

Additional Resources	The script files discussed within may be downloaded as part of the zip file containing this document.
----------------------	---

1 Introduction

The DE9941 is a small demonstration platform for the CMX994 Direct Conversion Receiver, the CMX998 Cartesian Loop Transmitter and the CMX7164 Multi Mode Modem. The DE9941 can be used to demonstrate transmit (Tx) and receive (Rx) performance with QAM, m-FSK and GMSK modulations. The CMX7164 is configured by a Function Image™ (FI) that is loaded to initialise the device and determine modulation type.

The 7164FI-1.x supports GMSK/GFSK modulation, with BT=0.5, 0.3, 0.27 or 0.25. The 7164FI-2.x supports 2-FSK, 4-FSK, 8-FSK and 16-FSK modulations which are root raised cosine filtered with $\alpha=0.2$; optional sinc filtering is also available. The 7164FI-4.x supports 4-QAM, 16-QAM and 64-QAM modulations, root raised cosine filtered with $\alpha=0.2, 0.35$. Custom pulse shaping modulation filters are also supported.

The DE9941 demonstration PCB was primarily aimed at demonstrating QAM, a non-constant envelope modulation, therefore the DE9941 transmitter architecture was based around the CMX998 Cartesian Feedback Loop (CFBL). Due to the nature of how CFBL works it is important to ensure that the PA is switched on and off in a controlled manner and this is correctly aligned with the modulation. This is critical to avoid transient spurs being created which can be problematic when the DE9941 is used in TDMA systems.

History

Version	Changes	Date
1.0	First Issue	01-08-14

Table of Contents

1	Introduction	1
	History	1
	Table of Contents	2
1.1	Applicability	3
1.2	Background Information	3
1.3	Scope of application	3
1.3.1	Non-constant envelope operation (7164FI-4.x, QAM)	3
1.3.2	Constant envelope operation (7164FI-1.x, GMSK; 7164FI-2.x, FSK)	4
1.4	Transient Requirements	5
2	Details of Changes	5
3	DE9941 Results using supplied scripts	9
3.1	QAM Modulation results	10
3.2	4FSK Modulation Results	12
4	Conclusions	14

1.1 Applicability

This document provides guidance to the users of the DE9941. The associated scripts that are referred to in this application note (downloaded as part of the zip file containing this document), will aid the user in evaluating the DE9941 and can be used with CMX7164 FI-1.x, FI-2.x and FI-4.x.

This Application Note references new features in the FIs, from the following and later versions:

- 7164FI-1.0.0.6
- 7164FI-2.0.1.4
- 7164FI-4.0.0.8

The same features will be included in future CMX 7164 Function Images: FI-5.x, FI-6.x etc.

Note: The mod state of a particular PCB can be determined from the Board mod box on the PCB. The number of figures with black dots is the mod state. Mod state 3 is shown thus:

Board Mod			
●	●	●	4
5	6	7	8

1.2 Background Information

Readers are recommended to study the datasheets for the key devices (CMX998, CMX7164), the User Manual for the DE9941 and the CMX998 Cartesian Feedback Loop DC Calibration application note available from the CML web site. This gives a detailed background to the operation of the CFBL system and is the basis for the CMX7164 in-built CMX998 support algorithms.

1.3 Scope of application

This Application Note discusses the origin of transient spurious products that can be generated by a CFBL transmitter, as used in DE9941. It covers a number of related issues that apply in the various modes of operation.

1.3.1 Non-constant envelope operation (7164FI-4.x, QAM)

Evaluation of the DE9941 with 7164FI-4.x revealed significant transient spurious products. Investigation showed that the power amplifier exhibited signs of instability at certain points in its power control range.

The PA (RF5110G, U2 on DE9941) is a general purpose 3.3V power amplifier that has seen widespread use in GSM and cellular applications but can also be used for other radio applications. The RF5110G circuit on the DE9941 was isolated from the rest of the DE9941 circuits for independent investigation. . Using the circuit components from the original RFMD datasheet an excessive amount of small signal gain was observed at 450MHz, while at lower control voltages the gain varied significantly with drive level. It was noted than in later versions of the RF5110G datasheet the application circuit was amended to suggest that some damping should be added to the first stage of the device's amplifier chain, this damping was therefore applied to the DE9941.

Note: The CMX7164 RAMDAC provides the power control ramp to the PA, as shown in Figure 1.

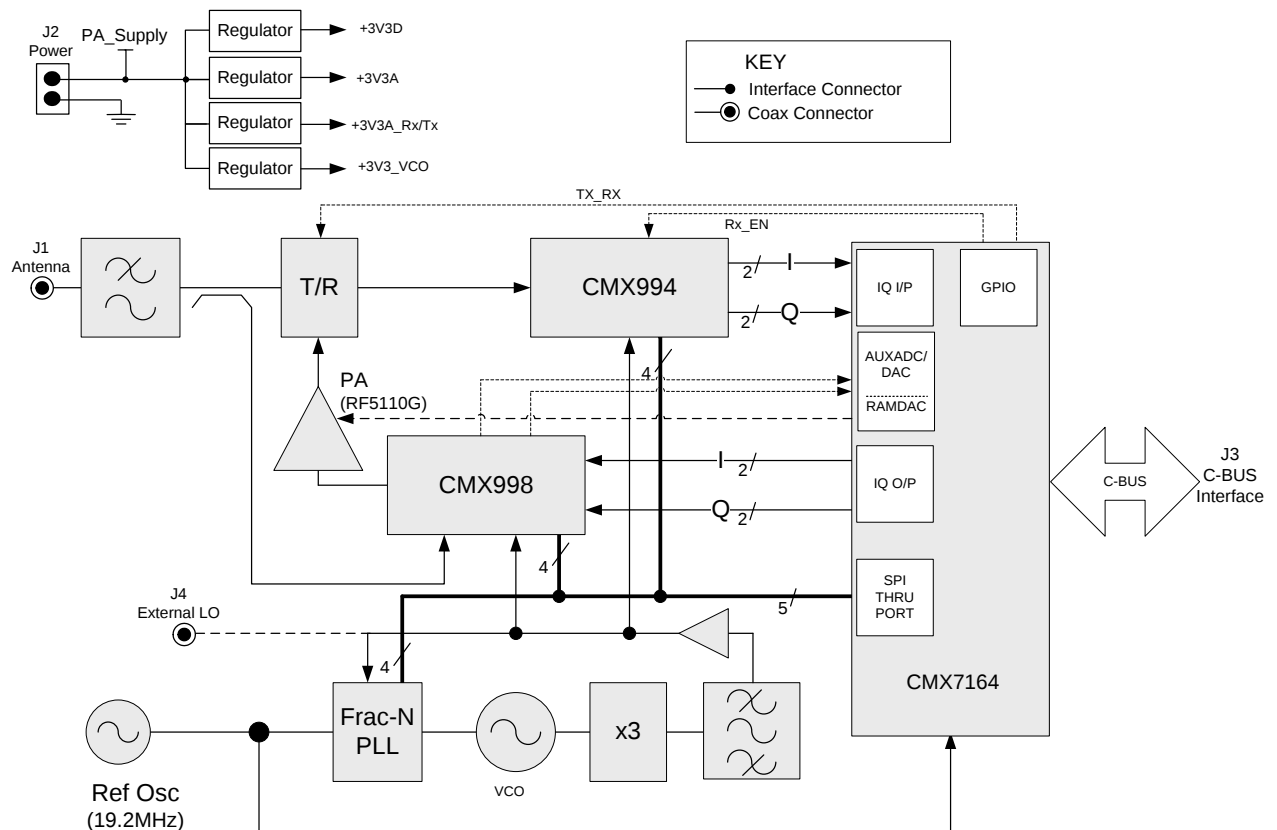


Figure 1 DE9941 Block Diagram

1.3.2 Constant envelope operation (7164FI-1.x, GMSK; 7164FI-2.x, FSK)

The nature of QAM modulation causes the I/Q signal envelope to ramp up at the start of a transmission when symbols are first modulated. Similarly, the I/Q envelope ramps down at the end of the modulation burst. When using a CFBL transmitter if the DC offsets in the loop have been correctly calibrated, this inherent modulation ramping has the effect of reducing on/off transients. FSK and GMSK modulations are constant envelope so they exhibit no inherent ramping effect which tends to result in spurious products at the start and end of the burst unless mitigating measures are put in place.

