

SPECTRUM CONTROL, INC.

A
Control Products
& Systems *Company*

- ✓ **What are the repercussions**
- ✓ **What applications are prone to EMI**
- ✓ **Know what specifications apply to you**
- ✓ **Types of filters**
- ✓ **Basic circuits of “Low Pass” filters**
- ✓ **I/O impedance & selection criteria**
- ✓ **Propagation Modes & Methods of suppression**
- ✓ **Timing impact**

What are the repercussions?

- ☑ **Cause catastrophic system failure in avionics equipment, or a piece of medical instrumentation may provide a false vital sign on a patients condition.**
- ☑ **This electrical energy could simply cause poor quality reception, & possible dropped calls and other system deteriorating**

What applications are prone to EMI?

- ✓ **Microcell Repeaters**
- ✓ **Switching Power Supplies**
- ✓ **RF Amplifiers**
- ✓ **Frequency Synthesizers**
- ✓ **Linear Power Amplifiers**
- ✓ **Medical Electronics**
- ✓ **Digitally Tuned Oscillators**
- ✓ **Automotive Controls**

Standards & Specifications



North America

- FCC Part 15- Telecommunications Industry**
- FDA Regulations: Medical Industry**
- Mil - STD- 461 and DO160: Military and Aerospace Industry**



Standards & Specifications Cont'd.

European Regulations

European Directive 89/336/ EEC: Regulation for all electronic devices and electrical equipment used in Europe. All products imported to the European community must conform to these regulations.

Generic Emissions

- EN 50081-1: Residential, Commercial, & Light Industrial**
- EN 50081-2: Industrial Environment**

Specific Emissions

- EN 55011: Conducted & Radiated for Industrial, Scientific & Medical**
- EN 55014: Conducted & Radiated for Household Appliances**
- EN 55022: Conducted & Radiated for Information Technology Equipment**
- EN 60555-2/3: Harmonics & Voltage Fluctuations in Household Equipment. Deals with Power Factor Corrections**



Standards & Specifications Cont'd.

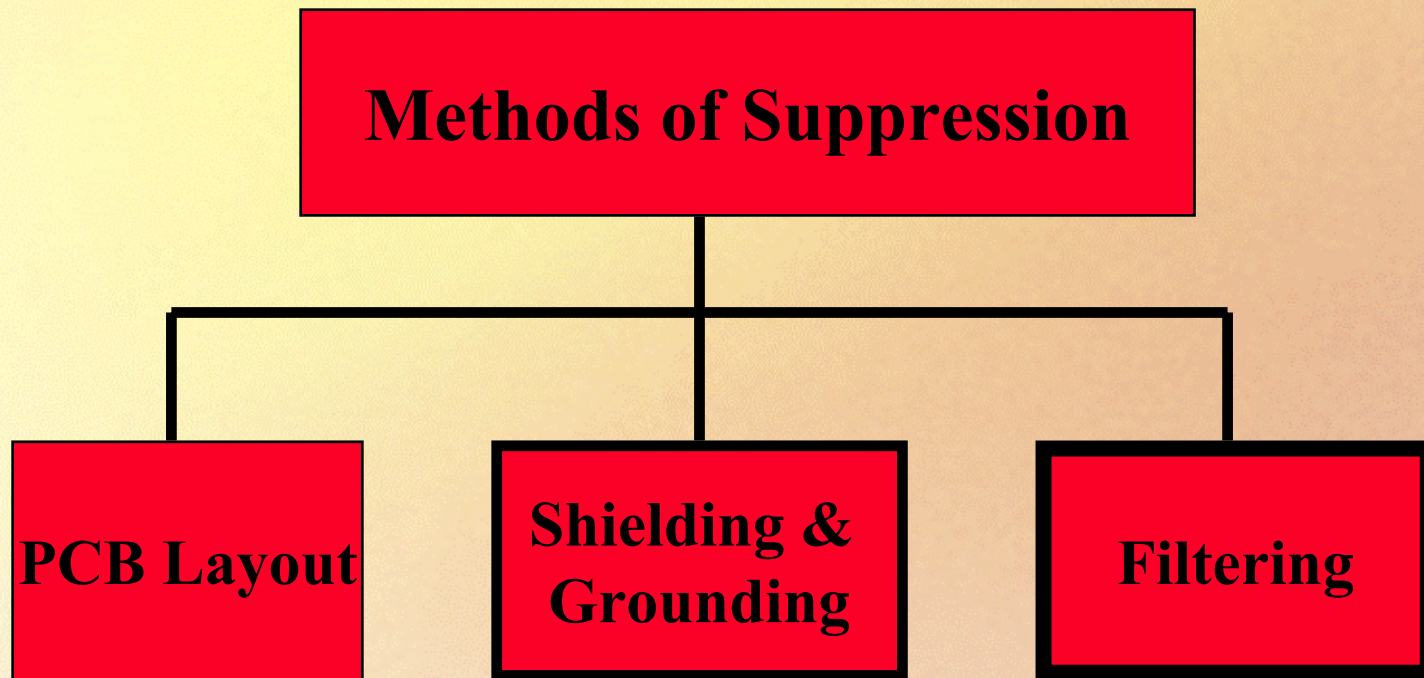
European Regulations Cont'd

Generic Immunity

- ☑ EN 50082-1: Residential, Commercial, & Light Industrial
- ☑ EN 50082-2: Industrial Environment

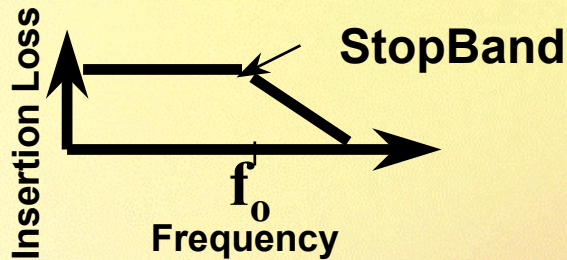
Specific Immunity

- ☑ EN 61000-4-1: Basic Immunity document, not a specific test
- ☑ EN 61000-4-2: ESD, Electrostatic Discharge
- ☑ EN 61000-4-3: Radiated RF Fields, radiated immunity
- ☑ EN 61000-4-4: EFT, Electrical Fast Transients, AC mains and I/O cable conducted immunity.
- ☑ EN 61000-4-5: Surge, AC mains conducted immunity
- ☑ EN 61000-4-6: Conducted RF Fields
- ☑ EN 61000-4-8: Power frequency magnetic field immunity
- ☑ EN 61000-4-9: Pulsed magnetic field immunity
- ☑ EN 61000-4-10: Damped Oscillatory field immunity
- ☑ EN 61000-4-11: Voltage dips, interruptions, and variations

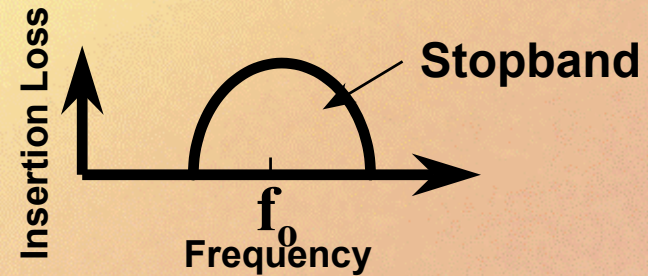


Types of Filters

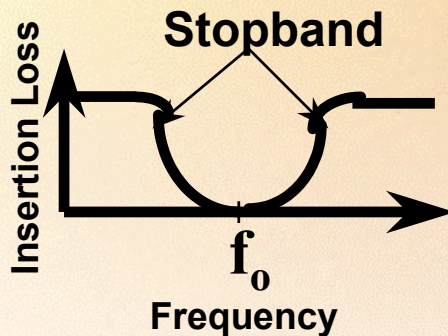
- **High Pass**



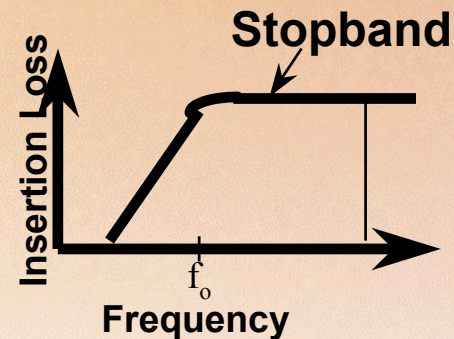
- **Band Reject**



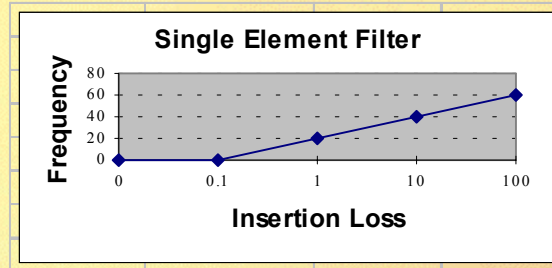
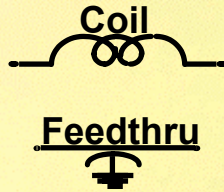
- **Band Pass**



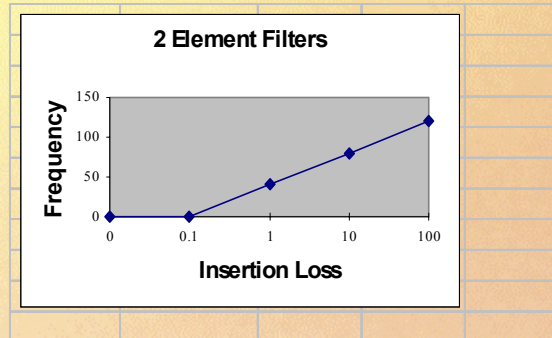
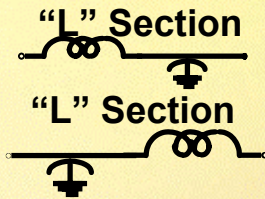
- **Low Pass**



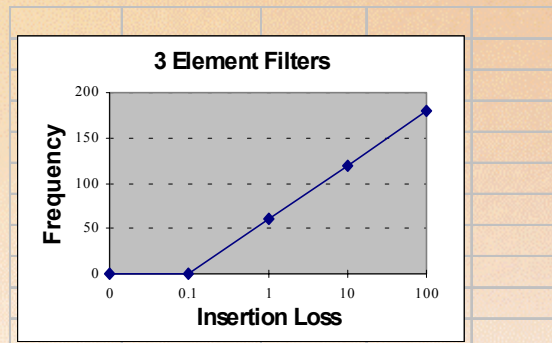
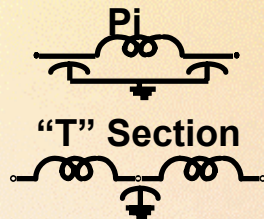
The Basic Circuits of Low Pass Filters Using a 50 ohm Source & 50 ohm Load



20 dB per Decade

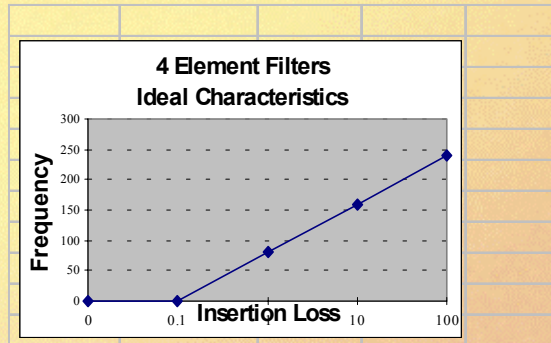
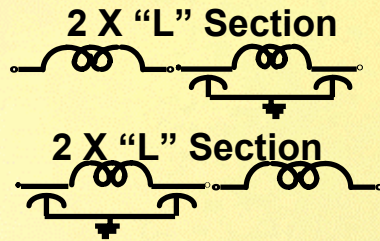


40 dB per Decade

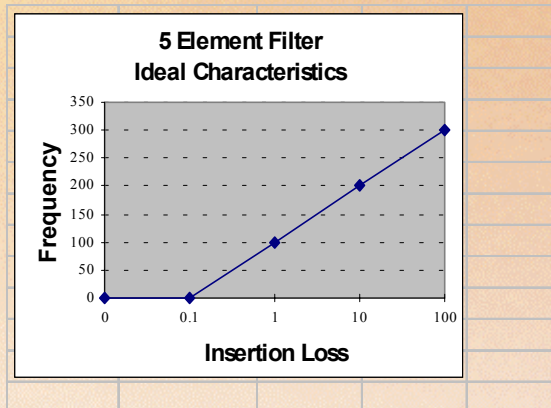
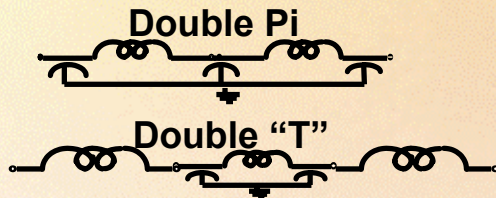


60 dB per Decade

The Basic Circuits of Low Pass Filters Using a 50 ohm Source & 50 ohm Load



80 dB per
Decade


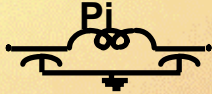
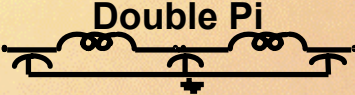
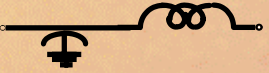
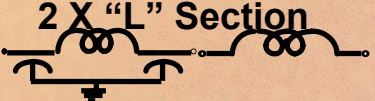
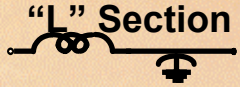
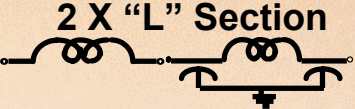


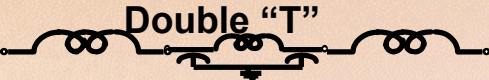


100 dB per
Decade

I/O Impedance & Selection Criteria

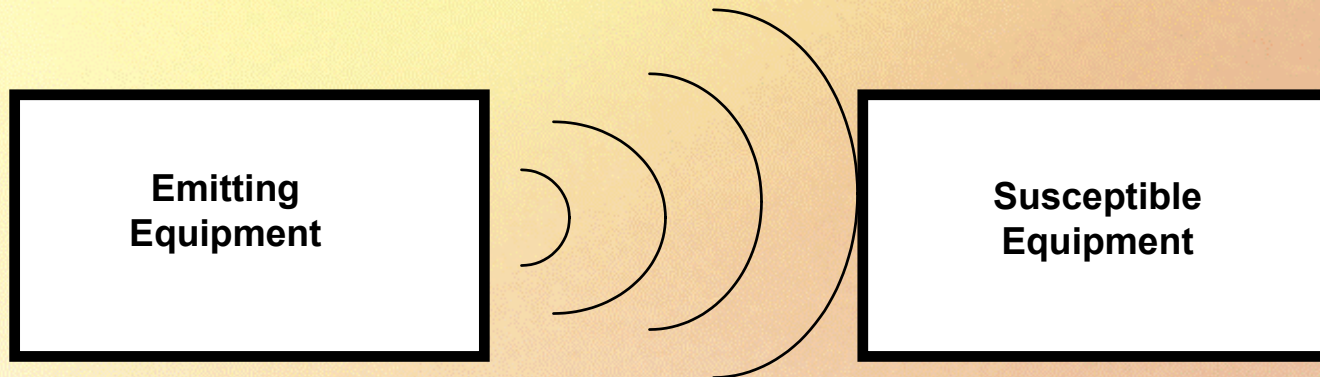


SPECTRUM CONTROL, INC.

