Steps in Designing Shielded Enclosures

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Outline

- Reasons for EMC
- Ways of Reaching EMC
- Company Background
- Standards
- Design of Shielded Enclosures
- Testing results
- Questions

Why do we need EMC?

- Unintentional Electro Magnetic Interference.
- Intentional Electro Magnetic Interference.

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Unintentional EMI

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Why do we need EMC?

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EMP SUITCASE
COMPACT 2100 SERIES
APELC proudly introduces the latest compact directed-energy solution. This portable and rugged Gigawatt-class source generates high-amplitude electric fields suitable for affecting electronics and testing system vulnerabilities. The development of APELC's EMP Suitcase was driven by input from DoD groups that required a powerful, reliable, compact EMP source capable of disabling or defeating electronics.
Exterior Dimensions
24.6 x 19.7 x 8.6 in.
RESET
FIRE
APELC
APELC
APPLIED PHYSICAL ELECTRONICS, L.C.
www.APELC.com
(512) 264-1804
Made in the USA

Repetetive Autonomous HPM-Test Source (DS110B)

120 MW Test Source

Autonomous device with
- integrated NiCad's
- Activation system
- Control electronics
- Charger / Service Unit

Availability
- DS110B 3 Months

Car Stopper

Performance Data DS110B

Electrical:

Radiated Power	~250 MW
Radiated Field	~120 kV/m @ 1 m
Pulse Width	< 10 ns
Frequency Range	100-300 MHz
Band Width	20%
Rep Rate	5 pps

Features:
- Portable
- Autonomous
- Omnidirection/Directional
- Short Range (2-20m)
- Tuneable Frequency Range

Application (Example)

- Destruction of electronic equipment and industrial production lines
- Neutralization of
  - Automotive electronics (car stopper)
  - Surveillance systems (Cameras, Sensors, etc.)
  - Control systems (e.g. industrial controllers)
  - Electronic mines
  - Computer, IT components
  - Television, monitors, radios, telephones

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Schutzvermerk nach DIN 34 beachten

Ways of reaching EMC

- At the component level (e.g.: Individual PC boards or chassis)
- Shielded enclosures
- Anechoic Chambers, Shielded Rooms and Faraday Cages.

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Advantages of Shielded Enclosures

- Can be incorporated after the system is designed.
- Portable compared to Shielded rooms.
- Can be a less expensive solution compared to shielding individual components or the shielded rooms.

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Applications of Shielded Enclosures

- Data centers where we need redundancy
- Industrial production lines for critical operations
- Department of Defense (protect communications)
- Other applications where EMC is critical

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Company Background

- Started in 1960, EEC specializes in modular design for electronic packaging solutions.
- Our sheet metal fabrication facility is spread over 125,000 sq.ft in Aurora IL and has 50 employees.
- We specialize in custom solutions for shielded, shock and vibration and seismic applications.
- Our Shielded enclosure line started over 25 years ago.

EMC Standards

- IEEE-299-2006
- MIL-STD-461
- NSA 94-106
- FCC Part 15
- Tempest
- MIL-STD-188 (HEMP)

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Design of Shielded Enclosures

- Selection of Enclosure Material
- Galvanic Compatibility
- Selection of Gaskets
- Input/Output
- Testing

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Selection of Enclosure Material

- Radiated Emissions/Susceptibility?
- Shielding levels required.
- Thickness of material.
- Other mechanical properties

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Selection of Enclosure Material

- Radiated Emissions/Susceptibility?

  For Radiated Emissions we want to choose a material that absorbs (e.g C.R.S or Stainless Steel).

  For Susceptibility we want to choose material that reflects (e.g Aluminum).

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Selection of Enclosure Material

- Shielding levels required.

$$\text{Attenuation}\,(dB) = 20\,Log_{10}\left(\frac{Field\ Strength\ Without\ Enclosure}{Compliant\ Field\ Strength}\right)$$

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$$\text{Shielding Effectiveness (dB)} = 20\,Log_{10}\left(\frac{120\times10^{3}}{5}\right) \approx 88\ \text{dB} \ @\ 300\ \text{MHz}$$

