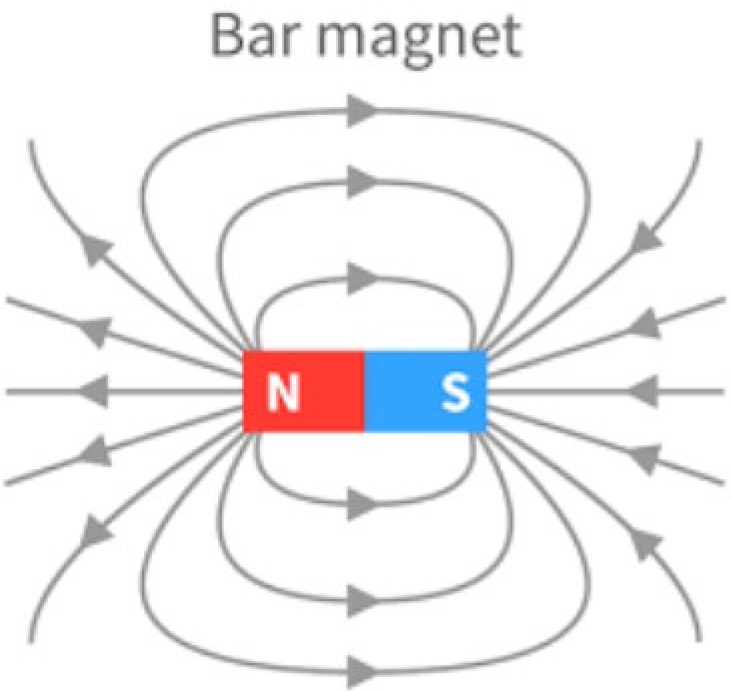
Ferrite components

Magnetic field refresher 1: Bar magnets



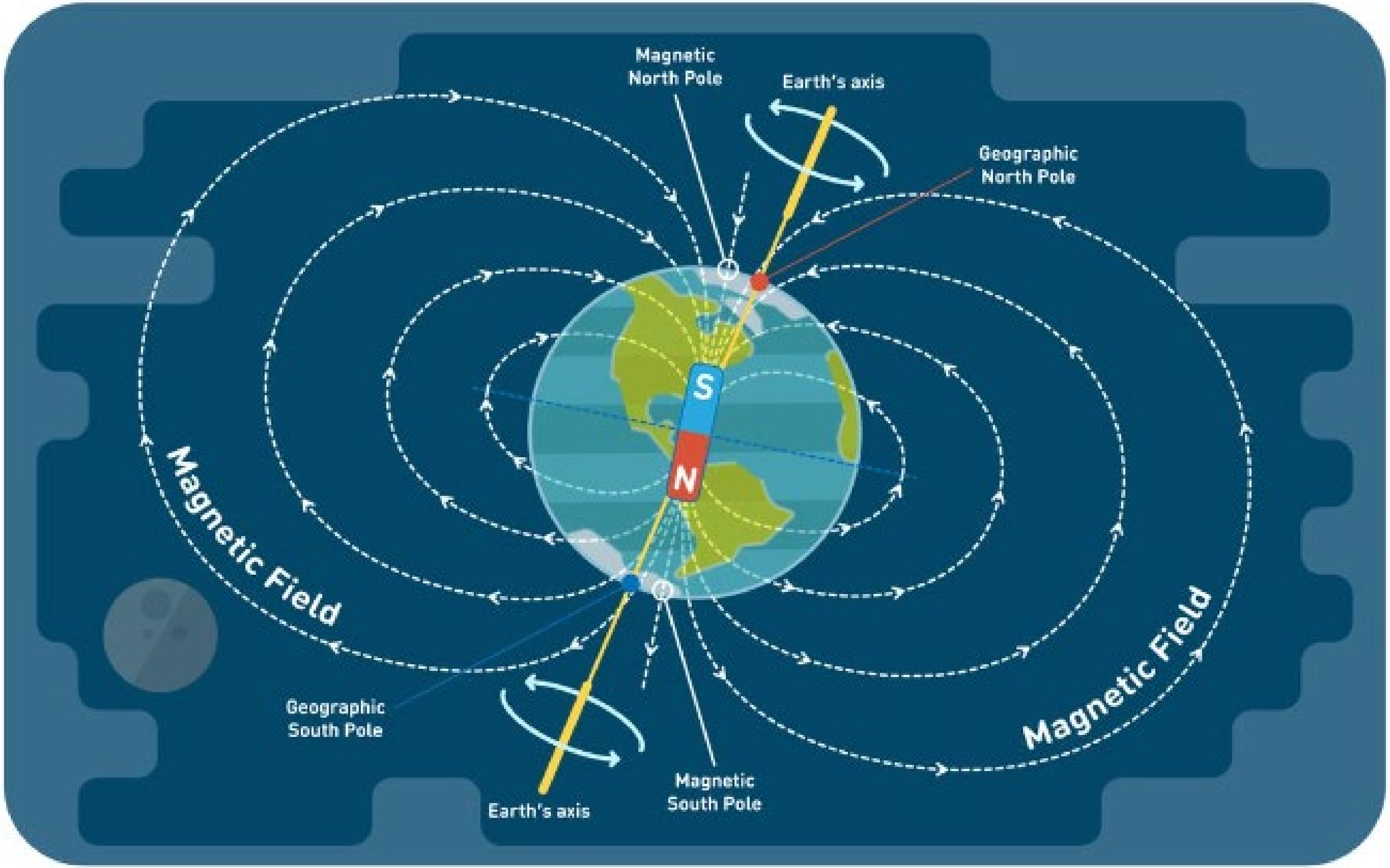
CONVENTIONS:

- Who determined which end is N and which is S?
- Field arrows show field lines flowing from N to S.

- Pointer (red) end of a compass needle points along a field line towards the South Pole of the magnetised object generating the magnetic field

Key points: potential energy, t_0 field spread, lines always terminate, NS convention & arrow direction

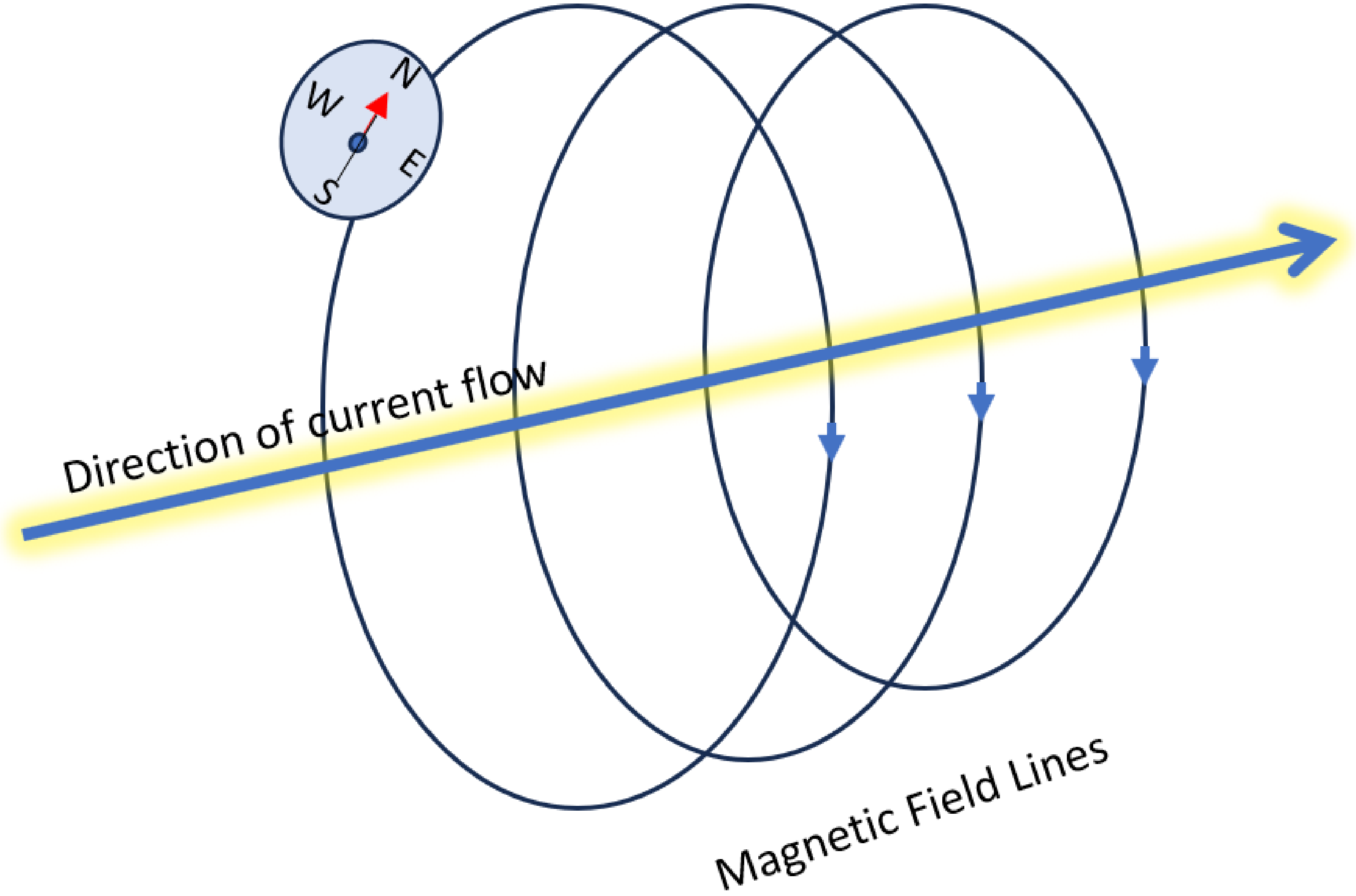
Magnetic field refresher 1: Earths magnetic field



https://www.space.com/earths-magnetic-field-explained

Key point: not necessarily insignificant (Flux Gate Compass)

Magnetic field refresher 3: Electromagnetism



Magnetic Field surrounding a wire carrying a current:

Arrows show direction of field lines.

Key point: concentric, d^2, t_0 field spread

Maxwell Refresher:

in a vacuum

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}}$$

c = speed of light (3 x 10^{-8} m/s)

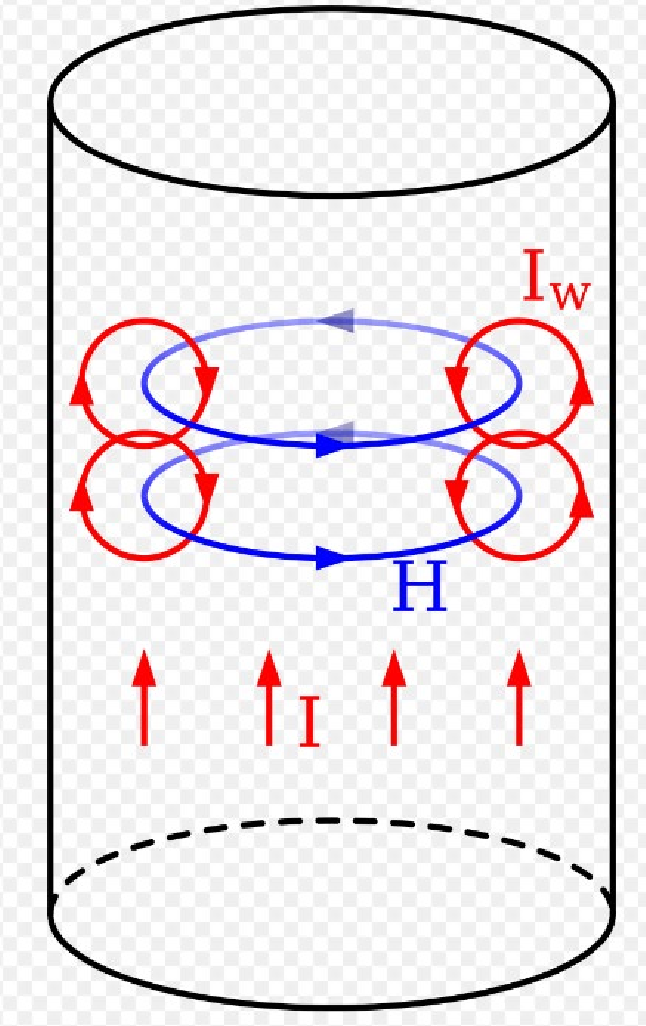
ε_0 **= permittivity of vacuum (the "electrical constant")**
($8.8541878188(14) \times 10^{-12}$ F/m)

μ_0 **= permeability of vacuum (the "magnetic constant")**
(4pi x 10^{-7} H/m)

but in other mediums: $v = 1 / \sqrt{\varepsilon 0.\varepsilon r.\mu 0.\mu r}$

Key point: C's and L's, range of relative material values, EM wavefront transmission speed, C's and L's

CONDUCTOR REFRESHER: WE USE SOME WIRE!



SKIN EFFECT IN WITHIN WIRES

Cause of skin effect:
A main current I flowing through a conductor induces a magnetic field H.

If the current increases, as in this figure, the resulting increase in H induces separate, circulating eddy currents IW which partially cancel the current flow in the centre and reinforce it near the skin.

Key point: all conductive mediums

$$\delta = \sqrt{\frac{1}{\pi f \mu \sigma}}$$

Where:-

δ = skin depth — metres

f = frequency — Hz

μ = material's permeability — $\mu_0\mu_r$

σ = material conductivity — Ω/metre

Simple example

For copper: $\delta = \frac{66.2}{\sqrt{f}}$

f	δ
50Hz	9.4 mm
1MHz	$\frac{7}{100}$ mm
30MHz	$\frac{12}{1000}$ mm

Proximity Effect:
gets more complex where windings are close together, and/or multiple layers of wire are present!

Key point: 14 SWG wire (Ω/metre) @ DC = 0.008 @ 30MHz = 0.3

Ferrite: Manufacturing variations (mixes)

Dust formula **$MO.Fe_2O_3$** Inorganic ceramic base. fused at >3000 °C

(**MO** is one or more metal oxides blended with iron oxide, ferromagnetic blend)

e.g.

MO = Manganese zinc:

- highest permeability.
- Supports high flux densities
- Volume resistivity: hundreds to thousands of ohms per centimetre.
- Usage: resonant circuits and magnetic power designs from low kilohertz range to LW & MW broadcast spectrum.

MO = Nickel zinc:

- Supports low flux densities
- Volume resistivity ranges from several kilohm to tens of megohm-centimetre.
- Usage: High frequencies (above 1 MHz), for low flux-density applications.

be alert for "B grade" products in the marketplace!
Cores using clay binders require high temperatures and lots of energy but offer good long-term stability. Lower spec. products use organic binders, fused at lower temperature to reduce cost, but their long-term stability is compromised with even moderate temperature cycling.

8% to 11% shrinkage during manufacture

20% variation in electrical characteristics – mechanical and electrical tolerances may be poor

Other blends (not considered here) include Manganese, and Magnesium zinc as the MO

High Permeability (μr), Low Coercivity (don't retain magnetism) and High Volume Resistivity

Key point: ceramic Ur =1, ferrite Ur(max) approx. 3000

Easy Sorting: Conductivity (1cm gap between AVO probes)

(when attempting to scratch mark the surface of the toroid: S = soft, easy to mark. H = hard, no surface marking)

Product	*composition*	resistance R (ohms)
• Fair-Rite Type 31	*Manganese Zinc (S)*	low (800k)
• Fair-Rite Type 43	*Nickel Zinc (H)*	high (>20M)
• Fair-Rite Type 61	*Nickel Zinc (H)*	high (>20M)

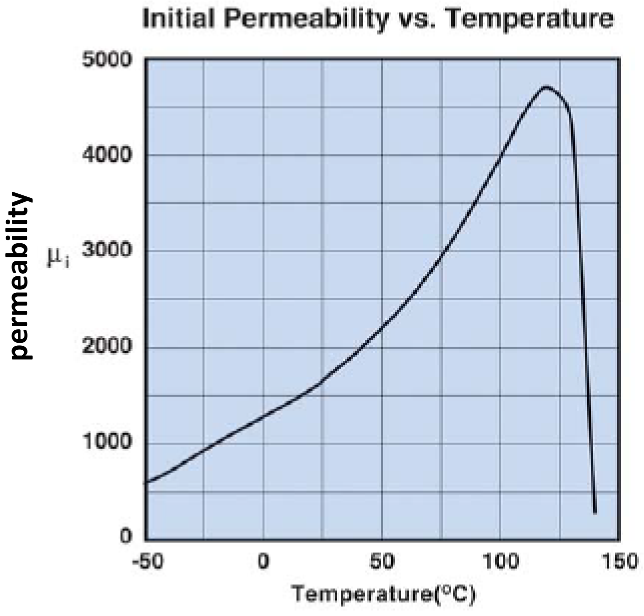
Eddy current losses are proportional to 1/R (reciprocal of the core material conductivity)

Eddy current losses are proportional to f^2 (square of the operating frequency)

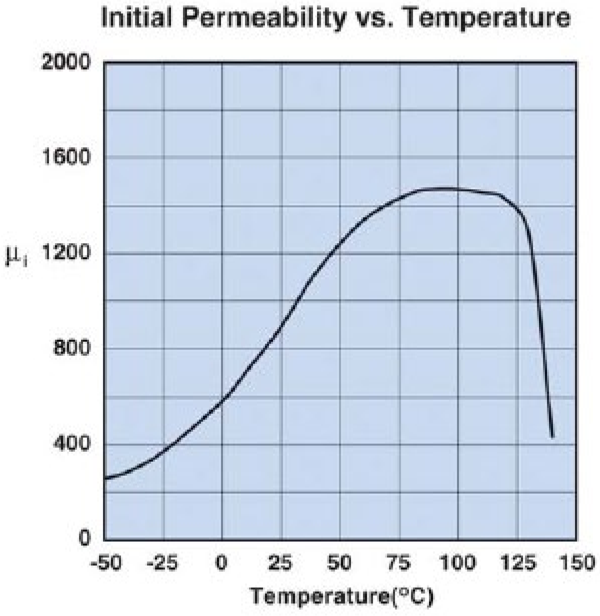
So: High resistivity becomes an essential factor in magnetic materials intended for high frequency operation

Key point: & check coercivity characteristics with a compass

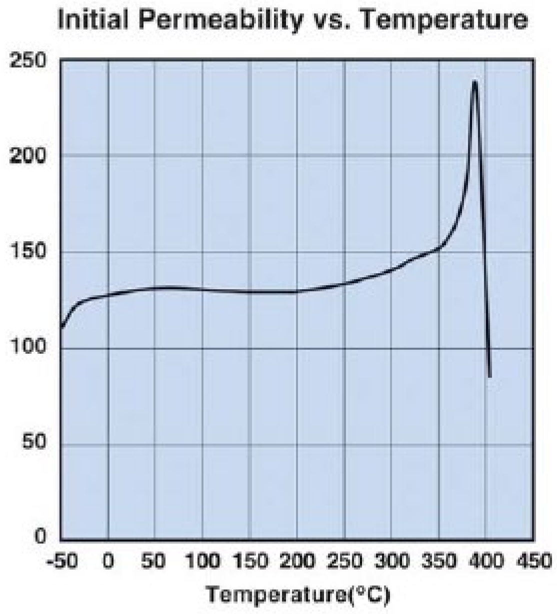
Temperature effects (various mixes)



Measured on a 17/10/6mm toroid at 100 kHz.



