A Guide to the Evolution of HF General Coverage Receivers at Collins Radio

The story of the evolution of receivers at the Collins Radio Company is an interesting walk both through the progress of technology, and also a look at how, and where, Collins Radio did business over that time period.

What is presented here will by no means be complete. To try and be all inclusive would be both too long, and almost impossible to get right. Even with that caveat, I am sure that there will be cases where someone will say that a sin of omission has occurred, or that this or that should been selected in place of one chosen here. For sure, there will be entire marketplaces that are omitted since, after all, there were eventually amateur radio, microwave, commercial, military, avionics, space and even a humble broadcast band receiver.

Since our audience is almost exclusively mainly interested in the area of HF and Amateur Radio, the focus here will be in that area that is overtly aimed at (or could be applied to) Amateur Radio use or collection. At the same time, this sampling will attempt to demonstrate the evolution of technology and manufacturing during the period represented. Again however, we will see Art Collins' almost premonition/vision of the importance and future roll of the computer come to life.

To start, one must be aware of the fact that Collins Radio did not set out to be a receiver manufacturer. This fact.. this mindset … was driven mostly by Arthur Collins' search for significant communications technology and progress in areas where he could make significant contributions. Additionally, early on, there were many more fairly mature for their time receiver companies already in business at the time the Arthur entered the scene. National, RME, Millen ……. Just to name a few.

For easily the first four or five years that Collins Radio was in business, they considered themselves soundly as a transmitter (and to some degree early on a transmitter parts) manufacturer. In fact, one of the first names chosen (there were several) by young Arthur when he first started in business was just "Collins Radio Transmitters". Renamed the Collins Radio Company by the time it incorporated in 1933, it still approached its future with the "Transmitter" mindset.

Never the less, receivers did enter the picture very early in the history of the company. One of the things that we do know – driven by a passion for getting business that smacked of recovery from a depression – is that Art would do almost anything to get a sale, or go after business. This passion led him in a number of documented cases, and there are probably more, where he provided a receiver "solution" to a customer who came to Collins looking for a communication system.

50A Receiver

During 1933 and 1934, there are three documented receivers, the 50A, 50B and the 51A that show up in early documentation. In these three cases, it is believed that just one receiver was built for one customer who also purchased a transmitter.

50B Receiver

The 50A and 50B pictured here are representative of the companies design philosophy at the time. All three of the receivers mentioned above are built with standard off the shelf National - with perhaps a little Millen thrown in - components. They are however constructed on, and with, typical Collins chassis and hardware components of the period, and may involve some further circuit development. We do not know for sure. They do have an appearance of being very similar to the National AGS of the period.

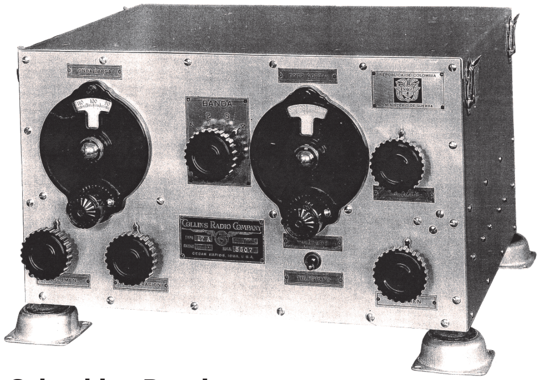
The third photo shows the complete system provided for the *Standard Fruit Company* and contained the 50B, a Collins 150C in an enclosed cabinet system with a door. This was the first totally rack mounted system believed sold by Collins.

Also in this same early period, we have documentation indications that Collins changed their receiver numbering from the 50 series to the now familiar 51 series. There was a (low volume) 51A and then we have one letter indication there was a 51B.

50B Receiver
In 150C System

The first "volume" production receiver built by Collins Radio was most certainly the Colombian Army Air Force contract 17A. Again, this piece of business was developed as a system solution for the customer in order to capture this, what amounted to, huge piece of business for its day. In 1935, the fledgling Collins Radio Company received their first really large order for a suite of equipment that included airborne receivers, transmitters (and support components) as well as ground station equipment. The airborne equipment was destined for a number of different types of aircraft with some model variations by aircraft.

There isn't a detailed accounting of these various models remaining, but we do know that the order was for $57,677 and that the dominant receiver design involved was the 17A pictured below. While the entire order is known to have been enough to provide communication for 50 aircraft, the exact volume of the 17A build is not known. There are at least 8 pictured in one photo that survives.



17A Colombian Receiver

Regarding the 17A receiver, little is known about the circuitry of this receiver other than it was a 4 band HF receiver with main and band spread dials and was intended for both AM and CW reception. Since the contract covered both fighter (Curtis Hawk) and bomber type aircraft, it is not known what type this one receiver was intended for.

