DISTRIBUTING RECEIVE ANTENNAS

Eric L. Scace K3NA k3na@arrl.net
George Cutsgeorge W2VJN

1 Introduction

In late 2007 the VP6DX expedition project team began working out the designs of low-band receiving antennas for use on Ducie Island. Some expedition requirements replicate those of contest stations, especially SO2R stations, multi-op stations and Field Day stations. The solutions tested at Ducie may help contesters improve their low-band receive abilities.

2 System requirements

Ducie Island, a slightly uplifted atoll of loose coral fragments heaped onto an elevated limestone shelf, has an east-west width of about 1.5 km. For reasons outside the scope of this article, we planned to construct two operating sites separated by about 1.2 km. [1] The east site included the 75 m SSB band's 4-square antenna; the west side included verticals for the 160 m and 80 m CW bands. [2] Our situation suggested these design goals:

Improve signal-to-noise ratio:

From 24º south latitude, a wide band of thunderstorms named the inter-tropical convergence zone (ITCZ) lies between Ducie and all three of the major DX population centers: Europe, North America and Japan. A receiving antenna with a narrow main beam in the desired direction and no side or rear lobes would exclude static from natural sources lying in directions outside of the main beam, thus improving the signal-to-noise ratio.

Reduce QRM; divide pileups:

The DXpedition, occurring at the very bottom of the sunspot cycle and during the season of common darkness with the most distant

[1] Upon arrival, we discovered that the intended landing location was impractical. As a result the actual operating sites shifted further east and somewhat closer together: 850 m separation.

[2] We landed materials for an 80 m CW 4-square antenna. Construction time limitations caused us to construct a single element vertical used on both 80 m CW and the 30 m band.

parts of Europe and Asia, offered the best opportunity for European and west Asian DXers to work Ducie Island. We anticipated large pileups on the low bands. An array of receive antennas that could partition the pileup between east and west Europe would help the Ducie Island operators give priority to areas with more limited propagation.

When the low bands open to Europe, they also open to North America. Figure 1 shows that great circle paths between Ducie Island and Europe cross North America. North American DXers generally respected requests to stand-by while we attempted to work weaker signals from those distant parts of the globe with shorter openings; however, a few dozen uncooperative North American signals could significantly impair copy of weaker European signals at Ducie Island. An array of antennas that discriminate against signals from at least part of North America would help reduce this impairment.

Support three operating positions:

We expected the 160 m, 80 m CW, and 75 m SSB operators to use specialized receive antennas.

Some opined that the 40 m CW and SSB operators could also benefit from specialized receive antennas. But the design team felt that the lower static levels, louder signal levels, and 4-square transmit antenna pattern would provide adequate results; therefore, the design included no support for 40 m. This design decision proved to be correct: the 40 m operators had no difficulties that would have been reduced by including that band into the receive antenna system.

Figure 1: Eq-az (great circle) chart centered on Ducie Island. Note that short path signals to Europe and west Asia cross over North America. Sector divisions on this map illustrate the ranges of azimuths covered by the eight receiving antenna beams available to the Ducie Island low-band operators.

Avoid damage from on-air transmitters:

On a previous DXpedition by a different team, receiving antennas were located near the low-band transmitting antennas. At the end of on-air operations that team discovered their transmissions destroyed the pre-amps in the receive signal distribution system. Low-band operators had struggled with weak signals throughout the expedition, attributing their difficulties to poor conditions. The Ducie Island design team wanted to avoid this problem.

Maximize results from construction labor:

To reduce the chances of cross-station interference, the 80 m CW and 75 m SSB operators sat at different operating sites. The design team contemplated building two sets of receive antennas, one at the east camp and one at the west camp. However, on any expedition time is limited. Using the available construction time to build a single, superior set of receiving antennas, shared by both camps, would likely yield better results.

Locating the receive antennas mid-way between the two camps also provided a greater separation from the transmit antennas.

Cover all directions:

Two directions with broad beamwidths would adequately cover Europe/North America (060° azimuth ±60°) and east Asia (305° ±30°), the main DX population centers. But Australia, New Zealand, South America and Africa all lie in vastly different directions; see Figure 1. We wished to also copy stations calling from these additional directions.

If possible in the construction time available, a set of receive antennas that covered the compass would also permit us to exploit long and skew path openings. The opportunity to definitively identify long and skew path openings on the low bands rarely presents itself.

Each operator selects direction independently:

Openings times and available callers are not identical for the lowbands, particularly when chasing skew and long path openings. Each of the three operators sharing the receive antenna system needs to choose his listening direction independently from the other operators.

Each operator may select two different directions independently:

The Elecraft K3 radio can include two phase-synchronous receivers. By connecting antennas with different directions to these receivers, the operator can exploit direction diversity to further separate the pileup. For example, he might configure his left ear to listen on a receiver attached to an antenna favoring east Europe and his right ear to an antenna favoring west Europe… or configure one ear on short path and one ear on long path. [3]

Deliver signals at levels approximately equal to that from the transmit antennas; limit signal suck-out:

In most modern transceivers, the operator may switch between listening on the transmit antenna port and listening to a separate RX antenna port with the push of a button. However, in many cases, if the receive antenna's signal levels differ significantly from the transmit antenna's signal levels, the operator must also activate an internal pre-amp with a separate control or adjust the RF and AF gain controls to compensate. This use of multiple controls does not encourage the operator to exploit all the antennas available. Therefore we wanted signal levels delivered from the chosen receive antenna to be roughly similar to those levels delivered by the transmit antenna.

3 Overview of chosen approach

Our solution to the above goals employed these elements:

- Four ladder-line beverages providing eight main beams.
- A bandpass filter-splitter on each of the eight outputs to separate 160 m, 80 m CW, and 75 m SSB outputs.
- A pair of remote-controlled eight-port antenna switches for each of the three operators to use to select directions for each of his two receivers.

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3 Unfortunately Elecraft could not provide the second receiver for the K3 in time for this expedition and we could not exploit this ability at Ducie Island.

- A pre-amp for each output from the remote-controlled antenna switches, with pre-amp input protection from relevant transmitted signals.

A sketch of the overall approach appears in Figure 2.

