Build a 3-amp Legal-Limit Bias-T that Covers 1.8-230MHz
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Introduction
A Bias-T permits the insertion and removal of a DC voltage onto the center conductor of a RF transmission line via a high isolation inductor. It is used to power remotely located RF switches, preamps, and antenna tuners when a separate DC feed is unavailable. Figure 1 shows a typical application whereby a remote antenna tuner is powered by a pair of Bias-Ts. As you can see, reversing the Bias-T permits it to be used for both inserting and recovering the DC operating voltage.

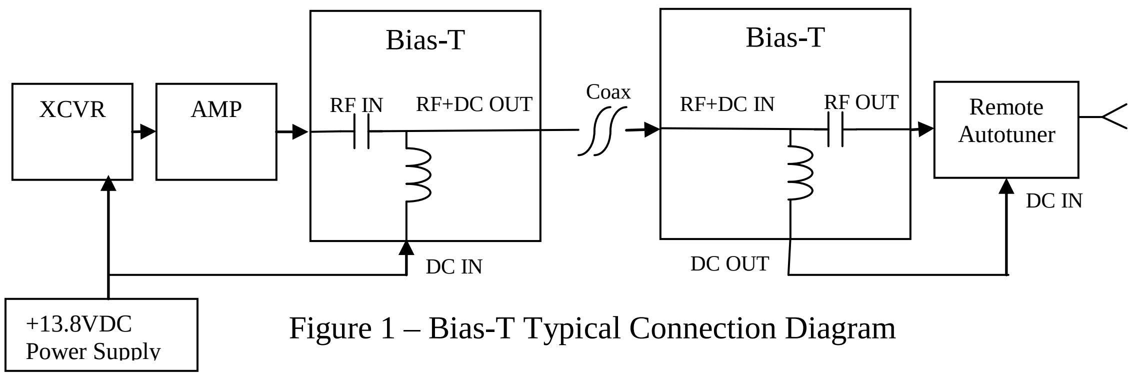

Figure 1 – Bias-T Typical Connection Diagram

Bias-T Design Considerations
Finding a DC/RF isolating inductor is the main challenge. The inductor must provide high reactance across the bands of interest, it must carry the required DC current (my goal was 2-amps), and the Q must be high to minimize inductor power dissipation due to the RF signal. I measured a large number of inductors on my Array Solutions AIMuhf vector network analyzer (Figure 2) and found that most either had multiple resonances across the HF spectrum or the Q was too low.

Figure 2: Inductor test set-up

I finally settled on two J.W. Miller inductors that appeared acceptable. One was the 5250-RC 100uHy inductor rated at 2-amps with a typical spec'd resonant frequency of 28.5MHz, and the second inductor was the 5240-RC 40uHy inductor rated at 3-amps with a typical spec'd self-resonant frequency of 145MHz.

Because of the possible 10-meter resonance of the 100uHy inductor, I made broad-band and narrow-band measurements of this inductor (Figures 3 and 4). Rp, the orange curve, is the finite parallel resistance of the inductor due to inductor Q and RF power will be dissipated in this resistance. As you can see, the 100uHy 10-meter resonance results in a fairly low Rp in that band. A low Rp is also indicated on 2-meters.