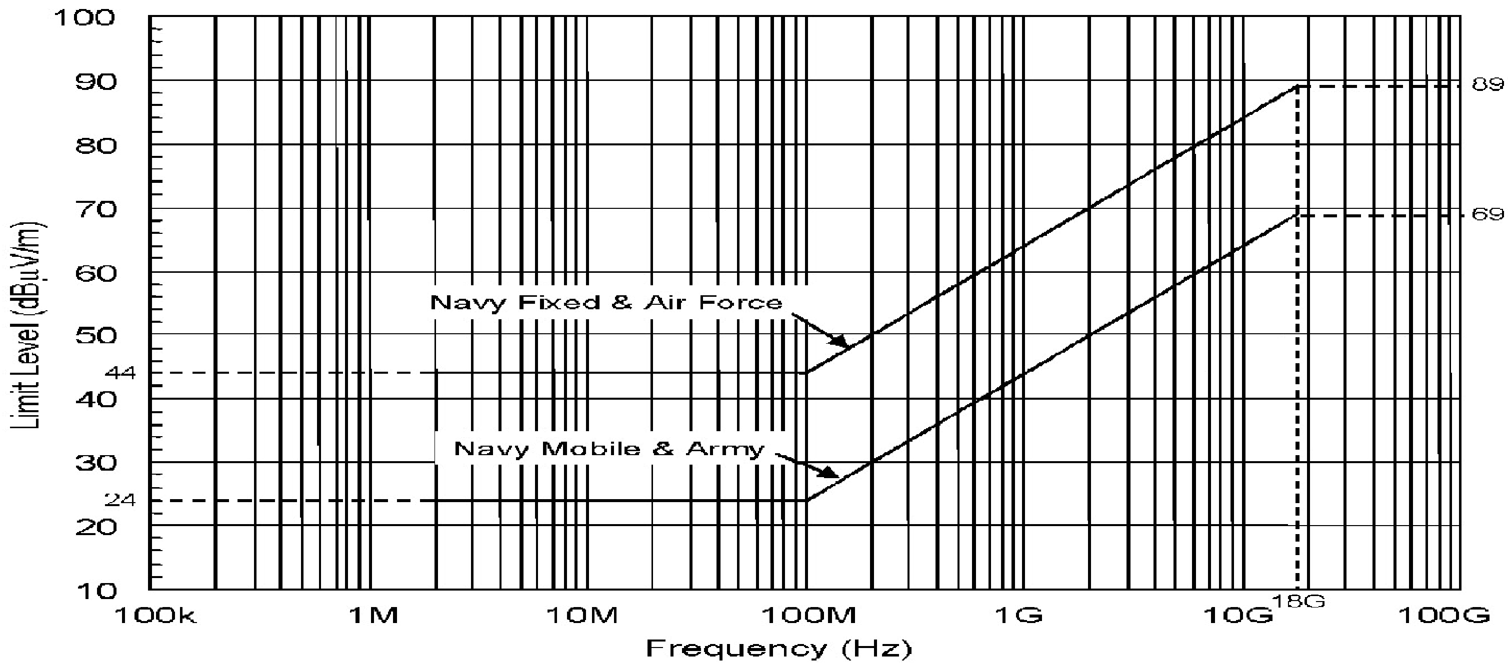

FIGURE RE102-4. RE102 limit for ground applications.

Selection of Enclosure Material

$$\text{S.E}\,(dB) = A + R + B$$

$$\text{A}\,(dB) = 3.338 \times 10^{-3} \times t\sqrt{\mu f G}$$

$$\text{R}_\text{E}\,(dB) = 353.6 + 10\log_{10}\frac{G}{f^3 \mu r_1^2}$$

$$\text{R}_\text{H}\,(dB) = 20\log_{10}\left(\frac{0.462}{r_1}\sqrt{\frac{\mu}{Gf}} + 0.136 r_1\sqrt{\frac{fG}{\mu}} + 0.354\right)$$

$$\text{R}_\text{P}\,(dB) = 108.2 + 10\log_{10}\frac{G \times 10^6}{\mu f}$$

G – relative conductivity (copper)
f – frequency (Hz)
μ - relative permeability (free space)
r_1- distance between source to shield (in)
t – thickness (mils)

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Selection of Enclosure Material

Other mechanical properties

- Weldability
- Formability
- Availability
- Protection against magnetic fields (Aluminum, 300 series Stainless steels)

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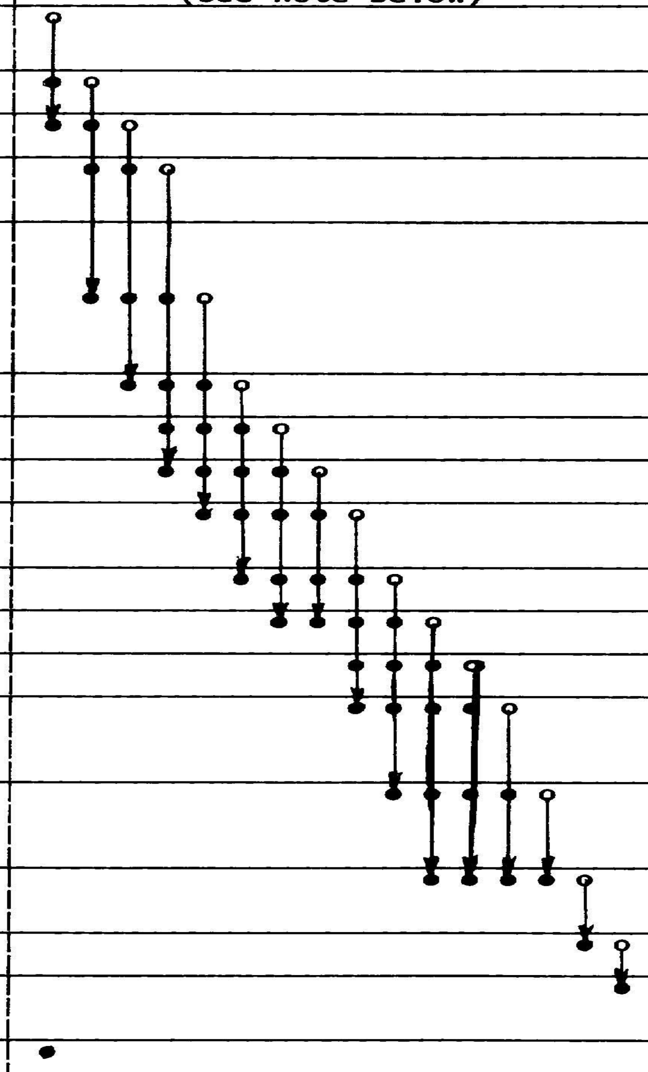
Design of Shielded Enclosures

- Selection of Enclosure Material
- Galvanic Compatibility
- Selection of Gaskets
- Input/Output
- Testing

TABLE VI. Compatible couples.

