RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #4

UAT Receiver Adjacent Channel Rejection

Prepared by George Cooley

UPS Aviation Technologies

SUMMARY

The Adjacent Channel Rejection of the UAT was characterized for CW interferers at various power levels. Although the 750 kHz IF filter was primarily used, wider bandwidths are briefly examined for thoroughness. LO sensitivity is also measured.

1. Introduction

The adjacent Channel rejection of the UAT receiver was characterized. The UAT primarily used an IF filter of 750 kHz, however data was also collected at wider bandwidths. At first data for a rough 750 kHz prototype board was examined and compared to network analyzer plots; both methods correlated. The 750 kHz IF matching circuit was then improved to simulate what "real world" conditions would reasonably yield. Data with varying CW interference levels was collected. A very stable low phase noise source was injected in lieu of the LO and swept past the limits of the IF filter passband to determine LO drift tolerance. The unit was then subjected to excursions in the temperature chamber to confirm the results. The tests were repeated at the system level with and without Forward Error Correction.

2. Adjacent Channel 750 kHz IF with –39 dBm CW interferer

A passive prototype of the 750 kHz SAW filter was spliced into the IF circuit. The advantage of this was that we could make a quick evaluation. The disadvantage: the match may degrade through the relatively long piece of coax. Indeed this proved to be the case. As initial measurements were being conducted, a better circuit that closely approximates the UAT IF was fabricated. Results for both filters are reported.

The UAT receiver module sensitivity measurements were made using the BER test. This test is described in appendix A and does not utilize FEC techniques. A correction factor of approximately 3 dB loss must be added to the receiver module values to obtain the sensitivity at the antenna terminals without FEC.

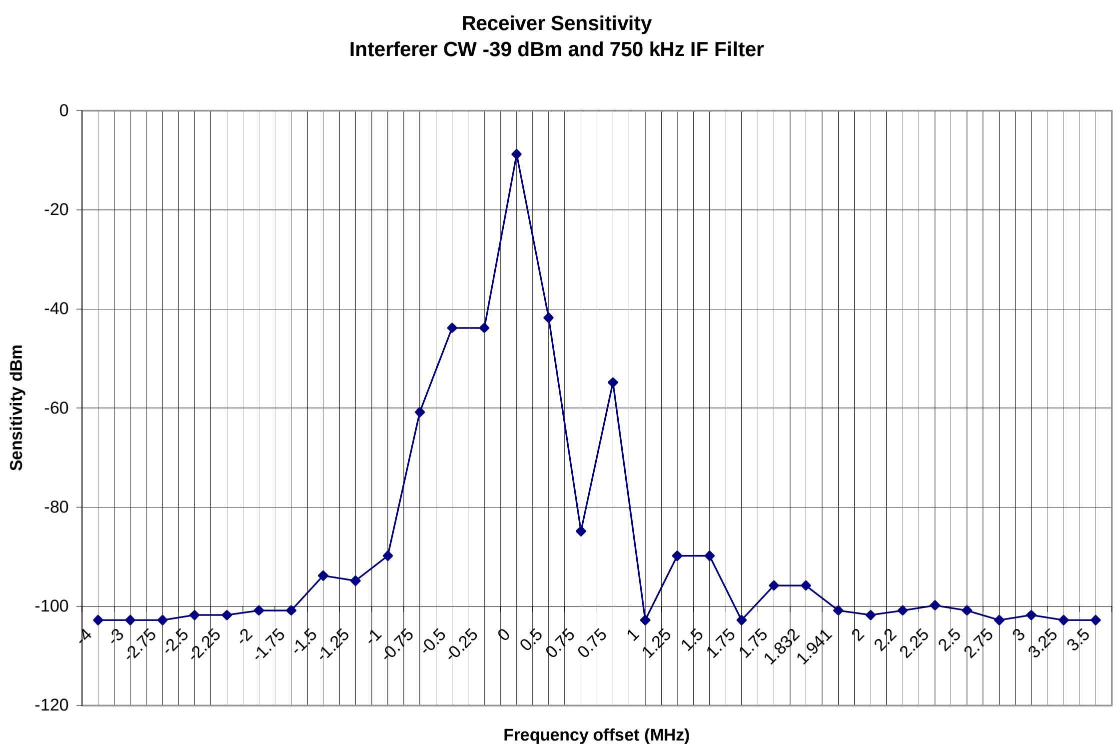

Figure 1. Receiver Sensitivity Passive 750 kHz Prototype

Figure 1 illustrates that as the interferer is removed from the UAT data signal, the sensitivity increases. –90 dBm or better can be achieved at 1 MHz away. At first glance, this plot may seem wrong, particularly if one considers the wild variations on the upper skirt. However checking the prototype circuit on a network analyzer, confirms that the receiver measurements closely correlate to the filter's response. The plot in Figure 2 shows how the higher frequency skirt does not roll off as fast as the lower one, resulting in poorer than expected adjacent channel rejection.

