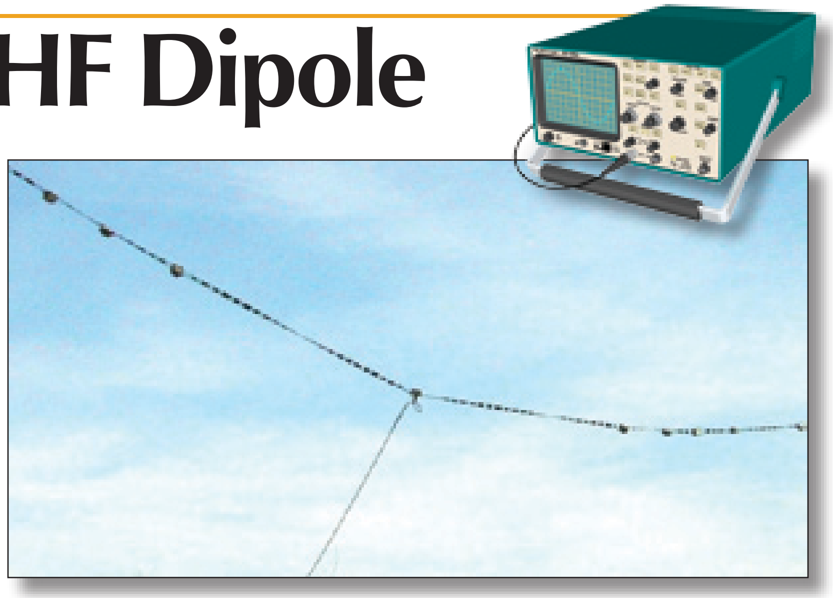
An All Band HF Dipole Antenna



Use relays without extra wires to select your dipole length.

Jim Weit, KI8BV

If you are like many of the amateurs I know, you have wanted to try out many of the HF bands at one time or another. Here is an antenna that can cover any or all of the HF bands that you might want to operate on. This antenna does not have strange radiation patterns or narrow bandwidth as do some multi-band antennas.

[This antenna should provide similar performance to the pneumatically switched multiband dipole presented in August *QST*.[1] The control systems provide a strikingly different approach to the switching mechanism. — *Ed*.]

Over the years I have put up many dipole antennas in my yard. I am lucky in that my lot is large enough for a full size 160 meter dipole. There are lots of large trees to hang dipoles between. Even on a large lot it is hard to arrange eight or nine dipoles in such a way that minimizes the interaction between them. The cost of all the coax needed to feed such a large number of antennas can get expensive. Then there is also the problem of the visual clutter, at least in the eyes of the neighbors.

An Idea Emerges

One day while trying to figure out where to hang one more antenna, it occurred to me that the only difference between a 10 meter and a 12 meter dipole was 14 inches of wire added to each end. The addition of 19 inches of wire at each end of the 12 meter dipole makes it a dipole for 15 meters. If there were a way to increase or decrease the length of the dipole whenever I wanted, I would have three dipoles in the same place, using the same supports, and using a single coax feed line. There would be no interaction between them, and they would have all the same characteristics as a dipole, because each one is a dipole. Well, I am sure that you can see that we could cover any set of bands that we want by simply adding or removing lengths of wire to or from the ends of a basic dipole. The big question is, how can we do this from the comfort of the ham shack anytime that we want?

One way to do this is to place relay contacts along each leg of the antenna at the points at which each dipole would end. Energizing pairs of relays connects lengths of wire to each end of the antenna, and de-energizing pairs of relays disconnects the lengths of wire and shortens the antenna. By making each leg of the dipole from two parallel wires, it is possible to get power and control signals from the shack, through the coax feed line to the relays. Since a number of relays must be controlled, some electronic components are needed at each relay to decode the control signals that are carried along the parallel antenna conductors. The relays and their control circuits must be housed in weatherproof enclosures. I call these assemblies *relay modules*.

We also need an enclosure with circuitry to generate the control signals that are sent to the relay modules using the same coax feed line that carries RF between the station and the antenna. I call this unit the *antenna controller*.

