Receiver Alignment

The concept of alignment — why it is necessary — general techniques — tools required — the effect of AGC — instability — aligning IF stages — aerial and oscillator circuits — short wave alignment — alignment using instruments — television receiver alignment.

The inclusion of a chapter on alignment may seem rather out of keeping with earlier and more elementary material. However it is reasonable to assume that by this stage many readers will have tried their hand at building one of the receivers described in Electronics Australia or elsewhere, and may by now be facing up to this very subject.

Such being the case, it seems appropriate to do three things:

(a) Explain what is behind this matter of alignment and why it is necessary at all;

(b) Discuss some of the side-issues as, for example, dial setting, alignment tools and so on.

(c) Give an alignment procedure for a typical modern superhet receiver.

Even if the reader does not happen to have a receiver on the table, awaiting attention, the information should be useful and will be available against the day when it may be required.

Forty years ago, the word alignment was virtually unkown. For the most part, each tuning circuit in receivers of the day was brought out to a separate tuning dial and tuning involved turning each dial to the appropriate setting for the particular station. In fact, a standard accessory at the time was a card listing local stations, with two or three spaces alongside each, in which the set owner could insert the dial readings for optimum reception.

As time went by, designers sought to simplify matters by making all the tuning coils and capacitors as nearly identical as possible, so that the dial settings would correspond fairly closely. Thus, the owner could remember if he wished that a certain station came in with all the dials set to about 70, another station with the dials about 55 and so on.

From here, it was an obvious step to take even greater care with the tuning circuits and arrange them so that they could all be adjusted simultaneously by rotating a single tuning knob. At first, the individual tuning capacitors were linked behind the panel with gears or belts. Later they were combined into the one assembly as a two, or three or even four-gang capacitor. Thus "single-dial tuning" became the vogue.

Single-dial tuning has been with us ever since and is obviously a very convenient feature. However, several tuning circuits will not remain exactly in step — or "track" — accurately just because they are superficially alike. Special provision has to be made to ensure that the ganged tuning circuits all resonate to the correct frequency at each and every setting of the tuning dial.

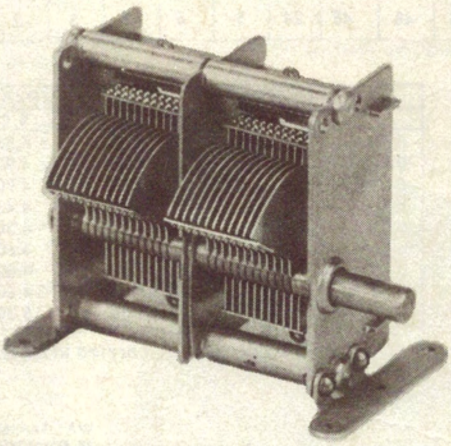
By very carefully maintaining the number of turns on the coils during manufacture and by matching the tuning gang sections, fairly good tracking can be obtained, as a matter of course, near the low frequency end of the range: that is, with the tuning capacitor plates well into mesh.

However, at the other end of the band, with the capacitor plates well out of mesh, the exact tuning of the circuits is affected, as much as anything, by "stray" capacitance — that to do with the position of the components, connecting leads and so on. Variation in this stray capacitance between one tuning circuit and another leads to tracking error at the higher frequencies, and therefore loss of efficiency.

To overcome this problem, it has become accepted practice to connect small trimmer capacitors in parallel with each tuned circuit. They are commonly adjustable between about 10 and 30pF. Sometimes they are separate components; sometimes included as part of the ganged capacitor.

Normal intention is for the trimmers to be set at about half capacitance, the tuning coils and the gang itself then being designed to cover the requisite band of frequencies — from about 1,700 to 535kHz for the ordinary medium-wave radio broadcast band.

If the stray capacitance across one or more of the tuned circuits happens to be a little high, then the relevant trimmer or trimmers are unscrewed a little. Conversely, if the strays happen to be low, the trimmer can be screwed in a fraction to increase the amount of capacitance to the anticipated figure.



