CML Microcircuits

COMMUNICATION SEMICONDUCTORS

Application Note

Two-Point Modulation for dPMR using the CMX7041

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1 Introduction

Two-point modulation is a simple and effective technique used for many years to provide baseband frequency modulation for various modulation formats. The move to continuous phase modulation in many radio systems has led to the adoption of different modulation techniques, principally I/Q vector modulation for many applications. As a result the art of two-point modulation has been somewhat neglected and many RF engineers, who have only worked with some of the more recent systems, are unfamiliar with the simplicity and benefits of the two-point scheme.

This document explains the basics of the two-point scheme in section 2 and goes on (in section 4) to show a practical example of the scheme for the low-cost digital PMR system known as dPMR. The dPMR system is defined in ETSI standard TS 102 490 [1]. Radio parameters are measured to the co-existence standard EN 301 166 [2]. The demonstration uses the CMX7041 modem IC to generate the modulation and control the two-point operation.

This document focuses on the CMX7041 device however the two-point modulation techniques can be used with a number of ICs from CML including:

FX829
CMX881
CMX882
CMX883
CMX7031
CMX7041
CMX7032
CMX7042

2 Contents

3 Introduction to Two-Point Modulation

In principal, frequency modulating a radio frequency (RF) signal is straight forward, requiring just a voltage controlled oscillator (VCO) connected to the modulating signal. The frequency of the RF signal is varied in a direct relationship to the modulating voltage.

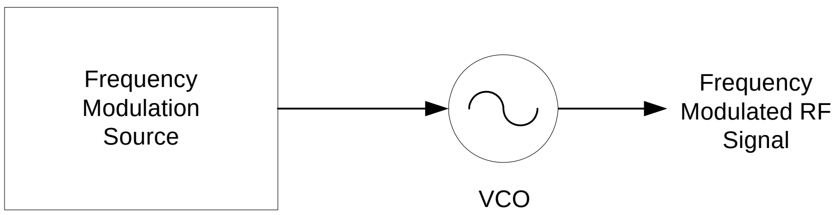

Figure 1 – FM Modulation

For various practical reasons a VCO is rarely used alone as a signal source in modern radio systems, however a VCO controlled by a phase locked loop is a common and practical signal source. The basic scheme is shown in Figure 2, the divide by N means the RF output frequency is N times the reference. This allows the output frequency to be selected simply by changing the N divider.

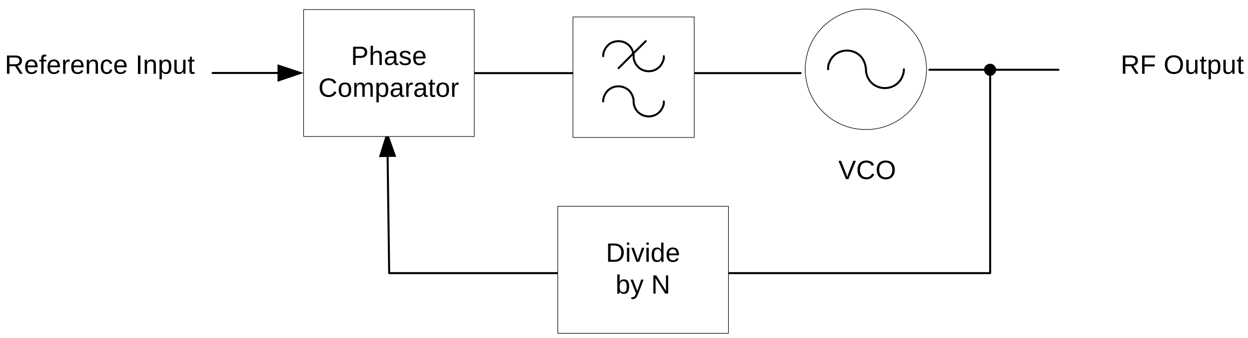

Figure 2 – Phase Locked Loop (PLL)

If the baseband modulation is now applied to the VCO, the Phase Locked Loop (PLL) has an impact on the response. Consider the case of a DC voltage applied to the VCO - the PLL will act to adjust the frequency back to the intended operating frequency by adjusting its control voltage. This correction will have a time constant controlled by the bandwidth of the loop filter. If an AC signal is applied to the VCO, the loop will attempt to remove the applied signal however if the loop filter is narrow. Relative to the modulating frequency, the loop effectively can not rapidly track the modulating signal so output signal becomes modulated.

