A Low-Loss VHF/UHF Bias Tee

A simple circuit lets your transmission line do double duty.

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When I became interested in satellite communications, I decided to operate the popular 2-m/70-cm mode. To reduce the system noise overall, low-noise amplifiers were installed at the antennas. To avoid running additional cables from the station up to the antennas to power and control the low-noise amplifiers, I decided to use the RF coaxial cable as the medium to carry out this task. This method provides a low-resistance path and eliminates additional cabling.

To perform this function, a device called a dc injector—more commonly known as a "bias tee"—is required. A bias tee allows dc power to be superimposed onto a transmission line without altering the RF characteristics, thereby allowing both signals to share a single cable. This article describes a low-loss bias tee that has been optimized for each band.

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Theory of Operation

Fig 1 shows a typical bias tee and the component values for the two bands of operation. The bias tee has three ports: a dc port, an RF port and a RF+dc port. The operation of the circuit is very simple. The series capacitor provides a dc block to stop the dc voltage from appearing at the RF port. This capacitor must have low-loss characteristics so it can safely pass the transmitted RF power. In addition to this, the capacitor's self-resonant frequency must be above the desired band of operation. To meet these requirements, a ceramic-chip capacitor was selected. These capacitors have low dissipation factors, little series inductance, high breakdown voltages and those with larger packages will safely transfer the transmitted power.

The RF choke has a dual role. First, it provides a means to inject dc power onto the center conductor of the coaxial cable. Second, it presents high impedance to the RF signal. This provides isolation between the RF signal and the dc port. In other words, it prevents the RF from flowing through the dc port. As a general rule of thumb, the inductive reactance should be at least 10 times the system impedance (the characteristic impedance of the coaxial transmission line). However, the self-resonant frequency of the inductor must be above the band of operation. The inductor must also be able to pass the dc current without altering its characteristics. The inductance value must be carefully selected. If the above inductor criteria are not met, the performance of the bias tee will be greatly degraded.

With an RF signal applied to the RF port and a dc voltage applied to the dc port, the output port will contain both of these signals. The coaxial transmission line conveys both of the components. The dc return path is the shield of the coaxial transmission line.

Fig 2 shows a typical bias-tee installation. Notice that the bias tee at the antenna end is installed with the RF port connected to the antenna. The dc voltage is blocked from reaching the antenna by the series capacitor. The dc voltage is extracted from the coaxial transmission line via the dc port of the bias tee, thus providing power to the low-noise amplifier.

Construction

A bias tee should be constructed in a small metal enclosure such as a Pomona box. RF path lengths should be minimized to reduce losses; therefore the connectors should be placed on the narrow ends of the box. It is essential that N-type connectors be used, especially for UHF operation. The electrical performance (SWR and insertion loss) would suffer if SO-239 or BNC connectors were used. The feedthrough capacitor can be mounted at any convenient location on the box away from the RF. The inductor is soldered between the feedthrough capacitor and the transmission line using the wire leads to support the inductor. The windings around the ferrite core should be evenly spaced. Remember that each time the wire passes through the center of the core, it is counted as a turn.

Since the series-blocking capacitor is a chip component, it was mounted on a double-sided PC board between 50-Ω microstrip lines. The lines can be made using a sharp hobby knife to cut and remove the excess copper foil. The bottom of the PC board is a solid ground plane of copper. Table 1 lists some 50-Ω line widths for several common PC board materials. There are also several programs available on the Web to calculate a line width if a different board material is used.

It is very important to insure a good ground between the connectors and the ground plane of the PC board. Fig 3 shows one method of transition

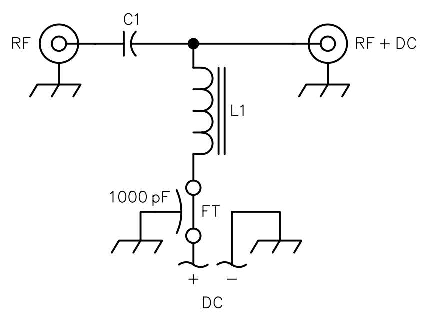

Fig 1—A schematic diagram of the bias tee.
L1—An RF choke wound on a Micrometals T25-6 ferrite core. For VHF, use 16 turns of #28 AWG wire. For UHF, use 9 turns of #28 AWG wire.
C1—Dielectric Labs chip capacitor. For VHF, 1000 pF (#C22AH102J7PXL). For UHF, 330 pF (#C22AH331JAPXL).