Measured on a 17/10/6mm toroid at 100 kHz.



Measured on a 19/10/6mm toroid at 100 kHz.

Ferrite Mix	31	43	61	
Permeability @ 20C	1500	800	125	(w.r.t. air)

Permeability value (ui) is related to the material itself – not the size or shape of the core

Ket Point: temperature variation causes big inductance swing, thermal runaway at low temperature (e.g. @80C in Type 43)

Ferrite: material data

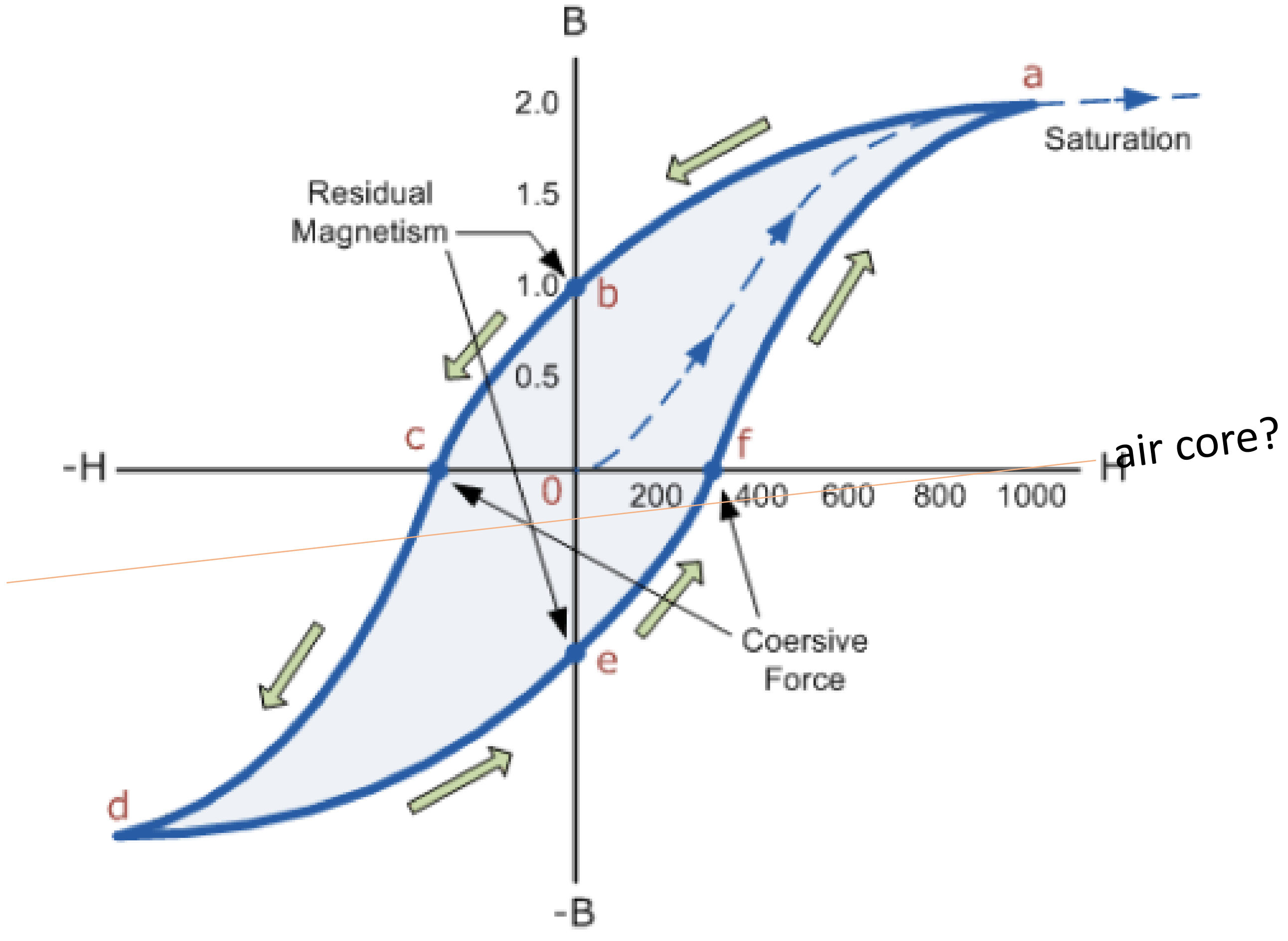
TYPICAL TOROID CORE SPEC SHEET PARAMETERS

??	Core Part Number
Mix	Type of ferrite mix employed (e.g. 31, 53, 61 etc.)
A	Core cross section
L	(Average) magnetic path length within the core
C1	Core factor – for a specific part number (derived from the Mix, A and L)
B	maximum flux density for a particular core (C1 dependent)
Ui	typical permeability (at some nominal frequency within the expected User's freq. range)
Z	Impedance of a (typically1 turn) winding on a core

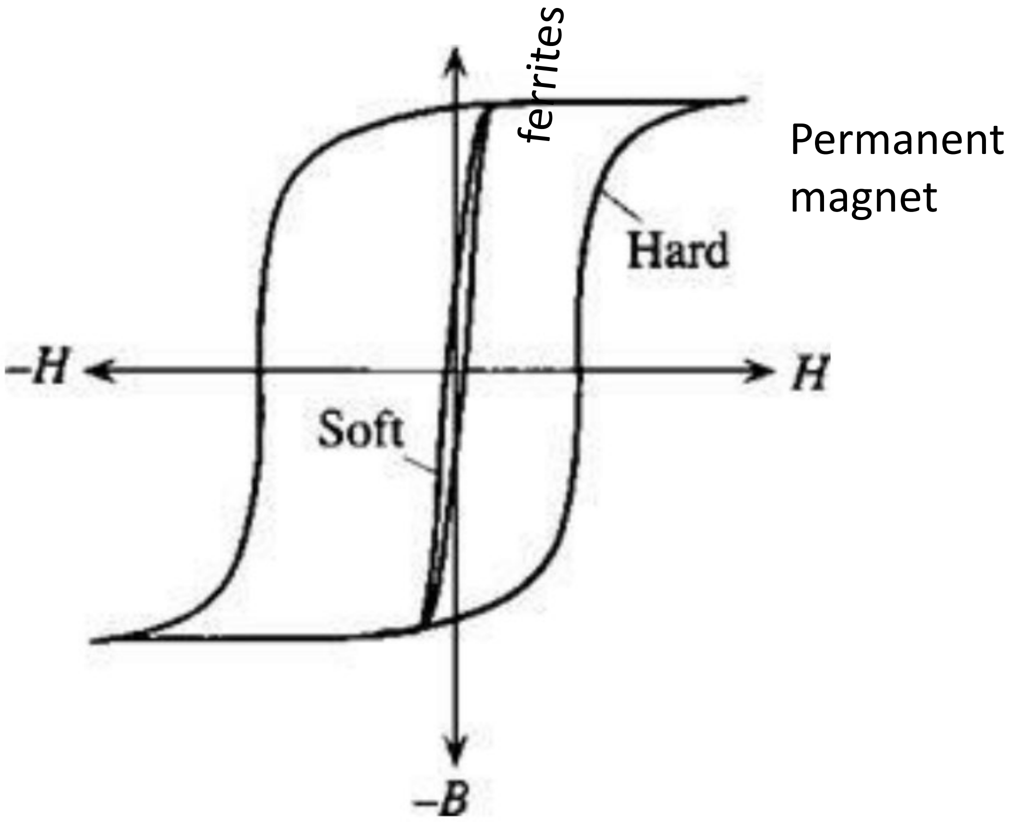
Permeability is a complex number, derived from u' (inductive) and u'' (material losses)
Its value mostly depends on the mix used for the core.

Key point: 10 turns on a ferrite core usually provides enough uH to measure. Maybe less if you have a VNA

BH Loop, Coercivity and Ferrite Core saturation



Typical hysteresis loop of a ferromagnetic material.



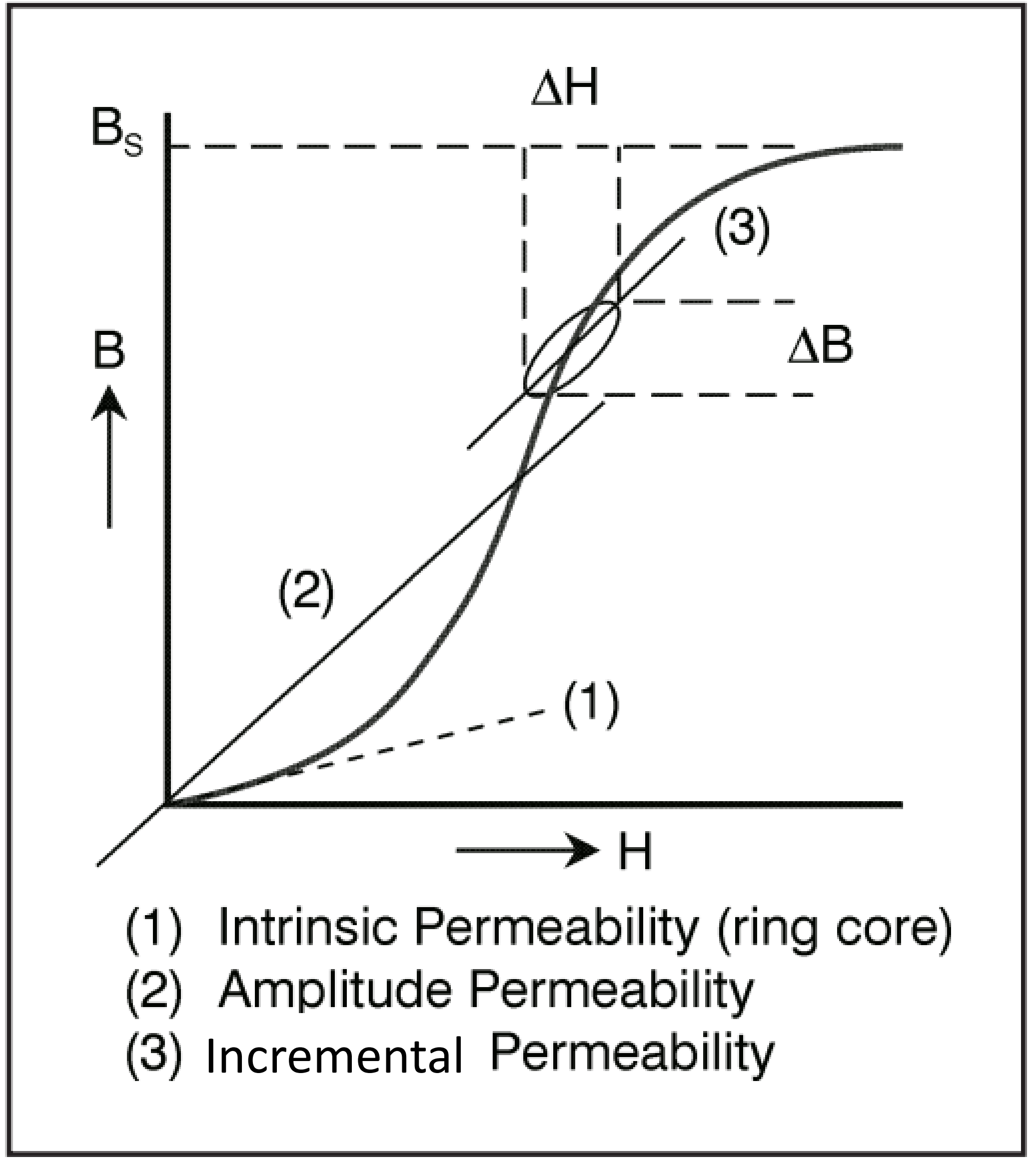
Soft vs Hard magnetic material hysteresis loop.

Key point: Area independent of load. represents core loss. Saturation usually bad, Fluxgate monitors shifts along the H axis

Permeability

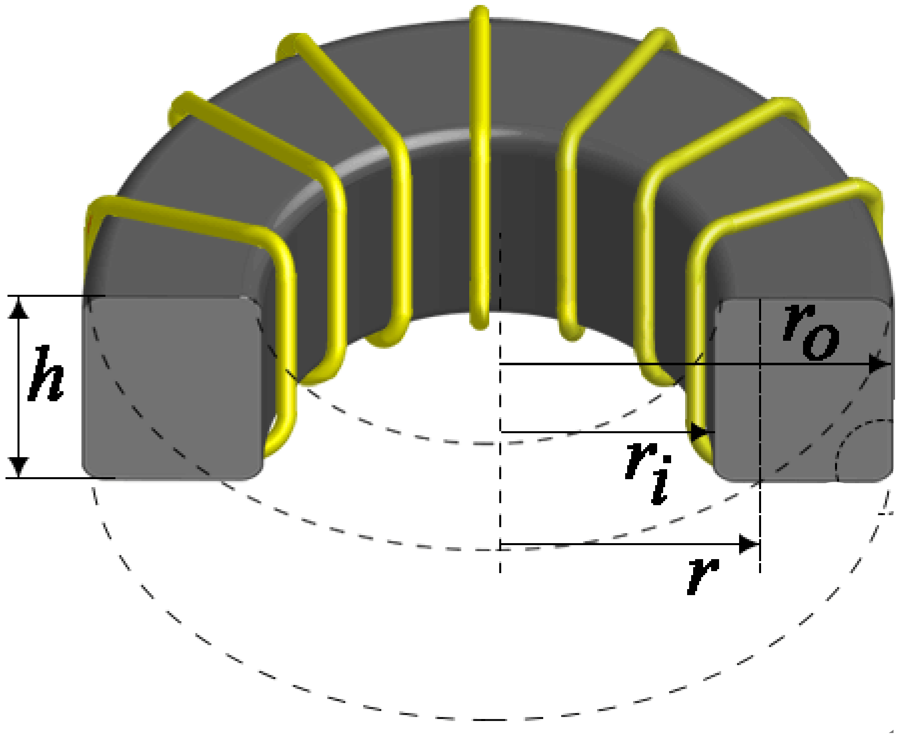
ratio between the magnetic flux density induced in the material (B) and the magnetic force required to cause it. (H)

$$\mu_i = \frac{1}{\mu_o} \cdot \frac{\Delta B}{\Delta H} \quad (\text{Lim. } \Delta H \rightarrow 0)$$



Key point: BH is non-linear, but Pri and Sec non-linearities cancel in a perfect classic non-B saturated transformer.

Find Ur, knowing a toroid's dimensions



$$L = N^2 u_o u_r A / l$$

more simply:

$$L = 0.0002 \cdot \mu_r N^2 h \log_e\left(\frac{OD}{ID}\right)$$

L = inductance (microHenries)

OD = outer diameter (mm)*

ID = inner diameter (mm)*

h = core thickness (mm)*

Ur = relative material permeability*

l = length of magnetic path (2πr)

* For a particular core, the manuf's Core Constant "C_1" absorbs these "starred" parameters

Key point: L gets bigger as A gets bigger, and as l gets shorter. *Shape and size can be optimised!*

Terms (used in product briefs)

- Wb = Magnetic Flux (Weber)
- T = Flux Density (Teslas or Gauss, where $1T=10^4Gs$)
- u_i = material Permeability
- H = applied Magnetic Field strength — Amps per metre
- B = total Magnetic Flux intensity (in a piece of material) — in Teslas
- L = inductance (of a winding) — usually in nanoHenries
- C_1 = Core constant (from manufacturers data sheet)
- Tanδ = material loss tangent (see next slide)

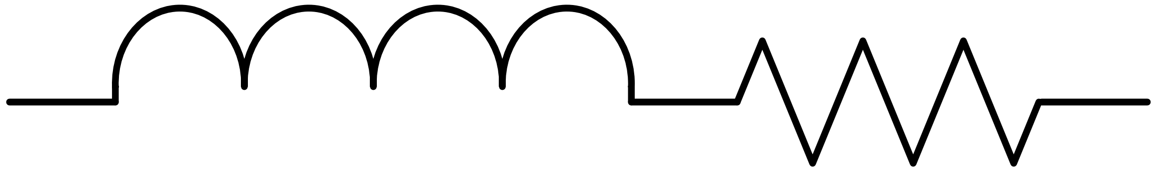
$B = u_o . u_i . H$ and $L = 4\pi N^2 10^{-9} / C_1$

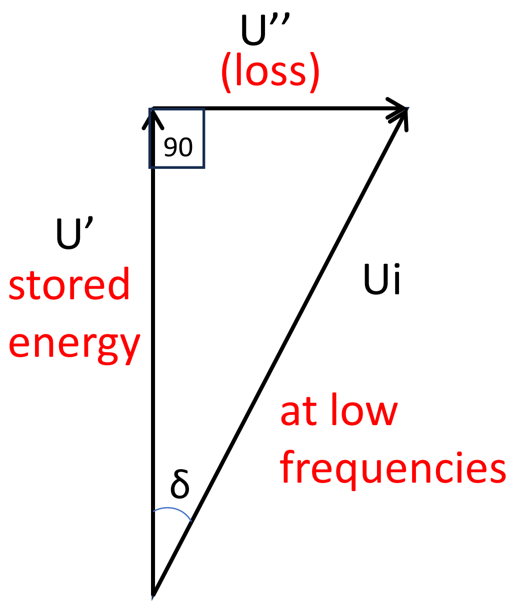
Modelling permeability

$$Ui = \sqrt{(u')^2 + (u'')^2}$$

Reactive portion:
L = Loss free Inductor

Loss portion:
R = Equivalent series resistor





PERMEABILITY

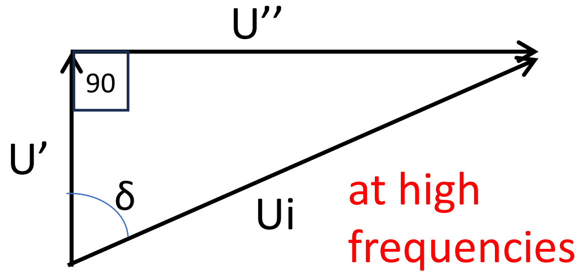
Ur on product sheets: a low freq. indication of the Mix's permeability

