application note

Advancing Wireless Test: Using the IFR COM-120B to quickly align problem IF stages

By David Hagood

An improperly aligned IF stage can rob a receiver of important sensitivity - sometimes as much as 20 to 30 dB. The resulting loss of coverage (or increase in transmitter power to make up for it) will increase the cost of operating a radio system. However, by using the advanced features of the IFR COM-120B's tracking generator, your receiver can be kept in top working order.

For example, a local radio repeater was suffering from reduced sensitivity. In fact, it was exhibiting unusual behavior by being more sensitive 5 kHz away from the receive frequency than it was at the receive frequency. By using the IFR COM-120B's offset tracking generator as described in this article, it was found that the IF filters had been misaligned with the outcome being a response curve that had two peaks; one 5 kHz low and one that was 5 kHz high. The result was that the receiver was 20 dB less sensitive than optimal at mid channel.

Alignment of the IF filters took the sensitivity from 2 μV to .2 μV. This alignment took about 20 minutes with the COM-120B, since you can directly see the IF response on the spectrum analyzer while simultaneously feeding an RF signal into the front end. Without the ability to directly see the response curve of the IF, it would not have been possible to insure the IF was correctly aligned.

Putting Your COM-120B In Action

In order to put this feature into practice, you will need to have the tracking generator option (Option #12) enabled and a means of probing the various stages of the radio's receiver chain - either a sniffer coil[1] or a standard 10x oscilloscope probe will suffice.

The COM-120B's spectrum analyzer is a receiver that is continuously sweeping across a selected frequency band. With a tracking generator that is tuned to the same frequency as the receiver you provide a known RF stimulus for the system being swept.

This is useful for tuning antennas, duplexers, band pass filters or notch filters. However, it is not useful for tuning a radio's IF strip, since the IF frequency is different from the receive frequency. In order to tune the IF, it is necessary to place the tracking generator at one set of frequencies, while the spectrum analyzer sweeps a different but related set of frequencies.

The COM-120B allows for just this mode of operation, allowing you to enter either:

1. the center frequency of the tracking generator or

2. the offset between the tracking generator and the spectrum analyzer center frequency.

You would use the first mode for tuning a radio's IF strip where the input frequency will remain at the radio's receive frequency, and the spectrum analyzer will be tuned to each IF frequency in turn. The second mode would be used to tune frequency translators where there exists a constant offset from the input frequency to the output frequency.

For this example, we will assume the radio to be aligned has the following specifications:

Receive frequency:	146.85 MHz
First IF:	10.7 MHz, approximately 100 kHz bandwidth
Second IF:	455 kHz center frequency, 15 kHz bandwidth

We'll assume the block diagram of the radio looks like this:

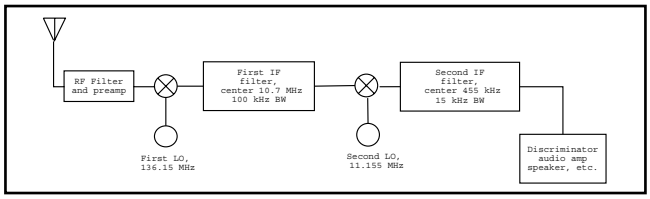

Figure 1.0 - Radio Receiver Block Diagram

First, connect the COM-120B's AUX port to the UUT[2]'s receive port. If the UUT is a transceiver or repeater, disable or terminate the transmitter into a suitable 50 Ω load.

Next, connect the sniffer coil/scope probe to the COM-120B's antenna port.

Select the main spectrum analyzer by pressing the ANLYZ button on the COM-120B. Move the cursor to the Track Gen field. Normally, you should see the DEFAULT softkey highlighted. This is the normal mode of operation in which the frequencies swept by the tracking generator are the same as the set of frequencies swept by the spectrum analyzer. However, we need to keep the tracking generator sweeping the receiver's receive frequency, while we move the spectrum analyzer center frequency around.

To do this, press the CONFIG softkey. A window will open with two fields: tracking generator center frequency and frequency offset. For this radio, we enter the radio's receive frequency of 146.85 into the Center Frequency field. At this point, the DEFAULT softkey will go out. Until we reactivate default mode, the tracking generator will sweep around 146.85 MHz regardless of where we put the analyzer center frequency. Press the RETURN softkey to close the window.

