SPECTRUM CONTROL, INC.

A Control Products & Systems Company

EMI

SPECTRUM CONTROL, INC.

- ☑ 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?

SPECTRUM CONTROL, INC.

- ☑ 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?

SPECTRUM CONTROL, INC.

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

Standards & Specifications

SPECTRUM CONTROL, INC.

North America

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

Standards & Specifications Cont'd.

SPECTRUM CONTROL, INC.

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.

SPECTRUM CONTROL, INC.

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**

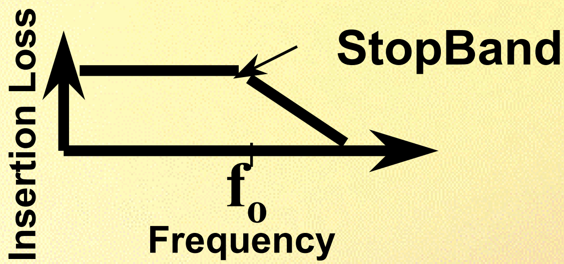
EMI

Methods of Suppression

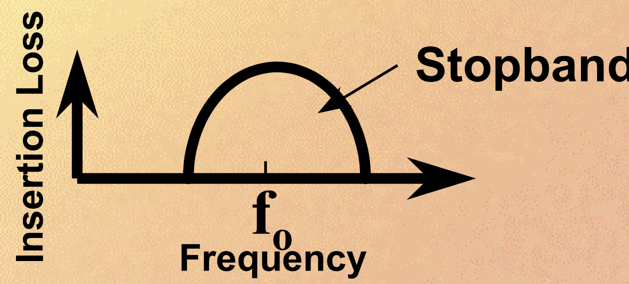
- PCB Layout
- Shielding & Grounding
- Filtering

Types of Filters

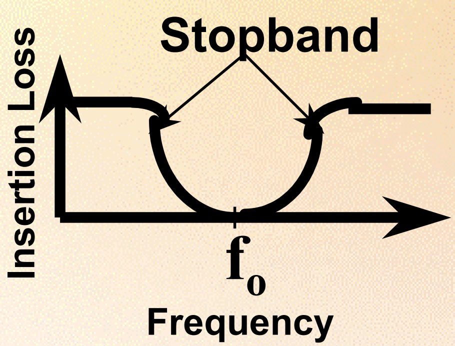
- **High Pass**



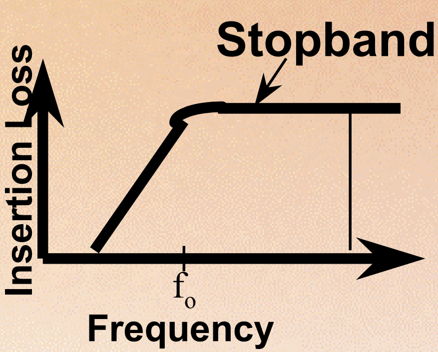
- **Band Reject**



- **Band Pass**

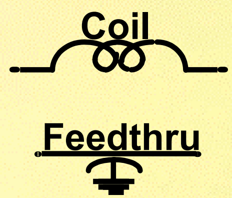


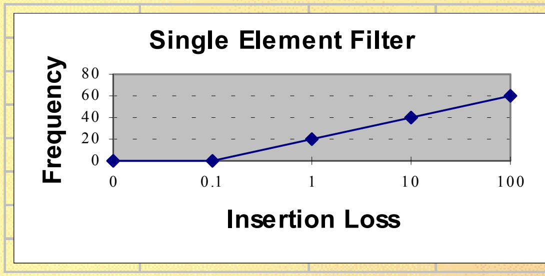
- **Low Pass**



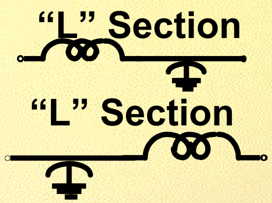
The Basic Circuits of Low Pass Filters Using a 50 ohm Source & 50 ohm Load

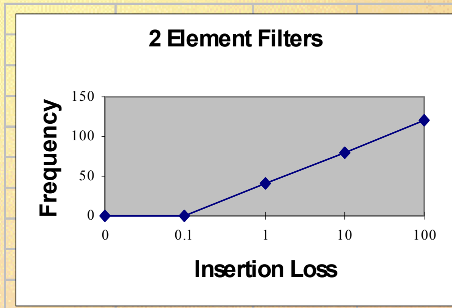
SPECTRUM CONTROL, INC.



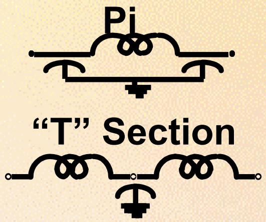


20 dB per Decade





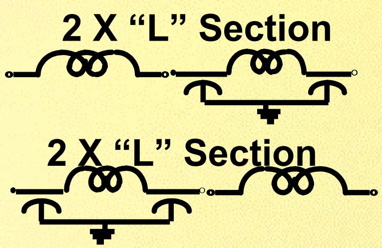
40 dB per Decade

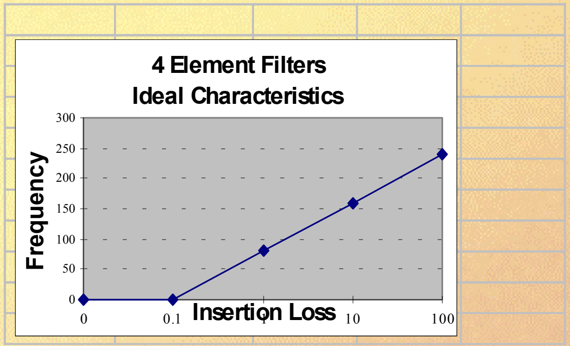


60 dB per Decade

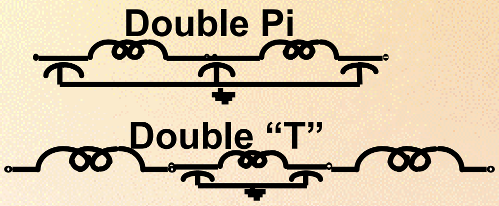
The Basic Circuits of Low Pass Filters Using a 50 ohm Source & 50 ohm Load

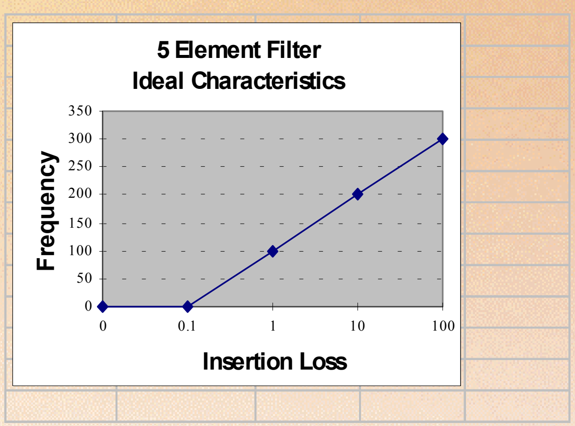
SPECTRUM CONTROL, INC.





80 dB per Decade

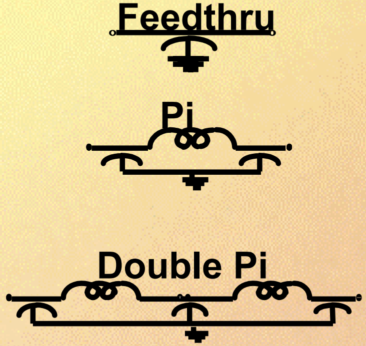
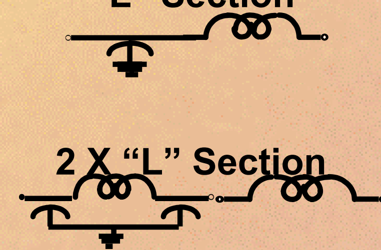
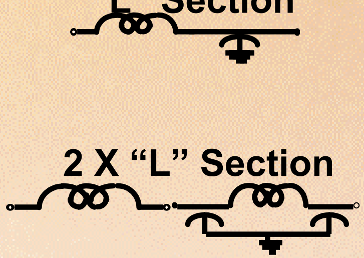
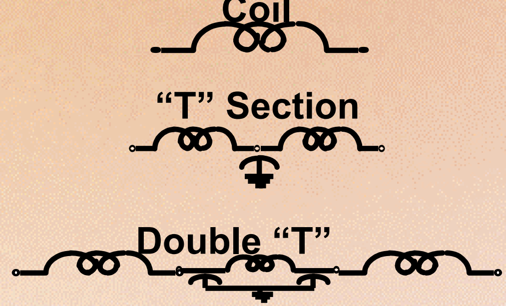




100 dB per Decade

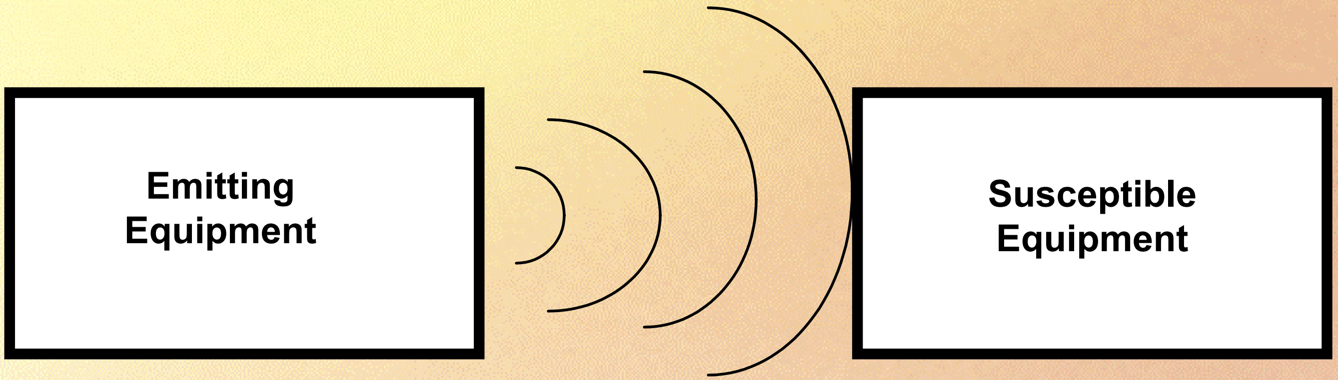
I/O Impedance & Selection Criteria

SPECTRUM CONTROL, INC.

		Output Impedance (Zo)	
		High	Low
Input Impedance (Zi)	High	Feedthru Pi Double Pi 	"L" Section 2 X "L" Section 
	Low	"L" Section 2 X "L" Section 	Coil "T" Section Double "T" 

