The Alignment of Superheterodyne Receivers Feb 19, 1999

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Disclaimer

The procedures outlined below require that a receiver be adjusted while in operation. Most receivers have potentials of hundreds of volts exposed while in operation, sometimes even on the metal chassis, and these voltages can be lethal. If you are not familiar with proper procedures for handling these voltages, do not attempt any of these procedures. The author and OVRC are not responsible for any damage or injury caused by executing these procedures.

0. Abstract

This article describes techniques for the alignment of AM and short-wave superheterodyne receivers, with emphasis on tube receivers. Emphasis is on practical techniques, with little theory behind what is done.

1. Introduction

The superheterodyne receiver architecture, patented by Major Edwin Armstrong in 1917, has been widely used since the late 1920's for all but the simplest receivers. In a superheterodyne receiver, the incoming signal, which could be at any frequency that the receiver is designed to cover (the Radio Frequency, or RF), is converted to another fixed frequency, known as the Intermediate Frequency (IF). The frequency conversion is done by mixing a locally generated signal (the Local Oscillator, or LO) with the incoming signal in an non-linear element known as a mixer (sometimes known as the first detector). In most consumer grade receivers, the mixer and LO function are combined into one element called a converter. Since the IF section of the receiver operates at a fixed frequency, it is quite simple and cost effective to achieve high gain and well defined frequency response. The frequency response of the IF is generally set to the channel bandwidth, and is responsible for adjacent channel rejection. Detection and audio amplification follow the last IF stage.

The main advantage of a superheterodyne architecture is that crucial channel selection filtering is done at one fixed frequency rather than (in a Tuned Radio Frequency, or TRF receiver) at RF where it must be maintain a constant bandwidth while being tuned across the band. In a superheterodyne receiver, there are a number of tuned circuits that all need to work in harmony, and it can sometimes become necessary to adjust some of these circuits for optimum performance. The purpose of this article is to describe some techniques for performing an accurate alignment on common consumer superheterodyne receivers. It is assumed that no servicing information such as a schematic diagram or alignment procedure is available. These techniques can be used for single or multiple band "AM" receivers. The alignment of FM and communications type receivers, and permeability tuned receivers will not be discussed.

2. Symptoms of Misalignment

A poorly aligned receiver can exhibit poor sensitivity, poor selectivity (several closely spaced stations coming in at once, and accentuated high frequency response: strong "S's" ), inaccurate dial calibration, and reception of a single station in different places on the dial. In extreme cases, the receiver may appear to be dead, although this would be most common after a component (especially an IF transformer) is replaced.

One symptom that does *not* indicate a misaligned receiver is "birdies" or "whistles" appearing across the dial. This is indicative of an oscillation, possibly due to a defective bypass capacitor.

The most common cause of a receiver going out of alignment is component drift and component replacement. Some component drift over the years is expected, but generally it should cause only minor degradation of performance. Another cause can be adjustment by "unskilled hands". I have seen this more than once, and have, in my earlier years, been responsible for a few cases myself! Finally, I am convinced that some radios never received an accurate alignment at the factory. In any case, alignment generally does not go far out by itself. If the alignment is way out, look for a “root cause” such as a bad component.

## 3. The Four Steps

There are four steps to every alignment. The first is to troubleshoot the radio to make sure that there are no faulty components. This first step can include a preliminary alignment. The second step is the alignment of the IF strip. This can be accomplished in several ways which will be discussed below. The third and fourth step is the alignment of the LO tuned circuit and RF tuned circuits, and these are often done at the same time.

### 3.1 IF Alignment

Three techniques will be described for IF alignment: The first is “by ear”, and is useful as a “first cut”, to be used if the receiver is not far misaligned or to determine if there are other problems with the receiver. The second uses a generator and meter to accurately detect the peak in the tuned circuits and is a better technique than “by ear”. The third technique, mainly for purists, actually indicates the frequency response of the IF strip and allows it to be shaped by staggering the tuning of IF stages, and is requires the most equipment.