Figure 1 is a block diagram of the complete multi-band antenna system. Only two pairs of relay modules are shown, but additional pairs can be added to cover as many bands as you would like. With just the two pairs of relay modules shown, this would be a three band antenna.

A module called a *splitter* is located at the center of the antenna. This module also acts as the center insulator. The splitter uses RF chokes and capacitors to separate (or split) the RF power from the dc power and control signals on the feed line.

Another part of the system is called the *injector*. The injector allows dc power and control signals to be injected onto the feed line at the operating position. The injector circuit is outlined on the controller schematic (Figure 2). The injector is shown in Figure 3.

The antenna controller provides dc power to the relay modules, and generates the control signals that turn pairs of relay modules on or off. The controller and injector are located in the shack. The only wires that run between the antenna and the ham shack is a single coax feed line, just like a regular dipole antenna.

Basic Operation

Refer to Figure 1. At power-on, +12 V is applied to the + terminal of relay module 1A through Q1, L1, L2 and up the center conductor of the feed line. It also passes through the inductor in the splitter module to relay module 1B. The negative side of the power supply is connected to relay module 1B through the outer braid of the feed line. It is also connected to relay module 1A through the splitter. The relay module operation is described below.

At this point dc power is applied to the control circuits in the first pair of relay modules (1A and 1B). Initially the relays in these modules are not energized so the relay contacts are open and no power gets to the next pair of relay modules. The antenna is now set for the highest frequency band, band 1. The dc power to the relay modules passes through the inductors, but RF does not. Injector capacitor C1 allows RF from the transceiver to flow to the antenna and prevents dc from the antenna controller from flowing to the transceiver. The capacitors in the splitter keep both of the parallel antenna conductors at the same RF potential.

Making it Work

The control circuits in modules 1A and 1B look for a momentary zero voltage condition between the parallel antenna conductors (Q1 turns off and Q2 turns on for 100 µs). This action causes the control circuit to

[1]Notes appear on page 66.

