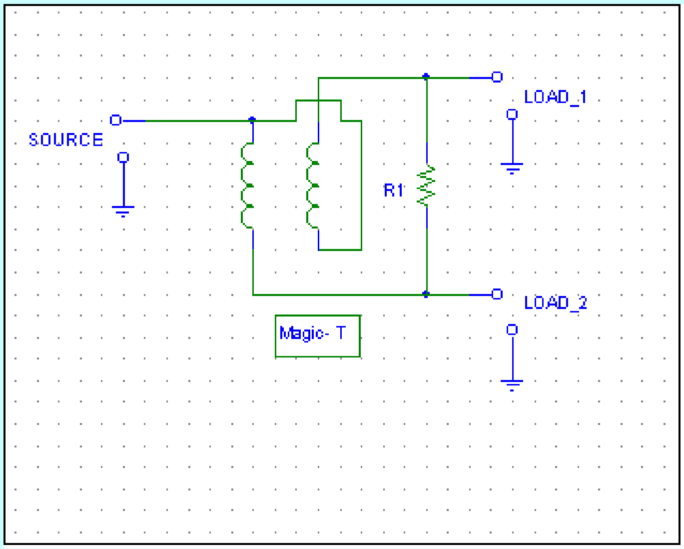
The magic "T" combiner is a very useful device. It can provide equal voltages, equal current, or equal power to matched or unmatched loads. It is not a magic bullet.

The basic element looks like this:



For 0.1 to 30 MHz applications, a nearly ideal transformer is a twisted pair of small (number 18 to 26 gauge) enameled wires with five to seven passes through a 73 material one-inch binocular core. The source impedance is parallel combination of the two load impedances, and generally is stepped back up through a 5:7 turn ratio (1:2 impedance ratio) transformer. R1 is twice the load impedance in splitter/combiner applications. (I've seen some commercially produced systems for amateur use that violate the design guidelines and offer terrible return loss and isolation.)

Like all passive splitters and combiners, this device is less than ideal. Isolation is maximum only when at least one port (sometimes two depending n application) are properly terminated.

This system does have an interesting characteristic, it can be used to force equal current into two different load impedances (or equal power by adjusting R1 to some value between zero and infinity). If R1 is open, each load is forced to have equal currents regardless of load impedances. If R1 is shorted, the loads always equal voltages (T1 can be removed and the entire circuit configured as a T connector). Keep in mind this rule is true ONLY at the port of the splitter. Transmission lines have the effect of changing voltage and current relationships.

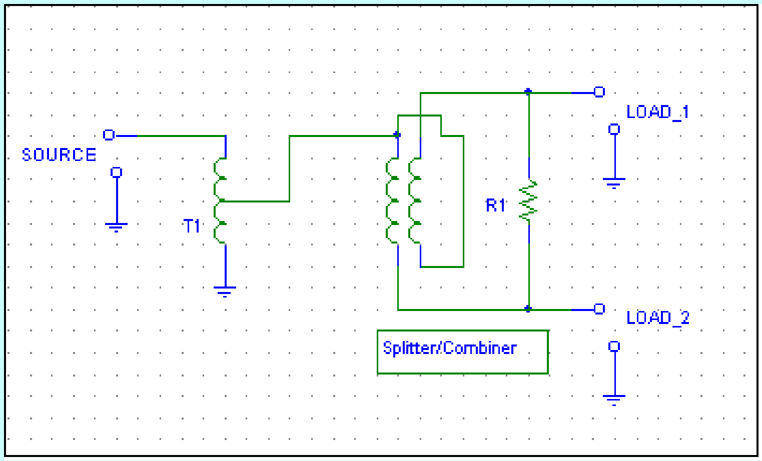
By forcing equal currents, a 1/2 wl transmission line can be used to feed a directional array instead of the more typical odd-1/4 wl line. With a 2:1 load resistance unbalance, I measured less than 0.1dB current error in such an application.

With a perfect load or source, the splitter generally serves no useful function at all. There are specific case where a splitter or combiner can be beneficial, but these are mostly case where amplifiers or amplified antenna systems are combined. As a general rule when the systems have bilateral impedance characteristics (an antenna without an amplifier would be an example of a system where source and return impedances are equal) a splitter or combiner is not necessary, and the combiner really serves no useful function.