#### 3.1.1 Alignment by Ear

The first step in this, and all IF amplifier alignment procedures is to identify the IF transformers. They are generally located above the chassis in metal cans generally with 1 or 2 holes in the top. IF transformers can also be located below the chassis, but these are generally not tunable. In the hole there could be a metal screw which is a trimmer capacitor or ferrite rod (generally 2 of them), or a threaded ferrite or powdered iron slug with a hex shaped hole in the middle. Beware of the trimmer capacitors; they can be “hot”, and you could get a shock, or burn out a part. Notwithstanding the safety issue, a metal screwdriver can usually be used on these. The best tool, however, is a non-metallic alignment tool with a small metal blade. Ferrite slugs must be adjusted with a non-metallic alignment tool; a metal one will de-tune the transformer. Note that there are usually two slugs in a slug tuned IF transformer; one can be reached from the top, and the other reached from the bottom, or a special tool can reach them both from either end.

Doing an alignment “by ear” is almost trivial: tune the radio to a weak station and adjust the IF transformers for maximum volume. The last IF transformer should be the first adjusted, and then move back towards the antenna. The last transformer will be located close to the detector tube, which will be type 75, 6Q7, 6SQ7, 6H6, 6AV6, 6AT6, or a diode of some sort. In Asian transistor radios, the IF transformer with the yellow slug is closest to the antenna, the one with the black slug is closest to the detector, and ones with white slugs are in-between. In these transformers, it is usually necessary to melt away the sealing wax with the hot tip of a soldering iron

All tuning should produce a sharp peak (although the transformer closest to the detector is often less peaky). If the peak is subtle or nonexistent, if the adjustment has be cranked more than 1 or 2 turns, or if the adjustment reaches the physical end of its range without a peak, then there is probably something else wrong. Go back and check all circuitry.

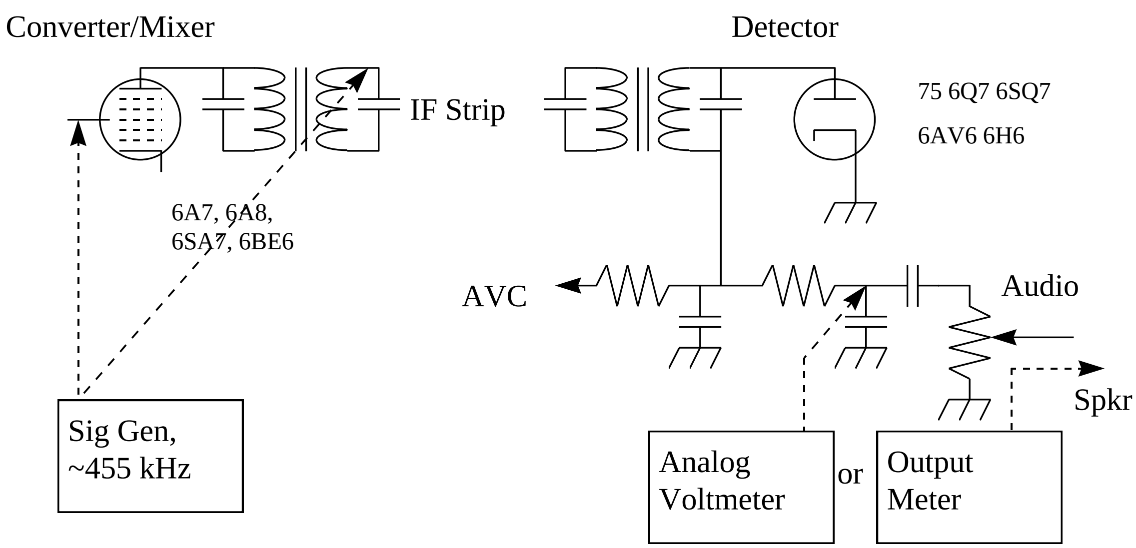
#### 3.1.2 Alignment by Instrument

An instrument alignment allows a more precise adjustment, and ensures that the IF is tuned to the frequency that it is designed for. Obviously, this frequency needs to be determined before alignment can proceed. First, check the back of the chassis, and the tube placement chart; the IF frequency is sometimes printed there. If it’s not there, then you may have to guess. If it uses octal or later tubes, then it is probably 460 kHz +/- 5%. Transistor radios standardized almost exclusively on 455 kHz. The precise frequency is not important; a 10 kHz error either way is immaterial. Sets that predate octal tubes are more of a challenge as there was less standardization. Frequencies of 185 kHz, 190 kHz, 260 kHz and others were used. It may be necessary to use a grid dip meter or to sweep the IF with a calibrated generator before proceeding.

