
Fair-Rite Products Corp.
Your Signal Solution®
DESIGN • DEVELOP • DELIVER

Solving Electromagnetic Interference (EMI) with Ferrites

- What are ferrites?
- How do ferrites help Suppress EMI?
- How to chose proper ferrite and component
  - Material Characteristics
  - Material and Core Selection
    - Frequency, bias, turns, temperature, size
    - Cable cores and PCB level components

What Is A Ferrite?

Ferrite is a ceramic material formed by reacting metal oxides into a magnetic material.

- Soft magnetic material is one that can be both easily magnetized and demagnetized, so that it can store or transfer magnetic energy in alternating or other changing wave forms

CHEMICAL COMPOSITION (metal oxides) + (iron oxide)

($MnO + ZnO$) + (Fe_2O_3) = Manganese - Zinc

($NiO + ZnO$) + (Fe_2O_3) = Nickel - Zinc

($MgO + ZnO$) + (Fe_2O_3) = Magnesium - Zinc

Definitions

- EMI – Electromagnetic Interference – Electromagnetic emissions from a device or system that interfere with the normal operation of another device or system.

- EMC – Electromagnetic Compatibility –
  The ability of a device or system to function without error in its intended electromagnetic environment.

EMI Suppression

Sources of EMI

- Digital System – Clock Pulses
- SMPS
- Oscillators
- Medical Equipment
- Microwave Equipment
- Radio & TV
- Frequency Converters
- Electronic Ballasts
- Switch Gear (contractors, relays)
- Household Appliances
- Power Supplies and Battery Chargers
- Motor Commutation
- Ignition Systems

Victims (Susceptible)

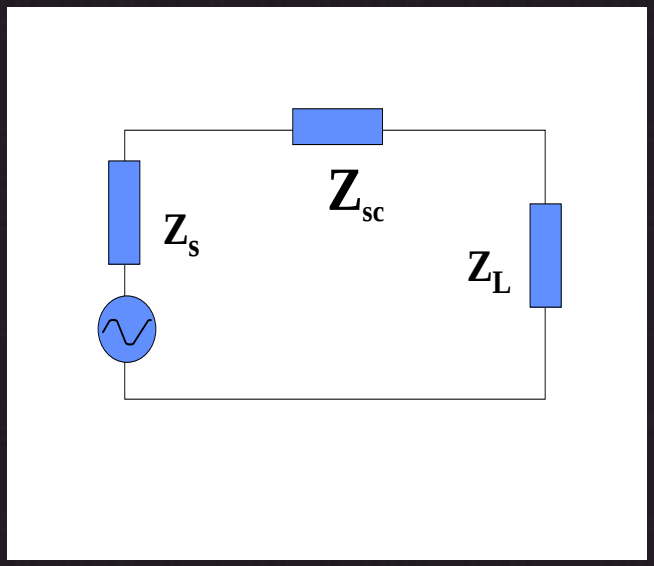
- Radio & TV Receivers
- Modems
- Engine Control Modules
- Data transmission systems
- Medical Equipment
- Computer

Properties of Ferrites

EMI Suppression

- A frequency dependant impedance that provides attenuation
  - Formulations optimized for frequency bands
- Ferrites absorb EMI energy - dissipate as small amount of heat
- Powder compaction allows for a multitude of shapes
- High permeability concentrates magnetic filed in core allowing for a dense overall package
- High resistivity provides electrical isolation between multiple lines and minimizes eddy current losses

How Ferrites Are Used To Reduce Noise



$$\text{Attenuation} = 20 \log_{10} \left(\frac{(Z_s + Z_{sc} + Z_L)}{(Z_s + Z_L)} \right) \text{ dB}$$

Z_s = Source impedance
Z_{sc} = Suppressor Core impedance
Z_L = Load impedance



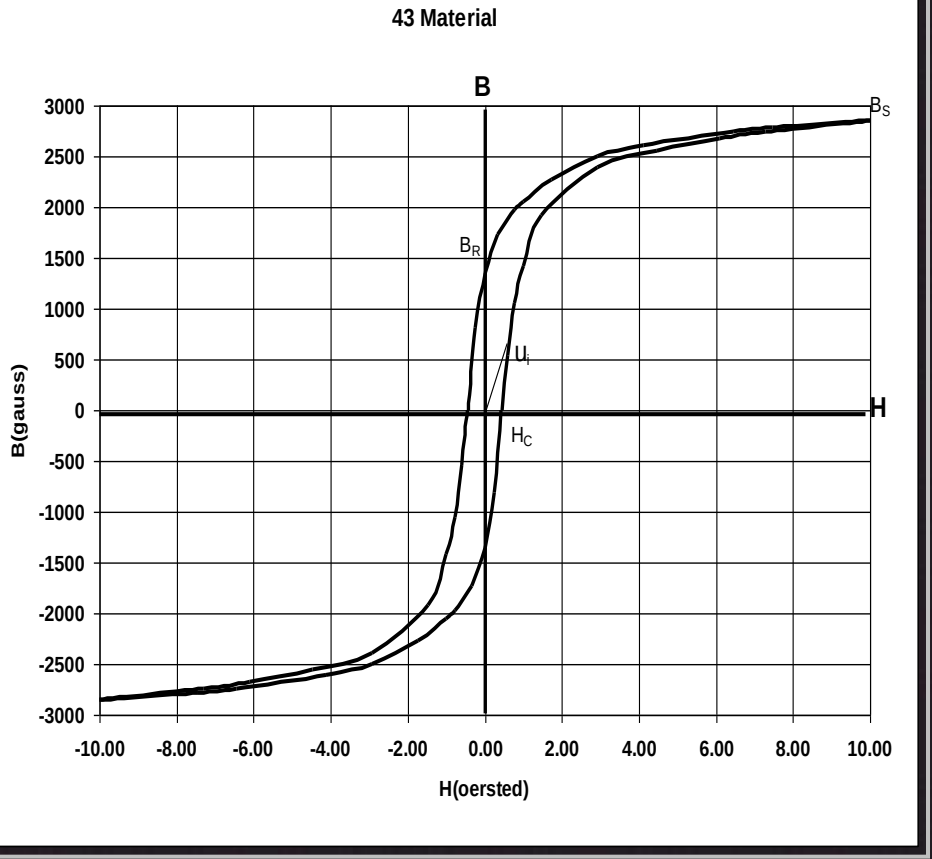





Magnetic Properties of Ferrite Materials

Property	Unit	Symbol	75	73	31	43	44	46	61
Initial Permeability									
@B < 10 gauss		ui	5000	2500	1500	800	500	500	125
	gauss	B	4300	3900	3400	2900	3000	3000	2350
Flux Density	mT		430	390	340	290	300	300	235
@ Field Strength	oersted	H	5	5	5	10	10	10	15
	A/m		400	400	400	800	800	800	1200
Residual Flux Density	gauss	Br	1400	1500	2500	1300	1100	1900	1200
	mT		140	150	250	130	110	190	120
Resistivity	Ω cm	p	300	100	3000	$1x10^5$	$1x10^9$	$1x10^8$	$1x10^8$
Curie Temperature	C°	Tc	>140	>160	>130	>130	>160	>140	>300
Recommended Frequency Range EMI Suppression	MHz		< 30	< 30	< 500	20 - 250	20 - 250	20 - 250	> 200

Material Characteristics



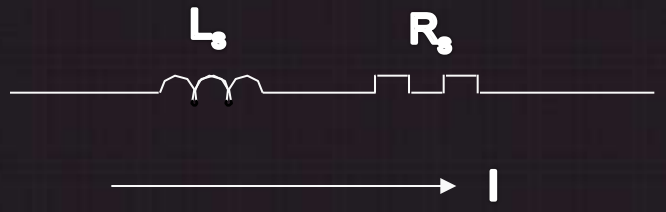
43 Material			
Property	**Unit**	**Symbol**	**Value**
Initial Permeability		μ_i	800
@ B < 10 gauss			
Flux Density	gauss	B	2900
@ Field Strength	oersted	H	10
Residual Flux Density	gauss	B_r	1300
Coercive Force	oersted	H_c	.45
Temperature Coefficient of	%/ C		1.25
Initial Permeability (20-70 C)			
Loss Factor	10^{-6}	$\tan\delta/\mu_i$	250
@ Frequency	MHz		1.0
Curie Temperature	°C	T_c	>130
Resistivity	Ω cm	ρ	$1\ 10^5$
Recommended Frequency Range	MHz		20 - 250

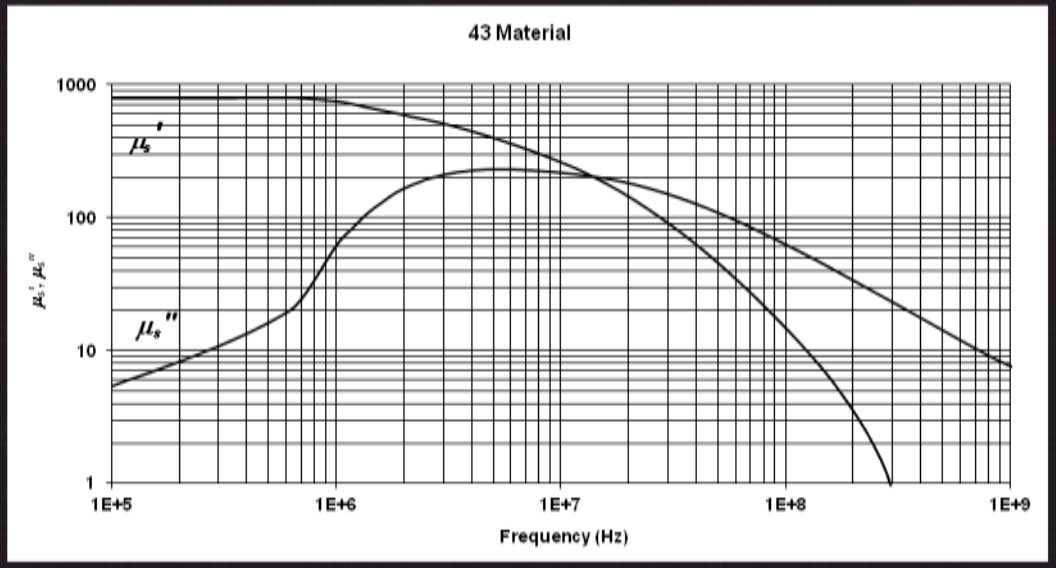
$$Z = R_s + j\omega L_s$$

$$R_s = \omega L_o \mu_s''$$

$$\omega L_s = \omega L_o \mu_s' = X_L$$

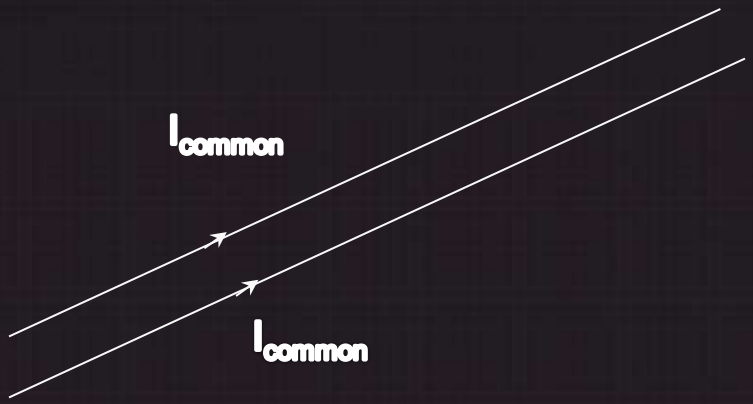
$$L_o = .0461\ N^2\ Ht\ \log_{10}\left(\frac{OD}{ID}\right) 10^{-8}\ [\ H\ ]$$

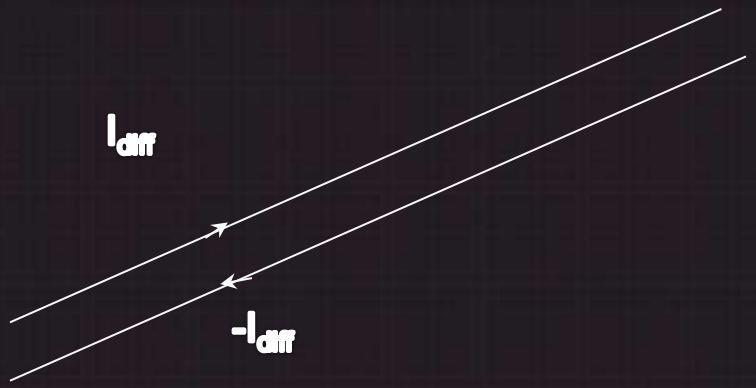




[Dim – mm]

Common-Mode vs Differential-Mode





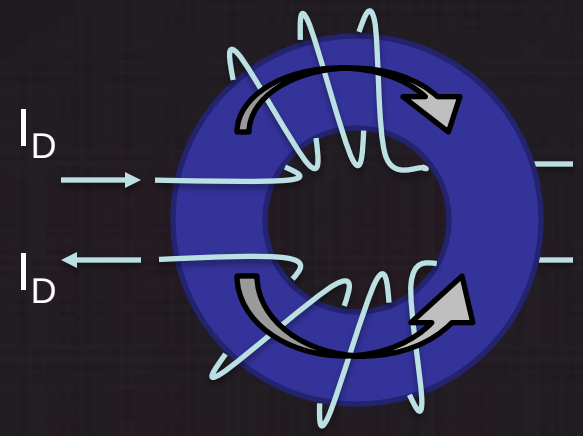
Common-Mode Currents

- **Noise Currents in phase (same direction) in the conductor pair.**
- **Usually found where radiated noise attaches itself to the conductor.**

Differential-Mode Currents

- **Can be Functional (desired) currents or Noise currents or combination of both.**

Common-Mode Choke

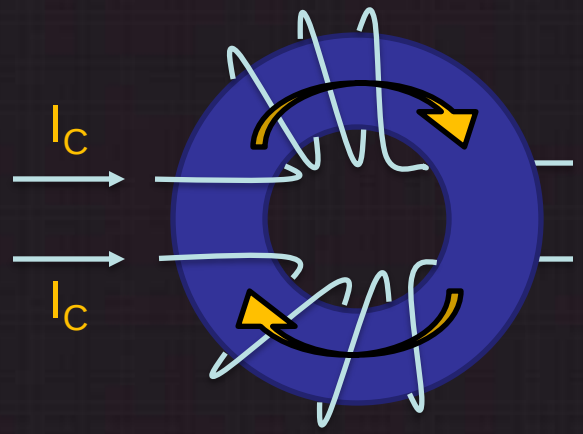


Differential Mode (functional) Currents

Fluxes cancel – * no inductance (impedance)

* no effect on currents

* core will not saturate with high I_D currents



Common Mode Currents

Fluxes Add – * inductance (impedance) in series with conductor

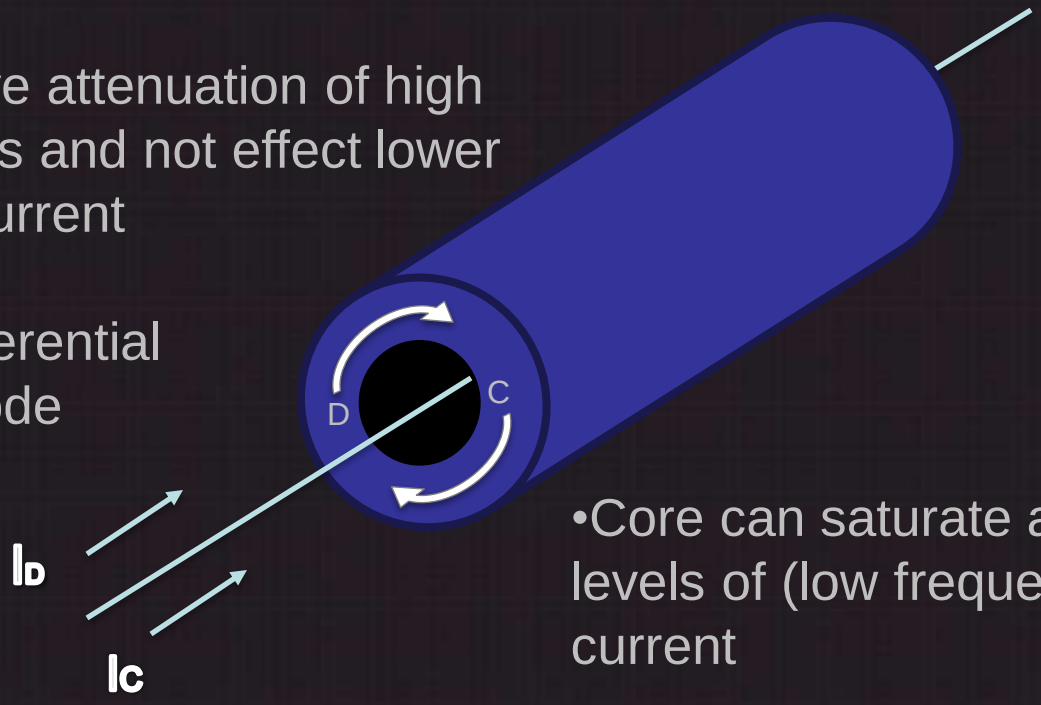
* effectively blocking Common Mode currents

