Ferrite and Common Mode Chokes

Kevan Nason, N4XL

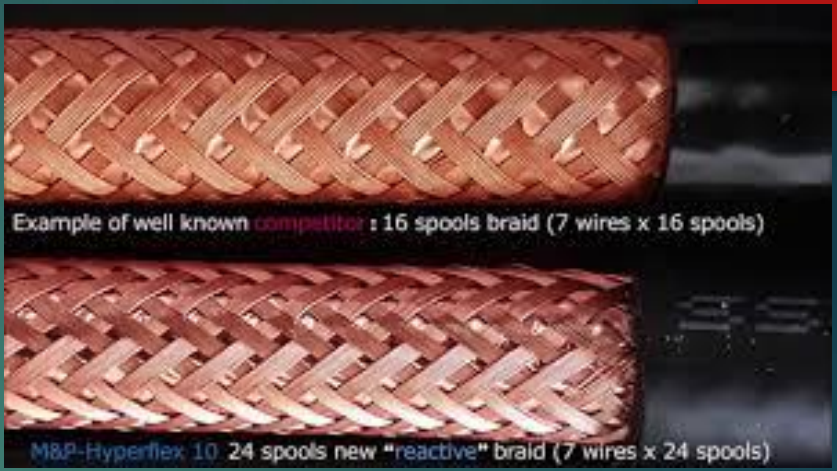
Ref 10

"I've always been a bit bothered by baluns, since I was never sure what they are supposed to do, let alone how they might go about doing it."

- Roy Lewallen, W7EL

Common Mode Current

Ref 6

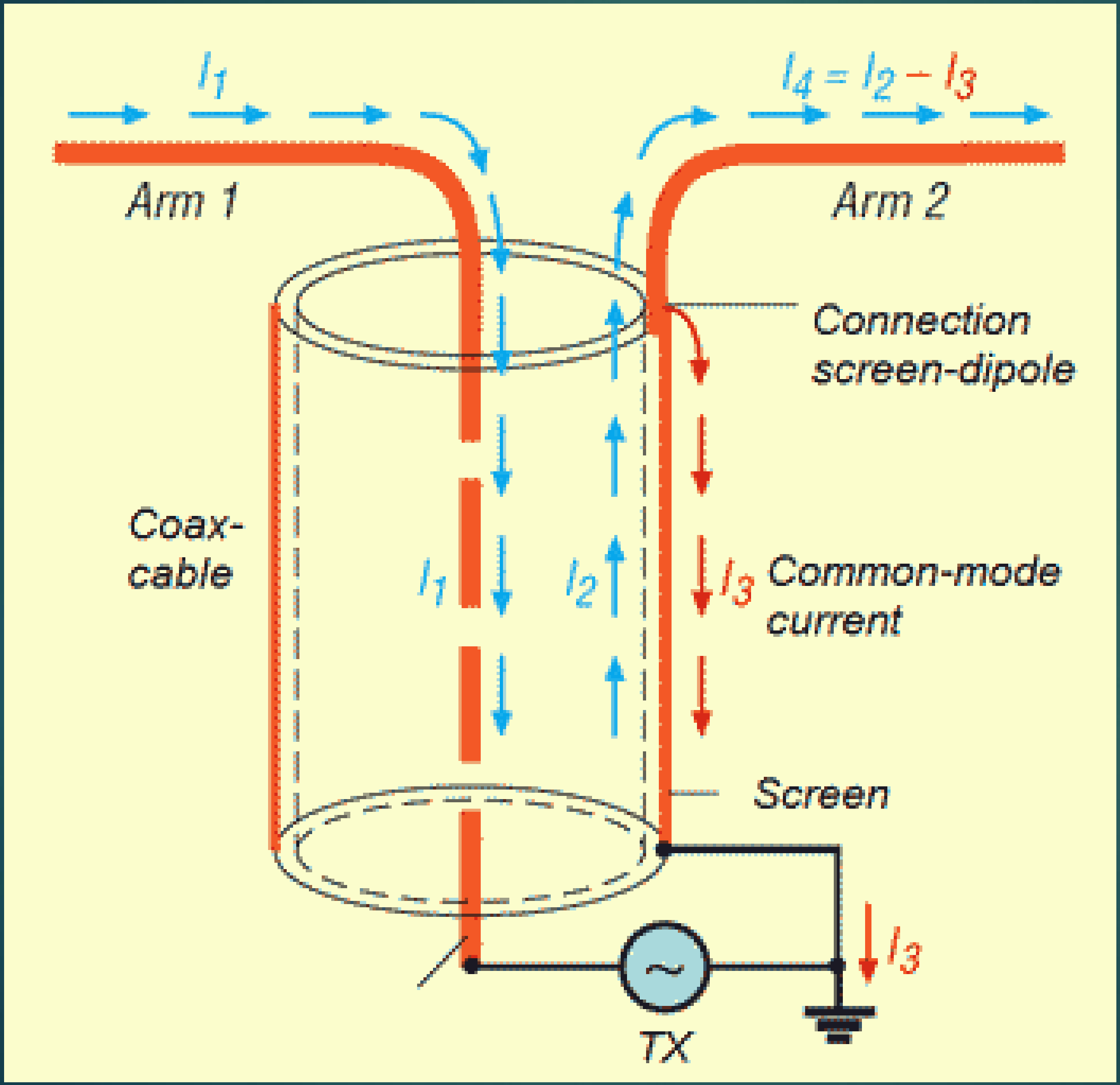


Common Mode Current is UNWANTED current flowing on the OUTER surface of the coax shield.

It also occurs with other cables (i.e. audio, USB, Microphone, etc.)

Common Mode Current

Ref 15



Skin Effect makes antenna current flow on the inside of the coax braid because it is closer to the charge carried on the center conductor

