New Broadband Suppression Materials

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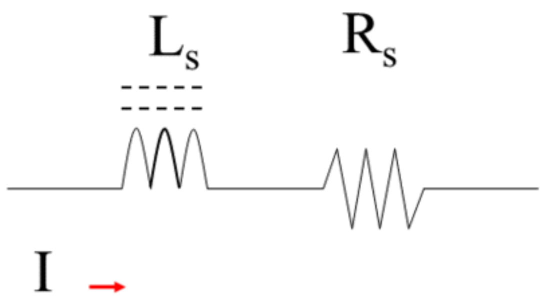
Agenda

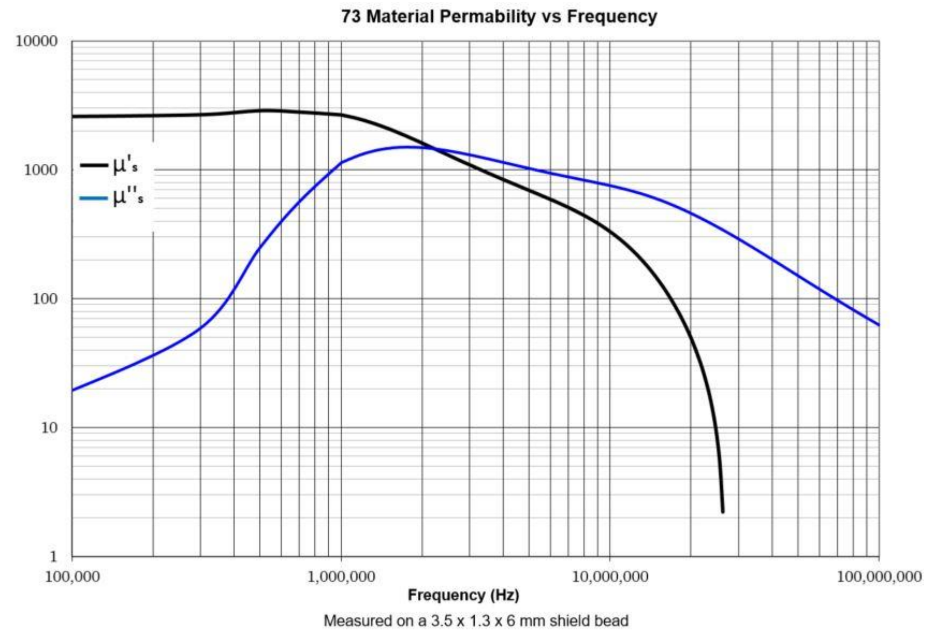
- General Suppression Ferrite Operation
- Current Suppression Materials
    - Broad Compositional Overview
    - Performance Characteristics
    - Comparison
- Motivations and Targets for Material Development
    - – Requisite performance characteristics for the application
    - – Material type selection
    - – Resultant material characteristics
- Performance Demonstrations

How do they work?

