International Radio Roofing Filters for Yaesu FT-1000MP Series Transceivers

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It is not an exaggeration to say that today's top ranked Amateur Radio transceivers have receivers that are far better in most respects than those of earlier generations. Fortunately for us (perhaps unfortunately for manufacturers) every advance in technology results in the raising of the bar for some parameter or other. In the very early days, there was a quest to be the most sensitive. The sensitivity goal was followed by a desire for optimum selectivity. Then came image rejection, linear and consistent tuning rate, reduction in front-end overload and on and on it went. Each advance seemed to highlight the next parameter that needed attention.

Today a remaining Achilles' heel of our highly refined receivers seems to be *near-in third order intermodulation distortion* (3OIMD). All mixers have products beyond the usual signal frequency ± the local oscillator. Generally other products are reduced significantly, but if the signals are very strong the undesired products can be heard. A particularly troublesome response is from the combination of signals at one frequency and twice another frequency, referred to as the third order ($K \times f_1 \times f_2^2$) response. The 3OIMD response of your receiver can generate an interfering signal(s) right on top of the one you are listening to from two (or more) signals outside your listening passband.

This parameter has been discussed a number of times in the past in *QST* and elsewhere.[1] This phenomenon manifests itself while you are trying to copy a weak signal on frequency f_1, and there are strong signals at f_1 plus a small increment and another at f_1 plus twice the same increment.[2]

This effect can be verified by switching in your attenuator, or turning off your receiver preamp. The 3OIMD response will be reduced three times as fast as the desired signal and often the 3OIMD signal(s) will disappear. Unfortunately, by reducing the receiver gain, you are also reducing the desired weak signal. Even though it is not reduced by as much as is the 3OIMD response, it may become difficult copy.

Fortunately, many casual operators don't notice this effect since there usually aren't as many really strong signals all over the band much of the time. The real problem shows up during contests when signals may be every 0.5 kHz (for CW) or every 2 kHz (for SSB contests) over the whole band. During DX pile-ups, the same situation may occur. The signals tend to be clustered more tightly, but the often weak DX station will request calls up 2 or 5 kHz, setting the stage for 3OIMD just when you're trying to figure out which station he's calling.

It's worth noting that while we test in the Lab with two signals for each mea-

Bottom Line

A transceiver popular with the contest and DX communities can be brought up to date at reasonable cost using InRad roofing filters.

[1]D. Potter, W2GZD (now W4RPI), "Intermodulation Reviewed," *QST*, May 1983, pp 17-18.

[2]For example, if you are trying to listen at 14,020 kHz and there are strong signals at 14,023 and 14,026 kHz.

Table 2

Comparison of Two FT-1000 Series Transceivers With and Without International Radio Roofing Filter Modification

Yaesu FT-1000MP Mark V, serial number 0K120017

Data taken on 20 meters with pre-amp off

Parameter	*Unmodified*	*Modified*
Noise Floor	–123 dBm	–130 dBm
Audio/IF Bandwidth	600 Hz	470 Hz
Blocking Dynamic Range, 20 kHz	130 dB	146 dB*
5 kHz	105 dB	130 dB*
2 kHz	102 dB	105 dB
1 kHz	104 dB[1]	106 dB[1]
IMD Dynamic Range, 20 kHz	88 dB	93 dB
5 kHz	76 dB	89 dB*
2 kHz	69 dB	79 dB*
1 kHz	68 dB	69 dB*

*Measurement was noise limited at the value indicated.
[1]Some filter blow-by was noted on this measurement.