To explain the issue further, the transients arise because CFBL is a closed-loop system and must acquire correct operating levels when enabled. This acquisition causes a transient. If the CFBL is operated in open-loop mode then this transient isn't exhibited and the system works as a conventional I/Q modulator i.e. the turn-on/turn-off of the RF envelope can be controlled solely by the PA gain control voltage.

It was expected that for constant envelope operation using the Cartesian loop in open-loop mode would largely eliminate the spurious with FSK and GMSK. However it was found that the presence of the loop filter components around the error amplifier cause distortion. This makes it impractical to realise one external component solution that works well in both open and closed-loop modes i.e. a multi-mode solution for QAM, FSK and GMSK. It was therefore necessary to find a different solution that allows the Cartesian loop to operate in closed-loop mode for both linear (QAM) and constant envelope (FSK and GMSK) modulations.

In closed-loop mode the preferred scheme is to set the I/Q signals to bias (DC offset nulled) and slowly enable the PA using the RAMDAC. This allows a controlled acquisition thereby avoiding the transient. In GMSK and FSK modes, initiating modulation creates a transient when the I/Q envelope steps from 0% to 100% (because it does not exhibit the inherent envelope ramping of the QAM modulation filter).

1.4 Transient Requirements

Data systems have a range of emissions requirements. In the USA, FCC requirements specify emissions masks with measurement conditions that may be defined differently depending on the technology.

In Europe, ETSI defines requirements in standards EN 301 166 (6.25 kHz channels), EN 300 113 (12.5, 20 & 25 kHz channels) and EN 302 561 (25, 50, 100, 150 kHz channels). Of these standards EN 300 113 is the most commonly applicable standard for modem designs using the CMX7164.

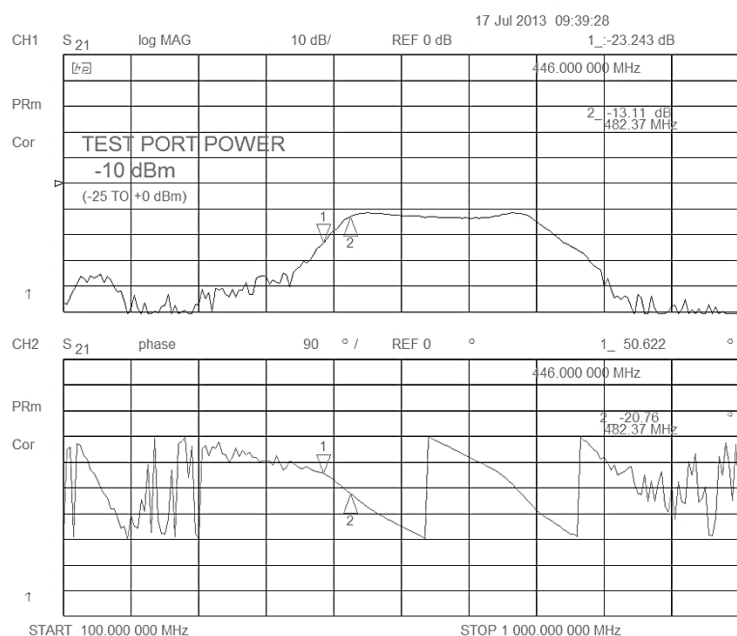
EN 300 113-1 V1.7.1 section 7.9.3.3 specifies the “Adjacent channel transient power measurements”. The definition states: “transient power is the power falling into adjacent (or other) spectrum due to the switching on or off of a transmitter”. The test method only measures the transients in the adjacent channel and the alternate channels. Further, for non-constant envelope equipment only, at 100kHz and 1MHz offsets the applicable limits are no more stringent than -27dBm. The EN 300 113 generic limit for spurious emissions is -36dBm which is measured as a mean power, so transients are not generally a problem. More details can be found in the ETSI EN 300 113-1 which is available free from the ETSI web site. For any product development careful study of the text of the applicable regulatory requirement is recommended.

In this document the measurement method is a composite technique which used peak-hold over a swept band and a limit of -36dBm. This is a worst case requirement that is more stringent than EN 300 113 actually requires. It should be noted that in most cases the un-modified DE9941 meets the formal test requirements of EN 300 113-1.

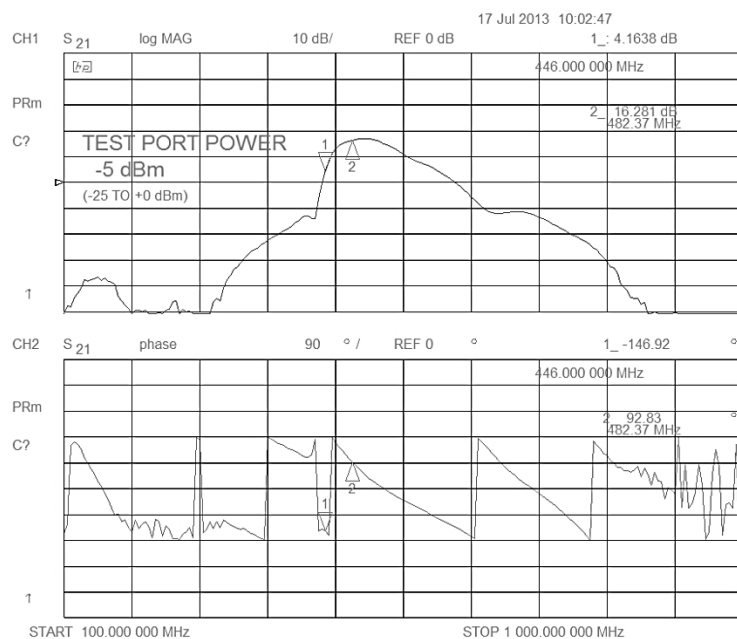
2 Details of Changes

The plots in Figure 2 highlight the very rapid changes in the gain response of the PA at lower control voltages and different drive level without the modifications around the PA. These rapid/steep changes in gain are not desirable and cause rapid changes in the CFBL loop conditions during closed loop operation. Note in all plots marker 1 is at 446MHz.

The plots in Figure 2 show that driving the RF5110G harder flattens the gain response over frequency and the rapid/steep changes in gain are suppressed. The updated RF5110G datasheet recommends an 18 Ohm supply resistor to Vcc1 (the first stage of the PA) instead of the previously recommended 11nH inductor. This change allows first stage saturation to be achieved at the same point as the following stages although it reduces the overall small signal gain. The reduction in RF5110G is beneficial in the DE9941 circuit because there was excess gain using the original circuit, so the reduction will improve transmitter wideband noise.



