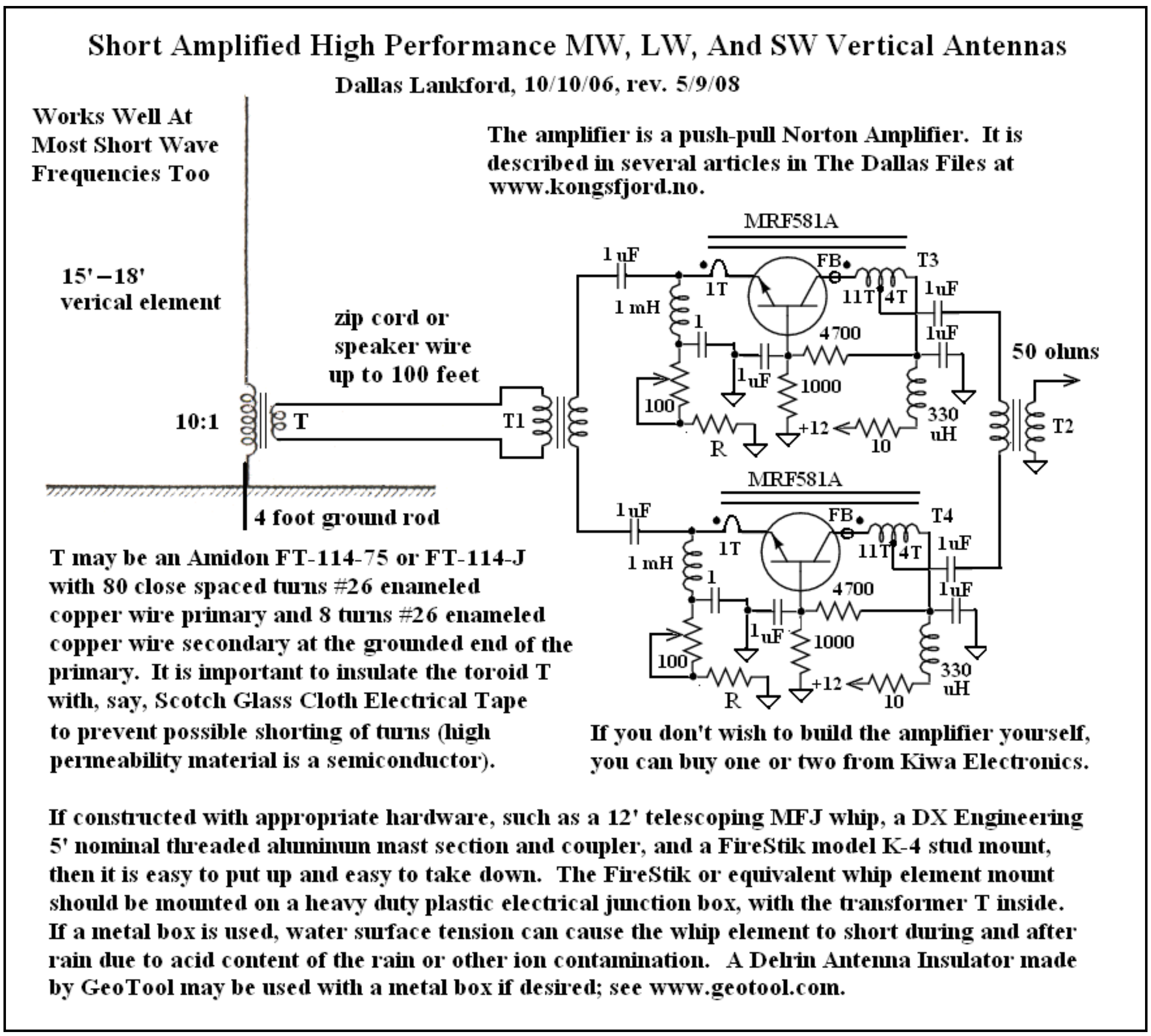
The Best Small Antennas For MW, LW, And SW

