# What is a "Balun" and Why Do We Need One, Anyway? Part 1

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Nov. 18 2017

A quick and dirty answer is that we want our ***computers not to freeze*** and our ***appendages*** (noses, lips, etc) ***not to get "bit"*** by RF current on exposed conductors in our radio shacks, such as microphones, cases and keyers.....and a BALUN is the mysterious device that accomplishes this goal....but this little series of articles is designed to answer the question in more depth than just that, so that the reader actually understands these devices, and can even construct them!

Figure 1 below shows where it all starts: a transmitter, modelled as a perfect signal source. With two wires coming out of it, since electrons can't "pile up" any one place for very long (without a static spark discharging them eventually).....the current coming out of one wire has to exactly equal the current coming in the other wire. At every instant. (This is a version of Kirchoff's current law, and comes from Maxwell's equations of electromagnetics.)

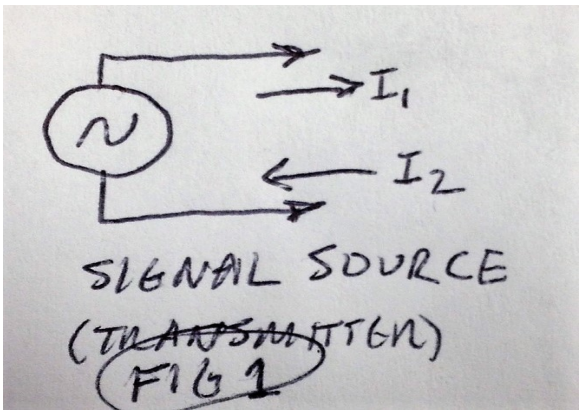
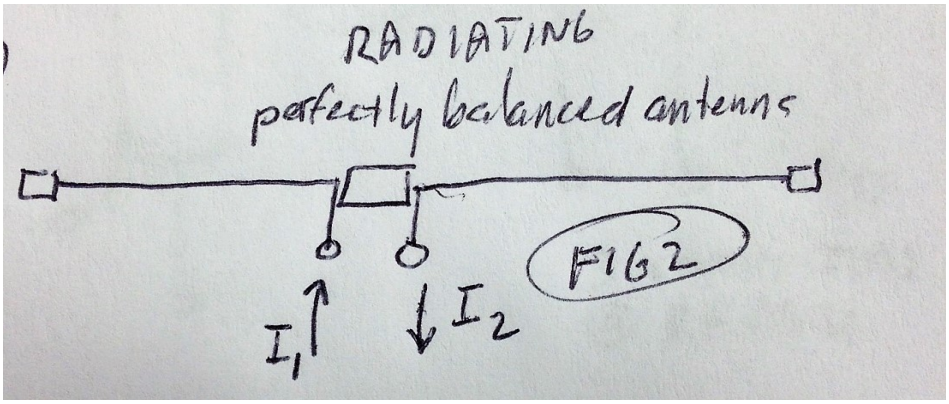


