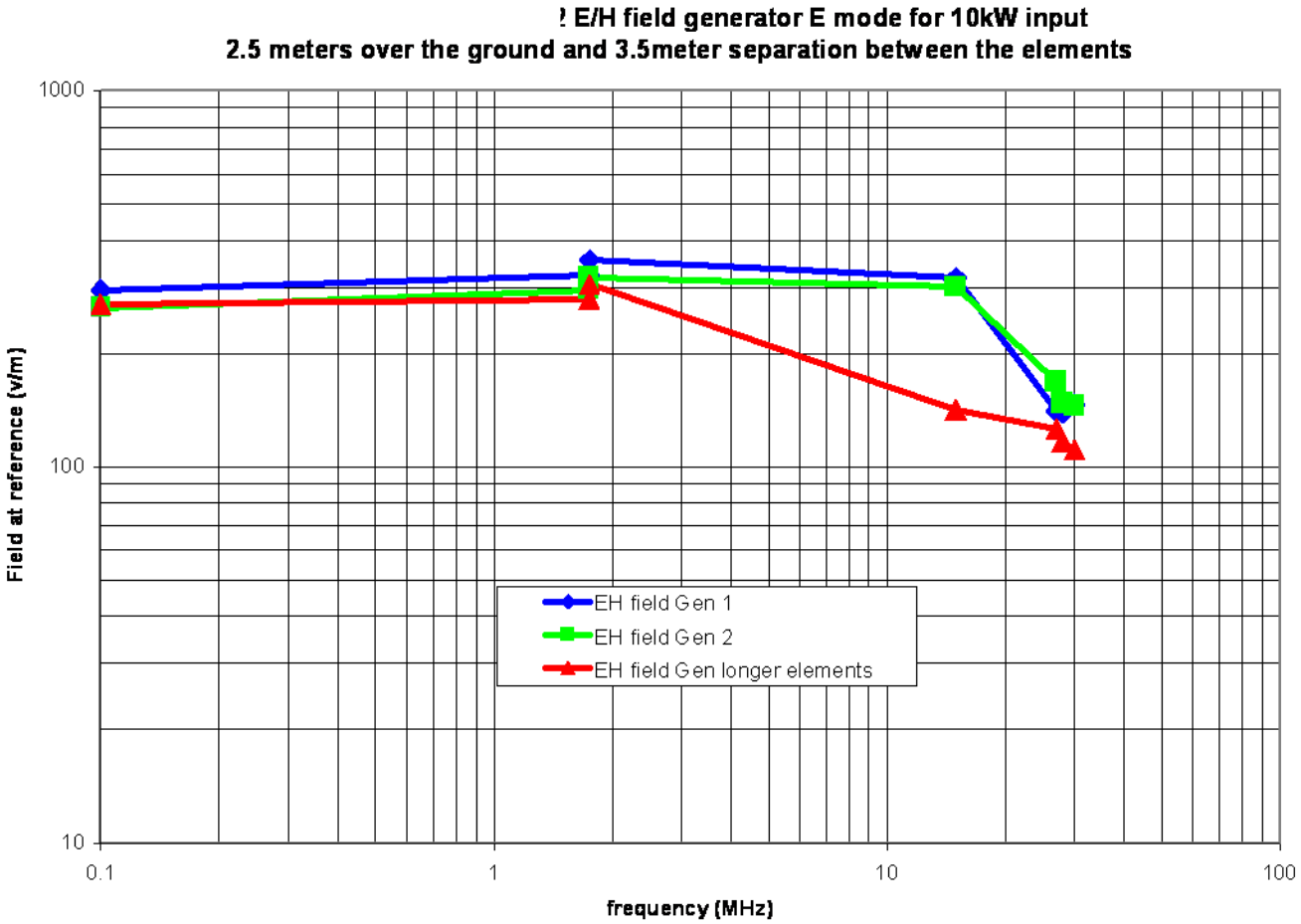


H mode

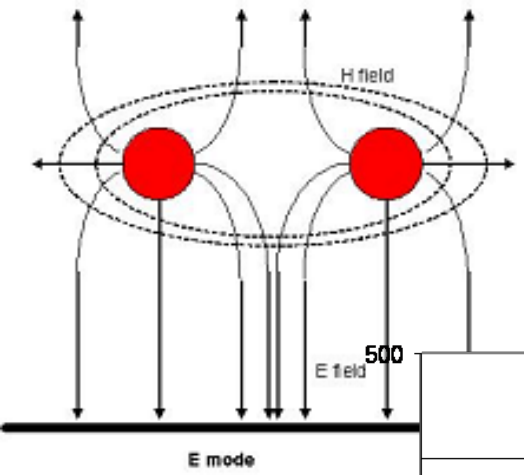