The Pin 1 Problem

A reason why some things are more susceptible to RFI than others

K9YC – Technical Grounding

Ref 1

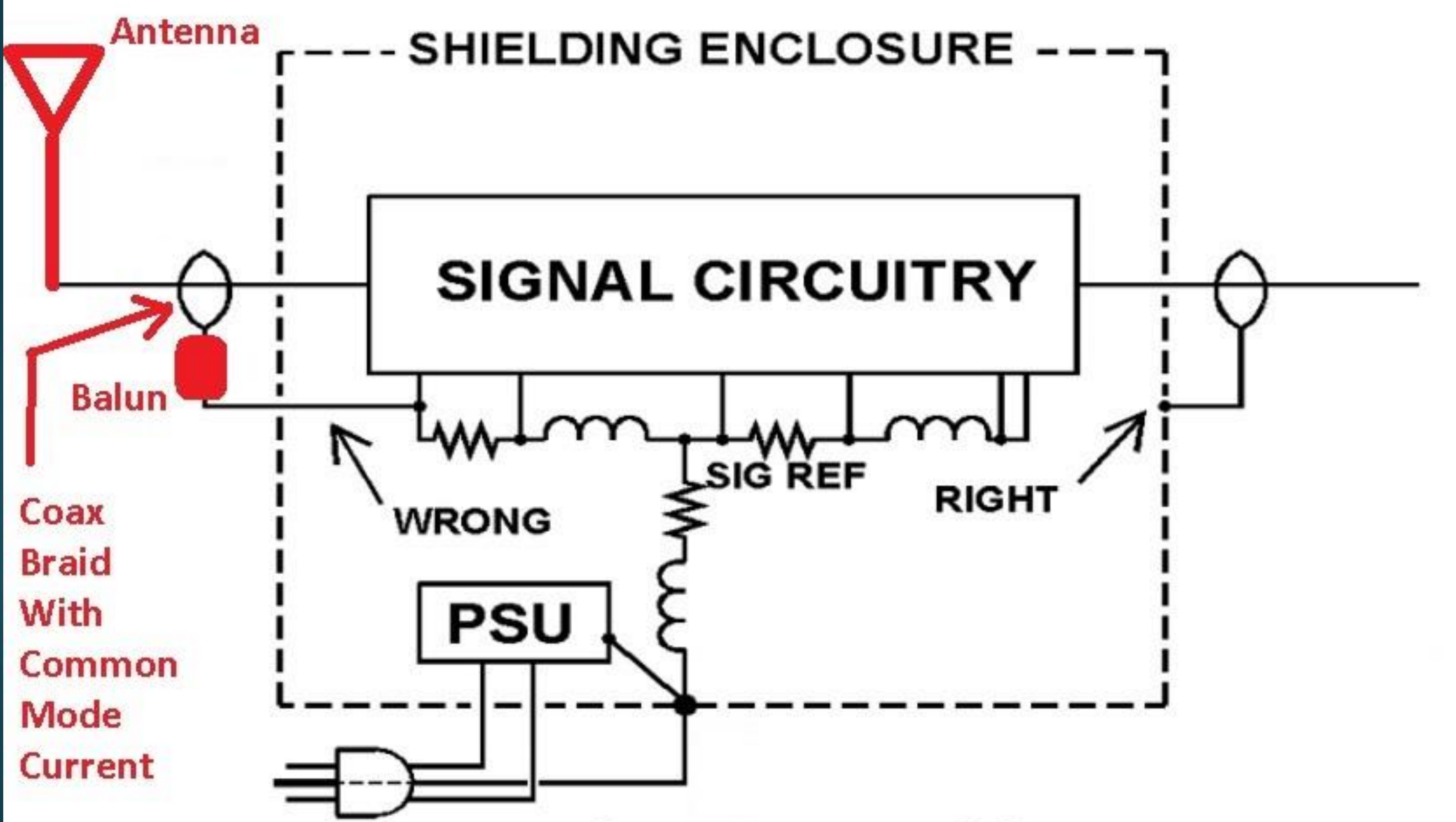


Fig 2 – The Pin 1 Problem

Pin 1 Problems Are Not Limited To Coax

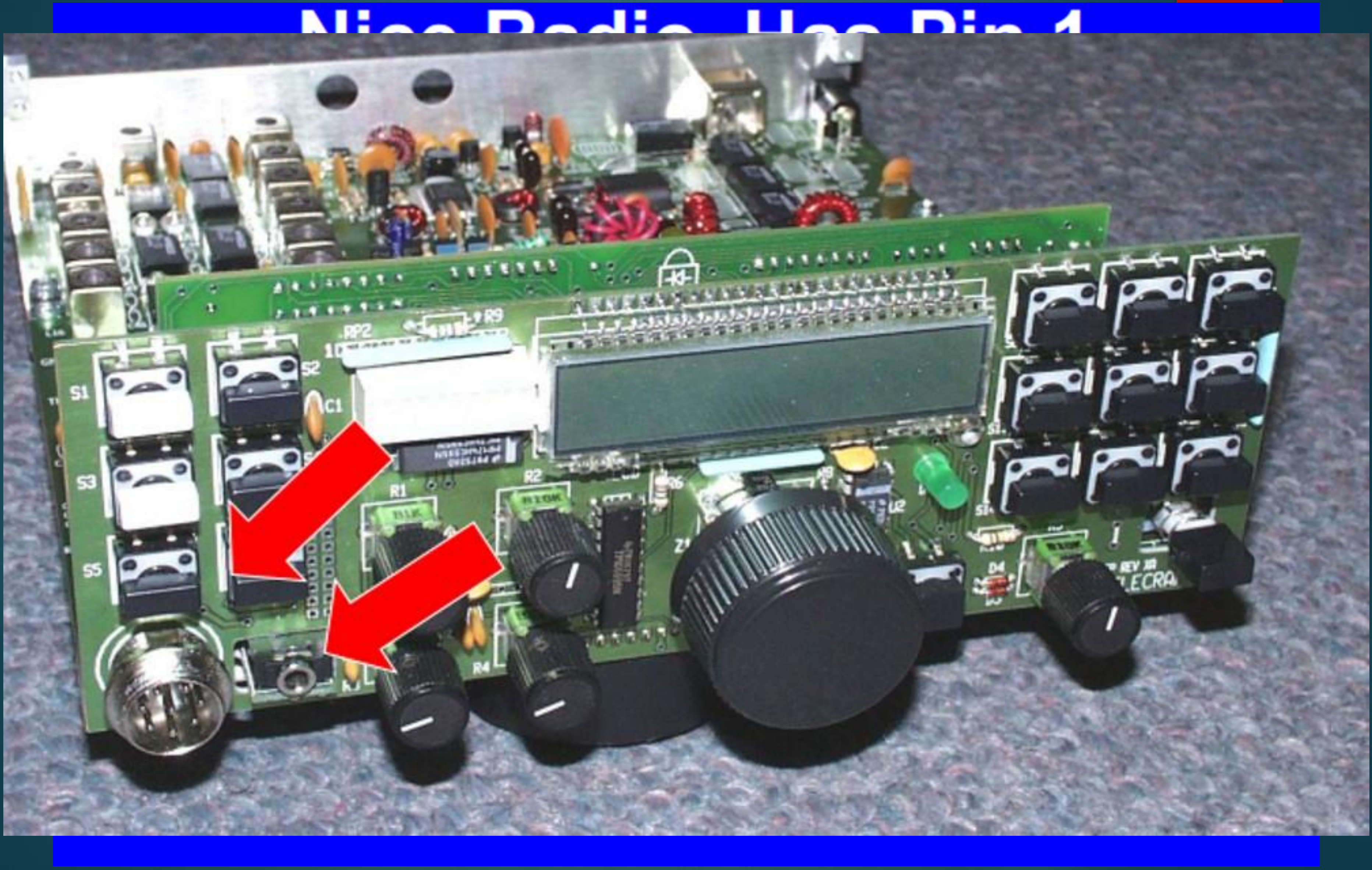
K9YC actually figured it out while working as an Audio Engineer at concerts

Pin 1 Problem

Ref 4

Pin 1 Problem

Ref 4



Pin 1 Problem

Ref 4

Where are the Chassis Connections for this laptop's sound card?

- Hint: It isn't an audio connector shell!
  - They <u>should</u> be, but they are <u>not</u>!

Common Mode Current – DJ0IP

Ref 6

Common Mode current has more than one cause:

- An imbalance in the antenna system
  (antenna + feedline).
- External signals being picked up on shield of the coax
  - RFI from consumer devices
  - RF from other transmitters (broadcast, ham radio, anything)

#84: Basics of Ferrite Beads: Filters, EMI Suppression, Parasitic oscillation suppression / Tutorial by W2AEW

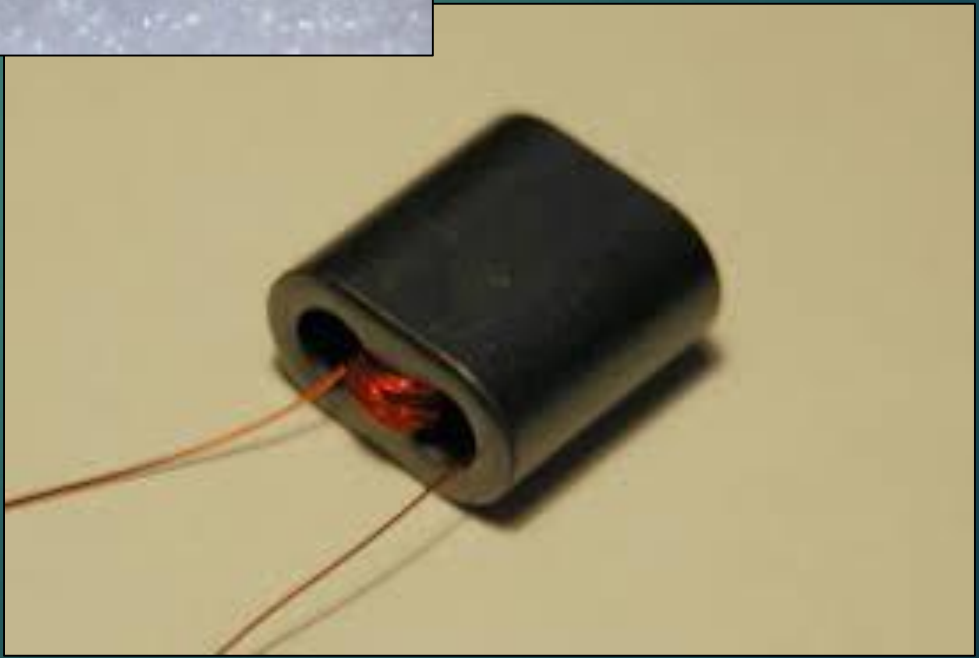
Ref 7

W2AEW YouTube Tutorial #84 - Ferrite Beads

Using Ferrite In The Shack

Using Ferrite In The Shack

Using Ferrite In The Shack



Common Mode Feedline Chokes

Common Mode Feedline Chokes

From M0PZT, http://www.m0pzt.com/baluns/

Ref 13

Common Mode Feedline Chokes

A 1:1 Guanella (current) balun, also known as a "choke", made by winding 3 layers of RG58 coax on a ferrite rod.