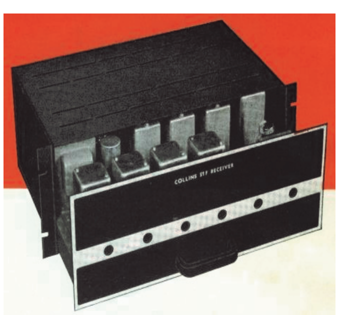
Following this Colombian contract activity, little remains of the records of individual receiver activity until we see the 51F receiver emerge in 1939. We should point out that, in April of 1939, Collins did announce the 18M/TCH Transportable Transmitter Receiver and in this context, the first actual production receiver was the 18M receiver that was completely independent inside the 18M.

In August of 1939, Collins Radio announced the 51F rack mounted single channel Phone or CW receiver and this would go on to have – what appears to be – just one build of receivers before the WW II efforts started to shut down commercial product development and focus at Collins.

The following "Guide" to the evolution of general coverage HF receivers is thus presented in this context. More information on the 51F can be seen in the article in this issue, and more technical information relating to feature evolution can be found in Don Jackson's nice Service Line article herein. Please see our website for a more complete pictorial guide to receivers @ http://www.collinsradio.org/receivers

Receiver Guide—HF General Coverage & Derivatives

General Coverage HF receivers of significance in the development of the receiver products at Collins Radio: Period covered is from 1939 though 2005. This spans from single channel fixed tuned single conversion superhet though the Software Defined Receiver (the 95S-1) from 1995, and the more current KGR-70 VLF/LF Receiver that is baseband A/D converted right off the antenna and then all "more classical" functions are accomplished in the processor…. Arthur would, indeed, smile. See the articles in this issue on the 95S-1 and the KGR-70 for more information on this amazing evolution of receivers over a 65 year period…..and it goes on - Not Your Grandfather's Oldsmobile.



51F Receiver

Single Channel
1.5—20.0 Mhz Phone/CW
Rack or Cabinet Mount Opt.
Introduced: August 1939
Used "New" RCA Metal Tubes

The first production volume announced standard product receiver was unique in many ways. It used a modular custom order factory construction method that came and went with this model. It could be ordered with one or two RF stages, crystal or variable injection oscillator, optional CW BFO and an optional Squelch module. It also sported a new style that was short lived as well. Less than 20 produced. Rare. It "reappeared" redesigned in January of 1946 as the post-war 51N-1. (Weight 22 lbs.)

51H-3/ARR-15 (R-105) Airborne Receiver

Autotune 10 Channel + Analog
1.5 - 18.5 MHz AM Phone/CW
Shock Mount Airborne
Introduced: 1944
26.5 - 28 Vdc 1.4A w/ Internal DY-34 Dynamotor supply 220 V.
Wt. 39 lbs. - Uses 70E-2 PTO

This receiver was developed early in WW II as a mate to the very successful ATC/ART-13 transmitter done initially for the Navy. The R-105 used the same channeling scheme as the ART-13 and could be channeled from the same control head providing pilot controlled "transceiver" operation on 10 channels—a first at that time. It did not see service in WW II but served through the Korean War & beyond.

51J & 51J-X Series

General Coverage - 30 Bands
0.5 - 30.5 MHz AM/CW
Rack or optional cabinet mount
Introduced: 1945
115 Vac Standard Power Req'd
Wt. 80 lbs. - Uses 70E-7A thru 70E15 PTO

Anticipating the end of the war, development was started in 1944 for this first post-war general coverage receiver. The Project Lead was Roy Olsen. Following Roy's departure in 1946, Lou Cuillard continued development, leading to the 51J-X and the 75A-X family of receivers. They all shared a unique combination of electrical/mechanical features using the new linear PTO, crystal controlled 1st injection oscillator and mechanical slug rack and geared tuning to achieve revolutionary electrical stability and frequency readout accuracy and reset ability. This line of receivers set a new standard and was remarkably successful.

R-390

General Coverage - 32 Bands
0.5 - 32.0 MHz AM/CW
Rack or optional cabinet mount
Introduced: 1950
115/240 Vac 60 Hz, 115 Vdc or 28 Vdc depending on options
Wt. 85 lbs., 33 tubes w/ 3TF7

The R-390 was developed by Lou Couillard at Collins Radio on a Navy contract during 1950 and production commenced in 1951. It was developed as an improved version of the 51J series which culminated in the 51J-3 in this timeframe. It was much more expensive than the 51J series and first contract cost to the government was $2500 per unit. The R-390 was developed to be much more rugged than the 51J series and also it was completely modular. Any functional module could be quickly removed and replaced at a field depot without the involvement of highly trained maintenance staff.

