JUMA TRX-2 SPUR ELIMINATION MODIFICATION

The JUMA TRX-2 all-band CW/SSB QRP transceiver in its original form suffered from a significant number of spurious responses that seriously impaired its usefulness on the 17m through 10m bands.

On the 160m through 20m bands, although there were certainly some spurii, they were relatively few in number, and their amplitudes were such that for the most part they were at or below the intrinsic atmospheric noise levels and thus posed little threat to weak-signal performance.

The situation above 20m was considerably different. On these bands the sheer number and amplitudes of these spurious responses were such as to make these bands essentially unusable for all but the strongest of signals.

Now, it should be stated that the spurious response problem is not solely confined to this transceiver – all modern transceivers exhibit this phenomena to some degree. The moment we decided to use the superhetrodyne principle and then compounded our decision by introducing the digital synthesiser we opened the door to a wide range of spurious responses. In addition, the direct-conversion or zero-IF receiver seems to be particularly sensitive in this regard. It would be surprising therefore if this transceiver did not exhibit any spurious responses.

The problem arises largely with the direct digital synthesiser (DDS) chip. Its spurious-free dynamic range of approximately 73dB is less than the overall receiver's dynamic range, and if the local oscillator signal can find its way into the receiver's signal conversion circuitry then there is always the possibility of us discovering one or more spurious artifacts of the digital synthesis process.

The spurii are the result of phase-truncation errors as well as distortion products inherent in the reconstituted output waveform, and are particularly troublesome when the output frequency is a significant fraction of the master clock. For best performance the output frequencies should be restricted to a small fraction of the maximum frequency, and for the Juma TRX-2 this is evident by the results of a full band frequency analysis which shows that for the lower amateur bands from 1.8MHz to 14.350MHz the receiver is reasonably free of these pests. As the local oscillator frequency is increased however, then they make their appearance.

In this transceiver, the local oscillator signal is generated at twice the signal frequency and is then fed into a high-speed differential comparator that is part of the DDS chip to generate a normal and inverted signal. This is then fed to a pair of cross-connected D-type flip flops, IC-7A and IC-7B. By using the !Q output of the A flip-flop as the data input of the second, and using the Q output of the B flip-flop as the data input of the first, one can divide the clock frequency by 2, and arrive at an I and Q phase-quadrature local oscillator signal. R42 is used to provide an adjustable DC offset to the comparator which allows for the fine adjustment of the absolute phase of the normal and inverted output signal, which then affects the I and Q phase balance to achieve maximum unwanted sideband suppression.

In the original design the local oscillator signal could enter the receiver input as a result of cross coupling in the digital multiplexer chip as well as reverse feed-through and mismatch. The spur elimination modification attempts to address these issues by using a better input match and a pair of balanced emitter followers to severely attenuate the reverse feed-through.

The question is, how well does this work? The short answer is very well. I measured the receiver’s response to spurious signals by terminating the input in a 50 ohm termination and then tuning the receiver over each amateur band in 10Hz steps (the smallest frequency step of the transceiver’s synthesiser) and noting the frequency and signal level at which a spurious signal was heard.

160 Metres
For this band, the unmodified receiver had 15 detectable spurii, all at a level that would have been masked by atmospheric noise with an antenna connected. After the modification, two spurs disappeared completely, and the remainder were reduced in level to the point where they were barely audible above front-end thermal noise.

80 Metres
On this band, the unmodified receiver had 36 detectable spurs, of which 7 were clearly audible even with an antenna connected. After the modification, 20 spurs were rendered completely inaudible, and the 7 which were clearly audible were now reduced in level to that of the inherent band’s noise level or lower.

40 Metres
This band exhibited 17 spurs, of which 5 were clearly audible. After modification, 12 spurs were inaudible, and of the 5 which were originally troublesome, 4 were reduced in level almost to the point of inaudibility, and the most troublesome one was significantly reduced.

30 Metres
This band had no detectable spurs either in the original configuration, or when modified. The only spurious response was outside the amateur frequency allocation at 10.00004Mhz, and this was a killer, but after the modification, although still clearly audible, its level was significantly reduced.

20 Metres
This band exhibited 25 spurs of which 3 were significant and clearly audible. After modification, 13 spurs were eliminated, 8 were reduced in level to where they were barely audible above receiver thermal noise, and only one was left that was still audible above antenna noise, the remainder were below antenna noise.

17 Metres
The unmodified receiver had 278 clearly detectable spurs on this band, of which 39 were severe. After modification, 203 spurs disappeared, 5 spurs were audible above background noise, and the rest were at or below front-end noise.

15 Metres
The unmodified receiver had at least 330 significant detectable spurs, of which the majority were of such a level as to severely affect the receiver's performance even with an antenna connected.

At these frequencies the level of atmospheric noise is less than for the lower bands, and thus spurious signals are much more troublesome.

After the modification, 159 spurs disappeared, 35 were still clearly audible although considerably reduced in amplitude, of the remainder most were either barely audible or close to atmospheric noise. Somewhat surprisingly, 8 additional spurs were detectable that were absent on the initial scan.

12 Metres
The unmodified receiver had 139 significant clearly audible spurs. After modification, 96 of these were eliminated or educed to being barely audible, 21 were still audible although significantly reduced in amplitude. Once again, there were 3 additional spurs that were not audible on the original receiver.

10 Metres
The original unmodified receiver was so bad on this band that I did not cover the entire band. I gave up after scanning the first 308kHz, after discovering more than 418 significant spurs. As with 12, 15, and 17 metres, this band was essentially unusable.

After modification, 158 spurs were rendered inaudible, 99 are still clearly audible even above atmospheric noise, and once again there were several (7) newcomers that were not present originally.

The vast majority of these spurious responses are very fast tuning, indicating that they are very high-order mixing products. In other words, if you alter the display by ±1 least-significant digit, then they disappear. Only a few tune in as an unmodulated carrier, and thus even those spurs of a significant level may not in practice turn out to be a nuisance since offsetting the frequency by ±10Hz will often eliminate them.

Nevertheless, it must be said that 10 metres is still significantly affected by spurious signals, more so than the other bands, and this is simply a limitation of the DDS chip that is being used. If a higher specification device were to be employed, using a significantly higher clock frequency, then the performance on the higher frequency amateur bands would be significantly improved.

Summary

1. The original transceiver’s performance on the 160 through 20 metre bands, although to some extent impaired by the presence of spurious signals, was such that quite acceptable results could be obtained.

2. Above 20 metres the spurious responses were of such a number and amplitude as to render these bands essentially unusable except for the strongest of signals.

3. After modification, the performance on the 160 through 20 metre bands was significantly enhanced to the point where spurious responses are of little consequence, and no worse than many other commercial transceivers.

4. The modified receiver’s performance above 20 metres is also significantly improved such that 17, 15, and 12 metres are now reasonably free of intrusive spurs although there are still quite a number that can be heard in the background.

5. The performance on 10 metres is still somewhat marginal by virtue of the audibility of a number of spurious responses, although it has to be said that most are of such a level as to be relatively weak, and others are of the very fast tuning variety so that they can be easily avoided.

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