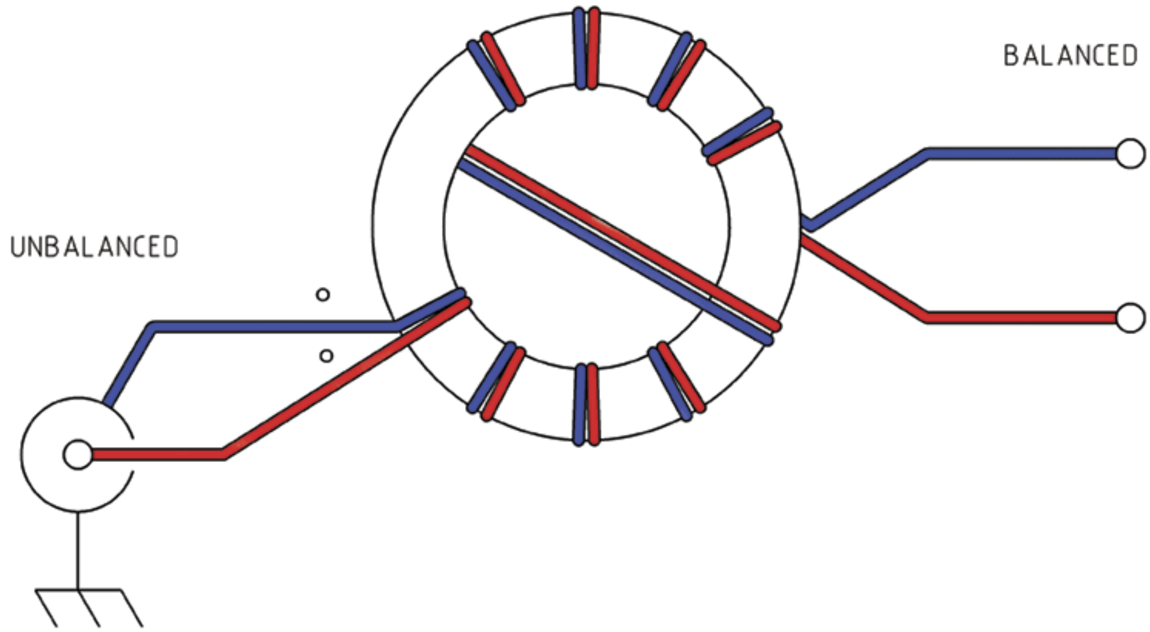
1) Transmission Line Transformer

a. First appeared on the scene in 1944 in a paper by George Guanella as a transmission line transformer, the 1:1 Guanella Balun is the basic building Balun building block.

SLIDE 2



b.

c. Then the 4:1 Unun presented by Clyde Ruthroff in 1959, SLIDE 4

Model 4113t

Joe Reisert W1JR in 1978 enhanced the 1:1 balun idea further by winding that coil of coaxial transmission-line onto a toroid-core. SLIDE 5

2) Balun Basics SLIDE 6
   a. Balun is an acronym for BALanced to UNbalanced.
      i. Twin lead, Window Line are examples of Balanced transmission line
      ii. Coaxial cable is an unbalanced transmission line.
   b. Unun
      i. SLIDE 7
   c. Common Mode vs. Differential Mode SLIDE 8
      i. Desired differential mode: opposite flowing currents in each conductor, it is called the differential mode. It deals with the "across" or between conductors characteristics.
      ii. Undesired common mode: Common mode current is the portion of conductor currents not matched by exactly opposite and equal magnitude currents.

         SLIDE 9 This is the portion of total current responsible for a feedline behaving like a single wire line. Common mode current is most commonly caused by improper feedline installation or antenna design. The feedline, in effect, behaves like two very different transmission lines connected to the antenna and equipment at the same time.
      iii. SLIDE 10 Coaxial Line Currents SLIDE 11

iv. SLIDE 12 **Reducing Unwanted Common Mode Current** A properly designed choke or current balun inserts a large amount of common mode impedance in series with the feedline without causing unwanted changes to differential mode operation.

v. SLIDE 13 Clamp On RF Current Meter to detect Common Mode Current

d. Current vs Voltage Baluns SLIDE 14

i. There are two types of baluns: Current Baluns and Voltage Baluns.

ii. A current balun forces symmetrical current at the balanced terminals. This is of particular importance in feeding antennas, since antenna currents determine the antenna's radiation pattern. In essence, current baluns are a universal device which will be used to drive either balanced or unbalanced lines or loads

iii. Voltage baluns are less effective in causing equal currents at their balanced terminals, such as at an antenna's feed point. Voltage baluns always try to force the output terminals to equal voltages, which means currents can be far from even! A voltage balun almost certainly guarantees some feedline radiation (or reception), because there are very few "perfectly balanced" loads.