Feedline Choke

Ferrite Mixes

Ref 3

There are two basic ferrite material groups: …

The NiZn ferrite cores (mix 43, 52, 61) have low permeability, exhibit high volume resistivity, moderate temperature stability and high 'Q' factors for the 500 KHz to 100 MHz frequency range. They are well suited for low power, high inductance resonant circuits. Their low permeability factors also make them useful for wide band transformer applications…

The MnZn ferrite cores (Mix 31, 73, 75) have high permeabilities above 800 μ, have fairly low volume resistivity and moderate saturation flux density. They offer high 'Q' factors for the 1 KHz to 1 MHz frequency range. Cores from this group of materials are widely used for switched mode power conversion transformers operating in the 20 KHz to 100 KHz frequency range…

Ferrite Impedance for #43 and #61 material

Ref 3

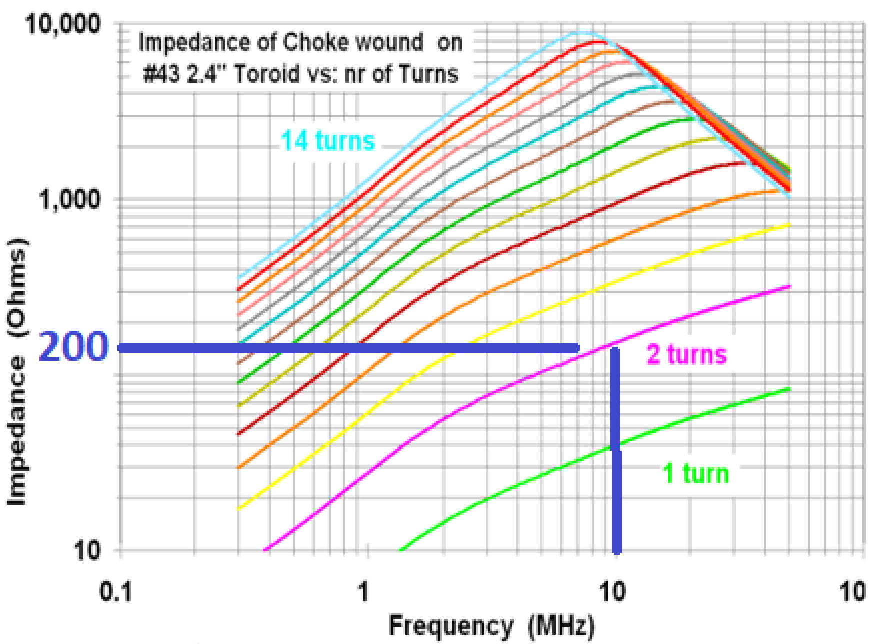


Fig 10 – Impedance of multi-turn chokes wound on the core of Fig 4 (Fair-Rite #43). (Measured data)

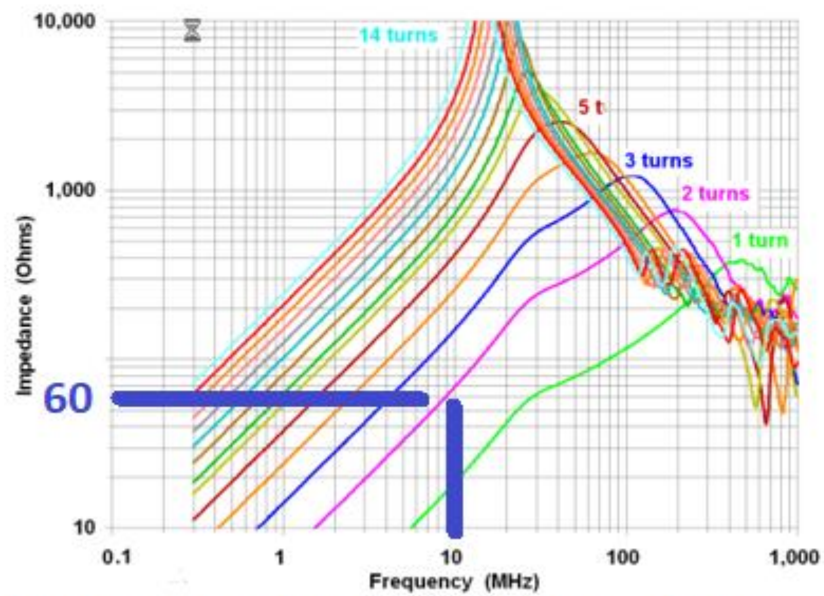


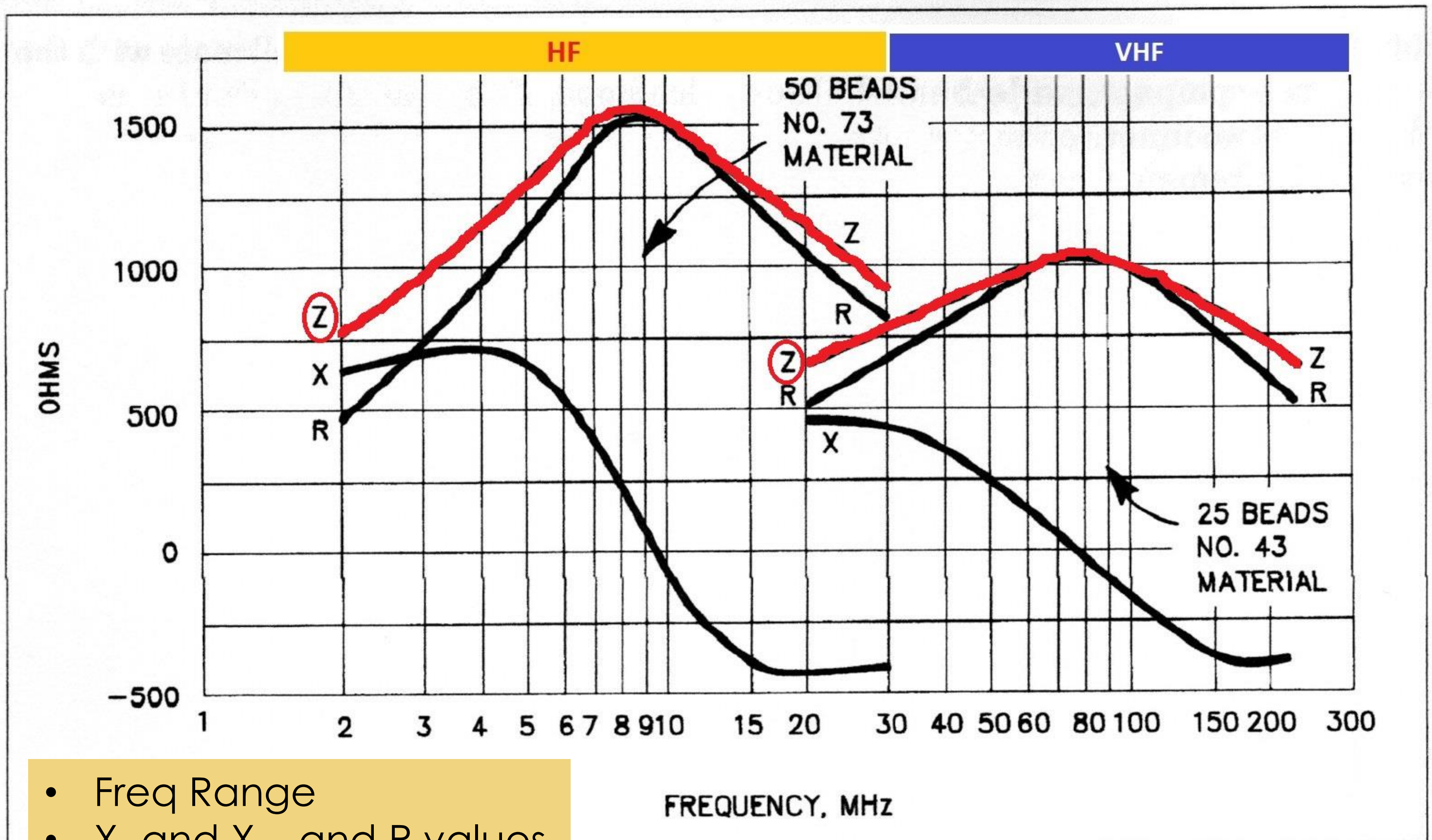
Fig 12 – Impedance of multi-turn choke on a core of the size/shape of Fig 4, on a material optimized for performance above 200 MHz (Fair-Rite #61). (Measured data)

