A COMPARISON OF SOME HF RADIOS FOR USE IN EME AS THE "TUNEABLE" INTERMEDIATE FREQUENCY (IF) STAGE.

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BACKGROUND:

For most operators, Microwave EME (1.2GHz and up) generally involves the use of a "transverter" and a suitable "tuneable IF". A 144 MHz tuneable IF seems to be the most common approach at least to 10 GHz however 432MHz seems to be gaining favour on 10GHz and above. At my home station all my EME microwave transverters use a 144MHz IF. For a number of years I have used an IC-746 as the tuneable IF and I settled on this after comparing it very closely with almost all 2m radios of the last 20 years. I have been very pleased with its performance and the filtering options available make it a stand out in pulling out weak signals. All the narrow filtering is done with mechanical filters yet it has all the DSP features of modern radios and seems to perform these well.

Recently I began considering how using a truly dedicated HF radio may help me in that eternal quest of improving my station and pulling out the really weak stations. For my VHF - UHF - SHF "troppo" station I have long been using HF radios coupled with transverters for weak signal work. This has always, for me, been a better approach than using a lot of the modern VHF-UHF radios (with the exception of a few). Subsequently I decided to use an intermediate transverter and convert my microwave transverters' 2m IFs down to 28 MHz. This would give me the option of trying out a number of different HF radios and seeing whether this helps in copying weak signals.

How has the "tuneable IF" radio got an influence on copying weak signals? This is an interesting question as in any radio receiving path the noise figure and ultimately the weak signal capability of the system is predominately set by the preamplifiers and other gain stages pre-demodulation. However from personal experience some radios seem to hear "better" than others despite the fact that on the test bench they have comparative MDS figures. Also when copying weak CW signals narrow filtering increases the S/N ratio but as the filters are narrowed too much, tuning across the band to find a weak signal becomes difficult. In addition, as the bandwidth of the filters is narrowed too much, "ringing" becomes an issue. Almost all modern commercial amateur radios use DSP to control filtering whilst older radios use mechanical filters. Some radios have a "better" user interface than others. **It starts to get complicated!** I've used the word better a few times now and it is clear to me that this issue of the "best" radio is very difficult to define. Almost all areas of "weak signal" performance can be experimentally measured: NF, Dynamic range, IP3, MDS, S/N ratios etc.... but for EME use the important parameter of a tuneable IF becomes S/N ratios (in my opinion). After using a few different HF radios as a tuneable IF for VHF – UHF – SHF, I was very certain that the choice of radio did make a difference to copying weak signals.

Not too long ago I read an article where the author compared a couple of radios that he had, on their overall ability to hear weak CW EME signals. An on air A/B comparison test seemed the logical thing to do, so I compared how each of the HF radios I had on their ability to copy a weak beacon signal on the 70cm band. The radios in question at the time I had to do these tests were: an ***IC-7700,*** an ***FT-2000*****,** a ***TS-940*****,** an ***IC-706***, an ***FT-817ND*** and my homebrew ***Pic-A-STaR.*** The IC-706 sees use in the car and my FT-817ND is usually used as a tuneable IF for my "hill-topping" microwave station. The other mentioned "base station" HF radios are used as my tuneable IFs for my VHF UHF SHF home station transverters. (Over the years I have come to settle on these for their performance and overall "useability" having had just about every transceiver produced in the last 30 years!).

As I expected, listening to a weak beacon signal demonstrated that there was no real difference between all these radios in "hearing". They all seemed pretty much to be similar in their ability with 2 exceptions:

1. The DSP on my Pic-A-Star was the only DSP to actually enhance the S/N ratio of the beacon signal
2. Filtering below 200Hz in the FT-2000 produces a lot of ringing, whereas the DSP filters in the IC7700 were still very easy to listen to by comparison down to 50 Hz. The DSP filter in the Pic-A-STaR was excellent down to 100Hz.