Differential Mode Application

Ferrite Bead

•Provide selective attenuation of high frequency signals and not effect lower freq functional current

•Affects both Differential and Common Mode signals

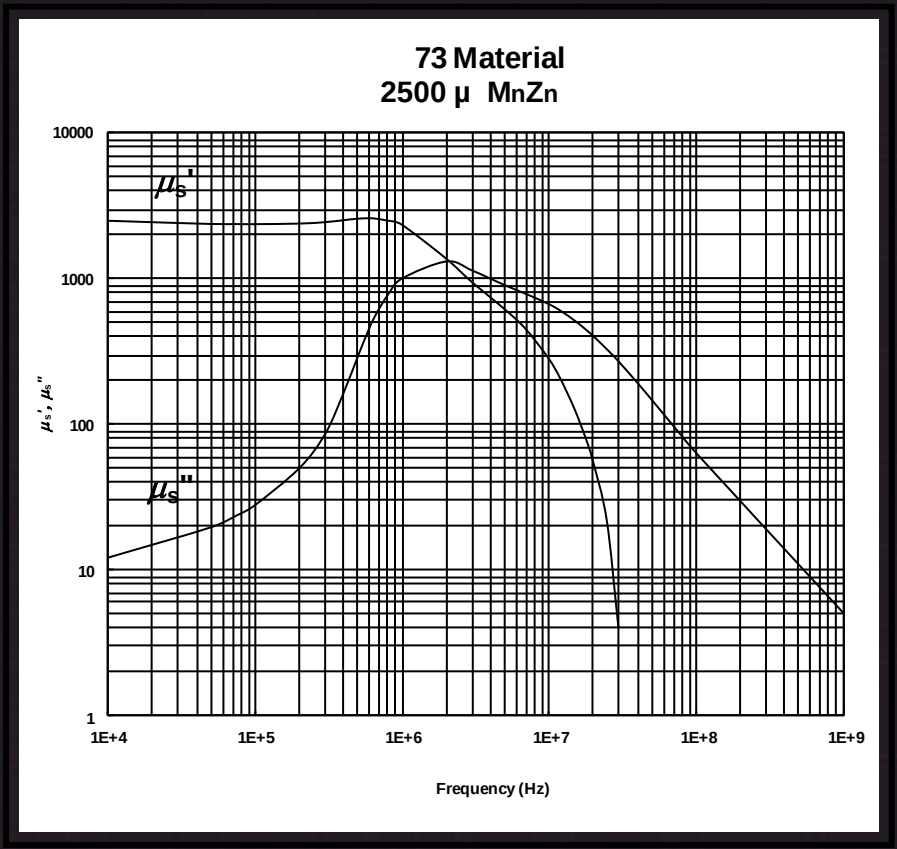


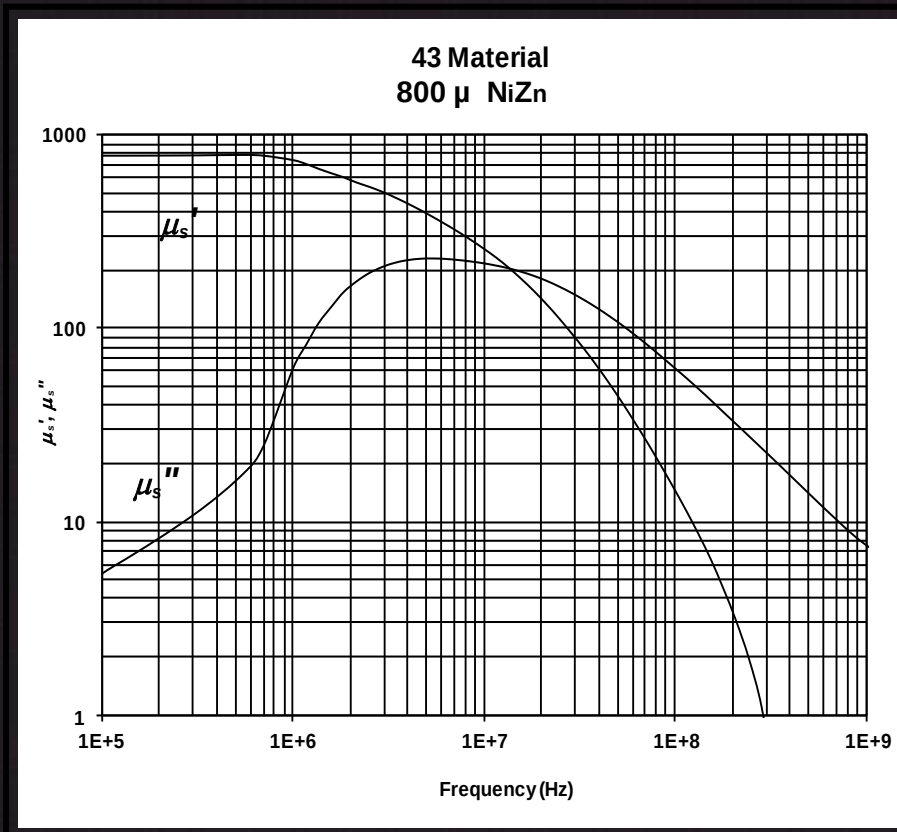
•Core can saturate at high levels of (low frequency) current

IMPEDANCE IS AFFECTED BY:

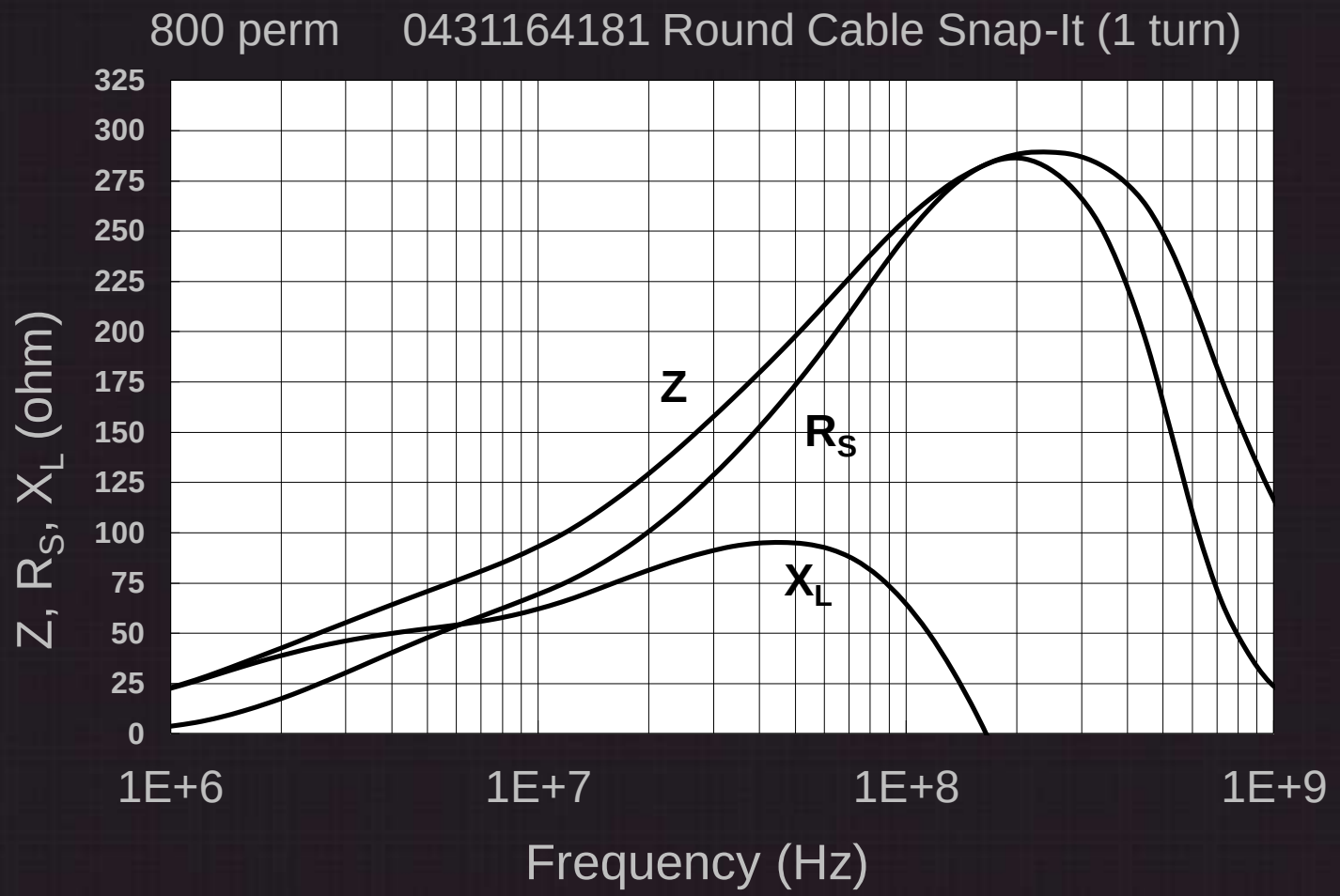
- Frequency
- DC Bias
- Temperature
- Flux Density
- Turns