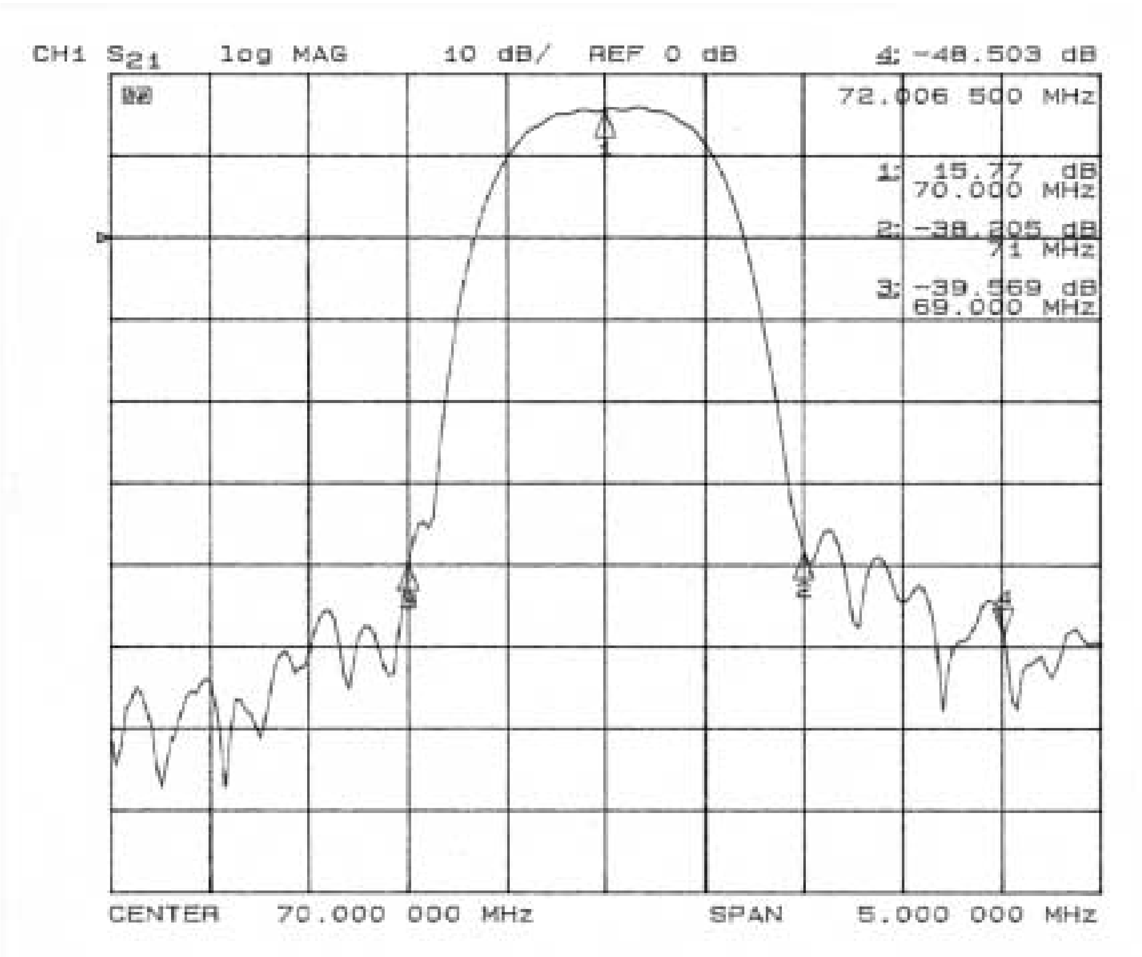

Figure 2. Network Analyzer Plot of 750 kHz IF Passive Prototype

A matching network that more closely approximates the UAT IF strip has more uniform skirts and is shown in figure 3. In both cases, sensitivities of better than –90 dBm (-87 dBm at antenna terminals) are achievable with a CW interferer removed 1 MHz away from the center of the UAT channel.