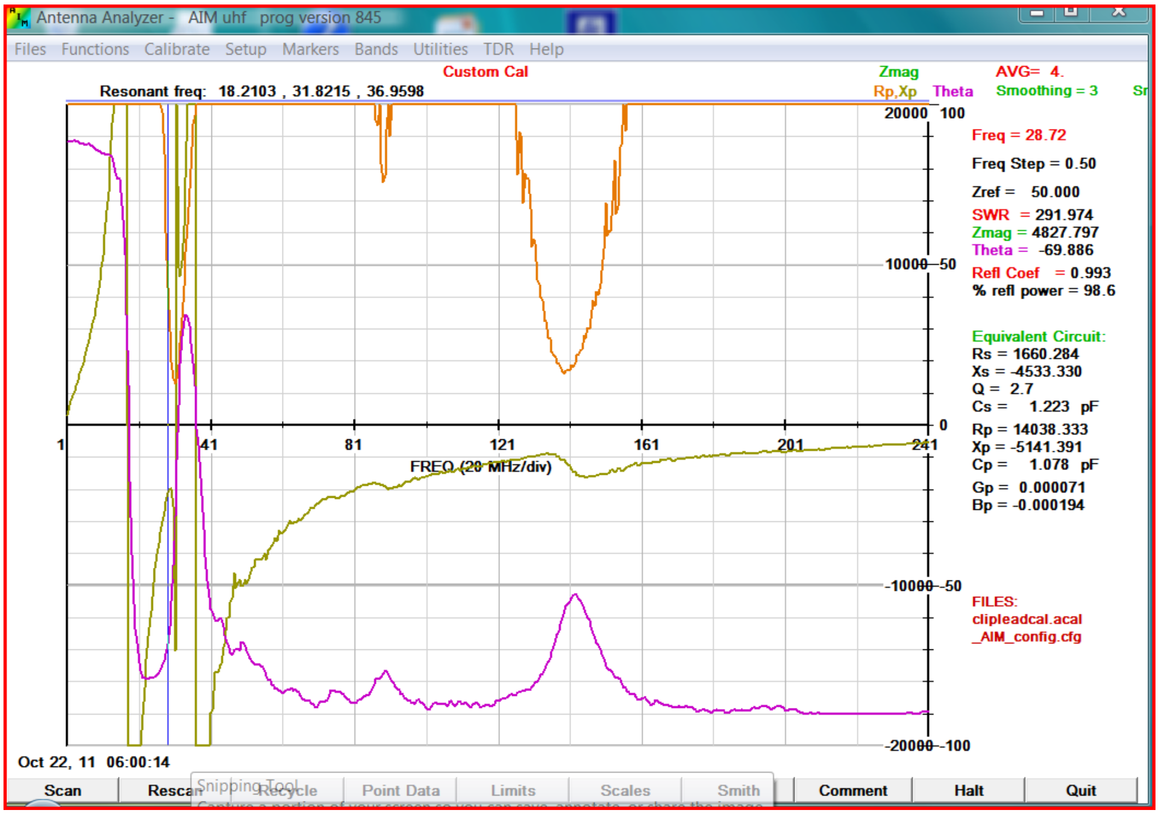

Figure 3: Wideband data sweep of 100uHy inductor

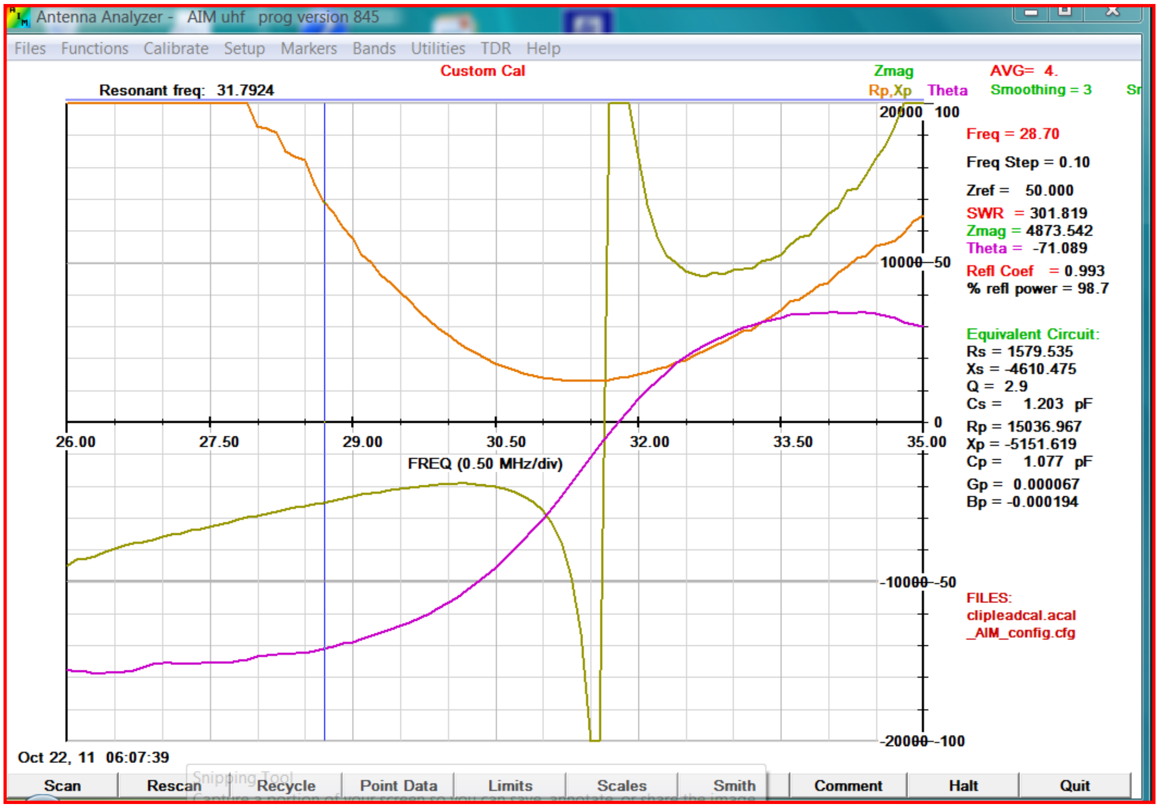

Figure 4: Narrowband data sweep of 100uHy inductor

The 40uHy inductor appears much better. As you can see in Figure 5, Rp stays high in the ham bands of interest.

