The Signal

OFFICIAL MAGAZINE OF THE
COLLINS COLLECTORS ASSOCIATION
Q4 2018 Issue #92

Rockwell Collins Comm Central

WHY COMM CENTRAL?

From its beginning, through to the present, one of Comm Central's reasons for existence has been as a test facility for advanced HF communications equipment and techniques. Comm Central still operates under Fèderal Communications Commission licenses as an experimental HF research station and an aeronautical flight test station. One benefit of this ongoing research is the sophistication of the station itself.

When equipment is beyond the experimental stage and the design is final, Comm Central gives us a "hands on" proving ground for Collins HF equipment. We have the opportunity to evaluate first hand the performance and reliability of our designs, while operating the station with the latest technology.

From its inception, there has always been a global communications need for Comm Central, even though over the years the scope and direction has changed. In 1958 it was chosen for the Short Order Network for the United States Air Force. In the 1960's Comm Central was the primary or back-up communications link for Air Force One and other aircraft in the VIP fleet. The station served as a radio patch for U.S. servicemen to call home from Southeast Asia.

By the mid 1960's there was more private party need for global communications. Again Comm Central was chosen for these services. During those years there were several around-the-world and polar flights which relied on Comm Central as their communications link to the world.

Comm Central still provides service to government and private agencies.

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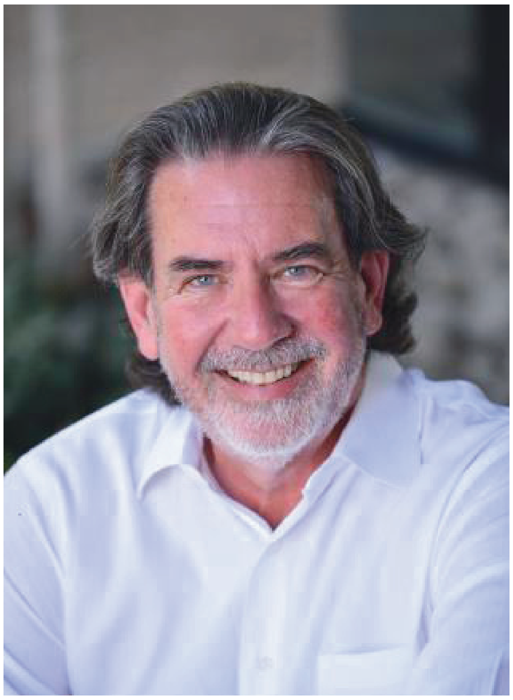
From the President's Desk...



A lot has been happening behind the scenes in the CCA this last quarter. Jim Stitzinger - WA3CEX suffered a stroke and is facing a long recovery - with this, he decided to step down as President of the CCA for the last year of his term. Jim will stay on the board and continue to contribute with advice and encouragement through the next year.

Ron Mosher - K0PGE, will stay on as Treasurer and keep us in line with his many reports and wisdom - thanks Ron for all you are doing!

Francesco Ledda stepped up to fill the Vice President role and has also taken over duties as the new Signal Editor. This is one of the most demanding positions in the CCA. He has a long engineering and management background in Communications, bringing a wealth of experience to us.

Bill Carns -N7OTX has agreed to step up as a board member again, filling the slot of Secretary. Thanks Bill and we all look forward to working with Bill again. Bill has been working on some fun Collins projects in his shack and I am sure we will see some of those show up in future Signal issues.

I, Scott Kerr - KE1RR was elected again to the board and the board asked me to take over as President again with Jim stepping down. We have a thoroughly experienced team and I am excited to see what the next few years will bring.

We have five main areas of activity in the CCA: The Signal magazine with Francesco at helm, our nets, the reflector, the web site, and Dayton.

Our nets continue to be very active, even with unpredictable propagation - our twenty meter net runs almost three hours each Sunday! Our 1st Wednesday AM net grows in popularity each month and the mid west and west coast SSB evening nets are still very active. We continue to look for more guys willing to step up as net controls. Drop me an email if you are interested - I know many of you might be timid if you have not run a net before but it is a ton of fun!

Our web site is a wealth of information with history and a huge resource of manuals - along with an RX for your Collins page that Bill Carns dreamed up years ago. An addition has been the work that Grant Laughlin, W5XJ has done with our Facebook page. Grant gets the latest news and events up on Social Media - just search for Collins Radio on Facebook and take a look.

The reflector continues to stay active with interesting discussions about repairs and restoration techniques.

Dayton is still alive and well even with the move from Hara Arena to Xenia. I am hoping that the changes the Dayton Hamfest Committee have made to the Flea Market will bring back more vendors and we will see more Collins out there to pick through. I will say that traffic at the Collins booth stays very active. If you have not made plans to visit Dayton, you need to put it on your bucket list to come and then attend our annual Banquet.

I really appreciate all the guys who have volunteered their time to make the CCA great! Looking forward to a great 2019!!

- Scott KE1RR
President, CCA
president@collinsradio.org

The Signal Magazine

OFFICIAL JOURNAL OF THE COLLINS COLLECTORS ASSOCIATION ©

Issue Number Ninety Two - 4th Quarter 2018

The Signal Magazine

Published quarterly by the Collins Collectors Association

Membership Chairman
The Collins Collectors Association
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Tallahassee, FL 32309-6892

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From the Editor...

Dear Friends,

Due to Jim Stitzinger' illness, I have been asked to step in as the Editor. I appreciate this opportunity, and I know have big shoes to fill!

As you are probably aware, Rockwell Collins has recently discontinued the manufacturing of mechanical filters, as the market has been dry for mechanical filters since digital domain processing is now in high demand and inexpensive. In this issue, we present an excellent article from Don Jackson about the digital radio principles. Rockwell Collins introduced digital processing-based receivers in the late '90s with the HF2050, the 95S-1 and 95V-1. At that time, practical signal processing was taking its first, fairly costly steps; again, Collins was leading the way.

Scott Johnson was kind enough to contribute again with a very interesting article about a Collins prototype of a sophisticated V/UHF transceiver that has never seen volume manufacturing. Who knows how many cool radios Collins designed that have never seen the light of day?

I wrote the article which is dedicated to an HF radio often referred to as the airborne version of the Collins R-390A/URR.

The front and rear cover pages of this issue are dedicated to the Rockwell Collins Comm Central. Very few people have had access to this "secure" facility, however a few pictures and a brochure are available. Comm Central is dedicated to experimentation and support for critical HF comm links.

We are looking for new contributors for future issues to the Signal magazine and new ideas. If you are interested in helping, please drop me a line.

Special thanks to my partner editor Buzz Beitchman and all contributors to this issue.

Best Regards,
Francesco Ledda, K5URG
Editor and Vice President, CCA
k5urg@yahoo.com

Digital Receiver Basics

By Don Jackson, W5QN

Almost all the receivers currently manufactured have a great deal of digital content. This generally means that the receiver has circuitry that converts the analog input signal into a binary (1's and 0's) form, and uses digital signal processing (DSP) techniques to perform most of the filtering and demodulation tasks that used to be done with analog circuitry. Since these tasks essentially become software programs in the DSP subsystem, Software Defined Radios (SDR) allow the modification, or change-on-the-fly of many operating functions. However, this article does not address the DSP part of a digital radio, but is intended to provide a better understanding of the basic theory behind the conversion of the analog signal to the digital domain. The Collins 95S-1 is an example of an SDR. Figure 1 is a block diagram of a typical digital receiver.