Is actually a complex value: Ui

Ui = Inductive permeability (U') + core losses (U'')

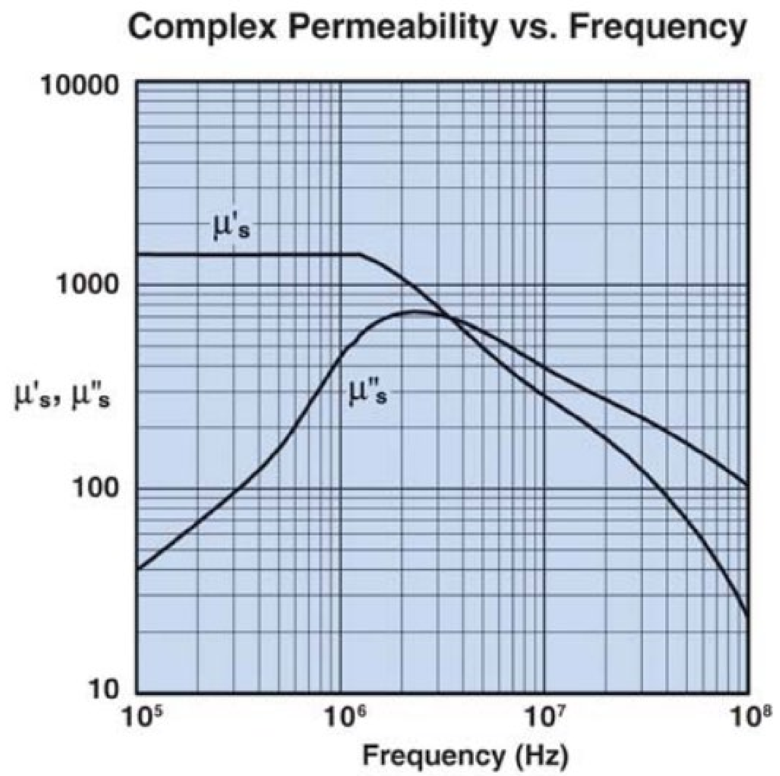
Ui for ferrite is frequency dependent

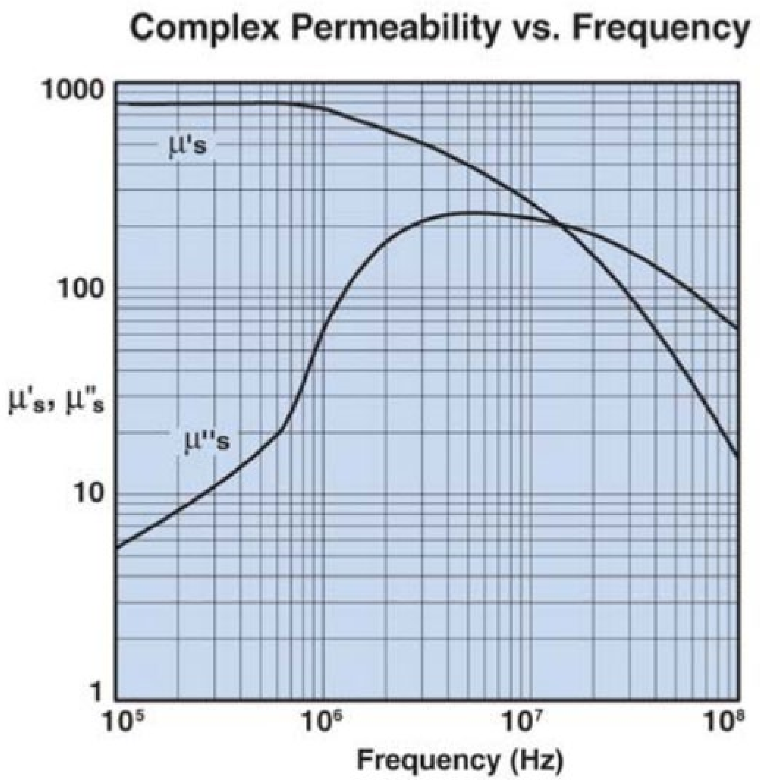
where winding impedance $Z = 2\pi f L + R$

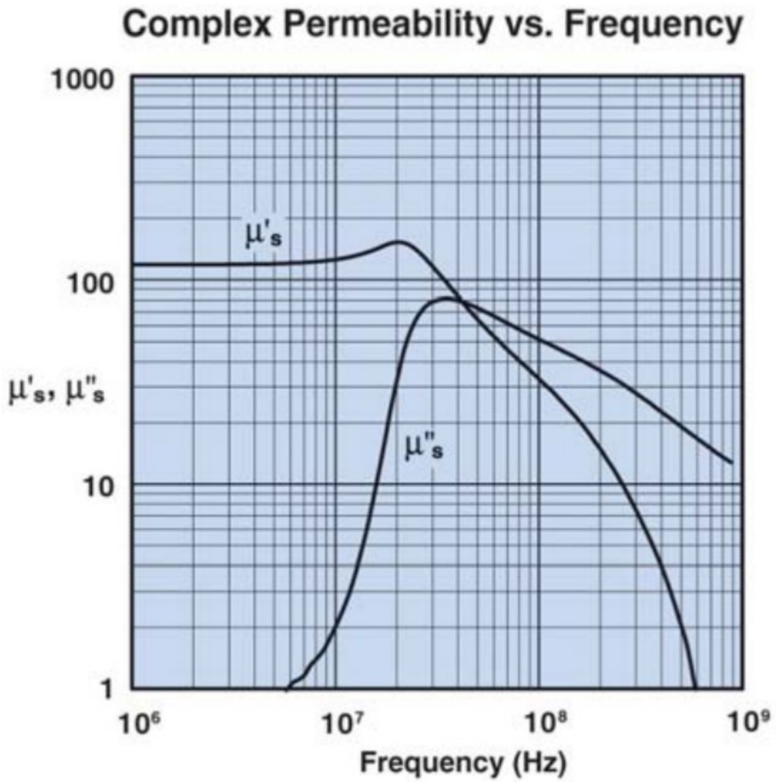


Key point: Ui is frequency, flux level and temperature dependent. Here, the R does not the winding (copper) resistance

Complex Permeability





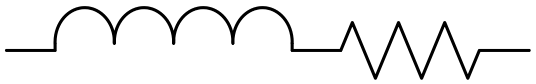


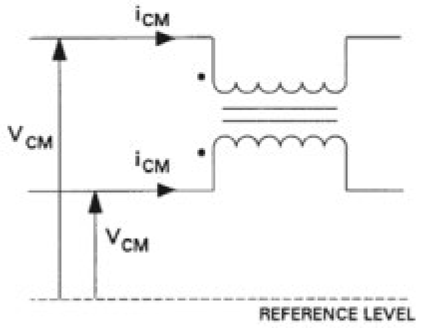
Ferrite Type	31	43	61
Nominal u_i @ 20C	1500	800	125
u' / u'' crossover	3MHz	12MHz	40MHz

Key point: Charts have "Log/Log" scaling. Permeability Ui relates to the material itself, not core size or shape.

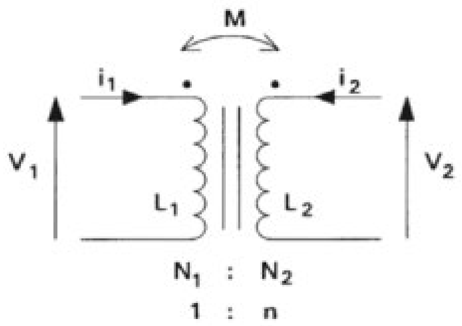
Tasks for a Ferrite Core

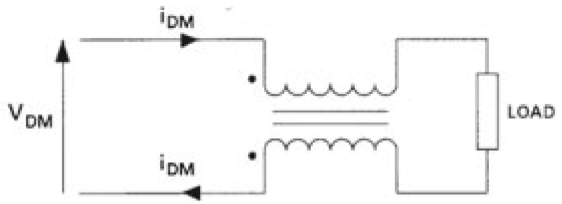
- As an inductor core
- For EMI suppression
  - Low core loss solution
  - High core loss solution





- As a transformer core
  - Low core loss, Tuned (high Q)
  - Low core loss, Wideband (low Q)



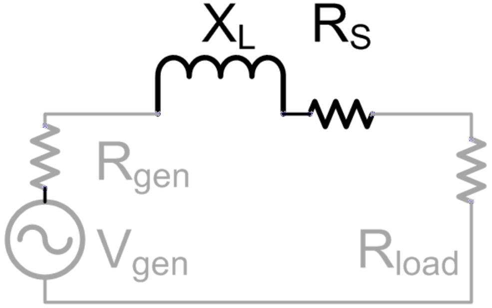


Key point: high dissipation or high VSWR, choke, classic transformer, transmission line transformer

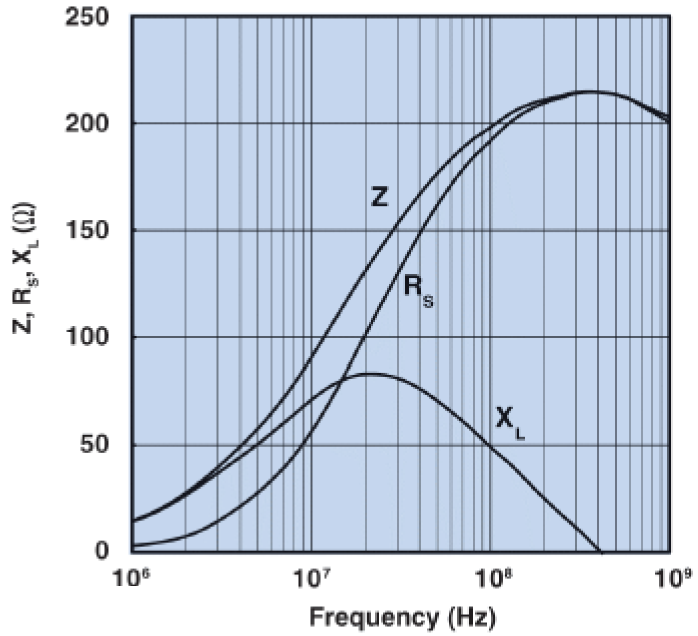
Modelling a ferrite suppressor component

Ferrite cored inductor: simplified equivalent cct.

Forms a voltage divider With R_{load}



$Z = \sqrt{XL^2 + RS^2}$ (where L is a loss free inductor, with reactance X_L, and R_S a notional resistor to represent ferrite core losses)



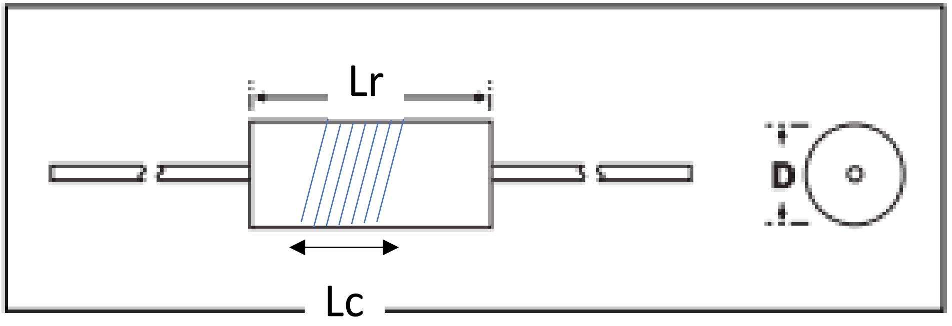
Impedance, reactance, and resistance vs. frequency for a ferrite core in 43 material.

Power dissipated by Rs heats up the ferrite.

Each ferrite mix has its own set of curves.

Key point: Chart has “Log/Log” scaling.   Heat increases U’’, and runaway can push material beyond Curie point

Axial Leaded Choke Cores



$$L = \frac{(A_r \times N^2 \times \mu_r)}{L_r} \times (2 - L_c/L_r)$$

Where: L = Inductance (in nanoHenrys)

Ar = $\pi(\frac{D}{2})^2$ = Cross-sectional area of rod (mm2)

Lc = Length of coil

Lr = Length of rod

μr = Rod relative permeability

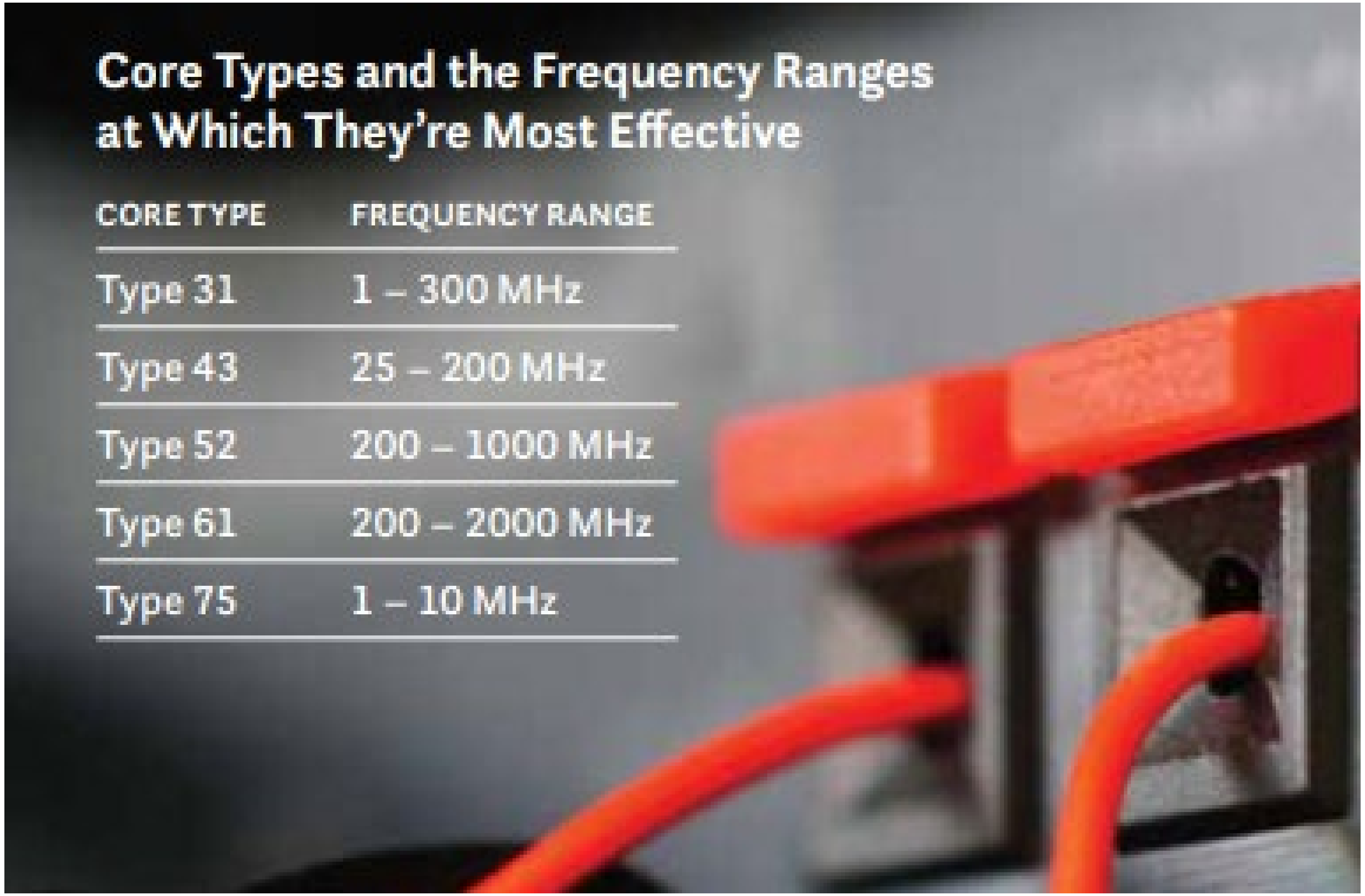
Key point: terminate all field lines, long rod = long air path

Measured Inductance vs “turns” on an FT240 core

Measured inductance			u_i = manufacturers quoted permeability @ B<10 gauss	for 1 turn
• Type 31	9 turns	220uH	1500	(18.5)
• Type 43	9 turns	100uH	800	(1.2)
• Type 43	7 turns	60uH		(1.4)
• Type 43	5 turns	40uH		(1.6)
• Type 43	4 turns	30uH		(1.9)
• Type 61	9 turns	10uH	125	(0.12)

Key point: type 61 barely characterizable on simple test set (0.1uH displayed resolution.)

Fair-Rite’s mix recommendations



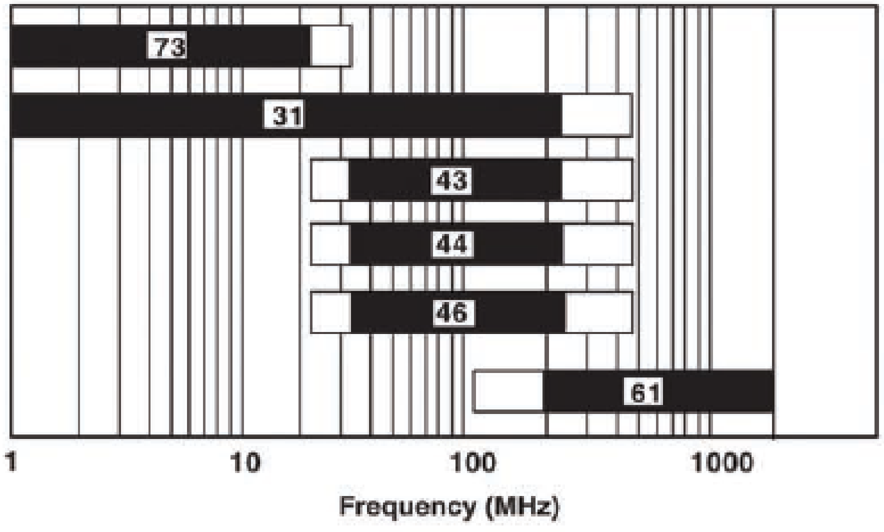
Core Types and the Frequency Ranges at Which They’re Most Effective

CORE TYPE	FREQUENCY RANGE
Type 31	1 – 300 MHz
Type 43	25 – 200 MHz
Type 52	200 – 1000 MHz
Type 61	200 – 2000 MHz
Type 75	1 – 10 MHz

Use for EMI suppression

e.g.

