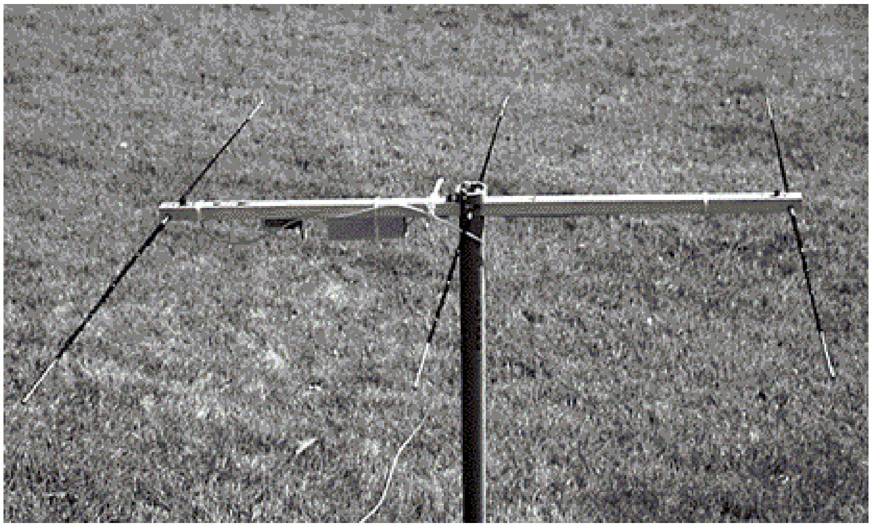
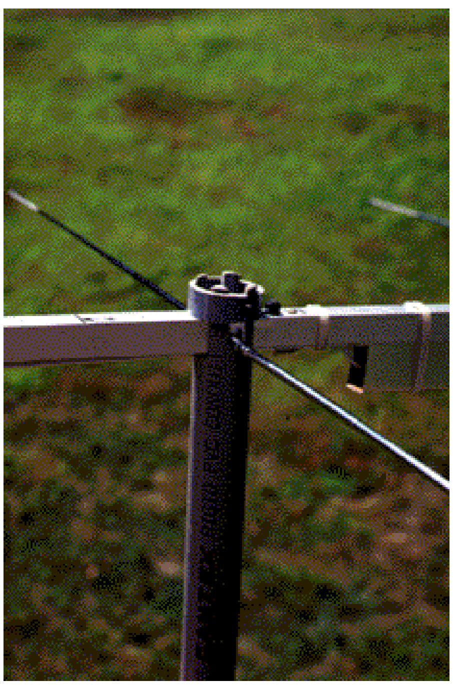
A Fox- Hunting DF Twin ’Tenna

Interferometers give sharp bearings, but they lack sensitivity for distant work. Yagis are sensitive, but they provide relatively broad bearings. Build an antenna that blends both on a single boom to cover both ends of the hunt.





By R. F. Gillette, W9PE

A good fox-hunting antenna must meet a number of criteria:

Small size

Gain to detect weak signals

High directivity to pinpoint the fox

Small antennas, however, do not normally yield both gain and directivity. By combining two antennas, all three requirements are satisfied in a way that makes a nice build-it-yourself project. This article describes an antenna with slide switches that configure it as either a Yagi or a single-channel interferometer. [**1**] When used as an interferometer, a GaAs RF microcircuit switches the FM receiver between two matched dipoles at an audio frequency. To make the antenna compact I used hinged, telescopic whips as the elements; they collapse and fold parallel to the boom for storage.

A Yagi

The Yagi is a standard three-element design, based on 0.2-λ spacing between the director, the driven element and the reflector. I used element-length data from an old *ARRL Handbook*. [**2**] The Yagi yields about 7 dBi gain and a front-to-back ratio of over 15 dB. Because I have a slide switch at the center of each element and the elements have small diameters, their resonant lengths are different from those shown in the *Handbook.* **Table 1** shows the *Handbook* data and the actual sizes I used.