Table 1—Microstrip Widths for various Board Materials and Thicknesses

Board Material	*H*	*W*
Rogers 4003	0.032	0.073
GML 1000	0.030	0.071
FR4	0.031	0.055

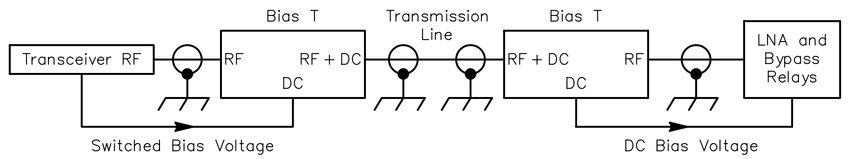

Fig 2—A block diagram of a typical station setup.

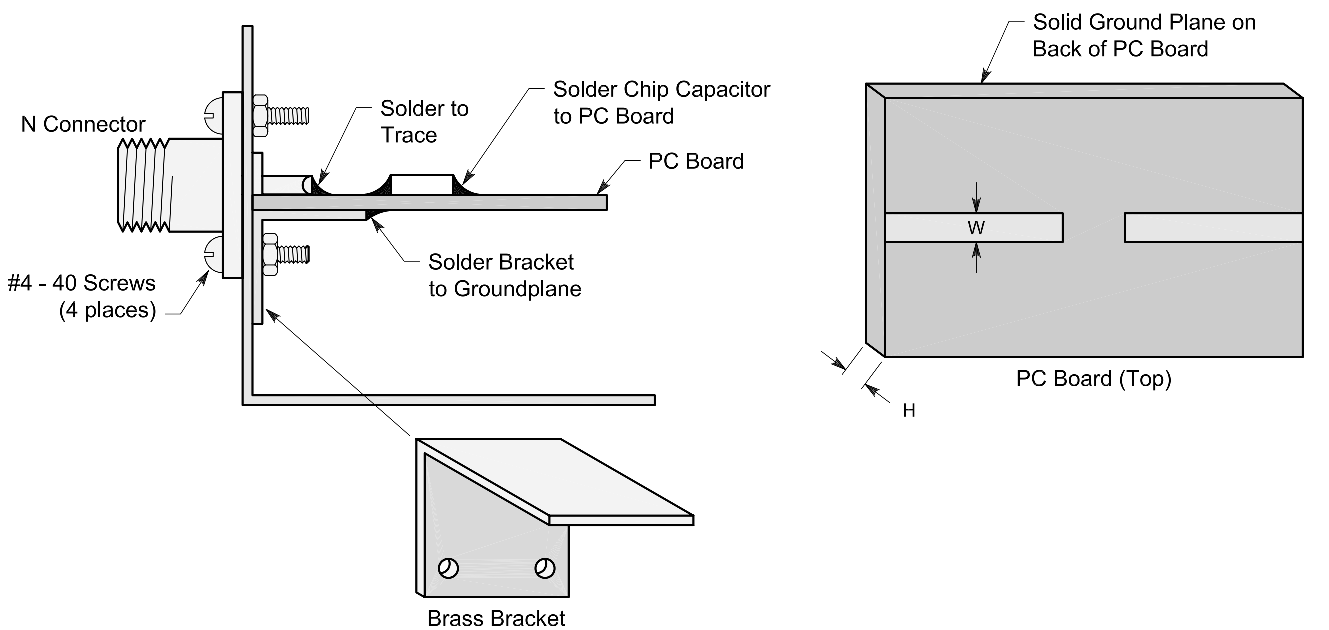

Fig 3—Construction details.

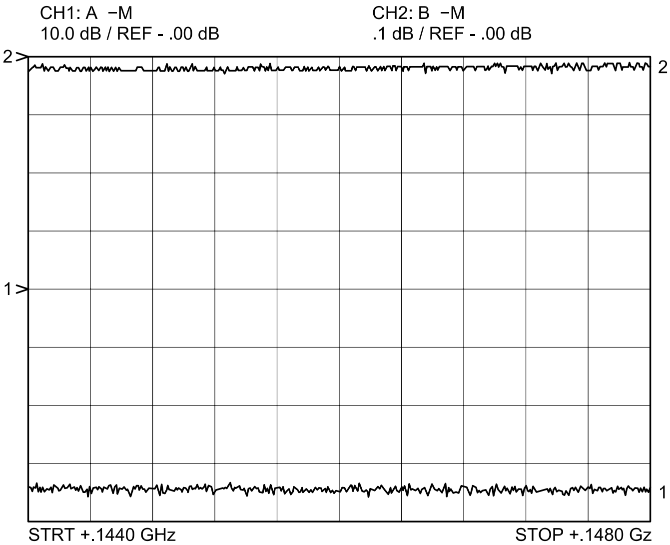

Fig 4—VHF bias tee return (1) and insertion (2) loss.

