

# RF directional couplers

Passive directional couplers facilitate RF measurements and have uses in receivers. Joe Carr explains what they are and how they work.

**D**irectional couplers are devices that will pass signal across one path, while passing a much smaller signal along another path. One of the most common uses of the directional coupler is to sample a radio-frequency power signal either for controlling transmitter output power level or for measurement.

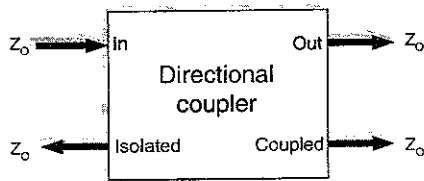


Fig. 1. Circuit symbol for a directional coupler.

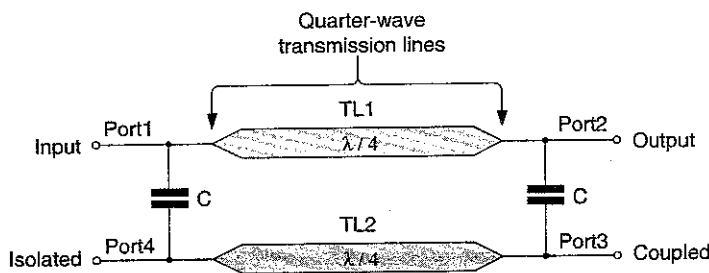


Fig. 2. Directional coupler made up of transmission line segments.

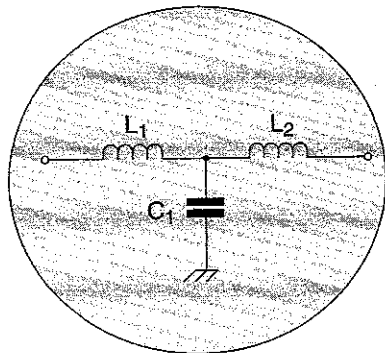
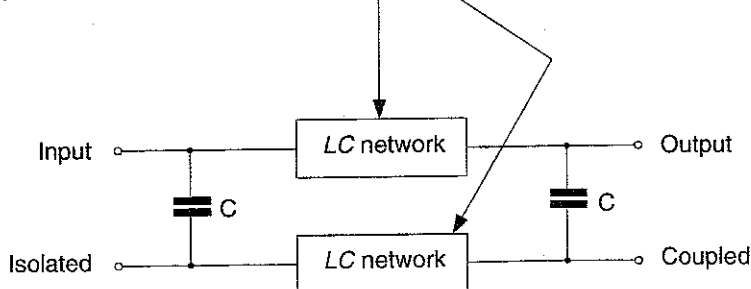


Fig. 3. LC lumped-constant version of the transmission line.



An example of how such a coupler can be used for measurement is a digital frequency counter connected to the low-level port, and the transmitter and antenna to the straight through, i.e. high power, ports.

The circuit symbol for a directional coupler is shown in Fig. 1. Note that there are three outputs and one input. The In-Out path is low-loss, and is the principal path between the signal source and the load. The coupled output is a sample of the forward path, while the isolated showed very low signal. If the In and Out are reversed, then the roles of the coupled and isolated ports also reverse.

An implementation of this circuit using transmission line segments is shown in Fig. 2. Each transmission line segment, TL1 and TL2, has characteristic impedance,  $Z_o$ , and is quarter wavelength long. The path from Port 1 to Port 2 is the low-loss signal direction. If power flows in this direction, then Port 3 is the coupled port and Port 4 is isolated. If the power flow direction reverses – Port 2 to Port 1 – then the respective roles of Port 3 and Port 4 reverse.

For a Port-3/Port-4 coupling ratio of  $-15\text{dB}$  or less, the value of coupling capacitance must be,

$$C_c < \frac{0.18}{\omega Z_o} \text{ farads}$$

The coupling ratio is  $20\log(\omega C Z_o)\text{dB}$  where  $\omega$  is  $2\pi f$ . The bandwidth is about 12 percent.

The circuit shown in Fig. 3 is an LC lumped-constant version of the transmission lines. This network can be used to replace TL<sub>1</sub> and TL<sub>2</sub> in Fig. 2. The values of the components are,

$$L_1 = L_2 = \frac{Z_o}{\omega_o}$$

$$C_1 = \frac{1}{\omega_o Z_o}$$

Figure 4 shows a directional coupler used in a lot of RF power meters and VSWR meters. The transmission lines are implemented as printed circuit board tracks. It consists of a main transmission line (TL<sub>1</sub>) between Port 1 and Port 2 – the low-loss path – and a coupled line (TL<sub>2</sub>) to form the coupled and isolated ports. The coupling capacitance in picofarads is approximated by  $9.399X$ , where  $X$  is in metres, when implemented on G-10 Epoxy glass-fibre printed circuit board.

