

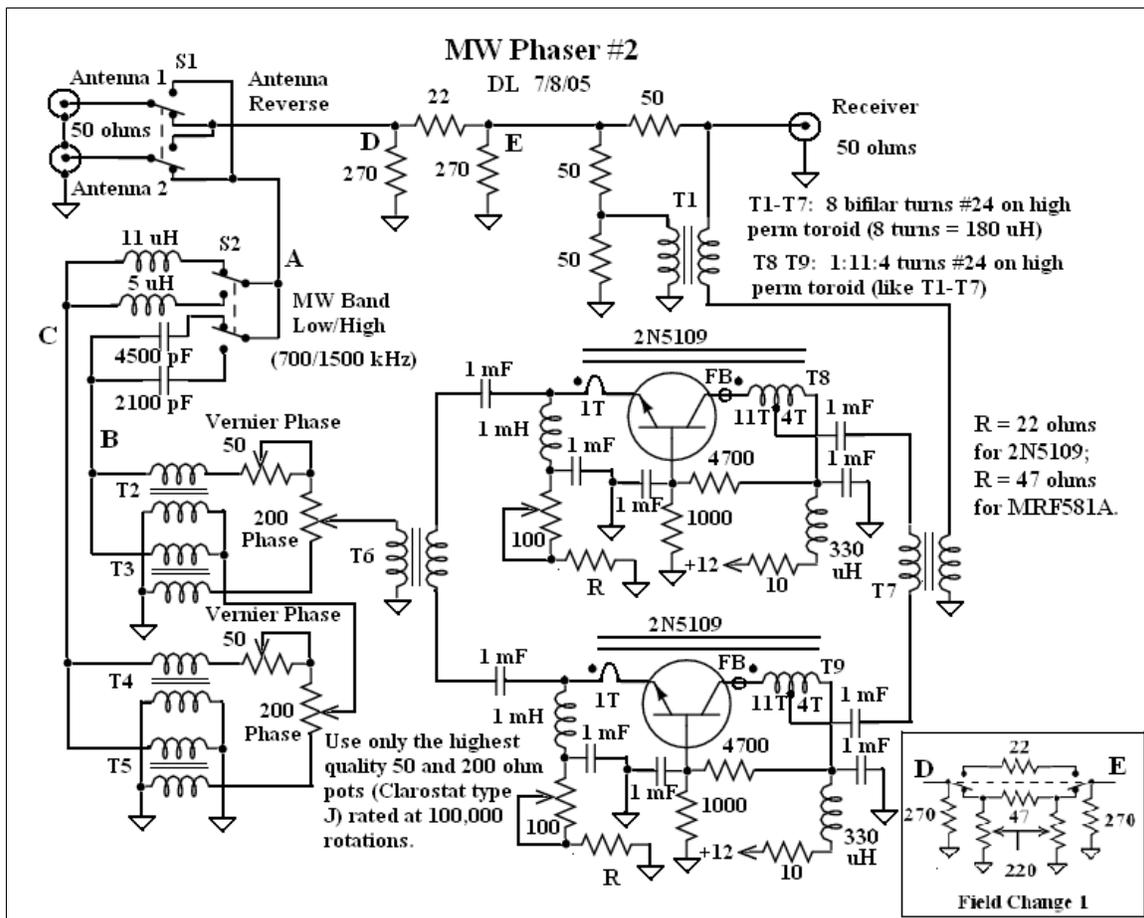
MW Phaser #2

Dallas Lankford

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Attention: 7/21/07 The main supplier of 200 and 50 ohm pots, Newark InOne, has recently raised the price of their 200 ohm Type J pots (now manufactured by Honeywell, formerly Clarostat, formerly Allen Bradley) to about \$50 each, and discontinued their 50 ohm Type J pots. They have a few (34 as of today) 50 ohm Type J pots for about \$20 each (buy them while you can). Surplus Sales Of Nebraska currently has 250 ohm Allen Bradley Type J pots (NOS = new old stock) for \$6 each. I have been using the 250 Ω AB Type J pots for several weeks in a new high performance phaser, and they seem to be suitable substitutes for the specified 200 ohm Type J pots. Time will tell. NTE may also have suitable 50 Ω pots, NTE number 501-0001, Mouser 526-501-0001 for \$12.50 each, but I have not tested any of these 50 Ω pots yet. Also, I have been informed that copies of MW Phaser #2 have been built and sold by a well known DXer without any reference to MW Phaser #2. This is theft of intellectual property and plagiarism. These copies of MW Phaser #2 could not have been made without the use of this article.