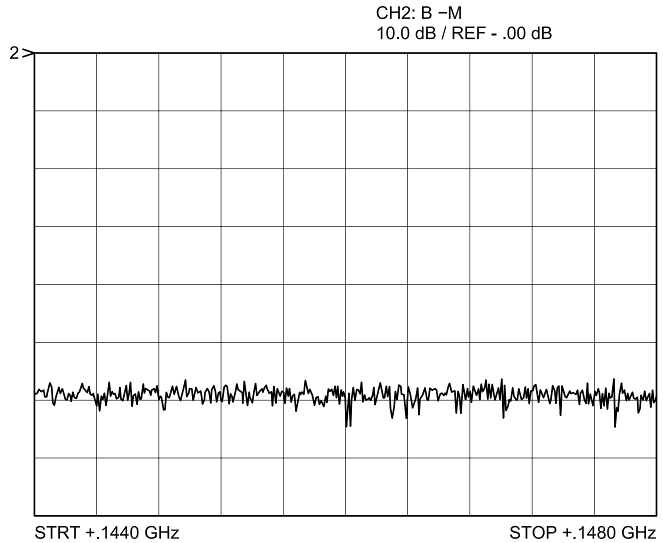

Fig 5—VHF bias tee RF-to-DC port isolation.

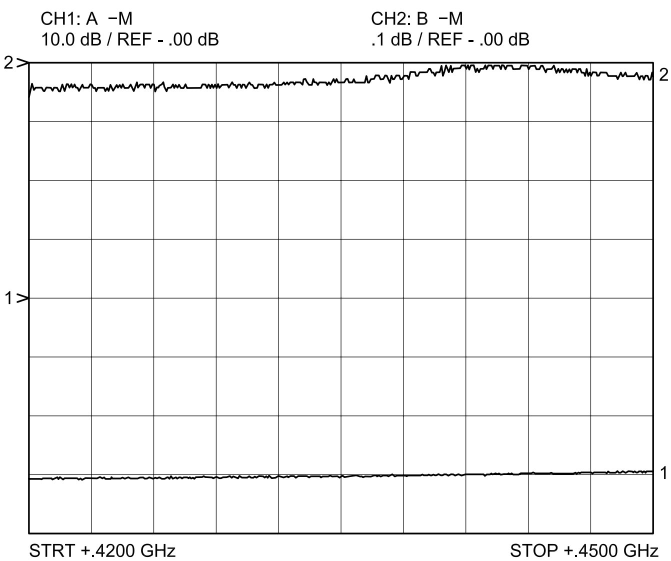

Fig 6—UHF bias tee return (1) and insertion (2) loss.

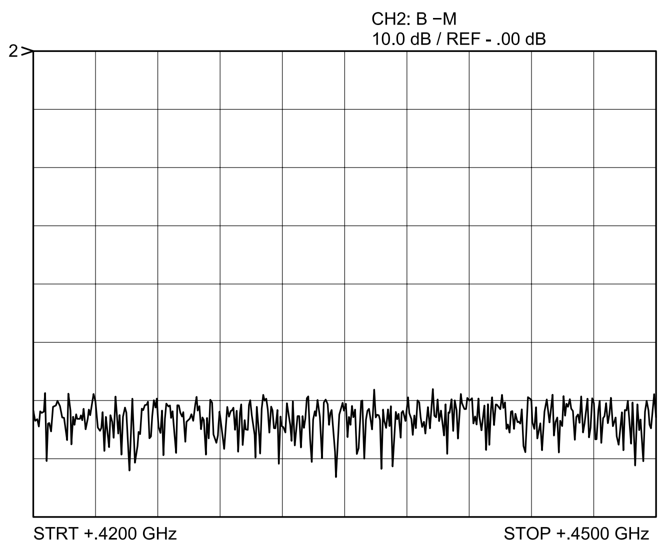

Fig 7—UHF bias tee RF-to-DC port isolation.

between the connector and the PC board. A right-angle bracket made of brass can be formed to the correct dimensions. The bracket is soldered to the ground plane and attached to the connector via the connector's two bottom mounting screws.

Measured Data

The following data were measured on an HP scalar network analyzer. Fig 4 shows the VHF bias tee's insertion loss and return loss. The average insertion loss was 0.02 dB and the minimum return loss was 35 dB, corresponding to an SWR of 1.036:1. Fig 5 shows the isolation between the RF and dc ports to be 60 dB. Figs 6 and 7 are the measured data for the UHF bias tee. The average insertion loss was 0.04 dB and the return loss was 30 dB (SWR 1.065:1). The isolation was also 60 dB.

As seen from the measured data, the bias tee has low losses, excellent SWR and isolation. The measured data were unaltered when the units were tested with a bias voltage of 28 V at 1 A. The bias tee has been operating at the 100-W level with no problems. A single bias tee could have been designed to cover both bands but the goal of low-loss characteristics would not have been achieved. □□