CCA Introduction – 32S-3/3A Out of Band Transmission Concerns & Remedy

PRIORITY ACTION REQUIRED

The 32S-3 is the center stone transmitter of the Collins S-Line offering. During its production run from the early 60s through into the late 80s, over 8000 units were produced. The survival rate has been excellent and many are still in use.

Now we find that, very early in its production run, a modification appeared that was supposed to increase Grid Drive on all bands. This mod became the "thing to do" and was propagated through a number of relatively high volume published media. This modification became standard fare, and it was rather common to do this whenever a transmitter was worked on or "Improved". We do not know how many transmitters were modified, but it is certainly probable that – over the years now – hundreds were thus modified, and the number could well be in the three figures range.

We write this introduction to Don's fine article to impress you with the need to consider your 32S-3 as suspect. If you do not absolutely know the history of your unit, it could have, at some point, gone in for maintenance and had this mod installed.

<u>Because of the "out of band" nature of the problem, it is very important that you inspect</u> (either with a Spectrum Analyzer or physically) your transmitter and see if this mod was ever done. If it was, as Don points out below, it needs to be removed. The fix is simply done. READ ON! . . . . and our thanks to Don for his great catch on this and his work with Dick and Bob.

The C20 Modification for the 32S-3/3A Transmitter

by Don Jackson, W5QN

Many years ago, this modification started circulating while the 32S-3 was still in production. Its origin is unclear, but it has been performed on countless 32S-3 transmitters. This was refreshed and exacerbated when Bud Whitney, K7RMT - without benefit of a Spectrum Analyzer - picked up the modification as a commonly accepted one and started both doing it and recommending it in his writings. In addition, the modification has been made available in other media and performed by numerous repair shops while doing a series of common modifications. As you will see in this article, the recommendation is that this mod be promptly removed and the transmitter returned to its original, as manufactured configuration (regarding this change only).

A few weeks ago I had my 32S-3 out of its cabinet, so I thought it would be a good time to install some of the common modifications often recommended. Among the modifications is a recommendation to change C20 from .01uF to .001uF to increase grid drive. C20 couples the BFO signal into the 1st Mixer cathode (V4), when in TUNE, LOCK KEY or CW modes. After doing this modification, I tuned up the rig at the bottom end ("0" logging scale) of the 14.0 MHz segment. I happened to be looking at my RF output signal on my spectrum analyzer and noticed two rather large spurious outputs on either side of the desired carrier. Their amplitudes were large enough to exceed the 32S-3 specification of -50 dBc. Much worse, the lower frequency spur was outside the 20m band! Alarmed, I changed C20 back to .01uF, and the spurs dropped down by 30 dB or so.

What Is Going On?

A few more measurements showed that the problem was the worst at the bottom end of all the bands, meaning that the spurs were being generated in the 1st Mixer. The 1st Mixer combines the crystal BFO with the VFO signal when in TUNE, LOCK KEY or CW modes. The spurs do not occur in SSB modes because the crystal BFO is applied to the balanced modulator, allowing the 455 kHz mechanical filter to clean up the 455 kHz input to the 1st Mixer.

So, in order to fully understand these observations, I needed to determine what combinations of the BFO and VFO signals and their harmonics could produce spurious signals that would fall in the vicinity of the 2.955-3.155 MHz IF bandpass filter. Spurious signals that fall within, or close to, the IF passband will be converted to the RF output, regardless of the selected band segment. A little number crunching with my old spur calculator program yielded the following possibilities:

Spur #1: 7th harmonic of the crystal BFO: (7 x .45635 MHz = 3.19445 MHz)
Spur #2: Mixing of the 2nd VFO harmonic with the 5th BFO harmonic: 2 x 2.69865 MHz – 5 x .45635 MHz = 3.11555 MHz
Spur #3: Intermodulation of the desired IF output 2nd harmonic, and Spur #2: 2 x 3.155 MHz - 3.11555 MHz = 3.19445 MHz

Interestingly, Spur #1 and Spur #3 are on the same frequency. In practice, Spur #1 is much lower in amplitude than Spur #3, so Spur #1 can be ignored for all practical purposes.