Dallas Lankford, 5/5/08, rev. 3/30/09

The amplified vertical antenna below was developed during experiments to see how short I could make a noise reducing vertical antenna while maintaining good sensitivity using only a 10.8 dB gain push-pull Norton amplifier (discussed in detail in other articles in The Dallas Files) to bring signal levels back up to a good level. The amplified 15 foot noise reducing vertical antenna is not an active antenna. The push-pull Norton amplifier, which is located at the receiver, is a low impedance device (as opposed to the high impedance FET's used in most active antennas) and consequently does not have the common mode noise problems which active whips and active dipoles sometimes have. This amplified short noise reducing vertical was tested with twin lead up to 100 feet in length. A pair of these separated by about 60 feet makes a good MW phased array. If you are not a builder, you can buy an equivalent Norton amp from Kiwa Electronics for about $110 plus shipping (as of May 2008). The gain of the 15 foot noise reducing vertical is about -15 dB, and its 2nd and 3rd order intercepts are typically greater than +120 dBm and +60 dBm respectively in the MW band. When used with a push pull Norton amplifier the cascaded input 2nd and 3rd order intercepts are greater than +95 dBm and +50 dBm respectively in the MW band. It is, in my opinion, the best small omnidirectional LW-MW-SW receiving antenna, period. A previous version used relay switching for improved performance at higher SW frequencies. Increasing the antenna transformer turns made relay switching unnecessary. I use two of them as my current phased receiving array. The antenna is now excellent for LW, MW, and SW. All of my longer and higher passive inverted L's and verticals and all of my active antennas have been permanently retired.



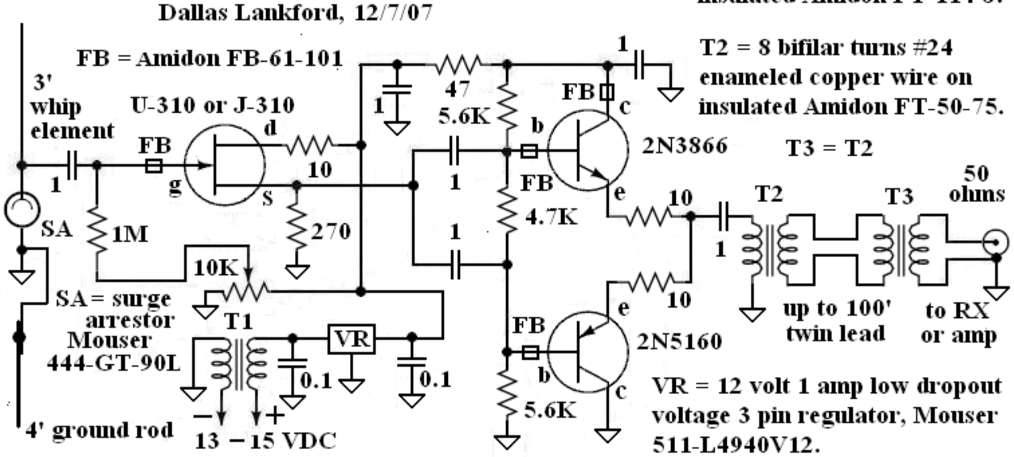
At least one person has claimed that noise reducing antennas are noisy. But when I quizzed him about his implementation, it turned out that he had not implemented the antenna correctly. If you do not follow the instructions, then you may end up with a noise increasing antenna like he did.

Although I have retired my active whips, there still seems to be a place for a high performance LW – MW – SW active whip antenna, such as for phased arrays at temporary locations, or as a compact substitute for the 15 foot noise reducing antenna above.

Revised Simplified Complementary Push-Pull Output
Active Whip Antennas
With Simple IIP2 Adjustment

Dallas Lankford, 12/7/07

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



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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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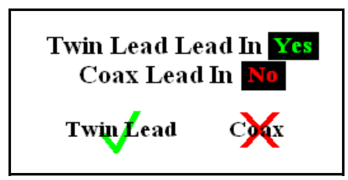
While this method of adjusting IIP2 is not ideal, it does have the advantage of being simple. A 12 volt voltage regulator is used to establish a constant DC supply voltage because IIP2 of the active whip is sensitive to changes in its DC supply voltage. A number of FET's were installed one at a time 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. (*but 11.86 in another sample)

Recently Horst Maier pointed out to me, based on simulations he had done, that the 2nd and 3rd order intercepts of my more complex U-310/2N5109/2N3866/2N5160 active whip antenna were independent of the supply voltage of the complementary push-pull output part of the circuit down to about 12 volts. That information was one of the things which motivated me to develop the active whip antenna above. And recently Jon Iza sent me information about a 1982 East German active whip antenna, the KAA 1000, which included its schematic. The KAA 1000 used a KP902A MOSFET front end followed immediately by a complementary push-pull output which also motivated me to develop the active whip antenna above. The transistors used in the KAA 1000 are believed to be obsolete and mostly unavailable, although one of the KP902A MOSFET's was offered for sale recently on eBay Germany.

