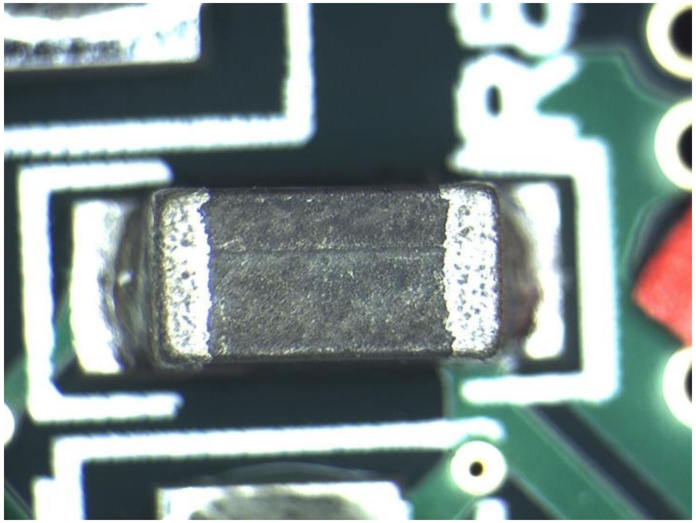
EMI Suppression Ferrites



Fair-Rite Products, Wallkill, NY
October, 2020

Agenda

- What is Ferrite?
- Ferrite Overview
  - Ferrite Applications
  - Material Differences
- Terminology
- Suppression Ferrites / Applications
  - How they work
  - How they are made
  - Material Comparison
  - Differential and Common Mode
- Selecting the right Ferrite
- What's New at Fair-Rite

Michael Arasim
Product Manager
PWR&IND

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Product Mnager
Suppression

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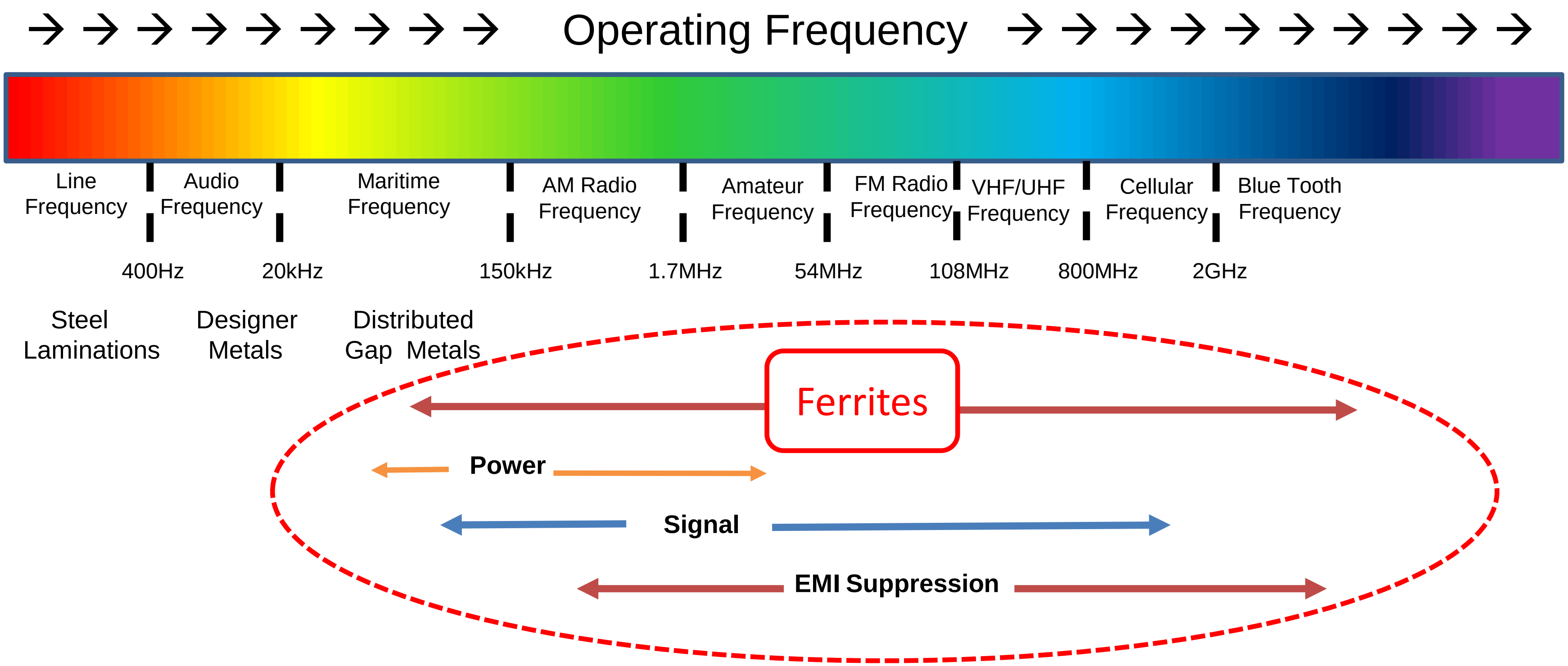
What Is Ferrite?

- Ferrite is a magnetic material formed by pressing and firing metal oxides into a ceramic material.
  - Iron provides magnetic properties
  - Oxygen provides high resistivity for low loss
- Two basic Materials: MnZn and NiZn
- High resistivity reduces losses allowing operation at high frequencies.
- A 'Soft' magnetic material is one that can be both easily magnetized and demagnetized.
- Four classes: Power, Inductive, Suppressive, Shielding

Why Ferrites?



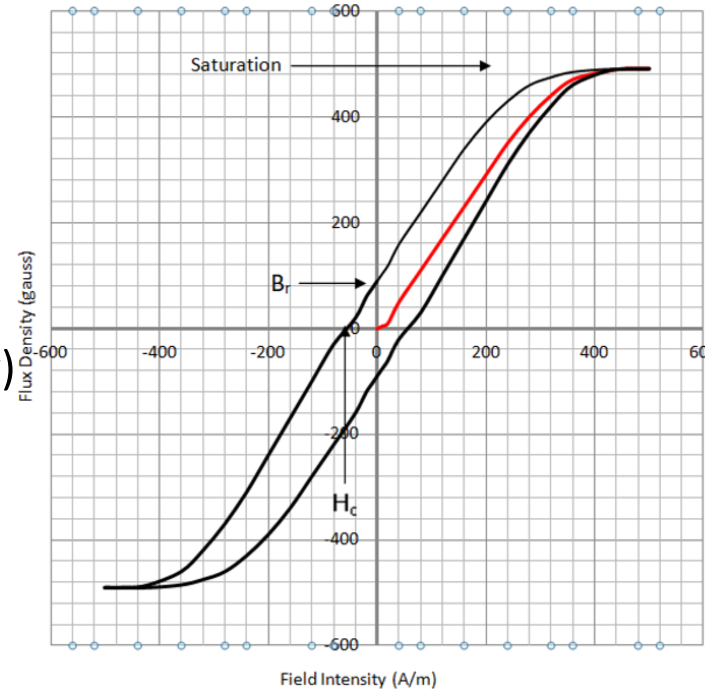
- Losses are proportional to Frequency: Ferrite has Low Losses
  - Hysteresis Losses (Magnetization)
  - Eddy Current Losses

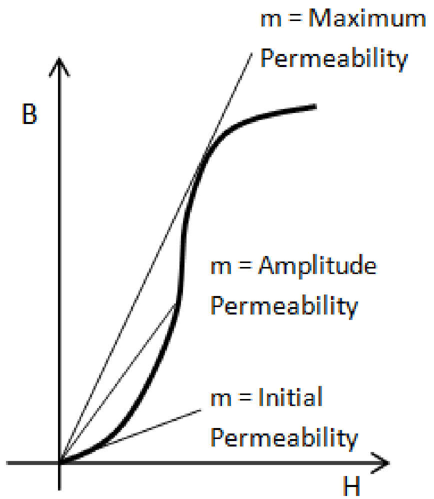
Uses and Applications for Soft Ferrites

- **Inductors:** Power and Signal / Fix and Variable
  - The Ferrite Core Acts as an 'Inductance Amplifier'
- HF **Transformers** \ Spark Generators
  - The Ferrite Core Acts Like an Efficient Flux Coupler
- **Antennas**
  - The Ferrite Core Acts Like a low loss 'Field Amplifier'
- **Sensors** (Hall, Proximity, RF Scanning, etc.)
  - The Ferrite Core steers the flux in a magnetic circuit.
- **Read / Write Heads**
  - The Ferrite Core acts to focus the flux
- **Electromagnets**: Beam Steering / Accelerators
  - The Ferrite Core allows high frequency electro magnet
- **EMI Suppression**
  - The Ferrite Core Acts Like a Frequency Dependent Resistor
- **Shielding** /RF Absorption
  - The Ferrite Core can steer flux or absorb electromagnetic energy

Speak the language

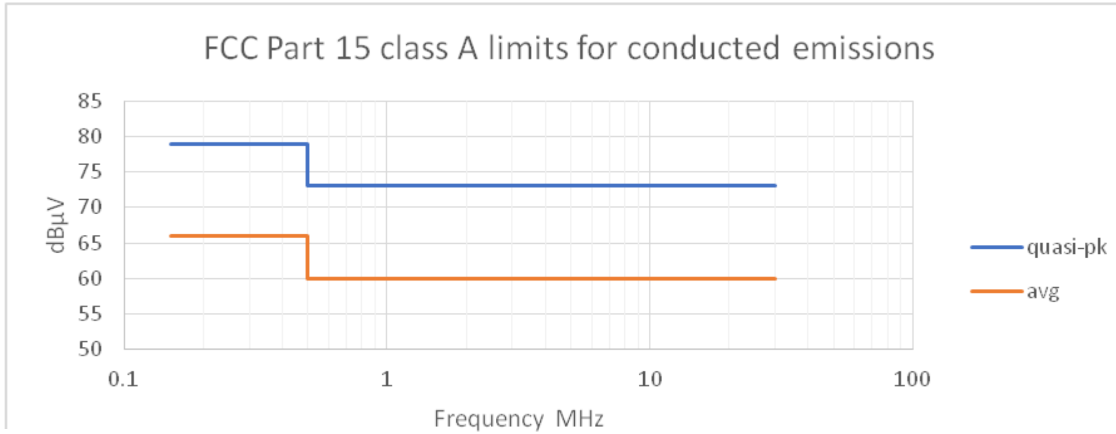
- Permeability B=μH
  - Initial (10kHz low B)
  - Incremental (μi vs DC bias)
  - Amplitude (μi vs B)
  - Effective (μi with air gap)
  - Complex (μ' μ" over frequency)
- Saturation
- Curie Temperature
- Power Loss Density
- Air Core Inductance
  - Permeability of free space (L_0)