For the 14.0 MHz band segment, we can translate these IF frequencies into transmitted RF output frequencies by subtracting the IF frequency from the appropriate XTAL OSC frequency:

RF Spur #2: 17.155 MHz – 3.11555 MHz = 14.03945 MHz
RF Spur #3: 17.155 MHz – 3.19445 MHz = 13.96055 MHz   **(out of band!)**

A chart generated from a spreadsheet calculator is shown in Figure 1 below. These frequencies are for a typical 32S-3. (Let me know if you would like a copy of this Excel spreadsheet.)

Inputs			
BFO Frequency	**=**	0.45635	**MHz**
VFO Frequency	**=**	2.69865	**MHz**
HF XTAL Osc.	**=**	17.15500	**MHz**
IF Frequencies			
Desired Output		3.15500	**MHz**
Spur #1 (7*BFO)		3.19445	**MHz**
Spur #2 (2*VFO-5*BFO)		3.11555	**MHz**
Spur #3 (IMD w/RF out)		3.19445	**MHz**
RF Out Frequencies			
Desired Output		14.00000	**MHz**
Spur #1 (7*BFO)		13.96055	**MHz**
Spur #2 (2*VFO-5*BFO)		14.03945	**MHz**
Spur #3 (IMD w/RF out)		13.96055	**MHz**

Figure 1 – Typical 32S-3 Spur Chart

Observing Spur #3 on a spectrum analyzer, you will notice that it does not vary in frequency as the VFO is tuned, whereas Spur #2 and the desired RF output frequency will vary. This is an important point because it means that the out of band spur at 13.96055 MHz remains at this frequency, regardless of the setting of the VFO.

Figures 2 and 3 show the RF output on a spectrum analyzer for C20 values of .001uF and .01uF respectively. The 32S-3 was tuned up for an RF output frequency of 14.000 MHz. "0 dBm" represents 100W RF output power.