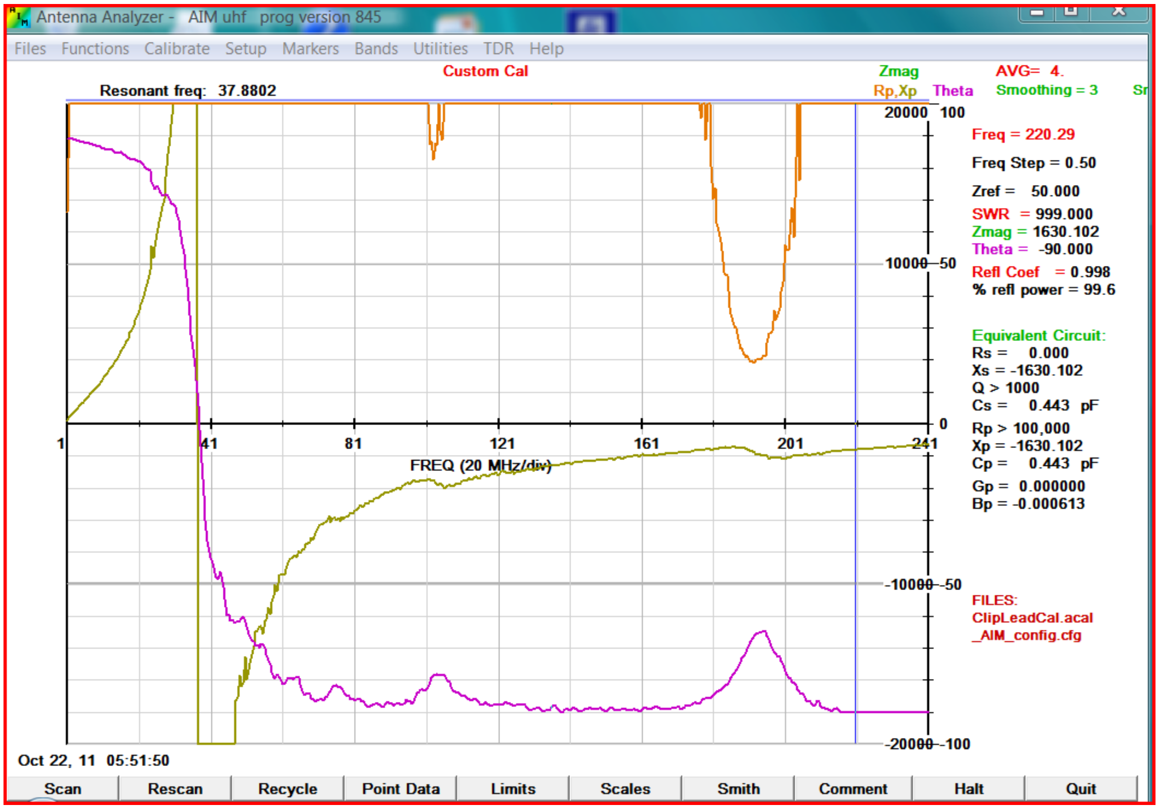

Figure 5: Broadband data sweep of 40uHy inductor

I tabulated Rp for the different ham bands in Table 1 for the 100uHy inductor, and Table 2 for the 40uHy inductor. And I calculated the inductor power dissipation at 1500 watts (Pdiss = V^2/Rp where V^2 = 75000 at 1500 watts and 50 ohms). For typical low duty cycle SSB or CW operation, the power dissipation will be about 25-30% of that shown.

Table 1: 100uHy Rp and calculated inductor power dissipation at 1500 watts

	160M	80M	40M	20M	17M	15M	12M	10M	6M	2M	1-1/4M
Rp	42KΩ	80KΩ	100KΩ	100KΩ	89KΩ	100KΩ	58KΩ	14KΩ	27KΩ	5.7KΩ	100KΩ
Pdiss	1.8W	0.94W	0.75W	0.75W	0.84W	0.75W	1.3W	5.4W	2.8W	13W	0.75W

Table 2: 40uHy Rp and calculated inductor power dissipation at 1500 watts

	160M	80M	40M	20M	17M	15M	12M	10M	6M	2M	1-1/4M
Rp	23KΩ	34KΩ	40KΩ	41KΩ	42KΩ	48KΩ	37KΩ	43KΩ	29KΩ	100KΩ	100KΩ
Pdiss	3.3W	2.2W	1.9W	1.8W	1.8W	1.6W	2W	1.7W	2.6W	0.75W	0.75W

Because of the low Rp of the 100uHy inductor on 10- and 2-meters, I decided to go with the 40uHy inductor.

Now that we have the inductor selected, we can build the Bias-T. However a hand-wired assembly like this will typically have excess inductance. This degrades the SWR at higher frequencies. Figure 6 shows the SWR/return loss of the Bias-T as originally built. Positive theta (the purple curve) indicates that the circuit is inductive. While the SWR is acceptable through 6-meters (6-meter SWR is 1.2:1) I wanted to see if I could improve the frequency response.

Figure 6: Bias-T Uncompensated SWR

A lossless transmission line can be modeled as an infinite number of incrementally small series inductors and shunt capacitors (Figure 7) whereby the characteristic impedance is given by $Z = (L/C)^{1/2}$.

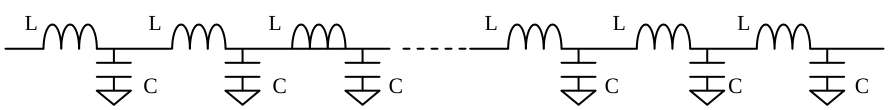

Figure 7: Transmission line equivalent circuit

Since $Z = (L/C)^{1/2}$, increased series inductance can be compensated for by increasing the shunt capacitance. I found that 6.8pf capacitors across the input and output significantly improved performance as you can see in Figure 8. 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 220MHz.

Figure 8: Bias-T SWR with compensation

Construction

I built the Bias-T into an inexpensive outdoor electrical cast aluminum box. Figure 9 is the cover hole drill template which ensures that the connectors and components don't interfere with the internal cover mounting brackets. I used a step-drill to drill the DC and UHF connector holes. After drilling the 5/8"D holes for the UHF connectors, insert the UHF connectors in the holes and mark the locations for the #4 (1/8"D) mounting holes with an ultra fine-pitch permanent marker.