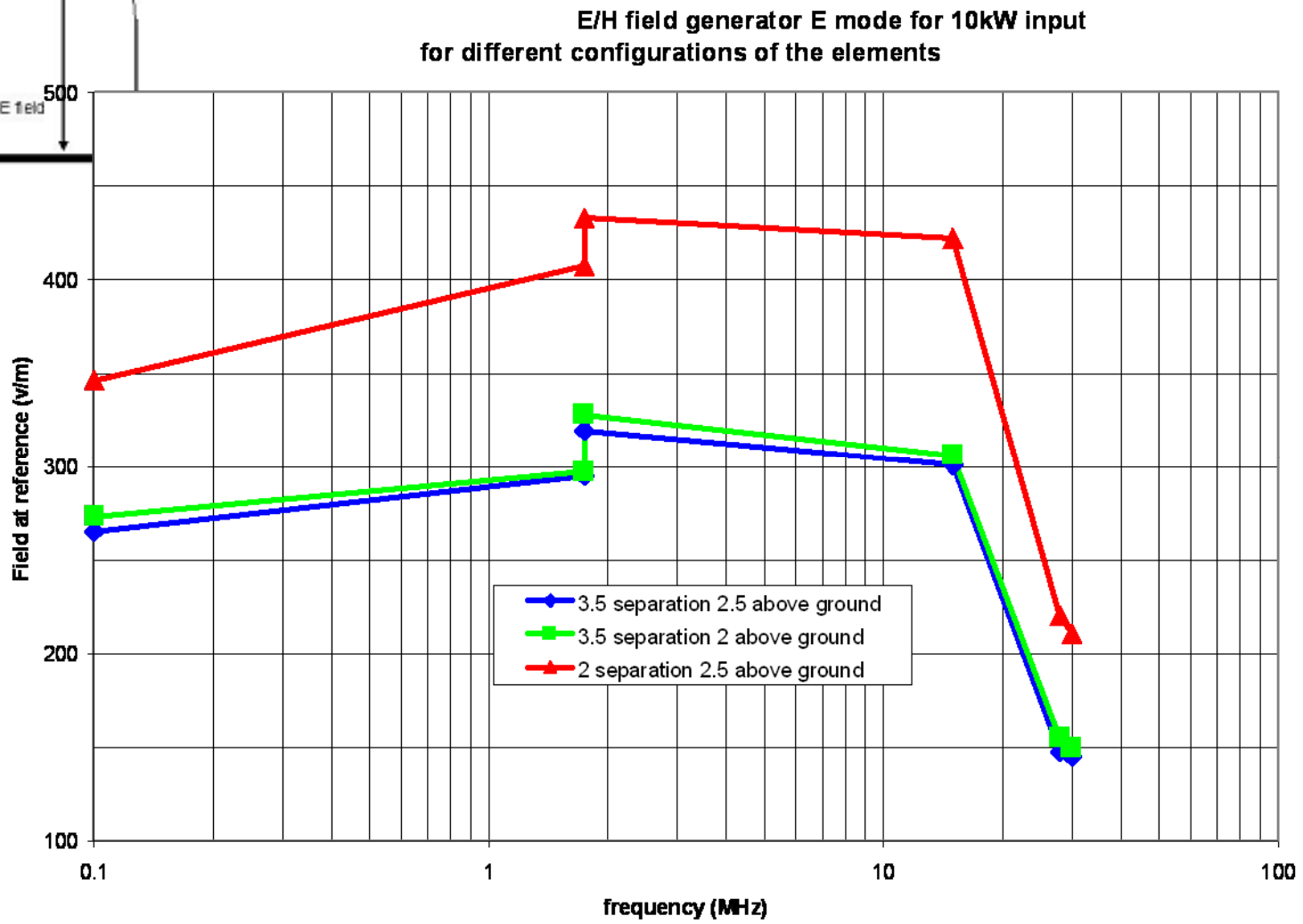
Chamber supported





Chamber supported



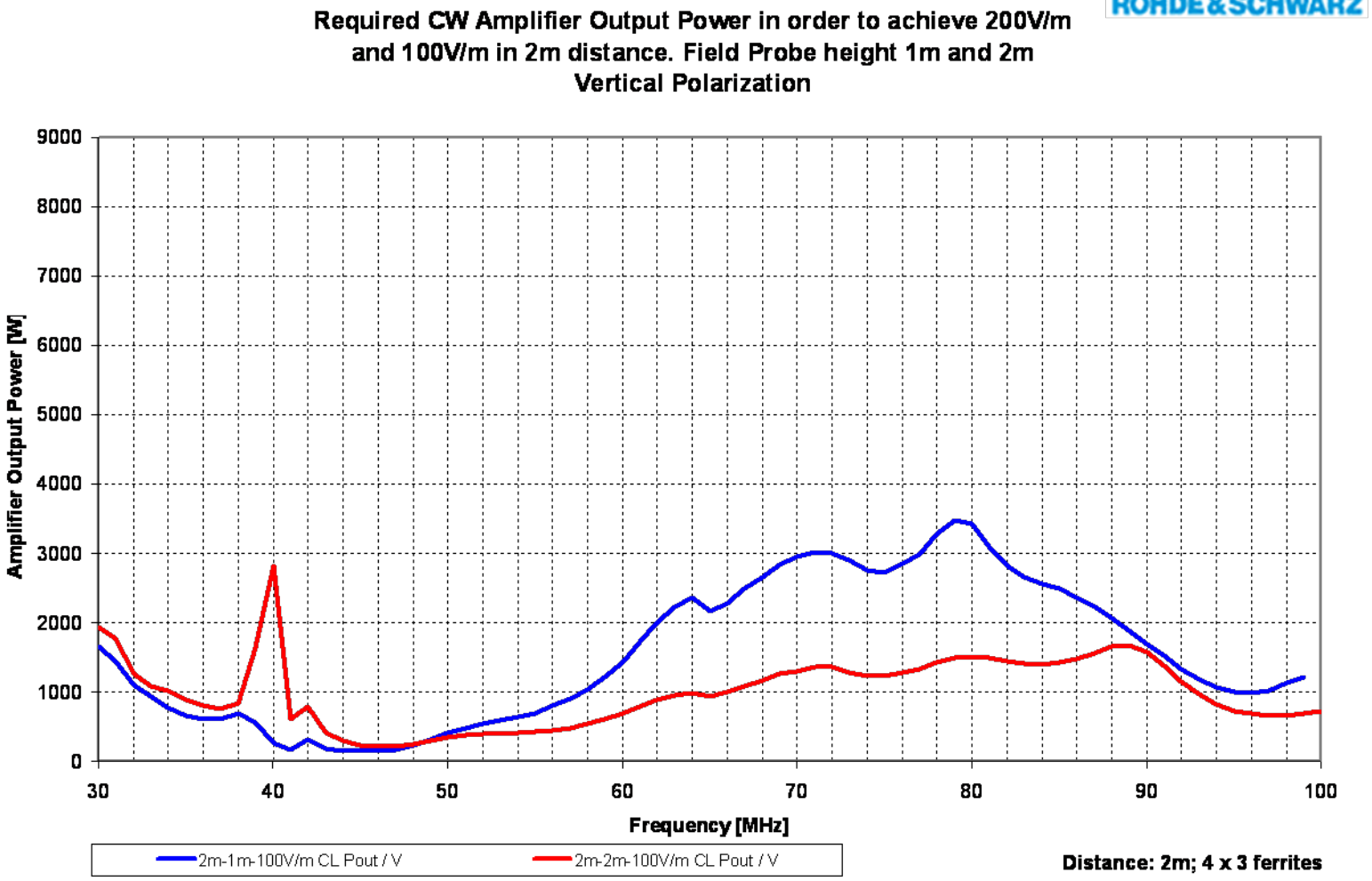


Large bicons(30MHz-100MHz)

fixed height positioner with pneumatic assisted polarization.