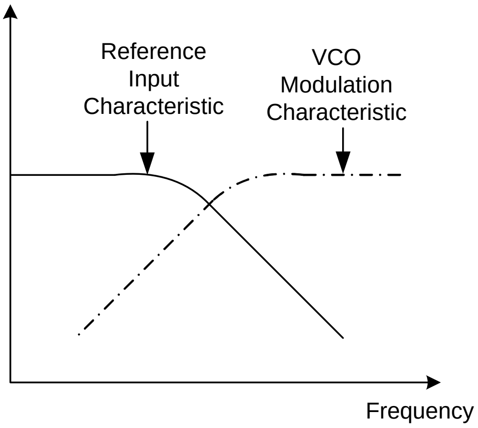

Figure 3 – Modulation characteristics of VCO and Reference modulation in a PLL

The PLL can modulate low frequency signals if the reference is modulated. A small deviation of the reference input signal would be multiplied by N resulting in a FM deviation at the output. In this case the PLL can only follow the reference as long as the frequency changes are relatively low. It turns out that the characteristics of VCO and reference modulation, within a PLL, are the inverse of each other (Figure 3). Thus if both the reference and VCO can be modulated a frequency modulated RF signal can be achieved with a flat modulation characteristic from DC to some practical limit for the VCO. The only thing that needs to be arranged to make this work is that the deviations caused by the two modulations are matched. This can usually be achieved by suitable gain scaling of the modulating signals as shown in Figure 4.

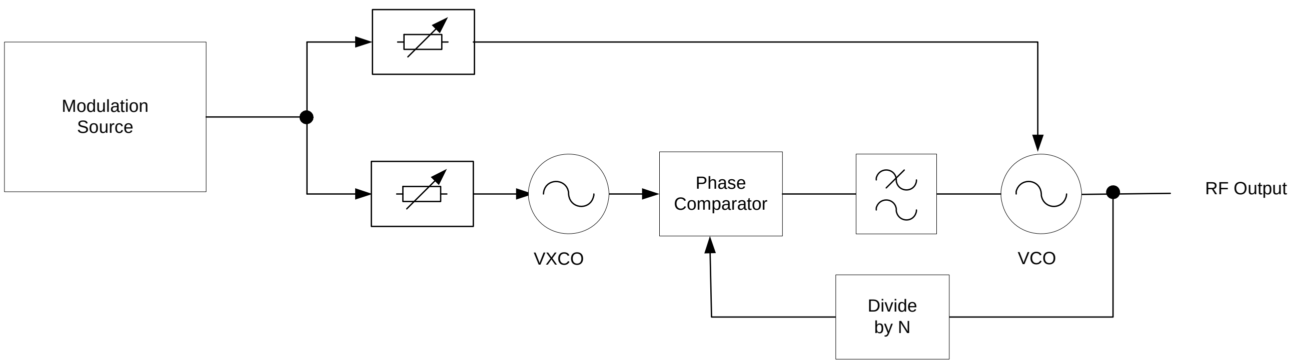

Figure 4 – Two-point Modulation of a PLL

This scheme has been used as the basis of many FM radios for many years. Prior to the use of fully digital modulations a number of schemes were used for signalling that used low frequency tones requiring modulation down to DC (e.g. the DCS system). Digital systems also often require DC coupling where specific steps are not taken to ensure that long runs of the same symbol do not occur in the modulation. A simplified block diagram of such a transceiver is shown in Figure 5.