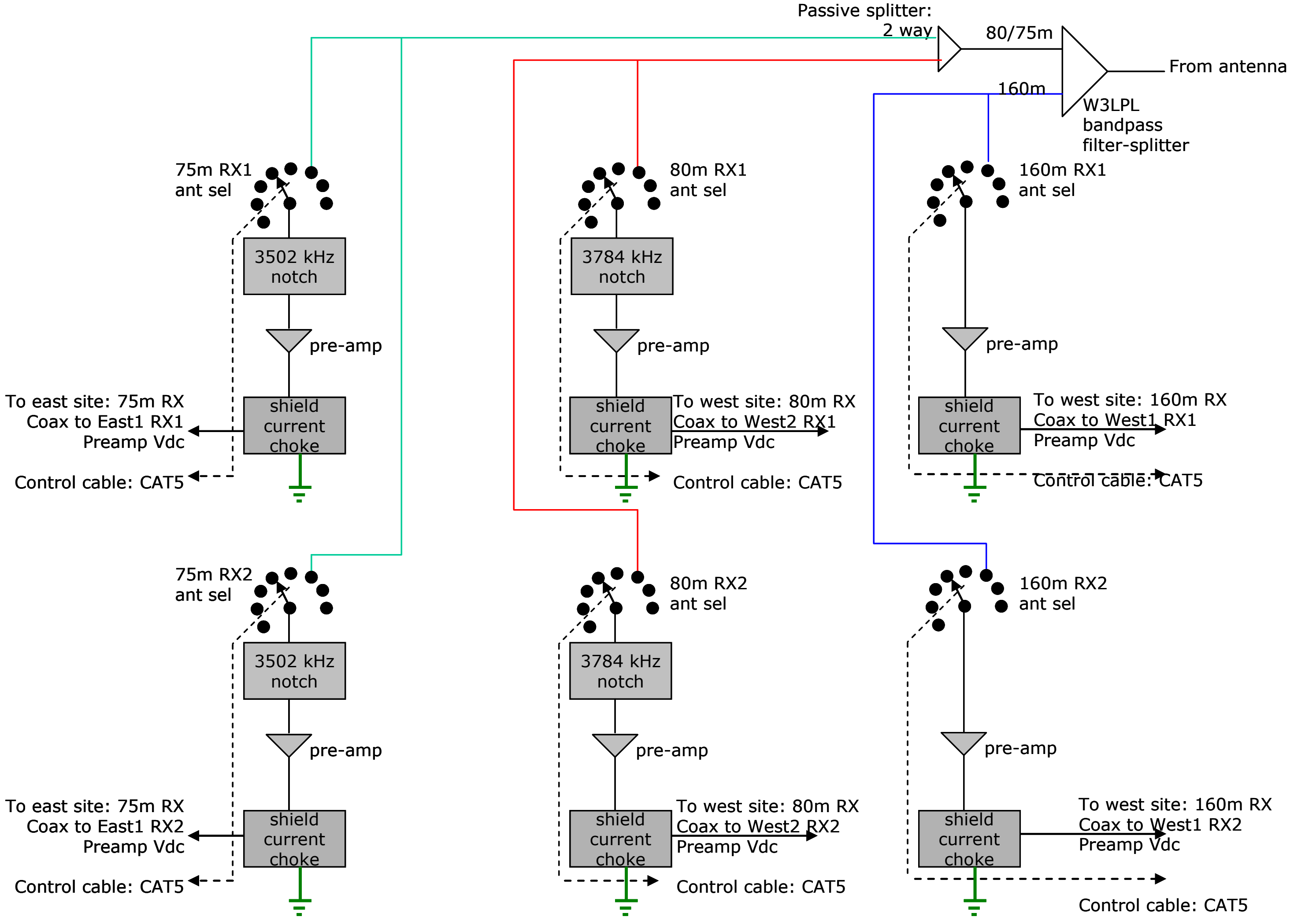
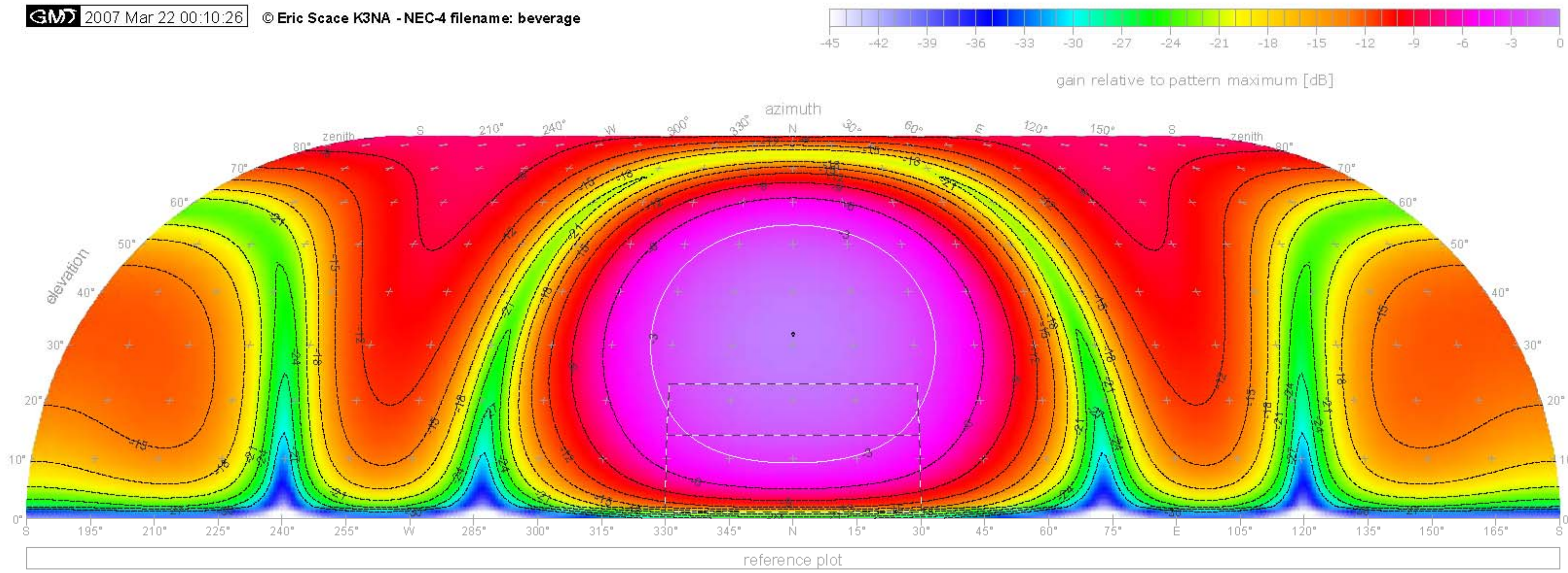


Figure 2: High-level schematic of the receive antenna system used at Ducie Island. For clarity the schematic shows only a few of the antennas and switching cables.



Beverage 215m (1 3/8 λ on 160m; 2 9/16 λ on 80m).
Height 3m.
Ground rods 2m. No radials.
Termination 300 Ω. Term & feed at 3m height.
Copper wire AWG 12.
Average earth.

Card deck created 07 Mar 22 Thu 00:07:23 -0500 NECInputClean v2.0 2004 Jul

NEC version 4.1.
K3NA NOUTrim v5.5 2007 Mar 16 Fri.
NEC x-axis is North azimuth.

1.825 MHz

finite ground. sommerfeld solution
ε = 13.0
σ = 5.0 mS/m

Drive impedance; voltage or current:
#1: 605.7 j -75.5 Ω 1.000A ∠ -90.0°

Target 1: 330- 30° az 1-14° el JA 80m elevation. Very low SSN. September
Target 2: 330- 30° az 1-23° el Eu-NA 80m elevation. Very low SSN. September
White contour: -3 dB below peak gain.

	Overall	Target 1	Target 2	Target 1+2	Remainder
max dBi:	-9.71	-11.38	-10.09	-10.09	-9.71
az:	360.0°	360.0°	360.0°	360.0°	360.0°
el:	31.5°	13.5°	22.5°	22.5°	31.5°
median dBi:		-14.44	-11.15	-12.63	-23.67
dev above dB:		+0.88	+0.27	+0.71	+5.27
dev below dB:		-1.24	-0.31	-1.16	-1.57
min dBi:		-26.16	-13.42	-26.16	
az:		330.0°	29.9°	330.0°	
el:		1.5°	14.5°	1.5°	
within 3 dB of max:	10.5%	21.8%	96.1%	51.4%	7.8%
below max-30 dB:	2.9%	0.0%	0.0%	0.0%	3.1%
below -15 dBi:	84.1%	44.2%	0.0%	26.6%	87.9%
power efficiency:	0.8%				
receive directivity:	+8.38 dB RDF				

Figure 3: Pattern for a 215 m long beverage mounted three meters above average ground on top band. Horizontal axis is azimuth; vertical axis is elevation. Contours and color/gray scale indicate gain relative to the peak gain of the main beam. Dotted box outlines the expected range of azimuth and elevation angles for signals from Europe or east Asia. Modeling engine is NEC-4.

4 Antenna choice

We decided to use beverage antennas of about 215 m length to improve the signal to noise ratio on the 160, 80 and 75 m bands. This improvement occurs because a well-engineered beverage antenna possesses a narrow main beam with moderate side and rear lobes; see Figure 3. The reduced sensitivity to signals (both natural and man-made) outside the main beam reduces both static and QRM from unwanted directions.

NEC-4 models for this beverage, mounted three meters over average earth, yield these parameters:

frequency [kHz]	1825	3500	3800
main beamwidth [at 20° elevation]	70°	50°	47°
peak gain [dBi]	−9.7	−4.3	−3.6
median gain outside target [dBi]	−24	−19	−19
worst side lobe [dBi]	−18	−17	−16

Compared to the 4-square antennas planned for transmitting on the 80/75 m, the beamwidth of the beverage is about half as wide. The 160 m transmit antenna, a single vertical, would receive static and QRM equally well from all directions. The beverage should provide a significant reduction in static and QRM, compared to our transmit antennas.

Practical experience gained during DXpeditions to Mellish Reef VK9ML, Rodrigues Island 3B9C and St Brandon's Île du Sud 3B7C proved that beverage antennas work as designed when mounted over dry, stony earth – even when adjacent to salt water. Beverage antennas work poorly when installed over stony earth impregnated with salt water, as was the case at Mellish Reef.

In studying photographs of Ducie Island, we recognized the island's uplifted limestone shelf provided a dry, stony earth that permits proper beverage antenna operation.