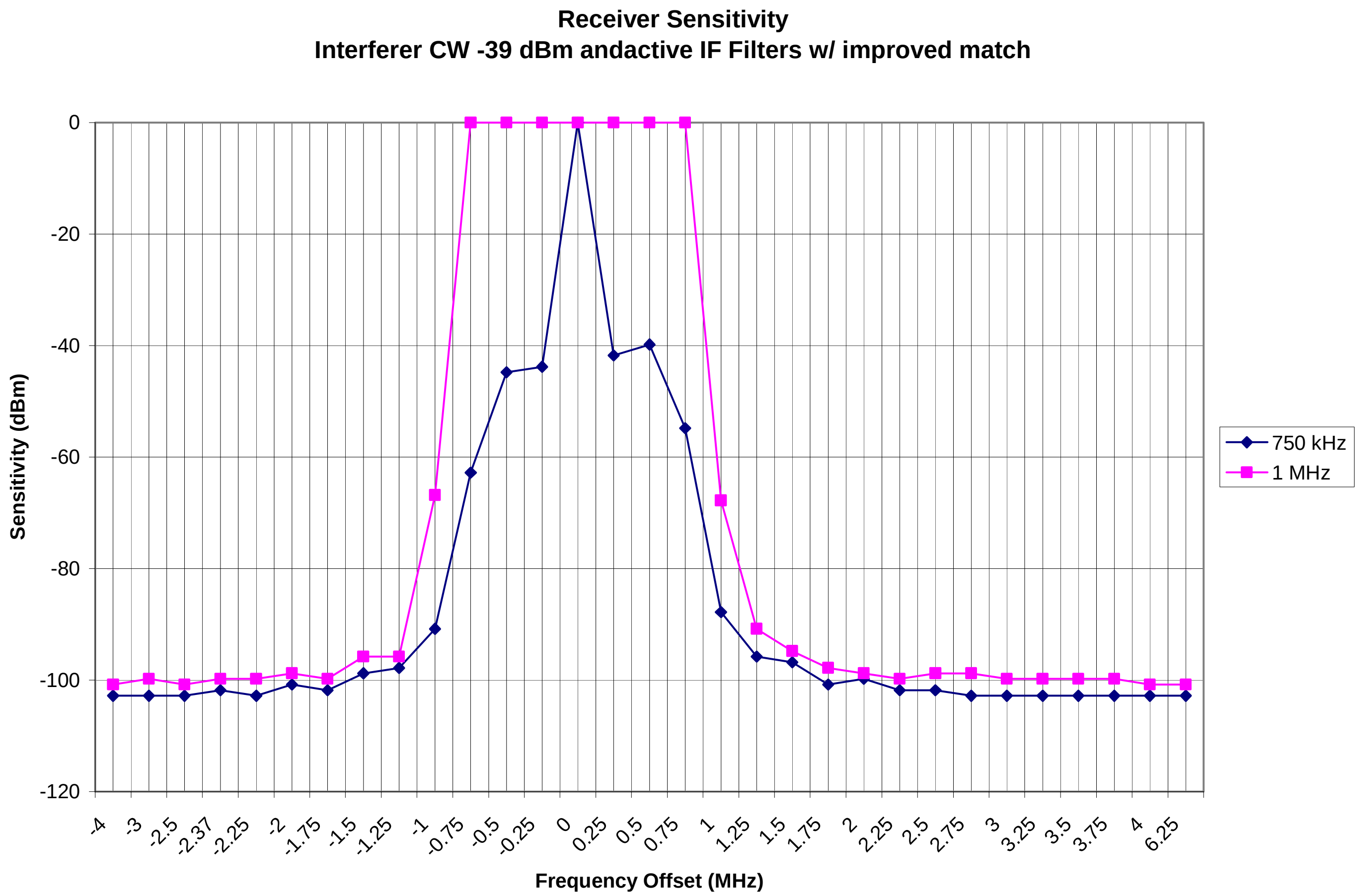

Figure 3. Receiver Sensitivity with improved active Prototype

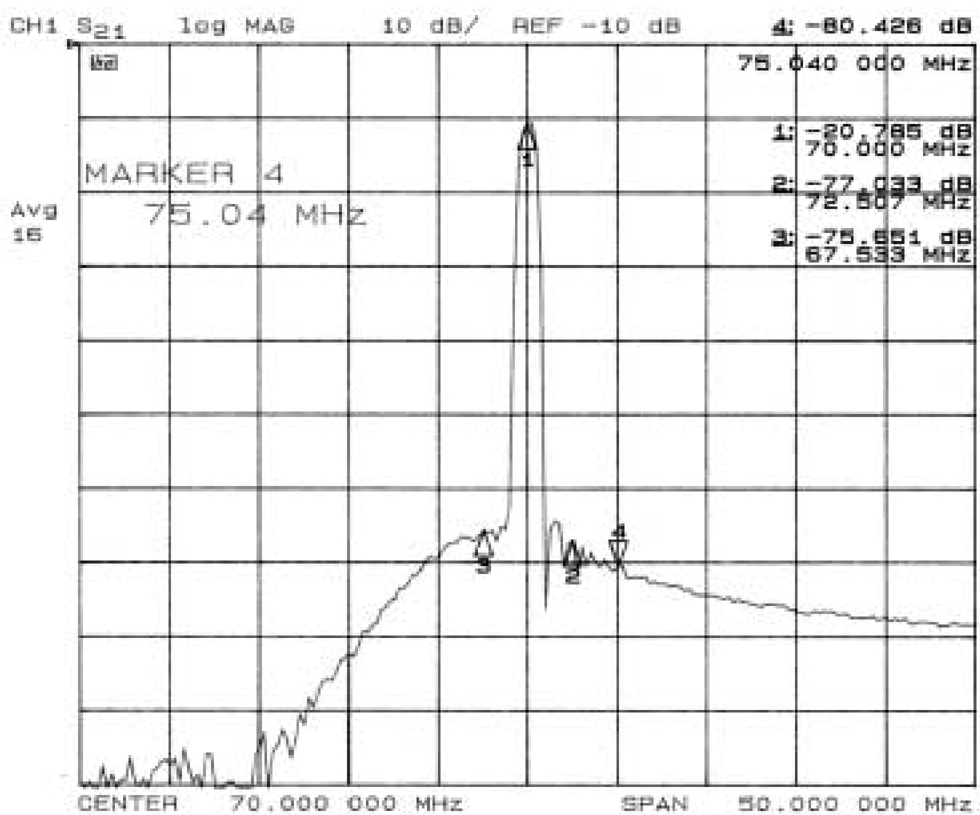

Figure 4. Network Analyzer Plot of 750 kHz IF Active Prototype

The more uniform skirts of the improved match can bee seen in figure 4. The receiver's improved adjacent channel rejection directly correlates with the better match.

As the interfering signal power level decreases, the adjacent channel rejection is expected to improve. To verify this, we decreased the power level of the interferer and plotted the corresponding improvement in adjacent channel rejection. Figure 5 summarizes our
measurements.