Group No.	Metallurgical Category	EMF (Volt)	Anodic Index (0.01 V)	Compatible Couples (see note below)
1	Gold, solid and plated; gold-platinum alloys; wrought platinum	+0.15	0	
2	Rhodium plated on silver-plated copper	+0.05	10	
3	Silver, solid or plated; high silver alloys	0	15	
4	Nickel, solid or plated; monel metal, high-nickel-copper alloys	-0.15	30	
5	Copper, solid or plated; low brasses or bronzes; silver solder; German silvery high copper-nickel alloys; nickel-chromium alloys; austenitic corrosion-resistant steels	-0.20	35	
6	Commercial yellow brasses and bronzes	-0.25	40	
7	High brasses and bronzes; naval brass; Muntz metal	-0.30	45	
8	18% chromium type corrosion-resistant steels	-0.35	50	
9	Chromium plated; tin plated; 12% chromium type corrosion-resistant steels	-0.45	60	
10	Tin-plate; terneplate; tin-lead solder	-0.50	65	
11	Lead, solid or plated; high lead alloys	-0.55	70	
12	Aluminum, wrought alloys of the 2000 Series	-0.60	75	
13	Iron, wrought, gray or malleable; plain carbon and low alloy steels, armco iron	-0.70	85	
14	Aluminum, wrought alloys other than 2000 Series aluminum, cast alloys of the silicon type	-0.75	90	
15	Aluminum, cast alloys other than silicon type; cadmium, plated and chromated	-0.80	95	
16	Hot-dip-zinc plate; galvanized steel	-1.05	120	
17	Zinc, wrought; zinc-base die-casting alloys; zinc plated	-1.10	125	
18	Magnesium & magnesium-base alloys, cast or wrought	-1.60	175	



Note: o indicates the most cathodic members of the series; • indicates an anodic member; Arrows indicate the anodic direction.

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Check the source to verify that this is the current version before use.

Design of Shielded Enclosures

- Selection of Enclosure Material
- Galvanic Compatibility
- Selection of Gaskets
- Input/Output
- Testing

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Selection of Gaskets

- Reason for having gaskets
- Type of opening
  - Wiping or compression
- Shielding effectiveness
- Galvanic Compatibility

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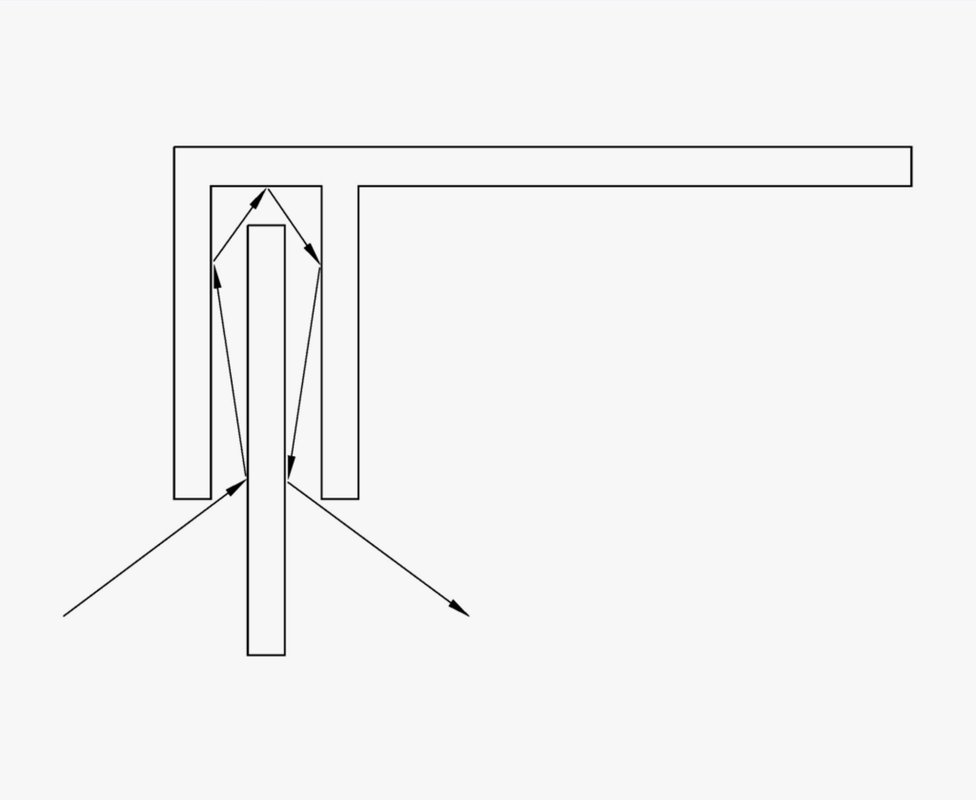
Door Opening Design



Advantages:

• High level of Shielding Effectiveness

Disadvantages:

• Must be manufactured precisely.

• Use of heavier gauge material.