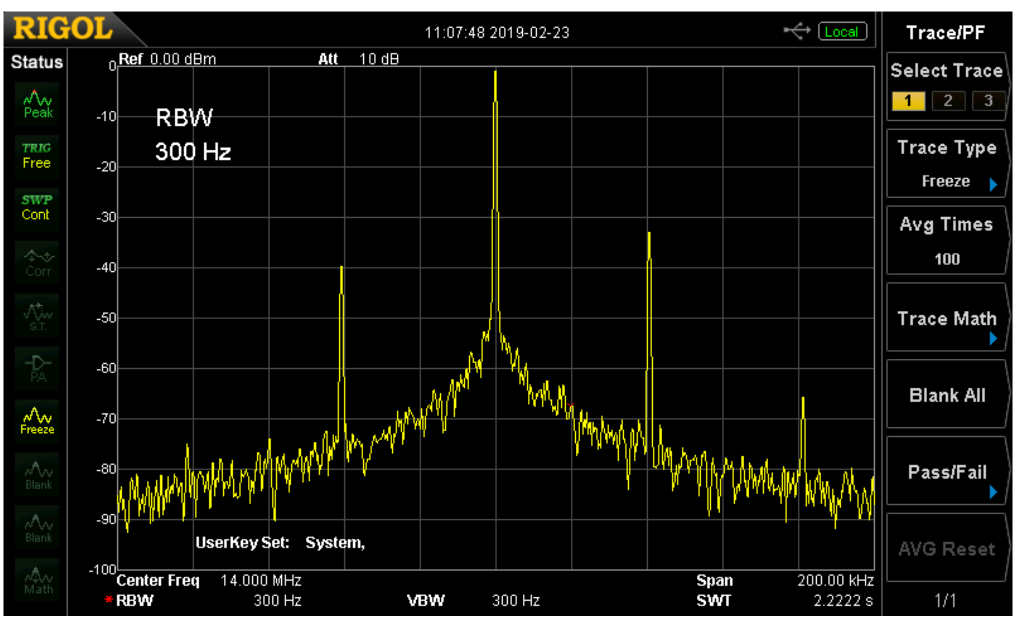

Figure 2 – RF Spectrum with .001uF C20

As can be seen in Figure 2, the spurs do not meet the 32S-3 specification of -50 dBc with a C20 of .001uF. Worse, the lower spur will be stationary, about 40 kHz out of band if the transmitter were tuned to 14.000 MHz. Figure 3 with the original C20 value of .01uF nearly eliminates those spurs, with remaining spurs well below the -50 dBc spec.

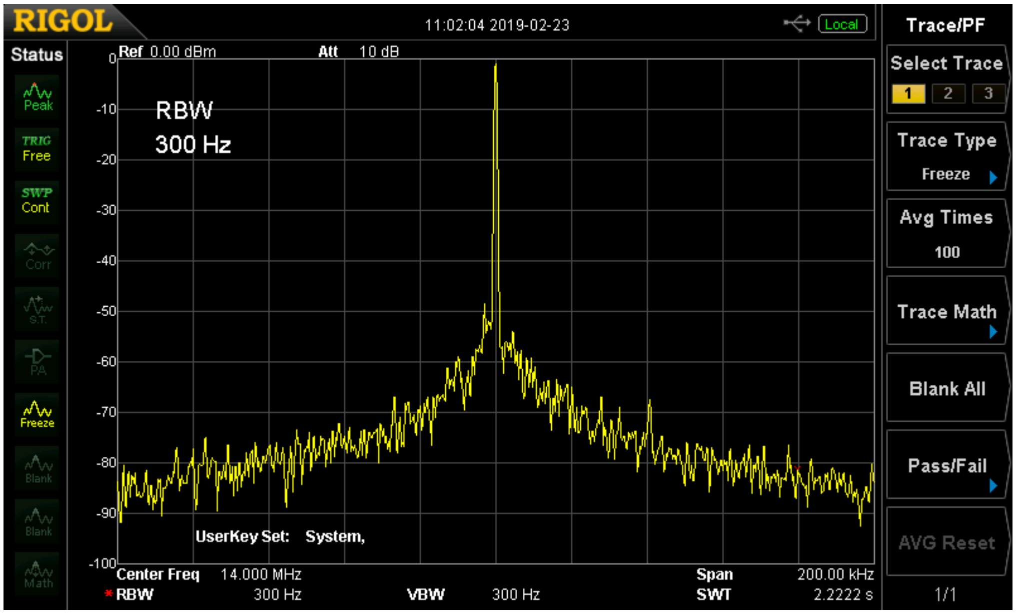

Figure 3 – RF Spectrum with .01uF C20

Why Does a .001uF C20 Cause These Spurs?

Determination of the precise cause is not a trivial task. Analysis and measurements indicate that the problem is likely associated with increase in BFO harmonic content with the .001uF installed. Increased BFO signal may cause this, and another possibility is the terminating impedance the 1st Mixer sees with a .001uF C20 vs. a .01uF C20. The cause is likely a combination of factors. A likely "smoking gun" can be seen in Figures 4 and 5. These are spectral plots of the crystal BFO signal as measured at the 1st Mixer BFO input port, V4 Pin 3. Figure 4 was with a .001uF, and Figure 5 is with a .01uF.