		Output Impedance (Z_o)	
		High	Low
Input Impedance (Z_i)	High	<p>Feedthru</p>  <p>Pi</p>  <p>Double Pi</p> 	<p>"L" Section</p>  <p>2 X "L" Section</p> 
	Low	<p>"L" Section</p>  <p>2 X "L" Section</p> 	<p>Coil</p>  <p>"T" Section</p>  <p>Double "T"</p> 

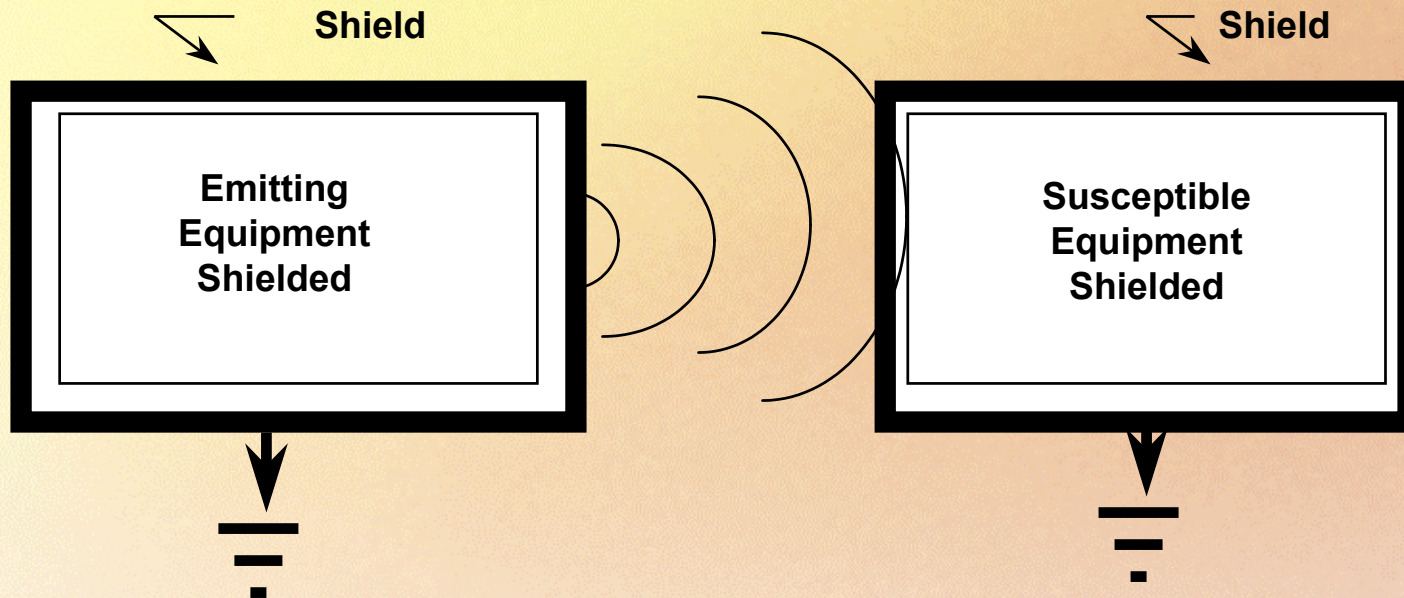
Propagation Modes

Radiated Emissions



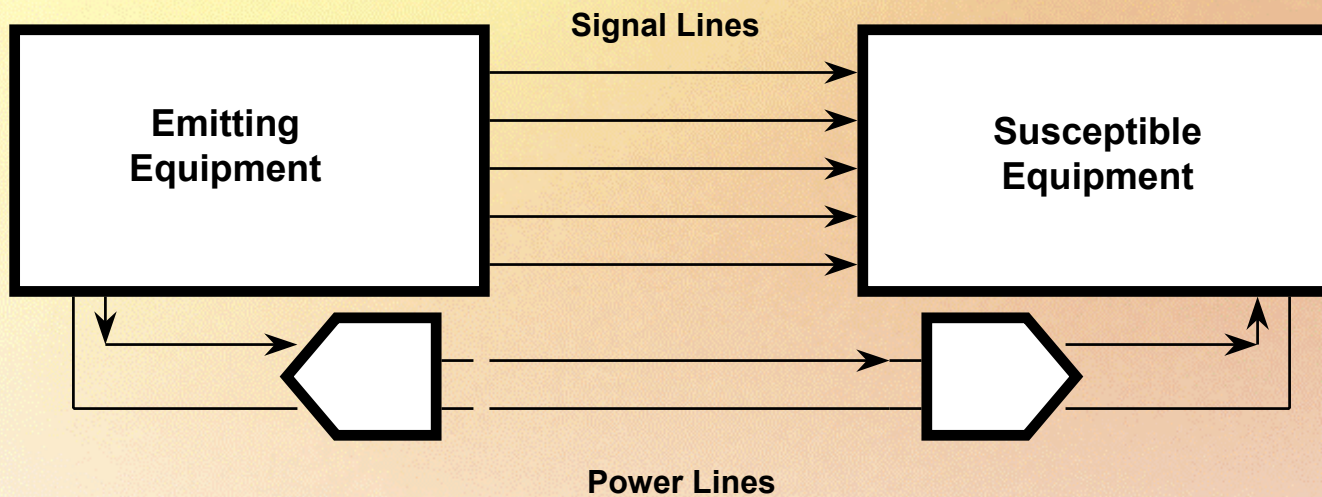
Methods of Suppression

Radiated Emissions - Shield



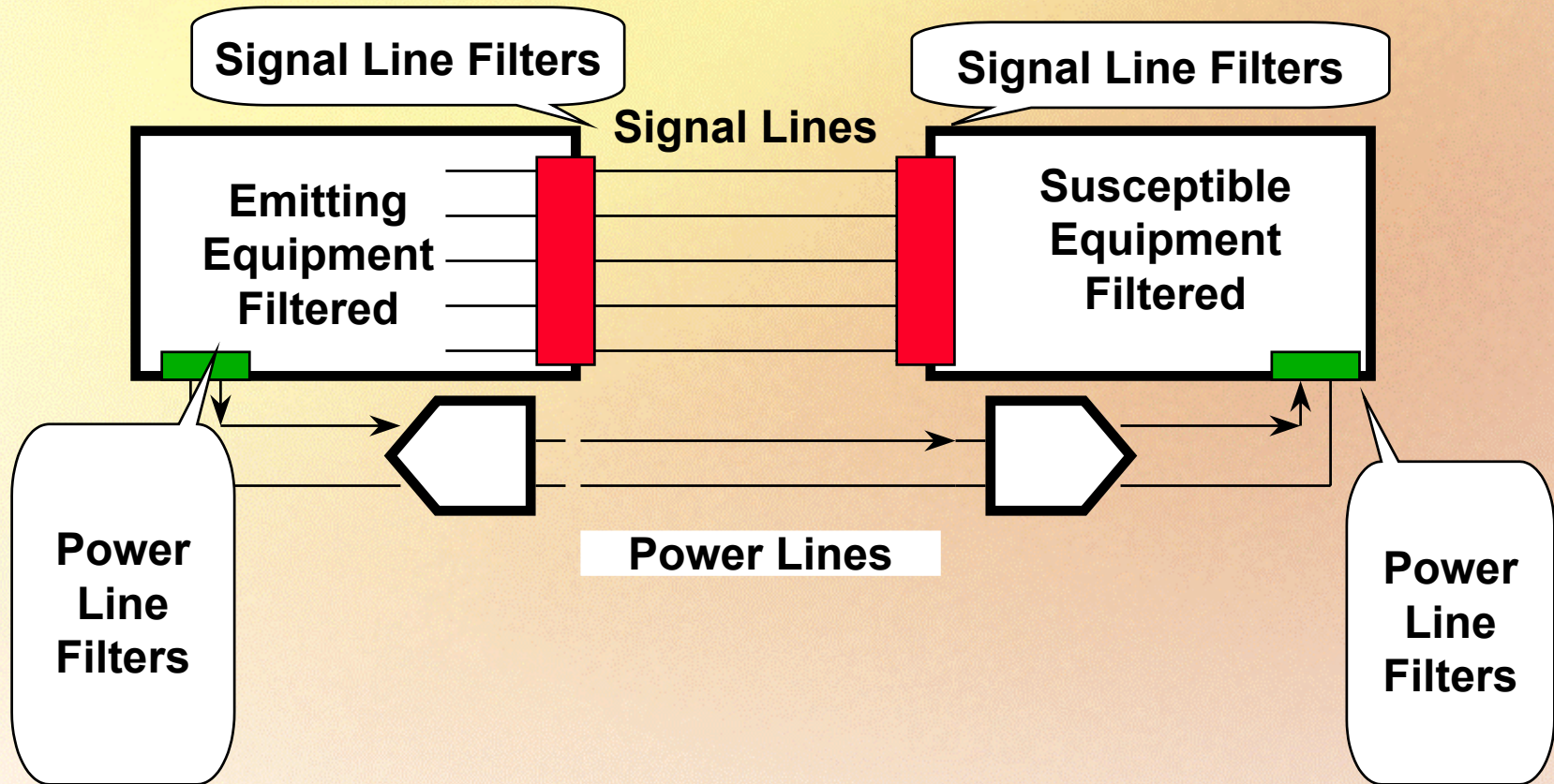
Propagation Modes

Conducted Emissions



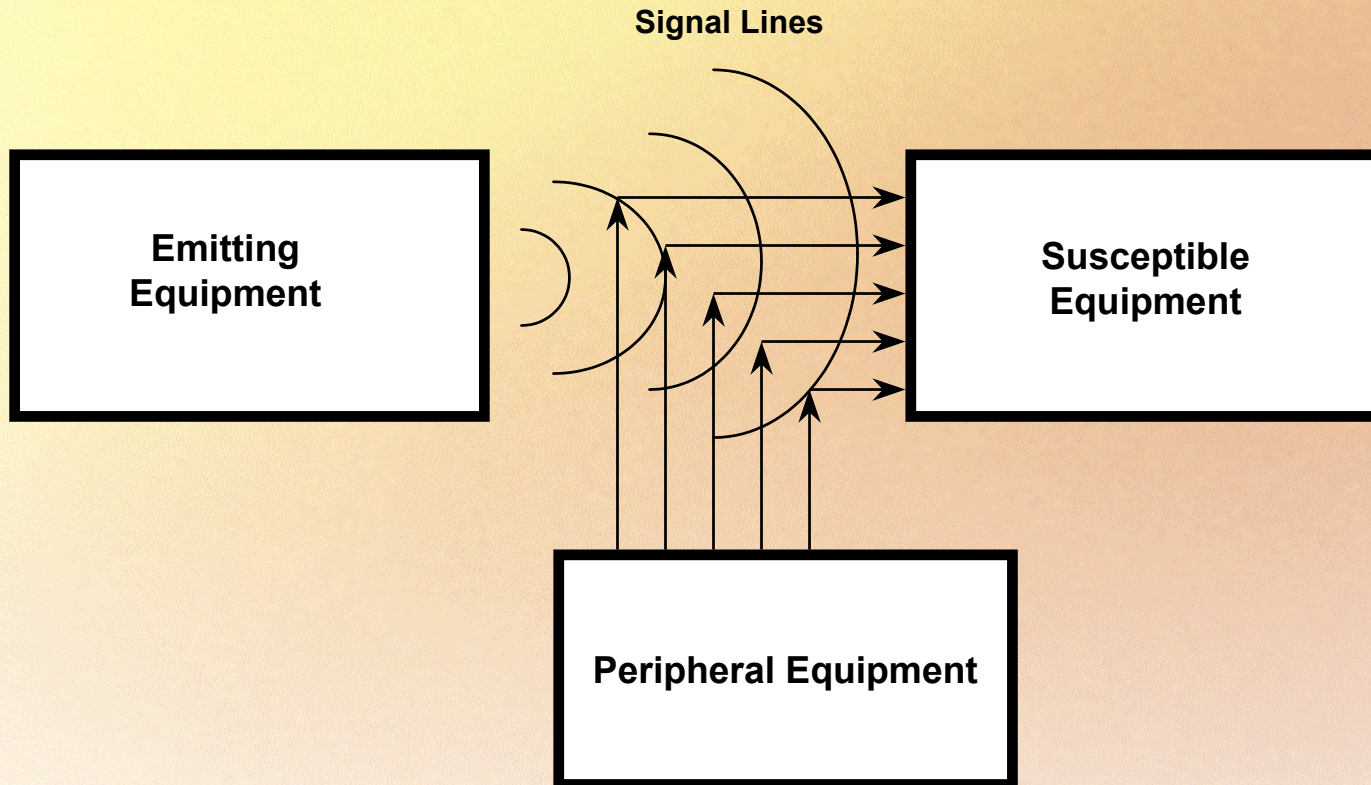
Methods Of Suppression

Conducted Emissions - Filters



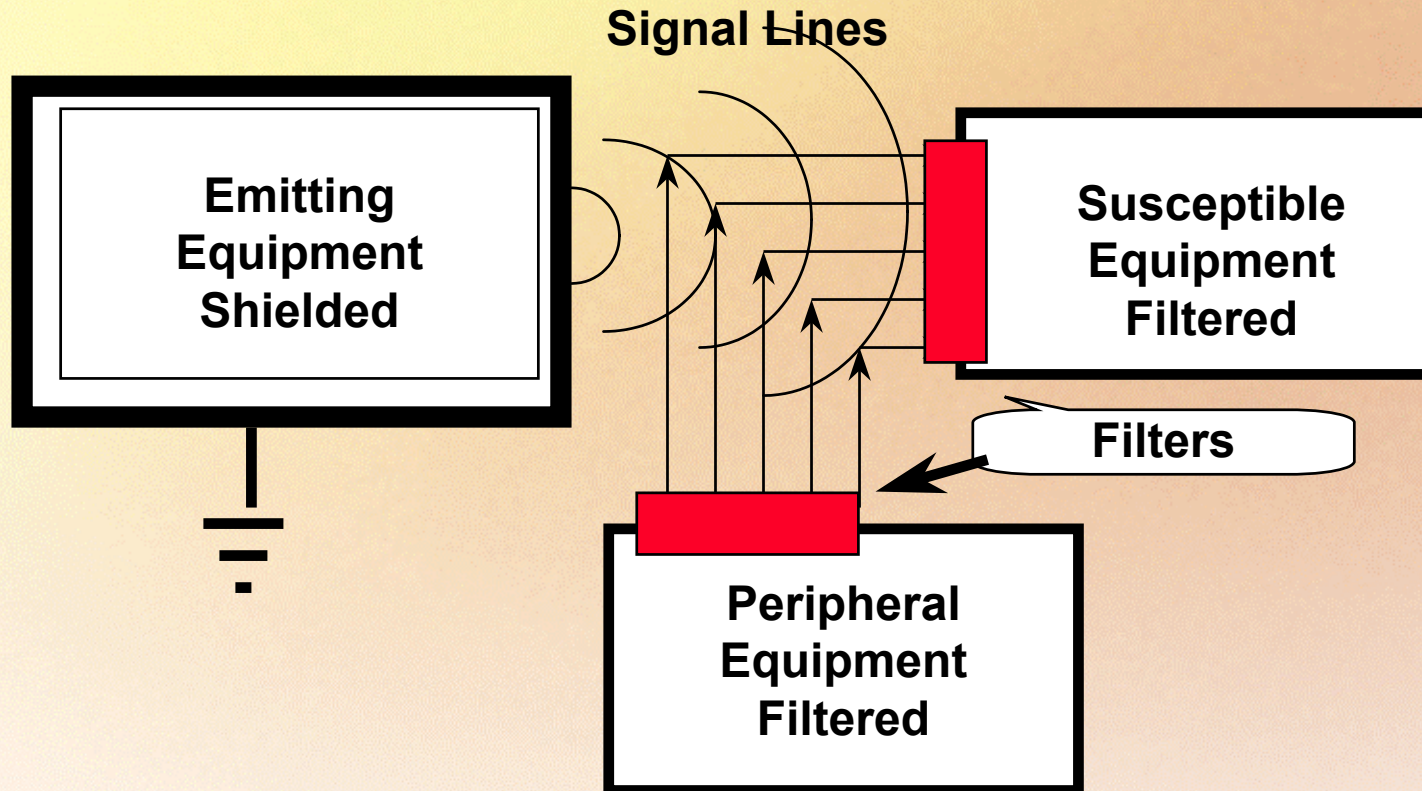
Propagation Modes

Radiated Conducted



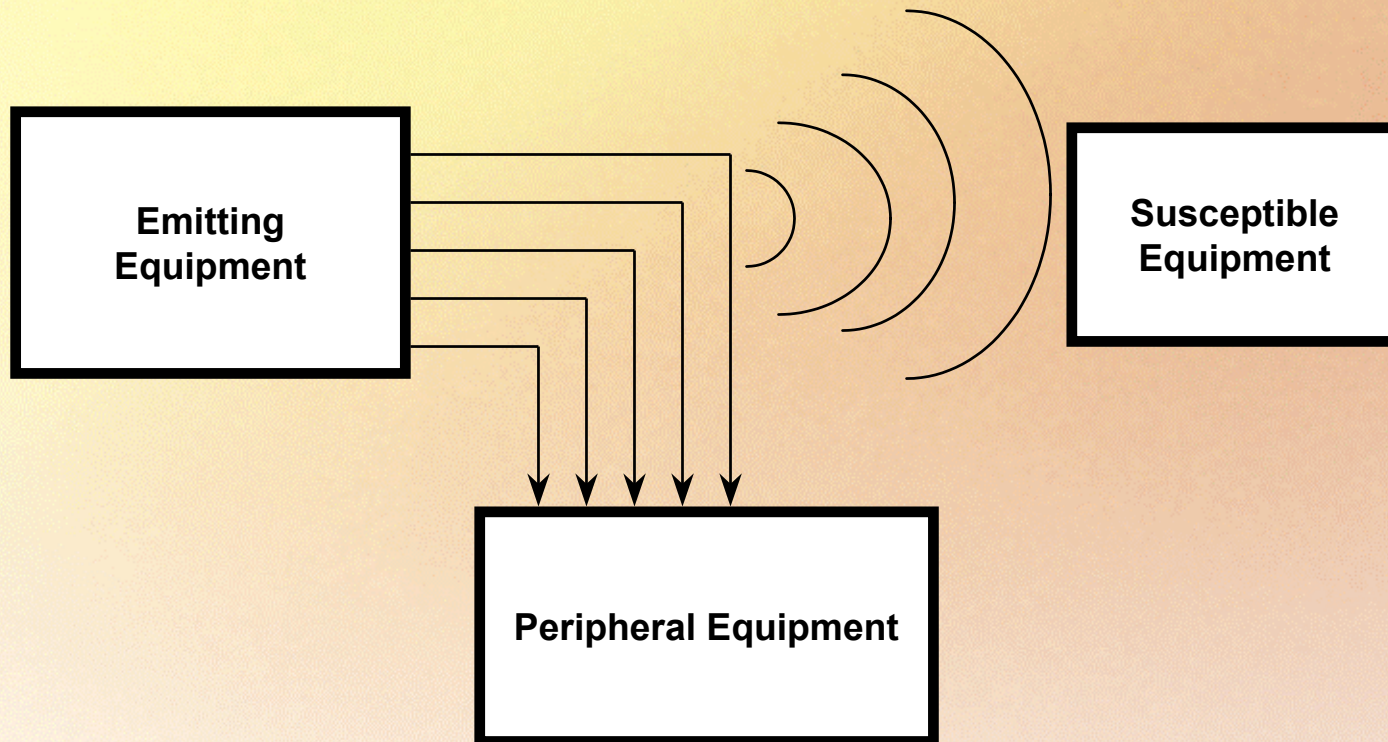
Methods of Suppression

Radiated Conducted-Shield / Filters



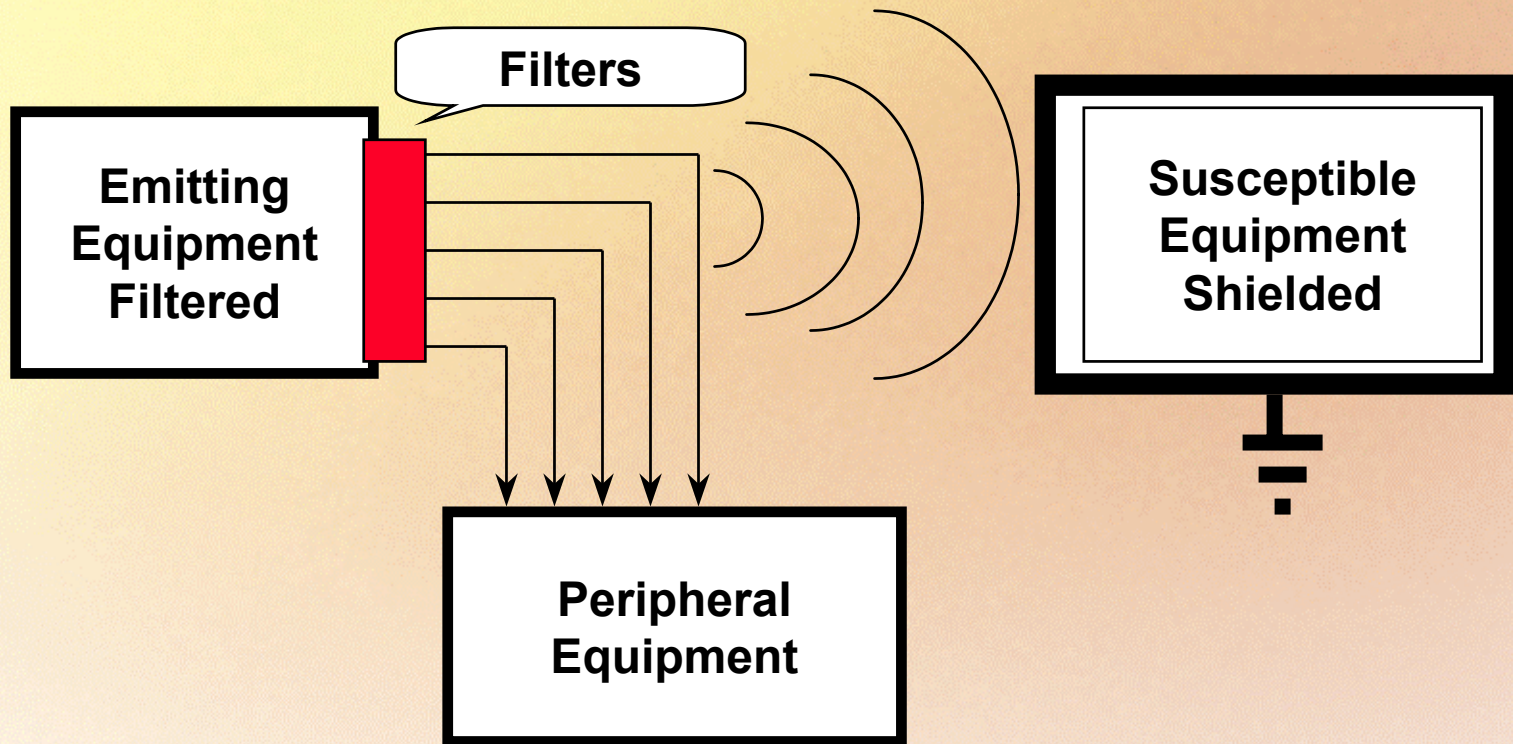
Propagation Modes

Conducted Radiated



Methods of Suppression

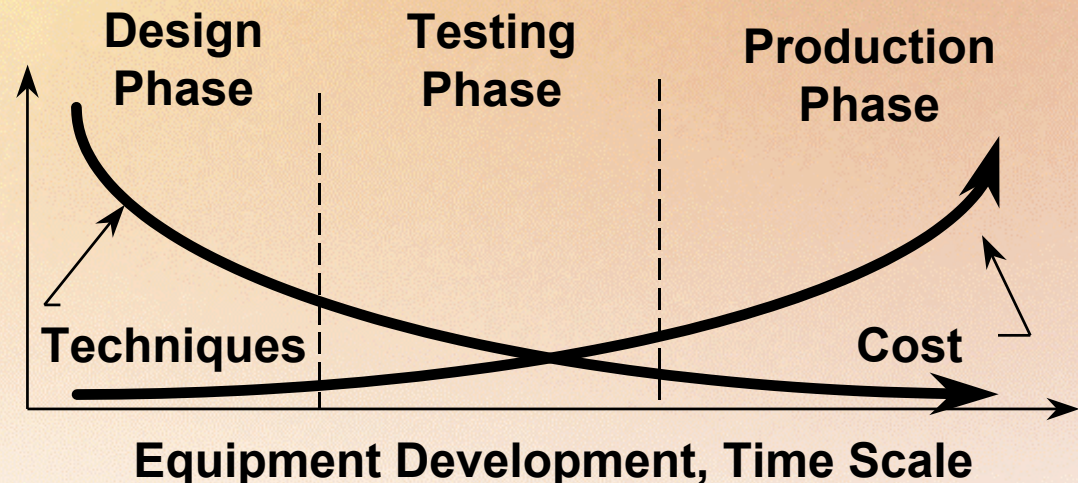
Conducted Radiated - Filter / Shield



Timing Impact

- /// The further along in the design cycle, the more challenging & more costly the solution.
- /// Consult and ask questions from the go, it may save you a considerable sum of money in design time and components.

Available techniques and relative cost to solve a noise problem



The Ten Commandments of Electromagnetic Compatibility

Ten Commandments of Electromagnetic Compatibility



- 1. Create control plan and tabulate all known frequencies and waveshapes to predict EMI profile.**
- 2. Filter Power Lines at immediate entry point.**
- 3. Filter all I/O lines and signal lines with selected tailored passband response filters.**
- 4. Design all modules to have an aluminum stiffener backplane under P.C board that bonds to printed circuit commons.**
- 5. Use multilayer boards wherever possible to contain fast rise time energy.**

Ten Commandments of Electromagnetic Compatibility



- 6. Monitor Surface resistivity of plating on all metal finishes to maintain less than 3 milliohms per square centimeter R.**
- 7. Install ferrite cores / beads over input power lines and signal lines, coax lines etc. to minimize common mode emissions.**
- 8. Twist all pairs of wires at 18 turns per foot to minimize magnetic pickup.**
- 9. Shield and wiper ground / bond all backplanes and interfaces to modules.**
- 10. Close or interbond all apertures and gaps longer greater than Λ (wavelength) / 20.**

Ten Commandments of Electromagnetic Compatibility



- 1. Create control plan and tabulate all known frequencies and waveshapes to predict EMI profile.**