Design of Shielded Enclosures

- Input/Output
  - Vents
  - Power Line Filters
  - Connectors

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Vents

Example: Determine SE @ 10 GHz for 1/8”Honeycomb 1” Long.

$$\text{Cutoff Frequency } C = \frac{6.92}{D} = \frac{6.92}{0.125} = 55.36\ GHz$$

Since 10 GHz < 55.36 GHz the honeycomb is usable.

$$\text{SE}\ (dB) \approx \frac{32 \times L}{D} \approx \frac{32 \times 1}{0.125} \approx 256\ \text{dB}$$

Rule of thumb for vents

$$\frac{\text{L}}{\text{D}} \geq 5$$

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Testing

- IEEE-299-2006
- NSA 94-106

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RADIOMETRICS
Midwest Corporation

Shielding Effectiveness Test Report

Tests Performed on an Equipto

R6 Shielded Equipment Cabinet

Radiometrics Document RP-6717A

Test Specifications
IEEE-299-2006

Tests Performed For:	*Test Facility:*
Equipto Electronics 351 Woodlawn Avenue Aurora, Illinois 60506-9988	**Radiometrics Midwest Corporation** 12 East Devonwood Romeoville, IL 60446

Test Date(s):
March 12 – March 22, 2010

RP-6553 Revisions:

Rev.	Issue Date	Affected Pages	Revised By
0	August 24, 2010		

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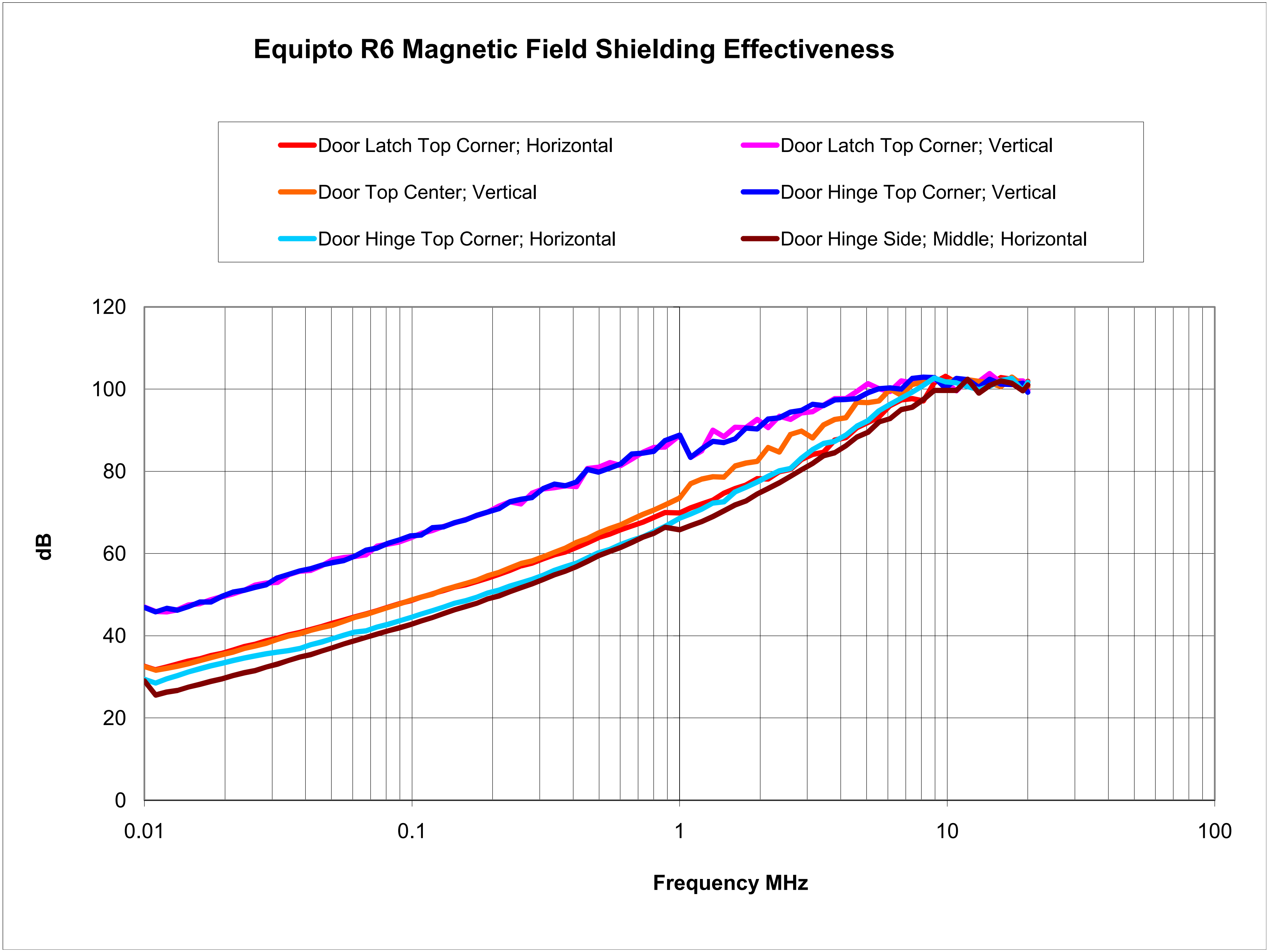
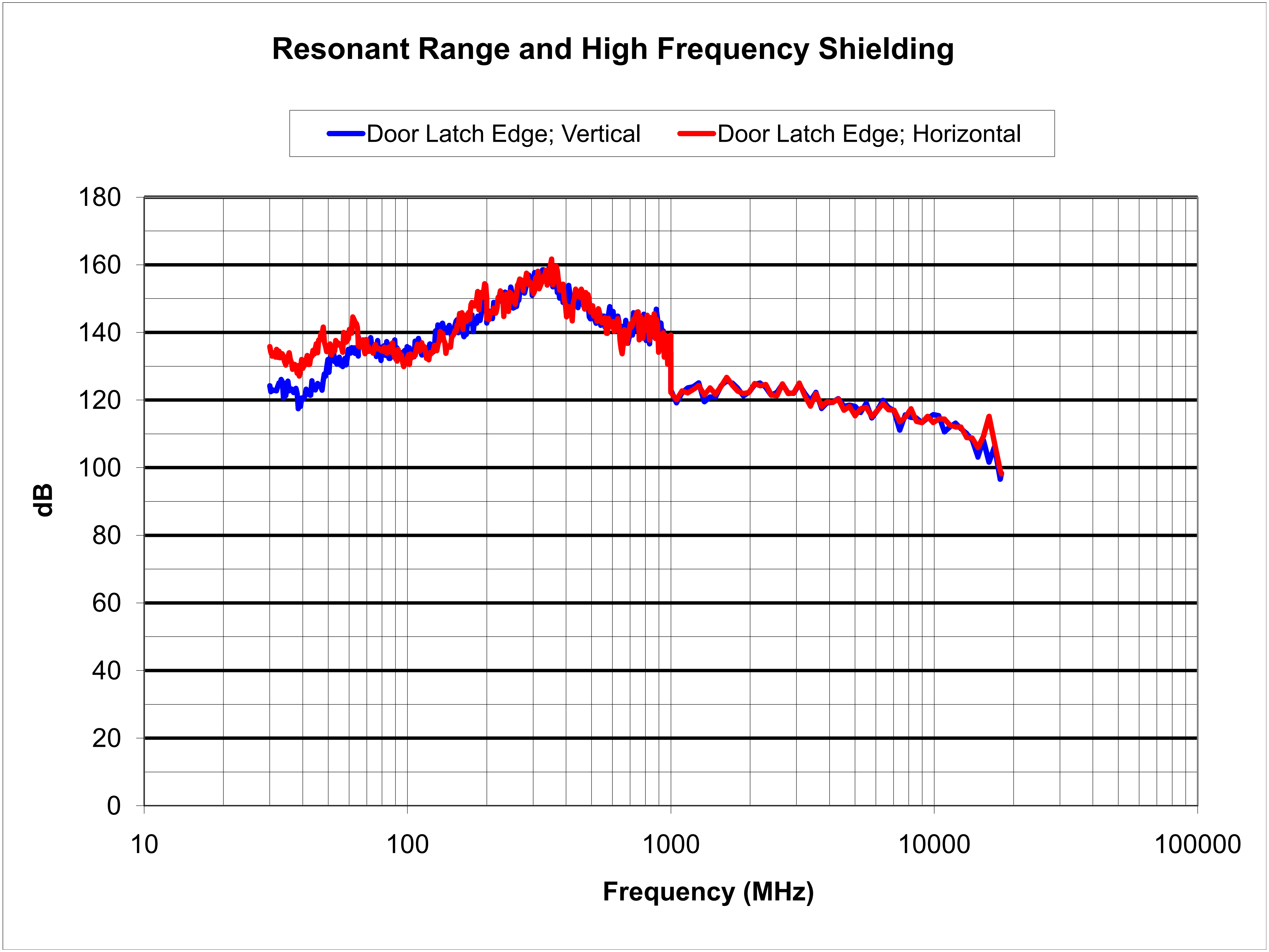


