CML Microcircuits
COMMUNICATION SEMICONDUCTORS

Application Note
CMX998
Exploring high data rate applications

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1 Introduction
The CMX998 has been proved extensively in TETRA 1 systems but there is an increasing need for higher data rates. This Application Note details measurements made using a CMX998 in a TETRA 2 system both as a proof of concept for TETRA 2 applications and for wideband applications in general. The evaluation is made using the CMX998 Evaluation Kit, the EV9980, with a small number of component changes.

2 Contents

3 History

Version	Changes	Date
1	First Release	24-7-2013

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4 TETRA 2

The main benefit of TETRA Release 2 (hereafter referred to as TETRA 2) is the increased data rates over the original TETRA 1 scheme but this is achieved at the consequence of increased radio spectrum (i.e. larger signal bandwidth). TETRA 2 mitigates the bandwidth requirement by using a number of QAM modulated sub-carriers that are summed together. The two nominal systems of TETRA 2 evaluated in this document are 50kHz QAM and 150kHz QAM.

4.1 Modulation Source Details

A SMIQ 02 is used to simulate TETRA 2 modulation because it doesn't have the capability to generate an exact TETRA 2 modulation as specified by ETSI. The TETRA 2 simulation is generated using 16 QAM modulation and a square root raised cosine filter with a Bt of 0.2. The symbol rate is set to achieve the correct bandwidth signal. With 50kHz QAM the symbol rate was 38.4kS/s and with 150kHz QAM the symbol rate is 115.2kS/s. In the following sections are results taken with the Rhode and Schwarz FESA30 of the SMIQ in the specified setup.

The above modulation setups were chosen to be representative of a TETRA 2 signal. In particular, the peak-to-mean of ~8dB is representative of a typical peak-limited TETRA 2 signal.

4.1.1 50kHz QAM Source

The following plots show the 1st adjacent channel performance, eye diagram, constellation diagram and symbol/error table. The adjacent channel is measured as defined in the TETRA 2 standard [ref 2].