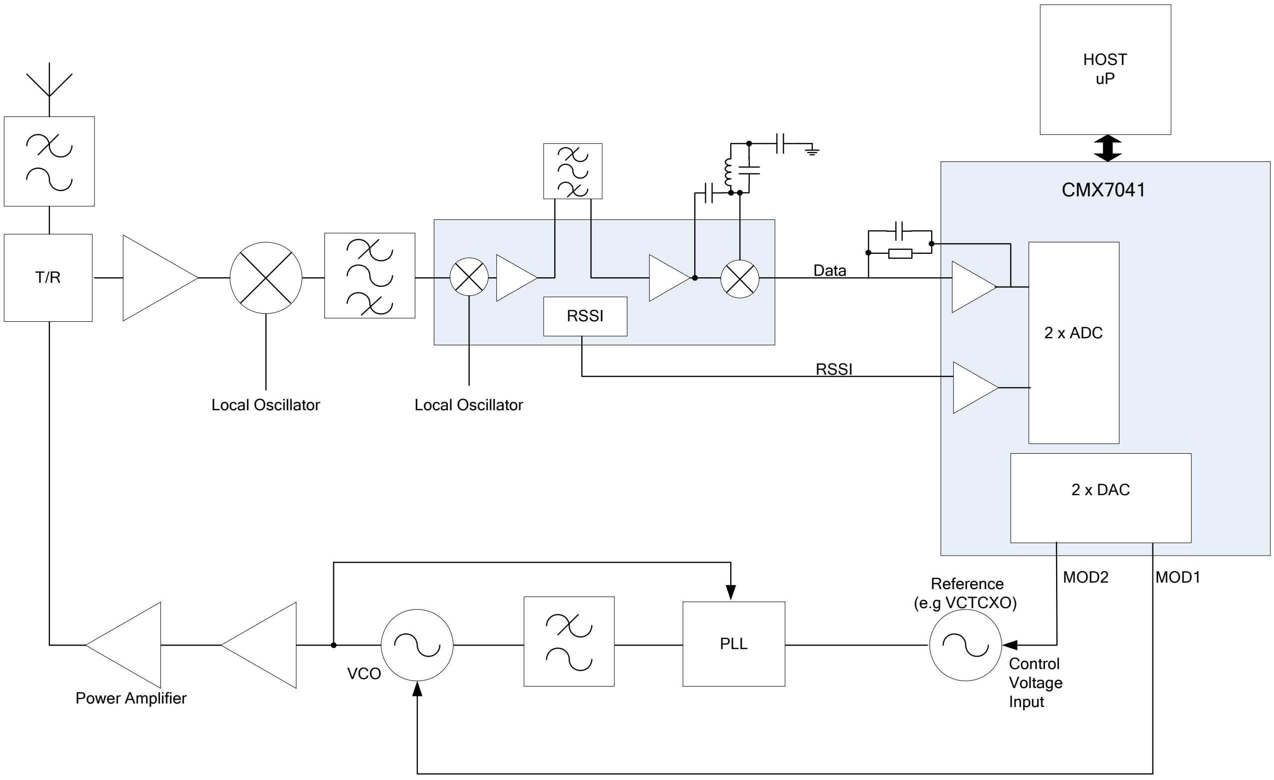

Figure 5 – Radio Transceiver using the CMX7041 implementing two-point modulation

4 Two Point Modulation Implementation for dPMR

The dPMR system [1, 2] is designed as low cost digital alternative to PMR446 radios. For dPMR to be cost competitive it is necessary that low cost transmitters and receivers are available. The CMX7041 offers this opportunity using the architecture shown in Figure 5.

The following sections demonstrate a practical two-point modulator for dPMR that can be implemented at very low cost.

4.1 Hardware configuration

The test setup uses a test PCB for CMX7xxx devices on which 2-point modulation options are implemented (internal reference PCB569A). A schematic of the relevant circuits is shown in Figure 6.

Circuit Description

The test circuit used a PLL based on a CMX7031 IC to implement the RF synthesiser. The CP1OUT port (Figure 6) comes direct from the CMX7031 charge pump output. The loop filter components implement a third order response. R141 and C105 provide an extra roll off, however this was not required in these tests.

The CMX7041 has two modulation outputs, MOD1 and MOD2. The level of these outputs can be controlled independently, so balancing of the 2-point modulation can be done in software without the need for a hardware adjustment. MOD1 is connected to the VCO and MOD2 to the 19.2MHz VCTCXO.

R192 and R193 provide a potential divider for the VCO modulation voltage. The actual voltage supplied to the varactor (D19) is very small as the deviation required is only just over +/-1kHz. A separate modulation varactor is used in this design to avoid the complexity of adding the VCO modulation voltage either in the loop filter or to the main VCO varactor. Both these options are possible; a common technique, for example, is to modulate the base of the diode. In this case adequate de-coupling is required for the RF and problems can occur with time-constants as the high frequency response of the modulation must be preserved. The complexity of these solutions can be avoided for the cost of an extra varactor.

The VCO is a negative resistance type with the main resonator using L14 – an air core inductor. The output is sent via C115 with a buffer amplifier (TR12). The MMIC (U28) provides an output level of +7dBm after the output attenuator. The attenuator is also used to provide a feedback for the PLL (Signal RF1-450), which is then capacitively coupled to the CMX7031 PLL.

The modulation of the reference is achieved in this example with a VCTCXO. The control voltage comes from MOD2 output from the CMX7041. The VCO used needs to be correctly centred. The test system used a 3.3V VCTCXO requiring 1.65V DC for nominal operating frequency (19.2MHz). Depending on the reference oscillator used it may be possible to use the DC offset adjustment provided by the CMX7041 to centre the frequency. A more generic solution is shown in Figure **6** where the voltage from an AUXDAC is used to apply a DC correction so the centre frequency can be adjusted. This is done using U22A.

It is often asked if the modulated 19.2MHz signal can also be used as the clock source for the CMX7041. Tests have shown that this works satisfactorily. The deviation of the VCTCXO is small, typically less than 1ppm, this does not case a significant degradation in the modulation generated from the CMX7041.