Series Model of a Ferrite Bead



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

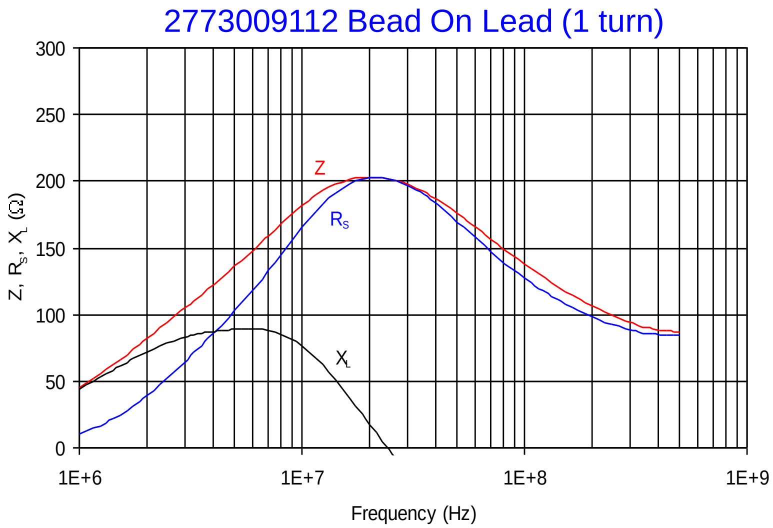


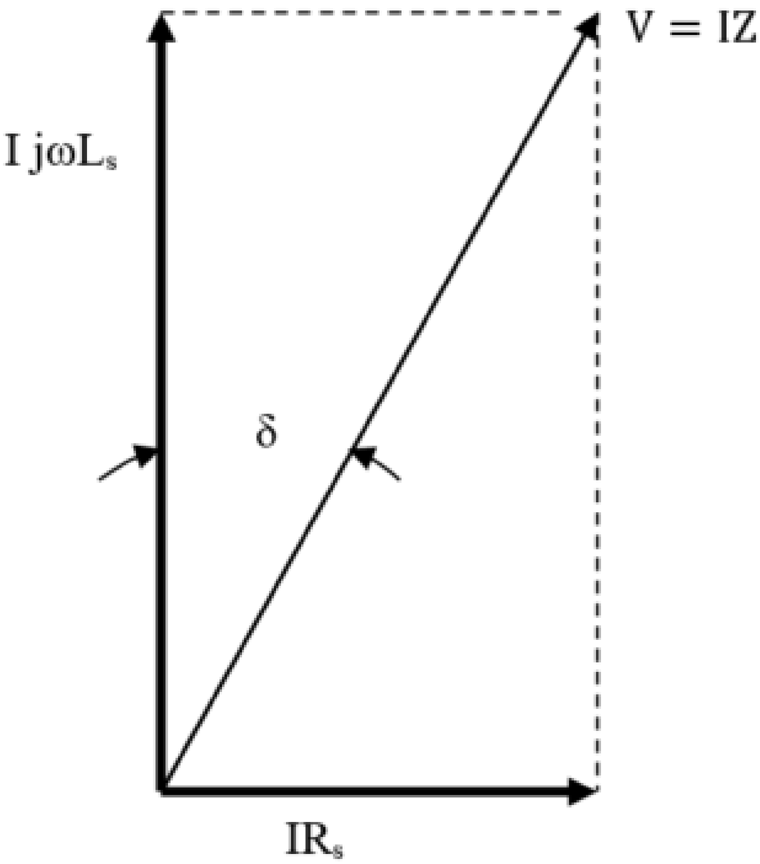
Complex Permeability Curve

Total Impedance

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

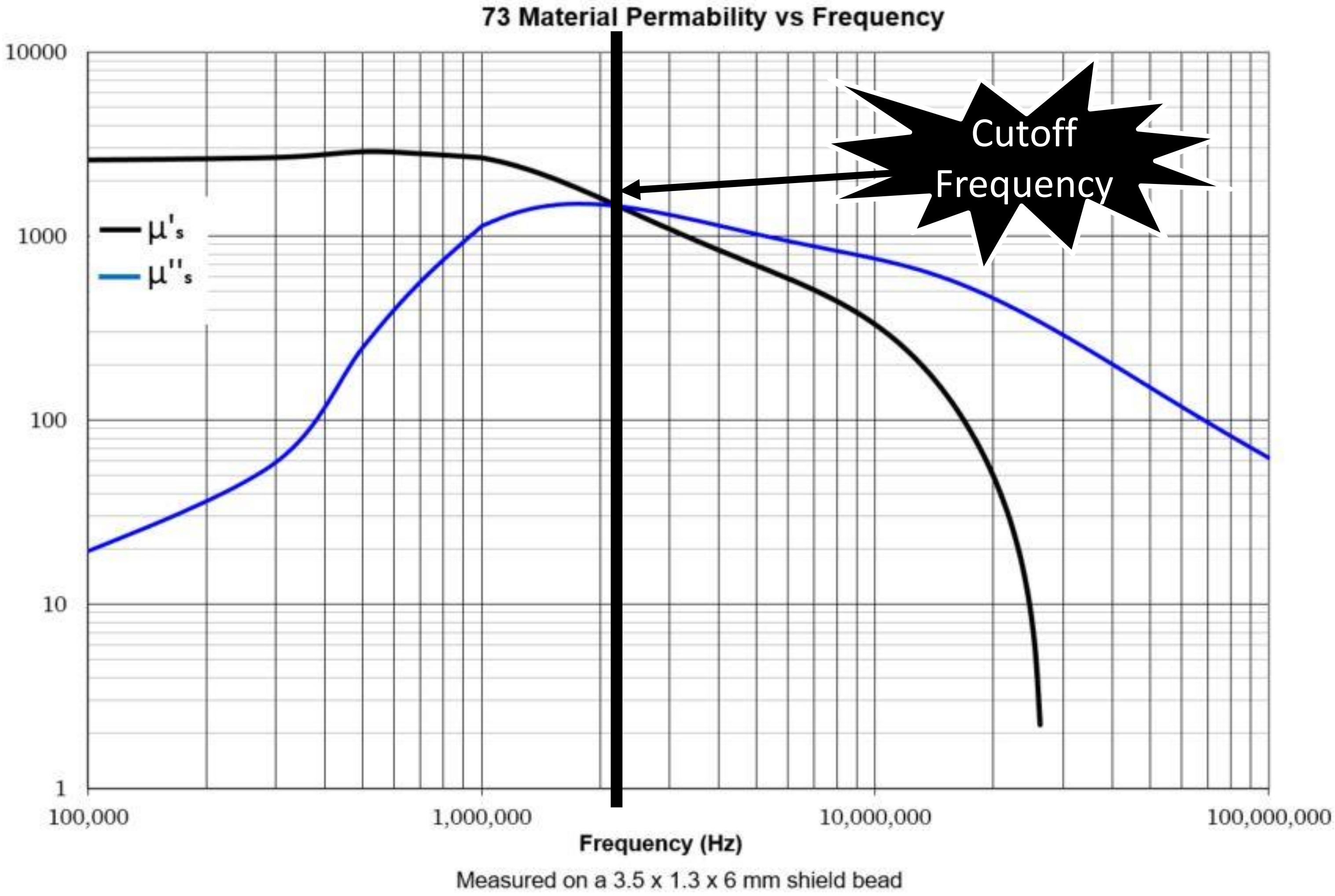
$$Z = j\omega L_0(\mu' - j\mu'')$$



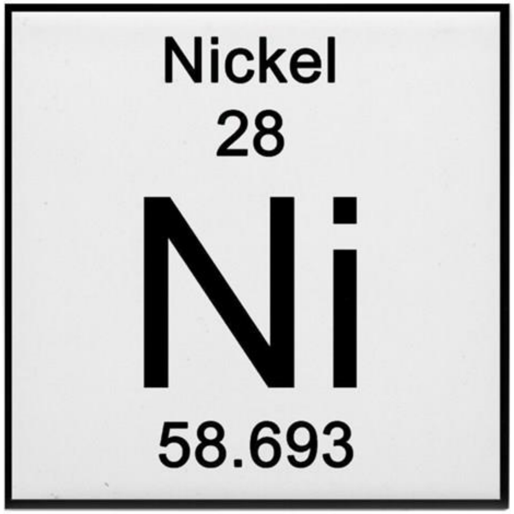


The ferrite material has magnetically coupled impedance into the circuit.

Complex Permeability



Manganese-Zinc or Nickel-Zinc?



Basic Material Types

- All iron oxide based ceramic type materials
- There are two main types of ferrite materials
- Each has targeted performance for specific applications
- Other variants exist for more specific applications

- NiZn
  - Low permeability
  - High bulk resistivity
  - High cutoff frequency
  - Performance not dependent on core size
- MnZn
  - High permeability
  - Low bulk resistivity
  - Low cutoff frequency
  - Exhibits dimensional resonance

Material Examples

NiZn

43 Material Characteristics

Property	Unit	Symbol	Value
Initial Permeability @ B < 10gauss		µi	800
Flux Density @ Field Intensity	gauss oersted	B H	3500 10
Residual Flux Density	gauss	Br	2200
Coercive Force	oersted	Hc	0.36
Loss Factor @ Frequency	10^{-6} MHz	tan δ/µi	100 1
Temperature Coefficient of Initial Permeability (20-70ºC)	% / ºC		1.25
Curie Temperature	ºC	Tc	> 130
Resistivity	ohm-cm	p	1×10^{5}