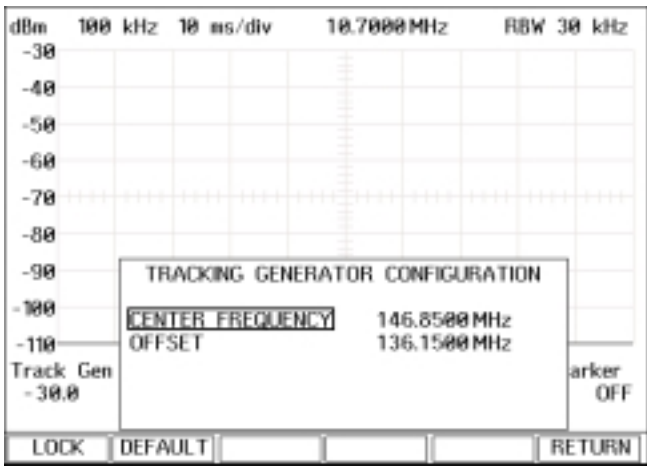

Figure 2.0 - Configuring the Tracking Generator

Now, we will tune the RF filters on the front end of the radio. Place the probe at the input to the first mixer and set the analyzer center frequency (at the top of the screen) to 146.85 MHz. Set the span to 100 kHz/division, set the attenuation to 0 dB, the tracking generator level to -30 dBm and turn the tracking generator on. At this point, the screen should look something like this:

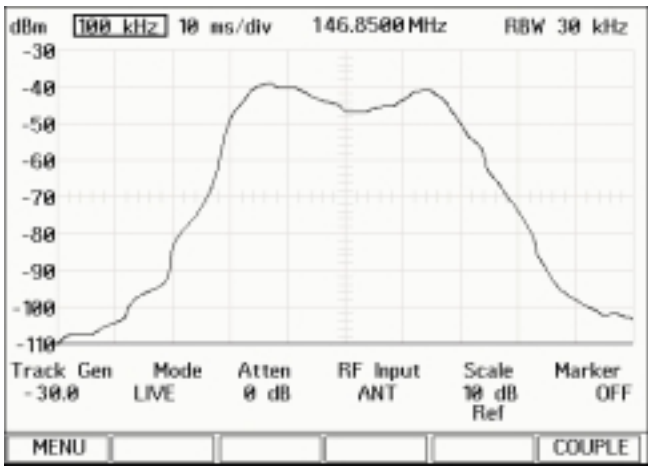

Figure 3.0 - Tuning the RF Filters on the Front End of the Receiver

At this point, we go through the recommended alignment procedures for the radio's input filters. Depending upon how much gain the RF amplifiers have, we may need to reduce the level of the tracking generator. We want to keep the top of the response below the top of the screen, but not by more than 2 divisions.

When we are done, the result should look like this:

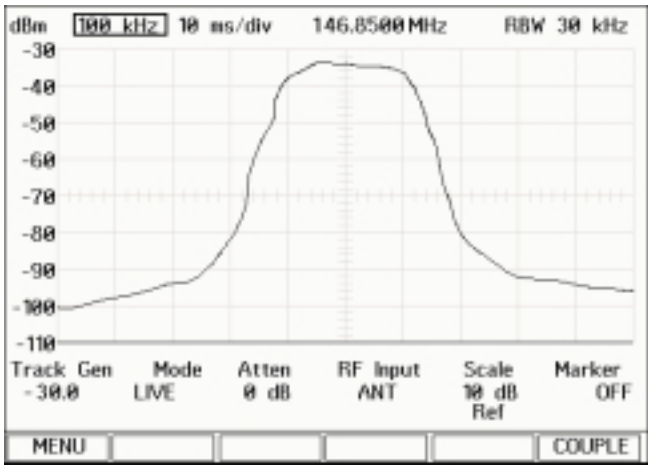

Figure 4.0 - Results of the Alignment after Adjusting the Radio's Input Filters

Now we move the probe to the input of the second mixer and change the center frequency to 10.7 MHz and the span to 50 kHz/division. After adjusting the tracking generator level to keep the top of the trace within 2 divisions of the top of the screen, we see that the first IF also needs adjustment.