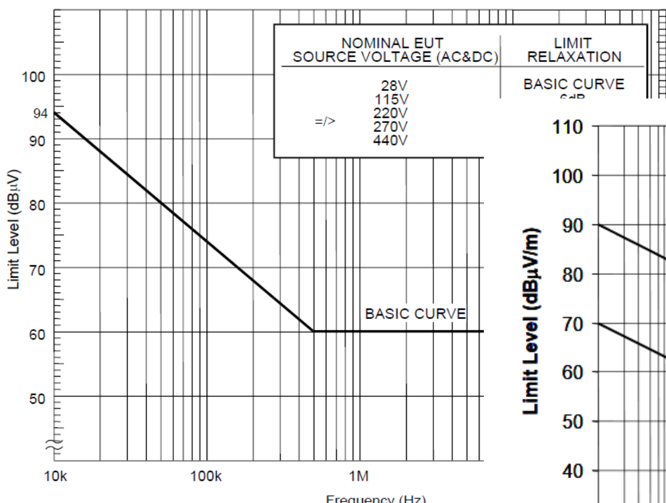


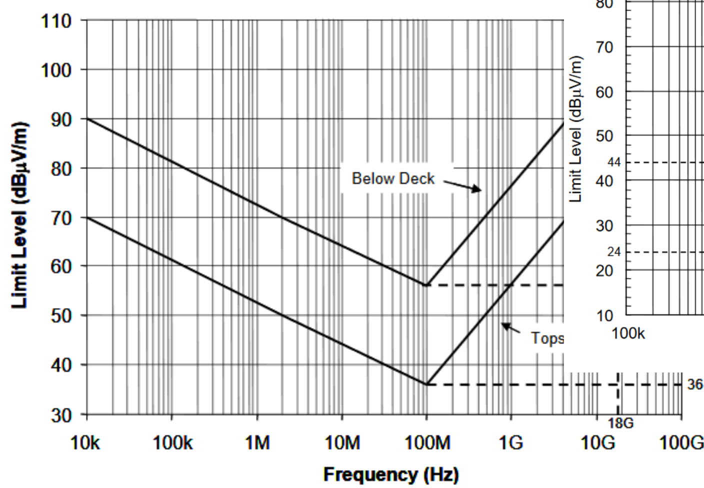


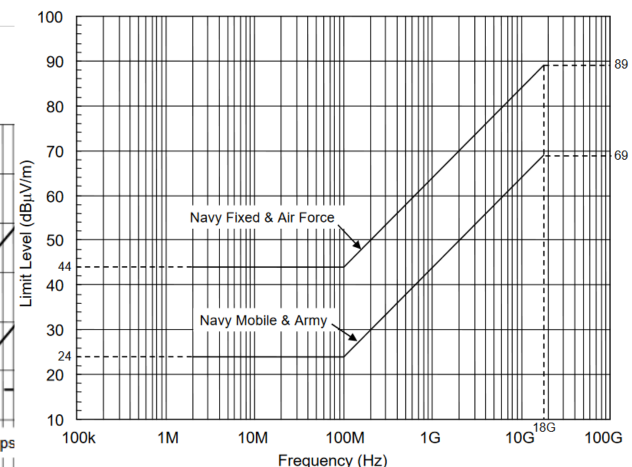
EMI Standards

- FCC
- MIL-STD-461
- DO160
- EMC-directive (2014/53/EU)

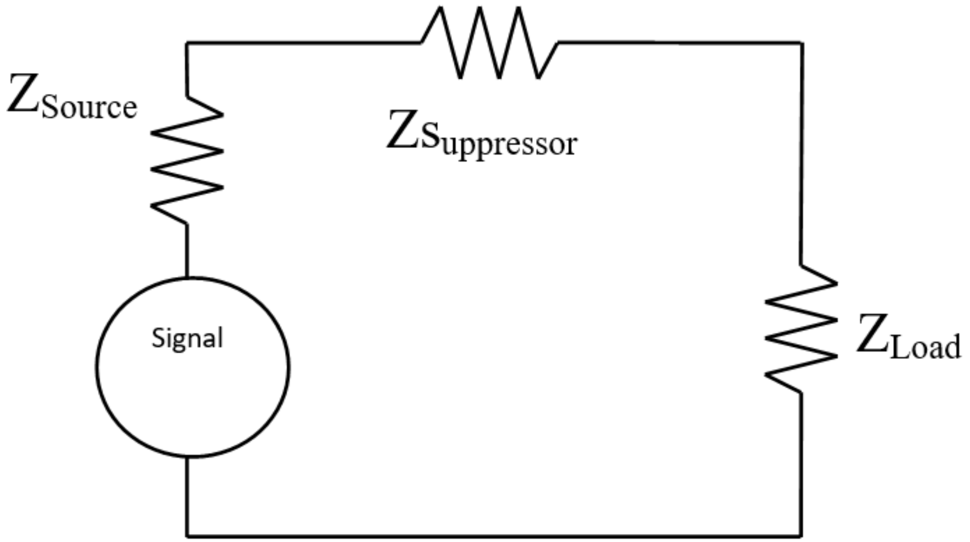








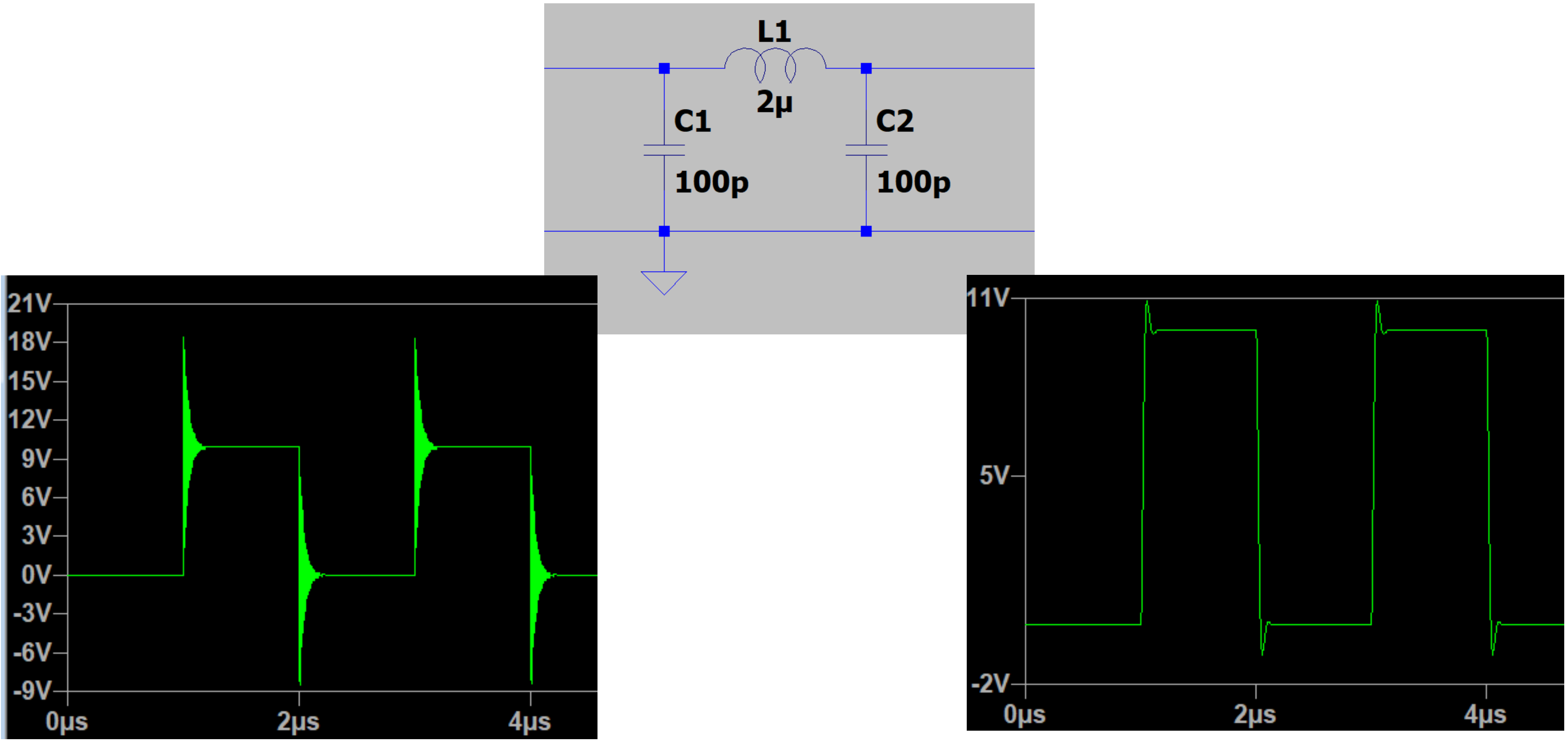
Impedance adds Insertion Loss



$$Attn(dB) = 20 * \mathrm{LOG}\left(\frac{Z_{Source} + Z_{Supression} + Z_{Load}}{Z_{Source} + Z_{Load}}\right)$$

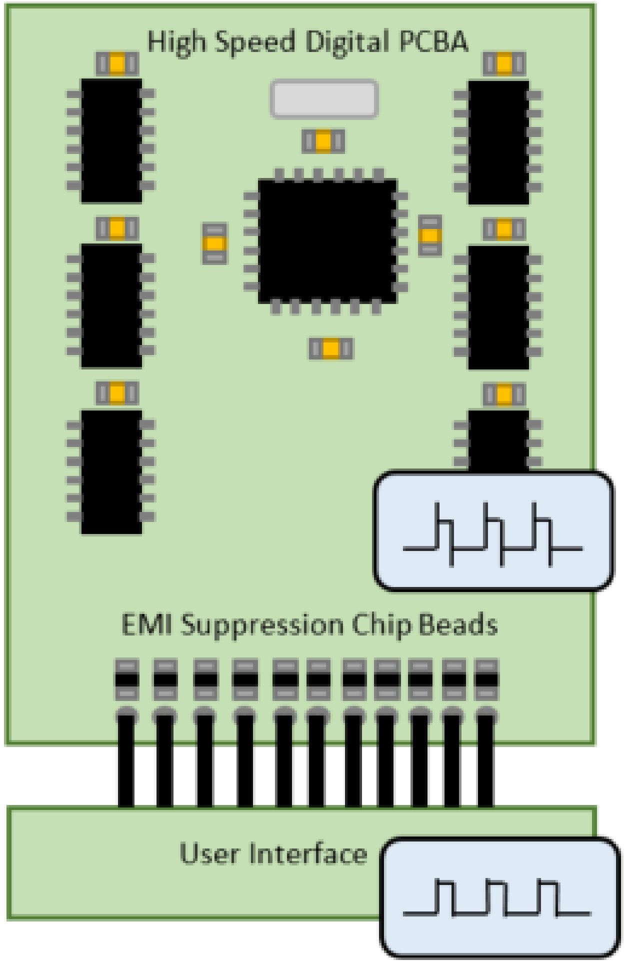
Attenuation is the difference of V_{out} with, and without, the suppressor in the circuit.

Inductive Filters



Inductive filters block higher frequencies but reflect energy back to the generating circuit causing peaking and ringing.

Suppression Devices

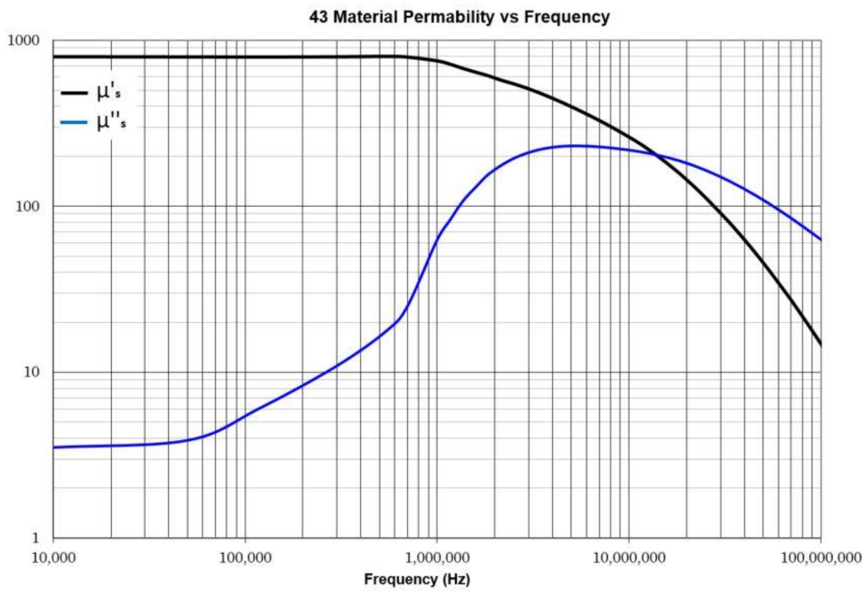


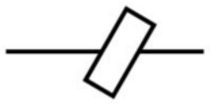
Ferrite materials developed with frequency dependent losses enable EMI suppression components giving designers another option to control unwanted noise.