25MHz-300MHz

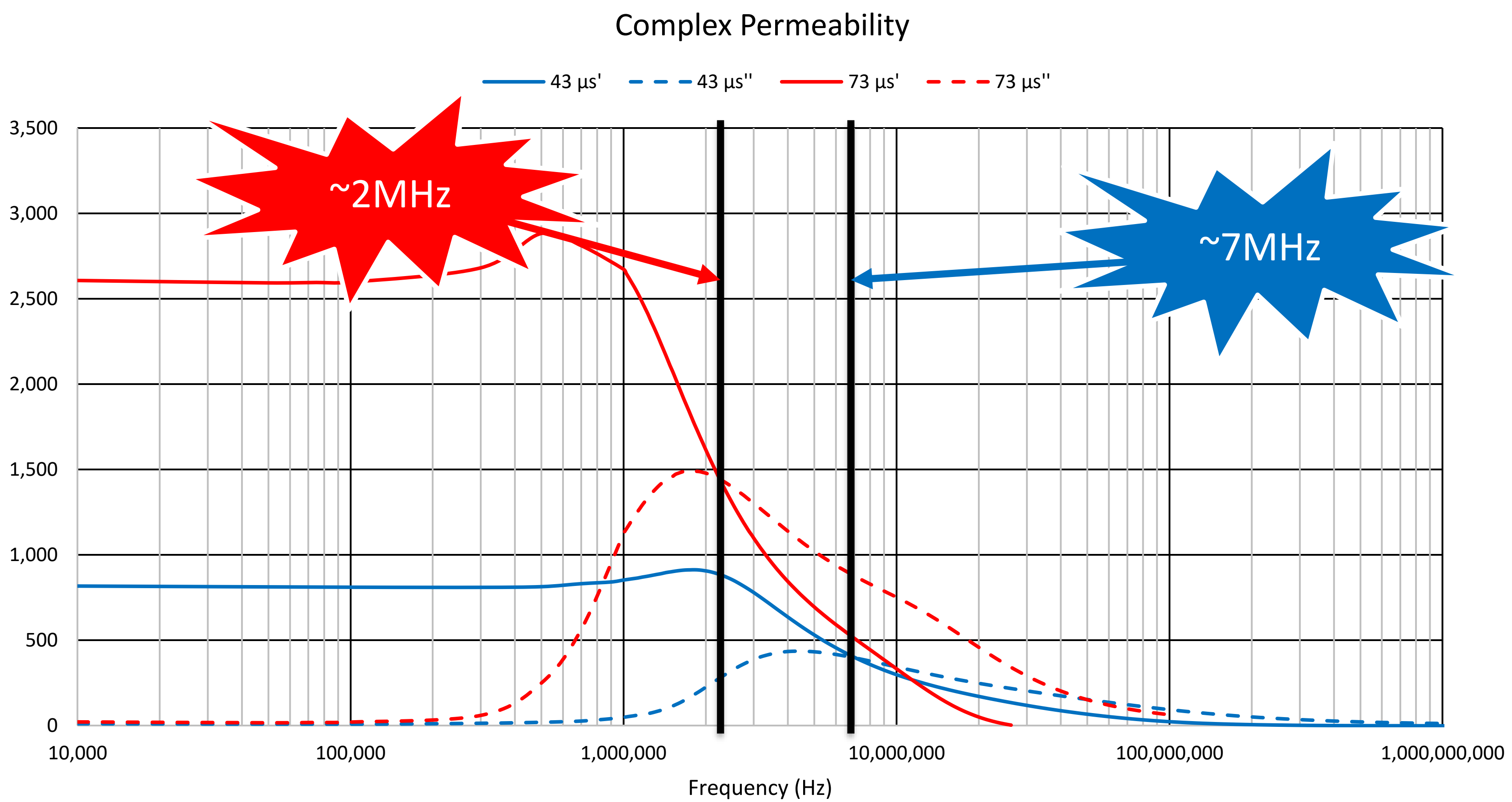
MnZn

73 Material Characteristics

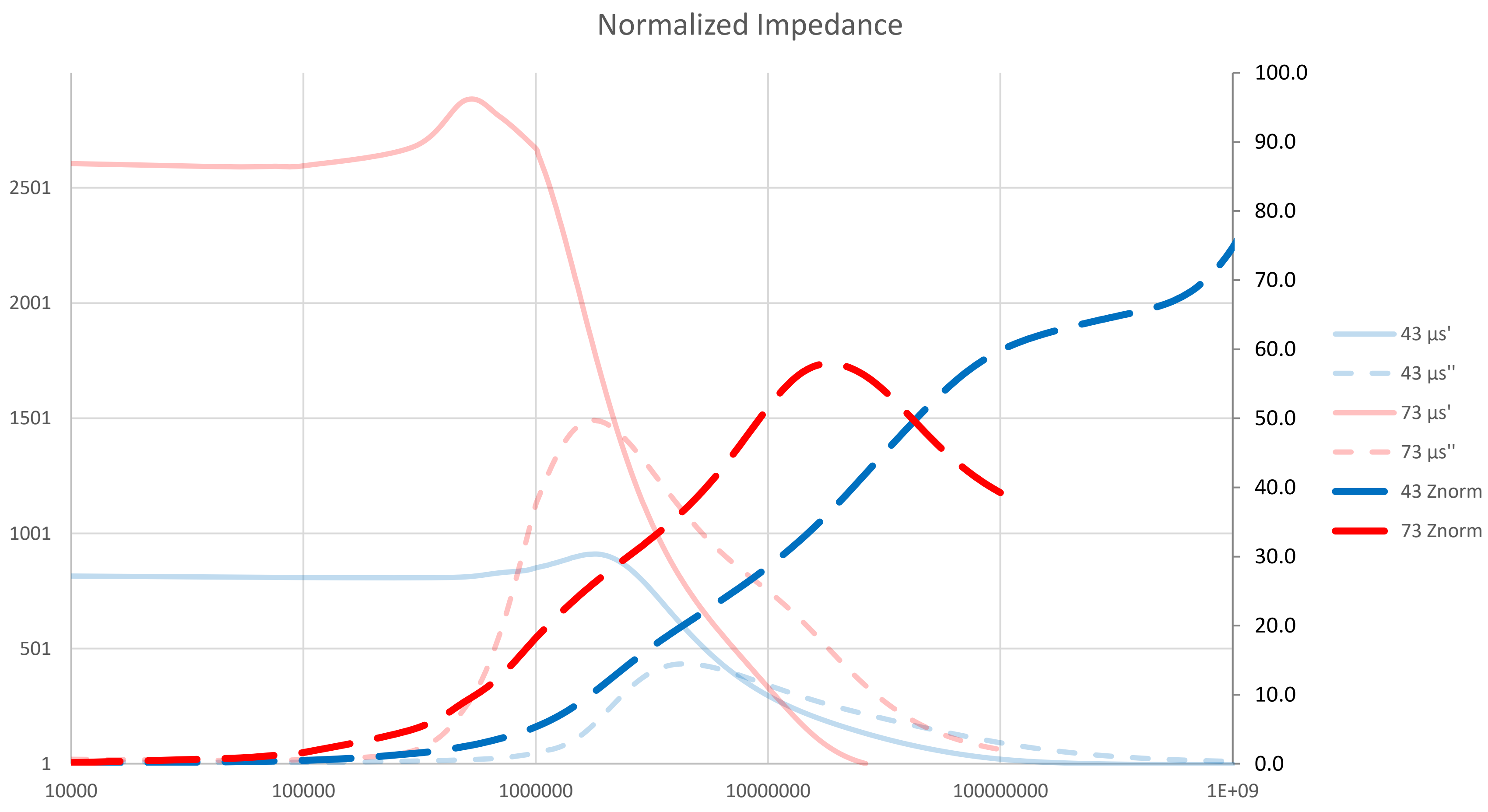
Property	Unit	Symbol	Value
Initial Permeability @ B < 10gauss		µi	2500
Flux Density @ Field Intensity	gauss oersted	B H	4200 5
Residual Flux Density	gauss	Br	1100
Coercive Force	oersted	Hc	0.18
Loss Factor @ Frequency	10^{-6} MHz	tan δ/µi	10 0.1
Temperature Coefficient of Initial Permeability (20-70ºC)	% / ºC		0.5
Curie Temperature	ºC	Tc	> 160
Resistivity	ohm-cm	p	100