Yaesu FT-1000MP serial number 7J21036

Data taken on 20 meters with pre-amp off

Parameter	*Unmodified*	*Modified*
Noise Floor	–123 dBm	–126 dBm
Audio/IF Bandwidth	600 Hz	470 Hz
Blocking Dynamic Range, 20 kHz	138 dB	141 dB
5 kHz	111 dB	128 dB
2 kHz	106 dB	108 dB
1 kHz	102 dB*	103 dB
IMD Dynamic Range, 20 kHz	94 dB	100 dB
5 kHz	76 dB	90 dB*
2 kHz	69 dB	71 dB
1 kHz	68 dB*	68 dB*

*Measurement was noise limited at the value indicated.

surement point (5 and 10 kHz, for the 5 kHz spacing, for example), in real life we get a spurious signal from every such pair. Thus we will get a 3OIMD response from 5 and 10 kHz off frequency signals, but also from 3.3 and 6.6 kHz and –4 and –8 kHz and 2 and 4 and 8 kHz, etc. This is why we usually don't just hear 3OIMD as a single signal—it just sounds like junk.

So What Can We *Do* About 3OIMD?

The key to fighting 3OIMD is to keep the interfering signals out of the stage that is generating the problem response. The optimum way to do this is to filter right at the antenna. This can be effective, but is really only feasible if you only operate on a single or small number of frequencies. The most frequently used approach these days is to design an RF stage (if needed at all) and first mixer that can handle the large signals with minimum distortion, and follow immediately with a *roofing filter*. The roofing filter need only be as wide as the widest bandwidth of signals you wish to process further downstream in the receiver—but that's the rub. Many receivers are designed to do everything—CW, SSB, AM and FM and thus settle on a roofing filter that is 15 to 20 kHz wide. The problem is that if you're a contester you end up with all those signals ±7.5 to 10 kHz away. In addition, the filter skirts may not be steep, so you may get signals even further removed. Note that IMD from signals spaced at 20 and 40 kHz (the *20 kHz IMD* data in *QST* Product Reviews[3]) comes out looking good with this filter, but not so for signals at 5 and 10 kHz (the recently added 5 kHz IMD reports).

The best of the newest transceivers solve this problem by having selectable roofing filters to allow an optimum choice for each mode. The Ten-Tec Orion is notable in having optional roofing filters as tight as 0.25 kHz bandwidth. The ICOM IC-7800 has two (15 kHz and 6 kHz) and the soon to be released Yaesu FTDX-9000 promises three (15, 6 and 3 kHz). Single conversion receivers, such as the Elecraft K2, can set both the roofing and selectivity with a single filter following the mixer.

The Ten-Tec Orion (main receiver) and Elecraft K2 are ham band only designs and thus have their first IF and roofing filters in the HF region. The ICOM and Yaesu transceivers include general coverage receivers with an upconverting architecture to a first IF in the VHF region. Narrow bandwidth steep skirted crystal filters in the HF region are much easier to make than those for the VHF region and only recently have filters as tight as those by International Radio been available.

Note that the roofing filters are generally wider than the selectivity setting filter (except for single conversion designs such as the K2). Thus, neither of the in-

[3]M. Tracy, "*QST* Product Reviews—In Depth, In English," *QST*, Aug 2004, pp 32-36.

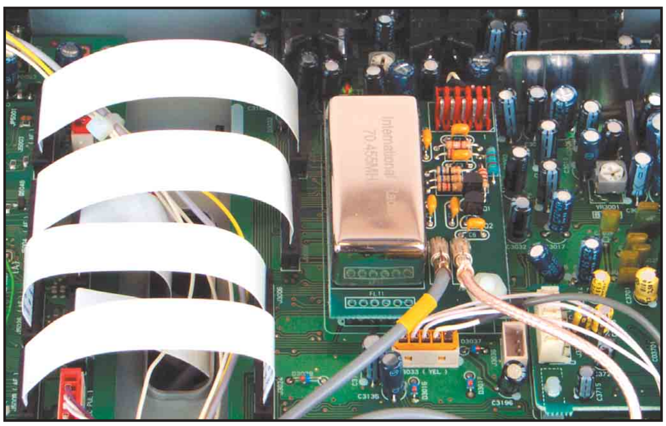

Figure 3—The International Radio roofing filter.