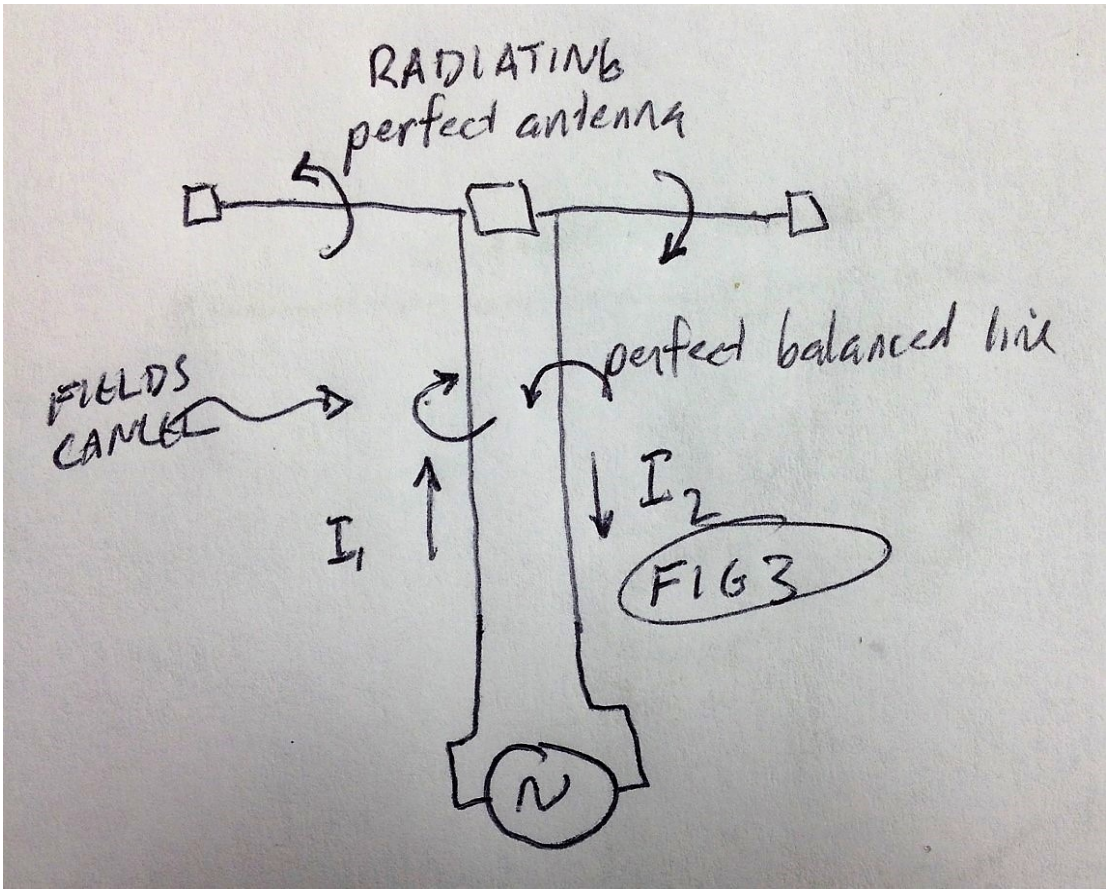
Figure 2 below shows where it is supposed to end – in a perfect antenna, which is perfectly "balanced" --- both wires are identical, and the trees, houses, everything around them are perfectly symmetrical, so that to an RF signal, both wires have exactly the same input impedance (Z); the wires look identical but they go in opposite directions, which is what allows this fascinating wire-device to magically cause an alternating current to spring forth and propagate for millions and millions of miles as an electromagnetic wave, the energy literally leaving the wires and entering the space surrounding them.



