

# Build a Legal Limit Bias T that Covers 1.8 to 230 MHz

**This simple device lets you send up to 3 A dc down your coax, along with the RF.**

## Phil Salas, AD5X

A bias T permits the insertion and removal of a dc voltage onto the center conductor of a RF transmission line. It is used to provide dc power to remotely located RF switches, preamps and antenna tuners to avoid the need for a separate dc power cable. Figure 1 (at the bottom of this page) shows a typical application in which a pair of bias Ts power a remote antenna tuner. As you can see, the bias T orientation permits it to either insert or recover the dc operating voltage.

## Design Considerations

A dc RF isolating inductor must provide high reactance across the bands of interest while carrying the required dc current. Also the Q must be high to minimize inductor power dissipation and thus loss of the RF signal.

I measured a large number of inductors on my Array Solutions AIMuhf vector network analyzer and found most had either multiple resonances across the HF spectrum, or the Q was too low for the desired efficiency. I finally settled on a J. W. Miller 40  $\mu\text{H}$  inductor. This inductor is rated at 3 A with a typical specified self resonant frequency of 145 MHz. Figure 2 shows the measured inductor data.  $R_p$ , the orange curve, is the finite parallel resistance of the inductor due to inductor Q. RF power will be dissipated

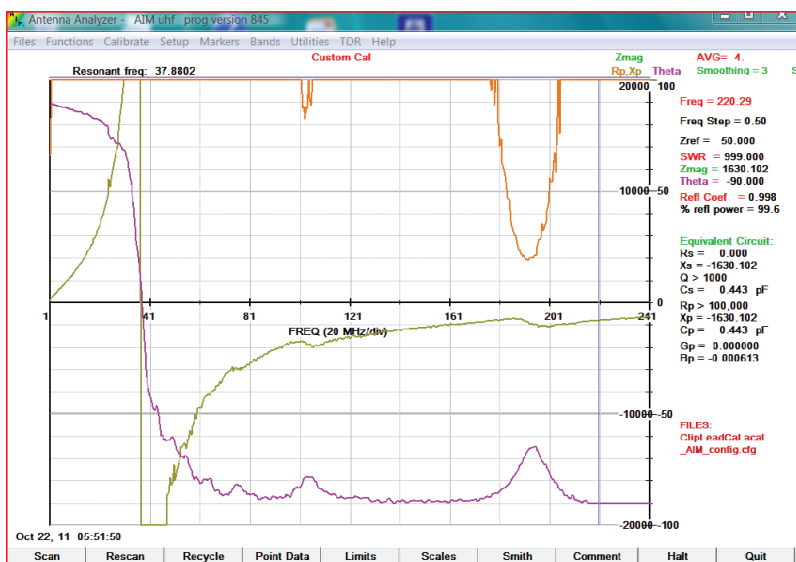


Figure 2 — AIMuhf data sweep of 40  $\mu\text{H}$  inductor.

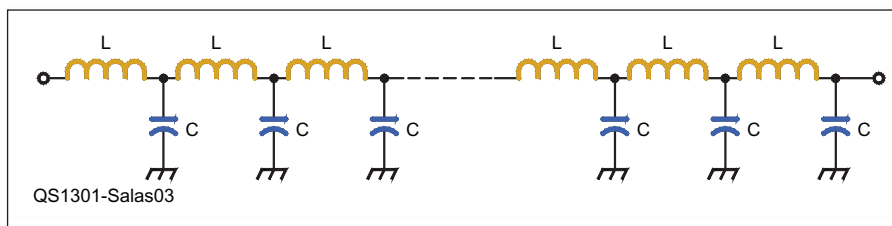


Figure 3 — Lumped element equivalent circuit of a transmission line.