Figure 4—The roofing filter installed in an FT-1000MP Mark-V.

terfering signals may be audible at all, until the second one shows up and the 3OIMD signal appears *within* the listening bandwidth.

Enter International Radio

International Radio (InRad) has been providing high quality selectivity setting filters for years, and has now responded to the need for roofing filters as well. They have designed a (almost) plug and play roofing filter for the Yaesu FT-1000MP series transceivers with a bandwidth of 4 kHz instead of the stock 12 kHz unit. The InRad filter has steeper skirts as well. Note that this bandwidth will start to improve intermod problems resulting from signals farther apart than a 1 kHz spacing (+2 in Table 2), and that is what we observed. Note that the downside is that this receiver will be sharp (barely communications quality) for AM reception and useless for FM. Fortunately, the MP series radios have a second receiver that can be used for these modes. Most serious contesters and DXers will be happy to make that trade.

Hooking it Up and Checking it Out

ARRL Lab Engineer Michael Tracy, KC1SX, has installed and tested a roofing filter in two versions of the FT-1000MP series so far—an FT-1000MP Mark-V and an early FT-1000MP. The first of these versions require that two small wires be soldered to existing pads on a PC board to provide pins for attachment. Other versions have the pins already in place and the filter can drop in. The filter module includes an amplifier to compensate for the filter insertion loss. Figure 3 shows a close-up of the filter board, while Figure 4 shows how it fits under the chassis (top, center) of the Mark-V.

Before and after lab testing for both radios is shown in Table 2 and the improvement is notable. Note that the filter also improves a related parameter—*blocking dynamic range*. BDR is a measure of how much stronger than the noise floor an off-frequency signal needs to be to reduce the gain of the receiver by 1 dB. Generally, this is less of a problem than 3OIMD, but can still be troublesome since it only requires a single out of band signal. A strong CW signal that you can't hear can result in the receiver gain going up and down, for example. While this is not great, it's usually not as bad as having a 3OIMD signal right on top of the one you're trying to copy.

We have no clear answer for why the results differ between the two radios tested. It should be clear that the better the original filter is, the less improvement there will be. It is also possible that the radio with the least improvement (an earlier version) was generating some level of 3OIMD response in the mixer ahead of the filter. In any case, the filters resulted in notable improvement in both cases. The sidebar relates to the radio with the least difference.

Manufacturer: International Radio, 13620 Tyee Rd, Umpqua, OR 97486; tel 541-459-5623; fax 541-459-5632; **www.qth.com/inrad/**. Price: $165.

How The Roofing Filter Sounds (or *Doesn't* Sound) on the Air

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During the K1KI multioperator-single transmitter effort in the October CQWW SSB Contest, we used one FT-1000MP without and one FT-1000MP Mark-V with the International Radio roofing filter. They were used on several bands during the weekend. For the single operator November ARRL Sweepstakes CW contest an FT-1000MP with the roofing filter was used as the main radio, and one without the roofing filter was used as a second radio.

In trying to figure out what could be said about the radio's performance with the roofing filter, what stands out is what *doesn't* happen. In the past when there were very loud signals (S9+20 dB or so) on the band, we'd often hear extra IMD products on our frequency, even if the loud signals were 10 to 20 kHz away. With the roofing filter installed, we just don't hear them at all, unless they are very close in frequency. Listening to other stations on CW or SSB is less stressful without the extra noises!

When looking for a clear spot on 40 meter SSB, the radio with the roofing filter is able to find more "holes" between the S9+40 dB international broadcast stations, and able to copy other stations that would not have been heard in the past.

After the first Ten-Tec Orions hit the bands in late 2003, there were several times when good friends with new Orions seemed to start up too close to our frequency. It turned out they couldn't even hear us. It became clear that the performance of that radio was superior to the FT-1000MPs used here. With the International Radio roofing filter, the situation seems to be back to even again in the never-ending goal to keep up with the competition!