Note that a strong radio station at twice the IF frequency can experience interference with itself because its second harmonic is the same as the radio's image frequency. (The action of a mixer inherently makes the receiver sensitive at 2 different frequencies: LO+IF and LO-IF. Generally, the LO-IF is the desired signal, and the antenna filter rejects the LO+IF signal, which is the image) This can happen to radio stations located between about 900 kHz and 930 kHz. If there is a radio station in this vicinity, and whistles are heard when tuning the station, try changing the IF frequency by 10 kHz.

The equipment required for this procedure is a generator operating at the IF frequency and a DC or audio output meter. The audio output meter is somewhat easier to use because it can be connected across the speaker voice coil, the output transformer, or the input to one of the audio amplifier tubes. If a DC meter is used, it must be connected to the receiver's AVC (Automatic Volume Control) system. Generally, select the terminal on the last IF transformer that does *not* go to the detector diode, and does not have high voltage on it. The meter should read a negative voltage with respect to the chassis which becomes larger when a signal is applied.

The RF generator should be set to the IF frequency and coupled to the RF grid of the mixer/converter, or the antenna section of the tuning capacitor. I generally couple it through a 0.001μF capacitor. In some sets, it may be necessary to couple this signal into the grid of one of the IF stages preceding the stage being adjusted to get adequate signal strength. The generator must be modulated if an output meter is used, and I generally use a modulated generator anyway so that I can hear what is going on. The receiver should be tuned to an empty part of the band, or the LO should be disabled by shorting the LO tuning capacitor to ground through a 0.01μF capacitor. The set-up is shown in Figure 1.