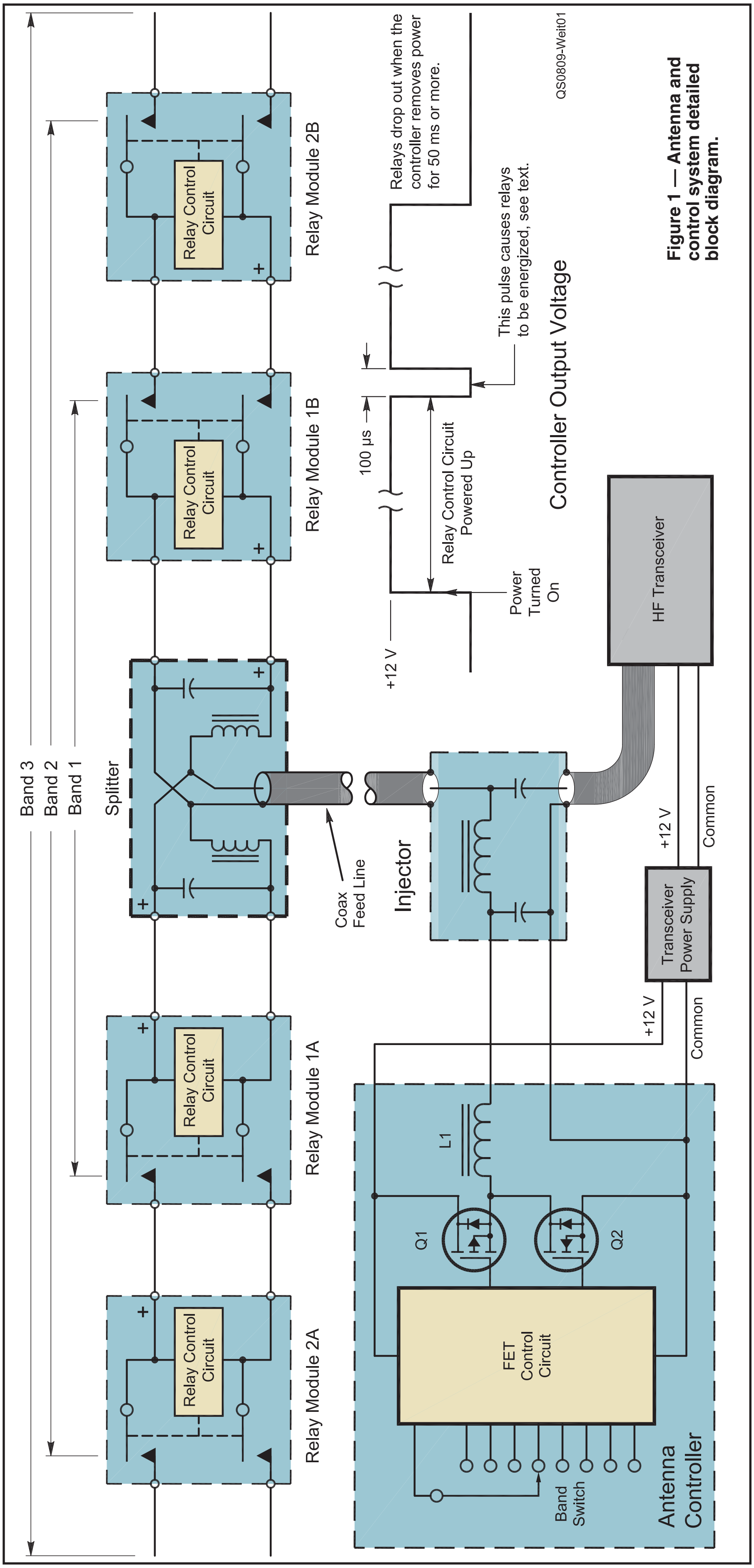


Figure 1 — Antenna and control system detailed block diagram.

energize the relays in the first pair of modules (refer to timing diagram on Figure 1). A 10 µF capacitor in each relay modules maintains power to the relay control circuit during the 100 µs that dc power is removed. Now the antenna is set for band 2, and power is applied to modules 2A and 2B through the relay contacts of modules 1A and 1B. On the next negative going pulse, the relays in the second pair of modules are energized, and the antenna is set to band 3. Any number of relay modules can be sequentially energized in this way. For practical reasons the 100 µs pulses must be about 40 ms apart. This means that eight pairs of relay modules (for a nine band antenna) can be turned on in about 320 ms, or less than a third of a second. By removing power to the relay modules (Q1 OFF and Q2 ON) for 50 ms, all relays will drop out, and the desired band can be selected with another string of 100 µs negative going pulses. With this control scheme, the circuits in all the relay modules can be identical regardless of their position along the antenna wires.

The Relay Module

Figure 3 is the schematic diagram of a relay module. The heart of the circuit is the PIC12F508 microcontroller. This chip is available in an 8-pin dual inline package (DIP). The industrial version is good for temperatures from –40 to 185°F. The basic function of the software is very simple. When power is first applied, the processor does nothing for 18 ms. This is enough time to make sure that any relay contact bounce from the module ahead of it is over. The processor then goes into the sleep mode. This shuts down the chip's internal 4 MHz oscillator and minimizes the current drawn by the processor. The next time the input (pin 7) goes low, the processor wakes up, energizes the relays, and goes back to sleep. It never does anything again unless it is reset by removing and reapplying power.

Two single contact relays are used. The contact rating of the relays is 10 A at 250 V ac. Since the relays don't interrupt RF power, it is the contact withstanding voltage rating of 750 V ac that is important. Simulations of the antenna using *EZNEC* predict that at 100 W of power to the antenna, the maximum RF voltage across any relay contact is 733 V.[2] This maximum occurs on the last relay module of an antenna that covers 160 meters while transmitting on 80 meters. I have measured the breakdown voltage across the contact of many of these relays and found that they can withstand a voltage of well over 1000 V ac. As long as your antenna is not built to cover 160 meters, the simulations indicate that you can use up to 200 W of RF power with these relays. My transceiver is rated for 100 W so I have not stressed the system beyond this power level.

