Bob’s TechTalk #37

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Beginner Talk

The Superheterodyne Receiver:

Wow, 'superheterodyne' is a big word. It is also the design that revolutionized receivers and is still the design of choice. What does this word mean and why is it so good? Today we'll explore those questions.

In the early days of radio the tuned radio frequency (TRF) receiver was common. Figure one shows its design. It consists of a number of tuned radio frequency amplifiers followed by a detector and an audio amplifier that can drive earphones or a speaker. Generally, these receivers tuned frequencies below one or two megahertz. Frequencies above that were considered unusable for broadcast. (The original ham band was all the undesirable frequencies below 200 meters* – above 1.5 MHz).

Let's take a quick look at the RF amplifier. When properly designed it amplifies linearly; multiple signals on different RF frequencies are all amplified equally. In a TRF receiver this is undesirable because you will hear all the stations at once. Thus each RF amplifier is tuned using an LC* circuit. This tuned circuit passes signals near its tuned frequency as shown in Figure two, and reduces signals away from the tuned frequency. The response of the filter depends on the 'Q' of the circuit. 'Q' is most influenced by the resistance of the coil.

The ability of a receiver to reject nearby signals is known as selectivity. In the TRF radio multiple tuned circuits are used for selectivity. As you change receiver frequency all these tuned circuits must tune together and track exactly – something that can be difficult to accomplish especially at higher 'Q's. Also, tuned circuits are effective relative to frequency. At higher frequencies two signals must be further apart to be attenuated the same amount for otherwise identical tuned circuits.

Let's briefly look at the other parts of the tuned receiver. The detector separates the intelligence (usually audio) from the RF signal. There are numerous types of detectors: diode detectors for AM; product detectors for SSB, DSB and CW; and discriminators or ratio detectors for FM. Detectors are a thesis on their own, so for now just remember it's a circuit that separates the modulation from the RF signal. Next is the audio amplifier. It just amplifies the audio so the intelligence may be heard through earphones or a speaker.

As TRF receivers are used for higher frequencies their selectivity becomes poorer and the tracking of all the tuned circuits becomes a nightmare, especially if band switching is involved (usually accomplished by changing plug-in coils.)

An advancement over the TRF is the regenerative receiver. It achieves high gain and selectivity by introducing positive feedback into an RF amplifier. It has a lot of desirable features. It uses less stages and parts than the TRF. It can operate effectively at much higher frequencies (into VHF). On the negative side, it is more difficult to tune, has poor stability and requires careful adjustment of the feedback. Still the regenerative receiver gained a lot of popularity and was used in radios like the Heathkit "Lunchbox" and the National 1-10. Regenerative receivers are easy to homebrew. Still, they don't have the ease of tuning we have come to expect in our receivers today.

Let's look back at the tuned RF amplifier. At lower frequencies it provides reasonable selectivity but multiple tuned circuits are hard to track when tuning the radio. BUT, what if the receiver only tuned one frequency? Then you could use multiple stages with tuned transformers between them. The transformers only had to be tuned once and could be designed for higher 'Q'. Also since the frequency was fixed things like crystals with their very high 'Q' could be used as filters to improve selectivity tremendously. Alas though, you'd need a receiver for each frequency you wanted to listen to… or would you?

Let's go back to the RF amplifier again. Remember we said that a linear amplifier will amplify two signals equally. Well, if we design that amplifier with some built-in non-linearity we get something of a different response. In a non-linear RF amplifier the two signals interact so that at the output there are four signals, the two original signals plus a signal that is at the sum of the two signals and another signal that is at the difference of the two signals (Actually there are other weaker signals too that we won't discuss here but do play a part in good receiver design.) Thus if you have a signal at 1 MHz and another at 1.455 MHz you will have four signals at the output. The two original signals plus slightly weaker signals at 2.455 MHz (the sum) and 0.455 MHz (the difference). This phenomena is called heterodyning and the circuit is called a mixer.

Figure 3 shows the design of a typical superheterodyne receiver. The desired signal is amplified by the RF amplifier and fed into the mixer. An oscillator operating at a frequency above or below the received frequency is ganged with the RF amplifier tuned circuit(s). As you tune the receiver the oscillator (called the local oscillator or LO) changes frequency so that it always remains a fixed frequency away from where the RF amplifier is tuned. This difference in frequency is called the Intermediate Frequency (IF) and is the fixed frequency where most of the gain and selectivity is accomplished. The RF amplifier can now be designed to provide good signal to noise capability and good overload capability instead of gain and selectivity. The detectors and audio amplifiers operate similarly to the ones in the TRF receiver.