Drive Level -10 dBm

V_{apc} ~ 2.1 Vdc**Figure 2a**

Drive Level -5 dBm

V_{apc} ~ 1.98 Vdc**Figure 2b**

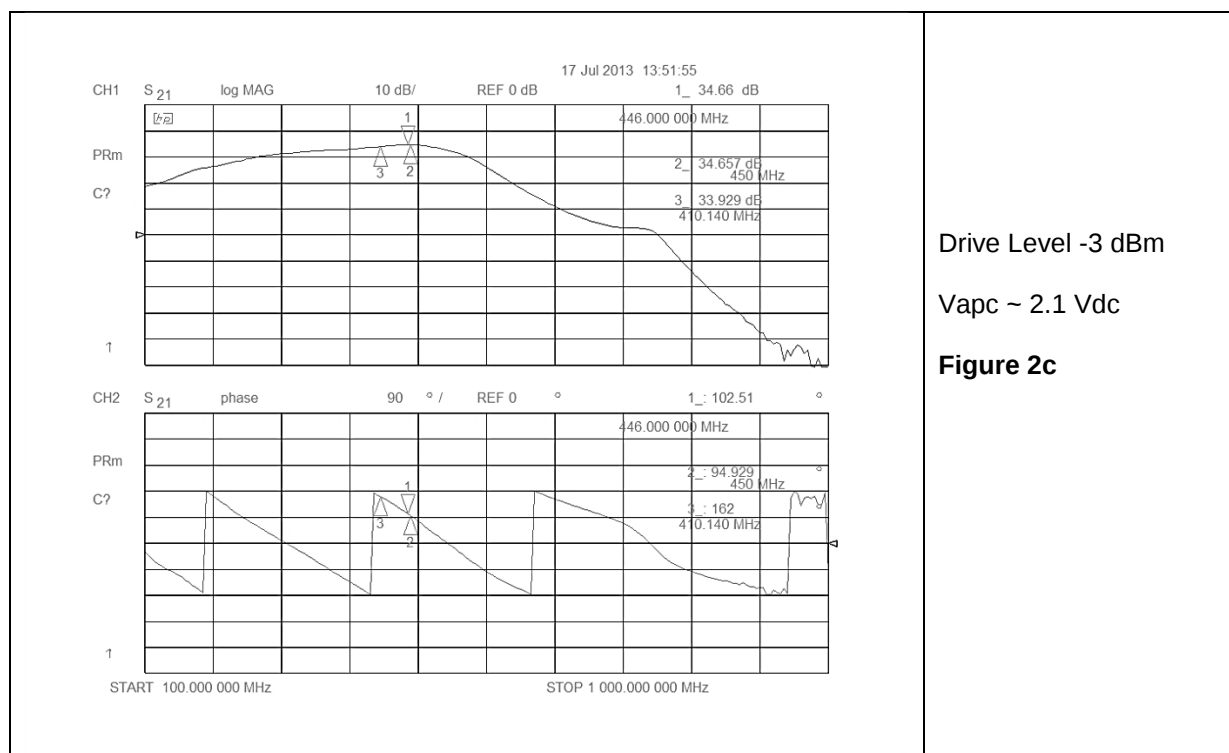


Figure 2 (a, b and c) PA Gain Responses at Different Drive Levels

The following changes are present in the DE9941 to reduce the sharp transitions in the PA's gain response, improve stability over its gain control range and increase the forward path gain (reduce the attenuator at the input to the PA):

1. L2 changed to 18R (was 11nH)
2. C47 changed to 1uF (was DNF)
3. R58 changed to 39R (was 100R)
4. R60 and R61 changed to 150R (was 82R)

These changes are applied as part of 'mod state' 4. It is recommended that all DE9941 of an earlier 'mod states' be modified as above.

A RAMDAC ramp profile was developed to reduce ramping transients. The values are shown in Table 1. The accompanying set-up script shows how to load the RAMDAC profile. It is also necessary to select a suitable scan rate to ensure the PA is turned on sufficiently before applying modulation. For QAM a scan rate of 0x70 is typically used.

0	0	455	460	465	470	475	480
486	494	502	510	516	522	528	534
540	545	550	555	560	565	570	574
578	582	586	590	594	598	602	606
610	614	618	622	625	628	631	634
637	640	643	646	649	652	655	658
661	664	667	670	673	676	679	682
685	688	691	694	697	700	703	703

Table 1 New RAMDAC Ramp Profile (decimal values)

The timing of the RAMDAC (PA) ramp relative to start and end of I/Q modulation also affects transients. The timings have been configured for QAM in Figure 3 and Figure 4. For the ramp up case (Figure 3) the DCMEAS pin output is shown and indicates that 7164 DC calibration routine was applied before the transmission.

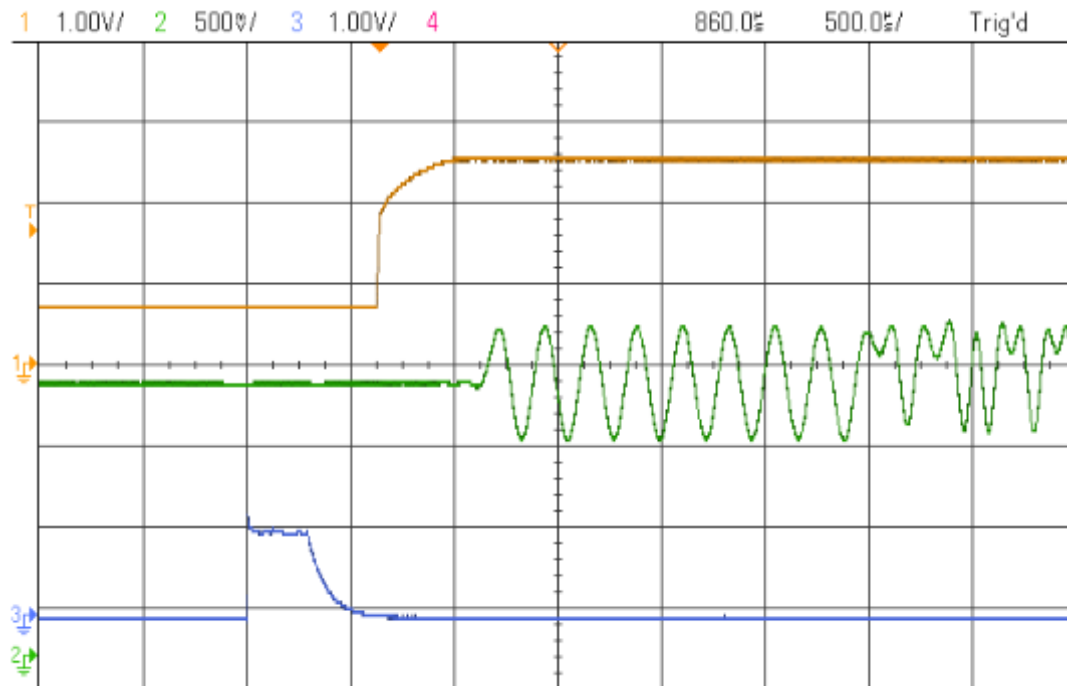


Figure 3 FI-4 PA Control Ramp Up (orange), Modulation Input (green) and DC Meas (blue)