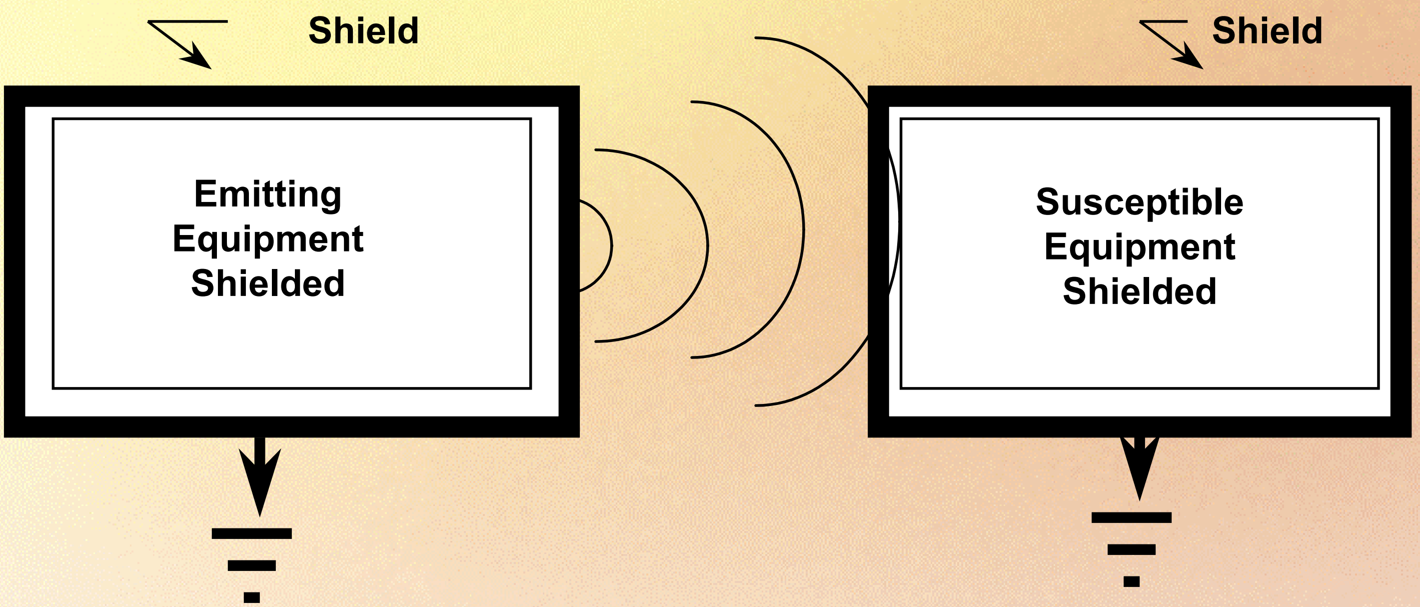
Propagation Modes

Radiated Emissions



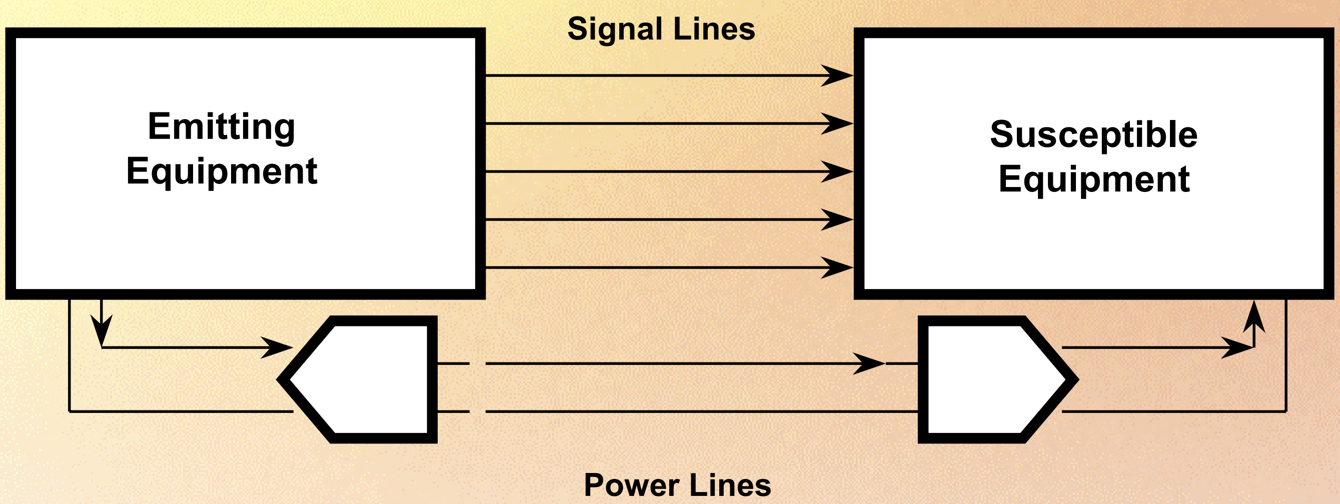
Methods of Suppression

Radiated Emissions - Shield



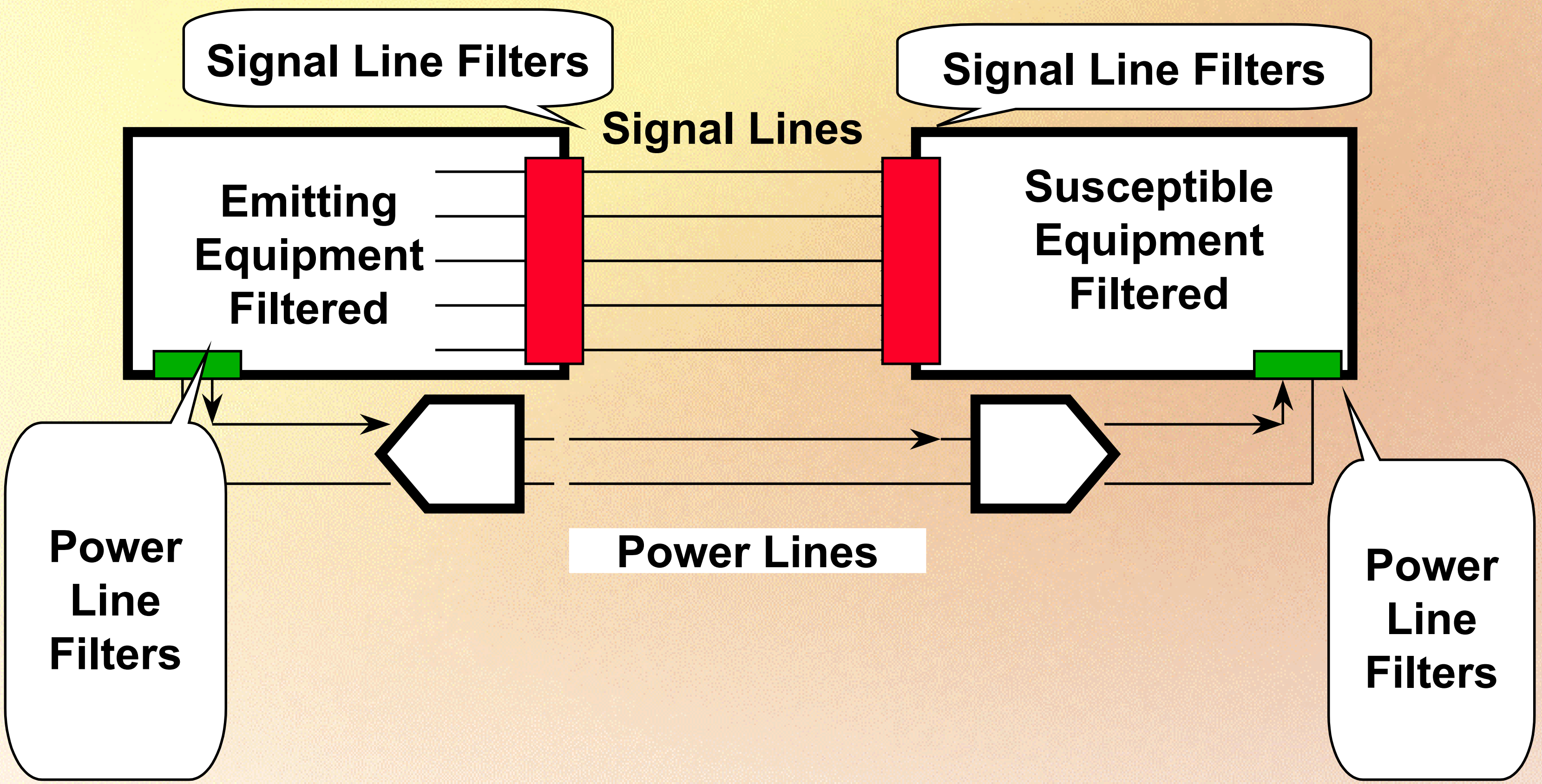
Propagation Modes

Conducted Emissions



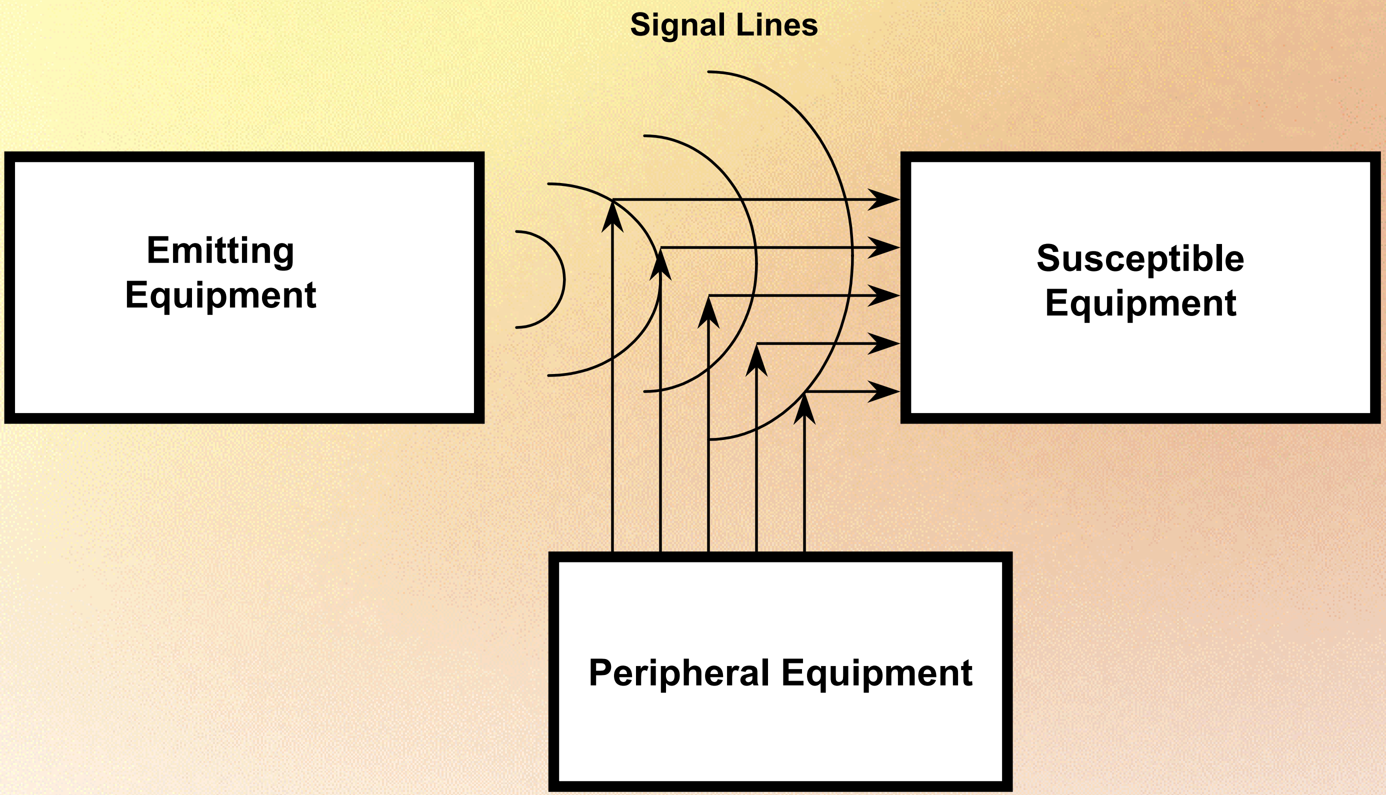
Methods Of Suppression

Conducted Emissions - Filters



Propagation Modes

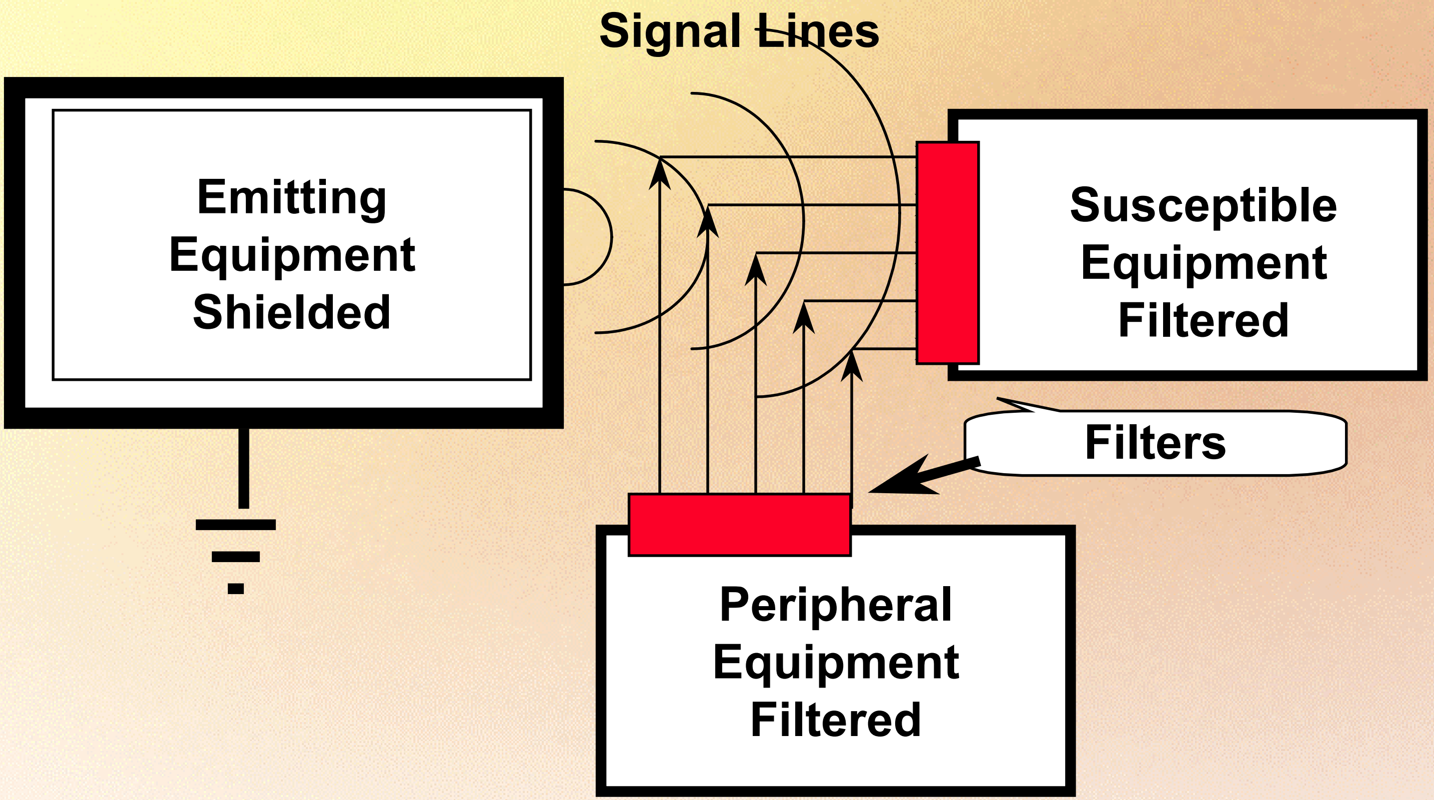
Radiated Conducted



Methods of Suppression

SPECTRUM CONTROL, INC.