#43 Mix Ferrite

#61 Mix Ferrite

Ferrite Impedance for #73 and #43 material

Ref 9

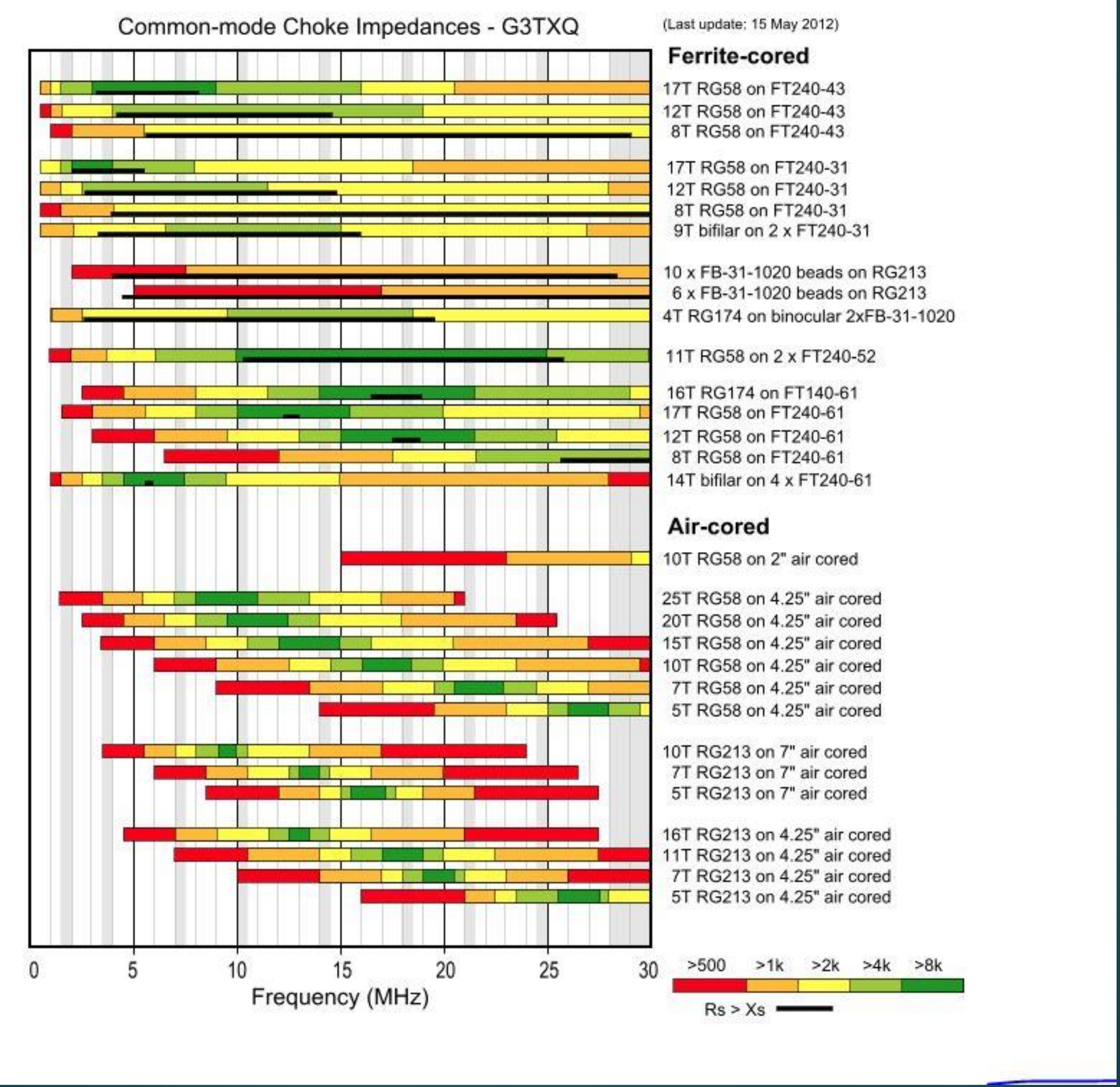


- Freq Range
- X_L and X_C and R values
- Point where mostly Resistive

F... us series impedance of coaxial-balun shield outer surface.

