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Medium Wave a practical approach.

by Graham Maynard

I was brought up in a blue spot, red spot and white spot world, where germanium transistors were tentatively tried, and if they did not work burnt fingers in more ways than one. I remember as a twelve year old saving pocket money to buy my first OC72 from the local R+TV shop, only to gulp with incredulity when asked for 32/6d. as stamped on the valve sized box, "B.But in P.W. they are only 8/6d... "

I constructed many transistor MW receivers and was not happy unless they could pick up Luxembourg and later the pop pirates. One summer I tried valves and was amazed at the performance of a bread-boarded 6K8, 6K7, 6V6 superhet. Even a reflexed ECL80 set worked well, one valve and all that bassy pop! Fond and indelible memories.

During the last twenty years I've tried bipolar, fet, integrated circuit and battery valve designs with inductive, crystal, ceramic and mechanical filters, balanced mixers, differential stages etc., but for serious DXing I use an old fashioned valve set, a 1953 Marconi Mercury type 1017 marine receiver. Indeed, was it not power, size and weight disadvantages that started the thermionic decline and not failings in attainable performance? There's no going back however, progress is the reality, but Oh how it costs! And, until I am able to afford a modern receiver capable of good MW performance my choice remains limited to secondhand professional valve gear.

I often wonder just how much useful information and knowledge is "lost", stored in books and old files, and how often "new" discoveries have turned out to be older than the people that have made them. Of recent years MW technology has advanced little, pushed aside by ssb, vhf, tv and other electronic development, but we must not allow useful experience to lie dormant, we must re-state the relevance of established information.

It is my intention to spread resources by writing some pages for our circle and I have already started gathering old magazines and books for study and reference. I'd welcome any help offered by other members on a loan or sale basis, and will pay costs for such items or photocopies. I'll also gladly photocopy and despatch, at cost, any out of print information or articles required for members reference, those mentioned are first class texts worthy of addition to any enthusiasts library and most are still available in magazine back issues.

I found particularly interesting "Working with the Ethodyne Receiver" by John Heys G3BDQ, P.W. Jan 86, which outlines some early 20's work by staff at the Burndept company. A Burndept receiver holds the distinction of being the first to receive an American broadcast in Europe, i.e. a broadly cast programme rather than an individual transmission. At 01:30 hours on 26th. Nov. 1922 WJZ New Jersey was heard at Blackheath, London by Mr. J. H. D. Ridley of the Burndept Company. Ref*1. He used a Dictaphone to record one of four American stations received on many nights during that winter and logged fifty-two American morse transmitting amateurs using 70 to 750 Watts. During 1922 British amateurs were allocated 150 to 200m. and 440m., broadcasters 350 to 425m. and shipping 300 and 600m.

The more I read the more I realise that it has all been done before and yet we still have our difficulties. What type of antenna? How to cure interference? Cardiod? Amplifiers? these questions, and more, are often asked by newcomers to the hobby, yet it remains hard to find answers. Ref*2.

Development of my own system has highlihted many problems, and though not yet finished, some conclusions, ideas and successes are worthy of note. Please feel free to contact me if you notice any errors or omissions in this writing, intended order of text is;- wire, whip, active antennas, loops and matching amplifiers, cardiod mixing and nulling with a phase amplitude mixer, members feedback, observations and queries, also some general and historical comment.

ANTENNAS. Generally only those listed in three groupings below are used in the pursuit of MW DX.

(i) whip, wire - sensitive in all directions; horizontal dipole - sensitive in all directions, a filled in figure 8, though bi-directional is possible. Emf develops at the terminal of an open ended wire as charges redistribute to maintain energy equilibrium between wire surface and surrounding electromagnetic field.

(ii) ferrite, frame and loop - all possess an easily alignable bi-directional response. Emf develops between winding ends as circumferential charges redistribute to maintain energy equilibrium between enclosed and external electromagnetic fields.

(iii) travelling wave or Beverage antennas - bi-directional, though uni-directional when reflectively terminated at the far end, named after Mr. Harold H. Beverage who researched characteristics. Emf develops at the end of a very long wire as whole wavelengths of redistributed charges within the wire move lengthways with the electromagnetic field that induced them.

Outstanding for DX work, Beverage antennas, with their beam like directivity, are the real enthusiasts choice. Few of us are likely to see one however, as their 300m. minimum straight line length must be well isolated from man and his interference sources. They are non resonant therefore all incoming medium frequency signals may be tuned. If several are erected in a fan or radial pattern then direction of reception may be selected along a global path in line with each wire.

Next best in sensitivity and signal to noise ratio are resonant wire antennas, wires that are long enough for charge flow along the wire to resonate in sympathy with incoming electromagnetic radiation. Unfortunately, because of the 3:1 range in MW frequencies, an antenna (130m.) resonant at long wavelengths possesses varying characteristics as wavelengths shorten. It is easier to use a wire (40m.) resonant at shorter wavelengths plus an antenna tuning unit to induce resonance at longer wavelengths. Switch breaks can be considered, but unpredictable coupling effects are likely between any floating section(s) and the portion still connected to a receiver. At low and medium frequencies these antennas are capable of excellent DX reception, however weak signal discrimination is limited by other stations whose signal strength varies both daily and seasonally, and noise levels which are so variable in built up areas.

During winter mornings when the background is "quiet" a resonant antenna is capable of producing local/distant signal level ratios in excess of 120dB. and this can reveal receiver imperfections not noted at other times. Solid state receivers in particular are more susceptible to overload when used with a good antenna, especially where front end EMP protection diodes are fitted or oscillators and block filters have harmonic response or shallow noise floors; 120dB. is a long way down. Therefore choose carefully any set intended for use with Beverage or resonant wires, spurious beats can obliterate DX and internal images introduce the embarrasing risk of false logging. *3*4

Ref*1. The Romance and Reality of Radio, by Capt. Ellison Hawks. 1923 hardback, published by T. C. & E. C. Jack Ltd.

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Ref*2. A DXer's Technical Guide, by Nick Hall-Patch and others. Paperback with small print, from International Radio Club of America, 1017, West Manhattan Ave., Tempe, AZ 89898.

Ref*3. High Frequency Receiver Design, by Jon Dyer, G4OBU. Parts 1 and 2, Radio and Electronics World, Feb. and Jul. 83.

Ref*4. A Survey of Receiver Reviews, by Hilary Humphreys. Amateur Radio, April 1985.

cont.

Much more commonly used are random length wire antennas and verticals where, as with the resonant wire, emf is generated with respect to local ground by passing electromagnetic fields. Close to the earth these fields are dampened by ground conductivity, therfore a given length of wire is more efficient vertical than when inverted L orT shaped. Ref*5. Height and R.F. insulation are more important than length.

As with all wire antennas they must not be close to buildings, large trees or other outdoor cables, and as little as 10m. free space around them can do much in reducing mains and television timebase interference.

Antenna wire should be capable of withstanding it's own weight plus winter wind and ice loading. Copper, whether enamelled or insulated, tends to stretch if left unsupported. Hard drawn copper wire suits resonant and dipole antennas but is thicker and heavier than necessary for random length applications. Green plastic coated garden wire is long lasting, cheap and effective at long and medium frequencies. It is a steel wire of higher resistance than copper, but for reception purposes other losses predominate and this is not a problem.

Insulators may be home made, cast in epoxy resin or cut from modern plastics block and rods. Copy the egg type construction because if it fails the wire and support remain joined. Ceramic egg insulators, dipole T pieces, hard drawn copper wire, co-axial and twin feeders etc. are available from Bredhurst Electronics, High St., Handcross, W. Sussex, RH17 6BW.

We are trying to discriminate really minute signals therefore it is most important that antenna emf is fed to the receiver with respect to antenna ground, not with respect to receiver ground. Nor should antenna ground be used to "earth" a mains powered receiver, a separate ground should be used with electrical and spatial isolation between them.

Screened coaxial cable is a good feeder for transfering antenna/ground emf to the receiver, and though it behaves like a shunt to low and medium frequency wires it cannot be shortened without bringing the antenna back into noise. Single coax can not be grounded at both ends as earth loop noise on the outer is transferred to the inner; makes a quiet neighbourhood sound electrically noisy. Balanced arrangements are inherently noise cancelling though more expensive and, depending on the receiver, require one or two matching transformers at cable ends. Ref*6.

