

## Front end receiver modification for DRM: AKD Target Communications receiver. Model HF3.



**Summary.** The receiver was modified and capable of receiving DRM, but performance was limited by the phase noise from the 1<sup>st</sup> Local Oscillator (LO).

With the receiver on test, fed with a signal direct from a DRM modulator, the phase noise from the 1<sup>st</sup> LO limited the SNR as reported by the receiver software to 21dB. If the 1<sup>st</sup> LO was replaced with the output from a Hewlett Packard frequency synthesiser, the measured SNR improved dramatically to a maximum of 35 dB (equivalent to the SNR achieved when using the AOR 7030 receiver).

With a good strength off air signal (the 15MHz transmission from Sines) the SNR was 17 to 18dB, whereas the AOR gave 23 to 24 dB.

Because of this phase noise, even with good signal strength, the receiver could not decode the audio (but was able to lock to the Fast Access Channel, FAC) for the higher data rate (less robust) DRM transmissions. For lower data rate transmissions, where an SNR of less than 20dB is adequate, audio could be decoded. In fact, most transmissions on shortwave are in the mid data rate category (requiring an SNR of 12-17dB), so this receiver will work in most cases.

### Modification Details.

The receiver utilises a fairly standard design, mixing the input signal with a (higher frequency) synthesized LO to give a first IF of 45.0MHz. This 1<sup>st</sup> IF has a +/- 3.75kHz wide crystal filter. The 1<sup>st</sup> IF is then mixed with a second (crystal) LO to give the second IF of 455kHz. This second IF has selectable ceramic filters, narrow (+/- 2kHz) for SSB use, and a slightly wider (+/- 3kHz) filter for AM.

The DRM signal is 10kHz wide (on SW, MW in Europe uses 9kHz) so both IF filters are too narrow. In practice a 1<sup>st</sup> IF filter of +/- 7.5kHz and 2<sup>nd</sup> IF filter of +/- 6kHz are about optimum for DRM reception.

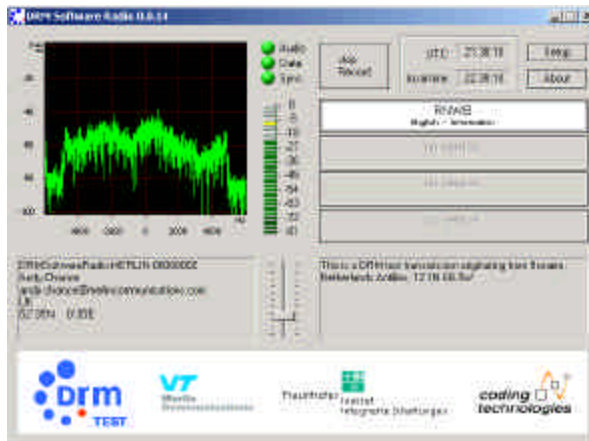
#### 1<sup>st</sup> Steps

The first modification attempt was to replace the first IF filter, and take a feed of the 455 kHz IF from just prior to the existing AM filter and feed it into an add on board. This consisted of an emitter follower buffer stage (to avoid loading the existing circuitry) and +/- 7.5kHz ceramic filter LTU455E. This then fed a 455kHz down converter board to produce the 12kHz IF to feed into a PC soundcard (the 455-12kHz converter board is the same one that is used in the [AOR 7030 receiver](http://www.aoruk.com/drm.htm) or <http://www.aoruk.com/drm.htm>)

The receiver and software did work at this stage, it was possible to listen to the DRM signal from Radio Netherlands (broadcast from Bonaire) in the UK, but it only worked for the more robust DRM modes. It was not possible to decode the signal from Sines in Portugal, even though the signal strength was much higher than Bonaire. The Deutsche Welle (Sines) signal used a much higher data rate (less robust signal). The AOR 7030 had no problems with either of these signals, and the software could provide audio from both.



This screen shot of the software was taken of using the output from the AKD HF3. It works, but the input was a test generator! A better receiver would give a flat top and steep sides.



Here a real signal is used, received in the UK from Bonaire in the Netherland Antilles. The audio is decoded OK.