500kHz-50MHz

NiZn vs MnZn Cplx Perm



NiZn vs MnZn Normalized Impedance

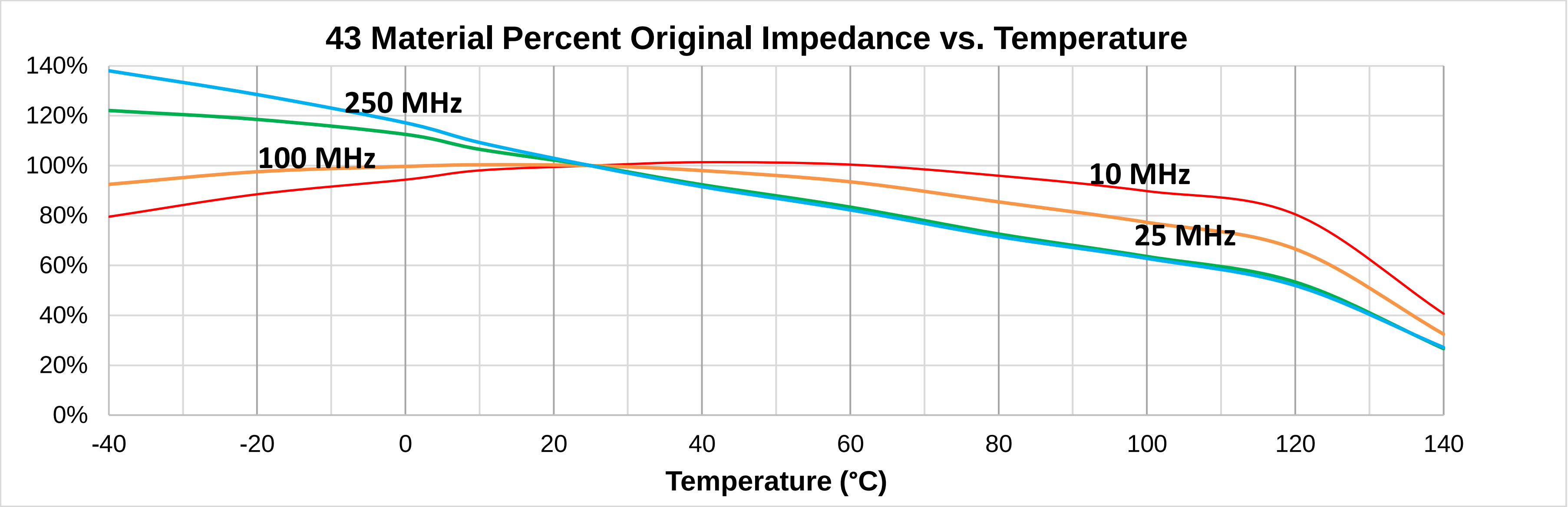


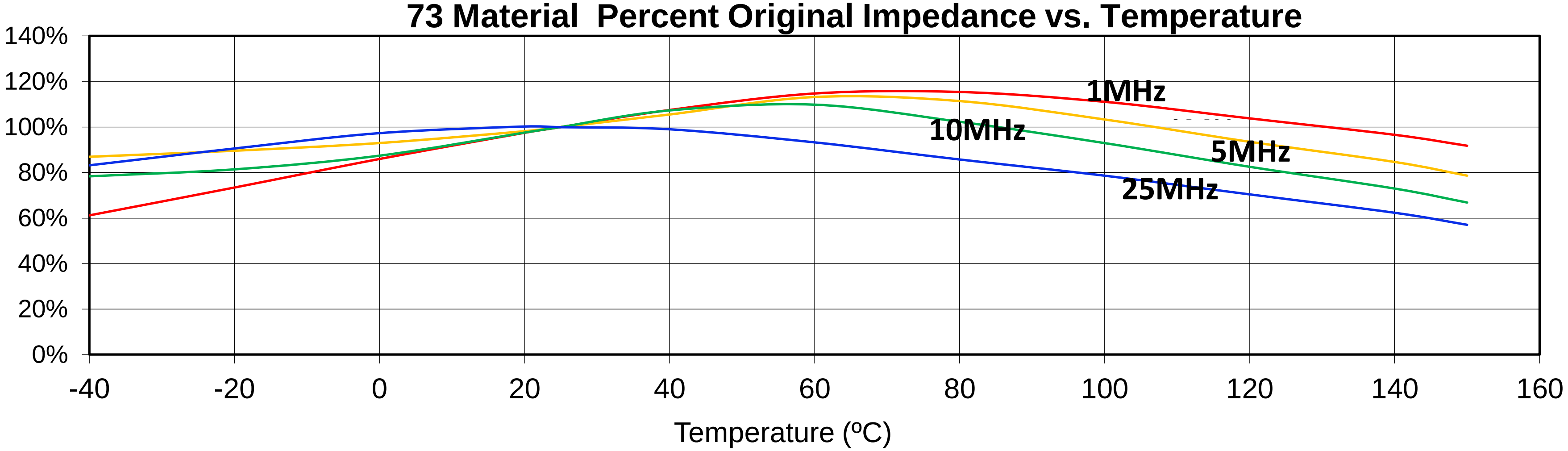
Current suppression materials are designed to suppress targeted frequencies of noise

- High permeability MnZn materials attenuate relatively low frequencies of noise
- Low permeability NiZn materials attenuate relatively high frequencies of noise
- This works very well IF you know the noise frequencies or have through trial and error found them