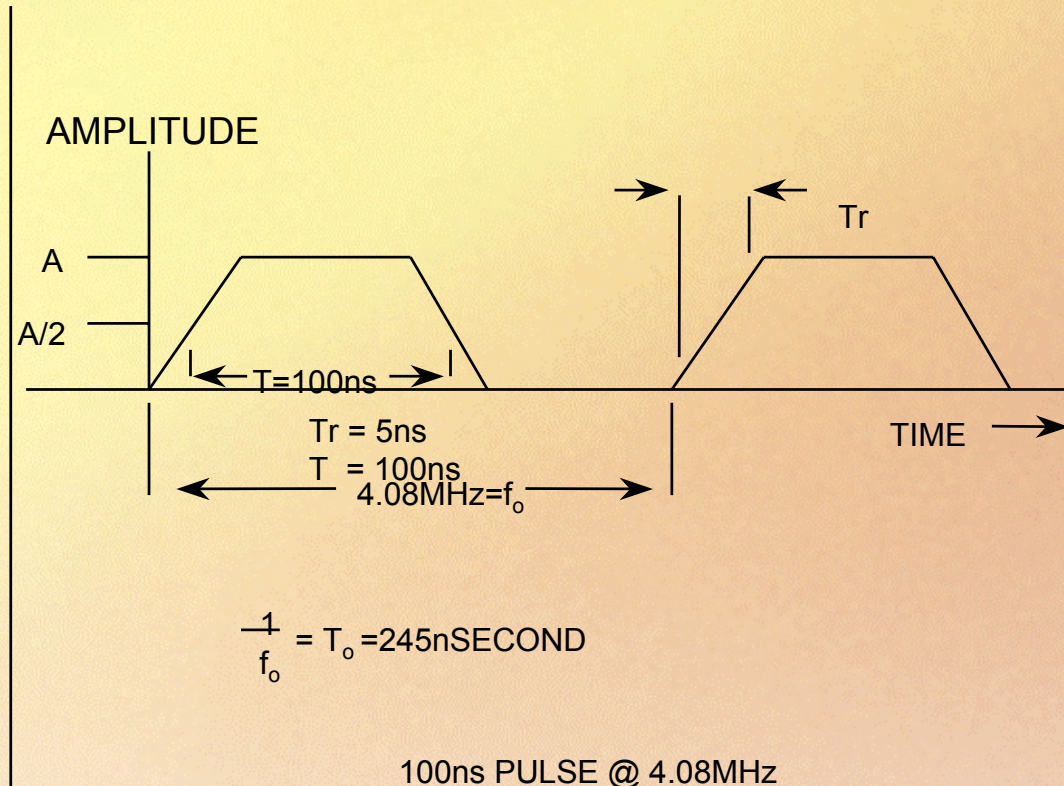
1992 European EMC Standards



Emission Standards: EN 55 022 Class B (Conducted Emission Radiated Emission)

	Freq Range	Limits
Radiated	30 - 230 MHz 230 - 1000 MHz	30 dB μ V/m @ 10 m 37 dB μ V/m @ 10 m
Conducted	0.15 - 0.5 MHz	66 \rightarrow 56 dB μ V quasi pk 56 \rightarrow 46 dB μ V ave
	0.5 - 5 MHz	56 dB μ V quasi pk 46 dB μ V ave
	5 - 30 MHz	60 dB μ V quasi pk 50 dB μ V ave

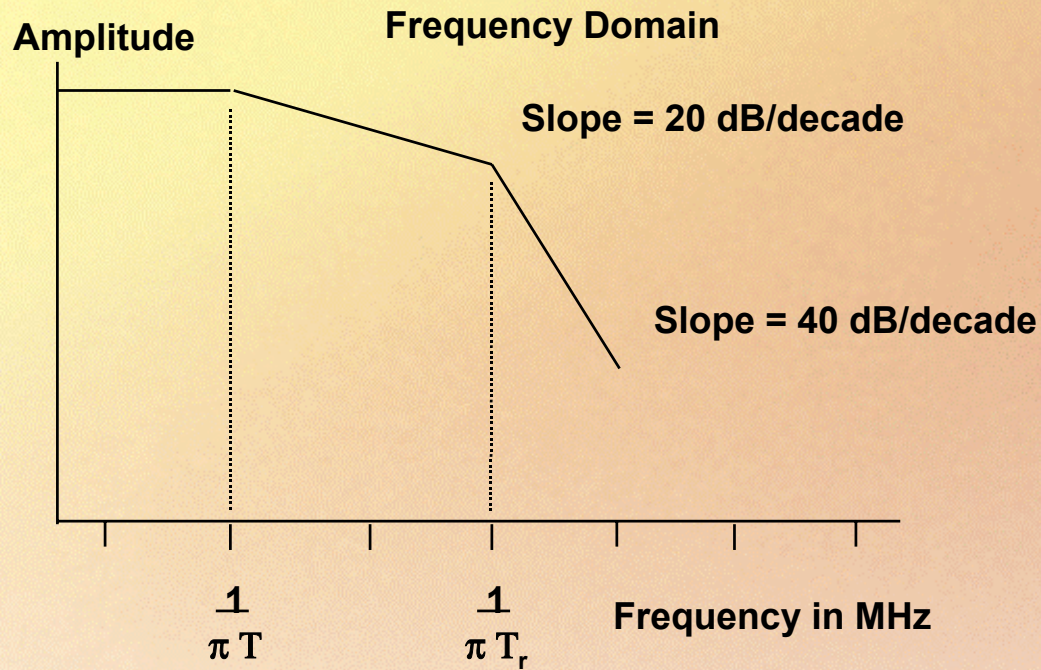
Time Domain



$$\frac{1}{f_o} = T_o = 245\text{nSECOND}$$

100ns PULSE @ 4.08MHz
5 nano second Risetime

Frequency Domain



4.08 MHz Expected Harmonics



	n^{th}	FREQ.		n^{th}	FREQ.
$f = \frac{1}{\pi T} = 3.183 \text{ Mhz}$			40 dB/decade	21	85.68
100 dBuV	1	4.08			
20 dB/decade	2	8.16		22	89.76
	3	12.24		23	93.84
	4	16.32		24	97.92
	5	20.40		25	102.00
	6	24.48		26	106.08
	7	28.56		27	110.16
	8	32.64		28	114.24
	9	36.72		29	118.32
	10	40.80		30	122.40
	11	44.88		31	126.48
	12	48.96	65 dBuV (- 12 dB) $f = 2 \times \pi \times \tau_p = 127.32 \text{ MHz}$		
			40 dB/Decade	32	130.56
	13	53.04		33	134.64
	14	57.12		34	138.72
	15	61.20		35	142.80
77 dBuV $f = \frac{1}{\pi \tau_r} = 63.662 \text{ Mhz}$				36	146.88
40 dB / Decade	16	65.28			
	17	69.36		37	150.95
	18	73.44		38	155.04
	19	77.52		39	159.12
	20	81.60	60.65 dBuV (- 16.35 dB)	40	163.20
			40 dB/decade	41	167.25
					etc.
			37 dBuV	156	636.62
			Frequency List		

Ten Commandments of Electromagnetic Compatibility

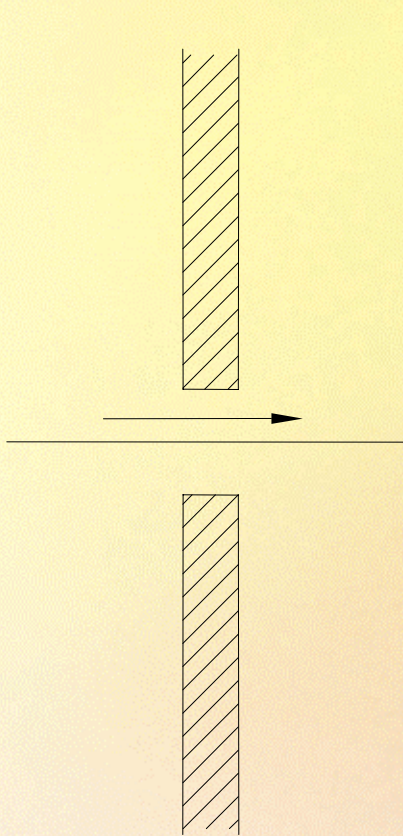


- 2. Filter Power Lines at immediate entry point.**

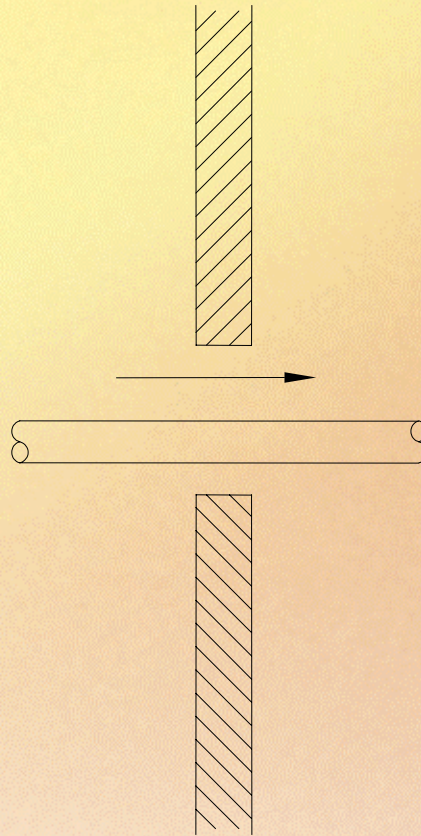


COMMON PENETRATION PATHS INTO EQUIPMENT

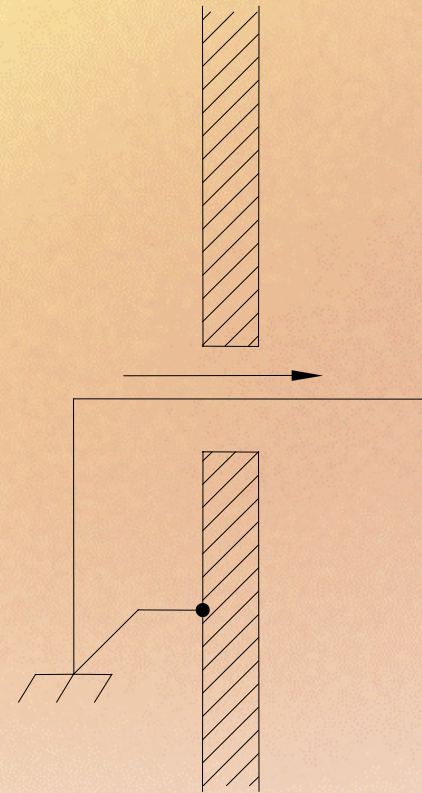
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INSULATED WIRE