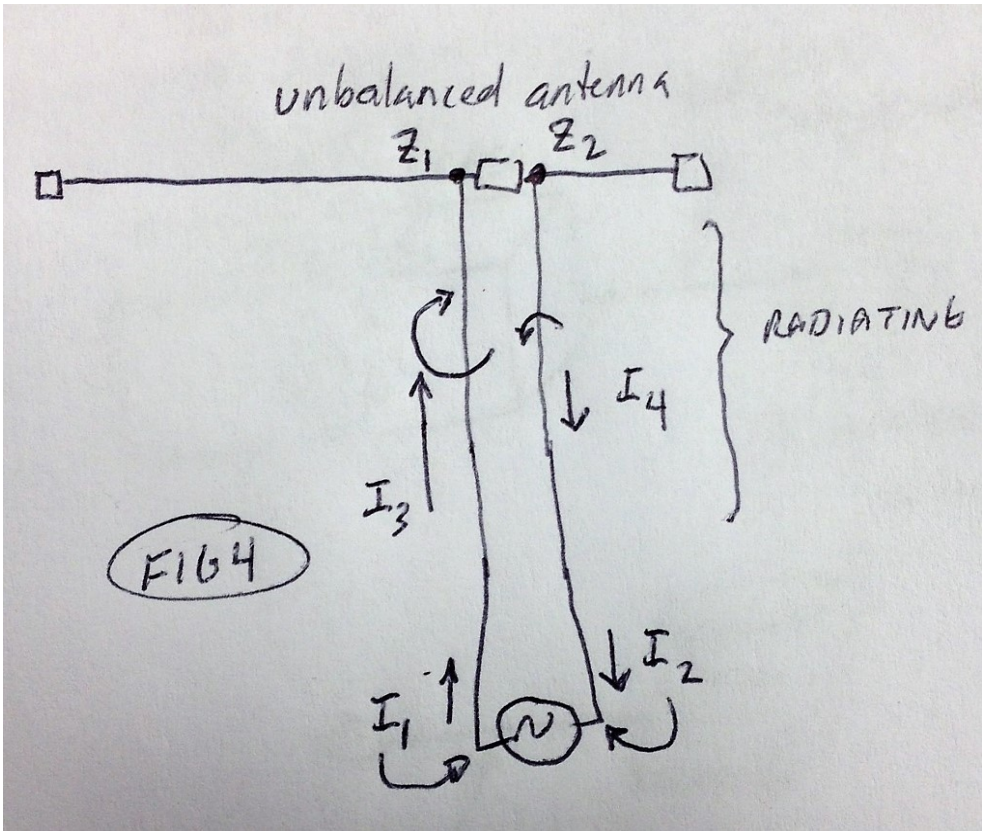

Remember for a moment that along either of those wires, the steadystate RF (rms) current and voltage change as we move along the length of the wire from the center to the end. Typically in a tune half-wavelength long antenna, the currents are maximized at the center and minimized at the ends, and the voltages the opposite. So the input impedance at the center is somewhere between 50 and 75 ohms, and measured at the ends, is thousands of ohms. The point is that along wires carrying RF energy, there can be nodes and antinodes of current and voltage.

Figure 3 below shows our perfect transmitter connected through a perfect balanced transmission line (think a perfect ladder line or open-wire transmission line) to our perfectly balanced antenna.

Because everything is so perfect and balanced, the currents in the transmission line are exactly equal and opposite at every point along the line. Using that Right Hand Rule we remember from Physics, we can predict the magnetic field that the current creates, and we see that the fields from the two balanced wires of the balanced transmission line cancel each other out (which doesn't happen perfectly in real life, because they are a finite distance away from each other so the fields aren't perfectly equal and opposite).




Now let's return to the REAL WORLD, where wires aren't perfectly equal in length, and the environment around them is not perfectly symmetrical --- so the input impedance of one of the wires of our antenna is no longer exactly equal to the impedance presented by the other wire.....




And as a result, the currents in the two balanced line transmission line are no longer perfectly equal --- and their fields no longer perfectly cancel. In fact, the transmission line itself is now part of the antenna system and is radiating some energy just like the antenna.....

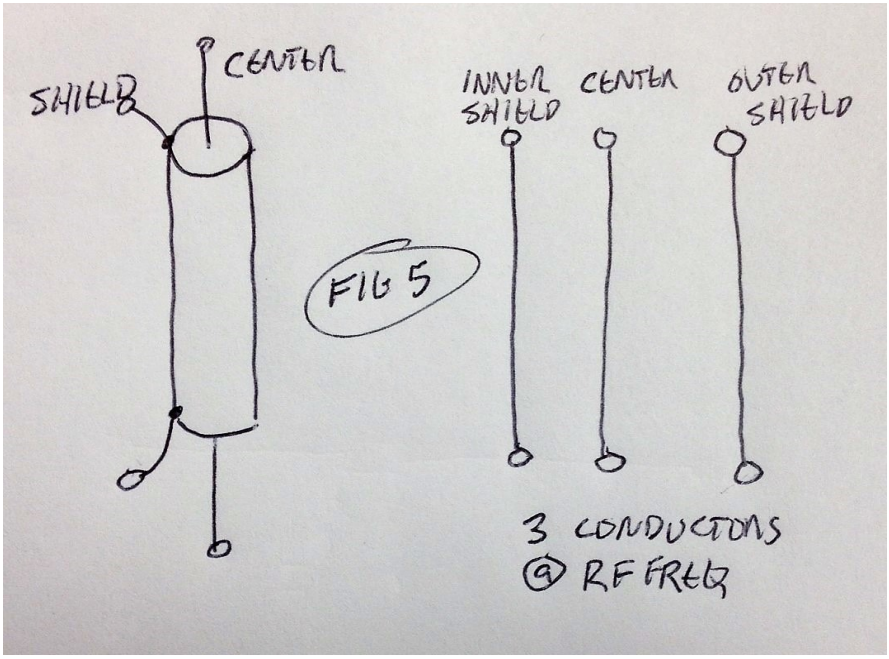
Note that this can happen even if we are using balanced transmission line --- the imbalance in the antenna (represented above by having one wire be decidedly longer than the other) – causes an imbalance in our transmission line and forces it to become part-antenna. While if we are lucky it will put out exactly the right signal to reach the fellow we're trying to reach (that CAN happen!) --- more likely it will result in more of a tendency for our station to be “hot” and digital and computer devices to be more likely to freeze or be upset. As we'll see later, a BALUN can help deal with the undesirable effects. But we're not there yet....