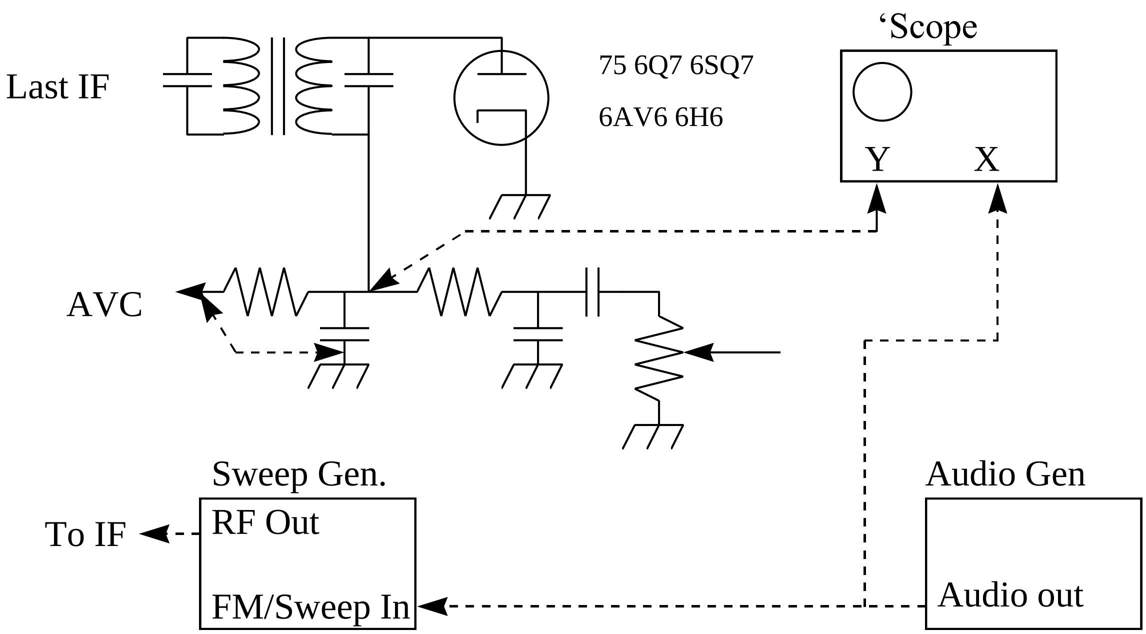

The signal generator amplitude should be advanced until sufficient signal is seen on the meter, and the IF transformers adjusted for peak response. As before, the last IF transformer is done first, and the procedure is repeated on subsequently earlier stages. The signal should be kept just high enough to get a reliable indication on the meter, no higher. Note that the two adjustments in a transformer tend to interact, so it will be necessary to re-peak the adjustments.

If the IF is very narrow after this procedure, it may block higher frequency sidebands, and result in a radio with poor audio high frequency response. This can be overcome either by doing a swept alignment, or by giving each adjustment a *very* slight intentional mistune. Generally, on IF cans with two adjustments, one is tweaked clockwise, and the other counterclockwise.

### 3.1.3 Swept Alignment

Swept alignment gives you the frequency response of the IF strip. A perfectly adequate alignment can be done by the previous method, but a swept alignment can be useful on 2 or more IF stages of a low frequency IF, where linear alignment results in a very narrow frequency response. It is essential for aligning an FM receiver, but this will not be covered here.

To perform this alignment, a sweep generator (with built-in or external audio oscillator) and an oscilloscope are required. I use a simple home-built sweep generator (described in the appendix) and an external audio oscillator connected to the “X” input of an oscilloscope. The “Y” axis connects to the AVC voltage as described in the last section. The set-up is shown in Figure 2. The frequency of the audio oscillator should be kept low; below 100Hz is fine. 60Hz can be used, but beware that hum will distort the apparent frequency response. Using the preferred technique with the audio connected to the DC coupled “X” input of the oscilloscope, any convenient waveform can be used. If the oscilloscope’s internal sweep is used, then the audio generator must produce saw-tooth waves, and the oscilloscope should be triggered from this waveform. Note that the AVC must be disabled by shorting it to ground at an IF transformer.




First, the generator must be set to the correct frequency and sweep width. I do this by replacing the audio generator with a DC power supply and monitor the output frequency with a frequency counter. With the power supply set to 0, I adjust the generator so that the center frequency is the correct IF frequency, and adjust the “X” position until the spot is in the middle of the screen . Then I adjust the power supply until the frequency is about 15kHz higher, and set the “X” axis gain so that the spot is at the edge of the graticule. This is repeated a couple of times. The power supply is replaced with the audio generator, and the audio amplitude is increased until the trace width fills the graticule.

Now, the signal is applied through a 100pF capacitor to the grid of the last IF, and the final transformer is adjusted for peak output in the middle of the oscilloscope trace (Since the AVC voltage is always negative in a tube radio, the peak will actually be a dip). Keep the signal just high enough to get a clean trace. The input signal is moved back towards to the antenna and each transformer is peaked. Finally, the signal is applied to a grid in the mixer/converter, and all transformers are re-peaked. Note that it may be necessary to disable the LO to prevent broadcast stations from interfering with measurements (short the LO side of the tuning capacitor to ground through a 0.01µF capacitor). To widen the IF response, turn one adjustment in each transformer clockwise, and the other counterclockwise a small amount (start with 10 degrees, or so).

From here, its a matter of trial and error to get a good compromise between gain, bandwidth, and skirt steepness.  A 3dB bandwidth of 10 to 20kHz is generally best for an AM receiver.

## 3.2 LO and RF Alignment

There is no good reason for using the swept techniques for the alignment of the RF and LO sections of a receiver; alignment can be done either by ear as in 3.1.1 (using known stations as references), or with a calibrated source and a meter as in 3.1.2. In either case, the first step is to identify what adjustments are available, as the number of adjustments determines the procedure.