- On Board Chips and Beads
- Cable Cores and clamps
- Connector plates

Suppression Ferrites

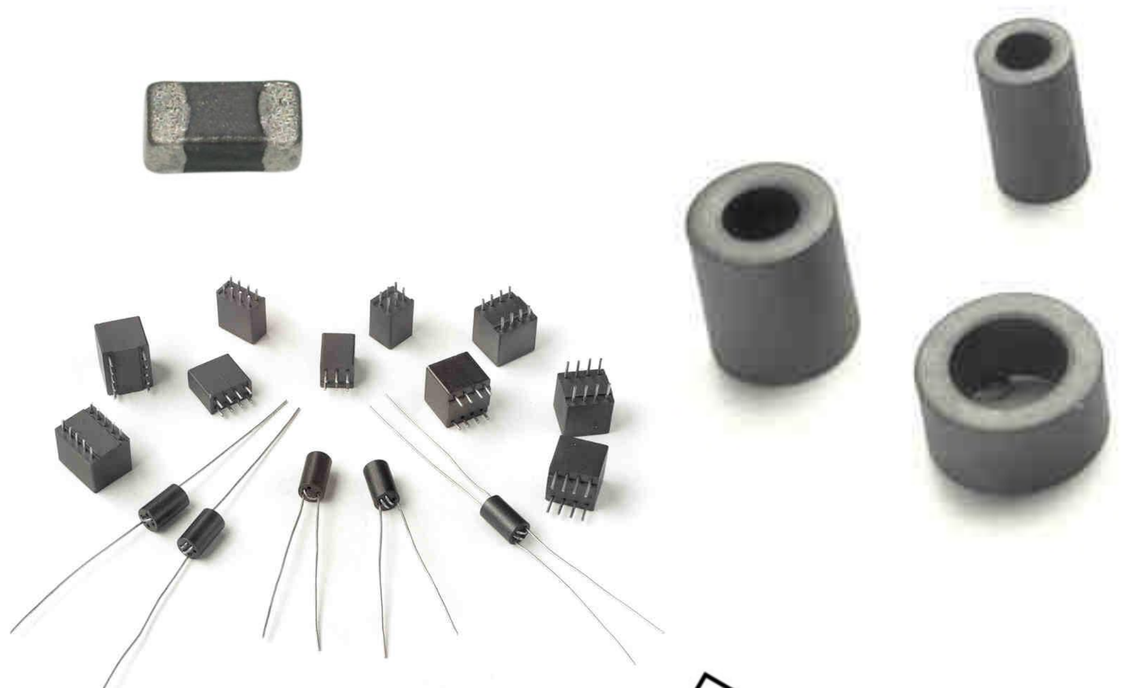
- Strengths
  - Lossy Core Material
  - Resistive / dissipative
- Trade Offs
  - Limited frequency band
  - DC Bias Concerns





IEEE Accepted Schematic Symbol for a Ferrite Suppression Device

Ferrite Beads



Made like and looks like an inductor….

IEEE Accepted Schematic Symbol for a Ferrite Suppression Device

Impedance Rated Devices, Not Inductors

Oxide Powder Composition

Iron Oxide

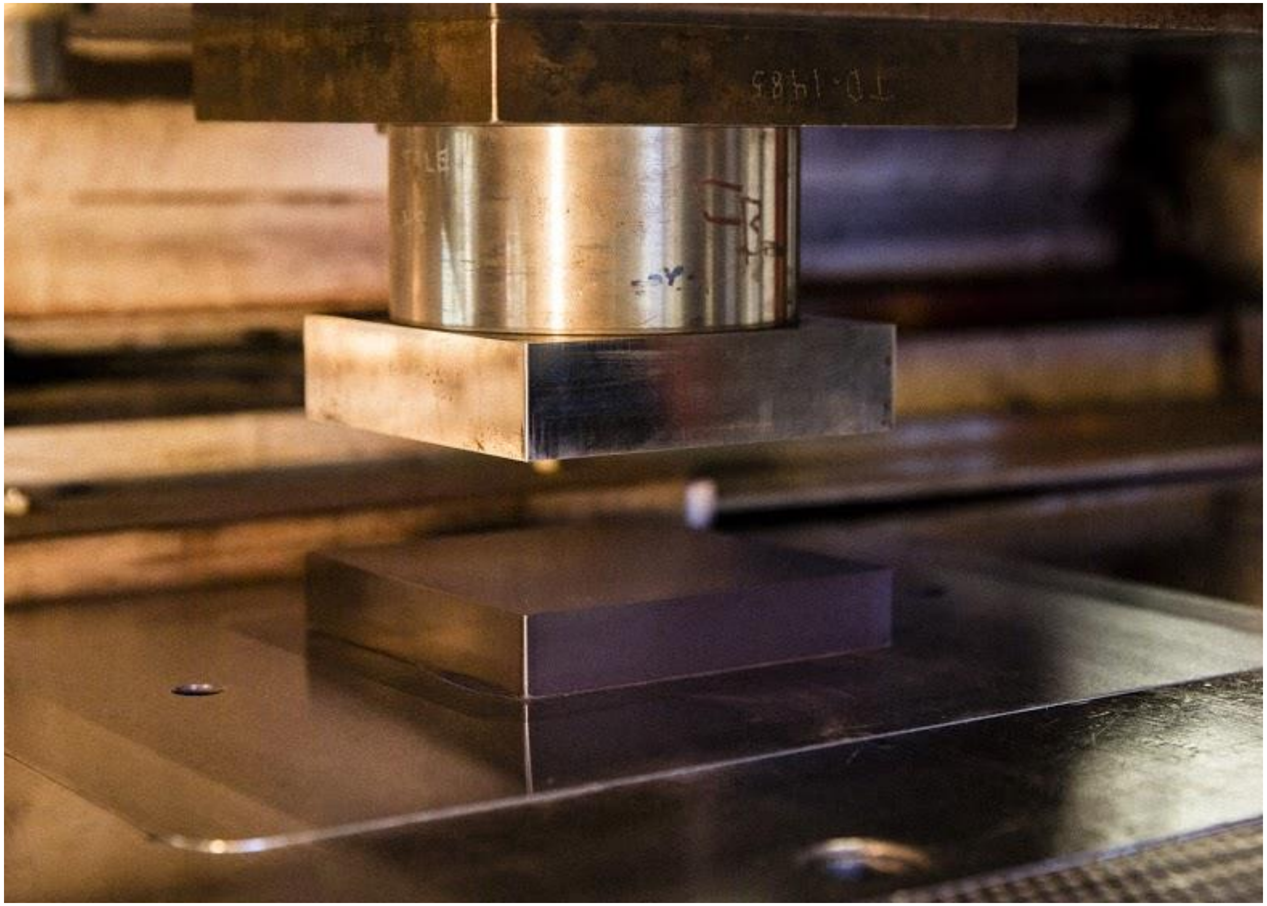
Manganese Oxide

Zinc Oxide

Nickel Oxide

Binders

Compaction Pressing



Dies easily form parts with high detail.

Sintering

Tunnel Kilns and Batch Kilns

Atmosphere controlled environment

Designed Temperature Profiles

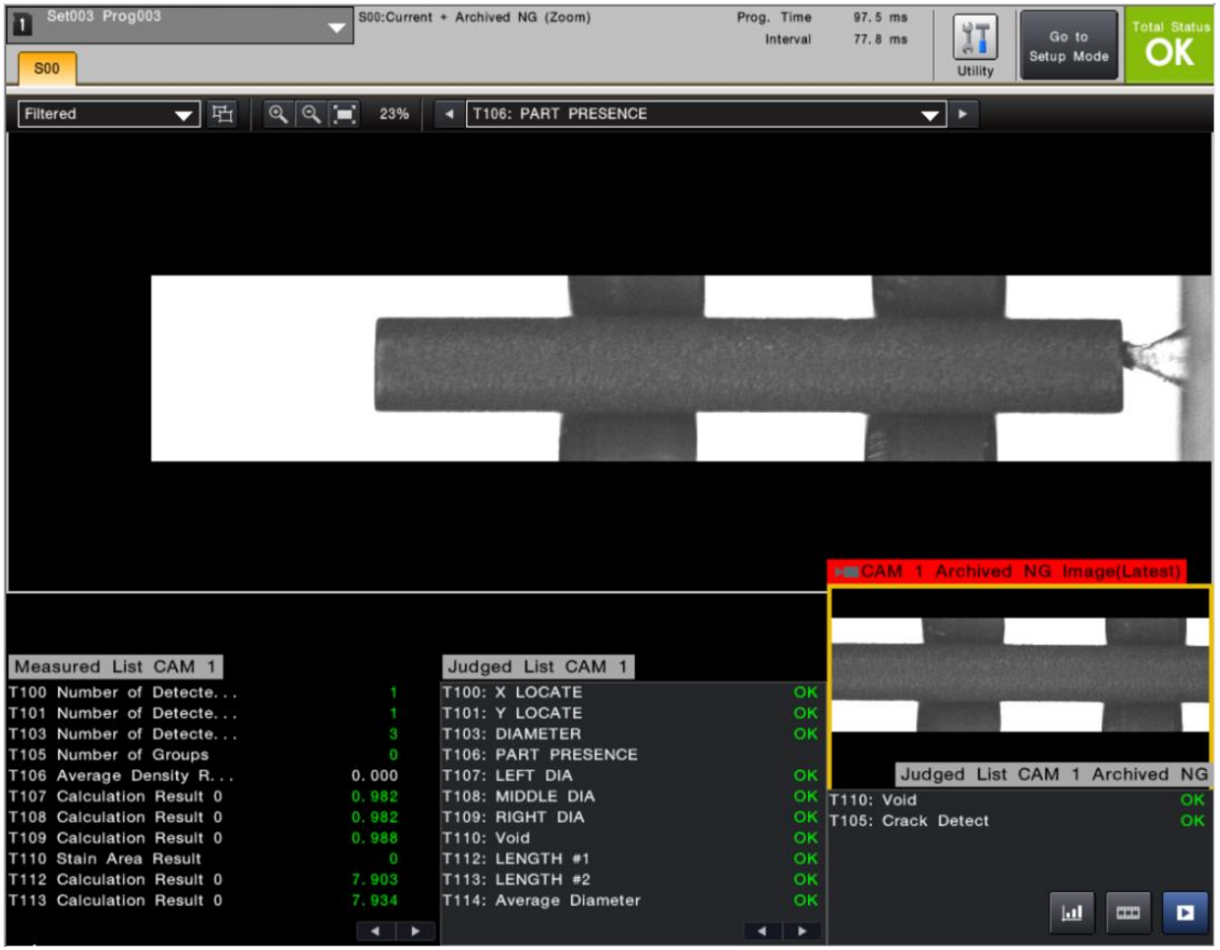
Finishing

Machining operations to hold tighter tolerances

Burnishing to remove sharp edges

Electrically insulating coatings applied

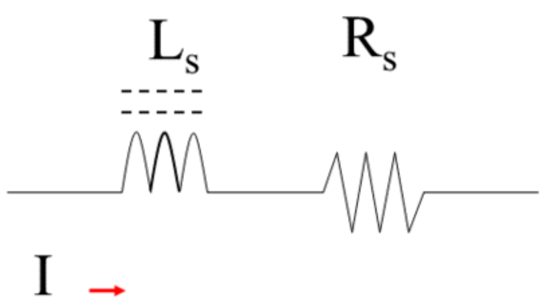
Extensive Quality Control

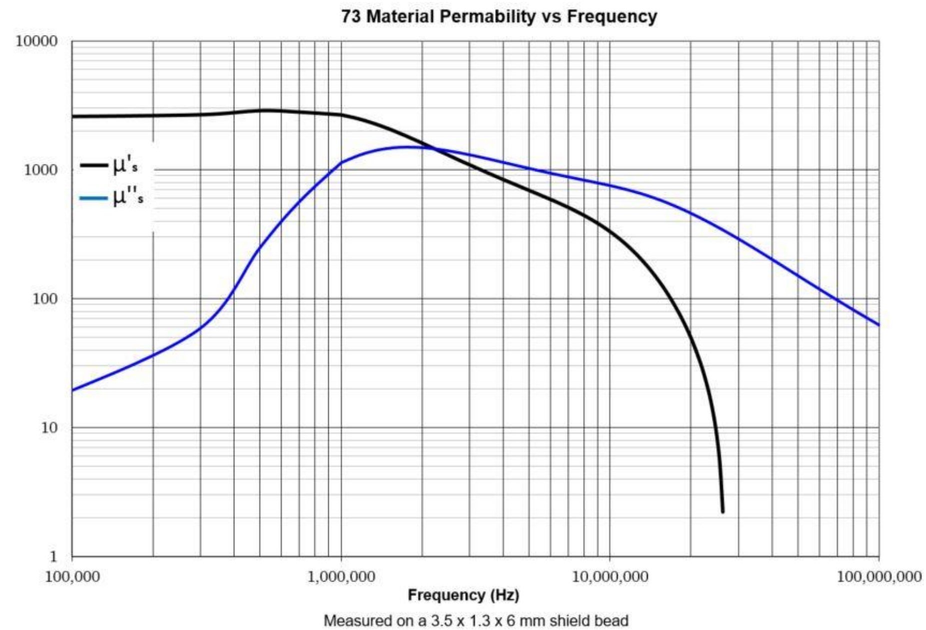


- Dimensional Inspection
- Electrical Inspection
- Physical Strength
- Weight
- Visual Insp.