Coaxial cables are low impedance by nature, whilst long and medium wave antennas, excepting single turn loops, tend to be of medium or high impedance. When antenna and ground are connected directly to a coaxial cable charge flow within the coax is severely damped and emf at the cable ends is very low.

An impedance matching transformer between antenna/ground and the coaxial cable can optimise energy transfer, and at the same time, electrically isolate the antenna ground from feeder ground. This transformer is a step down type that lowers the system background noise floor yet raises emf transferred to the receiver.

A suitable 2.5cm. diameter ferrite ring core costs only £1.25 inc. post and VAT from Electrovalue Ltd., 28, St. Judes Road, Egham, Surrey, TW20 0HB, Seimens part no. B64290K0618X830. It could be wound with 15 turns primary (antenna/ground) and 5 turns secondary (coax) of thin insulated connecting or 22.swg. enamelled copper wire. Try adjusting the numbers of turns whilst tuned to a signal between 900 and 1000kHz. A small price to pay for peace of mind and ear.

An improved method of matching is by making the antenna part of a resonant radio frequency circuit using series connected variable inductance; requires remote control circuitry though. Use a 5:5 turn 1:1 bifilar wound isolating transformer. (Two lengths of wire wound together) Join the primary winding end next to the secondary coax braid connection to an earth stake, the other primary end to a variable inductance in series with the antenna. This inductor may be the permeability tuner from a scrapped car radio or a transistor radio MW antenna coil with it's ferrite rod being controlled to move in and out by screw thread.

I have noted worthwhile improvement in daytime sensitivity and pre-receiver selectivity with this cicuit arrangement and tuning may be further sharpened by connecting a 33pF. capacitor directly between antenna wire and ground stake connections. Note however, this resonator does not improve antenna signal to noise ratio and need only be used with receivers that lack dynamic range, selectivity or sensitivity.

Coming back down the feeder, it is also important to match cable and receiver input impedances. Modern sets have 50 ohm, 75 ohm and balanced inputs capable of direct coaxial connection. Older sets were designed for use with medium impedance antennas and should not be directly connected to coaxial cable. There are two reasons for this; (i) optimum input gain and signal to noise ratio will not be achieved, and (ii) a strong adjacent signal can be directly imposed upon the first r.f. amplifier because input tuning is severely dampened by low impedance.

A second ferrite ring can be used for receiver impedance matching, £2.00 for two inc. post and VAT. Try 560 ohms in series with 20 turns between A and E, and 8 turns between coax inner and braid. This transformer and it's leads should be screened and positioned close to the receiver. If the receiver is mains earthed do not link the transformer E and braid connections, separately connect the feeder braid to a nearby earth stake. If the receiver is battery operated or not mains earthed link both E and braid to an earth stake. From here outwards the feeder can be any length, low loss coax is worthwhile when chasing very weak signals.

Dipole antennas are less sensitive than equivalent length wire ground systems though have slight directional advantage. One erected horizontally in line with a local transmitting mast will be less sensitive to it's output, the main pick up lobes are at right angles to the wire. For natural medium wave resonance they must be between 90 and 270m. long, rather large. Smaller dimensions are still useful, though impedance is higher and they require balanced matching. Try a balanced 10+10 turn ring core primary with the centre tap grounded via coax braid on the 5 turn secondary. The transformer can be between elements or at ground level between vertical twin feeder ends.

Ref*5. How Long is a Piece of Wire?, by W. J. J. Wiseman. Wireless World, April 1985.

Ref*6. Curing TVI to MF/HF Reception, Practical Wireless, Jan 1984, by A. J. Cawtorne T.Eng(CEI).FSERT.G3TDJ.

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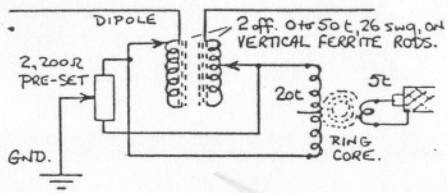
I was impressed by the loop like performance and nulling ability of a 2m. active dipole. Two 1m. lengths of wire taped to a bamboo cane were connected to parallelled - centre tapped inductance, trimmer and loop type differential matching amplifier. Unfortunately it was over sensitive to physical changes and further development was ruled out, any human movement within 2m. of the dipole upset it's null response.

A full sized dipole can not easily be adjusted to null trouble-some local signal, however some improvement should be possible by using reactive trimming to counteract the degrading effects of ground distorted, re-radiated and scattered signal components. This circuit may be tried with a dipole that is accurately aligned with an interference source. Obtain a minimum using the pre-set resistor, then dee-pen by adjusting one or other of the series induc-tors from rest position (zero turns). Repeat this procedure three or four times for accurate nulling.



Only one signal may be nulled with a given set of adjustments, so pick the most annoying or powerful one when a multifrequency mast is the problem. All other signals should remain unaffected, the filled in figure 8 reception pattern will remain.

Note that, just as with a daytime nulled loop, the night time performance of this circuit will be degraded by signal reflected, refracted, rolled, rotated or scattered by ionospheric changes. This is because dipole and loop antennas have a three dimensional semi-toroidal like response and are sensitive to both horizontally and vertically polarized radiation. Here a brief note about common rec-eption disturbances should link observations with the mechanics involved.

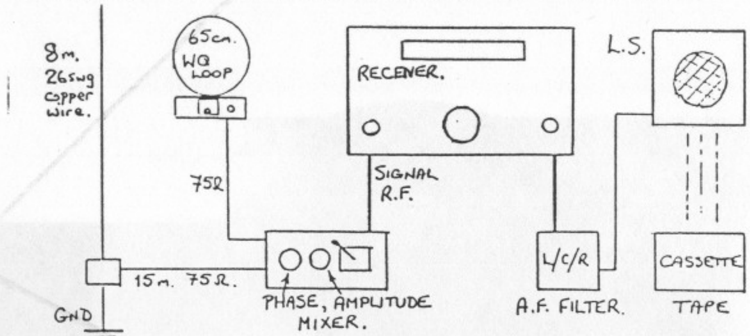
Group fading. A propagation disturbance that generally affects simple long distance sky-wave reception between dusk and dawn. Propagation of an entire carrier plus sidebands transmission is altered by ionospheric changes, and though received signal sounds normal it's strength constantly varies. Good receiver a.g.c. is helpful, multi-antenna/receiver diversity reception more so. Ref*7. Fast or flutter fading indicates highly disturbed conditions when DX reception is likely to be both poor and unpredictable.

Selective fading. A local electromagnetic field disturbance that is particularly objectionable and caused by two or more propagation paths between transmitter and receiver; generally ground plus sky on British and European signals. Here the changing phase relationships of more than one incoming signal generate alternating peaks and notches that sweep signal bandwidth. The sweep causes a cyclic variation of the form;- Normal sound, Tonal changes as a peak sweeps one sideband, Normal sound but slightly reduced a.f. volume with the S meter needle advancing a few dB.s as the carrier frequ-ency peaks, Tonal changes - peak on the other sideband, Normal sound, Tonal change as a notch sweeps one sideband, Loud distorted sound, often with receiver overload, as the S meter needle falls with carrier notch out, Tonal change - notch on the other sideband. The sequence is now repeated. Distortion, depth and frequency of fade increase as the signal path is influenced by day/night or night/day changes, though symptoms abate during deep night. Manual or audio derived r.f./i.f. gain control can help, a.g.c. does not.

Night effect. After dusk and before dawn, sky wave radiation becomes elliptically polarised, i.e. signal returning to earth comprises both horizontally polarized and vertically polarized components with amplitudes that change cyclically without simultan-eously becoming zero. Ref*7 and *8. Antennas that are sensitive to the horizontal component, such as horizontal dipoles and vertical loops, still produce an output when the vertical component is nulled. A good day time directional performance is thus much impaired, null positions become indistinct and vary widely about true position in a manner that is difficult to track.

When dipole or loop antennas form part of a cardiod system the single null is also troubled by night effect, however symptoms may be countered by constant manual adjustment of antenna signal phase and amplitude mixing controls. See phase amplitude mixer later.

At this point I'd like to outline my own system, especially the active whip and some of the ideas that led to it's design.