Equipto R6 Magnetic Field Shielding Effectiveness
Door Latch Top Corner; Horizontal
Door Latch Top Corner; Vertical
Door Top Center; Vertical
Door Hinge Top Corner; Vertical
Door Hinge Top Corner; Horizontal
Door Hinge Side; Middle; Horizontal
dB
120
100
80
60
40
20
0
0.01
0.1
1
10
100
Frequency MHz


Resonant Range and High Frequency Shielding
Door Latch Edge; Vertical
Door Latch Edge; Horizontal
180
160
140
120
100
80
60
40
20
0
dB
10
100
1000
10000
100000
Frequency (MHz)

RADIOMETRICS Midwest Corporation

Shielding Effectiveness Test Report

Tests Performed on an Equipto

R6 Shielded Equipment Cabinet

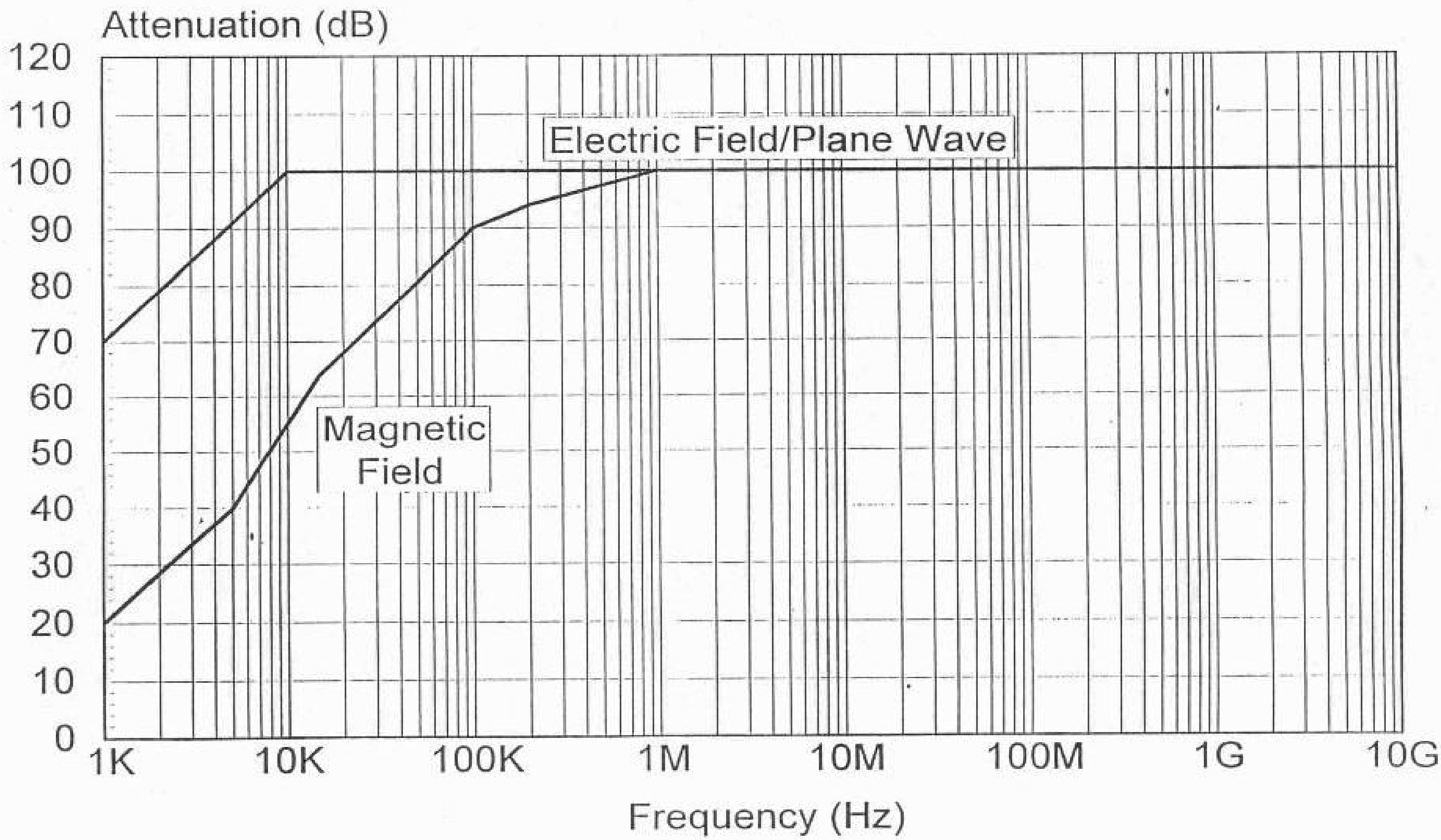
Radiometrics Document RP-6717

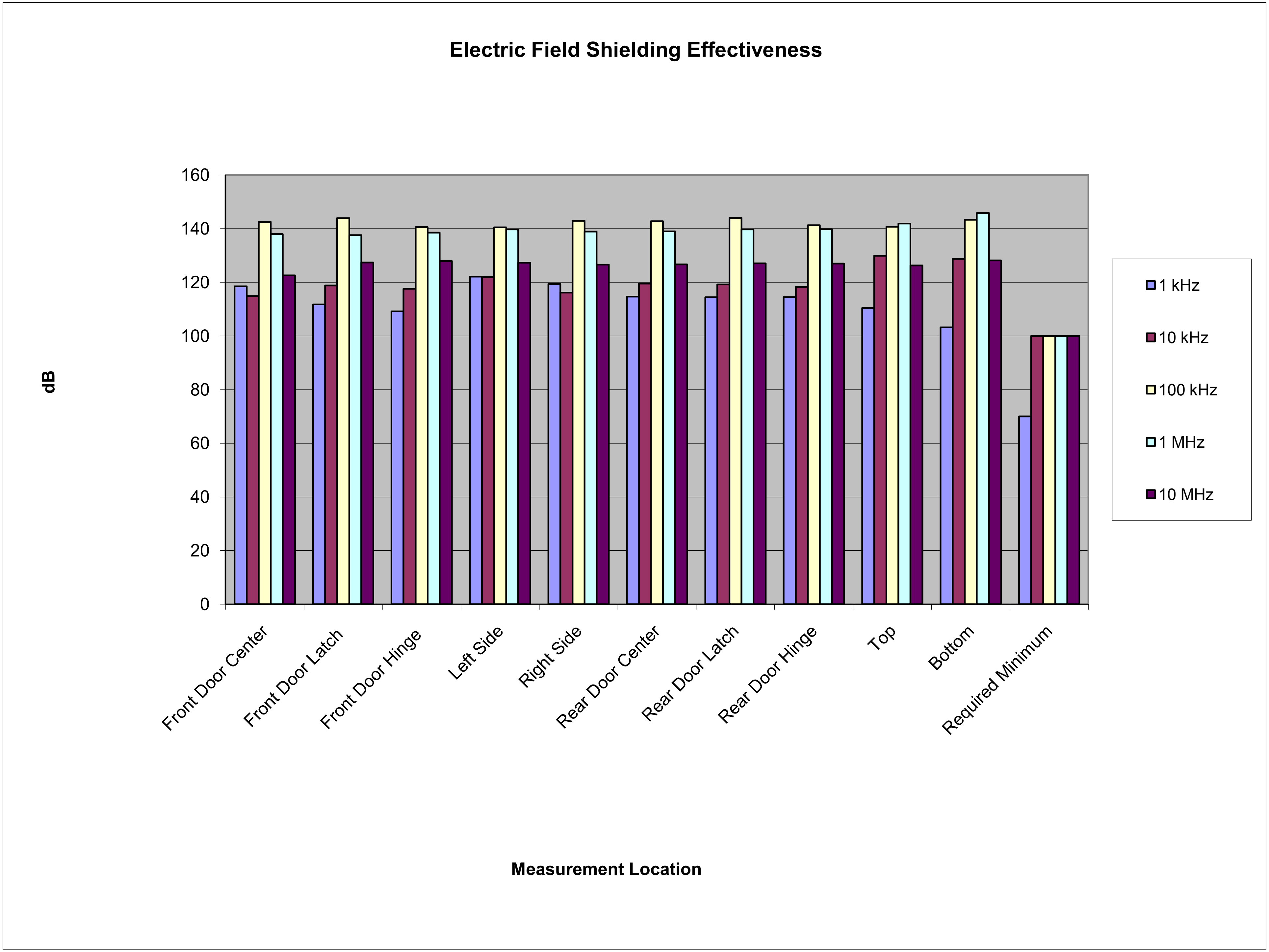
Test Specifications NSA NO. 94-106 (24 October 1994) "National Security Agency Specification for Shielded Enclosures"	
Tests Performed For: **Equipto Electronics** 351 Woodlawn Avenue Aurora, Illinois 60506-9988	*Test Facility:* **Radiometrics Midwest Corporation** 12 East Devonwood Romeoville, IL 60446
Test Date(s): March 8 through March 10, 2010	

