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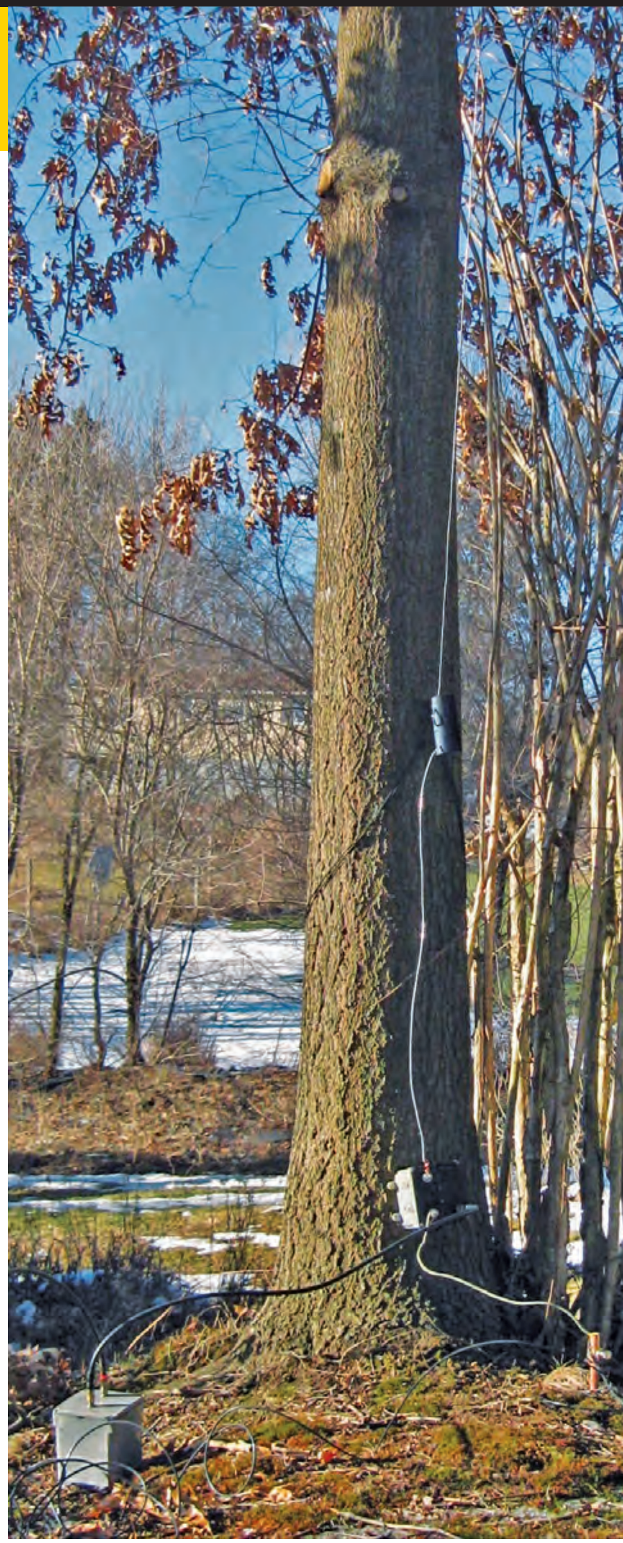
A Reversible LF and MF EWE Receive Antenna for Small Lots

This antenna was the second-place winner of the 2018 *QST* Antenna Design Competition.



Michael K. Sapp, WA3TTS

The EWE antenna, originally developed by Floyd Koontz, WA2WVL, is one of several variants of low-noise, non-resonant receiving antennas with a resistive termination.[1] The EWE provides a cardioid directional pattern with a deep rearward null and a broad forward beamwidth. The rear null zone can be used to reduce noise or attenuate strong interfering signals. The three-dimensional pattern shape of the null zone can be controlled to a certain extent by varying the termination resistance.