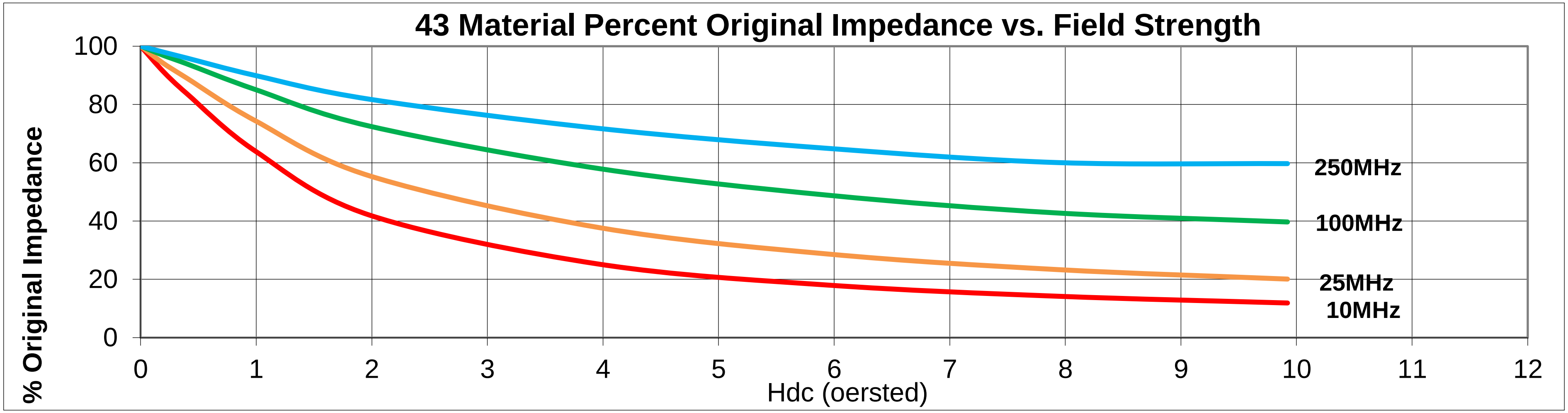
Secondary Characteristics

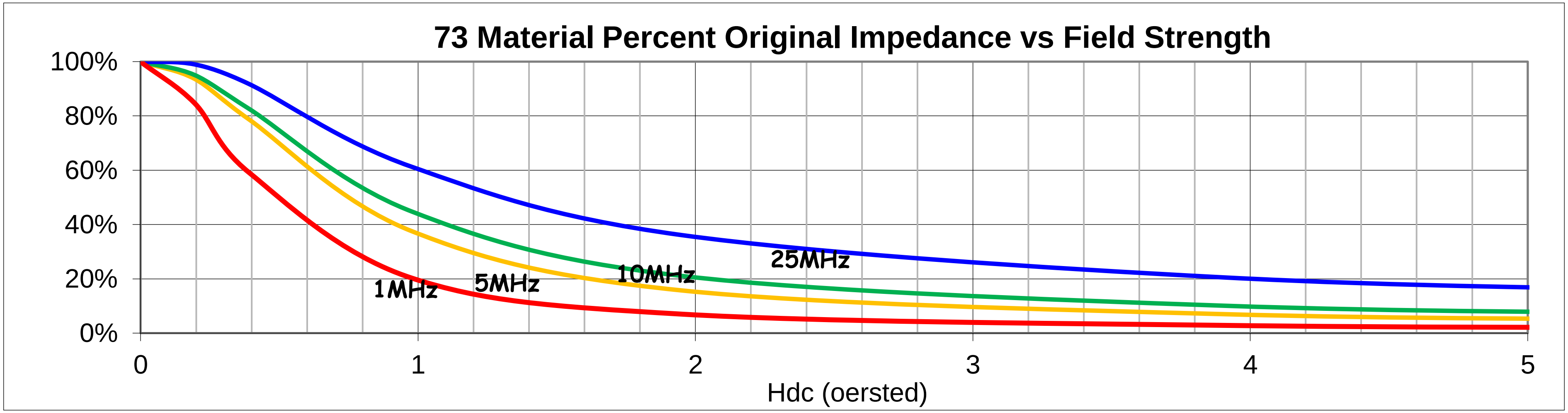
Temperature Performance Examples



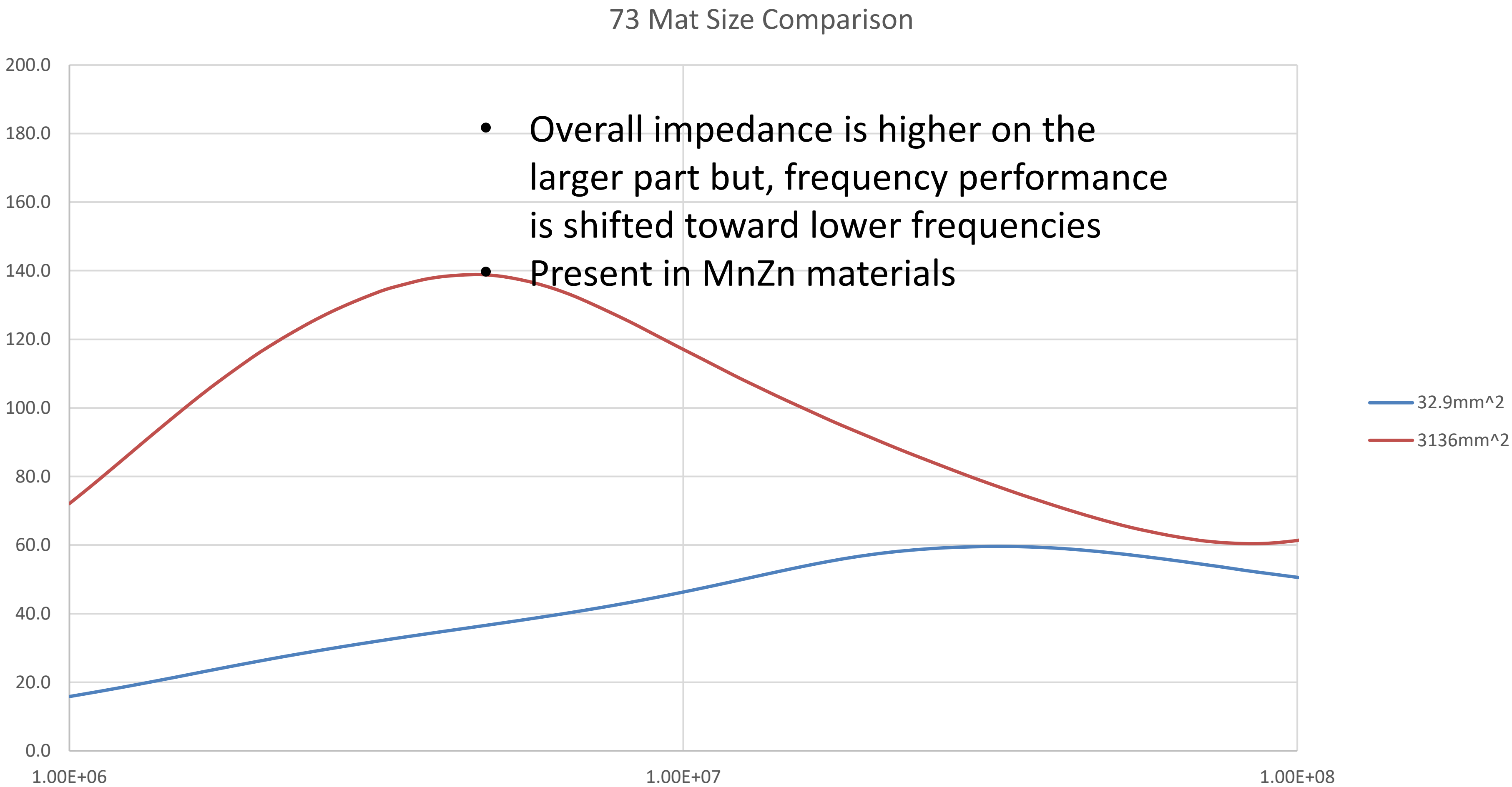


DC Bias Resiliency Examples



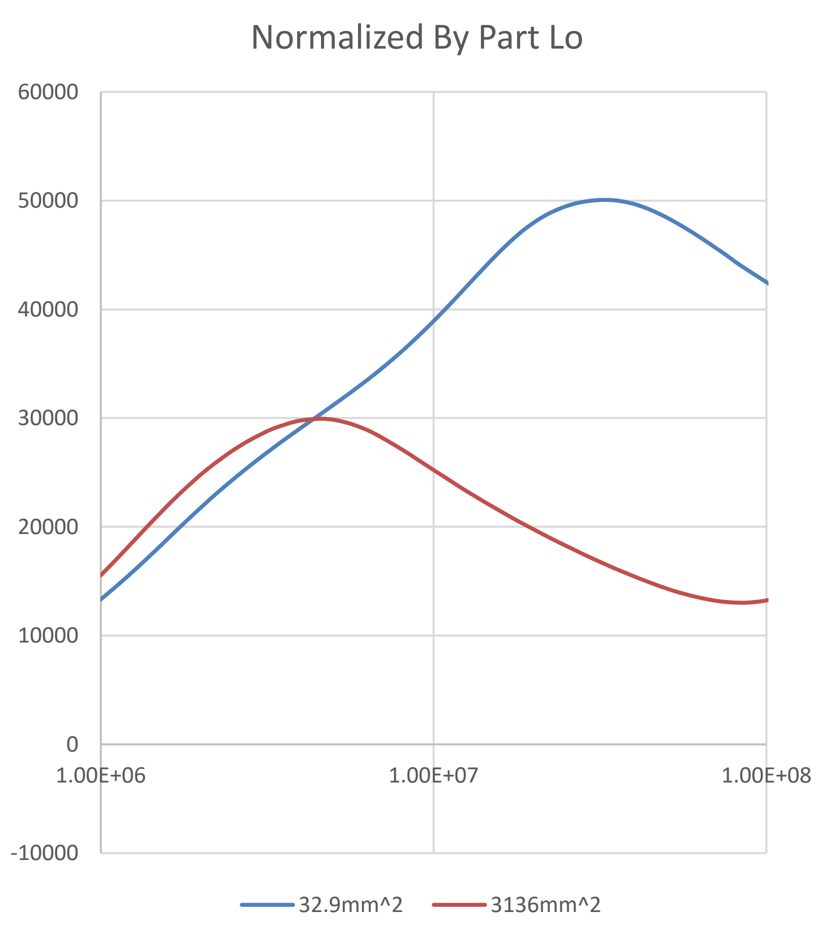


Dimensional Resonance



- Overall impedance is higher on the larger part but, frequency performance is shifted toward lower frequencies
- Present in MnZn materials

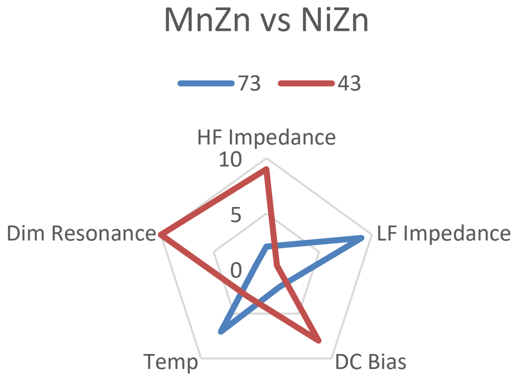
Dimensional Resonance



- The dramatic change in performance over frequency can be seen when normalized by the Lo (air core inductance) of each part

Constraints: Material development is always and give and take affair

- Key performance characteristics need to be considered as well as identifying what secondary characteristics are application critical
- Environmental factors need to be considered
- Frequencies, Signal levels and other operating conditions
- Size and geometries of the end parts



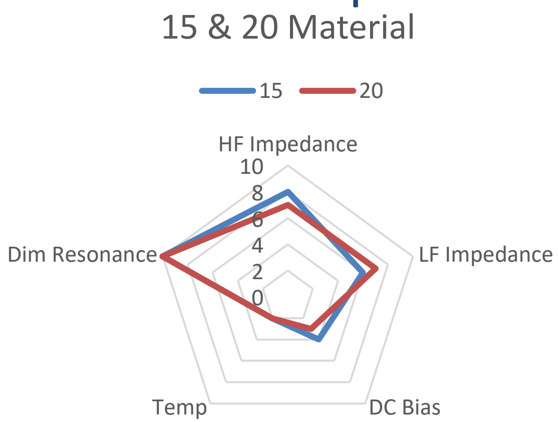
Challenge: Develop a broadband suppression material(s) able to provide immunity from uncertain frequencies of noise both radiated and conducted

- High permeability to increase low frequency performance
- Maintain resistive and inductive portions of complex permeability out to higher frequencies
- High bulk resistivity for eddy-current mitigation
- No particular target geometry

The Results!

NiZn Wins!

- NiZn ferrite was chosen due it's flatter frequency along with high bulk resistivities
- Low frequency attenuation was maintained via increased material permeabilities while flat frequency response handles high-frequency impedance
- The uncertain nature of the geometries being made a dimensional resonance-less material desirable
- Select material properties had to be sacrificed in order to hit performance goals



15 & 20 Material

NiZn

15 Material Characteristics

Property	Unit	Symbol	Value
Initial Permeability @ B < 10gauss		µi	1500
Flux Density @ Field Intensity	gauss oersted	B H	2700 10
Residual Flux Density	gauss	Br	1800
Coercive Force	oersted	Hc	0.2
Loss Factor @ Frequency	10^{-6} MHz	tan δ/µi	15 0.1
Temperature Coefficient of Initial Permeability (20-70ºC)	% / ºC		1.1
Curie Temperature	ºC	Tc	>105
Resistivity	ohm-cm	p	1×10^8