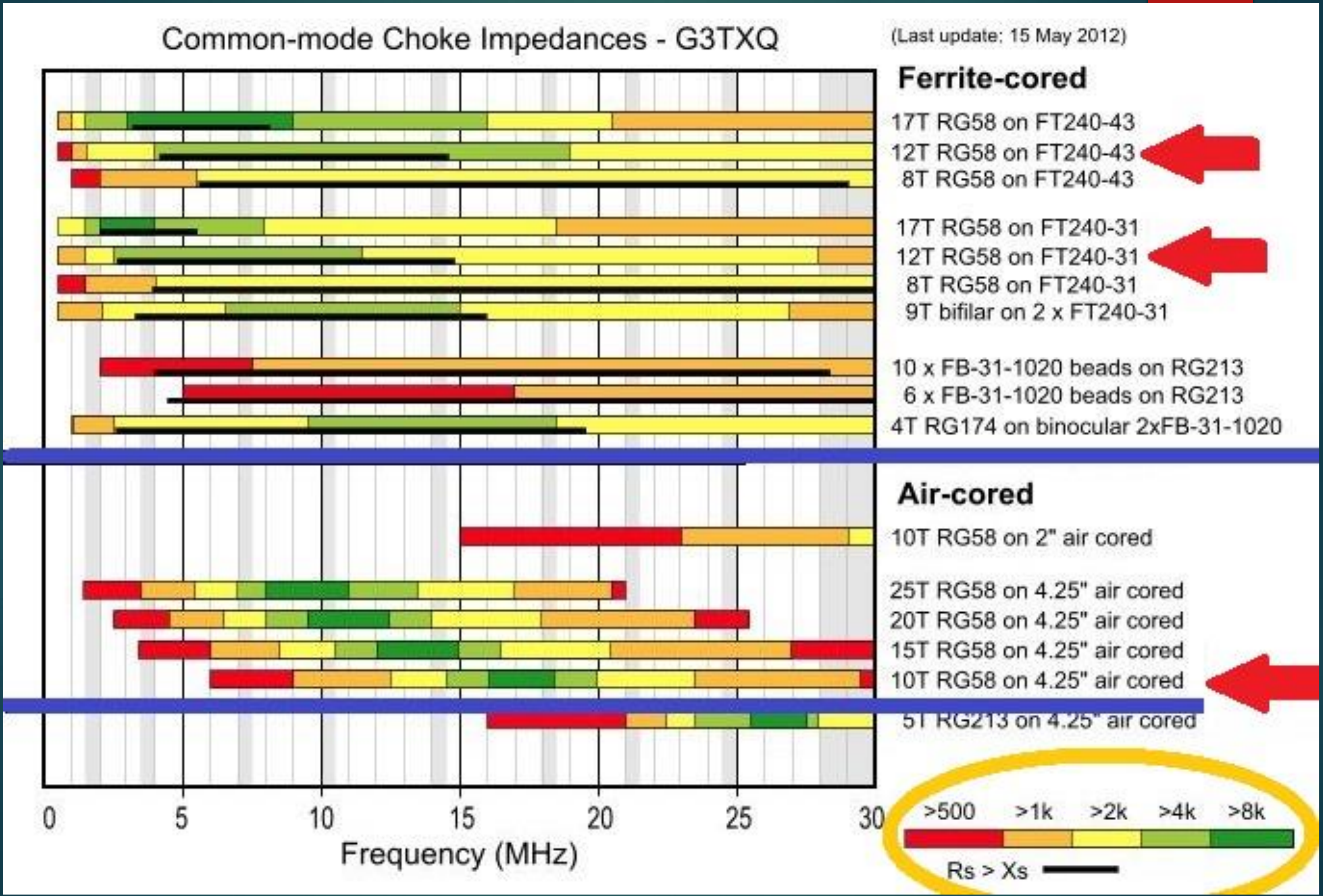
Common Mode Choke Impedances – G3TXQ

Ref 5



Common Mode Choke Impedances – G3TXQ

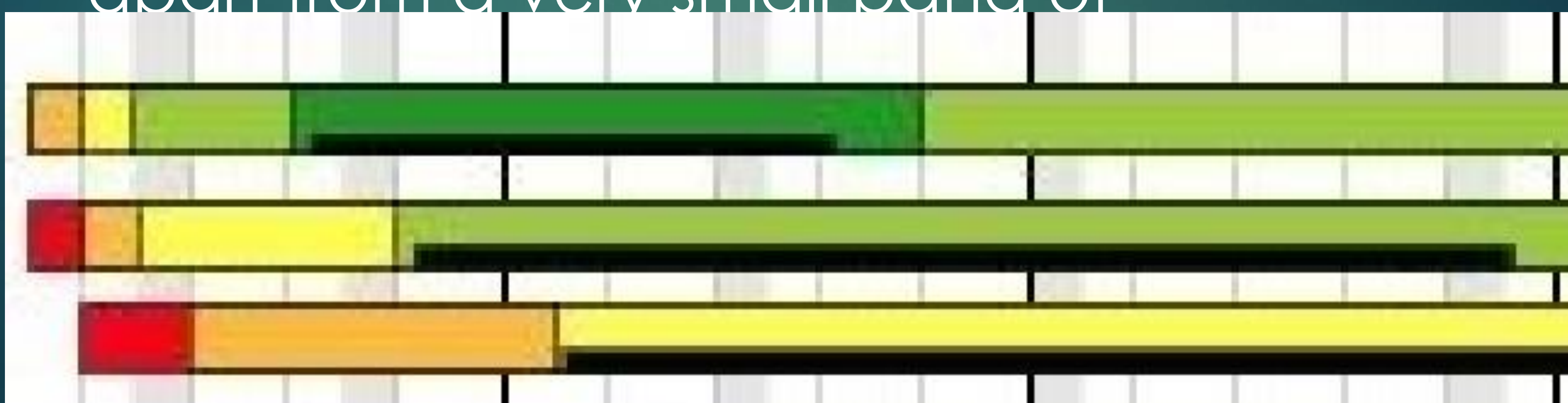
Ref 5



Reactive CM Choke Effects – G3TXQ

Ref 5

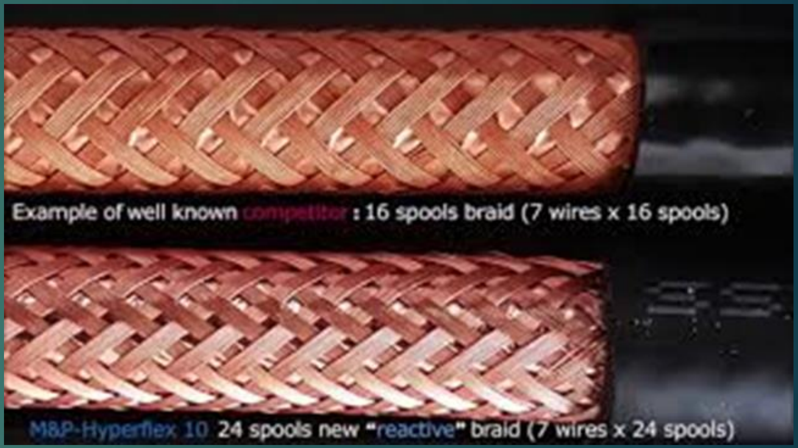
The black bars at the bottom of the coloured bars indicate the range of frequencies over which the choke impedance is predominantly Resistive - that is Rs>|Xs|. No black bars are shown for the air-cored chokes because their impedance is almost entirely Reactive apart from a very small band of

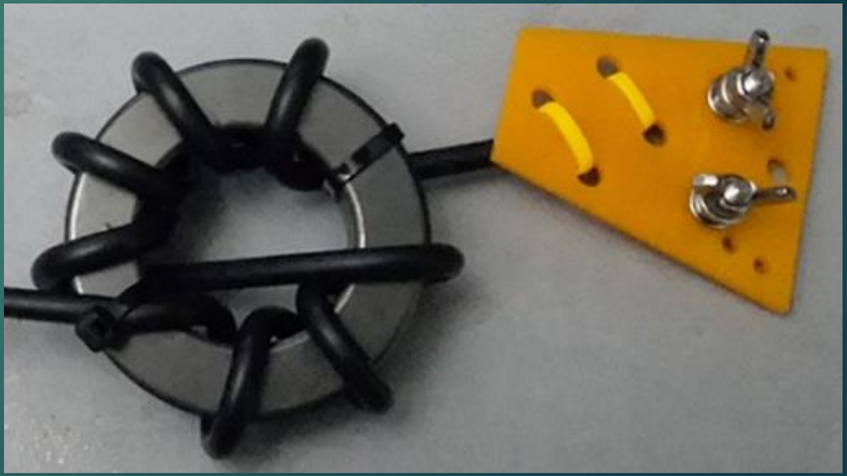


Reactive CM Choke Effects – G3TXQ

Ref 5

Reactive chokes have the disadvantage that they can "resonate" with a CM impedance path that is also reactive, but of opposite sign - in some cases that coupling can actually increase the CM





Ref 5

Why reactive chokes are undesirable

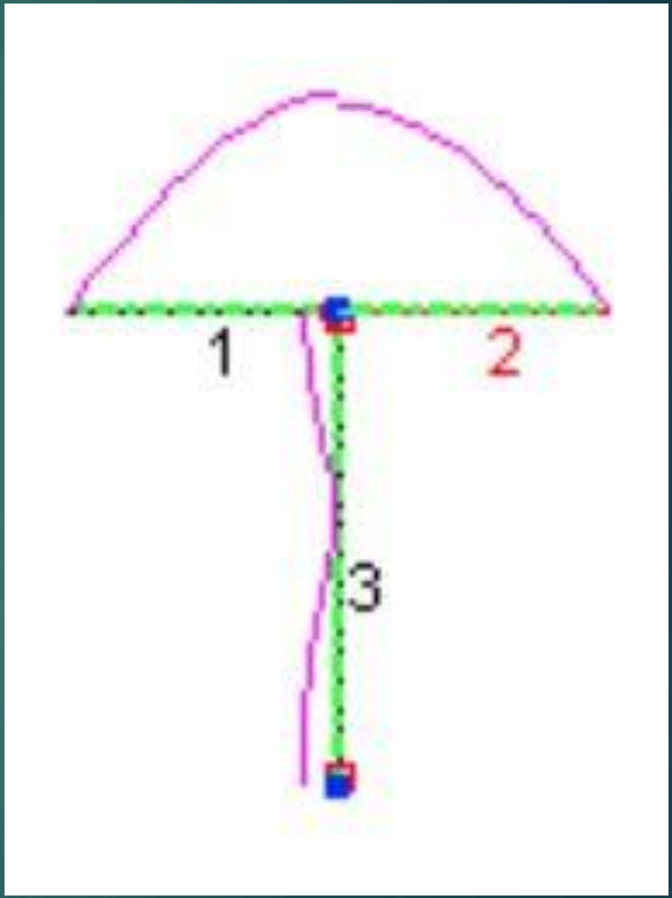
Let's take the example of a 20m half-wave dipole erected 30ft above average ground. It is fed by RG213 coax which drops vertically away from the dipole… 20 ohm ground