3) SLIDE 15 Generally a balun consists of two wires (primary and secondary) and a toroid core: the current in the primary wire generates a magnetic field in the core. This field induces an electric field in the secondary wire. The coil is typically wound on a ferrite rod or doughnut-shaped toroid.

a. A balun is a device which is used as a transition between an unbalanced line and a balanced line.
b. At high frequencies, a transformer's efficiency as a balun is limited because of limits in the value of the coefficient of coupling of a transformer. Different toroid cores are used.
c. The desired signal which is transmitted along the two wire conductors and through the balun is a differential signal (i.e., the signal appears between the two wires of the line).

4) Chosing the right Balun for the application SLIDE 16

Posted by Bob, KZ5R on 20th Nov 2014

At least once a week we receive a request a for high ratio balun (6:1, 9:1, 12:1) to manage the transition from high impedance ladder line / open wire feedline to coax. This is a common misconception and when using a loop, doublet or double extended Zep (and several others) for multiband operation will result in "operational frustration". This is because any type of open wire (including ladder line and twinlead) will present nearly the same complex impedance of the antenna feedpoint to the other end of the open wire and can result in many, if not all bands, being difficult or impossible to match.

An example would be the primary band a full size loop is cut for. Typically this will have a 100-125 ohm feedpoint impedance and when divided by the ratio of the balun, i.e. 12:1 (if trying to match 600 ohm open wire) the resulting 8-10 ohms is impossible for all but the absolute best tuner to match. In addition, when a low impedance match is created, the losses in the tuner are higher than a high impedance match.

This problem can be even worse for doublets. If the doublet is cut for resonance on the primary or lowest band, the feedpoint impedance will be around 60-70 ohms and the resulting impedance, after a high ratio balun, will be even lower than a similar loop antenna. This is why doublets work better when sized smaller (read shorter) than a standard resonant dipole of the same primary band.

The solution is using a balun with a much lower ratio such as a 1:1 or a 4:1 which will transform the balanced line to the unbalanced coax. Matching the resulting high impedance is far easier for a tuner and losses within the tuner are also minimized. Which ratio to use is the other frequently asked question and the answer is not as black and white as many would have you believe.

5) Making a low loss transmission line with BALUNS SLIDE 17

6) [But I Only Run 100 Watts!]

Posted by Bob, KZ5R on 18th Oct 2015 SLIDE 18

When a balun or unun is wound correctly, which is an important differentiator, a higher power rating will also mean a higher efficiency, low SWR and excellent overall Return Loss. Consequently, if you're a QRP operator running 5 or 10 watts, the best choice for you may well be the balun rated at 3 or 5kW. Of course this is usually impractical if your intended use is portable operation and want something small and light, but for a permanent installation the higher power is a much better choice. Keep in mind this may not be the case when using an inexpensive balun rated at high power. It is almost impossible to build a $20-30 balun that also offers high efficiency.

RFI in your shack, house, neighbors etc is another consideration. Many times to maximize choking impedance we will use two toroids in a stacked configuration. This also increases power handling but the primary design focus is the amount of common mode current that can be eliminated by using the two cores. Power handling is just a secondary resultant, but is always beneficial

7) Choosing the Correct Balun: DX Engineering and Balun Designs

a. Half-wave Dipoles SLIDE 19

A resonant half-wave dipole is typically fed with coaxial feedline and tuned to a specific area of a band.

A popular misconception is because the dipole is resonant, or because the dipole feedline is small in diameter, a balun is not helpful. There are also questionable claims that "feedline radiation is good", or pattern change without a balun is insignificant.

Indeed there are cases where a balun is not needed at the balanced to unbalanced transition between coax and dipole, but they are very specific cases where the feedline is suspended in air from the center of the antenna straight away from the feedpoint, and is grounded ¼ wavelength away from the feedpoint.

Omitting the balun in other cases will often cause feedline length to affect SWR, increased noise in the receiver, increased RFI, or any combination of these ill effects. In unlucky cases with higher Amateur power levels permitted, omission of a balun can cause coaxial shield or connector arcing to tower legs or other metallic objects.

SLIDE 20

The best balun for this application is a 1:1 ratio current balun.

b. Ladder Line or Open Wire fed Dipoles or Doublets SLIDE 21

This is a popular antenna system; many have been built using DX Engineering baluns. A simple multi-band dipole may be constructed by first choosing the lowest band on which operation is desired. The overall length of the multi-band dipole antenna should be shorter than one-half wavelength as shown in Table 1. For best efficiency, ladder line feed and a good antenna tuner with balanced connections are required. The ideal balun is a 1:1 ratio DX Engineering special application tuner balun. It can be connected through a short length of coaxial cable to an unbalanced tuner for tuning the different bands.

