The Art of Alignment

The aim of this demonstration is to give an insight into the need for alignment of radios or TVs and to show how to align a typical radio. I'll also briefly mention TV alignment and demonstrate the use of a signal generator with a wobbulator function and, if time permits, the use of a spectrum analyser.

I'll be using the following equipment

Philips PM5324 RF signal generator

Trio CS5270 100MHz oscilloscope

HP8558 Spectrum Analyser

Black Star Meteor 600 Frequency counter

Demonstration board with two tuned circuits

Battery valve radio Vidor CN435Z

Jasonkits AM/FM tuner

Test loop

Why do we need alignment?

First here's a brief history of the development of radio and the need for alignment.

In the early days of radio, just over 100 years ago, there were very few radio stations in operation and these were commercial point to point systems primarily for communication with shipping.

The transmitters were fairly crude by todays standards using a spark system or high frequency alternators. There was no real broadcasting to the general public. The receivers were usually a simple tuned circuit and a detector, what we'd call a crystal set, which were adequate for the time.

Although there were many early experiments aimed at transmitting speech, virtually all transmissions were using morse code.

As the century progressed and better technology, in the form of valves, became available it was possible to build a transmitter that could produce a cleaner carrier wave at higher frequencies. The spark transmitters were similar to arcing contacts and produced a broad band of signals even though tuned circuits were used in the transmitters. High frequency alternators were limited to 10s of kilohertz (or should that be kilocycles).

After World War 1 there was rapid progress in the development of transmitters and receivers and it became possible to transmit speech and music. In the UK this culminated in the formation in 1922 of the British Broadcasting Company, where a group of manufacturers came together effectively to promote their receivers by providing a broadcasting service to the general public. This became the British Broadcasting Corporation in 1927.

The receivers in use ranged from a simple crystal set to sets using two or three or sometimes more valves. As receivers using valves had to pay a duty for each valve used, the crystal set was extremely popular. If you want to read more on the development of broadcasting and the manufacturers, the book “The Setmakers” is highly recommended.

In the early days a crystal set would suffice and provided enough signal to allow listening on headphones if the transmitter was local. The main advantage of a crystal set was that it cost nothing to run but there were several disadvantages, the sensitivity was low meaning it could only receive local stations, only one person at a time could listen on headphones and its selectivity was poor. The latter was a result of only having a single tuned circuit as shown in figure 1. There were not that many transmitters so the poor selectivity as can be seen in figure 2 was not a major problem.

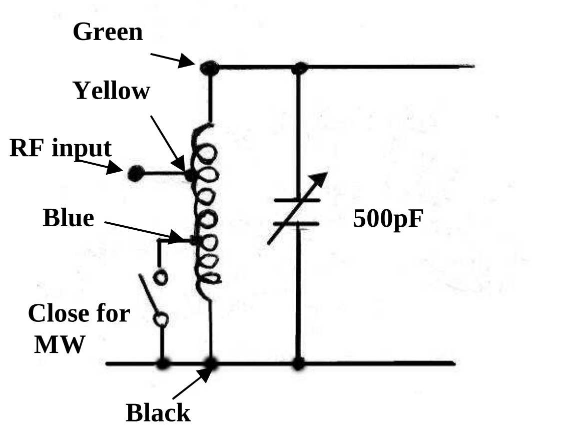


Figure 1 - Single tuned circuit using a Repanco DRR2 coil

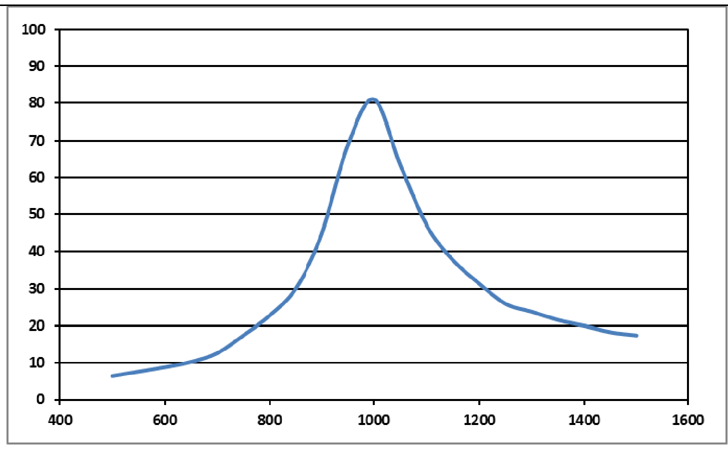
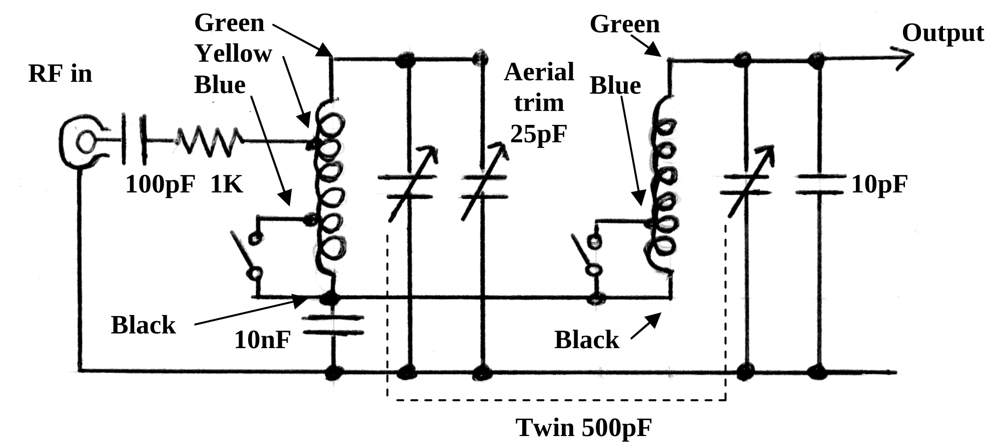


Figure 2 - Frequency response with the circuit tuned to 1MHz

To improve the selectivity two tuned circuits can be coupled together as shown in figure 3 with figure 5 showing the difference in selectivity.

As the 20s progressed more stations came on the air not only in the UK but overseas. More people bought, or built, radios and wanted to listen without having to use headphones. This meant using valves, which were used to amplify the audio enough to drive a loudspeaker and to amplify and detect, or demodulate, the signal. The detectors generally used feedback to get the valve to the point of oscillation, which increased the sensitivity and the selectivity but was prone to oscillating and wiping out reception in the local area if adjusted incorrectly. The sets still only used a single tuned circuit though.



Switches closed for MW

The 10pf capacitor is to allow the aerial trim capacitor to be set to its nominal centre value.

The demo unit has a switch across the 10nF capacitor to demonstrate a single tuned circuit.

Figure 3 – Demo unit with twin tuned circuits using DRR2 coils. The resistor and capacitor on the input represent an “artificial aerial” to prevent the low output impedance of the signal generator affecting the tuned circuit.

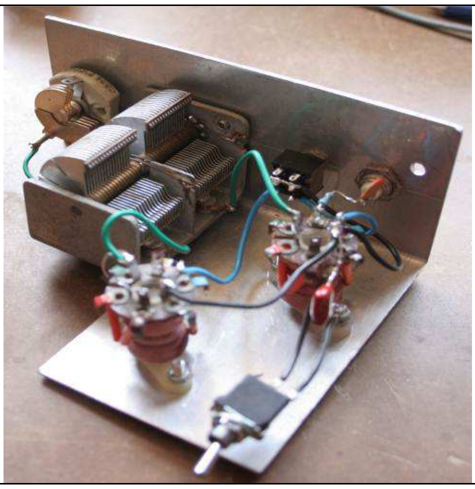


Figure 4 - Twin tuned circuit demo unit. The switch is to allow the unit to demonstrate the single tuned circuit.

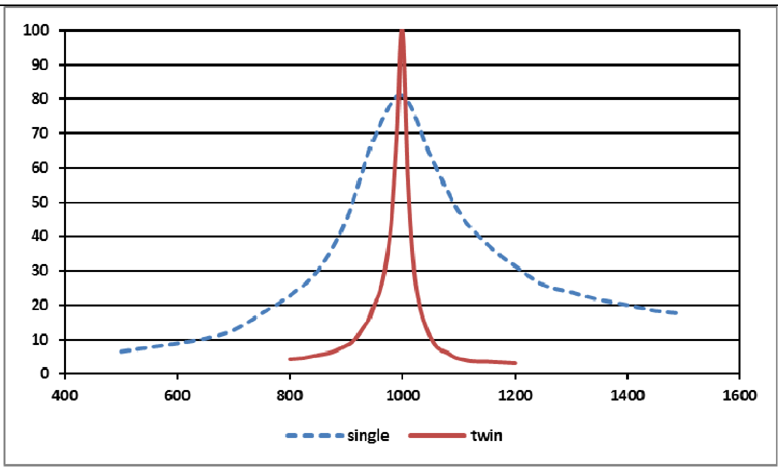


Figure 5 - Frequency response of the twin tuned circuit at 1MHz compared to the single tuned circuit.

To increase the sensitivity an RF amplifier can be added in front of the detector. A system of describing receivers came into use similar to that used for describing the wheel arrangements on steam locomotives. For radios it was of the form x-V-y where x was the number of valves before the detector, V was the detector and y was the number of valves after the detector so a 2 valve set with a detector and one audio amplifier would be a 0-V-1.

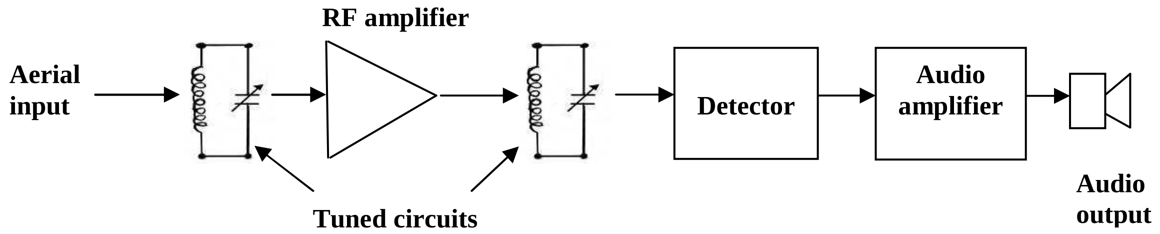


Figure 6 - TRF block diagram (1 - V - 1)

Adding RF stages and extra tuned circuits brought a new problem as to get the best results all the tuned circuits had to be tuned to the same frequency. Initially each RF stage would have had its own tuning control meaning several controls had to be operated to tune into a station. This was fine for the enthusiast but the general public wanted something simple to operate so the controls for each stage were ganged and one tuning control was used, adjusting all the tuned circuits simultaneously. This brought a new problem as all the tuned circuits had to be set so they were all on the same frequency as the tuning control was rotated.

Even if all the coils and capacitors were identical, small variations in the capacitance and inductance of each tuned circuit due to layout differences meant the resonant frequencies did not always track each other leading to a reduced output.