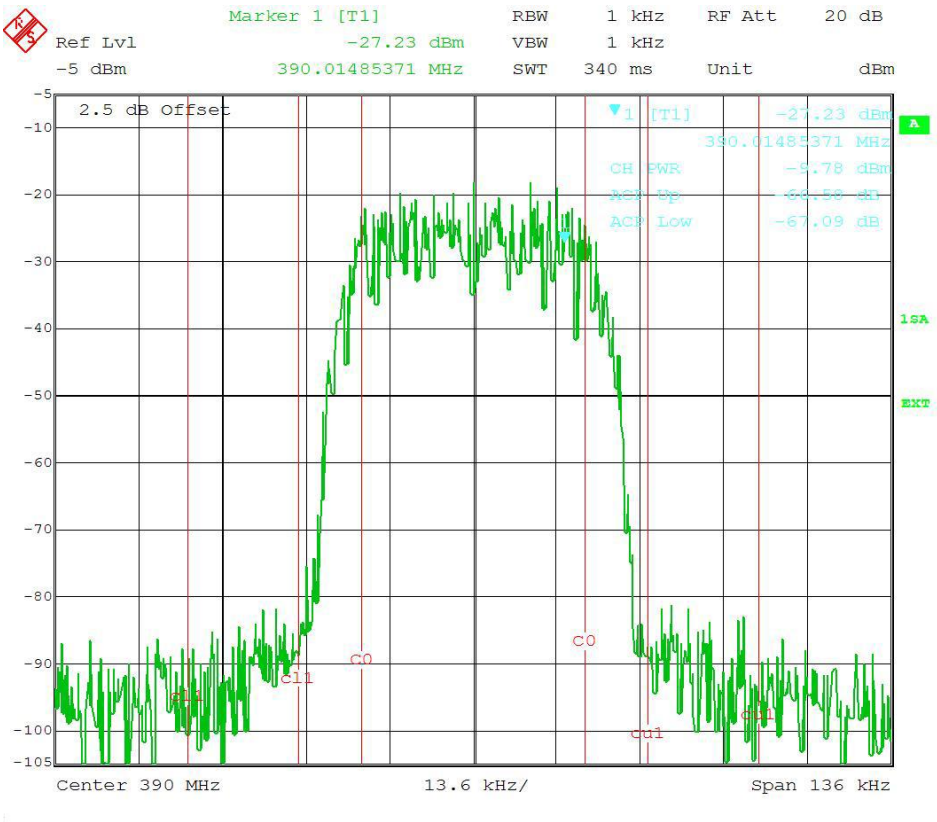

Figure 1. 50kHz QAM Source 1st Adjacent Channel Performance

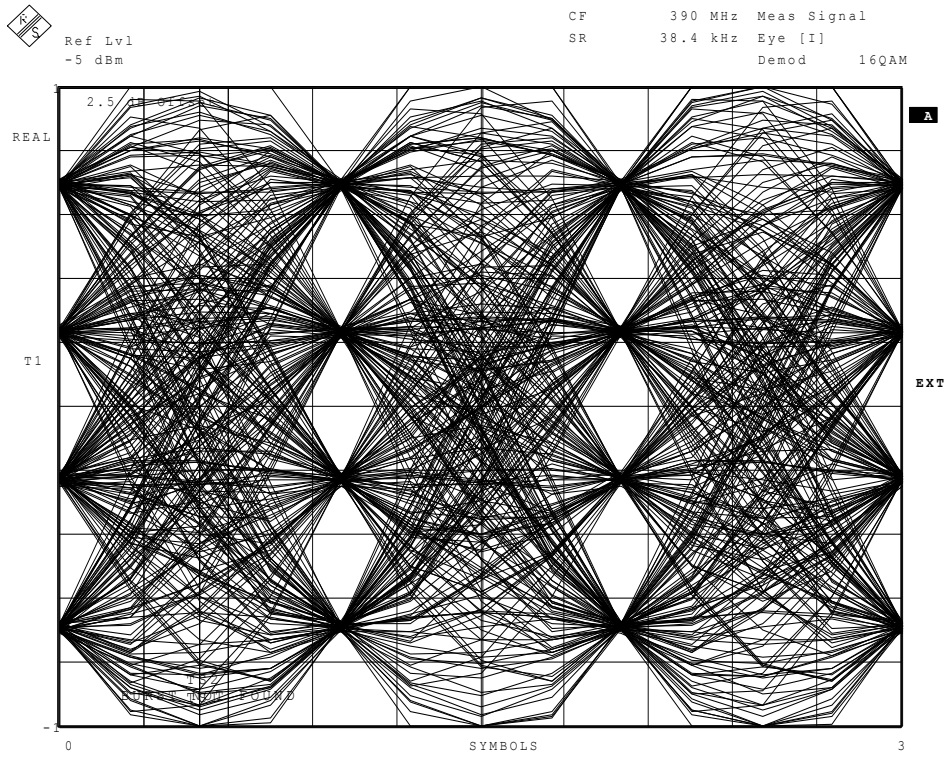

Figure 2. 50kHz QAM Source Eye Diagram

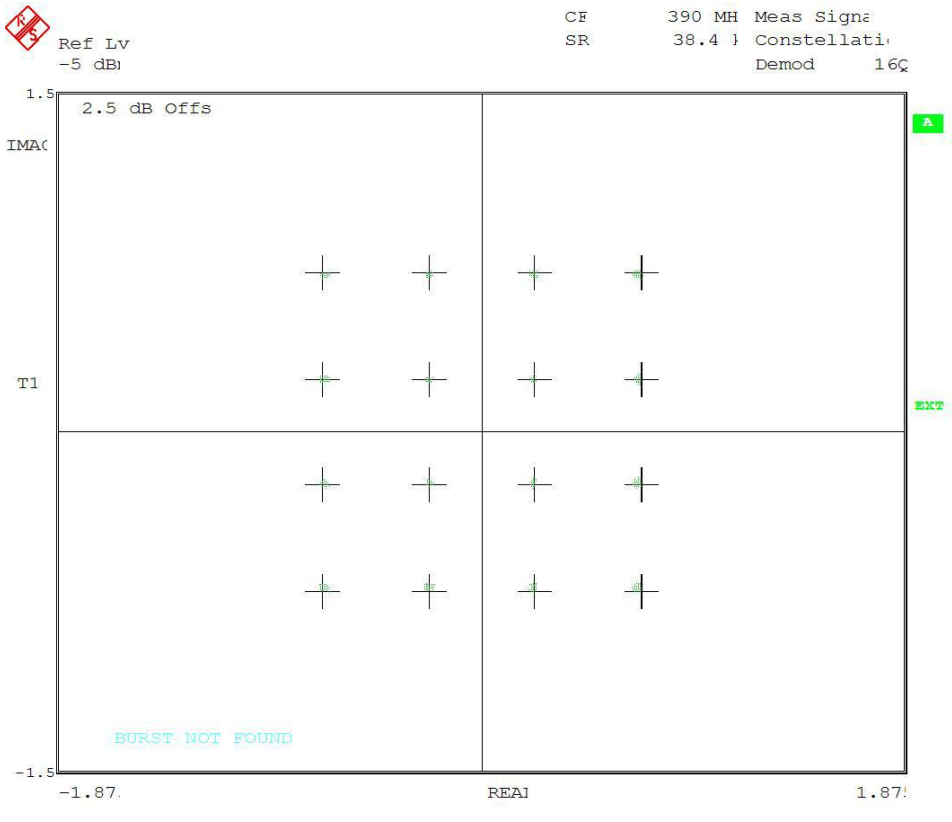

Figure 3. 50kHz QAM Source Constellation Diagram

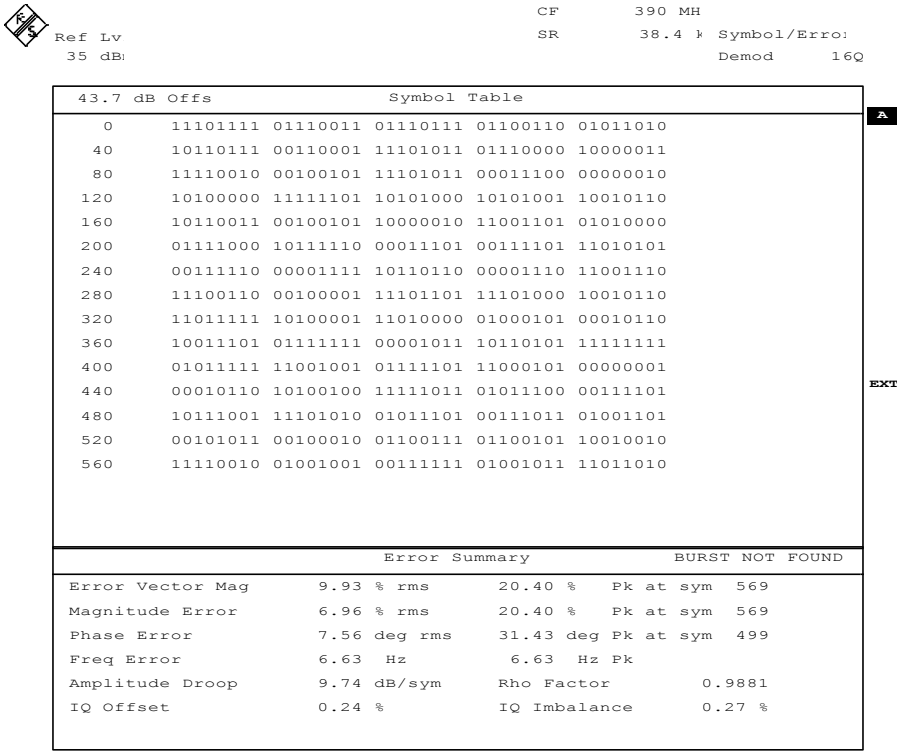

Figure 4. 50kHz QAM Symbol/Error Tables

4.1.2 150kHz QAM Source

The following plots show the 1st adjacent channel performance, eye diagram, constellation diagram and symbol/error table.