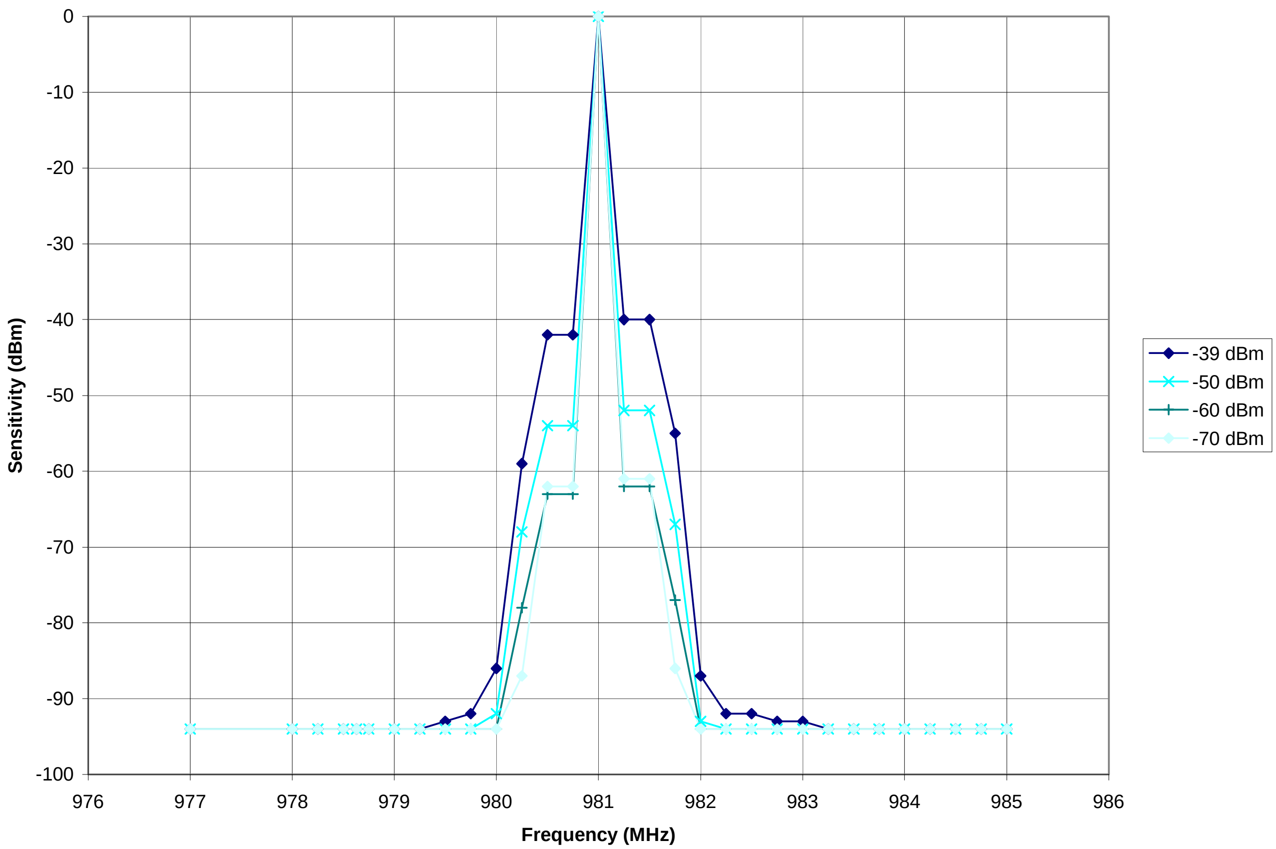

Figure 5. Receiver Sensitivity with various interference levels

To verify system level performance, identical tests were repeated on a full UAT receiver. The test setup described in Appendix A, uses an external UAT to generate the test signal. An interfering CW signal at –39 dBm is then injected and its frequency is varied. Figure 6 below shows the resulting sensitivity curves in the presence of an interfering signal for both the 750 kHz and 1 MHz IF. The FEC was turned on for the system tests.