The inductors for each tuned circuit were made variable over a small range and small trimmer capacitors were added across each of the tuning capacitors. These allowed the differences in the tuned circuits to be minimised as the tuning control was rotated over the required frequency band. Thus was born the art of alignment.

Adding extra RF stages also brought a more significant problem. As the signal was amplified through the receiver it became larger and radiation of the amplified signal from a later stage could feed back to the aerial and cause the whole receiver to oscillate unless the receiver was well screened. It was also not easy to keep all the tuned circuits tracking each other over the whole frequency range. Nevertheless several successful receivers were made using this type of circuit. Probably the most well known were the Philips Superinductance receivers.

The Superhet

However the days of these Tuned Radio Frequency (TRF) receivers were numbered when the superhet receiver became feasible. This was originally developed at the end of the World War 1 by Edwin Armstrong to help receive enemy radio transmissions but as it used more valves than a TRF it was initially only used by the military.

Superhet is an abbreviation of Supersonic heterodyne where the incoming signal is mixed, or heterodyned, with a local oscillator. This produces two new signals the sum and the difference of the two frequencies.

$$F_{sum} = F_{lo} + F_{sig}$$

$$F_{diff} = F_{lo} - F_{sig}$$

At the output of the mixer a tuned circuit extracts just the difference signal. This can then be amplified and demodulated as before. However this amplifier, known as the Intermediate Frequency (IF) Amplifier, can now be at a single frequency, which is different to the signal frequency. The amplifier can use fixed tuning and have a high gain and any radiation from it will not be at the signal frequency so will not cause the receiver to oscillate. Also it's much easier to build an amplifier to work at a single frequency with good selectivity than one that has to be tuneable over a wide range of frequencies.

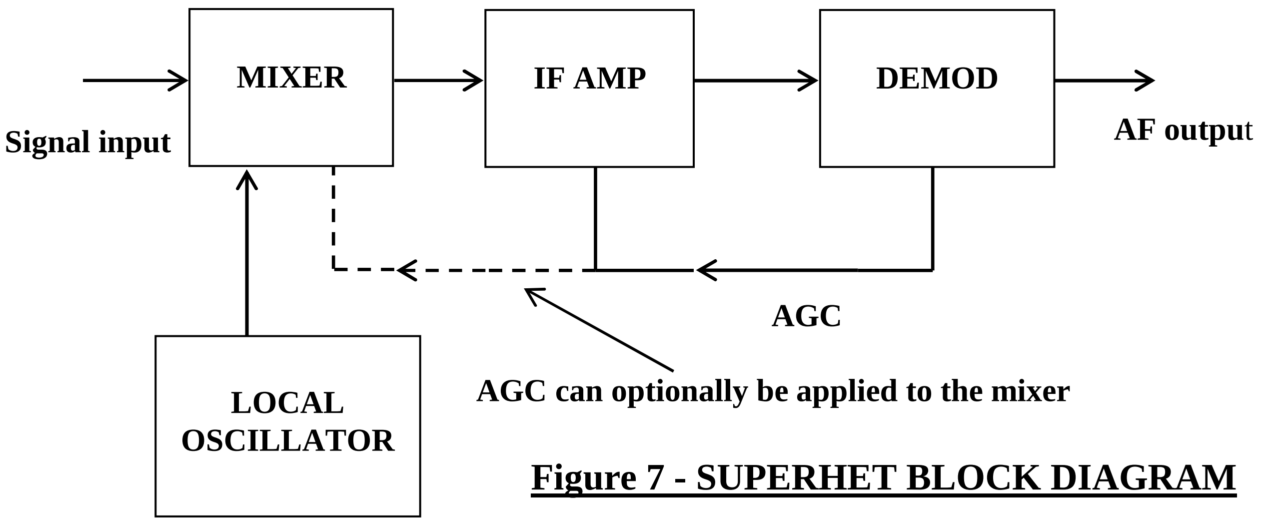


Figure 7 - SUPERHET BLOCK DIAGRAM

Although the local oscillator can be higher or lower than the signal frequency to get the same IF it is the general convention that the local oscillator frequency is higher than the signal frequency.

Take a typical medium wave receiver covering 531kHz to 1602kHz with an IF of 470kHz. If the local oscillator is above the signal frequency its range is 1001kHz to 2072kHz a ratio of 2.07:1. If the local oscillator frequency were below the signal frequency its range would be 61kHz to 1132kHz a ratio of 18.6:1. It's much easier to design an oscillator for a range of 2:1 than one for a range of 18:1.

In the 1930s with the increasing number of stations the superhet gradually took over. One other advantage of the superhet was the ability to control the gain of the IF amplifier by feeding a control voltage from the demodulator stage. This became known as Automatic Volume Control (AVC) or more correctly Automatic Gain Control (AGC) and kept the volume at a constant level irrespective of the strength of the incoming signal. This voltage could also be used to drive a tuning indicator in the form of a magic eye to indicate the optimum tuning position.

In the early days of the superhet the IF was low, sometimes in the order of 20kHz to 30kHz, but over the years the IF for broadcast AM receivers became standardised at between 450kHz and 480kHz, a range which fell neatly into the gap between Long Wave and Medium Wave frequencies.

Although the superhet became the most common type of radio it has several other issues, which are different to the TRF issues. One is the image frequency. If you look at the equations it should be obvious that there are two signal frequencies that will give the same difference

The wanted signal $F_{sig1} = F_{lo} - F_{if}$

The unwanted signal $F_{sig2} = F_{lo} + F_{if}$ at twice the IF away from the wanted signal.

Provided the unwanted signal is far enough away from the wanted signal the aerial circuit will attenuate it so that it is not audible. With a typical IF of 470kHz the image frequency is 940kHz from the wanted signal. This can still cause a problem on the Medium Wave, as the image frequency will still be in the Medium Wave range if the set is tuned to the low frequency end. E.g. If the receiver is tuned to 531kHz with an IF of 470kHz the image frequency will be at 1471kHz.

One other issue is the aerial tuned circuit and the local oscillator tuned circuit are both tuned to different frequencies. This can make it difficult for them to track with a constant frequency difference (the IF) especially if the tuning capacitors are identical e.g. the ubiquitous twin 500pf tuning capacitor used in millions of sets. What you have to remember is that it's the local oscillator frequency and the IF that determine what frequency the radio is tuned to and the aerial circuit serves to reject the image frequency and peak the received signal. That is why you always have to set the local oscillator range first before adjusting the aerial circuits. The usual method to set the local oscillator at a higher frequency is to add a padding capacitor (C9 in figure 11) in series with the local oscillator variable capacitor or coil. Another method is to have the two sections of the tuning capacitor with different values and with the vanes shaped so that when used with the correct aerial and local oscillator coils the error frequency difference will be minimal. This is OK for a manufacturer making thousands of the same radio where they can afford to have a custom part made for the radio but for the small manufacturer or the home constructor it is easier to use a standard part and put up with the errors. Of course one way to overcome this is to have an aerial trimmer in parallel with the aerial tuning section to peak the signal.

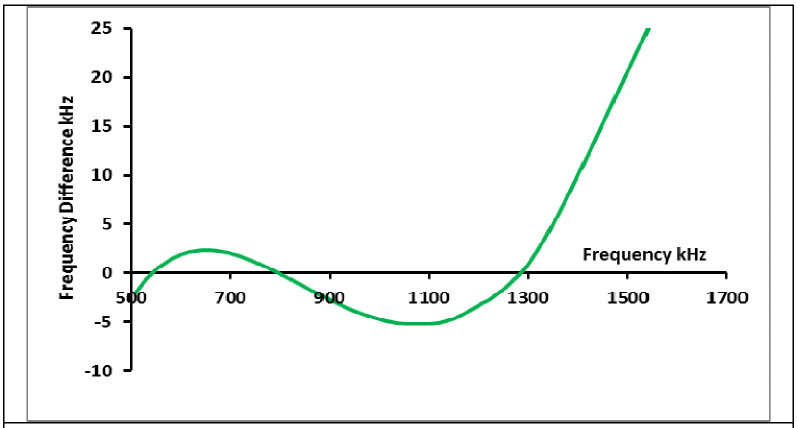


Figure 8 - Typical difference in aerial and local oscillator frequencies with twin 500pF variable capacitor.

If you do the calculations they will show that the aerial and local oscillator frequencies will only be the IF apart at three points over the tuning range as shown in Figure 8. At all other points there will be an error of typically up to 15kHz - 20kHz but it will be relatively small and almost insignificant when compared to the bandwidth of the aerial circuit.

Alignment

Now that we've seen why it's necessary to align receivers it's time to demonstrate aligning a receiver.

Figure 9 - Philips PM5324 signal generator

For this I'll be using a Philips PM5324 signal generator. This has ranges covering 100kHz to 110MHz with either Amplitude Modulation (AM) or Frequency Modulation (FM) making it ideal for checking and aligning both AM and FM domestic receivers. It also has two ranges covering 400kHz to 500kHz and 10.3MHz to 11.1MHz specifically for aligning the common AM and FM IF frequencies. As if this wasn't enough it can also sweep over a limited range on the IF settings and the 75 to 110MHz ranges. This is also known as a wobbulator.

Alignment tools

One important item is the tool you use to adjust the coils and capacitors during the alignment procedure. Using the wrong tool can irreparably damage the capacitor or more likely the coil being adjusted.

The cores of most coils can have a variety of methods to adjust them. A slot is probably the most common but hexagonal holes are also used. Using the wrong tool in a slot type adjustment can result in the core breaking. This is a common problem if the phantom twiddler has been at the set with his screwdriver.

Manufacturers also lock the cores in place so that the alignment doesn't alter during transportation. This can be done in a variety of ways. Pouring wax into the core, locking nuts and a rubber band between the core and the former are some of the common ways. Some cores are very tight in the former usually by design to alleviate the need for an additional locking mechanism.