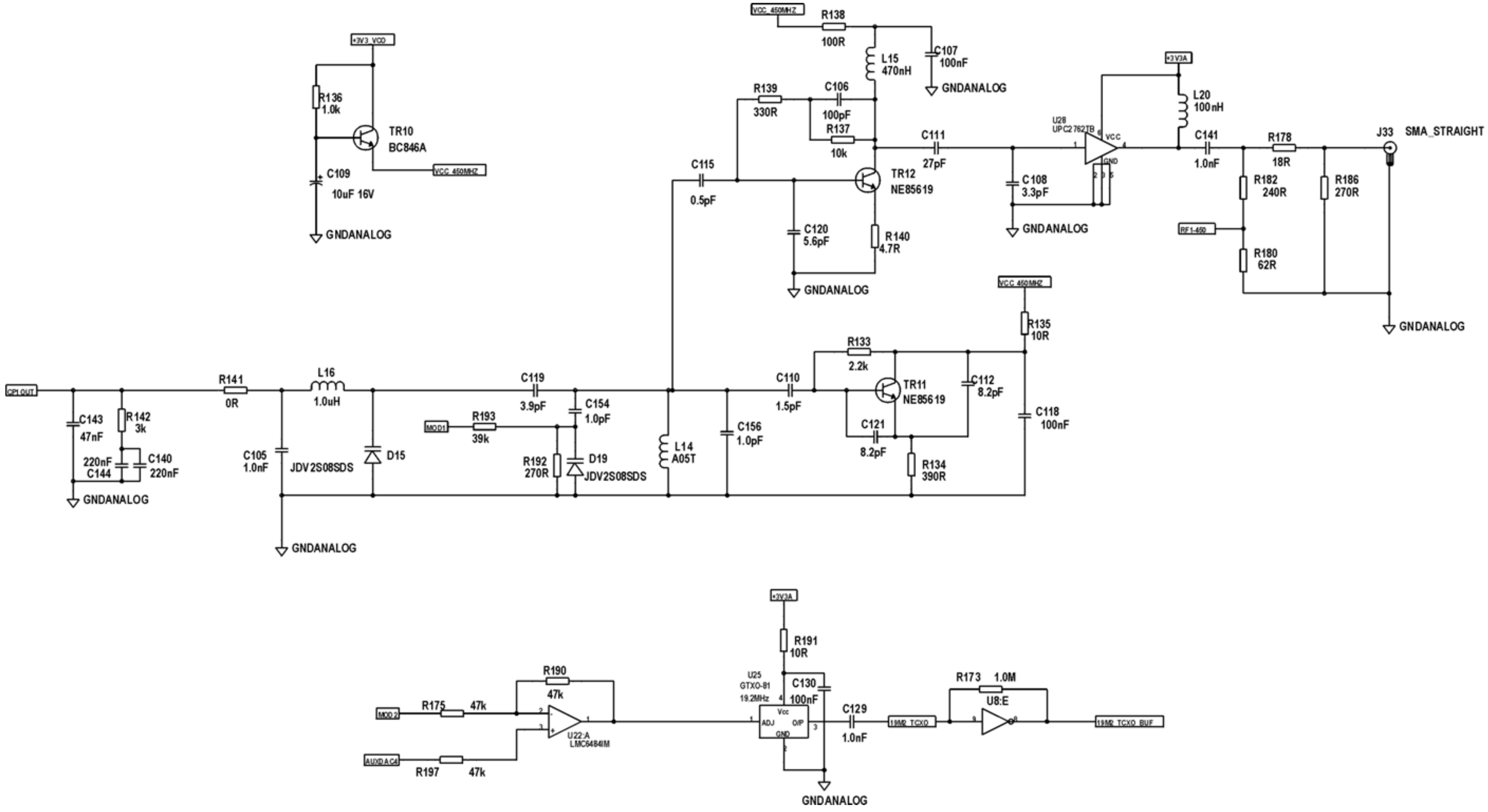

Figure 6 - Schematic of VCO and 2-point modulation circuit

4.2 Adjustment

Adjustment of two-point modulation is a little complex without a host to deliver fixed data patterns to the CMX7041. Normally an alternating sequence of +3,+3,+3,+3, -3,-3,-3,-3 is used. This may be provided as a test mode in future in CMX7041 however it is necessary to balance the modulation using another means. In these tests the following procedure was used:

1. Calculate approximate control voltages required based on VCO / VCTXO parameter (known MHz/V to give the required deviation)
2. Set up MOD1 / MOD2 levels using PRBS data and optimising the eye diagram[1]
3. The dc offset of the VCTCXO can be adjusted using AUXDAC4.
4. Adjust deviation keeping the relative levels of MOD1 / MOD2 constant. The deviation can be set using the pre-amble output and configuring the pre-able to FF (to give symbol -3) or 55 (to give symbol +3). These levels should be set at +/-1.05kHz.