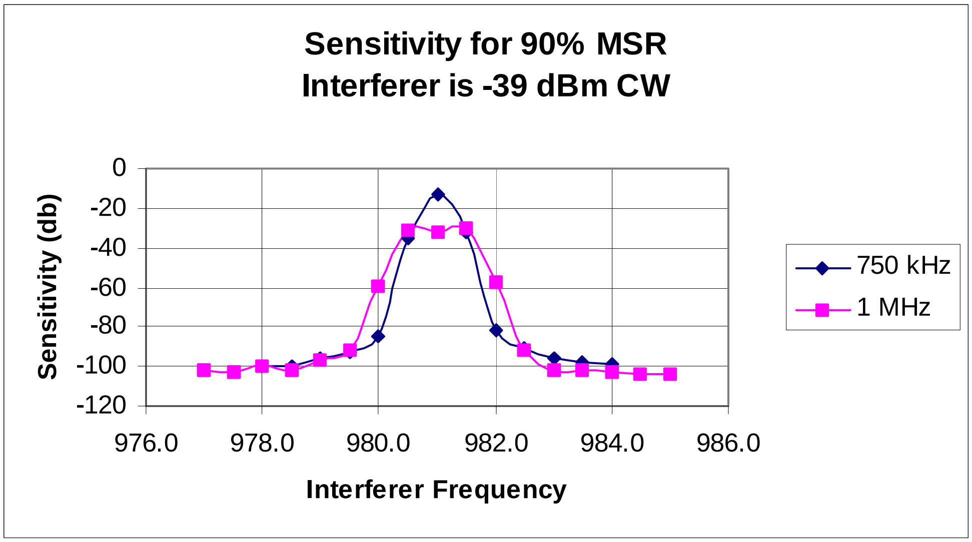

Figure 6. Receiver Sensitivity to achieve 90% MSR with 750 kHz IF

3. Local Oscillator Sensitivity

As the filtering on a receiver is narrowed, the long-term stability of an oscillator becomes more important. To measure this tolerance, the UAT's internal phased locked loop oscillator was disabled. IA stable and easily variable signal generator signal was injected in its place. The receiver's sensitivity with the generator adjusted to center the signal in the IF band was first measured. The generator was then moved to both sides of the centered signal and degradation in sensitivity was measured. This is a quick way of observing the effects of a drifting LO, which may be caused by such things as varying temperature or aging.

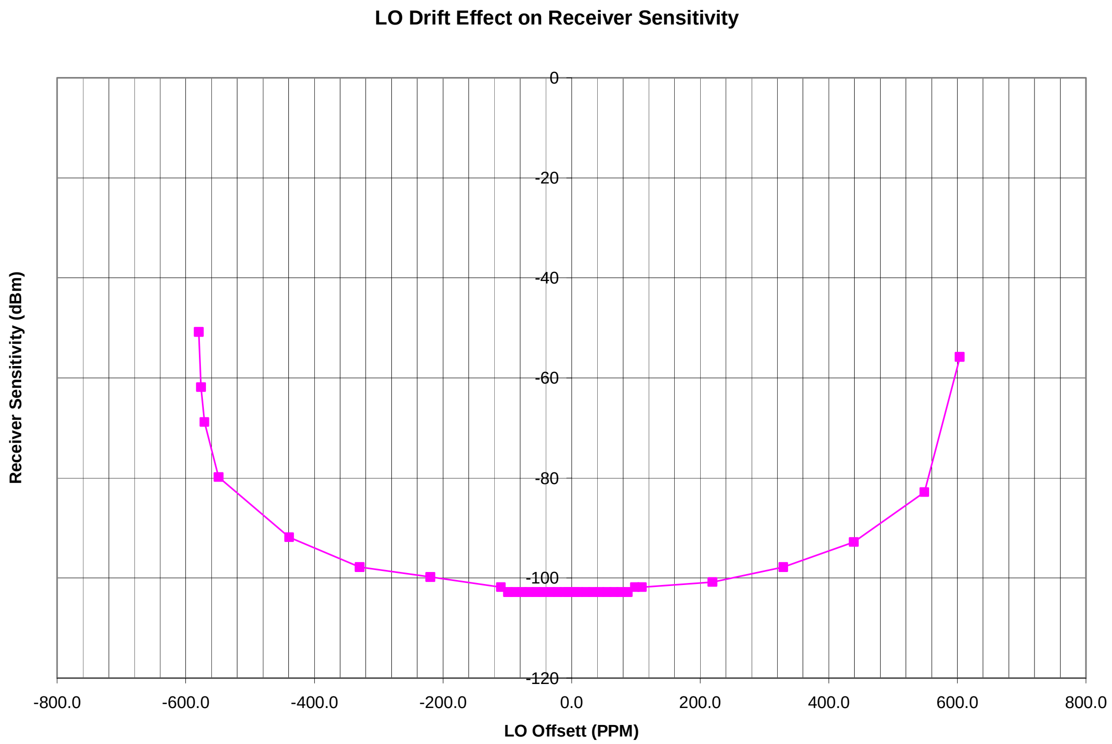

Figure 8. Sensitivity Degradation from LO Drift

A quick check of the UAT receiver vs. temperature showed that sensitivity did not degrade significantly with temperature. Figure 9 shows the sensitivity over temperature measurement.

