Collins 651S-1 Receiver

Restoration Notes
W7CPA
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Figure 1 – An Excellent 651S-1 Top Hat for the R-390A

I first heard details of the Collins 651S-1 whilst rag chewing with Ted, WA8ULG on AM. Ted mentioned he had paired this receiver with his Collins 820 D2 broadcast transmitter. He spoke highly of its performance and interesting odd-duck properties. It's devoid of typical ham radio features like noise limiters/blankers, notch filters and pass band tuning.

Visually, it resembles a 1970s Heathkit home audio device - real 70's modern. They sold for $10-30k so there were no QST ads. I then discovered that Bill Carns didn't have one in his extensive collection. So of course, I had to find one.

Options

The receiver had many options. Do your research before buying boards for a given chassis dash number.

VLF - an option to extend the frequency range down to 12kHz, perhaps to monitor submarine fleet encrypted RTTY signals. This was a small board attached to the shielded RF module.

Remote Control – a RS-232C/MIL-STD-188C computer interface was available to support the Collins 514S-1 Remote Control Unit or other computer-based systems. The U.S. Air Force used these on tactical weather systems.

Filters - 200Hz, 500Hz, 1.0kHz, 3kHz and 8Khz were optionally available. The base filter components were 16kHz, 6Khz and 2.7kHz.

ISB - an independent sideband unit was optionally available to support old school, encrypted full duplex voice operations.

RTTY - a teletypewriter control unit (TCU) provides remote RTTY control with a Collins 514S-1 unit.

FM - narrow-band FM was available with squelch.
SCAN - a frequency scan option also offered.

This article focuses on my restoration experience with notes that might be useful to the Collins collector community. The technology was top shelf for 1970 with a high MTBF. One can download the Principles of Operation from the Archives for a detailed time machine tour of discrete digital design and high performance RF stages using early JFETS and discrete transistors.

The CCA website "Archive" has all the manuals available for download. The CCA "Historical Archives" has the best Collins product brief to peruse complete features and specifications.

When compared to modern off-shore, pre-DSP top-of-the-line receivers, I wonder where they found their designs? There isn't room in this article to show even a summary level block diagram of the triple conversion design.

The fundamental RF path is as follows:

Antenna
Low Pass Filter
Switch Band Pass Filters
109.35 MHz First Mixer with Variable Injection
Crystal Filters
10.35 MHz Mixer with Fixed 99MHz Injection
10.35 MHz IF Amplifier
Crystal filters 500Hz, 3kHz, 1.1 kHz
450 kHz Mixer with 9.9MHz Injection
FET Filter Input Gates
Mechanical Filters (6kHZ, 200Hz, 2.7kHz)
FET Filter Gates and Preamp

450kHz IF Amplifier

Operational Experience

Compared to the modern Flex 5000A, the 651S-1 performs extremely well for SSB, CW and AM modes. I can copy CW at 0.2uV on 14.300. Sensitivity is excellent. I plan to get it online with my R-390A for my antique SSB and AM nets. The receiver is extremely stable. The temperature compensated 9.9 MHz reference OSC is superb.

My filter boards support, 16kHz, 6kHz, 3kHz (AM), 2.7kHz (SSB), 1.1kHz RTYY and 500 Hz CW band widths. Filters are installed on the two sandwiched IF Filter bards. The plug-in board is shown on the schematic within the dotted line sections. The filters are switched inline using JFETS and a 3.9vdv enable voltage. More on this card below.

The receiver has one annoying behavior. If you tune too fast, the synthesizer can't keep up and you can hear something that resembles a gerbil in pain. The design mutes this to limit these dying gerbil noises. The later 851S-1 model fixed this problem.

The meter is calibrated in DB referenced to 1uV and also provides audio level in dBm assuming a 600 ohm load on the back panel terminal lock.

The audio quality is excellent with the small rack mount oval speaker.

There is no connector for muting other than a pin on the expensive circular connector on the rear. I rigged up closure-to-ground-to-receive mute control by running a wire from the small board on the bottom rear to the unused ISB BNC. The Circular connector mute pin connects to this little board and you can solder directly to the pin without disassembly.

Acquisition Notes

The only high failure components in the receiver are the original 7 segment displays. The geezer Vacuum Florescent Display (VFD) tubes are vacuum tube technology with all that that entails. The models with plug-in LED displays are better but still early LED technology. See Figure 2 for VFD and LED examples.