Rather than use a single-wire, terminated (unidirectional) beverage, we built two-wire beverages. The two-wire system, when properly terminated, delivers two antenna pattern outputs: one with the main beam in the forward direction and a second output with the main beam in the opposite direction. For example, a wire pair running northeast-southwest would deliver two outputs with beams pointed at 045° and 225° azimuth. These outputs are fully independent: the operator may listen to either one or, if equipped with two receivers, to both. You can read more about two-wire beverages in the current edition of *Low-Band DXing.* [4]

Copper-clad steel ladder line formed the antenna element. We used Wireman part number 553, a 450 Ω insulated line containing 16-strand 18 AWG wire. This line proved easy to install. Robin WA6CDR and Milt N5IA used an extendable fiberglass tube, a standard utility company tool, as a "needle" to thread the ladder line above head height through the branches of velvet-leaf soldierbush (*tournefortia argentia)*, a tree that grows three to four meters tall on most parts of Ducie Island. The polyethylene "window" insulation format did not get caught on twigs or leaves and, at the end of the expedition, easily pulled back through the brush and re-wound on a storage reel.

Each end of the antenna element terminated in DX Engineering hardware, using their RBS-1P two-direction kit. An array of copper-clad steel ground rods established an earth reference at each end.

Flooded RG-6 75 Ω coax delivered signals for the two directions derived from each antenna element to a centralized, remote-controlled switching hub. The flooding compound, which limits migration of moisture, reduces the chances of damage from cuts or abrasion of the outer jacket.

To eliminate the possibility of antenna pattern degradation from common-mode signals, each coax run included a shield current choke (DX Engineering RFCC-1), installed about two meters from the antenna feedpoint.

In principle, the coax run back to the receiver should attach to the side of the choke with the earth connection. That earth connection should be separate from that used for the antenna; e.g., a separate ground rod installed a few meters from the antenna

4 Devoldere, John ON4UN, *Low-Band DXing*, 4th edition, 2005, ARRL, Newington CT USA: chapter 7 §2.15, pages 7-71 ff.

feedpoint earth reference. At Ducie Island, however, the installation team reversed the connections and used the antenna earth reference without any obvious ill effect. See Figure 4.

Parallel beverage arrays:

The team brought sufficient materials to construct a second, parallel beverage for each of the four receive antennas. The parallel leg would also terminate in the DX Engineering two-direction beverage termination kit. We planned a spacing of 40 m between the two legs.

By combining the signals from two parallel beverages in phase, the main beam narrows and a reduction in side lobe gain occurs, both of which contribute the improved signal-to-noise ratios. The 40 m spacing is about ideal for 80/75 m band, while also providing some improvement on 160 m.

To combine each of the two output directions, Eric built the homebrew combiner shown in Figure 5. Eric built and measured a variety of other designs; the circuit shown here, built on a small double-sided board, came closest to maintaining the system impedance of 75 Ω with minimal introduced reactance across both bands. Transformer T1 combines the two legs equally in phase, assuming both legs present the same impedance. With $75+j0$ Ω input impedances, T1's output impedance hovers around 37 Ω. Transformer T2 translates this impedance back up to about 73 Ω. The two transformers introduce some residual inductive reactance; C1 largely cancels out that reactance. Figure 5(c) charts the measured performance.

At Ducie Island the team had time to add a parallel leg to one of the beverage systems, the 045-225° system. Figure 6 shows the antennas as installed.

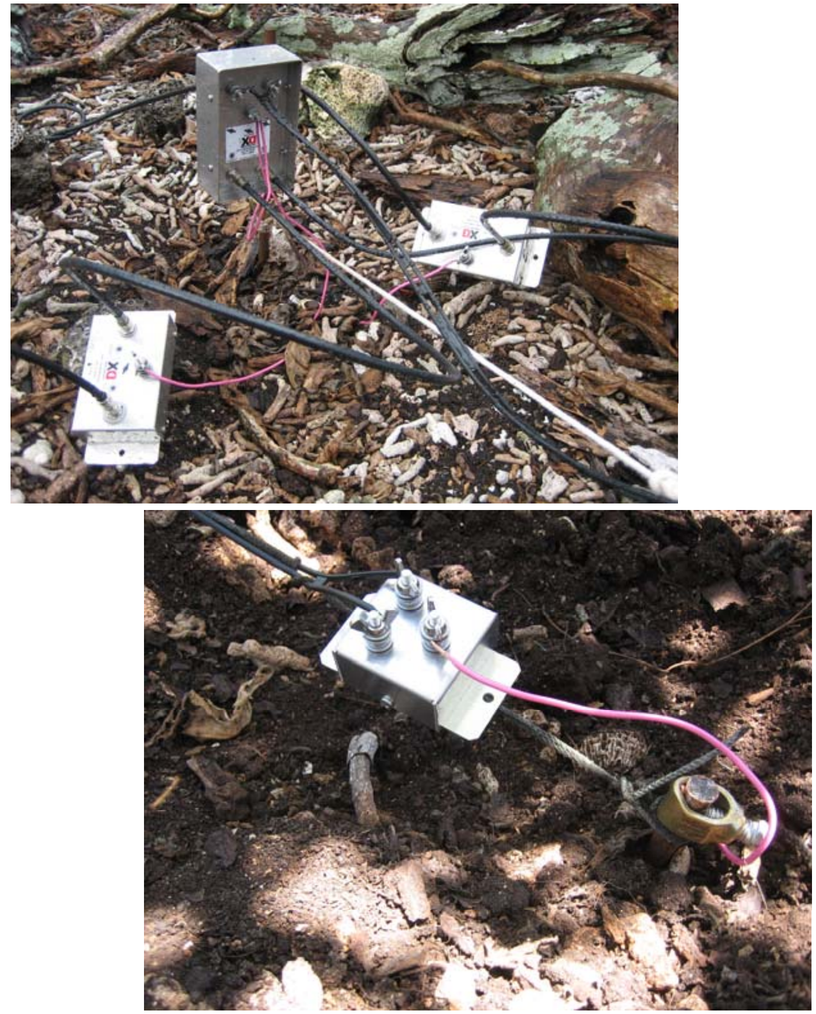
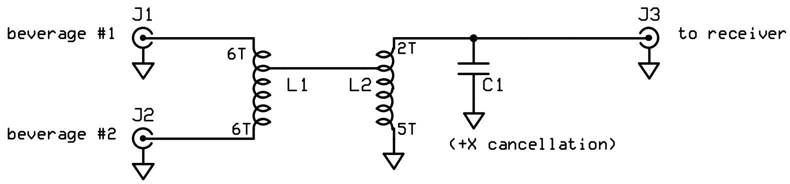


Figure 4: Photographs of the near and far end terminations of a Ducie Island two-wire beverage.

(a) Circuit diagram for beverage combiner:



(b) Parts list:

circuit	description	part, notes
c1	56 pF C0G 100 V	81-RPE5C2A560J2P1B03B
J1–J3	F female coax, PCB mount	161-5370
L1-L2	73-mix binocular core	Notes 2–4
box	NEMA die-cast aluminum	563-CN-6703

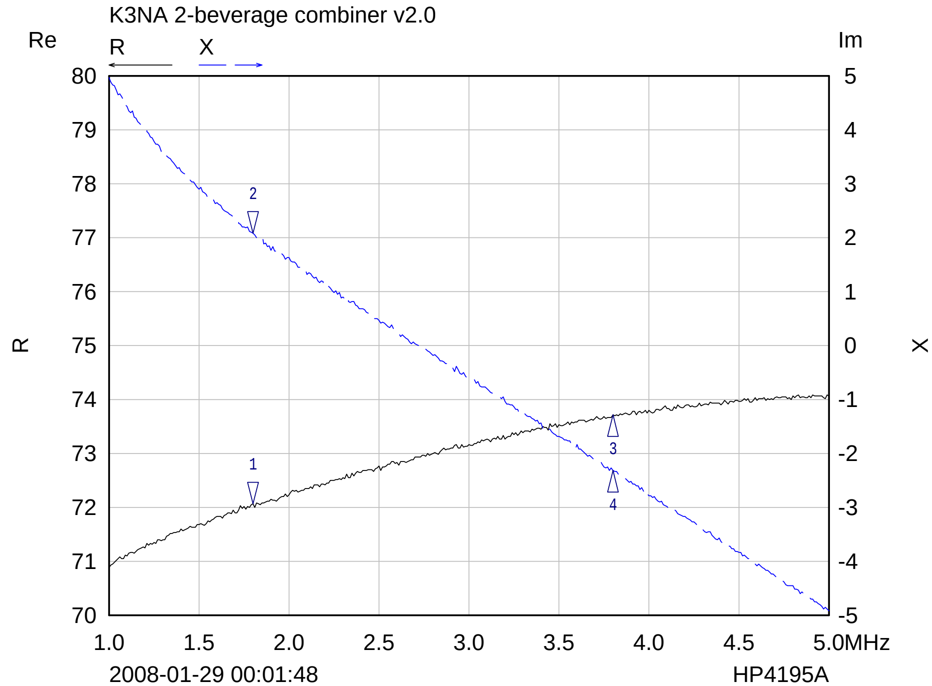
Note 1: Part numbers are Mouser unless otherwise noted.

