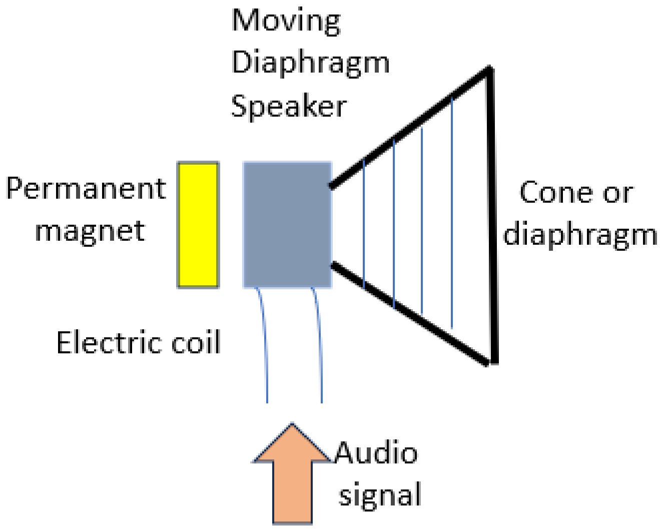
Lesson 12

Speakers

A speaker converts an electrical audio signal into a corresponding sound.

The incoming audio signals energise the coil which is repelled or attracted to the permanent magnet. The coil is attached to a diaphragm. As the coil and diaphragm moil back and forward in accordance with the audio signal, the diaphragm produces sound waves which are heard by the listener.

In a piezoelectric speaker, the coil and magnet are replaced with a crystal.



Microphones

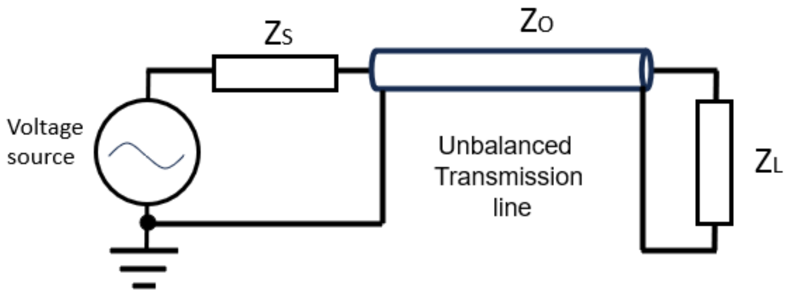
The common microphone in amateur use would be the dynamic microphone. They are referred to as the workhorses of the microphone world. They're cheap, durable and sound fantastic.

This microphone works the opposite to the speaker. Using a movable induction coil suspended in the field of a magnet, dynamic mics work like a speaker in reverse.

The sound wave vibrates the diaphragm and moves the coil. As the coil is in a magnetic field, an AC signal is generated and passed to the equipment for amplification.

Transmission lines

The way to transmit maximum power is to match the output impedance of the transmitter with the input impedance of the antenna. This is achieved by matching the correct transmission line to the transmitter. $Z_S = Z_O = Z_L$



Z_S = Impedance of the signal source, transmitter
Z_O = Impedance of the line
Z_S = Impedance of the load, antenna

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Ever wondered why the transmission lines are 50 or 75 ohms? Well, the answer is that 50 Ohms is the least compromise between the minimum loss impedance, maximum power and maximum voltage. Read a good article on this issue **HERE**.

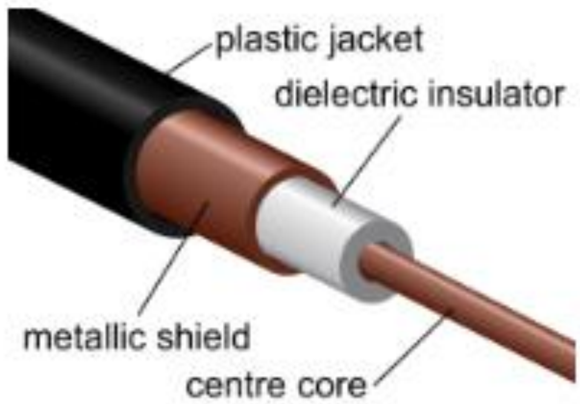
The characteristic impedance of coaxial cables (coax) is commonly chosen to be 50 Ω for RF and microwave applications. Coax for video applications is usually 75 Ω for lower loss.