RP-6717 Revisions:

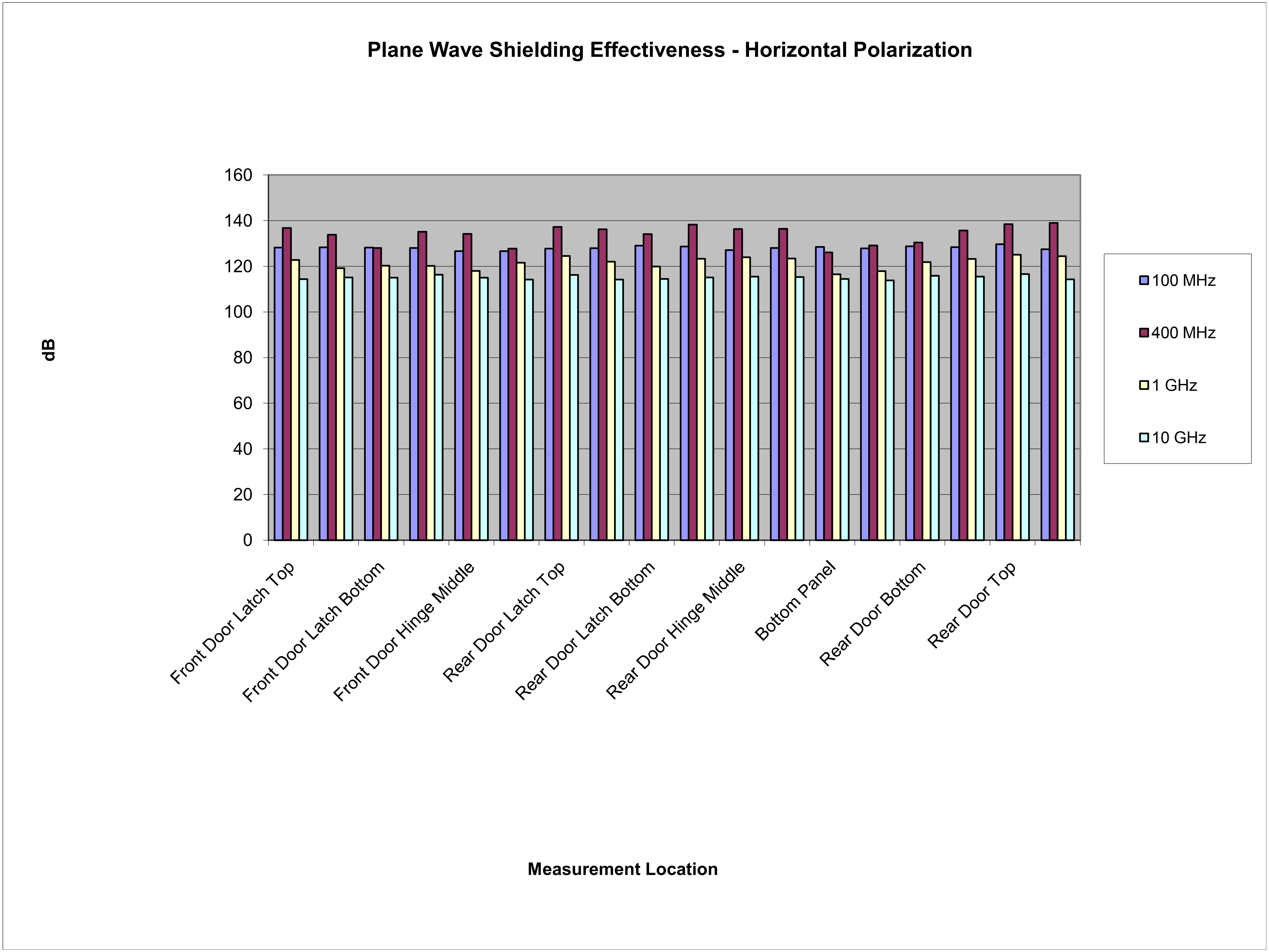
Rev.	Issue Date	Affected Pages	Revised By
0	July 12, 2010		