- Ferrite Beads
- Cores for single inductors
- Common mode chokes
- Differential mode chokes

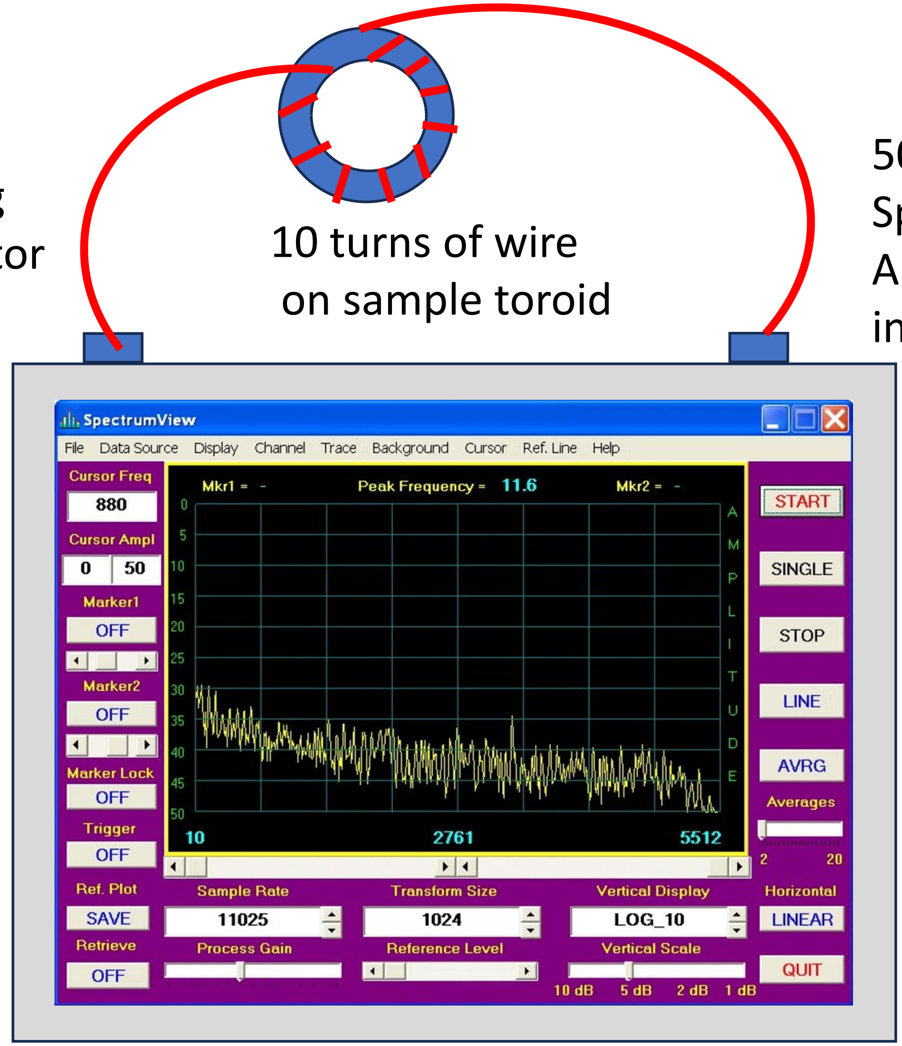


Available Fair-Rite Suppression Materials vs. Frequency

Key point: will high impedance suffice(XL + R), or is high absorption needed as well? (Low XL stored energy)

SPA + TG impedance test of various toroids

50 ohm
Tracking
Generator
output

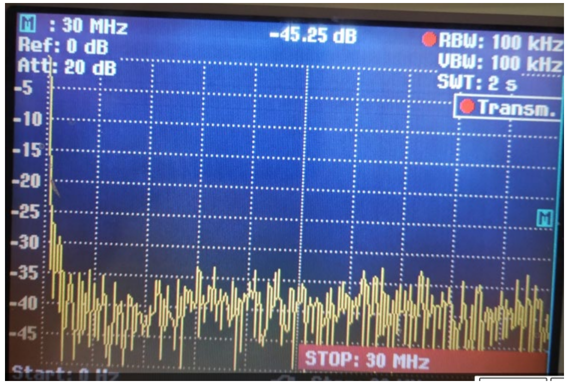


10 turns of wire
on sample toroid

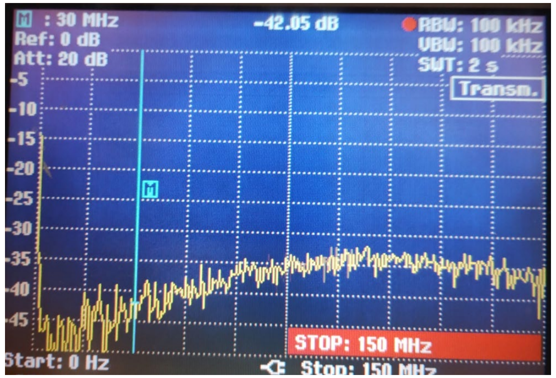
50 ohm
Spectrum
Analyser
input

test sample:

Test Rig: o/c check :

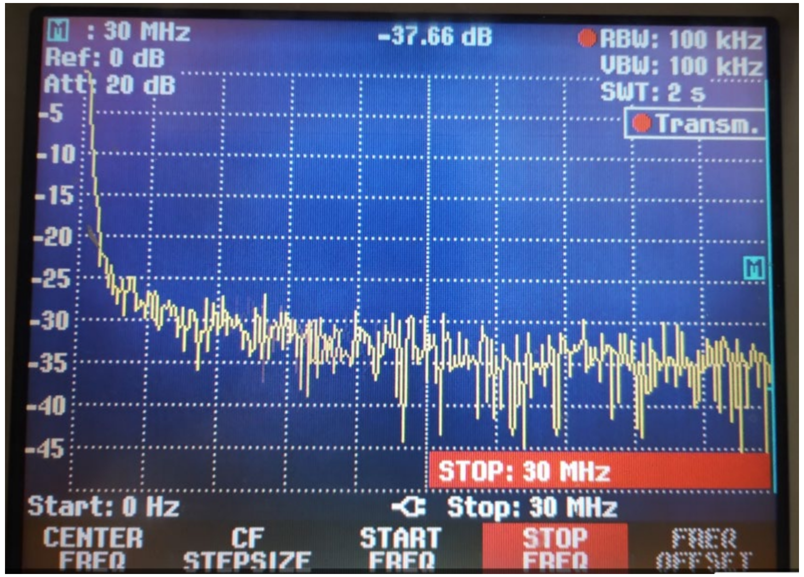


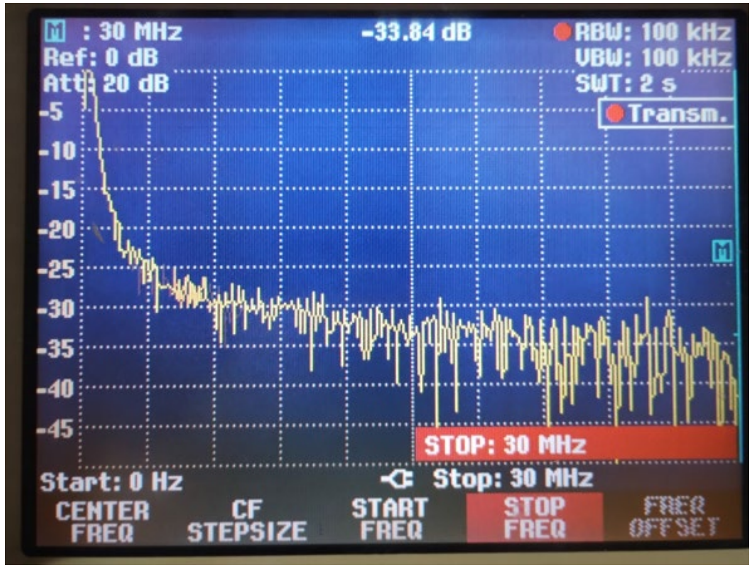
<30MHz: approx. 40dB loss

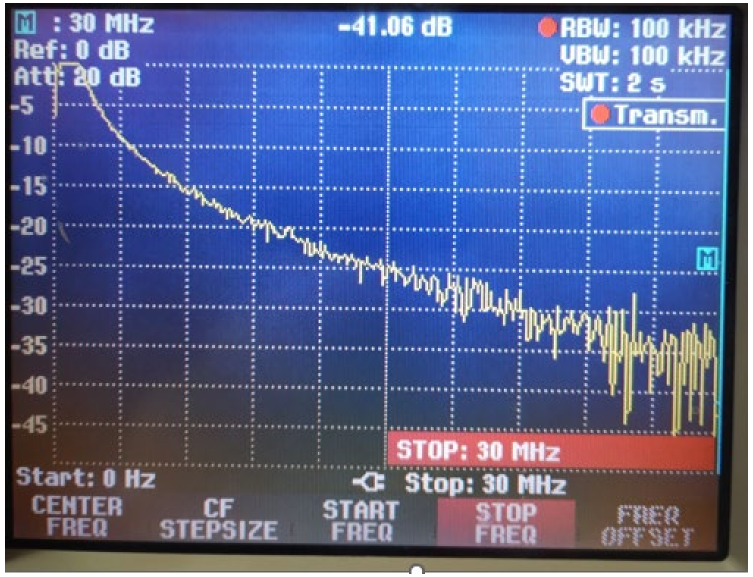


30-150MHz: >33dB loss

Simple choke: Ferrite type comparison
FT240 type 2.4” diam. Toroids: 0-30MHz

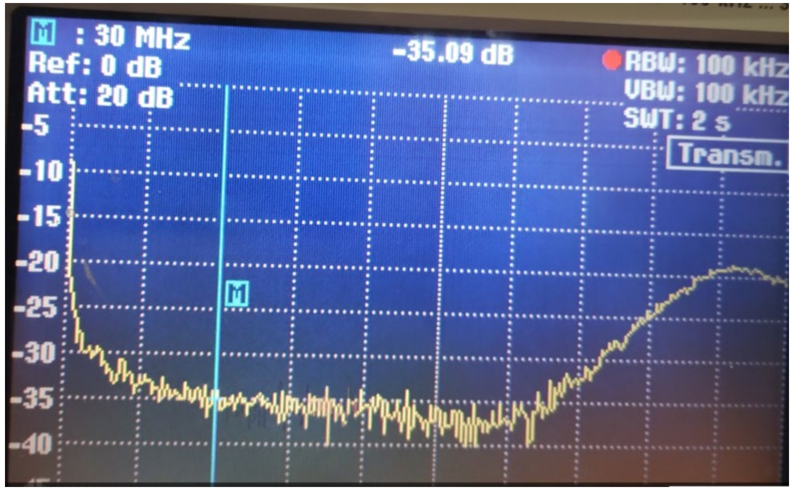


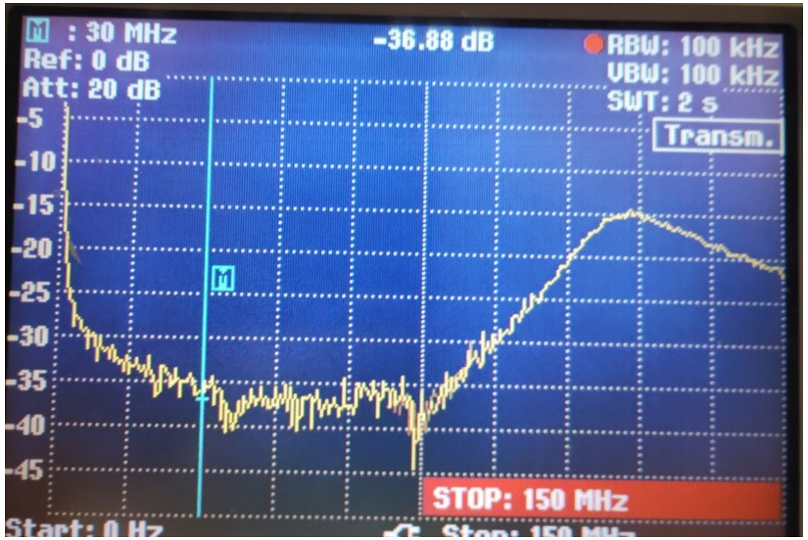


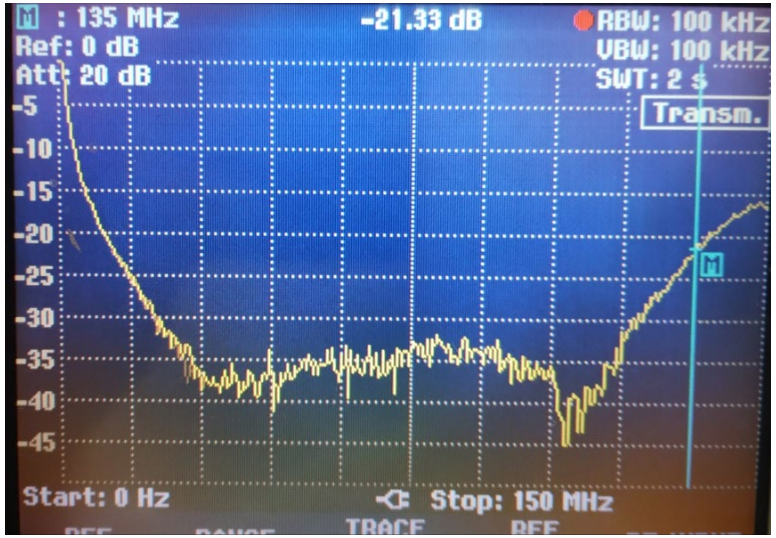


Ferrite Type:	**31**	**43**	**61**
>20dB loss @:	<1MHz	1.5MHz	>9MHz

Simple Choke: Ferrite type comparison
FT240 type 2.4” diam. Toroids: 0-150MHz







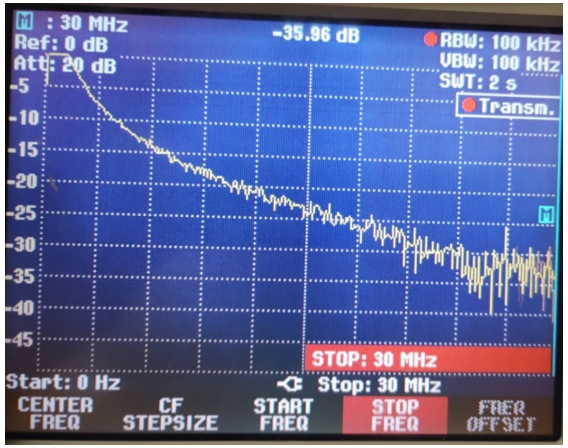
Ferrite Type: 31 — **43** — **61**

>20dB loss @:<1 - 130MHz — 1.5 - 105MHz — 9 - 135MHz

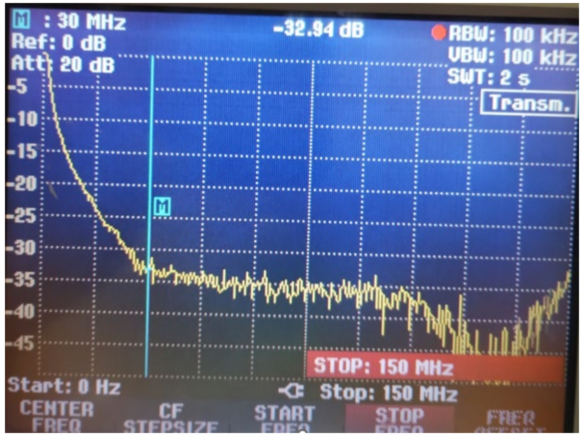
Simple choke: Toroid Size comparison
Type 61: FT140 (1.4” diam.) vs FT240 (2.4” diam): (>20dB Loss)

0-30MHz | **0-150MHz**

FT140

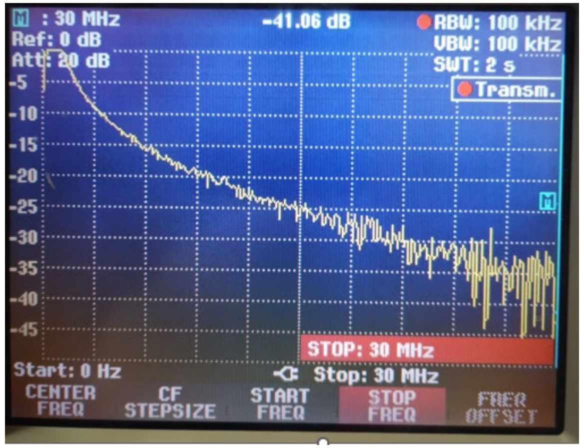


>10.5MHz

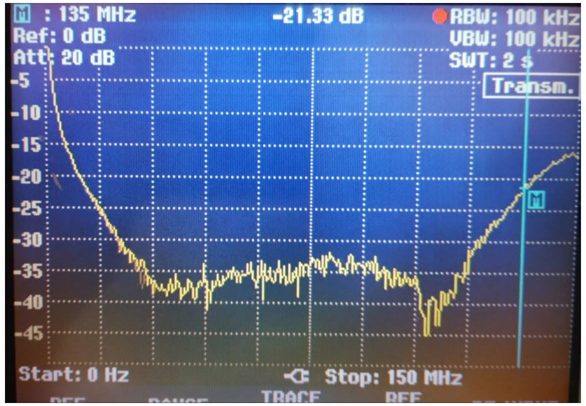


10.5 - >150 MHz

FT240



>9MHz

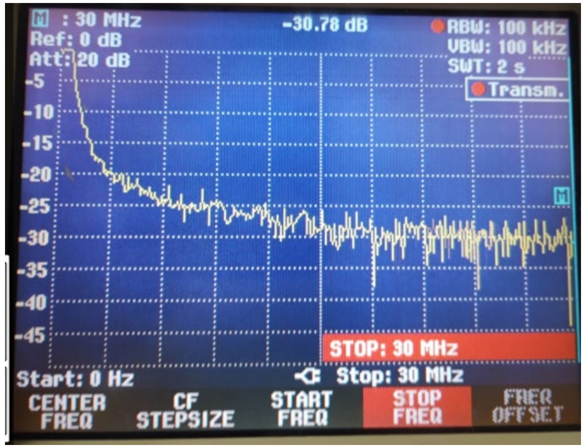


9 - 135 MHz

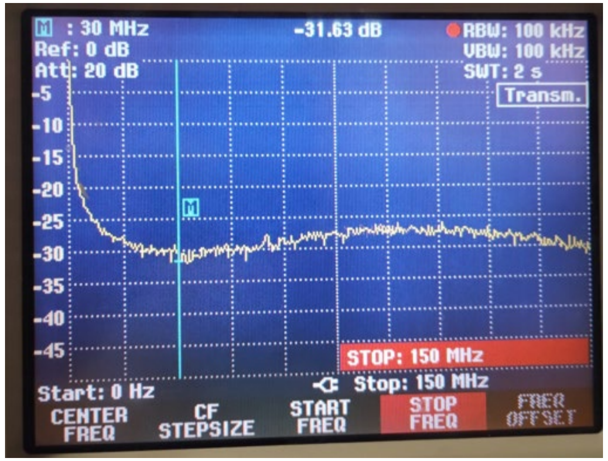
Simple choke: Toroid Size comparison
Type 43: FT50 (0.5” diam.) vs FT240 (2.4” diam): (>20dB Loss)