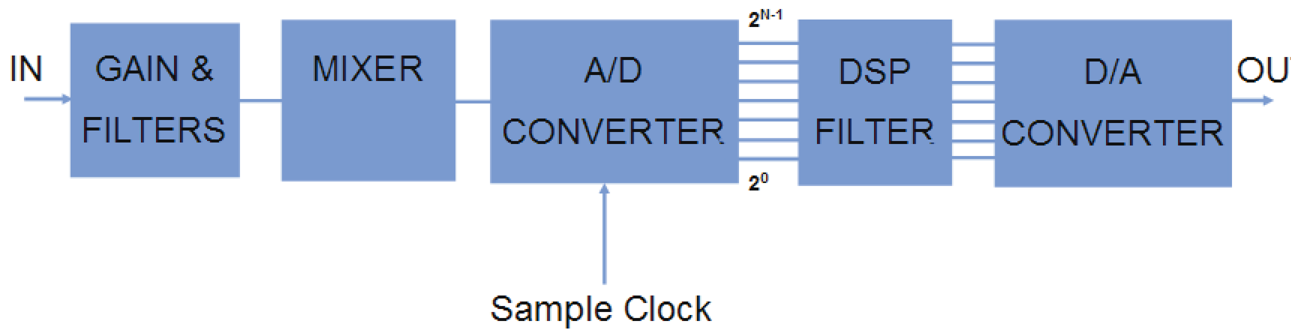

Figure 1 – Simplified Receiver Block Diagram

We will only look at the basics of the receiver design, concentrating on the conversion of the analog input signal into the digital domain using the Analog to Digital Converter (ADC). Analog gain and filtering is generally required to establish a low Noise Figure and reject undesired signals. A mixer stage converts the RF input frequency to a frequency suitable for the ADC. Narrow-band filtering, demodulation and digital-to-analog conversion take place in the blocks following the ADC, but these functions will not be considered in this article.

The Analog to Digital Converter

Although there are many variations of ADCs, our discussion will use a simplified conceptual approach. The ADC is the basic building block of any digital device that accepts an analog input and processes that input with digital techniques. The ADC periodically "samples" the amplitude of the analog signal, as determined by a sampling clock operating at a frequency, f_{CLK}, and assigns the amplitude of that sample to a "bin". If f_{CLK} were 1 MHz, the analog signal would be sampled a million times each second. There is a theoretical requirement for f_{CLK} called the Nyquist criteria, which states that f_{CLK} must be at least twice the bandwidth of the analog signal in order for the analog signal to be completely characterized. Note the use of "bandwidth" in this requirement, as opposed to "highest frequency". This is a common misunderstanding that will come up later in the article.

Conceptually, the ADC has one analog input port, and N binary output ports. The number of ADC "bits" is equal to N. Each output port can be in either a "1" or "0" state, and each port mathematically represents the exponent of the number "2". Together, the output ports form a binary number representing the approximate amplitude of the analog signal at a particular sample time. For example, a 3-bit ADC would have three output ports, with each port representing 20 through 2(N-1). The number of "bins" available is set by N, and is equal to 2N-1. Every ADC also has a "full scale" (FS) input range, which is the maximum input amplitude the ADC can handle. To illustrate, let's look at Figure 2, which shows the quantization characteristics of a 3-bit ADC with an FS of 2 Volts. Each sample of an analog input signal will be assigned to a "bin", and a corresponding binary code. The smallest voltage to which an ADC will respond is known as the "least significant bit" (LSB). The LSB is equal to FS/(2N-1), and is therefore approximately .286 Volts for the ADC of Figure 2. Any sample of the input signal with amplitude less than the LSB is assigned a binary code of "000", and any sample greater than FS is assigned a code of "111". A sample with .6 Volts amplitude would be assigned a code of "010". Figure 2 is an example of a "unipolar" ADC, meaning it only accepts positive input voltages. However, most ADCs can accept "bipolar" inputs, meaning the input can be positive or negative.

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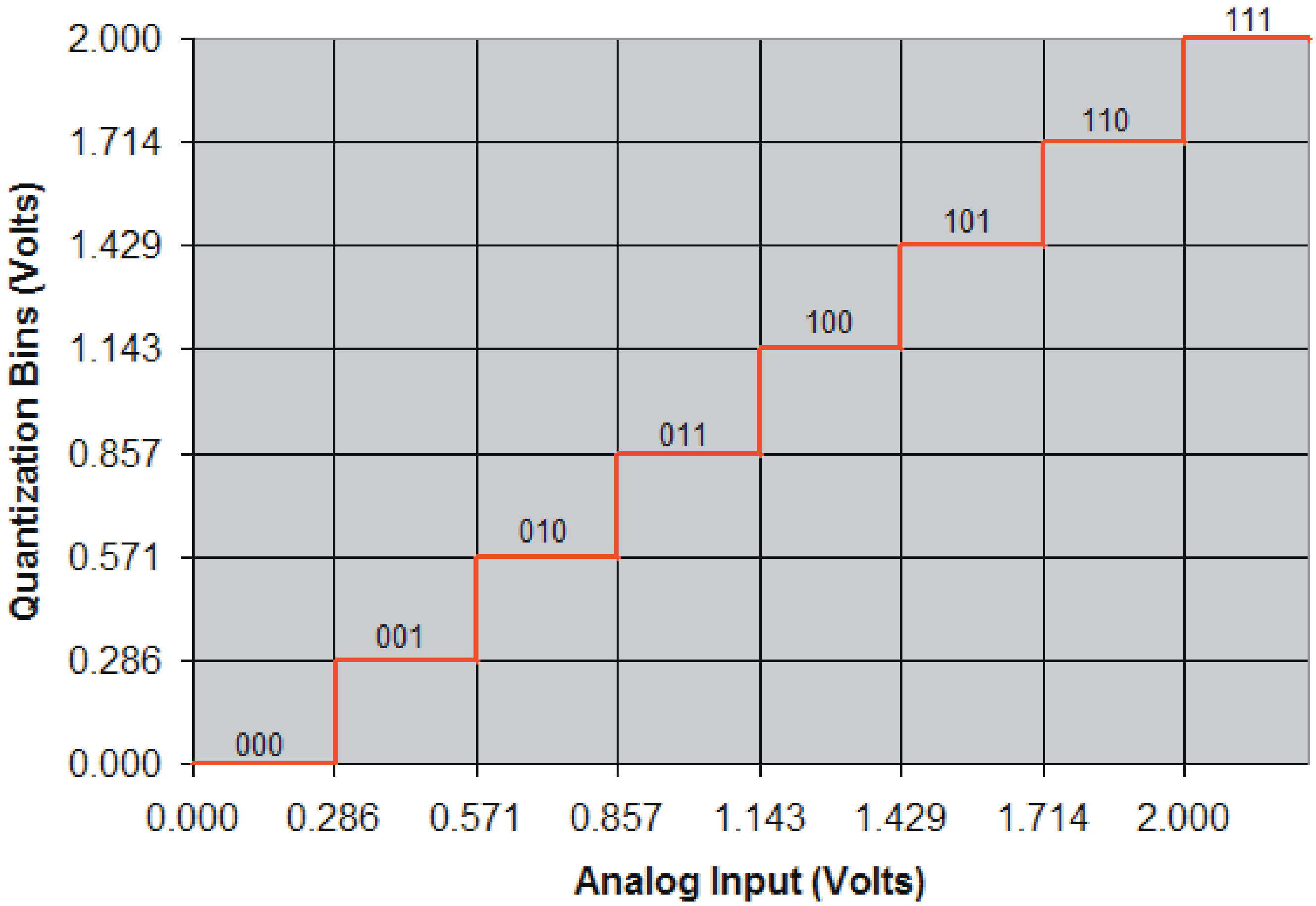


Figure 2 – Quantization Bins for a 3-Bit ADC (FS=2.V)

Considering that that the sampling process only captures the analog signal in quantized amplitude "bins", it is not surprising that undesired spectral products are introduced into the output. The "quantization error" is not a random noise, but manifests itself as discrete spectral lines in the ADC output that are a function of N and the input signal.

Now that we have a basic understanding of an ADC, let's consider a 12bit ADC with FS of ±1 Volt, and a sample rate, f_{CLK}, of 52 MHz. The LSB for this ADC is .488 mV. If we apply a sinusoidal signal to this ADC, it is clear that we will get nothing at the ADC output unless the peak voltage of the signal is at least .488 mV (-56 dBm in a 50 Ohm system).

Unless the signal reaches this level, none of the ADC output bits will "toggle" from 0 to 1. This doesn't seem very useful, considering a receiver must usually be able to detect signals down to .035 uVRMS (-136 dBm, 50 Ohm system, 2 kHz bandwidth, 5 dB Noise Figure), or lower.

Perhaps we could insert 80 dB analog gain in front of the ADC to solve the problem. This approach is impractical from a complexity and dynamic range point of view. But, let's look at the result if we input a signal to the ADC with amplitude high enough to toggle the lower couple of ADC bits.

Figure 3 shows the results of a SystemView simulation with a 10 MHz, -50 dBm signal at the ADC input. The simulation shows what we would see if the ADC output were converted to analog with an ideal digital to analog converter, and the result fed to a spectrum analyzer with a frequency span of 26 MHz and a resolution bandwidth of 200 Hz.