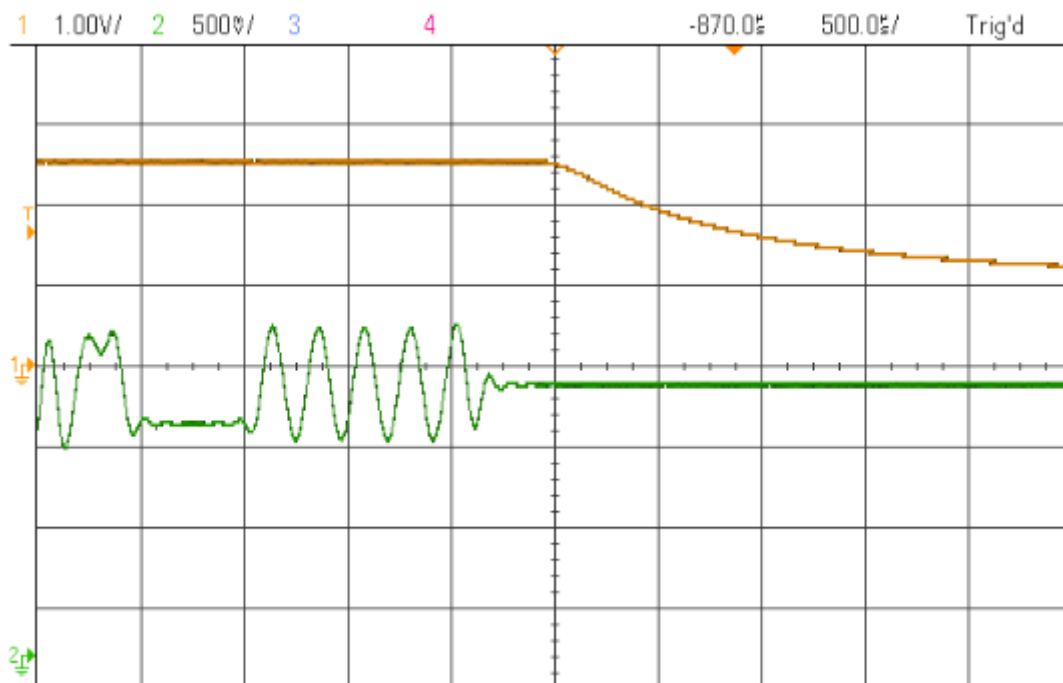


Figure 4 PA Control Ramp Down (orange) and Modulation Input (green)

To support operation with FI-1.x and FI-2.x modulations in closed loop CFBL designs, an I/Q envelope ramp up and ramp down facility has been added. This allows both the I/Q modulation envelope to be ramped and the ramp rate to be selected.

Using the modulation ramp allows the same hardware configuration to be used for the different constant envelope and linear modulation modes. The example scripts supplied with this document demonstrate the principle using FI-1.x, FI-2.x and FI-4.x; various baud rates are also supported. Note: timing have been optimised for a selection of baud rates however for other rates the user will need to adjust for best performance.

Typical plots of the PA ramp with respect to the I/Q modulation with modulation ramping enabled are shown in Figure 5 and Figure 6 with FI-2.x configured for 4-FSK, 9.6ks/s, RRC $\alpha=0.2$ and deviation 2.4kHz.

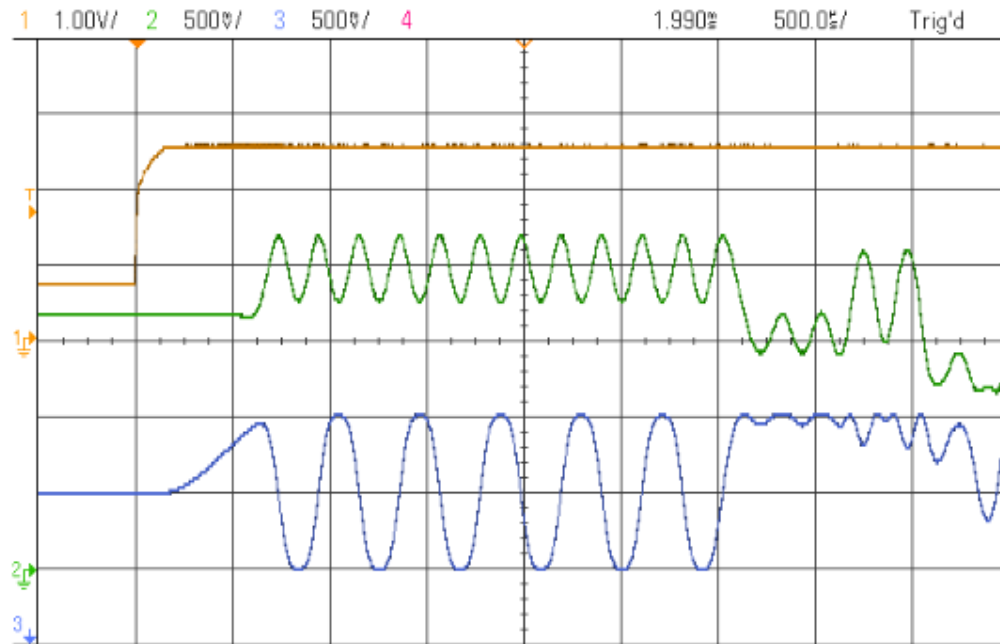


Figure 5 FI-2 PA Control Ramp Up (orange), Modulation Inputs with ramping (green and blue)

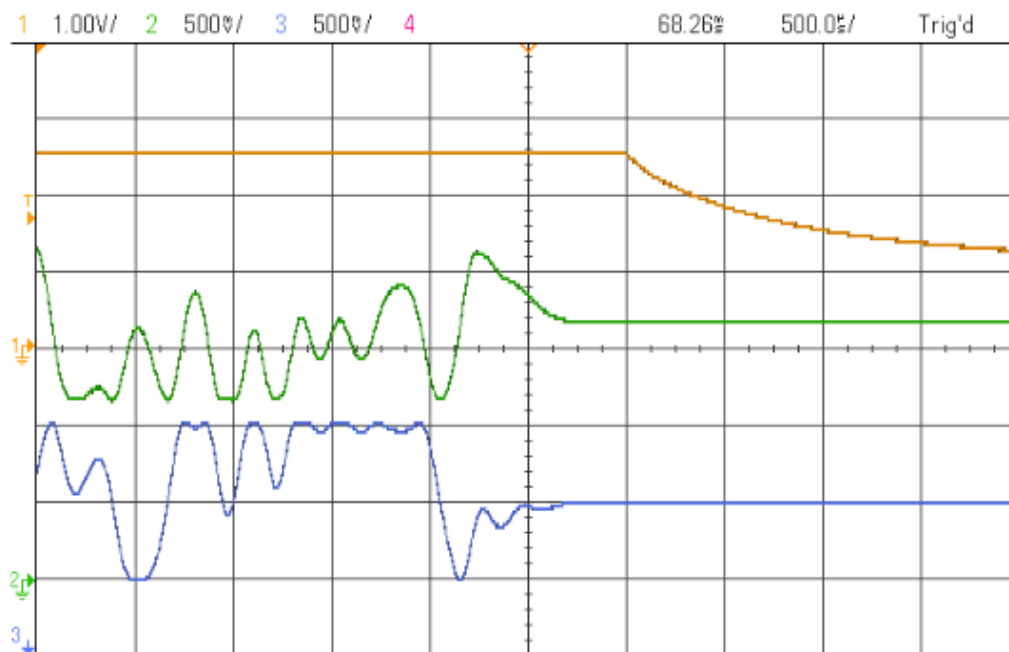


Figure 6 FI-2 PA Control Ramp Down (orange), Modulation Inputs with ramping (green and blue)

3 DE9941 Results using supplied scripts

A DE9941 mod state 4 PCB was evaluated using the QAM and FSK FIs from section 1.1 and the supplied scripts. The required FI must be loaded into the DE9941 before running the scripts.

Setup_Tx_Rx_DE9941.pes – This script must be run first. Select the Mod Size 4, 16 or 64 for QAM and 2, 4, 8, or 16 for FSK), the FI (1, 2 or 4), the baud rate from the values given in the CMX7164 User Manual, Rx or Tx operation, and Tx configuration for the DE9941.

Tx_only_test_DE9941_DCcal_pes – Select the FI, the number of bursts to be transmitted and the number of blocks per burst. Select whether the DC calibration is applied before every burst or at the start of every 50 bursts.