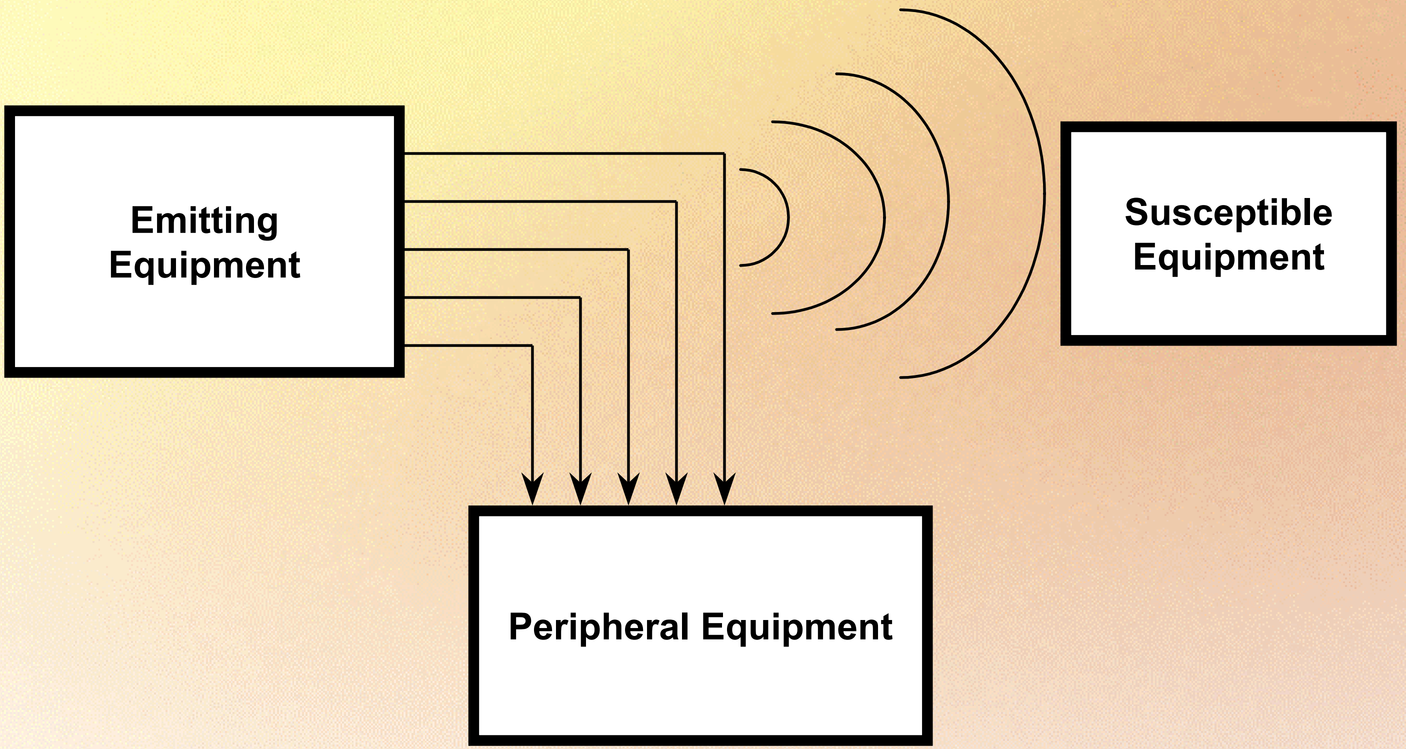
Radiated Conducted-Shield / Filters



Propagation Modes

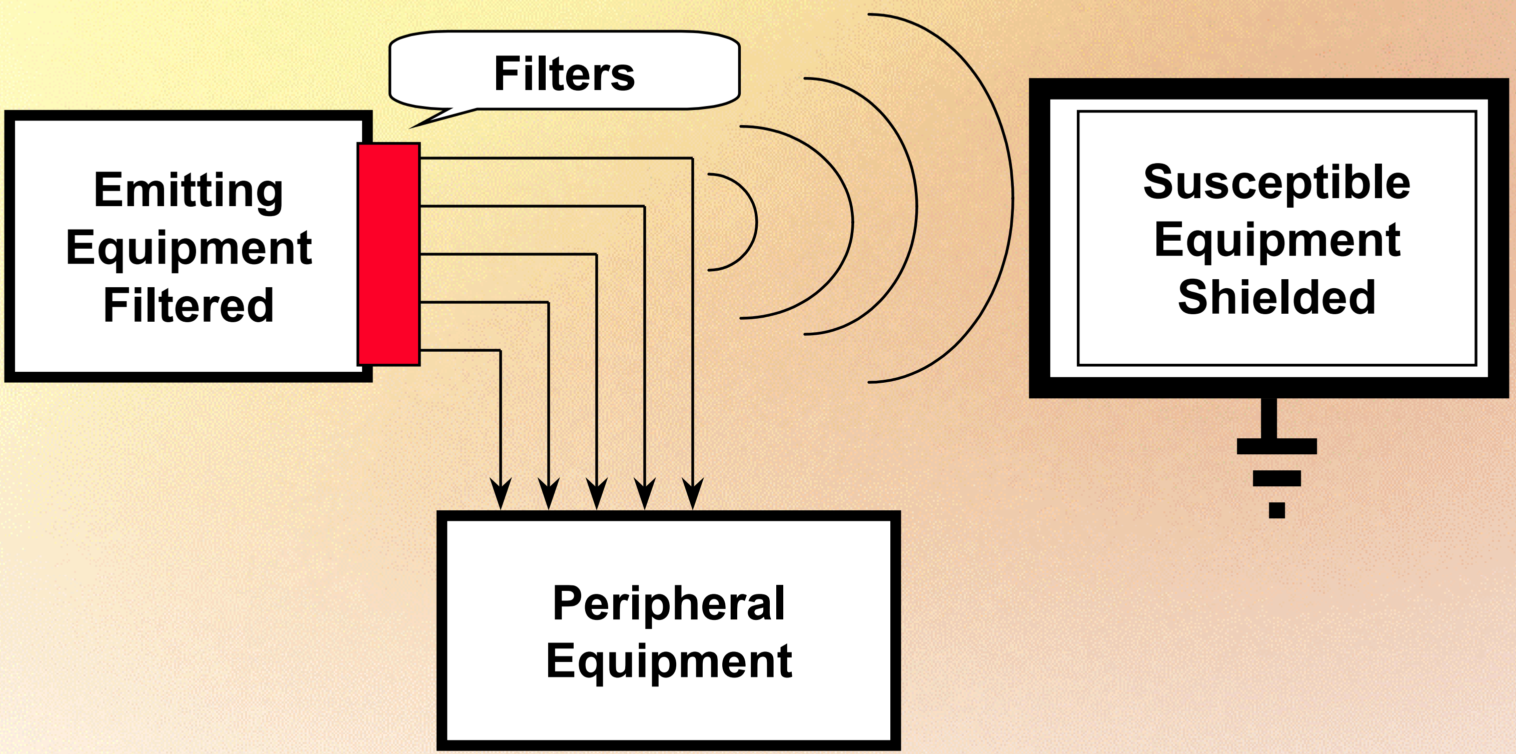
SPECTRUM CONTROL, INC.

Conducted Radiated



Methods of Suppression

Conducted Radiated - Filter / Shield



Timing Impact

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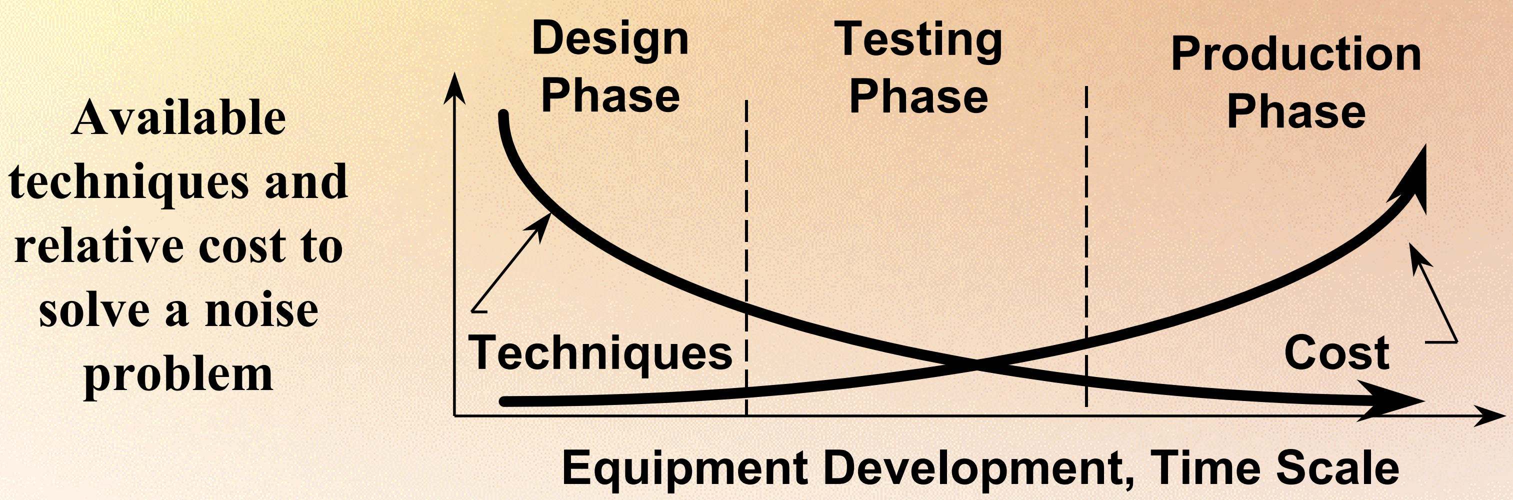
- The further along in the design cycle, the more challenging & more costly the solution.
- Consult and ask questions from the go, it may save you a considerable sum of money in design time and components.



The Ten Commandments of Electromagnetic Compatibility

Ten Commandments of Electromagnetic Compatibility

SPECTRUM CONTROL, INC.

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 al 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

SPECTRUM CONTROL, INC.

6. Monitor Surface resistively 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 Lambda (wavelength) / 20.

Ten Commandments of Electromagnetic Compatibility

SPECTRUM CONTROL, INC.

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

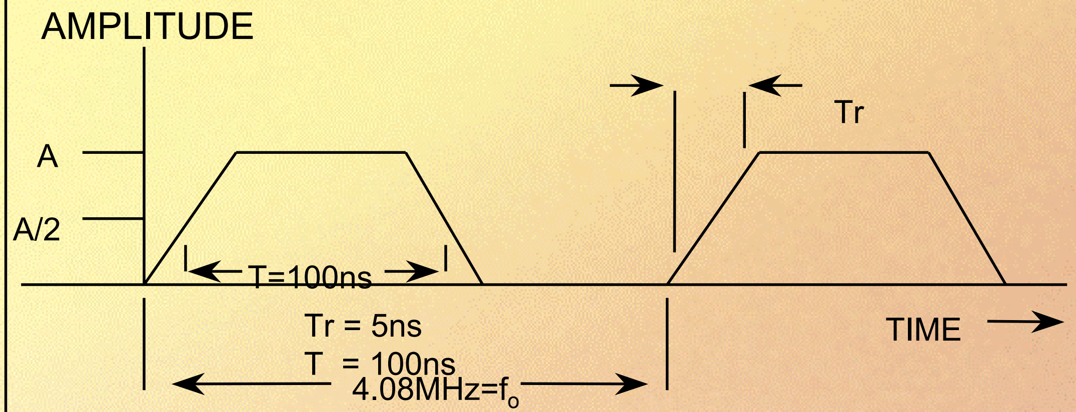
1992 European EMC Standards

SPECTRUM CONTROL, INC.

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

	Freq Range	Limits
Radiated	30 - 230 MHz 230 - 1000 MHz	30 dB μV/m @ 10 m 37 dB μV/m @ 10 m
Conducted	0.15 - 0.5 MHz	66 → 56 dBμV quasi pk 56 → 46 dBμV ave
	0.5 - 5 MHz	56 dBμV quasi pk 46 dBμV ave
	5 - 30 MHz	60 dBμV quasi pk 50 dBμV ave

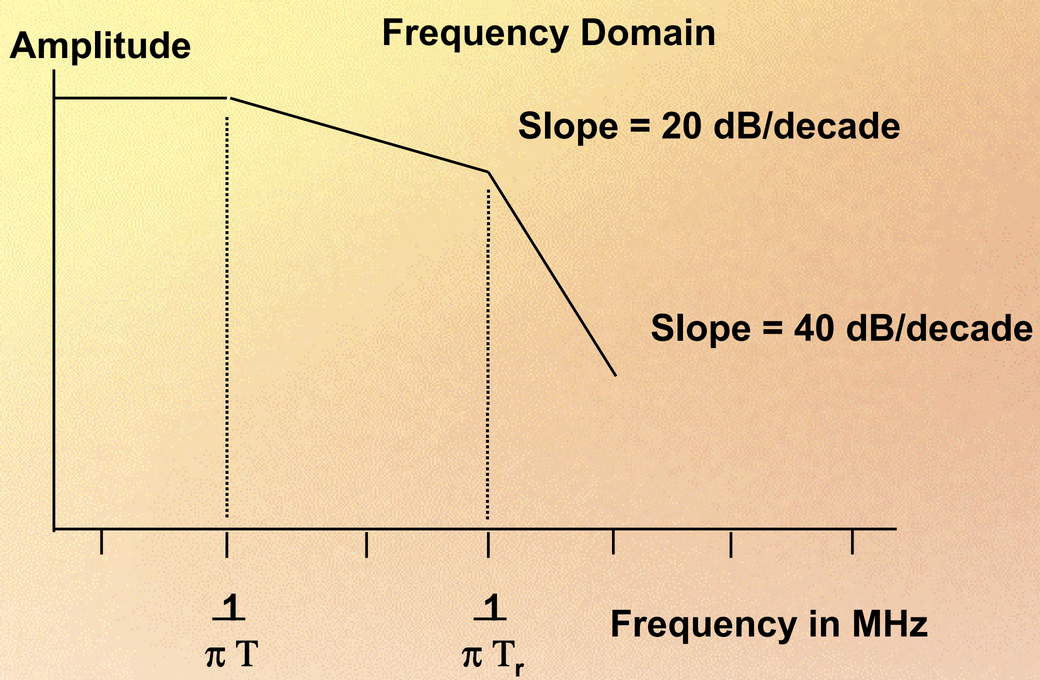
Time Domain



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

100ns PULSE @ 4.08MHz
5 nano second Risetime

Frequency Domain



4.08 MHz Expected Harmonics

SPECTRUM CONTROL, INC.

	n^{th}	FREQ.		n^{th}	FREQ.
$f = \frac{1}{\pi T}$ = 3.183 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)** $f = \frac{1}{2x\pi\tau_r}$ **= 127.32MHz**		
			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 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

SPECTRUM CONTROL, INC.