## 2<sup>nd</sup> Steps

Although the receiver was able to decode robust mode signals at this point, the amplitude response was very poor. Working through the stages: the first IF filter (which was originally a 2pole filter) I had replaced by a 4 pole 45 MHz monolithic crystal filter, type 45G15B1. These did not match in well with the existing circuitry, and were giving an 8dB p/p ripple across the wanted frequency range. Adding additional buffer stages to provide the specified terminating impedances brought the filter into spec, with less than 1dB p/p ripple across its passband.

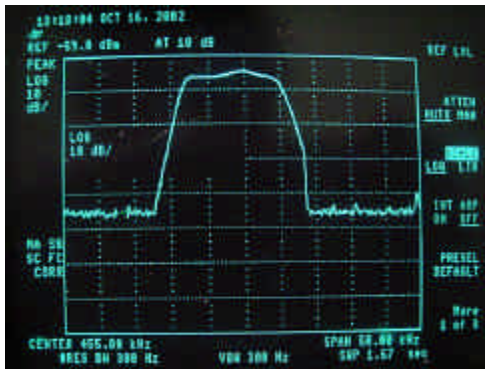
This improved the overall receiver response, however there was still a 10dB notch visible at -1kHz from centre, and a 20dB notch at +3kHz from centre. These notches turned out to be due to the existing ceramic filters. The loading they present in circuit varies with frequency, and at frequencies outside each edge of the filter passband it provides a low impedance path to ground, giving a dip in the amplitude response.

The SSB filter is permanently in circuit, switching to AM mode is accomplished by putting a short across the filter (input to output). To remove its effect on the IF response it was necessary to remove the filter entirely from the board, and put a permanent shorting link across.

(Note: in SSB mode this means the IF bandwidth is now set by the wider AM filter. See the *To do* section.)

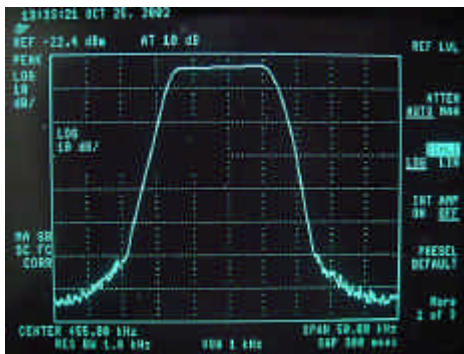
Removing the effect of the AM filter was achieved by cutting the track leading to the filter, so the 455kHz IF feeds solely into the add-on board. An emitter follower buffer amplifier was added to the output of this, and the output now fed to both the 12kHz converter board, and back to the receiver at the input of the AM filter.

This gave an overall response RF in to 455kHz out at the input of the 12kHz converter board of:



The response is significantly improved, but still shows some ripple and falls off a bit steeply at the high frequency end.

With a bit of adjustment to the three 455kHz IF coils, the final response below was achieved:



Response 10dB/div  
Centre 455kHz, 5kHz/div

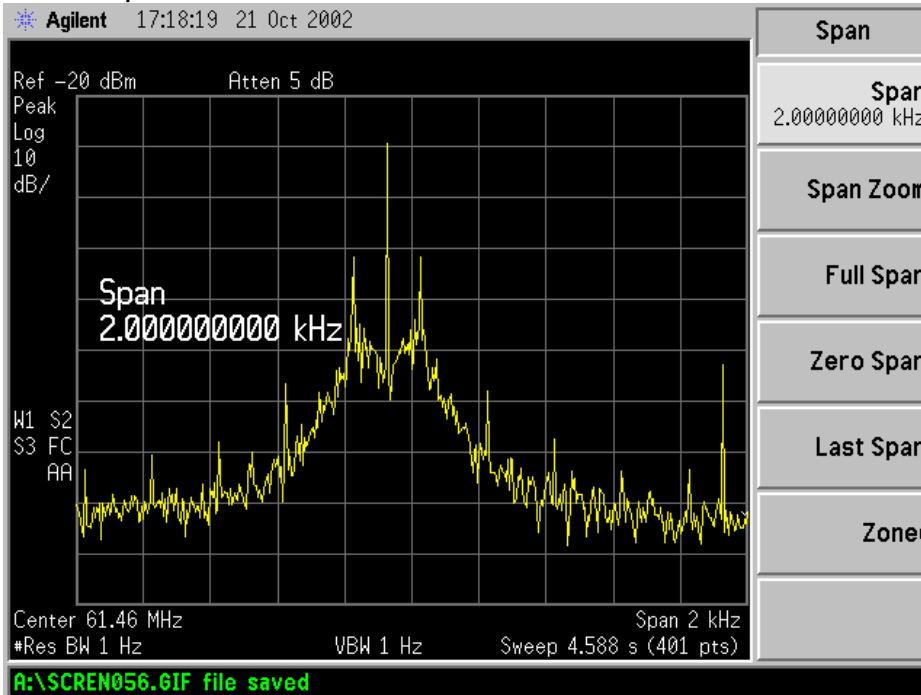


Response 2dB/div

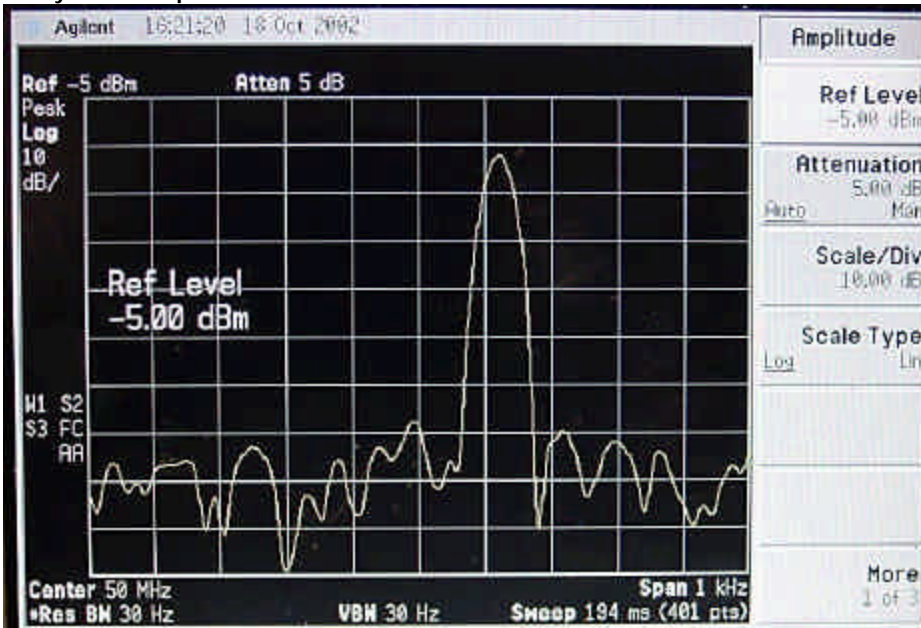
### 3<sup>rd</sup> Steps

With the receiver amplitude response virtually flat across the required +/- 5kHz bandwidth occupied by the DRM signal, the maximum obtainable SNR (as reported by the receiver software) was still only 20dB, even on the test bench fed directly by a DRM modulator. In comparison the AOR 7030 was capable of almost 35dB SNR under the same conditions. The problem is the first LO phase noise. Replacing the internal LO with an external HP (high quality, Expensive!) synthesizer produced a dramatic improvement in SNR to 35dB.