Garden size and the neighbourhood building height limit would reasonably allow for a wire 10m. long and 5m. high, but this is un-likely to be better than the present unobtrusive self supporting 8m. whip. I'll raise it to 10m. this summer, 6m. Shakespeare glass fibre roach fishing pole and 4m. timber, and fit a 50cm. diam. wire ball to soften it's electrostatic point. Ref*9. Ground connection is simply a 2m. steel rod driven into wet clay. An earlier wire 10m. long and 3.5m. high with matching transformers was converted to the permeability resonated type to improve sensitivity with my old Marconi, this was better, but having to peak for each new signal was a nuisance.

To ensure that antenna energy is not wasted in feeder cable or receiver circuits and is fully allowed to create r.f. signal voltage I decided to try an outdoor pre-amplifier capable of taking antenna/ground input and producing a 75ohm isolated output. The circuit is shown below. It covers medium frequencies with unity gain and has a dynamic range in excess of 120db. Any internal products have not been heard above received noise and the regional 1341kHz. 100kW. transmitter 20 land kilometers away is not a problem. Power consum-ption is 160mA. at 24Vdc., so it runs warm. All parts are available from Electrovalue Ltd., their catalogue is free, just write.

Ref*7. Wireless Direction Finding, by R. Keen, any edition. An old hardback, published by Iliffe and Sons.

Ref*8. Radio Engineering, by F. E. Terman Sc.D., second edition. An old hardback, published by McGraw-Hill Book Co. Ltd.

Ref*9. Lightning, by A. Martindale G3MYA. R.S.G.B. Radio Communication, monthly journal, Jan. 1984.

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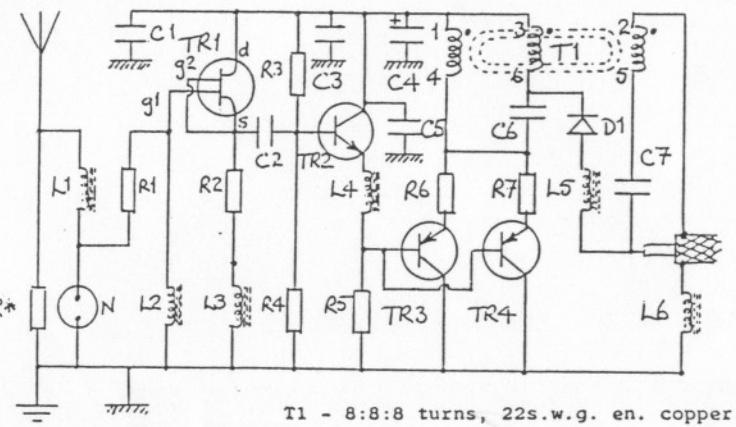


T1 - 8:8:8 turns, 22s.w.g. en. copper.

1 off 6k8 , ¼W, 5%.	R*.		1 off 470u, B78108S.	L1.	
1 off 5k6 , ¼W, 5%.	R1.		1 off 10m , CH4.	L2.	
2 off 1k , ¼W, 5%.	R2,5.		1 off 5m , CH2.	L3.	
2 off 56k , ¼W, 5%.	R3,4.		1 off 100u, B78108S.	L4.	
2 off 150R, ½W, 5%.	R6,7.		3 off 2.5m, CH1.	L5,6,7.	
4 off 100n, B32560.	C1,3,5,9.		1 off 40673.	TR1.	
1 off 330p, B31110.	C2.		1 off BC337.	TR2.	
2 off 100u, B41326.	C4,10.		2 off BD136.	TR3,4.	
3 off 47n , B32560.	C6,7,8.		1 off 1N4007.	D1.	

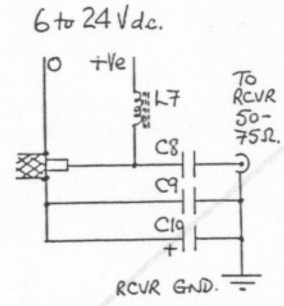
Neon SB1725. Core K0618X830. Board 21078. Box 21390.

Three design specifications for this active whip antenna are;-
(a) distant background noise received by the antenna during quiet periods must dominate system noise,
(b) input filtering should reduce high frequency response, so that signals received at the antenna's natural frequencies can not generate spurious amplifier products,
(c) signal handling capability to exceed 1V r.m.s. when feeding 50 to 75 ohm receiver inputs.

Signal freqency potentials develop across the antenna- L2- ground circuit, and are little affected by TR1 gate connection. Three stages of unity gain current amplification in TR1, TR2 and TR3,4 gradually reduce impedance. The output transistors TR3,4 share quiescent current and therefore operate with better linearity and lower temperature. Passive filters reduce gain beyond medium frequencies; low pass are (i) L1+R1 with the natural capacitance of L2+TR1, and (ii) L4. high pass are (i) natural antenna capacitance with R*+L2, (ii) C2, and (iii) C7. R* = 68k divided by the whip length in metres + or - 20%. The neon and R1 limit electrostatic discharge through TR1 substrate diodes.

TR1 follows antenna potentials; TR2 isolates TR1 from variable impedance effects occuring within TR3,4 as slew rate and amplitude vary with signal; TR3,4 feed the trifilar wound 1:1:1 output transformer, T1, at 75 ohms via R6,7. To prevent feeder induced noise the amplifier chassis operates at antenna ground potential, isolated via L5 and L6. The isolated output winding of T1 connects directly to the feeder braid

and signal is transferred by C7. T1 has two primary windings, with flux in parallel at RF but opposing at DC, so that core bias can not cause asymmetrical signal distortion. D1 prevents possible damage by accidental reversal of remote power supply connections.

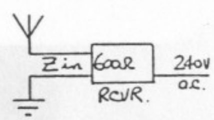


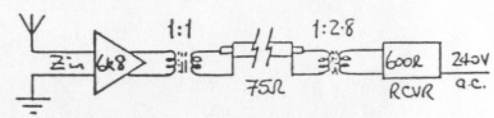
Note the power supply and receiver termination arrangement. Current flow through L6 causes a potential difference between the feeder braid and antenna ground, therefore the braid should not be directly connected to a receiver, nor can the battery or mains powered supply be earthed. The shopping list may be copied and sent to Electrovalue Ltd. Matrix board layout is easy to follow.

Antenna and ground wires and the coaxial feeder pass through holes drilled in the plastic box. They are soldered directly to board pins and then sealed in place. The box should be mounted just above ground directly below the whip.

Comparing the antenna to receiver gain figures of straight and active systems we have;-

Reference input. f = 1MHz. Active system.





Gain of antenna into 6k8 ref. 600R	+7dB.
Amplifier gain	0dB.
Termination gain, 75R output into 75R load	-6dB.
Matching transformer gain 75R : 600R	+9dB.

Total gain of the active system with respect to the reference one is therefore +10dB., at 500kHz it is approx 16dB. and at 1.5MHz approx 6dB. These gains, though not large, are acheived using uncomplicated antenna, ground and feeder arrangements; signals are transferred with undiminished level at lower impedance.

Use of a step down transformer + coaxial feeders + step up transformer with our reference system will also reduce interference, but the potential for ingress remains worse than when active. The amplifier also introduces antenna/ground isolation, see part two, so the 10 to 20dB. possible reduction of antenna circuit noise can be added to the active system gain to create an overall 20 to 30dB. improvement in signal dynamic range at receiver input.

My 10m. whip antenna is only 8 to 20m. away from five neighbouring family bungalows and 220m. from industrial pylons, yet I enjoy excellent medium frequency reception using the remote amplifier and a Collins type R390A-URR receiver. The R390A's 0 to 100dB. carrier level meter does not indicate noise between weak channels, yet night-time continentals register up to 95dB. and all locals pin the needle; readings taken using the 1kHz IF bandwidth. Weak signal resolution is substantially improved at all medium wave frequencies, and mains bourne or television timebase interferences are rendered almost inaudible!

Both R390A and Marconi Mercury type receivers possess triple RF tuned front ends with impressive image and spurii protection, yet both generate small, though different, tunable errors when correctly matched to the active whip. These errors do not occur when using the WQ loop, for although loop output is much larger, it is sharply tuned and directional.