This version of the EWE was optimized for weak signal reception on the 2200- and 630-meter bands, but it is also useful on the 160- and 80-meter bands. It also maintains a useful measure of directivity into the 10,000-meter band (30 kHz range), and a reasonably low standing-wave ratio (1.3:1 typical) throughout the lower LF/MF range. Key features of this reversible LF/MF EWE include:

- Antenna transformers based on four BN73-02 binocular ferrite cores superglued together in a series-connected arrangement providing an 11:1 transformation ratio.
- Perimeter ground wire around the four antenna ground rods, as well as center x-wire ground wires and rods to improve consistency.
- A high-impedance binocular common-mode choke near each antenna transformer connection.
- Midpoint grounding of the 75 Ω coaxial feed-line pair.
- An opposing-phase, common-mode choke in the station location for the dual-receive feed lines.
- A 75 – 50 Ω isolation transformer to isolate the antenna system from the receive converter and ac service ground while antennas are in use (single-point common grounding provided when antennas are not used).

As with other EWE antennas, the dimensions are not critical and can be reduced to fit a small lot with some corresponding reduction in signal capture.

Basic EWE Antenna

A simple EWE antenna is comprised of a length of wire configured into an inverted-U. For 160- and 80-meter applications, the antenna is typically 12 to 15 feet tall and 35 to 50 feet long. One vertical seg-

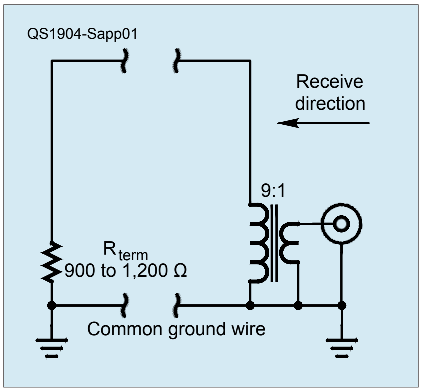


Figure 1 — Sketch of typical EWE receive antenna. Unidirectional low angle response is from the right side of the figure.

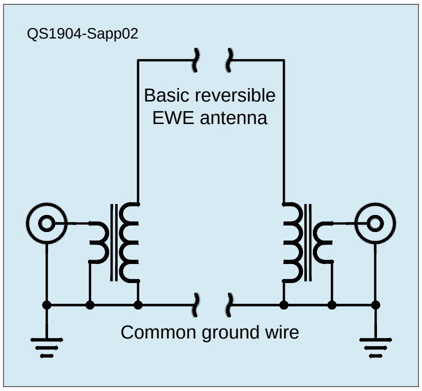


Figure 2 — LF/MF reversible EWE antenna at WA3TTS.

ment is connected to ground via a 9:1 transformer and the transformer end of the antenna becomes the forward receiving direction. The other vertical segment is terminated with a 900 to 1,200 Ω resistor to ground. The resistor end serves as the reflector end of the antenna. The horizontal wire section provides a phasing delay, and radio energy reflected from the termination resistor becomes additive at the matching transformer to provide the directional reception pattern across a relatively broad frequency range (see Figure 1).

A problem that can arise with the basic EWE antenna is that it can be very ground-dependent. Changes in ground conductivity cause the antenna pattern to be unstable over time with varying ground resistance.

Table 1
Parts List for MF/LF EWE Antenna

1. EWE Antennas (two) and Ground System

Quantity	Description
200 feet	#14 AWG insulated stranded copper THHN wire per antenna. 100 feet per antenna
240 feet	#14 AWG insulated stranded copper THHN wire for ground wires
4	Ceramic antenna insulators (or equivalent made from PVC, Teflon, or similar material)
250 feet	Nylon Paracord, ⅛- or ³⁄₁₆-inch diameter for antenna tie-off supports
4	Ground rods, 8 feet long, ⅝-inch diameter, copper-clad, cut in half
8	Ground rod lugs, brass or bronze, with stainless bolts
500 feet	RG6QS coaxial cable
25	Type F, male coaxial connectors, Belden SnapNSeal or equivalent
1	SnapNSeal connector tool, if needed
2	Dual type F grounding block for mid-point RG6QS cable ground
1	SPST copper-blade knife switch (antenna system ground to ac mains ground)
2	A/B coax switches, antenna type F, Pico Macom AB or equivalent, with internal 75 Ω termination resistors
2	Refridgerator-type plastic boxes, or equivalent, for A/B switch weather protection
	Scotch Brite pad and silicone oil for conductor preparation