2. Filter Power Lines at immediate entry point.

COMMON PENETRATION PATHS INTO EQUIPMENT

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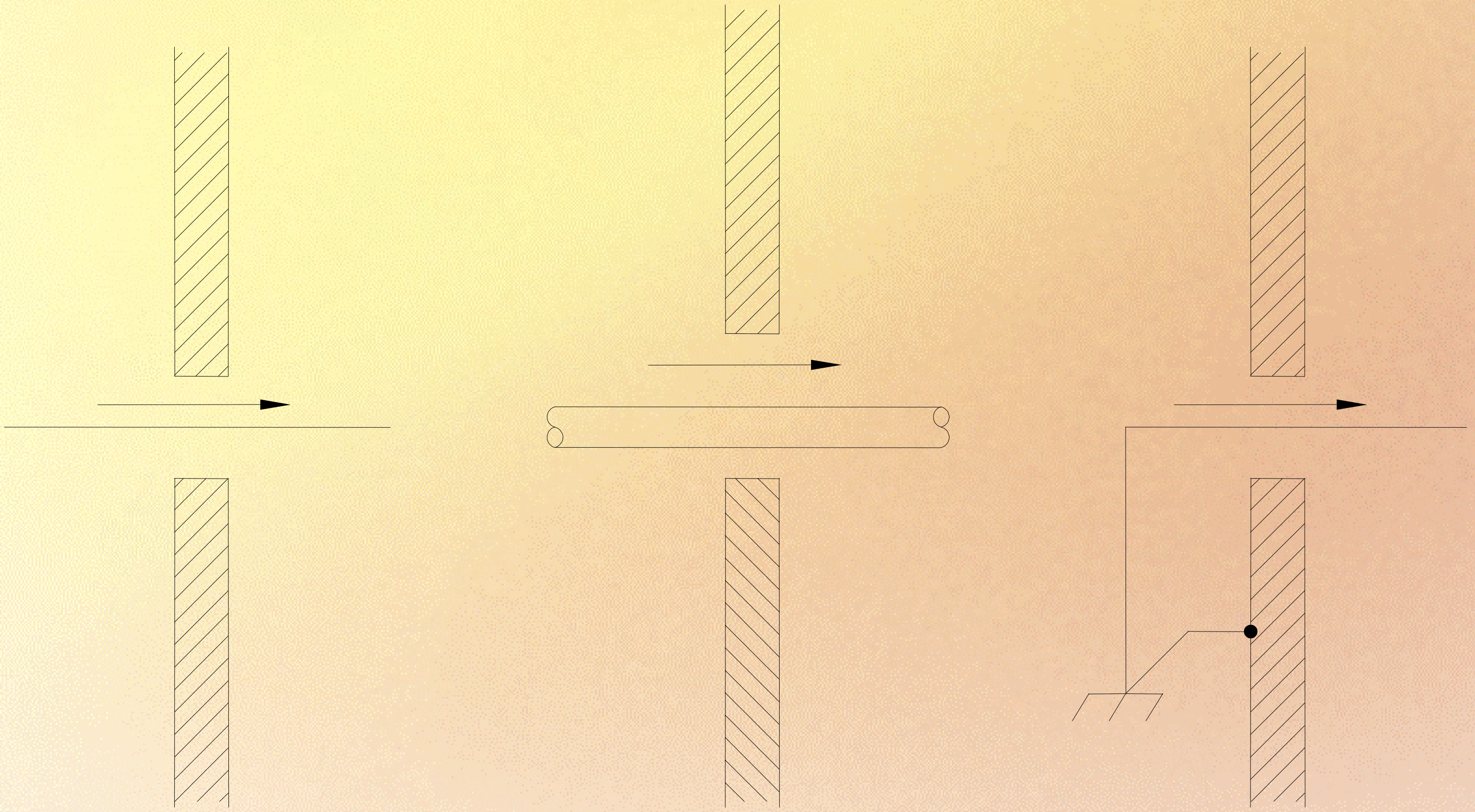
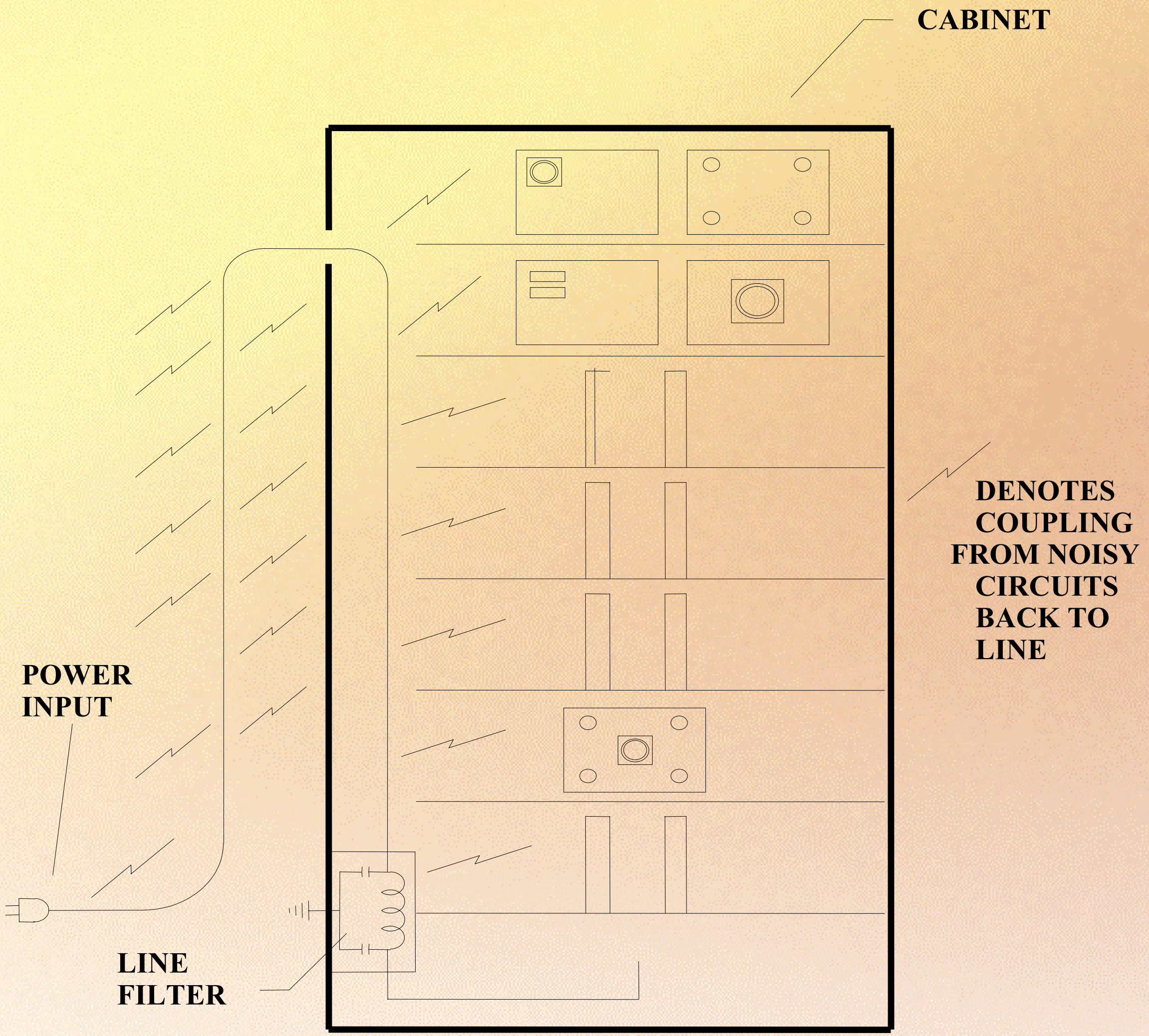