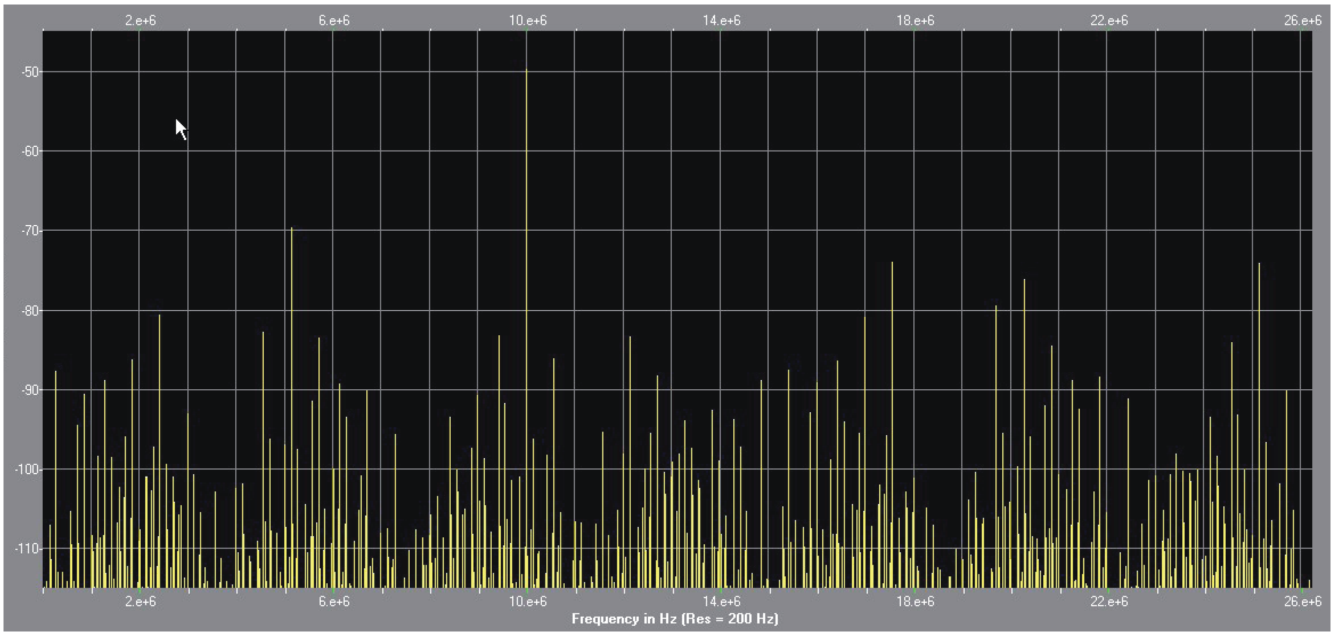


Figure 3 – 10 MHz Signal input to ADC, -50 dBm

We can see our 10 MHz signal at -50 dBm, but what are all those other spectral lines in the display? They are the discrete spectral lines created by the "quantization error" discussed earlier.

Although this quantization error power can be reduced by increasing the number of ADC bits, it is always present in an ADC. Clearly, this spectral energy is not good and could conceivably be interpreted by the receiver as actual signals. So, does this mean a 12-bit ADC can only detect signals from about -56 dBm to +10 dBm? And, even if it does detect the signal, what about all the quantization garbage?

Fortunately, there is a magic bullet that allows us to deal with both these problems. The solution is to add random noise, called "dither", to the ADC input along with the desired analog signal. Without getting too technical, dither randomizes the quantization noise spectral content. If the dither is of sufficient peak amplitude to toggle the bottom couple of bits of the ADC, it will randomize the quantization error spectra, spreading it out over the frequency band of $f_{CLK}/2$. In effect, this converts the total discrete spectral power of the quantization error into a random noise similar to the thermal noise we are familiar with.

After this conversion, the quantization error of the ADC can be treated as if it were thermal noise. The application of dither provides the following advantages:

1) Allows detection of analog signals of very low amplitude, regardless of the number of ADC bits.
2) Allows calculation of an equivalent Noise Figure for the ADC.
3) Using the ADC Noise Figure, a system sensitivity analysis can be performed in a manner similar to an analog system.
4) The system sensitivity becomes dependent only on the calculated system Noise Figure and DSP filter band width.
5) Amplitude of the desired signal is better preserved.

Interestingly, the dither added at the ADC input may be "in-band" or "out of band". It makes no difference as long as the total dither power is sufficient to toggle the bottom couple of bits. Figures 4, and 5 show the results of adding dither to the ADC input. Figure 4 adds the dither noise "out of band" using a noise source and 4 MHz lowpass filter. Figure 5 creates the dither "in band" using the internal noise of an RF amplifier and a 4 MHz bandpass filter.

In both simulations, the dither noise power appearing at the ADC input is identical. In Figure 4, a desired signal at 10 MHz and -100 dBm amplitude is summed with the dither noise. In Figure 5, the desired signal is input to a 50 dB gain RF amplifier ahead of the ADC.

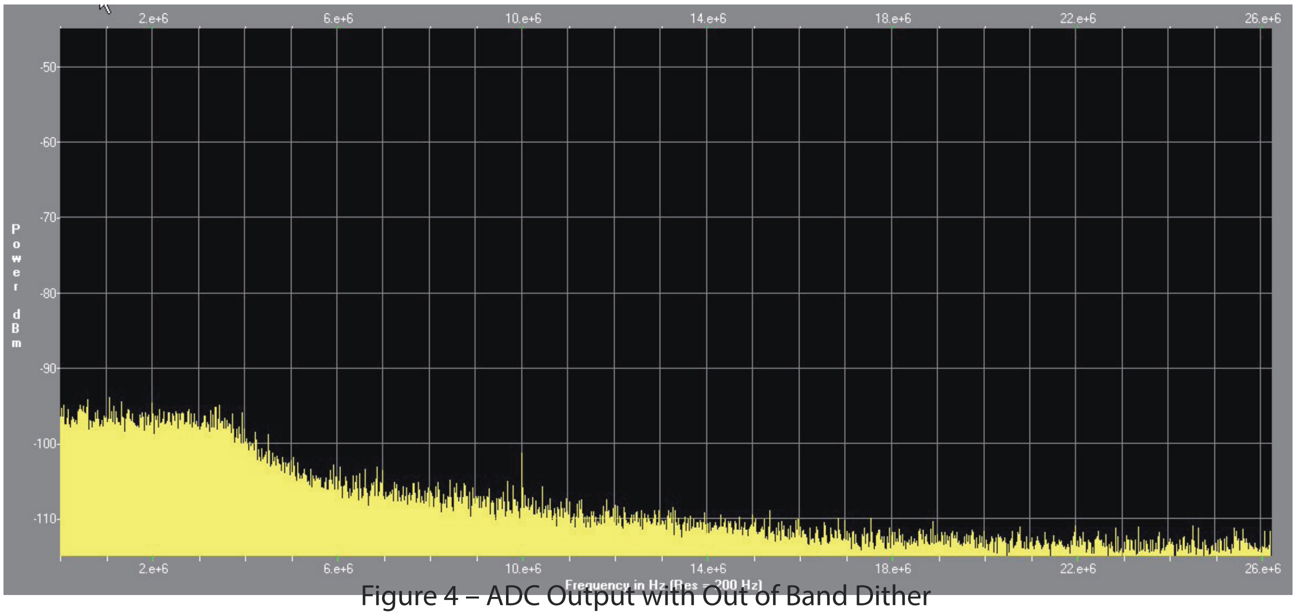


Figure 4 – ADC Output with Out of Band Dither

In Figure 4, we can clearly see the -100 dBm signal, far below a pure -56 dBm signal that would toggle the LSB. Pretty amazing! For this system, the dynamic range of the receiver (with a 200 Hz bandwidth) is about 120 dB (-110 dBm noise floor to +10 dBm FS). However, the equivalent Noise Figure of the system is about 36 dB, which isn't much to write home about.

Figure 5 uses the internal noise of a 50 dB gain amplifier with a Noise Figure of 4dB to generate the dither noise. This approach has the serendipitous affect of improving the system Noise Figure in addition to creating the dither. The Noise Figure of the system drops down to about 4 dB, but the dynamic range is reduced to about 107 dB.