How do they work?

Series Model of a Ferrite Bead





Complex Permeability Curve

A ‘perfect’ inductor in series with a resistor.
Each has an impedance.

1

Inductive Impedance

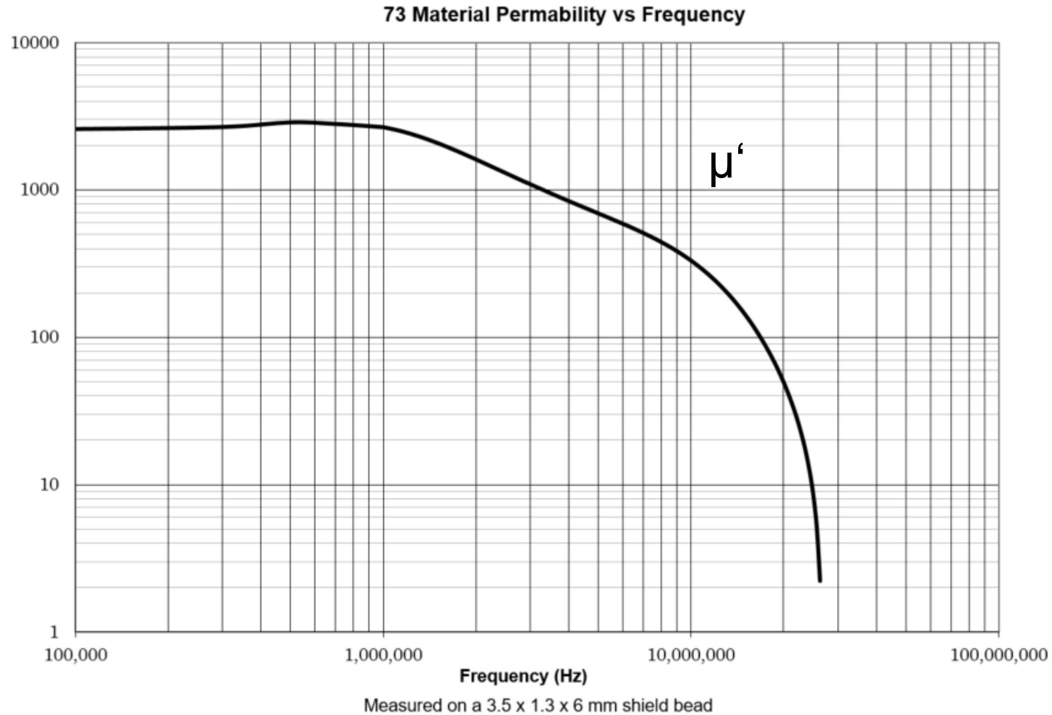
μ' is the inductive component of complex permeability.

$$Z_{L_S} = j\omega L_S$$

since..... $L_S = \mu_s{}' L_0$

We get.....

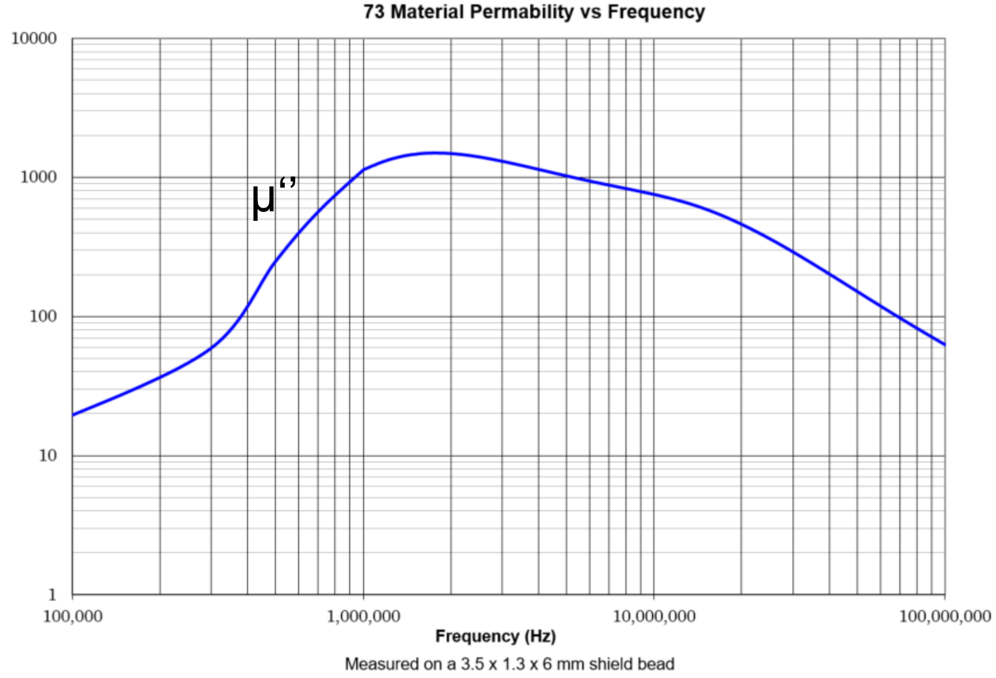
$$Z_{L_S} = 2\pi f L_0 \mu_s{}'$$



Inductance is frequency dependent

Resistive Impedance

μ'' is the resistive component of complex permeability.