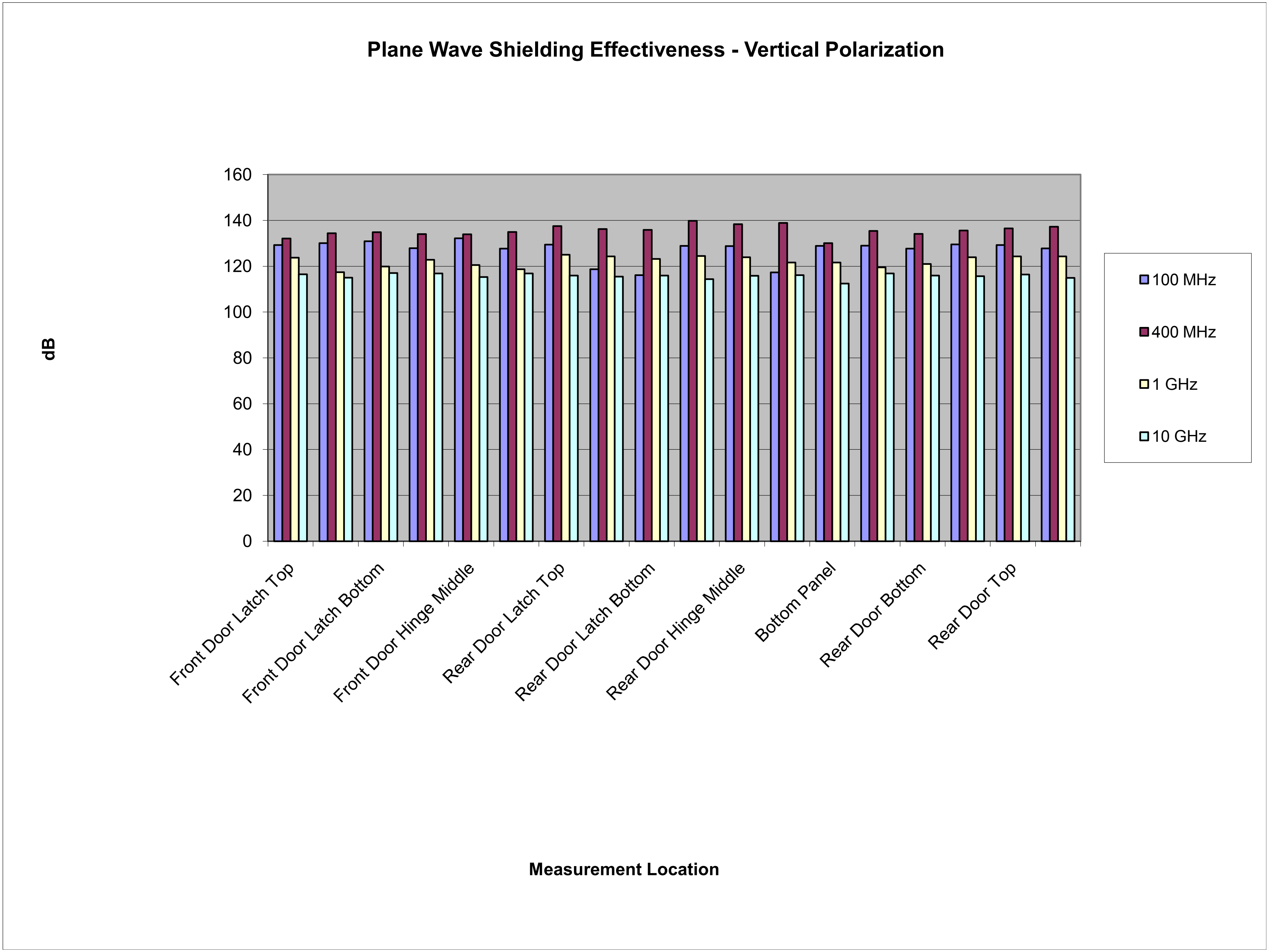
ELECTROMAGNETIC ATTENUATION REQUIREMENTS





Electric Field Shielding Effectiveness
dB
160
140
120
100
80
60
40
20
0
Front Door Center
Front Door Latch
Front Door Hinge
Left Side
Right Side
Rear Door Center
Rear Door Latch
Rear Door Hinge
Top
Bottom
Required Minimum
1 kHz
10 kHz
100 kHz
1 MHz
10 MHz
Measurement Location


Plane Wave Shielding Effectiveness - Horizontal Polarization
dB
160
140
120
100
80
60
40
20
0
Front Door Latch Top
Front Door Latch Bottom
Front Door Hinge Middle
Rear Door Latch Top
Rear Door Latch Bottom
Rear Door Hinge Middle
Bottom Panel
Rear Door Bottom
Rear Door Top
Measurement Location
100 MHz
400 MHz
1 GHz
10 GHz


Plane Wave Shielding Effectiveness - Vertical Polarization
160
140
120
100
80
60
40
20
0
dB
Front Door Latch Top
Front Door Latch Bottom
Front Door Hinge Middle
Rear Door Latch Top
Rear Door Latch Bottom
Rear Door Hinge Middle
Bottom Panel
Rear Door Bottom
Rear Door Top
100 MHz
400 MHz
1 GHz
10 GHz
Measurement Location

References

- The design of shielded enclosures by Louis T. Gnecco
- Chomerics (EMI Shielding Theory)
- MIL-F-14072D
- NSA 94-106
- MIL-STD-461F
- EMPrimus SCADA/DCS Testing
- www.APELC.com
- **www.diehl.de**

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Questions