Complex Permeability vs. Frequency

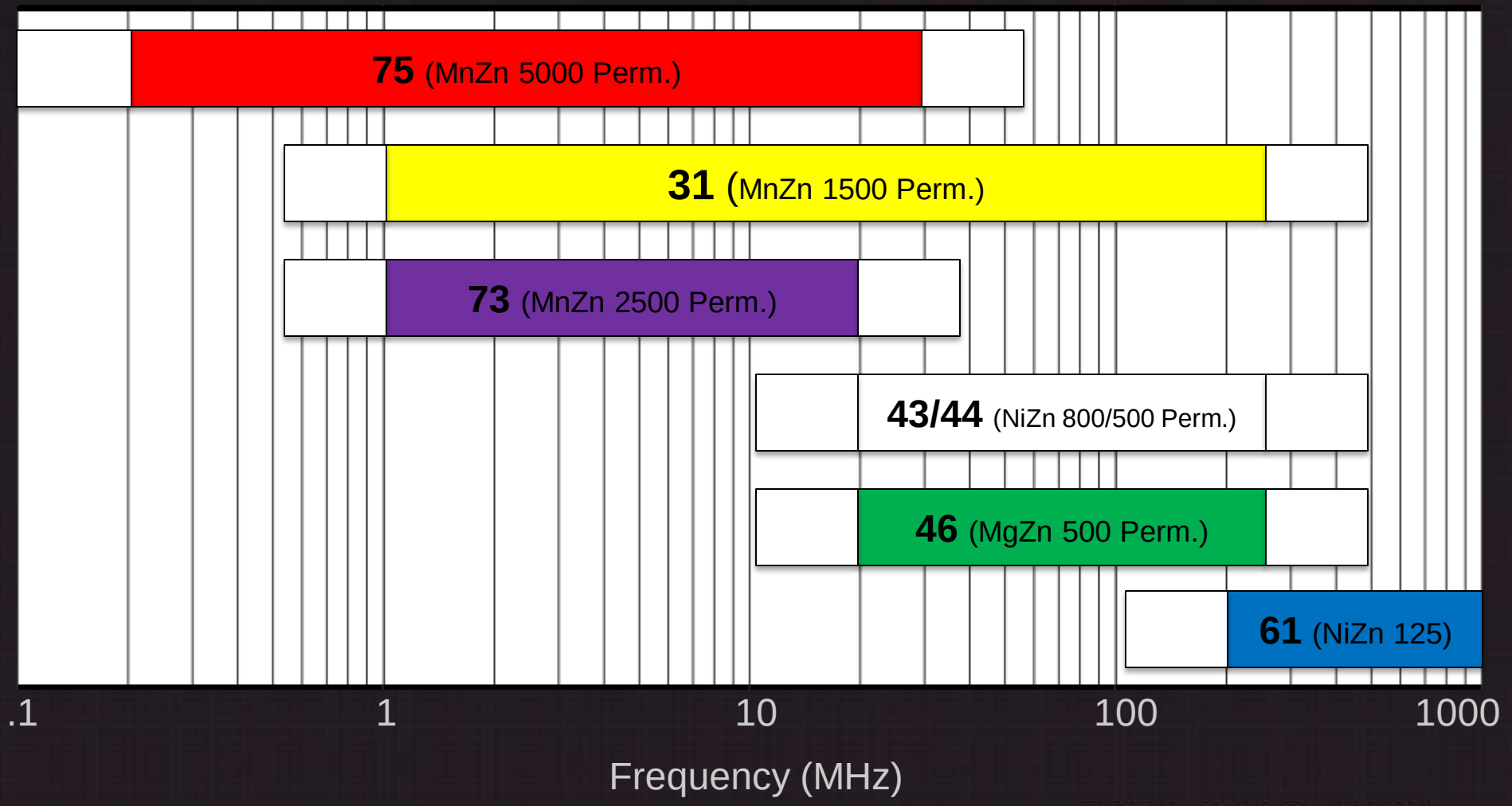




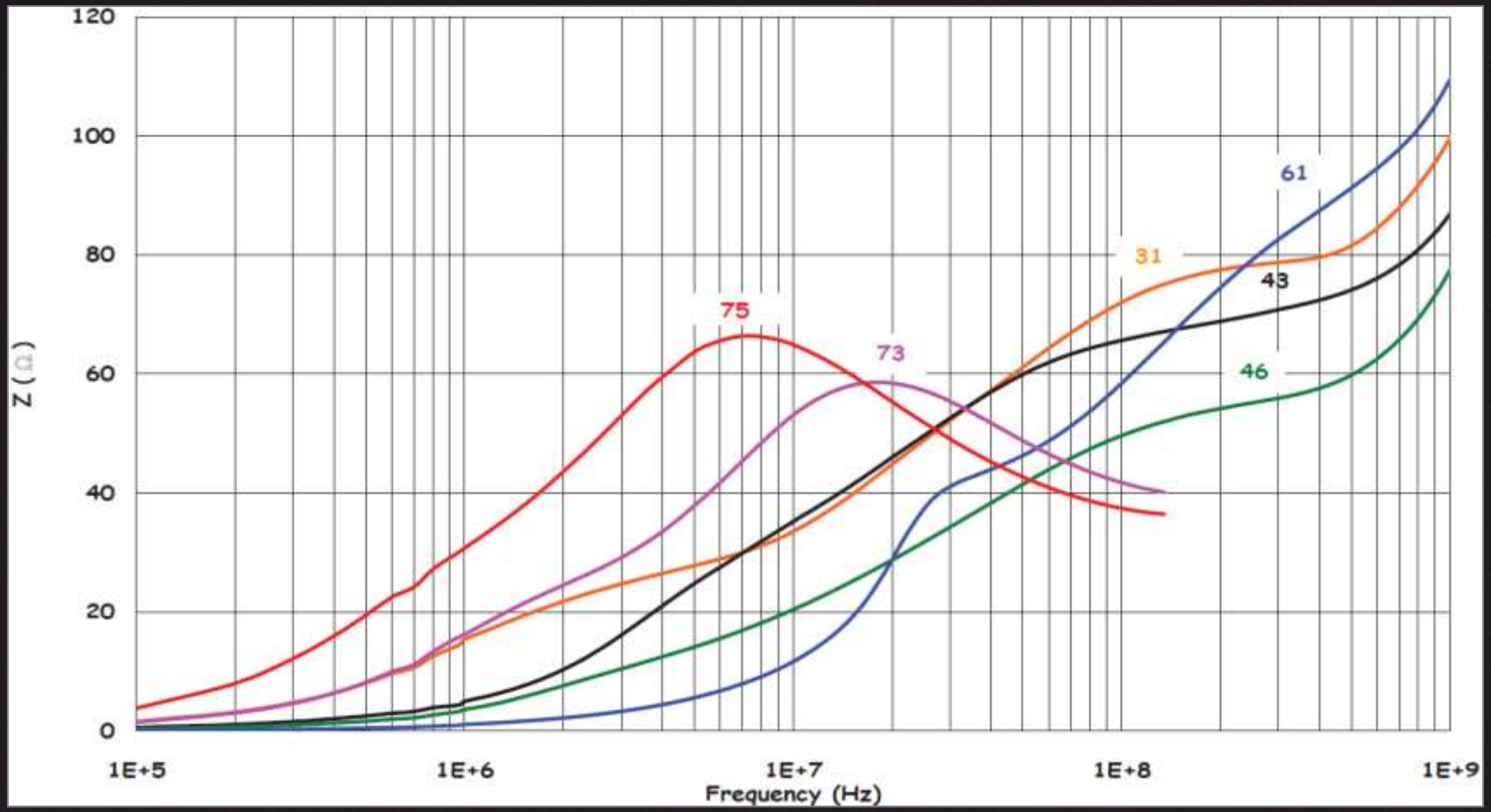
Impedance vs. Frequency



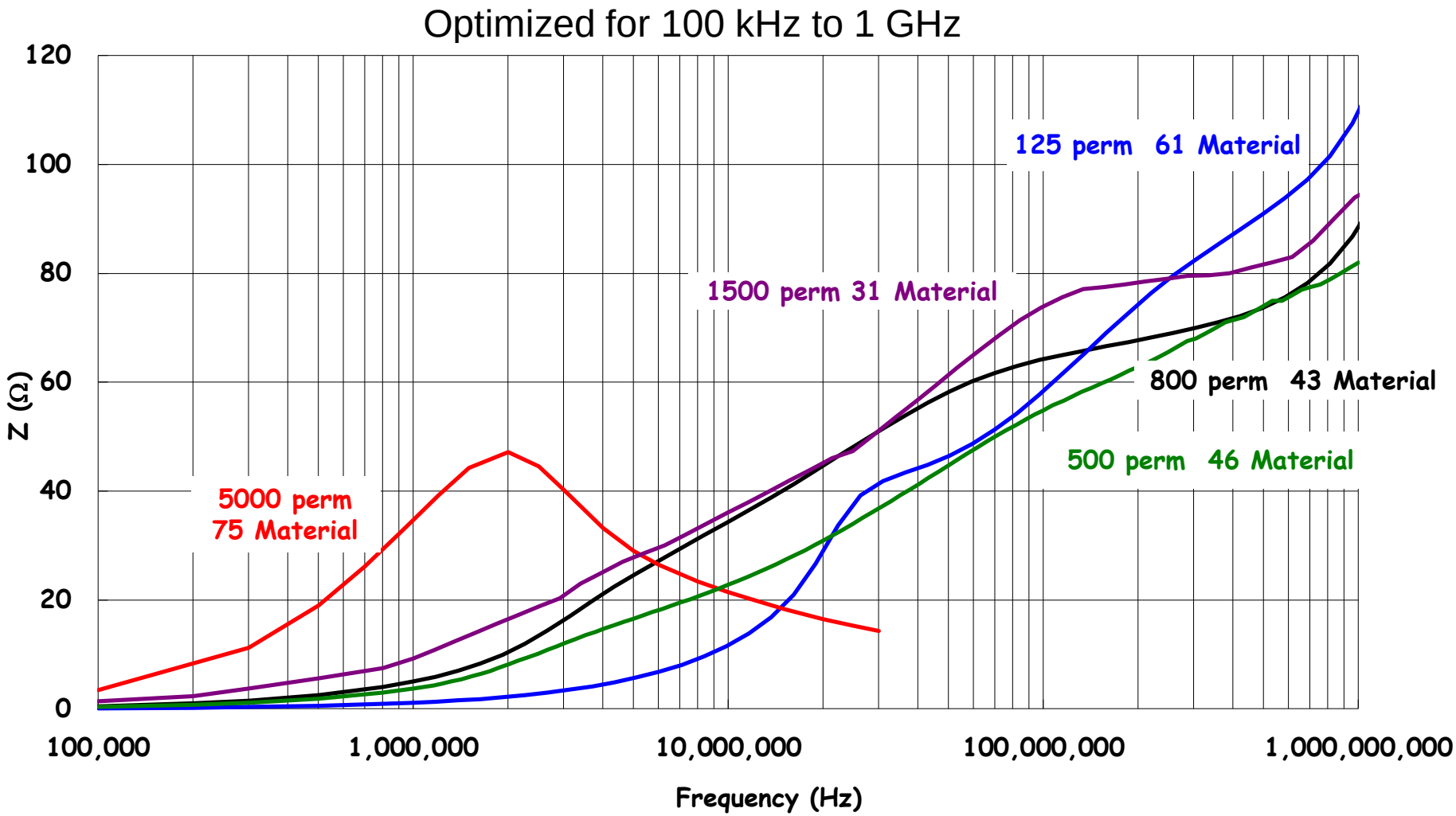
Suppression Materials Comparison



26xx000301 Bead 3.5mm x 1.3mm x 0.6 mm



Suppression Cable Comparison



Round Cable EMI Suppression Cores

Quick Link: www.fair-rite.com/rcc

Listed by frequency range and in ascending order of "B" dimension.

5000 perm

Low Frequencies 100kHz-30MHZ (75 Material)

Part Number	A	B	C	Wt. (g)	H (Oe)	Impedance (Ω)				
						200 kHz	500 kHz+	1 MHz+	2 MHz+	5 MHz
2675540002	14.3 ±0.45 0.562	6.35 ±0.25 0.25	28.6 ±0.75 1.125	17.7	0.43	30	80	133	154	95
2675102002	25.9 ±0.75 1.02	12.8 ±0.25 0.505	28.6 ±0.80 1.125	55	0.22	30	83	120	70	54

1500 perm

Lower & Broadband Frequencies 1-300 MHz (31 Material)

Part Number	A	B	C	Wt. (g)	H (Oe)	Impedance (Ω)					
						1 MHz	5 MHz	10 MHz+	25 MHz+	100 MHz+	250 MHz
2631540002	14.3 ±0.45 0.562	6.35 ±0.25 0.25	28.6 ±0.75 1.125	17.7	0.43	35	91	119	181	300	280
2631102002	25.9 ±0.75 1.02	12.8 ±0.25 0.505	28.6 ±0.80 1.125	55	0.22	31	79	103	156	260	280

800 perm

Broadband Frequencies 25-300 MHz (43 Material)

Part Number	A	B	C	Wt. (g)	H (Oe)	Impedance (Ω)			
						10 MHz+	25 MHz+	100 MHz+	250 MHz
2643540002	14.3 ±0.45 0.562	6.35 ±0.25 0.25	28.6 ±0.75 1.125	17.7	0.43	105	171	250	255
2643102002	25.9 ±0.75 1.02	12.8 ±0.25 0.505	28.6 ±0.80 1.125	55	0.22	91	145	235	275

125 perm

Higher Frequencies 200-1000 MHz (61 Material)

Part Number	A	B	C	Wt. (g)	H (Oe)	Impedance (Ω)			
						100 MHz	250 MHz+	500 MHz+	1000 MHz
2661540002	14.3 ±0.45 0.562	6.35 ±0.25 0.25	28.6 ±0.75 1.125	17.7	0.43	205	295	370	350
2661102002	25.9 ±0.75 1.02	12.8 ±0.25 0.505	28.6 ±0.80 1.125	55	0.22	190	300	380	400

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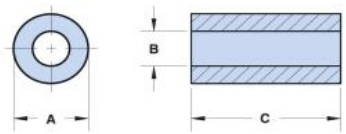
Lower & Broadband Frequencies 1-300 MHz (31 material) | Broadband Frequencies 25-300 MHz (43 material) | Broadband Frequencies 25-300 MHz (Economical 46 material) | Higher Frequencies 200-1000 MHz (61 material)



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More Info

View Chart Legend

Round Cable EMI Suppression Cores

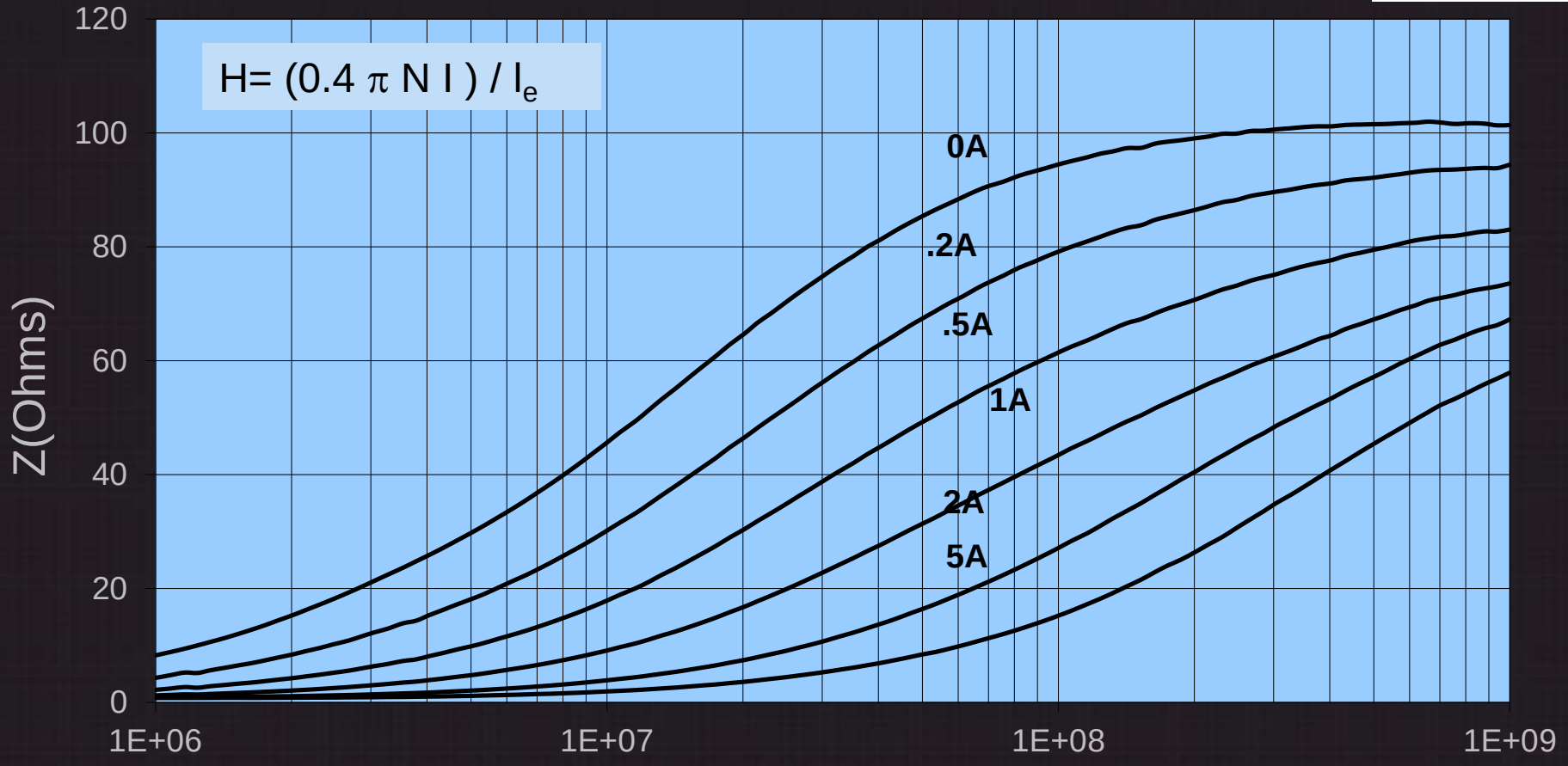
Lower & Broadband Frequencies 1-300 MHz (31 material)

Part Number	✓	A	B	C	Wt. (g)	H(Oe)	Imp. (Ω) 1 MHz	Imp. (Ω) 5 MHz	Imp. (Ω) 10 MHz+	Imp. (Ω) 25 MHz+	Imp. (Ω) 100 MHz+	Imp. (Ω) 250 MHz
2631250202		006.35 ±0.15 0.250	02.95 +0.45 0.125	25.40 ±0.75 1.000	2.90	.91	27	70	90	138	230	240
2631023002		009.50 ±0.25 0.375	04.75 +0.30 0.193	19.05 ±0.70 0.750	4.70	.60	19	49	62	95	160	185
2631480102	✓	012.30 ±0.40 0.485	04.95 +0.25 0.200	12.70 ±0.40 0.500	6.00	.52	18	45	58	88	140	167
2631480002	✓	012.30 ±0.40 0.485	04.95 +0.25 0.200	25.40 ±0.75 1.000	12.00	.52	34	88	115	175	295	267
2631540202	✓	014.30 ±0.45 0.562	06.35 ±0.25 0.250	13.80 -0.70 0.530	8.30	.43	17	44	58	88	140	160
2631540002	✓	014.30 ±0.45 0.562	06.35 ±0.25 0.250	28.60 ±0.75 1.125	17.70	.43	35	91	119	181	300	280
2631625002	✓	016.25 -0.75 0.625	07.90 ±0.25 0.312	14.30 ±0.35 0.562	10.30	.36	16	40	53	75	130	150