The results can be seen in Figure 7. Following adjustment modulation can be applied

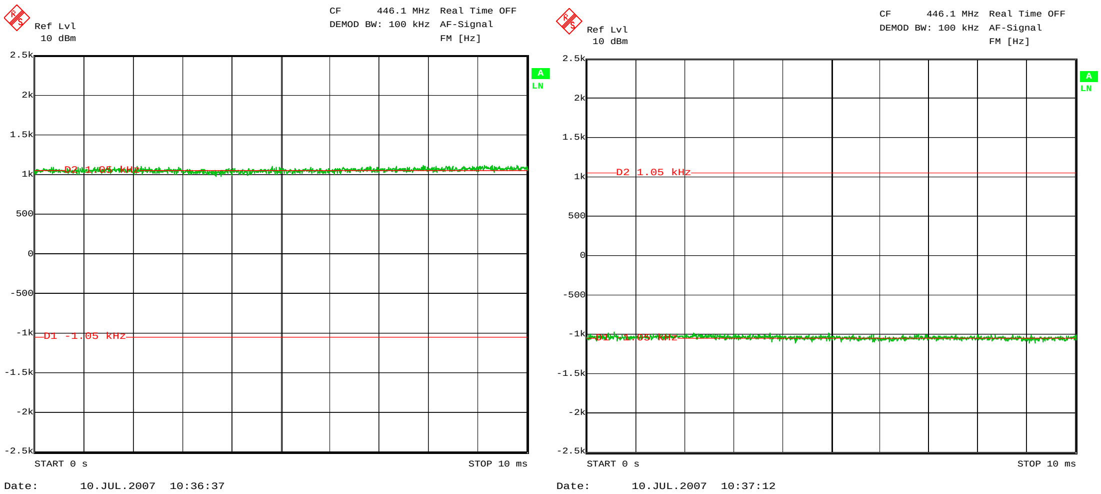

Figure 7 – Modulation with 55 (left) and FF (right) giving +3 and –3 symbols continuously

[1] The dPMR modulation is not supported by many test equipment vendors at present. Were it is not possible to use test equipment to measure the eye diagram the modulating signal can be demodulated by the CMX7041 which provide an eye diagram test output. During initial testing with the CMX7031/41 FI-2, which also provides the dPMR modulation, C4FM modulation (FI-3) was used for eye diagram adjustment as this is widely supported in test equipment.