R-390A

General Coverage - 32 Bands
0.5 - 32.0 MHz AM/SSB/CW
Rack or optional cabinet mount
Introduced: 1956
Same power opt. as R-390
Wt. 85 lbs., 26 tubes

Development commenced in 1954 on a cost reduced and improved version of the R-390 which became the R-390A. It featured mechanical filters for pass band definition and was intended to bring the R-390 into the Single Sideband era.. It was wildly successful with over 50,000 produced by Collins and associated subcontractors. Like the R-390, it features triple conversion or double—depending of frequency, and uses just 26 tubes. Discontinued in 1970 with some exceptions.

51S-1 (S-Line) General Coverage

0.5 - 30 MHz AM/SSB/CW
Introduced: 1959 - 1982 w/ over 12,000 produced
Wt. 28 lb. Shock, rack, or cabinet mounting optional
IF pass band Transformer or Mechanical Filter

651S-1 (651S-1B Shown)

General Coverage - 30 Bands
0.25 - 30.0 MHz AM/SSB/CW
Rack or optional cabinet mount. Wt. 30# - Synthesized
Introduced: 1970
115/240/28 Volt Optional

This receiver was a derivative of the 671U-4/718U-X Commercial comm product line at the Collins Division of Rockwell International. The receiver employed a significant change in receiver architecture at Collins—using initial up-conversion to 99 MHz, the use of roofing filters and then down conversion to the first IF. It was the voice of the future and shared many boards in common with its parent products.

Early versions used NIXIE tube display technology, while the later units employed LED displays. Production ran from 1970 though 1977. It was also the first table top receiver to be frequency synthesized and capable of digital control through a serial port.

HF-80 Rcvr Family

HF-80 851S-1 Variable Gen. Coverage 0.25-30 MHz
All Mode 38 lb.

HF-8050A One Synthized Channel 0.25-30 MHz
All Mode

HF-8054A 4 Ch. ISB
0.25-30 MHz
All Mode 1981-1989

Developed by Paul Zeigelbein (851S-1/2) and Sil Dawson (8050A & 8054A), this family of receivers led the industry in cost-performance and was a very successful high performance, lower cost family of receivers that was developed in conjunction with the entire HF-80 lineup of exciters, transceivers, receivers, controllers and amplifiers.

The entire story of the development project and program history is available in the Q4 issue of the *Signal Magazine* from 2013. It is a fascinating story of change in an organization. The products all featured a new design paradigm employing off the shelf components where possible and "just enough" performance to win in the market place. It was hugely successful and the products still serve today in many applications—some 25 years later. Mating exciters are the HF-8010A and the HF-8014B—the single channel and 4 ISB channel versions respectively. Amplifiers range from 1 KW (HF-8020) tube and solid state (HF-8023) workhorses to the more eclectic 3 KW (HF-8021) and 10 KW (HF-8022) monster amps. The transceiver is the HF-8070)

451S-1 Receiver –Limited Production (10)- circa 1980

0.2 to 30.0 MHz AM/SSB/CW—Derivative of Casper Project
Same construction as KWM-380
Frequency Synthesized 10 kHz steps w/ Mechanical Filters
Wt. 28 lbs, Project Lead : Jerry Vonderheid

851S-1A Prototype—Updated Display & Control

Developed during 1980s as follow on to 851S-1
General Coverage - Frequency Symthesized
0.25 - 30.0 MHz AM/SSB/CW

851S-2 Prototype

General Coverage - Very similar to 851S-1 production version
0.25 - 30.0 MHz AM/SSB/CW
Wt. 38 lbs.

HF-2050—Production

General Coverage - Synthesized, 1st DSP RCVR to production
0.1- 30.0 MHz AM/SSB/CW w/ 99 Stored Preset Frequencies
Feature VLSI circuitry and just four circuit cards
Rack or optional cabinet mount
Mil Std 461 Qualified (No Deviations) - 1150 units produced
Produced 1985 through 1988 - Project Lead: Dave Church
Major customer was Canadian Government

Collins Receiver Performance Over the Years

by Don Jackson, W5QN - AC03-11523

A Little Radio History

When radio receivers were in their infancy, there was only one type, which was known as the Tuned Radio Frequency (TRF) design. This design was very simple, consisting of several RF amplifier stages, all tuned to the desired receive frequency with L/C tuned circuits. Following the amplifiers was a detector stage and an audio amplifier. This design was adequate for receiving AM broadcast signals, but as the desired receive frequency increased, it became difficult to achieve the required gain to drive the detector without instability (oscillation) occurring. In addition, achieving adequate selectivity became very difficult at higher frequencies. Even if a single tuning stage could be constructed with this selectivity, having several stages "tune" together was very problematic.