A lot of us use COAXIAL TRANSMISSION LINE (“unbalanced” line) for our antenas, so it is time to examine the conductors of coax, which are shown in Figure 5. Because RF current flows not through the whole conductor, but moreso through the “skin” of the conductor, the coax line is much more complicated than the balanced transmission line, which has only two skins (one on each wire). The coaxial cable has THREE skins (conductors):

1. the inner conductor wire
2. the INSIDE of the outer shield

3. the OUTSIDE of the outer shield

Because of the lack of a field in the middle of the copper braid (there is basically zero field in the middle area between the inner and outer surfaces of the braid shield) --- this tells us that the currents of the first two conductors cancel, being equal and opposite. (Otherwise, there would be a resultant field inside the bulk copper braid). Because of imperfections (e.g., the copper isn't perfectly conductive) this may not be perfectly true, but to a first approximation, the inner conduct and the INSIDE of the outer braid have equal and opposite currents---and their fields cancel. So far, so good.




The PROBLEM comes when the current in that 3rd conductor --- the outer skin of the shield braid--- isn't zero. That current has no opposite current to balance it, and if it exists --- then the shield is an ANTENNA and is radiating....

And that also means that along the length of the outside of the braid....the voltage and current will be different, with nodes and anitnodes at various places.

Now let's see how this impacts ham radio operators running a real station with imperfect antennas and computers that seem to freeze up..... we now have all the information needed to explain this.