0-30MHz | **0-150MHz**

FT50

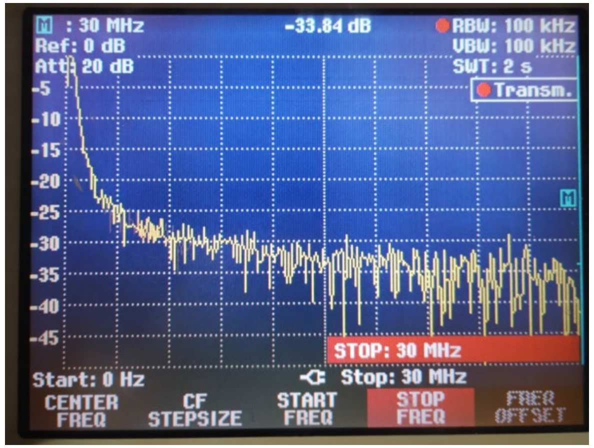


>3MHz

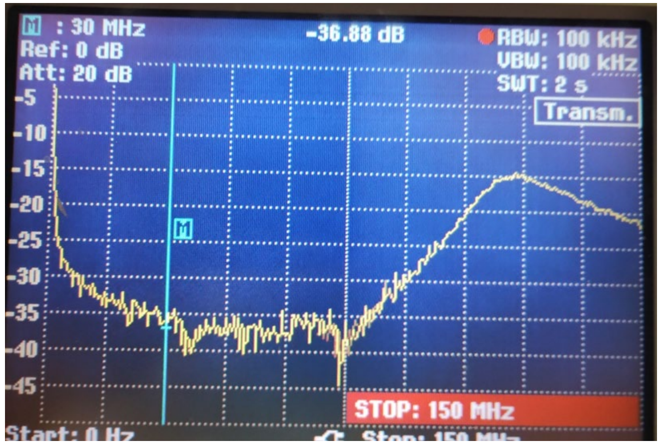


3 - >150MHz

FT240

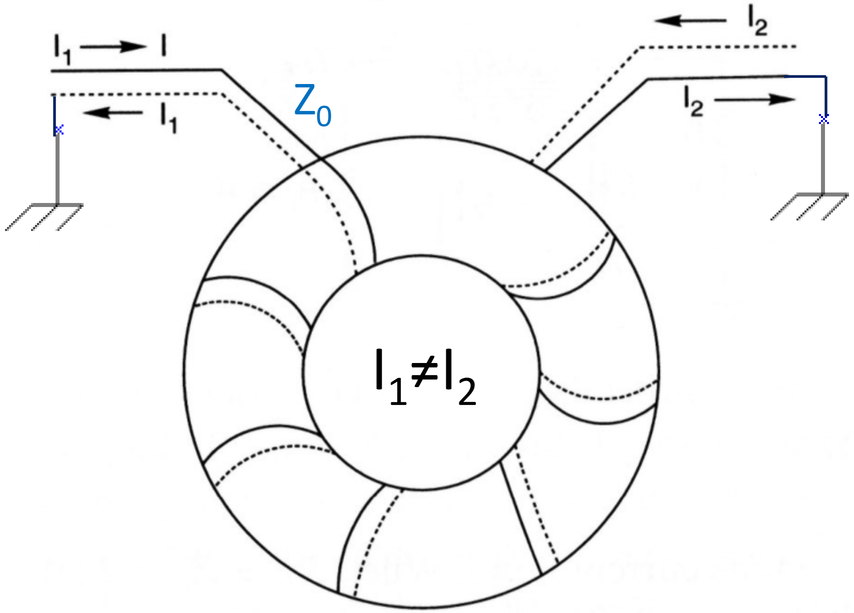


1.5MHz



1.5 - 105MHz

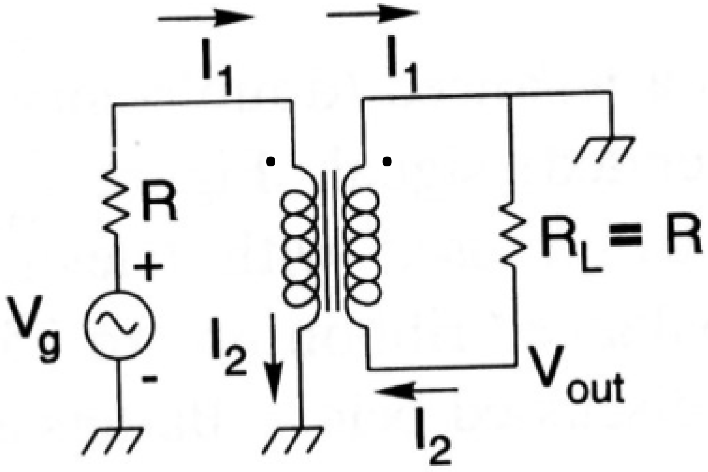
Use as a transmission line transformer core



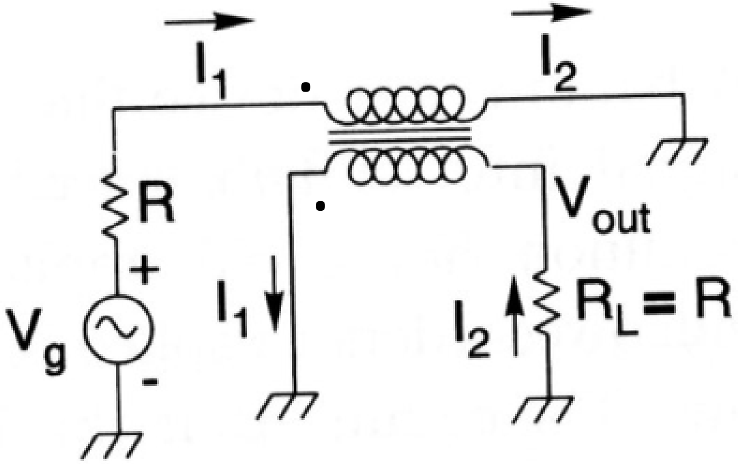
winding length assumed to be a portion of wavelength (Θ)
Propagation velocity is finite.

Line Impedance $Z_0 = R = R_L$

Drawn as a normal transformer with o/p voltage reversal
(but only 180 degrees at dc!)

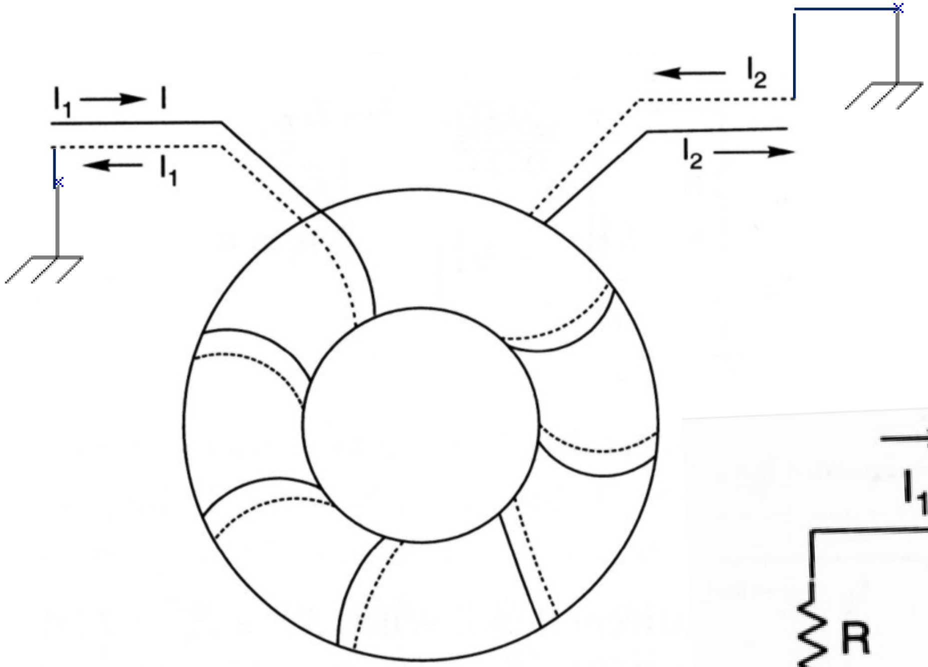


Same circuit, but it is evidently a common mode choke!



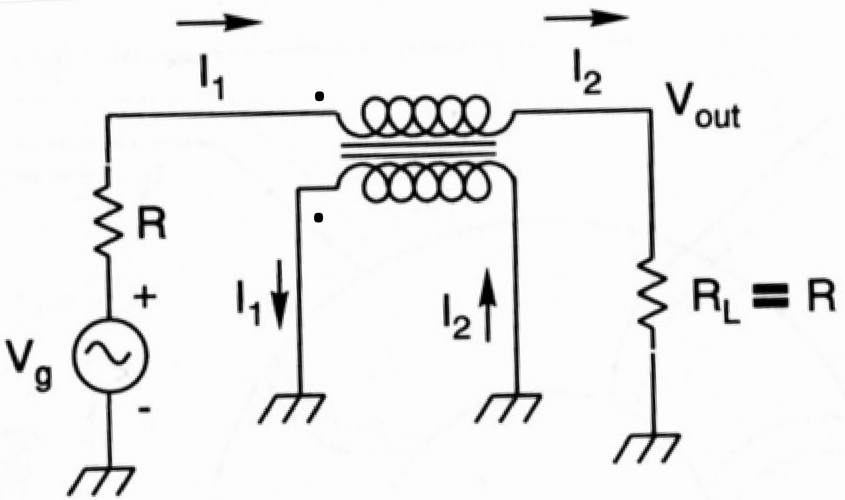
Key point: No common mode current flows. (Vout) ~ -(½Vg.e$^{(-j\Theta)}$*) Effective winding length = physical length x Ur?*

Invert the "secondary" end of the choke!

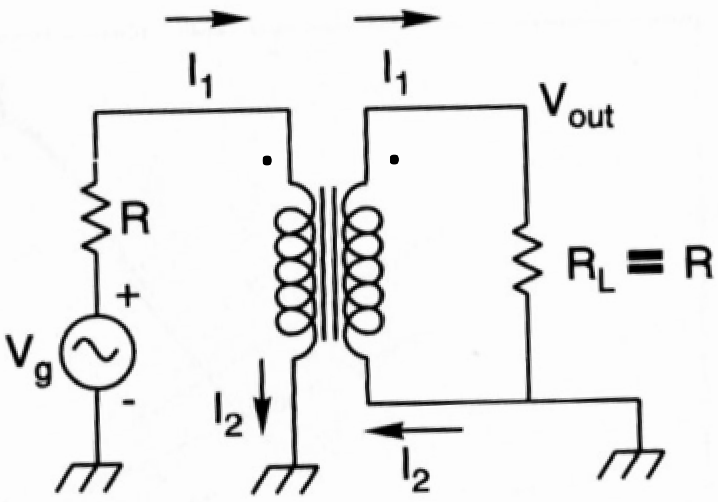


winding length assumed to be a portion of wavelength (Θ)
Propagation velocity is finite.

Drawn as a normal transformer (flux linked)



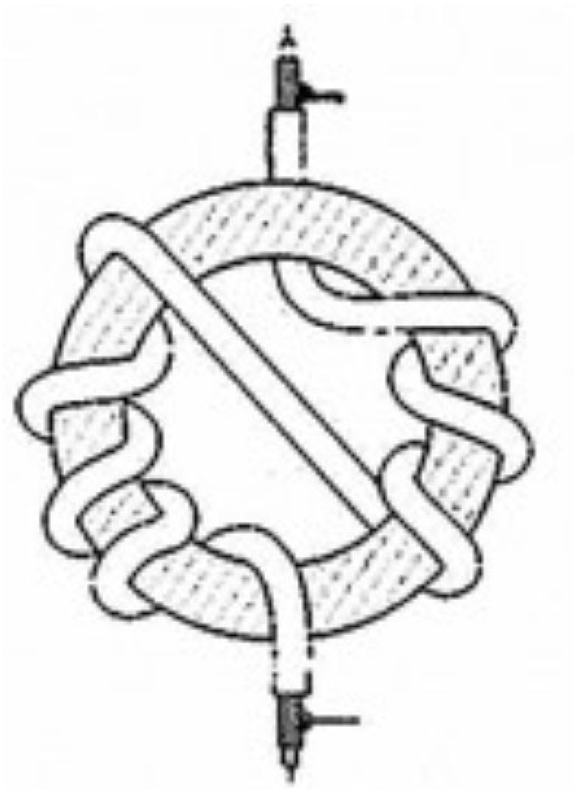
Same circuit, but evidently it is a common mode choke



Key point: O/p sense is now righted. (Vout) ~ ½Vg.$e^{(-j\Theta)}$ *O/p null when winding length = ½ wavelength, phase varies*
Check the sense of your windings!

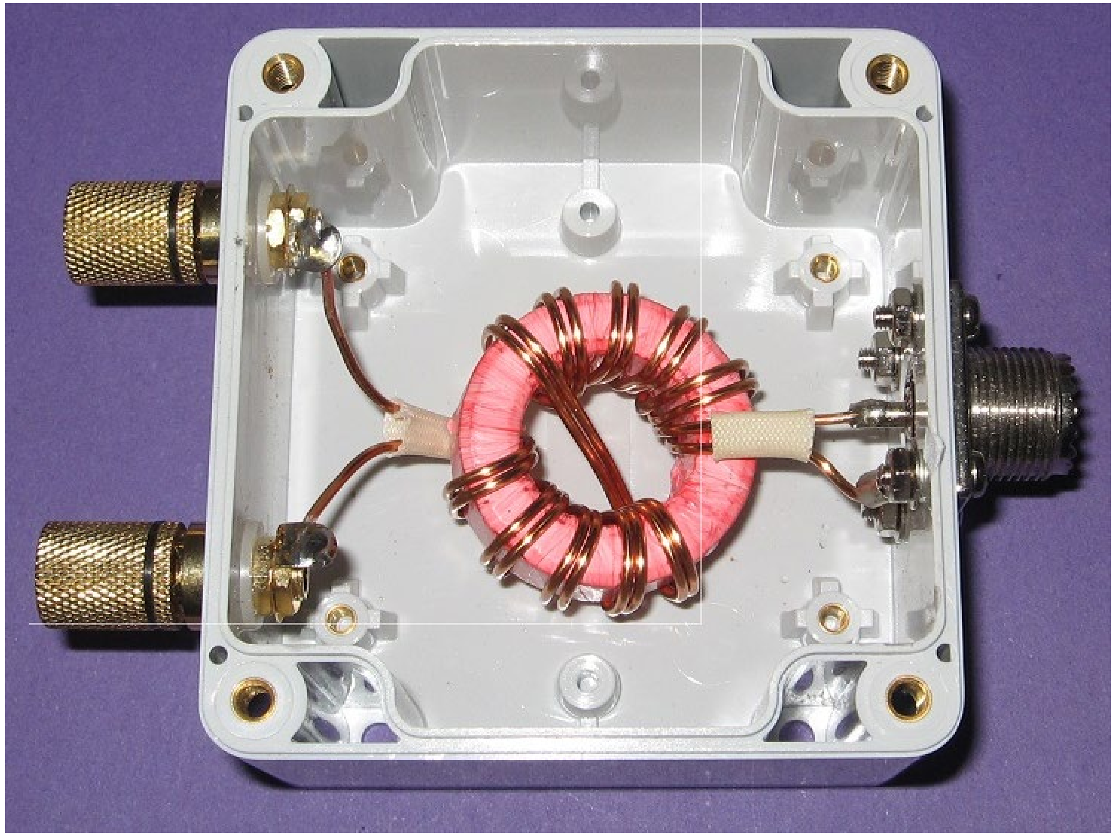
What’s all this then?

From: https://www.w8ji.com/toroid_balun_winding.html



INTENTION:

- Greater distance (so less capacitance to be charged up) between the turns having the biggest voltage differential



Key point: Central pass-through flux path is all in ferrite.