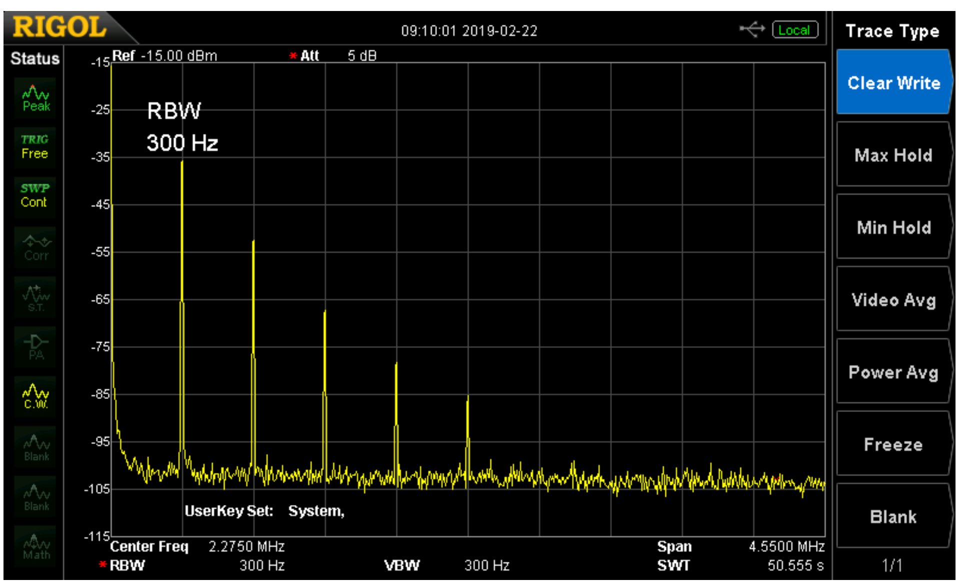

Figure 4 – BFO Signal with .001uF Showing Increased 5th Harmonic Level

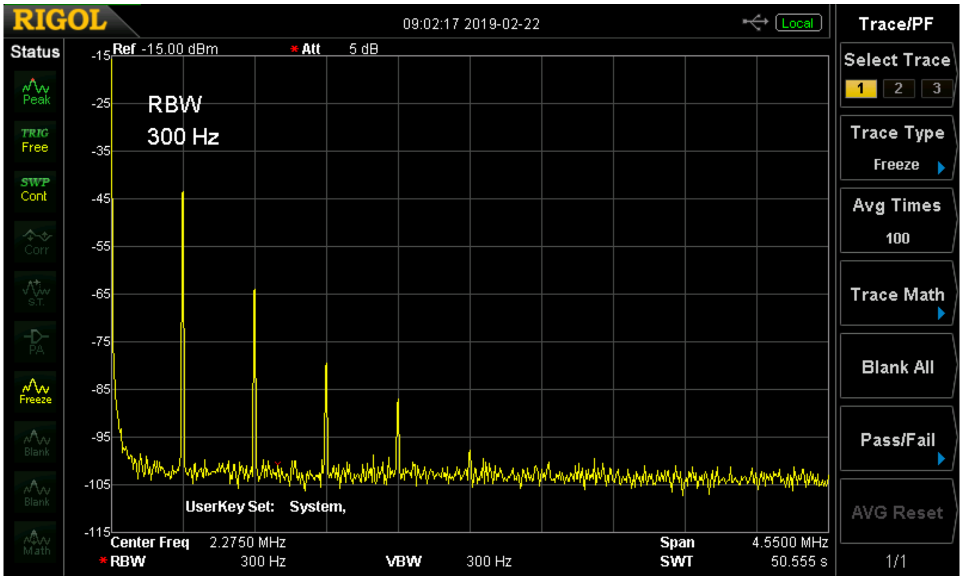

Figure 5 – BFO Signal with .01uF C20

Note that the fundamental of the BFO is about 8 dB higher with the .001uF installed. This higher BFO level with the .001uF is due to the lighter loading of the BFO oscillator. The lower level of the BFO with the .01uF installed likely contributes to the lower spur level. Of particular importance is the magnitude of the 5th harmonic. Recall from earlier in this article that the 5th harmonic of the BFO is a key contributor to the 2*VFO minus 5*BFO mixing spur. In the above figures, we can see that the 5th harmonic of the BFO is about 13 dB lower with the .01uF than with the .001uF.