Note 2: L1 contains two windings of six turns each. Each winding requires about 14 cm of wire.

Note 3: L2 contoains a five-turn winding (about 12 cm of wire) and a two-turn winding (about 6 cm of wire).

Note 4: Core is FairRite 2873000202 or Amidon BN-73-202. One pass through any hole counts as a "turn".

(c) Measured output impedance, loss and phase delay between 1 and 5 MHz when connected to 75+j0 Ω impedances on the inputs:



Mkr	Trace	X-Axis	Value	Notes
1 ▽	R	1.8 MHz	72.07 Re	
2 ▽	X	1.8 MHz	2.09 Im	
3 ▽	R	3.8 MHz	73.72 Re	
4 ▽	X	3.8 MHz	-2.31 Im	

Figure 5: K3NA beverage combiner.

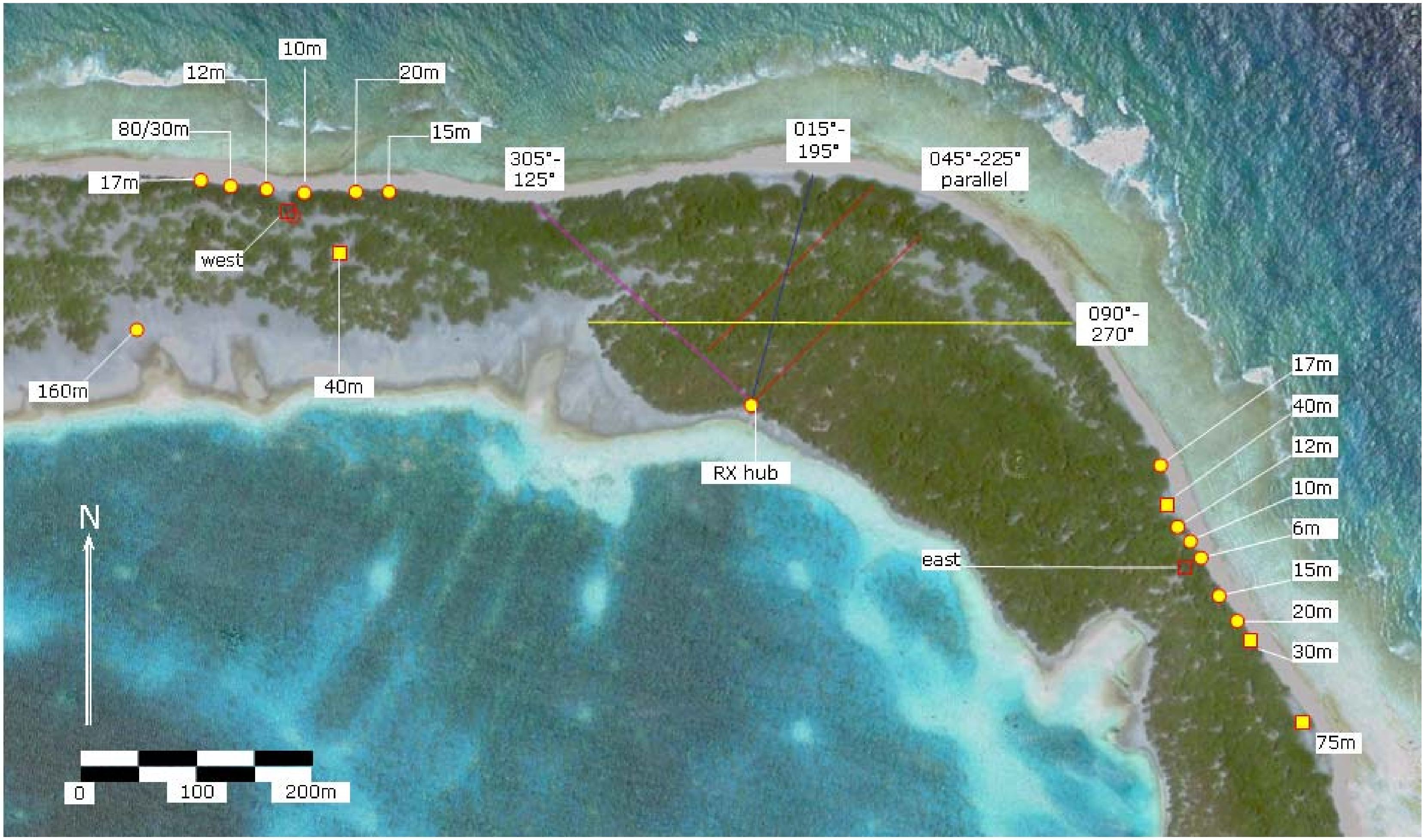


Figure 6: Transmit and receive antennas on Ducie Island, as built.

5 Bandpass filter-splitter

The homebrew bandpass filter-splitter box accepted as input the signal from one direction of a beverage. The circuit extracted to separate outputs a 160 m band and two 80/75 m band outputs. These filter-splitters were installed at the central switching hub.

Figure 7(a) shows the circuit: two W3LPL bandpass filters, one for the 160 m band and one for the 80/75 m band, in parallel. The 80/75 m output fed a Mini-Circuits splitter to clone two copies, one for the CW operator and one for the SSB operator.

The W3LPL filters can be paralleled because of their relatively high stop-band impedance. [5] The W3LPL design also tolerates a fairly wide range of input and output impedances, important here because temporary antennas may not adhere closely to the nominal design impedance… and because receiver impedances can also vary materially from nominal.

The component values used for these filters are for a nominal 50 Ω impedance. We didn't have time to scale and test the filters for a Z_o of 75 Ω. Figure 7(d) shows the measured response of the assembled filter-splitter in a 75 Ω environment. Despite the Z_o deviation, the package shows very good rejection and tolerable in-band loss:

160 m output:

- −2.1 to −2.7 dB in-band loss over 1800–1900 kHz.
- −47 to −56 dB rejection across 3500–3850 kHz.

80/75 m output:

- −4.8 to −12 dB in-band loss over 3500–3850 kHz.
- −76 to −99– rejection across 1800–1900 kHz.

Note the 80 m and 75 m outputs suffer an additional −3 dB of loss because of the passive splitter used to clone signals on that band for the two operating positions. Not every contest station requires this cloned output, and the board layout allows the builder to omit that splitter and its accompanying F connector. For contest stations with two operators listening on each band, the board layout permits the 160 m filter output also to be cloned with a passive splitter.

The rejection values assume particular importance in protecting the downstream electronics from out-of-band transmit signals picked up by these antennas; more on this topic shortly.

Construction notes:

Eric laid out this circuit on a double-sided board. To improve isolation between the two bands, he placed the 160 m filter and the 80/75 m filter at the opposite ends of the board. See Figure 7(c) for a photo of the assembled board.

A gas tube surge arrester with a low firing voltage provides some input protection against lightning-induced surges.

Because a filter-splitter could live outdoors, construction employed temperature-compensated capacitors in an attempt to maintain performance over a wide temperature range. A unit was stored in the freezer compartment of the kitchen refrigerator for a few hours, long enough to allow the components to stabilize around −10 C. Measurements at this temperature showed no material difference in performance compared to room temperature measurements. This range of temperatures would not be expected at Ducie Island, but might occur at a contest station or another expedition site.

Trimmer capacitors don't possess the temperature stability of fixed capacitors. The W3LPL filter design relies on tweaking the toroid windings in order to tune each stage of the filter for a flat passband over the desired frequency range. Eric used a network analyzer to view the passband characteristics while making adjustments to the spacing between turns on the toroids. (Other methods can also be used.) After getting a satisfactory passband, coil dope locked the turns in position.