antenna at INPE chamber

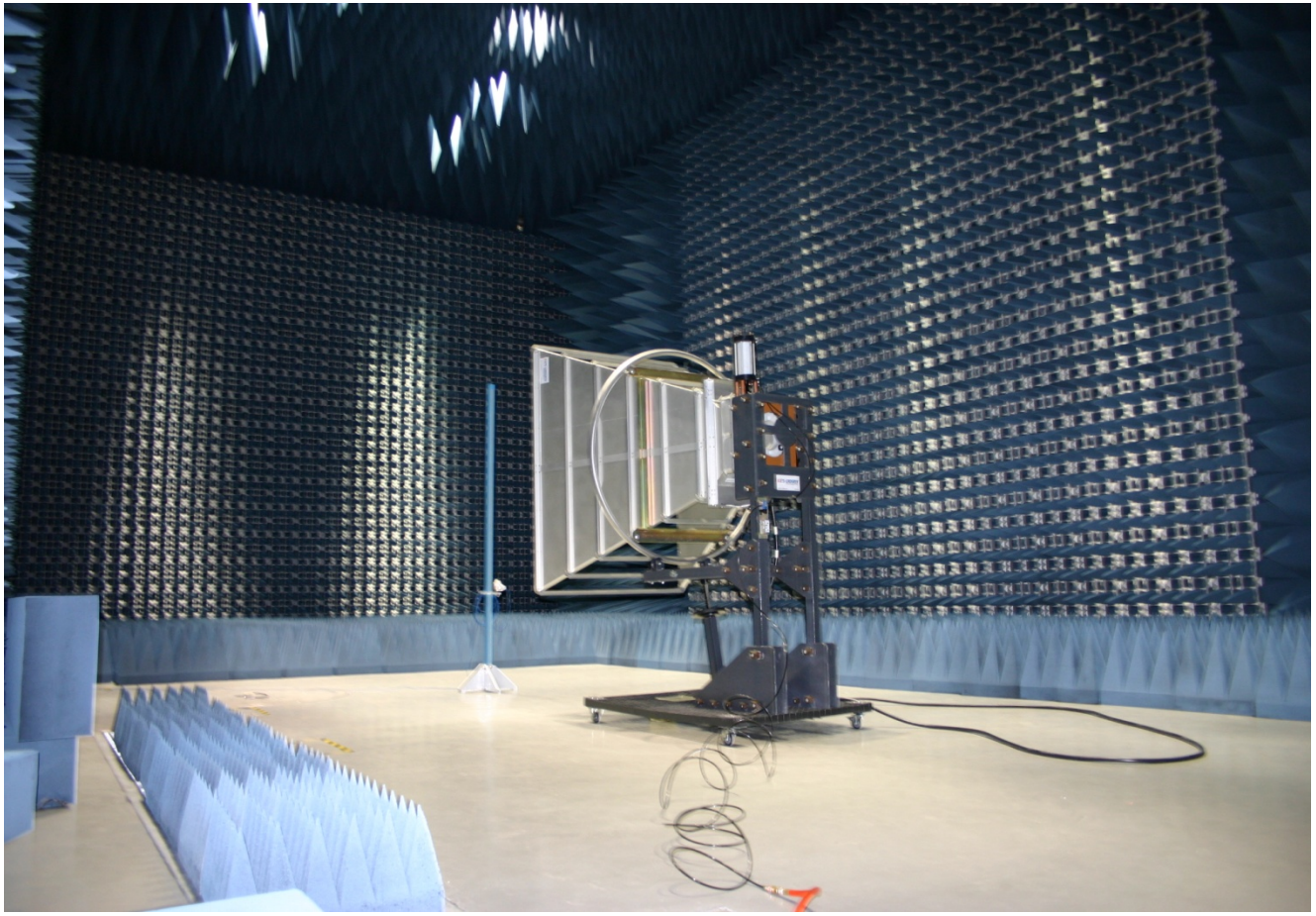
antenna at INPE chamber



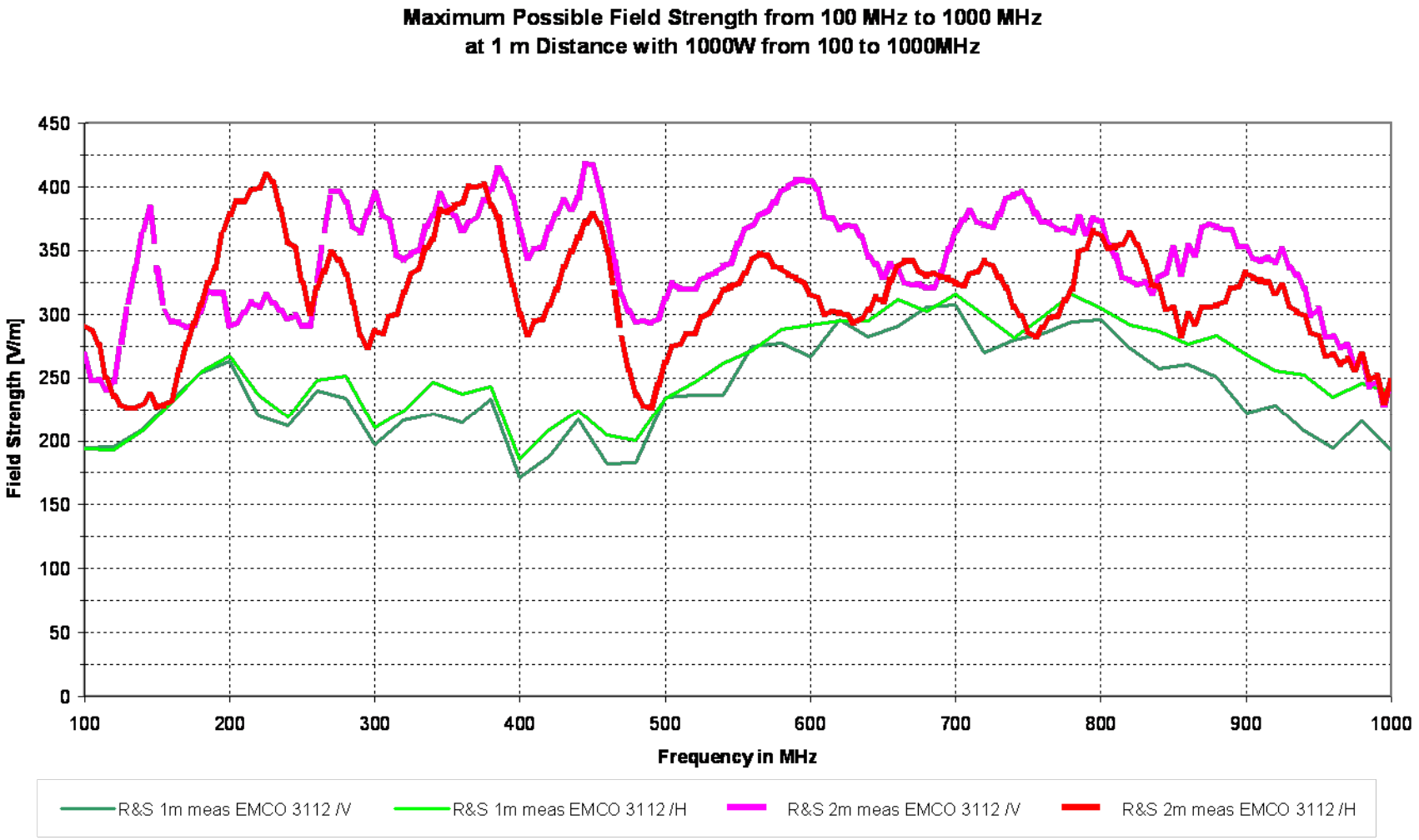
Ridge horn (100MHz-1000MHz)

fixed height positioner with pneumatic assisted polarization and manual boresight adjustment (±10 degrees)

