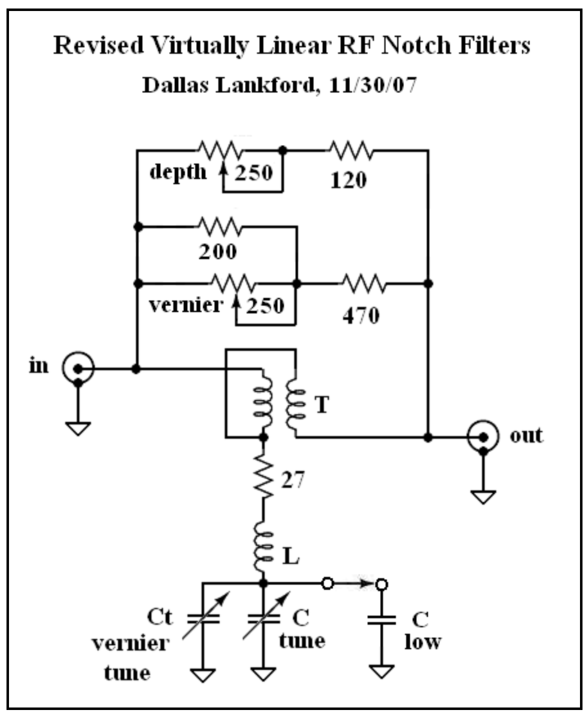
IIP2 Adjustments For Active Whip Antennas
With FET Gate Bias Adjustment

Dallas Lankford, 12/3/07

Some active whip antennas with FET inputs, like the Rohde & Schwarz HE010, do not have a FET gate bias adjustment or any other method of adjusting its IIP2; a two resistor voltage divider is used to fix the FET gate bias at about half the DC drain voltage and the IIP2 is whatever that gives you. The same is true of the pa0rdt Mini Whip. Other active whips with FET inputs, like most of Burhans' active whip antenna designs, are self biased with a fixed 1 Meg ohm resistor from the gate to ground. One of Burhans' designs used a voltage divider to fix the FET gate bias at about 1/3 the DC drain voltage. All of my active whip designs have used a pot to adjust the FET gate bias. A FET gate bias adjust can improve the IIP2 of an active whip antenna by 20 dB or more compared to a fixed FET gate bias. An early use of a FET gate bias adjust pot for an active whip antenna was in the 1982 East German KAA 1000. Having an IIP2 adjustment as part of your active whip antenna circuit does not necessarily mean that you will be able to adjust your active whip antenna for maximum IIP2 in practice, even if you have an ultralinear intermodulation distortion measurement system. For example, if you take the traditional approach of adjusting the pot by simulation, namely using a 50 ohm termination of the signal generators, filters, and combiner, followed by a coupling capacitor to the input of the whip antenna circuit (with the whip element removed), then what value should you use for the coupling capacitor in order to correctly simulate the active whip antenna (with whip element attached, and the active whip antenna at its outdoor location)? And there are other potential problems which we will not discuss here. Nowadays I generally use 6 pF to simulate a 3 foot whip element with the base of the whip element 6 feet above ground level. Others have used 12 pF, or 20 pF, or other values, for 3 foot whip elements as much as 20 feet off the ground. However, such large variations in the values of the coupling capacitors can significantly vary the IIP2 of high IIP2 active whip antennas. One should also consider the DC supply voltage and what effect long power leads have on the DC voltage at the active whip because the IIP2 of high IIP2 whip antennas is quite sensitive to small DC supply voltage variations. To get some insight into how "laboratory" adjustments compare to in situ adjustments, I took an active whip antenna with 3 foot whip element whose IIP2 had been maximized with a 6 pF capacitor simulation (sans whip element) to a location about 2 miles from the transmitting towers of KEEL 710 kHz and KWKH 1130 kHz and used a high performance RF notch filter and AR7030 to determine if the pot setting in the shadow of those two 50 kW transmitters was still accurate. With KWKH nulled, the effective IIP2 of the AR7030 was raised to about +130 dBm, and while the 2nd order product on 1840 kHz was clearly audible, it was quite weak. The FET gate bias adjust pot was varied, and it was found that the setting using the 6 pF capacitor gave about 10 dB lower IIP2 than IIP2 maximum with the whip element attached at this RF harsh environment. Based on these and other results, it is my opinion that the maximum IIP2 for an active whip antenna with FET gate bias adjust can only be maximized by taking the active whip antenna together with the signal lead in and power cables you will use in is final location to a site close enough to two transmitting antennas so that IMD2 can be minimized by using a high performance RF notch filter and high performance receiver. Such a suitable notch filter is described at right and below. If you do take this approach, be prepared to be questioned by the local law enforcement person who patrols high power transmitter sites.