A typical two-gang variable capacitor. Despite care in the manufacture of such units and the associated coils, the tolerances of these components plus stray capacitance effects make it necessary to align or "peak" tuned circuits operating from a common control.

Provided that the coils and gang sections are accurately manufactured, the tuning circuits thus aligned at the high frequency end of the band, remain reasonably in step over the whole tuning range.

In more recent years a further technique has been evolved which leaves even less to chance at the low frequency end of the tuning range. This involves the provision of an adjustable iron dust slug inside each tuning coil. Moving the core in or out of the winding changes the inductance by quite a large percentage.

Thus, in modern receivers, very accurate alignment can be achieved by adjusting the coil cores for exact inductance balance at the low frequency end of the band, and the trimmers for capacitance balance at the high frequency end of the band.

Note that the cores and trimmers perform different functions and they should always be adjusted to fulfil those basic functions. The fact that tuning circuits include variable iron cores therefore does not obviate the need for trimmers.

There is another facet to this matter of alignment which must be mentioned.

Originally, receivers used tuning dials simply numbered 0-100, leaving the set owner to memorise the tuning position for each station. Provided the receiver tuned over the necessary frequency band, the exact position of the stations within that band did not matter a great deal.

Thus trimmers could be set for proper tracking, without special reference to the dial reading. The only point which needed to be watched was that the trimmers were not all screwed in so far that they restricted coverage of the receiver at the extreme high frequency end of the band.

It is not necessary to refer to cores in this context because uncalibrated dials went out of vogue long before adjustable cores came in. Their use is covered however, later in the article.

More recently and, in fact, for many years, station call-signs have been marked directly on the dial scale. This means that the trimmer and core settings and the position of the pointer relative to the tuning gang shaft must be determined for accurate indication of the incoming station as well as for accurate alignment.

It involves also, one other important point. There is some variation from one type of ganged capacitor to another in the maximum and minimum capacitance figures and the shape of the moving plates. This affects the distribution of stations across the dial scale.

In an existing receiver, it can usually be assumed that the dial has been calibrated to match the particuler ganged capacitor and correct alignment should therefore bring the stations in on their calibrated positions.

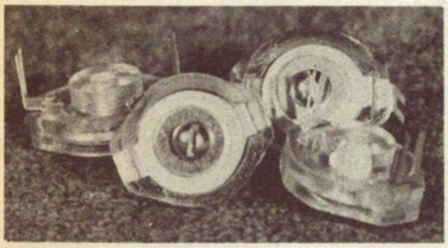
In a home-constructed set, however, there is a chance that a dial might be used having a scale calibrated for some gang capacitor other than the one used. In this case, no amount of manipulation of the cores and trimmers may succeed in getting all the stations to come in at the right positions on the dial.

In assembling components, constructors should therefore see to it that the dial scale is for the type of gang capacitor selected.

In the case of a superhet receiver, there is more to alignment than merely getting two or three tuned circuits to track, one with the other. This much will be evident from our explanation in chapter 13, of the superheterodyne principle.

Alignment involves getting all the IF transformer windings resonated to the appropriate frequency, usually 455kHz. It then involves getting the oscillator circuit to track with the aerial and possibly RF circuit, the requirement, in this case, being that the oscillator tune at all times 455kHz higher than the signal frequency.

This sounds a rather formidable task but the desired result can be achieved by following a fairly simple routine, which will be described later.



Trimmer capacitors come in various shapes and sizes. These illustrated have a clear polystyrene base and measure about ¾in diameter. As the screw is turned clockwise, it forces the top springy plate down, increasing the capacitance between it and the fixed plate beneath.

By now, the reader should have a fairly clear idea as to what alignment is all about. It should be equally clear that a receiver which has not been aligned cannot operate efficiently, because its various tuning circuits will be a long way out of step.