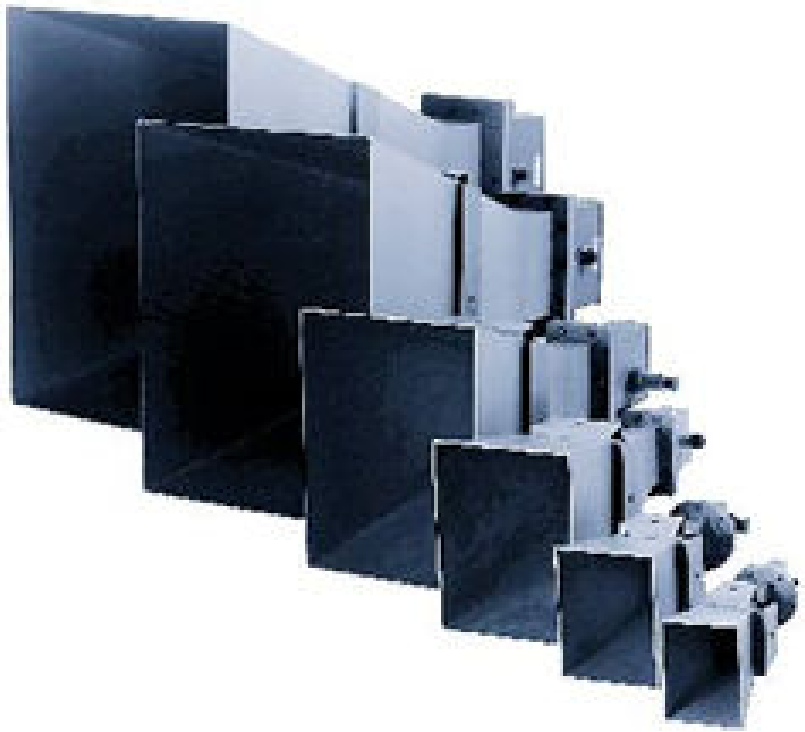
ridge antenna in INPE chamber



Field levels for 1kW input

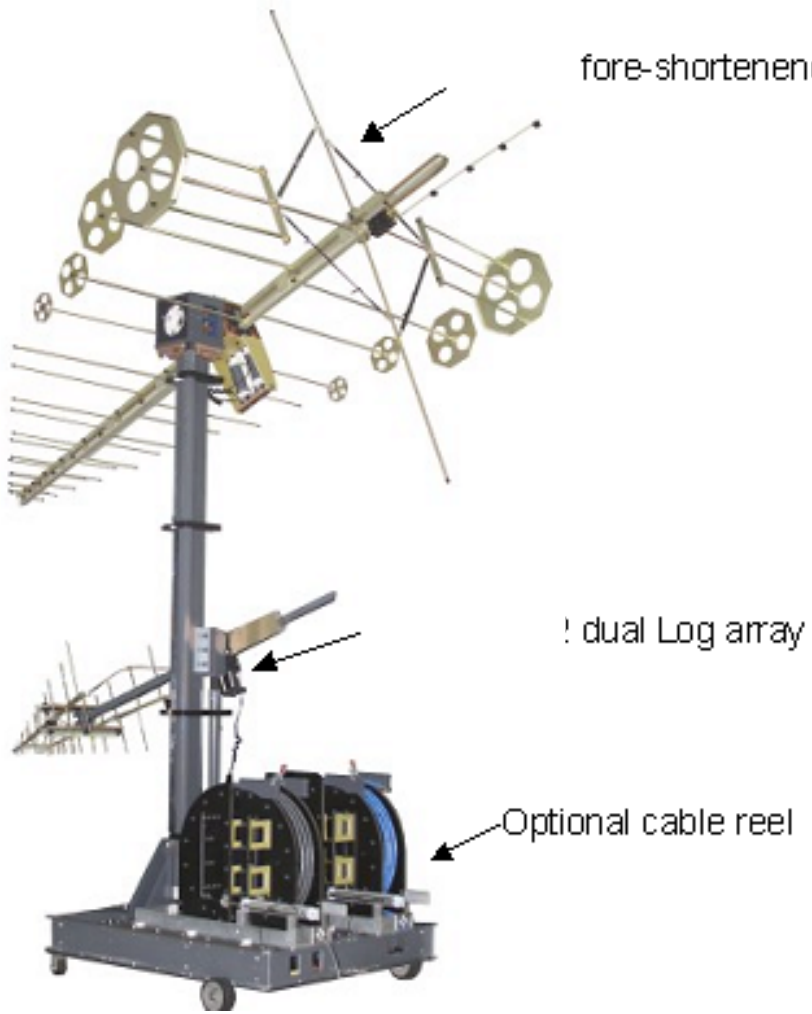


Above 1GHz (octave horns)



Gains of 15.5 to 17dBi