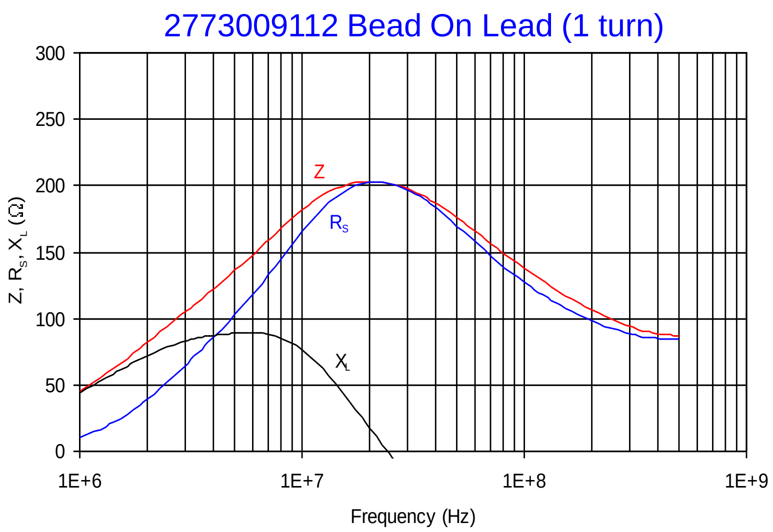
$$R_s = 2\pi f L_0 \mu_s''$$

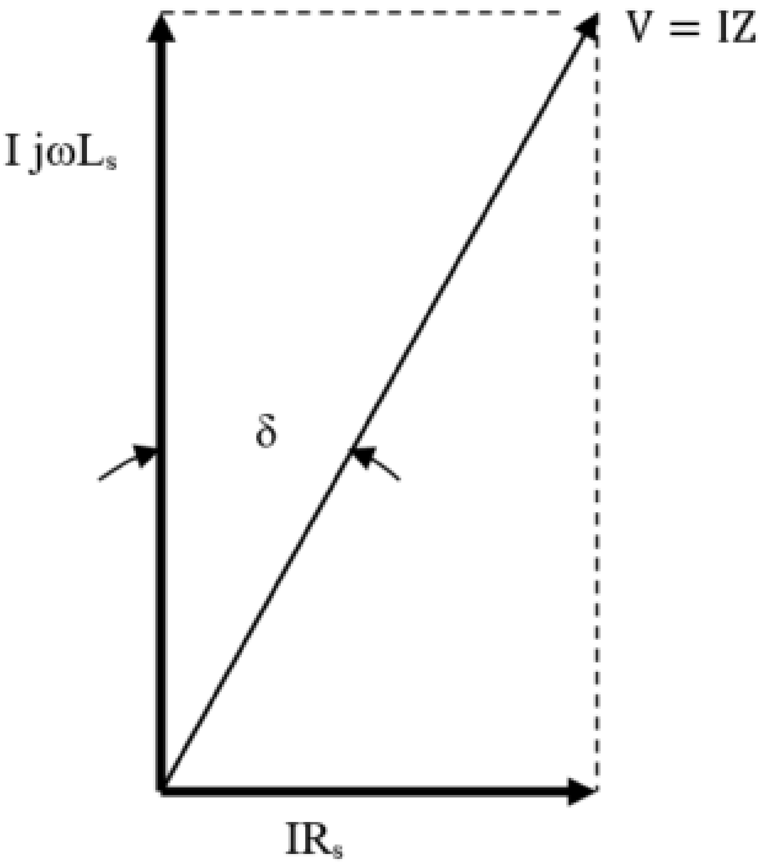
Resistance is also frequency dependent

Total Impedance

$$\tan\delta = \frac{R_s}{\omega L_s} = \frac{\mu''}{\mu'}$$

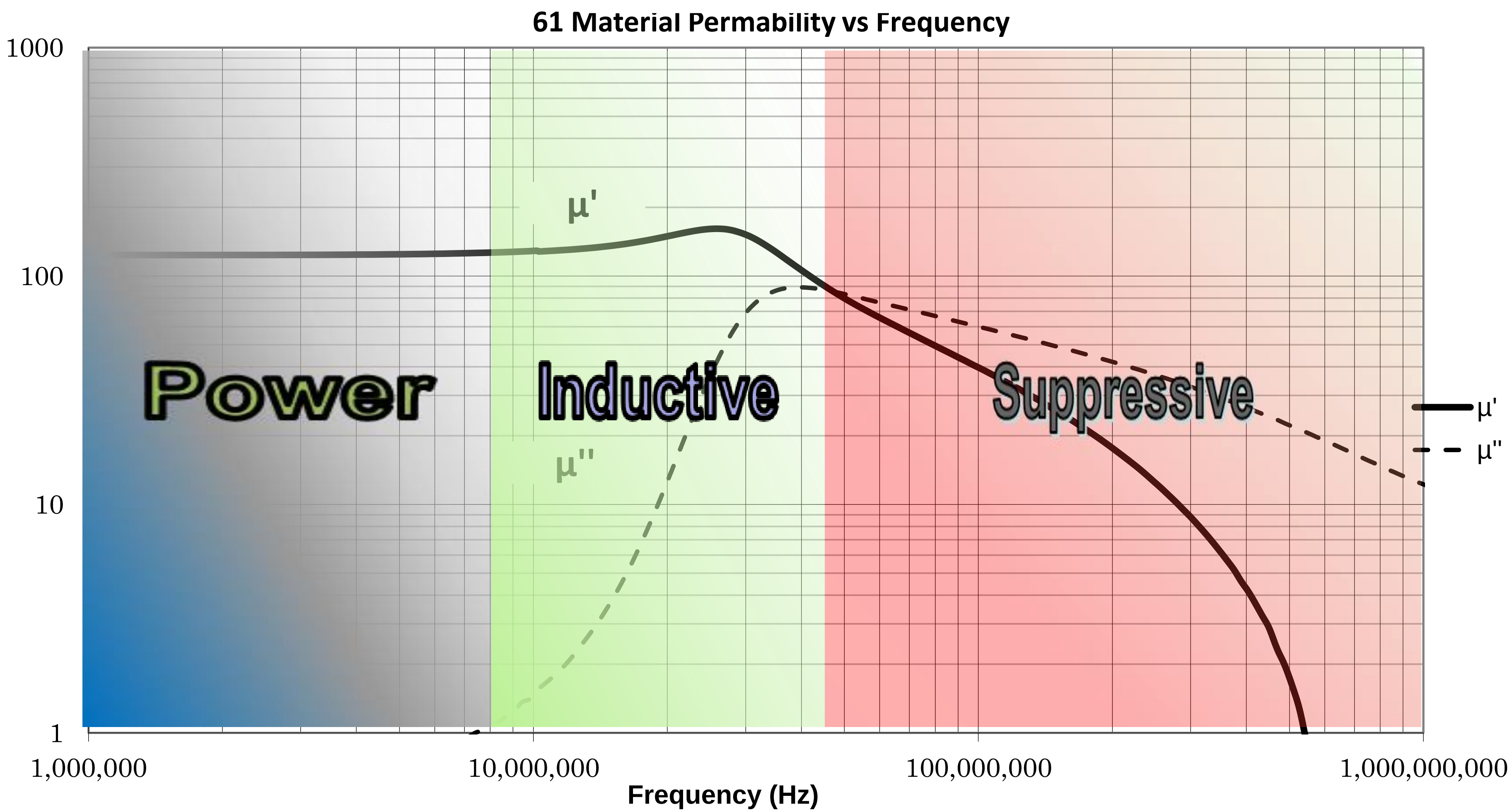
$$Z = j\omega L_0(\mu' - j\mu'')$$



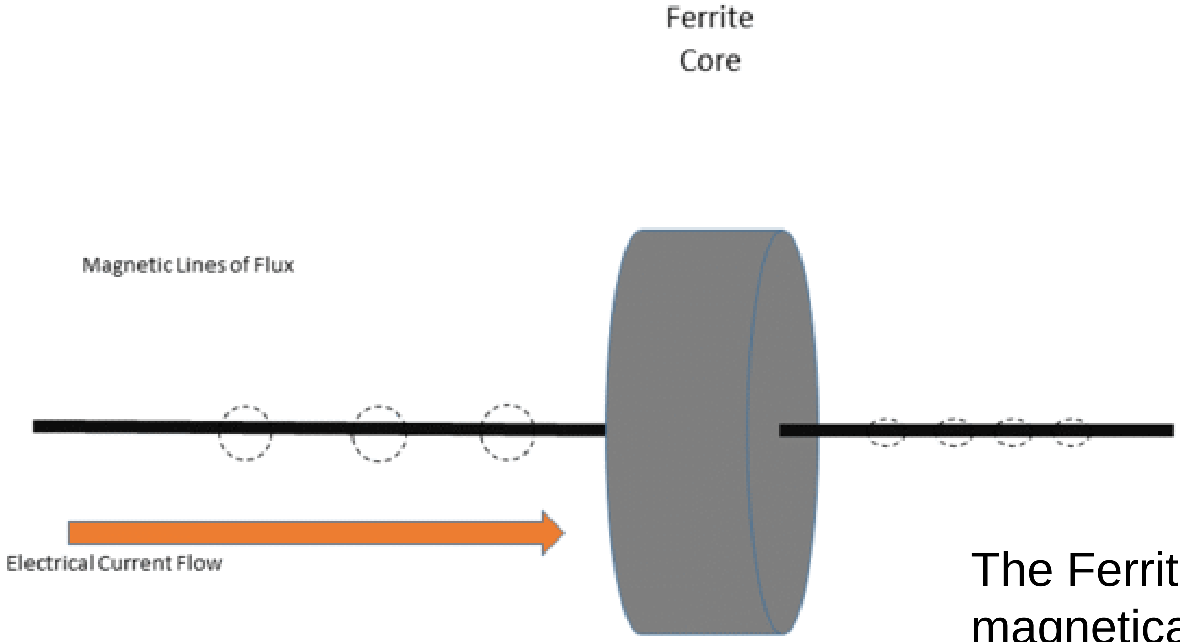


The ferrite material has magnetically coupled impedance into the circuit.

Application Areas of One Material



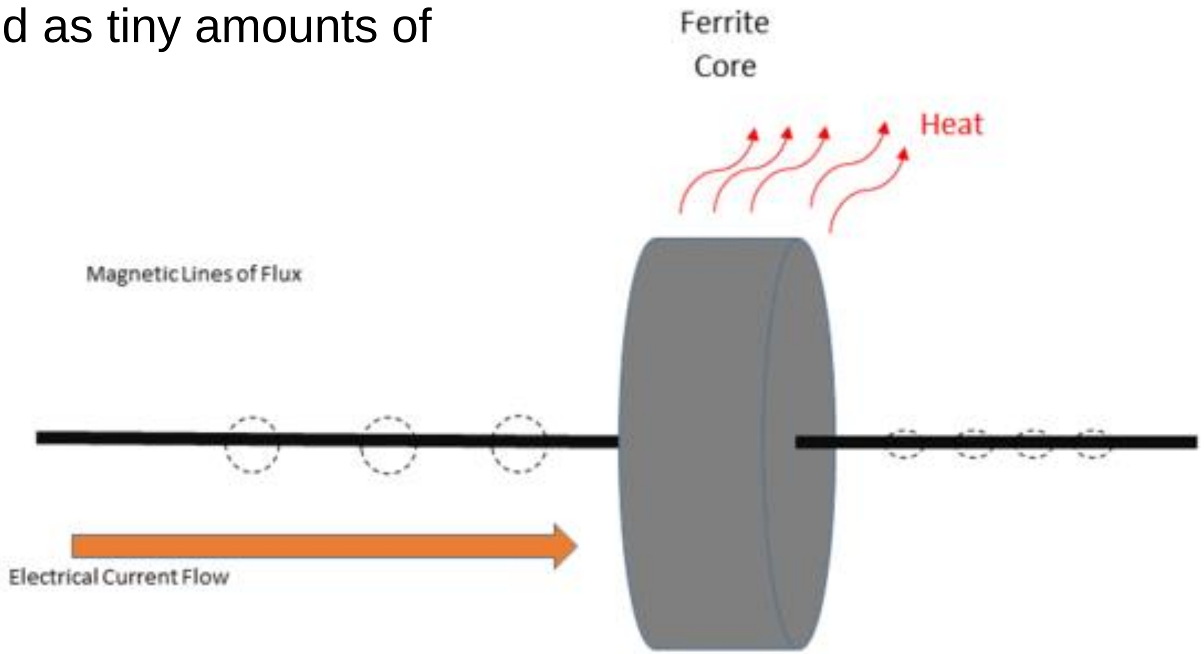
The Ferrite Core surrounds a conductor.



The Ferrite Core is magnetically coupled into the circuit.

1

Unwanted high frequency noise energy is absorbed and dissipated as tiny amounts of heat.



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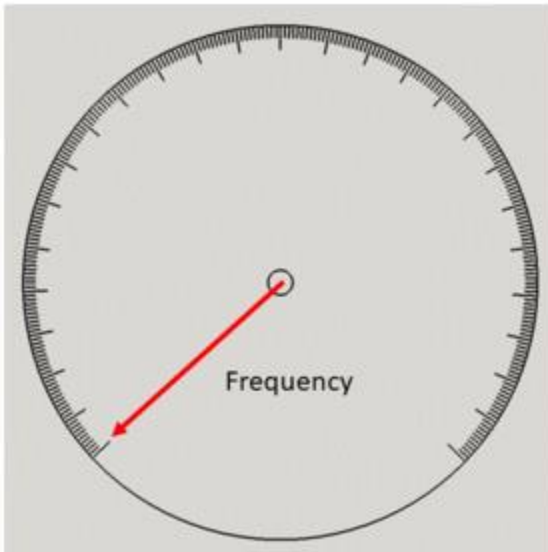
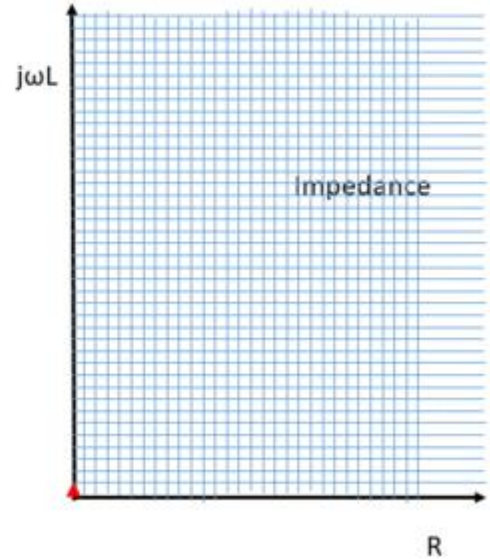
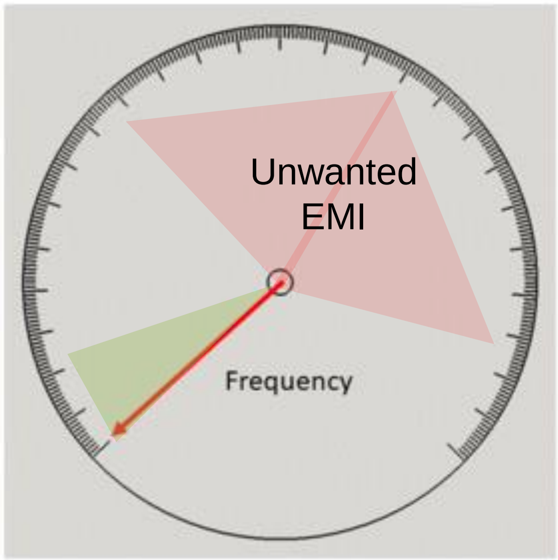
Impedance

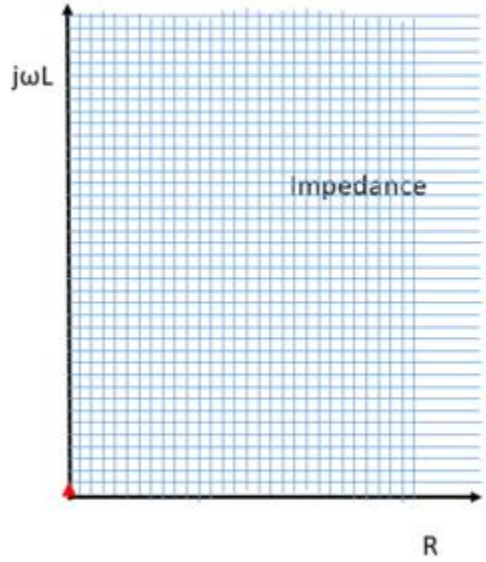




As the applied electrical frequency increases the EMI Suppression device presents a changing impedance vector starting from milliohms going to hundreds of ohms at high frequency.