INSULATED WIRE

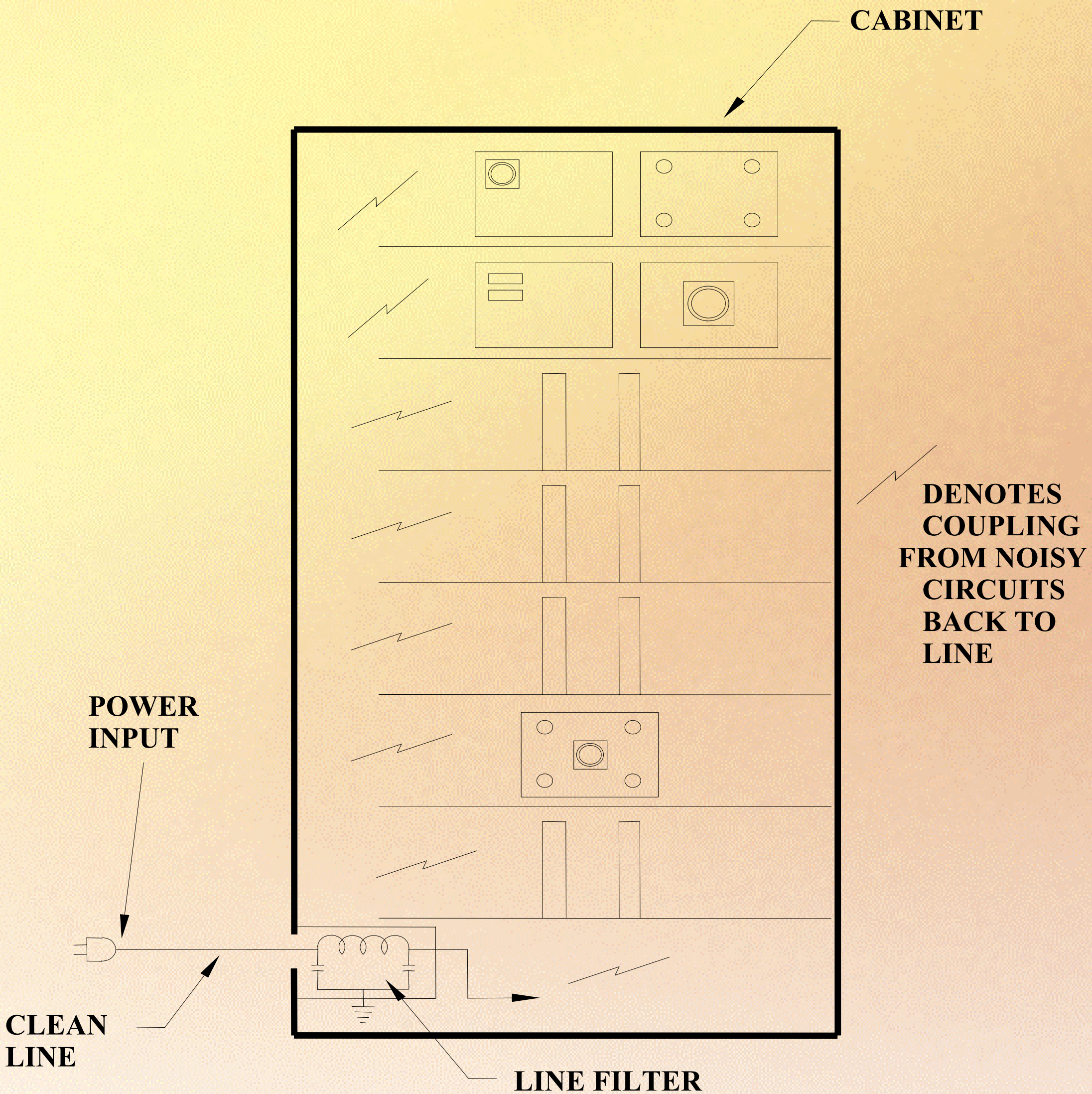
INSULATED, UNGROUNDED CABLE SHIELD

GROUND CONDUCTOR

Wrong Power Filter Installation



Correct Filter Installation

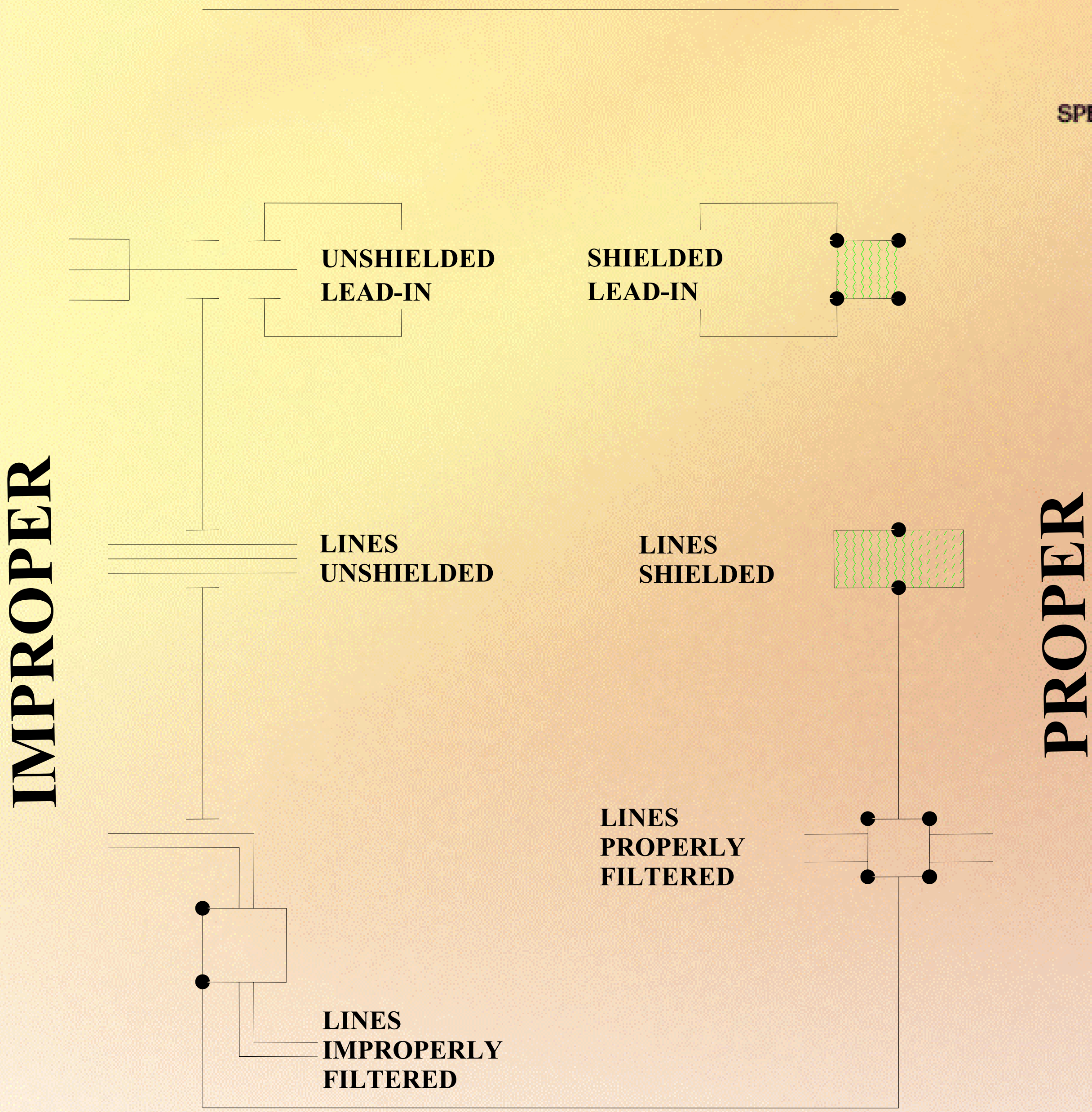


Ten Commandments of Electromagnetic Compatibility

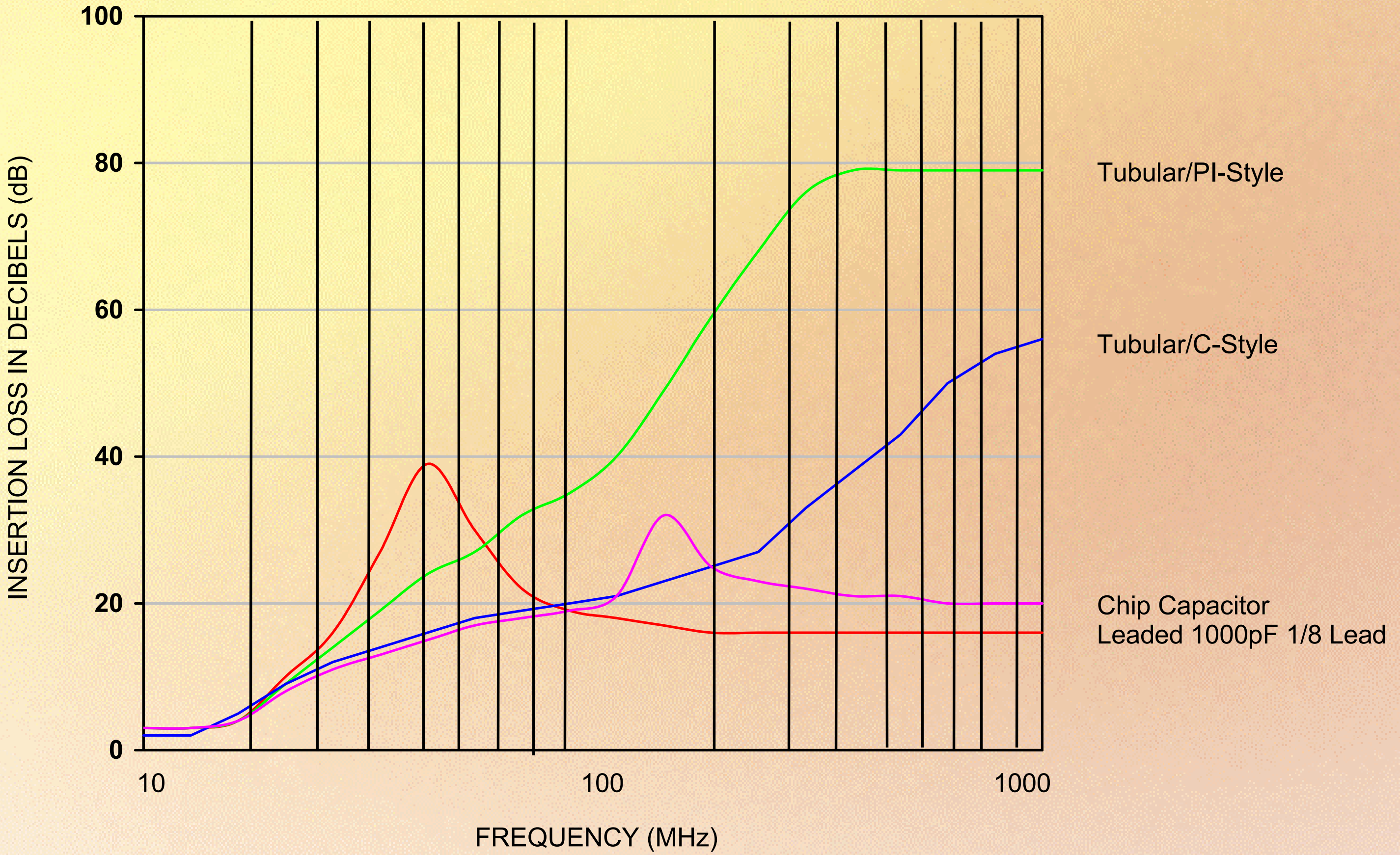
SPECTRUM CONTROL, INC.

3. Filter al I/O lines and signal lines with selected tailored passband response filters.

SPECTRUM CONTROL, INC.



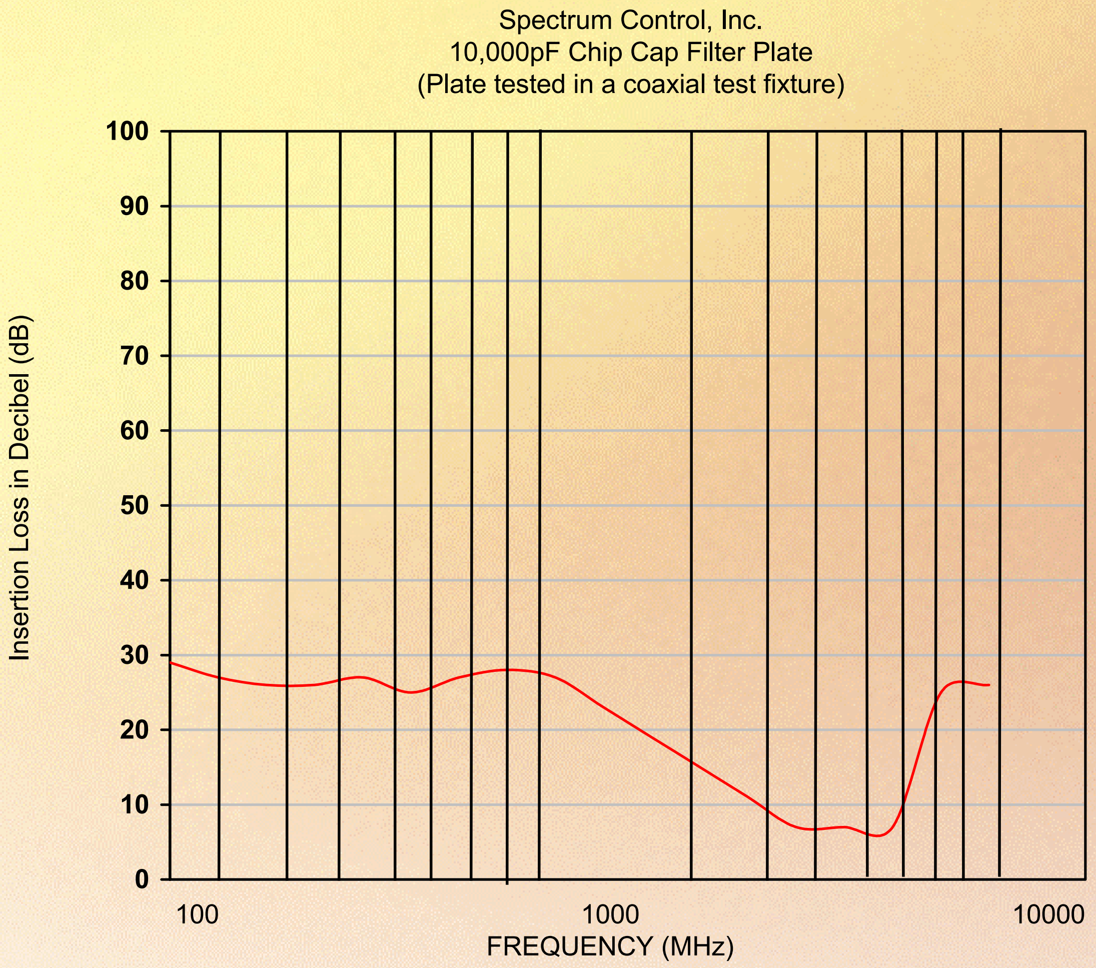
Chip Cap vs. Tubular
1000pF PI-Style vs. C-Style



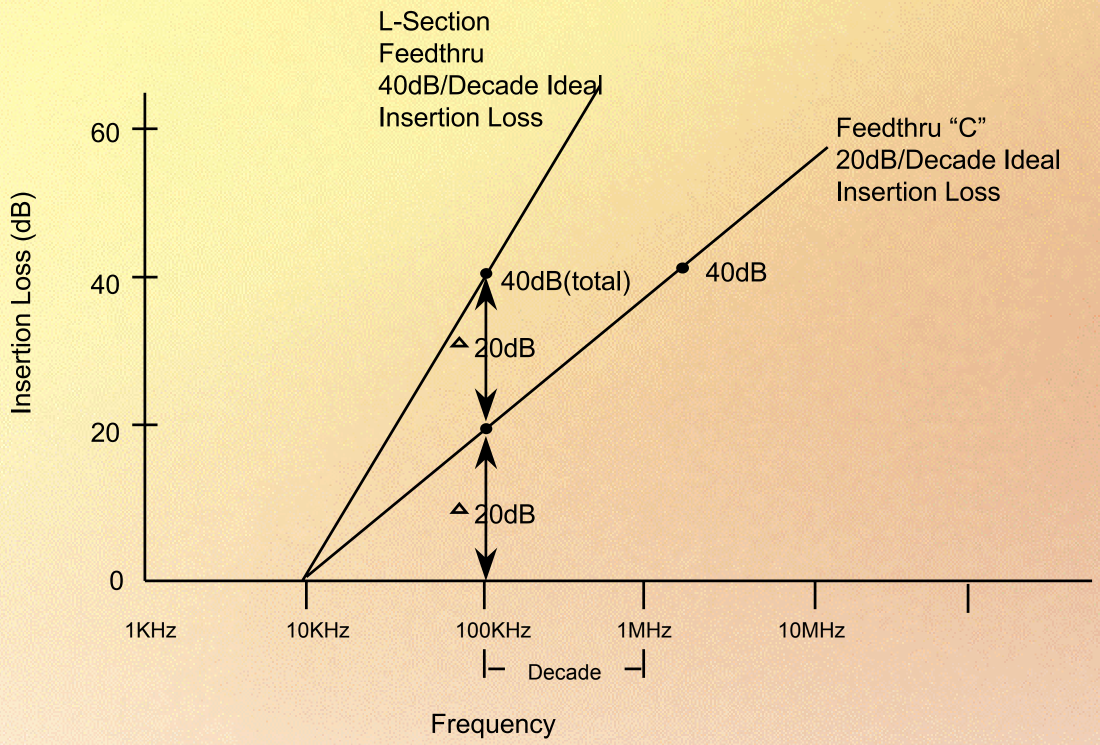
Typical Insertion Loss

Chip Results Actual

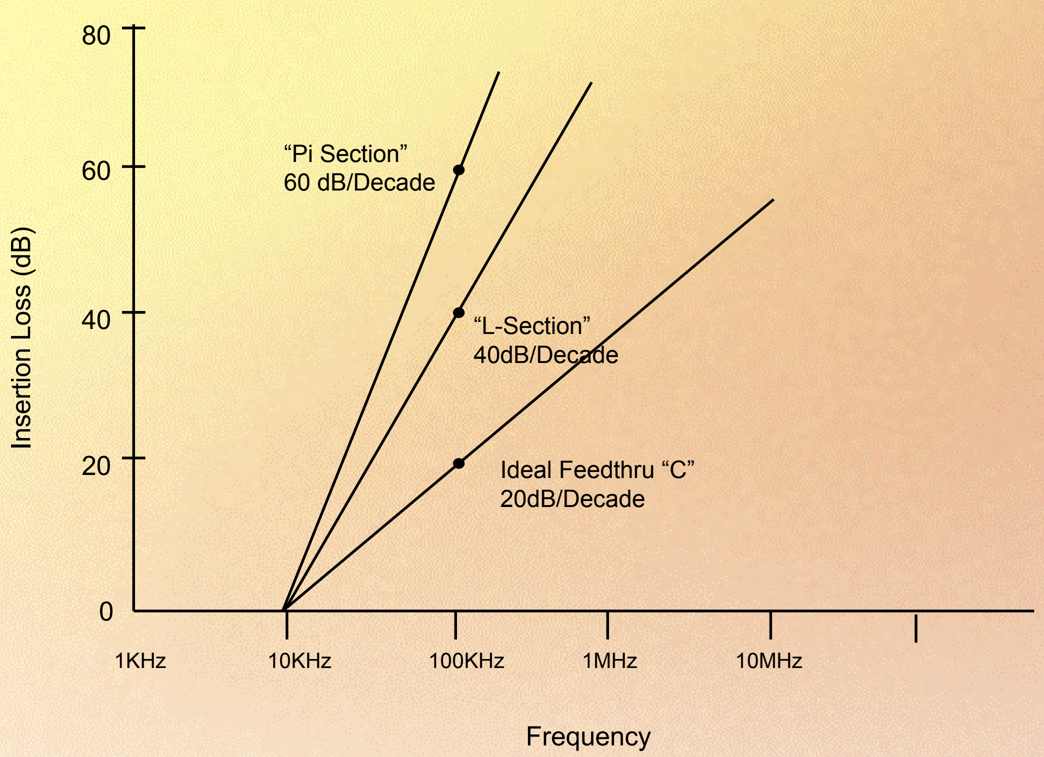
SPECTRUM CONTROL, INC.