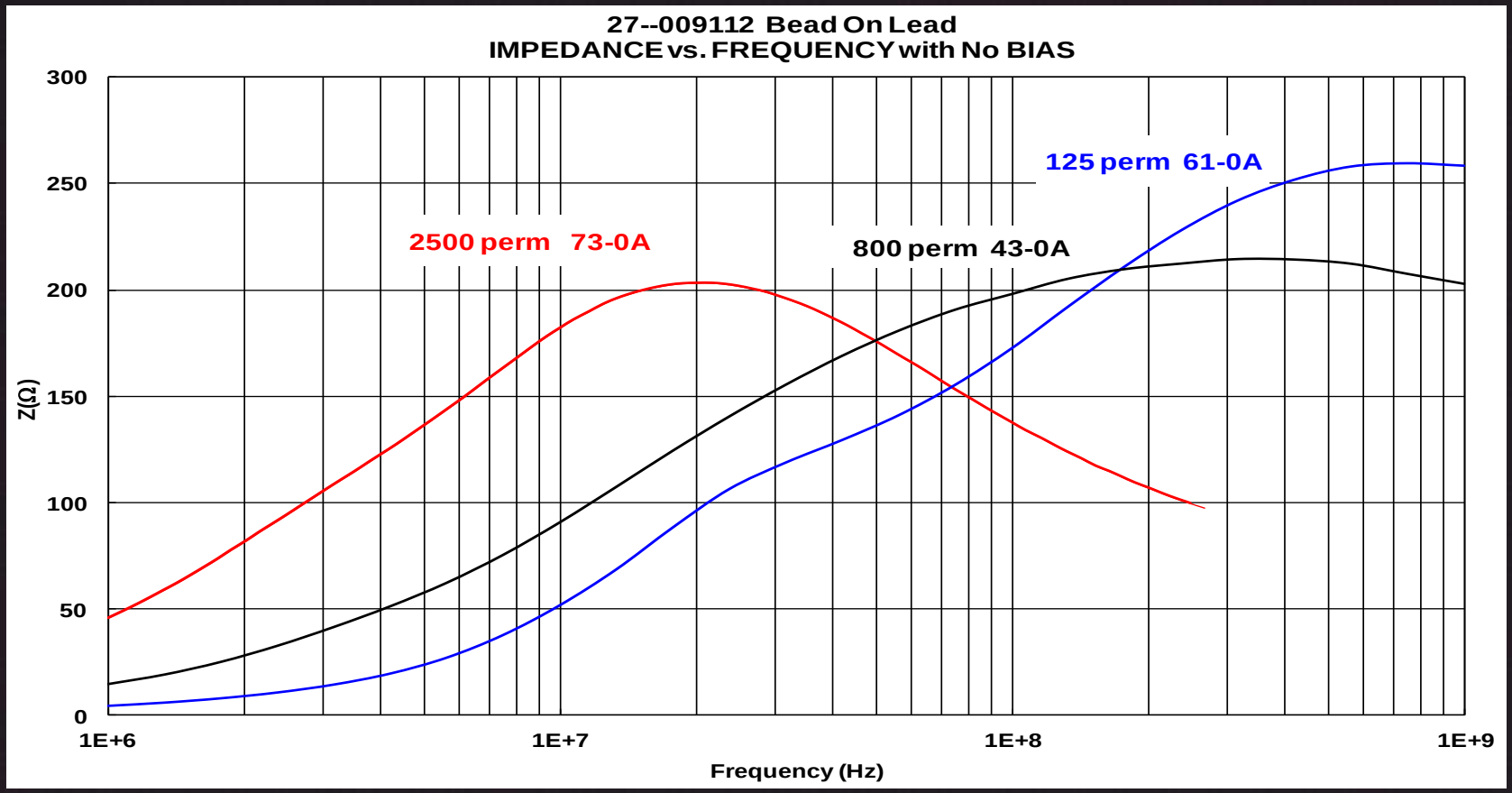
Done

Impedance vs. Frequency with DC Bias

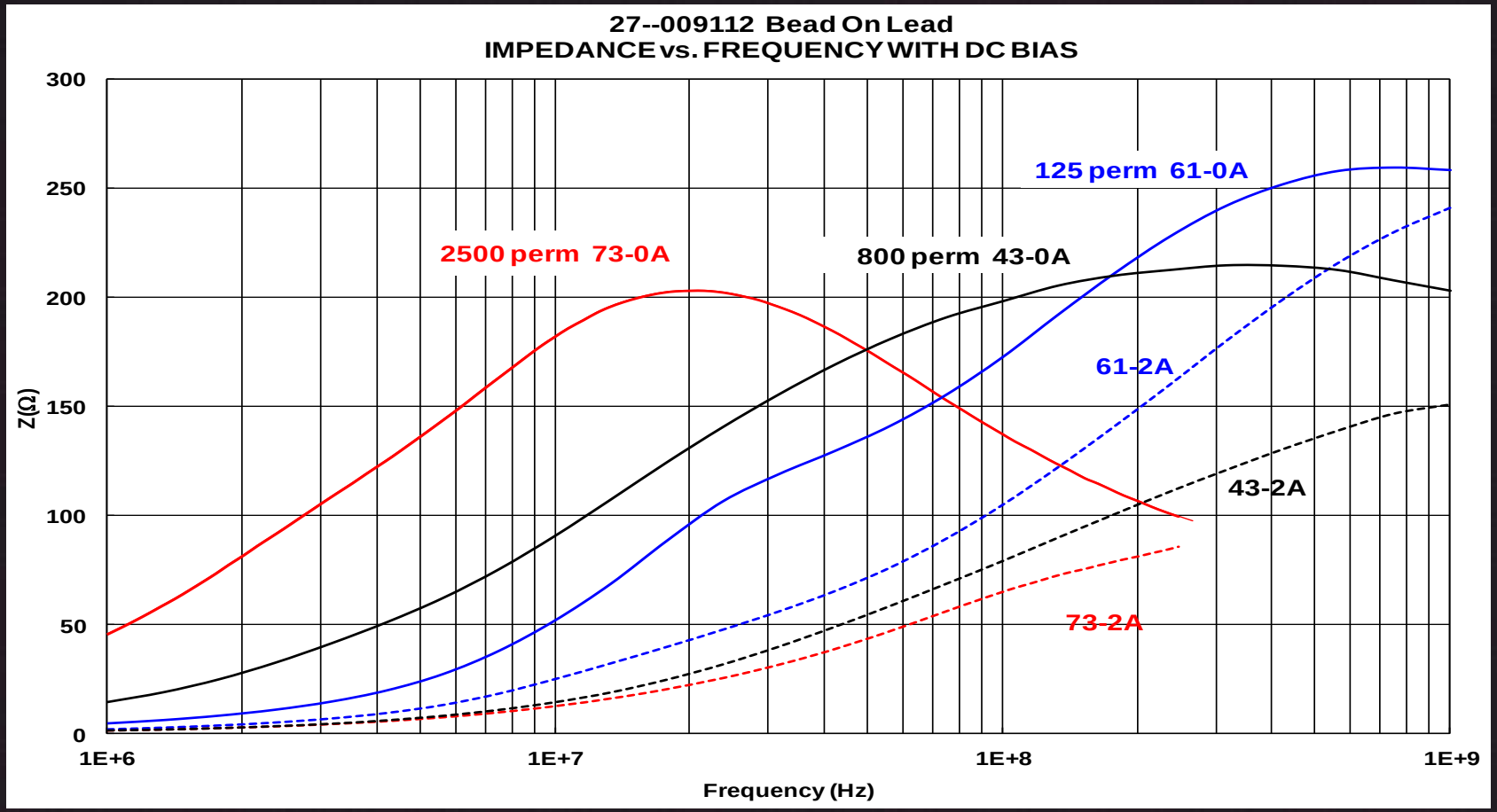
800 perm 2743021447 Surface Mount Bead

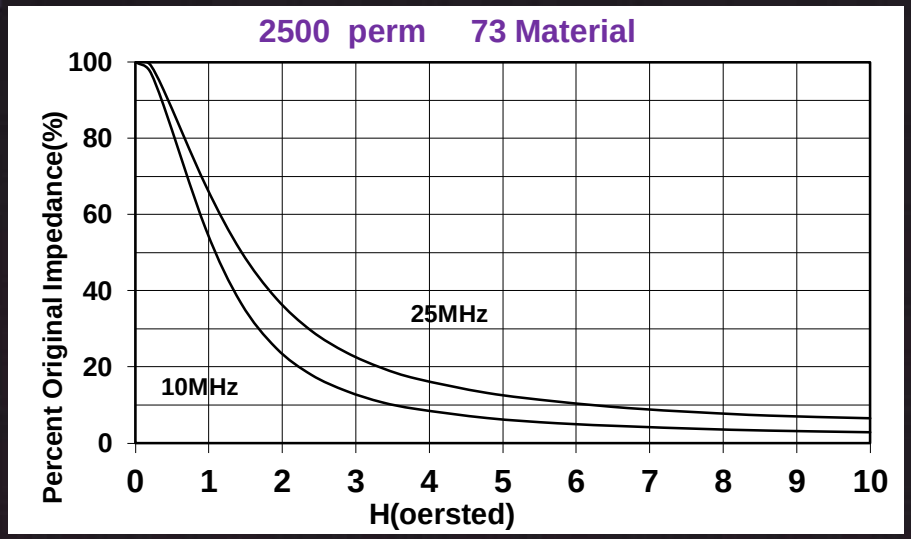


Material Comparison w/ DC Bias

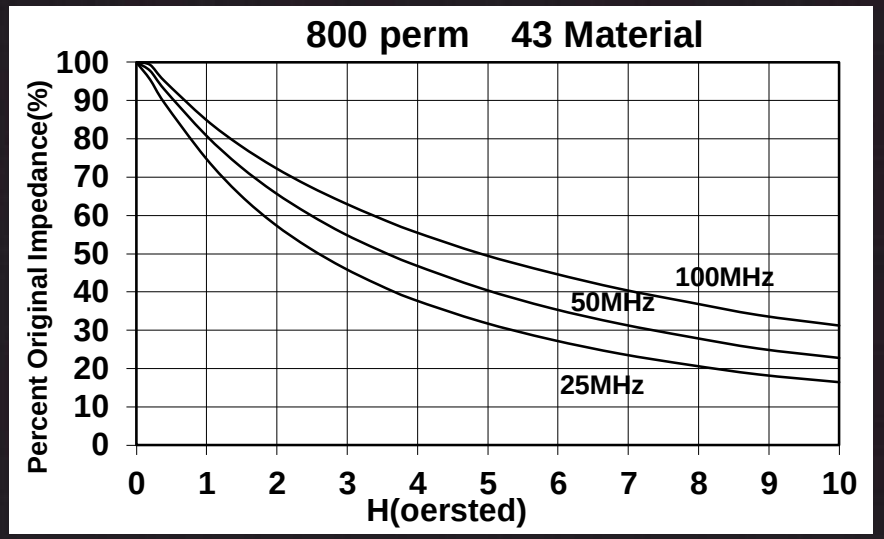


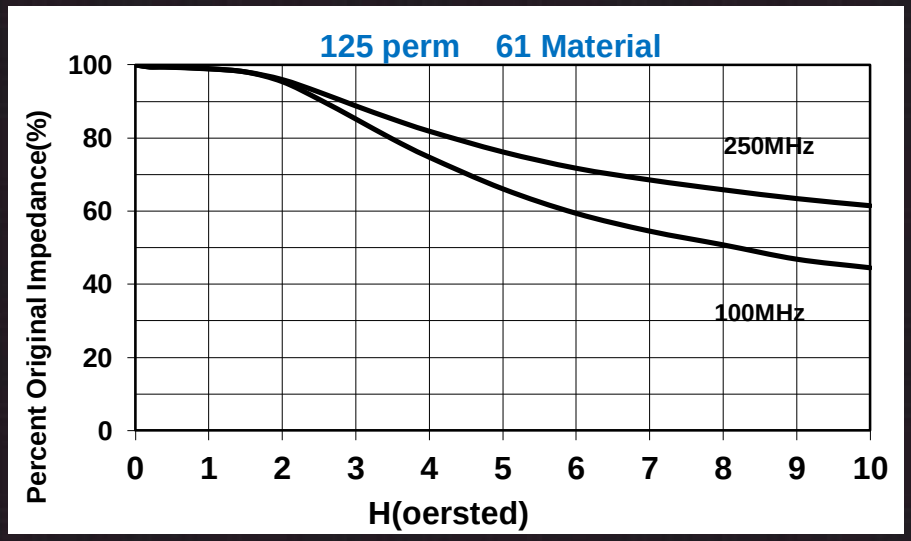
Material Comparison w/ DC Bias





$$H = (0.4\ \pi\ N\ I) / l_e \quad [Oe]$$

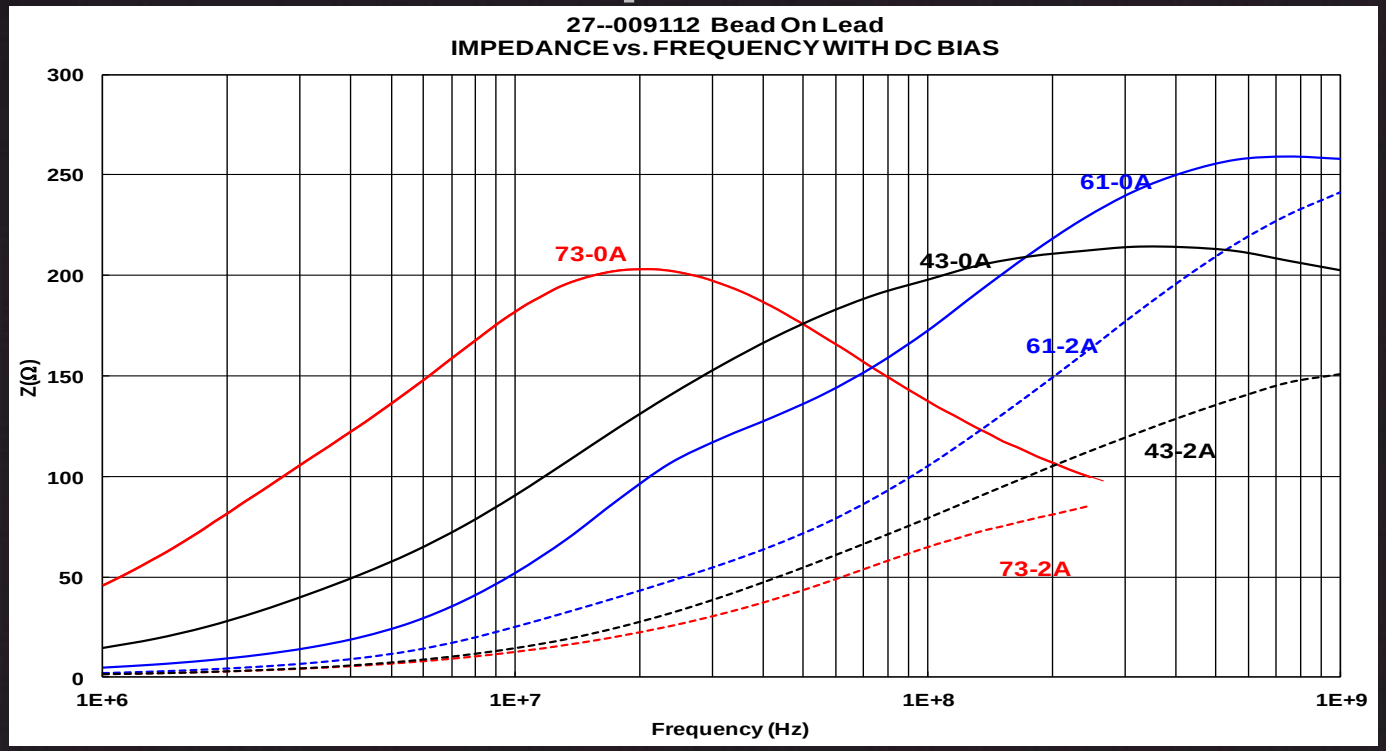




l_e = .508 cm N=1 I = 2 H=4.95 O_e

		% Original Z @ 25MHz
2500 perm	73	12%
800 perm	43	32%
125 perm	61	40%

Material Comparison w/ DC Bias



l_e = .508 cm N=1 I = 2 H=4.95 O_e

		% Original Z @ 25MHz	Z @ 25MHz measured		
			0Adc	2Adc	% Original
2500 perm	73	12%	200	25	13%
800 perm	43	32%	142	36	25%
125 perm	61	40%	110	50	45%

Round Cable EMI Suppression Cores

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Listed by frequency range and in ascending order of "B" dimension.

5000 perm

Low Frequencies 100kHz-30MHZ (75 Material)

Part Number	A	B	C	Wt. (g)	H (Oe)	Impedance (Ω)				
						200 kHz	500 kHz+	1 MHz+	2 MHz+	5 MHz
2675540002	14.3 ±0.45 0.562	6.35 ±0.25 0.25	28.6 ±0.75 1.125	17.7	0.43	30	80	133	154	95
2675102002	25.9 ±0.75 1.02	12.8 ±0.25 0.505	28.6 ±0.80 1.125	55	0.22	30	83	120	70	54

1500 perm

Lower & Broadband Frequencies 1-300 MHz (31 Material)

Part Number	A	B	C	Wt. (g)	H (Oe)	Impedance (Ω)					
						1 MHz	5 MHz	10 MHz+	25 MHz+	100 MHz+	250 MHz
2631540002	14.3 ±0.45 0.562	6.35 ±0.25 0.25	28.6 ±0.75 1.125	17.7	0.43	35	91	119	181	300	280
2631102002	25.9 ±0.75 1.02	12.8 ±0.25 0.505	28.6 ±0.80 1.125	55	0.22	31	79	103	156	260	280

800 perm

Broadband Frequencies 25-300 MHz (43 Material)

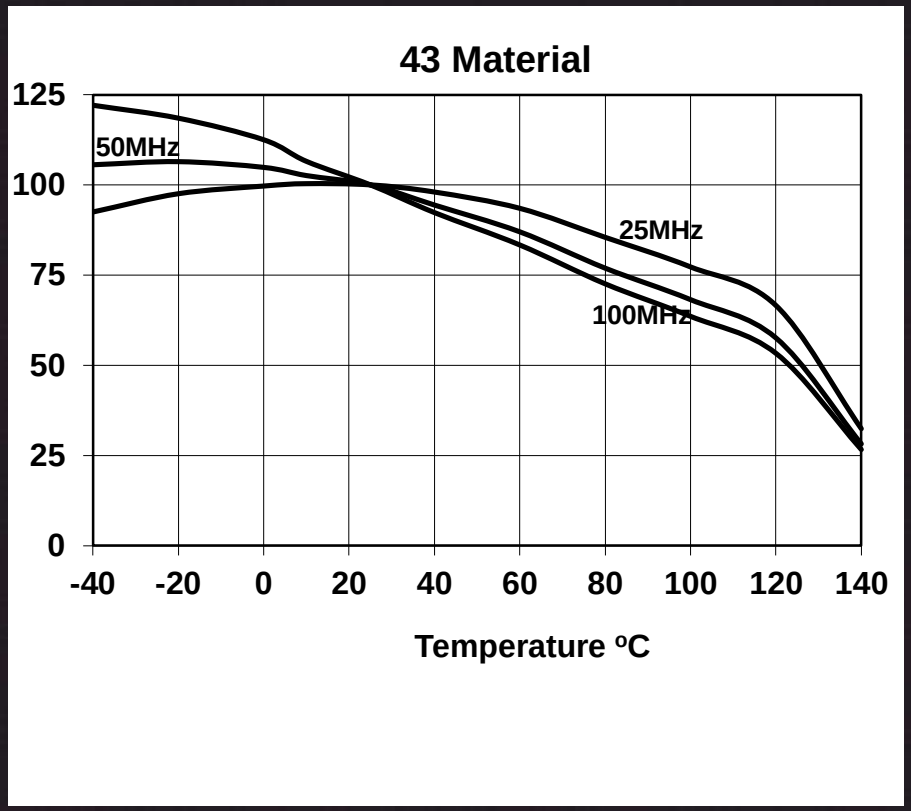
Part Number	A	B	C	Wt. (g)	H (Oe)	Impedance (Ω)			
						10 MHz+	25 MHz+	100 MHz+	250 MHz
2643540002	14.3 ±0.45 0.562	6.35 ±0.25 0.25	28.6 ±0.75 1.125	17.7	0.43	105	171	250	255
2643102002	25.9 ±0.75 1.02	12.8 ±0.25 0.505	28.6 ±0.80 1.125	55	0.22	91	145	235	275