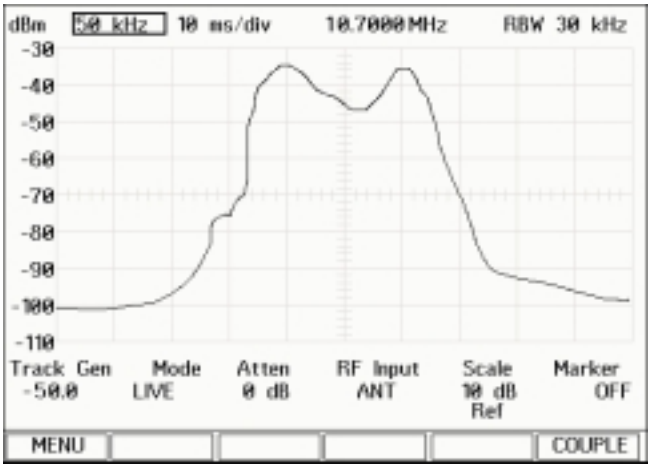

Figure 5.0 - First IF Display Indicating Alignment is Required

The tracking generator is still sweeping 146.85 MHz plus or minus 250 kHz (the new span setting) but the analyzer is sweeping 10.7 MHz plus or minus 250 kHz.

We can now align the first IF and adjust the first LO level for best signal. When we are done, we can see we've picked up 10 dB of signal.

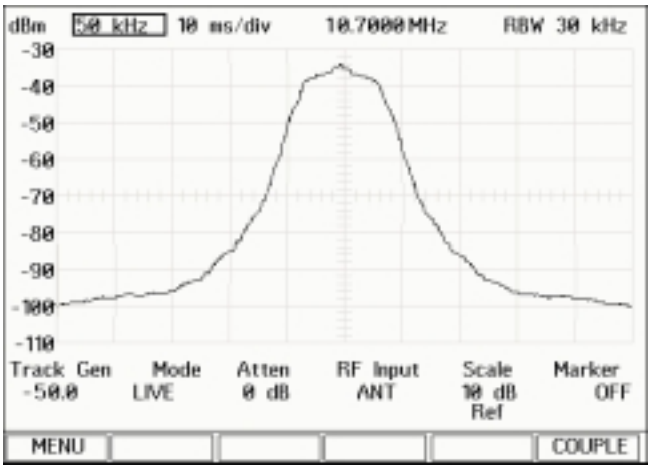

Figure 6.0 - IF After Alignment with Gain of 10 dB

Low side vs. High side Injection

Next we move the probe to the input of the discriminator and change the span to 5 kHz/division to narrow the viewed bandwidth. This now raises a further problem.

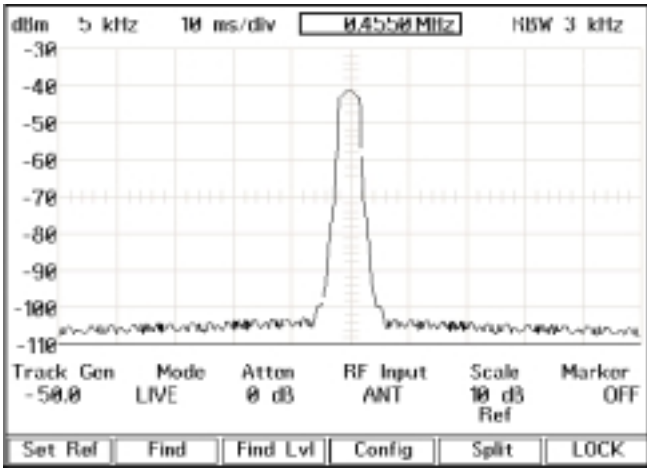

Figure 7.0 - Results of Changing the Span to 5 KHz/division

There are two ways an IF mixer can change the frequency of a signal. In the first scenario, or low side injection, the LO is lower in frequency than the input signal. As a result, the output frequency is F_{input} - F_{LO} and the spectrum is simply shifted down in frequency. If you have a second IF with low side injection, you would simply set up the tracking generator and analyzer for the next IF frequency and repeat the same procedure that we just went through.