One problem with the superheterodyne receiver shown in Figure 3 happens at higher frequencies. Lets look at receiving a signal at 28.455 MHz. At the higher bands the local oscillator usually operates below the received frequency so it would be be at 28.000 MHz. If there is a signal at 27.545 MHz, the only thing keeping it from appearing at the IF frequency is the 'Q' of the RF amplifier's tuned circuit(s). If the signal is strong enough it will be heard. This unwanted signal is called an image. It can be reduced by raising the IF frequency or by using two IF frequencies, two mixers and two local oscillators. Since the two IFs are fixed, the second LO can be crystal controlled. This type receiver is called "double conversion" superheterodyne. The first IF is usually only one stage but is high enough in frequency to reject the undesired image. Figure four shows a typical double conversion receiver. Triple conversion receivers exist too.

Since superheterodyne receivers have oscillators in them, especially double and triple conversion receivers, a byproduct of these oscillators can appear as a signal in the receiver. This byproduct is called a "birdie". They always appear in a given receiver at the same frequency and receivers may have more than one. Designers choose frequencies within the receiver to minimize birdies or put them at frequencies where they do less harm.

A variation on the superheterodyne receiver seen in many ham receivers since the sixties (or even fifties for expensive receivers) is to have the first LO crystal controlled and the first IF have a wide bandpass of 200 KHz, 500 KHz or more. The second local oscillator is then tunable over one fixed range of 200 KHz, 500 KHz or more and the second IF is fixed. This feature removes the requirement that the tunable LO be switched to cover different frequencies on different bands and allows the tunable LO to be designed to operate very accurately. the Heathkit LMO and Collins PTO are examples of such oscillators. Heathkit's LMO tunes 500 KHz between 5.000 MHz and 5.500 MHz, and the Collins PTO (70K2 used in the 75S3) tunes 200 KHz between 2.955 and 3.155 MHz.

Today's receivers benefit from new technologies that were only dreams a few years ago. Phase-lock-loop oscillators provide tuning with crystal control stability and accuracy. Software designed radio handle signal processing in onboard firmware. New amplifier designs provide sensitivity and signal to noise ratio improvements along with high immunity to overload. Filters provide high selectivity. Roofing filters, usually located just after the first mixer, reduce overloading and distortion from being created in the high gain stages of the IF by reducing or eliminating off frequency signals before they are amplified.

Heterodyning is also found in SSB transmitters. Generating an SSB signal at a fixed frequency allows easy design and the use of a crystal or mechanical filter to eliminate the unwanted sideband. The fixed SSB signal can then be heterodyned to the desired frequency and fed to a linear power amplifier for transmitting.

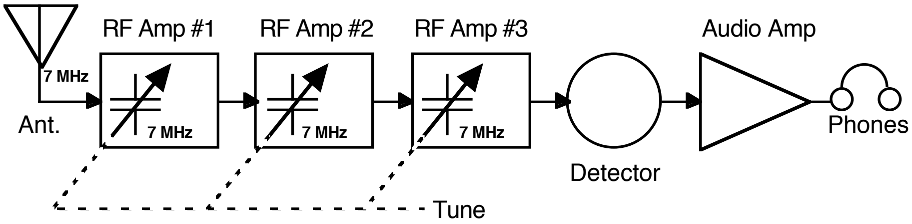

Figure 1 – TRF Receiver

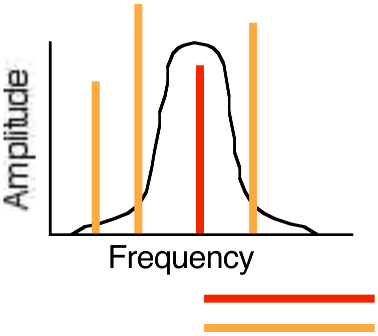

Figure 2 –Typical LC Response

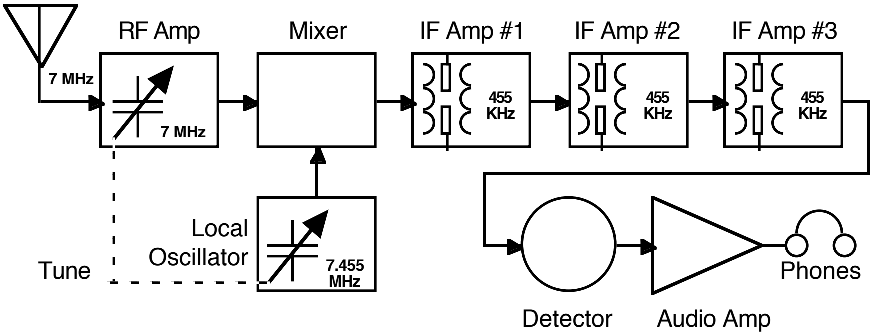

Figure 3 – Superheterodyne Receiver

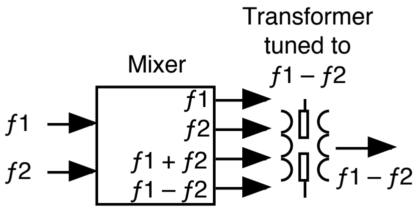

Figure 4 – The Mixer

73, from AF6C

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