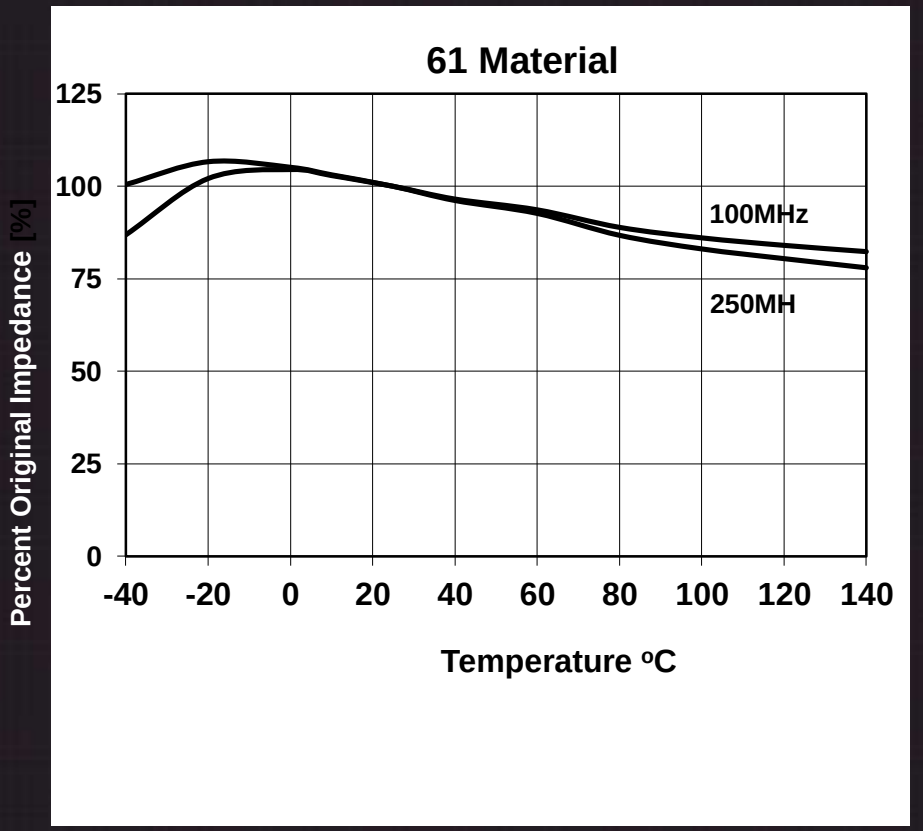
125 perm

Higher Frequencies 200-1000 MHz (61 Material)

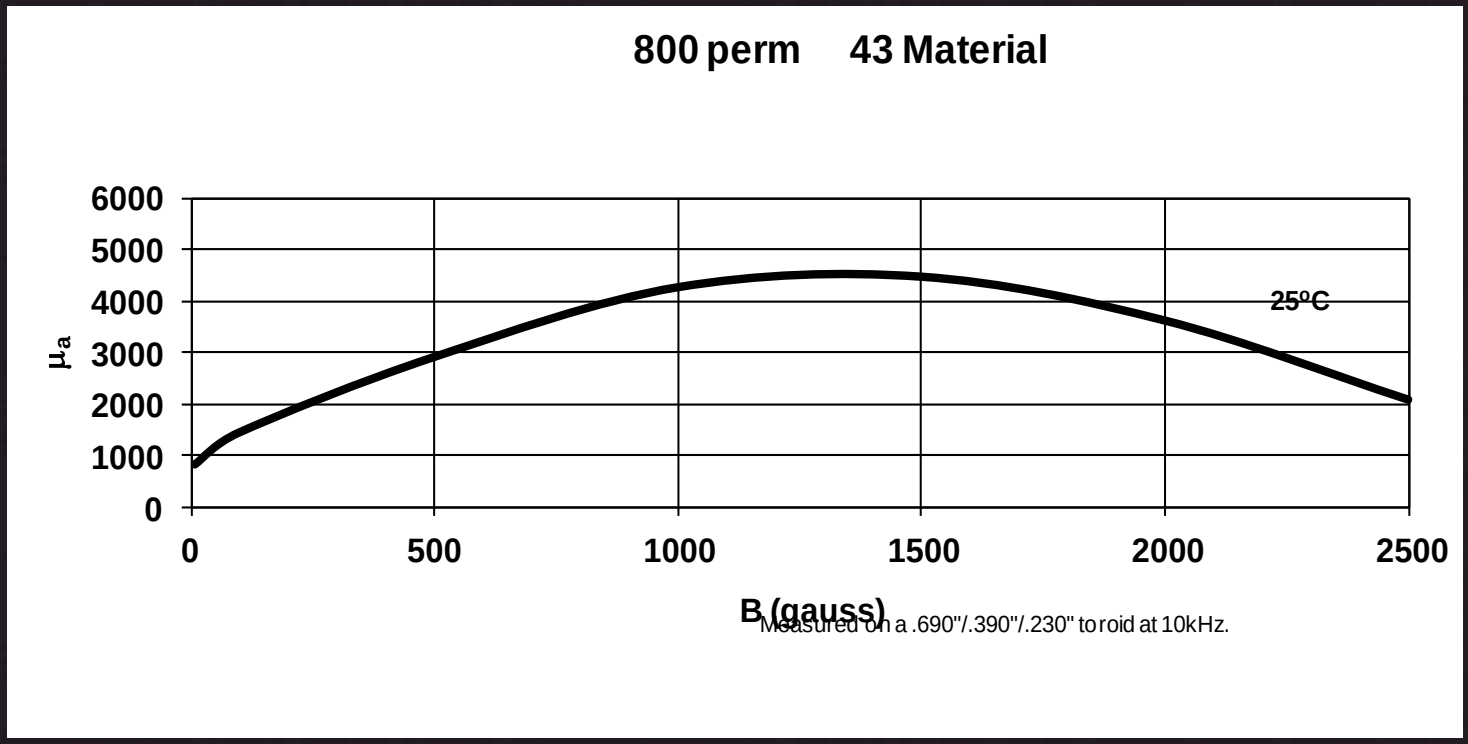
Part Number	A	B	C	Wt. (g)	H (Oe)	Impedance (Ω)			
						100 MHz	250 MHz+	500 MHz+	1000 MHz
2661540002	14.3 ±0.45 0.562	6.35 ±0.25 0.25	28.6 ±0.75 1.125	17.7	0.43	205	295	370	350
2661102002	25.9 ±0.75 1.02	12.8 ±0.25 0.505	28.6 ±0.80 1.125	55	0.22	190	300	380	400

Impedance vs. Temperature



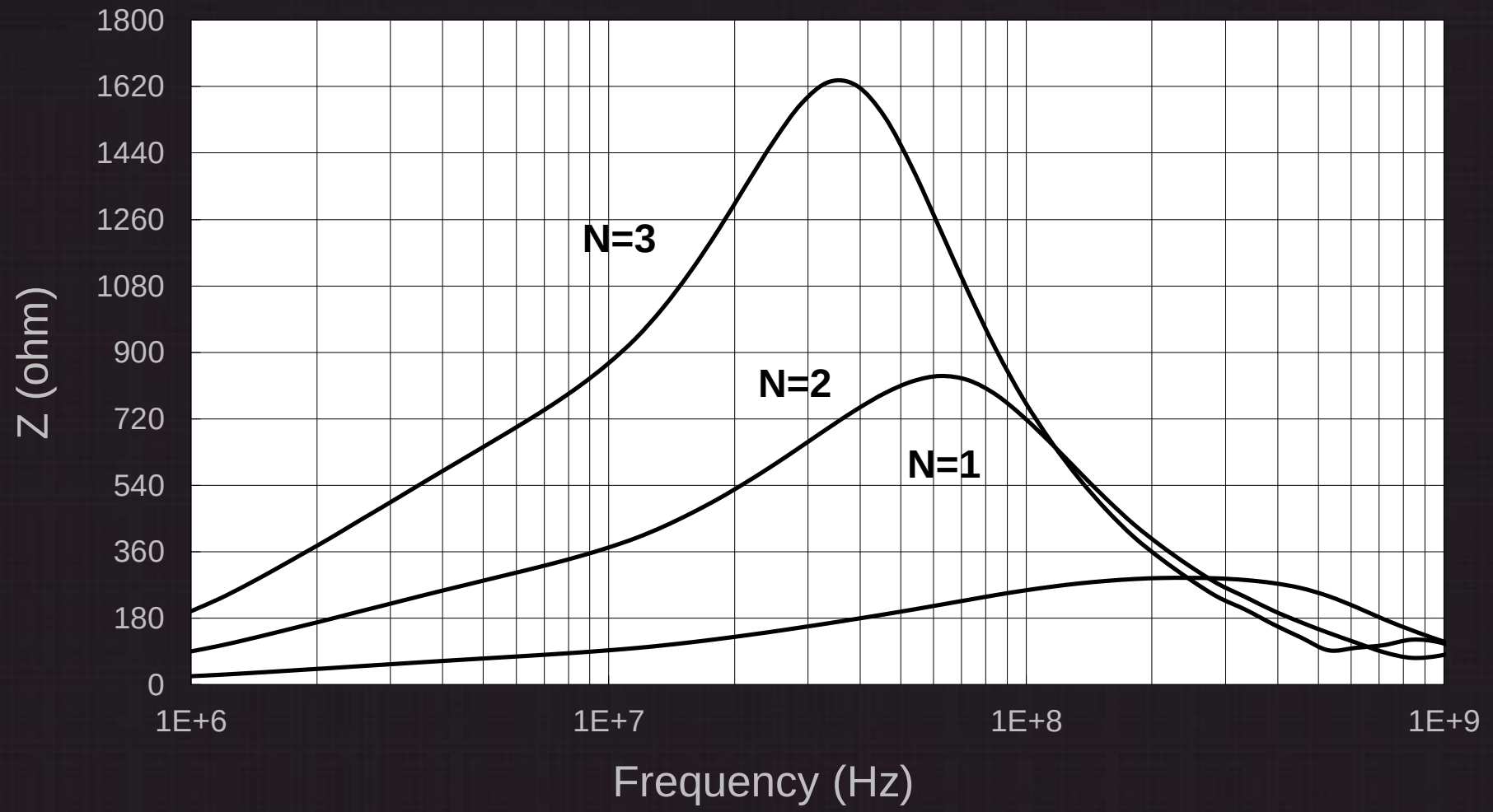


Amplitude Permeability vs. Flux Density



The Effect of Turns on Impedance

1500 perm 0431164181 Round Cable Snap-It



5000 perm 75 - Low Frequency Suppression Cable Components Optimized for 100kHz to 30MHZ

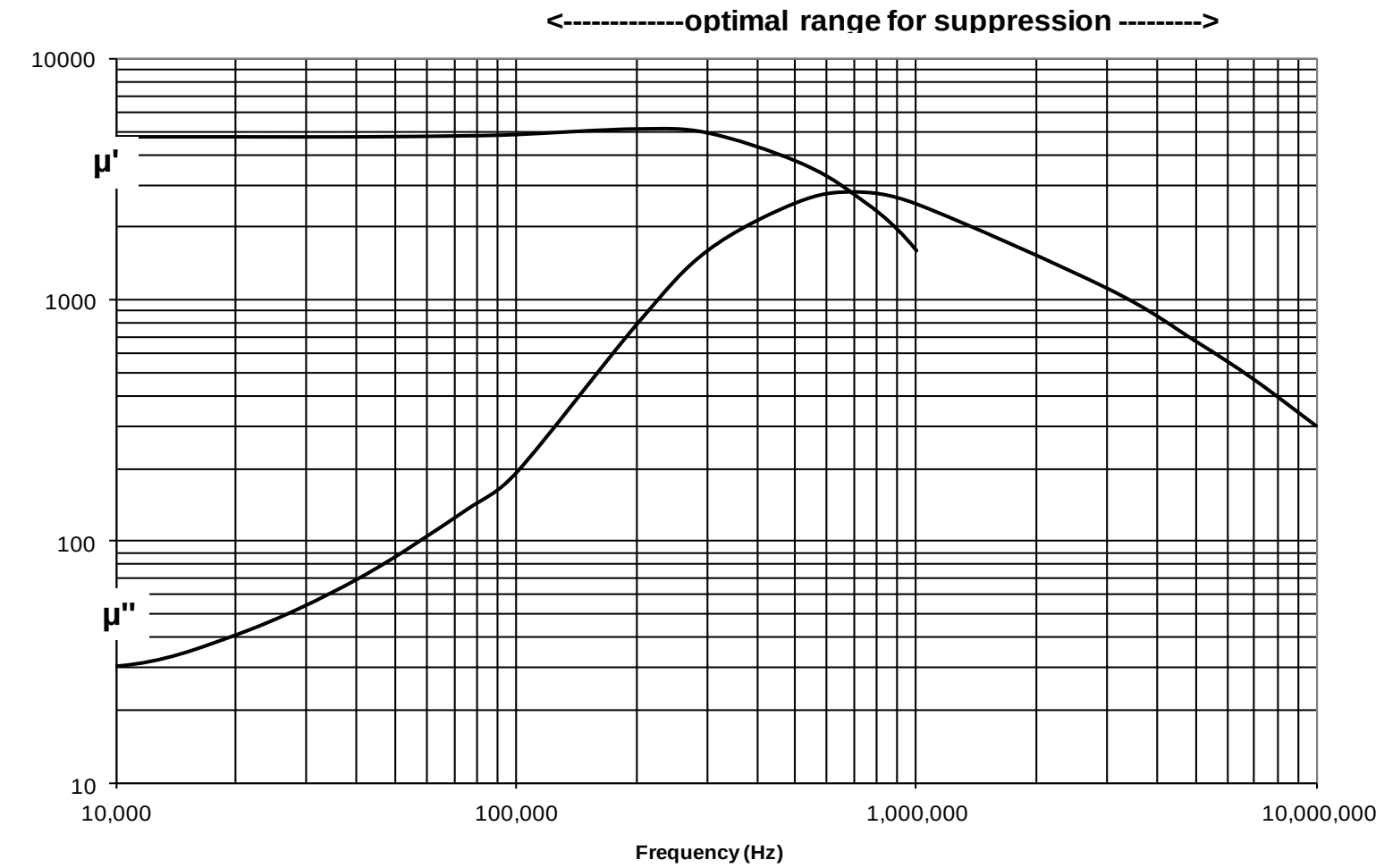
Part Number	Nominal Dimension [mm/inch] A (OD)	B (ID)	C (Ht)	Typical Impedance (Ω) + 500kHz # of turns 1+	2	3	5	1MHz # of turns 1+	2	3	5	5MHz # of turns 1+	2	3	5
2675023002	9.50 / .374"	5.10 / .201"	19.05 / .750"	43	170	394	1070	68	270	623	1700	96	380	867	2380
2675540202	14.30 / .563"	6.35 / .250"	13.45 / .530"	39	150	347	940	58	230	530	1470	52	210	475	1300
2675540002	14.30 / .563"	6.35 / .250"	28.60 / 1.125"	82	327	730	2040	133	540	1190	1190	95	380	860	2370
2675625102	15.88 / .625"	7.90 / .311"	28.60 / 1.125"	60	240	536	1460	83	320	718	2000	50	200	447	1240
2675665702	17.40 / .685"	9.50 / .374"	28.60 / 1.125"	56	220	504	1390	102	400	907	2530	85	340	765	2100
2675626402	18.70 / .736"	10.15 / .400"	28.60 / 1.125"	54	220	495	1400	71	280	647	1800	46	180	417	1150
2675102002	25.90 / 1.020"	12.80 / .504"	28.60 / 1.126"	83	340	755	2140	120	480	1090	3020	54	210	490	1296
2675821502	31.00 / 1.220"	19.00 / .748"	15.00 / .591"	29.5	120	268	752	43	170	391	1080	20	80	182	498