However narrow beams so scanning across EUT may be required.

Foreshortened logs



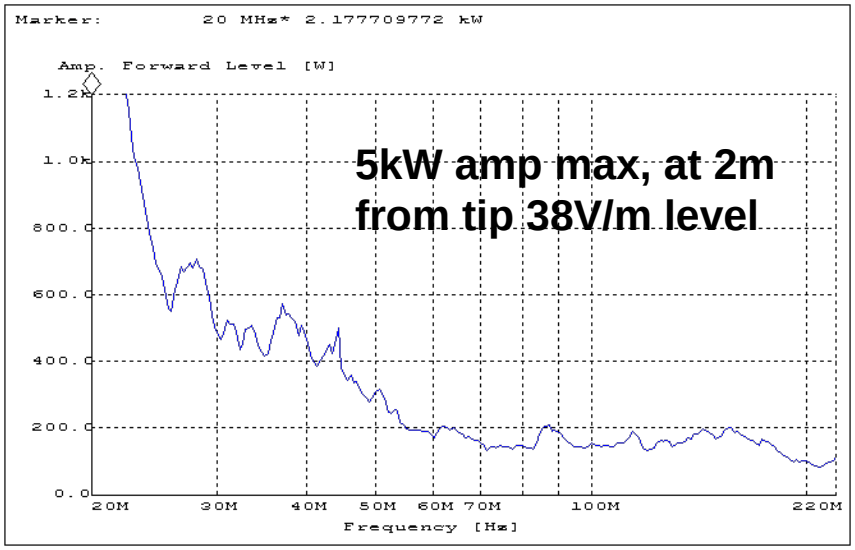
20 to 250MHz range of large Log P

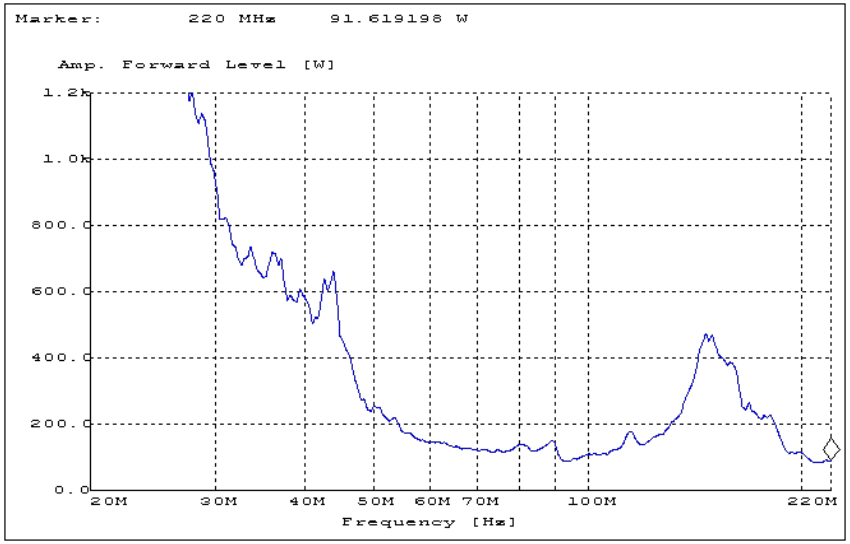
200MHz to 1GHz range for dual log.

