A134-4-1

DL-1 Delay-Line Phasing Unit

Mark Connelly - WA1ION

3 FEB 1994

The DL-1 phasing unit is a delay-line based design similar to Gerry Thomas's Phase One. His 1985 article "The Phase One - A Delay Line Phasing Unit" is available through the NRC and IRCA reprints services. Gerry's design was the first real usage of this technology as applied to medium-wave DXing. The Phase One was derived from an HF phaser presented by John Webb in QST (October 1982). The DL-1 updates the concept and uses a delay-line (RCD P2420-600NS-100) that is somewhat less expensive (about $20) and more available than the Allen Avionics LC300Z050A specified for the Phase One. Unlike the Phase One, there are no broadband amplifiers in the DL-1. It is a totally passive unit which is meant to work into a companion regenerative preselector (Mini-MWT-3) when additional gain is required. Tests here (3 miles from 50 kW WRKO - 680) indicate that, in urban and suburban settings, running a broadband antenna (e. g. untuned longwire) into a broadband amplifier is just a bad idea. Even if the broadband amplifier is robust enough not to generate noticeable second and third order intermodulation distortion products with amplifier outputs around +20 dBm (local station frequencies), the receiver may not fare as well. You want to boost weak signals without boosting already-strong local stations 100 kHz or more away from the frequency of interest. There are very few instances in which a broadband-amplification-after-broadband-phasing scheme will result in as low a noise floor and as good immunity to spurious signals as a tuned amplification approach would. In many cases, at least with longer wires and a good receiver such as a JRC NRD-535D, Drake R8, or Hammarlund HQ-180A, amplification is not necessary. This is especially true on "normal" nights when the desired DX left after "pest" nulling can still be of appreciable strength.

The DL-1 has enhanced flexibility in controlling nulls because the levels of Antenna Line 1 and Antenna Line 2 are both adjustable; also, each line can be connected alone to facilitate level balancing and appraisal of each antenna's directional pickup characteristics.

Noise-reducing principles have been incorporated by the provision for floating (non-chassis) grounds at the J3 and J4 inputs.

Principles of Delay-Line Phasing

In order to null out unwanted station "A" and hear subdominant (desired DX) station "B" when using two wires, the difference in phase between "A" and "B" on Antenna 1 should differ appreciably from the difference in phase between "A" and "B" on Antenna 2. This condition will most often occur when the "A" and "B" signals are coming from different directions and the wire antennas are oriented somewhat differently. What the phasing unit must do is to equalize the levels of Antenna 1's pest station "A" contribution to that from Antenna 2 and to provide a 180 degree phase shift of "A" from Antenna 1 to Antenna 2 entering the summation point. Level-equalization is most easily accomplished when the two wires are of similar length. If the equal-amplitude / opposite-phase condition is met, station "A" is nulled, leaving "B" in the clear. Station "B" might be reduced somewhat as well, or it may actually be increased in level, depending on how different the phase difference ("A" to "B") is on Antenna 1 relative to that difference on Antenna 2. The occasional instances of desired DX stations getting nulled along with co-channel pests from a different direction can be minimized by having more than two longwire antennas available. Three wires give 6 possible pairing combinations (1 vs. 2; 1 vs. 3; 2 vs. 3, 1+2 vs. 3, 1+3 vs. 2, and 1 vs. 2+3). If there are substantial angular spreads between the three wires, almost any nulling situation can be managed. Desired DX close in bearing to pests to be nulled can sometimes still be listenable if the vertical arrival (skip) angles differ. Use of Beverage-length (over 300 m / 1000 ft.) wires helps in such cases.

The goal of both the delay-line and the L/C type (e. g. MWDX-5) phasing units is to provide a continuously-variable phase shift of the signal contributions from one or both of the antenna inputs. The delay-line method provides continuous shift on one of the two lines: Line 2 in the DL-1 case. To provide a full 360 degrees of shifting, a 0-deg. / 180-deg. vector is provided by R2 across the T2 balun secondary and a 90-deg. / 270-deg. (approximate) vector is provided by R3 after the delay-line with range-switch S2 set to the tap providing a delay time of a quarter of a cycle of signal frequency (250 ns at 1 MHz). The 0/180 and the 90/270 vectors are summed to provide a variable-amplitude vector that can be "rotated" through a complete 360 degrees of shift. The delay time (tap) setting is a good deal less critical than you would think. I've labelled S2 positions as "low band", "mid-band", and "high band" but, in reality, the setting of S2 is not too important.