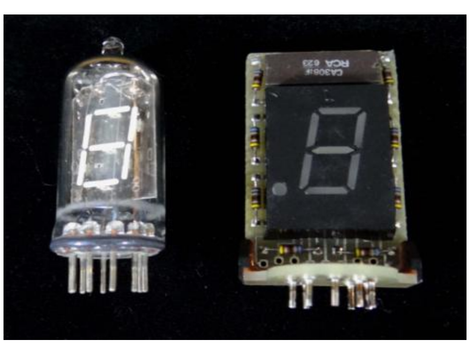

Figure 2 - VFD and LED Module

There are many different versions with plug-in board incompatibilities. Be careful buying spare cards. See the Principle of Operation tables for your chassis dash number. Also see the Information Bulletin I-72 for a list of the boards and the subassembly compatibility information. Be advised this is pretty complex stuff.

Bear in mind the information in Table 1 when making a purchase decision. The 1970 seven segment LED modules had no standards in both pin-outs and physical dimensions – quite "unobtanium" today. Modern LED modules could be adapted with a new PC board design affixed to 9 pin tube sockets.

Serial Numbers	Display Configuration
Up to 5000	VFD Display Tube
Up to 5000 with SB#10 Installed	Plug-in LED Modules
5001 and Beyond	LED Board Replaced 9 Pin Tube Modules

Table 1 - Display Configuration Serial Numbers

Restoration

I purchased a reasonably good unit and a parts unit. The poor condition desktop cover is another project by itself in the future. It is very thin aluminum with special feet. Of the 11 plug-in LED modules, only one had all segments working! I verified that the failure was the Packard Corporation LEDs and not the TTL driver chips as some had suggested.

I made the decision to back out Service Bulletin #10 and return to the original VFD tubes. I found 12 NOS on eBay to select from for best luminescence. This is huge task to get at the bottom of the display tube sockets to replace the 6 SB#10 jumpers with 82 ohm resistors per the original design. SB#10 disassembly instructions are not complete and it's easy to break the mini-coax solder connections on the tuning unit since they are soft pure silver. Move carefully and secure the tuning unit during disassembly.

The comma and period were little bulbs in fixtures that were long gone after SB#10 was applied. They were butted against a round hole and a comma-like hole in the metal front panel assembly. I used blue LEDs in tubular rubber grommets to replace the bulbs - see figure 3. The enable voltage is 25vdc. Choose your serial resistor to match the LED current requirements. I had to add yellow filter material to achieve the same blue-green color of the VFDs. I used silicon adhesive to keep the grommet in place. This was not pretty but easily removed and no holes were drilled in the process.

Figure 3 - Comma-Period LED

Mechanical Layout

The chassis is beautifully designed to support plug-in cards with high MTBF in a rugged environment. The cards have unique, heavy duty gold connector jacks and mini-coax plugs so there is no such thing as a common card extender and subsequently there is no way to plug a card into the wrong slot - a good thing in the field.

One can tack small braided wires to the board to debug signals without the card extenders.

Figure 4 shows the card rack with one cover off.

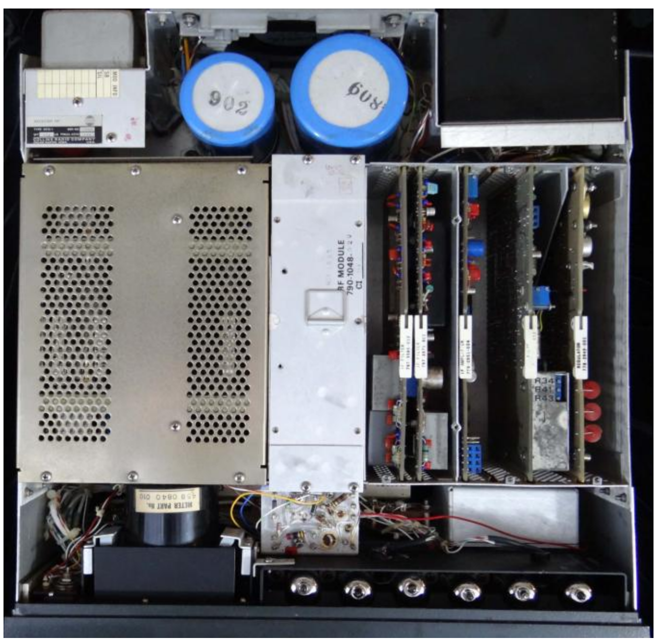

Figure 4 - Card Rack with One Cover Off

All connections are available on the back of the unit.

Figure 5 – Back

The chassis bottom shown in Figure 6 features high quality connectors, Teflon wires and mini-coax jumpers.