Another popular early receiver type was the regenerative detector, invented by Edwin Armstrong in 1914. With this approach, feedback in a tuned RF amplifier was adjusted to a point just below oscillation. This adjustment was touchy, but produced a great deal of gain in a single amplifier stage. It also resulted in a fairly narrow RF bandwidth for such a simple circuit. It was quite effective considering its simplicity, but it became a "transmitter" if it broke into oscillation, was not very stable, and had poor linearity. A modification to this design was an even more sensitive circuit, the super-regenerative detector. In this concept, the amplifier actually was designed to oscillate in a pulsed fashion. Of course, this created a low power pulsed transmitter by design, so was not popular for military or commercial applications.

The Superheterodyne Receiver

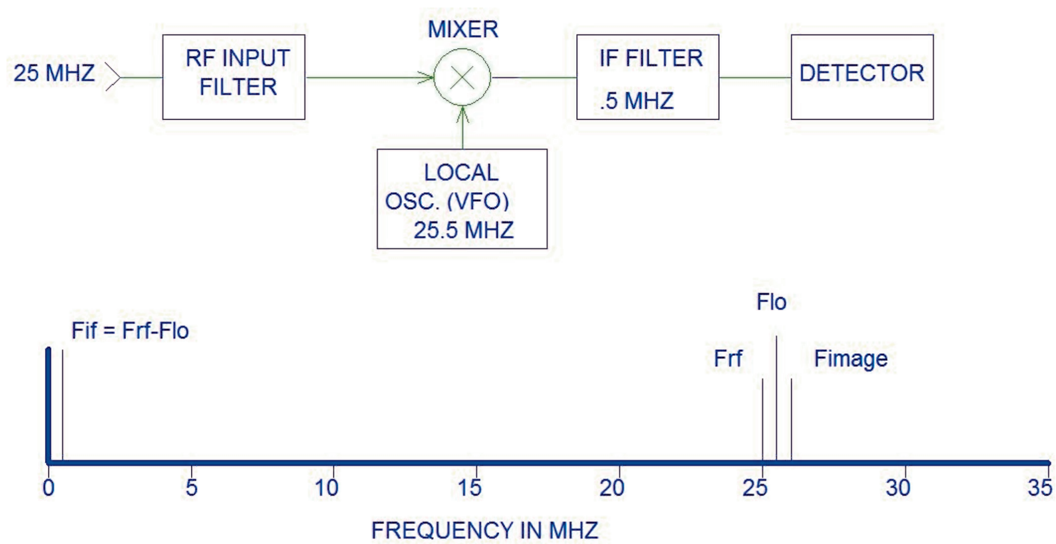
The superheterodyne (usually abbreviated to "superhet") receiver concept is the solution to most of the early receiver problems. The superhet design was also invented by Edwin Armstrong in 1918, and revolutionized receiver design. However, there is usually no "free lunch" in the engineering world, and the superhet design creates some challenges that must be considered. There are a huge number of possibilities for the "frequency conversion plan" used in superhet design, but we will follow along the trail of the Collins engineers starting with their earliest receivers, A-Line, S-Line, KWM-380, and the 95S-1. All are superhet receivers and have certain things in common:

at least one mixer
at least one local oscillator (f_{LO})
at least one intermediate frequency (f_{IF})

The mixer function is the most important concept to grasp in order to understand how a superhet receiver works. In its ideal form, a mixer is simply a device that multiplies two input signals (f_{RF} and f_{LO}) together. Considering the simplest case, where f_{RF} and f_{LO} are sinusoids, the mixer output consists of two sinusoids: f_{RF}-f_{LO}, and f_{RF}+f_{LO}, which we will call f_{IFhi} and f_{IFlo}. In the case of a complex f_{RF} input and a sinusoidal f_{LO}, the two IF output signals are essentially copies of the RF signal, translated to new frequencies. The only other difference between f_{IFhi} and f_{IFlo} is that they are "spectrally inverted" with respect to each other. Which of the two mixer outputs is "inverted" depends on whether f_{LO} is larger or smaller than $f_{RF.}$ Note that if f_{LO} is greater than f_{RF} , f_{IFlo} is a negative value. However, the sign is irrelevant to the problem, as a "plus" or "minus" sign simply indicates a phase inversion.

So, let's look at an example of a "single conversion" (one mixer) superhet receiver and examine the advantages and disadvantages. Assume we wish to receive an f_{RF} signal at 25 MHz, and we have a detector that functions well at .5MHz. If we apply a 25.5MHz f_{LO} to the mixer LO input, and f_{RF} to the mixer RF input, the output of the mixer will consist of f_{IFlo} at .5MHz, and f_{IFhi} at 50.5MHz. Clearly, we want to use f_{IFlo}, and remove f_{IFhi} from the input to the detector with a lowpass filter. A block diagram and spectral diagram are shown in Figure 1.