The LED is not necessary, but it is very

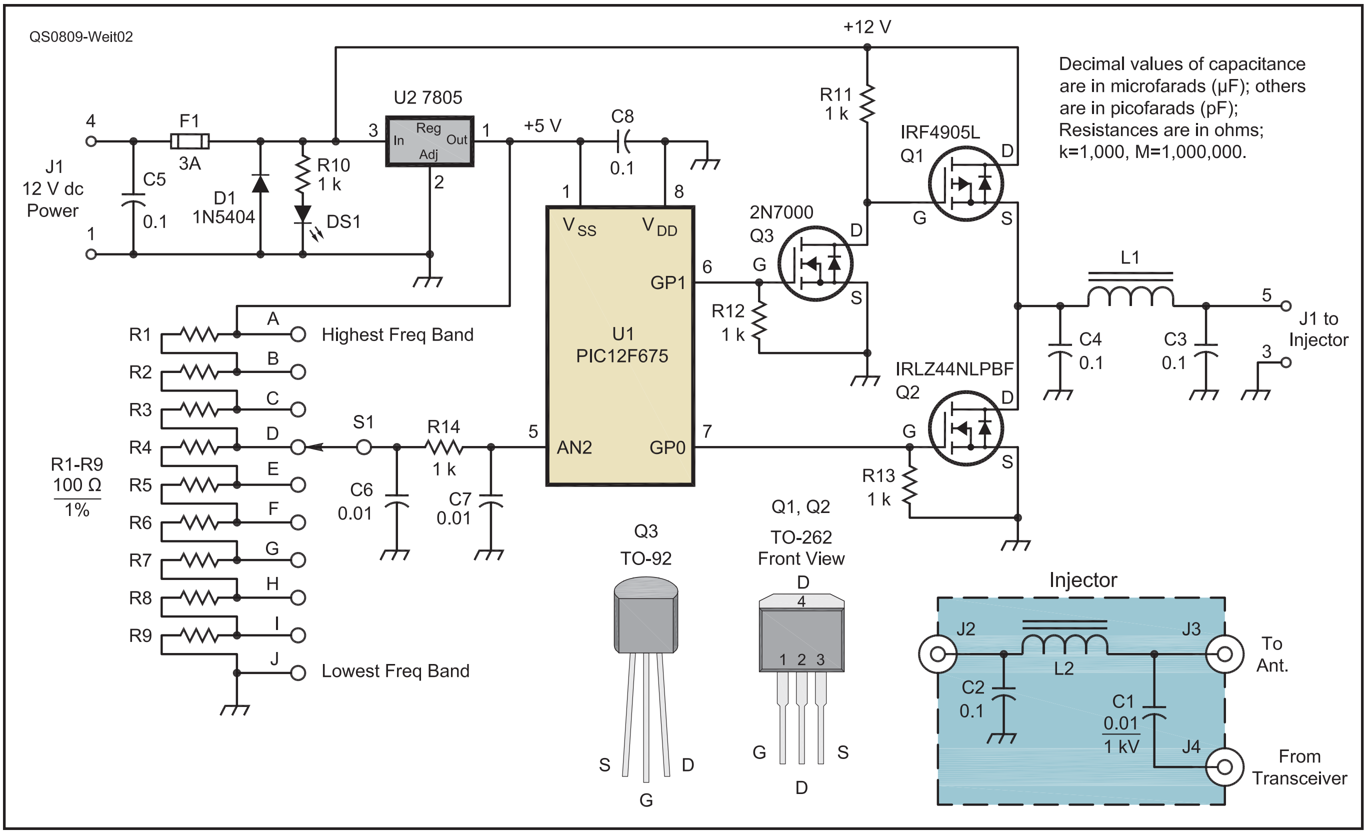


Figure 2 — Schematic and parts list for the controller and injector. Parts are available from distributors such as Allied Electronics at www.alliedelec.com, Digi-Key at www.digikey.com, McMaster Carr at www.mcmaster.com and Mouser at www.mouser.com.