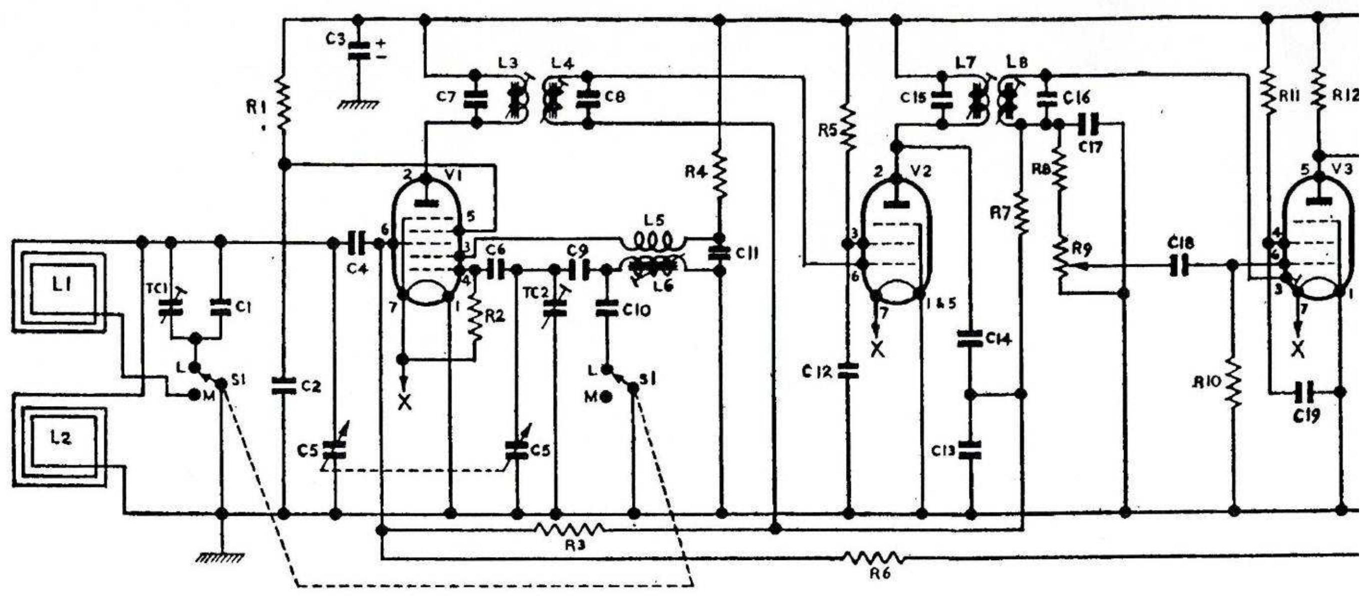
Never apply excessive force to a core as you are more likely to break it. Also note that in some cases the alignment can change as the rubber locking band has perished and the core is loose.

Figure 10 - A selection of adjustment tools

The notes above refer specifically to coils but there are similar requirements for the trimmer capacitors. In some cases the same tool can be used for both capacitors and coils.

Figure 10 shows some of the adjustment tools I have collected over the years. One came free with a tuner kit and others were free gifts on magazines. The important thing is to try to use the tool appropriate for the adjustment. All the tools are insulated or are made of an insulating material with a small metal blade. This is important for two reasons, one the circuit may be live either because it is an AC/DC set or the adjustment is in a circuit connected to the HT rail. The second is that a large piece of metal near a tuned circuit can affect the tuning.

Now let’s look at a simple AM radio. This is a Vidor CN435Z battery valve portable. It covers both long and medium wave has an IF of 470kHz. The service data is easy to come by and this includes the alignment instructions.



Alignment Procedure

I.F. Set to M.W. and short-circuit front section of tuning gang. Inject a 470kc/s signal between rear section of gang and chassis. Adjust cores L8, L7, L4 and L3, in that order, and repeat for optimum results.

R.F. Set gang to maximum capacitance and check that the line separating M.W. and L.W. scales coincides with the station indicator on front panel. If adjustment is necessary slacken the cleat screw on the tuning-control knob. Rotate knob sufficiently so that the scale is in the correct position. The R.F. adjustments should be carried out with batteries in their correct position, the lid open in its normal position and the panel raised to the minimum height required to reach the trimmers and oscillator-coil core. Do not connect generator directly to frames or tuning gang.

M.W. Set tuning control to 500m alignment mark which coincides with station indicator on the front panel. When using “Polar” tuning gang the calibration mark lower than 500m should be used. For sets with “Plessey” gang, the calibration mark higher than 500m should be used. Inject a 600kc/s signal by clipping “hot” side of generator output to chassis. Adjust L6 for maximum output. Set gang to mechanical minimum and inject a 1600kc/s signal. Adjust TC2 for maximum output. Repeat these operations for optimum results.

L.W. Set tuning control to 1200m. Inject a 250kc/s signal. Rock gang for maximum output. Adjust TC1 for maximum output.

Figure 11 - Vidor 435Z - Mixer, IF and Detector Circuit and Alignment Instructions

We’ll start with the IF. Now when these are manufactured, the manufacturers of the IF transformers will almost certainly have tuned them to approximately the correct frequency as specified by the radio manufacturers. This means that the IF would have needed very little alignment in the factory once the set was built.

The process is basically inject a signal at the specified IF frequency and adjust the last IF core for maximum output. In the Vidor radio above this would be the final IF secondary, L8. Then move back towards the mixer adjusting, in order, the last IF primary, L7, the first IF secondary, L4, and finally the first IF primary, L3. For each tuned circuit adjust the IF core for maximum output. In a typical valve IF amplifier each IF transformer normally has two tuned circuits, primary and secondary. This differs from the typical IF transformers used in transistor radios where usually only the primary side is a tuned circuit.

Note that the alignment procedure tells you to short circuit the front gang of the tuning capacitor. This disables the local oscillator preventing any strong local signals from interfering with the alignment. Once the IF alignment is completed the short is removed. This is not always necessary as the IF can be aligned with the local oscillator running.

We can use the signal generator in this way, injecting, in this case, a signal at 470kHz and peaking the IF transformer tuned circuits from the last to first as described in the alignment instructions, however we'll use the wobbulator function of the signal generator which will actually show the frequency response of the IF amplifier.

When I originally planned this talk I had intended to use the Vidor radio as an example of how to align a typical radio and set out the partial circuit and alignment instructions shown in figure 11. However when I started checking the alignment of the Vidor and the Jasonkits AM/FM tuner I found it easier to demonstrate the alignment procedure on the Jasonkits tuner. The procedure is essentially the same. Inject a signal at the required IF frequency, 472kHz for the Jasonkits tuner, start at the final IF transformer and work forward to the first IF. I'll still be using the Vidor to demonstrate some features of the alignment procedure, primarily Long Wave alignment as the Jasonkits tuner is FM and Medium Wave only.

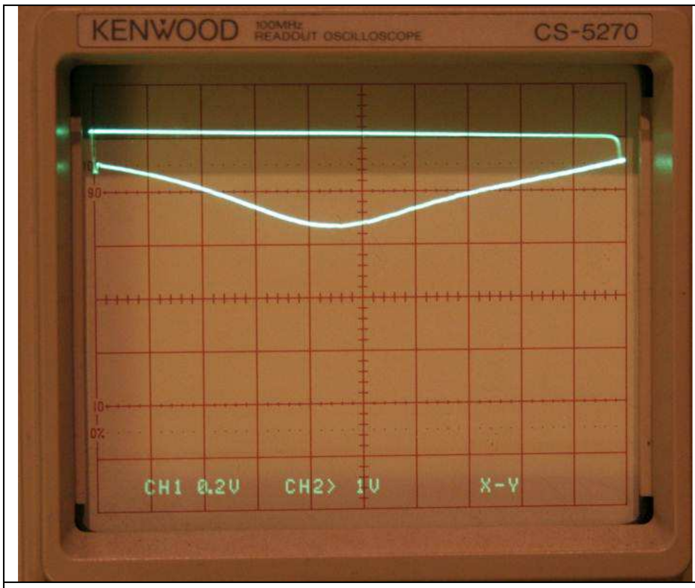


Figure 12 - IF response - off tune

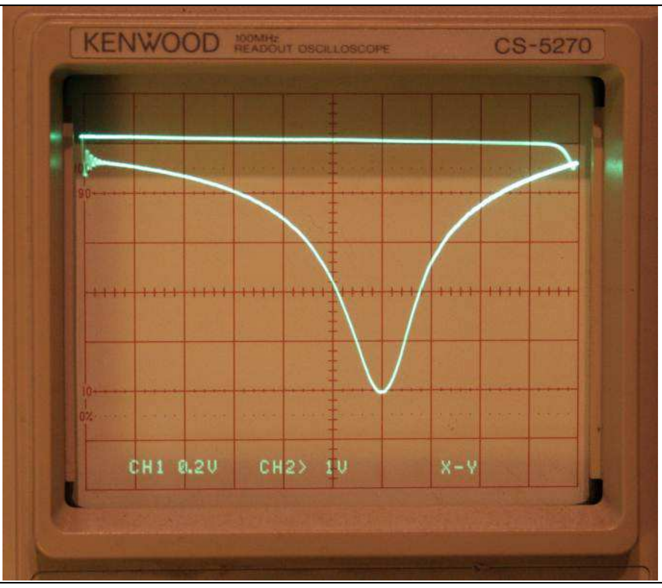


Figure 13- IF response - on tune

Once the IF is aligned the local oscillator needs to be set to the correct frequency range. A signal at the low end of the frequency range is injected and, with the tuning control set to the LF end of the band, the oscillator inductor tuned for maximum output. The injected signal is then changed to the high end of the frequency range, the tuning control set to the high frequency end and the oscillator trimmer capacitor adjusted for maximum output. The process is then repeated making smaller adjustments each time until no further improvements can be made. In some cases the alignment instructions tell you to set the tuning to specific points on the dial and inject a specific frequency. This explains why you can sometimes see marks on tuning dials that have no apparent purpose.

This process is usually done on medium wave first as long wave reception is sometimes achieved by switching a capacitor across the local oscillator coil to reduce its frequency.

Once the local oscillator is set up, move on to the aerial coil. As with the oscillator set the tuning to the low frequency end, set the signal generator to the low frequency and adjust the aerial tuning inductor for maximum output. This is not always possible with a frame aerial but can be done where separate coils or a ferrite rod aerial are used. Then change the tuning and signal generator to the high frequency and adjust the aerial trimming capacitor for maximum output and if necessary repeat the process.

If there are separate coils for each band then the local oscillator and aerial coils could be set up in any order. If you have access to the alignment instructions for the radio these will usually detail the order in which to adjust the coils and trimmer capacitors and which frequencies to use.

When it comes to aligning the local oscillator and aerial coils of a radio with a frame aerial or a ferrite rod aerial how do you inject the signal? The Vidor alignment instructions state “Do not connect generator directly to frames or tuning gang”. So how should you connect the generator? If there is an external aerial socket you can use that but it may be advisable to connect the signal via an “artificial aerial” (a low value capacitor and resistor in series with the signal generator output). This minimises the loading effect of the signal generator on the aerial tuned circuit.

Alternatively if a car radio aerial socket, popular on many 1960s transistor radios, is fitted use that, but not all radios have this. You can connect the signal directly across the aerial coil but this can affect the tuning due to the extra capacitance. If you do this use the artificial aerial circuit to minimise the loading effect.

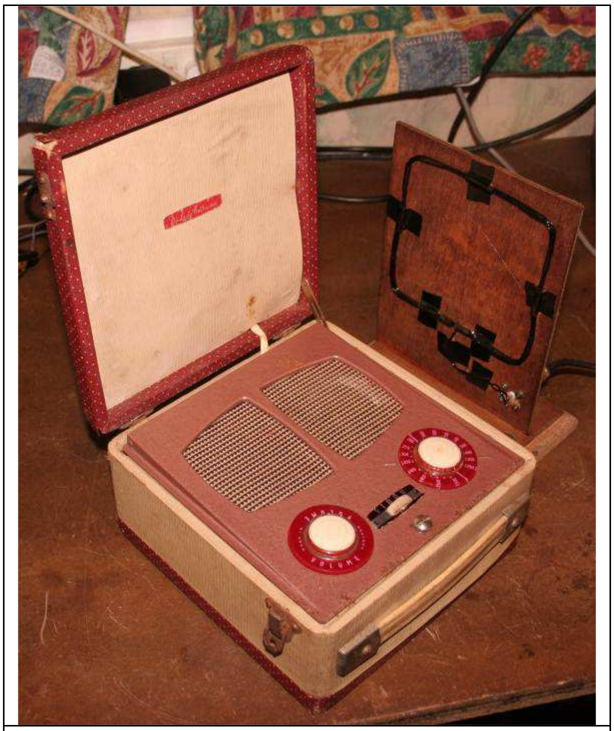


Figure 14 - Loop and Vidor radio

One other way, which will not affect the tuning, is to use a loop connected to the signal generator output and placed a few inches from the aerial. This described in the Bush service data for the BAC31 radio where it suggests a loop of 3 turns the same size as the frame aerial. You can either build one like that shown in figure 14 (details of which are in the appendix) or use one of the loop AM aerials supplied with most modern stereo units.