Impedance

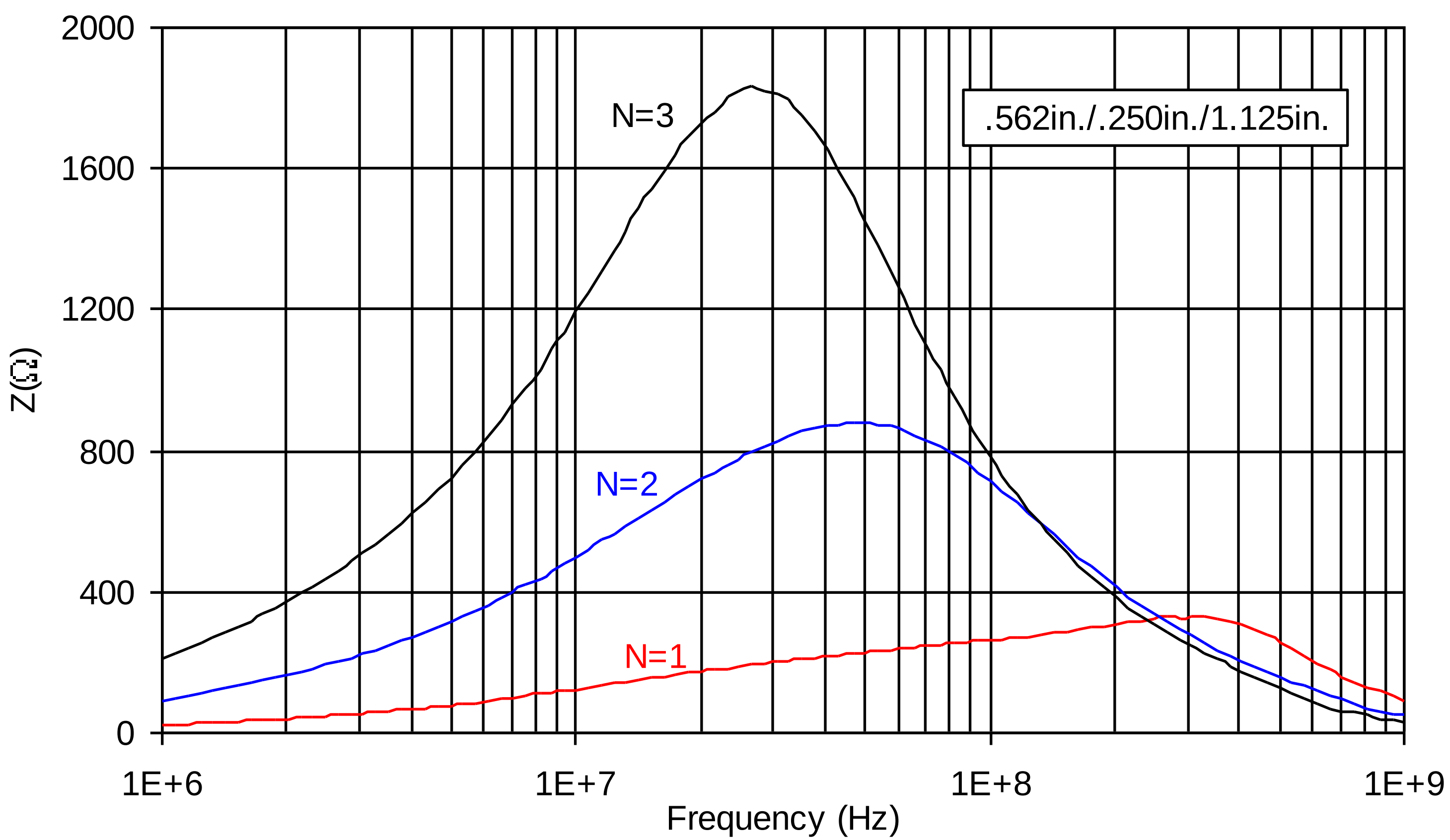




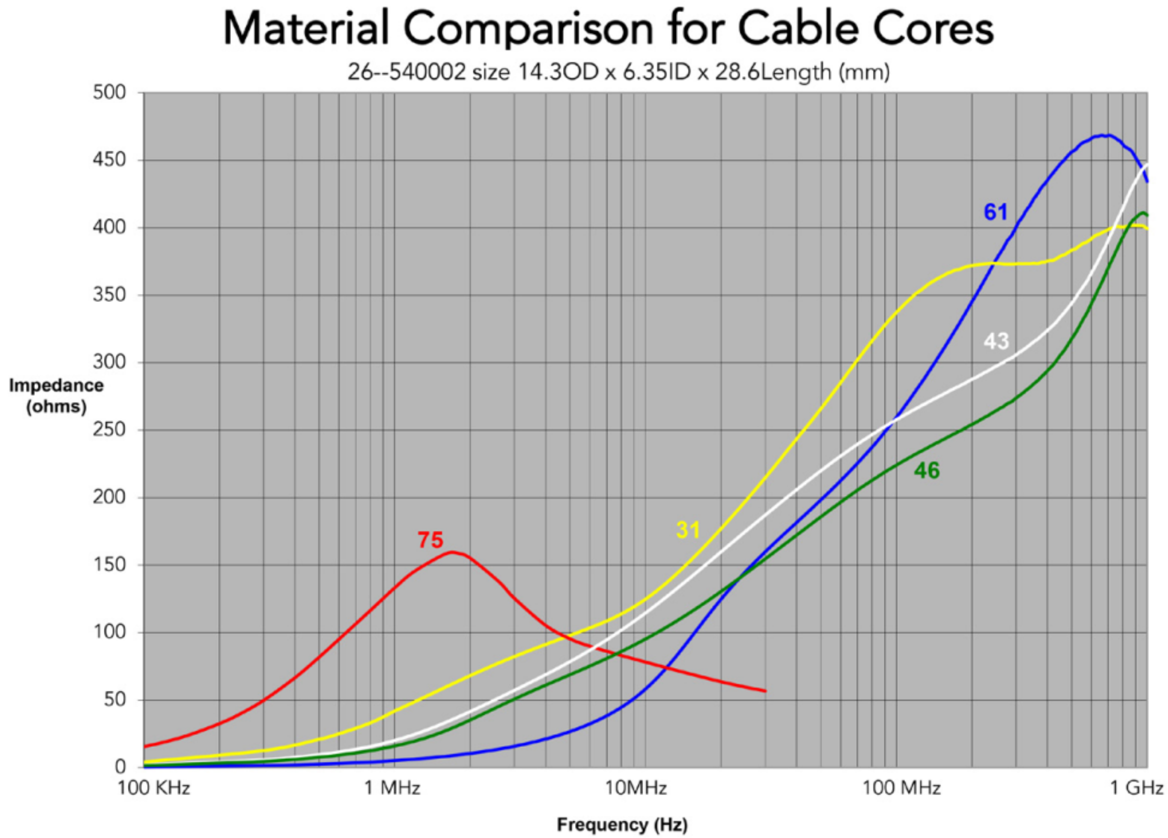
Signal frequencies pass virtually unaffected while unwanted high frequency noise sees significant impedance resulting in energy loss.

The Effect of Turns on Impedance

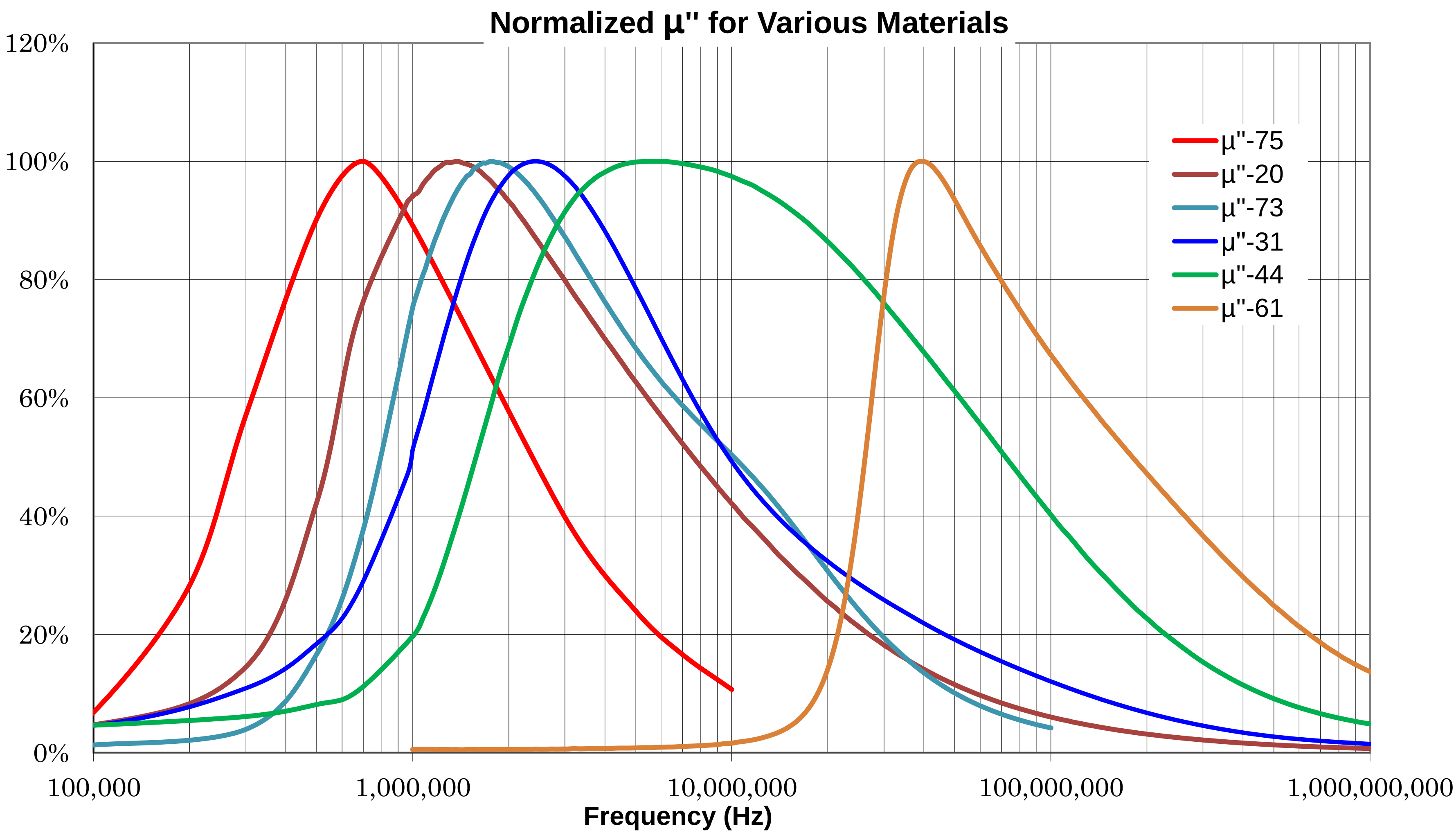
2643540002 Cable Bead



EMI Suppression materials have limited frequency bands where they operate most effectively. Material should be chosen as a function of the problematic frequencies.

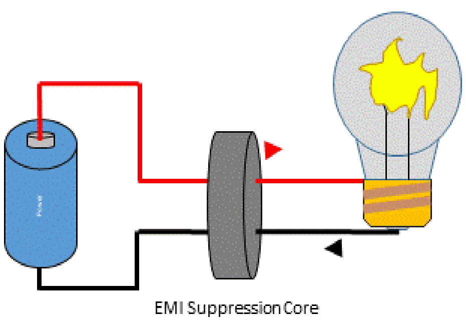


Normalized Resistive Component

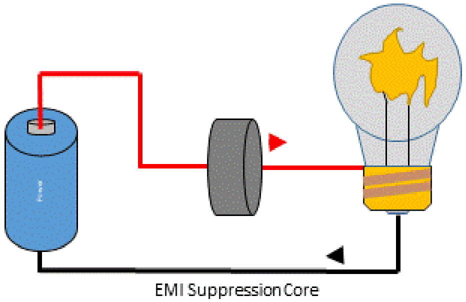


Differential Mode vs Common Mode

Common Mode Currents



Differential Mode Currents

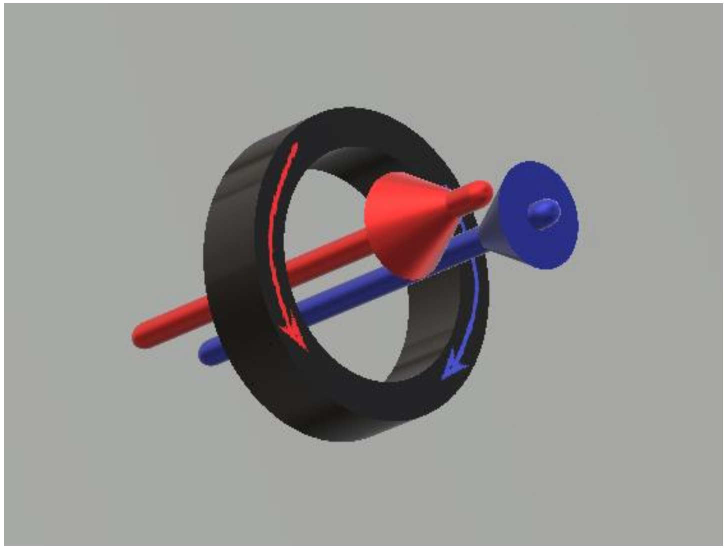


Current goes out and comes back through the suppression device.

Current travels only one way through the suppression device.