Most receiver designers choose the "in-band" approach for its superior Noise Figure improvement, and live with a degradation of dynamic range. This is the approach used in the Collins 95S-1. However, the specific application determines how the choice is made. The designer could apply both in-band and out-of-band dither, juggling the two in order to achieve a desired compromise between Noise Figure and dynamic range.

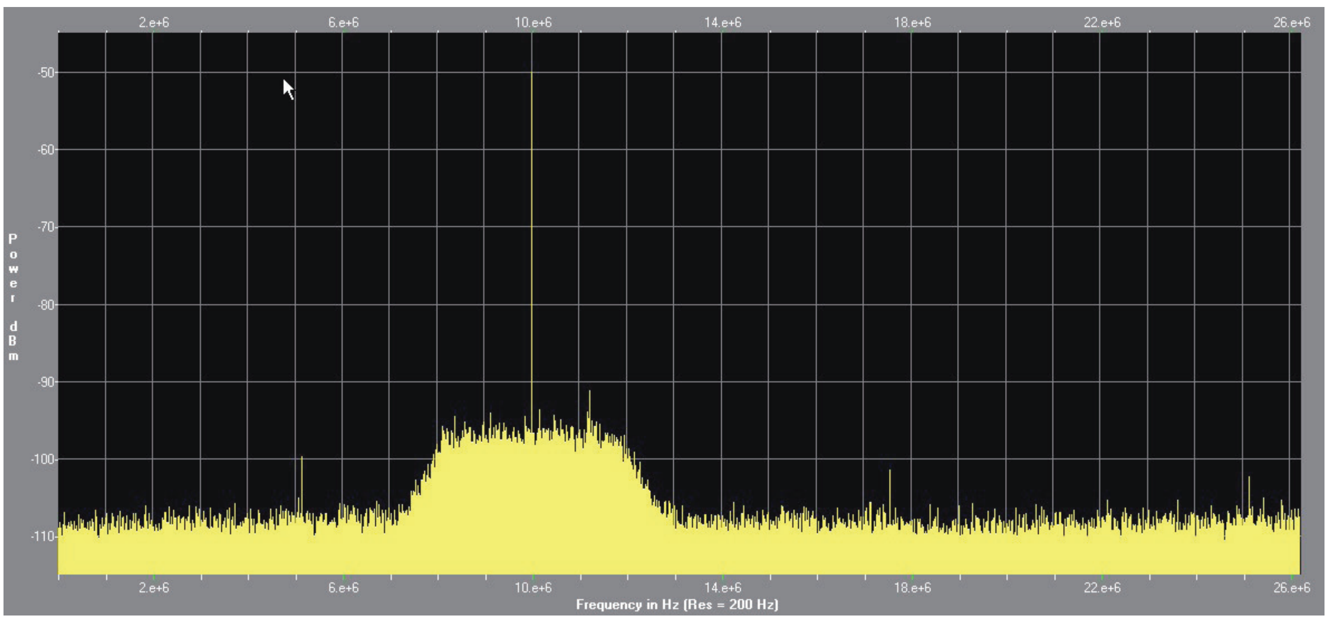


Figure 5 – ADC Output with In Band Dither

Calculate the Noise Figure of an ADC

One of the really handy things about converting the quantization error power into random noise power is this makes it possible to calculate an equivalent Noise Figure for the ADC. Although there are other sources of noise contributed by the ADC, such as jitter and internal thermal noise, quantization is generally dominant.

It is convenient to discuss the topic of Noise Figure in terms of dBm, so we will start by recalling that the 2.Vpk-pk full scale (FS) input capability of our ADC translates to +10 dBm (in a 50 Ohm system) which we will call PFS. The signal to noise ratio, SNR, of the ADC is calculated using the formula:

SNR(dB) = 6.02*N + 1.76

We can then calculate the total quantization power, PQ by subtracting the SNR from PFS :

PQ (dBm) = PFS – SNR

Knowing that PQ is uniformly spread by dither over the $f_{CLK}/2$ frequency band, we can calculate the noise Power Spectral Density of PQ in dBm/Hz as:

PSDQ (dBm/Hz) = PQ - 10*LOG($f_{CLK}/2$)

Noise Figure, a figure of merit for noise contribution, is the difference, in dB, between the equivalent noise Power Spectral Density (in dBm/Hz) at the input of a system, and the theoretical thermal noise Power Spectral Density of a resistor at room temperature, 174 dBm/Hz.

Therefore, we can calculate the ADC Noise Figure as:

NFADC (dB) = PSDQ - 174

Let's plug in the numbers for our example ADC and see how this works. For our ADC, N=12, PFS= +10 dBm, and f_{CLK} =52 MHz.

SNR(dB) = 6.02*12 + 1.76 = 74 dB
PQ (dBm) = +10 – 74 = -64 dBm
PSDQ (dBm/Hz) = -64 dBm – (74.1 dB) = -138.1 dBm/Hz
NFADC (dB) = -138.1 – (174) = 35.9 dB

Armed with knowledge of the ADC equivalent Noise Figure, the designer can perform a system cascade sensitivity analysis in the same manner as with an analog system.

*Note that the ADC Noise Figure can be lowered by increasing f_{CLK}, or increasing N.

Calculating the Dither Noise Power Required

The dither noise power must be sufficient to toggle the bottom couple of ADC bits. With too little dither, the calculated ADC Noise Figure is not achieved, and the quantization error is not completely randomized. Too much and dynamic range is sacrificed. A general rule of thumb is that the total dither noise power should be about 6 dB higher than the total quantization power, PQ (dBm). Therefore, in our ADC example, that power would be about (-64dBm + 6dB), or -58 dBm in a 50 Ohm system.

The Alias Phenomenon

No discussion of ADC basics would be complete without addressing the choice of the sampling frequency and "aliasing". We have already mentioned the Nyquist criteria, which states a minimum sampling rate must be twice the bandwidth of the input signal bandwidth. However, this does not address input signals that are above $f_{CLK}/2$. It turns out that the ADC does not discriminate between input signals that are in the desired "0 to $f_{CLK}/2$" band, and signals that are in any other multiple of $f_{CLK}/2$. There are different ways to visualize the concept of alias, but I like the diagram of Figure 6.

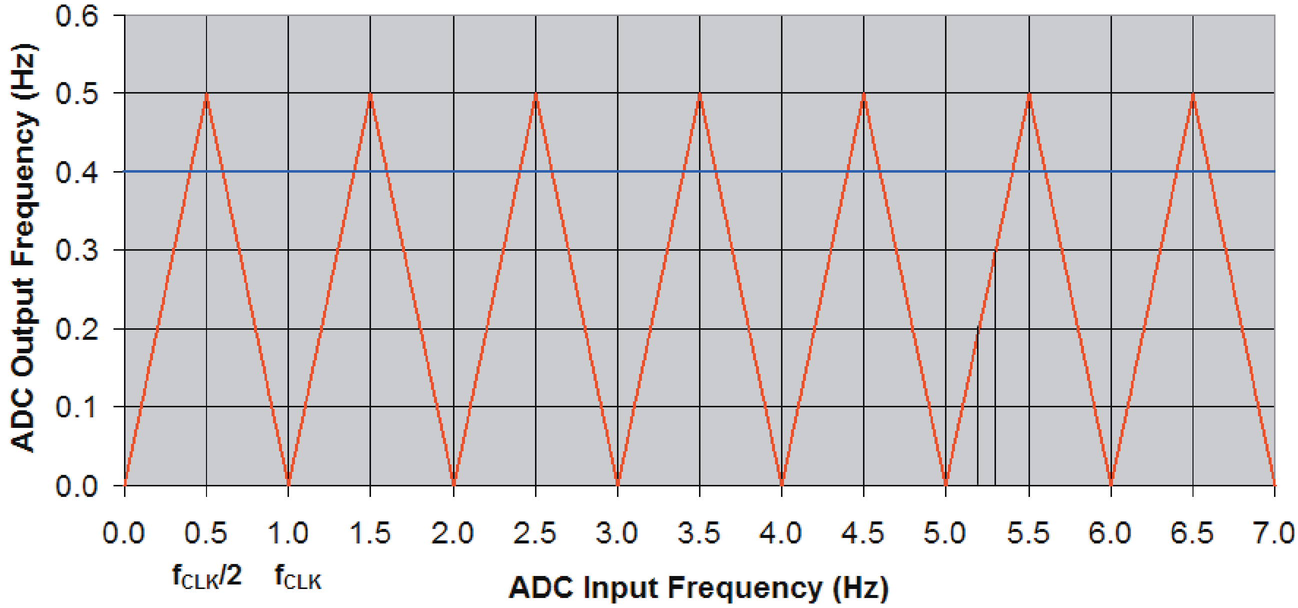


Figure 6 – Aliasing in the Frequency Domain

The diagram of Figure 6 shows a conceptual representation of the alias phenomenon. In the diagram, the X-axis represents the input frequency to the ADC, with f_{CLK} set to 1 Hz. The Y-axis represents the output frequency of the ADC with an ideal Digital to Analog Converter connected. As we know, input signals within the frequency band from 0 to $f_{CLK}/2$ can be perfectly re-created, and this is evident on the red plot. However, signals in all other frequency "$f_{CLK}/2$" bands will also be digitized by the ADC, which is generally not what we want.