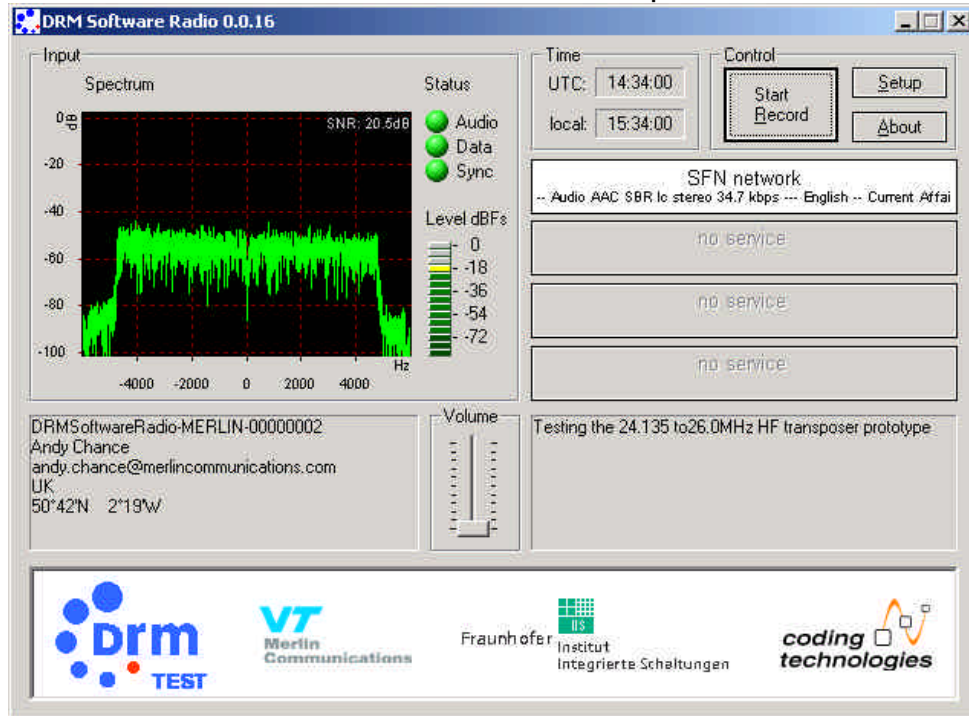
### HF3 1<sup>st</sup> LO phase noise



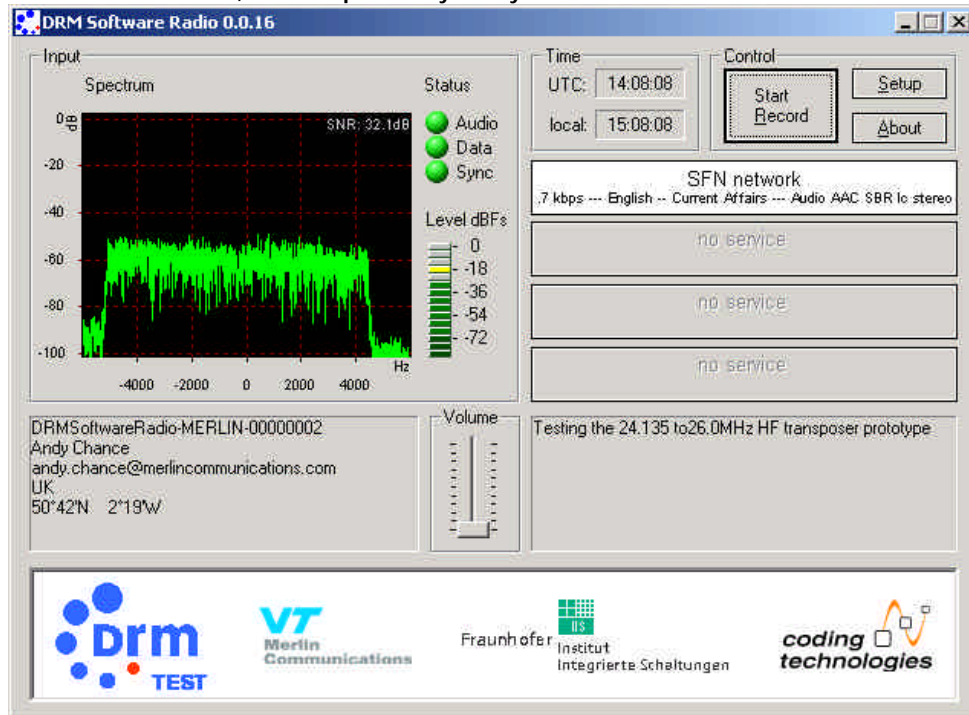
### HP synthesizer phase noise



Software Receiver screenshot after all modifications completed.