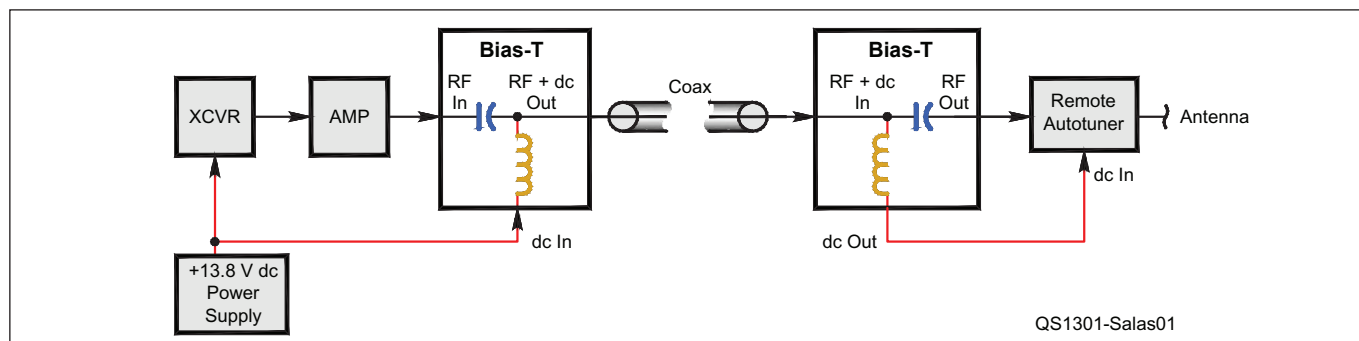
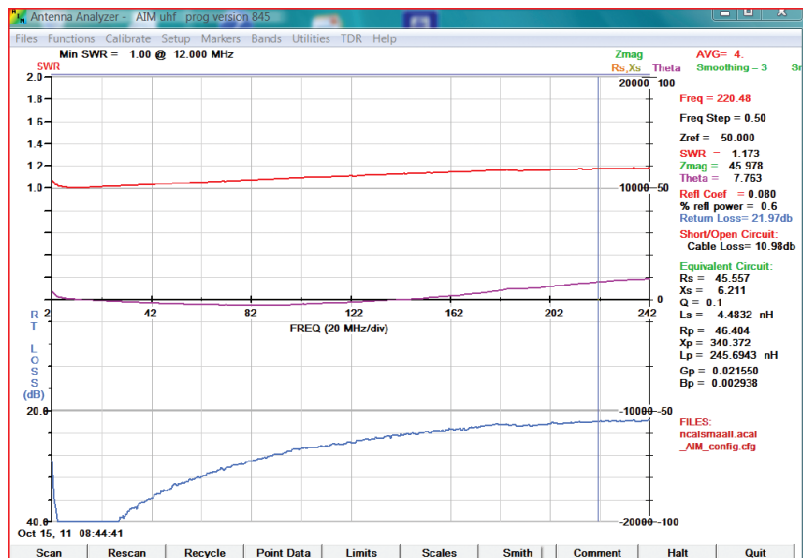
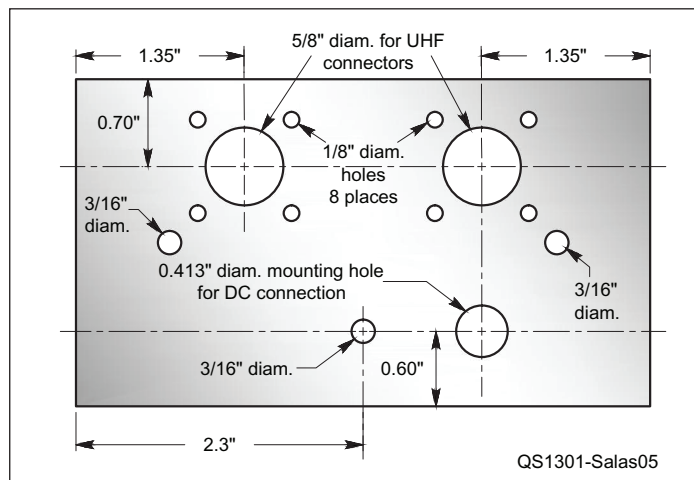


Figure 1 — Typical system connection diagram of a bias T.

**Table 1**  
**40  $\mu\text{H}$   $R_p$  and Calculated Inductor Power Dissipation ( $P_D$ ) at 1500 W**



**Figure 4 —** AlMuhf data sweep of the bias T SWR with compensation.



**Figure 5 — Cover plate hole locations with dimensions.**

in this resistance. As you can see,  $R_p$  stays high in the ham bands of interest.