For example, note the blue plot. Every input frequency where the blue plot intersects the red plot is a frequency that the ADC will interpret as a .4 Hz input signal. To be specific, the ADC cannot discern between the desired input at .4 Hz and alias signals at .6 Hz, 1.4 Hz, 1.6 Hz, etc. It is up to the designer to provide adequate filtering to reject the undesired alias signals. Note that for "odd" $f_{CLK}/2$ bands, there is no spectral inversion (increasing input frequency produces increasing output frequency), while for "even" $f_{CLK}/2$, there is a spectral inversion.

Although normally viewed as a problem, the aliasing phenomenon can be used to advantage.

Again looking at Figure 6, let's assume we have an ADC with a maximum f_{CLK} of 1 Hz, but we wish to design a receiver that covers the 5.2-5.3 Hz range indicated on the plot. Certainly, this input frequency range is far greater than the Nyquist requirement of $f_{CLK}/2$, or .5 Hz. However, recall that Nyquist says it is the bandwidth that matters, not the highest frequency of the input signal. Therefore, since the bandwidth of the signal is only .1 Hz (5.2-5.3 Hz), we meet the Nyquist criteria with an f_{CLK} of only 1 Hz. And, since the ADC cannot discern the difference between signals in the ".2-.3 Hz" region and the "5.2-5.3 Hz" alias region, our ADC will work just fine with f_{CLK} of 1 Hz. However, we must provide input filtering to reject all inputs that are not in the 5.2-5.3 Hz band. This technique is called "undersampling" and is common in receiver design. The only limitation on the ADC is that its internal "sample and hold" circuitry works satisfactorily at the desired input frequency.

Summary and Conclusions

Although it would seem at first glance that an ADC could not detect an input signal below its LSB quantization level, the use of dither noise to randomize the quantization error makes it possible to use the ADC with very low input levels, regardless of the number of ADC bits. With dither noise, an equivalent ADC Noise Figure may be calculated, allowing easy system sensitivity analysis.

The ADC Noise Figure may be lowered by increasing the number of ADC bits, and/or increasing the sampling clock frequency. Dither noise may be applied "in-band" or "out-of-band", although the in-band approach is more common since, when supplied by an input amplifier, it reduces the Noise Figure of the overall system.

Ideally, an ADC would have enough bits to allow dither to function with no external noise source or amplifier. This means that the ideal thermal noise floor alone, 174 dBm/Hz, could provide the dither. Since we know how to calculate the dither noise power required for an ADC, we can work backwards to determine how many bits would be needed to achieve this goal. Using the parameters of our previous ADC example, let's assume that we collect the dither noise in a 4 MHz bandwidth. The total noise power in a 4 MHz bandwidth would be -174 dBm/Hz +10*LOG(4 MHz) = -108 dBm. From this, we can calculate that the number of ADC bits required would be about 21. Such ADC resolution is already available at low frequencies, but not throughout the RF realm. As well, our calculation is over-simplified for a number of reasons, and doesn't take into account the noise created by the ADC input components themselves, which would have a spectral noise density greater than 174 dBm/Hz due to internal heating. But, this gives you a feel for the concept. When such ADCs become a reality, receiver "front ends" may consist of only an ADC with analog preselector filtering at the input to suppress undesired alias responses.

The Nyquist theorem requires that the sampling rate for an ADC be greater than twice the bandwidth of the desired input signal. It is important to note that it is the bandwidth of the signal, not the "highest frequency" that determines the minimum sampling frequency.

"Alias" refers to frequency bands that are multiples of the "0 to $f_{CLK}/2$" frequency band. An ADC cannot distinguish between desired signals and alias signals, so adequate analog filtering must be provided to sufficiently suppress all undesired alias signals. An advantage of the alias phenomenon is that it can be used to digitize frequencies much higher than $f_{CLK}/2$. This technique is known as "undersampling".

Cheers,
Don, W5QN

2018 CCA Financial Recap

Income

Bank Interest	$4.78
Cedar Rapids Income	$1,250.00
Dayton Banquet Income	$1,143.00
Member dues (Domestic)	$19,702.23
Member dues (Foreign)	$2,349.00
Mousepad Sales	$280.00
Signal Sales	$231.00
Total Income	$24,960.01
Gross Profit	$24,960.01

Expenses

Board Meeting Expenses	$1,362.72
Cedar Rapids Banquet	$2,241.53
Dayton Banquet	$2,764.91
Dayton Booth	$1,992.58
Internet Operations	$3,043.76
PayPal Fees	$870.69
Signal Magazine	$12,762.32
All Other Expenses	$393.44
Total Expense	$25,431.95
Gross Profit	$24,960.01
Net Income (Loss)	-$471.94

As you can see from the financials, the CCA continues to be in good financial health. We have reduced our printing costs for the Signal Magazine with a change in vendors and even with the expenses of the Cedar Rapids CCA event and banquet, we were able to operate at a break even and keep good cash reserves. We owe a debt of thanks to Ron Mosher for his excellent work in keeping the board informed each month of the CCA financial situation, which allows us to make wise decisions, Thanks Ron!

– Scott, KE1RR
President, CCA

A Collins VHF/UHF Mystery Transceiver Prototype

By Scott Johnson, W7SVJ

Several years ago, I purchased, for a few dollars, a pile of parts that had Collins written all over it (figuratively, not literally). It appeared to be a manpack or portable transceiver, with a removable battery pack, olive drab in color, and bore a generational resemblance to the ARC-186 VHF aircraft transceiver (knobs, parts selection, etc.) The radio was clearly somewhere between a functional prototype and a mock-up, since several of the expensive case parts were cast in plastic, rather than die-cast and machined aluminum (see figure 1). I made an effort to re-assemble the pile of parts, and the result is what you see in figure 2.

Figure 1

Figure 2

The radio appears to be from the mid to late seventies, judging by technology and date codes on the parts, and I surmised it could likely have been an entry in a DoD competition for a forward air controller or special forces set, something akin to the Motorola PET/ URC-101 series, or the later Magnavox URC-113. (See figures 3 and 4). Without the benefit of any available information, I have since decided that it was probably a lower cost alternative to these tactical radios, perhaps for a foreign government. At any rate, evidently no production contract was let, and this radio faded into obscurity.

Figure 3

Figure 4

Frequency coverage is from 116.00-149.975 MHz and 225.000 to 399.975 MHz in 25 kHz steps, with the output power being selectable two or ten watts. There is provision for an external COMSEC device, as well as remote control via front panel receptacles. There does not seem to be provision for frequency hopping ECCM (Have Quick), another clue that it was not intended for the US or NATO. Four preset channels are available, and programmable via the front panel. Audio interface is via a new family five pin connector. There is a guard receiver, presumably at 243.000 MHz. Mode is AM only, and noise squelch is provided. A press to test for battery level is provided, but no other front panel built-in-test. The build quality is good, but lacks any inspection stamps, staking adhesive, or any of the other trappings that would indicate a production set. There is no identification, no serial numbers, MCNs, or any Collins ID at all, save for the 13499 CAGE code on the battery box top. The battery pack was empty, but presumably the power source would be a pair of BB-390, BB-590, or similar DoD standard 12/24V packs. There is no provision for charging externally, so batteries must be removed to charge. Operating voltage is 24-30 V nominal. This radio is missing the transmitter power amplifier, receiver front end, antenna switching circuitry and module interconnect ribbon cable, so it is unlikely it will ever be a working example (see figure 5).