Table 1—Yagi Design

Item	*ARRL at 147 MHz (Inches)*	*Size used* (Inches)*	*Boom to Element Tip (Inches)*
Director length	36.125	34.75	17.00
Director to Driven El. spacing	15.75	16.00	
Driven El. length	38.125	37.75	18.50
Driven El. to Reflector spacing	15.75	16.00	
Reflector length	40.00	40.75	20.00

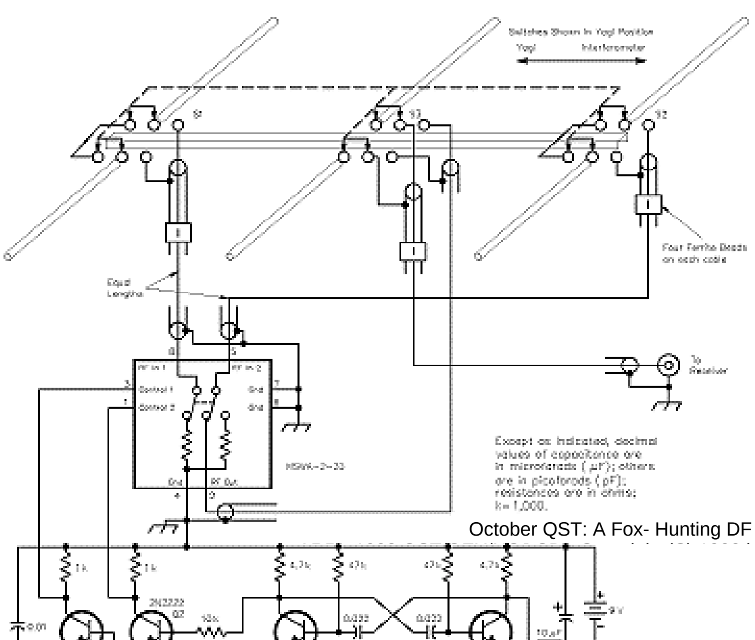
*SWR less than 1.3:1 from 144.5 to 148 MHz

To make sure that radiation from the coax does not affect the pattern, I used some ferrite beads as coaxial choke baluns. [**3**] This also prevents objects near the coax from affecting signal-strength readings. The Yagi also has a low SWR; with uncalibrated equipment, I measured less than 1.3:1 over most of the 2-meter band.

This Yagi has a lot more gain than a "rubber ducky," but we need more directivity for fox hunting. That's where the interferometer comes in.

An Interferometer

To form the interferometer, the two end elements are converted to dipoles and the center element is disabled. When the three switches in **Figure 1** are thrown to the right, the feed line to the receiver is switched from the center element to the RF switch output, and the end elements are connected via feed lines to the RF switch inputs. With the Yagi's feed point open and the driven element equidistant from both interferometer antennas, the center element should have no effect on the interferometer. Nonetheless, I think it's easier to collapse the driven-element whips and get them out of the way than to worry about spacing.



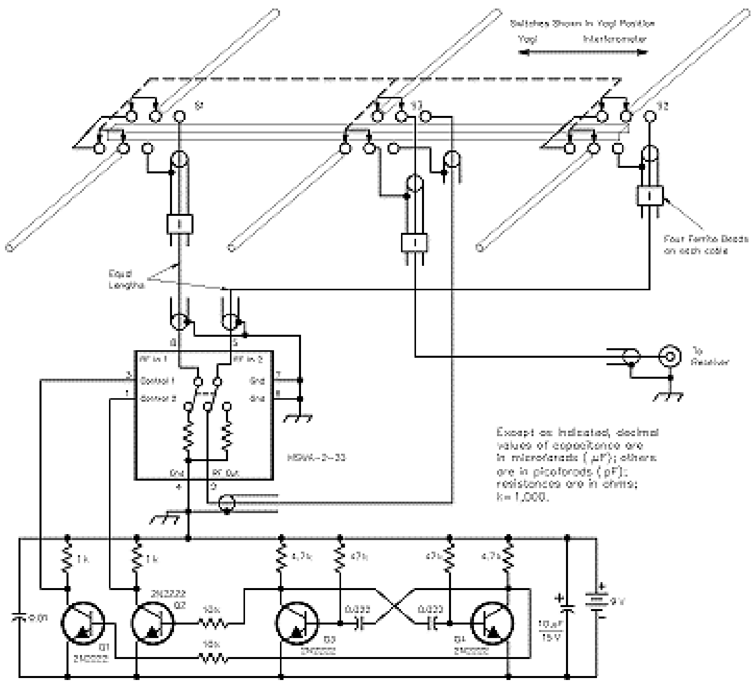


Figure 1—Schematic of the Yagi/interferometer antenna system.

Now if both interferometer coax cables are of equal length (between the antennas and switch) and the two antennas are the same distance from the transmitter (broadside to it), the signals from both antennas will be in phase. Switching from one antenna to the other will have no effect on the received signal. If one antenna is a little closer to the transmitter than the other, however, there will be a phase shift when we switch antennas.