Transmission lines connect the transmitter to the antenna. At lower frequencies this is achieved with balanced, open wires, or unbalanced, coaxial cable. At very high radio frequencies, the transmission line is a hollow conductor, circular or rectangular cross-section, called wave guides.

Unbalanced

An unbalanced transmission line, also referred to as asymmetrical line, usually consists of a conductor that is considered the signal line and another conductor that is grounded. This usually achieved with co axial cable (Coax). See previous figure.

The usual form of coax is a flexible cable with a braided screen. Coaxial lines are the norm for connections between radio transmitters and their antenna. A cut away view of a cox cable is shown below.

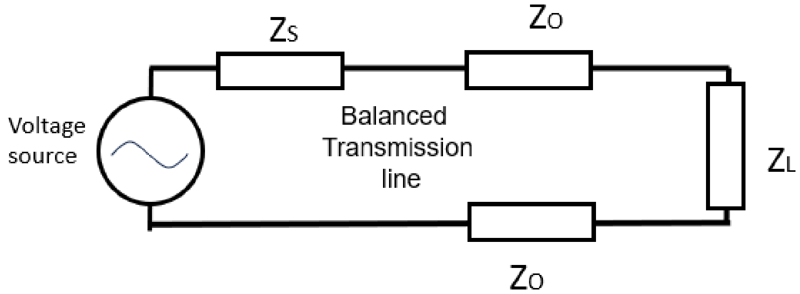


Cutaway image of a shielded cable. ***Image credit: Tkgd2007***

The manufacturers data sheet is a handy tool. See RG 58 **HERE.**

Balanced

The term "balanced line" means that the same level of current flows in each wire with reference to ground. The direction of current in one wire is 180 degrees out of phase with the current in the other wire. In a balanced line, none of the wires are connected to the ground.



Z_S = Impedance of the signal source, transmitter
Z_O = Impedance of the line
Z_S = Impedance of the load, antenna

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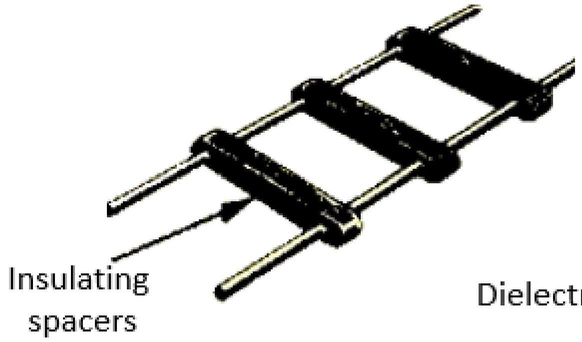
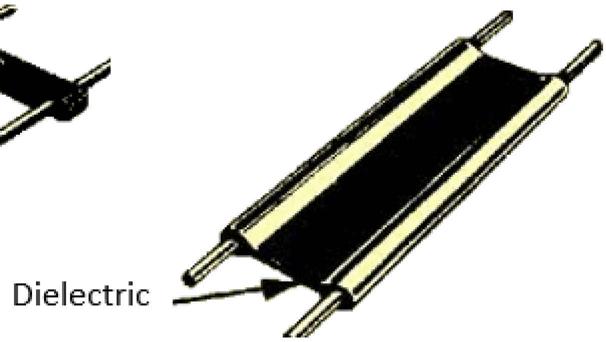
Balanced transmission lines, also called symmetrical or ladder lines, are described by the two conductors for the signal. A balanced line reduces the influence of noise or interference due to external stray electric fields. Two types of balanced transmission lines are shown below.