C1 — 0.01 µF, 1 kV ceramic disk capacitor.
C2-C5, C8 — 0.1 µF, 50 V ceramic capacitor, type Z5U.
C6, C7 — 0.01 µF, ceramic capacitor, type Z5U.
D1 — 1N5404 silicon rectifier (Mouser 821-1N5404).
F1 — 3 A, 5 × 20 mm fuse.
Fuse clips for F1 (Digi-Key 283-2335).
J1 — DIN jack, 5 pin, (Mouser 161-0505).
J2 — Phono jack (Mouser 16PJ052).
J3, J4 — UHF jack (Mouser 523-83-878).
L1, L2 — 100 µH RF choke (Digi-Key M8271).
LED1 — Red LED (Mouser 638-333ID).
P1 — Plug to fit J1 (Mouser 171-0275).
P2 — Phono plug (Mouser 17PP052)
Q1 — P channel FET (Digi-Key IRF4905L).
Q2 — N channel FET (Digi-Key IRLZ44NLPBF).
Q3 — N channel FET (Mouser 2N7000D75Z).
R1-R9 — 100 Ω, ¼ W, 1% resistor.
R10-R14 — 1 kΩ, ½ W, 5% resistor.
S1 — 12 position rotary switch (Digi-Key CT2123).
U1 — Microprocessor (Digi-Key PIC12F675-I/P).
U2 — +5 V regulator (Digi-Key LM78L05ACZFS).
Controller enclosure, extruded aluminum (Mouser 546-1455N1201).
Injector enclosure, diecast aluminum (Mouser 546-1590A).
Knob, 1 inch (Allied 543-1105).

handy while testing modules. Even with the antenna in the air you can see if it is working properly by observing the LEDs, most effective at night.

Figure 4 shows a completed relay module circuit board as well as two completed modules. The enclosure is composed of three pieces. The base is made from ¼ inch thick PVC that is 2 inches wide by 3 inches long. The base has holes at the ends for antenna wire attachment. The sides of the module are made from 2 inch square PVC tubing that is cut into pieces 1 inch long and glued to the base plate using PVC cement. After the square tubing piece is cemented in place, the circuit board mounting holes can be located by dropping a blank PC board into the enclosure, and then using the PC board as a template to drill the holes. Note that the PC board is not a perfect square and must be oriented properly before drilling the holes.

The completed PC board is mounted in the enclosure using four #6-32 × 1 inch stainless steel screws. The screws are also used as terminals to connect the antenna wires to the modules. Before the outside nut is put on each screw, put a dab of PVC cement around each screw as it comes through the base, in order to make sure water can't get into the module through the screws. Another nut and two star lock washers are used to make the connection to the antenna wire as shown in Figure 5. After the PC board is installed, mark the plus input terminal (the one with the plus sign in Figure 3) by scratching a plus sign into the PVC base near that terminal. It is easy to get mixed up when connecting the antenna wire to the modules without this mark. The top cover is made from clear PVC sheet, so the LED can be viewed, and can be cemented in place after the module is tested.

The Splitter

The splitter assembly acts as the center insulator of the antenna, and the connection point for the coax. It houses the RF chokes (L3 and L4) and capacitors (C4 and C5) that split the RF power from the dc power. The construction of the splitter is similar to that of the relay modules. Drill an extra hole in the base to attach a nylon cord that will be taped to the coax to act as a strain relief for the coax connector. Be sure to waterproof the connector after the coax is connected to the splitter. Board and interior views along with a completed splitter is shown in Figure 6.

The Controller

Refer to Figure 2. The controller is powered from the 12 V transceiver power supply (typically 13.8 V). The FETs, Q1and Q2, are controlled by an eight pin 12F675 microprocessor. This processor has an analog input to a 10 bit analog to digital converter. The band selector switch connects to a voltage divider (R1 to R9) that produces a particular voltage level

