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Modular Phasing Systems

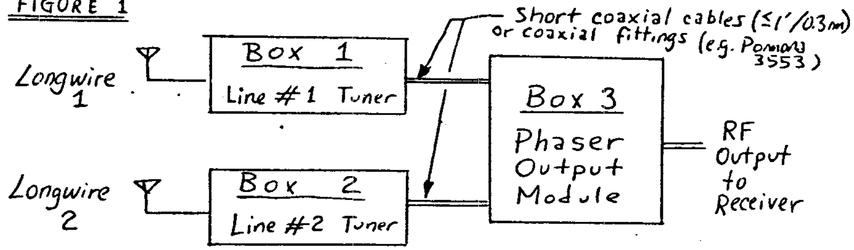
by Mark Connelly

Phasing, for the uninitiated, is the production of a phase shift between the tuned signals from two antennae: the two signals are then electrically added or subtracted from each other to produce a null of the dominant (unwanted) station on a given channel to allow reception of subdominants on the same channel and/or adjacent channel stations normally covered by slop. The end result of such nulling is comparable to that obtained by looping. Unlike looping, phasing can more often give reception of stations in the same direction or in the opposite direction of the unwanted signal that was nulled.

Recent experimentation has proven that a modular phasing system comprised of separate shielded tuners & output module will outperform the earlier design MWDX-1 unit.

In brief, the modular system resembles the block diagram of Figure 1.

FIGURE 1



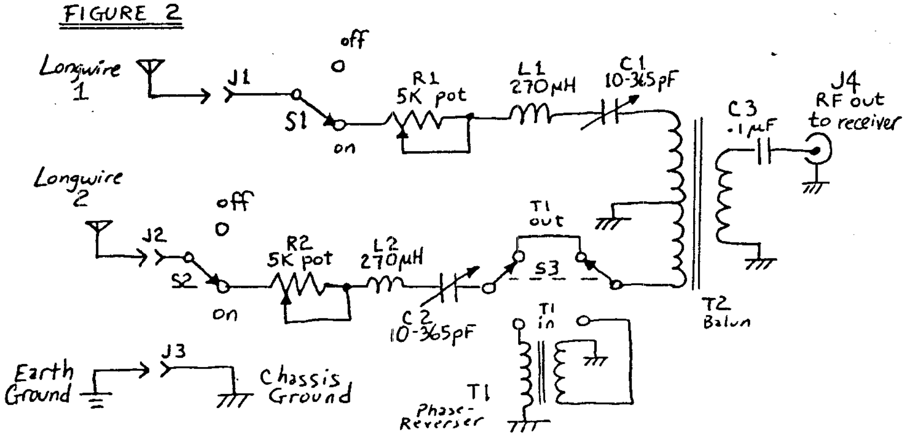
The two tuners should be of identical design; the "phaser output module", hereinafter abbreviated as POM, combines the two phase-shifted tuner output signals to yield a null of the "pest" station.

It has been proven that there is better crosstalk rejection [tuner #1's setting won't influence the peaking of tuner #2 as much] and decreased hand-capacitance effects (and, thereby, deeper & more stable nulls) when 3 shielded modules (chassis boxes) are employed.

How does one go about implementing the modular approach? For an initial example, we'll look at a very simple phasing circuit - one primarily designed for use with a pair of Beverage aerials.

Refer to Figure 2.

FIGURE 2



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T1 is a phase-reversing toroidal RF transformer consisting of a 25-turn bifilar winding; windings evenly spaced, occupying 1/2 of a Miller F-87-1 or Amidon FT82-61 core.

T2 is a toroidal balun RF transformer consisting of a 25-turn trifilar winding; windings evenly spaced, occupying 2/3 of a Miller F-87-1 or Amidon FT82-61 core.

Components J1, S1, R1, L1, & C1 of Figure 2 will be defined as Line 1. Components J2, S2, R2, L2, & C2 will be defined as Line 2.