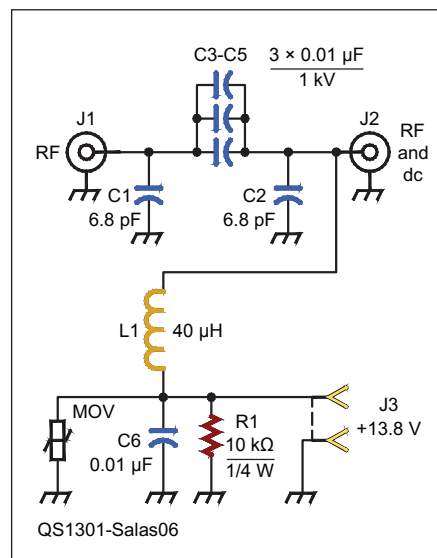
I tabulated  $R_p$  for the different ham bands in Table 1. And I calculated the inductor power dissipation at 1500 W ( $P_D = V^2/R_p$  where  $V^2 = 75,000$  at 1500 W and  $50\ \Omega$ ). For typical low duty cycle SSB or CW operation, the power dissipation will be about 25 to 30% of that shown.

Next I built the bias T. My first bias T circuit had acceptable SWR through 6 meters (the

6 meter SWR was 1.2:1). The SWR degraded, however, to about 1.7:1 on 2 meters, so I decided to see if I could improve the performance at higher frequencies.

A lossless transmission line can be modeled as an infinite number of incrementally small series inductors and shunt capacitors (see Figure 3) with the characteristic impedance given by  $Z_0 = (L/C)^{1/2}$ .

A hand wired assembly such as this bias T tends to be inductive unless you use good



**Figure 6**—Schematic diagram and parts list for the bias T. Mouser parts are available from [www.mouser.com](http://www.mouser.com).

C1, C2 — 6.8 pF, 1 kV capacitor (Mouser 75-561R10TCCV68).

C3-C6 — 0.01  $\mu$ F, 1 kV capacitor  
(Mouser 81-DEBF33A103ZA2B).

J1, J2 — SO-239 UHF coax sockets (Mouser 523-83-1R).

J3 — Chassis connector, dc power (Mouser 163-1060-EX).

L1 — 40  $\mu$ H, 3 A inductor, J.W. Miller 5240-RC (Mouser 542-5240-RC).

MOV — Metal-oxide varistor, 18 V dc (Mouser 667-ERZ-V10D220).

R1 — 10 k $\Omega$ , ¼ W resistor (Mouser 660-MFS1/4LCT52R103J).

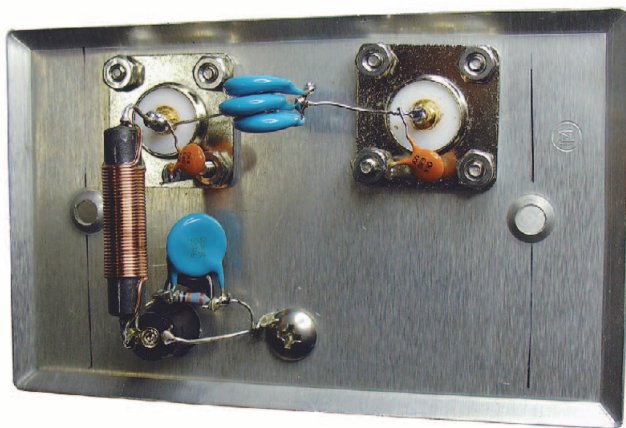
Electrical box, Reddot S100E (Lowes 71209).  
Metal box cover, Reddot S340E-R  
(Lowes 303624).

transmission line construction practices. Sure enough, my *AIMuhf* measurement data showed that the assembly was inductive. Since  $Z_0 = (L/C)^{1/2}$ , increased series inductance can be compensated for by increasing the shunt capacitance. With a little experimentation I found that 6.8 pF capacitors across the input and output significantly improved performance. As you can see in Figure 4 the SWR is less than 1.05:1 up to 50 MHz, less than 1.1:1 on 2 meters, and less than 1.2:1 at 220 MHz.

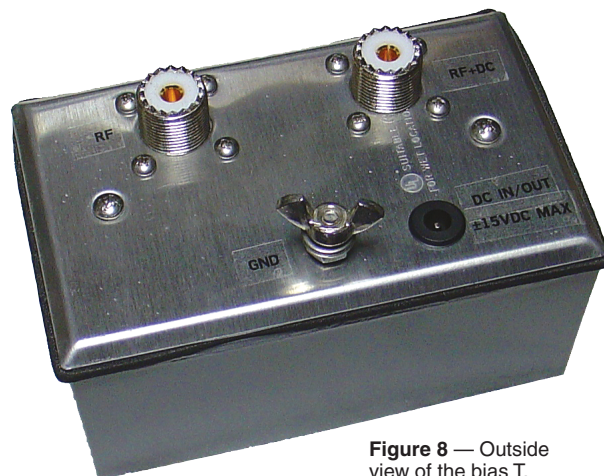
## Construction

I built the bias T into an inexpensive outdoor electrical cast aluminum box from a home supply store. Figure 5 shows the hole locations on the cover that ensure that the connectors and components don't interfere with the internal cover mounting brackets. I used a step drill for the dc and UHF connector holes.