Field direction sense has been retained in this design

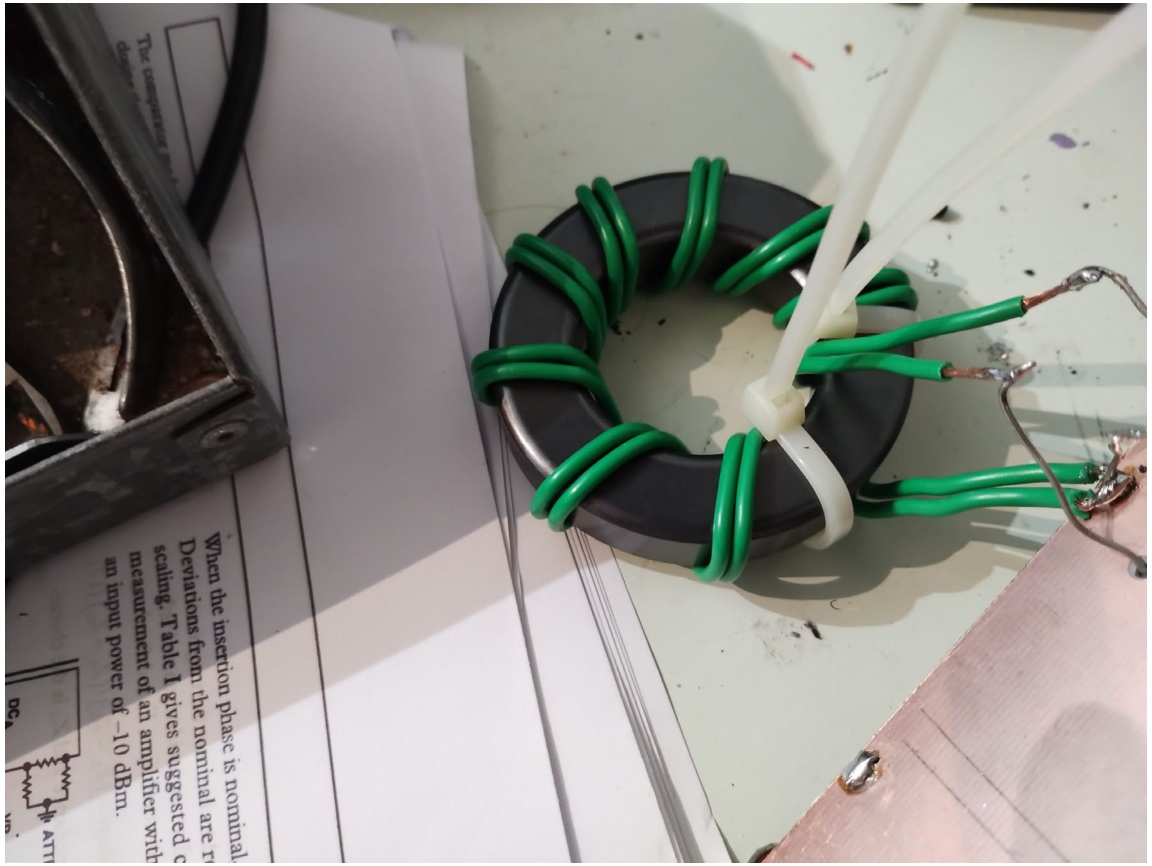
Result:

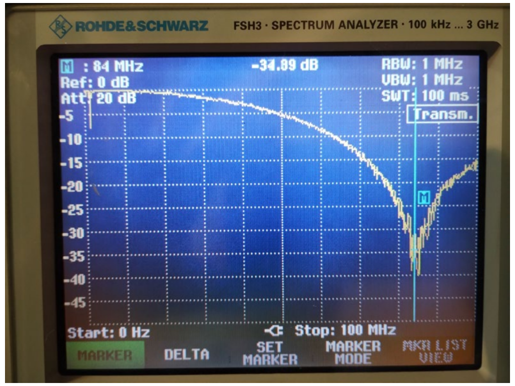
From: https://www.w8ji.com/toroid_balun_winding.html

"As intended, the self–resonant frequency is typically higher with the split winding method (due to lowered capacitance effects) – but the choking performance across a wide band might benefit from a carefully located resonance effects………."

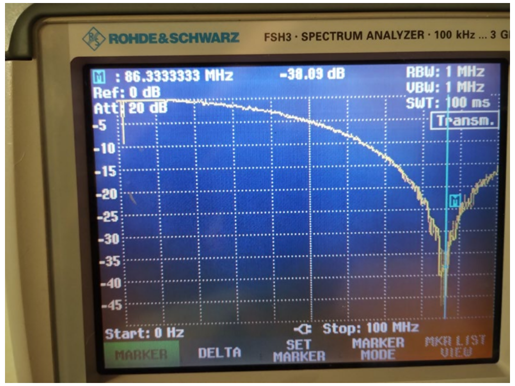
Frequency	15.7MHz	37.1MHz	135MHz	157MHz
Normal Winding	-47dB	-41dB	-4..6dB	-11dB
Split Winding	-33dB	-46dB	-19dB	-3dB

Key point: Is it just reduced capacitance effects, or is the effective magnetic path length altered as well?

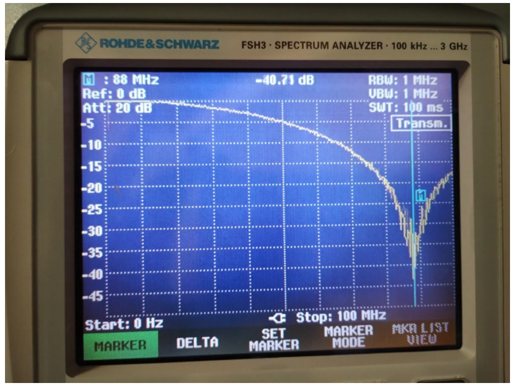




Type 31
(84MHz)



Type 43
(86.3MHz)



Type 61
(88MHz)

Wound on single FT240 sized ferrite rings
9 turn Pri, 9 turn Sec. (1:1)   50 ohm SPA and TG ports.
Stranded wire

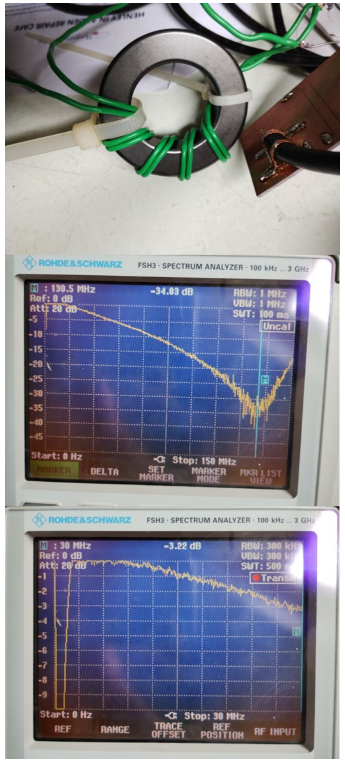
(Non-reversing connections?)

Key point: Read the text book before doing the experiment

1:1 Ferrite type 31 single core Transformer: insertion loss (dB) on HF amateur bands vs. No of Turns

No. of bi-filar turns	Max loss (dB)	Freq of max loss (MHz)	dB Loss @ 1.8MHz	dB Loss @ 2MHz	dB Loss @ 30MHz
9	31	80	1.3	0.5	1.9
8	37	91	1.6	0.4	1.7
7	42	100	1.7	0.4	2.0
6	42	106	1.2	0.4	2.5
5	34	130	1.7	0.9	3.2
4	26	142	1.6	0.9	3.7
3	25	170	1.9	0.9	4.3
2	25	180	2.9	1.6	5.8

measured with SPA and TG @ 50 ohms
(leads not cut down when unwinding the Pri and Sec)

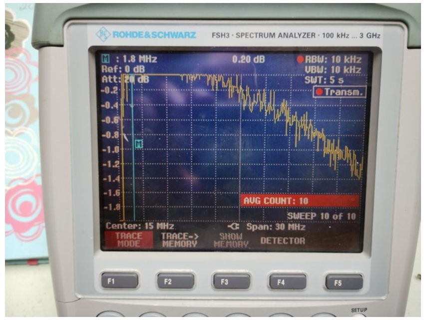


example photos from 5 turn test

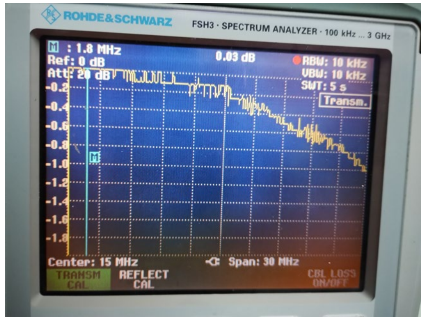
Summary: Best all-round HF band performance seems to be at around 8 or 9 turns with stranded wire (might improve if windings were tighter to the core, and if length of flying leads was minimised)

Key point: Just the summary performance!

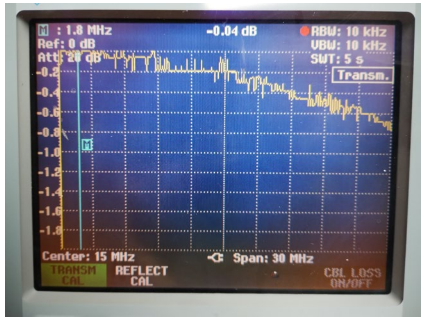
1:1 transformer I.L. using single FT240-31 toroid with 14AWG (1mm diam) solid copper wire (rather than stranded wire)
Bifilar windings



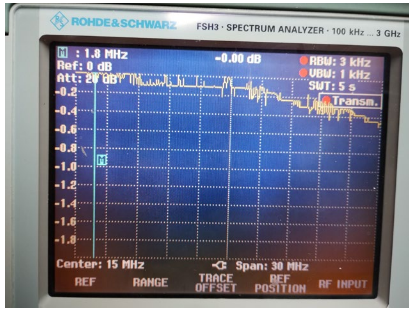
No of turns = 9
30MHz I.L. = 1.3dB



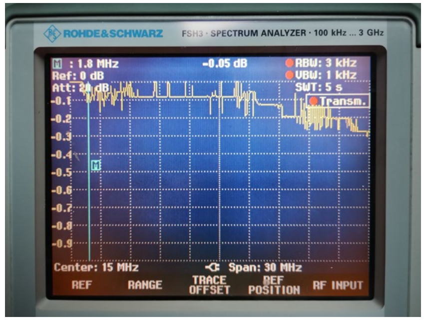
No of turns = 8
30MHz I.L. = 1dB



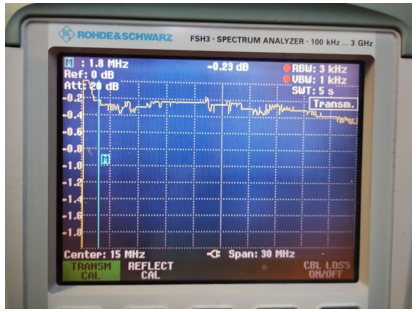
No of turns = 7
30MHz I.L. = 0.8dB



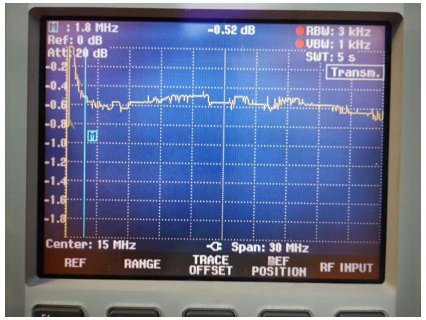
No of turns = 6
30MHz I.L. = 0.5dB



No of turns = 5
30MHz I.L. = 0.3dB



No of turns = 4
30MHz I.L. = 0.4dB

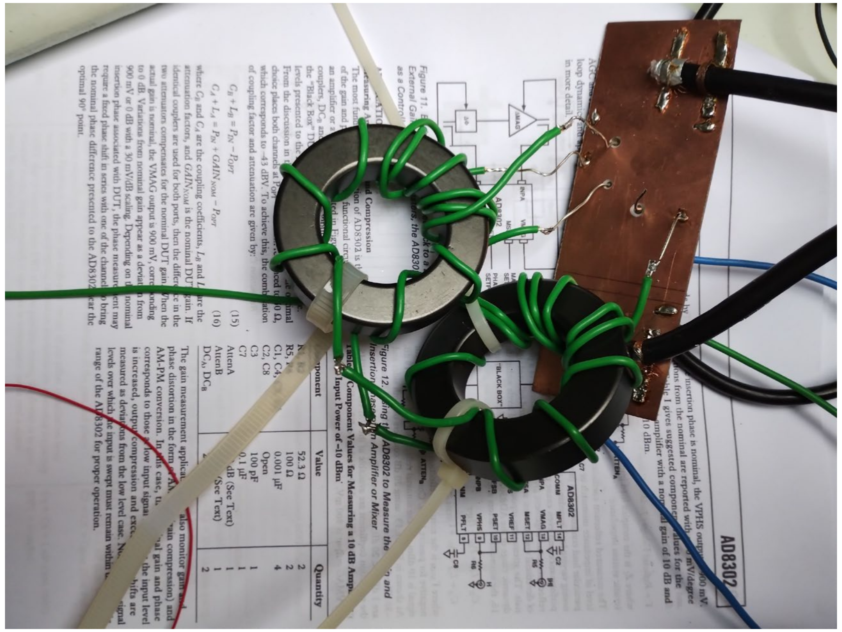


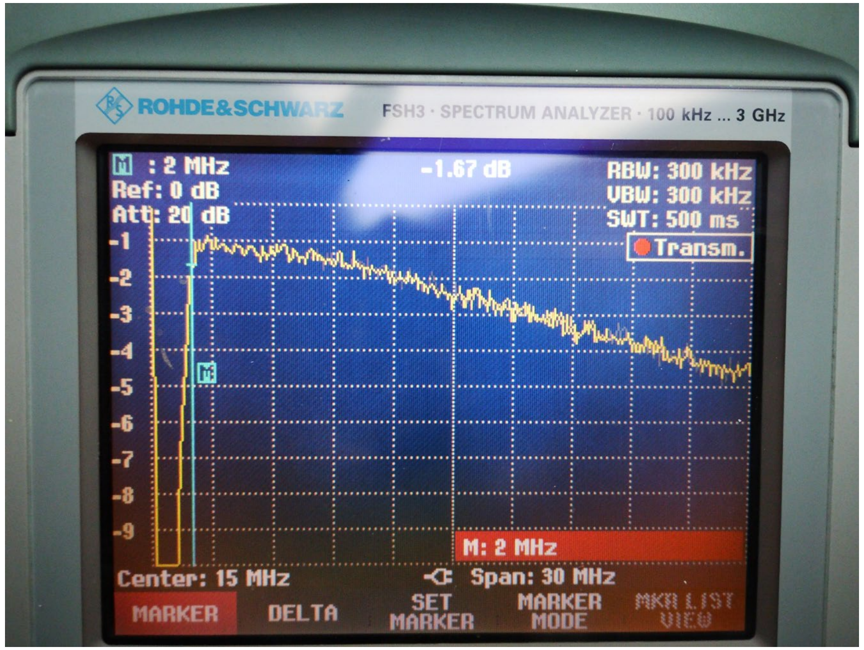
No of turns = 3
30MHz I.L. = 0.7dB

Optimum number of turns seems to be 5, and solid core seems to perform much better than stranded cable (0.4dB vs 3.2dB @ 5T)

Key point: Maybe this happened to be wired up in reversing mode?

1:3 and 3:1 back to back: Ferrite type 31 single core Transformers: insertion loss (dB) on HF amateur bands (1 x 3 turn primary, 1 x 9 turn secondary, per transformer)





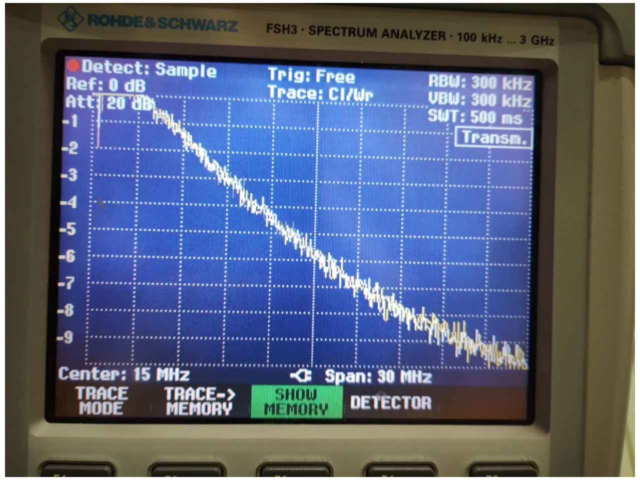
Band(m)	I.L.(dB)
160	2.7 to 1.7
80	1.4
40	1.5
20	2.3
15	3.6
10	4.1 to 4.5

(a single transformer has x0.5 above I.L.)

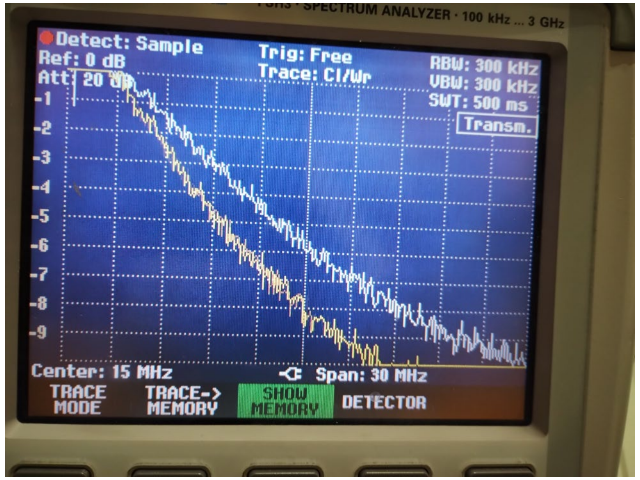
i.e. 9:1 impedance ratio on transformers (50 ohm to 450 on, 450 ohm to 50 ohm, using stranded wire

Key point: Solid vs stranded wire. Turns distribution. Wire size thought experiment

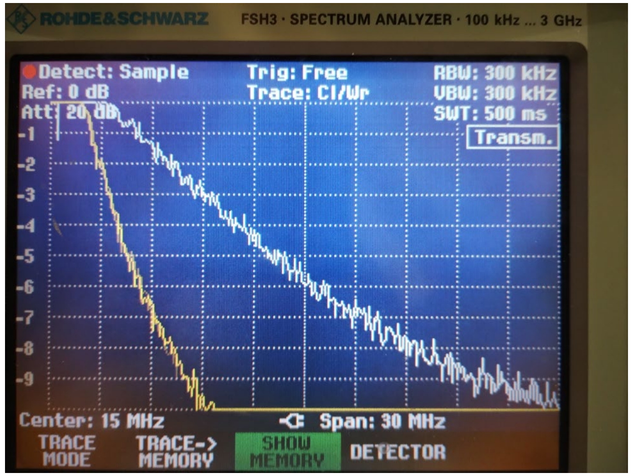
1:3 and 3:1 back to back: Ferrite type 43 single core Transformers: insertion loss (dB) on HF amateur bands
(Effectiveness of triple paralleled, dual paralleled, and single primary windings assessed.)



