Observations on Sound Card Audio Levels and MFSK16 Spurious Emissions

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A recent message from Tom, W8JI, on the MFSK e-mail reflector noted that some MFSK operators he observed on 160 meters had spurious signals, “ghost” images of their desired signals. This paper offers a quick series of measurements confirming the importance of proper audio levels if spurious transmitted signals are to be avoided.

<u>Test Equipment Used</u>

The normal station equipment used for MFSK at K8ZOA is a Gateway 233 MHz Pentium MMX laptop computer with an integral sound card, and a Kenwood 870 HF transceiver. A RigBlaster interface box is used to control the 870 and to attenuate the soundcard output to better match the expected low-level microphone input level. Stream v. 0.88a is used for MFSK software.

The presented measurements were taken with a second computer, a Texas Instruments TravelMate 5200, with integrated sound card, running Spectrogram version 5.1.2 by R. S. Horne, and a Watkins Johnson HF1000 general coverage receiver.[2] Spectrogram is a “freeware” sound card audio spectrum analyzer program for Microsoft Windows 9x computers. All data was taken in 16 bit input mode, 22 kb/s sample rate. From theoretical considerations, 16-bit data sampling should yield nearly 96 dB of dynamic range. In practice, somewhat less than this theoretical maximum is realizable.

There is no reason to believe that either soundcard performs significantly different than other soundcards routinely supplied with computers. At the times of purchase, both were “state of the art” laptop machines.

Two configurations were used as illustrated below. The laptop-to-laptop connection was used to measure the basic performance of the MFSK modulating source. The second configuration, using the HF1000 receiver permits off-the-air measurements of the transmitted signal. In all cases, the MFSK signal depicted in the spectrum plots is the idle tone, set to approximately 1042 Hz.

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2 Spectrogram is available at: http://www.monumental.com/rshorne/gram.html.