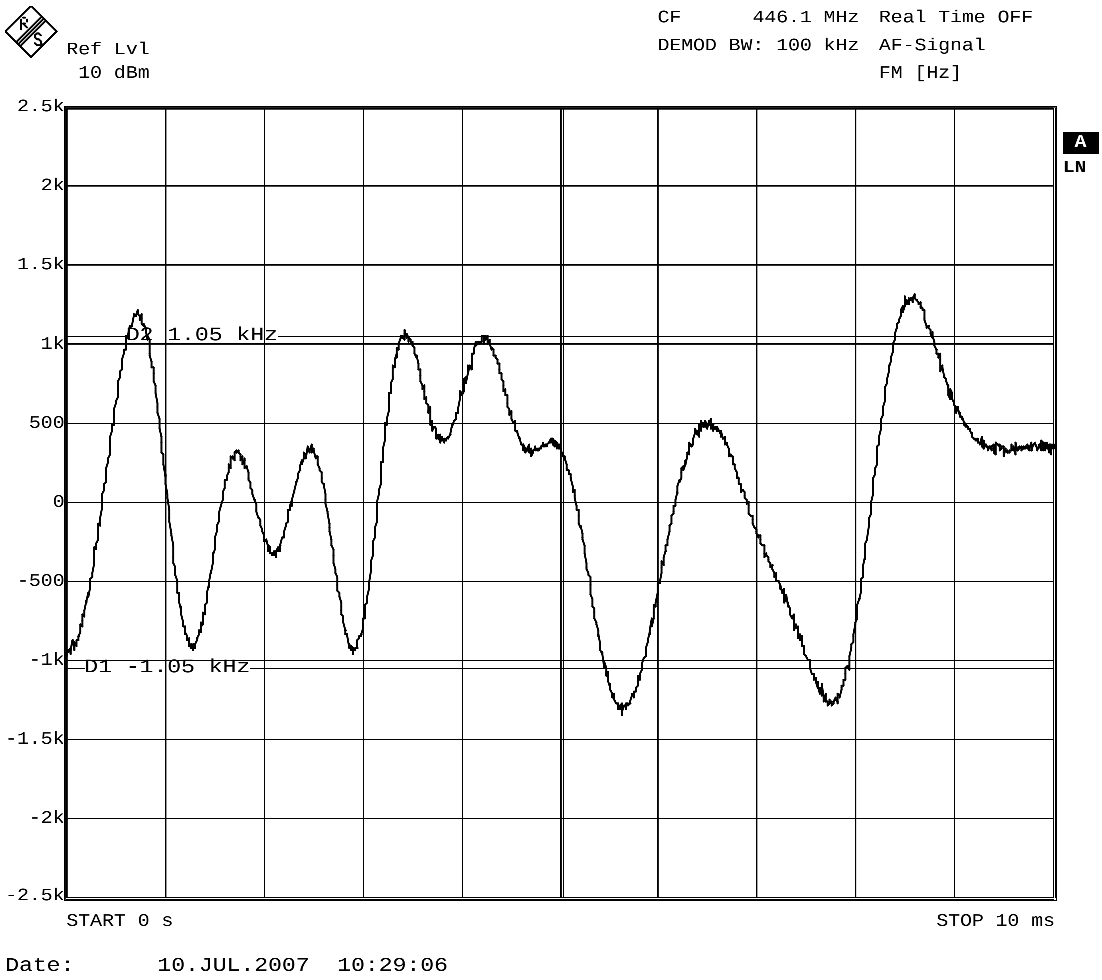

Figure 8 – 4FSK modulation after setting deviation

4.3 Transmitter Spectrum Results

The transmitter spectrum meets the requirements of EN 301 166 (-60dB adjacent channel power) as shown in Figure 9 and Figure 10. The ACP is typically –62dB or –63dB with PLL charge pump current (I_{CP}) of 2.5mA and –64dB or –65dB with I_{CP} of 0.625mA. (NB: The current is selectable in the CMX7x3x synthesisers).