The R1 (Line 1) potentiometer reduces the level of pest station signal from Antenna 1 in cases when it is substantially larger than pickup of the same station on Antenna 2. Without this capability, it would not be possible to equalize the Antenna 1 contribution with the 180-degree shifted Antenna 2 contribution and a null would not be produced.

The RCD P2420-600NS-100 delay-line has 20 taps on it; these provide more delay times than needed. The four taps connected to S2 have been chosen for best performance at medium-wave frequencies. I've tested the DL-1 on longwave, 160-meters, and tropical bands and nulls of electrical noise and of steadier signals have been obtainable. Of course, a switch with more positions could be used at S2 if a given DXer wanted to utilize more of the taps.

The user will find that nulling with the DL-1 can be simpler than nulling with L/C design units because there are fewer knobs to tweak. The broadband delay-line based phasing approach does have as an advantage the ability to QSY (change frequency) to scan the band and to check parallel frequencies on both medium-wave and shortwave quickly. These features can come in handy on Beverage DXpeditions and in other cases when a good opening is bombarding you with rare DX and you want to get maximum loggings in minimum time.

A tuned L/C phaser can provide somewhat higher signal levels than a broadband delay-line based unit such as the DL-1. Also, in urban areas, the preselection provided by an L/C phaser such as Super-MWDX-5 can reduce the likelihood of the receiver being overloaded and producing spurious signals. There are advantages and disadvantages to both delay-line and tuned L/C type phasing unit designs.

For adequate signal levels with the DL-1, the minimum suggested wire length for each antenna is 30 m. / 100 ft. Wires much shorter than Beverage length should be aligned for an angular spread of 45 to 135 degrees, or 225 to 315 degrees, between them. Slopers and Beverages may work best with a 180 degree spread as they would each have distinct inherent nulls in opposite directions. I use one sloper that nulls about 10 dB to the west and another that nulls about 10 dB to the east. Phasing with that set-up is good because virtually no eastward signals come off the westward-favoring sloper when the amplitude of its western pick-up is

A134-4-2

reduced to the same level as the fairly-low (180-degree shifted) western pick-up of the eastward-favoring antenna. The result is little or no cancellation of eastward Trans-Atlantic stations when pesty midwest clears are nulled. Indeed, stations easily heard on the phased wires (such as Algeria - 891 with WLS - 890 nulled and England - 1089 with WBAL - 1090 nulled) are often just loud hets on any loop used.

Operating the DL-1: Initial Set-Up

The controls, as shown in Figure 1, are R1 (Line 1: level), R2 (Line 2: 0/180 deg. level), R3 (Line 2: 90/270 deg. level), S1 (Ground Mode: FLOAT or COMMON), S2 (Frequency Range), and S3 (Function: Ant. Line 1, Ant. Line 2, Null-a, Null-b). Connect one antenna wire to J1 and the other wire to J2. Floating grounds (e. g. sets of ground rods separated in distance from mains / receiver chassis ground) may be connected to J3 and J4 for reduction in electrical noise. Coaxial feeders from remote noise-reducing 'Bevmatcher' style transformers can be connected to J1/J3 (Line 1) and to J2/J4 (Line 2). S1 is set to FLOAT if noise-reducing grounding is available; otherwise it should be set to COMMON. Frequency range switch S2 should be set to Low Band for coverage below 800 kHz, Mid-Band for 800 - 1400 kHz, or High Band for above 1400 kHz. There is a fourth position of S2 (Auxiliary or "X"), an experimental setting which may occasionally yield better nulling, especially in the Tropical Band frequency range. The settings of S2 are approximate, not overly critical, and somewhat affected by antenna length. Settings of S3, R1, R2, and R3 are discussed in the Nulling Procedure to follow.

Operating the DL-1: Nulling Procedure

The first part of nulling is to determine which of the three level pots (R1, R2, or R3) has the greatest initial effect in setting up a null. All three pots' knob pointers should first be set to "10 o'clock" where "8 o'clock" represents the fully counterclockwise (CCW) setting.

1. Set S3 to Null-a and observe the strength of the dominant "pest" station to be nulled as you run R1 through its range. If there is a distinct "dip" in strength and a possibly greater evidence of other stations, leave R1 at that null-initiating setting and skip to step 8 below, unless the dip occurs at the fully-clockwise (CW) (e. g. "4 o'clock" R1 pointer position).