Common Mode Chokes

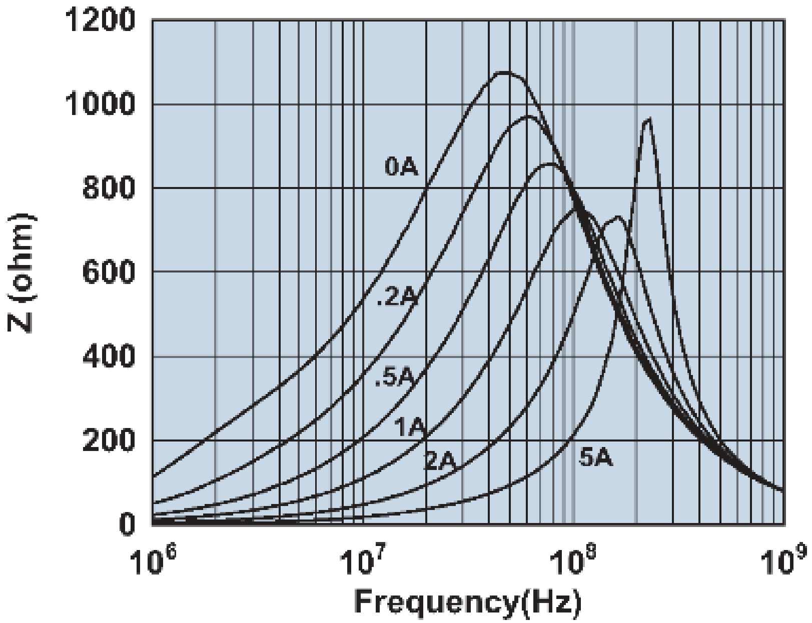
Equal and Opposite magnetic fields within the core cancel the effect of DC Bias



- No impedance to signals passing through the core.
- Provide impedance to leakage currents only.

Differential Mode Applications

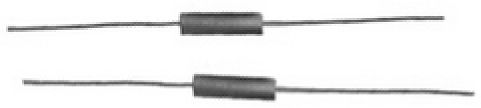
- Provides Impedance to all signals passing through the device.
- Subject to DC Bias Conditions

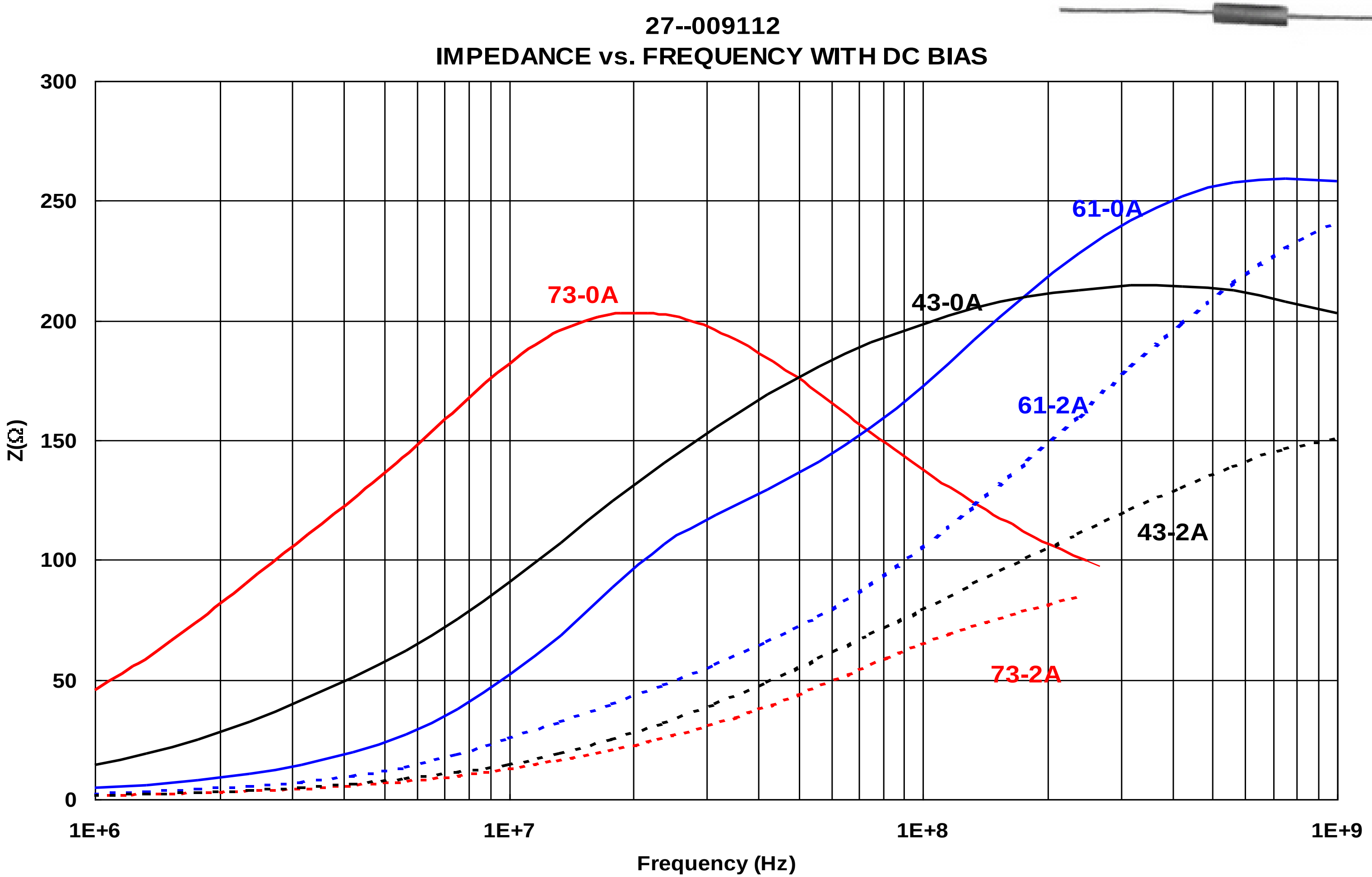


Impedance vs. frequency with dc bias.

Magnetic components change properties in the presence of a static field.

Material Comparison w/ DC Bias



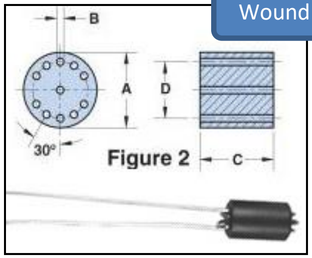


Suppression Components

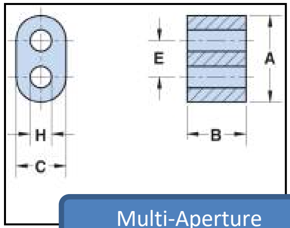
- Beads (rings, Toroids)
- PC Beads – Through Hole
- Wound Beads
- Multi-Aperture Cores
- SM Beads – Differential and Common Mode
- Chip Beads
- Solid and Snap-Its Cable Core Suppression

Selecting the Correct Ferrite Product

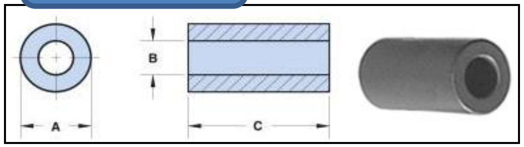
Wound Bead



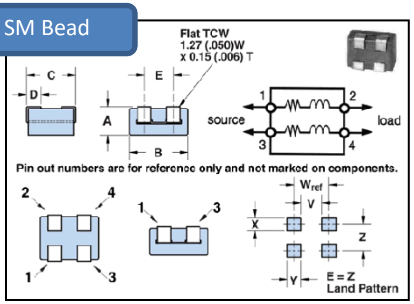
Multi-Aperture



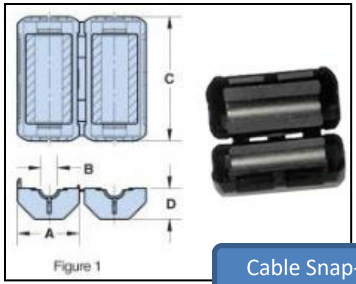
Shield bead/ Cable Core



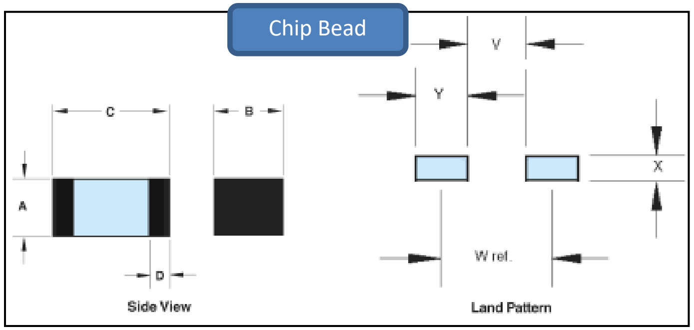
SM Bead



Cable Snap-It

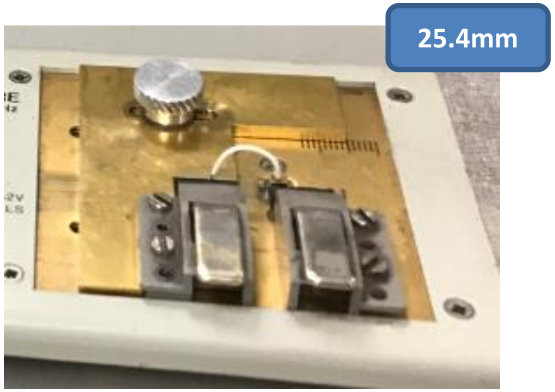


Chip Bead

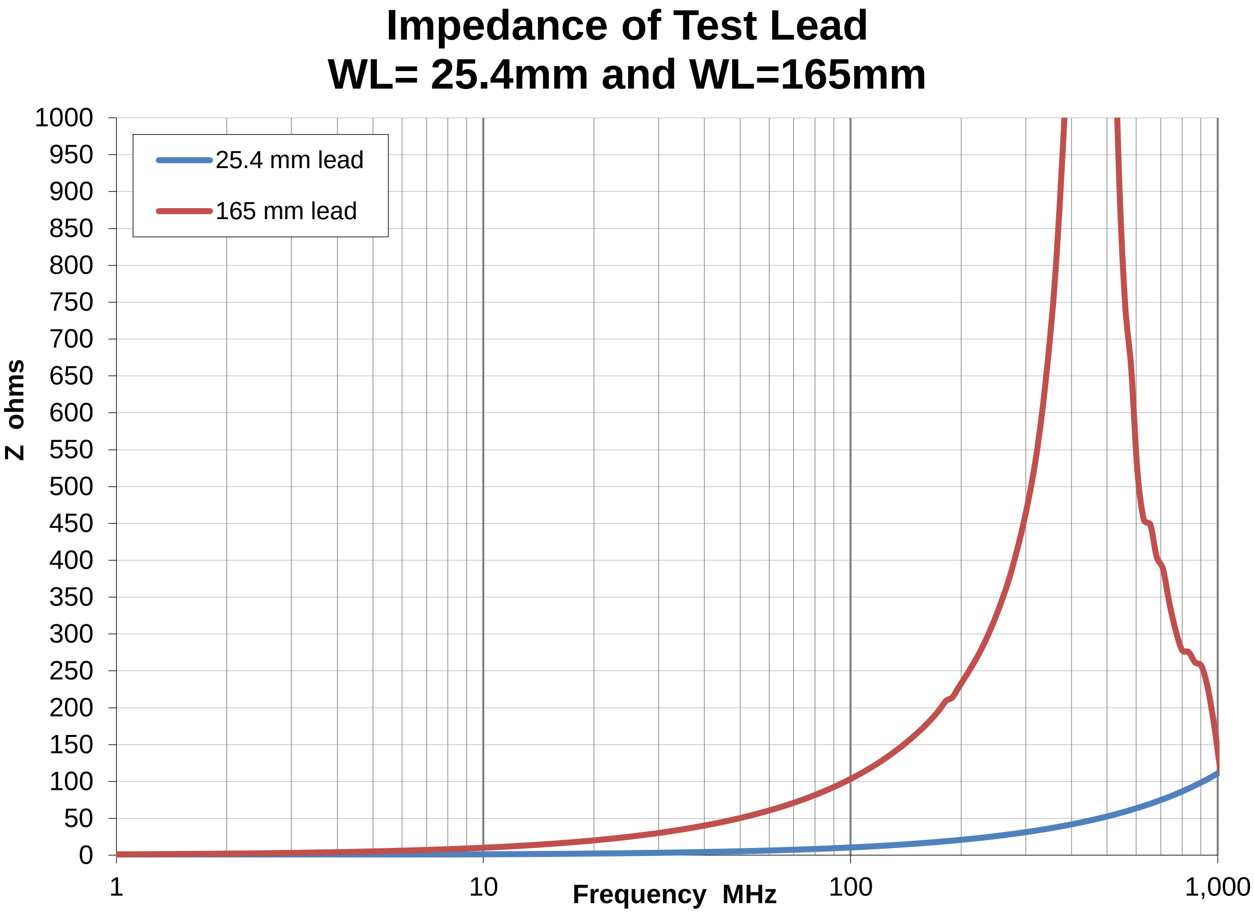


- *Know the source and mode*
  - *Differential or Common Mode*
- Know / Estimate the frequencies of concern
  - Best Material Selection
- *How much attenuation is required?*
  - Requires impedance of the source and load
- DC Currents
- Suitable form of product
  - Cable, bead, PC mount, etc.