Figure 1 – Single Conversion Superhet



The resulting receiver has the following advantages:

- The desired RF frequency can be varied by simply adjusting the LO frequency.
- Selectivity is provided by a filter at the relatively low IF frequency.
- The IF filter does not have to be tuned as the RF frequency is varied.
- Most of the receiver gain can be implemented at the low IF frequency.

Continued on p 45

These are huge advantages for a receiver design. So, why isn't the single conversion superhet a "free lunch"? Here are a couple of disadvantages:

The design requires a very stable LO, which is difficult for an analog variable 25.5MHz design.
Undesired RF input frequencies may produce output at the .5MHz IF frequency.

Clearly, designing a stable variable frequency oscillator (VFO) operating at 25.5MHz is much more difficult than it would be at a lower frequency. And, the problem just gets worse as the RF input frequency rises. Until the invention of the frequency synthesizer, which allowed multiple selected LO frequencies to be locked to a single stable reference frequency, this was a difficult problem to solve.

Receiver Responses to Undesired Input Frequencies

Undesired, or "spurious responses" as they are usually known, are the bane of the superhet, and considerable design attention is required to keep these responses at a low level. With a TRF tuned to 25MHz, the receiver detector theoretically will only see a 25MHz signal. However, since there are inherent non-linearities created by the amplifiers, input signals at the sub-harmonics of 25MHz (i.e. 12.5MHz, 8.333MHz, etc.) will also create an output at the detector. Unfortunately, the problem becomes far greater with a superhet design, and you now have at least one additional signal (the local oscillator) to contend with. Mixing of the LO (and its harmonics) with an RF input signal (and its harmonics) create a wide variety of input frequencies that produce an output at the detector. Let's consider our single conversion receiver of Figure 1. Assume a 25.25MHz signal at the input of this receiver. The 2nd harmonic of this signal is 50.5MHz. When this harmonic mixes with the 2nd harmonic of the LO (51.0MHz), the result is a .5MHz signal at the detector. Unfortunately, this is exactly at the center of our .5MHz IF band. The example given here is known as a "2RF X 2LO" spurious response, but there are many others to consider. And, as you can imagine, adding even more LO sources to the receiver escalates the "spurious response" problem.

The good news is that the class of spurious responses described above is considerably attenuated from the level of the desired signal because the strength of harmonics are much lower than the fundamentals. However, there is one "undesired" input that is of primary consideration, and is known as the "image" frequency, f_{IMAGE}. Consider the output of the mixer with a 26MHz RF signal present at the antenna. In this case, f_{RF}-f_{LO} would be -.5MHz. (Again, the "minus" sign may be disregarded.) This "image" response is passed through the receiver with the same gain as that of the desired 25MHz input signal. Therefore, it is imperative that the "image" be attenuated by input filtering or other means. Unfortunately, in our example, the 26MHz image is only 1MHz away from the 25MHz desired signal. A bandpass filter centered at 25MHz would solve the problem, but designing such a filter that would attenuate 26MHz by at least 50dB, and be automatically tunable with f_{RF}, would present an extremely difficult production engineering problem. The image frequency is given by the equation:

$$f_{IMAGE} = f_{RF} \pm 2 * f_{IF}$$

If $f_{RF} > f_{LO}$, the "minus" sign is used. For $f_{RF} < f_{LO}$, use the "plus" sign.

Double Conversion Superhet

So, how can we get around these two problems inherent in the single conversion design? Enter the double conversion superhet design. With double conversion, we typically have a first conversion that uses a stable crystal controlled LO, and a second conversion stage using a stable VFO that is used to tune to the exact desired RF input frequency.

Let's tackle the same receiver scenario as before, with an f_{RF} of 25MHz, and f_{IF} of .5MHz. In this case, let's choose a "first IF" (f_{IF1}) of 3MHz. Given this choice for f_{IF1} , the "first LO" (f_{LO1}) is chosen to be 28MHz. For stability, f_{LO1} will be fixed and crystal controlled. The "second LO" (f_{LO2}) is chosen to be 2.5MHz, providing conversion of f_{IF1} (3MHz) down to f_{IF2} (.5MHz). The block diagram and spectral diagram might appear similar to that in Figure 2 below.
How does this help us? First, our analog tuning function can now be provided by a VFO at 2.5MHz, which is much easier to realize than a VFO at 24.5MHz, as required by the single conversion design. This is not to say that even a low frequency VFO is an easy design task. It was not until around 1945, when Collins developed the "Permeability Tuned Oscillator" (PTO), that a suitably stable variable oscillator with excellent tuning linearity became available.