Figure 2 presents one RF cycle of the received signal with the array broadside to the transmitter, and another with the array oriented 1 from broadside. In both cases, the received signal is switched from one antenna to the other at about 30°. When the array is broadside to the transmitter, the received signal is a sine wave at the transmitted frequency. When the array is only 1 from broadside, you can see a phase jump: The instantaneous received frequency has changed. [**4**]

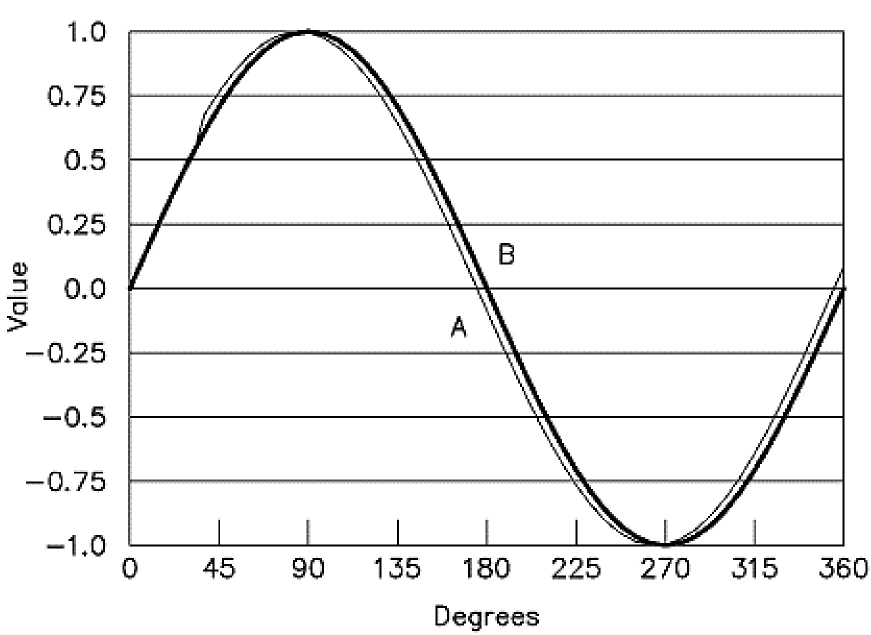


Figure 2—One-RF-cycle samples at two interferometer orientations. Trace A occurs when the antennas are precisely broadside to the transmitter. Trace B occurs when the antennas are rotated 1 from broadside. Trace B shows an instantaneous 2.5° phase shift when the antennas are switched. (The next phase shift occurs at 37.5×10^6 degrees.)

As shown, the instantaneous frequency is a little higher (this one cycle has a shorter period). Larger angles from broadside cause larger phase jumps. When the antenna switch is at an audio rate, say 700 Hz, the repeated phase shifts (700 times a second a jump forward and 700 times a second a jump back) result in a set of 700 Hz sidebands.

At this point, all that I needed was a circuit to switch from one antenna to the other at an audio rate. I chose a low-cost Mini-Circuits MSWA-2-20 GaAs RF switch driven by a simple multivibrator and buffer. The GaAs switch is rated to 2.0 GHz, hence this switching concept can easily be scaled to other ham bands. The PC board should work through the 440 MHz ham band. I would add a ground plane under the RF portion of the PC board and test it before using it at a higher frequency.

The RF switch is controlled by a set of equal-amplitude, opposite-phase square waves: 0 V at one control port and –8 to –12 V at the other. (Mini Circuits is unclear about maximum voltages for this device. For safety, don't power it with more than 9 V.—*Ed*.) The opposite controls the other switch position. I used a 9 V battery as the power supply, grounding the *positive* terminal. This results in a 0 V control signal to the RF switch when the buffer transistor is off and a V_{sat} (about 0.2 V less than the –9 V battery: –8.8 V) signal when the buffer transistor is saturated. The multi-vibrator has two outputs, and each drives a buffer resulting in the required equal-and-opposite-phase drive signals.

Circuit Construction

After I selected the Mini-Circuits RF switch, I realized that its small size would be best handled with a PC board. I made the prototype boards with a photocopy transparency technique. A file of the etching pattern and parts-placement diagram is available. [**5**] To encourage builders, I can supply a kit containing an RF switch and an etched (undrilled) PC board. [**6**]

A power on-off switch was not used, as the 9-V battery connector serves the same function. The battery fits tightly in the 3/4-inch **U** channel. I covered the circuit board with a plastic-lined aluminum cover, but plastic film and some aluminum foil, provide the same function. A cable tie will strap either into the **U** channel.