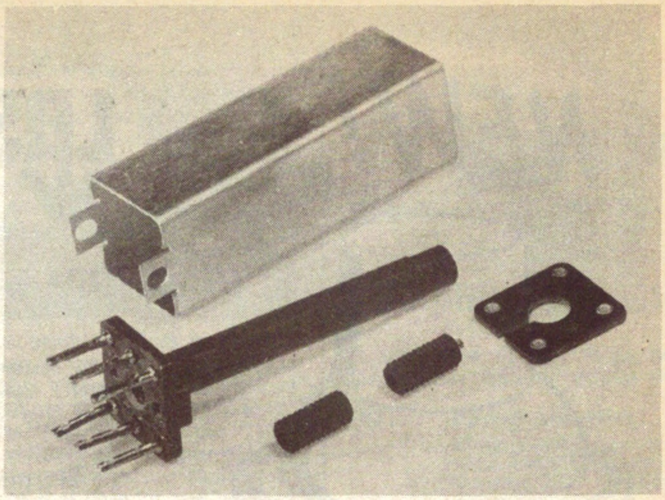
So much for section (a) — why alignment is necessary. Now for a few of the side-issues.

In a factory, receivers are aligned with the aid of a signal generator and an output meter and there is no doubt that the most accurate job can be done in the shortest time with their aid.

Since this is essentially an article for beginners, however, we do not plan to say overmuch about alignment procedures using such instruments.

The average home constructor is likely to have to rely on broadcast stations for a source of signal and to rely on his ears to indicate whether an adjustment has brought about an increase or a decrease in sound volume. Nevertheless, providing care is taken, quite good alignment is possible by these means.

If the alignment is to proceed smoothly, a few preliminary points must be checked.



The mechanical components of a typical IF transformer. The alignment slugs are threaded to screw directly into the central former. The hexagonal hole in the ends of the slugs is to take a special alignment tool.

Firstly, there is the action of the dial mechanism and the setting of the pointer relative to the dial scale and tuning gang plates.

If the receiver has a simple 0-100 dial scale with no station call sign marked, it is only necessary to see that the dial drives the tuning gang smoothly between the full-in and full-out positions and that the pointer travels over the scale with any overlap about equal at the two ends.

The pointer travel can be corrected in some dials by loosening a screw or slipping the drive cord through a loop. In others, it involves loosening the grub-screws locking the dial to the gang shaft and retightening the screws with the two in different relative positions.

With dials having the stations marked on them, the position is rather more confused. Because the capacitor plates are specially shaped precise tracking can only be expected if the pointer and its travel is locked to the gang shaft in one specific position — that for which the dial was originally calibrated.

With the two in the wrong relative positions, stations may be brought to correct calibration at the two ends of the bands by manipulation of the cores and trimmers, but those near the centre may be displaced slightly one way or the other.

Some dials — but not many — have a "dial set" line marked just beyond one end of the scale. The intention is that the dial shall be locked to the gang shaft with the pointer set to this reference line and the gang plates either full in or full out, depending on which end of the scale is involved.

Where there is no "dial set" line, the pointer can only be locked in a likely position and the alignment procedure followed out. If the stations can duly be made to fall in the calibrated positions, the pointer can be left set; if not, the pointer may have to be reset slightly one way or the other in relation to the gang shaft and the alignment procedure repeated, noting whether the new position has improved matters or otherwise.

Before going further, make sure that the dial will rotate the capacitor between the limits of its travel without obstruction, or straining the cord in a cord-drive type. If there is any such trouble, it should be corrected before spending time over the alignment.

In cord-drive dials, the tension of the cord is also important. If it is too loose, the cord will slip. If too tight, it may bind and ultimately break. In general, it is best to have the cord twisted twice around the control knob shaft, with the tension no higher than necessary to ensure positive drive.

Depending on the receiver, a special alignment tool may or may not be required.