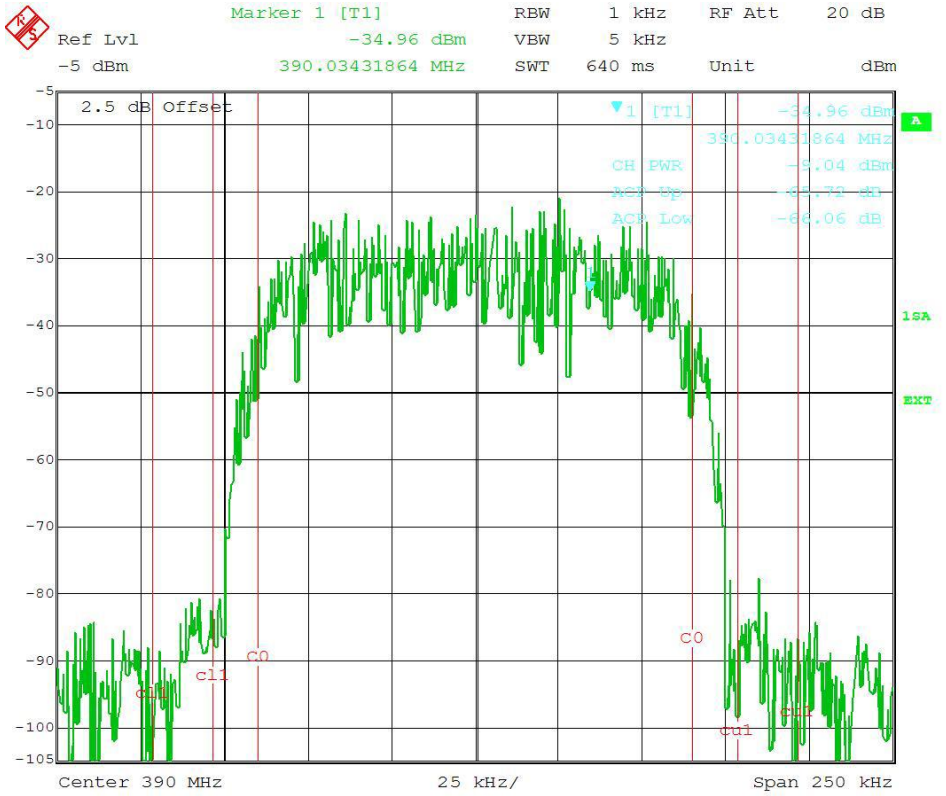

Figure 5. 150kHz QAM Source 1st Adjacent Channel Performance

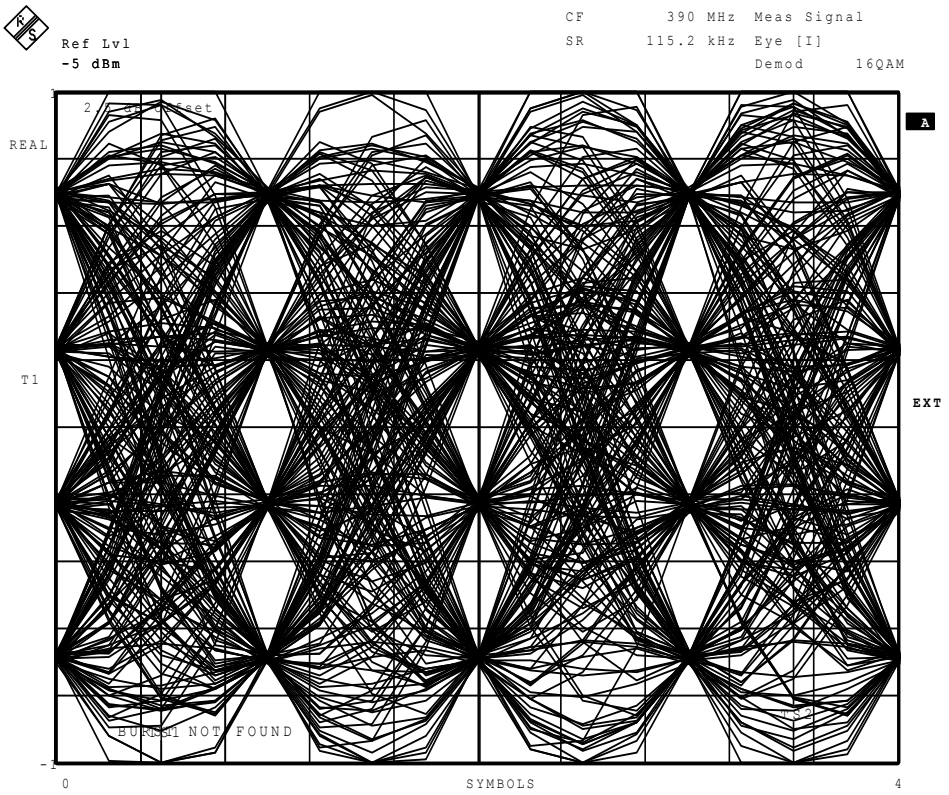

Figure 6. 150kHz QAM Source Eye Diagram

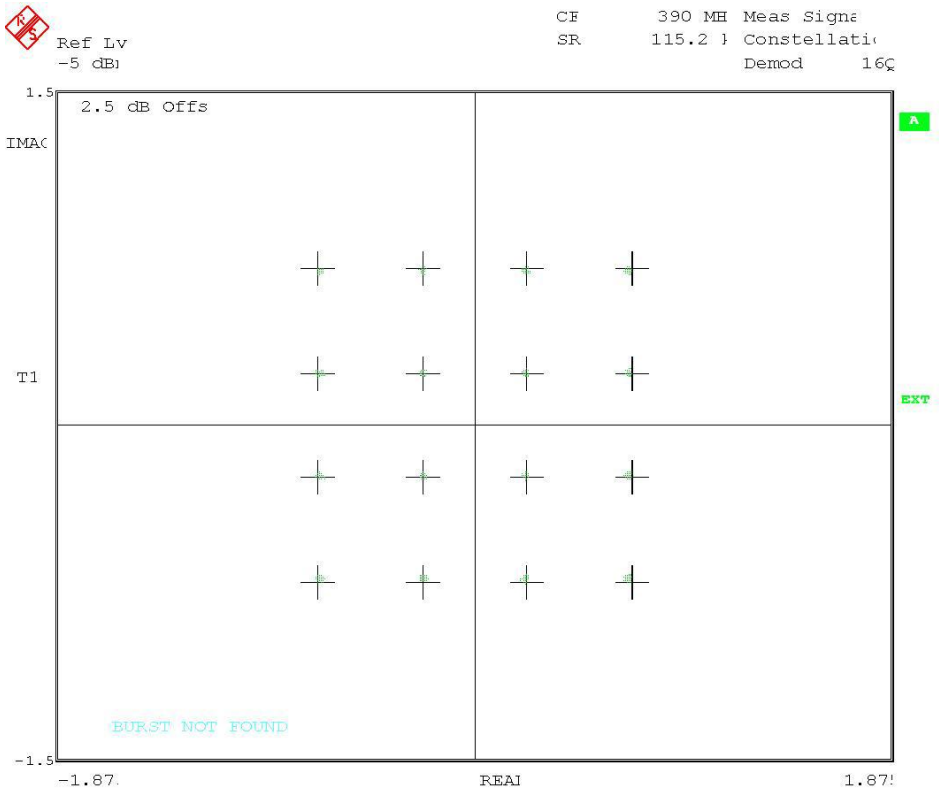

Figure 7 - 150kHz QAM Source Constellation Diagram

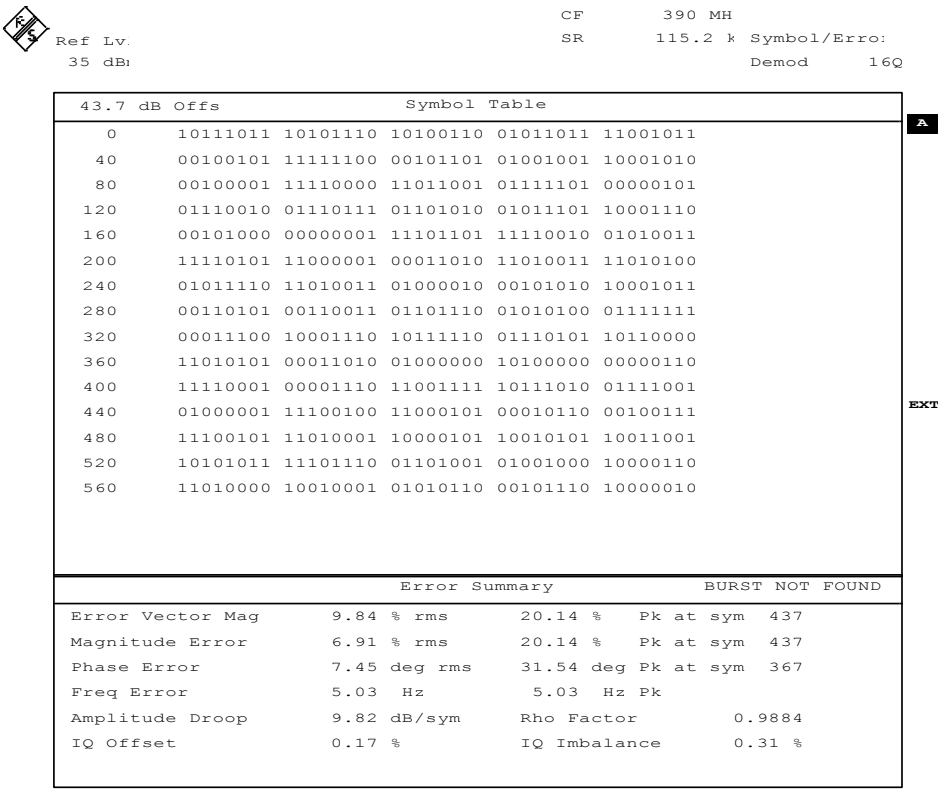

Figure 8 - 150kHz QAM Symbol/Error Tables

5 Measurement Results

5.1 50kHz QAM

The loop configuration is shown in Figure 9 using the CMX998 Cartesian Feedback Loop IC (CFBL) and the RF2175 PA device. The loop filter design used to obtain the results for 50kHz QAM is shown in Figure 10.