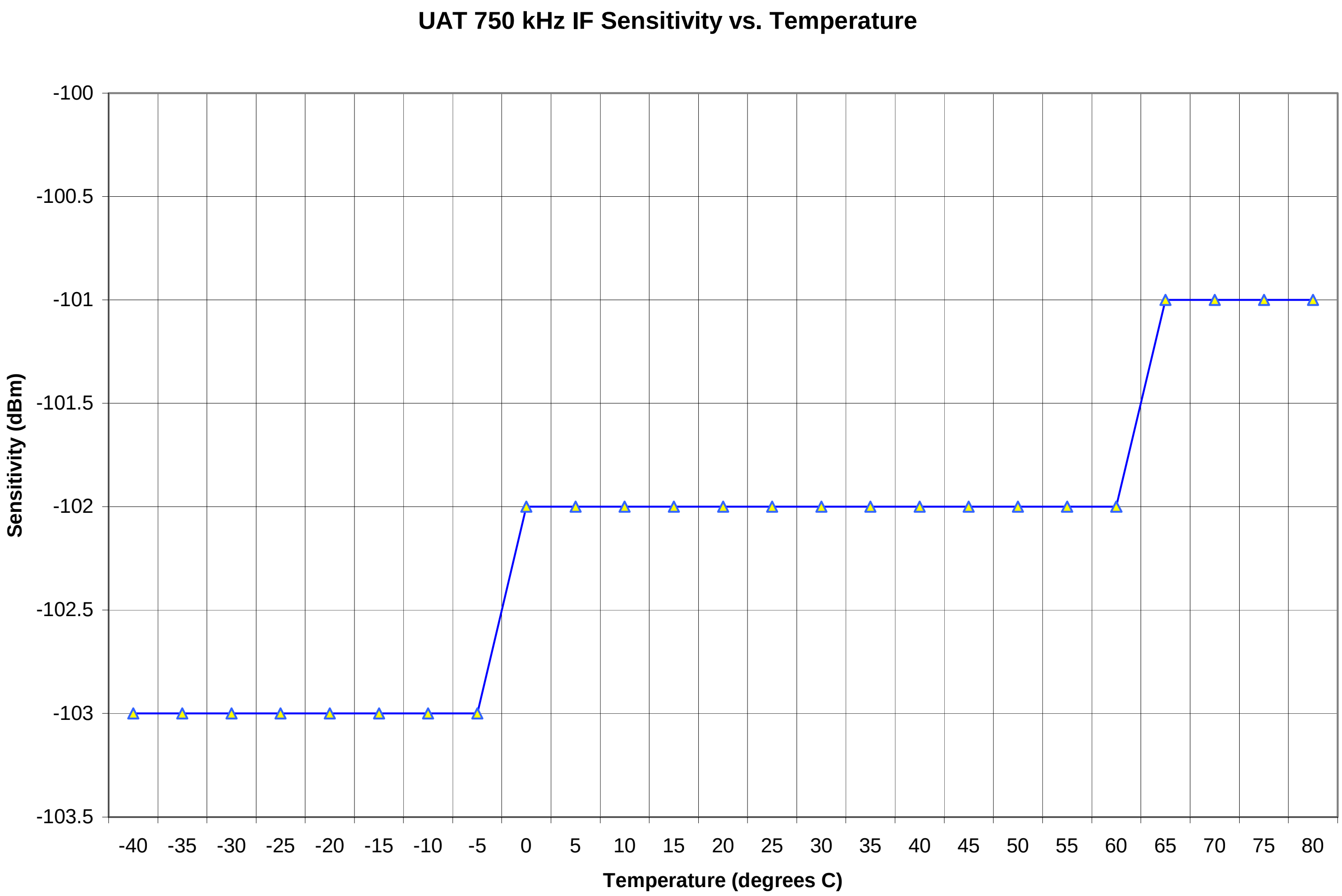

Figure 9. UAT Receiver temperature sensitivity with 750 kHz IF

4. Sensitivity Gain with Forward Error Correction (FEC)

Up to this point all of the receiver sensitivity measurements were performed without error correction. Figure 8 below shows the FEC improvement for a 750 kHz IF. For a 90% message success rate, the raw sensitivity is –93 dBm at the UAT antenna input. Turning on the error correction increases the sensitivity to –99 dBm.