As a matter of practice I use splitters and combiners regardless of system characteristics because they are not that expensive and they can, if the system is not perfect, reduce problems or performance shortfalls caused by impedance errors.

Receiving Splitters

Virtually all splitters are based on the Magic T with a matching transformer on the input. These splitters are certainly less than ideal, but they are simple and many times (but not always) better than a direct parallel connection.



T1 is a 7-turn transformer tapped at 5 turns (1.4:1 turns ratio, 2:1 impedance ratio) step-down transformer. 73 material binocular cores are ideal for 100kHZ to 30MHz applications.

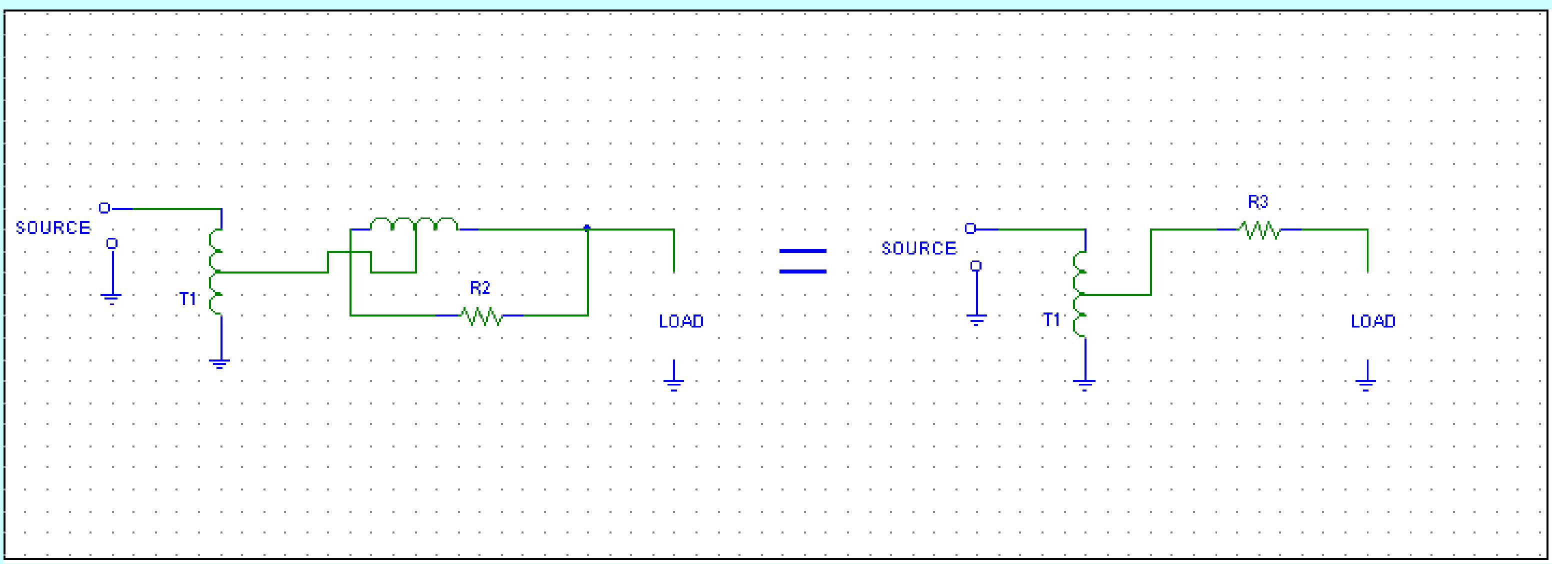
The magic T transformer is 5 to 10 turns of twisted pair wire through a 73 material binocular core. Configured as a center-tapped winding.

R1 is twice the expected load impedance. For 50- ohm systems use a 100 ohm resistor.

Losses

Typical loss of the Magic T is 3dB per port. The only other significant loss, when properly terminated, is a slight loss in T1. Normal loss of the entire system to either output port is 3 to 3.5dB. When combining in-phase signals, loss is only the loss in T1, there is no "combining loss".