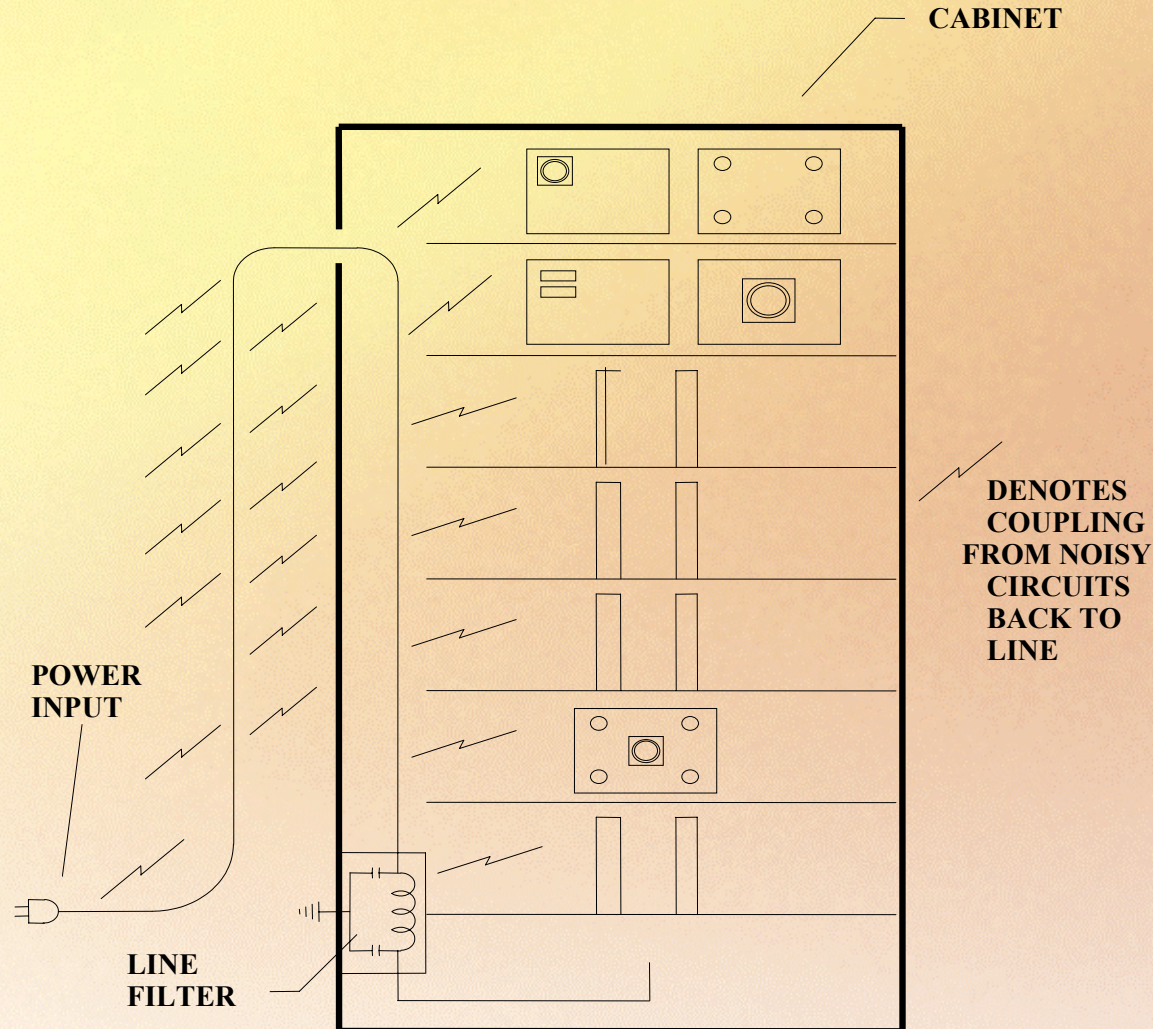


**INSULATED, UNGROUNDED
CABLE SHIELD**

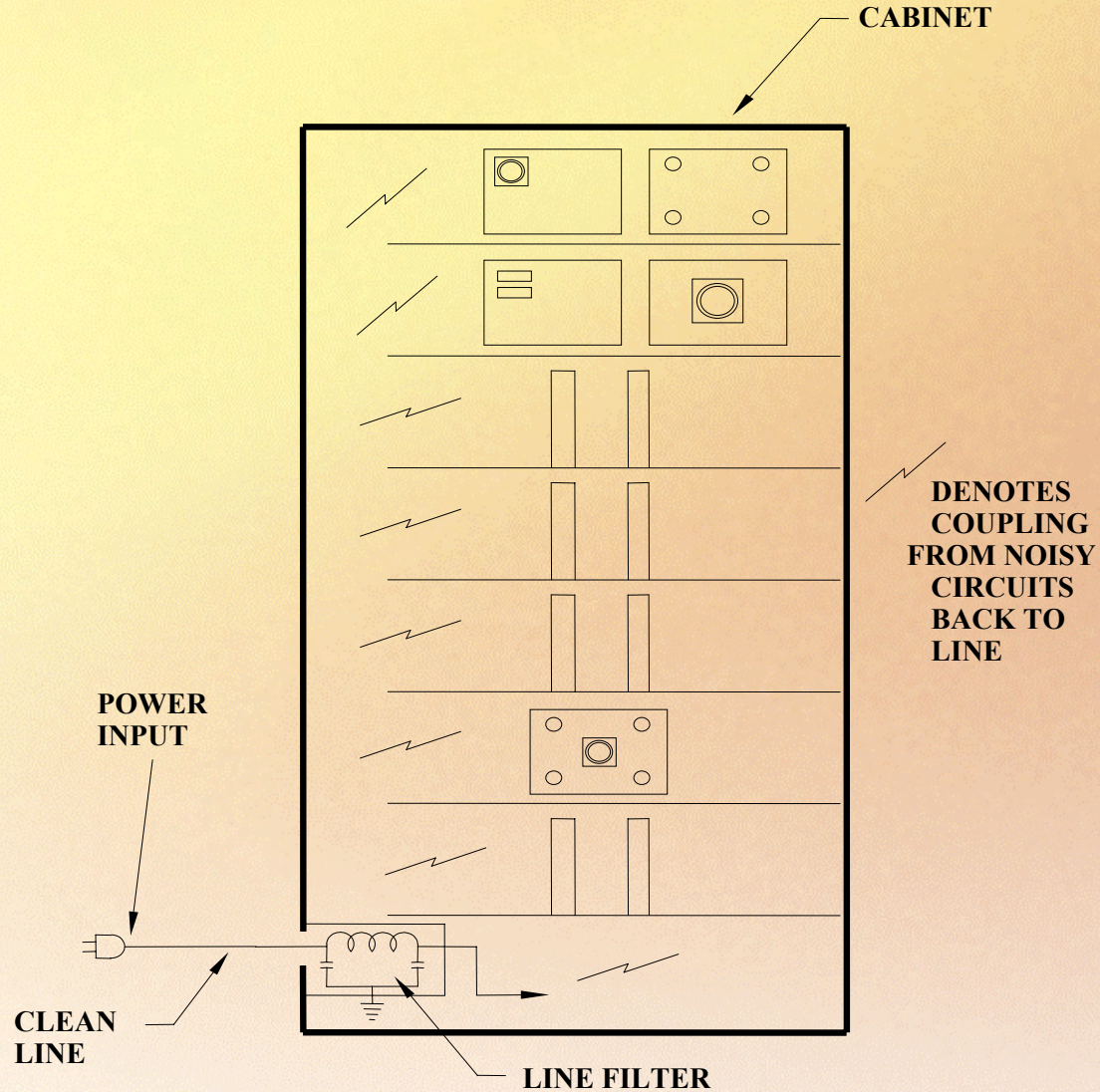


**GROUND
CONDUCTOR**

Wrong Power Filter Installation



Correct Filter Installation

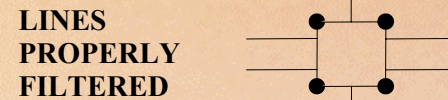
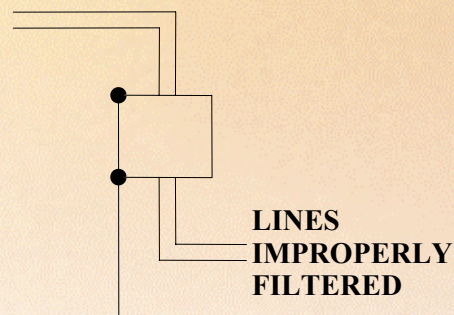
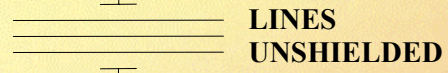
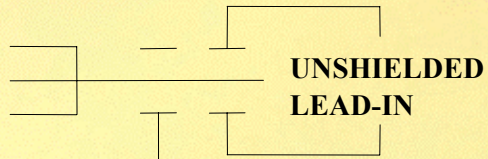


Ten Commandments of Electromagnetic Compatibility



- 3. Filter all I/O lines and signal lines with selected tailored passband response filters.**

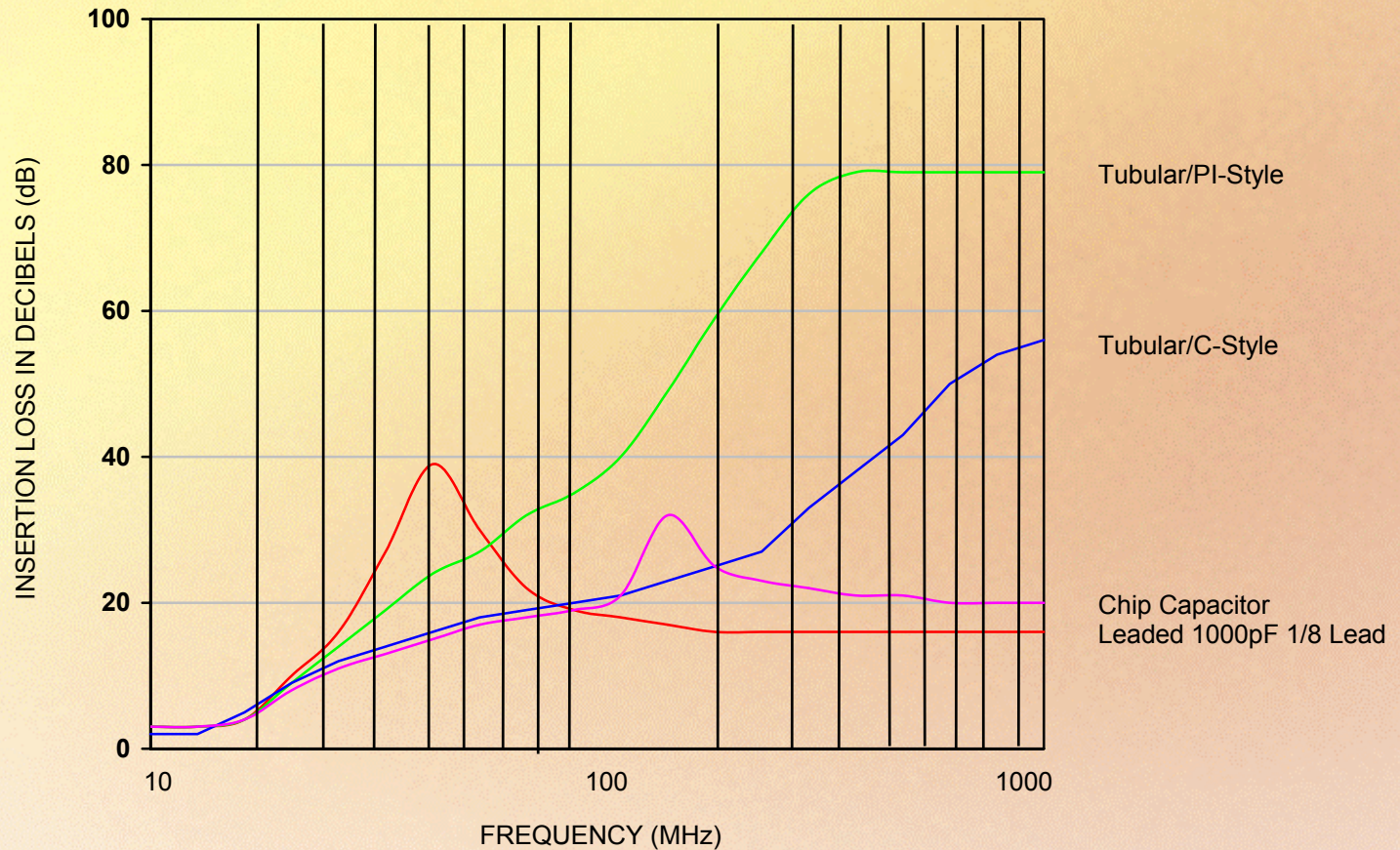
IMPROPER



PROPER

Chip Cap vs. Tubular

1000pF PI-Style vs. C-Style

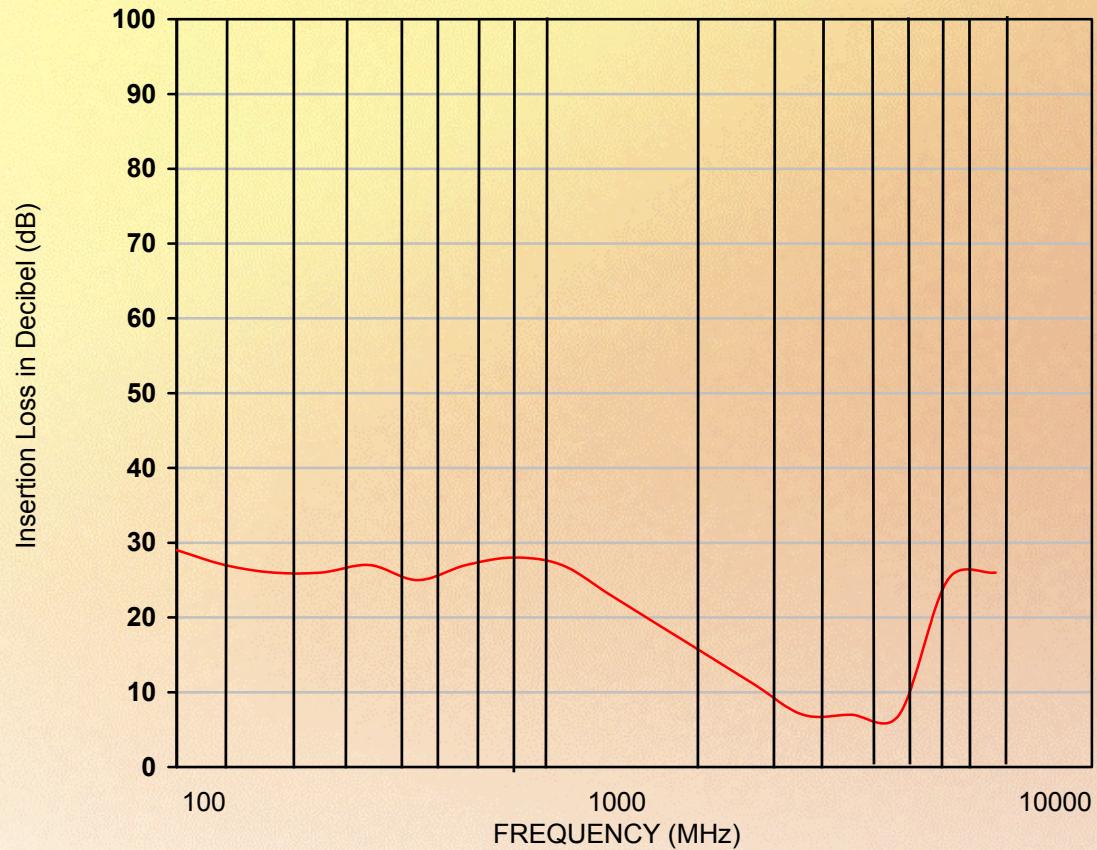


Typical Insertion Loss

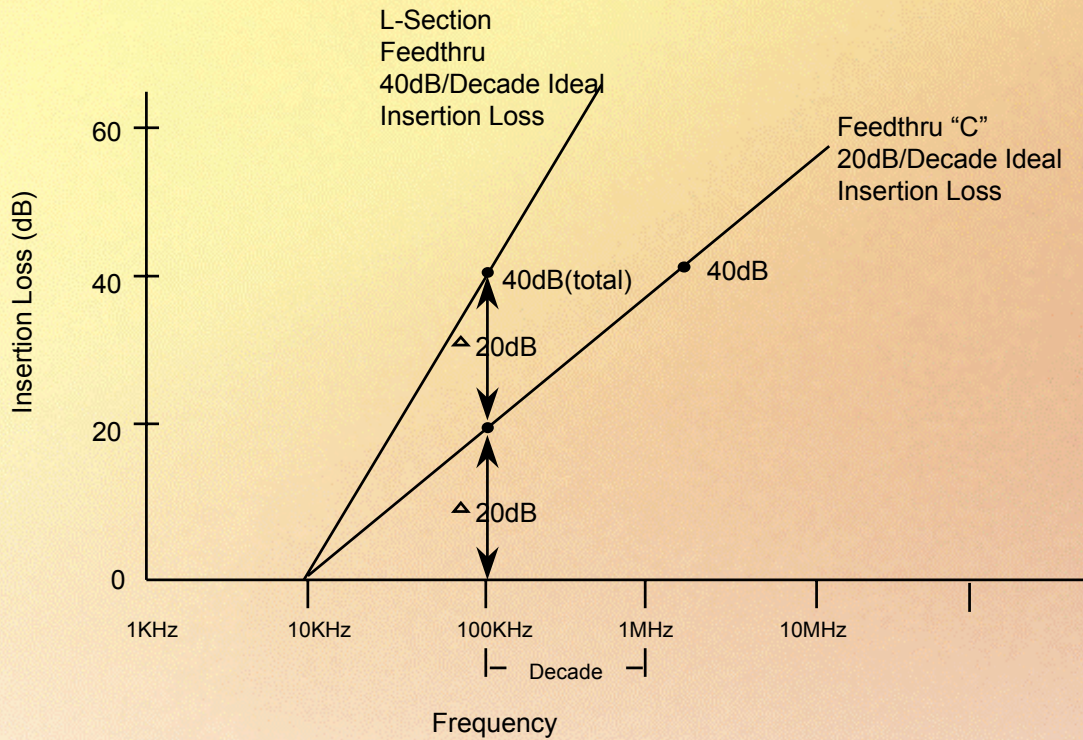
Chip Results Actual



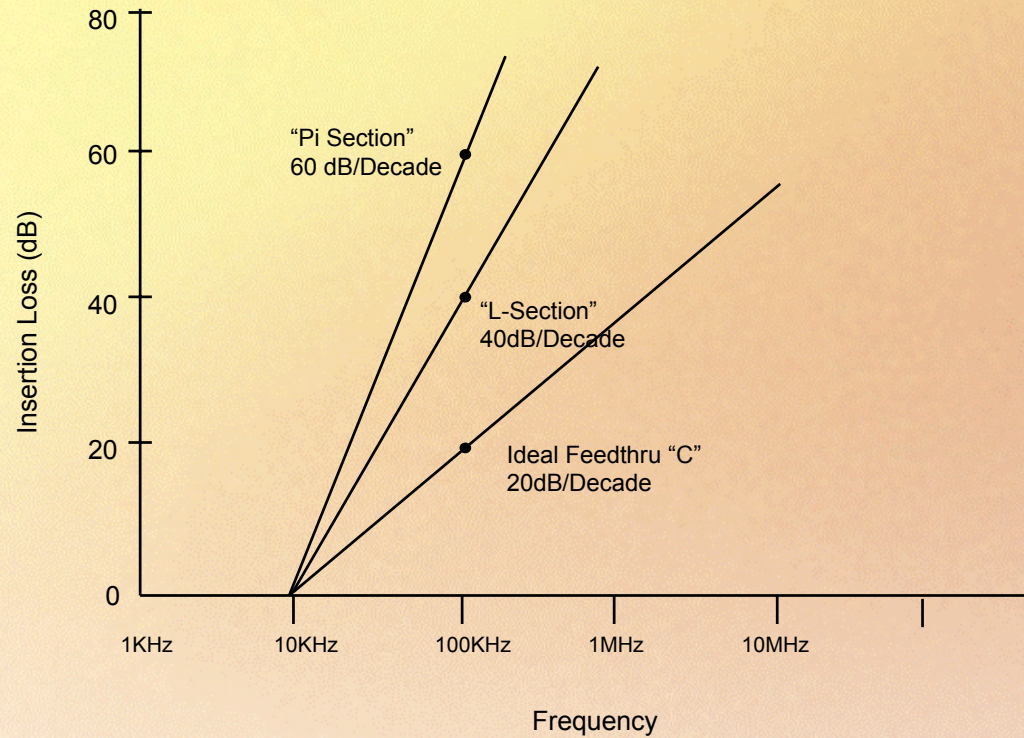
Spectrum Control, Inc.
10,000pF Chip Cap Filter Plate
(Plate tested in a coaxial test fixture)