### 3.2.1 Adjustment Identification

In the ideal world, you would like to have two LO adjustments per band (I will call them the HLO for the adjustment that has the most effect at the high end of the band, and LLO for the one that has more of an effect at the low end of the band), and two RF adjustments per band (HRF and LRF). Ideally, there should be an additional pair per band if there is an RF amplifier. In reality, there are usually fewer adjustments, and sometimes a single adjustment has an effect on multiple bands.  Few receivers identify the adjustments; schematics can be useful, but multi-band receivers can be very difficult to follow. Generally, I use trial and error, and some obvious rules of thumb.

The HLO adjustment is usually a trimmer on the LO tuning capacitor (the smaller gang, or the one not connected to the converter tube grid cap), or in parallel with the LO tuning capacitor. One side is always grounded. If the other side of the capacitor is touched with a screwdriver, the radio will detune, such that it receives stations at other frequencies. Adjusting this capacitor will have most effect when the radio is tuned to the high end of the band, and will have a similar effect to tuning the radio.

The LLO adjustment is sometimes a variable inductor associated with the LO tuning capacitor (in Asian transistor radios, it often looks like an IF transformer with a red slug), or a trimmer capacitor in series with the LO tuning capacitor. If it is a trimmer capacitor, neither terminal will be grounded. Adjusting the capacitor will have most effect when the radio is tuned to the low end of the band. If it is an inductor, it will have roughly equal tuning effect across the band. If there is no adjustment, the LO tuning capacitor plates can be bent instead. (I have not been lucky with this. I suggest only bending them outward, reducing capacitance, as bending them in will invariably cause a short.)

The HRF adjustment is usually a trimmer on the RF tuning capacitor (the larger gang, or the one connected to the converter tube grid), or in parallel with the RF tuning capacitor. One side is always grounded. If the other side of the capacitor is touched with a screwdriver, the volume of the station being received will change (often louder), but the set will not detune. Adjusting this capacitor will have most effect when the radio is tuned to the high end of the band, and will strengthen or weaken the signal being received, but will not detune the radio..

The LRF adjustment is sometimes a variable inductor (the antenna coil associated with the RF tuning capacitor), or in rare cases a trimmer capacitor in series with the RF tuning capacitor. If it is a trimmer capacitor, neither terminal will be grounded. It is very often missing. Again, tuning capacitor plates could be bent to effect an adjustment, but the effect is so minor it is of little use.

### 3.2.2 RF/LO Alignment Procedure

Once all available adjustments have been identified for each band, connect a generator to the antenna port (through a small capacitor, say 47pF), and a signal strength meter as described in section 3.1.2. Now, figure out a strategy. On multiple band sets, the first band to align is the one with the fewest adjustments available, usually one of the short wave bands. Don’t be surprised if some bands have no unique adjustments; the best you can do is compromise, or only align the band you plan to use the most.

There is one other adjustment often overlooked: this is the position of the pointer on the dial cord, or the indicator on the shaft of the tuning capacitor. Before starting, make sure that as the tuning capacitor is adjusted, the pointer traverses the dial (the complete band). There are sometimes calibration marks indicating the intended end points.

The table below indicates the procedure for the most common suites of adjustments. If a generator is not available, then stations at roughly 600-700kHz and 1300-1400kHz can be used. If you are adjusting a short-wave band, then substitute a frequency close to the low end of the band for 600kHz, and close to the high end for 1400kHz. It's best to avoid the ends of the band, because tracking is often much worse at the very ends.

The steps listed in the table should be executed in the order listed (for the number of adjustments that you have discovered on your radio), and then the procedure should be repeated until no further improvement is noted. As mentioned above, start with the band with the minimum number of adjustments. When doing subsequent bands, do not readjust the adjustments set on the first band.

| *Input Stimulus* | *Alignment steps for various receiver configurations* | | |
|---|---|---|---|
| | *HLO and HRF only* | *HLO, LLO, HRF* | *HLO, LLO, HRF, LRF* |
| Set generator to 600KHz, or low end of band. | Tune to signal, slide dial pointer to 600. | Rock tuning while adjusting LLO for peak. Slide pointer to 600 | Set radio to 600 on dial. Peak LLO . |
| Same as above | | | Peak LRF. |
| Set generator to 1400KHz | Set radio to 1400. Peak HLO. | Set radio to 1400. Peak HLO | Set radio to 1400. Peak HLO |
| Same as above | Peak HRF | Peak HRF | Peak HRF |

If you find that an adjustment reaches its mechanical end before reaching a peak, mistune one of the other adjustments while rocking the tuning capacitor until a peak is found. If this does not work, there may be components that are broken, or have drifted.