The results herein have been taken over 500 bursts of 10 blocks of payload data (payload data sent each burst is $10 \times 14 \text{ bytes/block} \times 8 \text{ bits/byte} = 1120$ bits of payload) plus the preamble/tail bits sent additionally to the payload. The values of these are set in the *Tx_only_test_SDR_DCcal_x.pes* script; see the CMX7164 datasheet for details. For example in the case of QAM the default length of preamble and tail have been used so the total bits sent is 64 preamble, 1120 payload and 4 tail bits which equals 1188 bits), therefore the burst length is approximately 38 ms based on a baud rate of 18 ks/s with 4-QAM, yielding an over air bit rate of 32 kbps. The off time between bursts is approximately 100 ms.

3.1 QAM Modulation results

The results in Figure 7 to Figure 11 are for 7164FI-4.0.0.8 producing 4-QAM, 18ks/s, RRC $\alpha=0.2$ in “transient mode”, i.e. when transmitting multiple, separate modulation bursts.

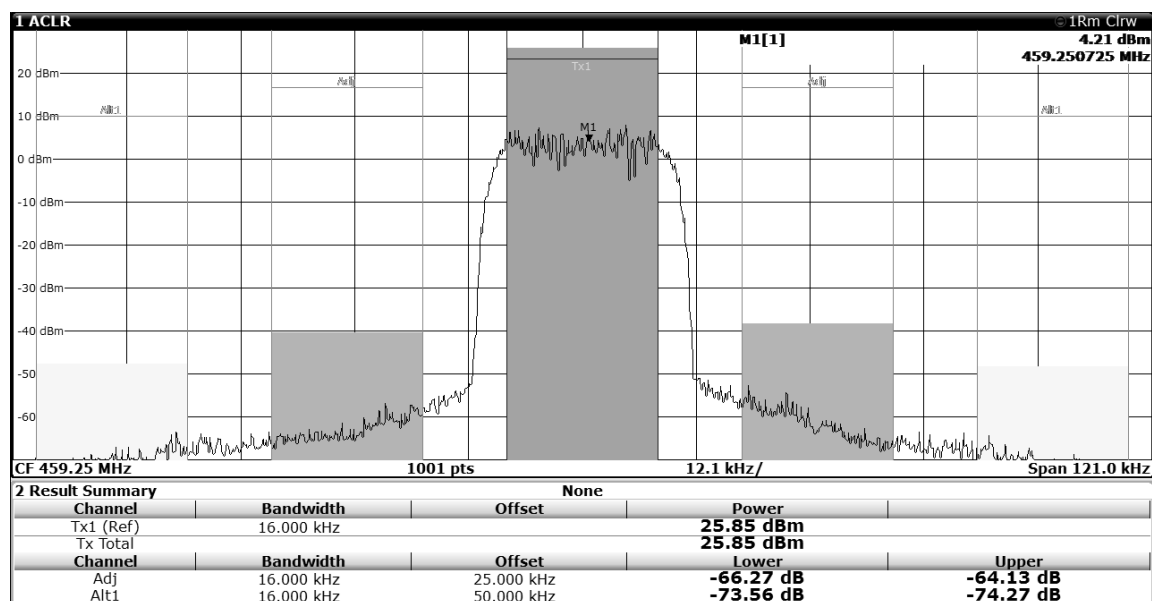


Figure 7 Tx ACP with 4-QAM in Transient Mode, 459.25MHz

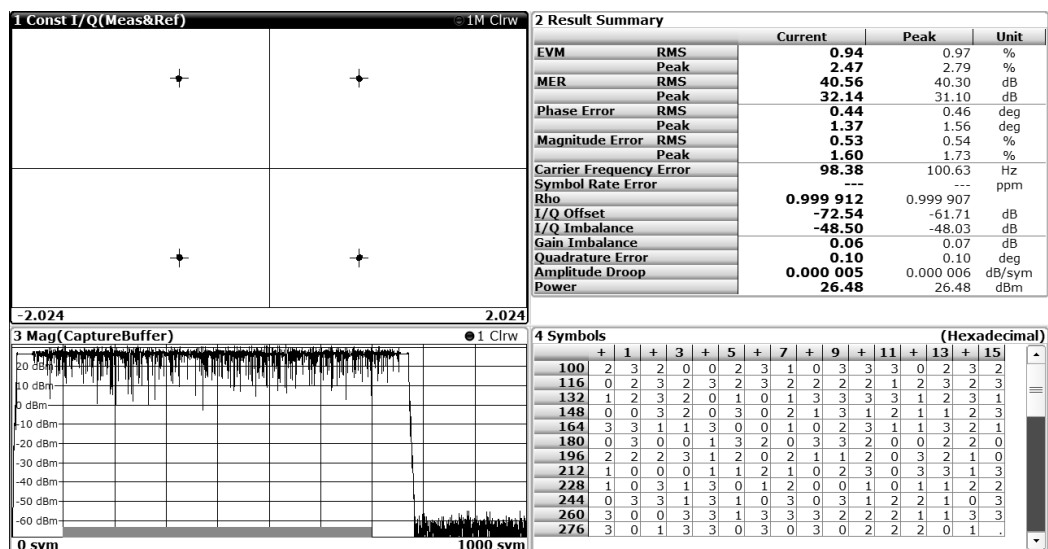


Figure 8 Tx Vector Accuracy with 4-QAM in Tx Transient Mode, 459.25MHz

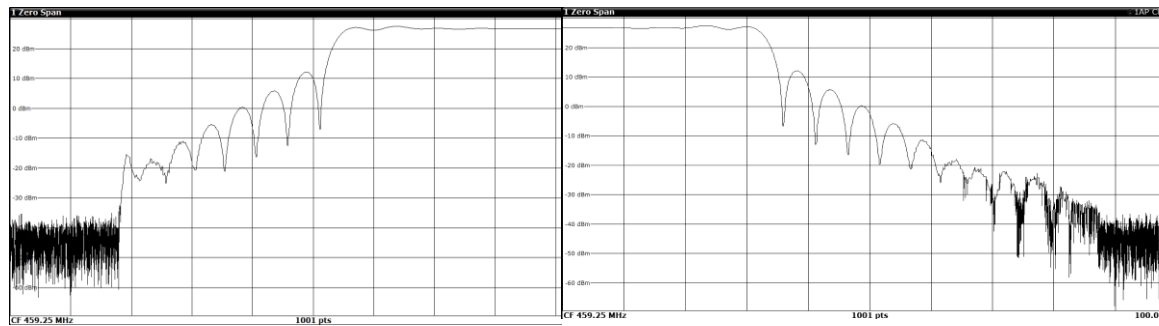


Figure 9 Tx Ramp Up and Ramp down with 4-QAM

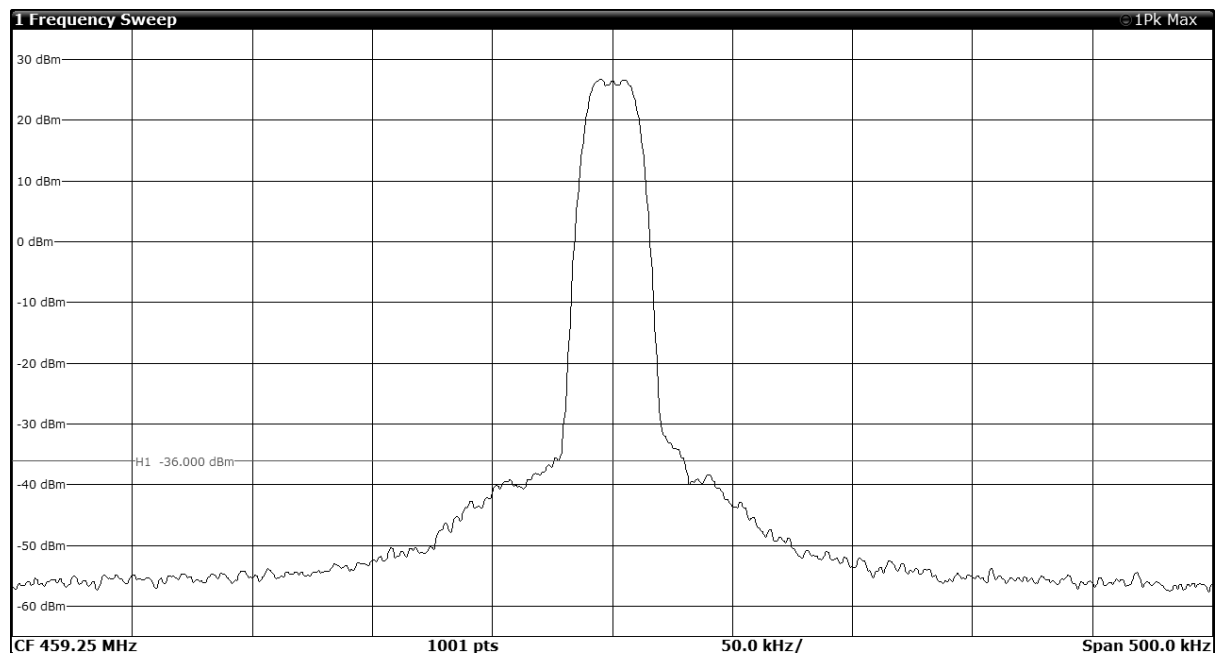


Figure 10 Tx Spurious in Transient Mode, 500kHz Span, 459.25MHz

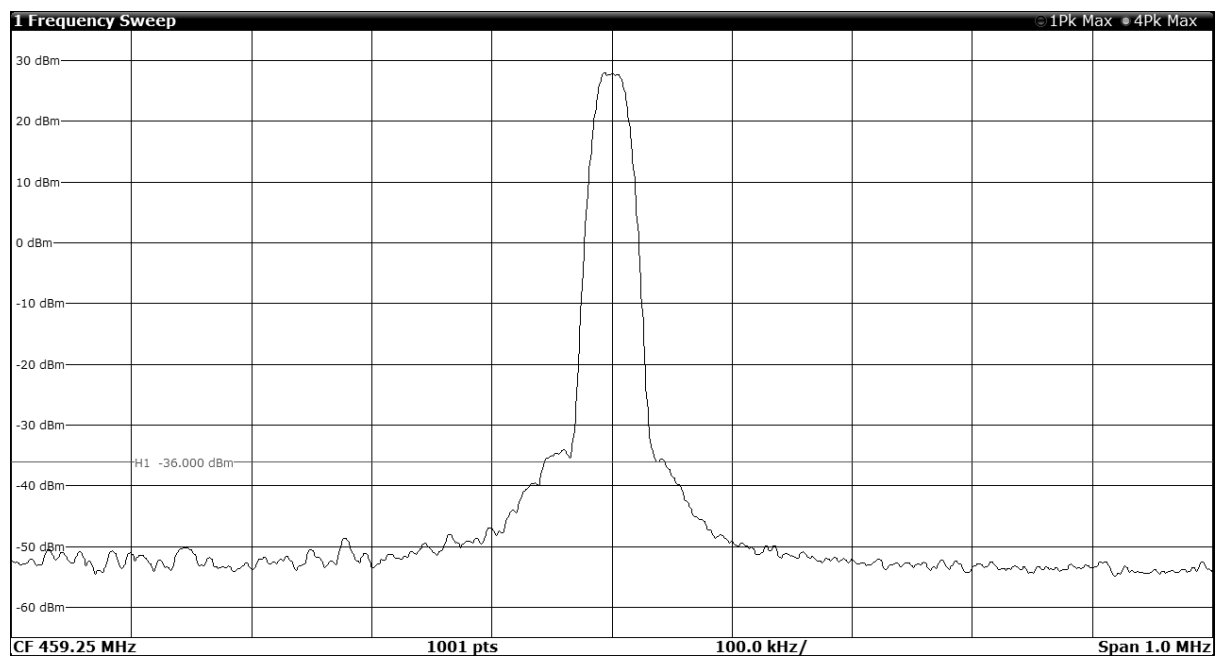


Figure 11 Tx Spurious in Transient Mode, 1MHz Span, 459.25MHz

3.2 4FSK Modulation Results

The plots in Figure 12 and Figure 13 compare the 7164FI-2.0.1.4 Tx transient performance with and without modulation envelope ramping.

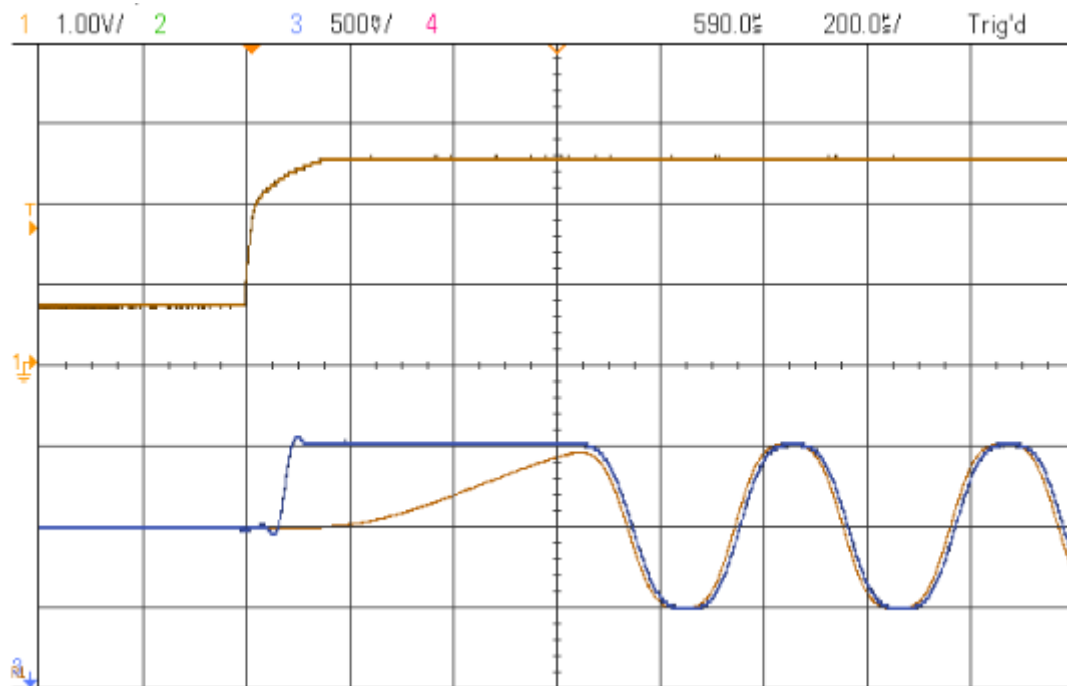


Figure 12 4-FSK Tx PA Ramp (orange) and modulation input (brown with mod ramping and blue without)