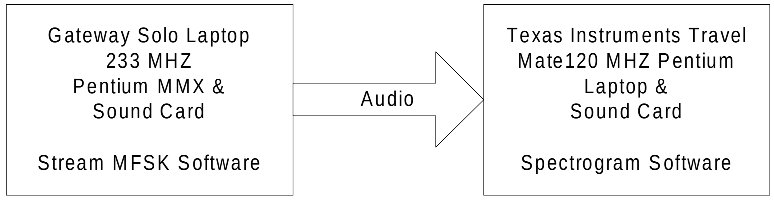

Figure 1

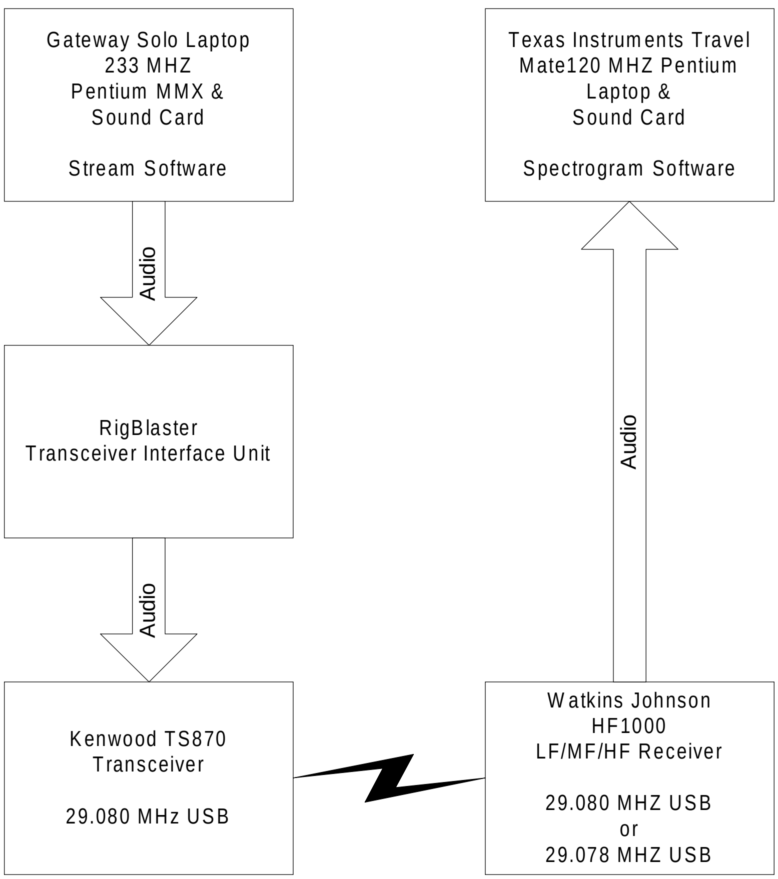

Figure 2

Soundcard to Soundcard Base Line
The following plot shows the TI Soundcard response with the input shorted. Note the spurious signals at approximately 700 Hz intervals, with levels nearly 90 dB below reference.

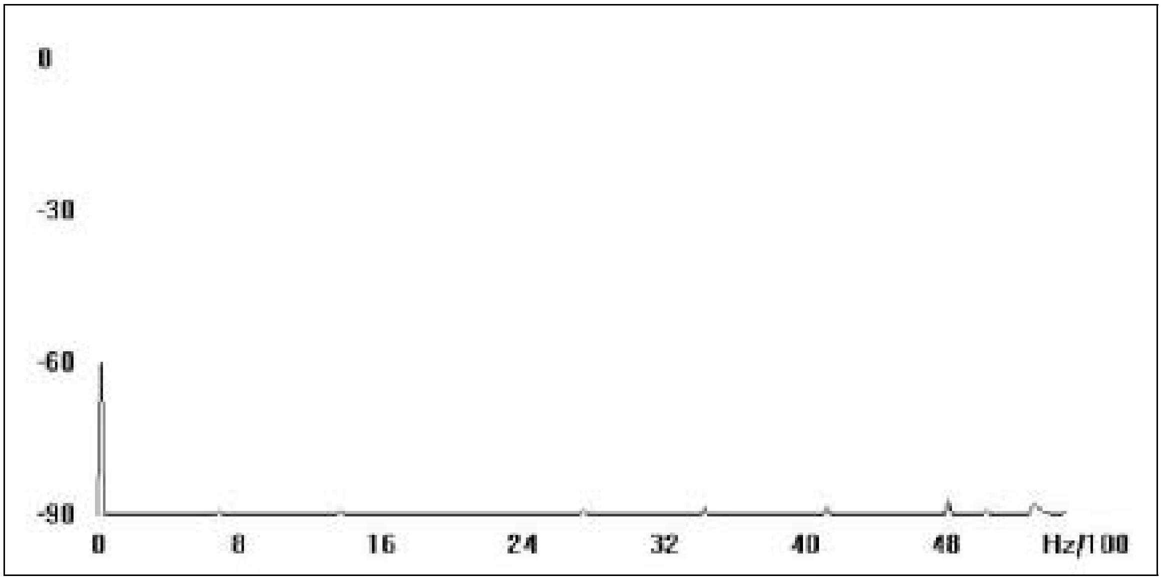

Figure 3

Soundcard to Soundcard Output
The next measurements established the performance of the soundcard, without regard to the transceiver performance. For this test, the Gateway soundcard speaker output, normally used to drive the microphone input of the Kenwood TS870, was connected directly to the TI 5200.

If the output volume of the soundcard is set at a low level, in this case about 20% of the maximum value, the soundcard output is reasonably clean, reflected in the following spectrum plot. (The MFSK idle tone is approximately 1042 Hz in all the tests.)