The simple phaser of Figure 2 is operated as follows:

I. PEAK LINE 1

Set R1 to zero ohms.
S1 to on, S2 to off, S3 to T1-out. Positions of R2 & C2 don't matter at this time. ADJUST C1 FOR MAXIMUM SIGNAL AT FREQUENCY OF INTEREST.

II. PEAK LINE 2

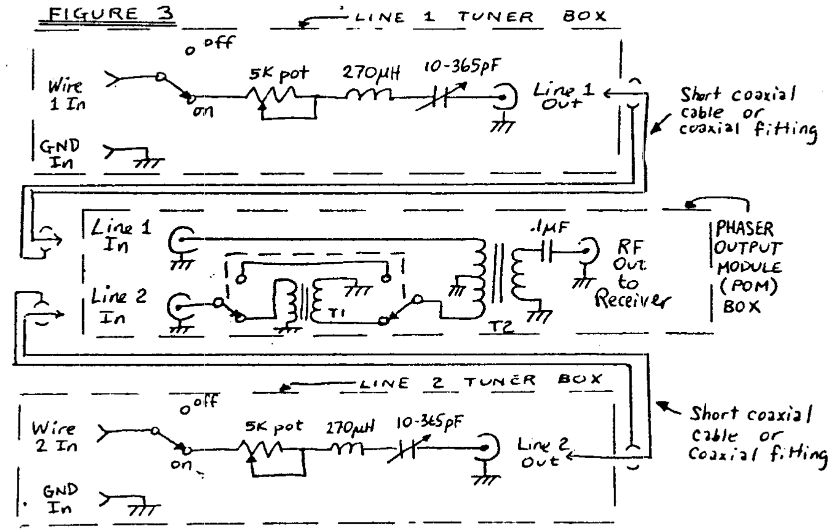
S2 on, S1 off. Leave C1, R1, & S3 in previously-set positions. Set R2 to zero ohms. ADJUST C2 FOR MAXIMUM SIGNAL AT FREQUENCY OF INTEREST.

III. NULL

Put both S1 & S2 to on. Flip S3 between T1-in & T1-out positions. Leave S3 in the position yielding the LOWER signal level of the "pest" station to be nulled. Increase R1 to see if a "dip" [point at which turning the control either clockwise or counterclockwise from the "dip" position will increase level] occurs. If a dip occurs, leave R1 at the dip position; otherwise, return it to zero ohms. Do the same with R2. Then, offset C1 to get or to enhance the dip. Do the same with C2. Finalise the null with SLIGHT adjustments of R1, R2, C1, & C2. Subdominant co-channel stations and/or formerly-slopped adjacent channel stations should now be audible, just as if a loop had been used.

As mentioned earlier, casting the phasing unit into two tuner modules and a POM will improve performance. Applying the strategy of Figure 1 to Figure 2, we get the scheme illustrated in Figure 3.

FIGURE 3

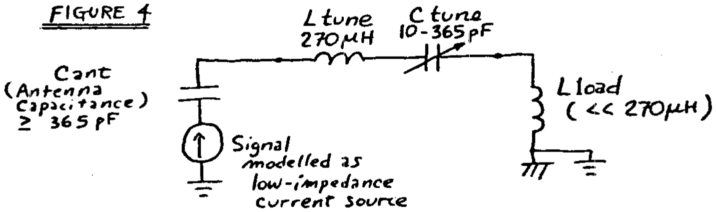


The type of tuner box illustrated in Figure 3 [two boxes shown] is known as a Passive Series Tuner (which we will abbreviate as PST). It is "passive" as it uses no active elements such as transistors or op-amps. It is "series" as the L & C elements are arranged in series between the antenna and the output load.

The PST operates into low-impedance "current-sinking" loads such as a short coupling link coil over a transistor radio's ferrite rod or such as an RF transformer winding of inductance substantially lower than the inductance of the tuner's coil. Furthermore, the antenna must be LONG, having a high effective capacitance to ground (preferably greater than the tuner's maximum capacitance, 365 pF in this case).