Table 2 is a complete bill of materials. You can use any telescoping elements, providing that they extend to over 20 inches and have a mounting stud long enough to accommodate the insulated washers. As an alternate to the stud, they can have ends tapped to receive a screw for the insulated mounting. I picked up my elements at a hamfest from the vendor listed; they are also available from most electronic parts houses. The Mini-Circuit RF switch is a currently available part.

Table 2—Bill of Materials

Quantity	*Item*
3 ft	3/4-inch aluminum **U** channel
6 sets	insulated shoulder washers for elements
1	9 V battery
1	9 V battery connector
1	10 µF, 16 V electrolytic capacitor
1	0.01 µF, 25 V capacitor
2	0.022 µF, 25 V capacitor
2	1 kΩ 1/8 W resistor
2	4.7 kΩ 1/8 W resistor
2	10 kΩ 1/8 W resistor
2	47 kΩ 1/8 W resistor
2	1 kΩ 1/8 W resistor
4	2N2222 transistors
1	Mini-Circuits MSWA-2-20 (Mini-Circuits Labs, 13 Neptune Ave, Brooklyn, NY 11235; tel 718-934-4500, 417-335-5935, fax 718-332-4661; e-mail **sales@minicircuits.com**; URL **www.minicircuits.com**)
3	DPDT slide switch (1-1/8-inch, 29 mm, mounting centers), Stackpole, 3 A, 125 V used

10 ft	50 Ω coax (0.140-inch maximum OD)
1	coaxial connector (receiver dependent)
1 lot	mounting hardware
1 lot	heat-shrink tubing or equal
4	cable ties
1	2×3.5-inch single-sided fiberglass PC board
1	1-inch PVC conduit
12	ferrite beads 0.14-inch ID, 0.5-inch long (Alltronics # FB-20; tel 408-943-9773; URL **www.altronics.com**)
6	20-1/2-inch telescoping antenna elements (Nebraska Surplus, tel 402-346-4750; e-mail **grinnell@probe.net**)
1	Special resist film (Techniks Inc, PO Box 463, Ringoes, NJ 08551; tel 908-788-8249, fax 908-788-8837; e-mail **techniks@idt.net**; URL **http://www.techniks.com/**)

Antenna Construction

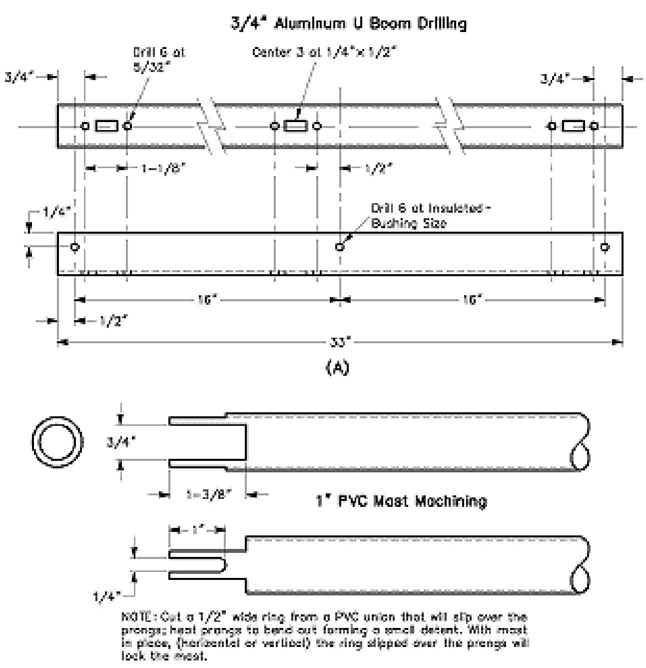
Figure 1 is the antenna schematic. It shows all three switches in the Yagi position; each would slide to the right for interferometer use.

Slide switches work pretty well at 2 meters (see **Table 2**). Each of the elements is mounted to the boom with insulating washers, and a strip of copper stock connects each element to its slide switch. (You can substitute copper braid, solder wick, coax shield or any short, low resistance, low inductance conductor for the copper stock.) This switching arrangement allows you to switch the reflector and director from being parasitic elements (electrically continuous) to being dipoles (center fed).

Because the elements telescope, you can adjust the interferometer dipoles to exactly equal lengths each time you switch the antenna configuration from Yagi to interferometer. Again, choke baluns block RF on the outside of each element's coax.