Many trimmers are adjustable with an ordinary small metal screwdriver. As a rule, they are connected into circuit so that the screwhead makes contact with that trimmer plate which returns to earth or to the "earthy" side of the circuit. If touching the trimmer with a metal screwdriver alters the signal level, the chances are that it has been installed the wrong way round.

The trimmers in many early type IF transformers are likewise adjustable with a small metal screwdriver. Fingers should be kept off the shaft, however, and the blade kept clear of the metal can, because the trimmers on the plate side often connect internally to the HT circuit.

Iron cores are often adjustable also with a plain metal screwdriver, notably cores which are attached to threaded brass rods protruding from top and / or bottom of the shield cans. In some cases, where the threaded rods are not earthed, touching them with a metal object will affect the behaviour of the coil, making it difficult to pick the proper peak position.

To overcome this difficulty, a type of alignment tool has been available for many years having a very small metal screwdriver tip embedded in a moulded handle.

Alternatively, if the cores are not too stiff in their action, a suitable non-metallic screwdriver can be made by filing a piece of ebonite rod or an ordinary plastic knitting needle to the appropriate shape.

In recent years alignment "screwdrivers" have been made available of nylon or similar materials and these are also very handy for adjusting cores which have a screwdriver slot moulded directly into their ends. A still further type of alignment tool has a hexagonal end meant to engage a similar hole in moulded cores of a somewhat different type.

Irrespective of the core style and tool, however, it is wise to keep in mind that core adjustment systems are seldom very robust. If a slug has become jammed, don't try to force it. It may shatter or become detached from its brass shank (if any) or the whole coil former may be twisted from its mountings inside the can.

From all the foregoing, most readers will have gained a fair insight into the broad principles of alignment, at least as far as the relatively simple TRF receiver is concerned. For this reason, and because TRF receivers are rare devices these days, we will devote the remainder of our discussion to the superhet.

Not long after the general adoption of the superhet, designers began to adopt also the technique of Automatic Volume Control, abbreviated commonly to "AVC." The general principle involved has since been extended to television receivers and other equipment concerned with the reception of signals other than those from the "entertainment" radio stations, and a more appropriate modern name for the technique is Automatic Gain Control — "AGC" for short.

In an ordinary broadcast receiver the AGC circuit is usually fairly simple. A DC control voltage, developed by the detector across its load resistor, is fed back as a bias voltage to one or more of the amplifier devices in the tuning section — RF amplifier, converter or IF amplifier.

On weak input signals, very little bias is developed by the detector or fed back to the controlled stages, so that these stages operate at almost full gain.

With stronger input signals, however, the detector develops a great control voltage and this, fed back to the controlled stages, reduces quite drastically the gain or amplification.

As a result of this quite automatic action, the receiver operates at full gain for weak signals but at much reduced gain for stronger signals. "Blasting" and overload effects are largely eliminated, together with at least some of the fading experienced when listening to distant signals.

A volume control still needs to be provided, of course, but it normally operates in the audio system. It allows listening volume to be set to the required level and adjustment to be made for any residual difference between weak and strong signals, not fully compensated by the AGC system.

AGC has much to recommend it from the user's point of view. However, it does complicate alignment somewhat and for a fairly obvious reason. With the receiver tuned to any given input signal, the AGC voltage attains a level depending on the strength of that signal and the gain of the receiver.

Now, if adjustment of a trimmer should increase the effectiveness of a tuned circuit, the resulting increased signal at the detector will produce more AGC voltage. This will decrease the gain, making the effect of the trimmer adjustment much less apparent than it would otherwise be.

Conversely, an adjustment which reduces the effectiveness of a tuned circuit will also reduce the AGC voltage and allow the gain to rise in consequence.

In other words, an AGC circuit in a receiver tends to mask the effect of any adjustments, and quite substantial changes in the efficiency of a tuned circuit through peaking might make only a slight audible difference in the loud-speaker output.