1x9 turns + 3x3 turns



1x9 turns + 2x3 turns



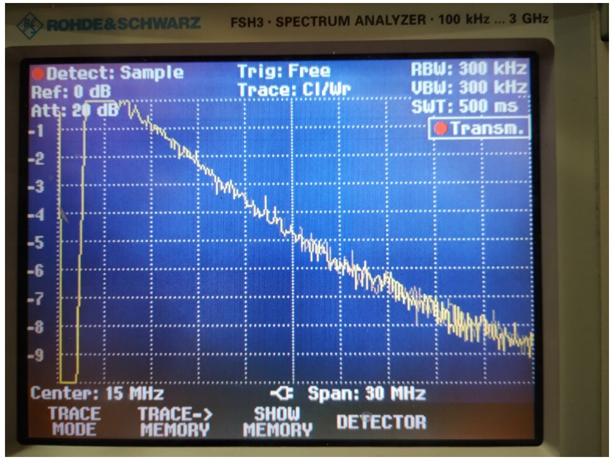
1x9 turns + 1x3 turns

Band(m)	**Insertion Loss.(dB)** - for the pair of transformers		
	3x3 turn	**2x3 turn**	**1x3 turns**
80	0.5	1	3
40	2	3	8
20	5.5	7.5	13
15	8	16	16
10	10	18	18

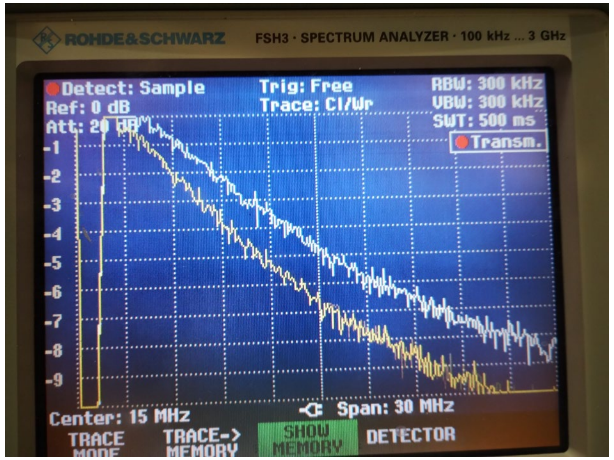
i.e. 9:1 impedance ratio on transformers (50 ohm to 450 on, 450 ohm to 50 ohm, using solid wire

Key point: multiple primaries seem beneficial

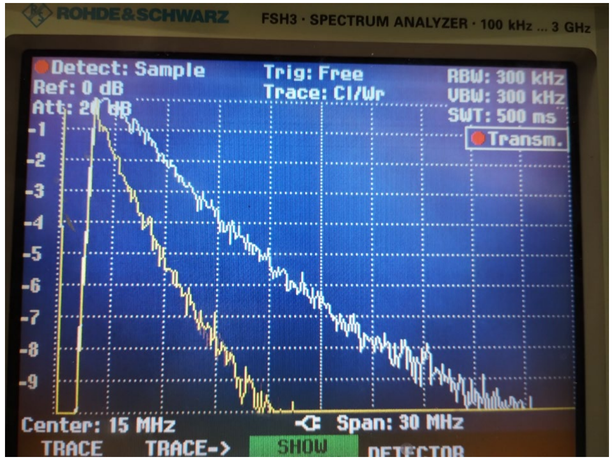
1:3 and 3:1 back to back: Ferrite type 61 single core Transformers: insertion loss (dB) on HF amateur bands
(Effectiveness of triple paralleled, dual paralleled, and single primary windings assessed.)



1x9 turns + 3x3 turns



1x9 turns + 2x3 turns



1x9 turns + 1x3 turns

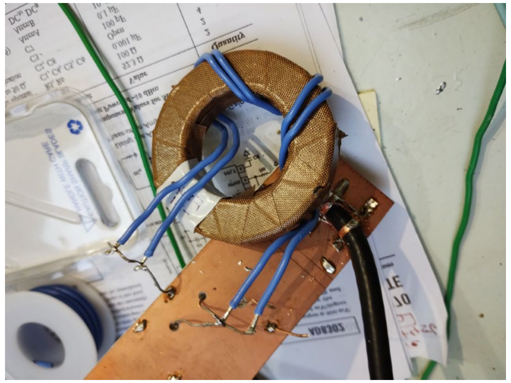
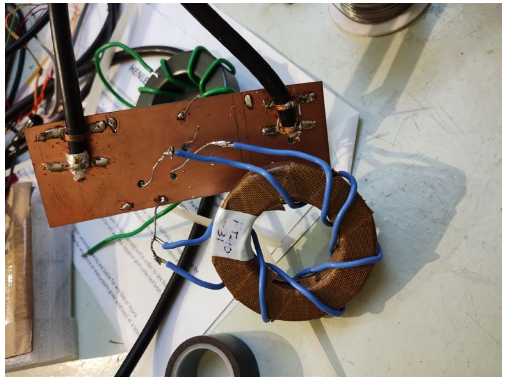
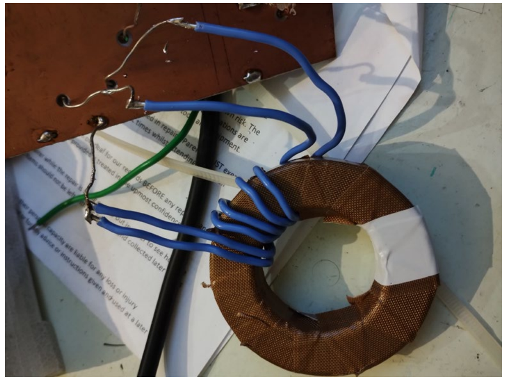
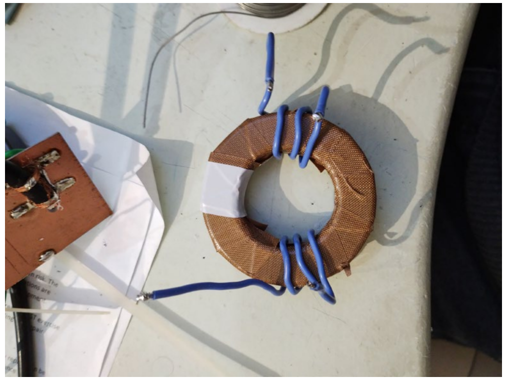
Insertion Loss.(dB) - for the pair of transformers

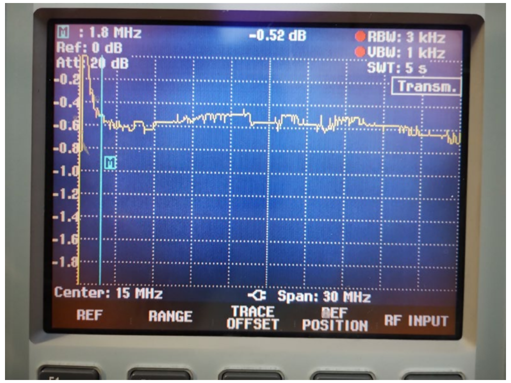
Band(m)	**3x3 turn**	**2x3 turn**	**1x3 turns**
80	0.5	1	3
40	1.3	2.5	6.5
20	4.5	6	11
15	7	8.5	13
10	8.5	10.5	15

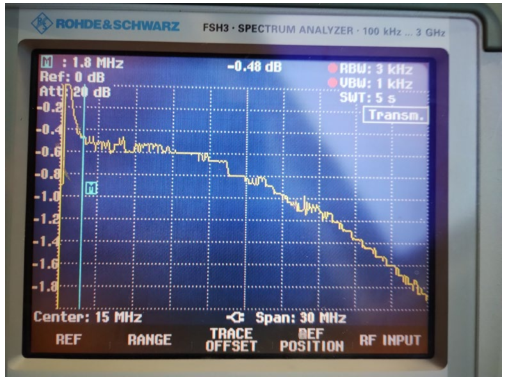
i.e. 9:1 impedance ratio on transformers (50 ohm to 450 on, 450 ohm to 50 ohm, using solid wire

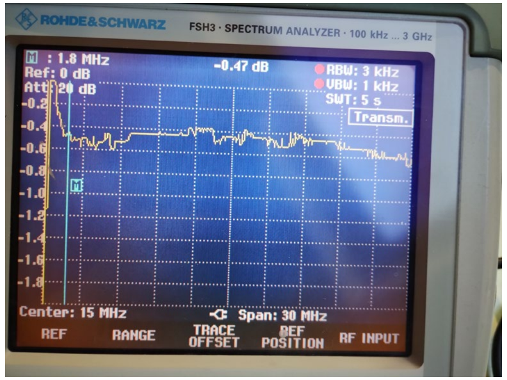
Key point: multiple primaries seem beneficial

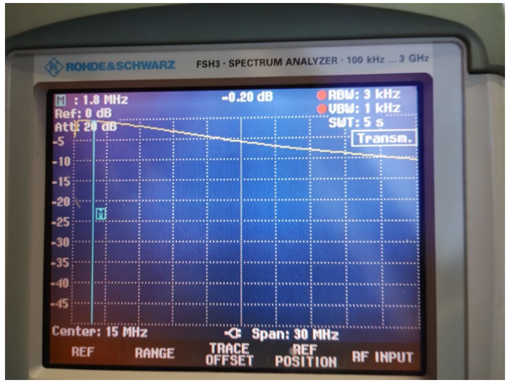
Comparison between winding styles vs 2 separate windings.   Freq range of interest: 1.8–30MHz
Single FT240-31 core, 3 turns of solid core 14AWG cable.









Distributed
parallel Bi-filar
0.6 – 0.7dB I.L.

Distributed
Equi-spaced
0.6 – 1.8dB I.L.

Close-spaced
parallel Bi-filar
0.6 – 0.7dB

Discrete
windings
0.2 – 11dB

Key point: Note SPA scale differences. Optimum seems to be either form of bifilar

DONTS: Effects of Stressing Ferrites

Physical Stress

- Grinding
- Clamping
- Encapsulating (potting)

Can alter:
core permeability (at low flux levels) by 20%
BH loop gap (core losses) – making them bigger

Heat stress
Ferrite permeability ultimately falls as its temperature rises (magnetisation current further increases)

Magnetic Stress
Exposure to high magnetic fields changes core characteristics – sometimes permanently

APPENDIX A: SUPPLEMENTARY SLIDES

Glossary of Terms

Symbol	Unit	Definition
A_L	Henrys	**Inductance Factor** is the inductance per turn squared in nH (L/n^2).
A_e	mm^2	**Effective cross sectional area** of core.
ℓ_e	mm	**Effective magnetic path length**.
V_e	mm^3	**Effective volume of core**.
C_1	mm^{-1}	**Geometric Core constant ($\sum \ell/A$)**
μ_i	-	**Initial (or intrinsic) permeability** is the ration between flux density ΔB in a closed ring core, and the applied field strength ΔH at very low a.c. fields (ΔH>0)
B_{sat}	mT	**Saturation Flux Density** is the maximum flux density achieved with a field of 796A/m (or 10 Oersteds) applied.
B_{rem}	mT	**Remanent Flux Density** is the flux density remaining in the core (following magnetisation to saturation) in the absence of an applied field.
H_C	A/m	**Coercive Force** is applied field strength required to reduce the remanent flux density to zero.
η_B	10^{-6}/mT	**Hysteresis Material Constant** is the hysteresis loss normalised to unit intrinsic permeability and unit flux density.
Θ_C	°C	**Curie Temperature** is that temperature above which ferrite materials lose their ferromagnetic properties and permeability drops to 1. This phenomenon is completely reversible and ferromagnetic properties return when the temperature is reduced to below Θ_C.
ρ	Ω-cm	Electrical **Resistivity** of ferrite material
μ_a	-	**Amplitude Permeability** is the core permeability at relatively high applied field strengths. μ_a is usually specified at given flux densities and temperature.
P_v	mW/cm^3	**Power Loss Density** (sometimes referred to as PLD) is the power loss in the core per unit volume at specified flux densities and temperatures.
$\frac{\tan \delta_{(r+e)}}{\mu_i}$	10^{-6}	**Relative Loss Factor** is the loss coefficient normalised to intrinsic permeability, associated with low field strength conditions.
$\frac{\Delta\mu}{\mu_i^2 . \Delta T}$	10^{-6}/°C	**Temperature Factor** is the proportional rise inductance per degree Celsius normalised per unit intrinsic permeability.

From https://neosid.com.au/files/Electromagnetic_Compatibility.pdf

Parameters for various ferrite mixes at HF

Freq (MHz)	31		43		52		61		67		73		F14	
	μi=1500		μi=800		μi=250		μi=125		μi=40		μi=2500		μi=220	
	μ'	μ''	μ'	μ''	μ'	μ''	μ'	μ''	μ'	μ''	μ'	μ''	μ'	μ''
1.8	1167.2	702.1	609.8	149.3	272.3	4.0	120.3	0.3	40.6	0.1	1540.4	1315.4	219	2
3.6	657.7	677.9	470.2	224.0	278.7	7.8	120.6	0.6	40.3	0.1	839.9	1057.1	235	4
7.1	359.1	476.1	332.0	228.0	305.2	73.8	123.4	1.2	40.2	0.1	457.4	803.3	265	36
10.1	275.3	385.3	259.7	220.4	258.2	138.7	127.4	2.1	40.3	0.1	296.7	685.7	257	89
14.2	223.4	323.8	201.2	204.3	186.8	151.2	136.8	6.2	40.5	0.1	157.9	562.0	222	111
18.1	187.9	284.9	159.9	189.3	150.8	138.8	150.8	20.1	40.8	0.1	86.2	458.8	189	117
21.2	165.2	262.4	135.3	179.4	132.2	126.8	153.7	41.5	40.9	0.1	49.4	396.2	172	121
24.9	144.6	241.0	113.7	168.7	118.0	116.8	140.7	64.9	41.2	0.1	25.0	336.2	157	124
28.5	129.2	224.5	97.5	158.4	107.2	109.4	124.5	76.6	41.4	0.1	8.8	289.8	146	126

Cross-reference for ferrite material mixes

u	Palomar	Indiana General	Stackpole	Fair Rite	Neosid	Ferroxcube/Phillips
125	61	Q1	C/11	61	F16	4C4,4C6,4C65
40	63	Q2	C/12	63		
40	67	Q2	C/12	67	F25	
20	68	Q3	C/14	68		
850	43	H	C/7D	43	F19	3D3,4A11,4A15
5000	75	O6		75		3E2A,3E4
1800	77	TC9	C/24B	77	F5/F44	3B7/3B9,3C96/3F3
1800	73		C/24	73	F5A	3C8,3C90/3C94

See: https://palomar-engineers.com/ferrite-products/ferrite-cores/toroid-cross-reference

Manganese-Zinc

Neosid	F6	F47	F44	F5	F48	P10	P11	P12	F5A	F5C	F9	F9C	F10	F57	F39	F59
Iskra	35G 5G			15G		8G 11G	14G 16G 6G	26G		25G	19G		22G		12G	
Ferroxcube Phillips Mullard	3B1	3F3	3C15 3C85	3C80 3C10 3C6 A9 A16	3C90 3C94		3B7 3H1 3H2 A13 A4	3H3 A14	3B8 3C81	3C2	3C11 3E1 3E2 3E4 3S1 A8	3E2A	3E25 3E45		3E5	
Tokin		2500B3	HBM 2500B2	1500B	B25	1800F 2000H	801F 2001F 2002F 2003F 2004F 2300F	2101F	500B	3000B 3100B	4000H	5000B	6000H	7000H	12001H	
LCC- Thompson AVX	A9 C1 C3 C5		B2 B5 B6	B3	F1 F2	T9	S1 S4	S3	B1 B4 S7	B31	A6 T6	A5 A8	A4 T4	A3	A2	
Vogt	FI 311		FI 324	FI 322					FI 323		FI 340		FI 360		FI 410	
TDK			H3T HV22 H3C PC30 DA2 PE22		HV38 PC40		H6A H6A3 H6B	H6Z H6K	H3S PE38	20 H7C2 HP3 NS10	H5A HP4	H7A H7B NS50 HP5	HS50 H1B H5B	H1D H5B2	H5C2	IP1
Kashke	K1201		K2006 K2008	K2002 K2004					K2005 K2401		K4000	K5000	K6000	K8000	K10000	K700
Siemens EPCOS		N47 N49	N67	N27 T26	N62 N87 N97	N26	N22 N29 N32	N28 N48	N72	N41	N30	N55	T35 T37	T44	T38 T42	
SEI						P Q5	Q3	Q7		L2 T1	T2 T3		T4		T6	
Hitachi (Nippon)	SB-5F		SB-3L SB-5L SB-7 SB-5LK		SB-7C SB-9C				SB- 5HK SB- 5M	SB- 5S SB- 9H SB- 7H	GP-7	GP-5 GQ-5C		GP-9	GP-11	
Fair-Rite	72 34 33		78	77					73			75			76	

Manganese-Zinc (continued)

Neosid	F6	F47	F44	F5	F48	P10	P11	P12	F5A	F5C	F9	F9C	F10	F57	F39	F59
FDK (Fuji)	H64		H49N H63		H45C			H21B F22Z	H45 H49W H45A		H24B	H24A H28A		H24Z	H25Z	
D.M.Steward									32		34	35		37	40	
Ferronics												B				
Ceram. Magnetics		MN8CX							MN80			MN30 MN60 MN60LL			MN100 MC25	
Magnetics		K	P		R		G C	D		F	T J	N			W	
DMEGC			DMR40		DMR90 DMR44			DMR70	R3K		R4K			R7K	R10K	
TDG			TF3		TP4A				TK		TD5A			TS7	TS10	
ACME			P4								A05			A07	A10	

From: https://neosid.com.au/ref-b.html

Nickel-Zinc

Neosid	F29	F28	F25	F16	F14	F13	F19
Iskra	2E	1E	2F 1F	3F	3C 2C		1C
Ferroxcube Phillips Mullard	4E1		4D1 4D2	4C6 4C65 B10	4B1 B2	4A11 B1	4A15 4S2
Tokin	10L	20L 40L	50L	100L 150L 80L	250L	600L 601F 700L	1000F
LCC-Thompson AVX	H6 H62 K6		H5 H52 K5	H3 K3 H32	H2	H1	
Vogt	Fi 110 Fi 091	Fi 130	Fi 150	Fi 212	Fi 222 Fi 223	Fi 242	Fi 292 Fi 293
TDK	F4N F5N K8 M5E M5M M5N V2F V3F V3N V4F V5F F3T F6T	M11 M11E M11M V1F	M8B M8C M8L M8N M9 M9D M9E M9M M9N	Q1D Q5M Q5B	D1B D1C L9 L9H 50 K5 Q1C Q2 D3B D8 L4N Q2M	45 CS-6 L8H L5 L5N L5T	CS-4 HF30 HF40 HF55 HF60 HF70 L6H L6E
Kashke	K10 K14		K40 K50	K80 K150	K250		K800
Siemens EPCOS	U17 U60	K12		K1	M11	K10	
SEI	K8		K7	K6 K10	K4		
Hitachi (Nippon)			SV-1AC QM-201 KP-2S		DL-4C QM-051	DL-6C	T-314 DL-8C
Fair-Rite	68		63 67	61 65	64 62	44	43
FDK (Fuji)	H56Z H55Z		H54Z	H53Z	H52A		
D.M.Steward	21		22	23			26 28
Ferronics			P	K			J
Ceram. Magnetics	N40	C2075		C2025 C2050			CN20

Listed below is an applications guide outlining the most popular use of Neosid material grades.

It is intended as a guide only.