2. Set S3 to Null-b and run R1 through its range. If a dip then occurs and R1 is not fully CW, leave R1 at that setting and proceed to step 8. If null-initiation still hasn't occurred, set R1 back to "10 o'clock" and switch S3 repeatedly between Ant. Line 1 and Ant. Line 2. If the pest station strength is noticeably higher on Ant. Line 1, adjust R1 such that signals from the pest station are about equal when S3 is switched back and forth from Ant. Line 1 to Ant. Line 2. If Line 2 had been stronger, return R1 to "10 o'clock". Put S3 on the null position (Null-a or Null-b) exhibiting the greater reduction in pest station strength (default to Null-a if there is no difference).

3. Run R2 through its range. If a dip then occurs, leave R2 at that setting and proceed to step 8. If null-initiation still hasn't occurred, set R2 back to "10 o'clock".

4. Run R3 through its range. If a dip then occurs, leave R3 at that setting and proceed to step 8. If null-initiation still hasn't occurred, set R3 to "12 o'clock" (center).

5. Run R2 through its range (now that R3's position has been changed). If a dip then occurs, leave R2 at that setting and proceed to step 8. If null-initiation still hasn't occurred, set R2 to "12 o'clock" (center).

6. Run R3 through its range (now that R2's position has been changed). If a dip then occurs, leave R3 at that setting and proceed to step 8.

7. Swapping the antenna inputs and/or trying a different S2 (Frequency Range) setting (before re-iterating steps 1 through 6 above) may help in the rare cases in which a null will not set up satisfactorily.

The second part of nulling is to maximize the null that has already been initiated.

8. Deepen the null through small, careful adjustments of all three pots (R1, R2, R3) in a repetitive sequence. Before doing this, make a mental note as to where the three knob pointers are set just in case you overshoot the ideal setting of one of the pots and have to backtrack. When you're done, previously-covered DX stations should be audible.

Application Notes

If there are several stations in a given section of the band on similar bearings, null solutions (settings of S3, R1, R2, and R3) will be similar. The controls can often be preset to close approximations requiring only minor re-tweaking to get to a given null. For instance, from a New England QTH, null control set-ups for WMAQ-670 (IL), WLW-700 (OH), WGN-720 (IL), CBL-740 (ON), WJR-760 (MI), WBBM-780 (IL), CKLW-800 (ON), and WLS-890 (IL) do not vary much from a single approximate set-up of the four controls. That comes in handy in situations such as mine where the majority of pest stations come from similar bearings. In the daytime, Maine stations (over 90 miles distant) can be logged through the phased remnants of normally-dominant WEIM-1280, WORC-1310, and WVEI-1440 (all in central Massachusetts 40 or so miles west of me) with a single setting of the DL-1 controls. This result is similar to what Gerry Thomas observed with his Phase One. Keeping a mental or written note of commonly-used control settings employed in the removal of groups of pests will speed up the nulling process as a DXer gains experience with the unit.

Loop versus wire operation is not recommended because a broadband source (wire) phased against a tuned source (loop) will make a thorough null of offending-station audio difficult because of the different frequency-response curves and group-delay properties of the two sources. Two loops of similar Q and gain could conceivably be phased by passing their outputs through the DL-1. The loop heads should be aligned at right angles to each other and at approximately 45 degrees to the pest station (one loop 45 deg. clockwise, one 45 deg. counterclockwise of the bearing of maximum pest pickup). When two-loop nulling is nearly completed using normal DL-1 procedures, the last few dB of null may be "squeezed out" through fine adjustment of either loop's physical position and/or loop tuning capacitor settings.

As with any nulling system (phasing or looping), the best results will be on daytime groundwave and on lower-angle skip at night. Nulls of low-band stations are somewhat more stable than those of high-banders. "Easy" nulls of daytime regional and "graveyard" stations (already exhibiting evidence of sub-

A154-4-3

dominant stations) should be pursued first in order to gain proficiency in adjusting the DL-1 controls.

High-angle skip, mixed groundwave / skywave, and various multipath / multi-skip situations are difficult nulls to set up on any looping or phasing system. Phased Beverages seem to do the best and Adcock arrays are supposed to work well also.

