Bob's TechTalk #22
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Impedance (Part VII of X)

Baluns:

The Skin Effect:
Before we begin our discussion on baluns, let's review a basic law of RF energy, the *skin effect*. When RF energy flows along a conductor, it tends to flow only near the surface of the conductor. As the frequency increases, the depth in which the energy flows in a conductor becomes less and less. This is called the skin effect, and is the reason high power coils are silver plated and often made of hollow tubing instead of solid material. At RF frequencies the size and conductivity of the surface area, and not the cross-sectional area, is important for controlling losses.

Balanced vs. Unbalanced Feedlines:
In previous articles we discussed two types of feedline, balanced and unbalanced. Balanced feedline normally has two parallel conductors separated by insulating material (sometimes air.) TV twin-lead is a balanced feedline; ladder-line and open-wire line (held apart with insulators every few feet) are other types of balanced feedline. Ideally, the energy flowing in each conductor is equal but is traveling in opposite directions. The electromagnetic field generated by the currents in the conductors tend to cancel due to the balanced nature of the current flow. This canceling occurs at a distance from the feedline. Close objects will influence the field and care must be taken running balanced feedline to keep it away from nearby objects, especially conductive ones. Neither conductor of a balanced feedline is connected to ground. Common balanced feedline normally has an impedance in the range of 200 Ω to 600 Ω. I've also seen 75Ω balanced feedline referenced.

Unbalanced feedline normally has one side connected to ground. Coaxial cable is an unbalanced feedline. Energy flows in coaxial cable along the outer surface of the inner conductor and the inner surface of the shield. An electromagnetic field is developed in the dielectric material between the two conductors. Energy flows equally in the two conductors but in opposite directions. Normally, no energy travels along the outside of the outer conductor; that's why it is called a shield! Coaxial cable is popular because it isn't influenced by its surroundings. Common coaxial feedline has impedances in the range of 50 Ω to 90 Ω.

Antennas can also be balanced or unbalanced. A dipole antenna and a quad or yagi driven element are examples of balanced antennas (unless they use a matching device designed for unbalanced feed.) A quarter wave vertical is an example of an unbalanced antenna.

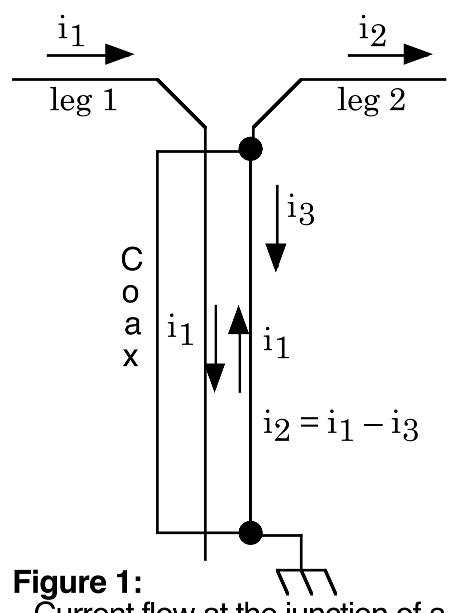

Figure 1: Current flow at the junction of a dipole and an unbalanced feedline.

The Problem:
What happens when an unbalanced feedline is used with a balanced antenna? A common example is a simple dipole fed with 75 Ω RG-

59U coax. Figure 1 shows the junction of a dipole antenna fed with coaxial cable.

Let's assume for the sake of simplicity that there is no reflection due to a mismatch of impedances. The center conductor of the coax connects to one leg of the antenna and the RF current (i_1) on the inside coaxial conductor travels into that leg; it has nowhere else to go. Thus the current entering the leg is also i_1. The story is different for the antenna leg attached to the shield. RF current (i_1) traveling on the inside of the shield can travel along two different paths, either onto antenna leg (i_2) or back along the outside of the coaxial cable shield (i_3) to ground through the radio. Because of the skin effect the outside and inside of the shield look like separate conductors to RF. Energy that travels back along the outside of the coaxial cable radiates. It can affect the antenna radiation pattern and cause TVI, RF feedback in the radio, a hot microphone, and many other evil effects. In a normal antenna setup, the length of the feedline doesn't affect the SWR (other than caused by losses.) However, with RF flowing on the outside of the shield, that path becomes a part of the antenna that changes with the feedline length, and that *will* affect the SWR.

If the path along the outside of the shield to ground happens to be an odd number of quarter wavelengths, then the point where the outside of the shield connects with the antenna will have a high impedance and very little RF will flow along the outside of the shield. On the other hand, if it is an even multiple, then that point is very low impedance and problems may arise!

RF can also be introduced to the outside of the feedline shield by radiation from the antenna itself. That is why the feedline should be brought out perpendicular to the center of a balanced antenna for a distance of at least a quarter wavelength whenever possible. This way RF is picked up equally from each antenna leg and cancels on the feedline.

How serious of a problem is created using unbalanced line with a balance antenna varies significantly. I've used numerous dipoles fed directly with coaxial cable very successfully. A simple adjustment of the length of feedline will often reduce any problems that are encountered. However, it is a trade-off, and while OK for temporary antennas, a permanent installation should be designed to keep RF off the outside shield.