MW Phaser #2 is a slight variation of one I built about 10 years ago. The previous one used twinax antenna lead in inputs and baluns to convert from balanced to unbalanced. I also used physically larger toroids in the first one. Previously Russell Scotka had built a copy of Misk's phaser which motivated me to make the modifications described below. I have used virtually every phaser which I could build, buy, or invent since the early 1980's, but none of them before or since MW Phaser #1 worked anywhere nearly as well. Other phasers generally suffer from one or more serious defects, including (1) they



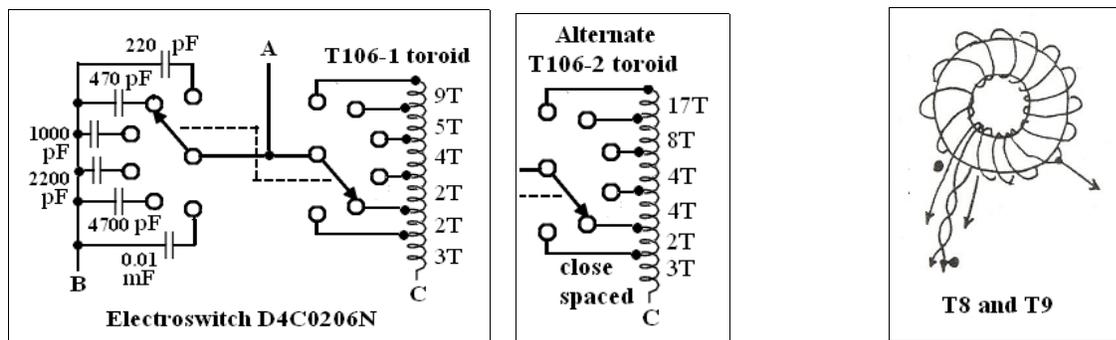
generally do not work well throughout the entire MW band on sky wave (nighttime) signals, especially at the higher MW frequencies, (2) they often do not work well on ground wave (daytime) signals; it may be quite difficult, and sometimes impossible, to generate and maintain deep, stable nulls, (3) they may cover up weak signals with internally generated noise (due to noisy active combiners and noisy amps), and (4) they may cover up weak signals with intermodulation distortion. MW Phasers #1 and #2 are modifications of the phaser designed by Misek; see *The Beverage Antenna Handbook, Second Edition*, by Victor Misek, 1987. The schematic below gives a variation of MW Phaser #2.

Here are some of the modifications I made to Misek's original design. In the phasing branch of the circuit I used a DPDT toggle switch as a band switch for approximately the upper half and lower half of the MW band. Actually, MW Phasers #1 and #2 use rotary switches to provide nulling from at least 150 kHz to 30 MHz. The "bands" and values of inductors and capacitors are given in the table below. The values may be rounded off to the nearest standard values. Of course, at SW frequencies the sky wave

300 kHz	26 uH	0.01 mF
700 kHz	11 uH	4500 pF
1500 kHz	5 uH	2100 pF
3200 kHz	2.5 uH	1000 pF
6400 kHz	1.2 uH	500 pF
14 MHz	0.6 uH	220 pF

nulls are generally not very deep or stable. but the phaser can generate very deep and stable nulls for groundwave shortwave signals (power line noise, neighbor's electronic noise makers, etc.). There is considerable overlap in the bands above; for example, the 700 kHz band produces good nulls in all directions over a frequency range of at least 350 - 1400 kHz. For the inductors I used an Amidon T106-1 powdered iron toroid wound with #24 enameled copper wire tapped at 3T, 5T, 7T, 11T, 16T, and 25T (T = turns), with the first 7

turns wide spaced and the remaining turns close spaced (the tapped inductances were checked with an inductance meter, but this was probably not necessary). The AL value of the T106-1 is 325, i.e., $L(\mu\text{H}) = .0325 T^2$. As can be seen, the inductances calculated from the formula were somewhat less than the measured inductances. I do not know if this is true in general for T106 toroids, or if I happened to buy a batch of T106 toroids