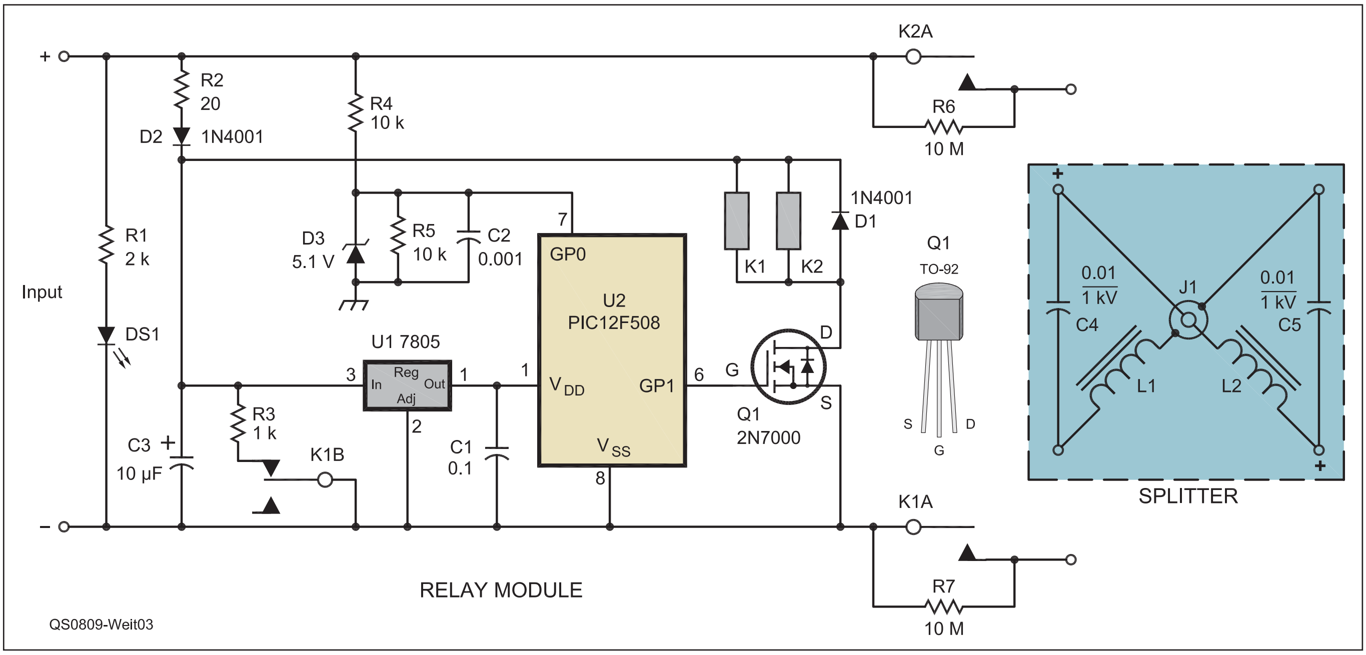


Figure 3 — Schematic and parts list for the relay module and splitter. The 10 MΩ resistors across the relay contacts prevent static buildup on unused antenna sections.

C1 — 0.1 µF, 50 V ceramic capacitor, type Z5U.
C2 — 0.001 µF, ceramic capacitor, type Z5U.
C3 — 10 µF, 50 V electrolytic capacitor (Digi-Key P10316).
C4, C5 — 0.01 µF, 1 kV ceramic disk capacitor (Digi-Key 399-4309).
D1-D2 — 1N4001 or equivalent silicon rectifier (Mouser 863-1N4001G).
D3 — 5.1 V Zener diode (Digi-Key 1N4733ACT).
DS1 — Red LED (Mouser 638-333 ID).
J1 — UHF jack, SO-239.
K1, K2 — Relay (Digi-Key Z1012).
L1,L2 — 100 µH RF choke (Digi-Key M8271).
Q1 — N channel FET (Digi-Key 2N7000D75Z).
R1 — 2 kΩ, ½ W, 5% resistor.
R2 — 20 Ω, ½ W, 5% resistor.
R3 — 1 kΩ, ½ W, 5% resistor.
R4, R5 — 10 kΩ, ½ W, 5% resistor.
R6, R7 — 10 MΩ, ½ W, 5% resistor.
U1 — +5 V regulator (Digi-Key LM78L05ACZFS).
U2 — Microprocessor (Digi-Key PIC12F508-I/P) with author's firmware.
Enclosures fabricated from type 1 PVC materials (McMaster Carr).
Stainless steel hardware (McMaster Carr).

for each band. The processor reads the voltage three times over a one second period to make sure you have finished turning the switch. If a band change is detected, the processor will kill power to all relay modules long enough for them to drop out. It then turns power to the relay modules back on and then generates the correct number of pulses to turn on the right number of relay modules for that band.