Amplification

Broadband amplification is possible, but not recommended with cheaper receivers such as portables or with any receiver in a high-RF urban area. The simultaneous application of a wide spectrum of MW, SW, and VHF signals to an amplifier or receiver input can be a challenge. By going from the 5" X 4" X 3" box suggested for DL-1 to a slight larger case, broadband amplifier components could be mounted in the same case as the phasing circuitry. The added components would consist of a gain control potentiometer, a 3-pole / 2-position amplifier on/off switch, a jack for DC power input, an the amplifier itself. Circuits which have good dynamic range are the BBA-C1 (as used in the Super-MWDX-5), the BUF-A (or BUF-B) preceded by a 1:36 step-up transformer (as used in the RTL-2 Remotely-Tuned Loop), and the Motorola MHW591 circuit used by Craig Healy in his VCR DX scheme. Also usable are the Mini-Circuits ZHL-32A and Dallas Lankford's Noiseless-Feedback (2N5109-based) amplifier (as well as some of his grounded-gate FET designs).

Tuned amplification can provide a higher signal to noise ratio and superior rejection of spurious responses that typically result from too many strong signals at the amplifier or receiver input. The recently-published MWT-3 article describes a suitable tuned amplifier. MFJ, Grove, and other vendors have commercially-available units advertised in Monitoring Times, Popular Communications, QST, and other hobby publications.

Figure 2 of this article shows the Mini-MWT-3, a regenerative preamplifier that is simple in design. Documentation will be limited to this schematic and to Table 3 (a hole list) as it is, in essence, a reduced-complexity version of MWT-3. The MWT-3 article and vendor catalogs (e. g. Mouser) will fill in other useful details for those wishing to build and operate the Mini-MWT-3.

DL-1 Construction Data

Table 1: DL-1 hole-drilling list

X = Horizontal distance, in inches, from the vertical centerline (VCL) on the side observed. Negative values of X are left of VCL, positive values of X are right of VCL.

Y = Vertical distance, in inches, from the bottom horizontal edge of the side observed.

D = Hole diameter in inches.

Hole loci are first marked on the box with a scriber and are then drilled with a .125" bit. Subsequently, as required, the holes are enlarged to the proper size by using progressively larger bits up to that corresponding to the final desired diameter.

Chassis Box = Mouser 537-TF-779 (metal): 5" X 4" X 3"

L E F T   S I D E

Hole #	Comp. Desig.	Description	X	Y	D
1	J1	Ant.#1 In - red banana jack	-1.375	0.75	0.3125
2	J3	GND.#1 In - black banana jk	-0.625	0.75	0.3125
3	G1	internal ground lug hardware	0.0	0.75	0.125
4	S1	GND mode switch - shaft	0.0	1.625	0.25
5	S1	GND mode switch - tab	0.0	1.375	0.125
6	J4	GND.#2 In - black banana jk	0.625	0.75	0.3125
7	J2	Ant.#2 In - red banana jack	1.375	0.75	0.3125

T O P   S I D E

Hole #	Comp. Desig.	Description	X	Y	D
1	R1	Line 1 pot. - shaft	-1.625	3.25	0.375
2	R1	Line 1 pot. - tab	-1.625	2.75	0.144
3	R2	Line 2 (0/180) pot. - shaft	-1.625	2.0	0.375
4	R2	Line 2 (0/180) pot. - tab	-1.625	1.5	0.144
5	R3	Line 2 (90/270) pot. - shaft	-1.625	0.75	0.375
6	R3	Line 2 (90/270) pot. - tab	-1.625	0.25	0.144
7	for Z1	tie wrap hole (see note)	-0.125	2.875	0.144
8	for Z1	tie wrap hole (see note)	-0.125	1.375	0.144
9	S3	Function switch - shaft	1.0	3.0	0.375
10	S3	Function switch - tab	1.5	3.0	0.144
11	S2	Freq. Range switch - shaft	1.0	1.25	0.375
12	S2	Freq. Range switch - tab	1.5	1.25	0.144
13	G2	internal ground lug hardware	1.875	2.125	0.125

Note: Z1 delay-line is secured by a nylon tie-wrap through Top Side holes 7 and 8.

R I G H T   S I D E

Hole #	Comp. Desig.	Description	X	Y	D
1	J5	RF out - BNC jack	0.0	0.5	0.375

Table 2: DL-1 "upper level" parts list

*: Note follows parts list.