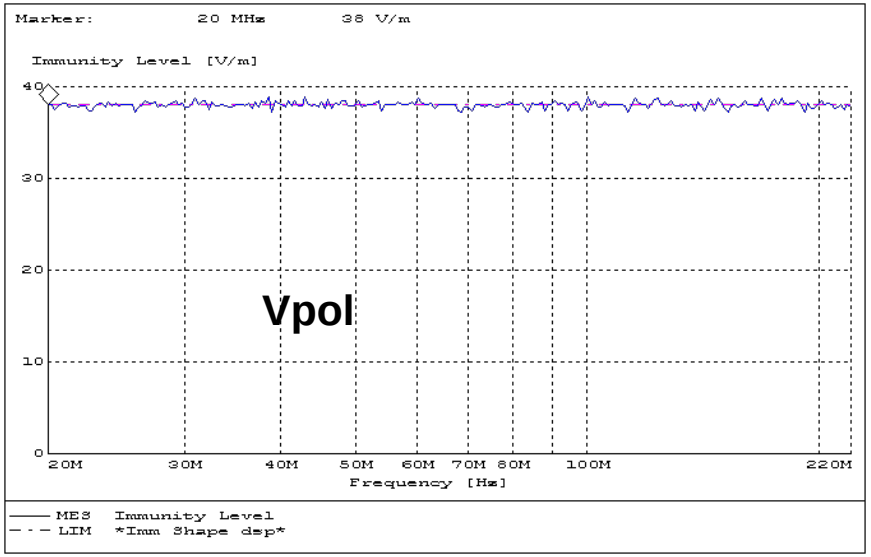
5kW max power.

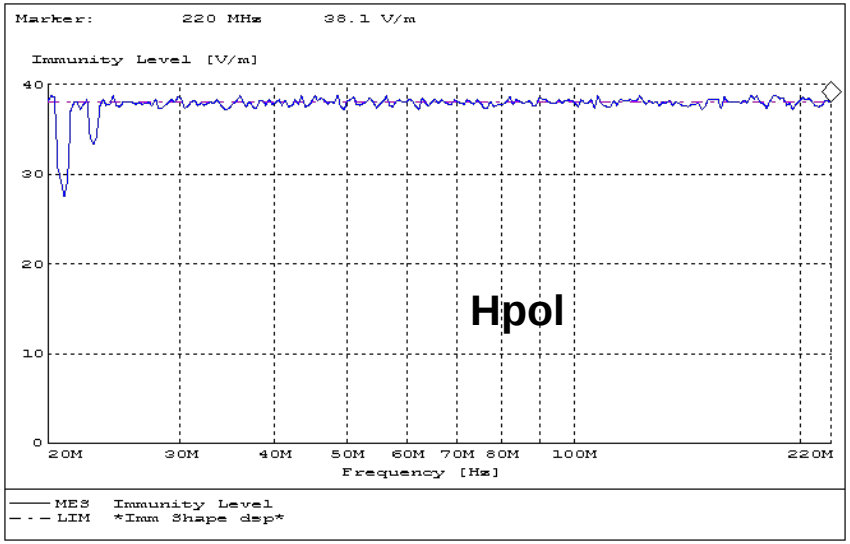
This solution is ideal for 95/54/EC but wont be able to generate 100V/m over the entire range

Foreshortened logs









Data courtesy of

Overview

Table II. Immunity antenna overview.

Frequency range	power	type	Standard
100kHz-30MHz	10kW	E/H field generator	ISO 11451-2 SAE J551-11 95/54 EC (20-30MHz)
30-100MHz	10kW	High power biconical	ISO 11451-2 SAE J551-11 95/54 EC
100-1000MHz	2kW	Dual ridge guide horn	ISO 11451-2 SAE J551-11 95/54 EC
1GHz-18 GHz	250-550W	Octave Horn	ISO 11451-2 SAE J551-11
20-200MHz	5kW	Fore shortened Log periodic antenna	95/54 EC 100 v/m above 40MHz
200-1000MHz	1kW	Dual array of Log periodic antennas	

Conclusions

- Hopefully you have gain knowledge on the chamber and antenna requirements for full vehicle testing
- These are expensive large facilities that only manufacturers could afford
- There may be a potential market for private EMC labs to set up full vehicle labs to take care of the increasing demand for full vehicle testing in Asia.