+ test parameter

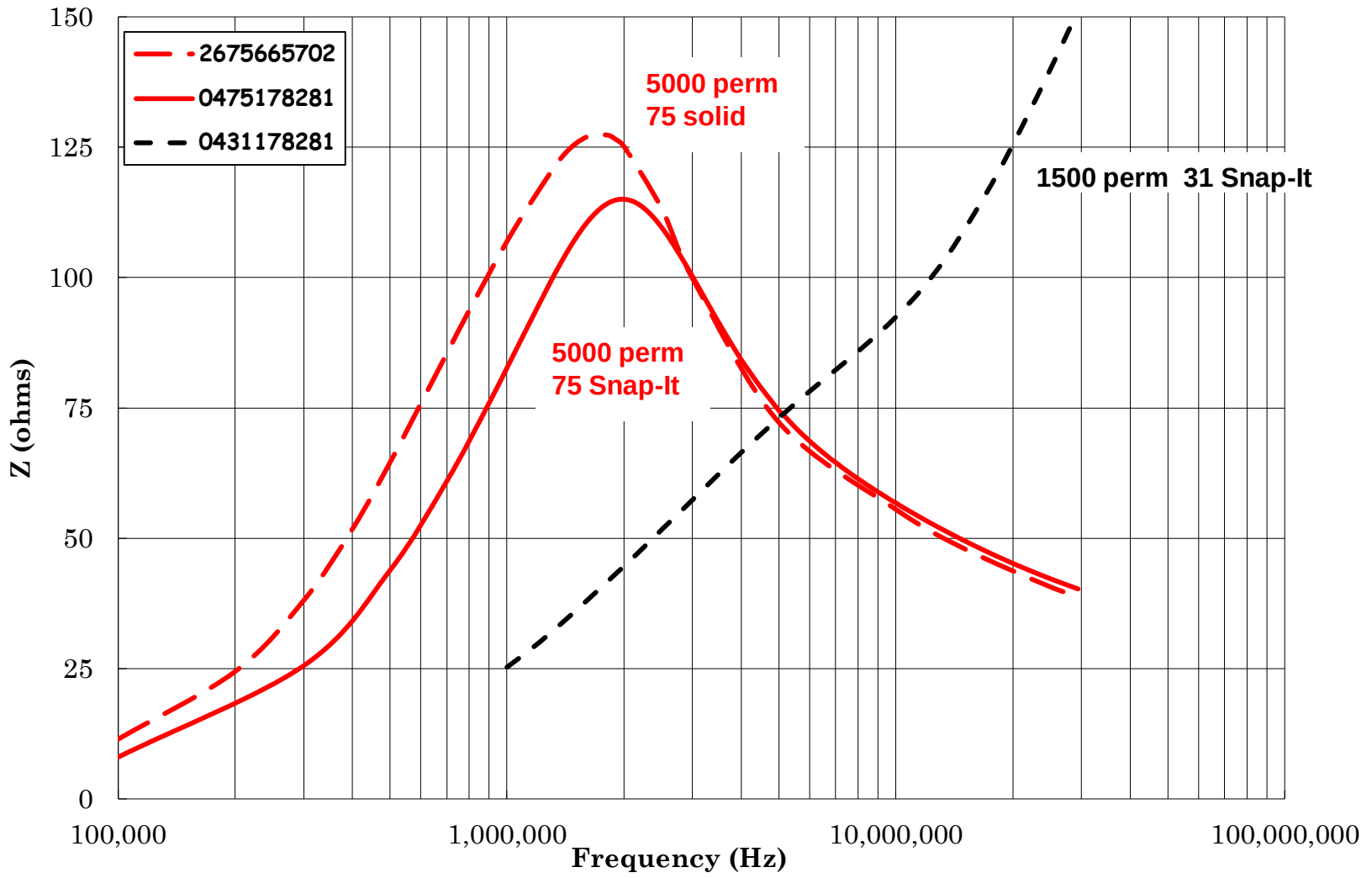
New Low Frequency Suppression Cable Snap-Its Optimized for 100kHz to 30MHZ

5000 perm 75 Snap-It Cores								
Dimensions (mm)					Typical Impedance (1 Turn)			Solid Equivalent
Part Number	Max Cable Dia	A	B	C	500 kHz	1MHz	5MHz	
0475181651	4.90	12.80	5.10	25.10	35	66	110	2675023002
0475164281	6.30	20.00	6.60	39.40	49	102	110	2675540002
0475178281	8.70	21.50	9.00	39.40	46	87	74	2675665702
0475167281	9.85	23.70	10.15	39.40	47	92	67	2675626402
0475164181	12.70	31.00	13.05	39.40	58	102	50	2675102002
0475176451	18.00	38.60	18.35	47.50	92	130	66	3 x 2675821502

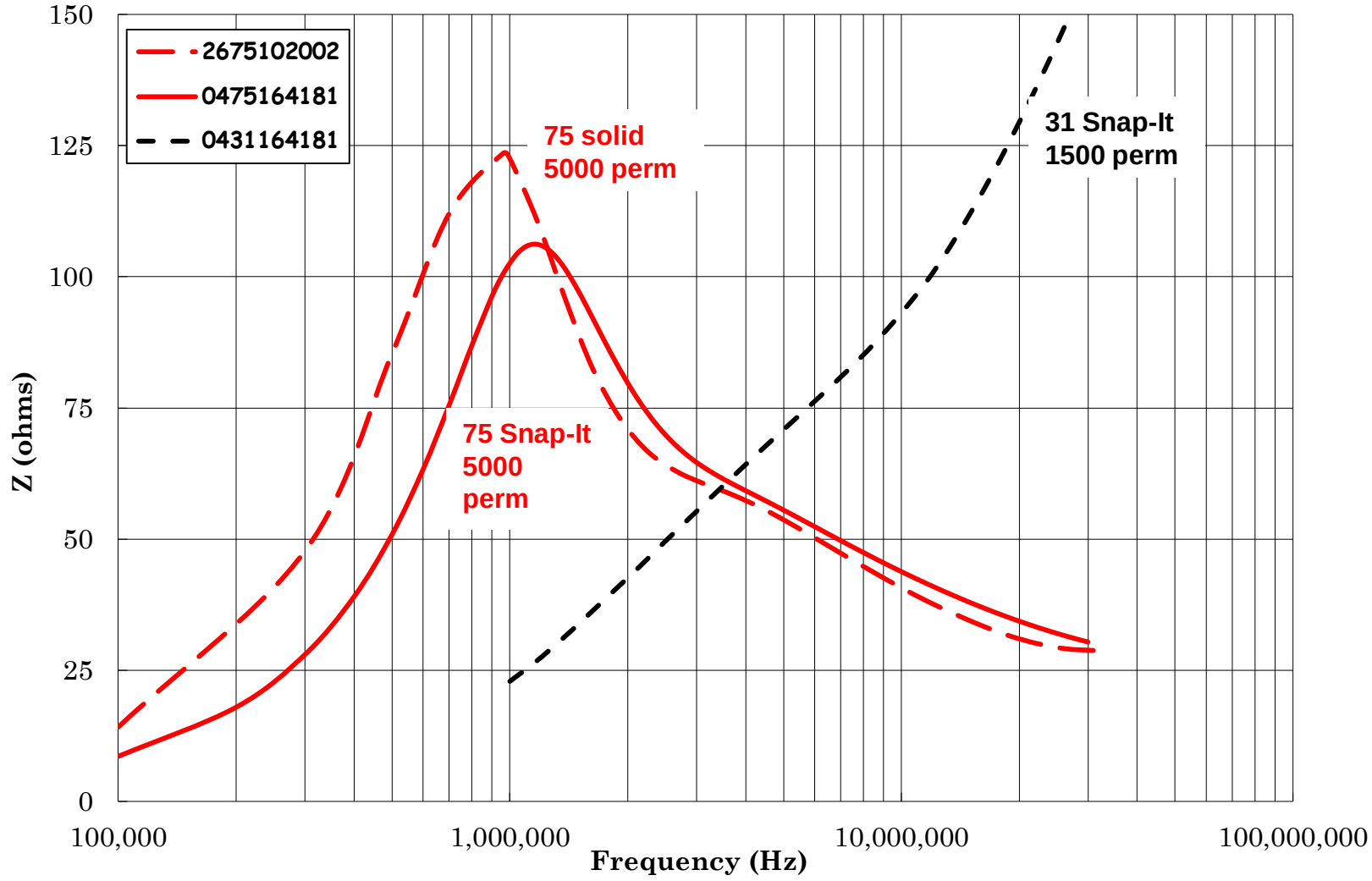
μ' / μ'' 5000 perm 75 Material Complex Permeability

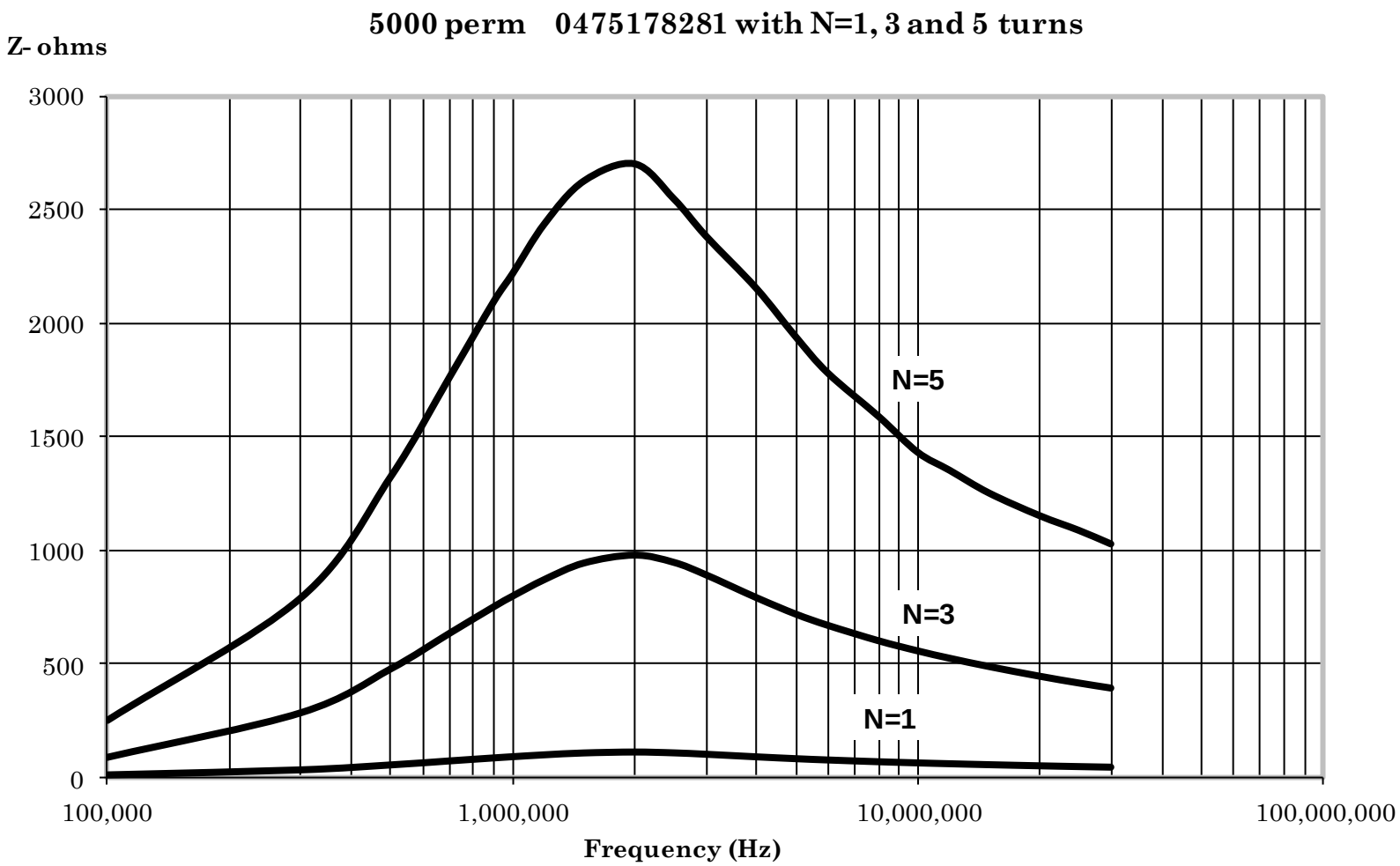


Comparison of 75 and 31 Material Cable Cores (max cable diameter 8.70 mm)



Comparison of 75 and 31 Material Cable Cores (max cable diameter 12.70 mm)

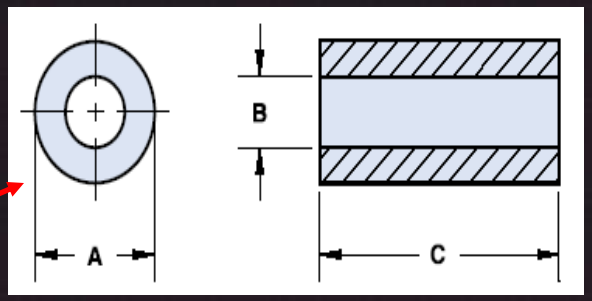



5000 perm 0475178281 with N=1, 3 and 5 turns
Z- ohms
3000
2500
2000
1500
1000
500
0
N=5
N=3
N=1
100,000
1,000,000
10,000,000
100,000,000
Frequency (Hz)

Product Range – EMI Suppression Products

Cable Components

- Round Cable EMI Suppression Cores
  - 75, 31, 43, 46, 61
  - 12Ω to 380Ω
  - 3.0” ID



- Round Cable Snap-Its
  - 75, 31, 43/44, 46, 61
  - 12Ω to 435Ω
  - 1.00” ID
  - [NEW 1.40”ID, 31, core only]

Board Level – SMD ferrites

Chip Beads

Package sizes
0402, 0603, 1206, 1806, 1812

Y Std , Z High , H GHz

Impedance Rated at 100MHz
10Ω to 2000Ω

Current Rated 100mA to 6A

SM Beads

Package sizes
.184 x .120 up to .58 x .27 DM & CM

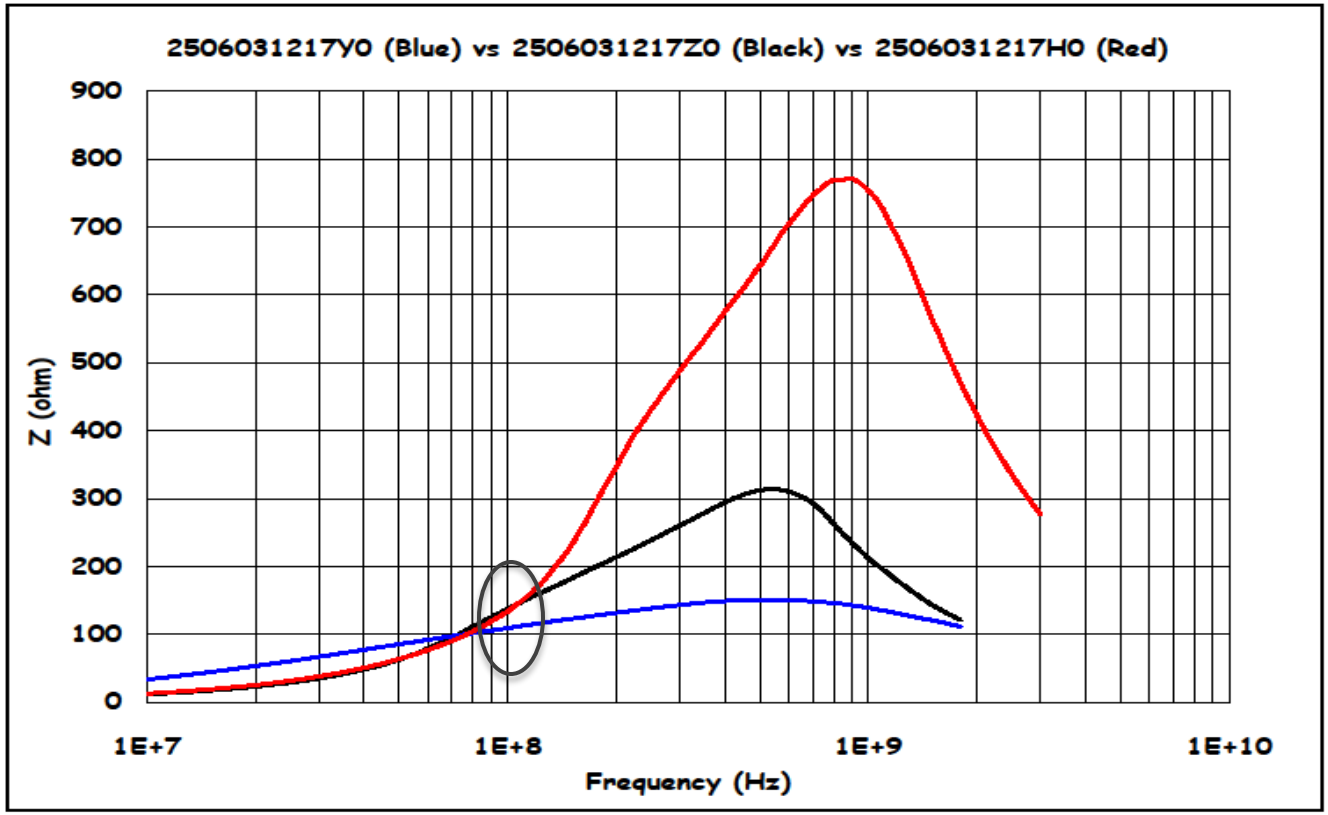
73(<50MHz), 43/44 (25-300MHz), 61 & 52 (250MHz-1GHz)