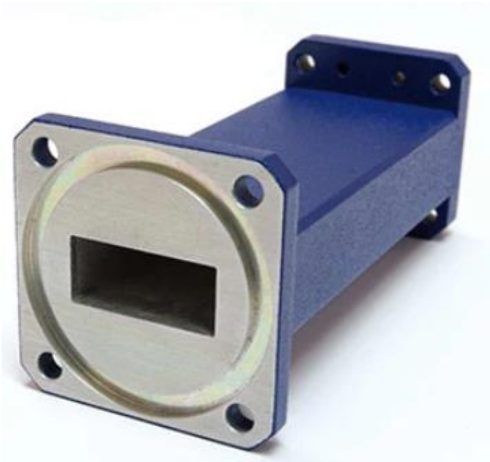




Balanced lines can be manufactured at home to meet your specific needs. A sample calculator can be found **HERE**.

Waveguides

A waveguide is a special form of transmission line consisting of a hollow metal tube. The tube wall provides distributed inductance, and the empty space between the tube walls provide distributed capacitance. Wave guides conduct microwave energy at lower loss than coaxial cables. An picture of a wave guide is shown below.



Impedance

The characteristic impedance, Z_0, of a transmission line is the ratio of voltage and current of a single wave along the line. The wave is travelling in one direction without reflections in the other direction. Different transmission lines have different impedances as shown below.

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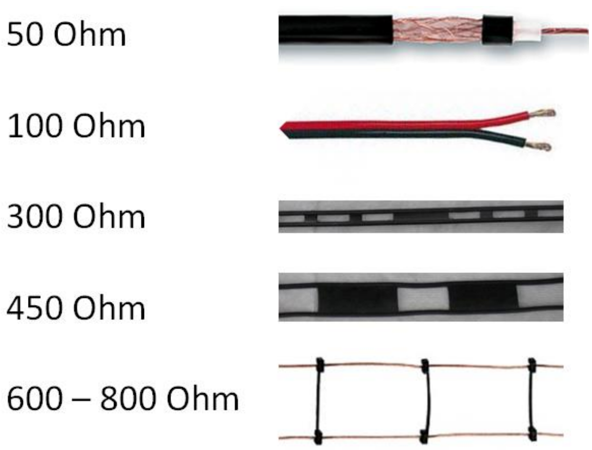

To measure the impedance, an impedance analyser, which measure complex electrical impedance as a function of frequency, would be used. Two measurements at a sweep frequency are needed. First measurement is between the centre conductor and shield with the other end of the line open. This results in a value Z_{OC}, the Open Circuit Impedance.
Second measurement is between the centre conductor and shield with the other end of the line shorted between the centre and shield. This results in a value Z_{SC}, the Short Circuit Impedance.

Using the formulae below, the impedance can be calculated.

$$Z_O = \sqrt{(Z_{SC} \ x \ Z_{OC})}$$

Example - If Zoc = 120Ω and Zsc = 30Ω, what is the characteristic impedance? **60 Ω**

Velocity Factor

The velocity factor (VF) of a transmission line is the ratio of the signal in the line compared to the speed of light. The speed of radio signals in a vacuum is the speed of light, so the velocity factor is 1.0 (unity). Velocity factor is an important characteristic of communication lines such as category 5 cables and radio transmission lines. Typical velocity factors range from 0.42 to 0.72.
Looking at the velocity factor for RG 58, it is 66% or 0.66.

Voltage Standing-Wave Ratio (VSWR)

VSWR stands for Voltage Standing Wave Ratio (SWR), also referred to as Standing Wave Ratio (SWR). describes the power reflected from the antenna.

Any impedance mismatches in a transmission line result in standing waves along the transmission line. SWR is the ratio of the maximum to minimum voltage on a transmission line. SWR is measured using a dedicated SWR meter.

$$VSWR = \frac{V_{max}}{V_{min}}$$

If $Z_S = Z_O = Z_L$ and you looked at the antenna signal with an oscilloscope, you would see a perfect sine wave. All the power is transmitted to the antenna. This is a matched condition.