L-Section Filters



Pi-Section Filters

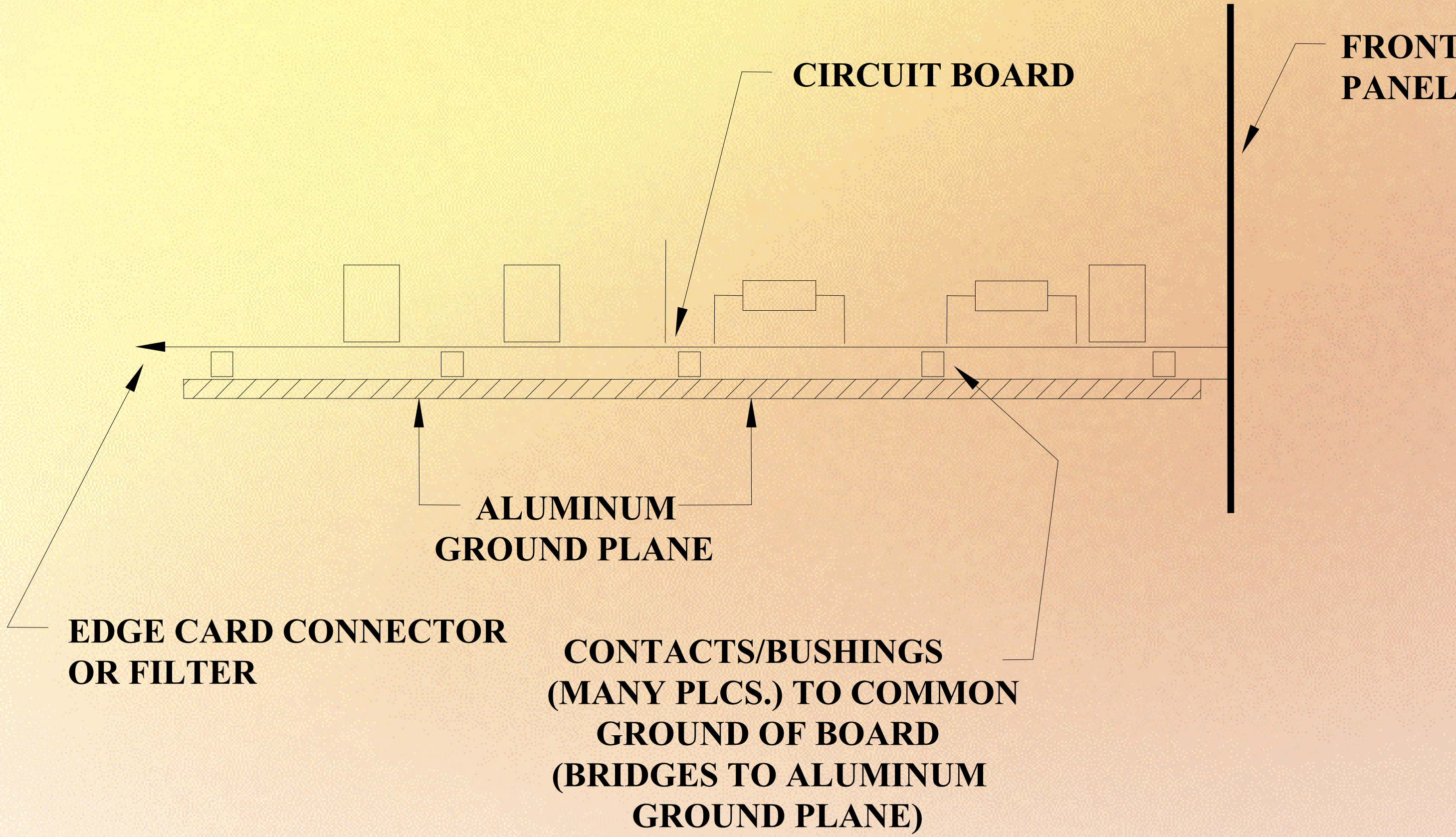


Ten Commandments of Electromagnetic Compatibility

SPECTRUM CONTROL, INC.

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

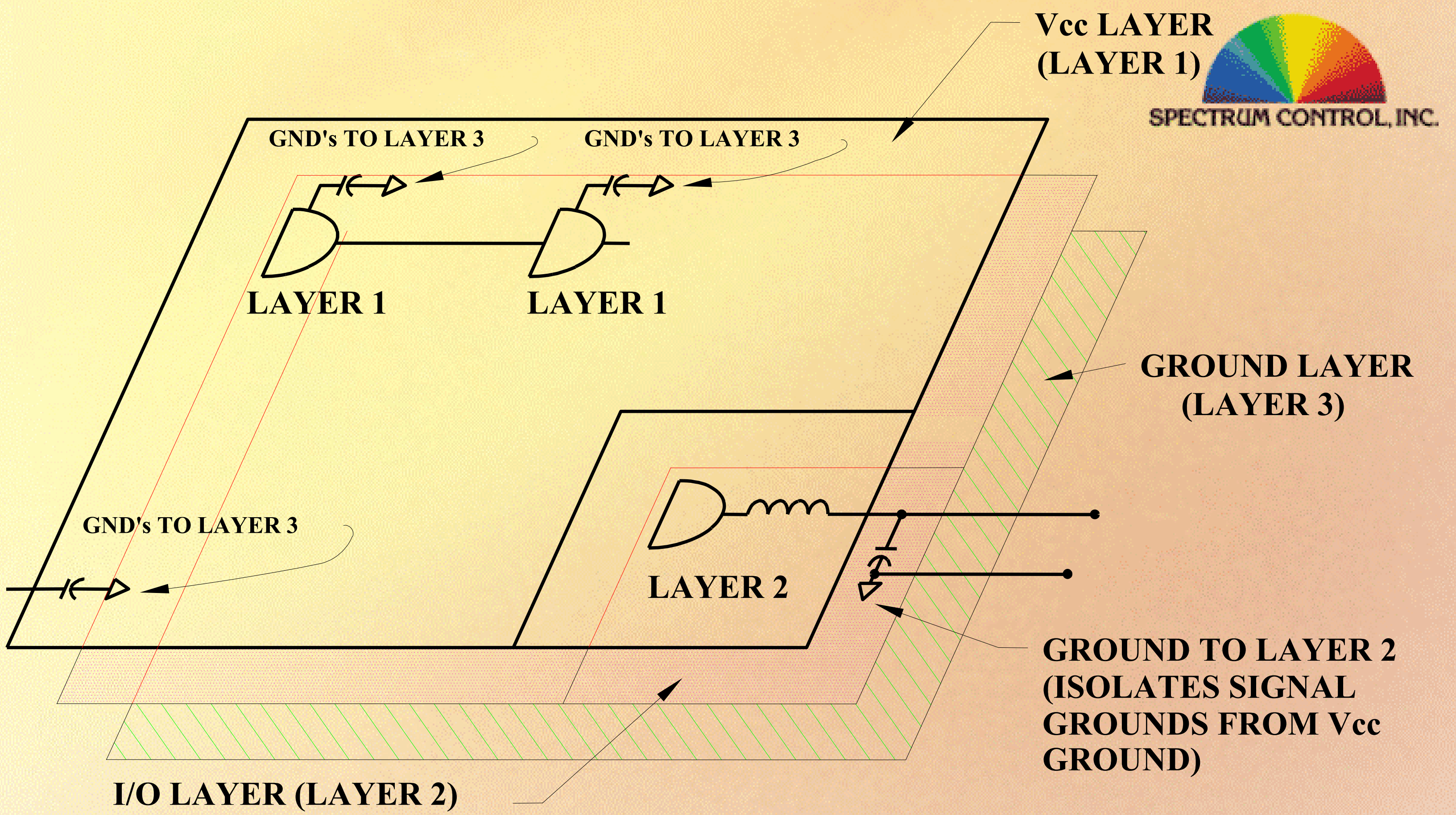
ALUMINUM GROUND PLANE FASTENED TO PRINTED CIRCUIT BOARD



Ten Commandments of Electromagnetic Compatibility

SPECTRUM CONTROL, INC.

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

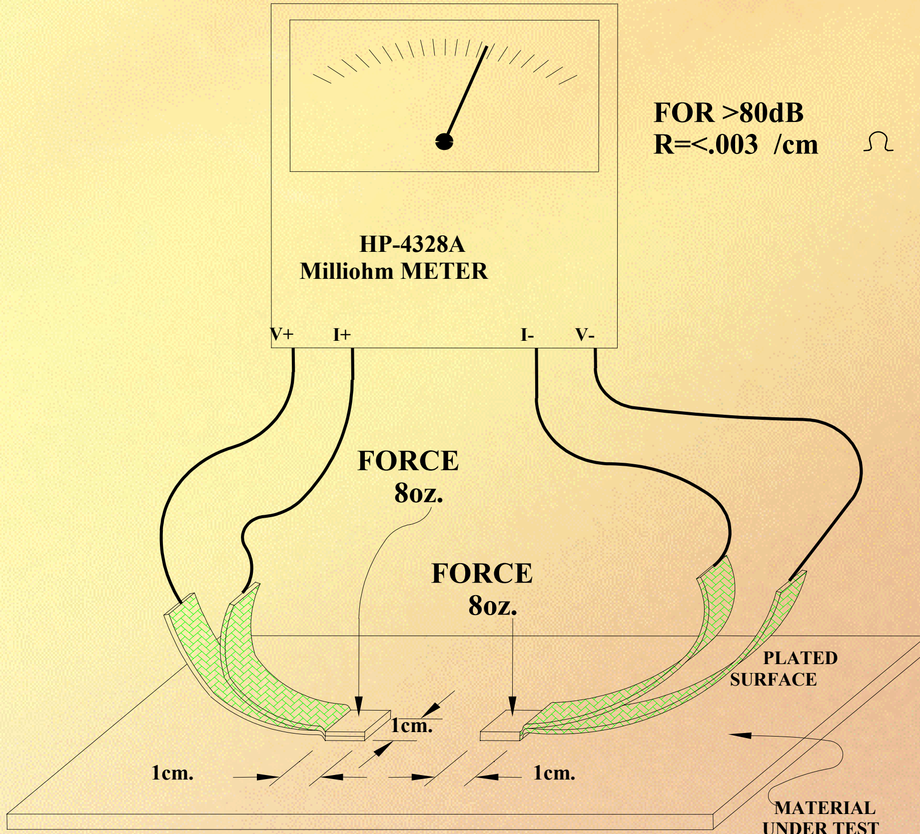


MULTILAYER PC BOARD
PROVIDES I/O ISOLATION FROM POWER GROUND
LAYER 3 SERVES AS Vcc COMMON

Ten Commandments of Electromagnetic Compatibility

SPECTRUM CONTROL, INC.