Figure 5

I find this to be a fascinating piece of Collins history, and would very much like to find out more about this little radio. If you have any information regarding history, nomenclature, or any other technical or marketing information, I would like to hear from you.

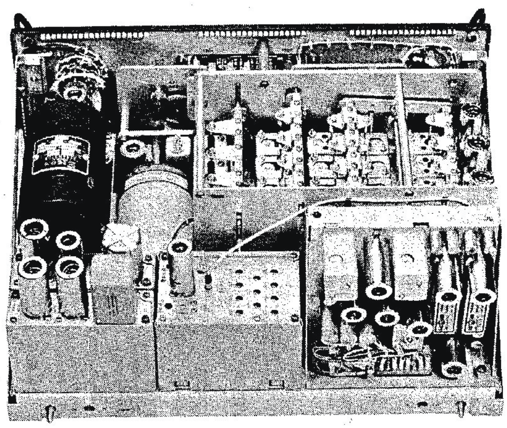
- Scott Johnson
scottjohnson1@cox.net
(480) 550-2358.

Collins

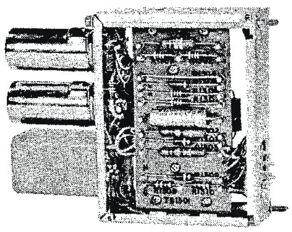
AN/ARR-41

AIRBORNE RADIO RECEIVER

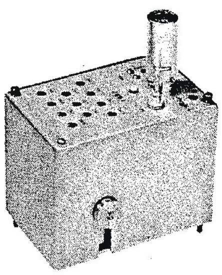
AIRBORNE RADIO RECEIVER
AN/ARR-41



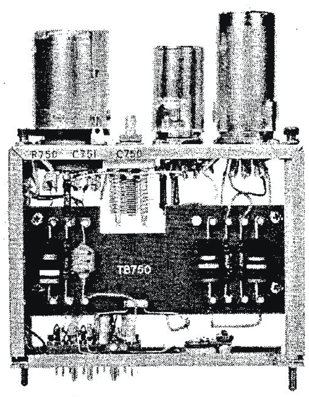
RECEIVER AN/ARR-41,
TOP INTERIOR VIEW



AUDIO MODULE



CRYSTAL FREQUENCY SELECTOR



CRYSTAL FREQUENCY INDICATOR

APPLICATION

Operating in the frequency ranges 190 to 550 kc and 2.0 to 25 mc the ARR-41 is capable of receiving MCW, CW, VOICE communication. The frequency of operation is direct reading in megacycles and appears on the counter type display. The receiver was designed for high frequency stability, selectivity and sensitivity.

DESCRIPTION

Collins design AN/ARR-41 Airborne Receiver is the result of development undertaken by the Collins Radio Company under Contract NOas 52-670c, sponsored by the Department of Navy, Bureau of Aeronautics. This receiver is based upon the proven performance of Collins 51J circuitry and is the outgrowth of more than 15 years of experience in military communication equipment development.

The AN/ARR-41 consists of a main chassis which forms the mounting base for a number of plug-in modular subassemblies. These subassemblies are all removable from the top of the chassis by means of captive hold-down screws. The rugged mechanical soundness together with line filters located on the front panel, provides good shielding of conducted and radiated noise, in accordance with the requirements of MIL-I-6181B.

The picture at the left shows a back view of the receiver with the dust cover removed. Plug-in subassemblies are as follows:

- R-F and I-F TUNER MODULE.
- 500 KC I-F MODULE.
- AUDIO AMPLIFIER MODULE.
- CRYSTAL SELECTOR MODULE.
- CRYSTAL FREQUENCY INDICATOR MODULE.
- DYNAMOTOR POWER SUPPLY MODULE.

Individual plug-in subassemblies which require mechanical linkage are fitted with quick disconnect couplers of the Oldham type. The use of these efficient couplers in the mechanical system permits quick disassembly for servicing. Once these mechanical linkages are synchronized, it is possible to remove and replace units without additional alignment.

A minimum number of tubes consistent with performance and adequately derated components insure a minimum of maintenance and repair in this equipment. In most cases, servicing can be accomplished with the aid of a voltmeter, a signal generator and a wattmeter.

The Collins R-648/ARR-41: The Airborne Version of the R-390A/URR, or Not?

By Francesco Ledda, K5URG

I always loved the look of the Collins R-648/ARR-41. It looks like a miniature airborne R-390A/URR. Anything that can fly is better!

This radio is rather small: 7 ½ "x 16" x 12" and weighs only 32 pounds. Being accustomed to the R-388 and the R-390A, I am amazed by how the Weight Watchers guys at Collins were able to pack such powerful technology into a small package. With is Veeder-Root counter type frequency indicator, it really looks like an R-390A/URR, but is it?

Figure 1: AN/ARR-41

A Few Historical Notes

In the 40s and early 50s, many of the heavier USAAF/USAF airplanes, like the B-29 and B-36, had an HF communication station that included the famous Collins AN/ART-13 and the BC-348. The ART-13 was an innovative excellent transmitter with an auto-tune antenna coupler while its companion receiver had a serious deficiency. Its 915kHz intermediate frequency was way too wide. I suspect that 915 kHz was chosen to avoid a double conversion scheme and to support the 200 to 500 kHz band.

The BC-348 was rather similar to the heavier BC-342, but the BC-342 well outperformed the BC-348.

In 1954, the Navy issued MIL-R-18625 for a new airborne receiver for AM and CW to replace the BC-348. The result was development of the AN/ARR-41.

Frequency range covered 190 to 550 kHz and 2 to 25 MHz; the spec included a counter type frequency display, strict selectivity requirements and weigh not exceed 40 pounds.

Getting Techy

The Collins brochure mentions the relationship of then ARR-41 to the 51J series. Let's explore that relationship, by comparing the block diagrams.

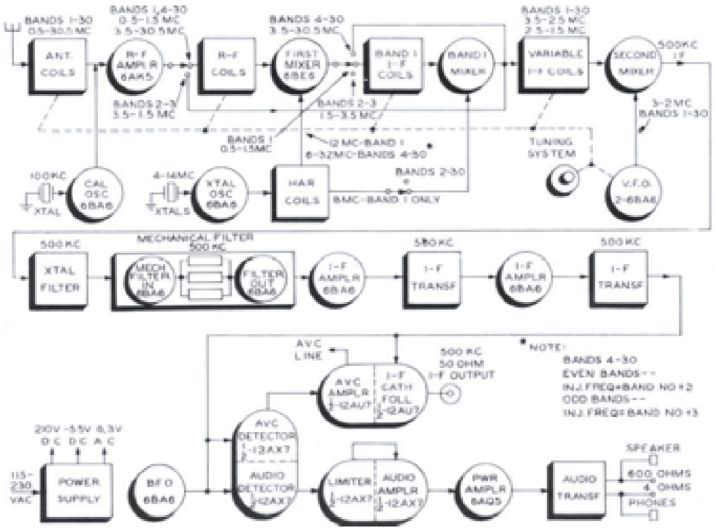
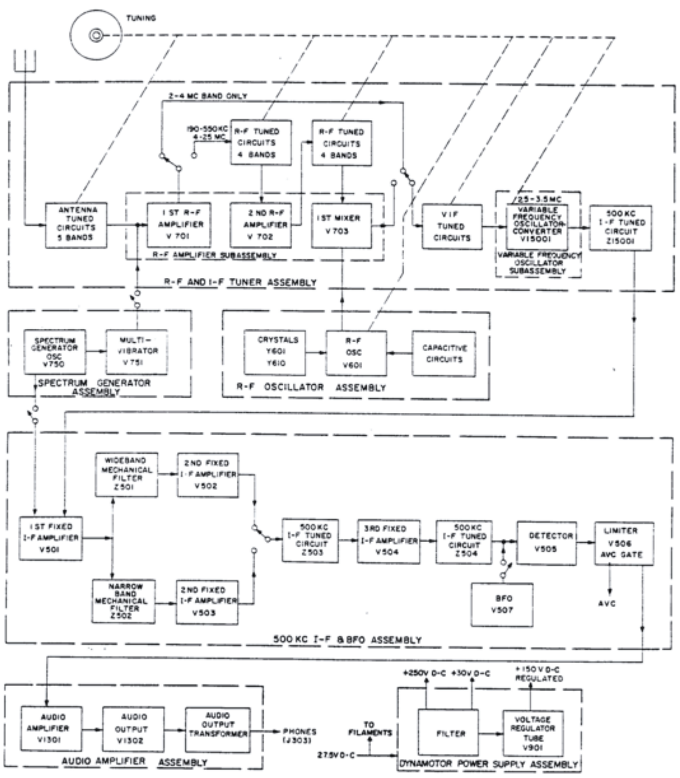


Figure 3, 51J-4 Block Diagram

Figure 4, AN/ARR-41 Block Diagram



Both receivers use the dual conversion approach, a 500 kHz IF with mechanical filters, and cams driven RF front end with variable frequency first IF. The architectures are the same, but the detailed circuit design is somewhat different. Collins had to make changes to accommodate the 190 to 550 kHz band and refined most of the design to include what was learned from the 51J, the 618S series and R-390/URR programs.