The controller does not know if you built your antenna without including a pair of relay modules for a particular band. For instance you might decide not to include relay modules for 30 or 60 meters. In this case, be sure to label the selector switch sequentially for the bands that you are using. Do not provide switch positions for bands that you are not using. When the switch is fully counterclockwise, the controller does not send any pulses to relay modules. Mark this position for the highest frequency band that your antenna is to cover. In the next switch position the controller will energize the first pair of relay modules. Be sure to mark this switch position for the band that is selected by the first pair of relay modules, and so on.

There is a 5-pin DIN connector on the back of the controller. Two of the pins are used to connect to the 12 V dc power supply. Two other pins are used to run the dc power and control signals to the injector. The control signal is connected to the injector using a standard phono connector. Controller and injector circuit boards are shown in Figure 7. The assembled controller is seen in Figure 8.

Assembling the antenna

After all the assemblies are built, everything can be tested by temporarily connecting the relay modules together using hookup wire. After all of the modules are built and tested, it is time to connect them together with antenna wire. I used 450 Ω ladder line with copper coated steel conductors for strength. You can use individual strands of wire as long as one conductor is insulated or spaced in such a way that the wires cannot short together. In one of the earliest versions of the antenna, I used 14 gauge hard drawn copper covered steel antenna wire, for one conductor, and 20 gauge insulated stranded hookup wire for the other conductor. I taped the two wires together every few feet. Having the conductors spread apart, as in the window line, actually increases the bandwidth of the antenna slightly.[3] A single conductor can be used for the run from the last relay module to the end insulator.

Because of the capacitive coupling across the relay contacts, each section of the antenna ends up a little shorter than the standard calculations indicate. It is best to make each

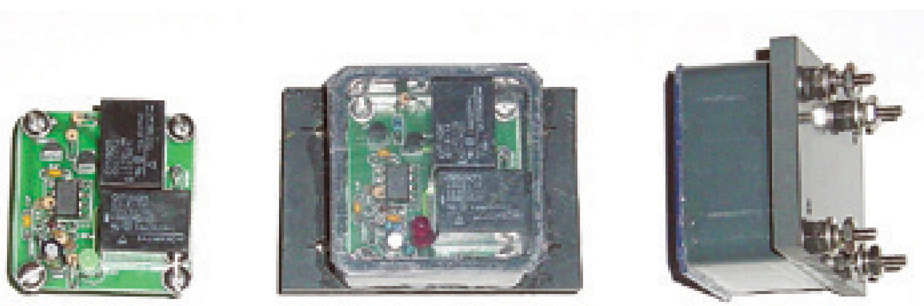


Figure 4 — Relay module. Shown is a completed PC board and front and side views of completed relay modules. The antenna wires will be connected to the studs on the back of the relay modules.

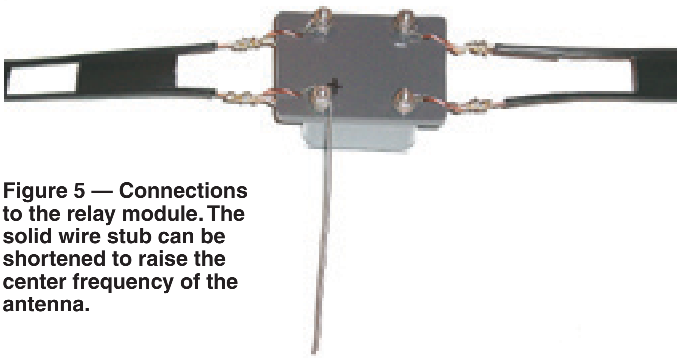


Figure 5 — Connections to the relay module. The solid wire stub can be shortened to raise the center frequency of the antenna.

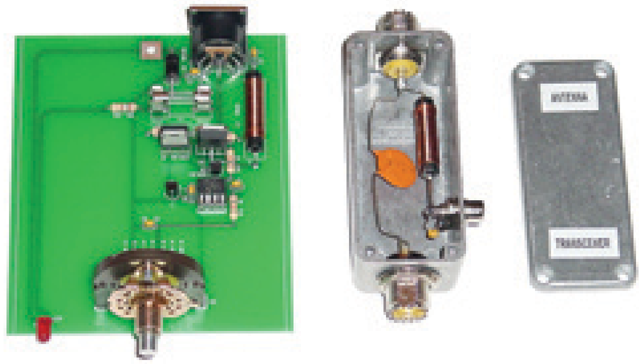


Figure 7 — Controller PC board and the injector with the covers removed.