Impedance Rated at 1MHz to 1GHz
9Ω to 600Ω

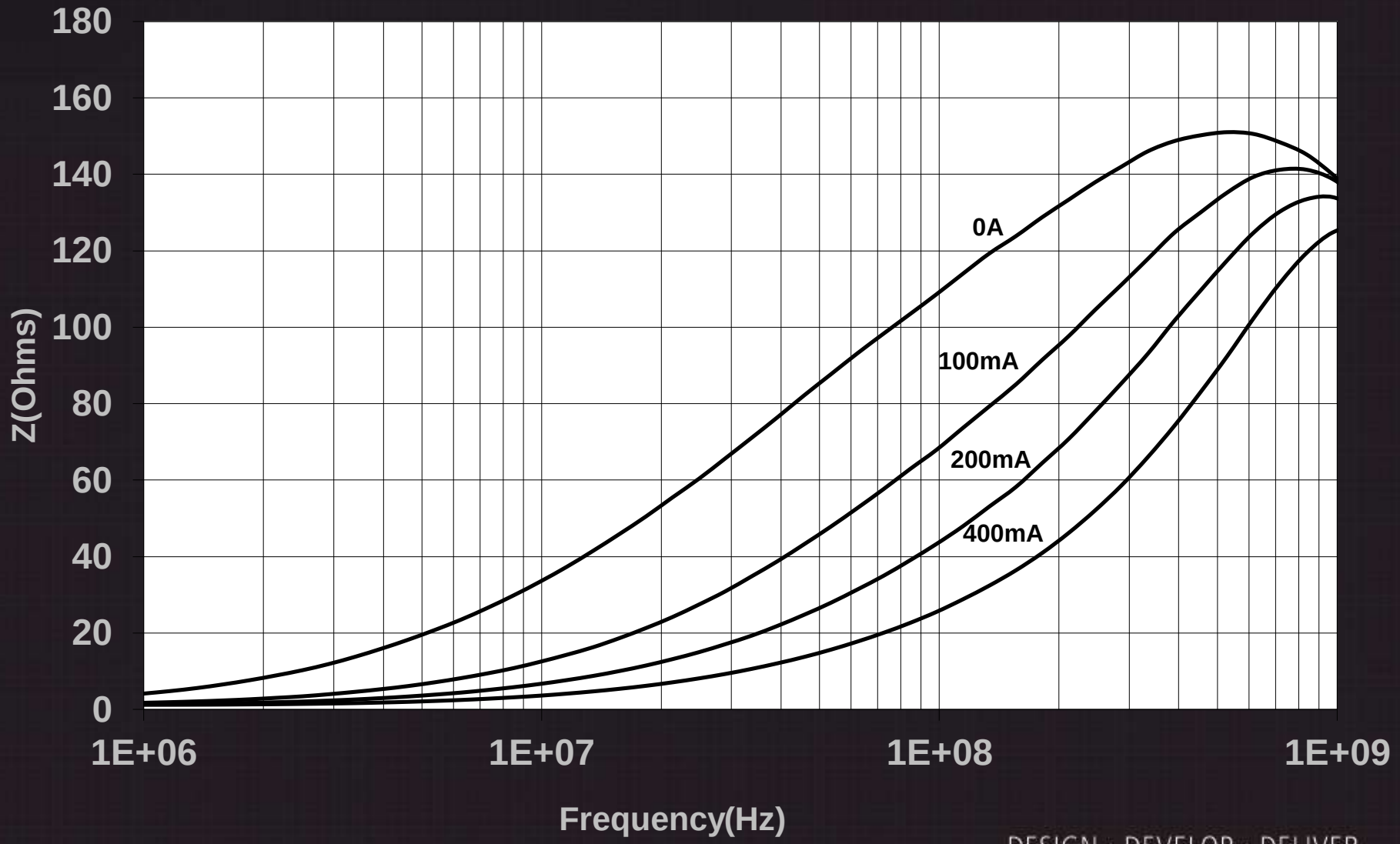
Current Rated 5A (to 10A)

Material Matters

0603 size 120Ω +/-25% Y Std speed vs Z High Speed vs H GHz Speed

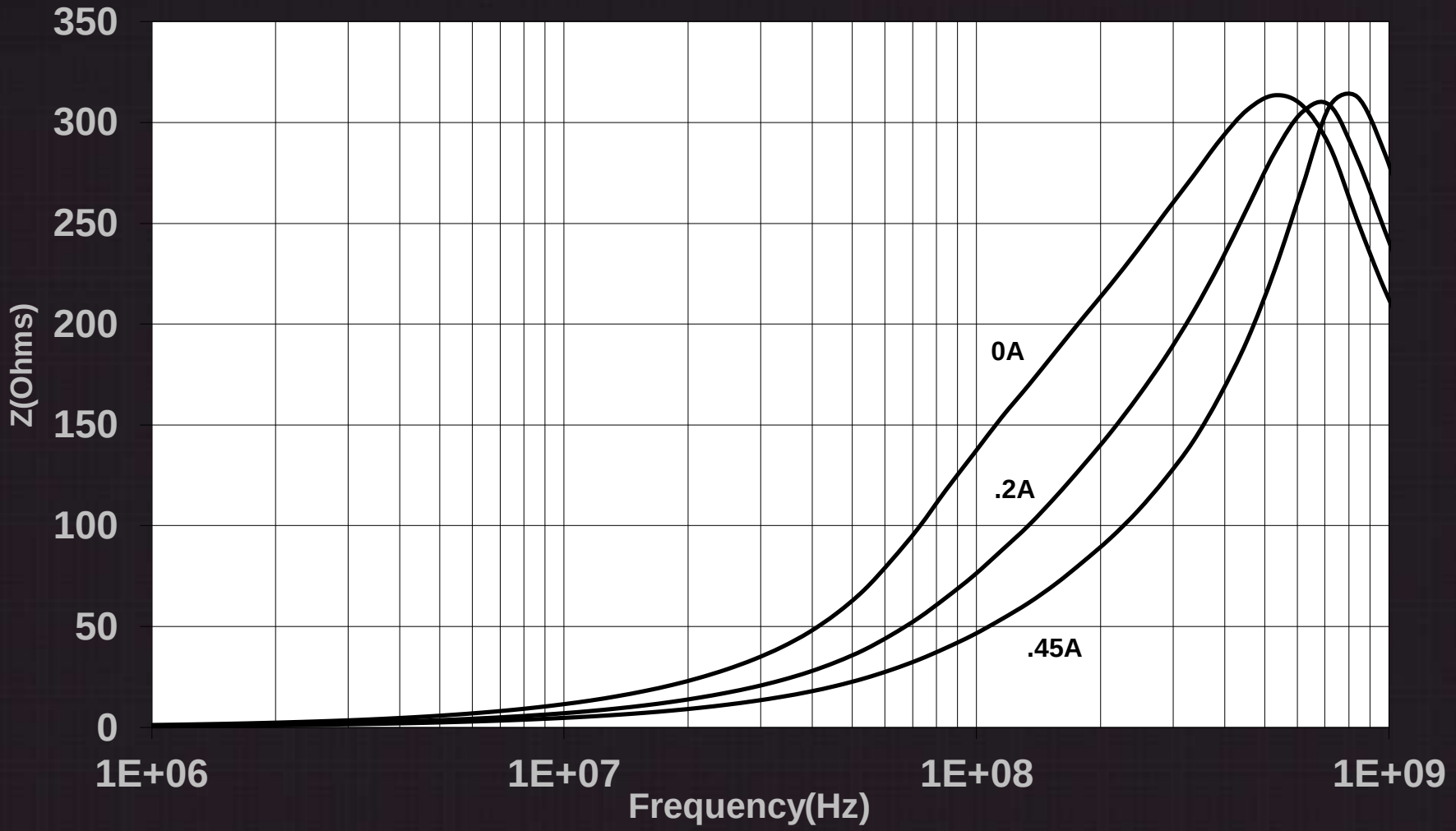


0603 size 120Ω Y Std speed 400mA Device 2506031217Y0



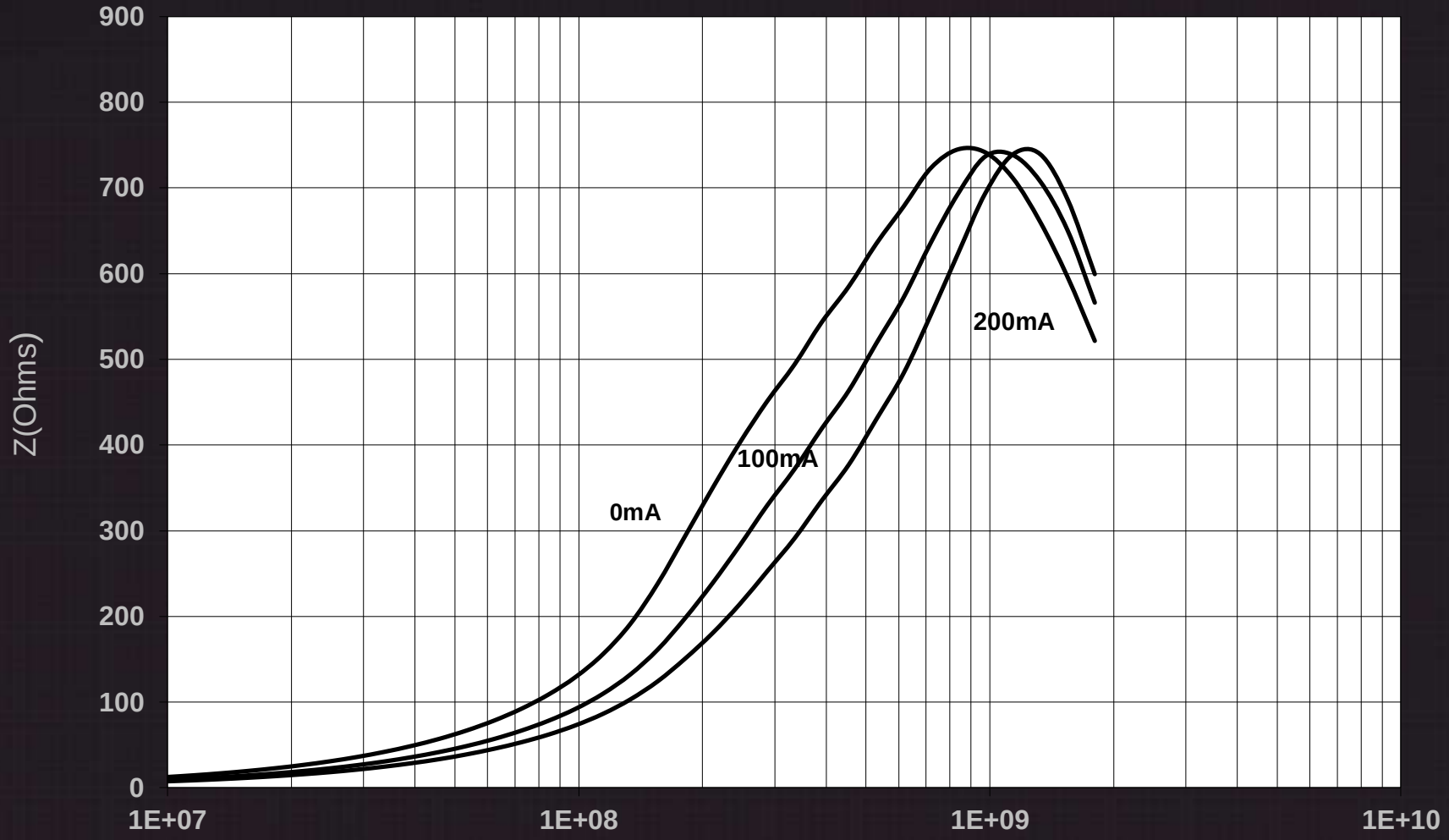
0603 size 120Ω Z High speed 450mA Device