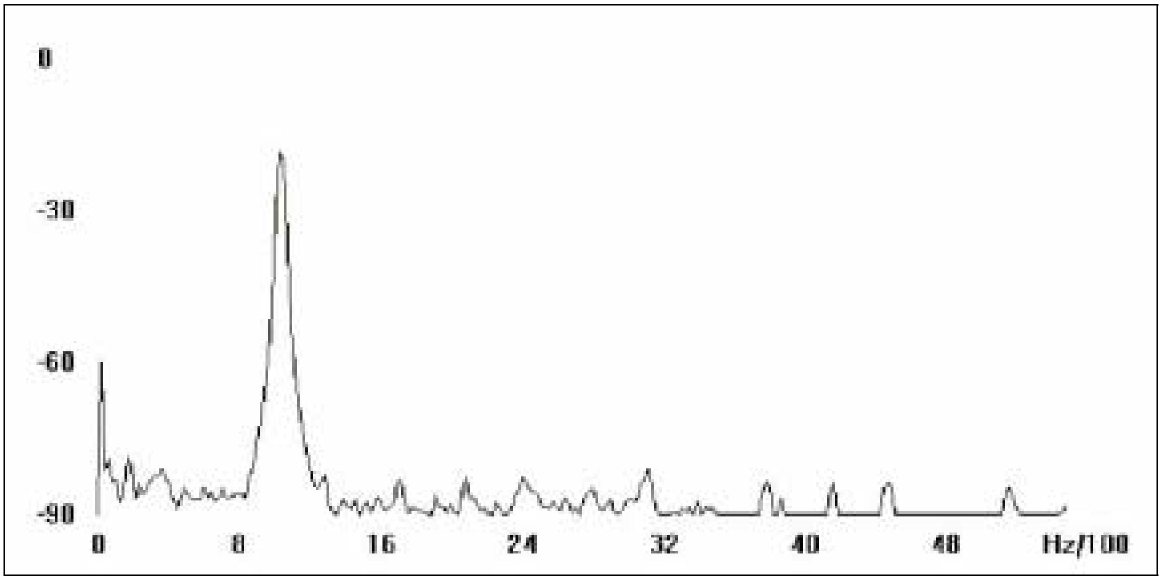

Figure 4

The second harmonic can just be seen and is approximately 62 dB below the fundamental. The third harmonic is slightly stronger and is approximately 55 dB down. Note that spurious signals not harmonically related to the MFSK idle signal could also be seen. There are likely a combination of artifacts from the output sound card and the sample artifacts shown when the measuring sound card input is shorted. These spurious signals are more than 60 dB below the MFSK idle signal.

Increasing the output of the transmitting soundcard causes a major increase in spurious signals.

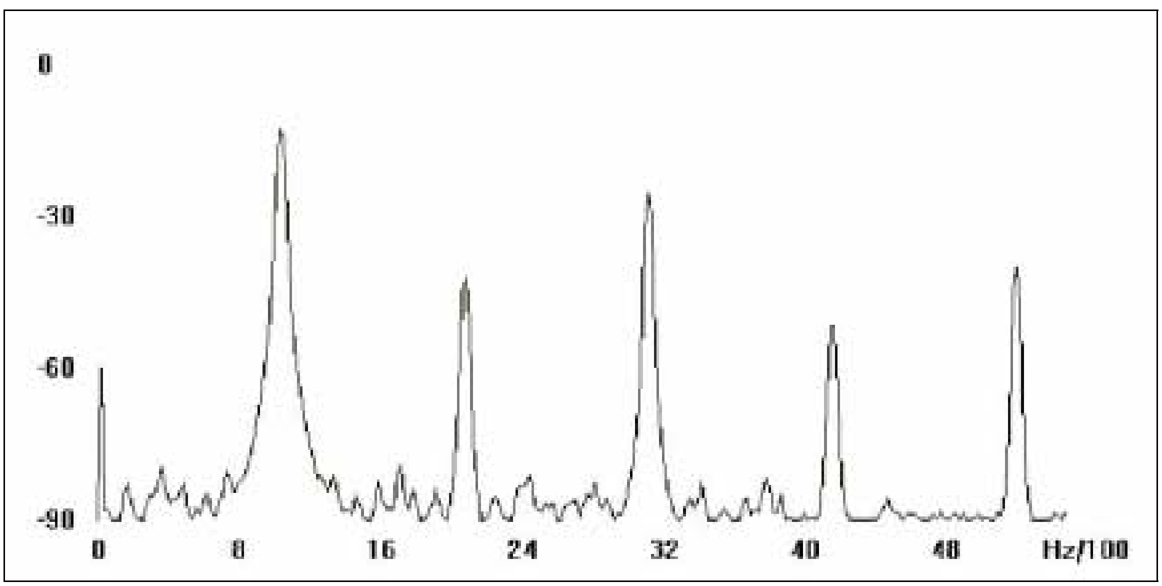

Figure 5

In the above plot, the transmitting soundcard volume control has been set to its maximum value. Harmonics up to the 5th are readily observed. (Harmonics beyond that are beyond the span of the spectrum analyzer software as configured for these measurements.) When running the soundcard at maximum output, the second harmonic is only 30 dB below the fundamental, while the third harmonic is even worse, at just 13 dB below the fundamental.