This approach yielded several benefits: reduced development schedule and design cost, improved reliability by leveraging past experience, use of existing supply chains and utilizing some common manufacturing jigs and assembly experience.

Collins was a master in leveraging its core designs to drive a multitude of products.

From a commercial point of view, it made the life of the Sale Department easier when approaching customers who might be resistant to accepting new technology: "Yes, this is a better version of the 51J that you already have and love".

Looking Under the Hood

The ARR-41 has a complement of 17 vacuum tubes. Except for the 5686 audio amplifier, all the tubes are easy to find even today and fairly inexpensive. The 5749 and 5750 are the excellent and reliable backbone of most radios from the 50s and 60s.

Tube PN	Alternate	Quantity
5749	6BA6	7
5750	6BE6	2
5726	6AL5	2
6AU6WA	6136	1
5654	6AK5	1
5814A	12AU7	2
5686	NA	1
OA2WA	NA	1

The ARR-41 is double conversion on all bands, excluding the 2 to 4 MHz band. The final IF is at 500kHz with two selectable mechanical filters, with 6.0 kHz and 1.4kHz bandwidth.

On visual inspection, my first impression was that its modular construction is very similar to the 618S - AN/ARC-38, a 2 to 25 MHz airborne transceiver.

The ARR-41 has 5 main modules and uses a plug-in dynamotor/power supply: the largest module is the R-F and I-F Tuner Assembly; this is mechanically very similar to the R-390A/URR in concept with mechanical gears, cams and Veeder-Root counter. On the right side of the R-F and I-F Tuner Assembly is where the reliable Collins 70H-5 PTO sits.

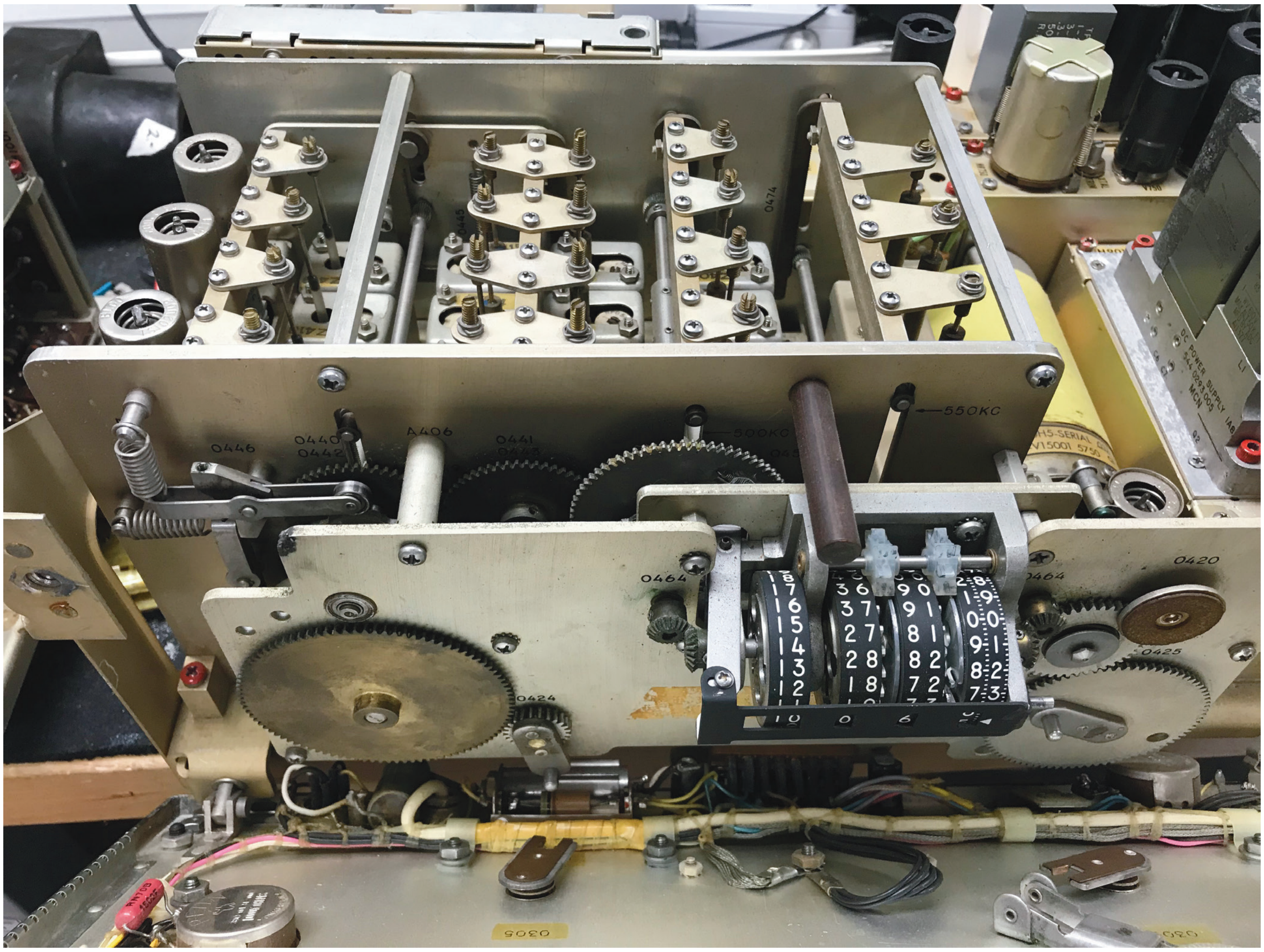


Figure 5, AN/ARR-41 R-F and I-F Block

The 500 KC I-F and BFO Assembly module includes a 3 stage 500 kHz amplifier and the two mechanical filters. This is followed by a detector, an AVC gate, a limiter and a BFO. This module has a few unusual design characteristics that should be mentioned:

- There are two 2nd IF amplifiers (V502 and V503), one following the 6.0 kHz mechanical filter and one following the 1.4 kHz filter. The selection of the filter is done by providing a grounding path for the cathode of the associated tube.
- The BFO tuning is controlled by a potentiometer through the clever use of a diode to change the capacitance of the Hartley oscillator.

It appears that the Collins designers wanted to avoid using any mechanical switches in the IF path and mechanical tuning of the BFO. This approach increased the reliability, simplified the mechanical design of the IF module and allowed the IF module to be located away from the front panel, thus simplifying maintenance.

Figure 6, AN/ARR-41 I-F Block

Variable Frequency Oscillator - PTO
The PTO is a 70H-5 and covers 2.5 to 3.5 MHz

RF Oscillator
The RF oscillator provides injection for the mixer (V703). This is a Colpitts type oscillator with 12 selectable frequency outputs employing only 10 crystals and 12 tuning capacitors. Attention must be paid during alignment to assure that proper harmonic is selected.

Spectrum generator Oscillator
This module provides a 100 kHz tuning calibration signal; this consists of a 5654 (6AK5) 500 kHz crystal oscillator followed by a synchronized 100 kHz multi-vibrator.

Audio Amplifier
The audio amplifier is the same as found in the AN/ARC-38. Yes, it is the same! They did not even change the reference designators.