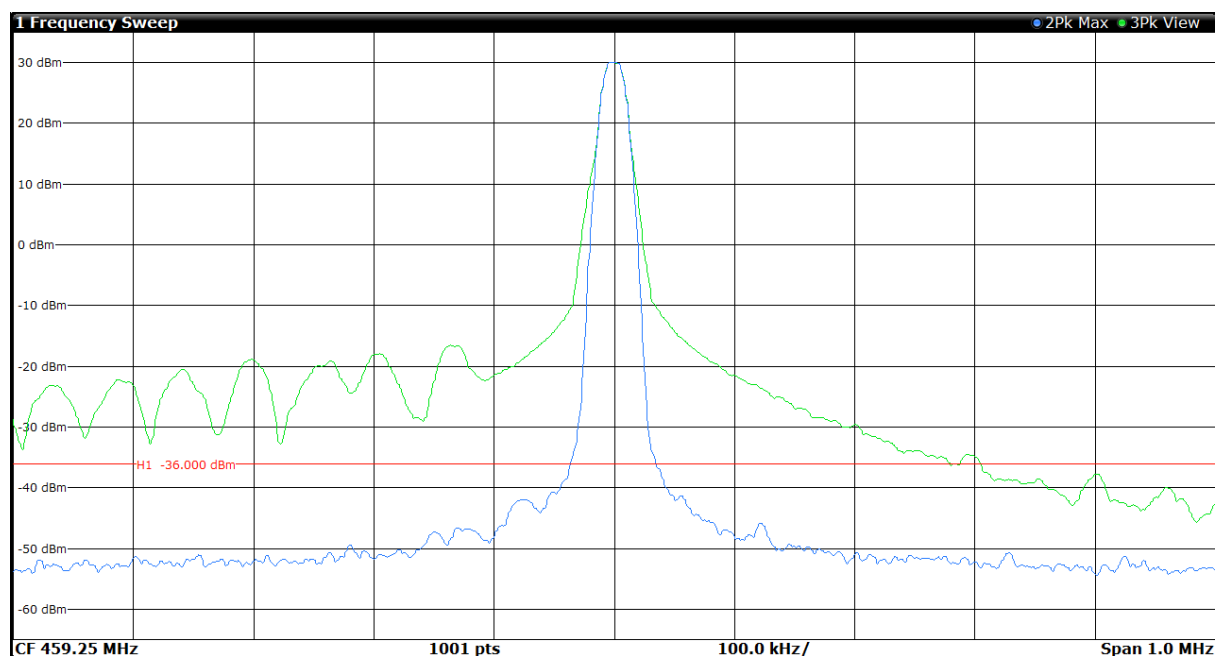
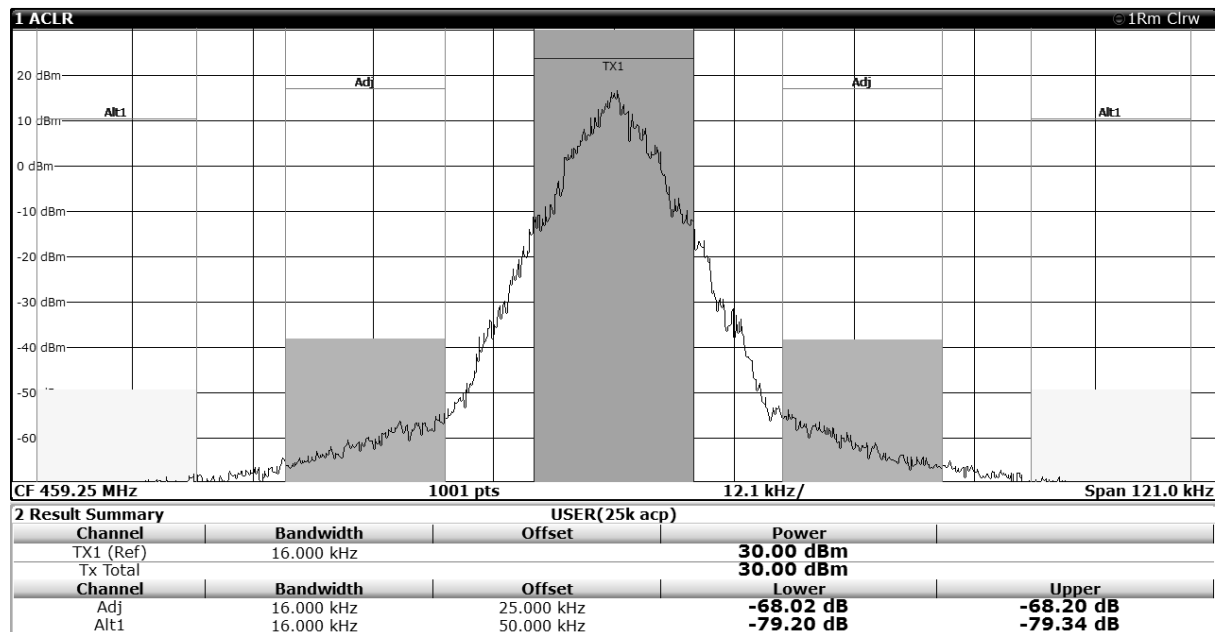
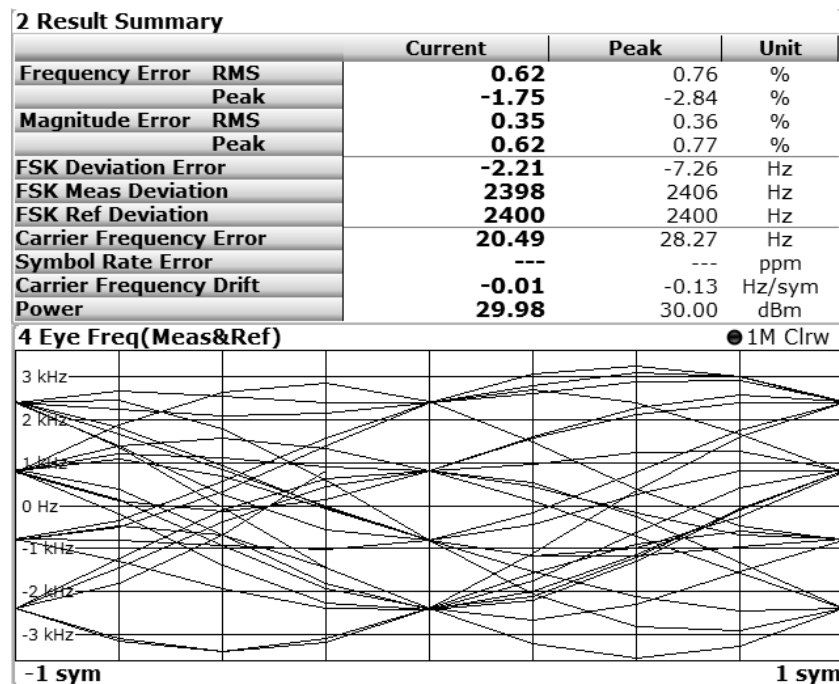
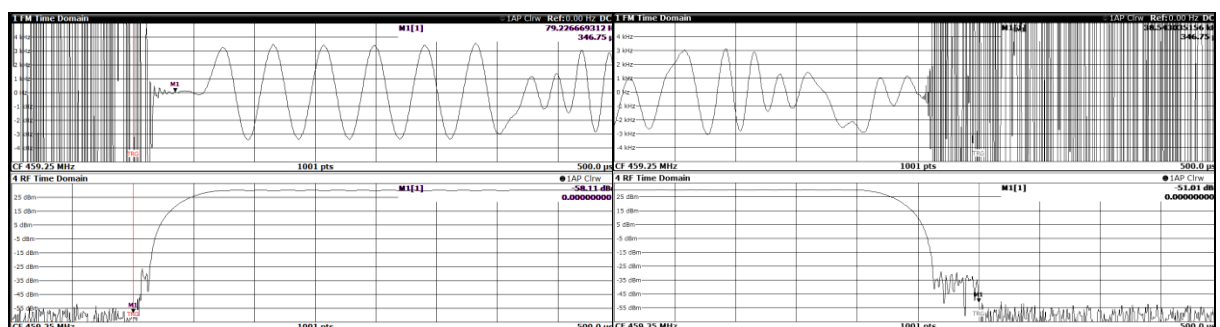


Figure 13 4-FSK Tx Transient Spurious 1MHz Span with (blue) and without (green) modulation envelope ramping

The plots in Figure 14 to Figure 18 show the 7164FI-2.0.1.4 performance with modulation envelope ramping with 4-FSK, 9.6ks/s, RRC $\alpha=0.2$ and deviation 2.4kHz.