Figure 4 shows the PST's total equivalent circuit, including external connections. At this time we'll assume no series resistance: pot in tuner set to zero ohms and resistance of load (e. g. balun or phase-reverser primary) negligible.

FIGURE 4



The resonant frequency of this tuner is f = 159155/√(LeCe)
where Ce = equivalent capacitance (in pF) =
1/((1/Cant)+(1/Ctune))
and Le = equivalent inductance (in uH) = Ltune + Lload

It should be noted that any RESISTANCE in the tuned line will degrade the Q (sharpness, selectivity) of the peak: this is why initial peaking must be done with the PST's pot set to zero ohms. In the ideal case, Cant is sufficiently higher than 365 pF that the 1/Cant term approaches zero in the Ce equation, causing Ce to equal Ctune. Also, if Lload is small, Le approximately equals Ltune, in this case 270 uH.

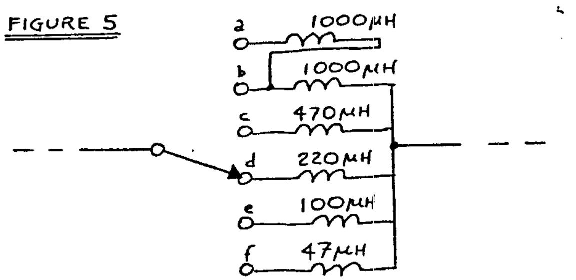
Applying the resonance equation,
fmax = resonant frequency at minimum Ctune (10 pF) = 159155/√((10)(270))
= 3063 kHz.

fmin = resonant frequency at maximum Ctune (365 pF) = 159155/√((365)(270))
= 507 kHz.

If a shorter than ideal antenna is being used, the Cant term can no longer be ignored: typically it might only be 100 pF, perhaps less.
If Cant = 100 pF, Ce = 1/((1/Ctune)+(1/100))
For Ctune = 365 pF, Ce is now only 78 pF. For Ctune = 10 pF, Ce = 9 pF.
fmax is now 159155/√((9)(270)) = 3228 kHz.
fmin is now 159155/√((78)(270)) = 1097 kHz.

It is obvious that the PST of Figure 3 will not tune the shorter antenna on a substantial segment of the MW BCB. This problem can be alleviated, to an extent, by changing the tuner's inductance. This is best accomplished with an inductance switch, as in Figure 5.

FIGURE 5



With the aforementioned shortwire (Cant = 100 pF; Ce = 9 pF min.; Ce = 78 pF max.), frequency ranges with the switch of Figure 5 are as follows: (Assume load inductance = 25 uH)

Switch Position	Ltune	Le	fmin	fmax
a	2000	2025	400	1179
b	1000	1025	563	1657
c	470	495	810	2384
d	220	245	1151	3389
e	100	125	1612	4745
f	47	72	2124	6252

In reality, few variable capacitors get down to 10 pF, especially when stray shunt capacitances are added in; therefore, the fmax figures figures above are overly optimistic. Realistically, you could expect to use position [a] to cover 400 - 700 kHz, [b] to cover 570 -1000 kHz, [c] 820 - 1300 kHz, [d] 1160 - 1700 kHz, [e] 1620 - 2500 kHz, and [f] to cover 2130 - 3500 kHz.

The PST's performance can also be improved by adding a small (e. g. 47 pF) shunt capacitor near the input to add capacitance to short aerials. A slight, but negligible, amount of loss is introduced, but with improvement in peak-tuning capability. The capacitor is best installed after the pot so that the resistance added by the pot will have a lesser effect on Q-spoiling.