You may have to adjust the position to get the best signal pick up but it’s a simple and effective way of connecting a signal for alignment purposes. It is also possible to adjust the level of signal by moving the loop closer or further away from the radio.

FM alignment

The alignment process is very similar for an FM tuner but here we have to set up the FM demodulator after the IF is aligned. This is where the wobbulator function is very useful as it allows you to see the frequency response of the actual demodulator.

The alignment instructions for the Jasonkits tuner give details of the FM alignment with and without the use of a wobbulator for FM but the AM alignment instructions are only for a signal generator. I suspect it was considered that FM alignment was more critical as FM was very new when the original construction article was published in 1956.

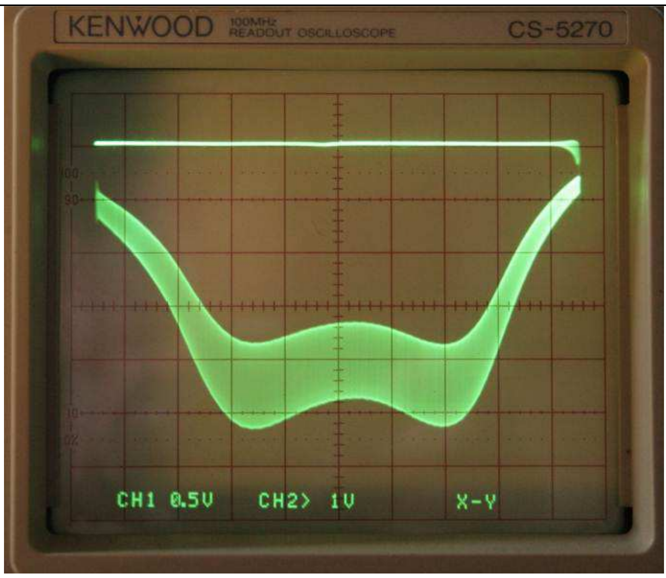


Figure 15 - FM IF frequency response

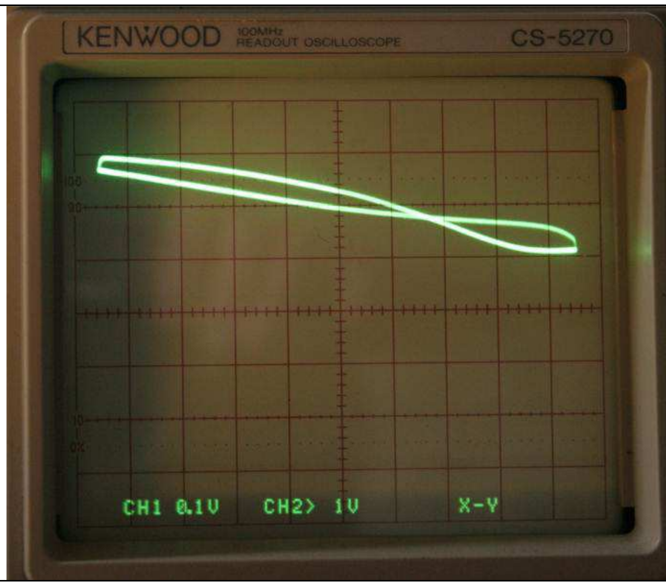


Figure 16 - FM demodulator before alignment

Figure 15 shows the IF frequency response of the FM IF amplifier. There is some residual IF signal which accounts for the width of the signal trace. Note that the flat line at the top is due to the wobbulator where the signal is blanked off while the trace returns to it starting position.

Figure 16 shows the response of the ratio detector with the coil off tune and figure 17 shows the response with the coil tuned.

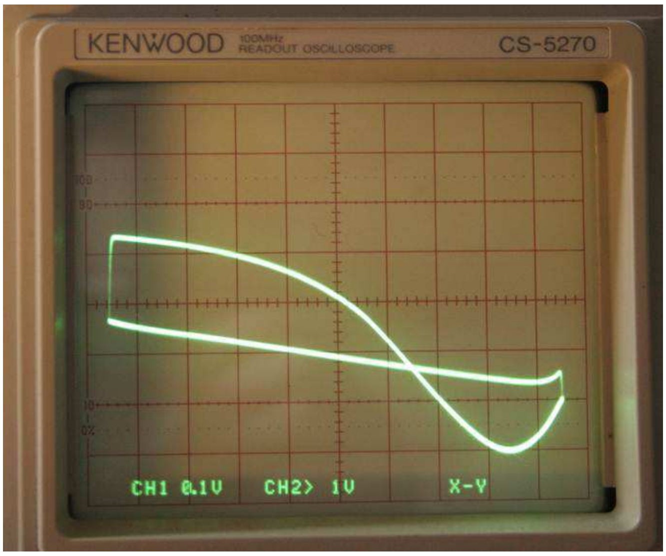


Figure 17 - FM demodulator after alignment

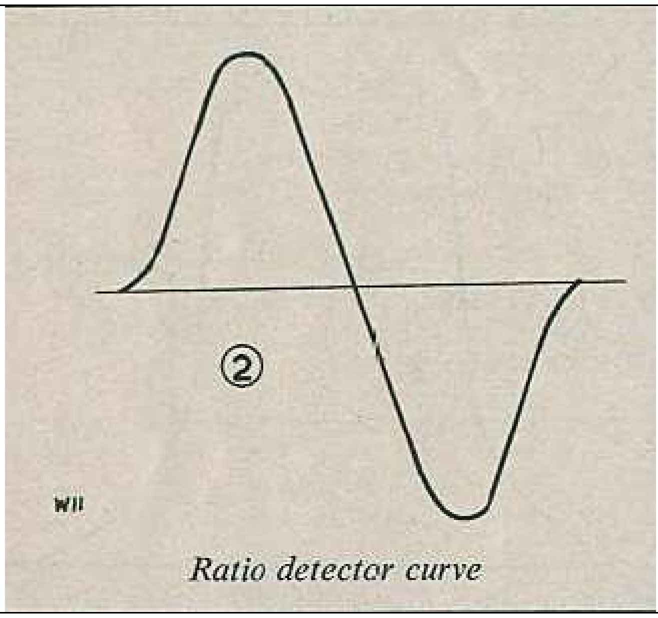


Figure 18 - S Shaped frequency of the ratio detector.

The response should be the classic S shape as shown in figure 18, taken from the original article. You can see the right hand side of the trace does follow the S shape but the left side does not. However the diagonal line between the maximum and minimum points is the part of the frequency response that actually demodulates the signal so provided that is linear there should be minimal distortion to the audio.

This looks like a fault but on investigation it looks more like a characteristic of the tuner.

TV Alignment

Aligning a TV IF strip is a little more involved as it has a wider bandwidth of 3.5MHz (405 line) or 5.5MHz (625 line). There is also the question of setting the IF frequency response to take into account the vestigial sideband. Alignment instructions typically give a set of spot frequencies to inject and which coil to adjust to obtain the required response.

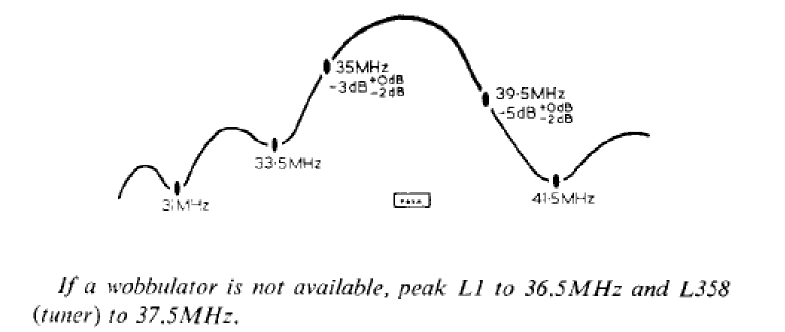


Figure 19 - From the alignment information for the TCE 1590 TV

Figure 19 shows the IF frequency response for the TCE 1590 portable 625 line B&W TV taken from the service manual. The sound IF is at 33.5MHz and the vision IF is at 39.5MHz. After video demodulation this produces the 6MHz intercarrier sound IF. In contrast to the typical 405 line IF the 1590 IF amplifier is basically a wideband amplifier with tuned circuits to reject adjacent carriers and to set the correct response at the vision carrier. It is simpler with fewer adjustments required. There are only 4 coils to adjust plus the FM sound coil. Compare this with the 17 adjustable coils in the Bush TV76.

Note the response at 39.5MHz, the vision IF, is lower than the peak. This is to account for the vestigial sideband of the transmitted signal. The dip in the response at 41.5MHz is a throwback to the 405 line era as it's the rejector for Channel 1 sound. In 1972 when the 1590 TV was developed 405 line TV was still in operation and would be for another 13 years hence the need for the Channel 1 sound rejector.

Alignment of a TV IF should not be undertaken lightly as it is a complex procedure. It was made worse by the introduction of colour where the phase response of the IF became more critical. Phase errors in a colour signal can cause incorrect or less saturated colours to be displayed. Teletext made the requirements much more critical as the teletext signals are on the extreme limit of the 8MHz channel bandwidth. Fortunately for the TV manufacturers around the time teletext was being fitted to more TVs the SAWF (Surface Acoustic Wave Filter) became available. These devices could be set up to provide the required IF frequency response by the component manufacturers reducing the number of IF adjustments significantly and making the IF response more consistent from set to set.

To show how involved the alignment procedure for a TV can be, there is a copy of the alignment instructions for the Bush TV76 405 line TV in the appendix.

Notes on Alignment

Please note that the frequency response plots in figures 12, 13 and 15 are inverted compared to the plots of figures 2 and 5. This because the measurement point is effectively across the AGC rail which goes more negative as the signal increases. Some oscilloscopes can invert the signal to show a more conventional view however the oscilloscope used only inverts on the CH2 input which has to be used for the X input.

It is usual for the alignment instructions to use the audio output as an indicator but a meter or oscilloscope connected to the AGC line can be a more accurate indicator.

It may be necessary to reduce the signal generator output when the IF tuned circuits are approaching final alignment to prevent the IF amplifier from being overloaded.