substantially out of spec. Other powdered iron toroids can be used instead of the T106-1; I would recommend using a mix which is optimal for the MW band, and a reasonably large toroid (about 1 inch outside diameter). Perhaps I should have used off the shelf inductors, but I decided to use a large powdered iron toroid to minimize the possibility of intermodulation distortion products. If you use off the shelf inductors, do not use tiny subminiature inductors. In the phasing branch I used 50 ohm pots as vernier phase controls which makes it easier to maximize nulls depths. Do not buy cheap 50 ohm and 200 ohm pots. Cheap pots will wear out quickly, becoming noisy, making it difficult to generate and maintain deep, stable nulls. In my opinion there is only one type of pot to use, Allen Bradley (previously marked AB) type J. Allen Bradley has not made pots for many years, but one can sometimes still find AB type J pots at hamfests. Clarostat bought out the pot division of AB and continued to make type J pots. I have used the Clarostat type J pots and they seem to be as good as the AB's. The only supplier I know who sells both the 50 ohm and 200 ohm pots is Newark InOne www.newark.com. It appears that Honeywell recently bought out Clarostat. Whether or not they will continue to make a good quality type J pot remains to be seen. Possibly some other make of pot rated at 100,000 rotations (or more) would be

satisfactory. I don't know. Misek used a single FET amp in his phaser, but Russell Scotka told me it caused intermodulation distortion products in high RF environments (Miami, FL). That motivated me to develop the dual 2N5109 push-pull Norton amp used in MW Phasers #1 and #2 and elsewhere; see Ultralinear 2N5109 Amplifiers in The Dallas Files at www.kongsfjord.no. The 100 ohm pots in the Norton amp are small 25 turn 1/2 watt pots which are adjusted so that each 2N5109 draws 16 mA (160 mV measured across the 10 ohm resistors). The 2nd order intercept of the amp can be increased by adjusting one of the 100 ohm pots to minimize 2nd order intermod while doing a 2 tone intermodulation distortion measurement. The 2nd order optimization is frequency dependent, so I just pick two of my favorite frequencies, say 600 + 700 = 1300 kHz, to optimize on. The 2N5109's should probably be heat sunk. I made heat sinks from some small rectangular sheets of copper formed into open cylinders around some drill bits, held onto the 2N5109 cases by tension. Ferrite beads (FB-101-61) are used on the collector leads of the 2N5109's for parasitic oscillation suppression. I have also used MRF-581A's, like KIWA does for their version of this amp. MRF581A's drawing 19 mA do not require heat sinks. The Phasing dots on T8 and T9 must be observed for correct negative feedback; otherwise the amplifier will probably oscillate. The 22 ohm and two 270 ohm resistors in the non-phased path are a 3.5 dB attenuator. The attenuator is necessary to prevent running out of phasing range (at one end of the phasing pots range or the other) for some sky wave signals and some antennas. Later (7/25/05) rear pannel switched 3.5 and 7 dB attenuators were found useful for some antennas arrays; see Field Change 1 above. To recombine the unphased signal with the phased and amplified signal I used a hybrid combiner based on Hayward's design. This completes the description of the major modifications I made to Misek's phaser.

How should you use this phaser (or, for that matter, any other phaser) in the MW band? If, like Misek did, you use it with a two wire steerable beverage antenna, then you should do what Misek did. Unfortunately, his Beverage Antenna Handbook is copyrighted, so it is not appropriate for me to reproduce the relevant parts of his book here. Fortunately, the handbook is available from Universal Radio and from other sources. Just do a Google on the net. Like many people, I do not have enough real estate for a beverage. But I do have a 200 foot by 300 foot lot, and that is sufficient for a pair of noise reducing inverted L and a pair of noise reducing vertical antennas spaced about 160 feet apart, 1/10 wavelength apart at the low frequency end of the MW band. The 1/10 wavelength condition is required for adequate residual signals when nulls are formed using two antennas of the same kind. My inverted L's have 15 foot vertical legs and 30 foot horizontal legs. The L's have 4:1 turns ratio step down transformers at the knees of the L, and the ground level end of the L is grounded with a 4 foot industrial grade ground rod (i.e., they look like the letter L rotated 90 degrees clockwise). The verticals are L's hung from tall trees. For best nulls the L's should be parallel and point in the same direction; the best nulls are in arcs about the line perpendicular to such L's. For example, my L's point East, and my best nulls are towards the North and South. Nulls to the East and West are good, but not as good as to the North and South. 160 foot spacing is not adequate for good nulling throughout the VLF band, especially at lower frequencies. Yes, I can null some VLF signals with the two 160 foot spaced inverted L's, but I generally can't null them completely, and in some cases there are few, if any, residual signals after nulling the primary signal. For VLF + MW nulling I use an inverted L and a big air core loop, cf. The Dallas Files at www.kongsfjord.no. Little separation between the inverted L and loop is necessary; you should not run the inverted L within about 20 feet of the loop. I also put up a 2nd big air core loop spaced about 160 feet from the 1st big air core loop (lying in the same plane) to see if they provided better nulling of undesired signals. It seems to be the case, but is not as dramatic as I had hoped for. In any case, all of my antenna arrays produce excellent ground wave and sky wave nulls. Some people have reported excellent nulling results using two random wire antennas and other phasers. I doubt this. Yes, they obtained some nulls. But it is unlikely that they obtained anything resembling the nulls obtained with a two wire beverage antennas, two spaced noise reducing inverted L's or verticals, or a noise reducing inverted L or vertical and a big air core loop using the MW phaser described here. But note that nulls may be unstable when the geomagnetic field is disturbed, as Bjarne Mjelde pointed out to me, and skywave nulls may be unstable during sunset and sunrise transitions.