Reactive CM Choke Effects – G3TXQ

Ref 5

No Balun

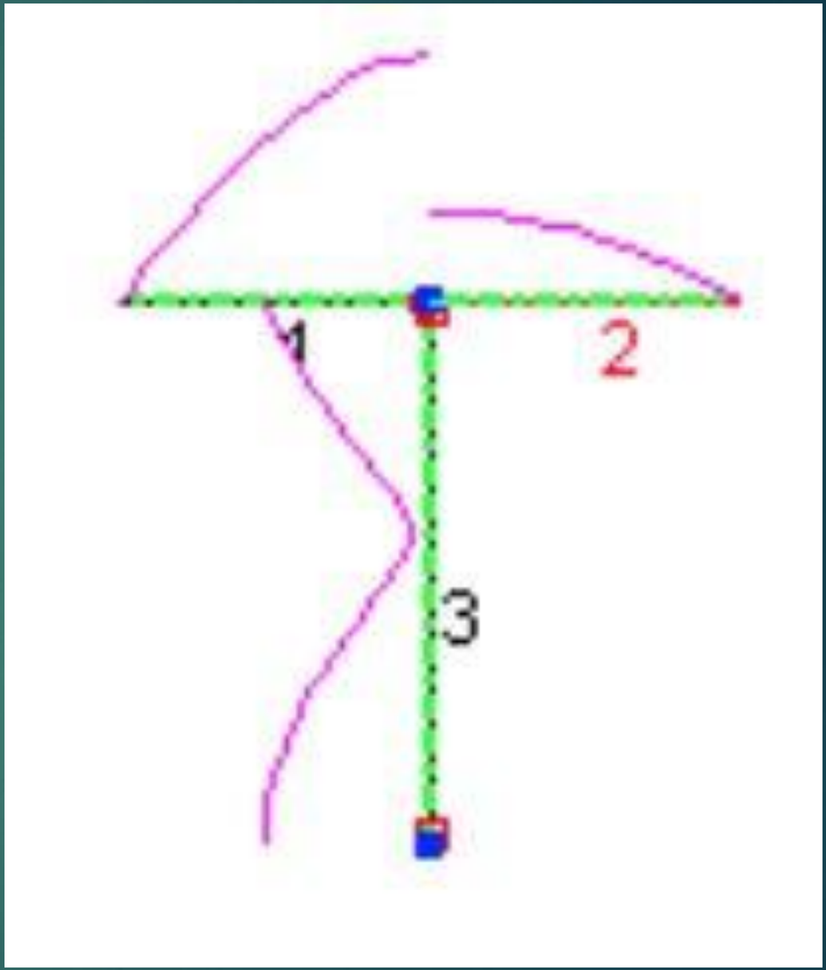
0.17A of the total 1A injected at the feed point will follow the Common-Mode braid path



Reactive CM Choke Effects – G3TXQ

Ref 5

But if we now install a reactive CM choke at the feed point, and it happens to … cancel the capacitive reactance of the braid path and create a fairly low impedance CM path of just 28Ω; the braid current will then rise to 0.64A - that's a majority of the current flowing at the feedpoint!

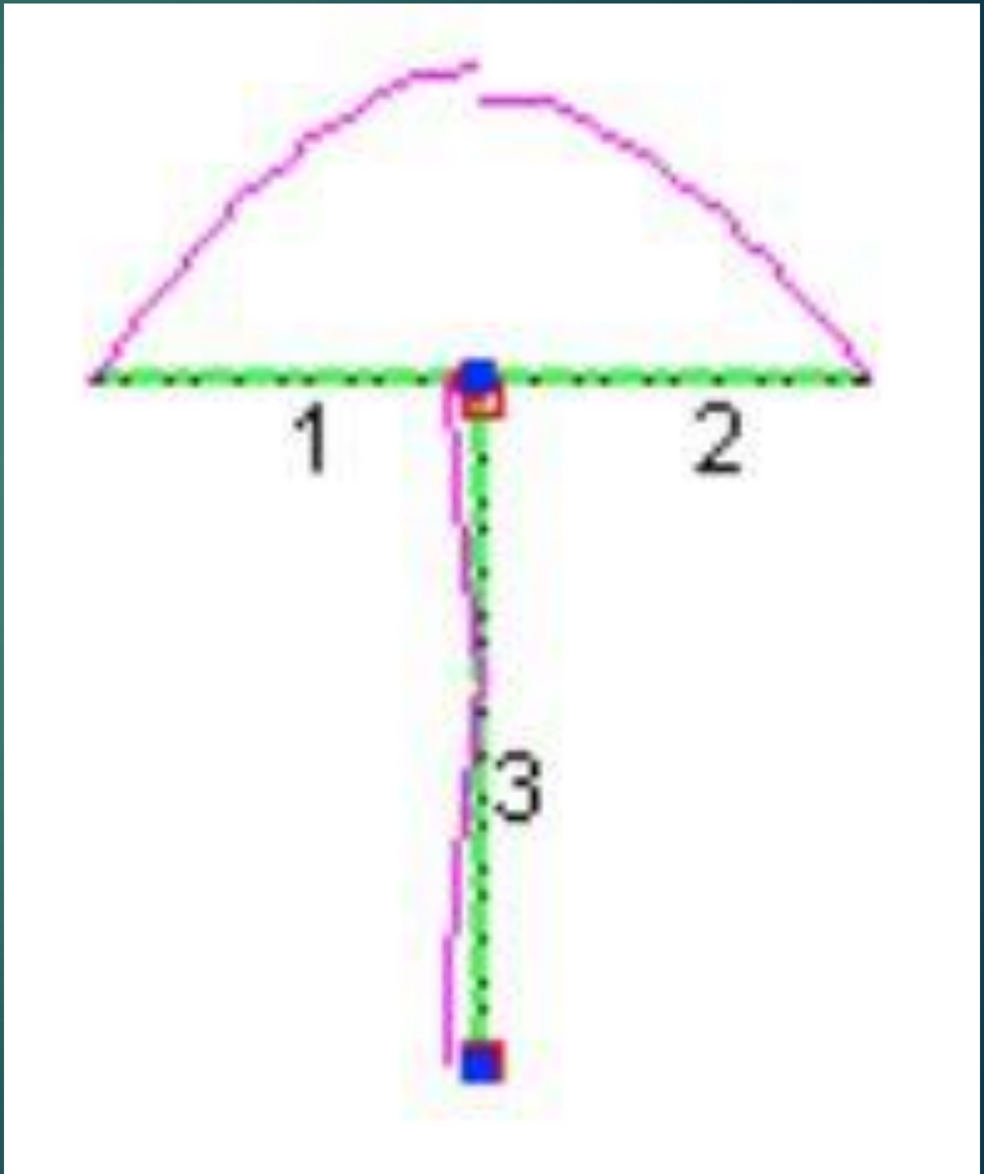


(NOTE: This is a worst-case example where the Common Mode Choke impedance exactly cancels the braid capacitance)

Reactive CM Choke Effects – G3TXQ

Ref 5

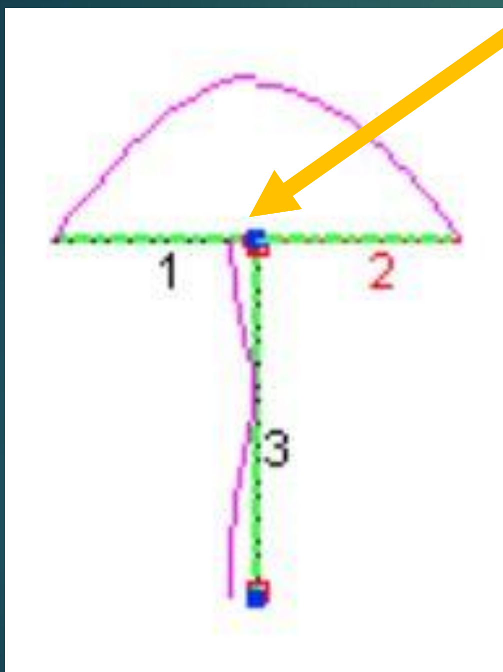
However, if we install a 200Ω Resistive choke at the feed point instead of a 200Ω Inductive choke we will effect an improvement



