“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 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

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

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.
Insulating rings around connectors prevents chassis contact!
Pin 1 Problem

Nice Radio: Use Pin 1
Pin 1 Problem

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

• Hint: It isn’t an audio connector shell!
  – They should be, but they are not!
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

W2AEW YouTube Tutorial #84 - Ferrite Beads
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/
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

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

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

- Freq Range
- $X_L$ and $X_C$ and R values
- Point where mostly Resistive
Common Mode Choke Impedances – G3TXQ

Ferrite-cored
17T RG58 on FT240-43
12T RG58 on FT240-43
8T RG58 on FT240-43
17T RG58 on FT240-31
12T RG58 on FT240-31
8T RG58 on FT240-31
9T bilhar on 2 x FT240-31
10 x FB-31-1020 beads on RG213
5 x FB-31-1020 beads on RG213
4T RG174 on binocular 2xFB-31-1020
11T RG58 on 2 x FT240-62
16T RG174 on FT140-61
17T RG58 on FT240-61
12T RG58 on FT240-61
8T RG58 on FT240-61
14T bilhar on 4 x FT240-61

Air-cored
10T RG58 on 2” air cored
25T RG58 on 4.25” air cored
20T RG58 on 4.25” air cored
15T RG58 on 4.25” air cored
10T RG58 on 4.25” air cored
7T RG58 on 4.25” air cored
5T RG58 on 4.25” air cored
10T RG213 on 7” air cored
7T RG213 on 7” air cored
5T RG213 on 7” air cored
16T RG213 on 4.25” air cored
11T RG213 on 4.25” air cored
7T RG213 on 4.25” air cored
5T RG213 on 4.25” air cored
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

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
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
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

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)
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

Original Configuration

“Unlucky” Reactive Choke

Resistive Choke

CM Current Reduction
Resistive CM Choke Effects – G3TXQ

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

High Permeability core

100W for 5 minutes
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

IZ2UUF 1:1 Balun Effect on a Resonant Dipole
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
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.
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!
There are multiple \( \frac{1}{4} \) and \( \frac{1}{2} \lambda \) points in coax feeding multiband antennas.

A balun should be chosen to cover all cases where RFI exists.
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.
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.
<table>
<thead>
<tr>
<th>Coax length (ft)</th>
<th>Braid current (A) - no choke</th>
<th>Braid current (A) - inductive choke</th>
<th>Choke resistance (Ω) for -30dB braid current (0.03A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.03</td>
<td>0.07</td>
<td>No choke needed</td>
</tr>
<tr>
<td>25</td>
<td>0.08</td>
<td>0.37</td>
<td>1200</td>
</tr>
<tr>
<td>30</td>
<td>0.17</td>
<td>0.64</td>
<td>1100</td>
</tr>
<tr>
<td>35</td>
<td>0.54</td>
<td>0.63</td>
<td>900</td>
</tr>
<tr>
<td>40</td>
<td>0.14</td>
<td>0.39</td>
<td>750</td>
</tr>
<tr>
<td>45</td>
<td>0.05</td>
<td>0.17</td>
<td>600</td>
</tr>
<tr>
<td>50</td>
<td>0.02</td>
<td>0.04</td>
<td>No choke needed</td>
</tr>
<tr>
<td>55</td>
<td>0.02</td>
<td>0.04</td>
<td>No choke needed</td>
</tr>
<tr>
<td>60</td>
<td>0.07</td>
<td>0.24</td>
<td>950</td>
</tr>
<tr>
<td>65</td>
<td>0.16</td>
<td>0.5</td>
<td>1000</td>
</tr>
<tr>
<td>70</td>
<td>0.55</td>
<td>0.56</td>
<td>950</td>
</tr>
</tbody>
</table>
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 transformers.

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

- 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 immediately. If you must stay on the air, lower power.
## Power derating

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

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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.’