L-Section Filters



Pi-Section Filters

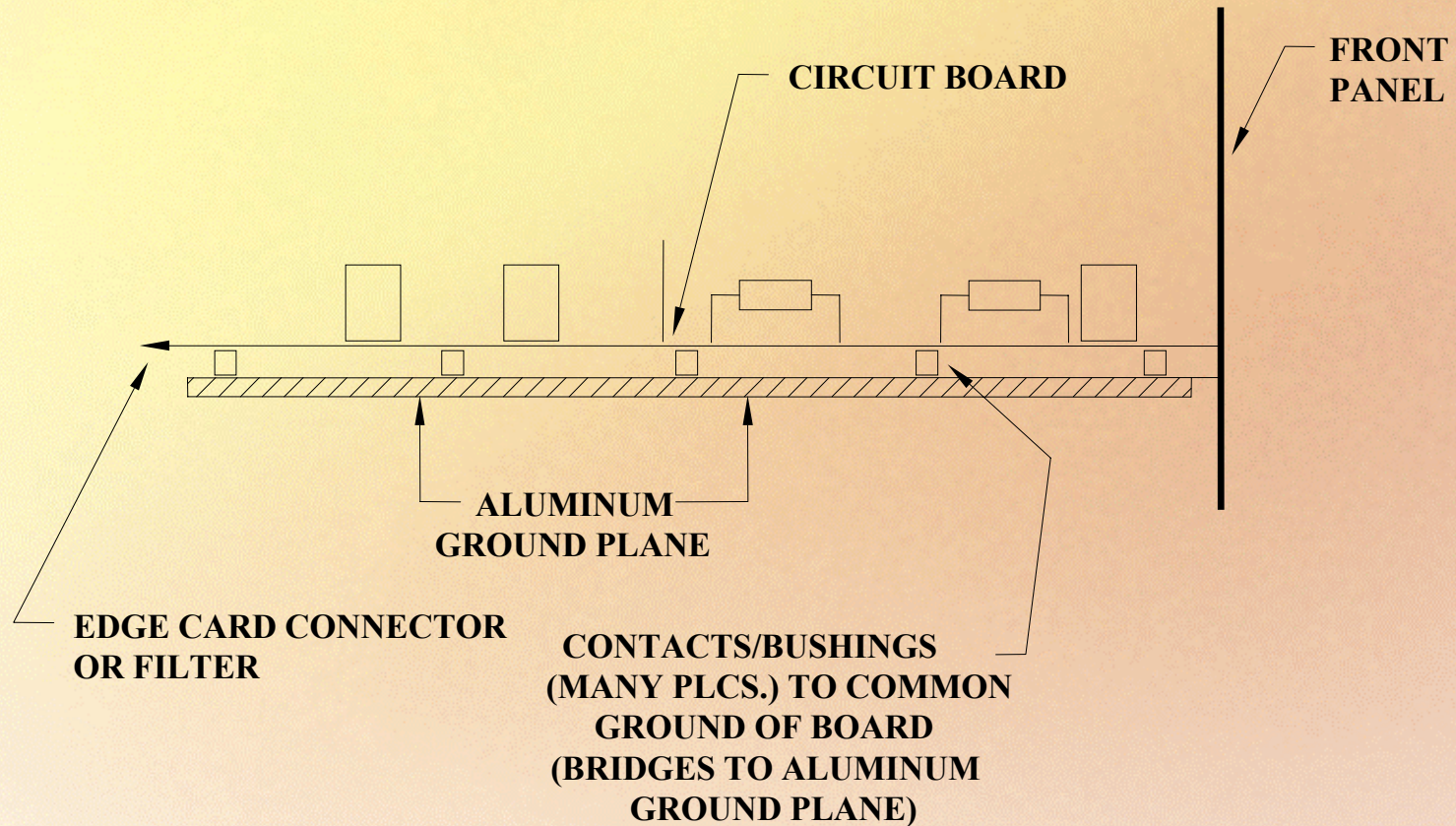


Ten Commandments of Electromagnetic Compatibility



- 4. Design all modules to have an aluminum stiffener backplane under P.C board that bonds to printed circuit commons.**

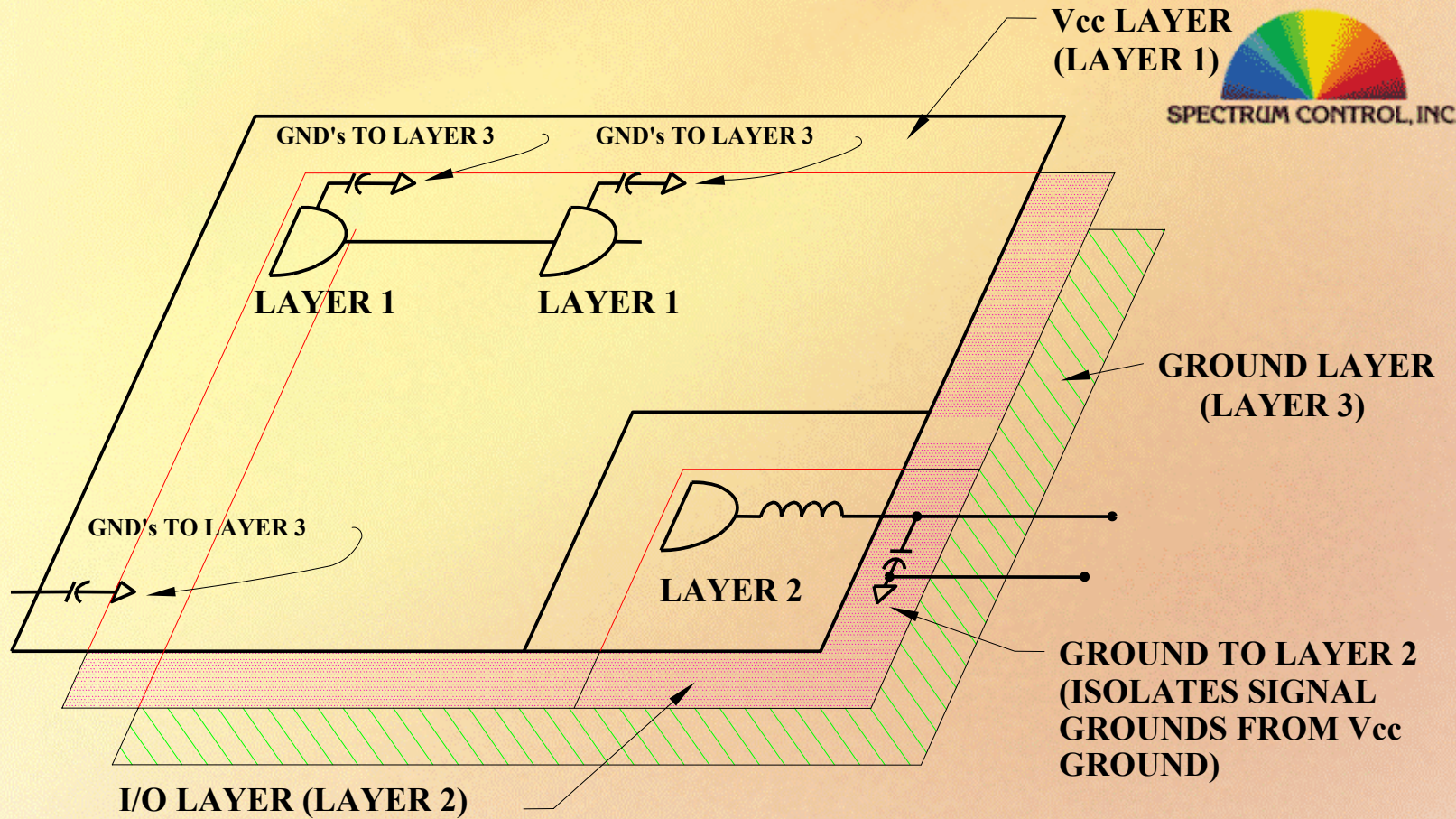
ALUMINUM GROUND PLANE FASTENED TO PRINTED CIRCUIT BOARD



Ten Commandments of Electromagnetic Compatibility



- 5. Use multilayer boards wherever possible to contain fast rise time energy.**

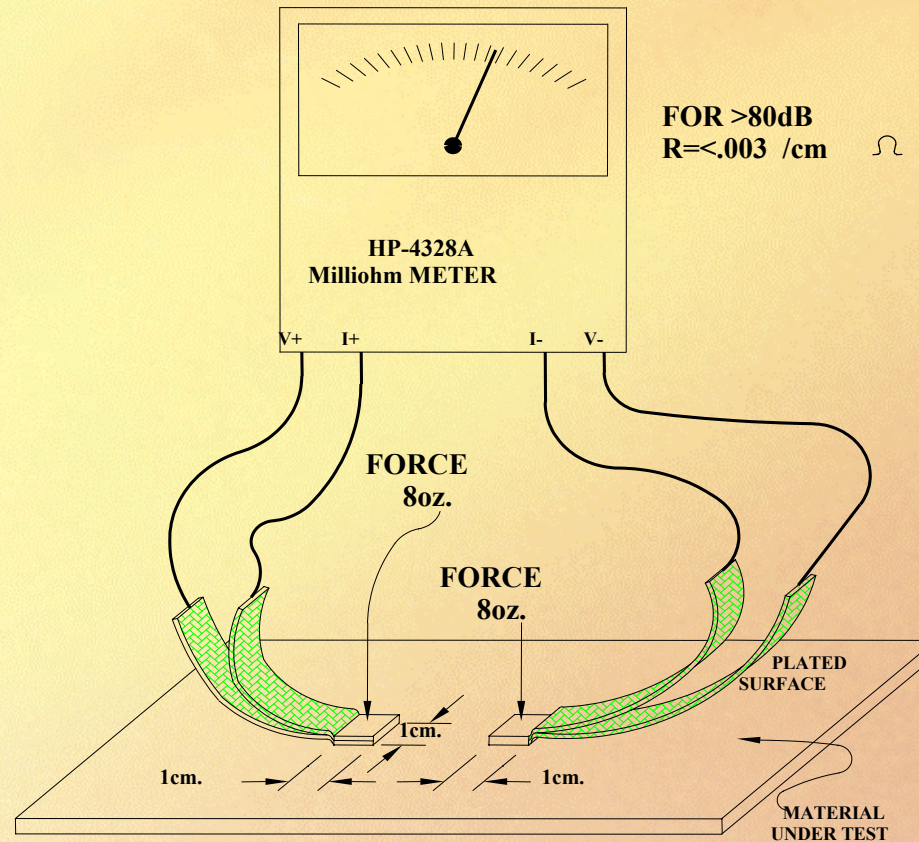


**MULTILAYER PC BOARD
 PROVIDES I/O ISOLATION FROM POWER GROUND
 LAYER 3 SERVES AS Vcc COMMON**

Ten Commandments of Electromagnetic Compatibility



- 6. Monitor Surface resistivity of plating on all metal finishes to maintain less than 3 milliohms per square centimeter R.**



PLATING	80z. Milliohms					
	TIN	.75	.77	.71	.8	.74
YELLOW CHROMATE	17	11	7	10	12	11
UNPLATED EDGE	1.6	1.8	2.0	2.2	1.7	1.8