2. Antenna Transformers (four)

Quantity	Description
4	NEMA boxes for antenna transformers
16	Ferrite cores, BN73-02, four per transformer
1 roll	Kynar insulated #30 AWG, wire-wrapping wire
4	Single-sided PCB FR4 2 × 4 inch, for antenna transformer mounting
1	Superglue or quick-set epoxy for securing antenna transformers to board
8	Sets of 6-2 or 4-0 stainless hardware for mounting transformer board to inside of NEMA box lids
8	Through-hole mount double-female F-connectors
8	Stainless-steel bolts, ¼ × 1 inch, for antenna and ground connections on antenna transformers, two each
16	Stainless-steel nuts and washers, for above
8	Large wire lugs (auto supply store) for wire connections to stainless hardware terminators

3. Antenna Transformer Common-Mode Chokes (four)

Quantity	Description
48	Ferrite cores, type FT-87A-W
32	Ferrite cores, type FT-82-75
8	Ferrite solid beads, type 43, ½-inch inner diameter
60 feet	Mini coax cable, Belden 9221
8	Through-hole mount double-female F-connectors
4	Electrical junction boxes, NEMA

4. Opposing Phase Common-Mode Choke

Quantity	Description
1	Electrical junction boxes and lids, commercial size, galvanized
4	BNC jacks, ground isolated
1	Ferrite core, Magnetics F-44932-TC, AsubL 7080 or equivalent
1	Ferrite core, 2.9-inch FT-90-W or equivalent

5. 75 – 50 Ω Isolation Transformer

Quantity	Description
8	FT50-75 ferrite cores cemented as a single 4 × 4 toroid transformer core. 15 turns primary (75 Ω), 12 turns secondary (50 Ω), #24 enamel wire (for use in 10 – 500 kHz range).

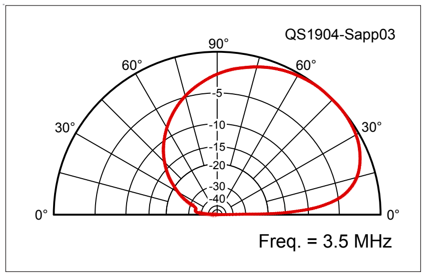


Figure 3 — Elevation radiation pattern of EWE antenna at 3.5 MHz.

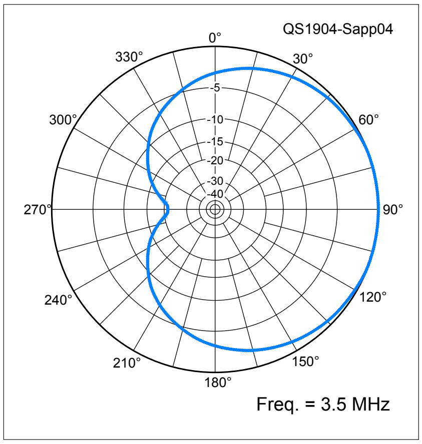


Figure 4 — Azimuth radiation pattern of EWE antenna at 3.5 MHz.

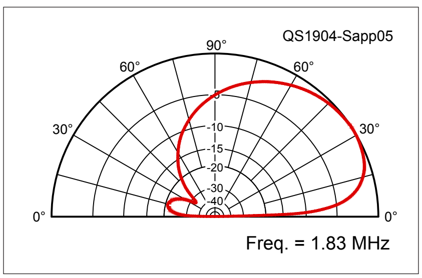


Figure 5 — Elevation radiation pattern of EWE antenna at 1.83 MHz.

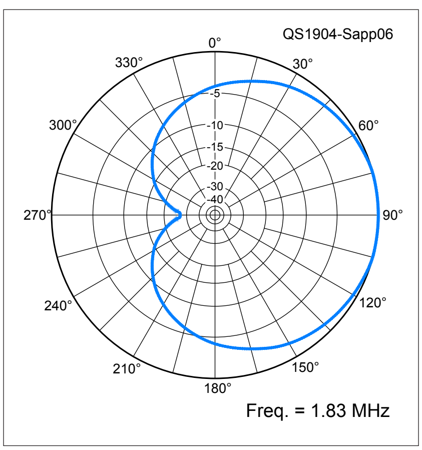


Figure 6 — Azimuth radiation pattern of EWE antenna at 1.83 MHz.