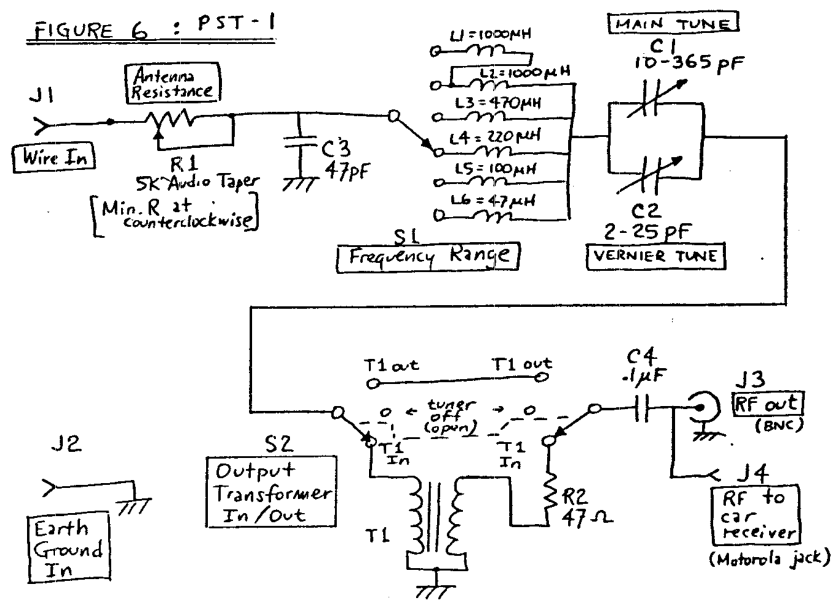
Another modification to the PST is the inclusion of an output transformer with lower primary inductance than those in the POM (Phaser Output Module). This internal transformer accomplishes two goals:
(1) It permits operation at higher frequencies than the POM's RF transformers would allow if directly connected to the PST's output.
(2) It allows "stand-alone" operation of the PST with a great variety of receivers with widely-varying input-impedance characteristics. (Stand-alone operation, in this case, means using the PST as a straight antenna tuner in situations where phasing is not necessary.)

There is some loss at lower frequencies (below 1100 kHz) with this internal transformer, but this shouldn't be a problem with wires of 30m./100ft. or greater length.

A small output resistor (in the 22 to 100 ohm range) is included at the internal transformer's output to (a) decrease loading effects on tuning , and (b) to reduce the chance of spurs caused by capacitive loads resonating with the secondary.

The tuning capacitor is often very touchy when tuning for nulls, so it's advisable to add a lower value "vernier" variable capacitor in parallel with the main 10 - 365 pF capacitor.

The revamped PST, designated as "PST-1" is shown in Figure 6. A jack for "stand-alone tuner" output to a car radio has been added.



The output transformer of the PST consists of a 15-turn bifilar winding with evenly-spaced turns, occupying 1/2 of a Miller F-87-1 or Amidon FT82-61 core.

A further refinement to the PST (beyond those embodied in the Figure 6 schematic) is the inclusion of a small-value pot (0 to 20 ohms or 0 to 50 ohms) in series with R1 to make fine nulling adjustments easier. Such pots are, unfortunately, difficult to purchase in desirable (non-inductive) non-wirewound versions.

At this juncture, it should be mentioned that one of the great benefits of a modular phasing system is that different-design tuners & POM's can be swapped around as system building blocks.

Working along this school of thought, three other types of tuner have been developed.

These are: AST (Active Series Tuner)
PPT (Passive Parallel Tuner)
and APT Active Parallel Tuner

This introductory article does not attempt to go into the details of CONSTRUCTION of any of the tuners or POM's: these will be dealt with in subsequent works. These subsequent articles will also delve into the finer details of PHASING STRATEGIES.

The Active Series Tuner "AST-1" is an amplified version of the PST-1. Figure 7 gives the overall AST-1 schematic. Figure 8 is the schematic of the Broadband Amplifier subassembly, designated as A1 in Figure 7.