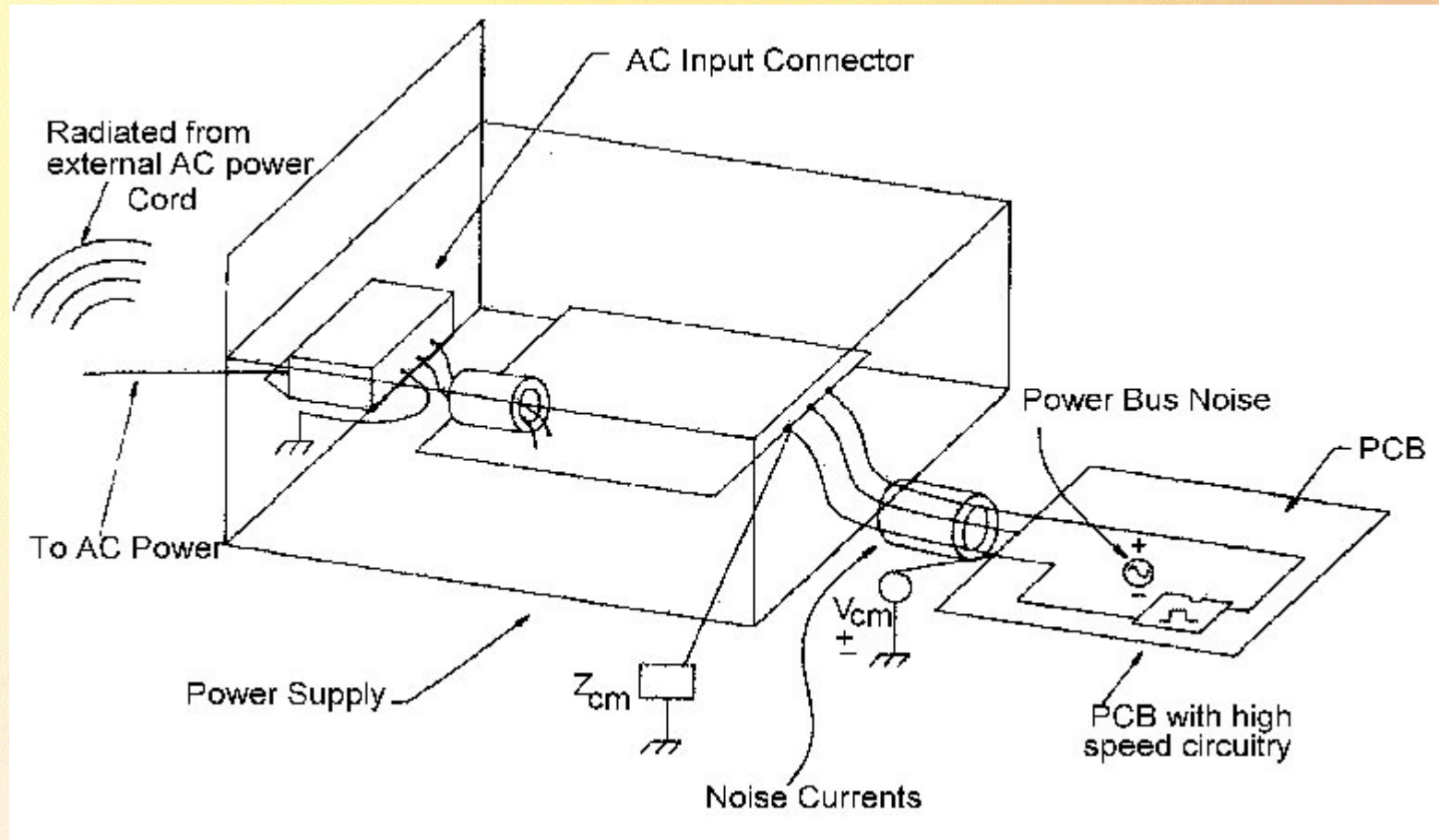
SURFACE RESISTIVITY OF PLATING

Ten Commandments of Electromagnetic Compatibility



- 7. Install ferrite cores / beads over input power lines and signal lines, coax lines etc. to minimize common mode emissions.**

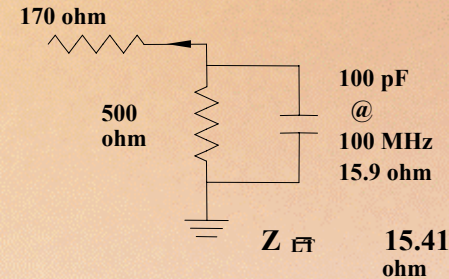
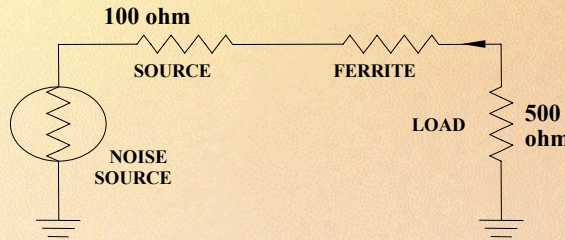
Ferrite Beads



Ferrite Bead Filtering

- Select bead Z at Fo from Data Steward type 25 is 170 ohm @ 100MHz = Zf
- Determine $Z_{source} = 100 \text{ ohm}$, $Z_{load} = 500 \text{ ohm}$

$$20 \log \frac{Z_{SOURCE} Z_{LOAD}}{Z_{f} Z_{SOURCE} + Z_{LOAD}} = 20 \log \frac{100 + 500}{170 + 100 + 500} = 2.16 \text{ dB}$$



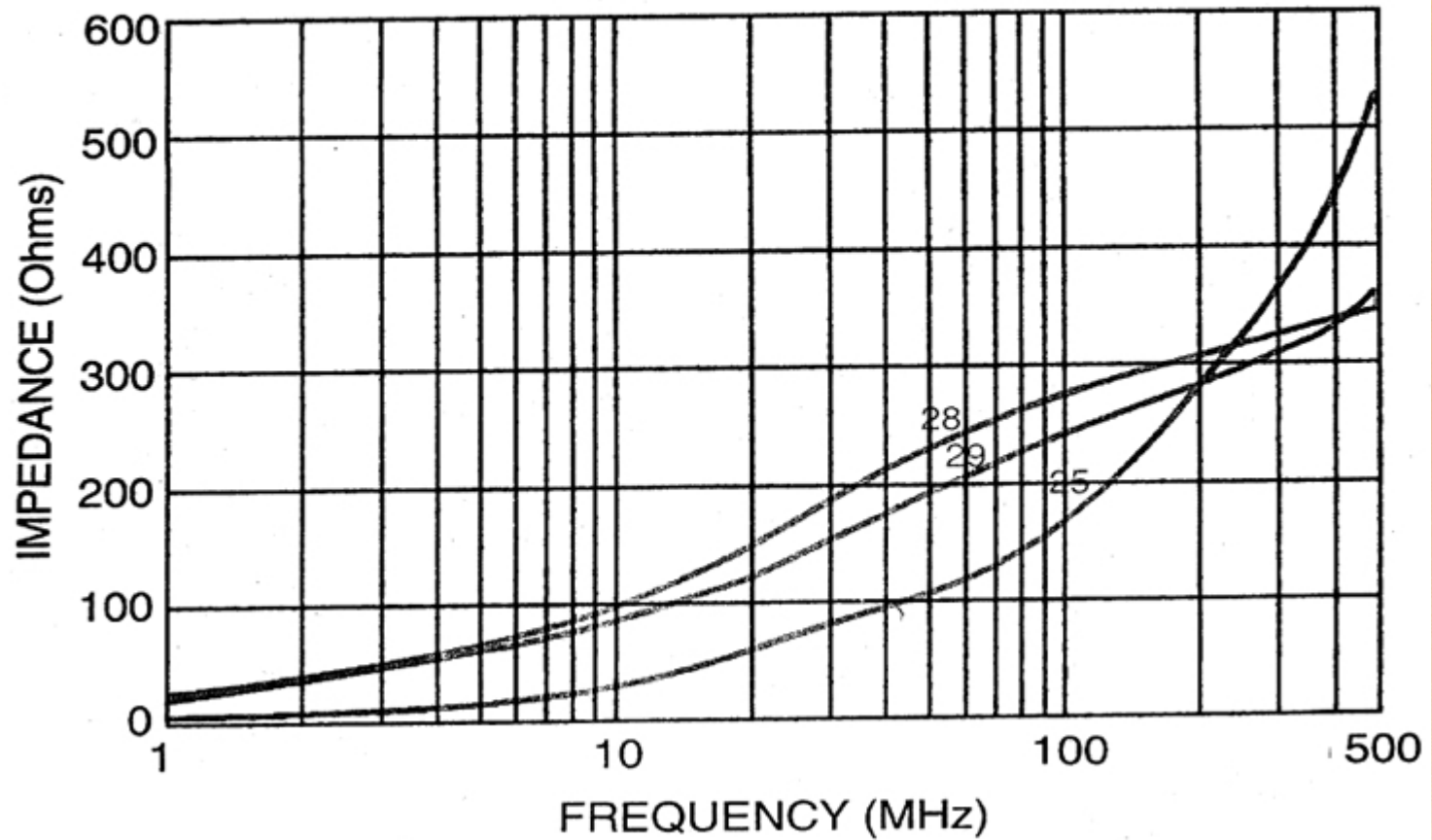
$$20 \log \frac{Z_{SOURCE} Z_{LOAD}}{Z_{f} Z_{SOURCE} + Z_{LOAD}} = 20 \log \frac{100 + 15.41}{170 + 100 + 15.41} = 7.86 \text{ dB}$$



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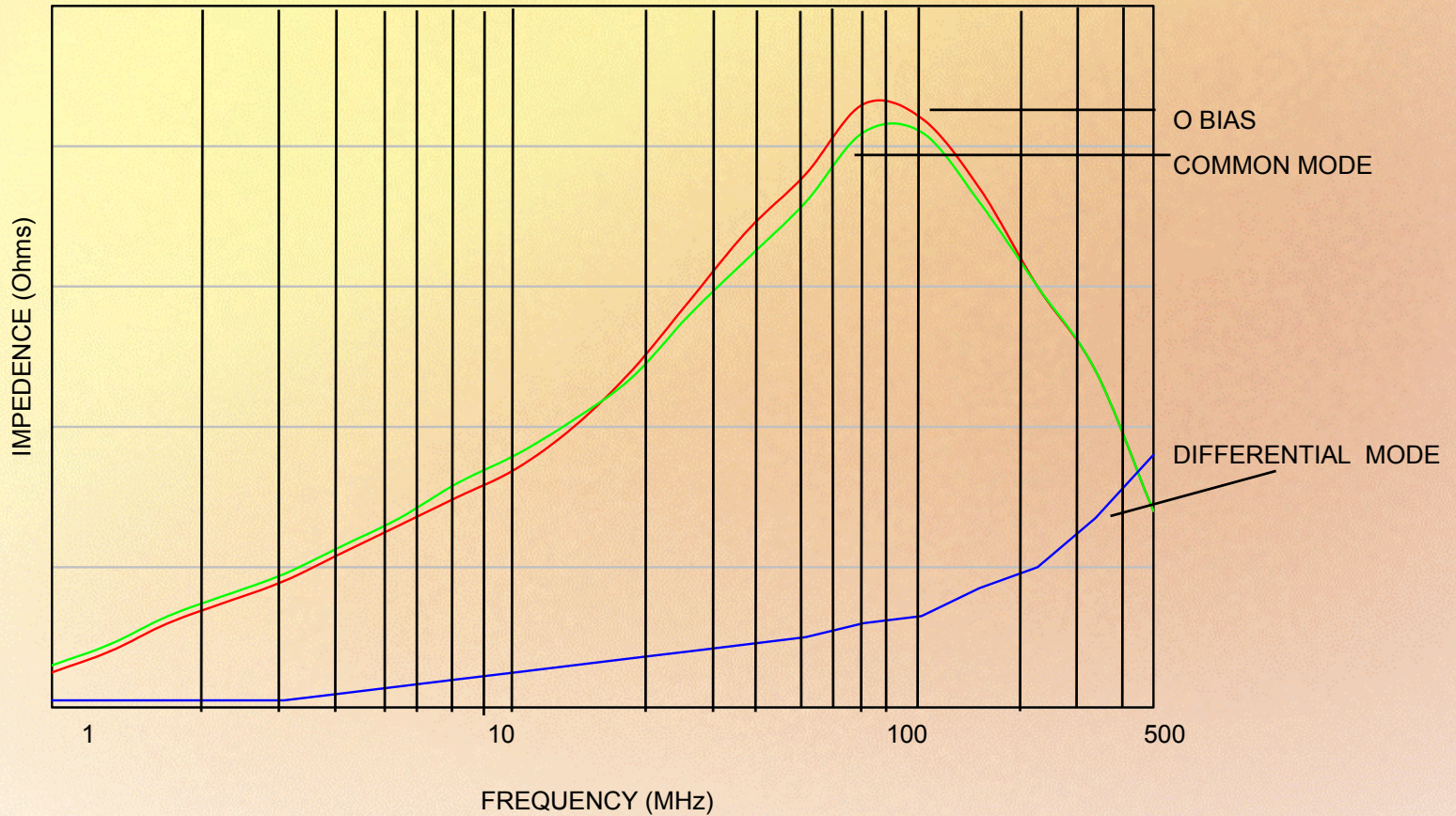
COMPARING MATERIALS