### Reflectometer directional coupler

A reflectometer directional coupler is shown in Fig. 5a). This type of directional coupler is at the heart of many commercial VSWR meters and RF power meters used in

the HF through low-VHF regions of the spectrum.

This circuit is conceptually similar to the previous transmission line, but is designed around a toroid transmission line transformer. It consists of a transformer in which the low-loss path is a single-turn primary winding, and a secondary wound of enamelled wire.

Details of the pick-up sensor are shown in Fig. 5b). The secondary is wound around the rim of the toroid in the normal manner, occupying not more than 330° of circumference. A rubber or plastic grommet is fitted into the centre hole of the toroid core.

The single-turn primary is formed by a single conductor passed once through the hole in the centre of the grommet. It turns out the 3/16 in (4.76mm) outside-diameter brass tubing, of the kind sold in hobby shops that cater for model builders, will fit through several standard grommet sizes nicely, and will slip-fit over the centre conductor of SO-239 coaxial connectors.

Another transmission-line directional coupler is shown in Fig. 6. Two lengths of RG-58/U transmission line, each

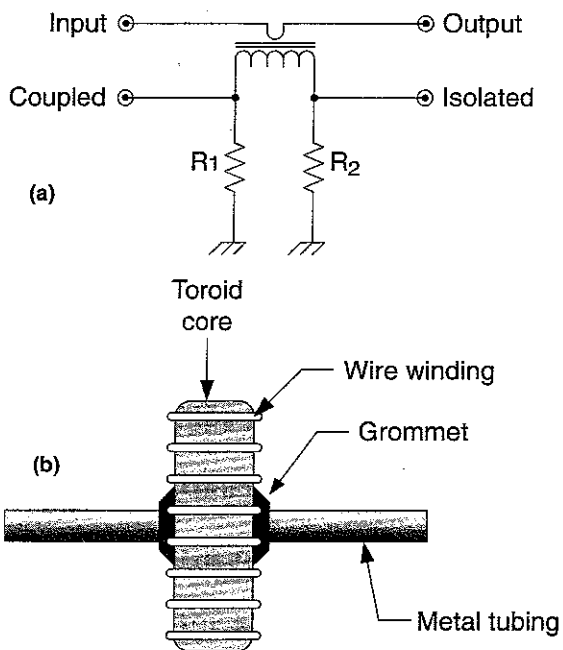


Fig. 5. Reflectometer directional coupler circuit, a), and details of the pick-up sensor, b).

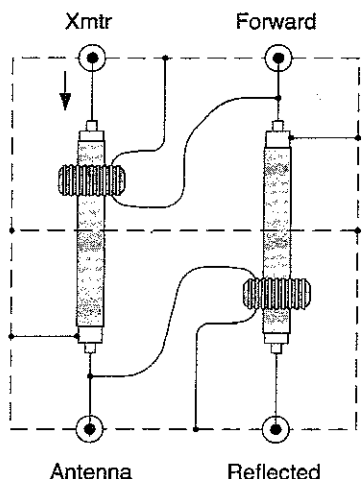


Fig. 6. Alternative directional coupler involving two short lengths of RG-58/U transmission-line.

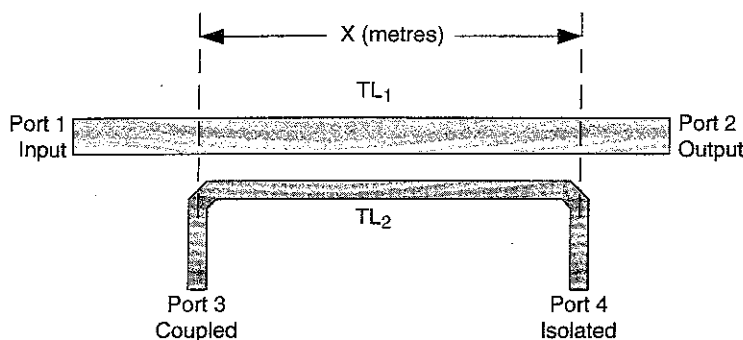


Fig. 4. Directional coupler of the type used in many RF power and VSWR meters.

around 6in long, are passed through a pair of toroid coils. Both coils are wound with 8 to 12 turns of wire. Note that the shields of the two transmission line segments are grounded only at one end.

Each combination of transmission line and toroid core forms a transformer similar to the previous case. These two transformers are cross-coupled to form the network shown.

The Xmtr-antenna path is the low loss path, while – with the signal flow direction shown – the other two coupled ports are for forward and reflected power samples. These samples can be rectified and used to indicate the relative power levels flowing in the forward and reverse directions. Taken together these indications allow you to calculate VSWR.

Directional couplers are used for RF power sampling in measurement and transmitter control. They can also be used in receivers between the mixer or RF amplifier and the antenna input circuit. This arrangement can prevent the flow of local oscillator signal and mixer products back towards the antenna, where they could be radiated and cause electromagnetic interference to other devices. ■

**Further reading**

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