FIGURE 7 : AST-1

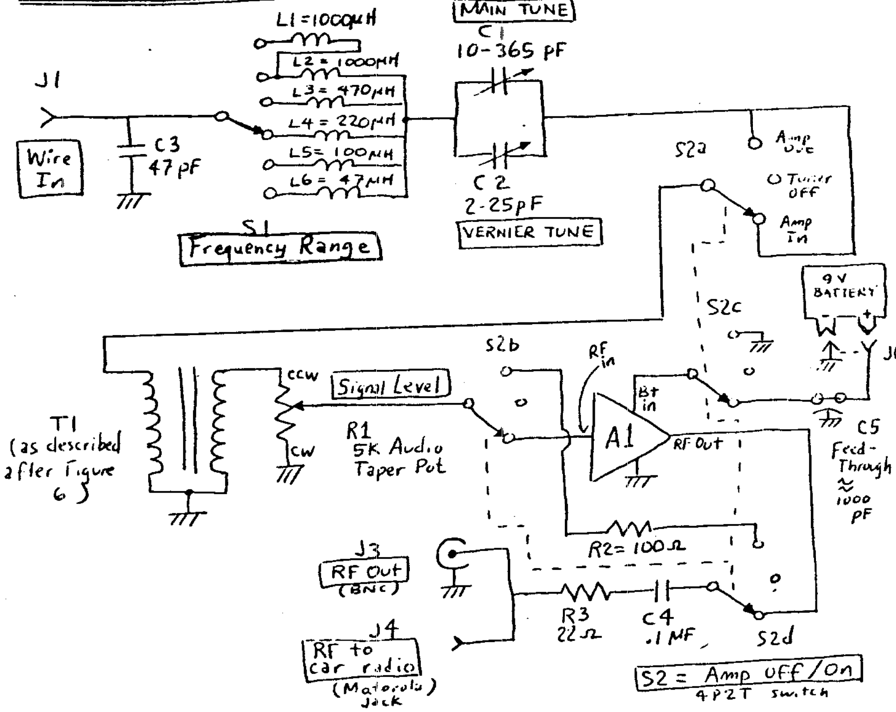
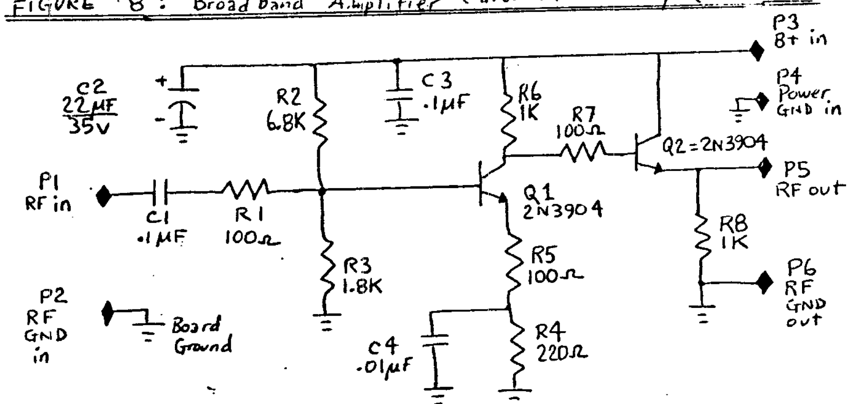


FIGURE 8 : Broadband Amplifier Card Sub-Assembly (A1 of AST)