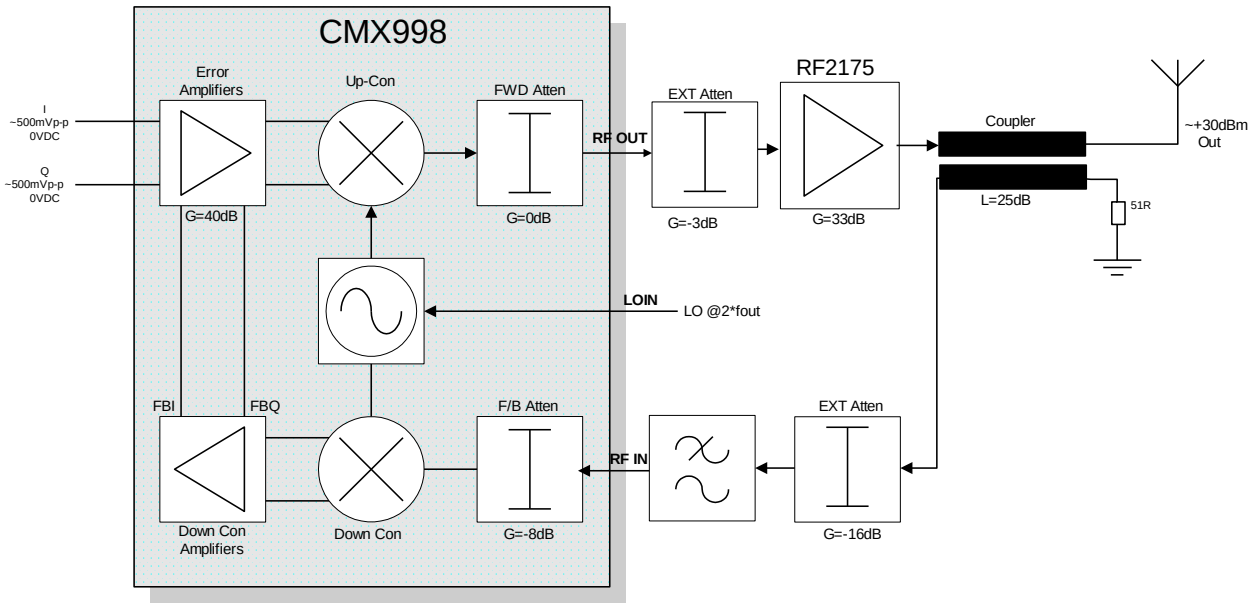

Figure 9 – Loop Configuration

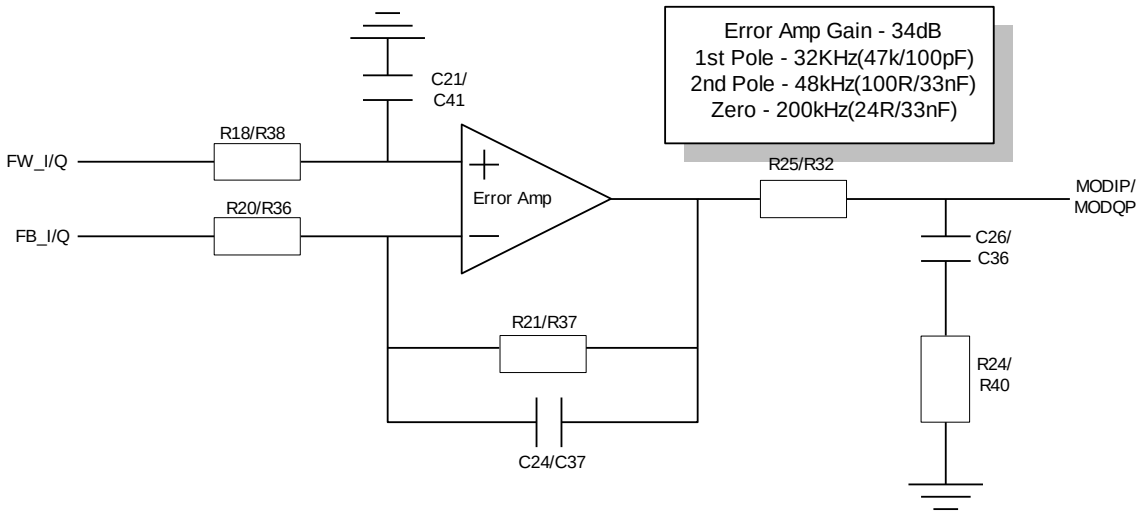

Figure 10 – 50kHz QAM Loop Filter Configuration

The loop filter is configured with an error amplifier gain of ~34dB. The 1st pole is at ~32kHz, the 2nd pole is at ~ 48kHz and the zero is at ~ 200kHz. With this configuration the following results are obtained. The plot in Figure 11 shows the comparison between the open and closed loop performance. The 1st Adjacent Channel is ~66/67dBc in closed loop which indicates ~30dB linearisation. The plots in Figure 13 and Figure 14 show the eye and constellation diagrams respectively. The vector error is ~11% which is comparable to the measurement of the source (see Figure 4). All measurements have been done at 390MHz with the LO at twice the frequency. In Table

1 are some wideband noise measurements for the 50kHz QAM setup and the TETRA 2 requirements have been included for comparison.

Offset (kHz)	Noise (dBc)	TETRA 2 Requirements (<3W) dBc
+112.5	-80	-68
-112.5	-78.3	-68
+262.5	-86	-72
-262.5	-85.3	-72
+500	-87.2	-78
-500	-85	-78
5000	-100	-95