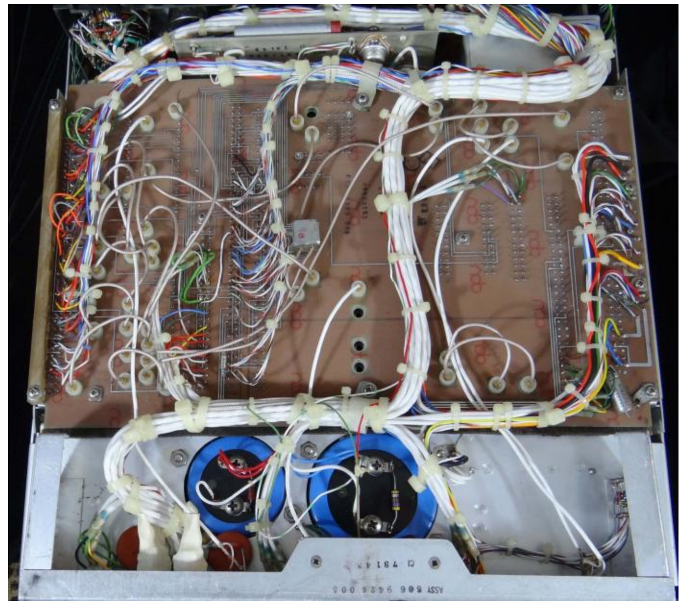

Figure 6 - Chassis Bottom View

The RF board in Figure 7 is fully shielded. The cavity is where the VLF option is installed. I am trying to find one of these. So far they are very rare.

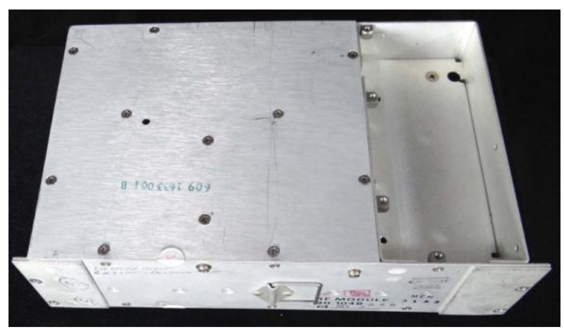

Figure 7 - RF Module sans VLF Option

When I initially put the receiver on the air, I was hearing SSB signals about 20-30Hz off frequency. The following calibration solved the problem perfectly.

The SYNTH reference card shown in Figure 8 has the precision 9.9Mhz oscillator you might want to put “on the beak”. If you have a good scope probe and a precision counter, there is an much easier way to adjust than described in the manual.

With the board plugged in normally, unscrew the nylon or stainless screw that seals the access hole above the precision trim pot. If the nylon screw breaks, pick it out and replace it with a stainless cap screw and o-ring washer. Place the scope probe on the input pin of the X10 module next to the oscillator can. Power on and warm the unit up. Now tweak the trimmer for 9.9000000 MHz and replace cover screw – easy. This is most amazing precision trimmer I have ever trimmed – a real pleasure.

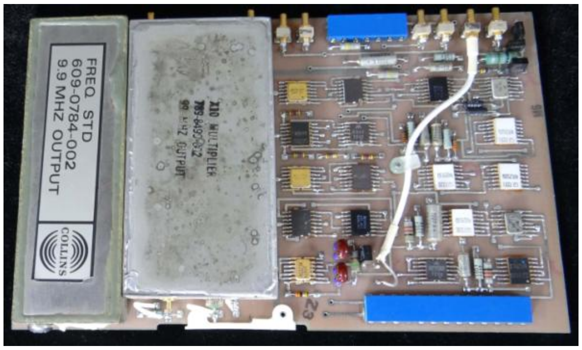

Figure 8 - SYNTH Reference Board

You might also recalibrate the variable BFO to zero beat when ON and the knob pointer is straight up as long as perfection is what we seek.

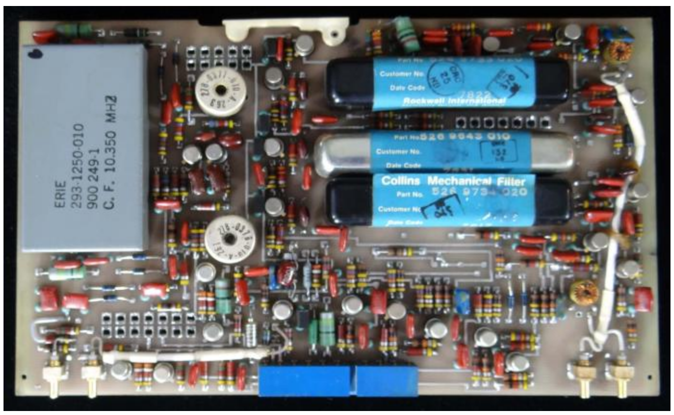

Figure 9 - IF Mechanical Filter Board

The 6kHz, 2.7kHz USB and 2.7kHz LSB mechanical filters are located on the main IF Filter Board shown in Figure 9. Optional filters are located on the board that plugs into the back of this card – the filter sandwich.