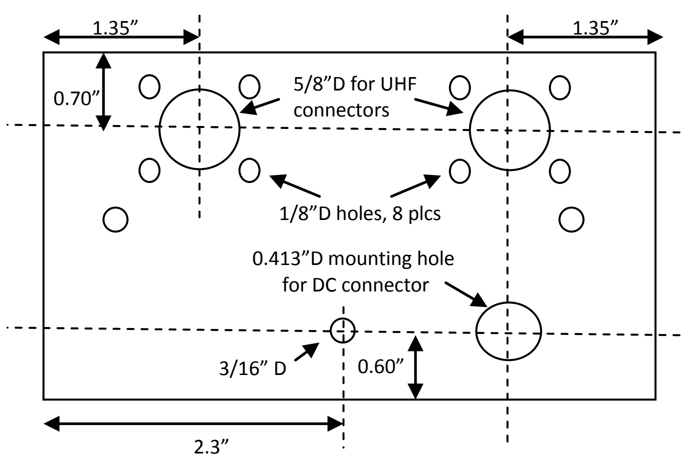

Figure 9: Cover Hole Dimensions

The complete parts list is given in Table 3, and the schematic is shown in Figure 10. All components mount on the outlet box cover. All mounting hardware is stainless-steel for outdoor use (the cover includes a weatherproof gasket). Three 0.01uf 1KV capacitors are paralleled and then soldered across the UHF connectors center pins. These capacitors are chosen not for their voltage rating as there should be virtually no RF voltage drop across them, but because I wanted physically large capacitors to handle power dissipation due to the high RF current through them under legal limit operation (~5.5 amps RMS). On the DC in/out side, the MOV provides transient protection for voltages over about 18VDC and the 0.01uf capacitor provides RF bypassing. I included a 10K resistor to always provide a DC path to ground but this is not really necessary. A photo of the internal view of the Bias-T is shown in Figure 11. Note the 6.8pf compensating capacitors at the input and output of the RF path.

Table 3: Parts List

QTY	Description	Mouser Part Number	Price ea.
4	0.01uf 1KV capacitor	81-DEBF33A103ZA2B	$0.38
2	6.8pf 1KV capacitor	75-561R10TCCV68	$0.65
2	SO-239 connectors	523-83-1R	$3.28
1	DC Power Connector, chassis	163-MJ21-EX	$2.77
1	DC Mating Cable	172-7445-E	$2.91
1	MOV, 18VDC	667-ERZ-V10D220	$0.36
1	40uHy inductor, 2-amp	542-5240-RC	$1.96
3	#4 solder lugs	534-7325	$0.14
1	10K ¼-Watt resistor	660-MFS1/4LCT52R103J	$0.08
1	Electrical Box, Reddot S100E	Lowes 71209	$3.35
1	Metal Box Cover, Reddot S340E-R	Lowes 303624	$1.07
8	4-40x3/8" stainless steel screws		
8	#4 stainless steel split-lockwashers		
8	4-40 stainless steel nuts		
2	6-32x1/2" stainless steel screws		
1	8-32x1" stainless steel screw		
1	8-32 stainless steel nut		
1	8-32 stainless steel wing-nut		
2	#8 stainless steel split-ring lockwasher		
2	#8 stainless steel flat washer		

Incidentally, most 2.1mm DC jacks will handle three amps - especially since typical applications only require intermittent high current draw (like a remote autotuner). However it is important to use a mating plug that can handle the current, especially when using pre-built cables as most pre-built cables use small gauge wire. The cable I call out uses 18-gauge wire.