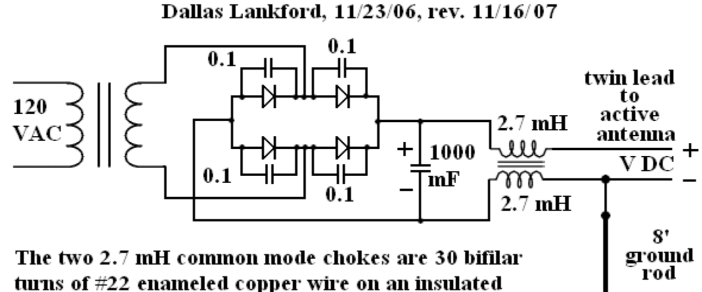
These active whip antennas are simpler than the more complex complementary push-pull output (CPPO) active whip antennas which were described in a previous article that is now retired. For example, this one does not contain a 2N5109 source follower between the U-310 FET stage and the 2N3866/2N5160 CPPO stage. And this one uses a 12 VDC power supply (or 13 to 15 VDC if you want to maximized IIP2 as described in the figure above), while the previous more complex active whips used a 24-30 VDC power supply. The 2N3866/2N5160 CPPO stage of this active whip antenna is operated with 10.3 VDC at the collector of the 2N3866. If it is later determined that the CPPO stage should be operated at a higher voltage, then the 47 ohm collector resistor can be replaced with a small choke. The CPPO stage was operated for many hours at 9 VDC and no increase of non-linearities were observed, so the 10.3 VDC specified should be satisfactory. With the 47 ohm resistor no heat sinks are needed for the 2N3866 and 2N5160. The U-310 also does not require a heat sink. Somewhat higher intercepts can be obtained by decreasing the value of the source resistor of the U-310, but when the source resistor is decreased the U-310 draws more current and so a heat sink for the U-310 would be desirable or necessary. All parts for this active whip are readily available. For example, you can buy the 2N5160 and 2N3866 on line from American Microsemiconductor for $9.65 and $2.75 respectively plus shipping. I believe there is a $39 minimum order. The U-310 is available from many suppliers, including Mouser. The FB-61-101 ferrite beads and FT-114-J, and FT-50-75 ferrite toroids are also available from many suppliers. A J-310 may be used instead of a U-310.

In the MW band IIP2 was +96 dBm (the 10K pot is adjusted for maximum IIP2 in the MW band) and IIP3 was +50 dBm. The tones and intermodulation products for the MW band intercept measurements were 600 + 700 = 1300 kHz, 2x600 + 700 = 1900 kHz, 1600 – 1100 = 500 kHz, and 2x1100 – 1600 = 600 kHz. MW intercepts, both IIP3 and IIP2, were independent of frequency. This is not the case for IIP2 of other active whips which I have measured. Some of the SW intercepts were IIP2(3 + 4 = 7 MHz) = + 81 dBm, IIP3(3 + 2x4 = 11 MHz) = + 48 dBm, IIP2(4 – 3 = 1 MHz) = +106 dBm, IIP2(9.005 – 6 = 3.005 MHz) = +96 dBm, IIP2(6 + 9 = 15 MHz) = +76 dBm, and IIP3(2x6 + 9 = 21 MHz) = +46 dBm. As can be seen, SW intercepts were not independent of frequency.



While studying active whip intercepts some time ago I discovered, much to my amazement, that long coax (50 feet) lead often degrades 2nd order intercepts of active whip antennas by 20 dB or more and degrades 3rd order intercepts of active whip antennas by up to 10 dB, depending on the type of active whip antenna. I have not studied the cases of longer coax lead in, or long coax lead in used with active dipoles, or long coax lead in used with (passive) noise reducing antennas. For active whips long (50 feet) twin lead lead in does not change 2nd or 3rd order intercepts. Also, I have not studied the cases for longer twin lead lead in with active whips, or for twin lead lead in used with active dipoles or (passive) noise reducing antennas. I rather expect that coax lead in will be a loser with respect to intercepts in all of those cases, while twin lead lead in will be a winner with respect to intercepts in those cases. Of course, if your antenna is not in a high RF environment, then it probably won't matter if you use coax lead in. On the other hand, more recently I have found that coax lead in can cause substantial man made noise in active whip antennas compared to twin lead lead in. It appears that the coax induced noise is via common mode, but unfortunately the noise is virtually impossible to eliminate completely throughout the MW band even with multiple common mode chokes. I am beginning to understand more clearly why active whip antennas have such bad reputations wrt man made noise. All except mine use coax lead in as well as DC power feed.