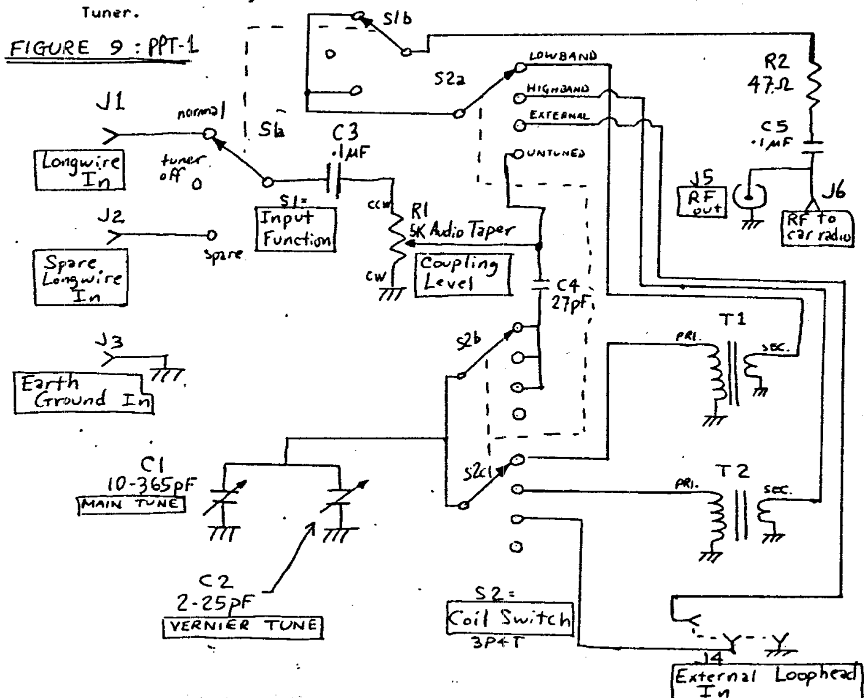
adjust it so a peaked signal can be obtained without spurious responses. Unlike the PST, the level pot on the AST does not cause any significant degradation of Q or any shifting of the peak settings of the tuning capacitors.

The Passive Parallel Tuner (PPT) is another worthwhile tuning module to consider. Old-time DXers will recognise it as a close relative of the so-called "degenerate loop coupler". It has the advantage of predictable tuning (thanks to loose coupling), not greatly effected by either source impedance (antenna length) or load (POM or receiver) impedance. The primary of the transformer in use for a given frequency is resonated by the tuning capacitor(s) and a link secondary (pickup coil) wound around the primary couples the peaked signal to the load.

Two transformer assemblies are provided within the box: one for low-band [approx. 500 - 1000 kHz] and one for high-band [approx. 950 - 1700 kHz]. Furthermore, a stereo jack is utilised for an external coil such as a ferrite rod antenna with added coupling coil or an external toroidal transformer similar to the internal transformers. Such external coils would be used if other frequencies (e. g. longwave or tropical-band shortwave) were to be tuned or if direct pickup of signals by the transformer primary (with no longwire) was desired.

The PPT offers superior Q, and therefore better rejection of spurs, than the aforementioned series tuners (PST, AST). As input & output coupling is "looser", the achievable output signal level is somewhat lower than that of the PST-1 and, needless to say, the AST-1. With ANY passive tuner (either PPT or PST), you should be using wires 30m/100ft long, or longer: with such wires either passive tuner will provide sufficiently generous output levels for the majority of MW DXing situations. Figure 9 is the schematic of the PPT-1 Passive Parallel Tuner.

FIGURE 9 : PPT-1



T1 of the PPT-1 is the low-band coil. The core for T1 is an Amidon FT114-61. A Miller F-125-1 or Indiana General F626-12-01 core would probably work as well. The primary consists of 64 turns of #28 enamelled solid magnet wire, turns evenly spaced, occupying 2/3 of the core. The secondary consists of 7 turns of insulated #28 solid wire-wrap wire, turns evenly [widely] spaced, over the primary (also occupying 2/3 of the toroid core).

T2 of the PPT-1 is the high-band coil. The core for T2 is an Amidon FT82-61. A Miller F-87-1 or Indiana General F624-19-01 core would probably work as well. The primary consists of 32 turns of #28 enamelled solid magnet wire, turns evenly spaced, occupying 1/2 of the core. The secondary consists of 5 turns of insulated #28 solid wire-wrap wire, turns evenly [widely] spaced, over the primary (also occupying 1/2 of the toroid core).

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For shortwire applications (wires of length significantly less than 30m/100ft), the Active Parallel Tuner (APT) gives the best tuning approach. Although designed to work with any length wire, it is with short to medium length wires that the APT shows a clear-cut advantage over the previously-discussed PST, AST, and PPT tuners.