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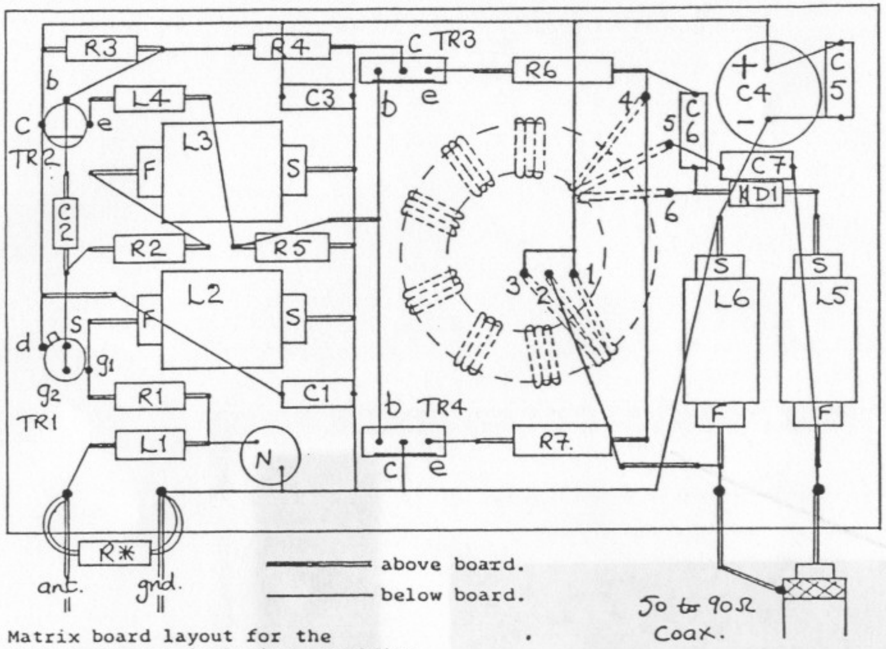


Matrix board layout for the
active antenna isolating amplifier.

An extra tuning stage between any wideband source and the receiver input is effective both in reducing internal products and boosting weak wanted signals with respect to "powerhouse" transmissions on adjacent channels. However, for optimum low noise performance the feeder should be unbroken and correctly terminated, because tuned circuit insertion can introduce losses, earth loop noise or screening problems. The pre-selector in my own system is combined with the phase amplitude mixer detailed later, but before that some general notes on loop antennas.

A loop of wire is an effective and self contained sensing element for electromagnetic radiation. It's sensitivity can be improved by increasing wound area, either by making the loop larger or by overwinding more turns.

When the area of a single turn loop is increased it's inductance rises and theoretical self resonant frequency falls. Now, although area increases at a faster rate than circumference, wave delays around the circumference create transduction phase changes before resonance drops to medium frequencies, and while a small single turn loop is insensitive much larger ones possess frequency dependent phase and sensitivity characteristics. Transition is gradual however, and a medium size loop, though quite inefficient and requiring input matching, has good wideband sensitivity and is useful as a bidirectional source for cardiod mixing. Size descriptions are based upon the circumferential length of sensible shapes, with small less than say 0.05λ and large greater than 0.5λ, where λ is the shortest wavelength to be received.

When more turns are wound over a given area then loop inductance increases much faster than the rate of circumferential increase and natural resonance at medium frequencies becomes possible. The resonance self amplifies induced signals and greatly improves antenna efficiency.

Again circumferential length is limited by wave motion along the wire, and windings must be shorter than 0.25λ for homologus interturn flux linking. Most solenoid and spiral wound loops have circumferential lengths of 0.1λ, though 0.2λ is possible by using appropriate wire and winding forms.

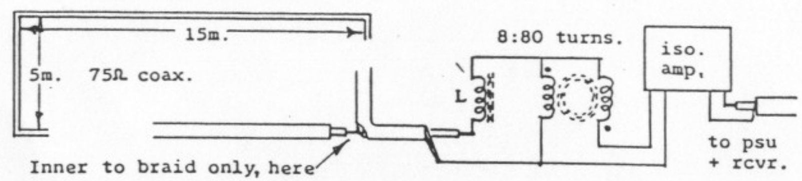
The tuned loop antenna's ability to peak a carrier and direct nulls towards unwanted transmitters has been popular with DXers. Ref*10. Refinements have led to improved, compact and amplified designs, but some inherent weaknesses are seldom overcome:-

(i) Whether screened or balanced these loops are rarely used outside. They receive domestic interference just as well as distant stations, especially during the daytime and early evenings. Also, the loop's position for an environmental noise null might not coincide with that necessary for specific DX reception.

(ii) At radio frequencies a tuned winding has an effective resistance many times that of the wire alone, and thermal agitation can generate noise potentials up to 25uV. between loop terminals. Ref*11. Often the signal strength meter on a sensitive receiver will be deflected by loop resonated noise without any carrier or interference being present. Larger diameter tuned loops possess lower Q and therefore are slightly quieter, but they are much more cumbersome and rarely tune all medium wave frequencies with the swing of a single variable capacitor.

(iii) Another problem occurs with cardiod reception, for when tuned loop output is mixed with that from a wideband whip/wire source the null occurs at only one frequency. A carrier can be notched out but disturbing levels of sideband splatter normally remain. Tuning the wire signal helps, but this causes further complication and effectiveness varies across the band. If an amplified loop is available it may be tuned 20 to 50kHz. away from the wanted signal. Here loop phase changes less with frequency, and mixing produces good carrier plus sideband nulls. Overall sensitivity is little reduced.

Comparisons between indoor loops and the active whip antenna clearly showed advantages of outdoor siting and prompted a series of experiments with medium size, single turn outdoor loops. General conclusions were;- the bigger the better, though exceeding a 0.5λ circumference could distort response; more simple to use coaxial cable capacitance to reduce and dampen the main resonance; for efficiency the step up transformer must be carefully wound; using an isolating amplifier and siting the loop away from buildings reduces mains bourne interferences by 20 to 30 dB., measured.



The present construction is shown above, inductance L, 4.7uH., reduces system damping at higher medium wave frequencies. The toroidal matching transformer is wound on a one inch core as earlier; primary- 8 turns spaced evenly around the ring, secondary- eight piles of ten between the primary turns. This loop is less capable of high frequency reception than the whip, therefore some isolating amplifier components (L1,L2,L3,N,R1,R2,TR1 and C1) may be ommited if desired, though the antenna pin must then be linked to TR1 end of capacitor C2.

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Performance is outstanding. When mounted on poles down the garden, with it's bottom 15 metres concealed by grass, this loop looks just like a thick wire antenna. The only planned improvement is a washing line suspension for the top span of coax. Cable weathering is inevitable, but extra support should at least minimize internal damage. Transatlantic reception is favoured by a West-Nor-West alignment, and sensitivity, noise levels and dynamic range are commensurate with those of the active whip. This design encloses a wound area more than ten times that of resonant loops, and it's output is stepped up by a similar ratio. These factors equate closely with the figure of resonant Q for normal tuned loops, approx. 120, and though both types have similar outputs the large one does not require tuning.

Outdoor, single turn construction is also quieter. It responds less to domestic interferences, and, since thermally agitated winding noise is proportional to the inductance by Q product, it can hear much weaker signals. Indeed, tuned loop winding noise often causes a response that makes the background sound erroneously quiet. Signals and noise are still there, but antenna gain falls at frequencies both above and below resonance, and, to an AM receiver this appears as a carrier with quiet sidebands. Broadband antennas do not cause this effect.

The tuned loop is useful where domestic or environmental circumstances limit antenna choice to an indoor type. Selective designs assist receivers in finding weak carriers, and one that can be rotated about both vertical and horizontal axes may be more accurately adjusted for deep signal nulls. Ref*12. Do keep hidden antennas in mind;- flagpoles, washing lines, sheds, trees, gutters and spouts outdoors, and room, wardrobe, bookshelf or cupboard loops indoors.

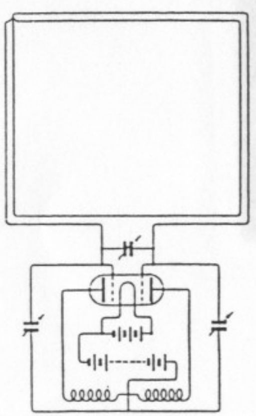


Fig. —Push Pull Valve Circuit for Reduction of Vertical.