The Spectrum Analyser

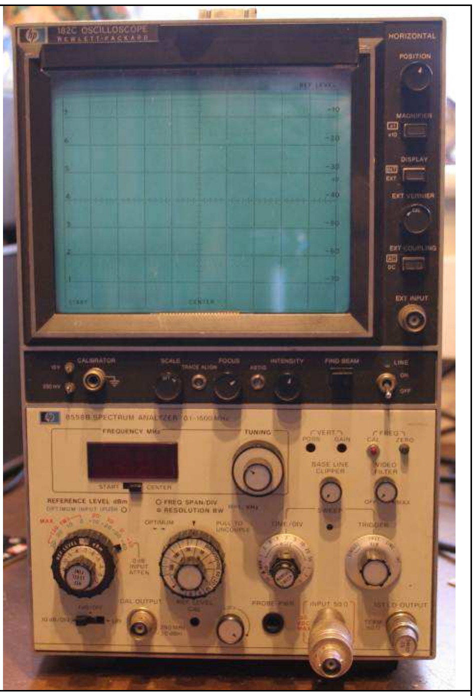


Figure 20 - HP 8558 Spectrum Analyser

The Spectrum Analyser can be a very useful tool especially for RF work. It looks like an oscilloscope but whereas the oscilloscope looks at signals in the time domain the spectrum analyser looks at signals in the frequency domain as shown in figures 21 and 22.

The display is actually an HP182 oscilloscope with space for two plug in modules. For use as an oscilloscope a Y amplifier module and an X (timebase) module can be plugged in. For use as a spectrum analyser both spaces are occupied by the single HP8558 module, which generates both the X and Y signals to drive the display.

A Spectrum Analyser is basically a receiver that can be swept over a frequency range, in this case from 100kHz to 1500MHz, and plot the amplitude of the received signal against frequency. The front panel controls determine the centre frequency, the frequency span of the sweep, the sensitivity, the bandwidth of the receiver and the speed of the plot. Other controls determine if the frequency, shown on the display, is shown at the start or the centre of the display, whether the vertical axis is linear or logarithmic and a control to zero the display.

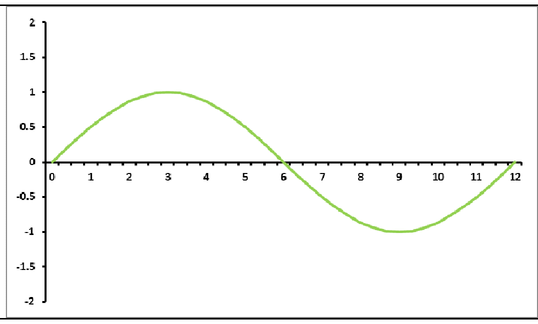


Figure 21 - Time Domain

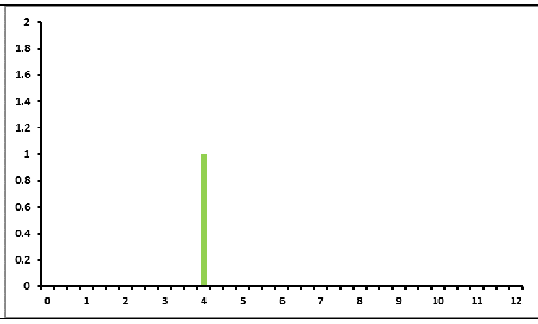


Figure 22 - Frequency Domain

We'll look at the output of the signal generator, set to 5MHz, on both the oscilloscope and the analyser in both the time and frequency domains respectively.

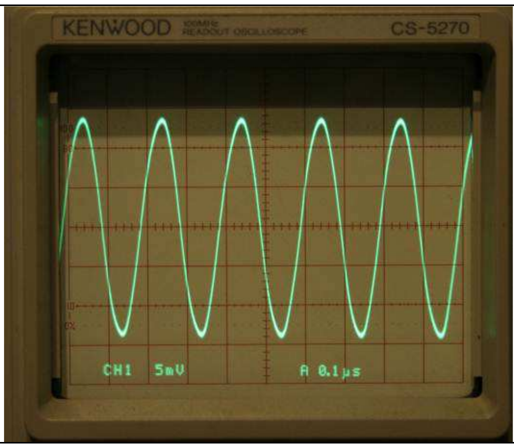


Figure 23 - 5MHz output from signal generator

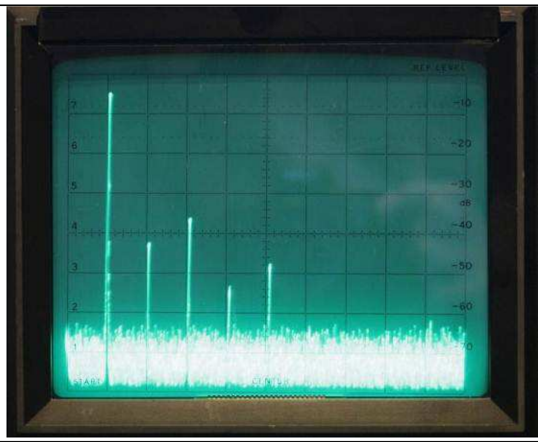


Figure 24 - Spectrum of 5MHz signal

The output looks like a sine wave but looking at the spectrum shows there are a few harmonics but these are at least 30db down on the fundamental amplitude. The fact that the oscillator is not a pure sine wave can be advantageous as the harmonics mean the signal generator can be used above 110MHz.

The Spectrum Analyser can also be used to look at TV and radio signals. By connecting an aerial to the input we can see which signals are available in this area.

These are the signals available in Band 2 (VHF FM), Band 3 (DAB) and Bands 4 & 5 (TV) in South Bradford overlooking both the Emley Moor and Holme Moss transmitters.

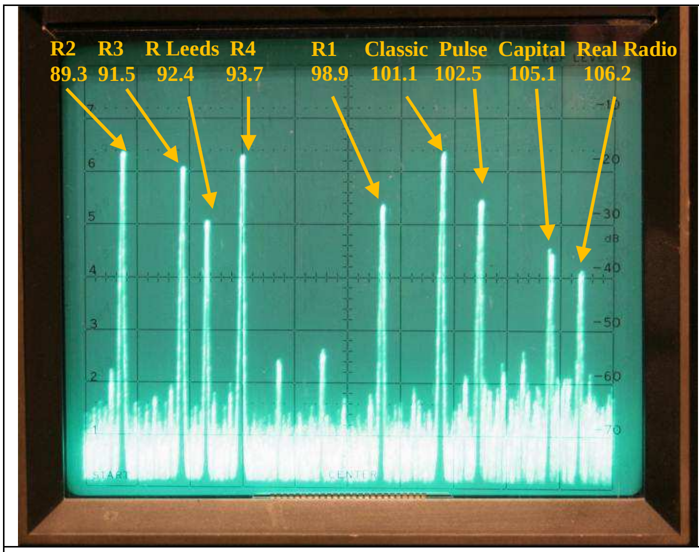


Figure 25 - FM signals - Frequencies in MHz

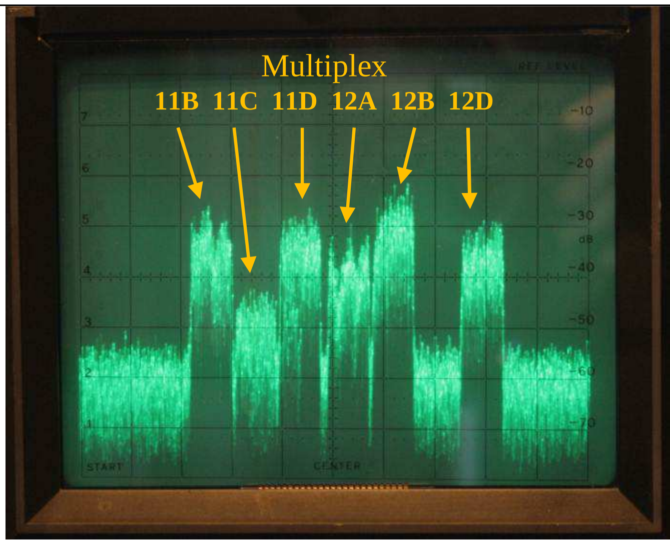


Figure 26 - DAB Multiplexes

On FM the BBC and Classic signals come from Holme Moss, Capital and Real Radio come from Emley Moor and The Pulse comes from the Vicars Lot transmitter which is close to the Moorside edge MW transmitter.

The main useable DAB multiplexes 11D, 12A, 12B and 12D come from Emley Moor with multiplex 11B coming from the Ainley Top transmitter near junction 24 of the M62. Multiplex 11C is from Tapton Hill, Sheffield and is occasionally receivable at sufficient strength to avoid the “burbles”.

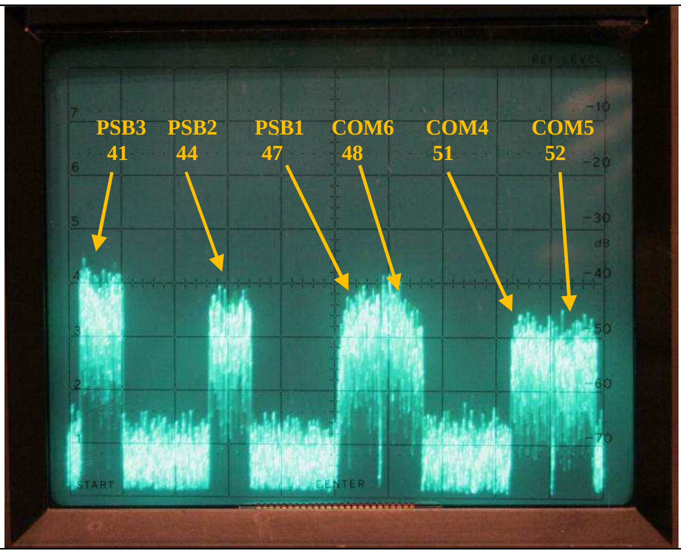


Figure 27 - TV (Digital) Multiplexes on Channels 41, 44, 47, 48, 51 & 52

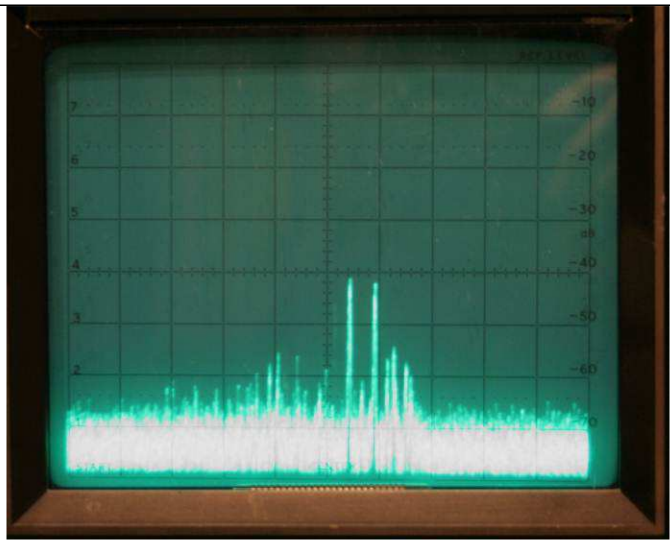


Figure 28 - Phone signals around 900MHz

On TV, PSB1 is the BBC multiplex, PSB2 is the ITV multiplex and PSB3 is the HD multiplex. These are the multiplexes that have to be broadcast by all digital TV transmitters. The COM multiplexes are mainly channels such as Dave and the shopping channels. These are only broadcast by the main and a few of the larger relay transmitters. Note that the Emley Moor channels reflect the old analogue channel allocations, 41, 44, 47 and 51, with the extra channels added.