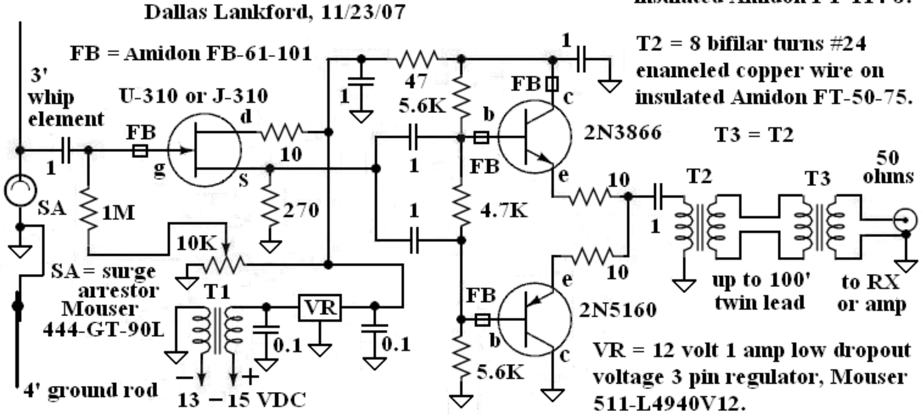
The transformer T in the RF notch filter is 80 close wound bifilar turns of #28 enameled copper wire on a 1 inch diameter by 2.5 inches long pill bottle for the MW band. The inductor L is 46 close wound turns of #22 enameled copper wire on a 1 inch diameter by 2.5 inches long pill bottle for the MW band. This gives a tuning range of about 710 kHz to 2050 kHz. A fixed 1200 pF silver mica capacitor "C low" is switched in to cover the remaining 540 – 710 kHz MW range. Capacitor Ct is a small trimmer capacitor, perhaps 5 pF or so, for vernier tuning the the notch frequency in the MW band. Input intercepts for the notch filter are IIP2 ≈ +130 dBm and IIP3 ≈ +70 dBm when the tones are spaced sufficiently far apart. System intercepts depend on the receiver or sensitive selective voltmeter used with the notch filter. Without the vernier controls you will never be able to notch a tone deeply enough to achieve a notch filter IIP2 ≈ +130 dBm. The pots are Clarostat/Honeywell Type J (formerly Allen Bradley Type J). Cheap pots will probably turn scratchy on you in a few hours, days, weeks, or months. Squirting cheap pots with your secret anti scratchy compound may eventually fail too. The 250 ohm pots are currently available from Surplus Sales of Nebraska as NOS at reasonable prices. In previous versions of this notch filter a 100 ohm Type J pots were used, but these are now about $50 each new. So instead of a 100 ohm Type J pot, a 250 ohm Type J pot in parallel with 200 ohms fixed resistor was used for the vernier depth control, which is approximately equivalent to a 111 ohm linear Type J pot.

If the above method of adjusting the IIP2 of an active whip antenna seems too complex, then the approach below may be more appealing. Several people requested a simple method for adjusting the IIP2 of my simple complementary push-pull output active whip antenna, and the method below is the result.

Simple IIP2 Adjustment For Simplified Complementary Push-Pull Output ActiveWhip Antennas

Dallas Lankford, 11/23/07

T1 = 30 bifilar turns #22 enameled copper wire on insulated Amidon FT-114-J.



10 ohm drain resistor should be 1% all other resistors 5% or better, adjust 10K ohm pot for 0.200 volts across 10 ohm resistor using 2% accuracy or better DVM.

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While this method of adjusting IIP2 is not ideal, it does have the advantage of being simple. A 12 volt voltage regulator is used to establish a constant DC supply voltage because IIP2 of the active whip is sensitive to changes in its DC supply voltage. A number of FET's were installed one at a time in a given active whip circuit and several parameters for each of the FET's were measured. No components other than the FET's of the active whip were changed. A 10 ohm 1% resistor was inserted in series with the FET drain to simplify measuring the total FET current. The FET current was found to be the most accurate measure of IIP2. For U-310's maximum IIP2 was 19.5 mA ± 0.1 mA (0.195 ± 0.001 VDC). For Motorola J-310's maximum IIP2 was 20.0 mA ± 0.1 mA. For Fairchild J-310's maximum IIP2 was 20.7 ± 0.1 mA. Measurements were made with a DVM having 2% accuracy. The voltage regulator output was measured as 12.04 VDC. The 511-L4940V12 regulator is rated as 12.00 ± 0.25 VDC. We picked 0.200 VDC as the adjustment voltage because it is approximately the mean of the voltages we measured. You can use the voltage for the particular FET you use. However our sample was not large enough to determine if that is a better strategy.