### 3.3 IF Trap

Some receivers have an IF trap, which is a series L-C connected from the antenna to ground. It should be adjusted for minimum sensitivity to a signal at the IF frequency when the radio is tuned to the low end of the AM band.

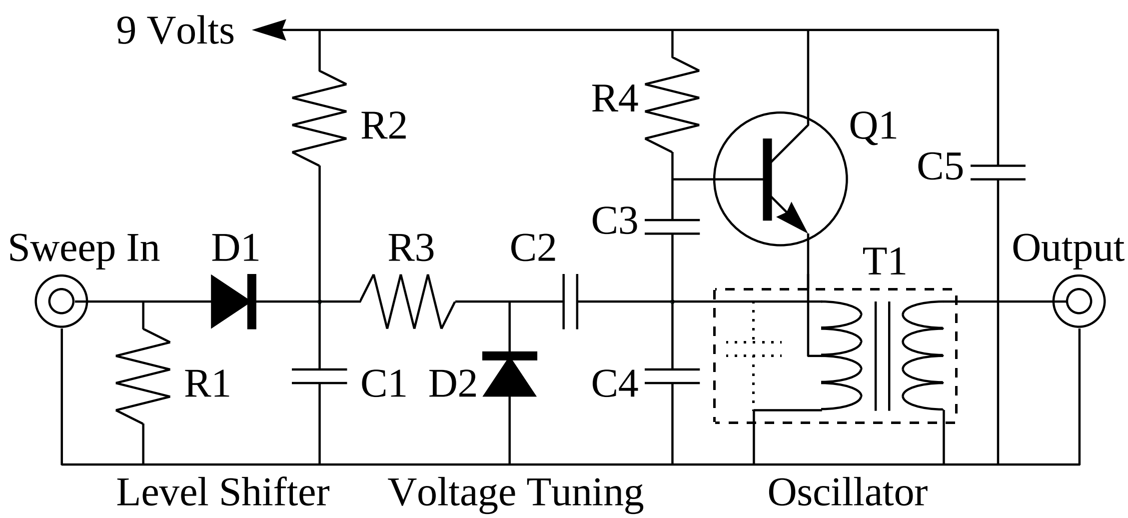
After alignment is done, the radio's calibration should be checked at a couple of places across the band, just to ensure all is well, and that the tuning capacitor does not short.

## 4. Conclusions

In preparing this article, I came to realize that writing a procedure that would apply to all receivers would be futile, and would result in a even more wordy document. Murphy's law states that the next receiver you try to align will not be covered by this article. In that case, experiment, use some trial and error, and be very suspicious if you need to adjust anything too far. Good luck!

## Appendix

A simple sweep oscillator can be made with an IF transformer from a transistor radio (I use the transformer with a white slug but others should work as well). The RF frequency, nominally 455 kHz or so, is adjusted with the transformer slug, and the DC bias on the sweep input terminal. The sweep rate is set by the audio oscillator connected to the sweep terminal, and the width of the sweep is set by the audio oscillator amplitude (about 5 kHz/volt). C4 may have to be adjusted so that the transformer can be tuned to 455 kHz. The oscillator can also be tuned to the bottom end of the AM band for radios that use other IF frequencies. All parts in this oscillator are easily available and not too critical.




| | | | |
|---|---|---|---|
| C1 | .01 µF | R1 | 47 ohm (or to match audio generator) |
| C2 | 100 pF | R2 | 3.3 K ohm |
| C3 | 47 pF | R3 | 10 K ohm |
| C4 | 100 pF | R4 | 220 K ohm |
| C5 | .1 µF | T1 | IF Transformer from transistor radio (white core has been tested), with capacitor under transformer removed. |
| D1 | 5 volt zener diode | | |
| D2 | 1N4002 diode | | |
| Q1 | 2N2222 transistor | | 9 volt battery |