Vendor codes for this and subsequent parts lists:

MCL = Mini-Circuits Lab. / P. O. Box 350166 / Brooklyn, NY 11235-0003 /Tel. 1-800-654-7949

MOU = Mouser Electronics / 11433 Woodside Ave. / Santee, CA 92071 /Tel. 1-800-346-6873

RCD = RCD / 520 East Industrial Park Drive / Manchester, NH 03109-1824 /Tel. 1-603-669-0054

RS = Radio Shack / Many locations worldwide

Schematic = Figure 1

Item	Designator	Description/Value	Vendor	Vendor Stock #	QTY
1	-	chassis box 5X4X3	MOU	537-TF-779	1
2	*	knob	RS	274-416	5
3	C1,2,3	capacitor, 0.1 uF	MOU	539-CK05104K	3
4	G1,2	screw, 4-40 X.375"	MOU	572-01881	2
5	G1,2	solder lug, #4	MOU	534-7311	2
6	G1,2	hex nut, 4-40	MOU	572-00484	2
7	J1,2	red banana jack	RS	274-662	2
8	J3,4	black banana jack	RS	274-662	2
9	J5	BNC jack	RS	278-105	1
10	R1,2,3	pot.,500 ohm,linear	MOU	31VA205	3
11	R4,5,6	resistor, 10 ohm	RS	271-001	3
12	R7	resistor, 150 ohm	MOU	29SJ250-150	1
13	S1	switch,DPDT,on/on	MOU	10TA560	1
14	S2,3	switch/3pole/4pos.r	MOU	10YX034	2
15	T1	RF transformer,1:1	MCL	T1-6-X65	1
16	T2	balun transformer	MCL	T2-1T-X65	1
17	Z1	delay line, 600 ns	RCD	P2420-600NS-100	1

Misc. items: hook-up wire, buss wire, solder,labels "AS REQUIRED"
*Item 2 note: for R1, R2, R3, S2, S3.

Table 3: Mini-MWT-3 (companion regen. preamp.) hole-drilling list

For X, Y, D parameter definitions and for drilling instructions: see Table 1. For Mini-MWT-3 schematic, see Figure 2.

Chassis Box = Mouser # 537-TF-779: 5" X 4" X 3"

L E F T S I D E

Hole #	Comp. Desig.	Description	X	Y	D
1	G1	GND H/W - internal lug	0.0	1.125	0.125
2	J1	RF source in - BNC jack	0.0	0.5	0.375

T O P S I D E

Mounting holes on C1 must be tapped to 6-32 thread.

Hole #	Comp. Desig.	Description	X	Y	D
1	C1	Tuning cap. - mounting H/W 1	-1.963	3.25	0.144
2	C1	Tuning cap. - shaft	-1.5	3.0	0.5
3	C1	Tuning cap. - mounting H/W 2	-1.037	3.25	0.144
4	-	C1's vernier knob - H/W 1	-2.14	2.375	0.125
5	-	C1's vernier knob - H/W 2	-0.86	2.375	0.125
6	R1	Input Atten. Pot. - shaft	-1.8125	0.75	0.3125
7	R1	Input Atten. Pot. - tab	-1.5	0.75	0.144
8	S2	Function switch - tab	-0.25	3.125	0.144
9	S2	Function switch - shaft	0.25	3.125	0.375
10	R2	Regen. Control pot. - shaft	0.0	0.75	0.3125
11	R2	Regen. Control pot. - tab	0.3125	0.75	0.144
12	G2	GND H/W - internal lug	0.875	0.5	0.125
13	S1	Bandswitch - shaft	1.125	2.0	0.375
14	S1	Bandswitch - tab	1.625	2.0	0.144

R I G H T S I D E

Hole #	Comp. Desig.	Description	X	Y	D
1	A1	Regen. Front-End card -H/W 3	-1.5	1.5	0.125
2	A1	Regen. Front-End card -H/W 1	-1.5	0.5	0.125
3	A1	Regen. Front-End card -H/W 2	-0.7	1.5	0.125
4	A1	Regen. Front-End card -H/W 4	-0.7	0.5	0.125
5	J3	B+ input - phono jack	0.0	1.125	0.25
6	J2	RF out - BNC jack	0.0	0.5	0.375
7	A2	Buffer Amp. card - H/W 1	1.125	2.2	0.125
8	A2	Buffer Amp. card - H/W 2	1.125	0.6	0.125