An amplifier is essential for serious loop DXing. Recommended, and used in professional direction finders are balanced input, signal frequency, antenna matching amplifiers. The illustrated 1922 circuit shows a single directly heated cathode valve having two grids and two anodes. Often used today are dual fet input, differential matching amplifier (d.m.a.) circuits, which match loop and receiver impedances and provide wide dynamic range. Ref*13.

Notes: Suitable 75Ω coax is currently available from J&N Bull Electrical, 260, Portland Road, Hove, East Sussex,, BN3 5QD, at £1.00 per 20 metre length, plus £1.00 postage. i.e. 60 metres for £4.00 all in. Repanco have ceased RF choke production. For the isolating amplifier use Siemens B78108S alternatives from Electrovalue;- 2 series connected 680uH for each CH1, 4700uH for CH2 and 2 series connected 4700uH for CH4.

Ref*10. Medium Wave DXing, by Charles Molloy, Practical Wireless, April 1970, pages 962,3 and 5.

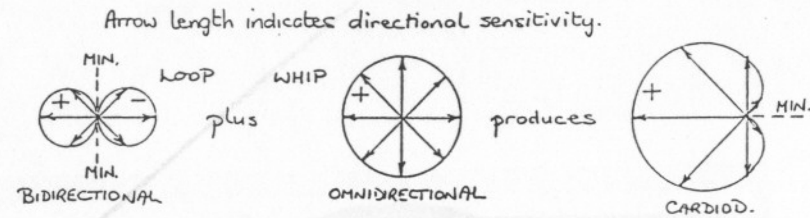
Ref*11. The Technique of Radio Design, by E.E.Zepler Ph.D.,M.Brit.I.R.E. published by Chapman and Hall Ltd., 1945.

Ref*12. The W-Q MW Loop, by G.S.Maynard, Practical Wireless, Nov 1985.

Ref*13. Differential Matching Amplifier for Loop Aerials, by Steve Whitt, Medium Wave News Reprint No.10.

All loop antennas are broadly sensitive in line with the winding wire, but sharply insensitive along their axes. Therefore, at any site directly between two transmitters attempts to null one signal will simultaneously upset reception of the other. Britain lies on a global path between America and Europe, so a single loop can not be expected to null continental signals and, at the same time, favour transatlantic reception.

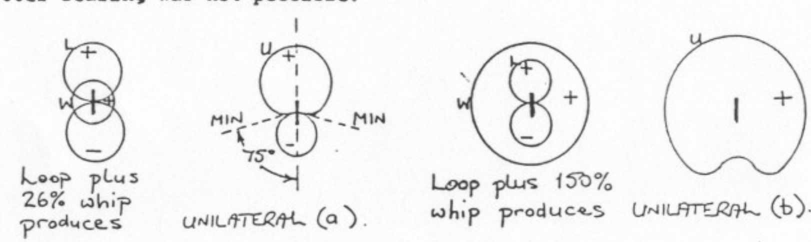
Cardiod, or heart shaped, sensitivity patterns are well known and may be generated by mixing equal amounts of phase matched loop and whip/wire signals. A broadly sensitive lobe predominates, and the now



single minimum is in line with the winding; forward sensitivity is increased and the null arc widened. In practice a cardiod response can almost double the transatlantic signal to noise ratio whilst providing general insensitivity towards the continent and one deep null for accurate alignment.

For a loop null of ___ dB. with respect to main lobe		6.0	20	40	60	80	100 dB.
Loop alignment tolerance in degrees, vertical and horizontal	loop alone	30	6	0.6	difficult		
	cardiod mixed	90	36	11	3.6	1.1	

Though loop and cardiod reception patterns are well documented in DXing and radio direction finding publications, there is little mention of unilateral reception. Ref*7. Unilateral refers to a polar response that, though neither figure of eight nor cardiod, possesses enough asymmetry to indicate direction. It might have two minima less than 180 degrees apart and be termed a cottage loaf diagram, see (a), or show a single rather indistinct minimum, see (b). Navigators avoided using unilateral responses because accurate determination of transmitter bearing was not possible.



Response (a) is generated by mixing loop antenna signal with less whip/wire signal than is required for the cardiod pattern. The relationship between the nulling angle w.r.t. the loop winding wire, and the level of mixed omnidirectional signal as a percentage of loop output, is tabulated below.

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Null angle, degrees	90	75	60	45	30	15	0
Whip signal, percent	0	26	50	71	87	97	100

Ninety degree nulls at 0% represent the normal loop response, i.e. no signal mixing, and zero degrees at 100% is of course full cardiod with the single null. Phase reversal of either antenna signal reverses the direction of a cardiod response and makes unilateral minima traverse oppositely.

Hence, an ability (i) to match and reverse the phase of loop and whip antenna signals, and (ii) to control their relative amplitudes, would be a basis for nulling ANY steady signal without rotating or tuning either antenna. The phase amplitude mixer described below is a practical development of this approach. It incorporates a sharply tuned mixing circuit which helps alleviate most intermodulation problems associated with the wide range of local to distant signal levels, and is capable of generating deep minima for use against Direct and Group Fading signals, or compromise settings for optimum nulling of Selective Fading and Night Effect signals. See circuit diagram.

This tuned mixer accepts dipole, loop, whip and wire inputs at low impedance and works with most screened feeders. Signal nulling may be acheived using a bidirectional/omnidirectional antenna pair, two similar but widely spaced antennas or impedance transformed angled Beverages. Phase variation is produced by a standard, 6:1 geared, three gang 500pF variable capacitor working as a passive (linear), three stage R-C network. At MW frequencies 15 to 105 degree adjustable lag is available on either input, and to prevent loss of cover the other undergoes a fixed 15 degree lag. The phase variation of one signal with respect to the other may therefore range between minus 90 and plus 90 degrees. If one signal is now reversed this range becomes plus 90 to plus 270 degrees and hence a fully variable 0 to 360 degree phase shift is realized. Two controls, the variable capacitor and a four way, ninety degree, quadrant selector switch, thus cover all possible antenna/feeder characteristics. Amplitude mixing levels are controlled by a dual gang cross fading potentiometer kindly made for this project by Electrovalue Ltd. Cross fading allows one control to cover a wide range of input signal amplitudes.

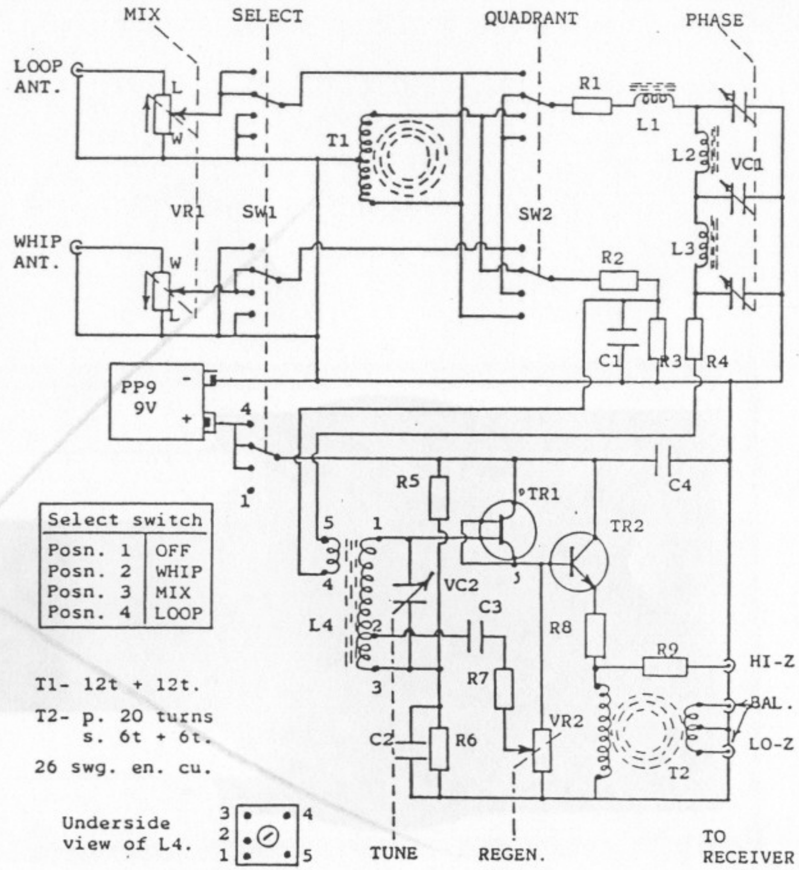
Sensitivity and linearity are maintained by tuned circuit mixing. Proportional mixing introduces losses and active mixing generates products, whilst isolated differential coupling to a resonant circuit produces frequency selective amplification. A second knob at this tuned circuit adjusts positive feedback, so selectivity is sharp and may be controlled to the point where an individual sideband can be chosen for exalted carrier reception.