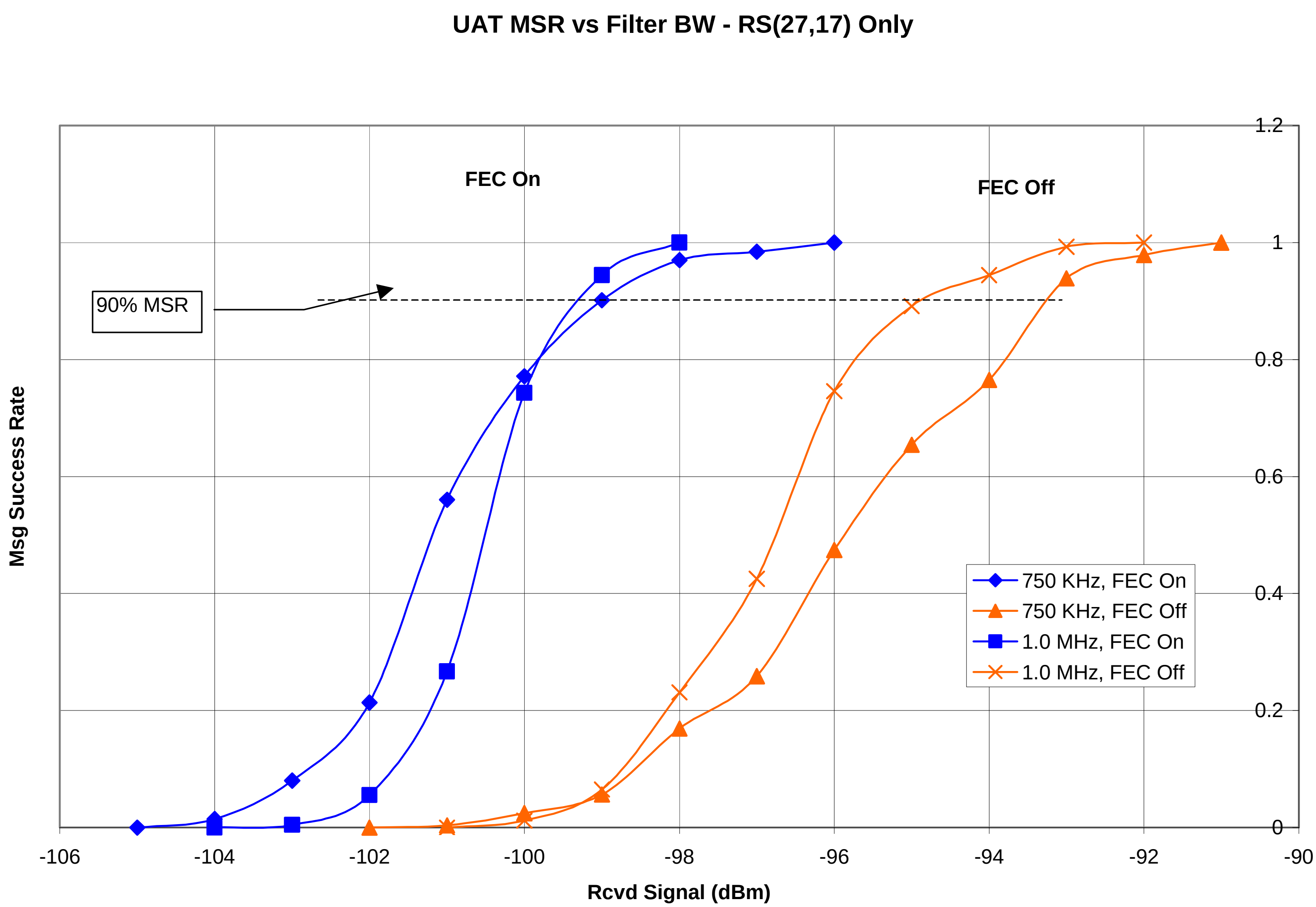

Figure 10. Sensitivity Improvement with Forward Error Correction

5. Conclusions

A 750 kHz IF yields the best adjacent channel rejection and will bode well with DME stations 1 MHz away. A 1 MHz IF may require the adjacent DME channels (stations 1 MHz away from either side of the UAT channel) to be cleared away. Local Oscillator stability of 20 – 30 PPM is recommended with 750 kHz IF. A 750 kHz filter appears to yield a lower noise floor and gives greater receiver sensitivity. Initial measurements indicate that data does not appear to be degraded by the narrower filter, however this has not been fully investigated. The narrower filter should be used to solve adjacent channel problems and not for the sole purpose of increasing sensitivity at the expense of greater inter symbol interference.

Appendix 1 Test Descriptions

A1a. Receiver Module Bit Error Rate Test Description

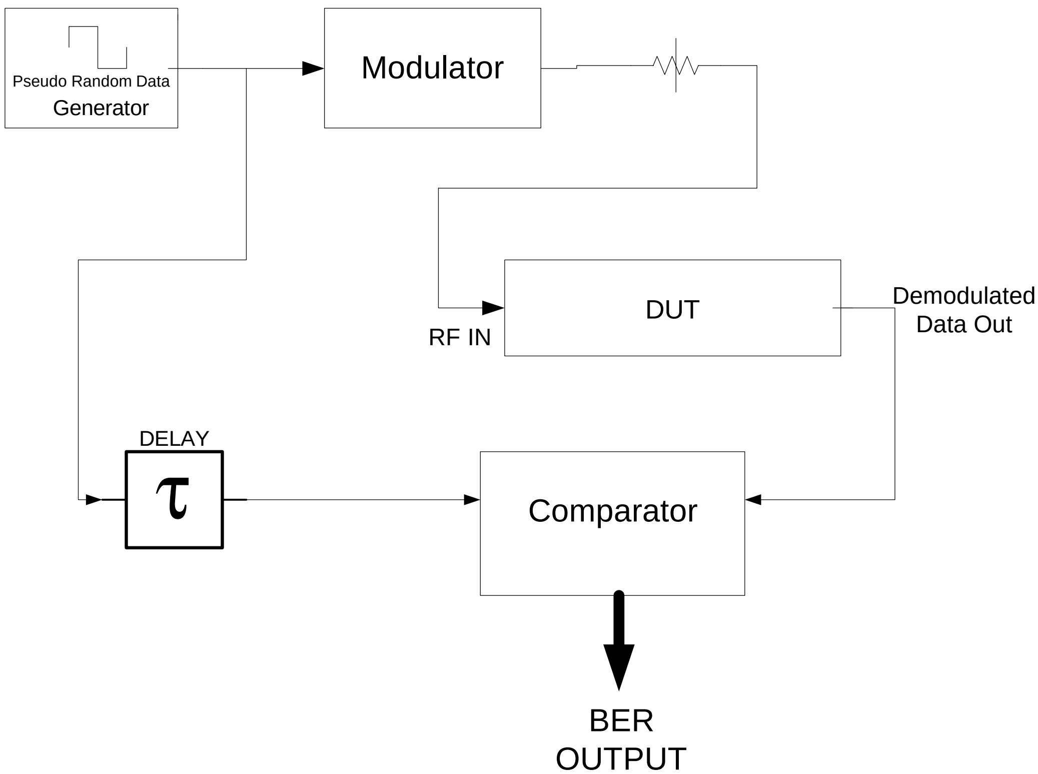

Figure A1-1. UAT Bit Error Rate test setup

The BER test, performed per manufacturing procedures, is depicted in Figure 1. The procedure involves injecting a RF signal modulated by a pseudo random data stream into the receiver. A variable attenuator decreases the modulator’s signal strength before it is injected into the receiver. The receiver's demodulated data is compared to the original data stream. The comparator voltage is directly proportional to the Bit Error Rate: the higher the voltage, the greater the error. A voltage of 0.05 corresponds to a one- percent error rate.