Receiver screenshot, 1<sup>st</sup> LO replaced by HP synthesizer

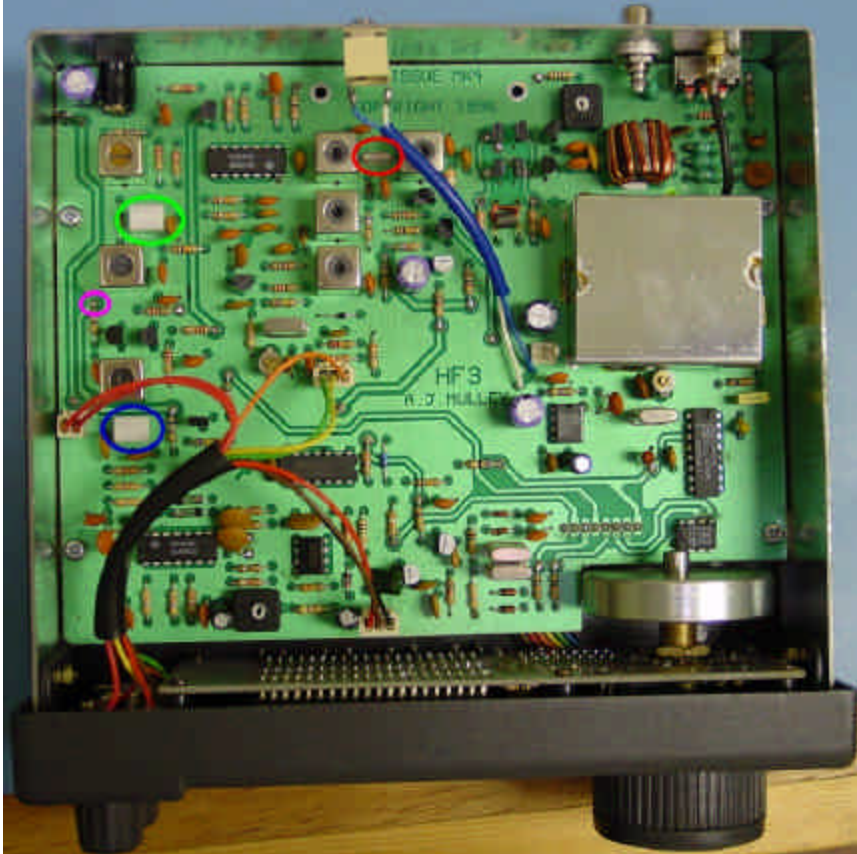


Note, both look very similar on the spectrum display but with very different SNRs. 20dB is just sufficient to decode the high data rate in use here.

**To Do:**

1. Further work is required to try and improve the 1<sup>st</sup> LO phase noise.
2. The SSB ceramic filter needs to be re-integrated to restore the original functionality of the receiver. It should be relatively simple to add it back in-line after the added 455kHz circuitry, along with some switching circuitry to select either the AM or SSB filter as appropriate.

**Before: AKD Target Communications receiver. Model HF3**



internals:

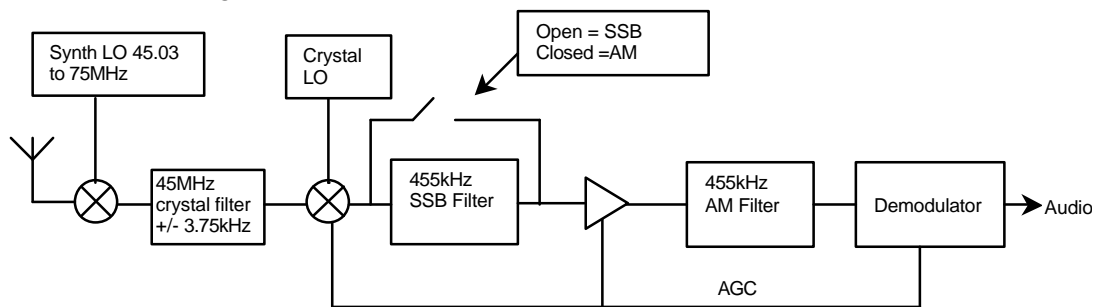
Red 1st IF (45MHz) filter

Green SSB 455kHz filter

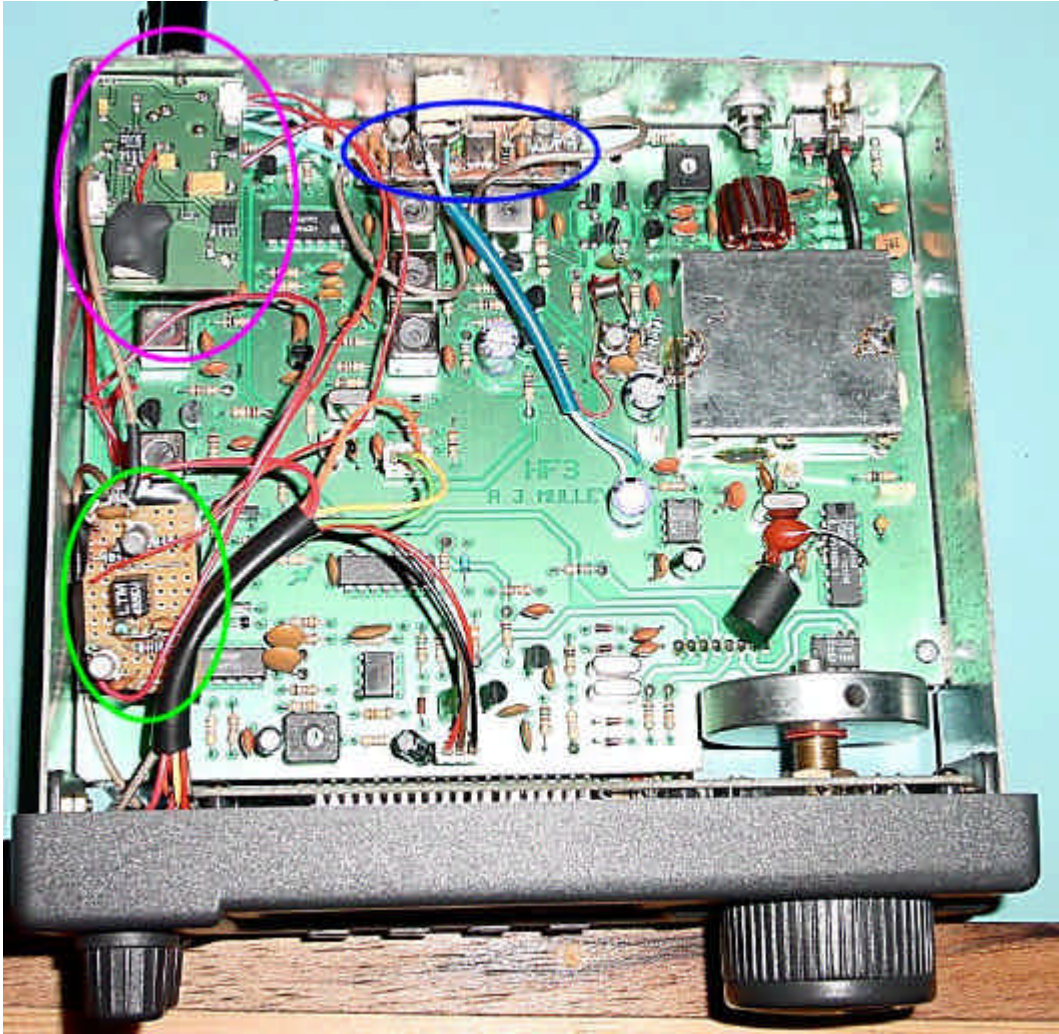
Blue AM 455kHz filter

Purple +12v switched, convenient point to supply add on boards.