The ON-OFF switch combines input control and enables direct comparisons between the mixed output and either individual input. Choice of Hi-Z, Lo-Z and Balanced outputs are available and a PP9 battery lasts for more than 450 hours. To prevent noise ingress and improve stability all components should be assembled inside a closed metal case. Internal layout and screening are not important as leakages are automatically compensated by mix and phase control adjustment as reception patterns are generated.

The tuned mixer at my QTH has become indispensible. It is built into a 10x7x3 inch aluminium box and provides five distinct modes of operation. These are:-

(1) Omnidirectional reception. With a whip/wire antenna and 'W' input selected any desired signal may be peaked using the 'tune' and 'regen' controls. Usefulness and signal to noise ratio are determined solely by antenna characteristics.

(2) Bidirectional reception. The normal figure of eight response produced by an amplified, pan and tilt, loop or dipole antenna system is selected with the mixer input switched to 'L'. Extra selectivity assists reception but the mixer does nothing to improve an antenna's basic transduction performance.



1 off 100R, lin. dual VR1.
1 off 10k , lin. VR2.

1 off 330R, ¼W, 5%. R1.
2 off 680R, ¼W, 5%. R2,9.
2 off 1k, ¼W, 5%. R3,7.
2 off 560R, ¼W, 5%. R4,8.
2 off 470k, ¼W, 5%. R5,6.
1 off 47u, Siemens L1.
1 off 68u, B78108S L2.
1 off 100u, chokes. L3.
2 off 3p.4w. rot.sw. SW1,2.

1 off 500p, 3 gang. VC1.
1 off 250p, var. VC2.

2 off 220p, B31110. C1,3.
2 off 100n, B32560. C2,4.

1 off 40673. TR1.
1 off BC337. TR2.

2 off K0618X830 core T1,2.

1 off IFT 13 coil, L4.
(with int. 250p removed)

Electrovalue Ltd. is the only known source for VR1.

THE TUNED MIXER CIRCUIT DIAGRAM AND SHOPPING LIST.

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(The mixers Select switch allows instant choice and comparison between (1) and (2) above, or one of the generated responses below.)

(3) Zero cleaning. Where the less than perfect null of a vertically rotating or environmentally imbalanced loop antenna is deepened by mixing small amounts of oppositely phased cancellation signal from another antenna. First obtain the best null as in (2), then select 'M' for the mixing facility. Rotate the 'mix' control 30 degrees from the L end and enmesh the phase control by 45 degrees. Select the only 'quadrant' position that provides a null and then repeatedly adjust 'phase' and 'mix' controls to sharpen it. Note that electrical or mechanical cleaning of one figure of eight minimum simultaneously makes the other one less distinct.

(4) Cardiod reception, where the mixer offers switchable choice.
When nulling capabilities are more important:-
Tune up the desired signal as in (2) and then loop null the unwanted signal to establish it's direction. Now turn the loop through 90 degrees so that it's winding is in line with the signal, select 'M', centre the 'mix' control and enmesh the 'phase' capacitor by about 60 degrees. Select the best nulling 'quadrant' and then deepen response using 'phase' and 'mix' controls.
When forward lobe sensitivity is more important, either
(a) generate a full cardiod null on the wanted signal and then turn the 'quadrant' selector two positions to reverse the polar response i.e. transpose the minimum and forward lobe characteristics, or,
(b) null an unwanted signal from the opposite direction; forward lobe sensitivity is so broad that this signal need not be exactly in line with the wanted one.
Once set a cardiod pattern holds well with loop rotation, though fine phase and mix control adjustment should be tried when tuning other signals.

(5) Unilateral reception, for fixed loop/dipole applications or where unwanted signals cannot be nulled using loop or cardiod patterns. One deep and one shallow null may be generated at equal angles with but on opposite sides of any loop antenna winding.
Using a rotatable loop antenna axial nulling, (2), will establish two unwanted transmitter directions. Aim the loop between transmitters then adjust the mixer as in (4). This method might help alleviate noise from multi-source jamming operations; try repeated sequential adjustment of loop bearing/tilt and mixer phase/mix to obtain the most useful double nulling response. Four interacting variables introduce a trial and error aspect, so comparative listening checks are essential after each adjustment.
With a fixed loop antenna any single transmission from any direction can be nulled by adjustment of quadrant, phase and mix controls.

NOTES

Phase amplitude mixers have been in use at my QTH for about five years, the tuned mixer is a more recent and very successful development. Mine works well with the similar low impedance outputs from active 10m. whip and active 5 x 15m. loop antennas. Deep, stable and broadband directable minima are easily generated for nulling an interfering signal and sharp tuning boosts wanted modulation or portions of it.

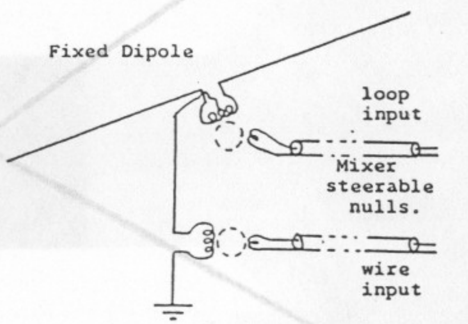
Don't worry that a 10m. whip will overload the isolating amplifier; if R* is sensibly chosen it's loading allows adequate sensitivity with good signal to noise ratio. Any particularly strong or troublesome local can be tamed by using a series tuned, high Q medium wave coil and variable capacitor across R*, see drawing; though use this method only as a last resort, transduction phase is disturbed and responses become distorted.

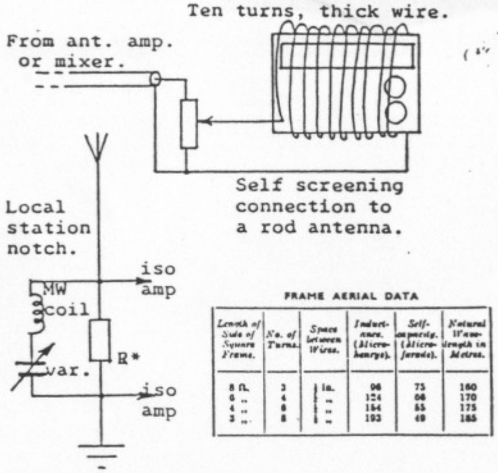
The high output WQ loop is useful for "off tune" mixer reception; it can be deliberately mistuned up to 100kHz off channel so that the generated nulls remove the carrier plus both sidebands. When a resonant loop is closely tuned to any mixer nulled signal there is a high rate of

phase change with frequency, and even though a carrier can be deeply notched, overall reception suffers from residual sideband splatter. A resonant loop antenna should not be retuned once used as a source for mixer generated reception patterns, phase changes upset the directional response.

The active 5 x 15 is aperiodic and relatively phase constant, so mixer nulls are directionally sharp, yet frequency broad; signals are taken out over several channels for transmitters that are in the same direction. Non resonant loop + whip + mixer responses are stable and little affected by environmental changes, necessary pre-receiver selectivity is simultaneously provided for both antennas and subsequent mixer tuning does not disturb the generated polar patterns. By notching out Europeans this system removes the heterodynes and splatter that often spoil transatlantic reception, wider i.f. passbands become suitable and listening is much more comfortable. Previously I had to use 1,2,3 or 4kHz bandwidths for TA's, now I rarely find it necessary to go below 4kHz, 8 is often possible, 16 occasionally!

Though mixer settings may be noted in a reception log book it must be appreciated that they seldom remain constant for any length of time. Stable receiving apparatus cannot counter ever changing ionospherically returned signals, and two handed phase + mix control adjustment is necessary to silence the cyclically varying resultant on early night time Europeans.