250603121 7Z0

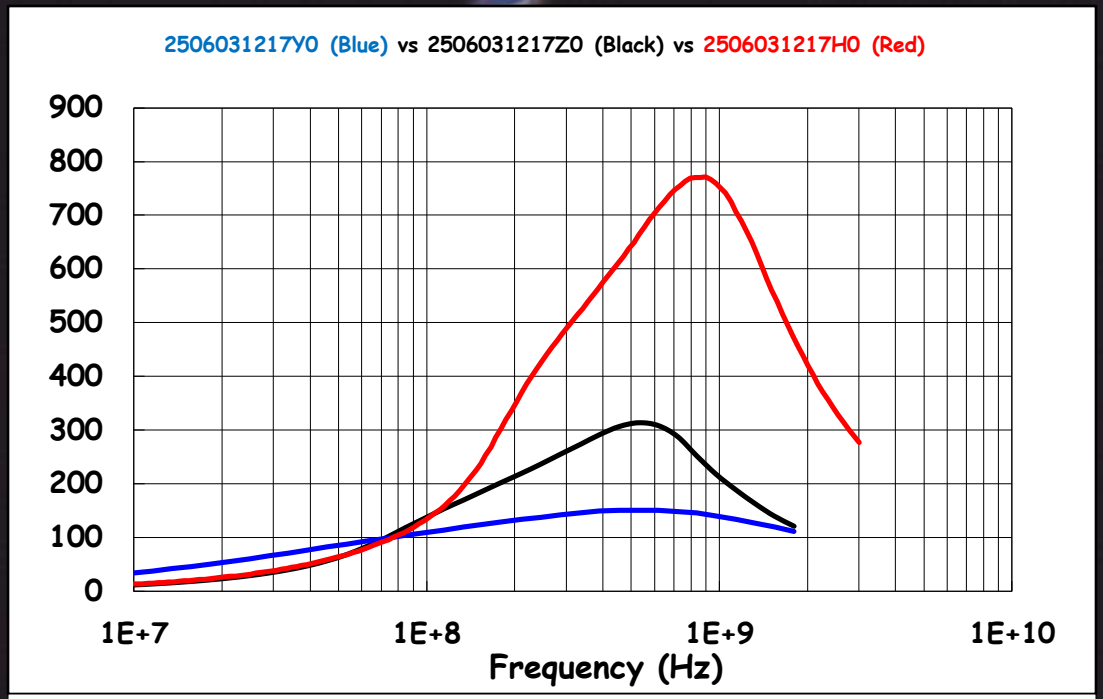


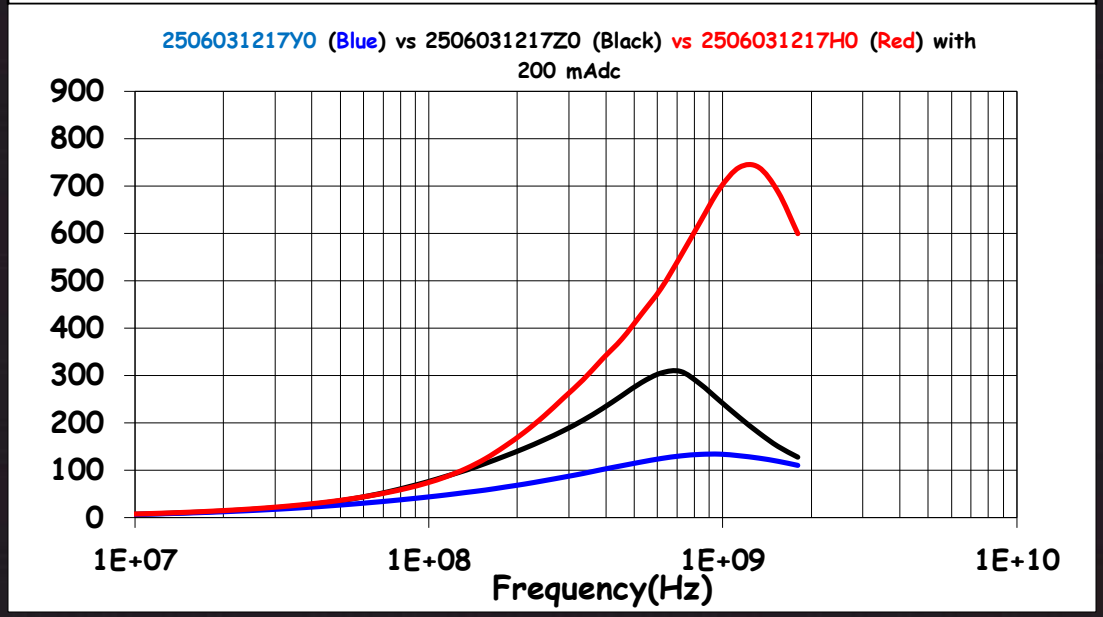
0603 size 120Ω H GHZ speed 200mA Device

2506031217H0



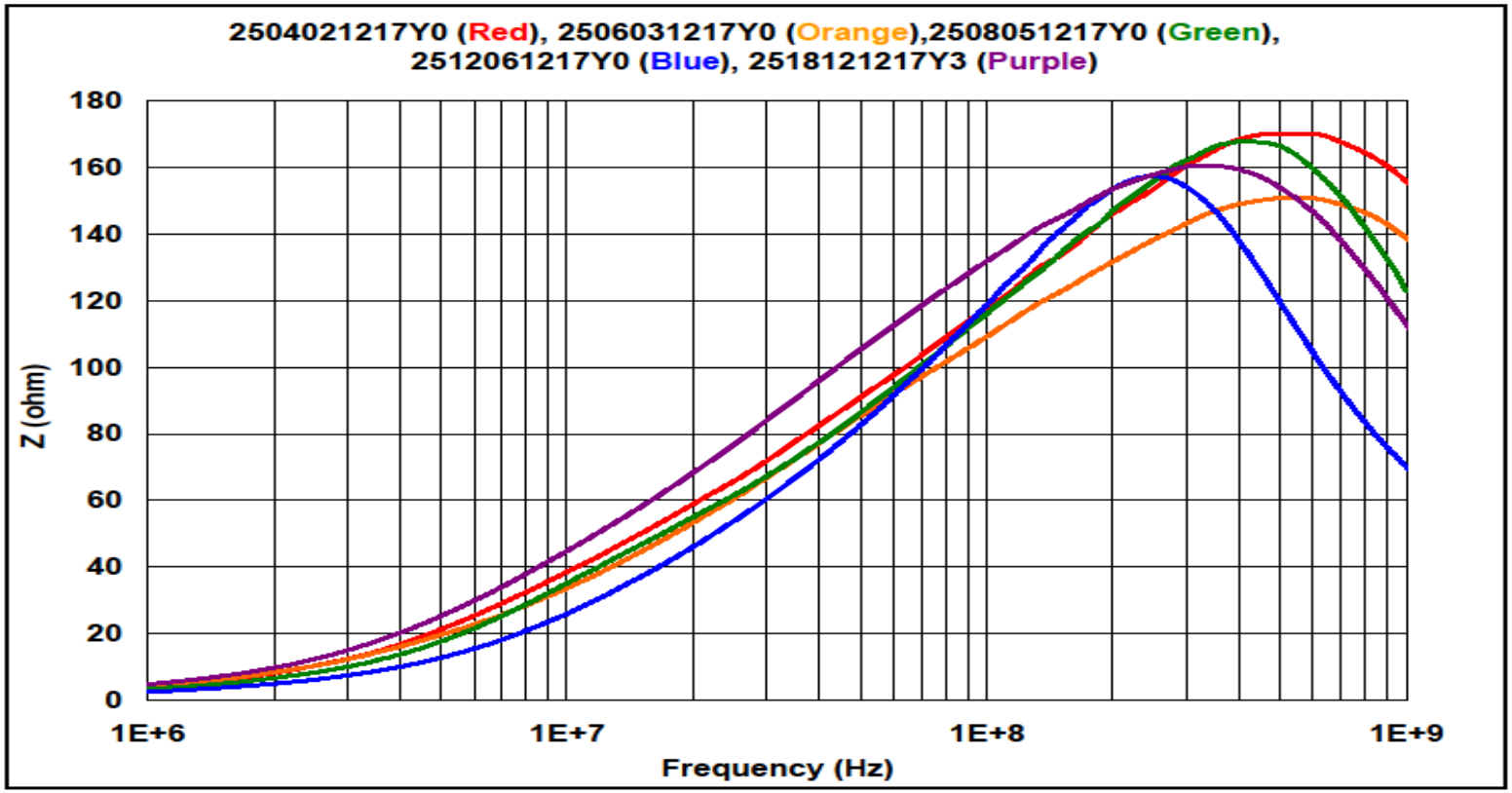
Material Matters



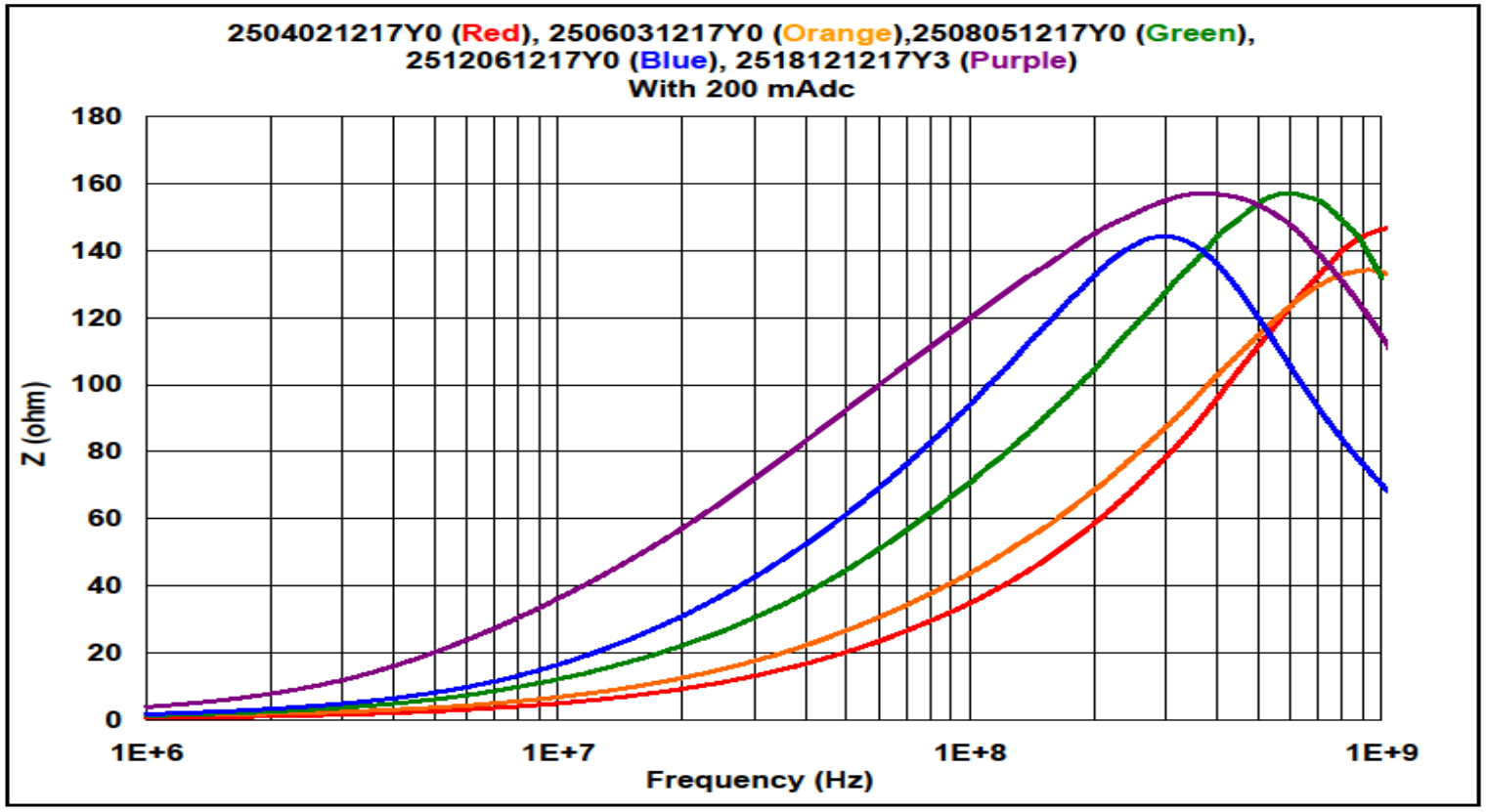


Size Matters all 120Ω 0402 to 1812 packages

Y Std Speed



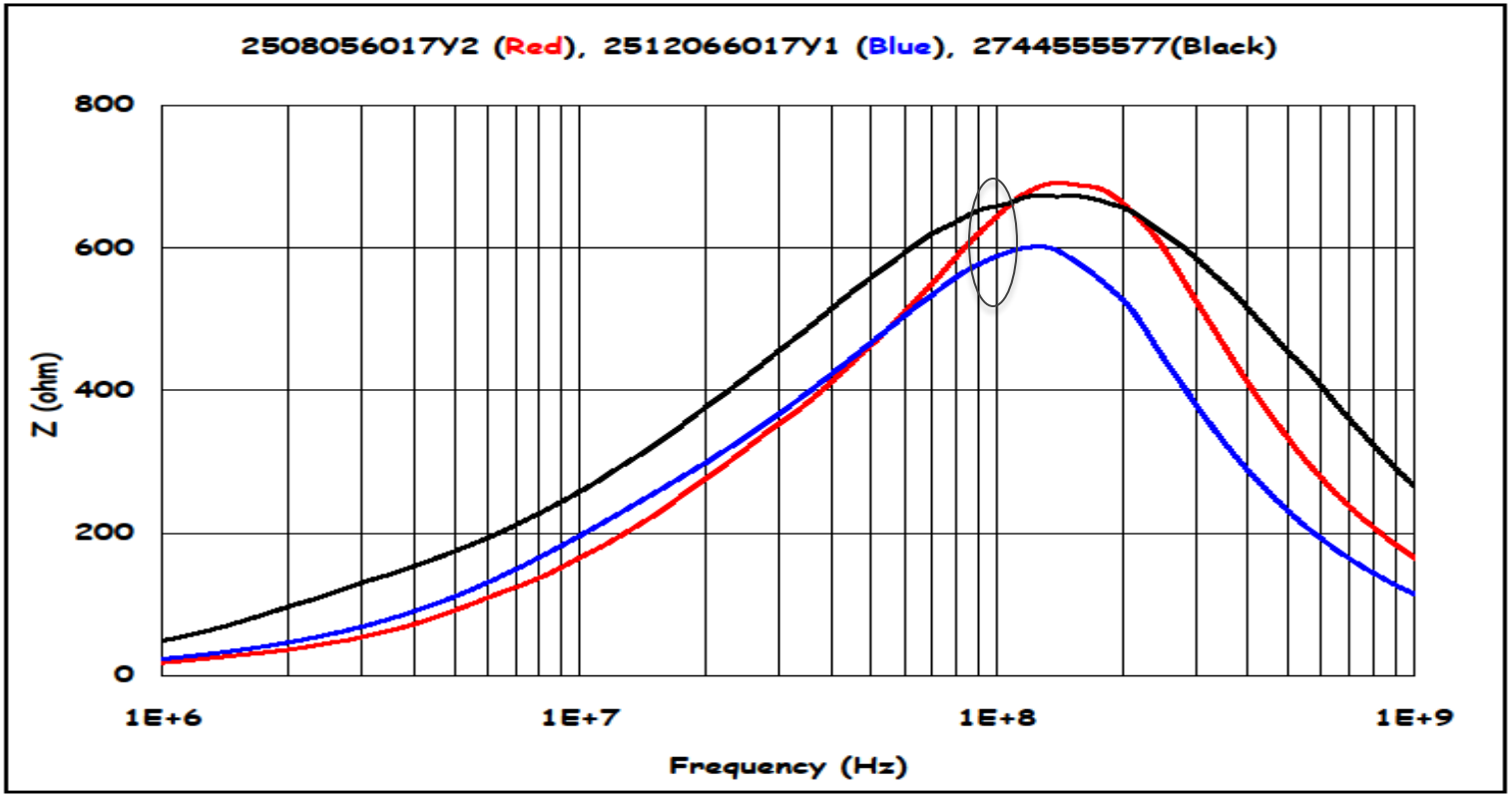
Size Matters all 120Ω 0402 to 1812 packages w/ bias



Chip Beads 0805 600Ω vs 1206 600Ω

Y Std speed

vs SM Bead .43" x .20" 600Ω 44 material

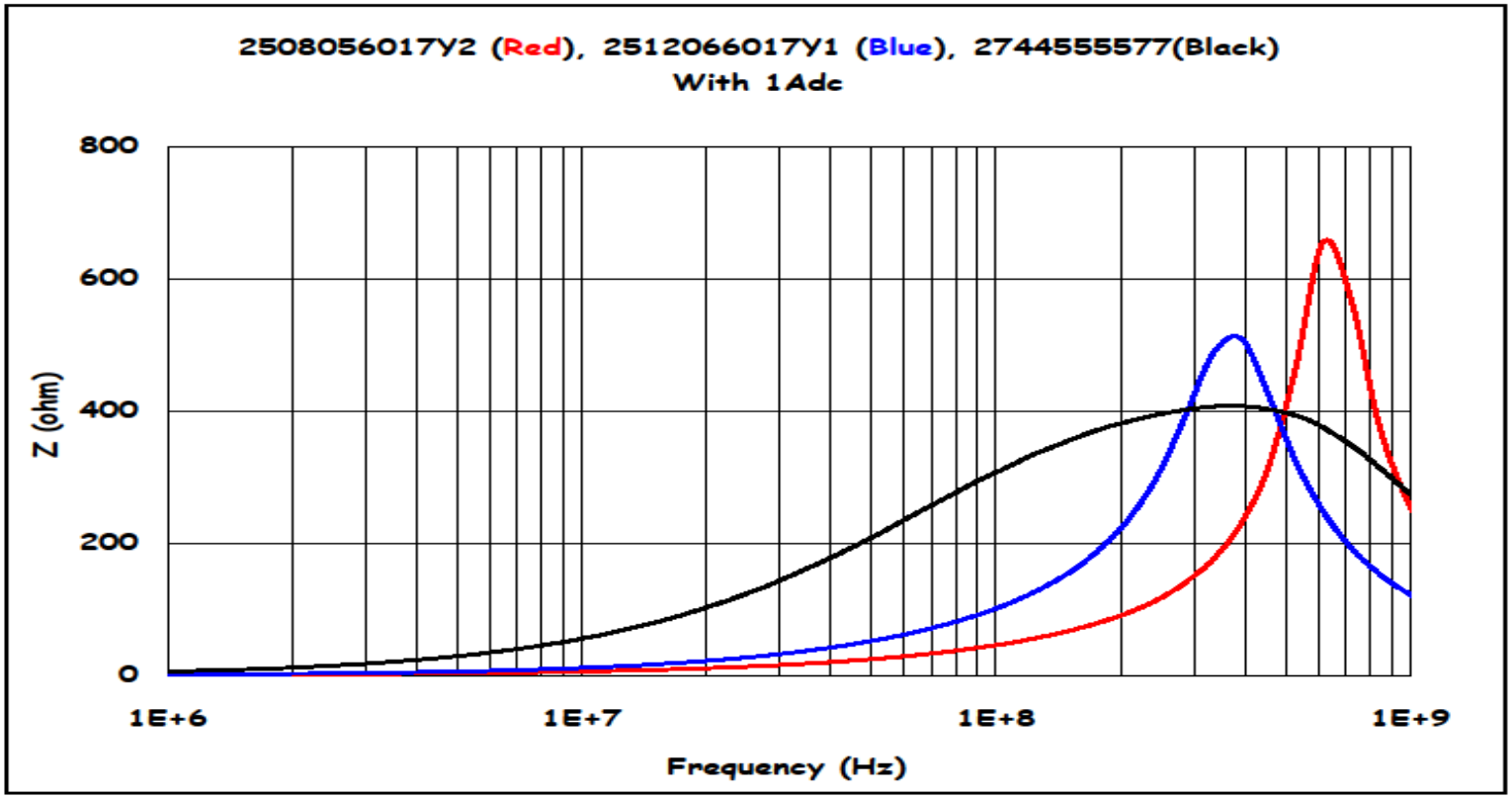


Size Matters

Chip Beads 0805 600Ω vs 1206 600Ω

Y Std speed

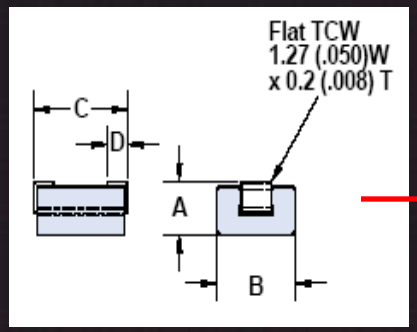
vs SM Bead .43 x .20 600Ω 44 material



Product Range:
EMI Suppression Products

Board Components

- **SM Beads**
  - 73, 43, 44, 52, 61
  - 12Ω to 600Ω
  - .2”x.1”x.1” to .6”x.3”x .2”
  - Current 5A (>15 w/duty cycle)
  - Differential and Common Mode



- **Chip Beads**
  - 0402 to 1812
  - Y, Z, H
  - 8Ω to2000Ω
  - 50mA to 6A

Review - Desirable Material Properties For EMI Suppression

- Materials optimized for optimum impedance in the intended frequency range
  - High permeability at the low frequency range (high u')
  - Low permeability at high frequency range (high u")
- Resistance to dc-bias (lower perm , larger size)
- Good thermal stability (Z vs. T)
- High Curie Temperature (Tc)