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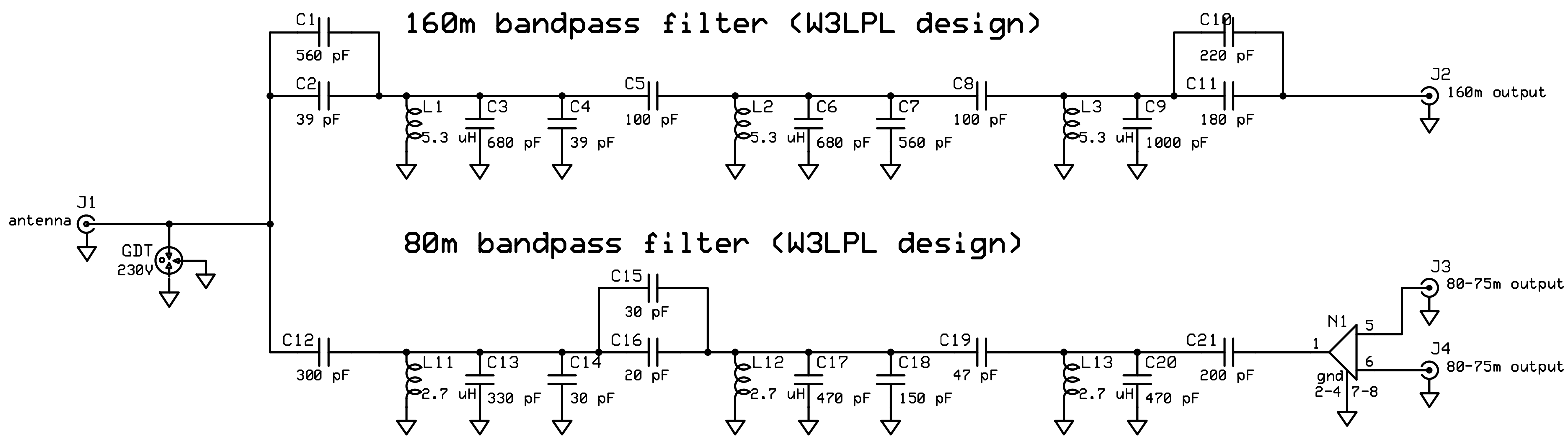
5 In contrast, other bandpass filter designs such as those by W3NQN have very low stop-band impedances. When paralleled, the low stop-band impedance of one band's filter short-circuits the desired frequencies for the input of the other band and vice versa.

(a) Circuit diagram for bandpass filter-splitter.



(b) Parts list for $Z_o = 50\ \Omega$

circuit	description	part, notes
C16	20 pF	81-RPE5C2A200J2P1Z03B
C14, C15	30 pF	81-RPE5C2A300J2P1Z03B
C2, C4	39 pF	81-RPE5C2A390J2P1Z03B
C19	47 pF	81-RPE5C2A470J2P1Z03B
C5, C8	100 pF	81-RPE5C2A101J2P1Z03B
C18	150 pF	81-RPE5C2A151J2P1Z03B
C11	180 pF	81-RPE5C2A181J2P1Z03B
C21	200 pF	81-RPE5C2A201J2P1Z03B
C10	220 pF	81-RPE5C2A221J2P1Z03B
C12	300 pF	81-RPE5C2A301J2P1Z03B
C13	330 pF	81-RPE5C2A331J2P1Z03B
C17, C20	470 pF	81-RPE5C2A471J2P1Z03B
C1, C7	560 pF	81-RPE5C2A561J2P1B03B
C3, C6	680 pF	81-RPE5C2A681J2P1B03B
C9	1000 pF	81-RPE5C2A102J2P1B03B
GDT	230 V gas surge arrestor	576-SL1024A230R Note 6
J1–J4	F female coax, PCB mount	161-5370
L1–L3	5.3 μH	Notes 3, 5
L4–L6	2.7 μH	Notes 4, 5
N1	2-port 75 Ω splitter	MiniCircuits PSC-2-2-75
box	NEMA die-cast aluminum	563-CN-2804

Note 1: Part numbers are Mouser unless otherwise noted.

Note 2: All capacitors C0G, 100 V unless otherwise noted.

Note 3: Nominal inductance is 5.3 μH. Use Amidon T50-2 (red) powdered iron toroid cores with AWG #24 magnet wire windings. L1 and L2 use 32 turns (about 52 cm of wire). L3 uses 31 turns (about 51 cm of wire).

Figure 7 (first page): K3NA W3LPL bandpass filter-splitter.

Note 4: Nominal inductance is 2.7 µH. Use Amidon T50-2 (red) powdered iron toroid cores with AWG #22 magnet wire windings. L4 and L6 use 23 turns (about 39 cm of wire), and closely pack the windings on L6. L5 uses 22 turns (about 56 cm of wire), and closely pack the windings.

Note 5: If you use a different board layout, the winding suggestions may not apply.

Note 6: I had these 3-terminal units on hand. Other 2-terminal gas plasma surge arrestors with lower firing thresholds would be suitable.

(c) Assembled bandpass filter-splitter:

(d) Loss from antenna port to each band's output port:

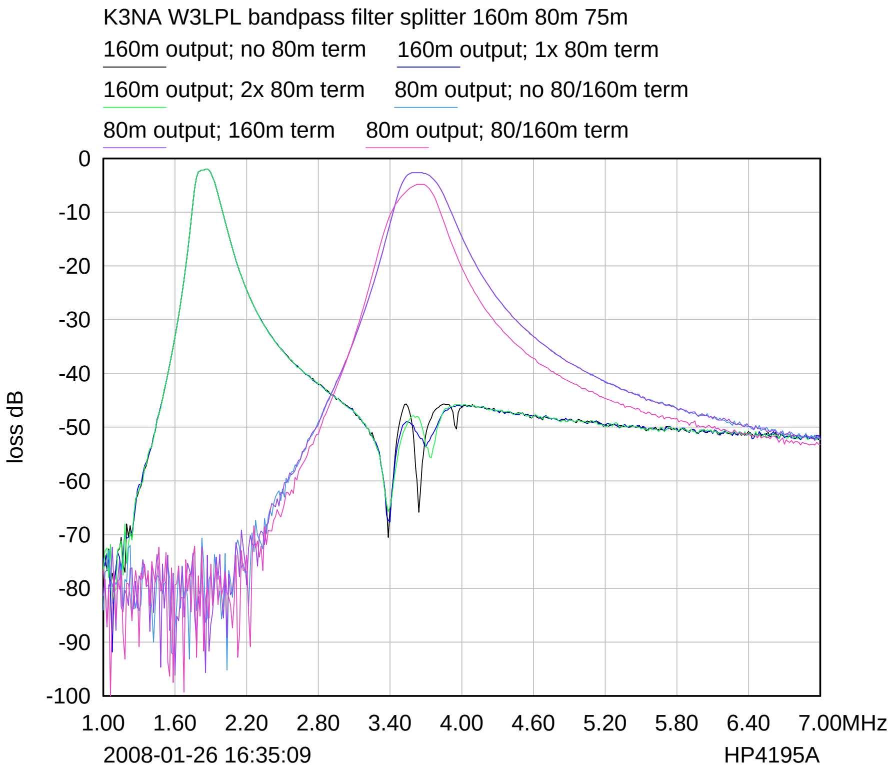


Figure 7 (second page): K3NA W3LPL bandpass filter-splitter.

6 Remote-controlled switch

For expediency, the VP6DX Ducie Island expedition used six (two per operator) off-the-shelf Ameritron RCS-10 remote control coax switches, a large transmit-power-level unit using SO-239 UHF connectors. The design team anticipated a 700 m control cable run between the remote switching hub back and the selector boxes at each operating position. Shielded, stranded-wire Ethernet cable connected the selector box to the remote switch. This cable is available relatively inexpensively in bulk; e.g., 1500 m reels, about as heavy as one strong person could safely manage during unloading in surf at the beach. To speed assembly at the island, we pre-installed and tested RJ45 connectors on the cable, operator selector boxes, and remote switch boxes.

Over this distance a significant voltage drop occurs. We exploited an advantage of the RCS-10 system by configuring: its control box to accept a +24 Vdc power supply input. Measurements and calculations prior to departure showed that, over this distance, the control box and Ethernet cable (with two paralleled conductors per control signal line) would deliver sufficient power to run the relays in the remote switch box. Behavior at the island confirmed the calculated design.

We used adjustable replacement laptop power supplies for the +24 Vdc source with a battery backup for use during generator outages. To save assembly time, supplies and equipment were pre-wired with PowerPole connectors. (Blue and black connector colors and prominent labels warned operators that these lines carried 24, not 13, volts.) West Mountain Radio's Rigrunner DC distribution boxes joined a power supply with subtending equipment such as these remote coax switch control boxes. (With care, the Rigrunner's PowerPole red connector housings can be replaced with another color such as the blue we used to flag +24 Vdc lines.)