Off-the-Air Measurements

It is logical to ask whether the soundcard output is "cleaned up" by running it through a single sideband transmitter, or whether even more problems are introduced.

Using the test configuration illustrated earlier, test signals were transmitted and measured. The Kenwood 870 was set to 29.080 MHz, USB and set to provide an output power of 50 watts into a 50-ohm dummy load. The microphone gain was adjusted during the tests as necessary to keep the audio level just below the point where the internal metering on the 870 started to show ALC action. Speech processing and TX Equalization were disabled, as is normal for data over SSB. The HF1000 was tuned to 29.080 MHz, USB mode, with 4.00 KHz bandwidth.

The following plot was taken with the same 20% soundcard setting used for the direct soundcard-to-soundcard measurements.

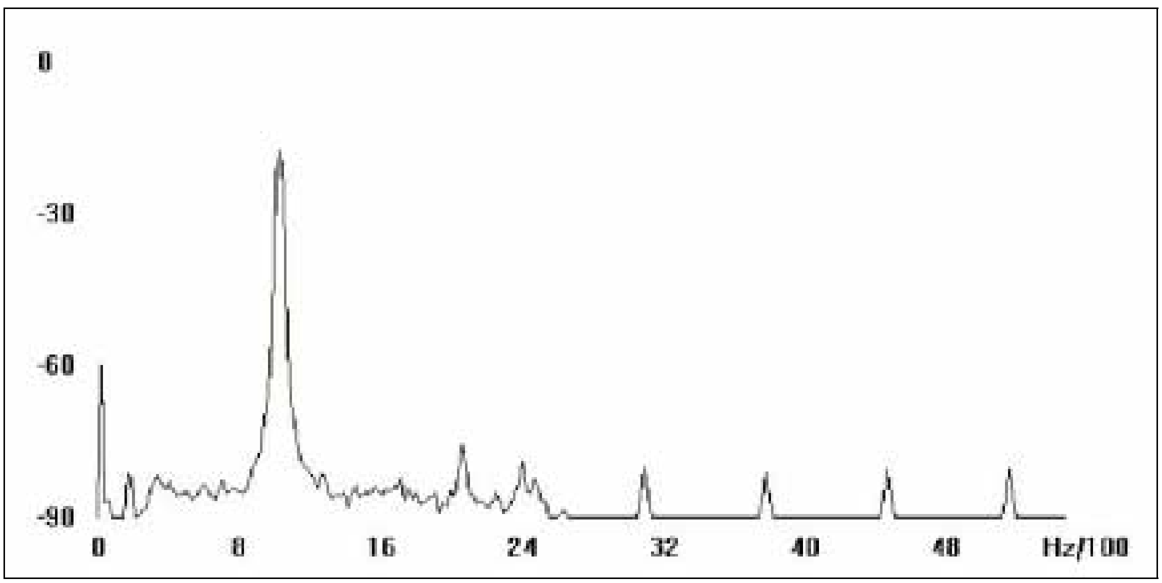

Figure 6

In general, the 870 adds little spurious to the direct soundcard output. The second harmonic of the idle tone is about 58 dB below the idle tone. The third harmonic is indistinguishable from a measurement spur at more than 60 dB below the idle tone. Here the 870's sideband filter offers some additional suppression of the third harmonic when compared with the levels seen looking at the soundcard output.

Unfortunately, the spurious signals generated when operating the soundcard at maximum volume are reproduced when fed into the transmitter, as illustrated below.