Caution: Do not transmit when the RF switch is selected. Transmit only when in the Yagi configuration. RF power will destroy the RF switch. To be safe, lock out your transmit function. Most H-Ts have this capability. When using a mobile radio, disconnect the microphone. It is, however, safe to transmit in the Yagi configuration—nice for portable operating.

Figure 3 gives dimensions for drilling a standard 3/4-inch aluminum **U** channel for the boom and shows how I cut a 1-inch PVC pipe (plastic conduit) for a mast and a mast locking ring. If PVC conduit is not available in your area, PVC water pipe (and a PVC union for the locking ring) will work. This mast allows mounting the antenna for either vertical or horizontal polarization.



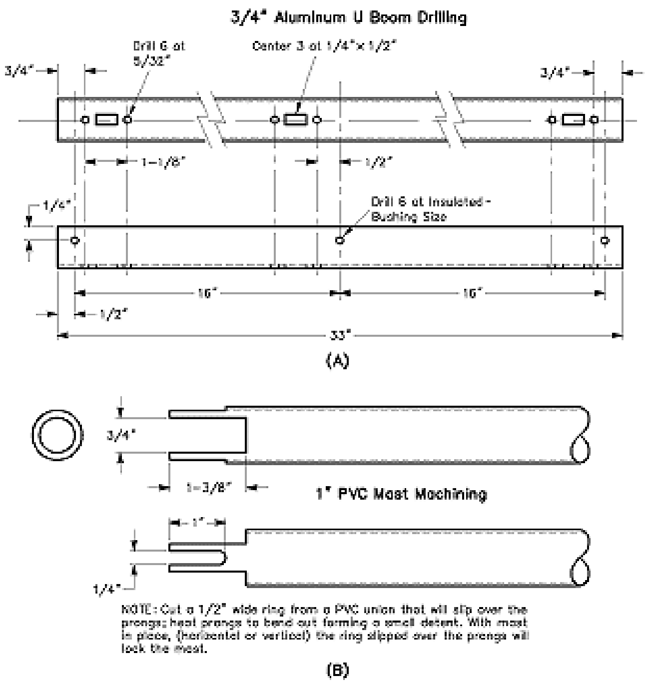


Figure 3—Boom-drilling and mast-machining details.

Be sure to test the plastic pipe you use for low RF loss. Do this by heating a sample in a microwave oven. Place a pipe sample and a glass of water in the oven. (The sample is not placed *in* the glass of water; the water keeps the microwave from operating without a load.) Bring the water to a boil, and then carefully check the sample's temperature. If the sample is not hot, its RF loss is low, and the plastic can be used.

Using the Antenna

When starting a hunt, set up the Yagi antenna by placing all switches in the Yagi position. Swing all of the telescoping elements perpendicular to the boom and set the whip lengths to achieve the proper element lengths (see **Table 1**), while keeping each element symmetrical about the boom. The cables or boom can be marked with the length data.

While the signal is weak, use the Yagi. It has 7 dBi gain, but its bearing resolution is only about 20. When the signal gets stronger, use the interferometer. It has less gain, but its bearing resolution is better than 1. If the transmitter begins overloading your receiver, collapse the whips (equally) to reduce the gain and continue triangulating. Near the transmitter, you should triangulate both horizontally (azimuth) and vertically (elevation). The antenna works both ways, and the transmitter may be located above or below you. Good hunting, and have more fun operating portable and/or portable mobile.

Richard was first licensed in his senior year of high school (1952) as WN9RSU. He didn't plan it, but his radio-lab instructor (the late Fr. John Galloway, W9RMS) made obtaining a Novice license a graduation requirement! As a new ham, he built many projects. He credits his ham home-brew experience with making him a better engineer. He has a BSEE from Illinois Institute of Technology and an MBA from Loyola of Chicago, both earned at night while he was working as an engineer. His ham home-brew experience helped him to be promoted to an engineer before he earned his degree. Recently retired from Northrop Grumman and working part time as a Consulting Engineer, he has again found time for home-brew, and it is still a lot of fun (and educational). As a licensed Professional Engineer, Richard couldn't resist giving up W9RSU (44 years) and taking W9PE as an Amateur Extra vanity call.

Antenna Alternative

As an alternative to the telescoping elements, George Holada, K9GLJ, suggested using fixed-length elements with banana plugs matched to banana jacks on the boom. Three pairs would be used for the Yagi, an extra driven-element pair for the interferometer mode and two short-element pairs to reduce the received signal level if an overload condition occurs. He also suggested a PVC boom allowing the elements to be stored inside the boom. Since my unit was complete I did not try his suggestion, but experimenting is the fun of building.