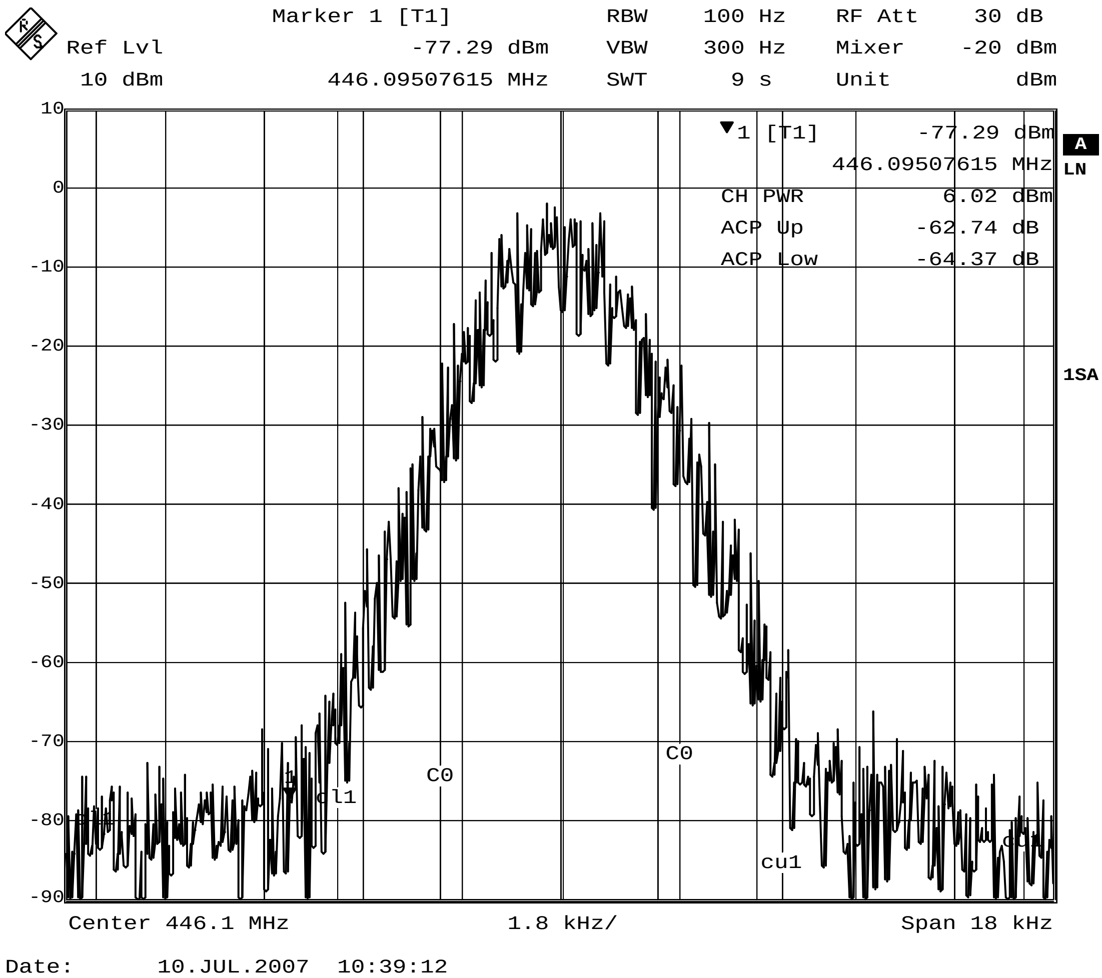

Figure 9 – Modulation spectrum with I_{cp} = 2.5mA

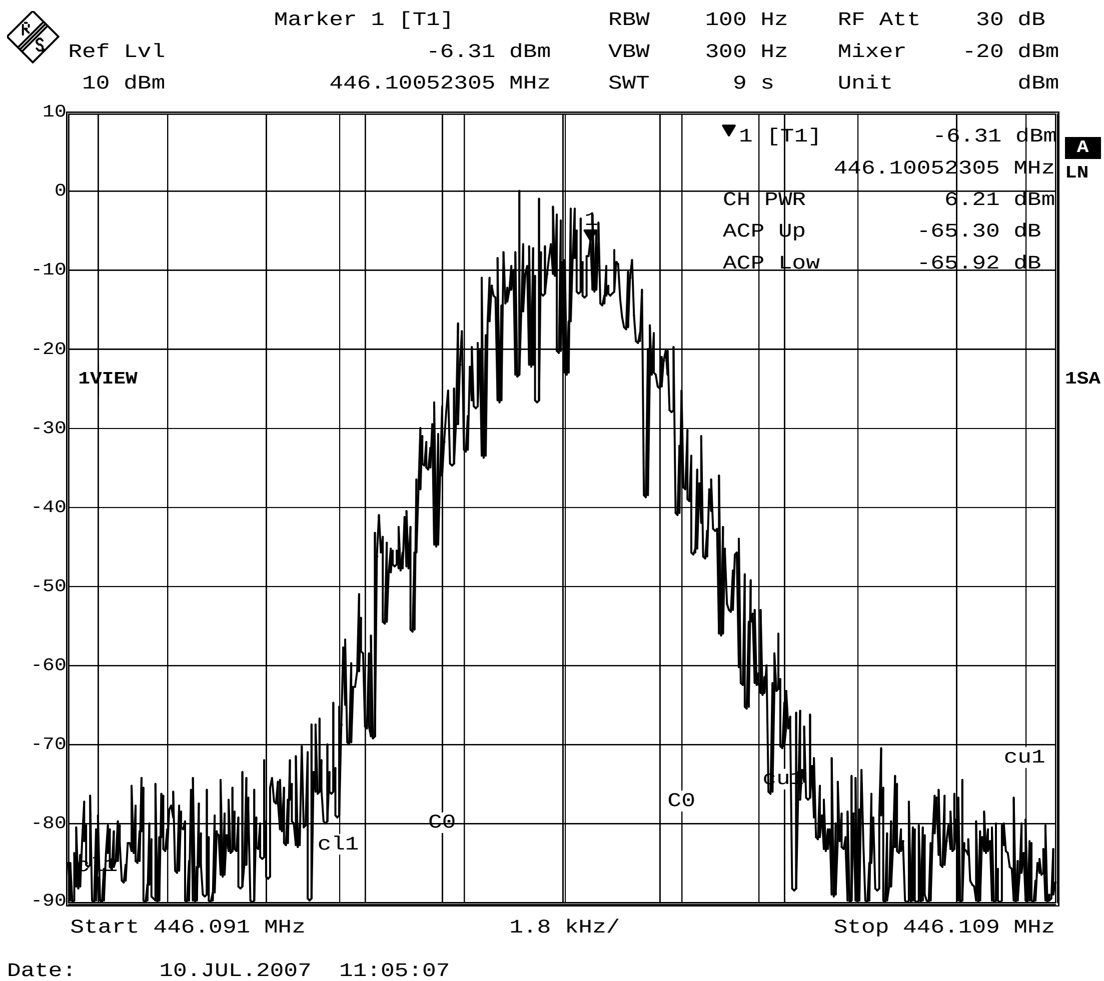

Figure 10 - Modulation spectrum with I_{cp} = 0.625mA

The output is very clean, as would be expected with VCO modulation, the only significant spurii being harmonics. Harmonics will require removal after the power amplifier with a low-pass filter. Results are shown in Figure 11 and Figure 12.