A simple remedy is to tie both ground rods together with a common ground wire.

The Two-Direction EWE Antenna

The original *QST* article describing the EWE suggests that it is possible to place an antenna transformer at both ends and send two receiving antenna feed lines to the radio station. This allows the termination resistor to be accessible at the radio location. Because the second antenna transformer steps down the ac impedance by a factor of the transformer impedance ratio, a low-value resistor can be used. Typically, it would be in the same resistance range as the characteristic impedance of the feed line used to connect the termination resistor to the antenna transformer (usually 50 or 75 Ω).

One can then swap the termination and receive feed-line positions at the radio receiver location to change receiving directions. One catch to this configuration is that the antenna transformers must have a common ground connection (primary and secondary) with the common ground wire at the antenna. I had the good fortune a few years back of exchanging emails with Floyd, who confirmed the need for a common ground wire on the EWE to make the antennas reversible, as well as to improve antenna pattern stability (see Figure 2). Typical *EZNEC*-modeled antenna patterns are shown in Figures 3 through 10.[2]

LF/MF Antenna Transformers

The antenna transformers (see Figure 11) were made by gluing four BN73-02 cores end to end. I first tried using Teflon™ tape with a copper tube as the primary turn. This approach did not seem to make a measurable difference in insertion loss on back-to-back transformer tests versus three-turn wire transformer primary windings. The four-core BN73-02

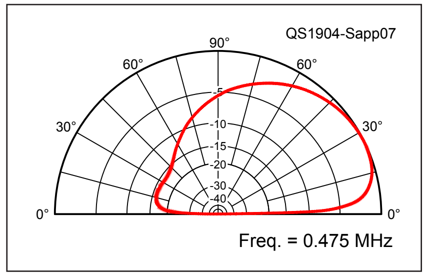


Figure 7 — Elevation radiation pattern of EWE antenna at 475 kHz.

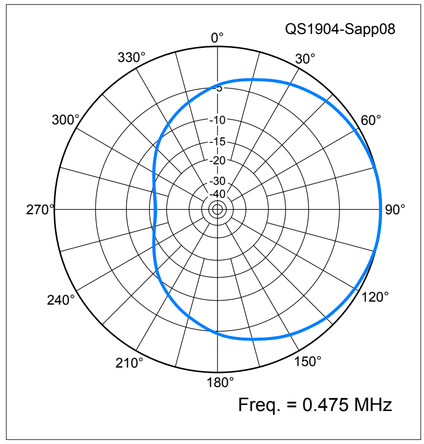


Figure 8 — Azimuth radiation pattern of EWE antenna at 475 kHz.

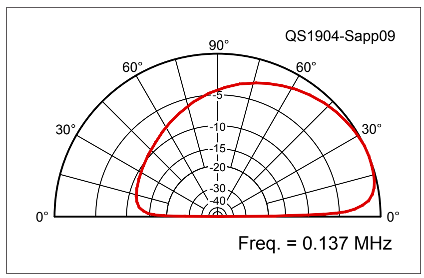


Figure 9 — Elevation radiation pattern of EWE antenna at 137 kHz.

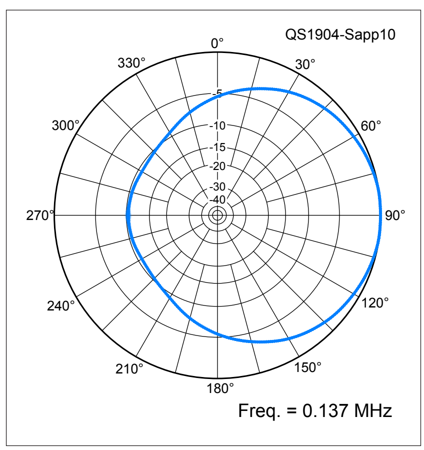


Figure 10 — Azimuth radiation pattern of EWE antenna at 137 kHz.