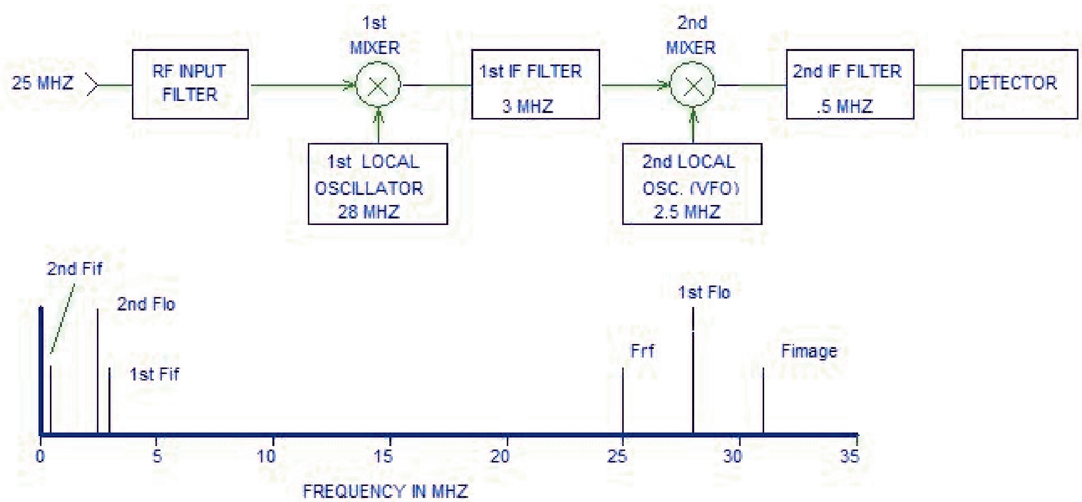


Figure 2 – Double Conversion Superhet

Secondly, our first conversion image frequency is now centered at 19MHz. The spacing between f_{RF} and f_{IMAGE} becomes 6MHz. Building a tunable RF input bandpass filter to provide 50dB image rejection becomes feasible with the double conversion superhet design. Note that although every mixing stage has an associated "image" frequency that must be considered, the image in the first conversion stage is nearly always of primary consideration.

Note that the bandwidth of the 1st IF Filter must be at least as wide as the tuning range for each "band" selected by a 1st LO crystal. In other words, if each selectable band covers .2 MHz, as in the S-Line, the 1st IF Filter must be at least .2 MHz wide, and the 2nd LO must tune over a .2 MHz range.

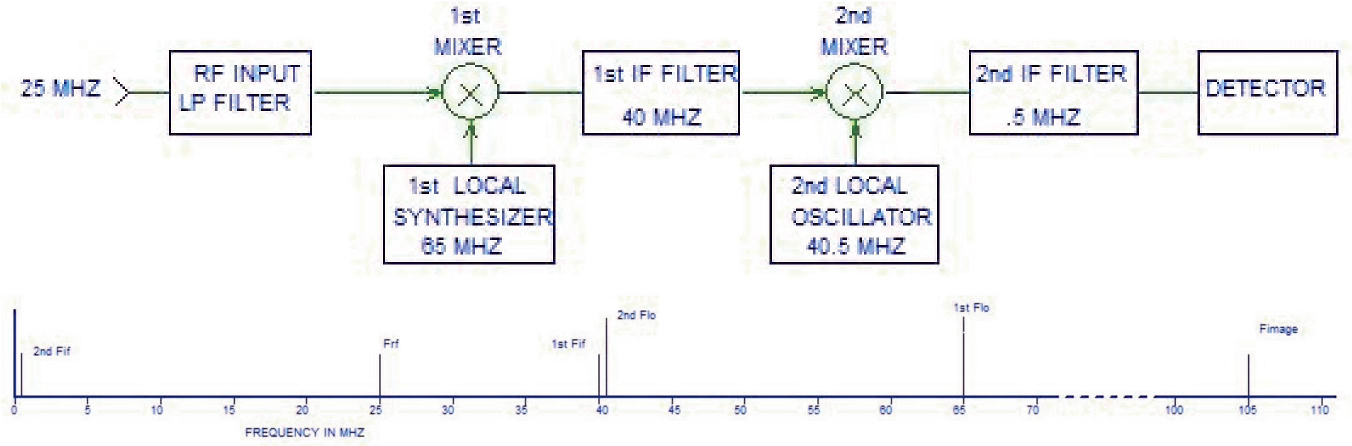


Figure 3 – Up-Converting Double Conversion Superhet

The primary disadvantage of the double conversion scheme is that the "spurious response" problem becomes more complex due to the addition of a second local oscillator. Very careful attention must be paid to the choice of IF and LO frequencies to eliminate the spurious responses to the extent possible.

Modern HF Receiver Design

The introduction of frequency synthesizers allowed another approach to the design of HF receivers. For the first time, the design engineer had a stable, tunable VHF local oscillator available. With such a device, the receiver designer could conceivably go back to the single conversion superhet. However, the image rejection problem was still an issue. Fortunately, effective solid state VHF amplifiers had become available, as well as relatively narrowband VHF crystal, SAW (Surface Acoustic Wave) and ceramic filters. These developments allowed the implementation of what is often called an "up-conversion" superhet design.