Now if there is a mismatch and the forward voltage is 100 V and the reflected voltage is 50 V, this is an SWR of 2:1. The reflected signal of 50 V adds and subtracts from the original signal as the waves go in and out of phase. Measuring voltages along the line, the voltages would vary from 50 V to 150 V. So, now the reflected signal of 50 V is third or 33% of the maximum voltage on the line.

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Example: Using the above figures, SWR = Vmax / Vmin = 100 / 50 = 2:1

A SWR of 1.5:1 means a peak voltage is 1.5 times the minimum voltage along that line.

See a demonstration graphic **HERE**.

Table below is from the ARRL Handbook.

VSWR	Voltage Reflected (%)	Power Reflected (%)
1.0:1	0	0
1.1:1	5	0.2
1.2:1	9	0.8
1.3:1	13	1.7
1.4:1	17	2.8
1.5:1	20	4
1.6:1	23	5.3
1.7:1	26	6.7
1.8:1	29	8.2
1.9:1	31	9.6
2.0:1	33	11
2.5:1	43	18.4
3.0:1	50	25
4.0:1	56	36
5.0:1	67	44.4
10.0:1	82	67

Interesting article can be found HERE.

The power of the forward and reflected waves are proportional to the square of the voltage due to each wave, SWR can be expressed in terms of forward and reflected power.

$$SWR = \frac{1 + \sqrt{\frac{P_{ref}}{P_{fwd}}}}{1 - \sqrt{\frac{P_{ref}}{P_{fwd}}}}$$

Example: 10 W transmitter and 2 W are reflected. What's the SWR? **2.6:1**

The SWR is a measure of how much power is delivered to an antenna but does not mean that the antenna radiates all the power. A low SWR means the antenna is well-matched but does not indicate that the power delivered to the antenna is also radiated.

Transmission Line losses

The loss of power in a transmission line is often specified in decibels per metre (dB/m) and depends on the frequency of the signal. The cable manufacturer often supplies a chart showing the loss in dB/m at a range of frequencies. A loss of 3 dB corresponds approximately to a halving of the power.

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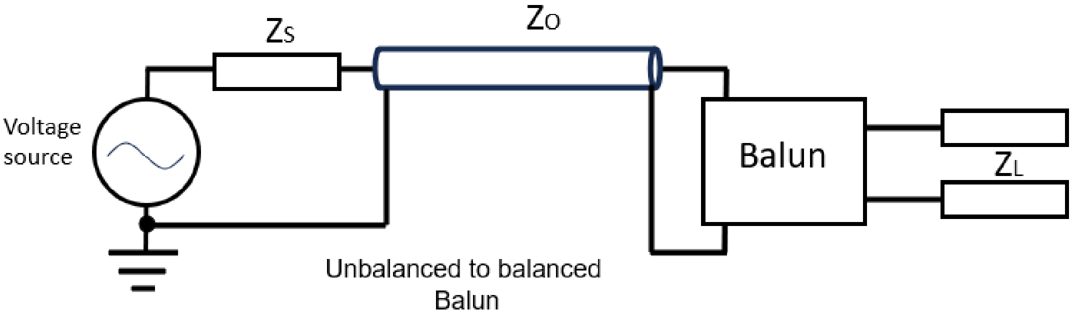
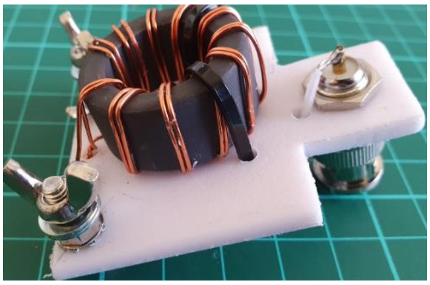
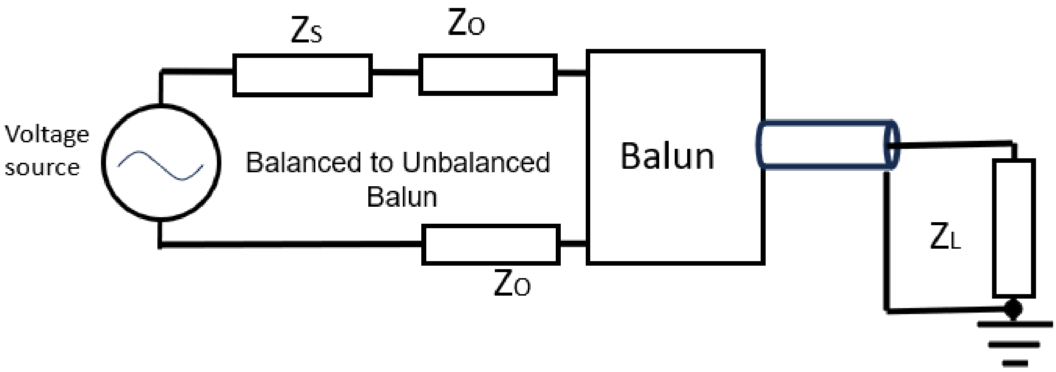
Balun