Table 1 - 50kHz QAM WBN measurements

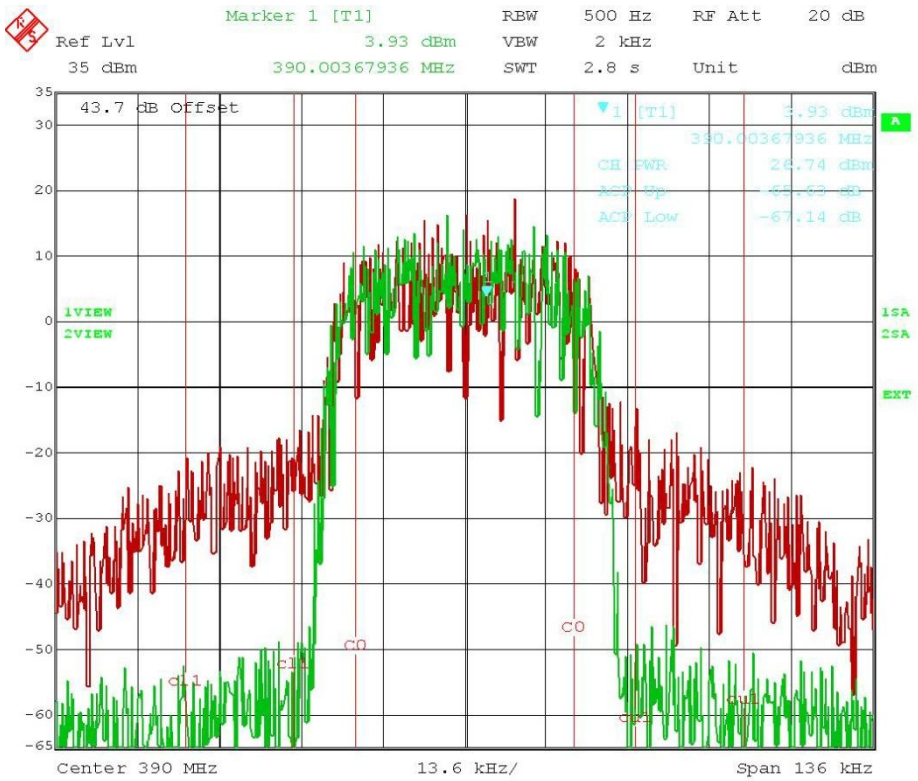

Figure 11 – 50kHz QAM Closed and Open Loop Performance

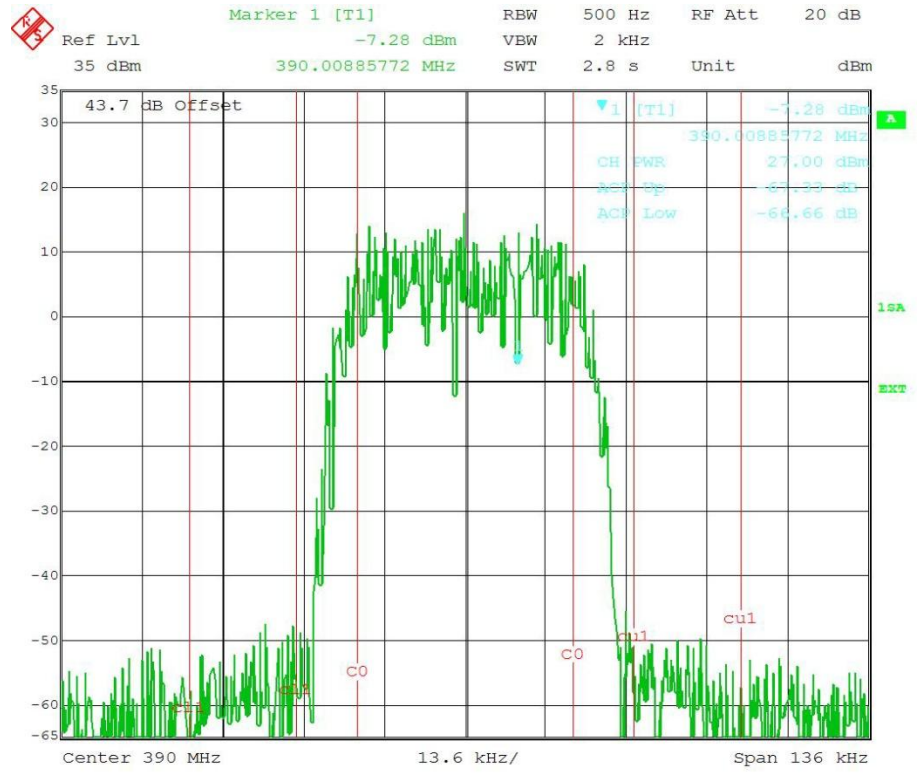

Figure 12 – 50kHz QAM 1st Adjacent Channel Performance

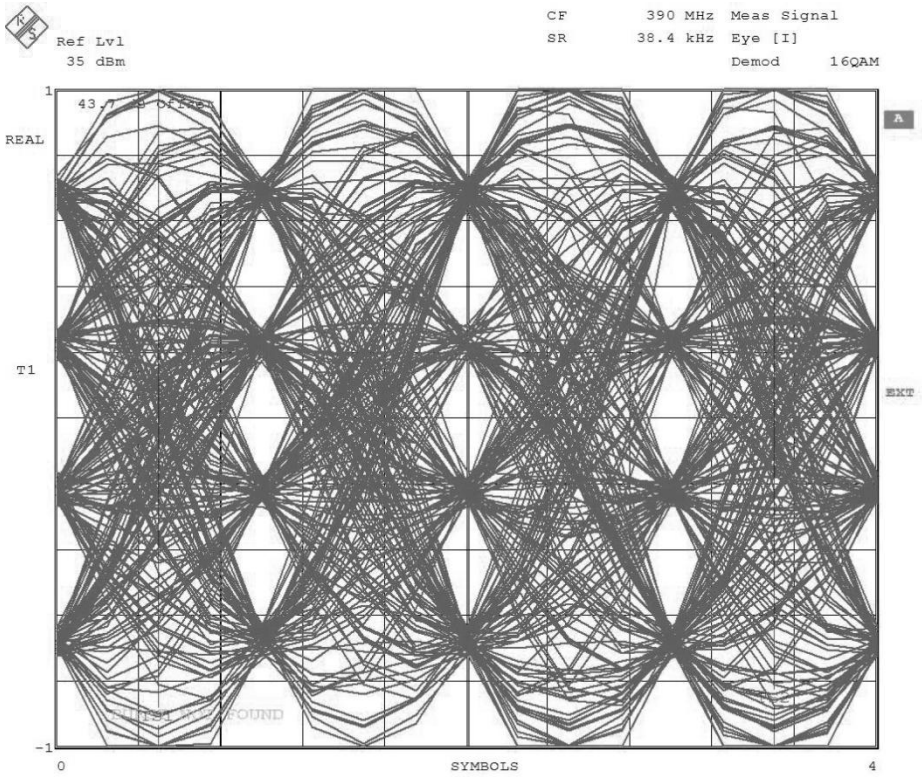

Figure 13 – 50kHz QAM Eye Diagram

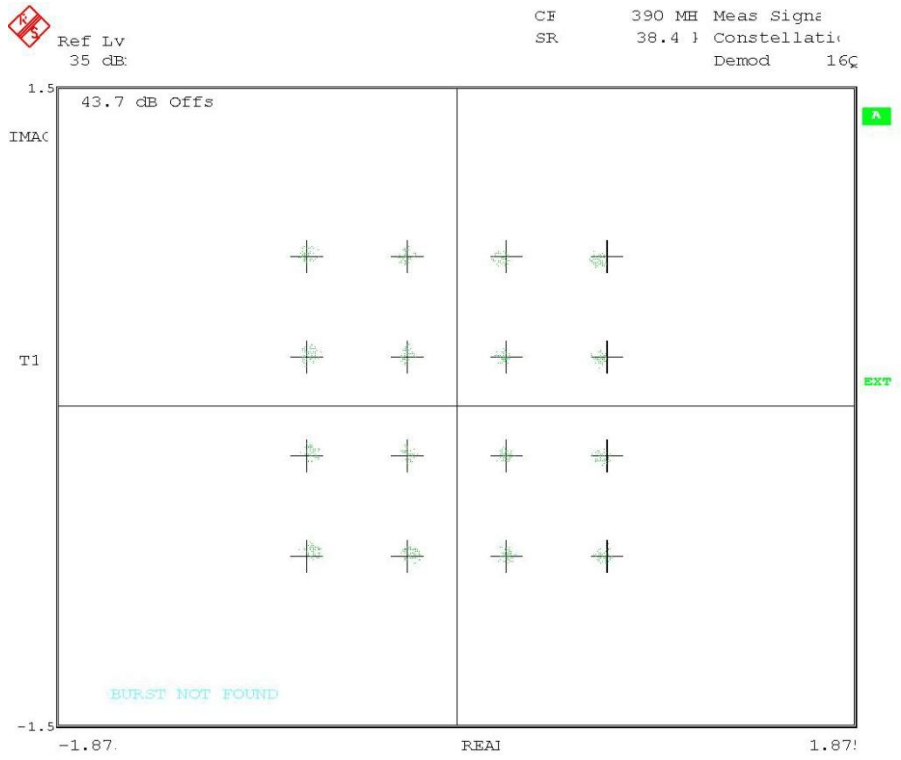

Figure 14 – 50kHz QAM Constellation Diagram

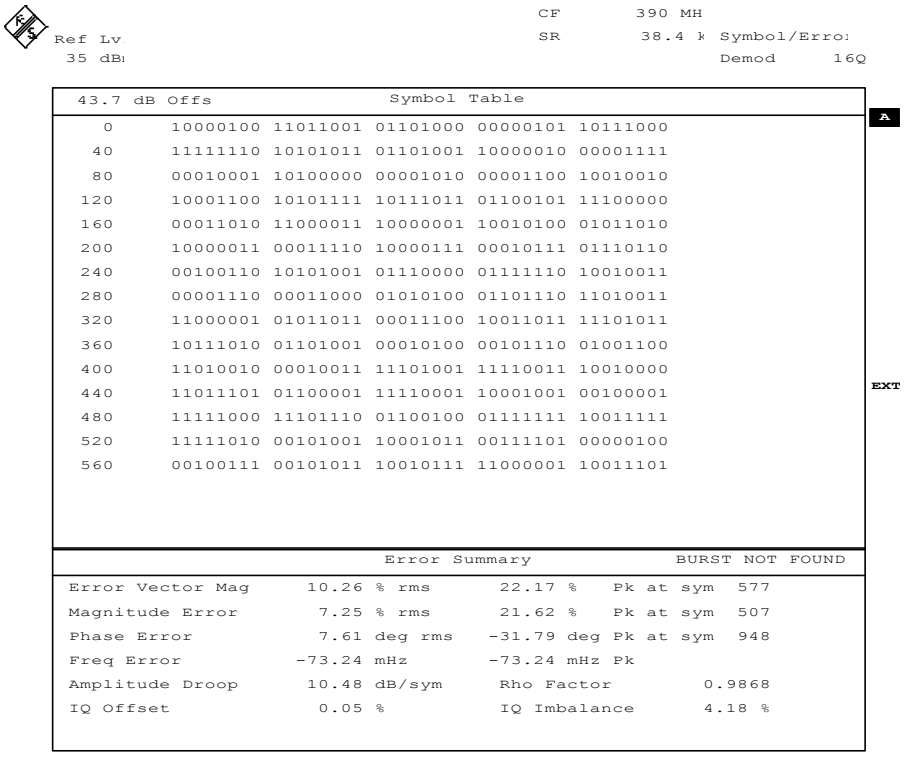

Figure 15 – 50kHz QAM Symbol/Error Table

5.2 150kHz QAM

The loop configuration is shown in Figure 9. The critical loop filter configuration is shown in Figure 16.

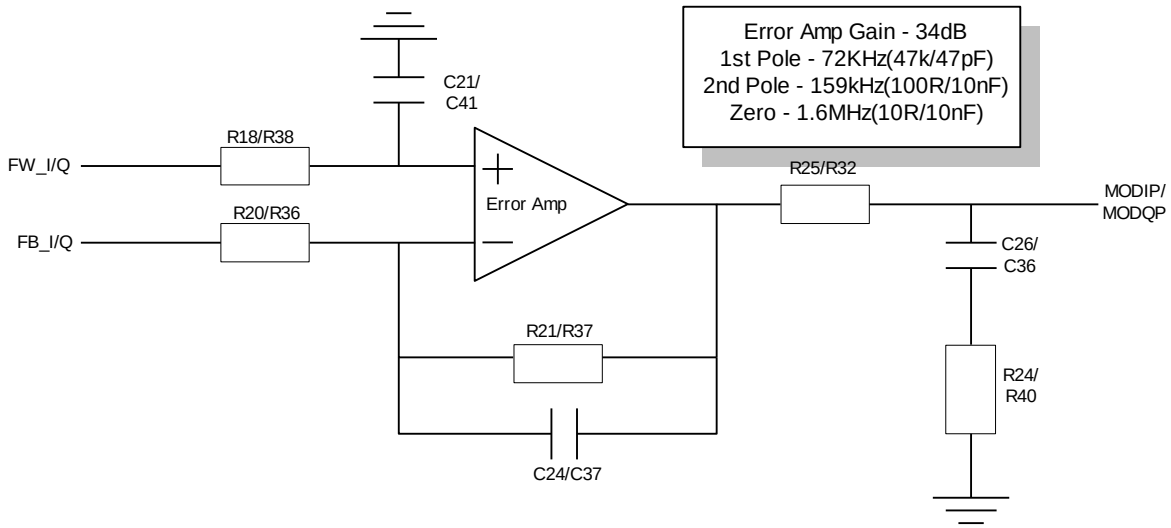

Figure 16 - 150kHz QAM Loop Filter Configuration

The loop filter is configured such that the error amplifier gain is ~34dB. The 1st pole is at ~72kHz, the 2nd pole is at ~ 159kHz and the zero is at ~ 1.6MHz. With this configuration the following results are obtained. The plots in Figure 17 and Figure 18 show the comparison between the open and closed loop performance. The 1st Adjacent Channel is ~64/65dBc in closed loop which indicates ~25dB linearisation. The plots in Figure 20, Figure 21 and Figure 22 show the eye diagram, constellation diagram and symbol/error table respectively. All measurements have been done at 390MHz with the LO at twice the frequency. Table 2 contains some wideband noise measurements for the 150kHz QAM setup and the TETRA 2 requirements have been included for comparison.