Pot cores/RM cores for inductors, transformers:

Grades: P10, P11, F5, F5A, F5C, F44, F48, F47, F9, F9C, F10, F39

Low power and pulse transformer cores:

Grades: F9, F9C, F10, F39, F57, F14

Balun cores:

Grades: P11, F9, F9C, F10, F19, F14, F13

High power transformer cores (E, U & Ring)

Grades: F5A, F44, F45, F47, F48, F5C, F5

Suppression cores:

Grades: F9, F9C, F10, F39, F19, F14, F8

Toroidal cores:

Grades: All grades.

Aerial Rods and Blocks:

Grades: F14, F8, F6, F16, F25, F29

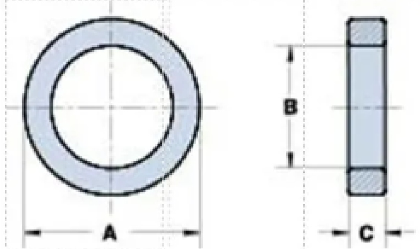
Screw cores, rods, tubes:

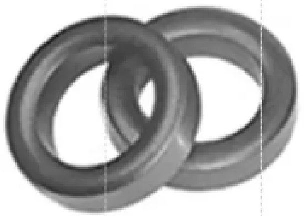
Grades: F14, F25, F29, F16, F8

High frequency welding impeders:

Grades: F14, F6

toroid-cross-reference for CORE SIZE





Palomar-Engineers.com - Ferrite Toroid Cross Reference by Manufacturer Part Numbers - In ascending order of outside diameter

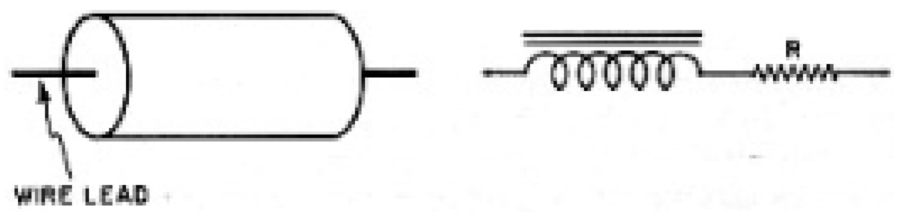
Palomar Part #	A - OD (mm/ in)	B - ID (mm/in)	C - Height (mm/in)	AVX	Neosid	EPCOS	Fair Rite	Hitachi	Indiana General	Magnetics	TDK	Ferroxcube
F23-( )	5.84/*.230*	3.05/*.120*	1.52/*.060*				59( )000101		F303-1/CF-101	40601-TC		TC5.8/3.1/1.5
F37-( )	9.53/*.375*	4.75/*.187*	3.18/*.125*	T-0950A	28-070-( )		59( )000201		F625-9/CF-102	41003-TC	T4.75-9.52-3.18	TC9.5/4.8/3.2
F50-( )	12.7/*.500*	7.14/*.281*	4.78/*.188*	T-1270A		B64290K44X830	59( )000301		F627-8/CF-108	41407-TC	T7.14-12.7-6.35	768T188
F50A-( )	12.7/*.500*	7.92/*.312*	6.35/*.250*	T-1270C	28-019-( )		59( )001101	OR12.7-6.35-7.9		41306-TC		204T250
F50B-( )	12.7/*.500*	7.92/*.312*	12.7/*.500*				59( )001901					
F82-( )	21.0/*.825*	13.1/*.516*	6.35/*.250*				59( )000601		F624-19/CF-111			
F87-( )	22.1/*.870*	13.7/*.540*	6.35/*.250*	T-2210B	28-082-( )	B64290A0638X8	59( )001801	OR22.1-6.35-13		42206-TC	T14-22-6.5	846T250
F87A-( )	22.1/*.870*	13.7/*.540*	12.7/*.500*	T-2210A	28-095-( )		59( )007601			42212-TC		846T500
F114-( )	29.0/*1.142*	19.0/*.750*	7.49/*.295*				59( )001001		F626-12/CF-114	42908-TC		TX29/19/7.6
F114A-( )	29.0/*1.14*	19.0/*.750*	13.8/*.545*				59( )001201			42915-TC		
F140-( )	35.6/*1.40*	23.0/*.900*	12.7/*.500*				59( )002701					TX36/23/15
F140A-( )	36.8/*1.40*	23.0/*.900*	15.0/*.590*	T-3600A		B64290A67X830	59( )002721			43615-TC	T23-36-15.1	TX36/23/15
F150-( )	38.1/*1.50*	19.0/*.750*	6.35/*.250*	T-3800B						43606-TC		
F150A-( )	38.1/*1.50*	19.0/*.750*	12.7/*.500*	T-3800A						43813-TC		
F193-( )	49.1/*1.932*	31.8/*1.250*	15.9/*.625*							44920-TC		
F193A-( )	49.1/*1.932*	31.8/*1.250*	19.0/*.750*							44925-TC		
F240-( )	61.0/*2.40*	35.6/*1.40*	12.7/*.500*				59( )003801		F568-1/CF-123	46113-TC		

See: https://palomar-engineers.com/ferrite-products/ferrite-cores/toroid-cross-reference

Beads

Beads Block Noise

Block spurious noise without d.c. losses? It can be done with a ferrite bead says the Electronic Components Division of Stackpole Carbon Co. They claim a ferrite bead is one of the simplest and least expensive methods of obtaining r.f. decoupling, shielding, and parasitic suppression without sacrificing low-frequency power or signal level.



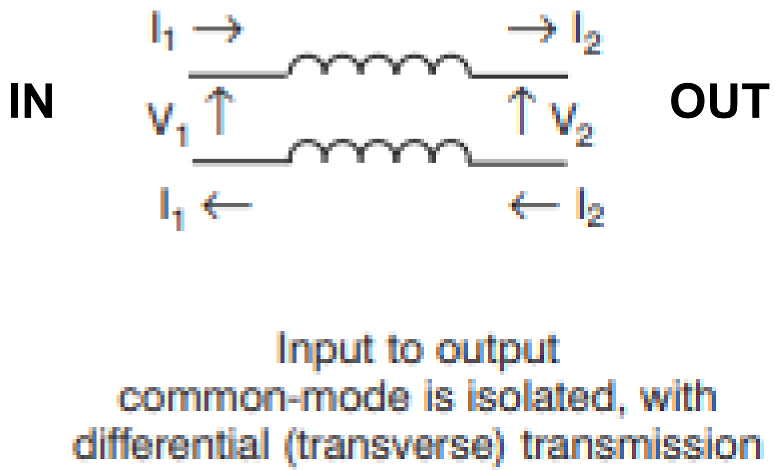
Typical ferrite bead and its equivalent series circuit.

Unlike conventional r.f. chokes, ferrite beads are compact; they do not couple to stray capacitance to introduce detuning or spurious oscillations. In addition, their impedance varies from quite low at low frequencies to quite high at noise frequencies. What else makes them different? Well, they need not be grounded, but grounding isn't detrimental to performance if they should touch the chassis.

Ferrite beads are available in a variety of sizes, from 0.038 inch o.d. and 0.150 inch long to 0.120 inch o.d. and 0.300 inches long. They come with either a single hole or multiple holes through their length, through which the current-carrying conductor passes. Some beads are being made with leads to which wires can be soldered.

Here's how they work. As noise current flows through a conductor (passing through a ferrite bead), it creates a magnetic field. As the field passes through the bead, the permeability of the bead at the noise frequency (r. f.) causes the impedance of the bead to rise rapidly, creating an effective r.f. choke. The higher the frequency, the higher the impedance and the greater the attenuation. Meanwhile, low-frequency current passes through the bead unimpeded. Several beads can be strung together for increased efficiency.

Transmission Line Transformer



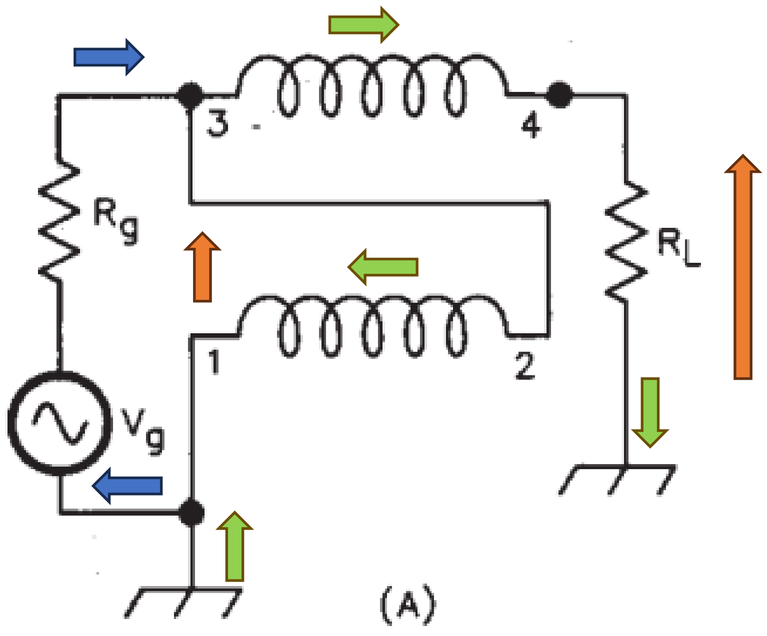
- Power in = (I1 x V1)
- Power out = (I2 x V2).
- For 100% efficient transformer, energy is conserved,

  so: (I1 x V1) = (I2 x V2)

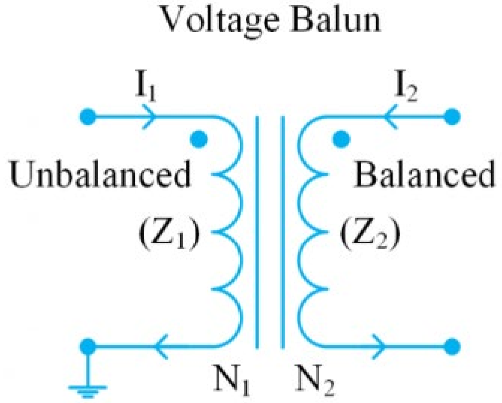
For 1:1 windings ratio
Where XL for a winding is >> RL and Rg then current flow will be constrained by the inductive reactance of the transformer windings

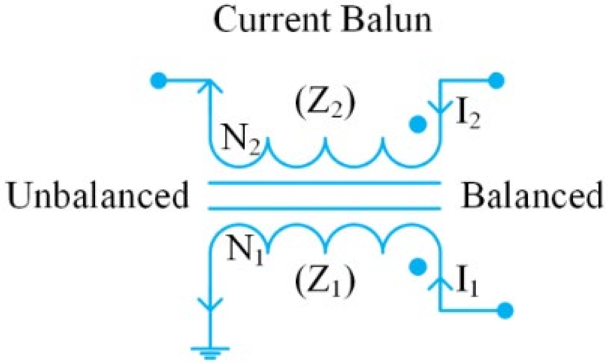
Used as

An “UnUn”



Should I use a Voltage or a Current Transformer?





Voltage Baluns

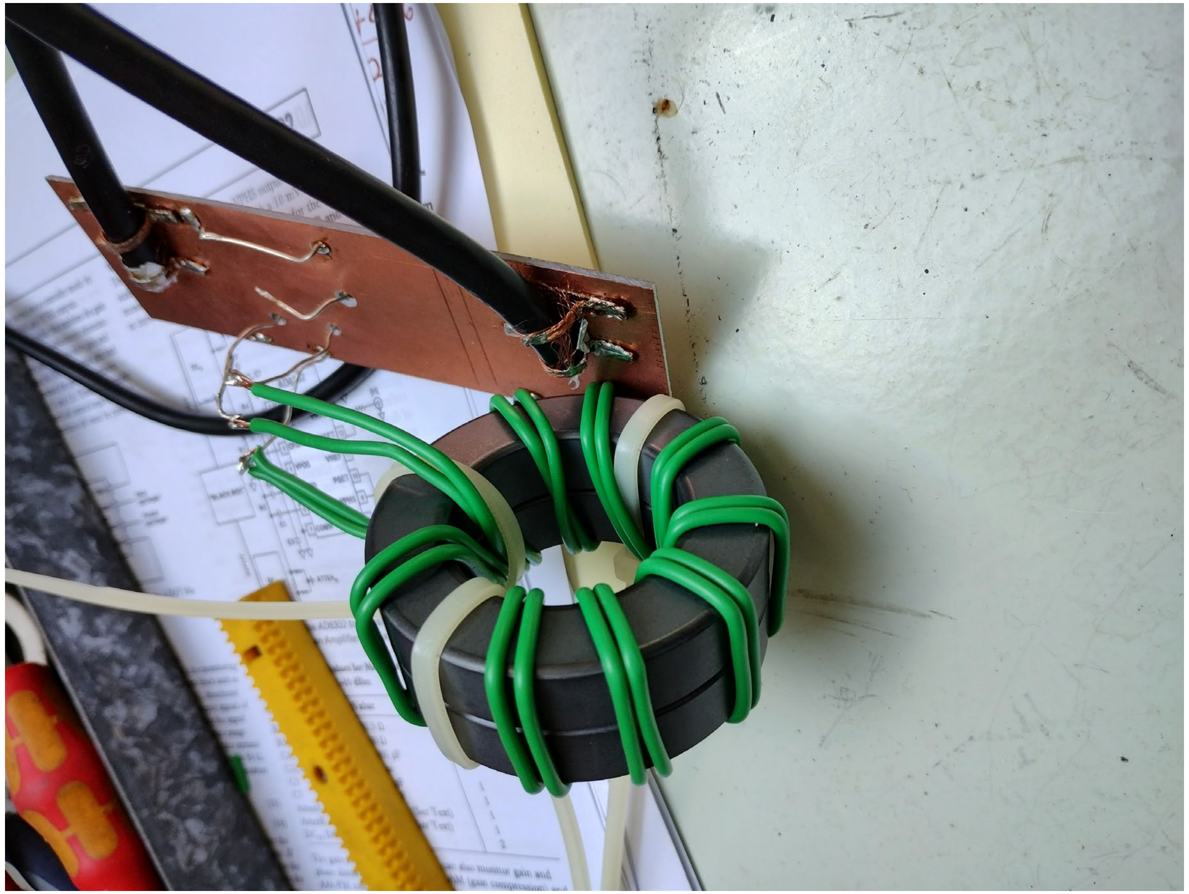
- always try to force the output terminals to equal voltages.
- sometimes introduce phase shift between each output terminal and "ground".
- If the impedance presented at each terminal is not exactly equal, feedline or load currents will not be equal and opposite. This means the feedline will radiate.
- do not provide common-mode isolation. (almost certainly guarantee some feedline radiation (or reception), because there are very few "perfectly balanced" loads or perfect voltage baluns.
- a voltage balun will always magnetize its core in direct proportion to load voltages. In a voltage balun, load impedance directly affects core heating and flux density.

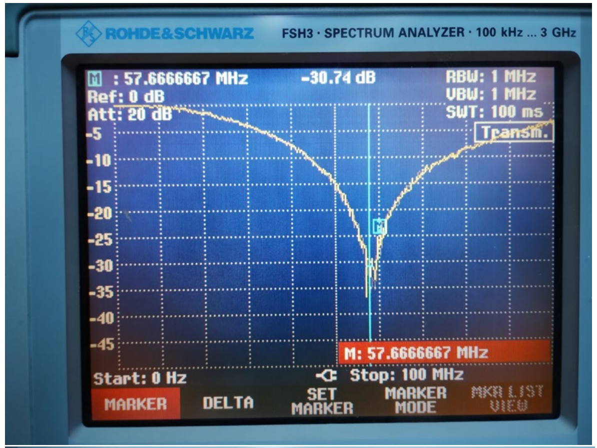
Current baluns, rather than voltage baluns, should be used whenever possible. Current baluns provide better balance and often have lower loss. Current baluns, especially 1:1 ratio baluns, tolerate load impedance and balance variations much better than voltage baluns. Current baluns can also be used as isolators or un-un's.

Current Baluns

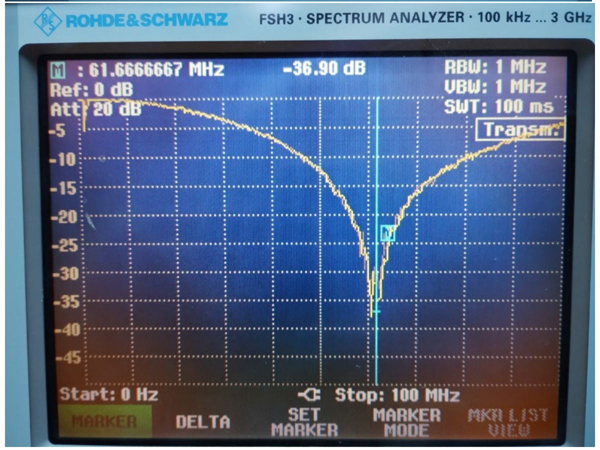
- allow each output terminal's voltage, with respect to "ground" or chassis, to float to any value required to provide equal currents to each feedline conductor.
- are universal devices that work with balanced or unbalanced loads equally well.
- add common-mode isolation between systems connected at each end.
- work well as broadband phase-invertors or as an un-un.
- isolate or add impedance to unwanted common-mode current paths, reducing or controlling common-mode current.
- work better than voltage baluns in most real-world systems.

In the case of a 1:1 ratio current balun, core flux density or "magnetizing stress" on the balun core is independent of load impedance or load mismatch. Only common-mode current affects the core. Current baluns cannot handle infinite power or mismatch, but for equal materials and cost they handle extremes in impedance much better than baluns that operate at higher ratios.





Type 31
(57.6MHz)



Type 43
(61.6MHz)

Wound on **2** x FT240 sized ferrite rings (non-reversing connections)

9 turn Pri, 9 turn Sec. (1:1) 50 ohm SPA and TG ports.

9 turn bifilar 1:1 Ferrite Transformer insertion losses (dB) on HF amateur bands (stranded wire)

No of Core rings	Ferrite Material type no:	160m	80m	40m	20m	15m	10m
1	**31**	**0.2**	**0.15**	**0.2**	**0.1**	**0.4**	**1.4**
	43	0.2	0.4	0.3	0.1	0.3	1.5
	61	0.7	0.4	0.2	0.1	0.5	1.8
2	31	0.3	0.2	0.3	0.3	1.3	3.5
	43	0.8	0.8	1.0	0.2	1.2	2.8
	61	1.5	0.5	0.5	1.5	2.5	3.8

Summary: Best performing material for an FT240 sized 1:1 transformer looks to be Type 31
Putting 2 cores together to increase X-sectional area also increases the insertion loss.
(using two well separated windings increases insertion loss to around 20dB – so not good!)