Despite being passive, the hybrid coupler-combiner-splitter is a remarkably useful rf component that solves a lot of practical problems. Joseph Carr explains how.

The rf hybrid coupler

The hybrid coupler, **Fig. 1**, is an audio or radio frequency device that will either split a signal source into two directions, or combine two signals sources into a common path.

The symbol shown in Fig. 1 is essentially a signal path schematic. Consider the situation where an rf signal is applied to port 1. This signal is divided equally, flowing to both ports 2 and 3.

Because the power is divided equally the hybrid is called a 3dB divider, i.e. the power level at each adjacent port is one-half of the power applied to the input port, i.e. –3dB.

If the ports are properly terminated in the system impedance, then all power is absorbed in the loads connected to the ports adjacent to the injection port. None travels to the opposite port. The termination of the opposite port is required, but it does not dissipate power because the power level is zero.

The one general rule to remember about hybrids is that *opposite ports cancel*. That is, power applied to one port in a properly terminated hybrid will not appear at the opposite port. In the case cited above, the power was applied to port 1, so no power appeared at port 4.

One of the incredibly useful features of the hybrid is that it accomplishes this task while allowing all devices connected to it to see the system impedance, R_o. For example, if the output impedance of the signal source connected to port 1 is 50Ω, the loads of ports 2 and 3 are 50Ω, and the dummy load attached to port 4 is 50Ω, then all devices are either looking into, or driven by, the 50Ω system impedance.

One source of reasonably priced hybrid devices is Mini-Circuits Laboratories. This company has a large selection of 0°, 90° and 180° hybrid combiners and splitters.

Applications of hybrids

The hybrid can be used for a variety of applications where either combining or splitting signals is required.

Combining signal sources. In **Fig. 2**, two signal generators connect to opposite ports of a hybrid, i.e. ports 2 and 3. Power at port 2 from signal generator 1 is therefore cancelled at port 3, and power from signal generator 2, port 3, is cancelled at port 2. Therefore, the signals from the two signal generators will not interfere with each other.

In both cases, the power splits two ways. For example, the power from signal generator 1 flows into port 2 and splits two ways. Half of it, i.e. 3dB, flows the path from port 2 to port 1, while the other half flows from port 2 to port 4. Similarly with the power from signal generator 2 applied to port 3. It splits into two equal portions, with one flowing to port 1 and the device under test, and half flowing to the dummy load.

Bi-directional amplifiers. A number of different applications exists for bi-

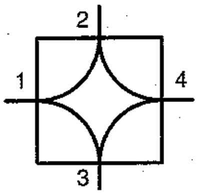

Fig. 1. Symbol for hybrid – a device that can split or combine two signals.

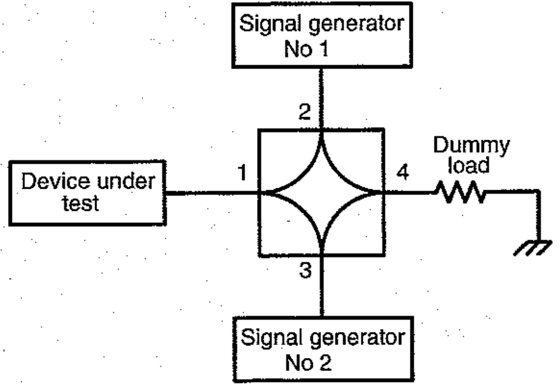

Fig. 2. Combining two signal sources. Power at port 2 is cancelled at port 3 and power at port 3 is cancelled at port 2 so the signals from the two signal generators will not interfere with each other.

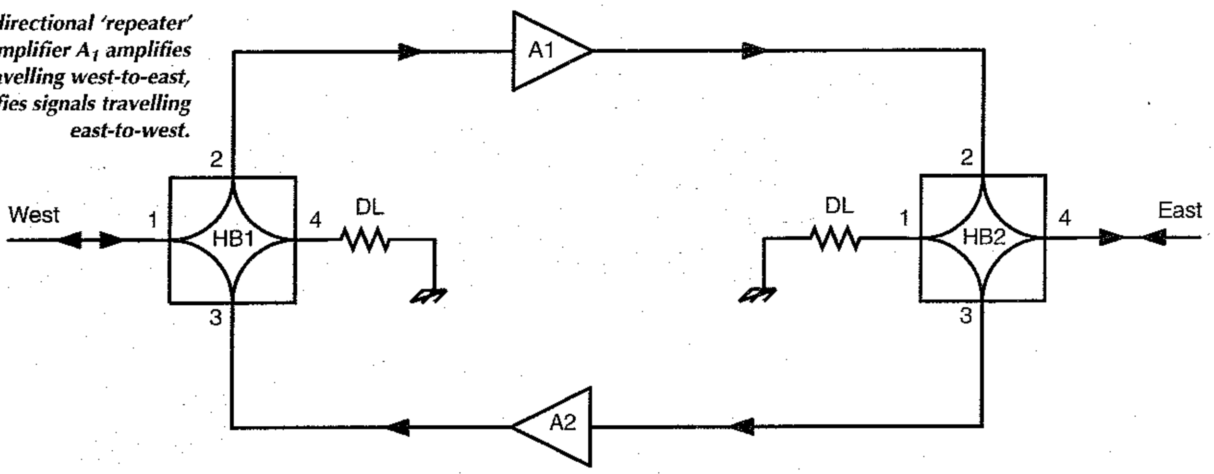

Fig. 3. Bidirectional 'repeater' amplifier. Here, amplifier A_1 amplifies the signals travelling west-to-east, while A_2 amplifies signals travelling east-to-west.