Offset (kHz)	Noise (dBc)	TETRA 2 Requirements (<3W) dBc
+162.5	-69	-60
-162.5	-70	-60
+312.5	-82.5	-63
-312.5	-82	-63
+562.5	-85.8	-70
-562.5	-85.1	-70
5000	-101	-95

Table 2 – 150kHz QAM WBN measurements

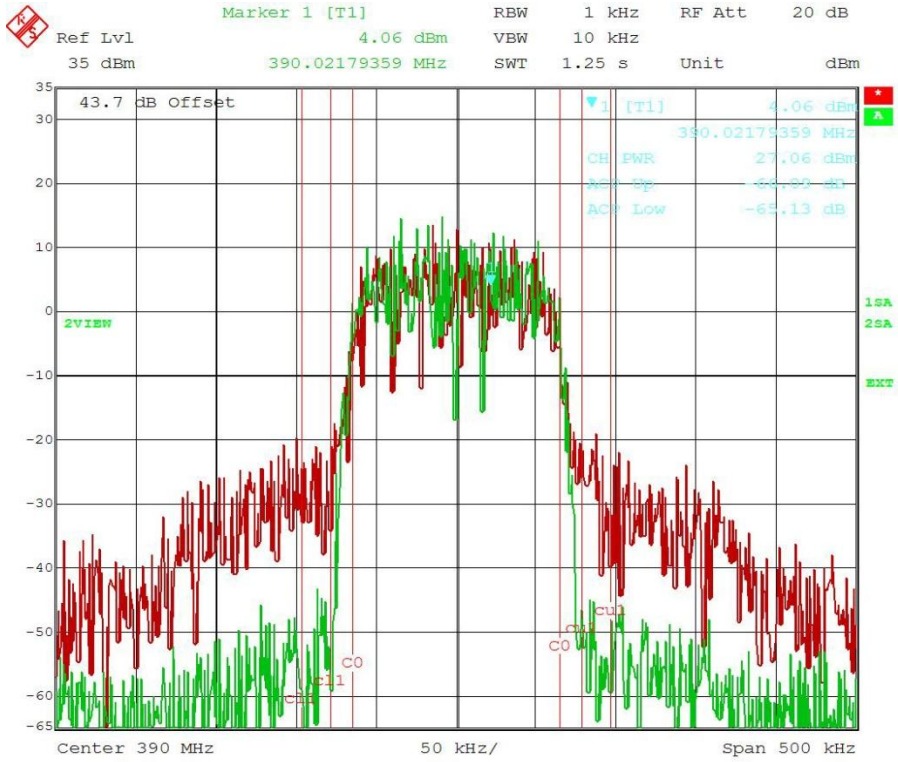

Figure 17 – 150kHz QAM Open and Closed Loop comparison

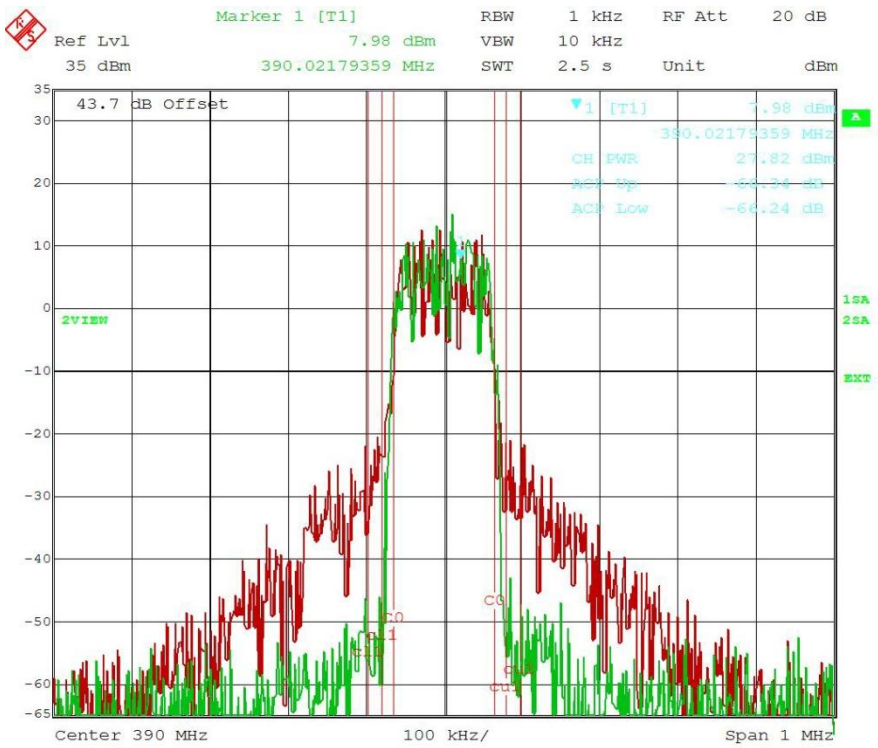

Figure 18 - 150kHz QAM Open and Closed Loop comparison with a wider span

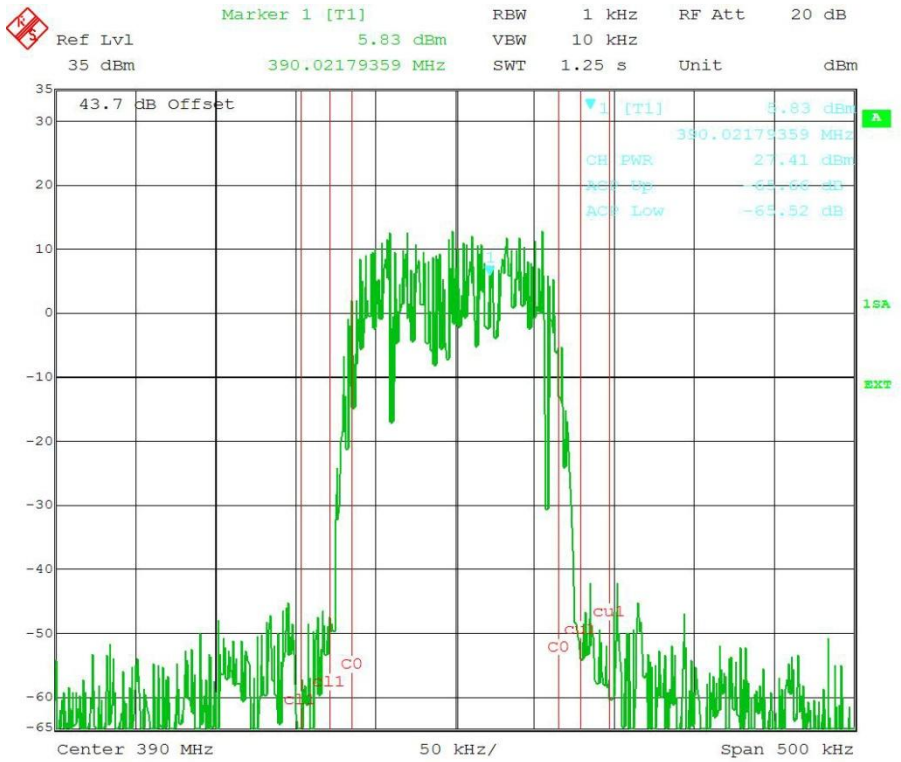

Figure 19 – 150kHz QAM 1st Adjacent Channel Rejection

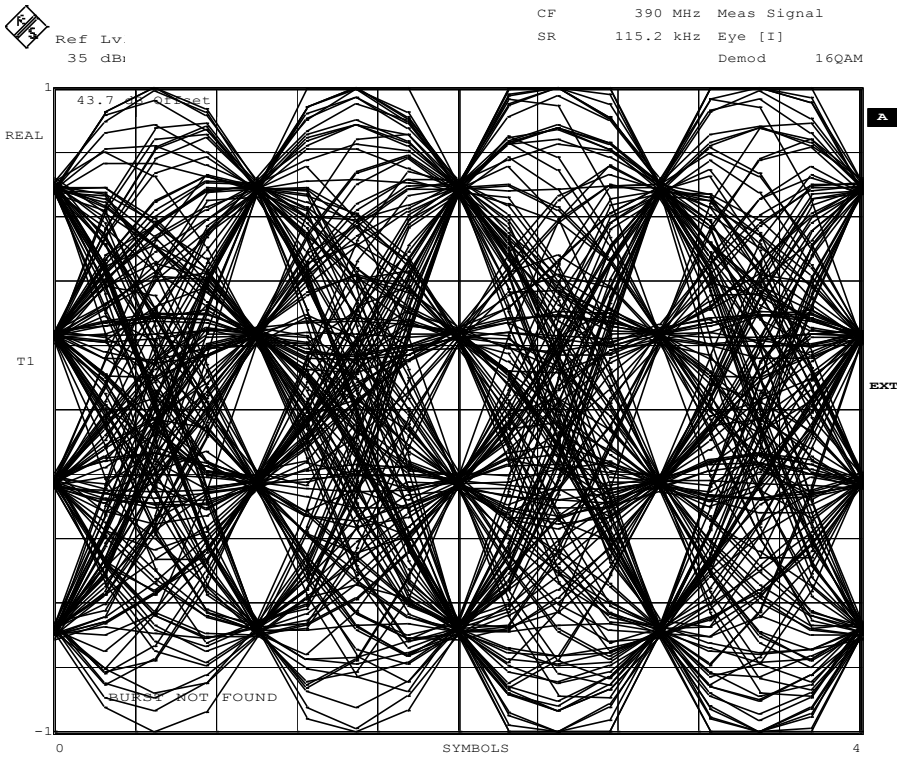

Figure 20 – 150kHz QAM Eye Diagram

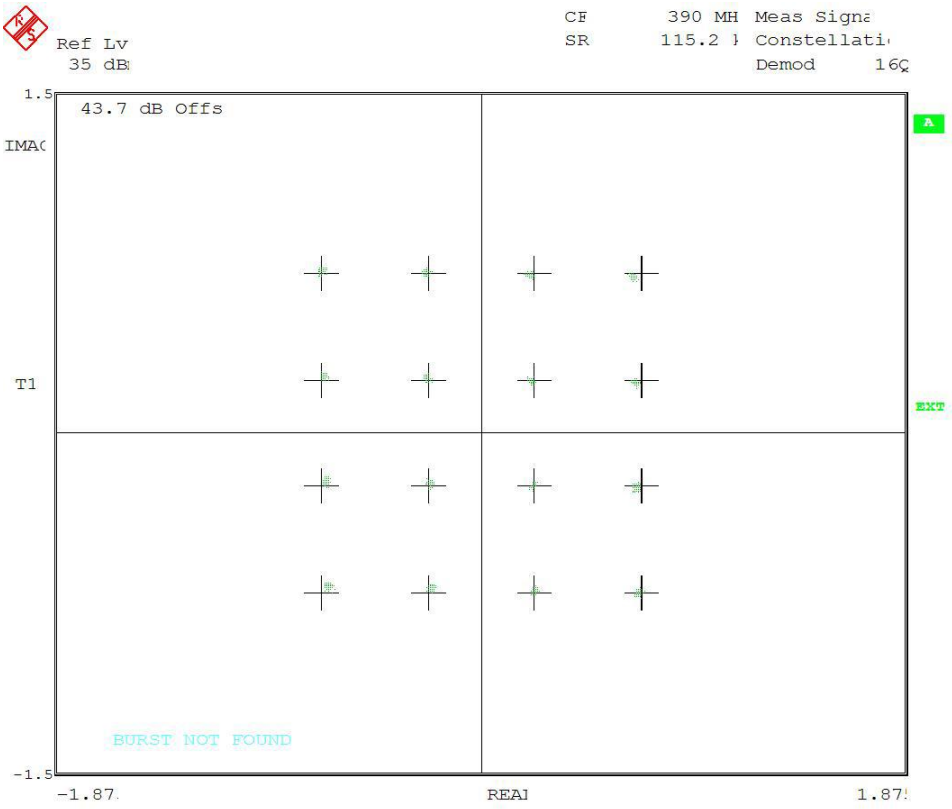

Figure 21 – 150kHz QAM Constellation Diagram

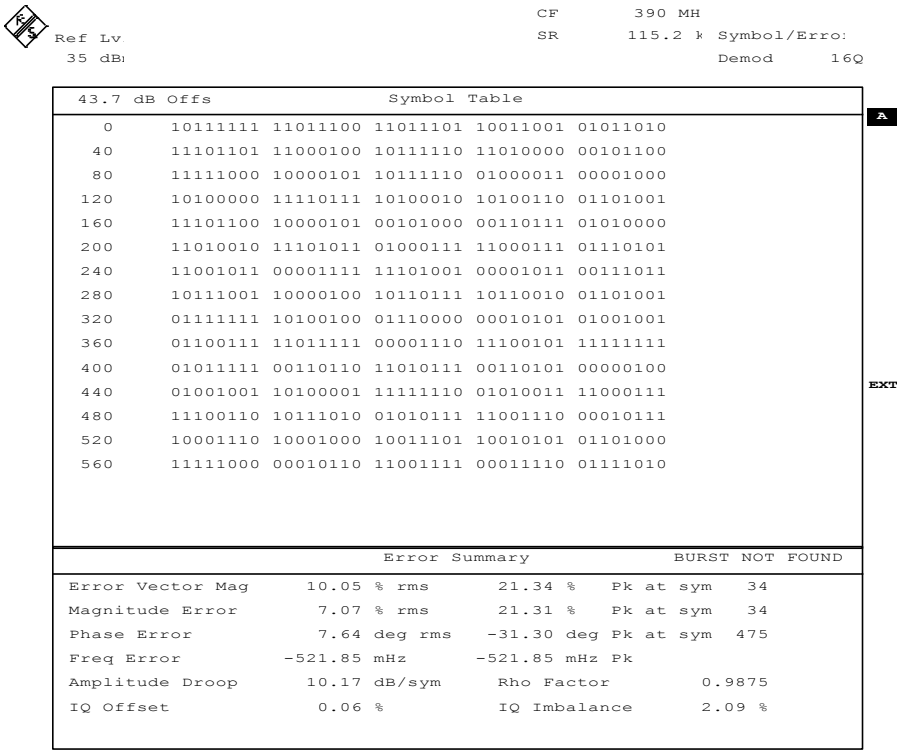

Figure 22 – 150kHz QAM Symbol/Error Table

6 Conclusions

The results taken with the CMX998 demonstrate that, with changes to the loop filter, the CMX998 Cartesian feedback loop can linearise systems with 150kHz bandwidth signals very well (~25dB linearisation measured in these tests). The results in this document show that for both 50kHz and 150kHz QAM the 1st Adjacent Channel ETSI requirement of 55dBc can easily be met and that the wideband noise requirement of –95dBc (@5MHz offset) can be met with good margin.

7 References

[1] CMX998 Data Sheet, Cartesian Feed-back Loop Transmitter, D/998/12 February 2013
[2] ETSI TS 100 392-2 V3.6.1 (2013-05). Terrestrial Trunked Radio (TETRA); Voice plus Data (V+D); Part 2: Air Interface (AI)

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