When the Magic T splitter or combiner is open-circuited on one port, the electrical equivalent is:



In a properly designed magic-T, R2 is twice the value of any port. This resistor is stepped down by the impedance ratio of 4:1 in the center tapped winding (no part designator) when a load port is opened. In a 50-ohm system, this effectively results in 25 ohms (R3) in series with the load impedance of 50 ohms. The resulting impedance of 75 ohms is doubled by T1 to 150 ohms. Assuming ideal components the input SWR, when the output is open on one port, is 3:1.

Loss will be 1.25dB from mistermination of the source by the 3:1 VSWR (assuming it is a 50 ohm source) with an additional loss of 1.7dB as power divides between R3 and the output port. The **theoretical open circuit loss (including transformer**

losses) is about 3 dB, the same as if a load were connected. The SWR, however, is NOT matched (1:1) like it is with a proper load on all ports!

The Magic-T behaves in a similar manner if one output port is shorted, with the exception R2 appears directly across the load. This is the equivalent of a 100-ohm resistor shunting a 50-ohm load. This impedance (33.34 ohms) is quartered by the center tapped winding of the Magic T to 8.3 ohms. T1 steps this impedance up to 16.6 ohms. The result is once again a 3:1 VSWR.

This means signal level at port 1 theoretically does not change when port 2 is open or shorted, or any termination between an open or short. The impedance (and SWR) DOES change, so mismatch loss and phase angles will vary a great deal.

Like many systems, these losses are based on source and load impedances being ideal. This is almost never the case, and the optimum value of R2 is often significantly different from being twice the load resistance. Because of that, our actual systems may show significantly more level change than the ideal theoretical amount (theoretical is no change) when one port is incorrectly terminated.

Consider this device in a receiving antenna system. If the preamplifier system does see the correct load impedance, the overall system will probably lose more gain than we might expect. The gain loss will very likely come with the penalty of lower IM performance. This is particularly true if the low-headroom amplifiers typical of amateur radio "preamplifiers" are used.

Even with high dynamic push-pull CATV transistor amplifiers, I've often found it necessary to optimize the splitting system. For example, my receiver distribution system has 8 antenna inputs. Antennas are all independent in directional control (multi-op), or can be linked to a common direction control (normal use). The antenna input ports are amplified and then split to feed multiple receivers, any of which can instantly switch to any splitter output.

My switching matrix looks like this:

	RX1	RX2	RX3	RX4	RX5	RX6
Europe 3x Bev						
Europe 2x Bev						
Europe BSEF Vert						
8 circle of verticals						
Front Beverages						
Middle Beverages						
Rear Beverages						
Japan/NW Beverage arrays						

This is 48 combinations of receivers and antennas.

My stock my R4C's typically have ~20-ohm input impedances on 160-meters. My receiving system is designed around 75-ohm cables and hardware. It is cheap, very q good quality, and connectors are reliable and easy to install. If I connect a ~20 ohm R4C on one port and a higher-impedance receiver (or worse yet an open-circuit) on the other port, the result is t results in starving the already low-sensitivity R4C receivers for signal (despite the use of a "splitter") if they are used in conjunction with higher sensitivity higher impedance receivers like FT1000's. The solution is to make every load (all the receivers) look like 75-ohms, readjust R1 to a new value, or use emitter-follower "active splitters".

I opted to make all of my receivers "look like" 75 ohms and terminate unused ports, but your choice may be different.

Amplifiers

Caution must be used in selecting amplifiers. Virtually all commercial amplifiers I have tested have very limited dynamic range. They are fine for amplifying high-loss antennas like Flags and EWE's, but terrible when connected to large Beverage systems. Adding an additional 6dB or more gain to the output of a Beverage just to overcome splitting losses (plus problems associated with uneven power division) almost always pushes these amplifiers "over the top". If you are going to use single-ended amplifiers with small low-power devices, be prepared to use multiple amplifiers (one for each receiver) and place them after the splitter system.

It is far better to buy or build one good amplifier, but it should be a very high dynamic range device!