The overall APT-1 schematic is given in Figure 10; the "Front End Card" FET-input subassembly (A1 of the APT-1) is diagrammed in Figure 11.

FIGURE 10 : APT-1

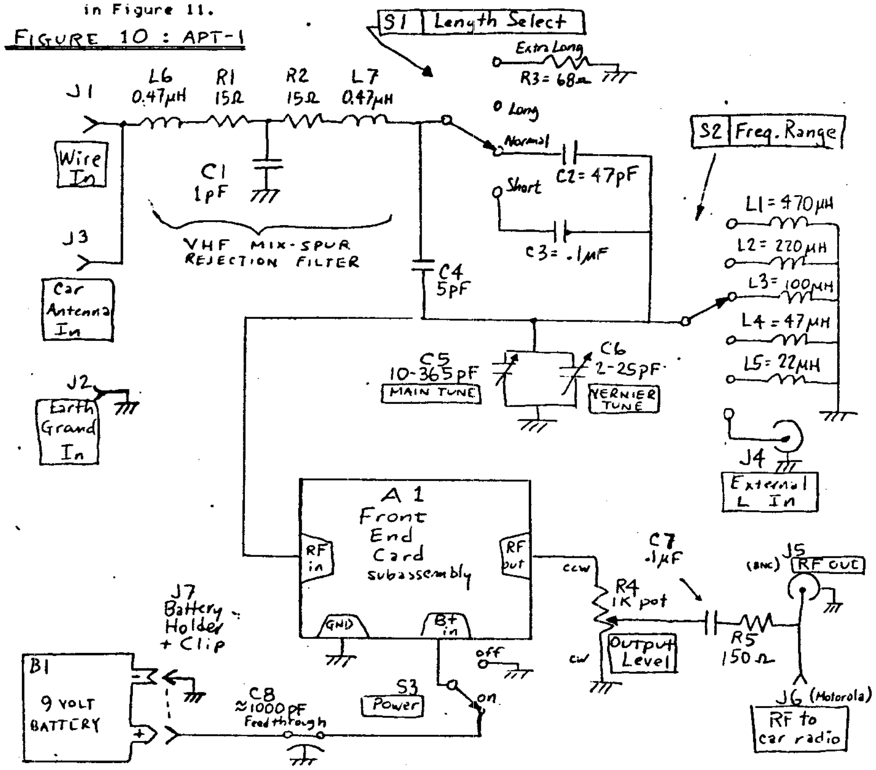
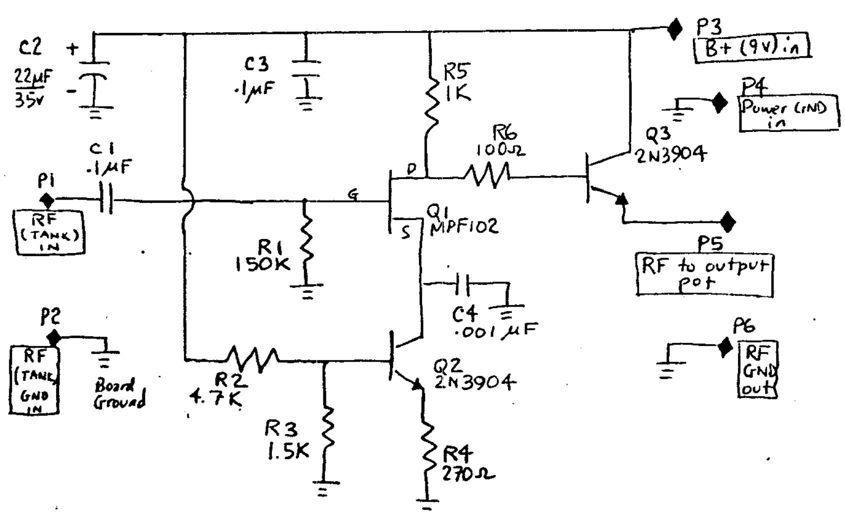


FIGURE 11 : Front End Card Subassembly (A1 of APT-1)



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A fifth kind of "tuner" which can be presented to the input of a POM or to a receiver is one which many DXers already have: an active loop antenna. This is actually a form of Active Parallel Tuner with its tuning inductance not shielded (and hence able to pick up signals on its own). A loop, of course, can also be used as a longwire coupler by winding 5 or so turns of the wire's shack end around the loop coil & connecting the bared longwire end to loop chassis ground.