If you have what appears to be a dead mechanical filter it might not be the culprit. I successfully used a bench debug process to repair what appeared to be a dead USB filter – the second JFET (JAN 2N4416A) was the culprit. The 1st JFET is also a possible culprit. If you change the SSB first JFET, note the factory select gain resistors R69 and R83 to match SSB levels. They range from 1.2k to 3.3k.

Remove the IF Filter Board and remove the optional filter(s) board from its back. Place the board on the bench and ready the following voltages from bench supplies: +15 vdc, -15vdc and 3.9vdc. Connect +15vdc to pin#15, -15vdc to pin#1 and ground to pin#2 and 22. Connect a 450kHz signal (100uV at least) to the 450 input bus. There is a pin on one of the connectors on the back of the board that is handy to inject 450kHz. The 3.9vdc enable voltage connects to pin#3 (LSB), pin#5 (USB) or pin#6 (AM 6kHz). Monitor the IF output on coax jack p2.

A 2N2907 receives the enable voltage. This turns on the 1st JFET to pass 450kHz input to the mechanical filter, then a final JFET switch/preamp stage before P2 output. Figure 10 illustrates the preamp gain provided by the 2nd JFET. The top trace is input.
The bottom trace is the filter output destined for the IF Amplifier board.

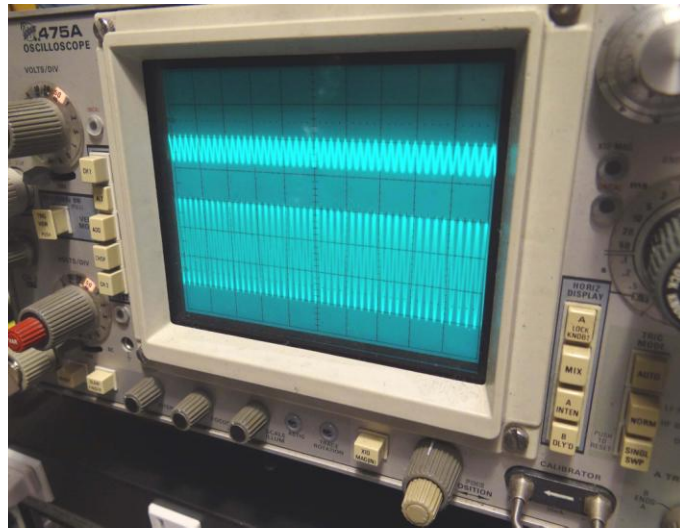

Figure 10 - IF Filter Preamp Gain

You should be able to move the enable signal to pins 3, 5 and 6 and see the output for each. If not, the filter might be dead. In my case Q18 (output JFET JAN 2N4416A) was the culprit and not the expensive mechanical filter.

The board positions are also available on a chassis side panel.

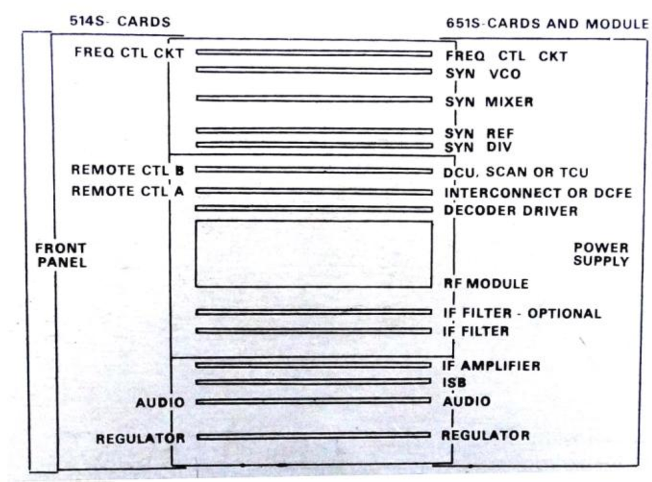

Figure 11 - Board Positions

Figure 12 shows the 651S-1 ready to install in the rack mount from the back side.

Figure 12 – Front View Prior to Rack Mount

Summary

I believe that the expression “moving the frontiers of science forward another 5/8s of an inch” seems quite appropriate for the 651S-1 in 1970. There are no switches or mechanical relays in the signal path. It is all realized in silicon. Additionally, VHF first stage roofing filters might be a first or at least bleeding edge technology for the day.