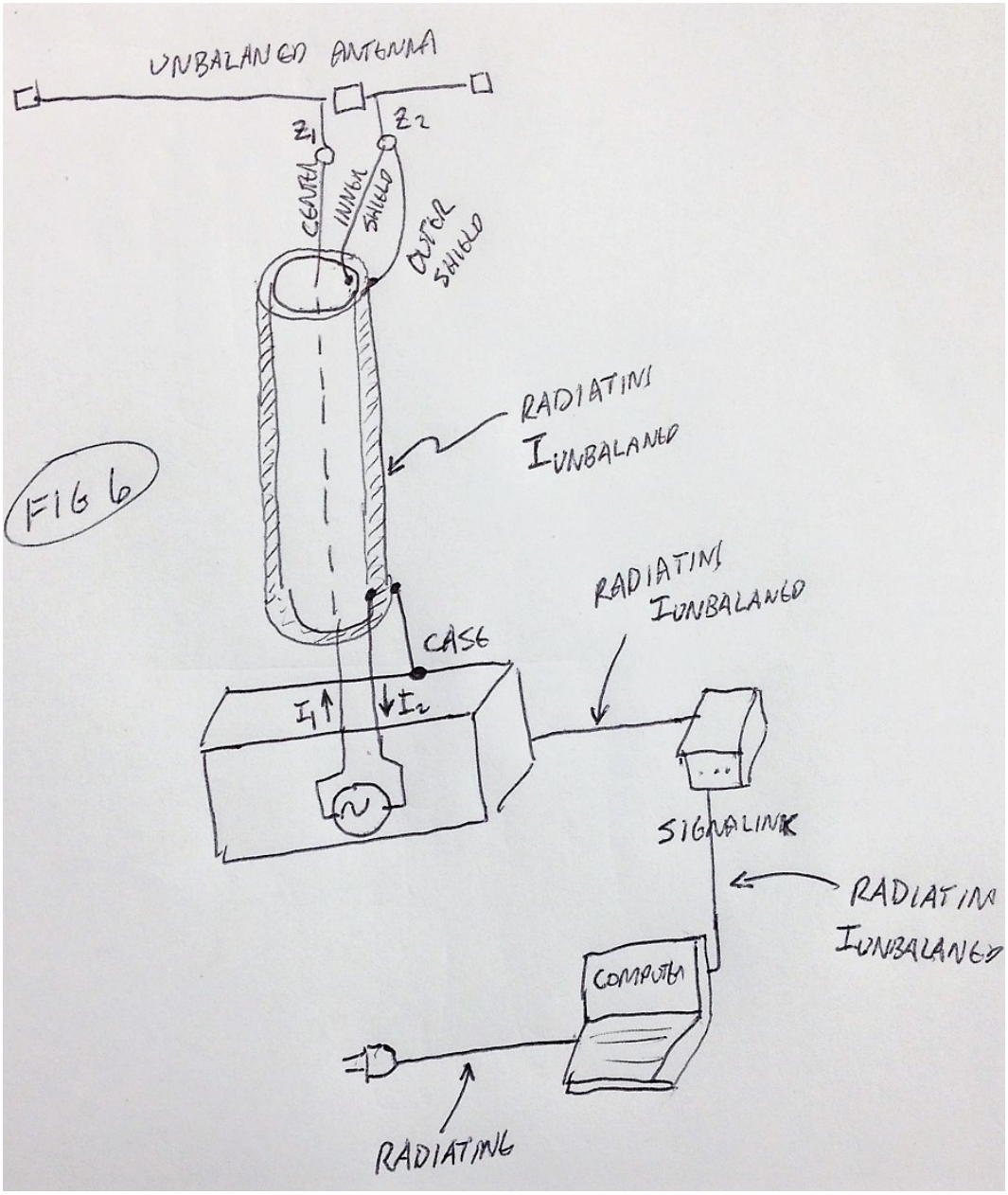



Figure 6 sums it all up. Our transmitter put out equal and opposite currents I1 and I2...but our imperfect and unbalanced antenna has one of its wires connected to the THIRD CONDUCTOR – the outer shield of the coax...and that outer shield is connected to the CASE of our transmitter, which is one way or the other (through actual wires or capacitive coupling) connected to our Signalink (and microphone) and that connects to the Computer, and the computer connects to the house wiring and on and on....and all of this can now be part of our antenna....

So the current coming out of the braid of our coax sees a part of an antenna as part of the impedance it sees--- but it also sees (in parallel) the outer surface as a additional path, leading back to

the case of our transmitter and the Signalink and on and on....and some of the current heads THAT way....

Now any time we have an RF current running along an unbalanced conductor, it is going to have nodes and antinodes --- meaning at any instant the voltage at point A might be 10 V rms, while the voltage a few feet away at point B may be 20 V RMS --- and you now see the problem. The “ground” potential of the case of the transmitter is no longer equal to the “ground” potential of the signalink, which is different now from the “ground” potential of the Computer..... and currents are flowing everywhere.

All it takes is 0.6 Volts to cause some diode or transistor to conduct; or maybe 2 volts to change a logic 0 to a logic 1 or vice versa on some chip input; and all this RF running around causes USB ports (which are very high speed serial transmission lines, running as fast as 480 MHz) to see truly WILD signals that don't make any sense at all.. and may cause the circuits trying to deal with those inputs to have wild voltage show up as both inputs, and on their internal memory address lines...which may cause them to access portions of their firmware out of sequence.....and crash the internal microcomputer or logic states of the USB port, or even the entire computer.....

And now you see how it is these unbalanced, unwanted, radiating currents flowing in places where we DIDNT WANT THEM.....that both bite your lip if you touch the mic, and foul up your computer if you are trying to use it.

And the purpose of the mysterious BALUN is to decrease (by orders of magnitude if possible) all these unwanted currents.

In Part 2 we'll look at how Baluns accomplish this task.