SLIDE 22

Ladder feedline for a multi-band dipole must be in odd multiple lengths of 1/8 wavelength on the lowest operating frequency. This helps optimize impedance presented to the balun and tuner over the frequency range of the antenna.

The best balun for this application is a 1:1 ratio current balun.

c) Long-Wire Antennas SLIDE 23

Long wire antennas are typically horizontal antennas, fed at one end, and well over 1/2-wavelength long at the lowest operating frequency. The impedance of a long wire antenna varies as the frequency is changed, but the normally accepted values are from a few hundred to a few thousand ohms depending on length, height, ground conditions and frequency. The only way to know the impedance is to measure it or at least model it with antenna software. A 4:1 balun using good coaxial cable leading to an antenna tuner will provide a relatively well behaved installation. The output terminal closest to the red "D" in the DX Engineering label connects to the antenna. The other terminal connects to the antenna's ground or counterpoise. The case of the balun should be attached to a separate ground rod.

Long-wire Feed using a 4:1 Balun. The antenna ground side should be attached to a radial system as with a vertical antenna.

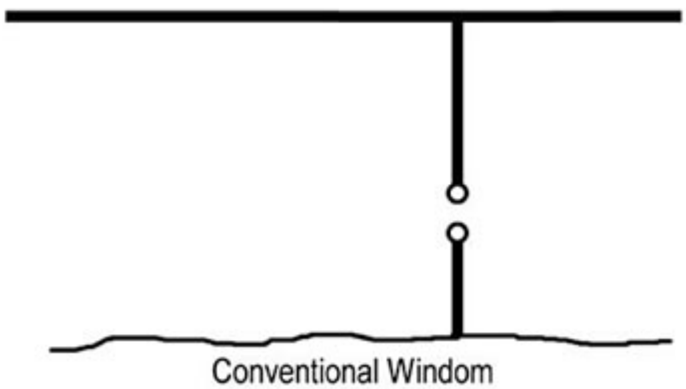
d) **Shorter End Fed Antennas** SLIDE 24

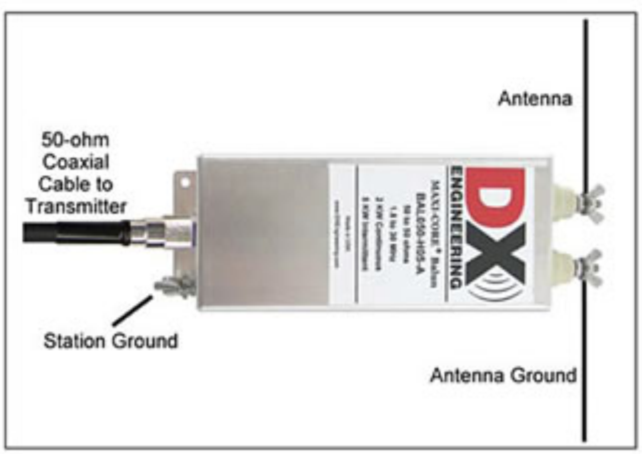
Antennas that are typically horizontal antennas, fed at one end, and less than 1/2-wavelength long at the lowest operating frequency.
According to Balun Designs, a 9:1 unun is used.

e) SLIDE 25

The True or Conventional Windom antenna, shown below, is fed with a single-wire line, and fed as an unbalanced system against a reasonable RF ground or counterpoise. The feed is similar to a longwire antenna, except the horizontal wire is fed with a few percent offset from the center.

When you use a single wire feed, ground the unused balanced terminal to the counterpoise or radial system. DO NOT connect that system to the station ground. Isolating the station ground from the antenna ground will keep unwanted RF off station equipment, and reduce potential problems with unwanted RF in the house.





The best balun for both antennas, assuming they operated where standing waves on the feed system are low, are 4:1 baluns.

f) SLIDE 26 **<u>Horizontal Full-Wave Loop</u>: The best balun for operation at resonance is a 4:1 ratio current balun.**

g) **<u>Vertical Full-Wave Loop</u>: The best balun for operation at resonance is a 2:1 ratio current balun.**

h) For ground mounted <u>quarter-wave verticals</u>, the best device for this application is a 1:1 ratio current choke.

SLIDE 26  This is a classic "Ugly balun" or air core solenoid balun. They CAN work, however because capacitance in the coil is quite high (without looking, I believe RG-8X is ~5pF/ft), they are self-resonant tank circuits. This means that they can present quite useful impedance on a couple of bands at most, but otherwise may be all but invisible on other bands. They can be strung together along the coax, but you end up using a lot of extra coax that equates to more loss, and it's far more expensive than just buying a proper toroid for $5.