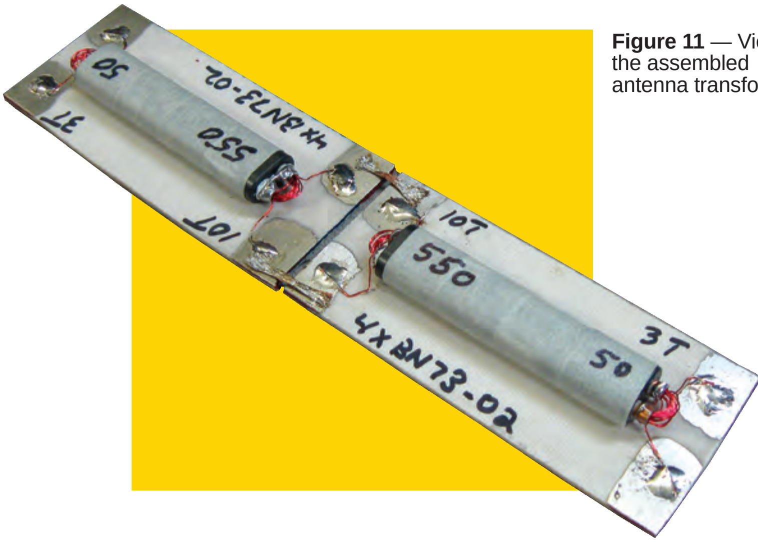


Figure 11 — View of the assembled antenna transformers.

transformers have 0.1 dB insertion loss each at 500 kHz and 137 kHz. The insertion loss increases to 1 dB at 22 kHz. If you want the low-end transformer frequency response to roll off at around 100 kHz, then use three superglued BN73-02 cores instead. If you only want 630- and 160-meter operation, use a pair of superglued BN73-02 cores for the 3-to-10 turn ratio transformer. Kynar insulated #30 AWG wire-wrap wire is a good match for the BN73-02 core size. The 3-to-10 turn ratio provides approximately an 11:1 impedance transformation (50 to 550 Ω, or 75 to 825 Ω, in 50 or 75 Ω systems). BN73-02 cores were selected on the basis of their superior IMD performance.[3]

Expanding to Four Directions

With two reversible EWE antennas positioned in a more or less orthogonal orientation, it is possible to have a four-way receiving setup. This arrangement can also be easily tested for SWR with an antenna analyzer and the dc loop resistance can be easily checked to ensure proper antenna operation.

I also find it useful to apply a momentary dc sealing current at a 12 or 24 V potential every few weeks via 100 Ω or so of current limiting resistance.[4] This application of momentary sealing current keeps the coaxial and antenna connections at a low dc resistance value. With 100-foot range feed lines, a dc loop resistance in the 8 to 10 Ω range (including choke resistances) has been shown to be a good indicator of proper antenna system operation.

Grounding Arrangements

For the EWE antenna ground system, a perimeter wire around the four outer ground rods made a worthwhile improvement in receive system performance. The idea is to equalize differences in ground potential at all four antenna-transformer locations, as well as to provide a measure of ground potential equalization across the antenna ground area.[5] This limits ground potential differences that would otherwise contribute to common mode energy ingress into the antenna system.

Each ground rod is 4 feet long and each is made from an 8-foot-long, ⅝-inch-diameter copper-plated ground rod. (Remember to call 811 before you dig or drive ground rods to ensure you won't hit underground utility lines.) For ground wire, I used #14 AWG vinyl-coated THHN house wire. I used brass/bronze ground rod connectors, which have a single large stainless-steel fastener. I use scouring pads and silicone oil two or three times a year on the ground rod and wire connections to keep them clean and low resistance. It has been my experience that while attempting to receive *WSPR 2.0* signals at 2,000 times below the average noise floor (–33 dB SNR), even small antenna and feed-line connection improvements make a noticeable difference.

Depending on the local noise environment at any given point in time, sometimes a lower noise solution is available by grounding the 75 Ω termination resistor to the station ac service ground (see Figure 12). At my particular location, the effect appears to be most noticeable on the 2200-meter band and in the lower to middle non-directional beacon band (190 to 300 kHz) to attenuate local noise sources.

Note that the horizontal and vertical gain values are in the –7 dBi range for 137 kHz, versus the –8 dBi range for 475 kHz. However, also keep in mind the 20 × Log(F) component of the free space path loss (FSPL) is 10.8 dB lower for far field signals arriving at the antenna at 137 kHz (–17.3 dB) versus 475 kHz (–6.5 dB).