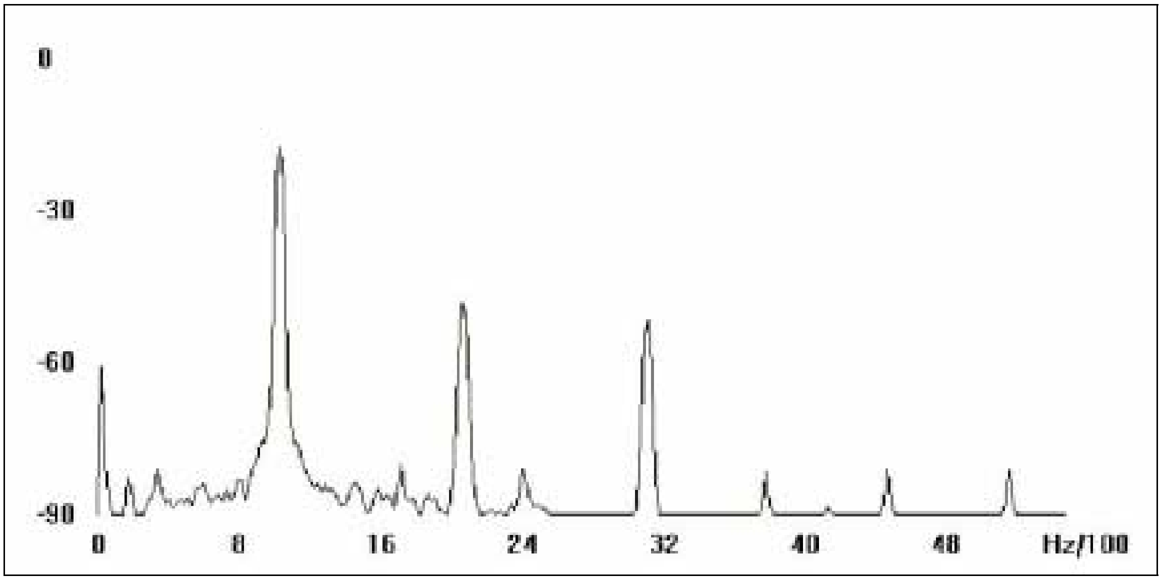

Figure 7

In this case, both the second and third harmonics of the idle tone are only about 30 dB below the fundamental. This is actually an improvement over the direct soundcard output, as the third harmonic is attenuated an additional 17 dB or so by the 870's sideband filter.

As a final check, the HF1000 was tuned to 29078 KHz, *i.e.* 2.0 KHz below the theoretical transmitted carrier frequency, so that any carrier leakage and the unwanted sideband suppression could also be seen.

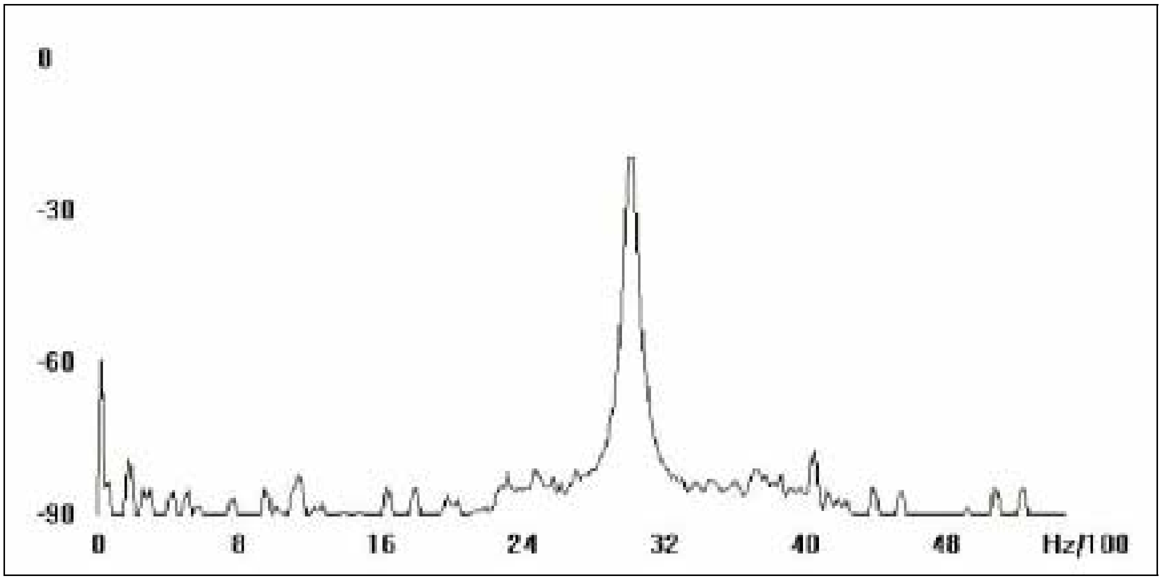

Figure 8

Since the receiver is offset by 2 KHz, the idle tone will appear at 3.042 KHz, the suppressed carrier at 2.0 KHz and the unwanted sideband image of the idle tone at 958 Hz.