To null a signal, select the frequency "band" closest to the desired frequency and set the vernier phase pots to mid range (12 o'clock when the knobs are calibrated). Next rotate first one phase pot (200 ohms), and then the other, watching the receiver S-meter for a dip in signal level. It may be a good idea to first null a ground wave because they are more stable. After a dip is found with one phase pot, then try to deepen the dip with the other phase pot. If little or no dip is found with either phase pot, use the reverse antennas toggle switch to reverse the antennas and start over. Alternate back and forth between the phase pots until the deepest null is found. Then alternate back and forth between the vernier phase pots, trying to make the null deeper. If the null is not very deep, use the antenna reverse toggle switch to reverse the antennas, and start over, resetting the vernier pots to mid range, followed by alternating between adjusting the phase pots, etc. Sometimes good nulls may be found with the antenna reverse toggle switch in both positions, but one of the nulls may be somewhat better than the other. So it is a good idea to check both. Once a null is generated at a particular frequency in a particular direction, there is usually an almost as good null at nearby frequencies in the same direction. This characteristic is sometimes useful for nulling strongly fading signals if there is a more stable signal in the same direction at a nearby frequency; null the stable signal, then tune the strongly fading signal, and finally adjust the phaser controls to try to deepen the null on the strongly fading signal.

Below is a parts list for MW Phaser #2 (MWP2) and other phasers which have evolved from it, including MW Phaser #3, and MW Phaser #4 (A and B), all of which will be referred to as MWPx (to be described in an article to appear at www.kongsfjord.no). Most of the work on the parts list was done by Bjarne Mjelde, with me filling in some of the blanks. We hope that the parts list will be helpful for those who wish to build one of these phasers. However, this is not a step-by-step construction article, nor is it intended to be. We assume that anyone who attempts to build MWPx will have considerable experience building other similar equipment.

MWPx Parts List

<i>Component</i>	<i>Value</i>	<i>ELFA part #</i>	<i>Other part #, remarks</i>	<i>Qty</i>
resistor	22 ohm	60-703-61	see remark below:	1
resistor	270 ohm	60-716-17		2
resistor	50 ohm	60-707-91		3
resistor, amp	4700 ohm	60-730-43		2
resistor, amp	1000 ohm	60-722-84		2
resistor, amp	10 ohm	60-700-07		2
resistor, amp	22 ohm (2N5109) or 47 ohm (MRF581A)	60-703-61 or 60-707-67	for all fixed resistors use 0.25 watt metal film, Mouser part #: 271-VALUE where VALUE is the resistor value per Mouser table of values	2
pot, amp	100 ohm, 25 turn, 0.5 watt	64-347-16 (15T 0.25 watt, which is adequate)	Mouser part #: 594-64Y101	2
ferrite bead	FB-101-61	58-727-42	Amidon Part #: FB-61-101	2
capacitor	1 uF	65-743-05	Mouser part #: 80-C330C105K5R	10