Common-Mode Chokes

The opposing-phase common-mode choke uses ground-isolated BNC connectors and a commercial galvanized electrical junction box to also function as a magnetic shield. The electrical junction box is grounded to the ac mains, but the choke itself is floating relative to the ac-mains ground. Only the cable shields are shorted across the antenna side of the choke. This cable shield short stops the pair of coax feed cables from acting like an open-wire transmission line for common-mode suppression. Local 50 kW AM signal levels present as common-mode energy and were noticeably attenuated with the cable pair shields tied together. Keep the two EWE feed lines as far away as possible from other RF cables and ac-power branch-circuit lines to minimize stray capacitive coupling. The schematic of the opposing-phase common-mode choke is shown in Figure 13, with a photo in Figure 14.

Reversible EWE Antenna Switching

I use 75 Ω A/B switches located outdoors near the antennas in plastic

Fitting the EWE Into Your Space

My real estate limitation is a 50 × 200 foot lot. My house is toward the front of the property and garage in the middle. This leaves about a 50 × 100 foot backyard to share antenna space with the two reversible EWEs at the back of the property and my HF vertical setup as a ground plane secured at the back of my garage. The EWE antennas are supported by available trees in a 30 × 40 foot space. This makes the diagonals 50 feet long, the length of the horizontal sections of the two EWE antennas.

The height of the EWE antennas is approximately 25 feet. I allow one horizontal EWE section to droop about 2 feet below the other to minimize capacitive and inductive coupling between the antenna wires. For LF weak signal receiving, it is essential to understand that in a high-impedance circuit (including nearby EWE antenna wires), it only takes a few picofarads of capacitance for conductors such as antenna wires or coaxial cables to share RF energy at LF/MF frequencies. Figure 12 details the essential design of this four-way LF/MF EWE antenna system.