Power Supply
MIL-R-18625 describes the possibility of a 28VDC or a 3-phase 115V 400Hz power supply. I am not sure if the 3-phase supply was ever manufactured. The internal DC power supply for plate and other voltages consists of a dynamotor and an OA2 150V voltage regulator.

I purchased my ARR-41 on eBay and the previous owner had modified the unit by removing the dynamotor and replacing it with a 115V 60Hz transformer with rectifiers and filters. I was not happy with this modification, and I did restore the unit to the 28VDC configuration. I could not locate a dynamotor, so I decided to use a solid-state inverter from a Collins AN/ARC-51BX; a good choice. For an untrained eye, it looks like a factory-made mod, and it is quiet and vibration free. Dynamotors are nice, until you turn them on and have to listen to their screaming.

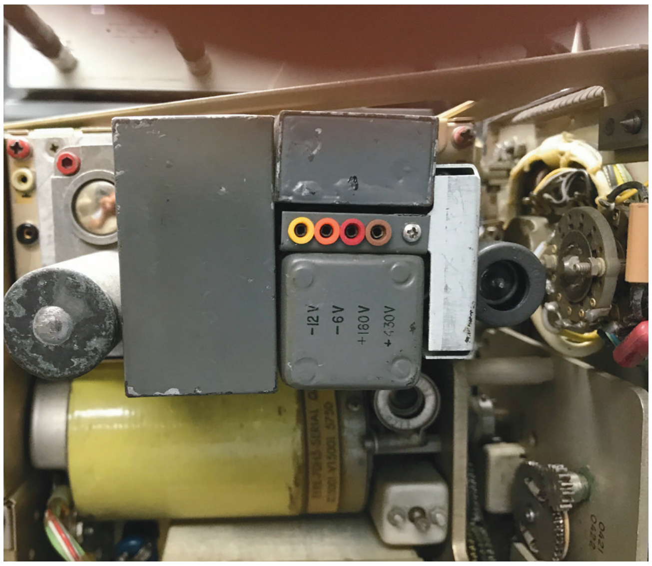


Figure 7, AN/ARR-41 – Modified Power Supply

My Other Comments

The R-641/ARR-41 is sensitive, has good selectivity and is a solid receiver. The tuning is rather fast but is also accurate. It does not have the frequency range and features of the R-390A, but, again, it is a good radio.

From an engineering point of view, I am impressed by how the Collins engineers utilized their available technology to design a fairly "hot radio" and, at the same time, kept it very simple.

Simple means fewer parts, less heat and fewer things to break. The repairman could replace a module in few minutes without any special tools or time-consuming mechanical rigging or alignments: simply unlock two dzus screws, those screws that lock and unlock with a 1/4 turn, to remove the cabinet, and few others to switch a module.

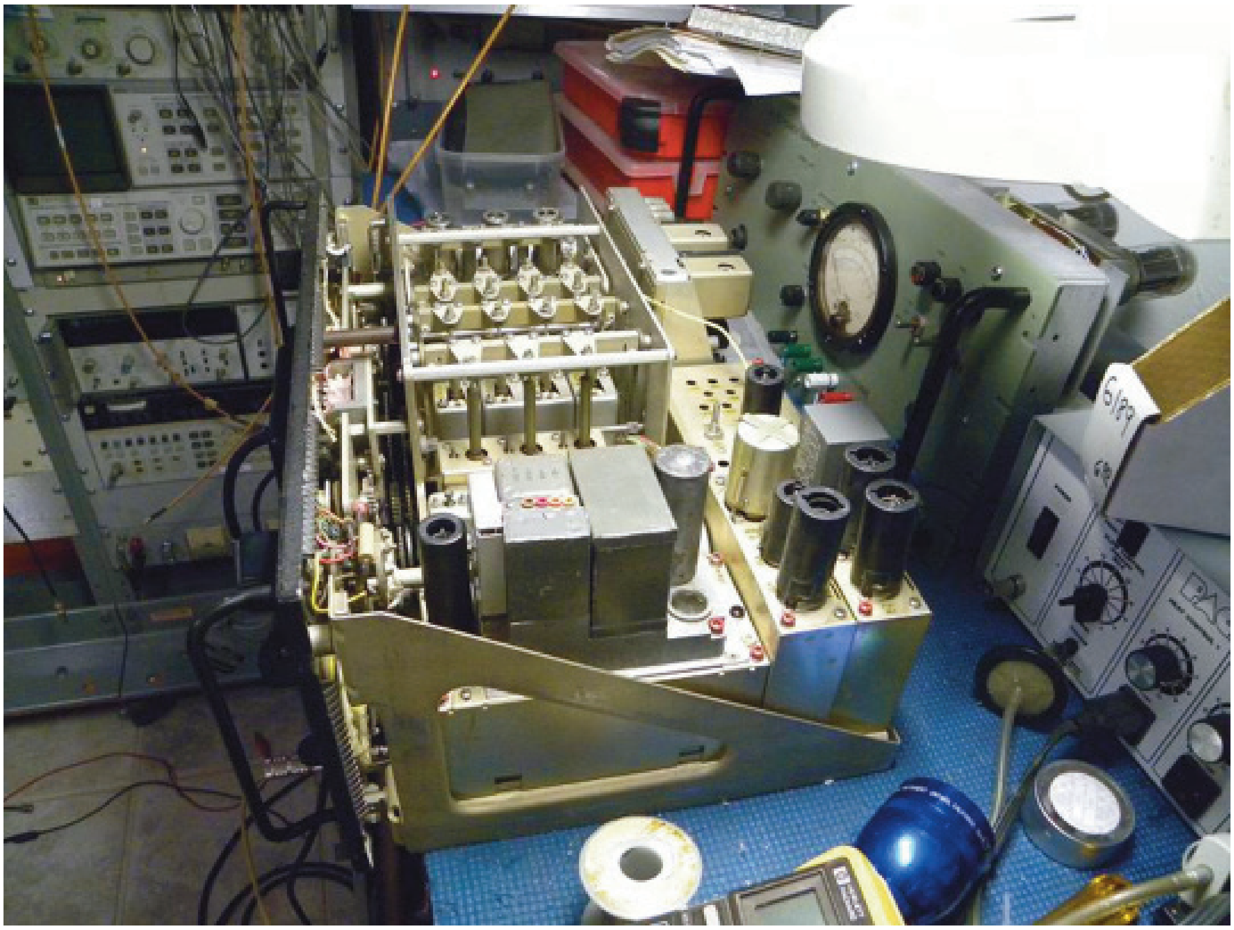


Figure 8, AN/ARR-41 –Internal View

From an operational point of view, the ARR-41 was a great improvement in every respect compared to the 1930s designed BC-348. In many installations, the ARR-41 was retained when the ART-13 was removed and replaced by the ARC-38. The ARC-38A brought SSB, but the ARR-41 was not upgraded to SSB.

This radio was readily available in the surplus market in the early 80s. Its R-390 look made it a rather valuable commodity. These days, it is not as common as it once was, but it can be found at ham fests and on eBay. The airplane mounting rack is rarer and often demands top dollar.

THE EQUIPMENT ROOM

On the other side of the control room glass doors are the racks of equipment that the operators control. Currently, Comm Central's basic operation includes four Collins HF-80 10 kilowatt receiver/transmitters, three Collins HF-80 1 kilowatt receiver/transmitters, associated HF-80 family radio and control equipment, and a sophisticated switching system. Included in this complement of equipment is SELSCAN®, the latest optional equipment developed for the Collins HF-80 series. SELSCAN® gives the HF-80 equipment and Comm Central a new level of efficiency and reliability. It is a microprocessor based unit that works the problems of propagation and selects the best channel upon which to operate. Operation of a SELSCAN® HF network provides automatic connectivity between SELSCAN® equipped stations. Over the years, new innovations like SELSCAN® have given Comm Central its extraordinary reliability to complete the two million calls that have already gone through Comm Central.

The antenna system just outside of Comm Central has the flexibility to respond to almost any propagation contingency. The Cedar Rapids antenna system includes: six HF billboard and two IF billboard antennas, three log periodic rotatable antennas, and two omnidirectional antennas. The antenna connections come through copper feedlines and are terminated in a high powered switching system in the equipment room. This antenna matrix enables the operators to remotely connect the desired antenna with the selected transmitter. The Cedar Rapids system plus the equipment in Newport Beach provide the diversity necessary for overall global circuit reliability.