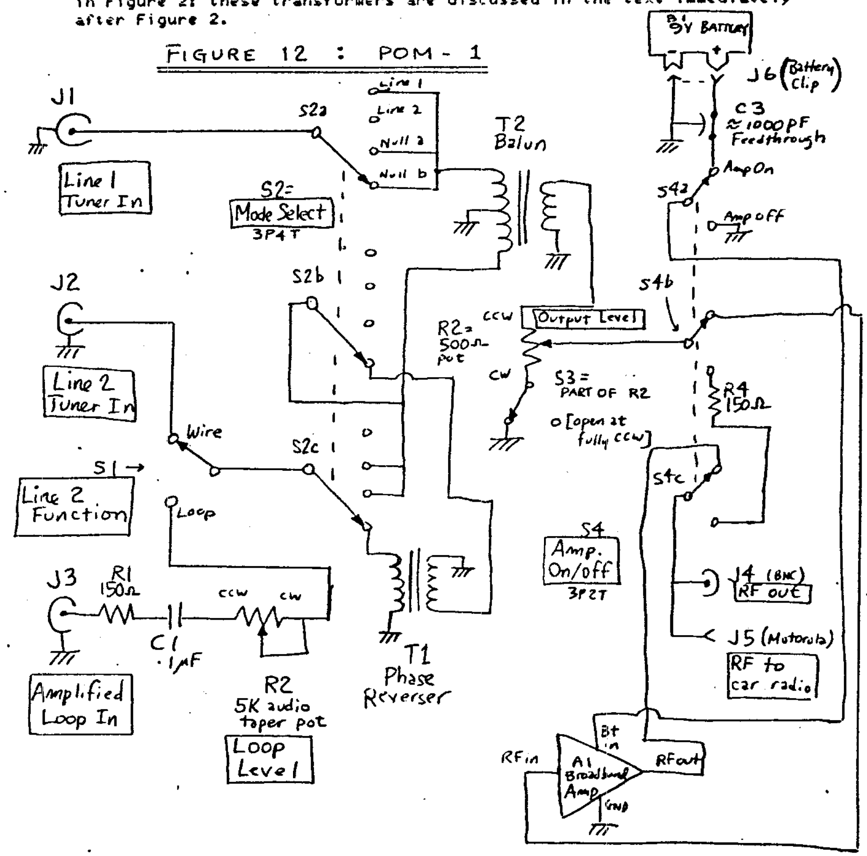
Now that tuners have been touched upon (remember, tuner construction & operation will be covered in subsequent articles), we should turn to the Phaser Output Module (POM). A simple POM is that shown in Figure 3 near the beginning of this article.

This unit can be improved upon in several ways. These includes

(a) improved input switching for faster operation with some tuners - notably the active tuners.
(b) output level control by means of a pot that won't effect nulls.
(c) ability to phase a wire against an active loop (à la Schatz LSCA)
(d) the possibility of amplification of POM output in cases where the desired signal left after pest-nulling is too weak: a common case when shorter wires & less-sensitive receivers are being used.

The improved version of the POM has been designated as POM-1; its overall schematic is shown in Figure 12. Its Broadband Amplifier Card subassembly A1 is the same design as A1 of the AST, shown in Figure 8. POM-1 RF transformers T1 & T2 are identical to those in Figure 2: these transformers are discussed in the text immediately after Figure 2.

FIGURE 12 : POM - 1



Future articles in this series on Modular Phasing Systems will detail tuner & POM construction as well as tuning & phasing strategies.