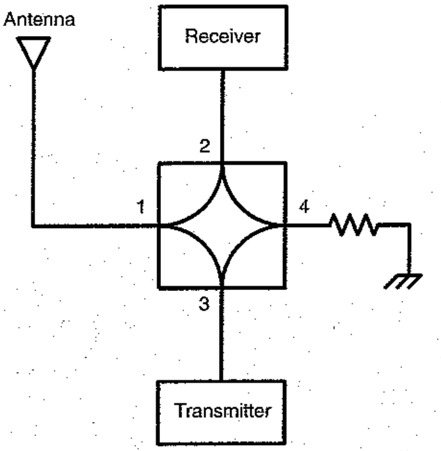

Fig. 4. Use of hybrid as a transmit/receive switch. Here, the transmitter output and receiver input connect to opposite ports of a hybrid device so transmitter power does not reach the receiver input.

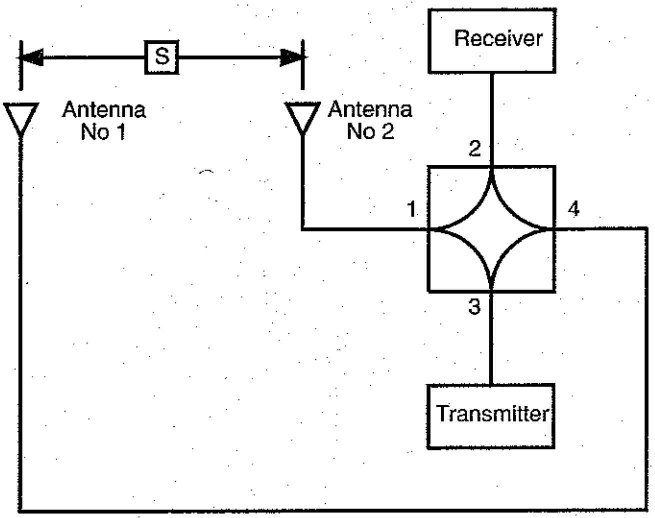

Fig. 5. Combining two antennas in transmit/receive switch. Using a second antenna instead of the dummy load reduces losses. With this configuration, you can get various directivity patterns using two identical antennas.

directional amplifiers. These are amplifiers that can handle signals from two opposing directions on a single line.

The telecommunications industry, for example, uses such systems to send full duplex signals over the same lines. Similarly, cable tv systems that use two-way cable modems require two-way amplifiers.

Figure 3 shows how the hybrid coupler can be used to make such an amplifier. In some telecommunications textbooks the two directions are called east and west, so this amplifier is occasionally called an east-west amplifier. At other times this circuit is called a repeater.

In the bidirectional east-west amplifier of **Fig. 3**, amplifier A_1 amplifies the signals travelling west-to-east, while A_2 amplifies signals travelling east-to-west. In each case, the amplifiers are connected to hybrids HB_1 and HB_2 via opposite ports, so will not interfere with each other.

Otherwise, connecting two amplifiers input-to-output-to-input-to-output is a recipe for disaster... even if only a large amount of destructive feedback results.

Transmitter/receiver isolation. One of the problems that exists when using a transmitter and receiver together on the same antenna is isolating the receiver input from the transmitter input. Even a weak transmitter will burn out the receiver input if its power were allowed to reach the receiver input circuits.

One solution is to use one form of transmit/receive relay. But that solution relies on an electromechanical device, which adds problems of its own – not the least of which is reliability.

A solution to the transmit/receive problem using a hybrid is shown in **Fig. 4**. Here, the transmitter output and receiver input are connected to opposite ports of a hybrid device. Thus, the transmitter power does not reach the receiver input.

The antenna connects to the adjacent port between the transmitter port and the receiver port. Signal from the antenna will flow over the port 1 to port 2 path to reach the receiver input. Transmitter power, on the other hand, will enter at port 3, and is split into two equal portions. Half the power flows to the antenna over the port 3 to port 1 path, while half the power flows to a dummy load through the port 3 to port 4 path.

There is a problem with this configuration. Because half the power is routed to a dummy load, there is a 3dB reduction in the power available to the antenna. A solution is shown in **Fig. 5**. In this configuration a second antenna is connected in place of the dummy load. Depending on the spacing, *S*, and the phasing, various directivity patterns can be created using two identical antennas.

If the hybrid produces no phase shift of its own, then the relative phase shift of the signals exciting the antennas is determined by the length of the transmission line between the hybrid and that antenna. A 0° phase shift is created when both transmission lines are the same length.