However, with high side injection, the LO is above the input frequency of the signal and the output frequency is F_{LO}-F_{input}. This causes the spectrum to be inverted: as the input frequency moves up, the IF signal moves down. This causes a problem for the offset tracking generator mode: as the analyzer sweeps up in frequency, so does the tracking generator. However, as the tracking generator moves up in frequency, the IF signal moves down in frequency and the only time the spectrum analyzer is looking at the correct frequency is at the center of the sweep.

Dealing with High Side Injection

To work around the problem of high side injection, we will open up the resolution bandwidth to 3 MHz. Here's what that looks like:

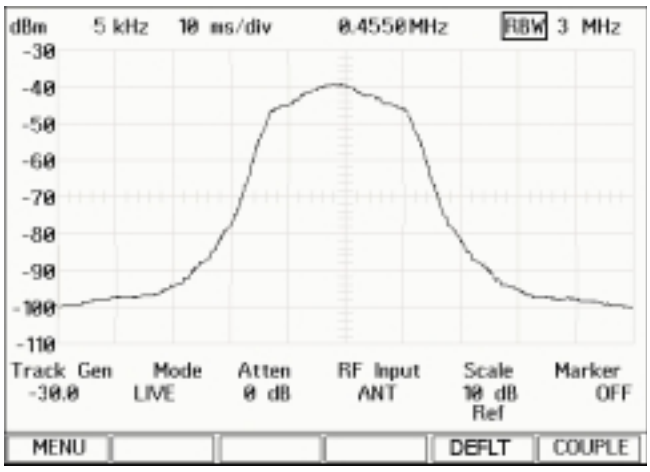

Figure 8.0 - Opening up the Resolution Bandwidth to 3 MHz

In normal spectrum analyzer operation, there are several signals present at all times and the RBW of the analyzer must be set narrow enough to resolve them. However, in the case of sweeping a mixer, the only signal present should be the tracking generator signal. Opening up the RBW will allow the spectrum analyzer to see the tracking generator signal even if it is 1.5 MHz away from where the spectrum analyzer is looking.

Since most IF bandwidths are less than this, we can see the tracking generator anywhere, so what we see is the effective response curve of the IF strip.

The only time this won't work is if there is a strong signal present in the IF bandwidth that isn't the tracking generator signal. However, such a signal would usually indicate some other problem with the radio that needs to be found and fixed, so using this trick will allow the COM-120B to test the inverted spectrum.

Finishing Up Your Alignment

After the final alignment of the IF strip, you should then finish the checkout of the radio by using the RF Generator mode to feed an appropriate modulated signal into the radio and verifying the discriminator and center frequency of the radio. You should also reset the tracking generator back to DEFAULT mode (move the cursor to the tracking generator field and press the DEFAULT key). This will eliminate any future confusion with the next person to use the tracking generator feature.

Using The Split Screen Spectrum Analyzer To Verify The Input and Output Frequency of the LO

To look at both the input frequency of the LO and the output frequency at the same time, you may use the Split function on the tracking generator. Each side of the screen has its own settings for the tracking generator, so you can look at input or LO signals "punching through" the mixer (a sign the mixer null may need to be adjusted) while at the same time looking at the output frequency.

You can also check for image rejection[3] by programming

one side of the split screen to sweep the actual input frequency, the other side to sweep the image frequency. Remember, if the desired signal isn't reversed by the IF, the image will be and if the desired signal is reversed, the image won't be. One or the other will be reversed, so it will be necessary to open up the spectrum analyzer resolution bandwidth on one side of the display.

The offset tracking generator feature was added to the COM-120B as an aid for tuning IF filter stages of radios. By correctly aligning a radio's IF filters the best possible sensitivity can be achieved, allowing users the greatest range possible for the least power.

IF alignment using the spectrum analyzer and offset tracking generator provided in the IFR COM-120B, provides an easy to use tool to simplify the adjustment of receivers for optimum performance.

Notes

[1] A sniffer coil can be fabricated by winding a few turns of 30 gauge wire on a toothpick or other small form, then connecting the wire to a length of coax with a BNC connector on the end. Shrink-wrap the connections, then shrink-wrap the coil. This probe may then be placed near portions of the radio's circuitry, and the RF signal sampled by induction.

[2] **U**nit **U**nder **T**est, the radio you are trying to repair.

[3] Image Rejection is the ability of the receiver to reject undesired signals caused by the input signal mixing with the LO.

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