Aurora Standards Converter

Now lets have a look at the Aurora standards converter, 625 line signal in and 405 line signal, modulated onto a carrier, out. The instructions do warn about not connecting it to an aerial and here's why.

Figure 29 shows the output of the Aurora on Channel 2 (Holme Moss). The centre is the vision carrier at 51.75MHz and to the left is the sound carrier at 48.25MHz. Note the sidebands on both sides of the vision carrier. This is a double sideband signal similar to the original Alexandra Palace transmission. The actual Channel 2 transmissions filtered out most of the upper sideband leaving a 0.75MHz vestigial sideband. This improves the utilisation of the RF spectrum.

Figure 30 shows the harmonics of the signal. The dominant harmonics are the 3rd, 5th, 7th etc harmonics of both the vision and sound carriers. Note that at each higher harmonic the sound vision carrier spacing has increased. At the fundamental they are the specified 3.5MHz apart but at the 3rd harmonic they are 10.5MHz apart. The spacing increases with the harmonic number. You may have noticed that the odd harmonics have a large amplitude whereas the even harmonics are significantly lower in amplitude, at least 40db down. The reason for this is the way the carrier is generated inside the modulator IC. It's a 1:1 mark space square wave. One characteristic of this type of square wave is there are no even harmonics so a 1kHz square wave will have harmonics at 3kHz, 5kHz, 7kHz etc but none at 2kHz, 4kHz, 6kHz etc. The amplitude of the harmonic is also related to the harmonic number. The 3rd harmonic is 1/3 of the amplitude of the fundamental, the 5th harmonic is 1/5 of the fundamental etc.

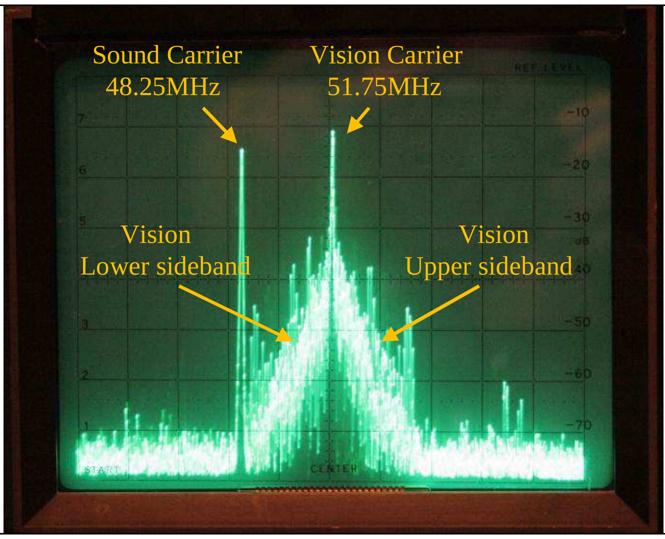


Figure 29 - Aurora RF output

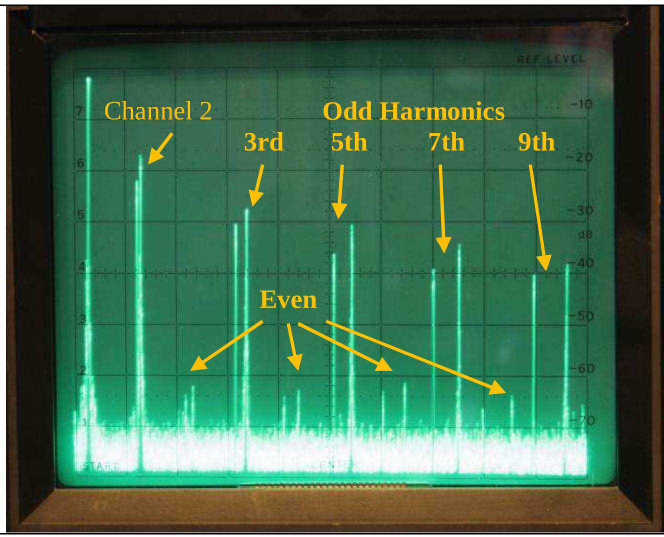


Figure 30 - Aurora harmonics

Because of the harmonics from the Aurora you should chose the channels carefully if you are combining the signals from two Auroras to simulate a Band 1 and Band 3 system as some of the Band 1 channel harmonics fall in band 3. Alternatively combine them through filters. You can get a triplexer which is intended to combine FM, DAB and UHF signals but could be used to combine a Band 1 and Band 3 outputs from two Auroras.

I've included a table listing the harmonics of Aurora outputs and which channel combinations to avoid for multiple Aurora installations in the appendix. Also a list of the UK UHF TV and DAB channels.

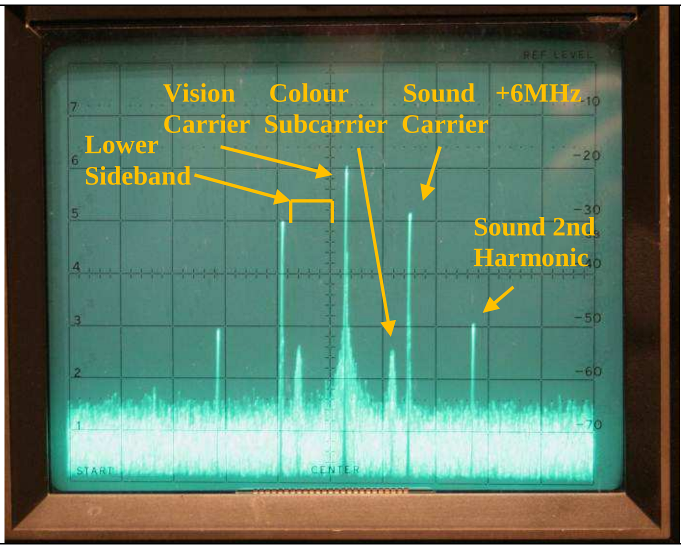


Figure 31 - RF output from PM5519 pattern generator.

Figure 31 shows the output from a Philips PM5519 pattern generator set to output the purity screen, a single colour.

It shows the vision carrier with the sound carrier 6MHz and the colour subcarrier 4.43MHz away from the carrier.

Like the Aurora output this is also a double sideband signal. Because of the way the signals are generated by the generator the sound carrier appears twice, above and below the vision carrier.

The actual transmitted signal was a vestigial sideband signal with most of the lower sideband removed. This is different to the 405 line signal as the sound carrier is above the vision carrier on UHF 625 line signals and below it on VHF 405 line signals.

Note also the second harmonic of the sound carrier 12MHz away from the vision carrier. This is a characteristic of the generator. If you look carefully you can also see a third harmonic of the sound carrier 6MHz below the 2nd harmonic on the lower sideband side.

Summary

Aligning a radio or TV is not as daunting a task as it might at first seem. For the best results a signal generator with a frequency range that covers both IF and LW and MW frequencies and up to 110MHz if FM receivers are to be aligned, is needed.

However if the IF amplifier in a radio is OK you'll probably only need to identify and adjust the oscillator and aerial coils and trimmers. This is possible without instruments but you need to be able to receive stations at both ends of the frequency range to be able to adjust both the coils and the trimmer capacitors. Adjust the coil at the low frequency end, adjust the capacitor at the high frequency end then repeat until there is no improvement.

I would however recommend getting the service manual for any radio and especially TV if you intend to align or re-align it for the correct alignment procedure.

As with most tasks if you do have the requisite test equipment take time to learn how it works. Read the manual, if you have one, or ask on one of the many forums. There are usually people who have had experience of using all forms of test equipment and used them to align the most complex of radios. It is not necessary to have an all singing all dancing signal generator. A simple generator is often just as effective and can be easier to use.

When you decide to align a radio or TV start with something simple or even check the alignment of a known working radio. Make small adjustments at first so you can put it back how it was if things go wrong. With a little practice you'll probably wonder why you hadn't tried it earlier.

KW Golbourne November 2013

Appendix

1. Bush TV76 Alignment procedure

RECEIVER UNIT ALIGNMENT

EQUIPMENT REQUIRED

1 A signal generator, output impedance 80ohms, calibration accuracy ±100 kc/s, covering the following frequencies:—

(a) Vision and sound i.f.: 30 Mc/s to 40 Mc/s.

(b) R.F. Band 1: 40 Mc/s to 70 Mc/s, modulation 400 c/s at 30 per cent.

(c) R.F. Band 3: 174 Mc/s to 216 Mc/s.

2 Audio wattmeter, range 0–1000 mW.

3 Vision-alignment meter, range 0–100V, 1 mA F.S.D.

4 A supply, variable from zero to 6V, to provide a variable-gain-control voltage during alignment. This can be derived from a 6V dry battery and a potentiometer.

5 A low-capacity, insulated trimming tool.

PRELIMINARY NOTES

1 The receiver unit and signal generator should be switched on 15 minutes before commencing the alignment procedure.

2 Before using the signal generator it is essential to check its calibration accuracy. This should be done immediately after the warming-up period.

3 All the alignment instructions should be carried out with the Channel Selector set to Channel 6 and the TUNING control set to the centre of its range. The Local/Distant selector should be set to the Distant position for both bands, the Interference Limiter RV2 and Contrast control RV3 to maximum counter-clockwise position and the Volume control to maximum.

4 No adjustments should be made to the aerial, r.f. and oscillator deck, as the unit is aligned at the factory with special equipment and should not require realignment. If by accident the alignment should be disturbed, the Tuner Unit must be returned to the Service Department for realignment.

5 Connect the vision-alignment meter between the video output (see Fig. 6) and the receiver h.t. line. Connect the audio wattmeter across the sound-output-transformer secondary. The biasing voltage required during alignment should be applied between the junction of R46, R47 and chassis, the positive side of the supply being connected to the chassis side of RV3.

6 Connect the signal-generator output (terminated with an 80-ohm resistor) as indicated for the individual operations of the Alignment Procedure. A damping unit, comprising a 470-ohm resistor in series with a 0·001μF capacitor, should be connected as specified.

7 Generally the core positions of a unit requiring realignment will be close to their correct settings, therefore pre-setting before alignment will be unnecessary. If, however, the positions of the cores have been disturbed extensively, the cores of all coils should be screwed fully out (i.e., flush with the opening in the top of the screening can or the base of the coil former). The cores of L10, L16, L17, L21, L22, L24, L26, L27, L32 and L35 are adjusted from the top of the chassis and those of L15, L18, L20, L23, L25, L28 and L33 from underneath the chassis (see Figs. 6, 7, 8 and 9).

8 All cores are sealed with Ragosine compound and no difficulty should be experienced in readjusting them. If new cores are fitted this compound must be applied to the core to prevent accidental movement during transit.

9 If one i.f. valve is changed, realignment of the adjacent i.f. stages may be necessary. When more than one i.f. valve is changed all associated stages must be realigned. If an i.f. transformer is replaced the new i.f. transformer must be trimmed and the receiver unit checked against the figures quoted in the alignment procedure.