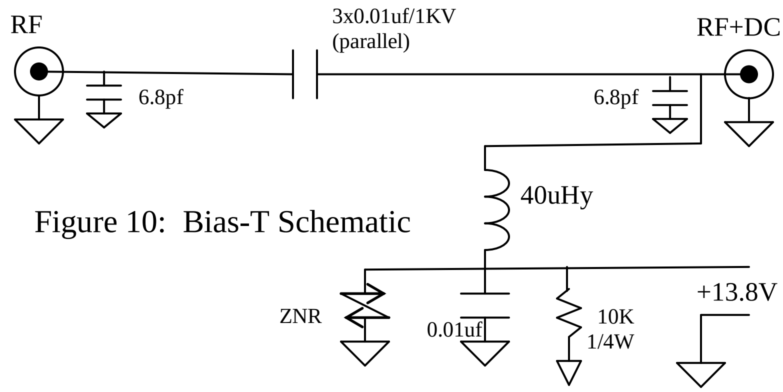

Figure 10: Bias-T Schematic

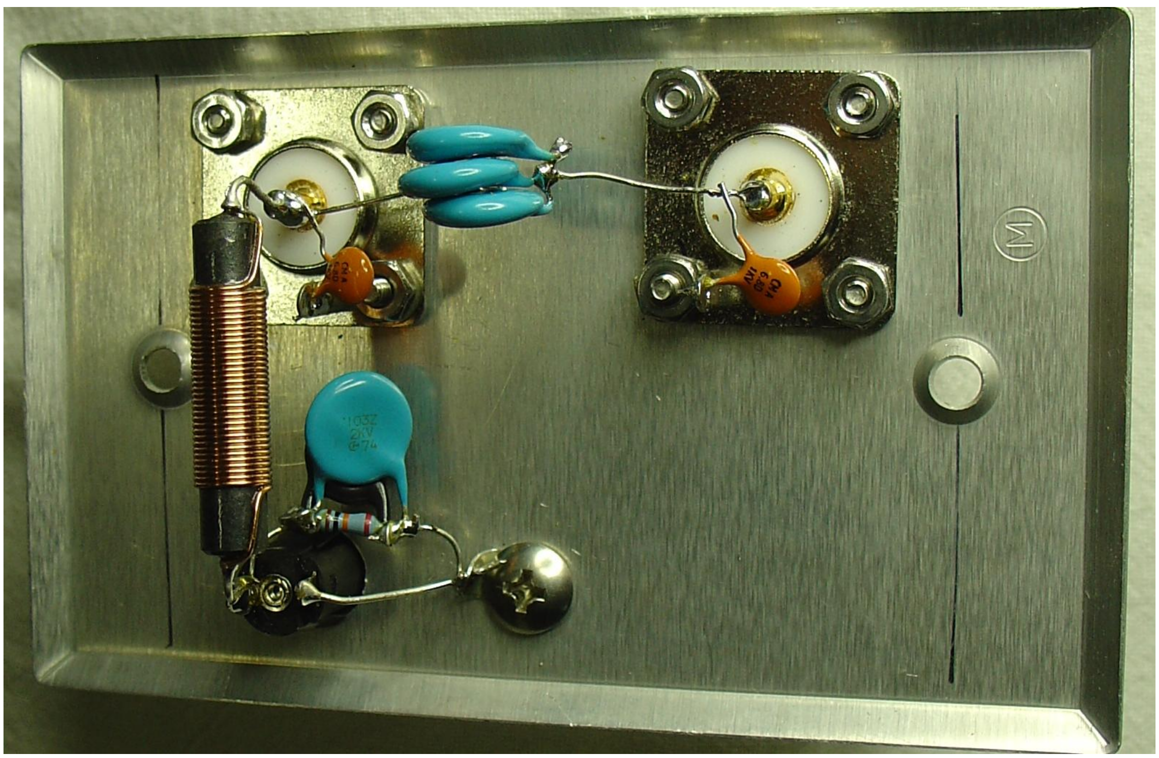

Figure 11: Inside view of the Bias-T. Note the input/output compensating capacitors.

Figure 12 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 is fine. Casio “Black on Clear” labeling tape sprayed with Krylon clear-coat provides the labeling, however a black permanent-marking pen is a good alternative weather-proof marking method.

Figure 12: Outside view of the Bias-T

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-amps of DC while simultaneously handling RF power up to 1500 watts over a broad frequency range.