A134-4-4

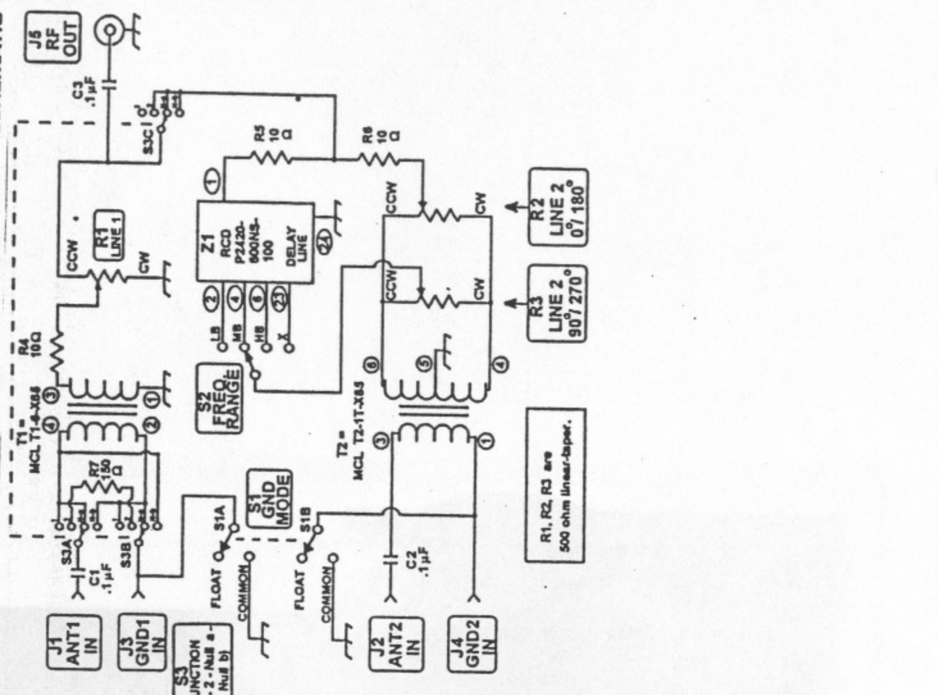

FIGURE 1: DL-1 DELAY - LINE PHASING UNIT - SCHEMATIC

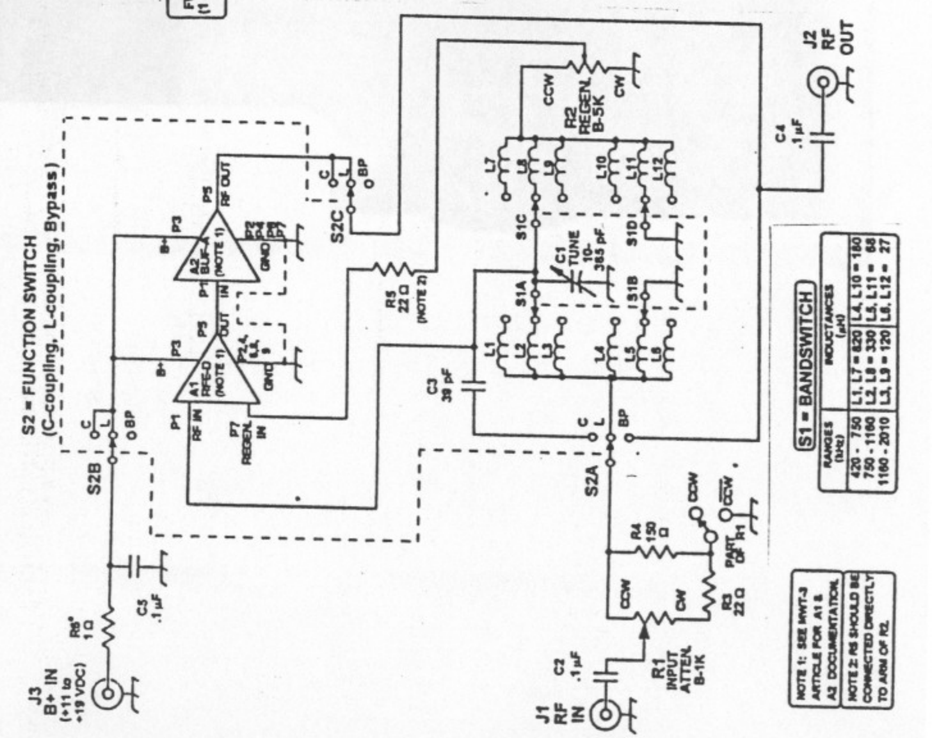

FIGURE 2: MINI-MWT-3 REGENERATIVE TUNER - SCHEMATIC