<i>Component</i>	<i>Value</i>	<i>ELFA part #</i>	<i>Other part #, remarks</i>	<i>Qty</i>
capacitor	4500 pF	65-694-79	Mouser part #: 39-GM472K	1
capacitor	2100 pF	65-694-20	Mouser part #: 39-GM222K	1
capacitor	0.01 uF	65-695-11	Mouser part #: 39-GM103K	1
capacitor	1000 pF	65-693-70	Mouser part #: 39-GM102K	1
capacitor	500 pF	65-693-21	Mouser part #: 39-GM471K	1
capacitor	220 pF	65-692-89	Mouser part #: 39-GM221K	1
inductor, amp	330 uH	58-502-19	Mouser part #: 542-77F331	2
inductor, amp	1 mH	58-086-88	Mouser part #: 434-02-102J	2
pot, phase	200 ohm	N/A	Newark part #: 01F6262	2
pot, vernier	50 ohm	N/A	Newark part #: 01F6259	2
rotary swich	2 pole, 6 position	N/A	Mouser part #: 690-D4C0206N	1
toroid	Amidon T106-1 or T106-2	58-723-11 (= T106-2)	Amidon part #: T106-1or T106-2	1
transistor	2N5109 or MRF581A	N/A	BHIAB Electronics, Sweden (2N5109 only), or Mouser part #: 610-2n5109, or contact RF Parts (USA) for MRF581A	2
BNC (f)		46-265-29	Mouser part #: 31-2221	3
toggle switch	DPDT	35-222-57	Mouser part #: 611-7201-081	1
12VDC input connector, 2.1 mm		42-051-34	Mouser part #: 163-4302	1
gnd binding post		40-734-58		1
12 VDC LED power indicator			No specific part numbers are listed for this.	1
screws, nuts, flat washers, split ring lock washers, ground lugs, etc.			I like stainless hardware, but plated steel will do, and nickel plated brass ground lugs. (DL) No specific part numbers are listed for these.	
#24 enameled copper wire			No specific part numbers are listed for this.	
insulated stranded wire			I like #22 stranded silver plate with Teflon insulation, but less fancy will do. (DL) No specific part numbers are listed for this.	

<i>Component</i>	<i>Value</i>	<i>ELFA part #</i>	<i>Other part #, remarks</i>	<i>Qty</i>
resistor	220 ohm	60-715-00	Mouser 271-VALUE; see above	2
resistor	47 ohm	60-707-67	see above	1
high permeability toroids, T1 - T9	AL ~ 3000	58-760-99	Amidon Part #: FT-50-75	9
aluminum box	222 x 146 x 106 mm	50-026-05	Mouser part #: 400-4589	1
self adhesive rubber feet		48-865-52, pkg of 24	Mouser part #: 517-SJ-5009BK	4

Parts in the list above are available from the web sites below.

ELFA: www.elfa.se (site available in Swedish, Norwegian, English, etc.)

Amidon: www.amidoncorp.com

Mouser: www.mouser.com

Newark InOne: www.newark.com

RF Parts: www.rfparts.com

RHIAB: www.rhiab.se

Below are photos of MWP2. The antenna reverse toggle switch is mounted between the two antenna input BNC's on the right rear panel; mounting it on the front panel may cause degraded nulls (but see the discussion of MWP4B in an article to appear at www.kongsfjord.no). The push-pull Norton amp is on the left side; one of the 2N5109 heat sinks is clearly visible. The phase shifter is in the front center. The switched capacitor and inductor array and ceramic rotary switch are on the right. The 3.5 dB attenuator and hybrid combiner are mostly mounted on the three blue insulated standoffs on the left rear panel beside the output BNC. Field Change 1 using a DPDT toggle switch can be mounted there. In a photo below you can see that the phasing toroids, white with red and green wire, are free standing behind the phasing pots. If heavier toroids are used, they should be mounted somehow. The red LED power indicator is not necessary, but is useful (as I learned the hard way from a defective power plug) to indicate that power is applied.. Individual capacitors are used for the switched capacitors. The switched inductors are implemented with a single toroid and multiple taps. The tapped toroid can be seen behind



the capacitors and rotary switch. A ground lug is provided on the rear panel; grounding the phaser sometimes improves the quality of some nulls with some antennas. The fluted knobs are Dakaware, which were used by Collins Radio in some of their classic radios. The pointer knob is NOS URM-25. The metal box used for MWP2 in the photos below is smaller than the metal box listed in the MWPx Parts List above. It is recommended that the larger box be used in order to accommodate Field Change 1, to provide more spacing between front panel controls (improved ergonomics), and to provide sufficient front panel space for mounting the antenna reverse toggle switch if so desired. These changes will be discussed in detail in the article MWPx Phaser Variations at www.kongsford.no.