IMPORTANT: Where there is a considerable degree of misalignment it may be necessary to pre-align the receiver before commencing detailed alignment (see note 7 above).

ALIGNMENT PROCEDURE—Receiver Unit Type 103

Adjacent Sound Rejection

Inject a 33·15 Mc/s signal at a level of about 20 mV at socket " D " on the i.f. chassis. Set the external bias to zero and adjust L16 for minimum video output.

Adjacent Vision Rejection

Inject a 39·65 Mc/s signal at a level of about 20 mV at socket " D." Set the external bias to zero and adjust L22 for minimum video output.

Sound Rejection

Inject a 38·15 Mc/s signal at a level of about 20 mV at socket " D." Set the external bias to zero and adjust L23 and L26 for minimum video output.

Sound I.F. Alignment

Inject a 38·15 Mc/s signal, modulated 30 per cent. at 400 c/s at a level of about 20 mV at socket "D", and adjust L21, L32, L33 and L35 for maximum audio output. Adjust the external bias during each trimming operation to keep the audio output down to the lowest conveniently readable level in order to avoid overloading.

Vision I.F. Alignment

IMPORTANT: To avoid damage to the OA70 crystal diode CD1, it is essential when damping the final vision i.f. transformer, to connect the damping to the top of L27 screening can. A small hole is provided in the top of the screening can for this purpose.

The alignment must be carried out in the order shown. The external bias must be adjusted during each operation to maintain a video output of 10V.

Operation	Input Frequency	Input Level	Damping Circuit Across: L. No.	Tags on Former	Adjustment	
	Signal injected at socket " D "—					
*1	36·15 Mc/s	20 mV	L28	4 – 6	L27	For maximum video output.
2	36·15 Mc/s	20 mV	L27	1 – 3	L28	
3	35·9 Mc/s	20 mV	L25	4 – 6	L24	
4	35·9 Mc/s	20 mV	L24	1 – 3	L25	
5	36·15 Mc/s	6 mV	L18	4 – 6	L17	
6	36·15 Mc/s	6 mV	L17	1 – 3	L18	
7	36·15 Mc/s	200 μV	—	—	L15	
	Signal injected at Tuner Test Point (see circuit diagram):—					
8	36·15 Mc/s	20 mV	L15	4 – 6	L10	

* Remove 80-ohm terminating resistor from Generator Output Lead.

Final Alignment of Rejector Circuits

Inject a 34·65 Mc/s signal at socket " D " at a level of 200μV. Adjust the external bias to give a video output of 20V d.c. Then proceed as follows:—

1 Adjacent Sound Rejection

Inject a 33·15 Mc/s signal at socket " D " at a level of 10 mV. Adjust L16 for minimum video output.

2 Adjacent Vision Rejection

Inject a 39·65 Mc/s signal at socket " D " at a level of 10 mV. Adjust L22 for minimum video output.

3 Sound Rejection

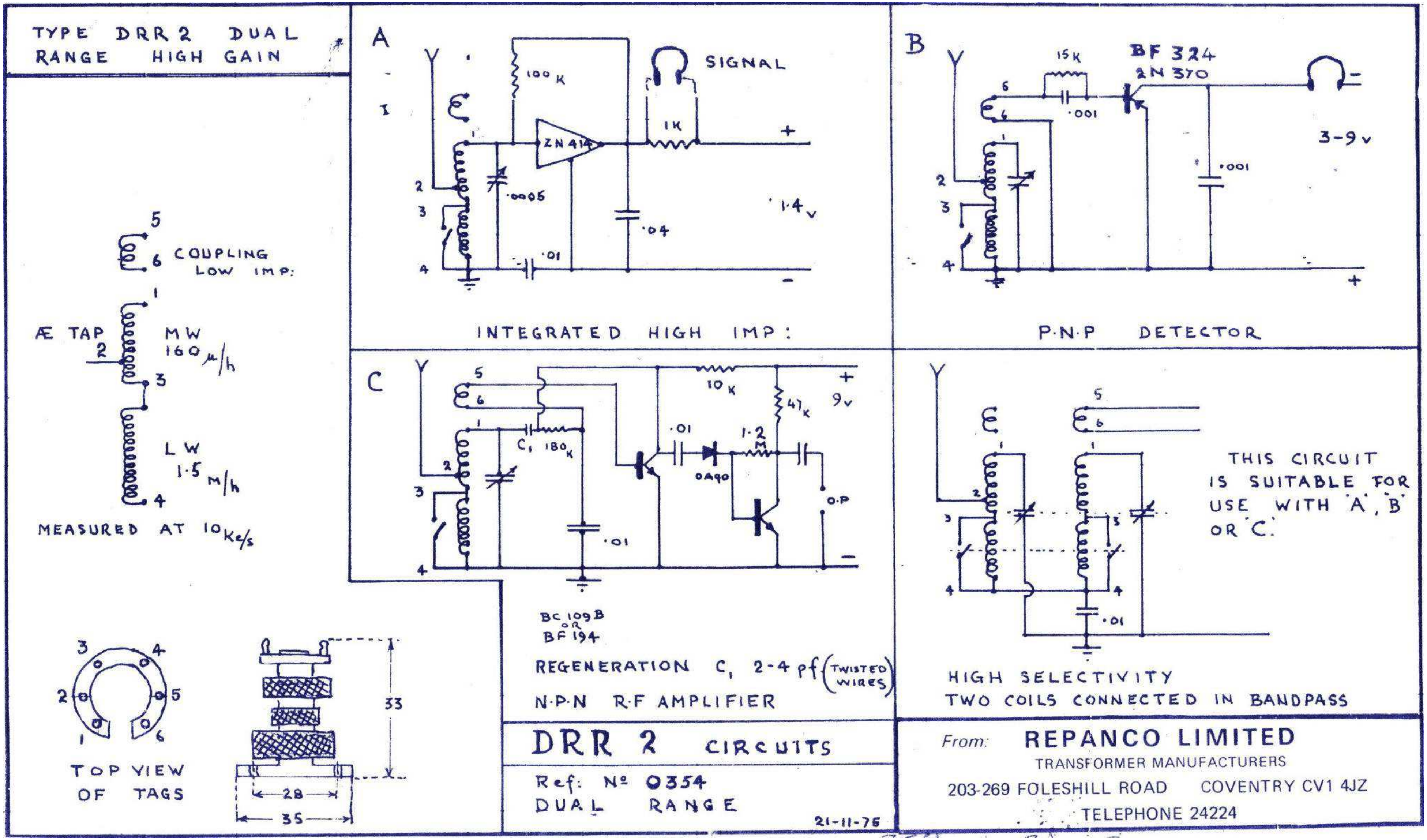
Inject a 38·15 Mc/s signal at socket " D " at a level of 10 mV. Adjust L23 and L26 for minimum video output.

Final Adjustment of Sound I.F.

1 Inject a 34·65 Mc/s signal at socket " D " at a level of 650μV. Set the external bias control to give an output of 20V on the vision alignment meter.

2 Inject a 38·15 Mc/s signal, modulated 30 per cent. at 400 c/s at a level of 200μV. Adjust L20, L21, L32, L33 and L35 for maximum audio output. During this operation, adjust the volume control to maintain the audio output at approximately 50 mW.

2. Repanco DRR2 data and application sheet



3. Aurora harmonics

Carrier frequencies			Harmonic frequencies															
			3		5		7		9		11		13		15		17	
Channel	**Sound**	**Vision**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**
1	41.50	45.00	124.50	135.00	207.50	225.00	290.50	315.00	373.50	405.00	456.50	495.00	539.50	585.00	622.50	675.00	705.50	765.00
2	48.25	51.75	144.75	155.25	241.25	258.75	337.75	362.25	434.25	465.75	530.75	569.25	627.25	672.75	723.75	776.25	820.25	
3	53.25	56.75	159.75	170.25	266.25	283.75	372.75	397.25	479.25	510.75	585.75	624.25	692.25	737.75	798.75	851.25		
4	58.25	61.75	174.75	185.25	291.25	308.75	407.75	432.25	524.25	555.75	640.75	679.25	757.25	802.75				
5	63.25	66.75	189.75	200.25	316.25	333.75	442.75	467.25	569.25	600.75	695.75	734.25	822.25					
6	176.25	179.75	528.75	539.25														
7	181.25	184.75	543.75	554.25														
8	186.25	189.75	558.75	569.25														
9	191.25	194.75	573.75	584.25														
10	196.25	199.75	588.75	599.25														
11	201.25	204.75	603.75	614.25														
12	206.25	209.75	618.75	629.25														
13	211.25	214.75	633.75	644.25														
14	216.25	219.75	648.75	659.25														

Harmonics of Aurora RF output.

Frequencies in MHz.
Harmonic frequencies highlighted in Orange fall in Band 3 channels.
Harmonic frequencies highlighted in Green fall in UHF bands 4 & 5.

Band 1 / Band 3 combinations to avoid.
Channels 1 & 12, Channels 4 & 7, Channels 5 & 8.

4. UK UHF Channel allocations

UK TV frequencies (UHF)											
Channel	**Lower limit**	**Vision (MHz)**	**Colour sub carrier**	**Sound (MHz)**	**Upper limit**	**Aerial Grouping**					
						A	**B**	**C/D**	**E**	**K**	**W**
21	470	471.25	475.68	477.25	478	Group A - RED				Group K - GREY	Group W - BLACK
22	478	479.25	483.68	485.25	486						
23	486	487.25	491.68	493.25	494						
24	494	495.25	499.68	501.25	502						
25	502	503.25	507.68	509.25	510						
26	510	511.25	515.68	517.25	518						
27	518	519.25	523.68	525.25	526						
28	526	527.25	531.68	533.25	534						
29	534	535.25	539.68	541.25	542						
30	542	543.25	547.68	549.25	550						
31	550	551.25	555.68	557.25	558						
32	558	559.25	563.68	565.25	566						
33	566	567.25	571.68	573.25	574						
34	574	575.25	579.68	581.25	582						
35	582	583.25	587.68	589.25	590		Group B - YELLOW		Group E - BROWN		
36	590	591.25	595.68	597.25	598						
37	598	599.25	603.68	605.25	606						
38	606	607.25	611.68	613.25	614						
39	614	615.25	619.68	621.25	622						
40	622	623.25	627.68	629.25	630						
41	630	631.25	635.68	637.25	638						
42	638	639.25	643.68	645.25	646						
43	646	647.25	651.68	653.25	654						
44	654	655.25	659.68	661.25	662						
45	662	663.25	667.68	669.25	670						
46	670	671.25	675.68	677.25	678						
47	678	679.25	683.68	685.25	686						
48	686	687.25	691.68	693.25	694			Group C/D - GREEN			
49	694	695.25	699.68	701.25	702						
50	702	703.25	707.68	709.25	710						
51	710	711.25	715.68	717.25	718						
52	718	719.25	723.68	725.25	726						
53	726	727.25	731.68	733.25	734						
54	734	735.25	739.68	741.25	742						
55	742	743.25	747.68	749.25	750						
56	750	751.25	755.68	757.25	758						
57	758	759.25	763.68	765.25	766						
58	766	767.25	771.68	773.25	774						
59	774	775.25	779.68	781.25	782						
60	782	783.25	787.68	789.25	790						
61	790	791.25	795.68	797.25	798						
62	798	799.25	803.68	805.25	806						
63	806	807.25	811.68	813.25	814						
64	814	815.25	819.68	821.25	822						
65	822	823.25	827.68	829.25	830						
66	830	831.25	835.68	837.25	838						
67	838	839.25	843.68	845.25	846						
68	846	847.25	851.68	853.25	854						

Analogue TV Vision - AM Negative modulation 625 lines. Colour – PAL. Teletext
Sound – FM & NICAM
Greyed out channels are those re-allocated for 4G mobile phones.