BO562-200



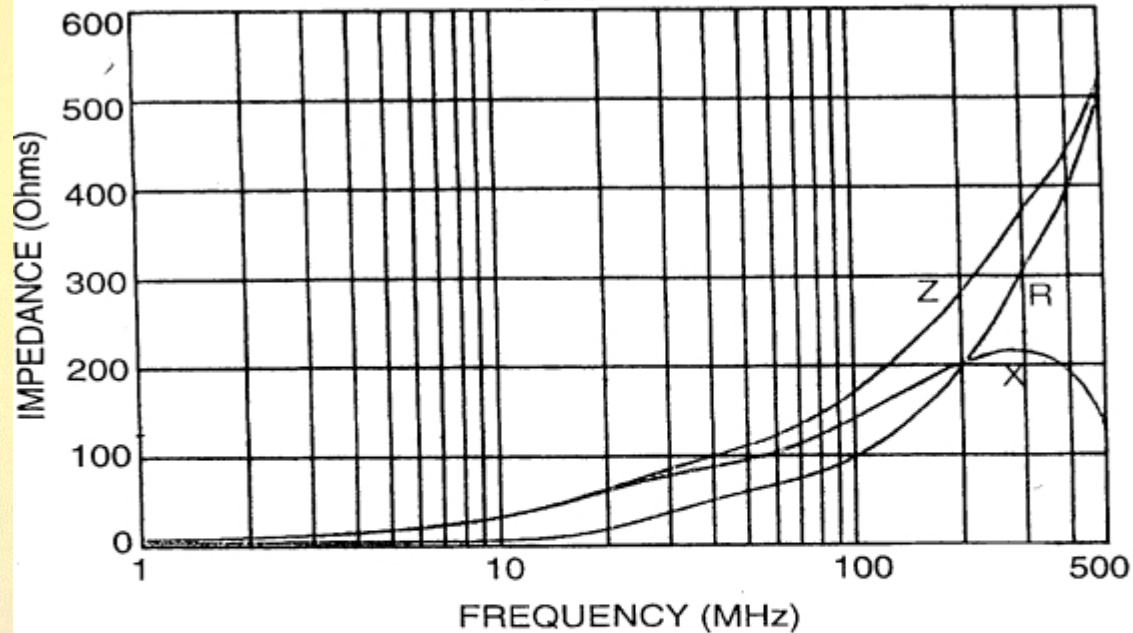
Impedance vs. DC Bias

Common vs. Differential Mode

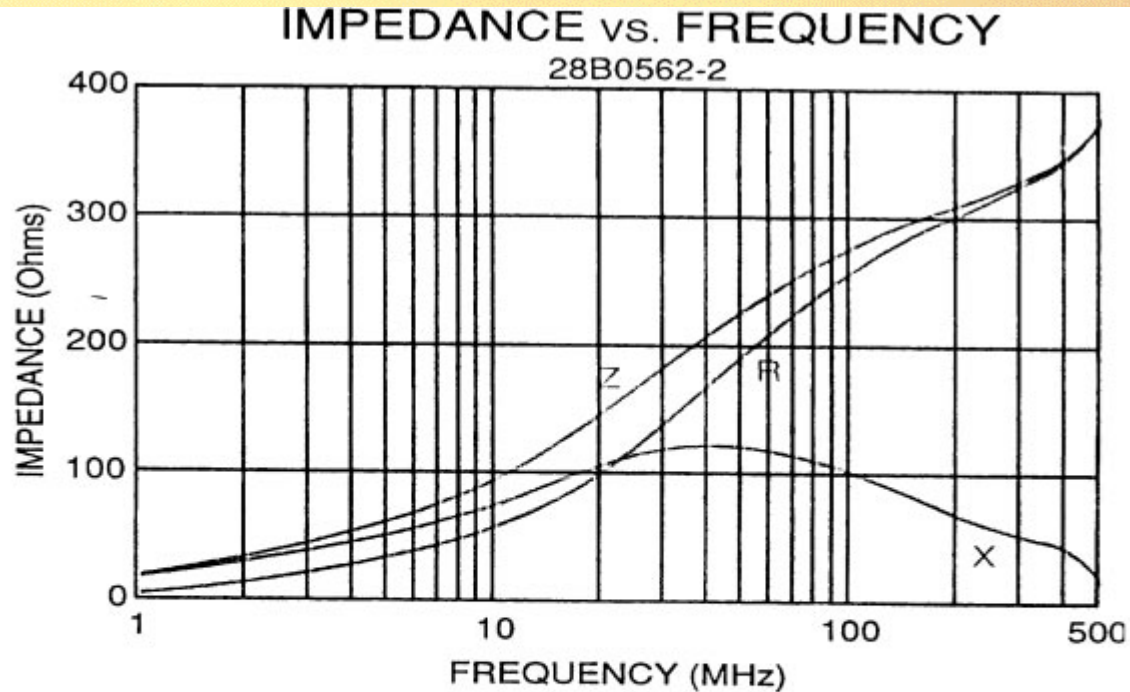


IMPEDANCE vs. FREQUENCY

25B0562-2



Property Units	Frequency Range MHz	Initial Permeability (μ_i)	Saturation Flux Density (B_s) Gauss	Residual Flux Density (B_r) Gauss	Coercive Force H_c	Curie Temperature (T_c) °C	Volume Resistivity (ρ) Ohm-Centimeters
25 Material	100 - 500	125	3650 @ 10 Oe	2600	1.6	$\geq 225^\circ \text{C}$	10^8
28 Material	30 - 300	850	3350 @ 10 Oe	2200	0.4	$\geq 175^\circ \text{C}$	10^5
29 Material	30 - 300	600	3300 @ 10 Oe	1500	0.35	$\geq 165^\circ \text{C}$	10^8



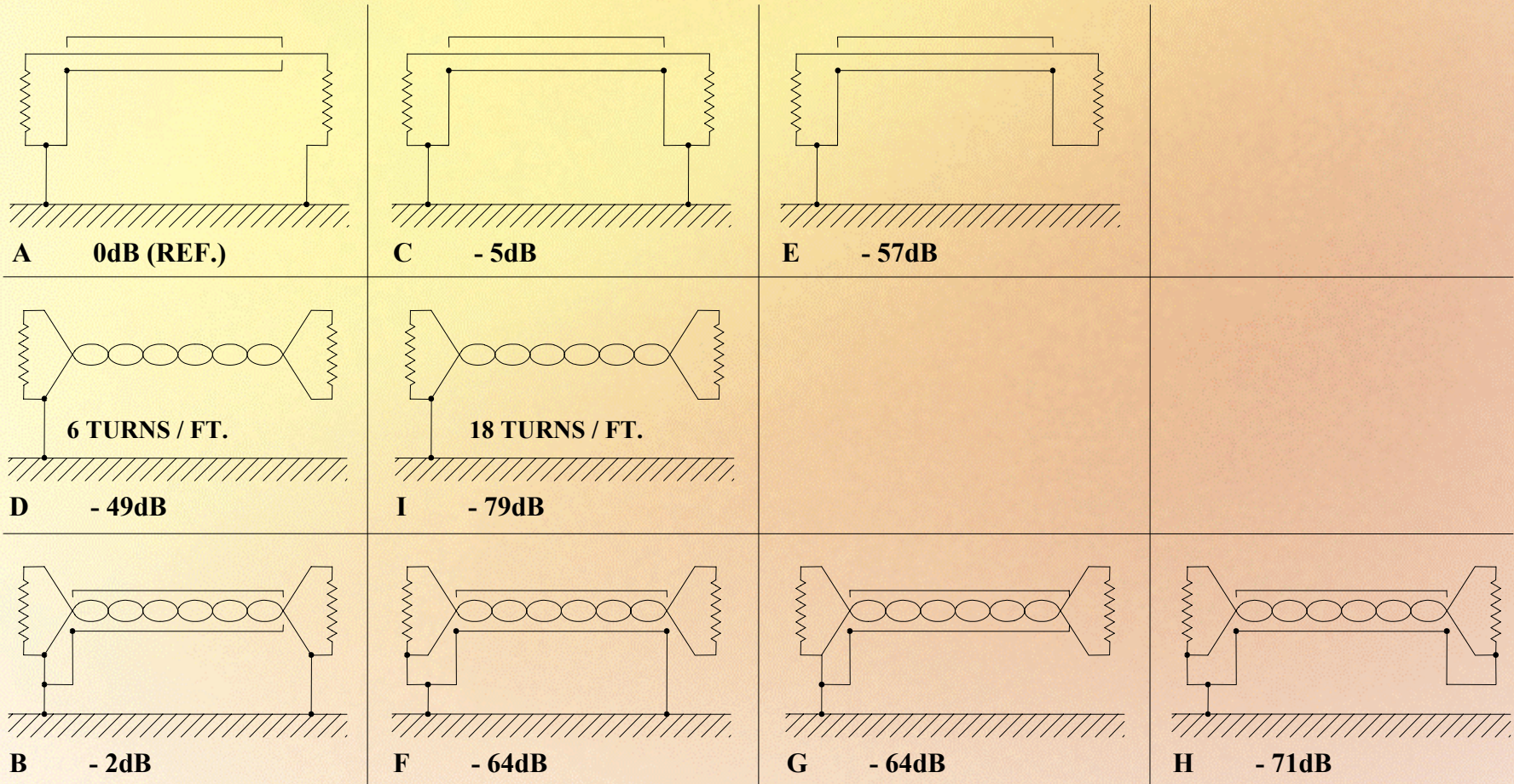
Property Units	Frequency Range MHz	Initial Permeability (μ_i)	Saturation Flux Density (B_s) Gauss	Residual Flux Density (B_r) Gauss	Coercive Force H_c	Curie Temperature (T_c) °C	Volume Resistivity (ρ) Ohm-Centimeters
25 Material	100 - 500	125	3650 @ 10 Oe	2600	1.6	$\geq 225^\circ \text{C}$	10^8
28 Material	30 - 300	850	3350 @ 10 Oe	2200	0.4	$\geq 175^\circ \text{C}$	10^5
29 Material	30 - 300	600	3300 @ 10 Oe	1500	0.35	$\geq 165^\circ \text{C}$	10^8

Ten Commandments of Electromagnetic Compatibility



- 8. Twist all pairs of wires at 18 turns per foot to minimize magnetic pickup.**

RELATIVE SUSCEPTIBILITY OF CIRCUITS TO MAGNETIC INTERFERENCE

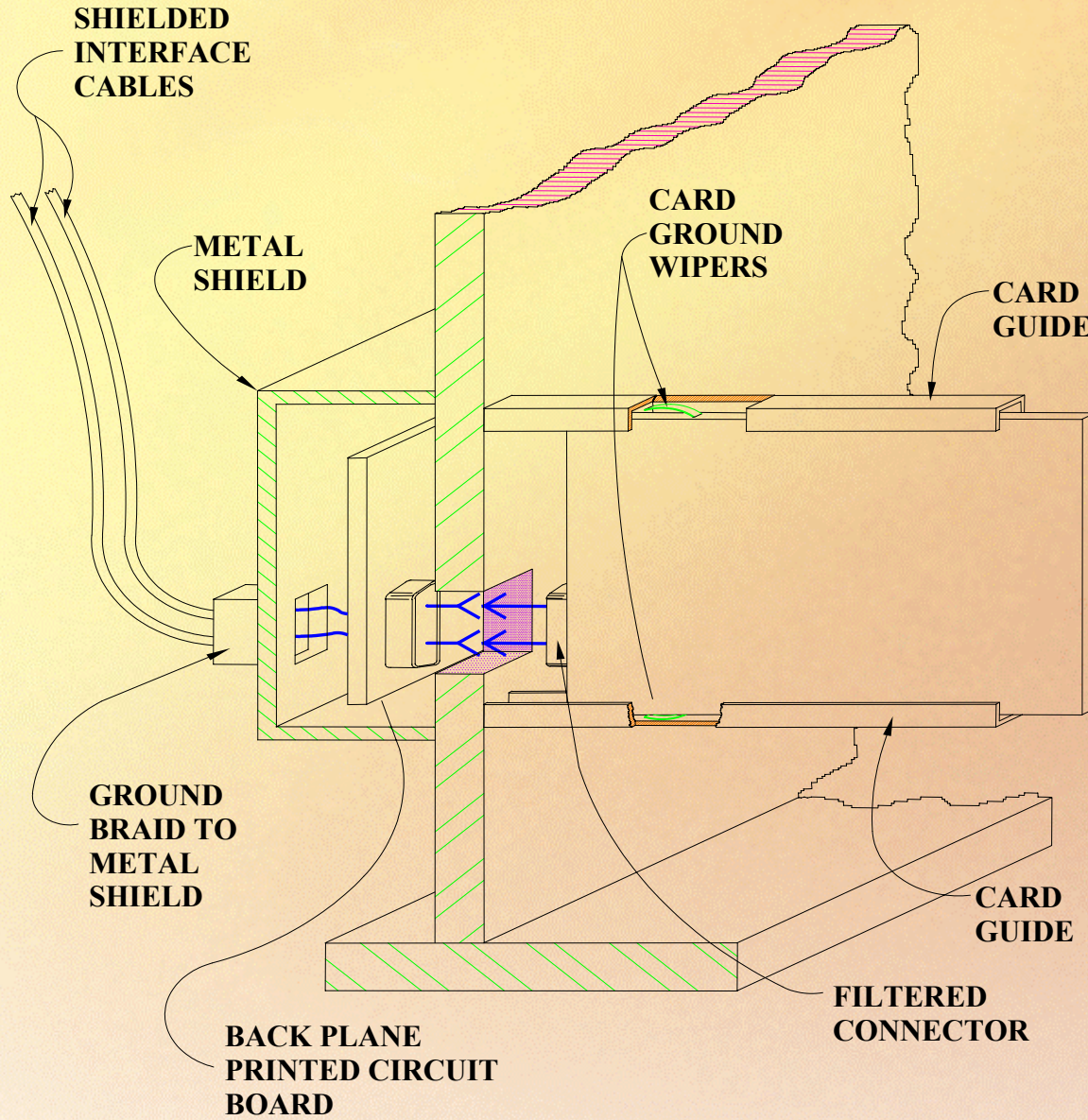


VALUES GIVEN ARE FOR CIRCUITS 1 INCH ABOVE GROUND PLANE

Ten Commandments of Electromagnetic Compatibility



- 9. Shield and wiper ground / bond all backplanes and interfaces to modules.**

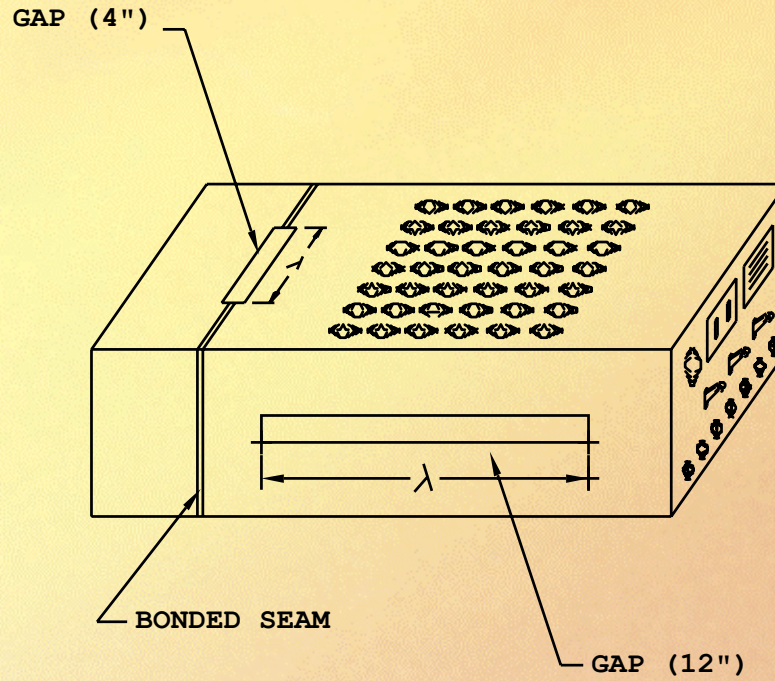


SHIELD BACKPLANE WIPER GROUND CARD

Ten Commandments of Electromagnetic Compatibility



- 10. Close or interbond all apertures and gaps longer greater than Λ (wavelength) / 20.**



FREQ.	Max. Gap
120 MHz	4.92"
600 MHz	0.98"
1.5G Hz	0.394"
3.0 GHz	0.197"

$$\frac{3 \times 10^8 \times 39.37}{\text{FREQ.}} = \lambda$$

$$\frac{\lambda}{20} = \text{Aperture Max.}$$

simplified →

$$\frac{591}{F \text{ MHz}} = \text{Max. Gap Inches}$$

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