The best way to counter this masking effect is to align such a receiver on very weak signals, as from distant transmitters. Unfortunately, during evening hours, when most homebuilders would want to work on a receiver, there is often a hopeless confusion of weak signals between the strong locals, most of them subject to fading effects which can be most misleading.

If you have to rely on stations for alignment, the best plan is to carry out a rough alignment procedure on local stations to make the dial track correctly, leaving fine adjustment of the trimmer, etc, to some daylight period when it should be possible to pick up a couple of weak but steady signals at the respective ends of the band.

Out of all this comes one of the golden rules of alignment. Peak all receiver circuits as far as possible on weak input signals, advancing the volume control, if necessary, to make them audible.

So much for AGC action and its complicating effect on alignment. Now for a few words on instability.

In a well-designed receiver it is possible to peak all adjustments for optimum performance, without any complication arising. Each adjustment merely increases the gain and sensitivity till it reaches the maximum of which the set is capable.

In some cases, however, poor design, wrong choice of components, wrong placement or long active leads may allow an excessive amount of signal from one or more stages to couple into an earlier point in the circuit, producing a positive feedback or regenerative effect.

As the gain is increased by progressive adjustments, the receiver may suddenly become unstable or "burst into oscillation," to use another very common phrase.

Oscillation in a large receiver sounds much the same as oscillation in a small regenerative receiver, except that it is produced deliberately in the latter case and controlled by the "reaction" knob.

Instead of the station signals being heard clearly, each one is accompanied or even blotted out by a loud whistle which varies in pitch as the set is tuned across the station carrier.

Many superhets produce faint whistles on odd stations, particularly when operating near powerful transmitters. They are fairly distinct, however, from the strong whistles on every station produced by instability. And while a set is unstable, complete alignment is impossible.

The cure for instability in most cases involves elimination of the cause — improoved design if the circuit is of doubtful origin, use of the proper components or rearrangement of the wiring and layout.

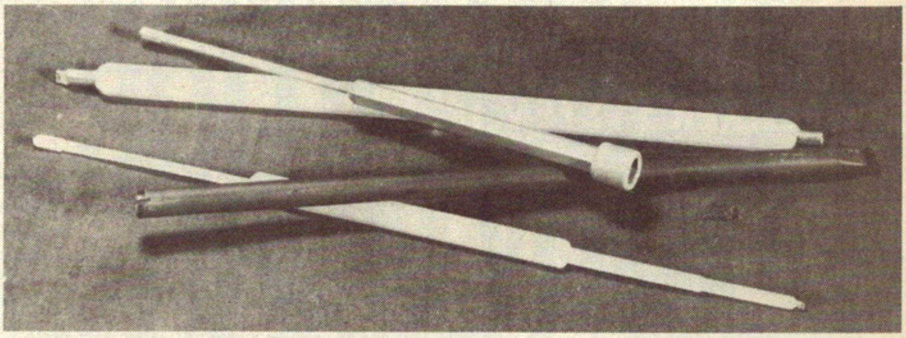
Needless to say, this is good argument for care in the first place, when building a receiver, whether it be a TRF or superheterodyne.

So much then for instability or oscillation.

The basic principles of a superhet receiver have been explained in an earlier chapter and do not require further elaboration here.

It is sufficient to recall that the incoming signals are passed through a conventional aerial (and possibly RF) coil, then heterodyned with a signal from a local oscillator stage to produce a resultant known as the intermediate frequency.

Matters are arranged so that each incoming signal, as it is tuned, is changed to the one intermediate frequency — usually 455kHz. All transformers in the IF amplifier section therefore need to be peaked to this figure.



A selection of alignment tools used for adjusting radio and television receivers. They are normally non-metallic, or use a minimum of metal, to minimise any effect on the circuit being adjusted by the proximity of the tool.

Fortunately, the task of aligning a superhet receiver is not as difficult as it might appear at first encounter and a home constructor can do a passable job of alignment without instruments and without help, provided a certain routine is followed.