**Basic receiver block Diagram**

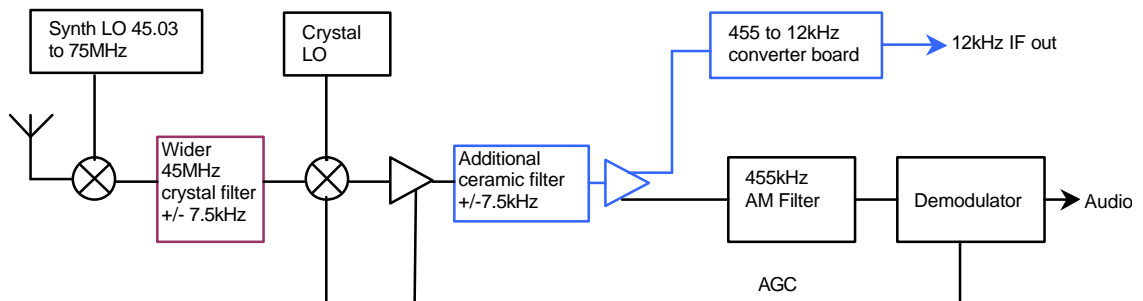


After: Modified AKD Target Communications receiver.



- Purple 455kHz to 12kHz downconverter board.
- Green additional 455kHz IF stages with wider (+/- 7.5kHz) ceramic filter.
- Blue Replacement 1<sup>st</sup> IF filter (4 pole crystal, +/- 7.5kHz).

**Modified receiver Block Diagram.**



Software window, note good shape of received DRM signal (if you can see it). Using test encoder for ideal' input signal.

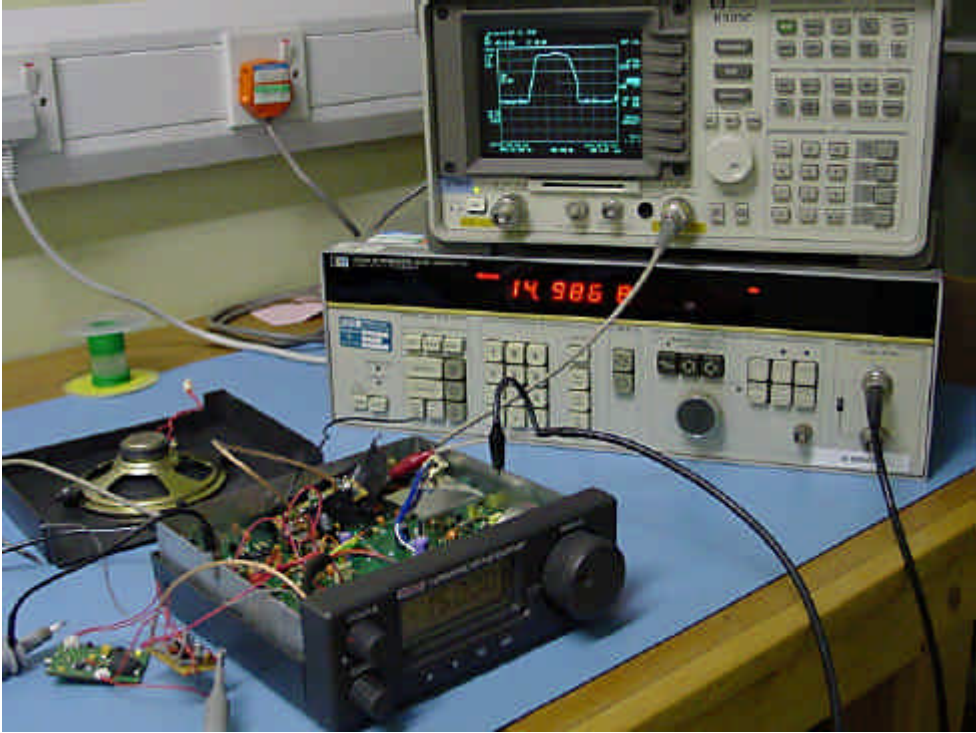
Modified AOR 7030

Target HF3 under test



Thales DRM encoder and synthesiser

Checking the receiver IF response.



Testing with DRM signal. The 455kHz IF is displayed on the spectrum analyser.