5. DAB Channels & Frequencies

Channel	Frequency	Area
10A	209.936 MHz	Welsh Valleys
10B	211.640 MHz	Derbyshire, Oxfordshire, Herefordshire and Worcestershire, North Sussex and Reigate, Weymouth and Dorchester, Kings Lynn and West Norfolk, North West Yorkshire
10C	213.352 MHz	Gloucestershire, Border Region, Northamptonshire, Ceredigion and Powys, North Yorkshire, East and Central Northern Ireland, Surrey, East Hampshire and NW Sussex, North Devon, North West Region 2, Salisbury
10D	215.064 MHz	Herts, Beds and Bucks, Somerset, North East Region 2, Lincolnshire, Wrexham and Chester, South Warwickshire, North West Wales, Edinburgh 2, South West Scotland, Plymouth (new frequency), Highlands and Islands
11A	216.936 MHz	4 Digital National
11B	218.640 MHz	Ayr, Dundee and Perth, Liverpool, Bournemouth, Humberside, Teeside, Bradford, Huddersfield and Halifax, Inverness, Wolverhampton, Shrewsbury, Telford, Bristol and Bath, Leicester, North and West, Cumbria, Cornwall, Norwich, Greater London 3, Sussex Coast
11C	220.352 MHz	Aberdeen, Glasgow, Birmingham, Cambridge, Cardiff and Newport, Exeter and Torbay, Swindon and NE Wiltshire, Greater Manchester, Kent, South Hampshire, South Yorkshire, Tyne and Wear, Channel Islands, Isle of Man, North West Northern Ireland
11D	222.064 MHz	Digital 1 National (England and Wales), Central Scotland, South West Northern Ireland
12A	223.936 MHz	Digital 1 National (Scotland), Greater London 2, Lancashire, Plymouth (current frequency), Swansea, West Midlands Region, Yorkshire Region
12B	225.648 MHz	BBC National
12C	227.360 MHz	Greater London 1, North West Region, North East Region, Severn Estuary Region, Nottingham, Central Scotland 2
12D	229.072 MHz	Coventry, Northern Ireland Region, Stoke, Edinburgh, North Wales, Thames Valley, Essex, Pembrokeshire and Carmarthenshire, West Wiltshire and Bath, Leeds, Peterborough, South Cumbria and North Lancashire

DAB Services (Yorkshire)

MPX	Ensemble	Services
11B	Bradford & Huddersfield	The Pulse, Heat, Radio Leeds, Panjab Radio, Pulse 2, Sunrise Radio Yorkshire
11D	Digital 1 National	Absolute Radio, Absolute 80s, Absolute Radio 90s, BFBS, Classic FM, Jazz FM, Kiss, Planet Rock, Premier Radio, Smooth, Smooth 70s, Talk Sport, Team Rock Radio, UCB UK
12A	Yorkshire	Capital FM(Yorkshire), Choice, Gold, Heart (Digital), Real Radio, Real XS, UCB Gospel, UCBInspirational, The Wireless, XFM
12B	BBC National	Radio 1, 1Xtra, Radio 2, Radio 3, Radio 4 (FM), Radio 4 Extra, Radio 5 Live, Radio 5 Sports Extra, 6 Music, Asian Network, World Service
12D	Leeds and Wakefield	Absolute R Classic Rock, Absolute Radio 60s, Aire FM, Heat, The Hits, Kerrang, Radio Leeds, Magic 828

6. Loop Details

To build a replica of the loop shown in figure 14 you'll need the following items

10ft of insulated wire*

Insulating tape

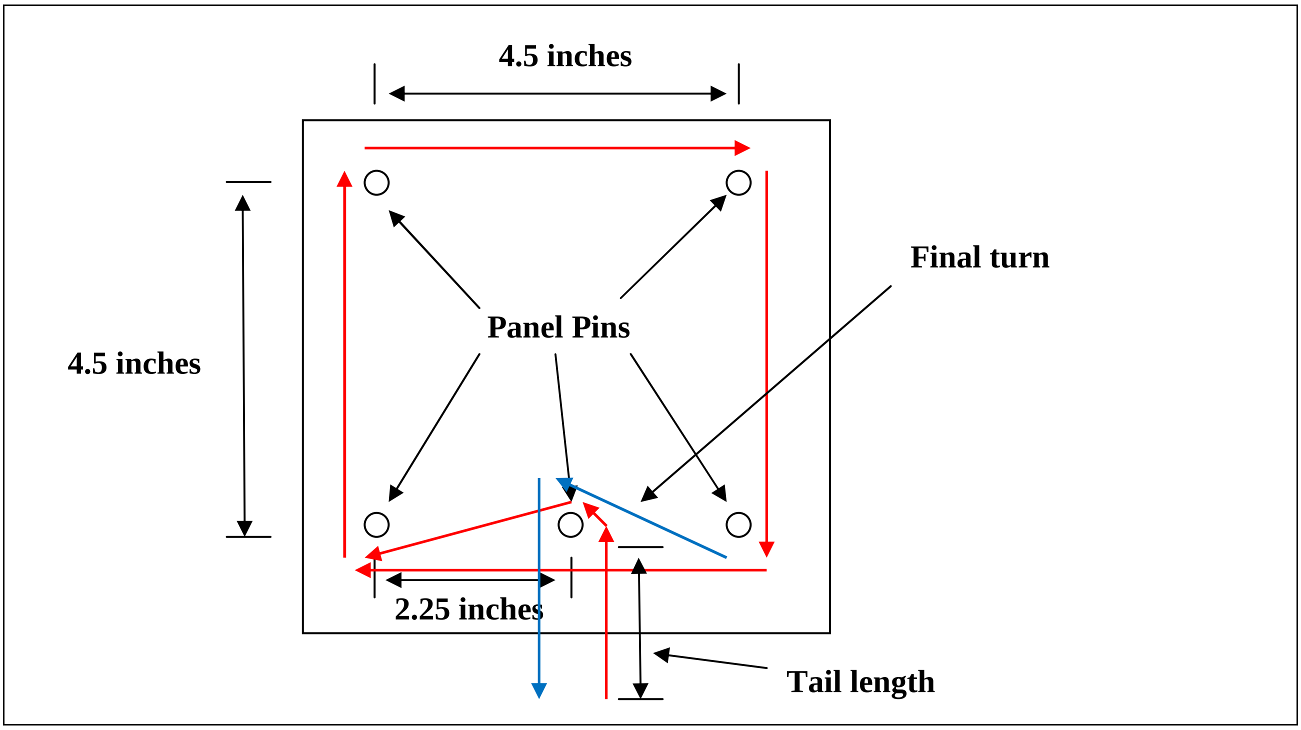
Coaxial connector. I used a BNC connector but any type of coaxial connector can be used.

Mounting board approx 7" x 6". This can be any insulating material such as wood, plastic, stiff cardboard etc.

Plus 5 panel pins and a piece of wood approx. 6" x 6" to wind the coil on.

*The length quoted is suitable for a coil with approximately 6" connection tails. For longer tails add 2ft for each extra foot required. E.g. for a 2ft tail 13ft of wire will be needed.

Hammer the 5 panel pins into the wood to form a square former with 4½ sides as shown below. The 5th pin is to wrap the tails round.



Take the wire and wrap around the panel pins 6 times. Ensure the first and last turns go round the 5th pin as shown to form the connection tail.

Wrap two short pieces of insulation tape around the turns on each side.

Twist the tail wires and secure with insulation tape if needed.

The coil can then be removed from the former.

Mount the coil on the mounting board, fit the coax connector to the board and wire the two connection tails to the connector.

The board can be fitted to a base to keep it upright when aligning radios. A block of wood screwed to the board is the simplest option. I routed a slot in the base of the coil I made and moulded the edges so it would look good for the demo. You don't have to go to the same extremes unless you really want to.

Once I'd built and tested the loop and found how effective it was I started thinking of other uses.

It can be used as an aerial for radios without an internal aerial fitted. This is similar to the loop aerials commonly supplied with modern stereo systems for Long and Medium wave. In this role it's not as efficient as a proper aerial but it does work and has directional properties which may help reduce interference. It may also work as a replacement for the loop aerials for modern stereo systems but it may be worth adding a few more turns for this application.

I also discovered that it can pick up the local oscillator of the Vidor radio I was using for these demos. There was enough signal to trigger the frequency counter so it's a non-contact method of measuring the local oscillator frequency. You could also connect it to an oscilloscope and view the local oscillator signal.

By connecting it to a small medium wave transmitter, of the type discussed on the vintage forums, it can be used over a short range to broadcast signals to several radios simultaneously.

7. Other Anecdotes

1. Back in the 60s when I was building crystal sets in Birmingham I used to tell school friends that on a crystal set you could get Radio 1, Radio 2, Radio 3 and Radio 4 ….. all at the same time. We did live about 8 miles from the Droitwich transmitter though. Radio 3 was a little weaker as that came from the Daventry transmitter.

2. I had a 100ft aerial in the back garden and with a decent earth I could get about 1V dc from one of my crystal sets on Long Wave 200kHz.

3. The physics master at school organised a trip for the Radio club to visit the Droitwich transmitter. I took along a crystal set with no aerial and a telephone earpiece connected to the output. I remember listening to Radio 2 while standing next to the transmitter.

4. At the time the LW transmitter was two 200kW transmitters with their outputs paralleled up. Each transmitter had a single output valve with an anode current of 14A at 14kV HT. The engineer taking us round said if they wanted to do maintenance on one of them they just switched it off. I asked “Don't you lose any listeners when you do that?” His reply was “Only a few fringe area listeners and we're not too bothered about them”.

5. On the Vidor CN435 the measured IF is 475kHz. Where I live the Moorside Edge transmitter is literally line of sight 8 miles away. This puts out Absolute Radio on 1215kHz with an output power of 400kW. On Long Wave if I tune to 265kHz you can hear Absolute Radio. This is an example of the image frequency although in this case it falls in a different band.

6. The Spectrum Analyser, along with the PM5324 signal generator, were both obtained from the company I work for when they were clearing out the equipment cupboard earlier this year. A search on the internet showed that the Spectrum Analyser would have cost around $12,000 in 1983, which was more than the new car I bought that year.

7. I find it ironic that the 800MHz part of the UHF broadcast spectrum formerly used for TV is now being used for 4G mobile applications so that people can watch TV on their mobile phones.