On my test bench all transceivers could hear down to better than -145dBm on 10m in a narrow CW setting, so they were all sensitive enough. They all seemed to cope very well in pulling out the weak beacon signal on air but I felt that this was perhaps partly due to the nature of the signal being very stable. This does not necessarily correlate to EME use which are not only subject to QSB but Doppler shifting of the frequency also adds to the complexity. In addition finding a weak signal on some relatively unknown frequency is far more difficult than "dialling" up a frequency and pointing an antenna at a beacon.

So what factors are important to me in establishing whether a particular radio is good as a tuneable IF for EME use? For me in order of importance they are:

- *Good narrow CW filtering* (i.e. no ringing at narrow BWs). This helps me find weak signals
- *Low internally generated IF and AF noise*. I feel this gets overlooked very often and I think it is almost the single most important factor. If the gain distribution is poor than the S/N ratio at the "user-end" suffers.
- *Ability to pick out a weak signal as I tune across the band*. This is partly related to S/N and tuning rates combined
- *Frequency stability*. Not a huge issue for most recent radios except for digital modes.
- *Operator convenience features*. Bells and whistles to make operating a joy as opposed to a chore!

All the above mentioned radios have their own unique features which I was keen to see if they actually provided an advantage:

IC-7700: has very good narrow filters done in DSP. It also has an APF function which is essentially an audio filter of 3 different bandwidthsthat is centred on the received CW pitch. This I found to be an excellent feature on the IC746 when I was using it as the tuneable IF.

FT-2000: Has a “CONTOUR” feature which when set up in the menu is like an audio peaking filter but can actually “enhance” the audio frequency of interest by as much as 20dB . The Q and gain is adjustable.

TS-940: The older Kenwoods have an AF peaking filter and the equivalent of modern day continuous PBT known as VBT. This is VERY effective in both narrowing the IF passband and accentuating the audio of a cw signal. There is no ringing noticed right down to the minimum bandwidth. The TS-940 also has a narrow mechanical filter in the IF of 500Hz.

Pic-A-STaR: DSP selectable filter widths with both “context” and “depth” controls on the passband. This equates to Q (or BW) and attenuation (steepness) of the skirts. As already mentioned the DSP Noise reduction facility is the only DSP I have come across that truly increases readability by increasing the S/N ratio on weak signals.

The IC706, and FT-817 had no “remarkable” features that distinguished them from the other radios.

I also decided to check if using my IC746 directly on 2m was a disadvantage or not. It has mechanical filters: 250Hz and 500Hz and it has an APF function.

ON AIR COMPARISONS:

As I wished to gain an “overall result” for the transceivers specifically with EME use I asked a very obliging station in VK2JDS to run a constant carrier off the moon on 1296MHz. Dave has what appears to be a very well optimised setup and with him running approximately 50W, I could detect his signal a few dBs above the noise (~3dB) at the time of testing. This seemed a reasonable level by my reckoning and so I began doing comparisons with all the radios by simply changing the coax feeds from the intermediate 144 MHz transverter to the particular HF radio under test. In order to keep the results meaningful I placed a high quality variable attenuator in line. This was adjusted to account for differing gain in the HF boxes.

The signal from Dave (VK2JDS) remained at a very constant level over the duration of the whole test. Each radio was “optimised” using it’s specific features to bring out Dave’s signal to the best possible using the criteria of getting the best S/N into the headphones. Then I would tune off and verify that I could find the signal again after a reasonable frequency excursion of 2KHz or more. The radios were all adjusted to the narrowest passband level possible. (This was not really possible with the 817 and 706 except for some IF Shift to improve the received cw).

FINDINGS:

All radios could find Dave’s signal but with settings optimised for best S/N the IC7700 was a clear winner. The internal noise generated by its receiver was very obviously very low compared to the others. What surprised me is that it was harder to find the EME signal whilst tuning with the FT2000 but once found the “contour” feature set to “enhance” the signal does actually improve the S/N dramatically (more than just turning up the audio level). However the internally generated noise is very high (almost fatiguing) and I did have to “search” harder to find the signal. This in part is due to

the course tuning in a narrow CW mode. I did have it set to the finest in the menu but it was easier to use the RIT control as opposed to the main VFO tuning knob. I must restate that I was doing these tests in narrow CW modes (<200Hz).