Not all remote-controlled antenna switch designs work properly for this application. The remote-controlled switch must not short unused antenna ports to earth, as these signals might be used by the second receiver. [6]

While the RCS-10 units offered an off-the-shelf solution that could meet our needs, quality control and signal isolation were relatively weak aspects of this particular equipment. The hardware, as delivered, exhibited many poor solder joints. One switch box had to be completely disassembled and re-soldered to work properly: a major undertaking (fortunately done at home!) as the manufacturer rivets the SO-239 connecters to the chassis. Replacement rivets were not on hand and reassembly after repair took a lot of fidgeting in close quarters with short bolts, nuts and lockwashers. The end of this article contains some ideas for improvements and further suggestions.

Tip: The RCS-10, like many remote-controlled switches, uses a rotary switch with a mechanical stop to select the desired antenna. This stop prevents the operator from easily comparing signals between the two antennas at either end of the switch range. In some rotary switches you can remove the mechanical stop or replace the switch with a model without a stop. If that possibility does not exist, then you should arrange the choices so that the two affected antennas are the least likely to be compared. At Ducie Island we sequenced the switch selections in this order (clockwise): 195°, 225°, 270°, 305°, 015°, 045°, 090° and 125°. The 195° direction, used only near sunrise for long path, was never compared to the 125° direction as that direction was in full daylight at the time.

7 Pre-amp

The output of each remote-controlled switch fed a co-located, low-noise pre-amp. The pre-amps compensated for losses in the

6 Shorting one output of the bandpass filter-splitter might also increase somewhat attenuation of the other output(s), an undesirable result in this application. This observation is speculative as the condition was not tested when measuring the performance of the filter-splitter.

system. The highest frequencies (3750–3850 kHz) exhibited the greatest loss:

- −1.7 dB for 100 m RG-6 cable between the antenna feedpoint and the filter-splitter input. Only the 090°/270° beverage had this long run to the central switching hub.
- −6 to −12 dB: W3LPL bandpass filter plus Mini-Circuits splitter.
- −12 dB for a 700 m run of RG-6 from the remote switching hub to the operating position.
- Other parts of the system (coax shield current choke, antenna switch) had negligible losses.

Total loss adds up to −20 to −26 dB between antenna feedpoint and receiver on this band. Beverage signal output on the 80/75 m at the feedpoint is greater than that on the 160 m band, which helps offset a bit of this loss.

To overcome much of these losses we used the DX Engineering RPA-1 pre-amp, which provides about +16 dB gain, 3.5 dB noise figure, and +43 dB third order intercept. Voltage fed down the RG-6 from the radio tents provided power to the pre-amp.

This pre-amp consumes 140 mA at a nominal +13 Vdc, yielding a nominal internal resistance of 93 Ω. Belden flooded RG-6 coax offers about 5 Ω per 100 m of DC loop resistance (center conductor plus shield). With the 700 m runs planned for Ducie Island, 35 Ω of cable resistance would drop the voltage delivered to the preamp by about 3.5 V, down below its operating range of +10 to +18 Vdc. To compensate, the higher supply voltage of +24 Vdc used for the remote controlled switch also fed the pre-amps.

8 Pre-amp protections

As mentioned earlier, one must protect the pre-amp input from strong signals picked up while transmitting. At Ducie Island up to seven full-power transmitters could be on-air simultaneously. Three systems worked together to provide this protection.

Bandpass filter-splitter:

The bandpass filter-splitters knocked down signals outside the operator's own band. For a pre-amp used on the output of a 160 m remote-controlled switch, for example, the 160 m portion of the bandpass filter-splitter reduced the signal levels for transmitters on any other band by about −50 dB, low enough not to bother the pre-amp.

After the filter-splitter, this pre-amp remained exposed only to the operator's own 160 m in-band transmit signal.

Power interruption:

When the operator transmits, he is not listening; therefore, the pre-amp can be turned off during transmission. A homebrew "power interrupter" sat next to the radio; it injected the pre-amp supply voltage (+24 Vdc in this implementation) into the two RG6 coax runs (one for each receiver) out to the remote switching hub. Figure 8 shows the circuit.

A +13 Vdc control line, when grounded, triggers two relays to remove the pre-amp supply voltage from the coax, disabling the remote pre-amps for both receivers. At Ducie Island the microHam microKeyer II's LNA PTT port manipulated this control line; we configured the microKeyer II to turn off the pre-amp about 20 ms before triggering the transmitter PTT, guaranteeing that the pre-amp would be off well before the start of transmission. (VOX transmission was forbidden at VP6DX; we reconfigured the microKeyer so it would not connect the microphone to the transmitter until the operator stepped on the footswitch.)

The vast majority of amateur transceivers provide mediocre isolation between their antenna port(s), including their receiver input ports: typically in the range of −40 to −45 dB. When transmitting 100 W out the transmit antenna port, the radio also leaks copy of the signal at about 10 mW (+10 dBm or S9+77 dB) out the receive antenna port. That signal leakage also includes harmonics, IMD products and their phase noise sidebands, typically 50 dB below the leaked carrier (-40 dBm or S9+27 dB).

(a) Circuit diagram for power interrupter

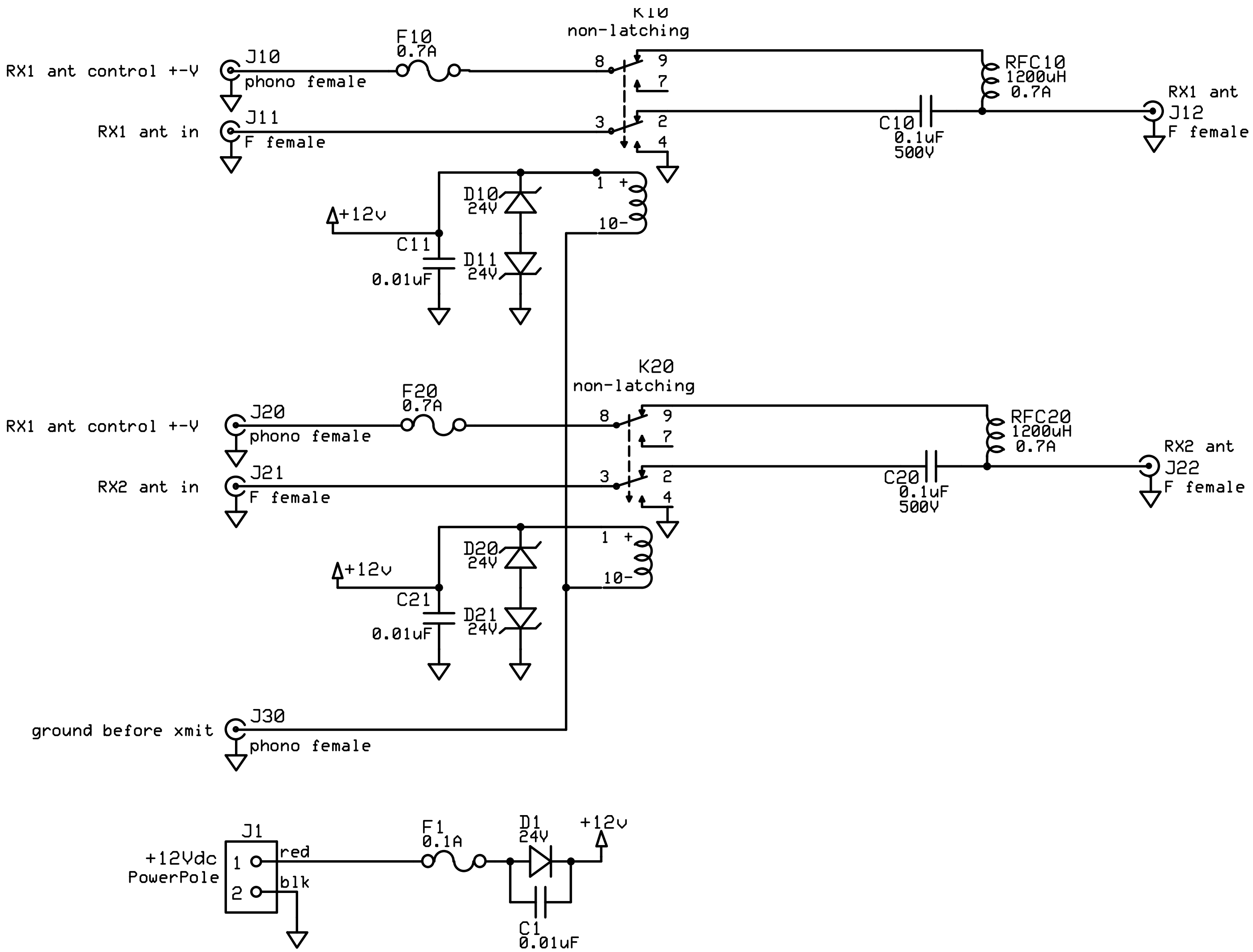


Figure 8 (first page): Power interrupter.