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



PLATING	8oz. 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

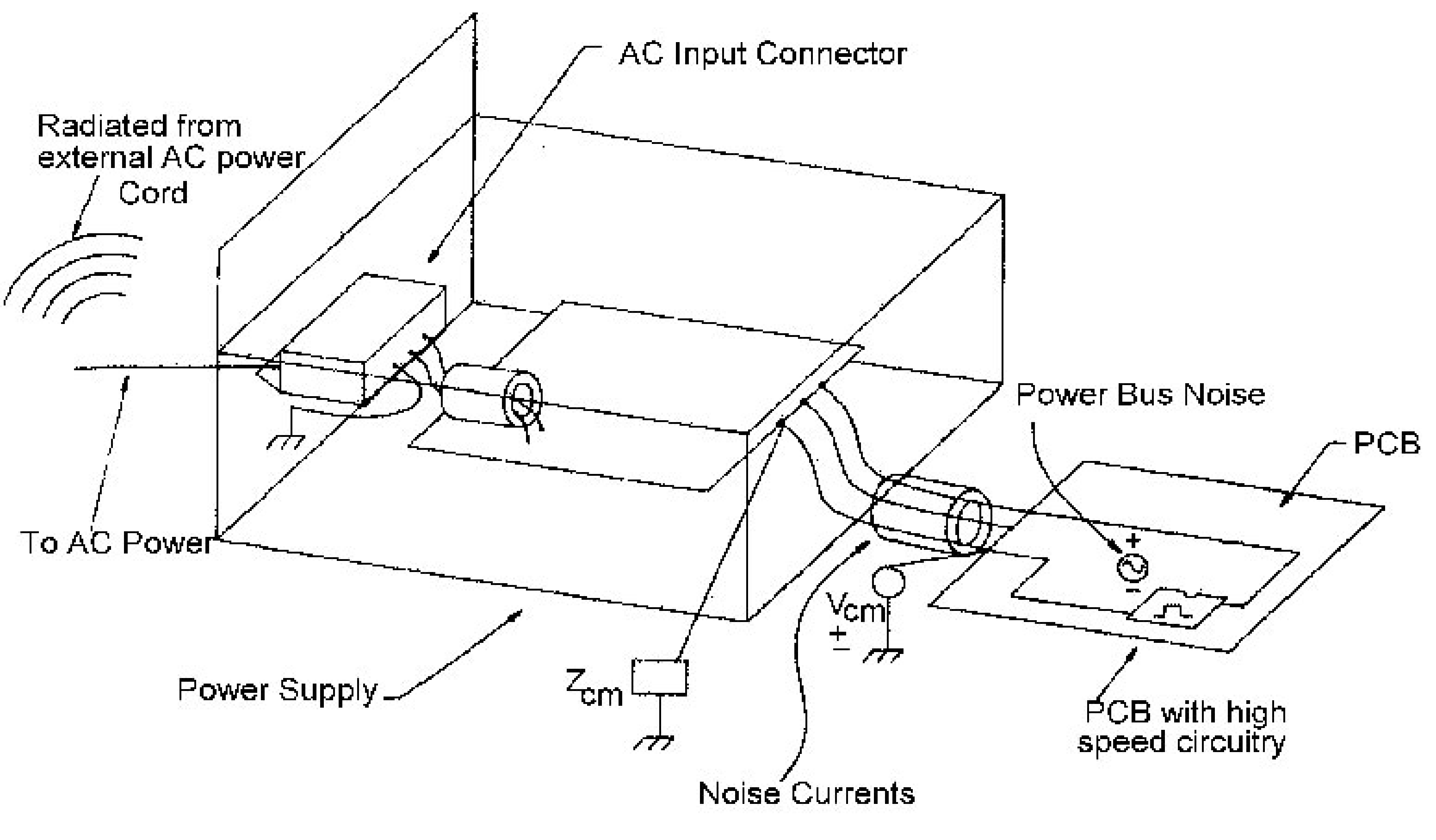
SURFACE RESISTIVITY OF PLATING

Ten Commandments of Electromagnetic Compatibility

SPECTRUM CONTROL, INC.

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

Ferrite Beads

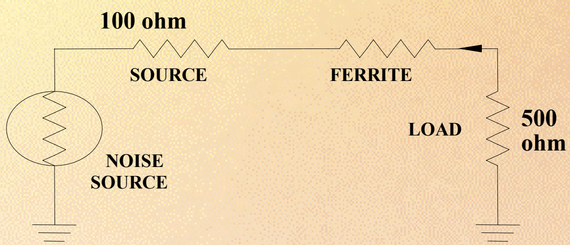


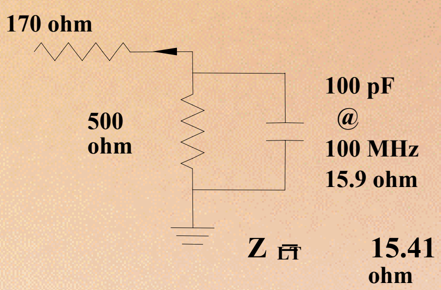
Ferrite Bead Filtering

- Select bead Z at F_0 from Data Steward type 25 is 170 ohm @ 100MHz $=Z_F$
- Determine $Z_{SOURCE} = 100$ ohm , $Z_{LOAD}=500$ ohm

$$20 \log \frac{Z_{SOURCE} + Z_{LOAD}}{Z_F + Z_{SOURCE} + Z_{LOAD}} = 20 \log \frac{100 + 500}{170 + 100 + 500}$$

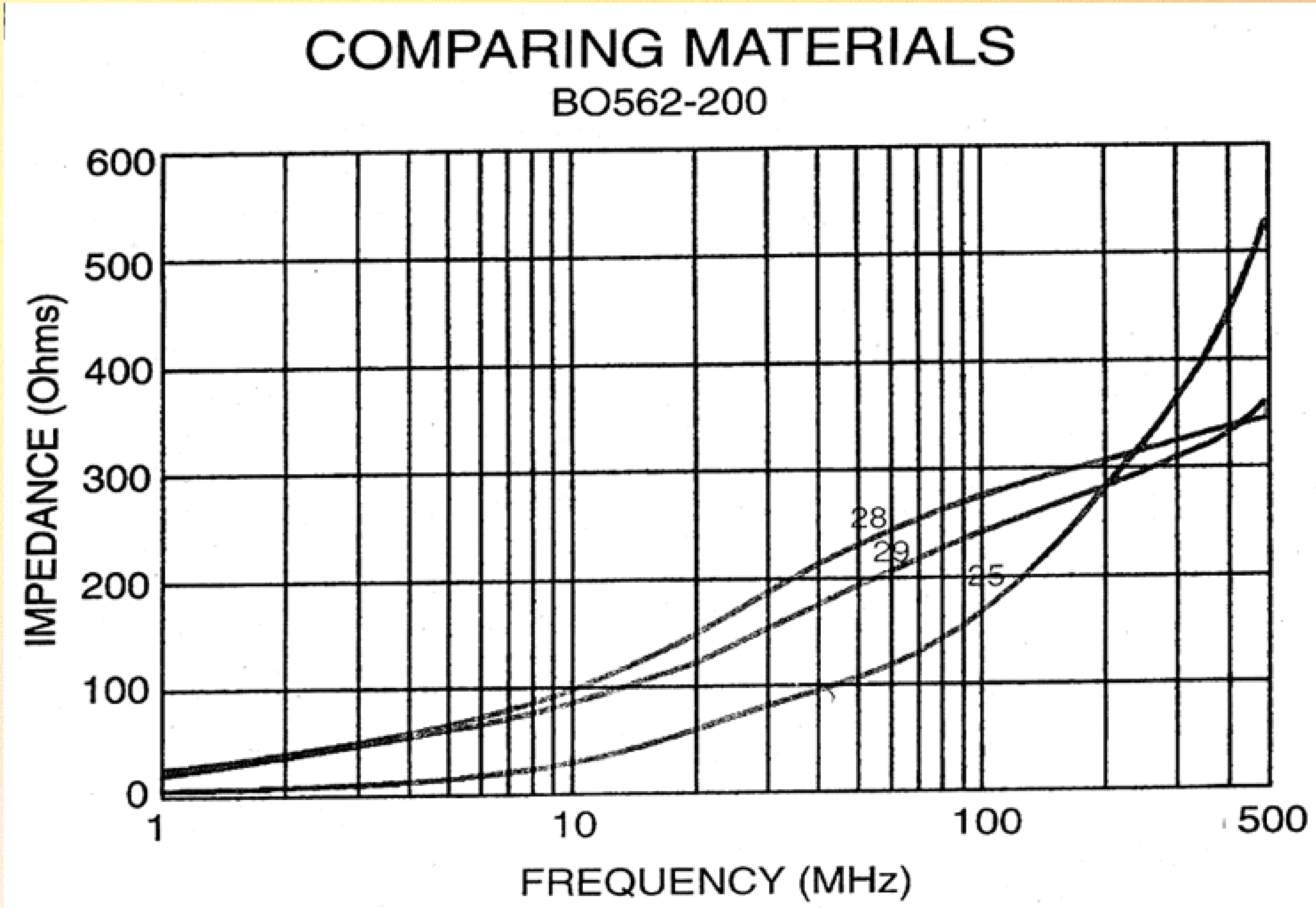
$$= 2.16 \text{ dB}$$





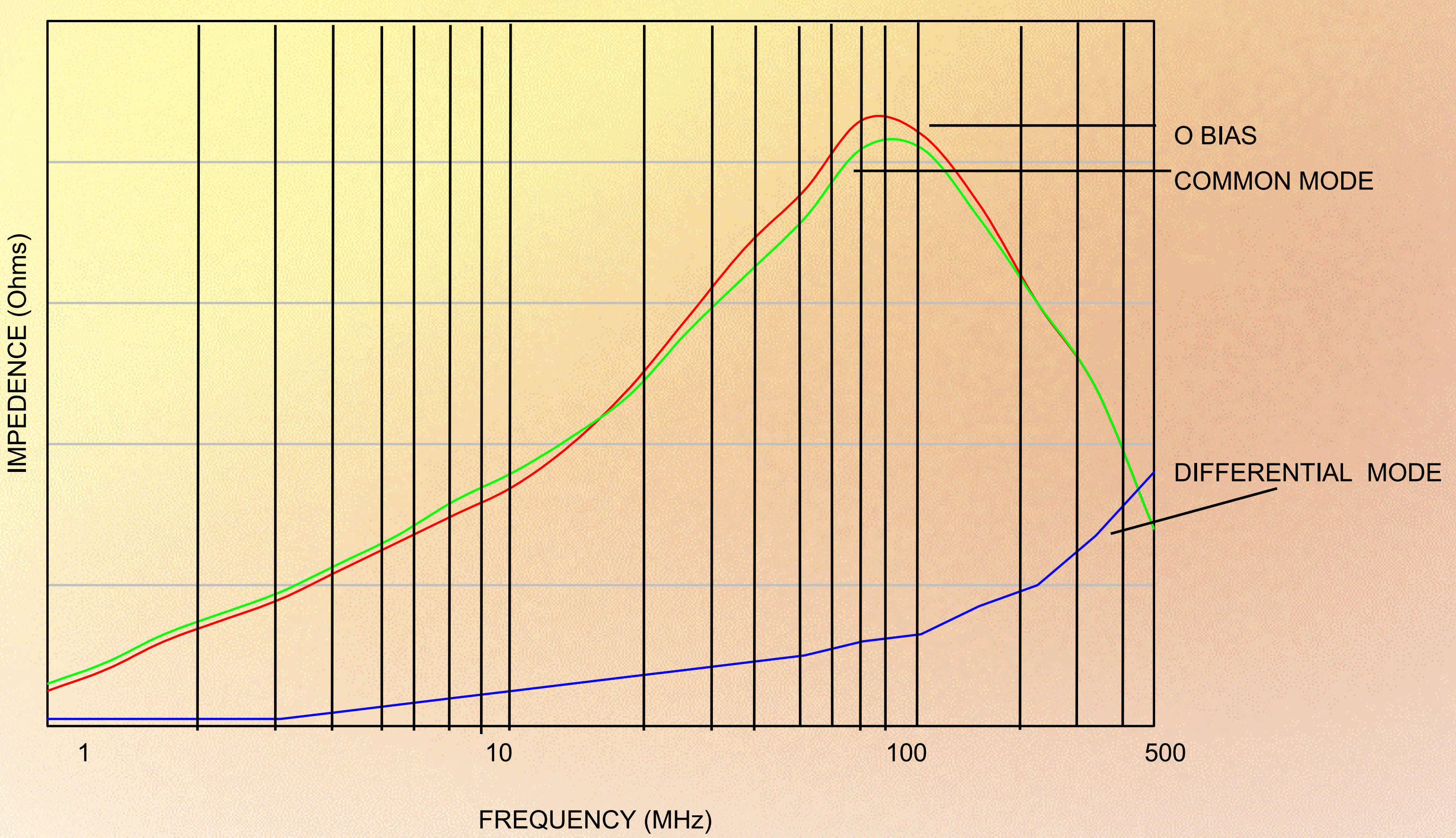
$$20 \log \frac{Z_{SOURCE} + Z_{LT}}{Z_F + Z_{SOURCE} + Z_{LT}} = 20 \log \frac{100 + 15.41}{170 + 100 + 15.41}$$

$$= 7.86 \text{ dB}$$


COMPARING MATERIALS
BO562-200
IMPEDANCE (Ohms)
600
500
400
300
200
100
0
1
10
100
500
FREQUENCY (MHz)
28
29
25

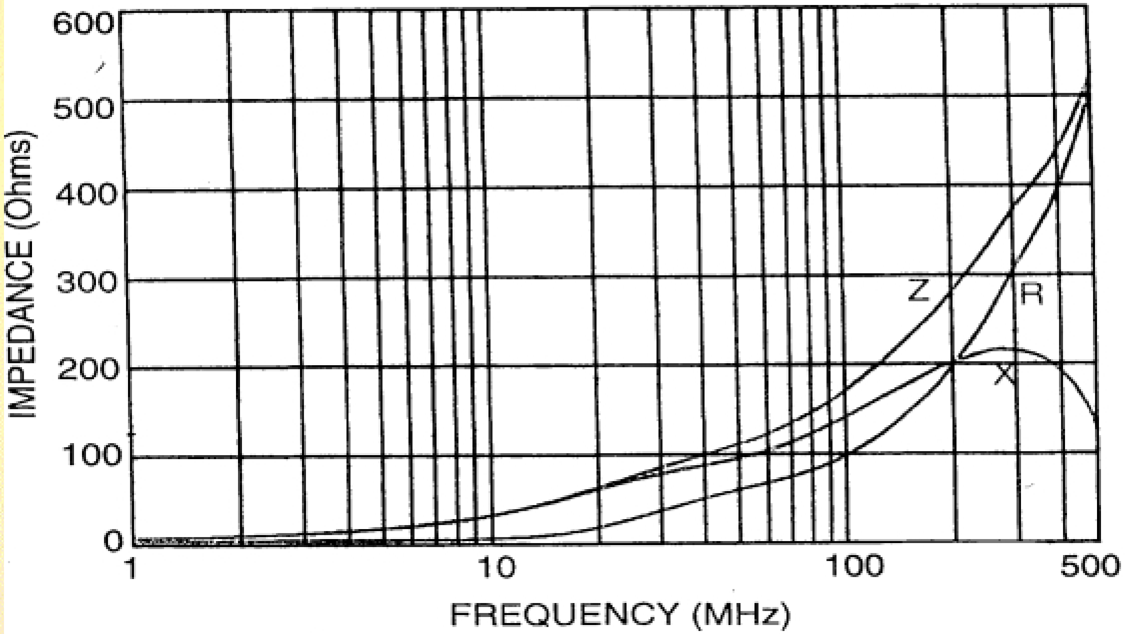
Impedence vs. DC Bias
Common vs. Differential Mode

SPECTRUM CONTROL, INC.