A balun, derived from the mix of the words balanced to unbalance. A balun is a device that allows balanced and unbalanced lines to be connected without disturbing the impedance of either line.
In amateur circles there are many types and configurations of baluns. We will only focus on the transformer type balun.
A balun can work both ways. Transforming an unbalanced line to a balanced line or transforming a balanced line to unbalanced.







Review the transformer calculation in Lesson 5.

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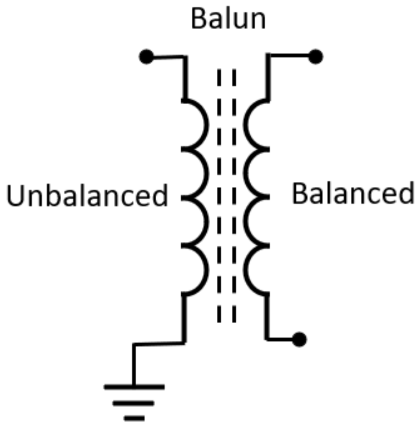


The same formula from the transformer lesson can be applied to Baluns.

$$\frac{N_P}{N_S} = \sqrt{\frac{Z_P}{Z_S}}$$

Example: Unbalanced line of 50 Ω to match to a balanced ladder line of 450 Ω.

$\sqrt{\frac{Z_P}{Z_S}} = \sqrt{\frac{50}{450}} = \sqrt{0.11} = 0.33$ $\frac{N_P}{N_S} = 0.33$ 1 NP / 3 NS = 0.33

1:3

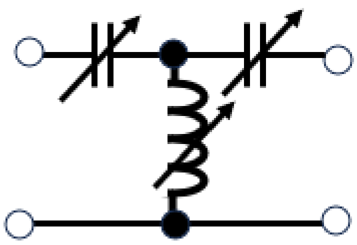
Unun

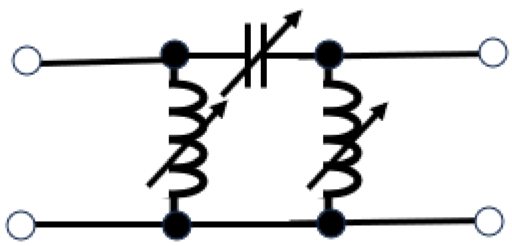
An Unun is a device that matches an unbalanced line to another unbalanced line. Ununs are often used if an unbalanced feedline is driving an unbalanced antenna. A whip antenna with a low input impedance would benefit from an impedance transforming Unun to efficiently couple a 50Ω feedline with the antenna.

Antenna tuning units

An antenna tuning unit does not change the antenna. This is why the ATU are referred to as Antenna Matching Units (AMU). The ATU or AMU make the transmitter think it is connected to the ideal transmission line (Z_O) and antenna (Z_L). The ATU has variable inductors and capacitors to provide the transmitter with the correct impedance.

Two common configurations are shown below.


T configuration ATU


Pi configuration ATU

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Go to Lesson 12 questions.

Have fun and stay safe.

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