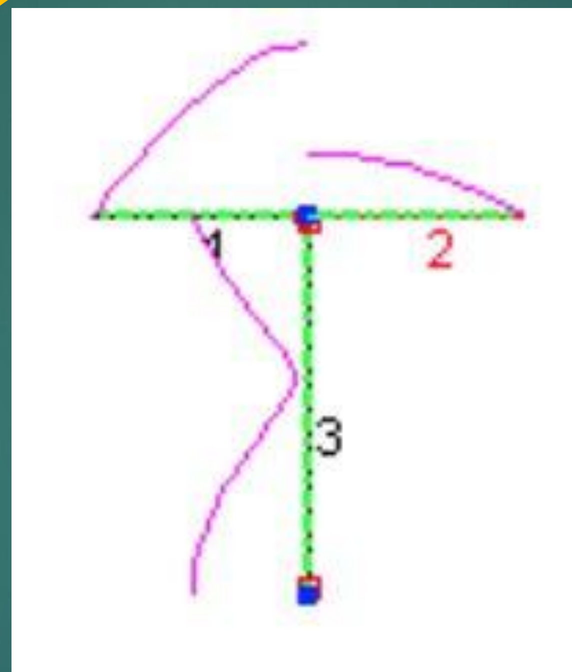
Reactive CM Choke Effects – G3TXQ

Ref 5

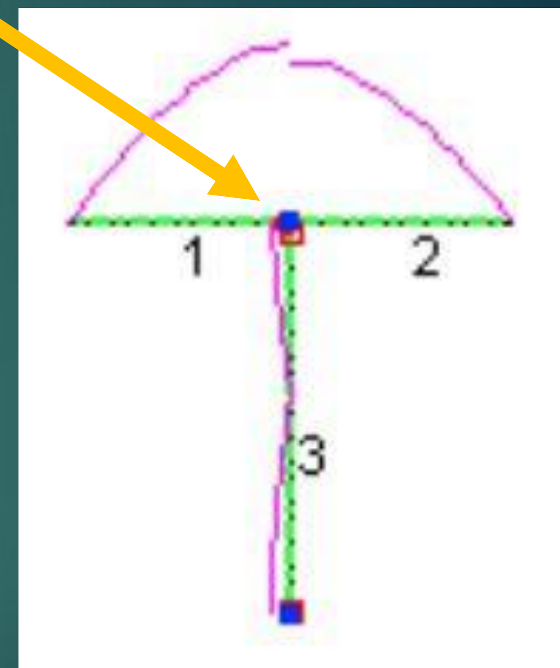
CM Current Reduction



Original Configuration



“Unlucky” Reactive Choke



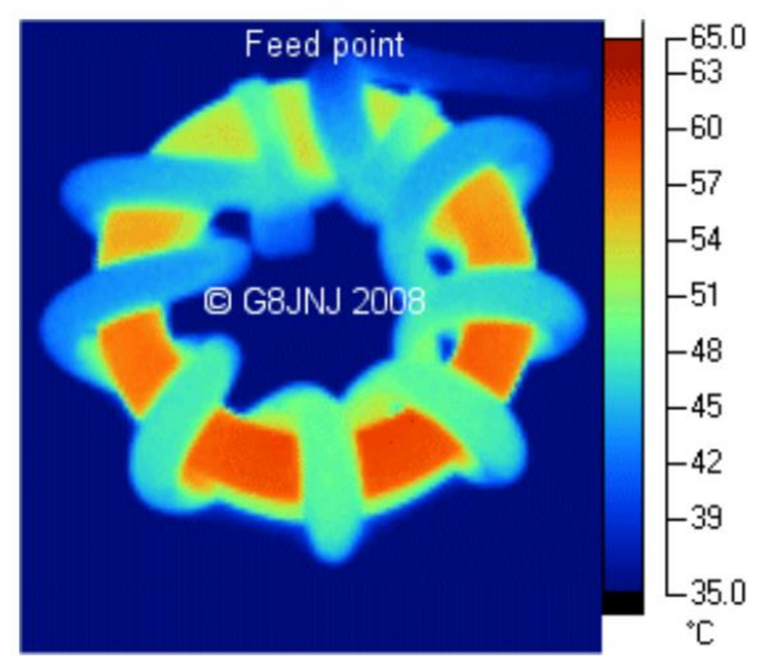
Resistive Choke

Resistive CM Choke Effects – G3TXQ

Ref 5

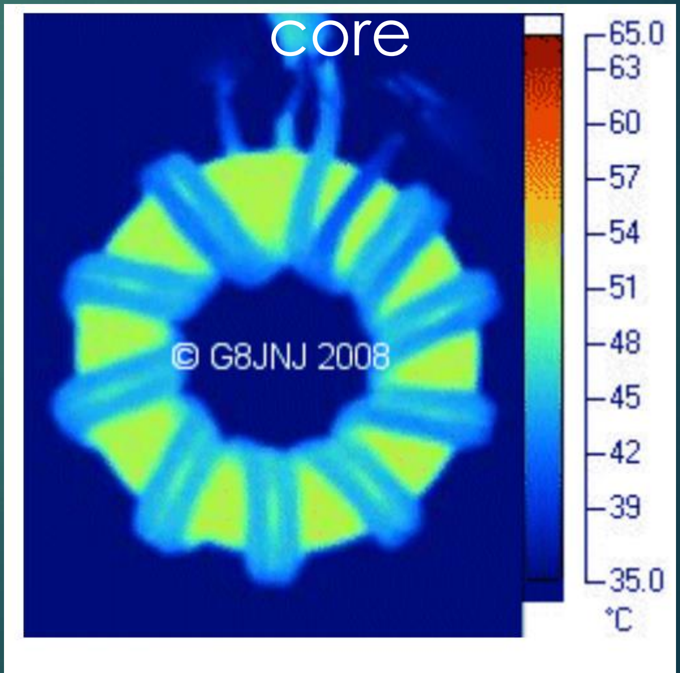
Resistive chokes have the disadvantage that if they have insufficient impedance to reduce the CM current to a very low value, there may be significant core heating.

Low Permeability core



100W for 5 minutes

High Permeability core



Ref 5

Aim to choose a choke which has a high impedance and is Resistive over the frequency range of interest.

For high power applications RG400 coax can be used in place of RG58 with little change to the choke impedances

The effect of a 1:1 balun on a resonant dipole – IZ2UUF

Ref 8

IZ2UUF 1:1 Balun Effect on a Resonant Dipole

Ref 1

K9YC General Rules For Baluns

1) More impedance is better.

2) All ferrite chokes should be designed to operate in the frequency range where their series equivalent resistance is large and their series equivalent reactance is small.

3) These conditions are satisfied at or near the choke's resonant frequency.

We do this by selecting a suitable material, core size, and number of turns

Varying Length Of Coax

If your antenna SWR is good at the antenna feed point, but not in the shack Old Timers will often tell you to either install a Common Mode Choke or vary the length of your coax until you get a decent SWR match.

You can also sometimes see this effect when using an external (to your radio) SWR bridge. SWR should be the same along the entire feed line. If the external meter shows one SWR and your radio’s built in meter shows another then you might have a common mode current problem.