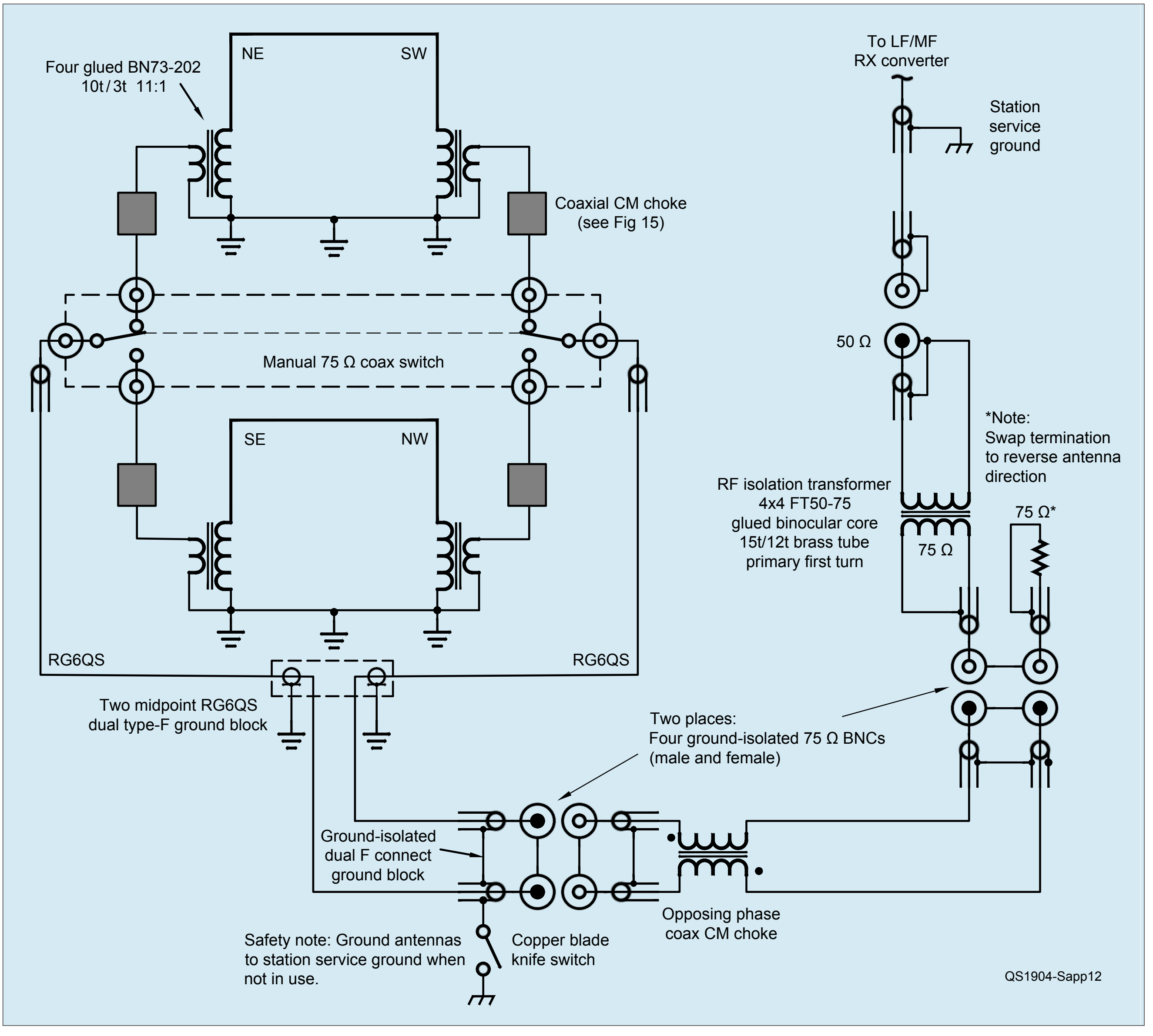


Figure 12 — The essential design details of the four-way LF/MF EWE antenna system.

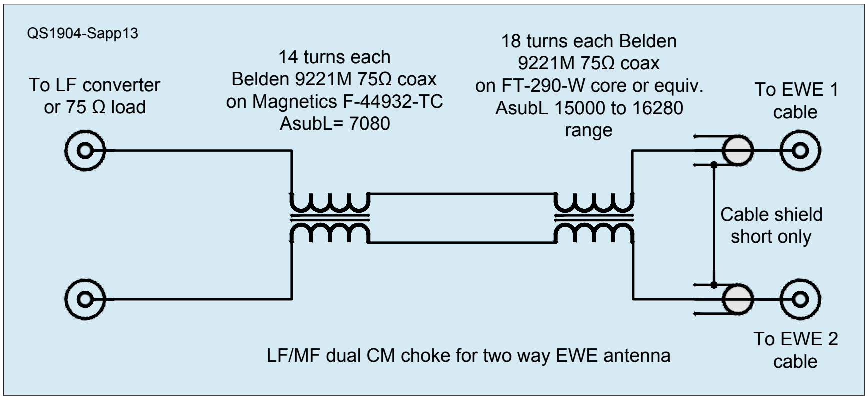


Figure 13 — Schematic diagram of the opposing-phase common-mode choke.

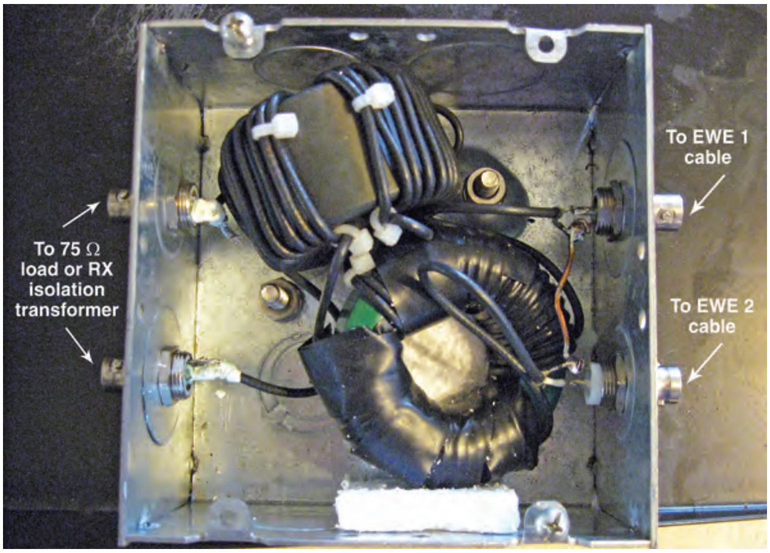


Figure 14 — Photograph of the opposing-phase common-mode choke.