FRAME AERIAL DATA

Length of Side of Square Frame.	No. of Turns.	Space between Wires.	Inductance. (Microhenrys).	Self-capacity. (Microfarads).	Natural Wave-length in Metres.
8 ft.	3	[illegible] in.	96	75	160
6 ..	4	[illegible] ..	124	66	170
4 ..	6	[illegible] ..	164	55	175
3 ..	8	[illegible] ..	193	49	185

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Application of these notes should afford improved medium wave reception with almost any receiver, though not all receivers are suitable for medium wave work. Latest models have fantastic book specifications but their medium frequency off air performance might be no more satisfactory than that of a well used, reasonably priced set some twenty, thirty or even forty years old. Guard against disappointment by seeking recommendations, and when possible ask for a home trial before buying. Search for internal images and spurious responses of powerful locals at mid-day, check strong signal handling characteristics after dusk and use the dawn period to reveal cross modulation or inadequate dynamic range effects.

DX listening generally calls for passbands of 3 to 4kHz, and prior to 1970 this degree of selectivity was usually produced by a cascade of low frequency tuned i.f. stages in double or triple conversion superhet designs. These older receivers were built with simple, envelope detector AM demodulation yet they remain useful, pleasant to listen to and do not cause listening fatigue. The 1960's saw release and, at first, limited use of receivers employing "block" i.f. filters;- precision, multi-element, electro-mechanically resonant assemblies operating at medium or high frequencies e.g. mechanical, crystal, ceramic. These filters generally out perform tuned low frequency i.f. stages, they offer better long term stability and simplify manufacturing requirements. Today all communications receiver designs boast of the block filtered, flat topped and steep sided selectivity response, but at a cost, for AM broadcast signals often sound hard and lifeless, and in poor conditions levels of spitch, splatter and monkey chatter are increased.

It is the block filter's multi-element construction that causes these problems. Excitation of one or more internal elements by a sideband of the tuned signal, or by the tuned carrier or sidebands beating with noise or the carrier or sidebands of an unwanted adjacent signal, can generate i.f. signals that are greater in amplitude than the carrier already tuned. The i.f. envelope is driven beyond 100% modulation or beyond the detector's envelope following capabilities at higher audio frequencies, and harsh signal distortion results, especially on louder broadcast material and percussion or sibilance transients. The block filter plus envelope detector combination is thus capable of generating audio products that are higher in frequency than those modulation frequencies normally passed by the filter alone, and this adds further to the discomfort experienced when listening in less than ideal conditions. A.f. and r.f. gain control adjustments do not help, though the mixer can when tuned exactly to the wanted carrier.

DXers who use sets which employ ordinary LC i.f.s will not have observed this type of distortion, but then they will not have enjoyed the block filter's pillar like tuning capabilities. Conversely, those who use receivers that employ one or more block filters often develop accommodating ears which naturally tolerate the sound, or, they listen through a filtered a.f. system and don't realise what they are missing.

Dissatisfaction with this either-or situation regarding selectivity and quality on sets that are otherwise well suited to medium wave reception prompted further thought and experimentation. I produced a rounded top for the block filtered response of my R390A by applying positive feedback to an external 455kHz tuned i.f. stage. Bandwidth is smoothly adjustable between flat and 750Hz, and this allows response optimization for a wide range of conditions and receiver passbands. The i.f. signal is externally demodulated, then h.f. filtered and fed back to the receiver's 'diode'a.f. input. Independent tuning of this external stage allows it's response to be frequency shifted, and weak signals that are passband tuned for minimum interference may receive additional selective gain or benefit from a slanted response. Night time 9kHz whisles may also be reduced to tolerable levels without resorting to treble cutting, narrow i.f. passbands or to phase distorting notch filters.

Alone, this stage had two disadvantages. It did nothing for carrier notched selectively faded signals, and, in reducing block filter and splatter distortions it dampened audio bandwidth. Additional circuitry was clearly justified and the following development remains successful.

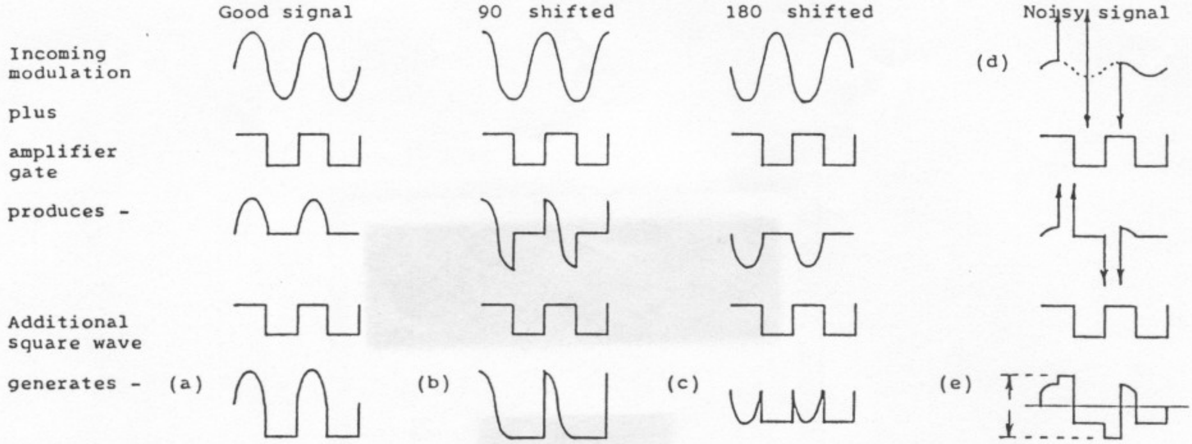
A separate free runing oscillator is tuned to and synchronized with the wanted carrier. It's output is used to turn the external i.f. on and off at 455kHz in a configuration that adds an in phase, but inert, square wave to the tuned carrier. See waveform sheet. I.f. modulation levels are now always less than 100%, and irrespective of bandwidth the signal cannot possibly suffer carrier related filter, fading or receiver mistuning distortions. The new large amplitude i.f. carrier also drives simple envelope detectors well into the linear portion of their dynamic characteristic and all demodulated signals suffer less from harmonic distortion and noise "capture". I.f. amplification is carrier synchronous and this favours wanted modulation, especially weak signals. Noise and splatter interferences are only partially in phase and therefore only partly amplified. Transient noise spikes are clipped by supply limitations within the external stage and little affect audio.

The full synchro-i.f. stage circuit diagram is shown below. It suits any receiver that provides a 10 to 100mV rms. 455kHz i.f. output at 50Ω. With normally modulated signals it's audio output into a 47 to 100kΩ load is fifty times the i.f. input; directly compatible with valve sets but a pre-set volume control is necessary when used with solid staters.

Receiver i.f. signals are fed via C1 to L1. With the carrier function switch set to 'direct' and VR1 turned fully clockwise L1 is swamped by the low impedance source. Stepped up signal appears across VC1 and is buffered by TR1 and TR2. TR3 provides i.f. amplification and components C6 to L5 demodulate and filter audio. Gradual anti-clockwise rotation of VR1 sharpens selectivity by first reducing L1 damping, then allowing resonance and finally positive feedback from TR1 via source resistor R3. See curves of four measured responses;- flat, 8kHz, 4kHz and sharp. The centre frequency, f_o, is normally 455kHz though VC1 allows +/- 5kHz shifting to optimise receiver signals, i.e. one is not limited to double sideband AM reception, either sideband may be amplified or offset receiver tuned.