First connect the set to an aerial and earth, preferably the ones with which it is to be used; connect the speaker and switch the power on. Tuning across the band, you will probably be able to hear quite a few stations, if the set is otherwise in order.

Try to find a weak but steady station near the low frequency end of the band.

Tune the receiver as accurately as possible to the station you choose. The best way to do this, or in fact to make any of the adjustments about to be described, is to rock the setting backwards and forwards over the correct point, gradually converging on it.

You can now adjust the IF transformer cores or trimmers as the case may be (most modern IF transformers have core adjustments) for maximum sound output from the speaker.

It is possible that what was previously a weak signal now becomes a strong signal as the sensitivity of the receiver rises. This being the case, do the best you can on the original station, and then tune accurately to a weaker adjacent station and go over the procedure again.

The IF windings do not usually need to be peaked in any special order but be sure not to miss any. There may be a slight amount of interaction between the adjustments, so it is a good idea to go over the IF adjustments a second time.

When you have finished with the IF transformers they should be fairly close to the nominal frequency. This is 455kHz for most receivers nowadays, but occasionally you will strike a receiver with a different arrangement.

For this method of alignment it doesn't matter and, further, even if you do finish up a few kHz off the specified frequency, it will not be serious. The main thing is that all IF circuits be accurately aligned to the one frequency.

Having satisfactorily completed the alignment of the IF amplifier it remains to adjust the aerial and oscillator circuits. If your receiver has an RF amplifier stage, the adjustments for the RF coil are exactly the same as for the aerial coil.

With most modern receivers the adjustments consist of trimmers and variable slugs associated with both aerial and oscillator coils, and the padder or tracking capacitor is a fixed mica type.

In the case of the variable slugs, tune to a station which you can easily identify toward the low frequency end of the band and adjust the oscillator coil slug until the station coincides with its position as marked on the dial.

Then tune to a station toward the high frequency end of the band and adjust the trimmer associated with the oscillator section to bring this station to its correct position on the dial. Repeat the above adjustments a couple of times because each adjustments does have some effect on the other.

If everything is in order, ie, the dial and tuning capacitor correctly matched, all stations should now coincide with their marked positions on the dial.

Should the AGC system tend to make the strong local stations appear broad it would be in order to remove the aerial or operate the set with a short length of wire while making the adjustments to the station positions.

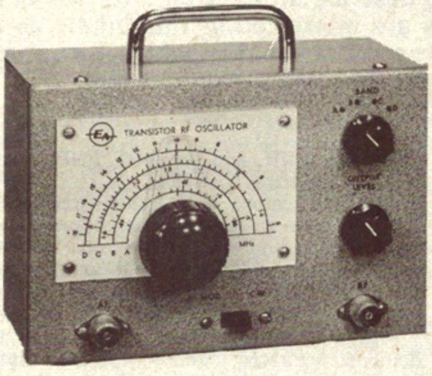
Finally, the aerial coil slug and the aerial trimmer should be adjusted to obtain the strongest signals. The slug adjustment should be made with the receiver tuned toward the low frequency end of the band and the trimmer adjustment toward the high frequency end.

The aerial circuit should preferably be adjusted with the aerial with which the receiver is to be used connected, and it is a good idea to go over it several times to make sure that you get the best results.

In passing it should be noted that many modern portable and "mantel" receivers do not have an aerial or RF coil of the type used in older sets and more elaborate modern receivers. Instead they employ a "ferrite rod aerial", or "loopstick", which performs the function of an aerial as well as that of an input tuned circuit. By their very nature, the inductance of these aerials cannot be varied over more than a small range, but this also means that they tend to require little if any adjustment. If needed, however, the adjustment is performed by sliding the coil along the ferrite rod.

By this time the set will probably be very sensitive, and you may not be able to find exactly the sort of signal you require. In this case it is quite in order to tune the set off a station and adjust for the greater noise output.

Modern aerial coils are designed so that the alignment is little affected by the aerial be it long or short, but some of the earlier aerial coils may not be above reproach in this respect. In any case we suggest that you do the final adjustment of the aerial trimmer with the aerial connected.