The old TS 940 fits somewhere in between. It has a very low level of IF noise and the VBT along with the AF filter really helps to make the weak signal stand out. Even though it's tuning rate is courser than the other radios, it was very easy to find the signal; almost as easily as the IC-7700 but not as "enhanced" as the FT-2000

I was very surprised at how my Pic-A-STaR performed. It has an IF noise level that seemed less than the FT-2000 but more than the TS940 and IC7700. Finding Dave's weak carrier was easier than the FT-2000 but not quite as easy as the IC7700. Once found, the DSP and the filter options enhanced the CW signal more than the IC7700's APF function and more than the FT-2000's contour feature!

The IC-706 and FT-817ND were not even close to the other radios. The received signals were way down in readability (S/N). In defence of these however I did not have any narrow CW filters fitted.

What did I learn?

The radios all seem to have a particular feature that definitely helps to improve the copying ability of weak signals via EME in their own way. On 1296MHz and perhaps on 13cm I can't seem to think there is sufficient difference to say that one is "far superior". The IC7700 seems to be the best both from a user interface and from the point of view of "finding" a weak signal. The FT-2000 and the Pic-A-Star seem to have the edge in "enhancing" the signal whereby decoding the CW would be a little easier. But you possibly need a slightly stronger signal to start with so you can actually find it! The TS940 sounds great. The VBT is certainly a very nice arrangement and would be less fatiguing to listen to over a longer period of time.

I also checked my IC746 and found that it performed very well. The filters are mechanical and not in DSP so there is no ringing and there is the APF feature like the IC7700 which helps improve S/N. The IF noise level created is better than the FT-2000 but not as good as the IC7700. I still use this radio because of it's wide receiver when I operate on 13cm and I feel that I am not compromising on the receive in any way in comparing it's performance with the other radios.

Upon reflection, there is another issue: as the EME frequency is increased, the "Doppler-Smear" also becomes larger. The frequency spread which can get up over 250Hz at 10 GHz means that narrow filters cannot be used. Because of this I feel that the difference between the performance of these radios would widen as we go up in frequency. The high IF noise and the inability to use the "contour" enhance feature as effectively in a wider bandwidth would most likely make the FT2000 a poorer choice. I think the Pic-A-STaR would be less effected as the bandwidth is increased as the real enhancement came from it's DSP algorithms. The Q on the AF tune function of the TS-940 is such that it is quite wide in peaking B/W and I don't feel that performance would drop as the received signal becomes wider. Having used the IC7700 on 10 GHz signals already I can quite confidently say that it's performance doesn't change.

SUMMARY / CONCLUSIONS:

1. On 1296 MHz EME and with my present setup, the IC7700 is the "better" of the tested radios ***overall*** for finding weak signals but the other radios tested were quite good and each in their own way had features that helped improve S/N. The Pic-A-STaR and FT-2000 especially helped boost the S/N on the weak signal which would probably make decoding CW easier but their **noisier** IF's negate this somewhat.
2. The FT2000 had the noisiest IF chain. This can be quite fatiguing to listen to. It may also present a real problem as signals become more spread as we go higher in frequency with EME. (This may be the subject of further testing / comparisons when next I get on 10 GHz.)
3. A true "base station" HF box is better than a portable radio which lack some truly CW enhancement only features.
4. The DSP based "noise reduction" features of the radios did not help except for the Pic-A-STaR which made a very large difference to the S/N ratio.

The testing conducted had no real scientific basis other than "perceived" findings that rely more on my previous and current experiences in dealing with weak signals. I have no doubt that others would find disagreement in some of my findings. They are represented as nothing more than ***MY*** observations at ***MY*** station and specifically look at EME. If nothing else I hope they provide some stimulation for others interested in weak signal modes to carry out their own tests to help improve the quality and performance of their own stations regardless of whether the weak signal modes are through EME or other modes of propogation.

73 de VK3NX