(b) Parts list

circuit	description	part, notes
c1, c11, c21	0.01 µF 500 V	140-500z5-103z-rc
c10, c20	0.1 µF 100 V	281-sr211c104kar
d1	1n5400 50 V 3 A	821-1n5400
d10–d11 d20—d21	28 V 500 W	863-sa28ag
f1	250 V 0.1 A Slo-Blo 3ag fuse	576-0313.100hxp
f10, f20	250 V 0.7 A Slo-Blo 3ag fuse	576-0313.700hxp
f1, f10, f20	pcb mount fuse clip	504-1a1119-10
j1	PowerPole red-black	Note 3
j10, j20, j30	phono female, pcb mount	16pj092re Note 2
j11–j12, j21–j22	f female coax, pcb mount	161-5370
k10,k20	12 Vdc non-latching signal	655-d3002
rfd10, rfc20	1200 µH 0.7 A rfi suppression coils	434-13-152m
box	nema die-cast aluminum	563-cn-6703

Note 1: Part numbers are Mouser unless otherwise noted.

Note 2: These phono jacks must be spaced above any traces on the board; otherwise the metal shell will short the traces to ground. Voltages injected into each coax run may be different from each other and from the +13 Vdc used to power the relays k10 and k20.

Note 3: Assemble a pair of PowerPole connectors using solid awg #14 bare wire, crimped and soldered. Solder the other end of the bare wire into the holes on the board so that the rear of the connector housing sits flush against the board.

Figure 8 (second page): Power interrupter.

The power interrupter box uses small signal relays not only to interrupt the voltage supplied to the pre-amps, but also to short the receive antenna ports to earth. This additional function substantially reduces signal leakage.

For the 160 m operator, the bandpass filter and pre-amp power interrupter together protect the remote pre-amps from all the other on-site transmitters.

But the 80 m cw pre-amps remain exposed to one transmitter: the 75 m ssb transmitter, whose signals fall within the passband of the bandpass filters that precede the 80 m cw pre-amps. Similarly, the 75 m ssb pre-amps remain exposed to the 80 m cw transmitter.

In-band rejection:

George w2vjn solved this remaining problem with notching filters. These filters place a sharp notch (more than −40 dB) on the unwanted transmitter’s frequency while introducing little additional loss (less than 1 dB) to the desired receive frequencies. Here’s George’s discussion of the design and implementation:

—In early December 2007, k3na asked if I knew of a way to operate on 75 and 80 meters with separate stations for the upcoming Ducie Island operation. Eric was concerned about the close proximity of the beverage antennas to all of the transmitting antennas. I had been working on some new stub ideas and I knew they could provide 15 to 20 dB of attenuation between the cw and the ssb ends of the band. This seemed to be somewhat marginal. In addition there would be 5 to 8 dB of on-frequency attenuation which seemed excessive, as the signal levels coming from the beverage antennas would already be quite low. A quick preliminary design of a simple band stop filter with the Elsie [7] program showed a possible solution. A three element Butterworth design could provide 40 dB of attenuation at the null frequency and would not attenuate the desired listening frequency by more that a dB or so (see Figure 9). The inductor requirements were

7 Elsie is a filter design program available at www.elsie.com.

modest, as a Q of 75 or more at the operating frequency would be adequate. Two of the inductors were in the 50 to 60 µH range, while one was in the less than 500 nH range. A few commercially available inductors having values in the desired µH range were obtained and a selection was made based on Q measurements. The design was then tweaked to use the selected inductors. The nH chokes that were tested had miserably low Qs and were deemed not suitable. A few turns around a type 2 powdered iron toroid core showed more promise and was used in the final design.

—To optimize the null depth each element (tuned circuit) must be adjustable. The shunt elements L1 and C1 require only a small variation in capacitance for tuning, and trimmer capacitors can do the job. The trimmers were padded with a series capacitor and a shunt capacitor to reduce the sensitivity of tuning as the null is very sharp.

—Construction was done on readily available prototype PC boards as there was not enough time to do custom work. Simple point to point wiring is adequate. Four units were built to meet the requirements, two for 80 m CW and two for 75 m SSB.

—Figure 9(c) shows the construction. The units needed to be rugged enough to withstand the long journey via air, sea and ground to their operating positions on Ducie Island. Small aluminum boxes were used. The boards were mounted on four threaded standoffs. Type F connectors were used according to the 75 Ω system requirements.

—A three element filter is simple enough so that formal methods are not required, and alignment can be done by alternately adjusting each tuned circuit. Watching the loss at the desired pass frequency and the null depth on a network analyzer while adjusting allows a good compromise to be found. Figure 9(d) shows the sweep response of one of the units.

Thanks, George!

9 As built at Ducie Island

As mentioned earlier, we did not build out the entire system at the island:

- With just a single receiver in the Elecraft K3 radios, we required only half of the switching matrix.
- We built the second, parallel leg for the 045°/225° beverage. While this antenna performed superbly, we did not feel very strongly that we needed the second leg on the other beverages. We also worried that adding the second leg to, for example, the 015°/195° beverage might introduce a gap in coverage between the two beverage arrays (especially on the 80/75 m band, with its narrower beamwidths). That gap that would run right through the middle of the United States and down the center of Europe.

10 Results

Overall this system performed superbly. Comparing results to the goals:

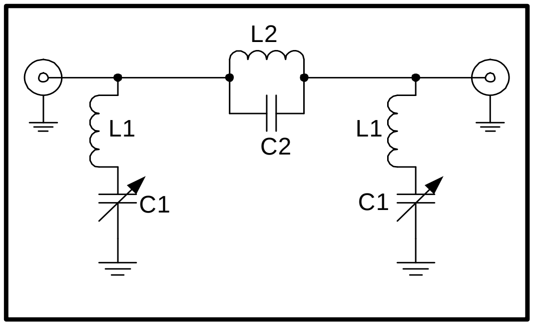
Improve signal-to-noise ratio:

No question exists on this point: the beverage systems delivered superior signal-to-noise ratios compared to the transmit antennas for these bands. Dietmar DL3DXX summed up the situation one evening around midnight, after he had finished a lengthy 160 m operating session with Europe on a band filled with static: “No beverages? Then no QSOs.”

Eric K3NA pointed out that an operator could tell when sunrise began in the Caribbean by comparing the 045° and 015° beverages. The static level on the 045° beverage dropped significantly as sunrise moved across the Caribbean and D-layer absorption attenuated QRN from the thunderstorms in that region. The 015° beverage still heard plenty of static from sources within its main beam.

Eric says, “This was the first DXpedition where I felt we could hear anyone calling us on top band. In fact, at times I could hear stations calling us much better than they could hear me.”

(a) Notch filter circuit diagram

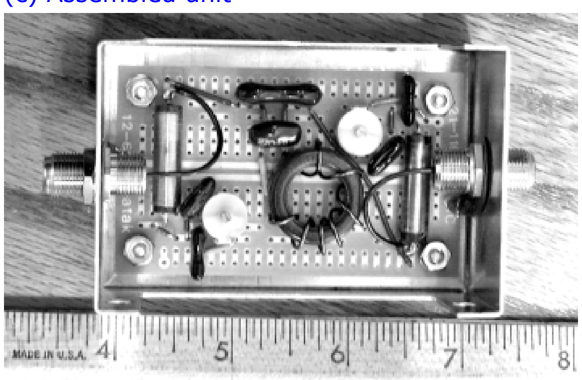


(b) Parts list

	3502 kHz notch	3784 kHz notch
C1	36.7 pF	31.6 pF
C2	5280 pF	5360 pF
L1	55 μH	55 μH
L2	0.39 μH	0.33 μH

Note: C1 and C2 are made up of several capacitors in parallel, including a trimmer capacitor.