Making one transmission line half wavelength longer than the other results in a 180° phase shift. These two relative phase relationships are the basis for two popular configurations of phased array antenna.

You'll find more options in a good antenna book.

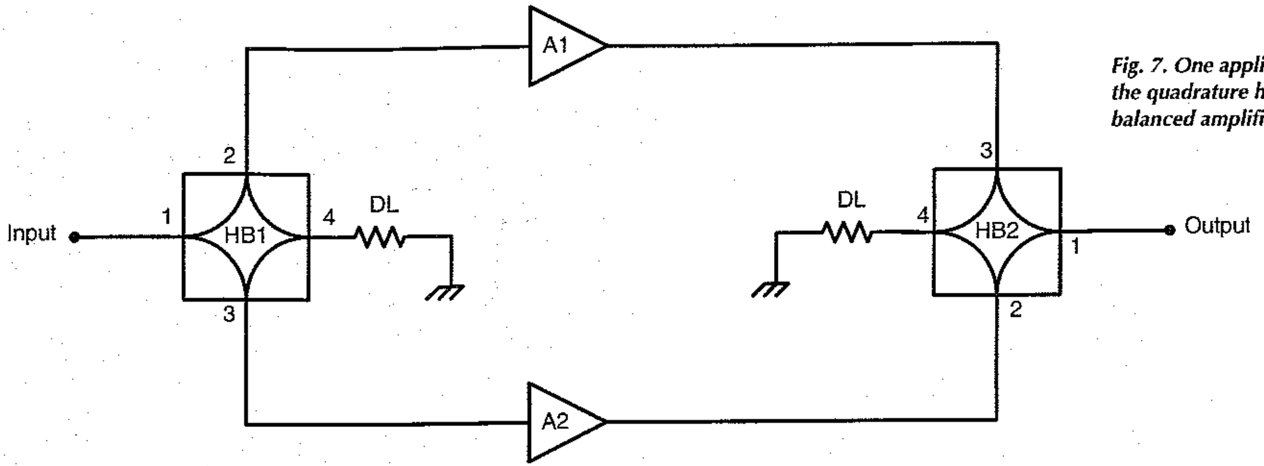

Fig. 7. One application for the quadrature hybrid is the balanced amplifier.

Phase-shifted hybrids

The hybrids discussed thus far split the power half to each adjacent port, but the signals at those ports are in-phase with each other. That is, there is a zero degree phase shift over the paths from the input to the two output ports.

There are, however, two forms of phase shifted hybrids. The one shown in **Fig. 6a)** is a 0°-180° hybrid. The signal over the port 1 to port 2 path is not phase shifted (0°), while that between port 1 and port 3 is phase shifted 180°. Most transformer-based hybrids are inherently 0°-180° hybrids.

A 0°-90° hybrid is shown in Fig. **6b)**. This hybrid shows a 90° phase shift over the port-1/port-2 path, and a 0° phase shift over the port-1/port-3 path. This type of hybrid is also called a quadrature hybrid.

One application for the quadrature hybrid is the balanced amplifier shown in **Fig. 7**. Two amplifiers, A$_1$ and A$_2$ are used to process the same input signal arriving via hybrid HB$_1$. The signal splits in HB$_1$, so becomes inputs to both A$_1$ and A$_2$. If the input impedances the amplifiers are not matched to the system impedance, then signal will be reflected from the inputs back towards HB$_1$.

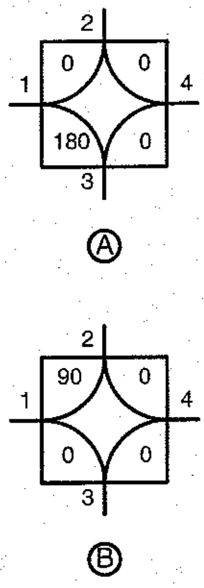

Fig. 6. Symbolic phase shifted hybrids, a 180° hybrid, a) and a 90° hybrid, b).

The reflected signal from A$_2$ arrives back at the input in-phase, at 0°, but that reflected from A$_1$ has to pass through the 90° phase shift arm twice, so has a total phase shift of 180°. Thus, the reflections caused by mismatching the amplifier inputs are cancelled out.

The output signals of A$_1$ and A$_2$ are combined in hybrid HB$_2$. The phase balance is restored by the fact that the output of A$_1$ passes through the 0° leg of HB$_2$, while the output of A$_2$ passes through the 90° leg. Thus, both signals have undergone a 90° phase shift, so are now restored to the in-phase condition.

Use with receiving antennas. Examples given above combine a receiver and transmitter on a single antenna or antenna system. It's also possible to use the hybrid for antenna arrays intended for receivers.

Antennas spaced some distance *X* apart will have different patterns and gains depending on the value of *X* and the relative phase of the currents in the two antennas. This means that you can connect the antennas to ports 2 and 3, and the receiver antenna input to port 1. A terminating resistor would be used at port 4.

You can use either 0°, 90° or 180° hybrids depending on the particular antenna system.

In summary

The hybrid coupler-combiner-splitter is a remarkably useful passive rf component that will solve a lot of practical problems. ■

Further reading

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