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	≥ 225° C	10^8
28 Material	30 - 300	850	3350 @ 10 Oe	2200	0.4	≥ 175° C	10^5
29 Material	30 - 300	600	3300 @ 10 Oe	1500	0.35	≥ 165° C	10^8

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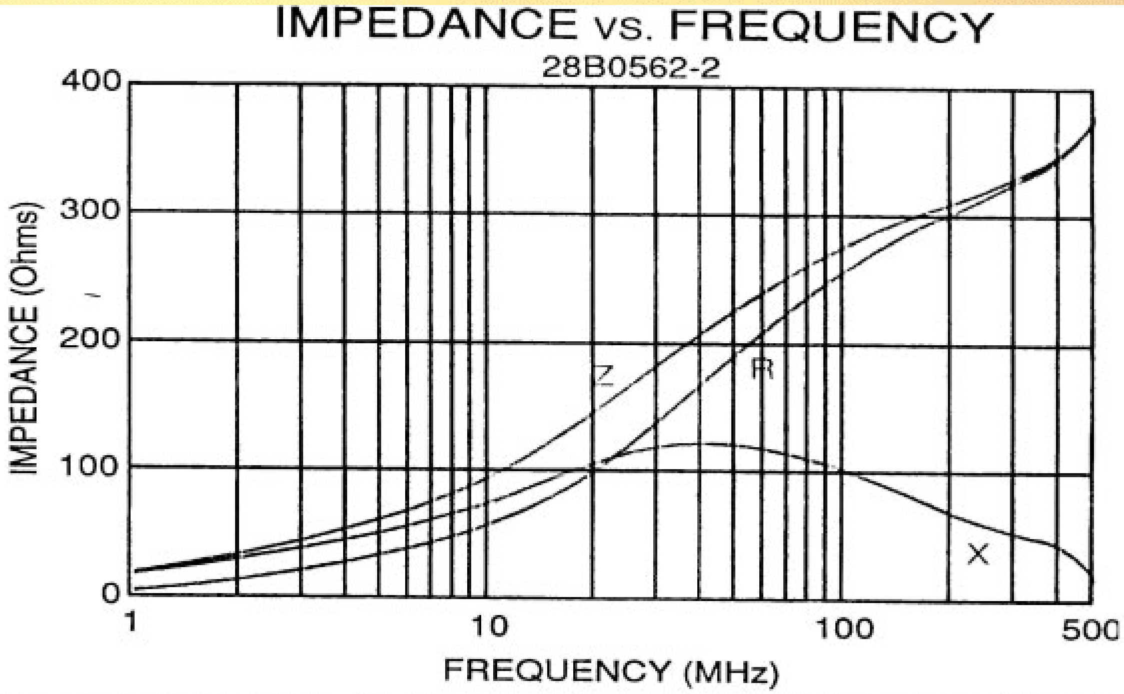

Property Units	Frequency Range MHz	Initial Permeability (μ_i)	Saturation Flux Density (B_s) Gauss	Residual Flux Density (B_r) Gauss	Coercive Force H_c	Curie Temperature (T_c) ° C	Volume Resistivity (ρ) Ohm-Centimeters
25 Material	100 - 500	125	3650 @ 10 Oe	2600	1.6	≥ 225° C	10^8
28 Material	30 - 300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

Ten Commandments of Electromagnetic Compatibility

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

RELATIVE SUSCEPTIBILITY OF CIRCUITS TO MAGNETIC INTERFERENCE

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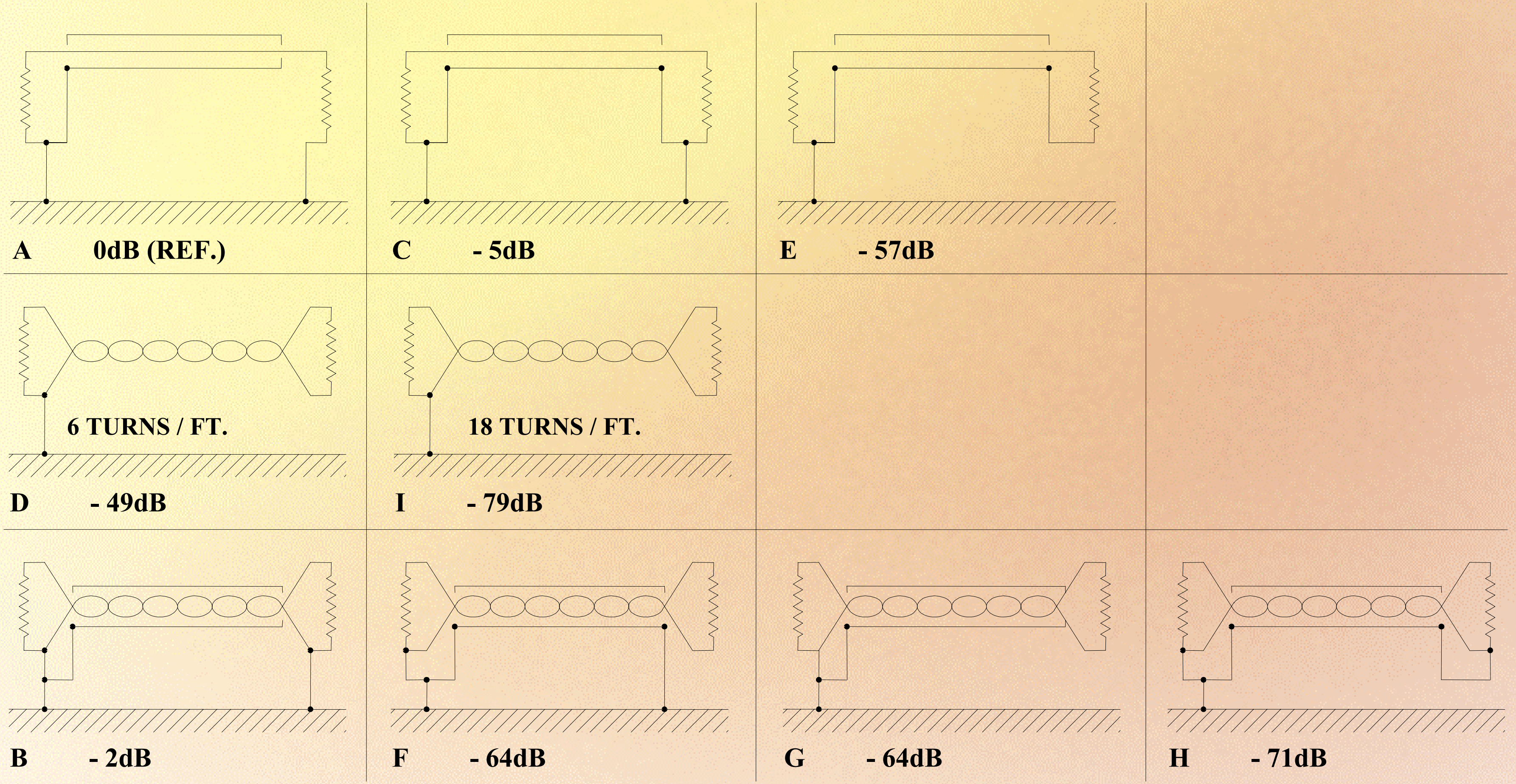

VALUES GIVEN ARE FOR CIRCUITS 1 INCH ABOVE GROUND PLANE

Ten Commandments of Electromagnetic Compatibility

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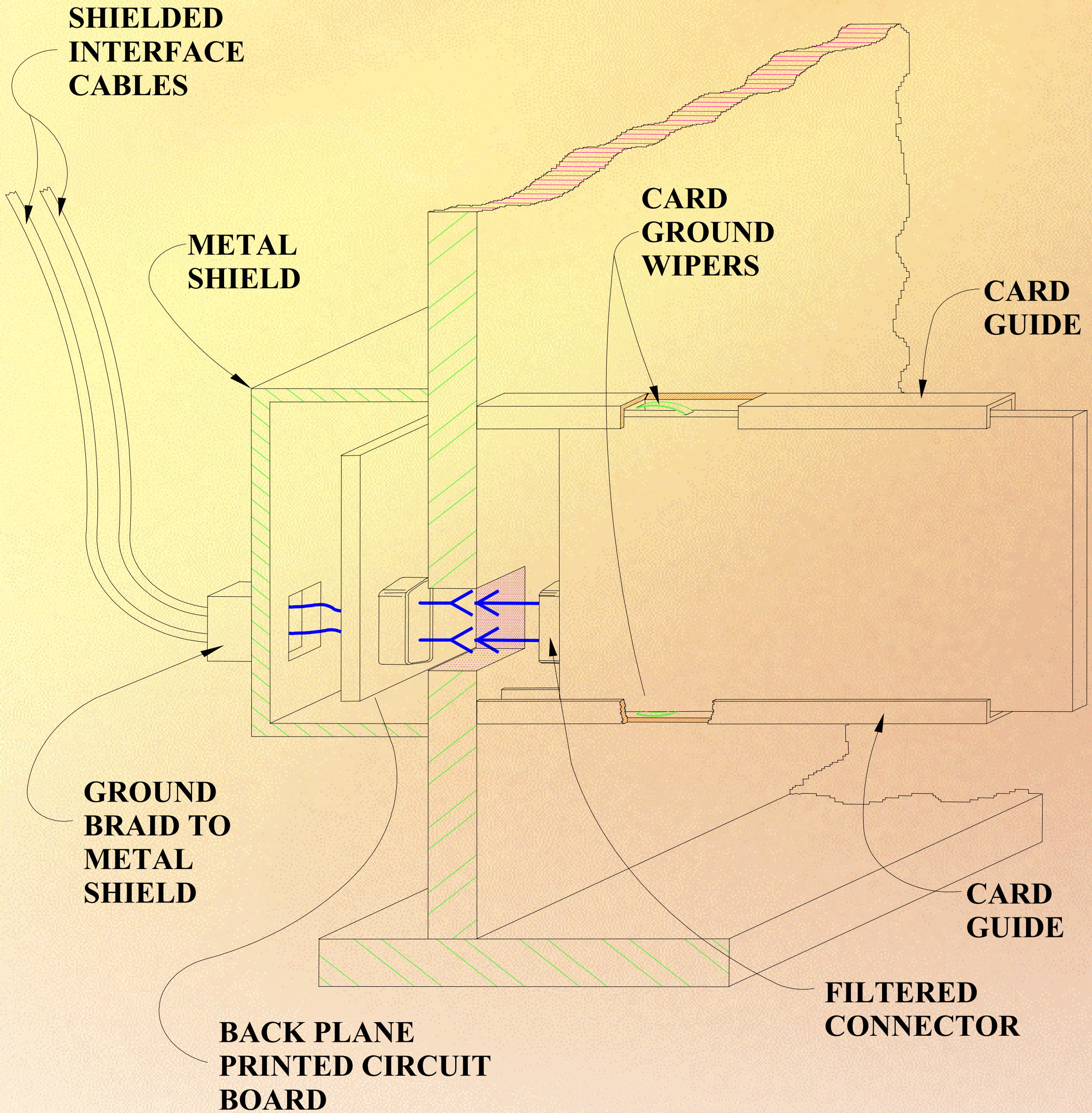
9. Shield and wiper ground / bond all backplanes and interfaces to modules.



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SHIELD BACKPLANE WIPER GROUND CARD

Ten Commandments of Electromagnetic Compatibility

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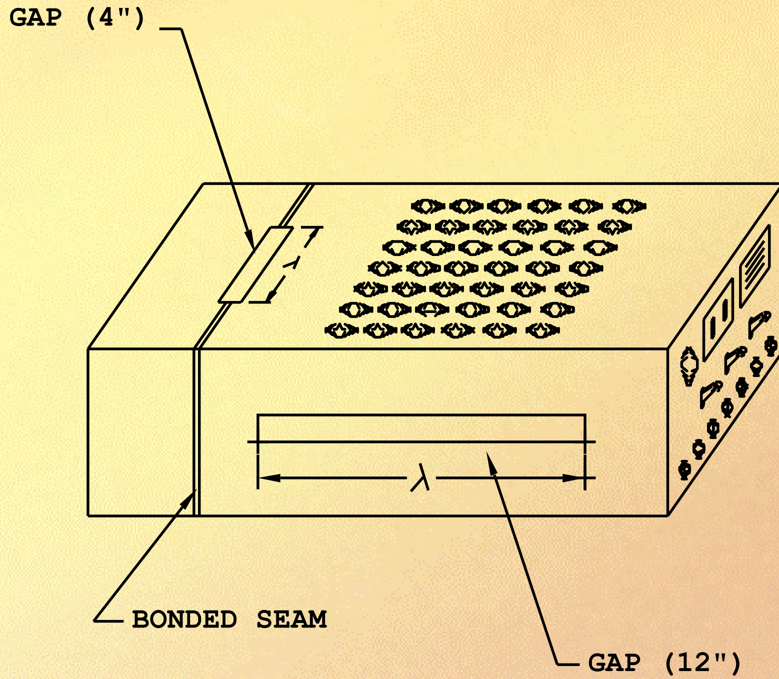
10. Close or interbond all apertures and gaps longer greater than Lambda (wavelength) / 20.



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 → $\boxed{\frac{591}{\text{F MHz}} = \text{Max. GapInches}}$

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