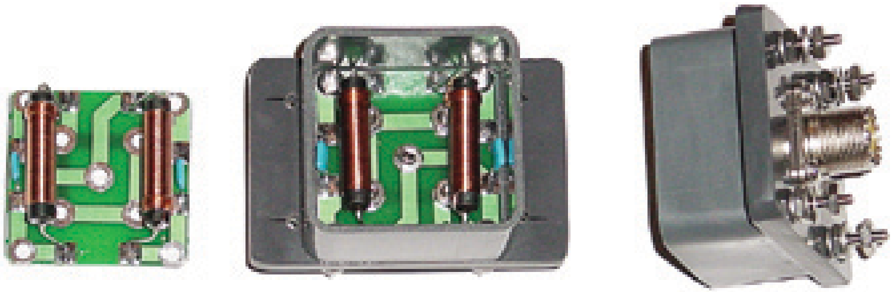


Figure 6 — Splitter module. The splitter acts as the center insulator of the antenna. The coax feed line and antenna wires connect to the back of the module.

Figure 8 — Completed antenna controller. This one is set up to cover all HF bands except 30 and 60 meters.

section shorter than the standard calculation. Each section can then be tuned by adding a length of stiff wire to one of the relay module screws on the input side of the module (refer to Figure 5). Keep in mind that shortening the length of a section also shortens the length of any lower frequency bands. The lowest band that your antenna is built for will be the normal length of a standard dipole. Table 1 shows the lengths that I ended up with for an antenna covering the bands listed.

After the antenna is raised, check the SWR on the lowest frequency band first and adjust the overall length to get the desired center frequency. Then go to the highest frequency band and adjust the length of the first pair of stubs for the desired center frequency. Then go to each higher frequency band in order, and adjust the stub lengths to get the center frequencies that you want.

Conclusion

Various versions of this antenna system have worked well for me for more than 5 years. I hope that this antenna system will make it possible for you to enjoy as many of the HF bands as you would like. Source code for the controller and relay module microprocessors are available from the ARRL Web or at the author's Web site, **www.mactenna.net**.[4] It also includes additional construction details, programmed processor chips and complete parts kits.

As with any antenna, make sure that it is disconnected from your transceiver and grounded when not in use.

Table 1

Length Measurements for Seven Band Antenna at a Height of 50 Feet Over Average Earth

The antenna length is measured from center to center of the relay modules. The lengths for your antenna may be different depending on which bands are covered, antenna height, wire size and type of ground.

Band (Meters)	*Center Frequency (MHz)*	*Antenna Length (Feet)*	*Stub Length (Inches)*
10	28.85	14	4½
12	24.96	17.7	3¼
15	21.30	20	5¼
17	18.15	23.5	4¼
20	14.25	30	4½
40	7.225	62	7
80	3.85	121.8	

Thanks to WA1FXT for his help with this article.

Notes

[1]G. Kath, N2OT, and C. Bishop, WB2EPQ, "A Pneumatically Switched Multiband Antenna," *QST*, Aug 2008, pp 30-32.

[2]Several versions of *EZNEC* antenna modeling software are available from developer Roy Lewallen, W7EL, at **www.eznec.com**.

[3]J. Hallas, W1ZR, "The Fan Dipole as a Wideband and Multiband Antenna Element" *QST*, May 2005, pp 33-35.

[4]**www.arrl.org/files/qst-binaries/**.

Photos by the author.

Jim Weit, KI8BV, was first licensed as K3CMN in 1957 and currently holds an Amateur Extra class license. A member of the ARRL, Jim graduated from Cleveland State University with a BSEE degree in 1967 and has worked in development engineering for most of his career. He is presently CEO of a small corporation.

His ham radio interests include fox hunting and experimenting with antennas. He is a VE and an active member of the Sandusky Radio Experimental League. Jim can be reached at 3410 Tiffin Ave, Sandusky, OH 44870 or at **ki8bv@mactenna.net**.