The 32S-3 Drive Increase with the .001uF Modification

One of the initial questions I had about the C20 modification was how changing from a .01uF value to a .001uF value could increase the 32S-3 grid drive. On the surface, that seemed counter intuitive. In order to determine what might be happening, I resorted to a Spice model of the circuitry between the BFO tube plate and the 1st Mixer tube grid. It turned out that this circuitry has a bandpass characteristic, primarily due to the LC network at the BFO plate. The maximum response of this network is normally around 410 kHz or so with a C20 of .01uF. However, when C20 is changed to .001uF, the response peak moves up to around 445 kHz, increasing the 455 kHz output. Figure 6 shows the two scenarios.

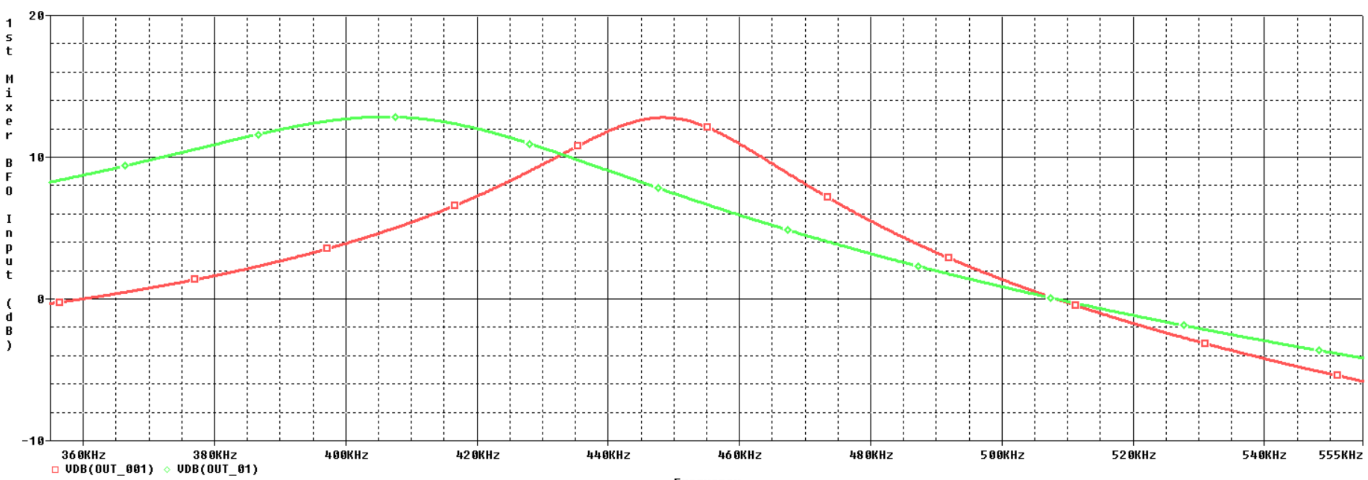

Figure 6 – Spice Simulation of the BFO Plate to 1st Mixer Grid Circuitry

As Figure 6 indicates, the simulation predicts that changing C20 to a .001uF increases the BFO drive to the mixer by about 5 dB at 455 kHz. Note that this is only a simulation, and behavior in the actual 32S-3 is highly dependent on the exact component values, particularly the LC components connected to the plate of the BFO tube.

How to Replace C20

First, determine if you need to replace C20. You can do this by taking the 32S-3 out of its cabinet and checking the value of C20. It should be .01uF. Alternatively, if you have a spectrum analyzer, tune the unit up at the low end of a band, and observe the output signal. If it is similar to Figure 3, you are ok. If it looks more like Figure 2, it’s time to replace C20. The good news is that this is an easy fix.