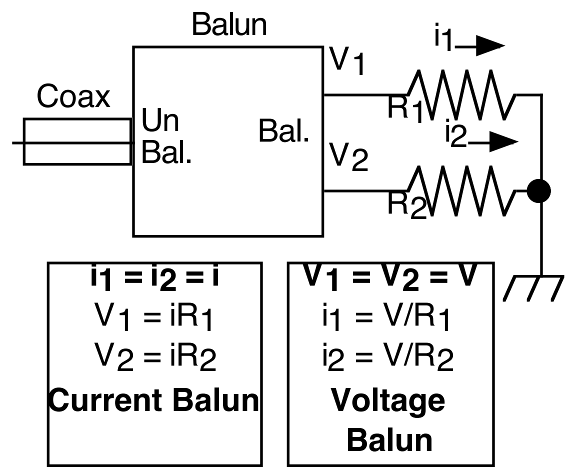

Figure 2:
Voltage vs. Current Balun

Enter the Balun:

A balun (short for ***bal***anced/***un***balanced) is a device that allows connecting a balanced device and an unbalanced device. Since balanced and unbalanced feedlines tend to have different impedance ranges, baluns also allow matching different impedance ratios. 1:1, 4:1, 6:1, 9:1 ratios are common ratios. There are many different designs for baluns, but there are just two types: *current* baluns and *voltage* baluns. Figure two shows a balun fed with coax with the balanced side connected to two resistors each going to ground (these represent the legs of a balanced antenna.) If the two resistors are of different values, a current balun will send the same RF current (i) through each resistor, and this current then determines the voltage across the resistor by Ohm's law. The voltage balun places the same RF voltage (V) across each resistor and the voltage then determines the current flowing through the resistor by Ohm's law. If the resistors are the same value, then both baluns operate similarly. Since antennas are current devices, the current balun is generally considered superior.

Balun Designs:
Numerous balun designs exist. The transformer type uses either air-core coils or, more popularly, ferrite-core coils. Air-core baluns are generally bulky, ferrite-core baluns are more compact, but are easily damaged if the ferrite core becomes saturated. Since they are transformers they can easily be designed for different impedance ratios. Another type of common balun is the choke balun. They work by creating an high impedance on the outside of the coax shield, thus preventing (or 'choking off') current flowing along the outside of the shield. The simplest choke balun is made by coiling eight to ten turns of the coaxial cable feedline near the antenna. This works well on the 20 - 10 meters bands and can be made to work across the HF band. The effect on the energy flowing within the coax is insignificant. Another type of choke balun is the 'bead balun' or W2DU balun. By placing ferrite beads over a length of coax, an effective 3.5 - 30 MHz choke can be constructed. Using another ferrite bead material, baluns that work in the VHF range are also possible. Since the beads only see the energy along the outside shield of the cable, the chance of them saturating and being damaged is very slim.

While many baluns are broadband, a simple frequency dependent balun may be made using a piece of coaxial cable that is electrically one-half wavelength long at the frequency desired. Just bend the piece of coax into a "U" shape or loop and bring the ends together and against the ends of the feedline. Tie all the shields together and connect the inner conductor of the feedline to the inner conductor of one end of the piece of coax. Also tie this point to one leg of the antenna. Tie the other antenna leg to the inner conductor of the remaining end of the piece of coax. This type balun also steps up the impedance at a ratio of 1:4, making it ideal for feeding folded dipoles and other antennas that have 200Ω to 300Ω feed points. Since an electrical half-wave of coax can be quite long on the lower bands, this type of balun is more often used on higher frequencies. Choosing the coaxial cable with the lowest velocity factor will help keep the balun length short.

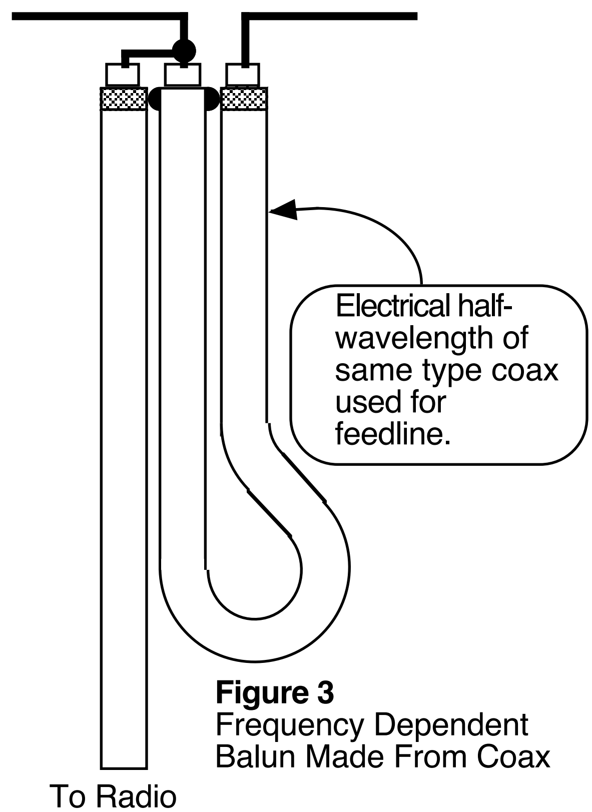

Figure 3
Frequency Dependent Balun Made From Coax

Next month we'll look talk more about the W2DU balun and also introduce the Noise Bridge; an interesting device for making antenna and feedline measurements.

73, from AF6C

This article is based on the TechTalk article that originally appeared in the October 2003 issue of RF, the newsletter of the Orange County Amateur Radio Club - W6ZE.