Beware the fine print



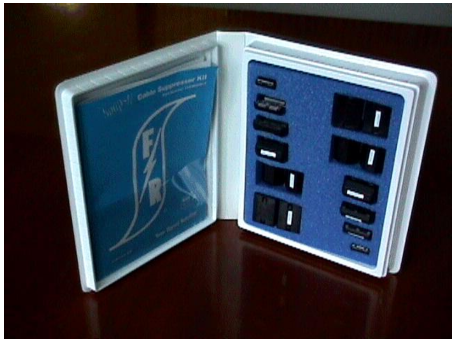
- Long test lead means
  - Unrepeatable test results
  - More contribution of the test lead to overall impedance



Cable Suppression Cores

- What frequency is targeted?
  - 75 Material – 100kHz to 30MHz
  - 31 Material – 1Mhz to 300MHz
  - 43/44/46 Materials: Broad Band 25-300MHz
  - 61 Material: High Frequency 200-1000MHz
- Cable Size

Try and See:
Engineering Kits



Engineering Kits

- 75 Material Snap-Its
  - Low Frequency Problems
- 31 Material Snap-Its
  - Low to Broad Band Problems
- 43 Material Snap-Its
  - Broad-Band Problems
- 46 Material Snap-Its
  - Economical Broad-Band
- 61 Material Snap-Its
  - High Frequency Problems
- **31 & 61 Snap-Its - 0199000017**

Mounting Plate 35.75" X 19"
Total weight is approx. 47 lbs

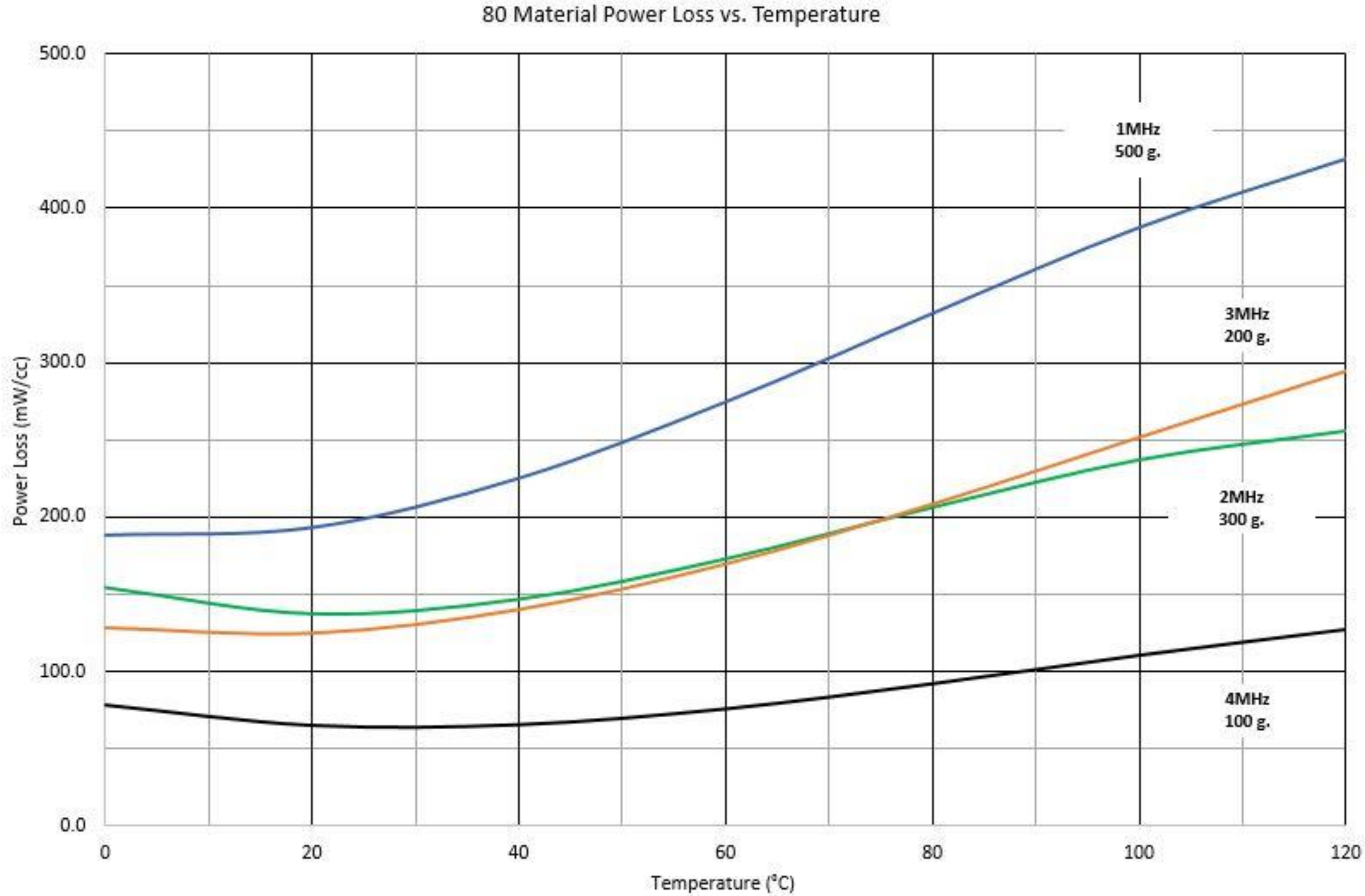
What's New - Fair-Rite 80 Material

Property	Unit	Symbol	Value
Initial Permeability @ B < 10 gauss		μ_i	600
Flux Density @ 25°C. @ Field Strength	gauss oersted	Bmax H	4700 5
Residual Flux Density	gauss	B_r	500
Coercive Force	oersted	H_c	0.4
Loss Factor @ Frequency	10^{-6} MHz	$\tan \delta/\mu_i$	10 1.0
Curie Temperature	°C	T_c	> 300
Resistivity	Ω - cm	ρ	200

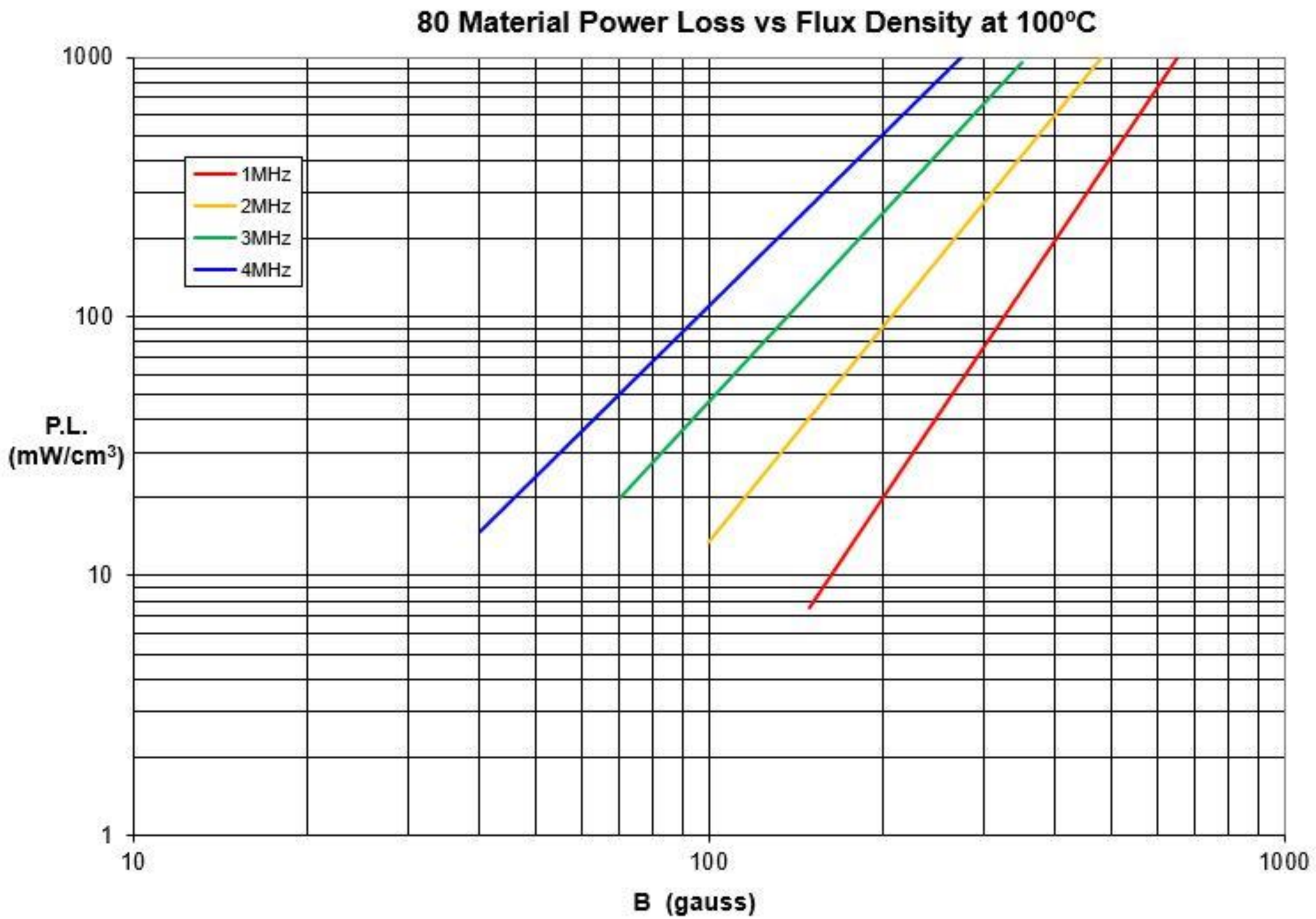
Optimal Frequency Range: 1 – 4 MHz

Stable temperature response operating up to 5 MHz.

80 Material


80 Material Power Loss vs. Temperature
500.0
400.0
300.0
200.0
100.0
0.0
Power Loss (mW/cc)
0
20
40
60
80
100
120
Temperature (°C)
1MHz
500 g.
3MHz
200 g.
2MHz
300 g.
4MHz
100 g.

80 Material


80 Material Power Loss vs Flux Density at 100°C
1000
100
10
1
P.L.
(mW/cm³)
1MHz
2MHz
3MHz
4MHz
10
100
1000
B (gauss)

Summary

1. EMI Suppression devices add real impedance to the signal line absorbing energy thus providing frequency-selective selective attenuation.
2. Critical frequencies drive the selection of the suppression material.
3. DC Currents can affect performance of EMI Suppression Devices.

Additional Information Resources

- Fair-Rite Products Catalog – 17th Edition (18th Edition coming soon!)
  - How to choose Ferrite Components for EMI Suppression Applications
- Web Site: www.Fair-Rite.com
  - Low Frequency EMI Suppression
  - Specifying Ferrites for EMI suppression
  - How to choose Ferrite Components for EMI Suppression
  - Flexible Ferrite Sheets
  - **Ask The Advisor and Technical Forums**

Fair-Rite