Typical RF signal generators. At top is a commercial unit, while immediately above is one of our more recent designs.

It may be worth mentioning in passing, that some broadcast band superhet receivers have no padder capacitor, either fixed or variable. The necessary tracking between the aerial and oscillator tuned circuits is ensured by having dissimilar sections in the tuning capacitor. The aerial (and possibly RF) tuning section is normal but the oscillator section plates are smaller and differently contoured.

The alignment procedure is exactly as set out for the fixed padder type of receiver.

To this point we have spoken only of the broadcast band. The procedure for the shortwave band or shortwave bands is essentially the same, but there is the added difficulty that it is often hard to find and identify a suitable station for alignment.

Conditions vary a great deal, and sometimes change within a matter of minutes. Therefore, do not be discouraged if first results are not very satisfactory. Of course, the aerial is more important than in the case of the broadcast band, because you frequently wish to listen to very weak signals. However, shortwave stations are heard strongly in Australia, and even a poor aerial will often receive them at considerable strength.

Another problem is that most conventional dual-wave receivers will "double spot" on strong signals. Double spotting is due to the fact that the local oscillator can produce the required 455 kHz beat when it is in either of two conditions — 455 kHz higher or lower than the wanted frequency. Thus, a second spot is always twice the IF (910 kHz in this case) away from the correct dial setting.

While the simple aerial tuned circuit will easily reject the second spot on the broadcast band, it is inadequate on the short-wave bands, and a strong signal will inevitably be found at two points on the dial. For alignment purposes, and assuming normal circuitry, the setting having the higher frequency of the two is almost always the correct one.

An excellent source of signals for shortwave alignment and frequency calibration of receivers are those radiated by standards stations such as the American WWV and WWVH, and the Australian station VNG in Lyndhurst, Victoria. Generally WWV and WWVH are heard in Australia at good strength on 5MHz, 10MHz and 15MHz, while VNG may be found on 4.5MHz, 7.5MHz and 12MHz.

The signals from these stations can easily be identified by the audio tones which are superimposed on the RF carrier and the fact that the tones are interrupted by a one-second pulse. There are interruptions at regular intervals for call sign announcements and other purposes.

If suitable test instruments are available, of course, a more precise job can be made of alignment. As we said earlier, we are not so much concerned in this chapter with readers who are sufficiently advanced to own or have access to test instruments, but a brief explanation may help the beginner understand what it is all about.

The best instrument for alignment is a modulated oscillator or the more elaborate instrument which usually goes under the name of a signal generator. These instruments can produce radio frequency signals anywhere in the spectrum required for alignment and the strength of the signals can be controlled by turning a knob on the front panel.

The signal is modulated usually by a 400Hz tone, so that when reproduced by the receiver a single whistling note is heard from the loudspeaker. With a signal thus available at any desired frequency, at any desired strength and producing a constant output tone, alignment is much simplified.

The alignment of television receivers involves special techniques and special equipment and in no circumstances should beginners tamper with TV tuners or IF systems.

Unlike the tuned circuits in broadcast receivers, those in a television receiver are not peaked for maximum gain. They have to be adjusted to pass a band of frequencies, from 5 to 6 megahertz wide, over which the audio and video signals from a television station are distributed. If the tuned circuits in a TV receiver were simply peaked in the normal way, the receiver might well become unstable. In any case it would produce only a poor picture, with no sound, or sound with little or no picture.

Even the sound channel in a television receiver is "special," involving a frequency modulated signal, as distinct from amplitude modulation used by ordinary broadcast stations.

Alignment of picture IF channels in a television receiver is normally performed with the aid of a "sweep and marker" signal generator and a cathode-ray oscilloscope.

The alignment problems inside a television tuner are even more complicated than for the IF systems, such that tuner alignment is rarely attempted other than at the factory or at special tuner service depots.