In this design concept, the RF input signal in the HF band is converted to a first IF in the VHF range, where it is filtered by a fixed bandpass filter. A second conversion mixes f_{IF1} down to f_{IF2}. But, why is this any better than the single conversion implementation? The answer becomes apparent when you calculate the image frequency for this scheme. Let's once again assume an f_{RF} of 25MHz, and f_{IF2} of .5MHz. As an example, choose f_{IF1} to be 40MHz. This means f_{LO1} is 65MHz. Using our formula for calculating f_{IMAGE}:

$$f_{IMAGE} = f_{RF} \pm 2 * f_{IF} = 25\text{MHz} + 2*40\text{MHz} = 105\text{MHz}$$

In fact, notice that for f_{RF} between 1MHz and 30MHz, f_{IMAGE} is from 81MHz to 110MHz. What this means is that the required image rejection over the entire HF tuning range can be achieved with a simple 30MHz lowpass filter at the receiver front end. Tunable bandpass preselector filters are not required. This approach not only provides much improved image rejection using a simple input lowpass filter, it also provides "IF rejection" (an RF signal appearing at the antenna that happens to be at f_{IF1}) and attenuation of f_{LO1} radiated at the antenna port. The KWM-380, 651S-1, HF-2050, and 95S-1 all use this basic up-conversion concept. Figure 3 shows an example of the "up-conversion" frequency plan with an RF input signal of 25MHz.

Collins Receiver Conversion Schemes

Collins engineers were well aware of the advantages of the double conversion superhet advantages, and every receiver from the 51J series through the 75S series used this basic conversion philosophy. With the double conversion approach, high performance general coverage of the HF band can be achieved by simply changing crystals in the first LO, while all circuitry beyond the first mixer remains the same. Below is a table showing the pertinent frequencies for a selection of Collins receivers.

It is clear that Collins used a variety of conversion plans to optimize receiver performance, spurious responses and tunable bandpass filter design. The 51J-4 uses single, double and triple conversion schemes, depending on the region of the HF band to be tuned. The modern receivers using digital synthesizers all use the up-conversion scheme, and these designs show a marked improvement in image rejection compared with their early vacuum tube counterparts.

Conclusions

The superhet concept is the basis for all Collins receivers, even the most modern design, such as the 95S-1. The specific conversion scheme chosen was dependent on receiver specification requirements and the technology available.

This discussion by no means is intended to suggest that the proper choice of superhet schemes solves all receiver design problems. It does not. However, the basic conversion scheme is usually the starting point for a receiver design, and this dictates basic requirements for each stage in the receiver. From that starting point, many other factors must be considered to meet a variety of issues. A wide variety of receiver "spurious responses" to signals at the receiver input port (in addition to the image) are created by mixing of harmonics of the local oscillators. Additionally, internally generated signals (local oscillator harmonics or digitally generated artifacts) can result in unwanted outputs if careful attention is not paid to shielding and grounding. Nevertheless, I hope this discussion provides an idea of the basic concepts involved in the choice of a frequency conversion plan for a superhet receiver.

Cheers,
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Corrections & Addition regarding the Q3 & Q4 2013 issues:

The Editorial Staff would like to apologize and offer the following corrections. For Q3 2013, the **On The Cover** caption at the bottom of page 5 mistakenly identified the launch as Apollo 8. It should have been "Gemini 8" .. For Q4 2013, in the TACAMO article: - First sentence in text above Figure 21 on page 17 should read "The E6B aircraft was reconfigured . . ." - and the Figure 21 caption should read "E6B" - Figure 20 caption should read "HPTS E6B in Flight with Drogues Coming Out . . . ." - Finally, Page 14, footnote 1) The LEBUS mechanism is a free running guide for the incoming wire that assures that placement of the wire on the reel is exact. Adapted from the drilling industry.