Several additional points can be seen in the above spectrum plot.

- The “noise pedestal” of the transmitter is clearly seen, at about 55 dB below the idle tone It extends from about 2300 Hz to 4300 Hz. After applying the 2 KHz offset, this corresponds to a baseband transmitted signal range of 300 Hz to 2300 Hz. . Both values correspond exactly to the menu settings on my 870. This gives confidence that the signals observed are actually those radiated, and are not artifacts generated in the HF1000.

- The carrier suppression is good, approximately 67 dB below the idle tone. The 870’s carrier supression specification is “50 dB or more.” Presumably this is with respect to peak power, 100 watts. In this case, the idle tone is 3 dB below peak power, so the actual carrier suppression is 70 dB below maximum output power.

- The unwanted sideband is approximately 64 dB below the idle tone. The 870’s unwanted sideband suppression specification is “50 dB or more.” (Since both the wanted and unwanted sidebands vary directly with power, no adjustment for peak power is required.)

How Much Suppression is Enough?

Depending on how the operator adjusts the soundcard levels, the radiated spurious signals range from –30 dB to –60 dB from the idle tone level. The FCC’s rules do not directly cover in-band spurious emission, other than the catchall “good amateur practice” requirement.

A spurious signal only 30 dB down has significant interference potential. If, for example, the transceiver is operating at 100 watts output power, a spurious at –30 dB is radiated at 100 mw. Or, looked at another way, if the desired signal is S-9, assuming a standard 6 dB per S-unit, the spurious signal is at an S-4 level, certainly a signal that can cause unwanted interference to other operators. If a strong signal is involved, say S9+20 dB, a spurious 30 dB down will be over S7!

60 dB of suppression, in contrast, seems to have only minimal interference potential. Whilst under highly favorable conditions, microwatt signals can be copied, note that most amateur transceivers are not specified for more than 60 dB of in-band spurious suppression.

Consequently, MFSK operators should be careful to set their soundcard volume output levels to a low level. Note, however, that the very lowest volume settings may produce another problem, whereby the noise and hiss generated by the soundcard may become important causes of unwanted signals. The optimum level will likely require a setting that requires attenuation between the soundcard output and the transceiver’s microphone input. If the operator has two computers and a second receiver, tests along the lines discussed in this paper can quickly be made to optimize audio levels. If only two computers are available, the soundcard-to-soundcard tests will quickly reveal an optimum soundcard output setting.

What Nominal Tone Frequency?

Even if output levels are properly adjusted, some additional transmitted spurious improvement can be obtained by proper selection of the nominal idle tone frequency. If an idle tone of, for example, 500 Hz, is selected, its harmonics of 1,000, 1500, 2000 and 2500 Hz will fall within the normal transmit passband of a SSB transmitter and thus can be radiated. In contrast, if an idle tone of, say, 1500 Hz is selected, its second harmonic of 3000 KHz will be outside the transmit passband of most SSB transmitters and will thus have additional attenuation.

On the upper end of the scale, given the upper cut off frequency of a typical SSB transceiver, and the fact that the highest MFSK16 tone is more than 200 Hz above the idle tone, it is unlikely that an idle frequency of more than 2200 Hz will be suitable.

Of course, receive considerations also dictate the nominal idle tone frequency. In the case of the Kenwood 870, it is possible to adjust the upper and lower receive SSB passband frequencies independently, within reason. When set at the narrowest setting, the receive passband is 1000 Hz to 1400 Hz. Centering the 240 Hz bandwidth of MFSK16 in that passband yields a theoretical idle frequency of 1080 Hz. Whilst no second harmonic suppression can be expected with this idle tone, certainly the third harmonic will be reduced by the transmit passband selectivity.

Taking these competing considerations into account, it seems that an idle tone in the 1000 Hz to 2000 Hz range is reasonable.