Figure 14 FI-2 Tx ACP with 4-FSK, 9.6ks/s, RRC $\alpha=0.2$ in Transient Mode, 459.25MHzFigure 15 FI-2 Tx Vector Accuracy with 4-FSK, 9.6ks/s, RRC $\alpha=0.2$ in Transient Mode, 459.25MHzFigure 16 FI-2 Ramp Up and Down with 4-FSK, 9.6ks/s, RRC $\alpha=0.2$, 459.25MHz

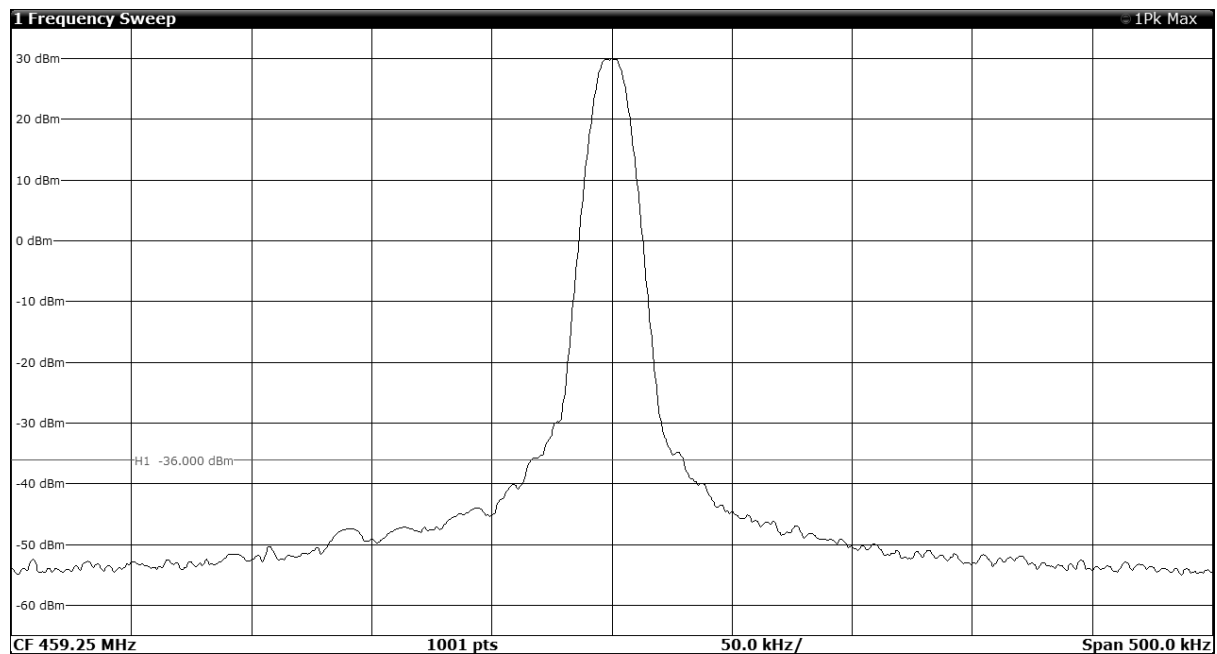


Figure 17 FI-2 Tx Spurious in Transient Mode, 500kHz Span, 459.25MHz

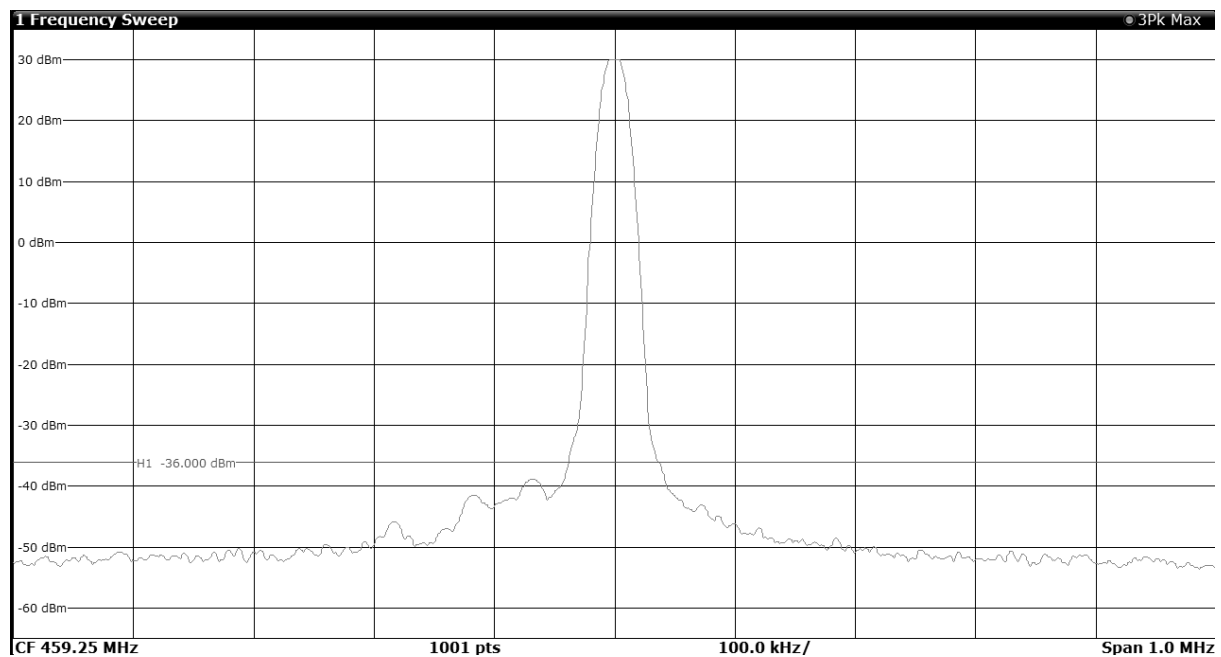


Figure 18 FI-2 Tx Spurious in Transient Mode, 1MHz Span, 459.25MHz

Similar tests have been applied with GMSK using 7164FI-1.0.0.6 and the same good transient performance has been observed.

4 Conclusions

For good transient performance the recommended (see section 1.1) or later FIs should be used with the modulation envelope ramping feature enabled for FSK and GMSK.

The Tx transient performance of the DE9941 has been improved to comfortably meet spurious requirements.

CML does not assume any responsibility for the use of any algorithms, methods or circuitry described. No IPR or circuit patent licenses are implied. CML reserves the right at any time without notice to change the said algorithms, methods and circuitry and this product specification. CML has a policy of testing every product shipped using calibrated test equipment to ensure compliance with this product specification. Specific testing of all circuit parameters is not necessarily performed.

 CML Microcircuits (UK) Ltd COMMUNICATION SEMICONDUCTORS	 CML Microcircuits (USA) Inc. COMMUNICATION SEMICONDUCTORS	 CML Microcircuits (Singapore) Pte Ltd COMMUNICATION SEMICONDUCTORS
Tel: +44 (0)1621 875500 Fax: +44 (0)1621 875600 Sales: sales@cmlmicro.com Tech Support: techsupport@cmlmicro.com	Tel: +1 336 744 5050 800 638 5577 Fax: +1 336 744 5054 Sales: us.sales@cmlmicro.com Tech Support: us.techsupport@cmlmicro.com	Tel: +65 62 888129 Fax: +65 62 888230 Sales: sg.sales@cmlmicro.com Tech Support: sg.techsupport@cmlmicro.com
- www.cmlmicro.com -		