10MHz-300MHz

NiZn

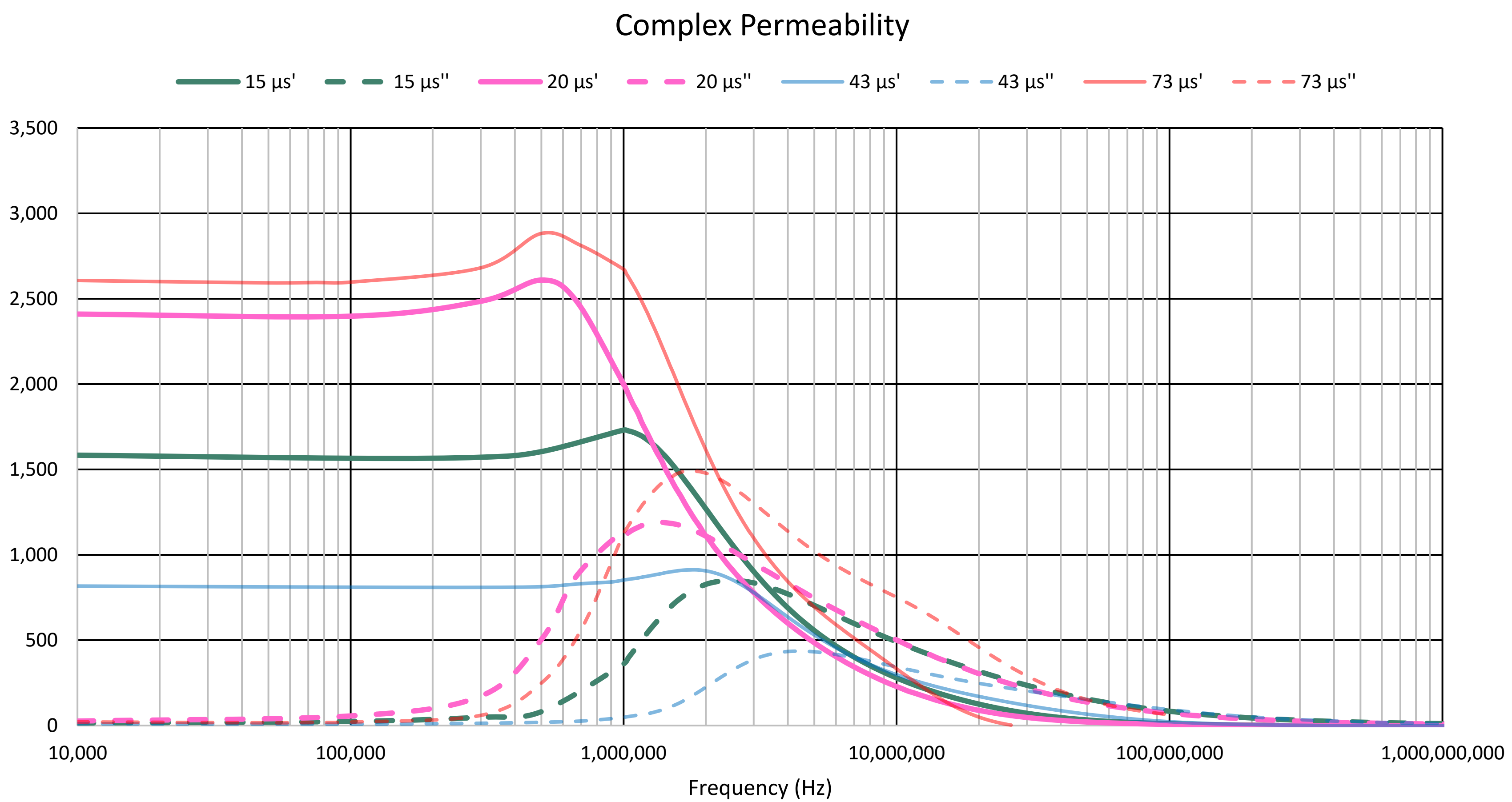
20 Material Characteristics

Property	Unit	Symbol	Value
Initial Permeability @ B < 10gauss		µi	2300
Flux Density @ Field Intensity	gauss oersted	B H	2700 10
Residual Flux Density	gauss	Br	1800
Coercive Force	oersted	Hc	0.18
Loss Factor @ Frequency	10^{-6} MHz	tan δ/µi	10 0.1
Temperature Coefficient of Initial Permeability (20-70ºC)	% / ºC		0.8
Curie Temperature	ºC	Tc	>95
Resistivity	ohm-cm	p	1×10^7