Figure 15 — Photo of the coaxial common-mode choke, used on each antenna termination.

kitchen boxes for antenna switching. This arrangement works for me because I tend to use WSPR mode extensively and often leave the antenna directions the same for several hours or overnight. When I do make antenna switch changes, I do not mind walking out to the switches to reset antenna directions.

It is important to note that 75 Ω TV A/B switches are typically designed to automatically terminate the unused port in 75 Ω. The internal switch termination is rather convenient in this two-EWE configuration. For example, if both antenna switches are set in the **A** position, then both ends of one EWE come back to the radio station location via the two cables. If **A** is the northeast/southwest antenna, then I have those two options for termination and receiver connections.

But, if I set one A/B switch to **A** and the other A/B switch to **B**, then there are two antenna transformers selected on two EWEs and the other two antenna ends automatically terminate in 75 Ω inside the A/B switches. Thus, you can run two separate receivers on the two EWE antennas. In my A/B switching setup, I can choose northwest and northeast or southwest and southeast for feeding individual receivers. With the aid of a two-port 180° LF/MF combiner, it is possible to combine northwest and northeast to obtain an east-west bidirectional pattern.

Trees and LF/MF EWEs

I support my LF/MF EWE antennas from available trees in my yard, with little choice but to live with the situation. A fishing reel and sling shot get the nylon support cord over the trees to the desired 25-foot level. A decision was made to close-couple the vertical sections of the EWEs to the trees, based in part on W5JGV's work with a tree-coupled antenna for LF/MF.[6] For LF, if you view the live tree as a high-impedance RC circuit, the EWE wire is capacitively coupled in near proximity. We also know that LF/MF energy can transfer via relatively small capacitance values at LF/MF in high-impedance circuits. My assumption is that the live tree both absorbs RF energy and re-radiates a portion of the RF energy. Basically, I am attempting to minimize the tree RF absorption loss with close coupling of the EWE wire to the tree trunk.

Notable Reception Results

The EWE antennas have been used over several years with *WSPR 2.0* reception reports on the 630-meter band as far away as Alaska, Hawaii, and Australia to the west, Europe to the east, and Cayman Islands to the south (ZF1EJ). Although my e-probe antenna is set up and works reasonably well, it has only made transcontinental receptions in the lower 48 states on the 630- and 2200-meter bands and at lower *WSPR 2.0* capture rates versus what the EWE antennas are capable. ZF1EJ is regularly captured to the south with the e-probe on the 630-meter band. The southeast EWE seems to hear ZF1EJ much better than the southwest EWE, possibly from pattern skewing due to local objects in the nearby environment.

In one particularly good opening to the west, over 50 K9FD captures were made on my northwest EWE antenna in one overnight fall session on the 630-meter band. The northwest EWE always seems to capture K9FD signals better than the southwest EWE for some reason. I have had a transcontinental 630- to 80-meter CW cross-band contact with VE7SL, with reception on the northwest EWE. The farthest station received to the east has been DH5RAE in *WSPR 2.0* mode in the 630-meter band on the northeast EWE. VE7BDQ was received at his estimated 200 mW ERP on the 137 kHz band on *WSPR 2.0* mode on the northwest EWE in midwinter.

Additional performance and reception reports are found in the *QST*-in-Depth version of the article (**www.arrl.org/qst-in-depth**).

Conclusions

After several LF/MF-listening seasons, the EWE antennas have provided excellent weak-signal reception at my station location. Front-to-back (F/B) ratios have been observed to generally match the *EZNEC* model pattern predictions in the LF/MF range. At higher angle, short-hop D-layer paths, the F/B ratio is only 5 or 6 dB, which is consistent with the modeled antenna patterns. F/B ratios of 10 to 13 dB or more (137 and 475 kHz, respectively) occur on signals arriving at low angles.

For the 160- and 80-meter bands, the height of the antenna raises the peak front antenna pattern incoming signal angle more than what one would desire for long-distance weak-signal and low-angle reception. From casual reception observations made on the 160- and 80-meter bands, there is still a measure of useful directivity with the 25-foot-tall by 50-foot-long antenna size. For future testing, I may try some type of switch arrangement midway up each vertical section of the EWE wire and

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