With the carrier switch set to 'synchronous' TR4,5,6,and 7 are brought into operation. I.f. signal is stepped up by L6, buffered by TR4 and used to synchronize the L7/TR5 oscillator at carrier frequency. VR2 is pre-set to just oscillating and VC2 allows +/- 5kHz tuning, for synchronous sideband amplification. Actually, because AM sidebands are themselves phase coherent, the oscillator remains synchronous with deeply carrier notched selectively faded signals or when using exalted carrier tuning techniques. TR6 amplifies oscillator output at high impedance and produces square wave drive to switch TR7 on and off 180 degrees out of phase with the signal at TR2. TR3 bias is maintained by L2 but it does not amplify unless TR7 is conducting. Now, as carrier voltage at the emitter of TR2 becomes positive, TR7 conducts, TR3 amplifies and produces output across L3. TR7 and TR3 turn off at the same instant that TR2 swings negative, amplification ceases and L3 returns to quiescent level. When TR3 amplifies R5 and 7 accurately control gain, prevent instability and reduce TR7 noise injection into L3. In this mode all AM signals sound good when accurately tuned and locked, but because only one half of the modulation envelope is used recovered audio suffers a just perceptible degradation in transient attack; thus the 'enhanced' position was included. Here the synchronous square wave is linearly added to normally amplified TR3 output, and very pleasing low distortion audio results. Using good quality amplification and loudspeaker equipment BBC and IBA broadcasts have produced impressive sounds, with measured daytime signal to noise ratios up to 70dB at full audio and 16kHz i.f. bandwidths.

SYNCHRONOUS PRODUCT AMPLIFICATION.



In (a) modulation is unaffected. With a carrier fade the square wave maintains detector coherence. With (b) detector output is 2.5dB down, while in (c) modulation is inverted and output is very low. Detection at (d) would turn the wanted signal into noise; here detector switching is controlled by the noise, not the signal. Carrier controlled amplifier gating and square wave addition produces (e). Here, the square wave controls detector switching, thus, demodulation is carrier coherent. Noise and interferences, chopped by synchronous switching and clipped by supply rail limitations, are less able to mask recovered audio.

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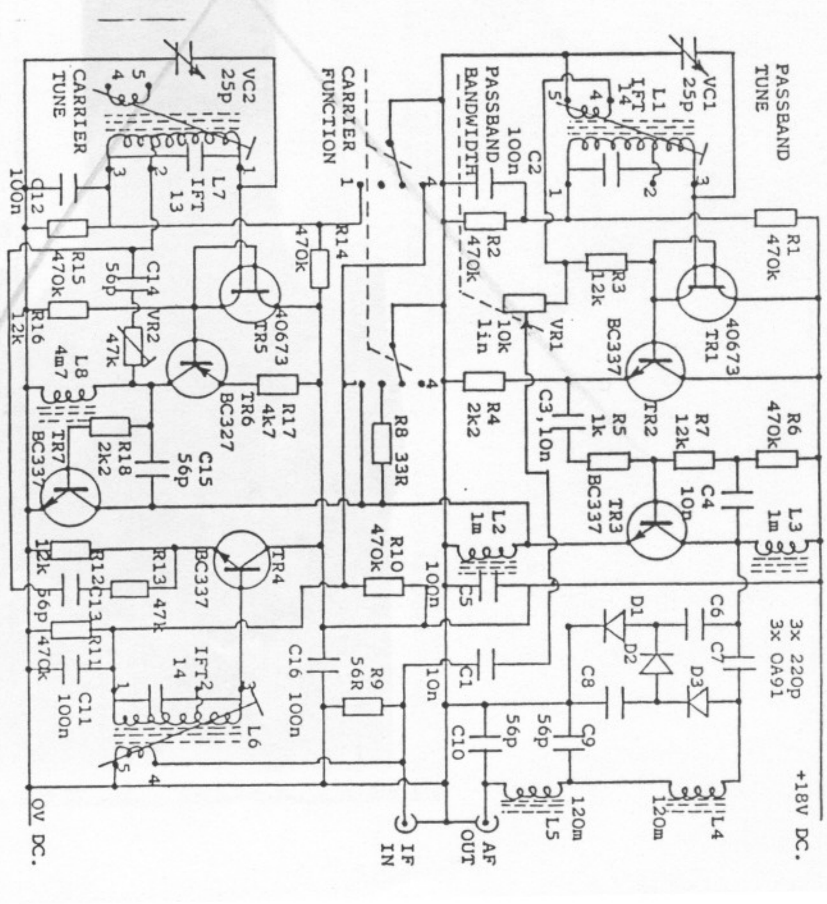
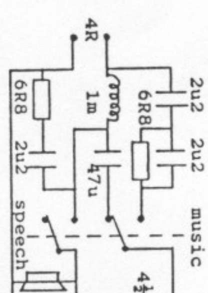
SYNCHRONOUS CARRIER EXALTATION.

The modulation percentage is now always less than 70%, and distortions caused by receiver passband ripples, demodulator inadequacies, slight propagation disturbances or over enthusiastic broadcasters are considerably reduced. All waveforms, except noisy, have been viewed on an oscilloscope.

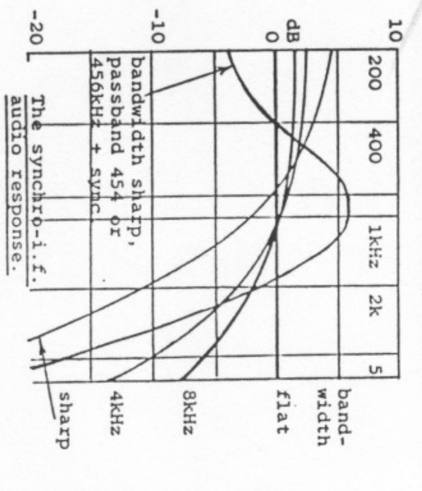


The Synchro-i.f. circuit diagram.

Carrier function sw.	
Posn 1	DIRECT (out)
Posn 2	ENHANCE
Posn 3	SYNCHRONOUS
Posn 3	SSB (no sync)



The loudspeaker circuit.
1x 4½ inch 4R, RS 249-902
2x 8 inch 8R, RS 248-886



The synchro-i.f. audio response.

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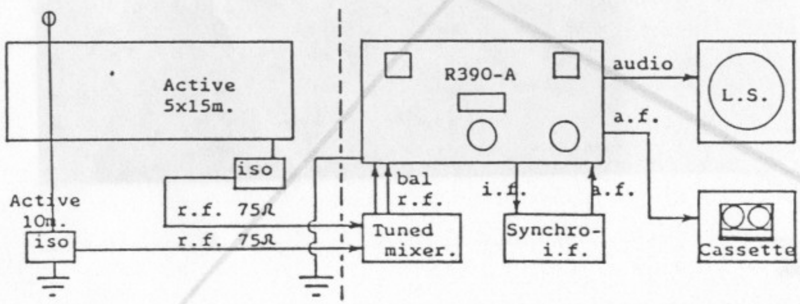
For SSB TR4 is off. L7/TR5 form a tunable free running oscillator and TR3 acts as a product amplifier. Signal at L3, the carrier from TR7 modulated by ssb from TR2, is then demodulated normally and produces quality audio. VC1,2 and VR1 provide sideband shaping to augment the receiver's normal passband response.

I normally bandscan and tune for best reception in 'direct'. When DXing VC1,2 and VR1 are adjusted as necessary. If the signal is good I select 'enhance', if poor or propagation disturbed then 'synchronous' is chosen.

When the tuned mixer and synchro-i.f. are together used with any receiver then a novel and exceptional facility exists. If by careful application of positive feedback the mixer is sharply tuned to one sideband of a weak signal then the receiver sees a peak in modulation frequencies between say 500Hz and 2.5kHz and the carrier plus it's aetherial heterodynes are reduced. The synchro-i.f. can then regenerate the carrier and selectively amplify only those signals that are phase coherent and already boosted.

Each unit offers its own advantage, but together they are amazing. All AM broadcast and communication signals are improved - good quality, weak, noisy, splattered and severely fading - indeed, since construction both units have remained connected and deemed indispensable.

The preparation and writing period for this article has been one of continuing development. My MW system is now more analytical, less fatiguing and easily controlled -



That's it!

I've spent hundreds of hours studying books and periodicals, constructing and dismantling loops, designing and testing circuits, analysing theory and examining results -- until -- at last-- a satisfaction has dawned.

It is now my pleasure to sit back -- to enjoy quality reception - - to chase elusive DX or listen to other people's locals -- wondering - - at the magic that surely survives in radio's oldest broadcast band.

Good listening,

Graham

G S Maynard, 16 Woodford Avenue, Newtownabbey, N. Ireland, BT36 6TL.

Mail order;- Iso-amp, 1m.Wloop+amp, tuned mixer, synchro-i.f., send SASE.

18th MAY 1987.