Low Noise Active Antennas AC/DC Power Supplies
Dallas Lankford, 11/23/06, rev. 11/16/07



The two 2.7 mH common mode chokes are 30 bifilar turns of #22 enameled copper wire on an insulated Amidon FT-114-J ferrite toroid.

Any active whip antenna should always be used with a low noise AC/DC power supply, such as the one at right. Details of such power supplies are found in another article in The Dallas Files .

If implemented correctly, active whip antennas can be as immune to man made noise as loops or any other antennas, despite claims to the contrary. People who have made those contrary claims probably did not use common mode chokes, or low noise AC/DC power supplies, or find a low noise location for the whip; see, for example, here for John Plimmer's interesting man made noise experiences with a loop and an active whip.

Don't be misled by claims of improvements for my active whip antenna, such as using lower performance BJT's, or modifying the bias chain to include diodes which have been claimed to improve temperature stability; see the web discussion below relating to Figure 6. In view of who made the claims it is not surprising that they are not improvements.

The amplified diode circuit in Figure 7 below ***might*** be suitable for temperature compensation when, for example, the active whip is mounted in direct sunlight, provided the amplified diode mod does not degrade my active whip intercepts and other desirable characteristics. Personally, I would just put my active whip in the shade and not change my original circuit. Or better yet, do not use an active whip at all. Like I said earlier in this article, the short amplified vertical antenna is a much better choice for a small omnidirectional antenna unless you live on top of a rock and cannot drive a ground rod into the ground (but in that case a relatively inexpensive 2' by 2' copper sheet laid on top of the rock will probably suffice for a ground).

The figures and associated discussion below were not composed by me. They are from an audio web site. However, I did modify one of my active whips to verify that including diodes in the bias chain does not improve temperature stability. The person who said that diodes improve temperature stability obviously did not make any measurements. As a matter of fact, the temperature stability of my active whip can hardly be improved.

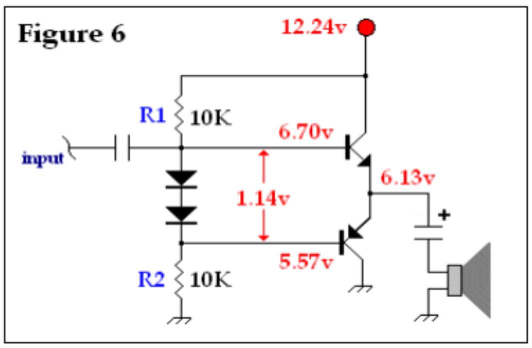


Figure 6 illustrates an improved biasing method over that of Figure 5 by using a pair of silicon diodes. You see this circuit used a lot by hobbyists. The voltage divider consists of 2 resistors and the 2 diodes. The 2 series connected diodes are connected in parallel to the NPN and PNP transistor base-emitter junctions which serves to keep the transistors turned on slightly. The net effect of the diode pair is the same as R3 in Figure 5. The voltage drop per diode was measured at 0.57 volts. The AC resistance of these 2 forward biased diodes is non-significant. There is major problem with the diode/resistor voltage divider; no way to adjust the diodes forward voltage drop. If each diode's forward threshold voltage is unequal to the base-emitter junction voltage of each transistor, either not enough forward bias is applied, or the 2 transistors may be turned on too much reducing efficiency and possibly cause excessive heating. Additionally, the pair of diodes lack the ability to provide temperature compensation when the transistors get hot.

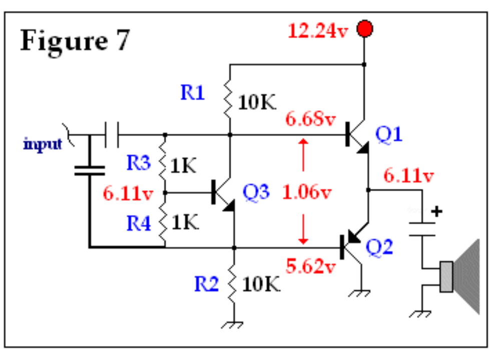


Figure 7 shows the best way to bias our complimentary pair. Our familiar 10K-10K voltage divider is kept, but a transistor Q3 with its own biasing resistors R3 and R4 are added. You might think of R3 and R4 as a voltage divider within a voltage divider. Q3 is referred to as an amplified diode and receives local feedback which allows it to track of the output transistors temperature changes as long as it is close thermal contact with the complementary follower output pair. This usually involves mounting Q3 on the same heat sink as the finals. If the output transistors heat up, so does Q3 and this results in a a smaller voltage drop across Q3 which translates into less forward bias to Q1 and Q2. Within limits, Q3 with its own base-emitter junction provides variable forward bias for the output transistors.