Varying Length Of Coax

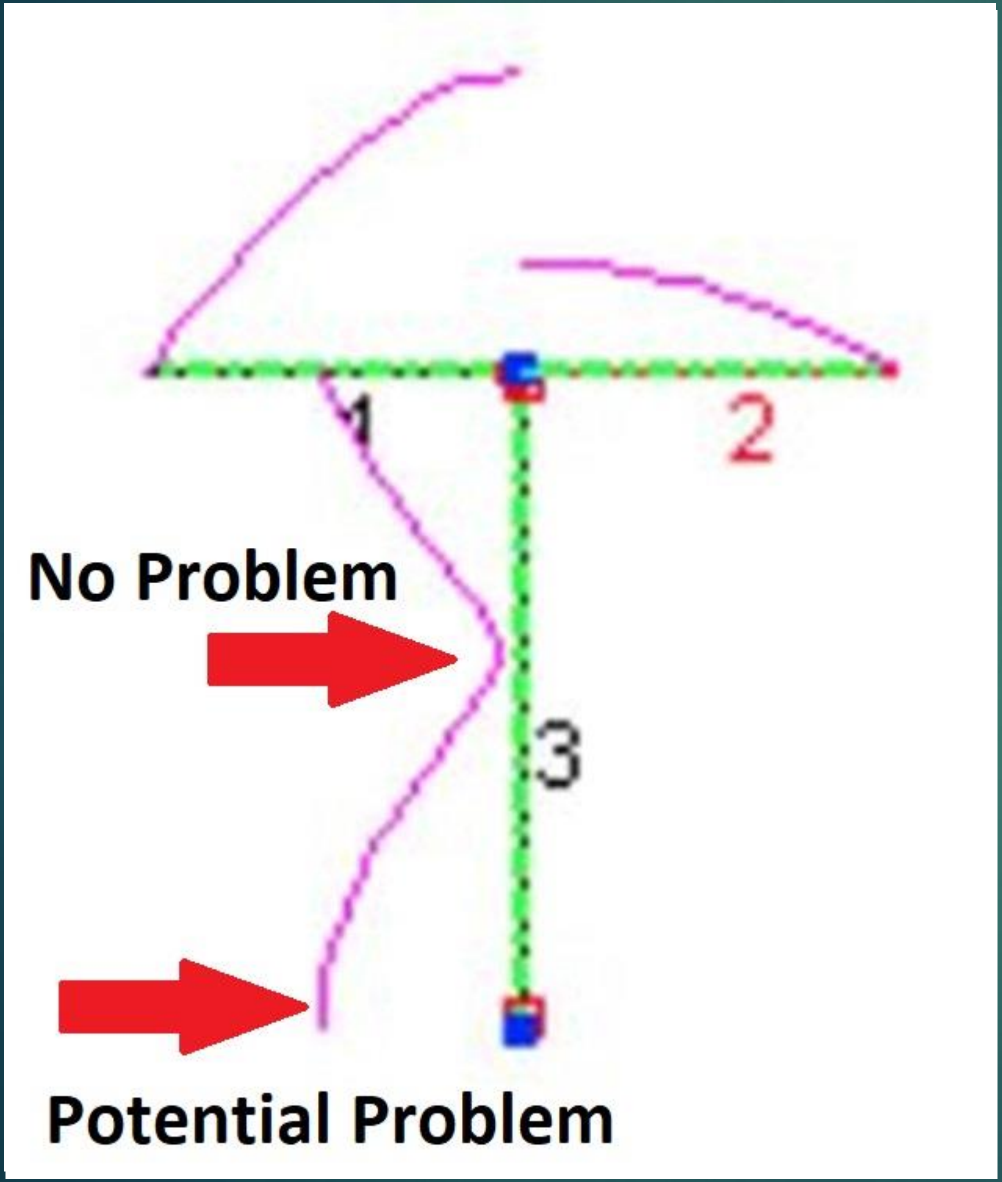
Ref 5

G3TXQ:

As we vary the length of the coax, the braid path impedance changes.

When the coax is close to a quarter-wave long the CM path is high-impedance and relatively little current flows along the braid whether we include a choke or not; when it is close to a half-wavelength long substantial current flows if we don't include a choke. But there is no length of coax where an "unlucky" reactive choke impedance could not make things worse!

Varying Length Of Coax



There are multiple 1/4 and 1/2 λ points in coax feeding multiband antennas.

A balun should be chosen to cover all cases where RFI exists

Varying Length Of Coax

Ref 5

G3TXQ:

The situation gets more complex with a multiband antenna - in fact the potential for a Reactive choke exacerbating the situation on at least one of the bands increases.

Varying Length Of Coax

Ref 5

The following table shows for a range of coax lengths from 20ft to 70ft on this model the braid current without a choke and with a worst-case inductive choke; it also shows the impedance required in a Resistive choke to keep the braid current 30dB below the level of the dipole current

Varying Length Of Coax for a 20 mtr Dipole

Ref 5

Coax length (ft)	Braid current (A) - no choke	Braid current (A) - inductive choke	Choke resistance (Ω) for -30dB braid current (0.03A)
20	0.03	0.07	No choke needed
25	0.08	0.37	1200
30	0.17	0.64	1100
35	0.54	0.63	900
40	0.14	0.39	750
45	0.05	0.17	600
50	0.02	0.04	No choke needed
55	0.02	0.04	No choke needed
60	0.07	0.24	950
65	0.16	0.5	1000
70	0.55	0.56	950

Ref 14

Tom Rauch, W8JI

- I mainly use 73 material [*high permeability*] for receiving applications in LOW POWER applications between 0.1 and 30 MHz.
- For high power applications at HF it is often necessary to use lower permeability cores.
- A downward slope in permeability with increasing frequency is useful for controlling impedance in broadband

Ref 14

Tom Rauch, W8JI

- We often assume heat means a core is very lossy or is "saturating", but this often isn't true. We must consider the power level, duty cycle, and ability of the core to dissipate heat and look at the full picture.
- Very small cores, such as small thin .5 inch diameter cores used on bead-type choke baluns, can only dissipate a fraction of a watt in open air

Radioworks comments on core saturation and power

Ref 16

- Rated power assumes an SWR of less than 2:1 unless otherwise noted. The rated frequency is 3.5 MHz. Duty-cycle is CW or SSB with normal processing. High duty cycle modes, like RTTY, may over stress a balun and require improvement in load matching, lowering the power, or switching to a higher power rated balun.
- When a ferrite core balun saturates, you will notice an upward drift in SWR long before the balun fails. Core saturation can be caused by too great a mismatch at the load (antenna) or by running too much power or a combination of both. If you see an upward movement in SWR, locate the problem

Power derating

		PEP Watts Rated						
Mode	Derating Factor	10,000	7,500	5,000	3,000	1,500	2,000	1,000
Continuous Carrier (AM,FM,Digital)	31.25%	3,125	2,344	1,563	938	469	625	313
Continuous Carrier - 50% on/off	43.75%	4,375	3,281	2,188	1,313	656	875	438
CW - 50% on/off	75.00%	7,500	5,625	3,750	2,250	1,125	1,500	750
SSB + Processor	75.00%	7,500	5,625	3,750	2,250	1,125	1,500	750
SSB - 50% on/off	100.00%	10,000	7,500	5,000	3,000	1,500	2,000	1,000

References

1. A Ham's Guide to RFI, Ferrites, Baluns, and Audio Interfacing, Revision 7, Jan 2019 by Jim Brown K9YC
2. Picture of Common Mode Noise Filters, Palomar-engineers.com
3. Ferrite Mix Selection, Palomar-engineers.com
4. Power, Grounding, Bonding, and Audio for Ham Radio by Jim Brown, K9YC
5. Amateur Radio (G3TXQ) - Common-mode chokes
6. Common Mode Current, DJ0IP http://www.dj0ip.de/common-mode-chaos/
7. #84: Basics of Ferrite Beads: Filters, EMI Suppression, Parasitic oscillation suppression / Tutorial by W2AEW, YouTube
8. The effect of a 1:1 balun on a resonant dipole, IZ2UUF, YouTube
9. Reflections II Transmission Lines and Antennas, M. Walter Maxwell, W2DU
10. Baluns: What They Do And How They Do It, Roy Lewallen, W7EL
11. The design of Ruthroff broadband voltage transformers – M. Ehrenfried – G8JNJ

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12. A Ham's Guide to RFI, Ferrites, Baluns, and Audio Interfacing Revision 7 Jan 2019 by Jim Brown K9YC http://k9yc.com
13. Baluns, Charlie, M0PZT, http://www.m0pzt.com/baluns/
14. Balun and Transformer Core Selection, Tom Rauch, W8JI, https://www.w8ji.com/core_selection.htm
15. How to choose feed line chokes, line isolators, baluns, or ununs for coax fed dipoles, verticals, hex beams, slopers, loops, windom, OCF, G5RV, ladder line, and yagi antennas, By Bob Brehm, AK6R, RFI Tip Sheet #RC-1, Palomar Engineers
16. Radioworks comments on core saturation, http://radioworks.com/nbalun.html

Questions?

"There is no free lunch."

Frequent quote from W8JI in regards to claims of improved antenna designs

Paraphrasing K9YC:

'Don't let your inability to make a perfect antenna prevent you from making an effective one.'