After drilling the  $\frac{5}{8}$  inch diameter holes for the UHF connectors, I inserted the UHF connectors in the holes and marked the locations for the #4 ( $\frac{1}{8}$  inch) mounting holes



**Figure 7** — Inside view of the bias T. Note the input/output compensating capacitors.



**Figure 8** — Outside view of the bias T.

with an ultra fine pitch permanent marker. I then center punched and drilled these mounting holes.

The complete parts list and the schematic are shown in Figure 6. All components mount on the outlet box cover. The mounting hardware is stainless steel for outdoor use (the cover includes a weatherproof gasket). The three 0.01  $\mu\text{F}$ , 1 kV paralleled capacitors were not chosen for their voltage rating, as there should be virtually no RF voltage drop across them. I did want, however, physically large capacitors that were capable of handling the power dissipation due to the approximately 5.5  $\text{A}_{\text{RMS}}$  RF current through them under legal limit operation. On the dc in/out side, the metal oxide varistor (MOV) provides transient protection for voltages over about 18 V dc and the 0.01  $\mu\text{F}$  capacitor provides

RF bypassing. I included a 10 k $\Omega$  resistor to provide a constant dc path to ground.

Figure 8 is an outside view of the bias T. I used a #8-32 wing nut on the ground lug, but a standard #8-32 stainless steel nut can be substituted. Casio "Black on Clear" labeling tape sprayed with Krylon clear coat adds the text. A black permanent marking pen is a good alternative weatherproof marking method.

### Conclusion

A bias T can be the ideal solution for providing dc operating voltages through your coax cable to remotely located devices. The weatherproof unit described here can provide up to 3 A of dc while simultaneously handling RF power up to 1500 W from 1.8 to 220 MHz.

ARRL Life Member and Amateur Extra licensee Phil Salas, AD5X, has been licensed continuously since 1964. Because of his interest in ham radio he obtained BSEE and MSEE degrees from Virginia Tech and SMU respectively. This led to a 33 year career in Microwave and Lightwave R&D. Now fully retired, Phil spends his time tinkering with ham related projects and relaxing with his wife and best friend Debbie, N5UPT.

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## New Products

### Cushcraft 6 Meter and HF Squalo Antennas

Cushcraft's Squalo antenna is a half-wave, horizontally polarized omnidirectional antenna offering a 360 degree pattern with no deep nulls. The square shape allows full electrical length with compact dimensions. Squalo antennas are intended for horizontally polarized mobile or fixed operation on SSB, CW or AM. Elements may be stacked for added gain. The 6 and 2 meter models



are packaged with rubber suction cups and magnets for vehicle top mounting and a horizontal center support for mast or tower mounting. The 10, 15 and 20 meter models are designed for mast or tower mounting. Power rating is 100 W PEP for CW or SSB. Prices: ASQ-2, 2 meters, 10  $\times$  10 inches, \$119.95; ASQ-6, 6 meters, 30  $\times$  30 inches, \$139.95; ASQ-10, 10 meters, 50  $\times$  50 inches, \$159.95; ASQ-15, 15 meters, 65  $\times$  65 inches, \$189.95; ASQ-20, 20 meters, 100  $\times$  100 inches, \$229.95. For more information, to order, or for your nearest dealer, call 800-973-6572 or see [www.cushcraftamateur.com](http://www.cushcraftamateur.com).

### Compact Antenna Tuner from MFJ

The MFJ-902B antenna tuner uses air variable capacitors (600 V, 322 pF) and three stacked powdered iron toroids. Rated to handle 150 W on 80 to 6 meters, the

tuner is intended to be used with compact transceivers such as the ICOM IC-706MKIIG, Yaesu FT-100D, Kenwood TS-50 or any other 100 W class transceiver with a built-in SWR meter. The MFJ-902B measures 2.25  $\times$  4.5  $\times$  2.75 inches (HWD) and weighs less than 2 pounds. Price: \$109.95. For more information, to order, or for your nearest dealer, call 800-647-1800 or see [www.mfjenterprises.com](http://www.mfjenterprises.com).