(c) Assembled unit



(d) Typical measured response

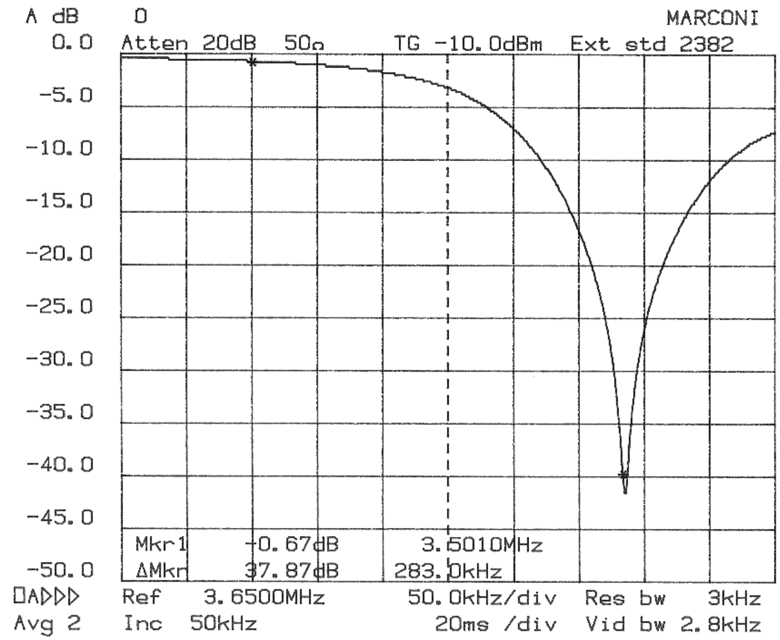


Figure 9: W2VJN in-band notching filters.

Reduce QRM; divide pileups:

Beverages patterns appeared to behave exactly as expected. The ARRL DX CW contest occurred early in the DXpedition, and the contest exchange told us the location of stations. If a W6 called, but was weaker on the 015° beverage (which covered California) and louder on the 045° beverage, we could be certain he would give us an exchange with Georgia or some other eastern USA state. The transition area where stations exhibited equal strength on these two particular beverages was distinct and narrow: From Texas through Arkansas to Indiana and Michigan.

These distinct patterns meant that the operator could focus on east coast USA during their sunrise enhancement, using the 045° beverage that displayed relatively weak response to closer, louder west coast stations. Similarly the 015° beverage favored Scandinavia, eastern Europe and western Siberia over western Europe, a big advantage for us right after Ducie Island sunset. We had a two to three hour window to work these remote parts of the world on unfavorable polar paths before their local sunrise.

I am definitely looking forward to an opportunity to try directional diversity reception with a similar beverage array feeding the K3's dual receivers on the next expedition!

Support three operating positions:

No problems on this point. During the second half of the expedition demand for 75m SSB from North American and even Europe dropped off. On some nights we removed the notch filters and ran just one station on 80/75 m CW/SSB; the freed-up operating position became the second station on 30 m.

Avoid damage from on-air transmitters:

Not only were the pre-amps adequately protected, the operators could not detect the presence of any other on-air transmitter.

Maximize results from construction labor:

Low-band QSO totals for VP6DX from sixteen days on-air:

band	all	CW	SSB	EU	NA	AS
160 m	6 615	5 053	1 562	13%	71%	14%
80/75 m	18 213	9 650	8 563	35%	47%	12%

The 80/75 m QSO total represents a new record for a DXpedition, and the 160 m total stands second in the record books behind 5A7A's 7653 QSOs. (which included many Europeans worked on a short hop from Libya).

The 440 m long east-west beverage, also with a narrower beamwidth, appeared to be too long; i.e., the main beam seemed too narrow. Stations from the extreme southern Caribbean or northern South America (P4, YV) often had poor signal-to-noise rations compared to others further north (good copy on the 045° beverage) or south (closer to the center east-west beverage's main beam). Callers from Australia and southeast Asia left similar impressions to the west. Milt N5IA and Robin WA6CDR later re-routed the eastern half of that beverage to form a very shallow bent V-shape in order to widen the beam. Unfortunately, few stations called us from these areas overall, making it difficult to form an opinion about any improvement.

Cover all directions:

Europe, North America and Asia made up 98% of the 160 m contacts and 94% of 80/75 m totals. With the exception of some long-path contacts with east Europe, two or three single-wire beverages could handle many of these contacts. One might question whether the results justified the additional hardware for and incremental work to install two-wire beverages and the fourth east-west beverage. While small in percentage terms, we were happy to work the DXers represented in those 1300 QSOs. And the long path QSOs on the 195° and 225° beverages with Ukraine and European Russia stations on top band, across over 22,000 km and into their afternoon daylight, represent an unforgettable DXing experience.

Based on expedition experience in Burma, the team also brought materials to construct a low dipole for listening to high elevation angle signals on 160 m. This receive antenna was never built; none of the top band operators found any opening where signals might have been better copied on a high-angle antenna.

Each operator selects direction independently:

The ability for each low-band operator to choose his listening direction without concern for the impact on another operator was well-appreciated by the low-band team.

Deliver signals at levels approximately equal to that from the transmit antennas; limit signal suck-out:

The beverage distribution system delivered better than expected signal levels to the receivers. When comparing signals received on the transmit antenna to the same signals on the appropriate beverage, the absolute signal strengths were about the same. The static levels, however, dropped dramatically on the beverage. The transceiver's internal pre-amp was unnecessary.

Signal suck-out did not occur. Operators never detected a change in receive signal level when one of the other operators selected the same receiving antenna.

11 Potential improvements

Every implementation can inspire ideas for improvements. Readers contemplating the use of some of these techniques in their own stations might consider the following possibilities and, hopefully, share their results with the rest of the contesting/DXing community. If someone wants to help us with some of these ideas, we will be very grateful for the assistance!

General:

- Weatherproofing any kind of box-mounted coax connector takes time and care, and both can be in short supply during an expedition, during Field Day, and during the rush to prepare the station for a contest. An alternate approach would place box(es) inside a NEMA IP67 enclosure, using cable glands to seal out the weather.
- For field connections, consider using watertight RJ45 connectors with an IP67 environmental rating. Although more costly, these connections speed assembly time.
- RG-6 coax paired with a CAT-5 cable and molded into a single assembly, suitable for outdoor use, is available. This cable appears to be more costly than individual runs of RG-6 and CAT-5. However, in a situation where assembly time is limited, the time savings may justify the incremental expense. Flooded cable is preferable in the outdoor environment.

Beverage array:

- If planning the use of parallel beverages with their narrower beamwidths, consider using more beverage systems; e.g., five or six two-wire systems for ten to twelve directions. This choice affects the choice of selector switch.
- If space permits, prefer the use of parallel beverages over long beverages.

Coax shield current chokes:

To avoid cabling errors in the field, label the coax connector to go to the antenna and the connector for the coax run to the receiver.

Bandpass filter-splitter:

- For those wishing to share a receiving antenna on three bands, Frank W3LPL reports success in paralleling three of his bandpass filters (e.g., 160, 80 and 40 m) without too much in-band loss.
- We plan to investigate a modified design for 75 Ω characteristic impedance.

Remote-controlled switch:

- One can easily design a smaller, better-performing switch unit using sealed small signal relays. Constructing this unit with F connectors would eliminate the large number of F-UHF adapters used at Ducie Island.

- Daisy-chaining a pair of relays and careful board layout can boost isolation between the various antennas.
- A single box could contain both switches for the two receivers on a band, dramatically reducing the number of coax jumpers.
- We plan to investigate sending selection signals down the coax, along with DC power; this step will eliminate the expense and construction time associated with the control line.
- LED indicators identifying the selected switch position can speed acceptance testing and troubleshooting in the field. Use bright LEDs to enhance visibility on sunny days.
- Include a pair of test points for quick field checks of voltage delivered to the box.
- An operator selection box with a circle of illuminated push-buttons would permit quick comparison of short and long path (or any other two non-adjacent choices). Two such circles of buttons would allow control of antennas for both receivers; this should include a “slave” button to allow both receivers to use the same antenna selection.
- If selection signals were transmitted down the coax, the same box could include the DC power injection/interruption tasks as well as shorting to earth the receiver antenna ports when transmitting. One should be able to create such a box in a smaller volume than two RCS-10 control boxes.

Pre-amp:

- An LED power-on indicator can speed acceptance testing and troubleshooting in the field. Use a bright LED to enhance visibility on sunny days.
- Include a pair of test points for quick field checks of voltage delivered to the box.

Notch filter:

- Chassis-mount F connectors often loosen up when tightening a cable; opening the box to re-tighten the connector nut and lock-washer takes time and breaks the weatherproof seals (if any). Board-mounted F connectors don’t suffer this problem.
- The sharp notch worked well for our DXpedition with its fixed transmit frequencies around 3502 and 3784 kHz. In a normal contest station the notch needs to be adjusted to track the transmitter around the band. George’s filter design certainly permits such adjustments. We haven’t tried doing this in real time.

— END —