A1b. UAT System Message Success Rate Test Description

A message success rate (MSR) test uses a UAT as a data generator. The signal is attenuated before being injected into the UAT under test. The UAT's "RX Msg. OK" signal is monitored and compared with the number of originated messages to determine the message success rate for a given signal level. Figure 4 below illustrates the MSR test setup.

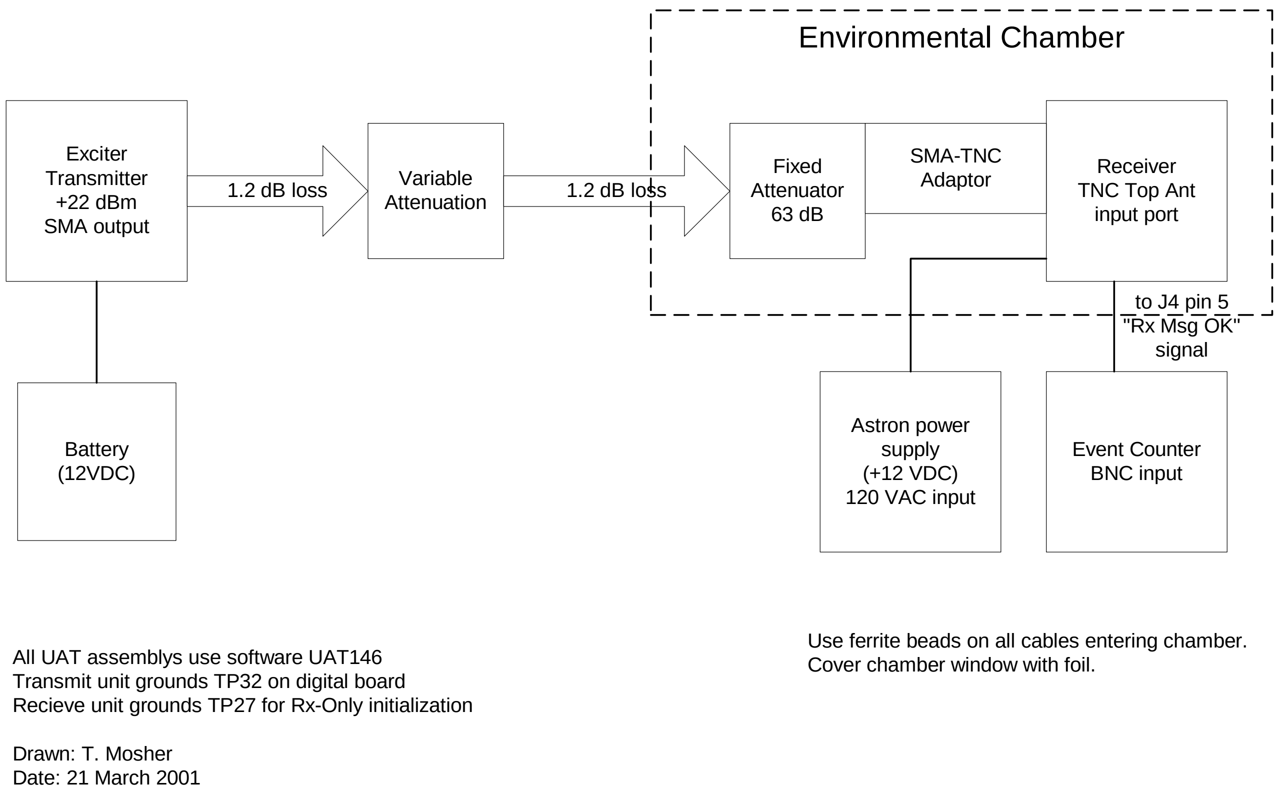

Figure A1-2. UAT Message success Rate test setup

Appendix 2 Raw Data Tables

A2-a Adjacent Channel rejection with of 750 kHz and 1 MHz IF BW
These values reflect the receiver module sensitivities. Add 3 dB loss for UAT assembly.

Interferer Frequency MHz	Offset from UAT Center Fo MHz	Rx Sensitivity 750 kHz IF dBm	Rx Sensitivity 1 MHz IF dBm
977	-4	-102.8	-100.8
978	-3	-102.8	-99.8
978.5	-2.5	-102.8	-100.8
978.63	-2.37	-101.8	-99.8
978.75	-2.25	-102.8	-99.8
979	-2	-100.8	-98.8
979.25	-1.75	-101.8	-99.8
979.5	-1.5	-98.8	-95.8
979.75	-1.25	-97.8	-95.8
980	-1	-90.8	-66.8
980.25	-0.75	-62.8	0
980.5	-0.5	-44.8	0
980.75	-0.25	-43.8	0
981	0	0	0
981.25	0.25	-41.8	0
981.5	0.5	-39.8	0
981.75	0.75	-54.8	0
982	1	-87.8	-67.8
982.25	1.25	-95.8	-90.8
982.5	1.5	-96.8	-94.8
982.75	1.75	-100.8	-97.8
983	2	-99.8	-98.8
983.25	2.25	-101.8	-99.8
983.5	2.5	-101.8	-98.8
983.75	2.75	-102.8	-98.8
984	3	-102.8	-99.8
984.25	3.25	-102.8	-99.8
984.5	3.5	-102.8	-99.8
984.75	3.75	-102.8	-99.8
985	4	-102.8	-100.8
987.25	6.25	-102.8	-100.8