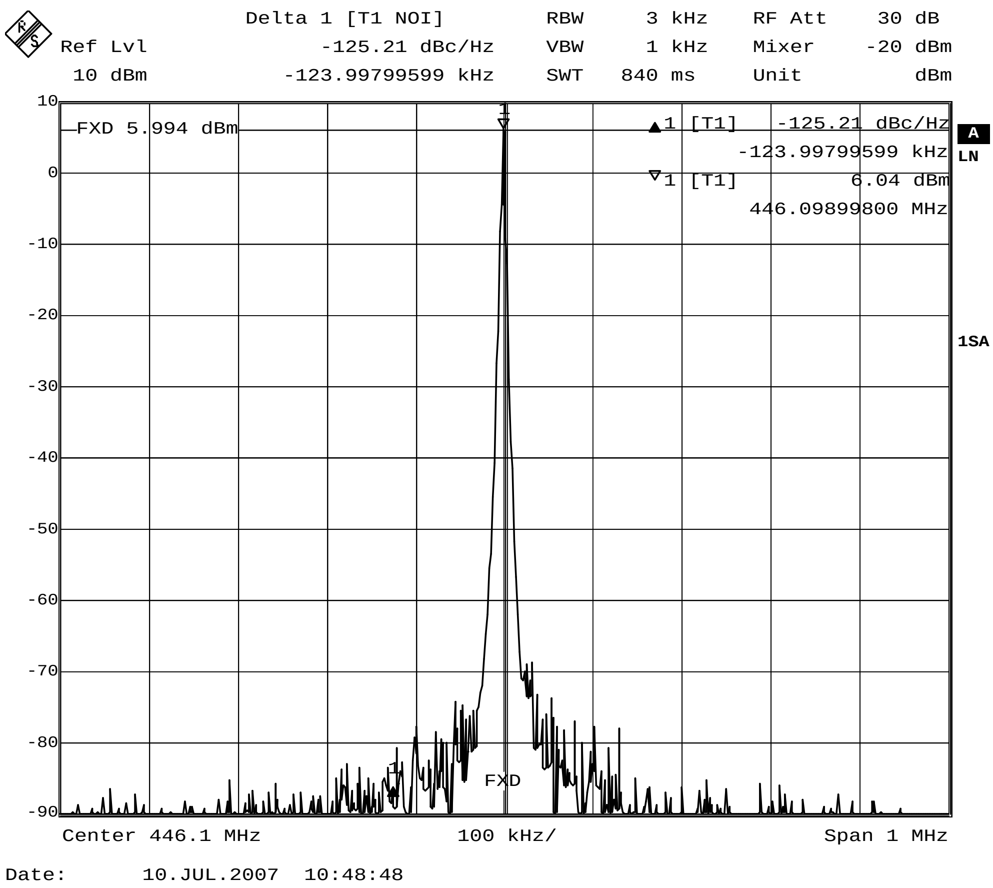

Figure 11 – Modulation spectrum on 1MHz span showing lack of spurious products

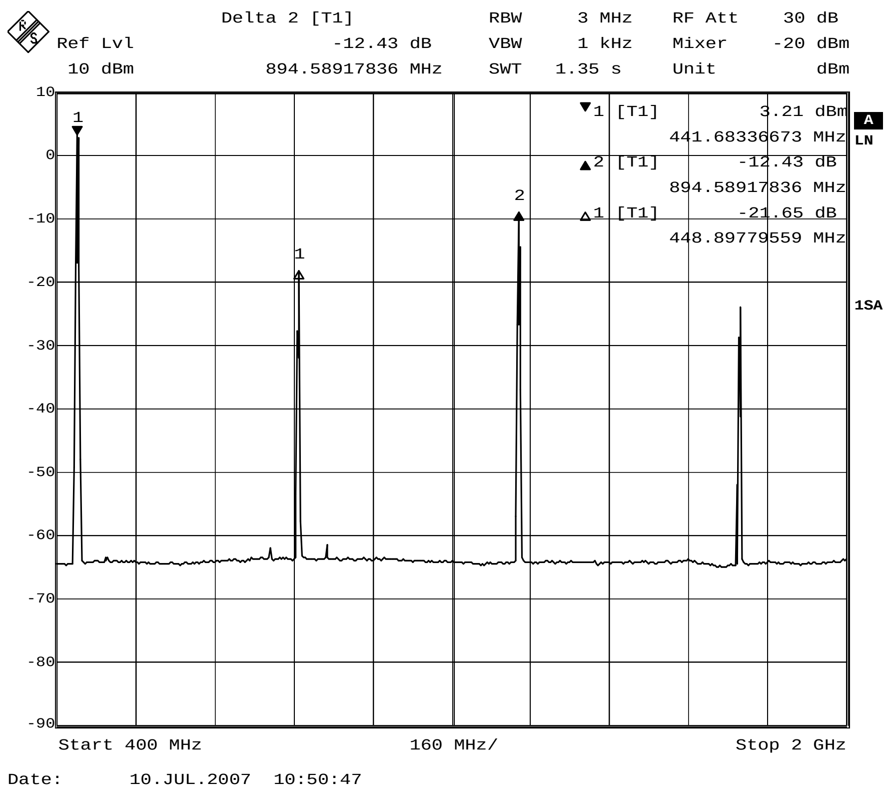

Figure 12 – VCO Harmonic levels

5 Conclusions

This document has demonstrated the practicality and simplicity of the two-point modulation system. While not appropriate for modulation requiring the transmission of absolute phase information, it remains an attractive low cost solution for modulations like analogue FM, 4FSK, GFSK etc.

The CMX7041 with a two-point modulated transmitter and FM discriminator receiver is a effective, practical and low cost solution for dPMR.

6 References

[1] "Electromagnetic compatibility and Radio spectrum Matters (ERM); Peer-to-Peer Digital Private Mobile Radio using FDMA with a channel spacing of 6,25 kHz with e.r.p. of up to 500 mW", TS 109 490, V1.3.1 (2007-04)

[2] "Electromagnetic compatibility and Radio spectrum Matters (ERM);Land Mobile Service; Radio equipment for analogue and/or digital communication (speech and/or data) and operating on narrow band channels and having an antenna connector;", EN 301 166 V1.2.1 (2007-07)

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