HF Collins Radio Receivers
A sampling of Conversion Scheme Characteristics

Collins Model	RF Input (MHz)	1st LO (MHz)	1st IF (MHz)	2nd LO (MHz)	2nd IF (MHz)	3rd LO (MHz)	3rd IF (MHz)	Image Rej. (dB)	Weight (lb)	Volume (cu.in.)	Date (approx)	Spectral Inversion	Dim (in)
51F	1.5-20.0	(RF +/- .456) ?	0.456					75(at 5MHz)	22	1330	1939	?	7X10X19
75A-1	3.2-21.8	5.7-23.3	2.5-1.5	2.0-3.0	0.500			50	57	3578	1946	NO	21.1X12.2X13.9
75A-1	26.0-30.0	31.5-33.5	5.5-3.5	6.0-4.0	0.500							NO	
51H-3/ARR-15	1.5-2.5	2.0-3.0 (PTO, High Side)	0.500					?	39	1775	1950	YES	7.9X10.4X21.6
51H-3/ARR-15	2.5-3.5	2.0-3.0 (PTO, Low Side)	0.500					?				NO	
51H-3/ARR-15	3.5-5.5	4.0-6.0 (PTO X2,High)	0.500					?				YES	
51H-3/ARR-15	5.5-8.5	6.0-9.0 (PTO X3, High)	0.500					?				YES	
51H-3/ARR-15	8.5-12.5	8.0-12.0 (PTO X4, Low)	0.500					?				NO	
51H-3/ARR-15	12.5-18.5	12.0-18.0 (PTO X6, Low)	0.500					?				NO	
R-390	.5-8.0	Sel.Xtal (7.0-12.6)	9.0-18.0	Sel.Xtal (12.0-18.6)	3.0-2.0	3.455-2.455	0.455	?	85	3192	1950	NO	10.5X19X16
R-390	8-32.0	Bypassed	Bypassed	Sel.Xtal (11-34)	3.0-2.0	3.455-2.455	0.455					NO	
75A-2/3	1.5-2.5	Bypass	1.5-2.5	1.955-2.955	0.455			50	50	3482	1950/1952	YES	21.1X12.5X13.2
75A-2/3	3.2-21.8	Sel.Xtal (5.7-23.3)	2.5-1.5	2.955-1.955	0.455							NO	
75A-2/3	26.0-30.0	Sel.Xtal (31.455,33.455)	5.455-3.455	5.910-3.910	0.455							NO	
R-390A	.5-8.0	17.0 Xtal	17.5-25.0	Sel.Xtal (20.5-27)	3.0-2.0	3.455-2.455	0.455	60	85	3192	1954	NO	10.5X19X16
R-390A	8-32.0	Bypassed	Bypassed	Sel.Xtal (11-34)	3.0-2.0	3.455-2.455	0.455					NO	
75A-4	1.5-2.5	Bypass	1.5-2.5	1.955-2.955	0.455			50	35	2804	1955	YES	10.5X17.25X15.5
75A-4	3.2-30	Sel.Xtal(5.7-31.5)	2.5-1.5	2.955-1.955	0.455							NO	
51J-4	.5-1.5	12.0 Xtal	11.5-10.5	8.0 Xtal	3.5-2.5	3.000-2.000	0.500	40	43	2993	1957	YES	10.5X19X15
51J-4	1.5-3.5	Bypassed	Bypassed	Bypassed	Bypassed	2.000-3.000	0.500					YES	
51J-4	3.5-30.5	Sel.Xtal (6-32)	2.5-1.5	Bypassed	Bypassed	3.000-2.000	0.500					NO	
75S-1/2/3/3B	3.4-30.0	Sel.Xtal (6.555-33.155)	3.155-2.955	2.69865-2.49865	0.455			50	20	1408	1958	YES	7.75X14.75X13.2
51S-1	.2-2.0	28.0 Xtal	28.2-30.0	Sel.Xtal (31-32)	3.0-2.0	3.500-2.500	0.500	50	28	1508	1959	NO	7.75X14.75X13.2
51S-1	2.0-7.0	Sel.Xtal (12.5-8.5)	14.5-15.5	17.500	3.0-2.0	3.500-2.500	0.500					NO	
51S-1	7.0-30.0	Bypassed	Bypassed	Sel.Xtal (10-32)	3.0-2.0	3.500-2.500	0.500					NO	
651S-1	.25-30.0	109.1-79.35 Synth.	109.35	99.000	10.350	9.900	0.450	80	30.2	1304	1970	NO	6.25X13.2X15.8
KWM380	.5-30.0	39.645-69.145 Synth.	39.145	39.600	0.455			60	48	1814	1979	NO	15.5X6.5X18
851S-1	.25-30.0	109.35-79.35 Synth.	109.35	118.800	9.450	9.900	0.450	90	15	2780	1982	NO	7X20.9X19
HF-2050	.014-2.0	12.0 Synth.	12.014-14.0	111.014-113.0	99.000	96.000	3.000	80	32	1796	1984	YES	5.25X19X18
HF-2050	2.0-30.0	Bypassed	Bypassed	99.5-129.00	99.000	96.000	3.000					YES	
95S-1	.005-30	51.2-81.2 Synth.	51.2	51.200	0.00			100	9	482	1997	YES	1.72X19X14.75
95S-1	20-2000	Bypassed	Bypassed	20-2000 Synth.	0.00							NO	
451S-1(non-prod)	.2-30.0	39.645-69.145 Synth.	39.145	39.600	0.455			60	28	1814	1980	NO	15.5X6.5X18