Figure 7 shows the location of C20 under the chassis. It is relatively easy to get to, and can be replaced with careful soldering techniques. If you aren’t comfortable with complete replacement, the spur problem can be solved by simply soldering a .01uF capacitor to the leads of the existing .001uF capacitor. The C20 shown is a .01uF with value code “103”. A .001uF capacitor would have a value code of “102”.

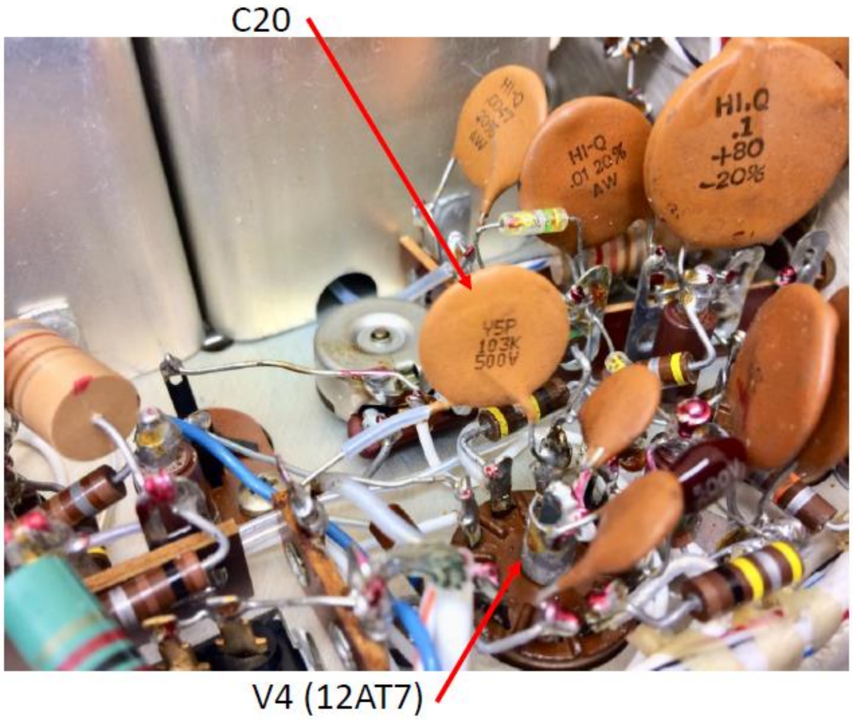

Figure 7 – Location of C20

I recommend that the First Mixer Balance Adjustment (4.5.7 in the 32S-3 manual) be performed after installing the .01uF capacitor. In fact, I was concerned that installing the .001uF capacitor without performing this alignment might actually be a contributing factor to the spur problem. However, experiments showed that the First Mixer Balance has virtually no affect on these spurs.

For those of you with 32S-1 transmitters, this particular spur problem does not apply to that unit. In the 32S-1, the CW mode is not implemented by direct application of the crystal BFO to the 1st Mixer. All 455 kHz energy is passed through the mechanical filter, so the spur problem discussed in this article is not an issue.

Conclusions

The spur issue with a .001uF C20 has been demonstrated on the four 32S-3 units tested. All units worked properly with a .01uF C20, and every unit had the spur problem with a .001uF installed. In every case, the C20 modification caused the 32S-3 to fail its -50 dBc spurious specification. Much more importantly, it significantly strengthens a spurious output that falls outside the ham bands. Since the spurs are generated in the 1st Mixer, RF output spurs are created on all band segments, although they are most noticeable toward the low end of each 200 kHz band segment.

These spurs only show up in TUNE, LOCK KEY and CW modes. In SSB modes, the spurs do not occur because the mechanical filter cleans up the 455 kHz signal.

The bottom line is, if you have a .001uF installed for C20, replace it as soon as you possibly can. The slight increase in grid drive from the .001uF is certainly not worth the unintended consequences.

A big thank you to Bob Jefferis, KF6BC, Dick Weber, K5IU and Bill Carns, N7OTQ for their help with this article.

Cheers, Don, W5QN