5MHz-200MHz

Fair-Rite Products Corp.
Your Signal Solution®

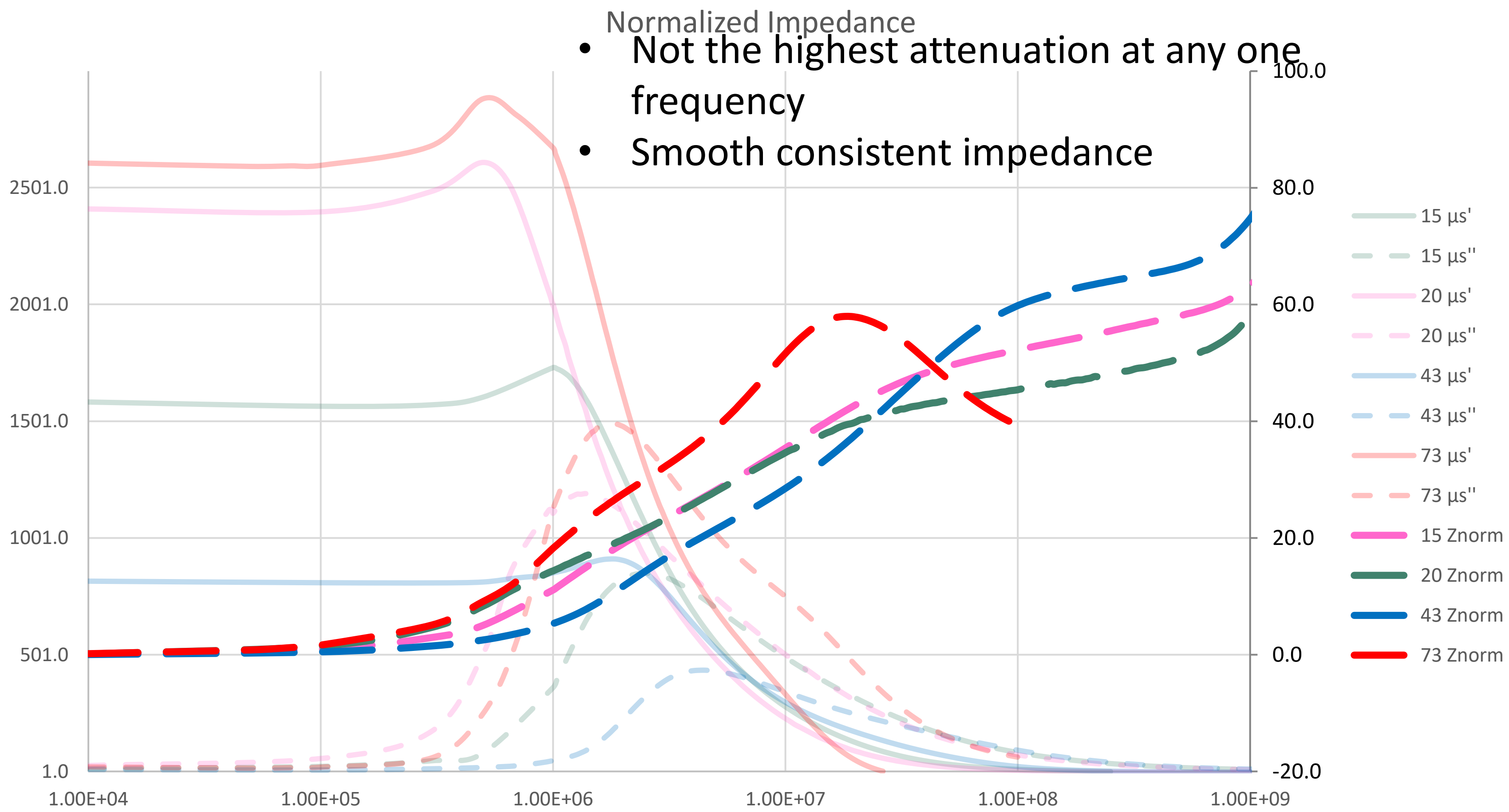
Cplx Perm Hi Perm NiZn



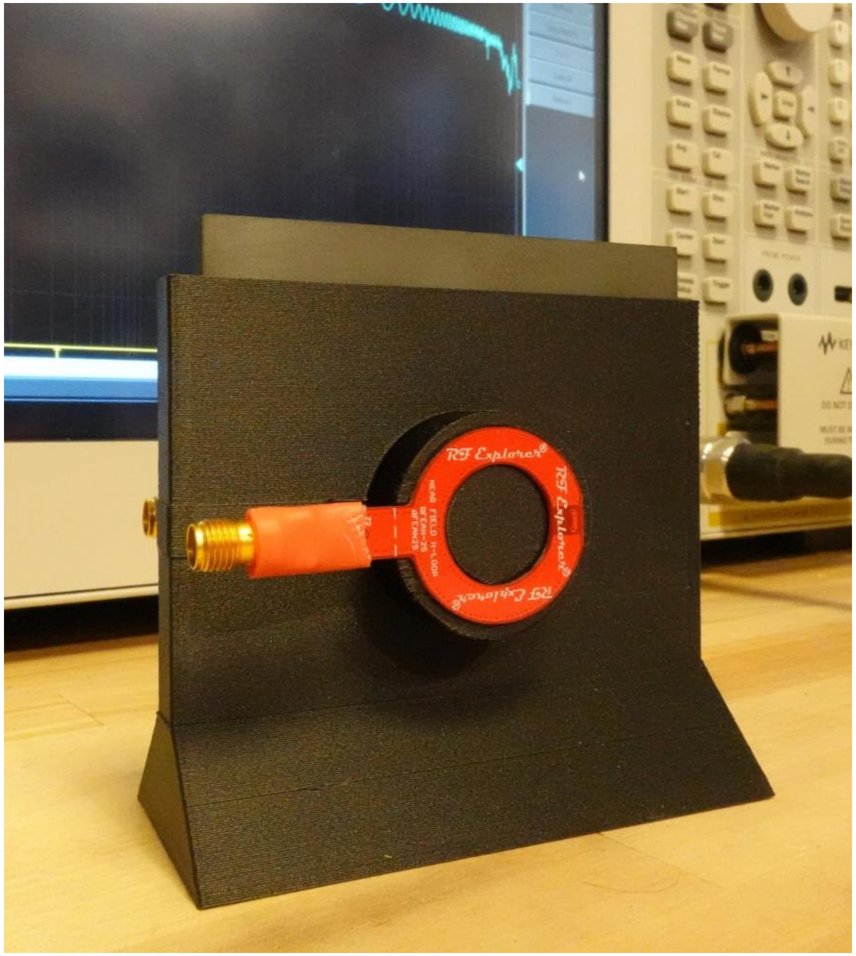
DESIGN | DEVELOP | DELIVER

Impedance Performance

- Not the highest attenuation at any one frequency
- Smooth consistent impedance

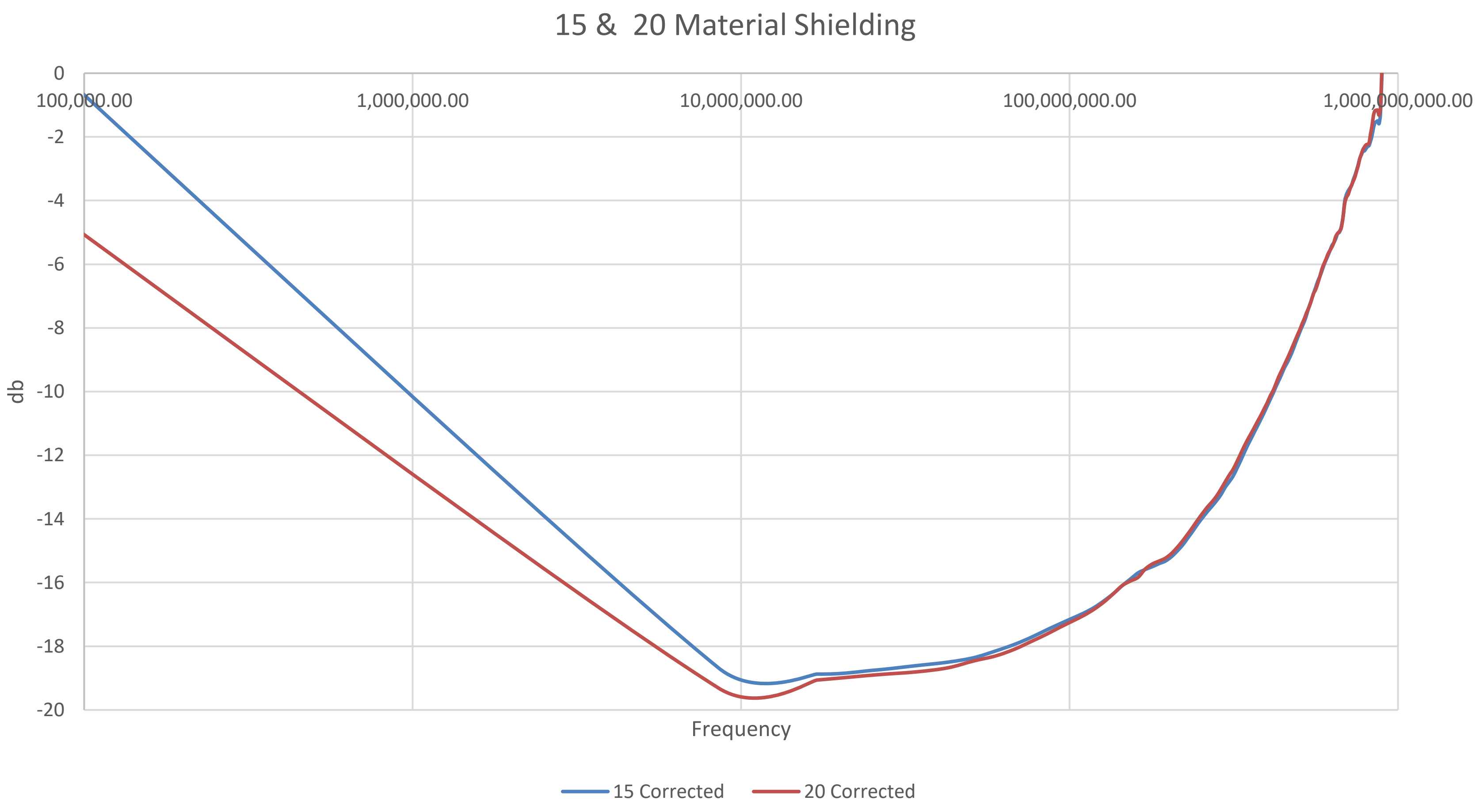


Free-Space Characterization for Radiated Emissions



- Fixture created via additive manufacturing to characterize material samples in a consistent fashion
- Samples measured for S21 over a swept sinusoidal stimulus on VNA

Free-Space Characterization for Radiated Emissions



Conclusions

- All ferrite materials are some compromise of performance characteristics
- Developing a new material requires a complete knowledge of the problem it is trying to solve
- High permeability NiZn materials provided the necessary characteristics to mitigate the widest range of uncertain EMI but, other alternatives can be considered for more targeted EMI suppression

Thank you!

Questions?