UHF Range and B/G Test Channel for Channel Converters

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ABSTRACT: *The authors have studied the oscillation frequencies in the modulators and channel converters in a Head End for cable TV. The standards used are channel 46 from the UHF range of B/G and the test channel is (n). The study of the work is the digital signals with a one-circular chain PLL and they are made from modules forming both analog and digital signals.*

Keywords: CATV/HFC, BER, PLL, Transmodulator, Upconverter

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1. Introduction

The forming of the group signal in the Head End is done in few ways – in serial, parallel and mixed connection of the channel converters' outputs (UpC – in the common case for Downstream) by using splitters and taps. The necessary level of group signal in the whole operating frequency range of the CATV/HFC systems is achieved by:

• Connecting of an electronic amplifier between the output of the last summator and the coaxial (trunk) cable in the CATV system;

• Connecting an optical transmitter (with built in amplifier) between the output of the last summator and the optical fiber/splitter in dependence of the architecture of the cable distribution system.

Regardless which of the two methods is used (CATV or CATV/HFC) the stability of the carrier frequencies (f_{pc}, f_{sc} for analogue AM-VSB signals and f_c for the digital M-QAM signals), as well as of the intermediate frequencies (IF_{pc}, IF_{sc} and IF_c), is from an essential importance for a reliable, qualitatively and seamlessly transmission of information to the subscribers.

There are several methods for supporting the stability of the carrier (channel and intermediate) frequencies of the analogue and digital signals (PLL, DLL, DCM, HRC/IRC), but in the basis of most of them is the PLL (Figure 1), where the stability of the output frequencies is defined mainly by the stability of the reference oscillator (RO). The signals from RO and VCO (voltage controlled oscillator) are feed to a phase detector (PD), who is determining the phase relationships between them. If the signals are in phase, the variation of the output voltage is equal to zero. If there is a phase difference between the two signals, alterations in the output voltage ($\pm\Delta U$) occur, whereat the variations are proportional to the phase difference ($\pm\Delta\varphi$).

With the most complicated phase detectors can be also determined the sign of mismatch of the phases. By a low pass filter (LPF) that eliminates the high frequency composites of the voltage from the PD, ($\pm\Delta U$) go on the VCO. If the LPF is missing, we observe the "Jitter" effect – a sharp variation of the output voltage's fronts. The VCO produces phase corrected sync signals, one of which is used as an input signal for the PD. Because the frequency values of the VCO and RO are different ($f_{VCO} >> f_{RO}$), it is necessary to include frequency dividers (integer and fractional), by which f_R and f_{VCO} become comparable, which itself allows their comparison in the PD. The change of the output frequency of the VCO is performed step-by step programmatically, controlled via microprocessor μP, as a being set different values of the dividers by I^2C bus or SPI bus [1], [2], [3].

The control can be accomplished in any module or for any modules from an outside/standalone block, in which the μP [4], [5], [6]. is situated. In the first case the μP needs to be built in every module [4], [7], [8].

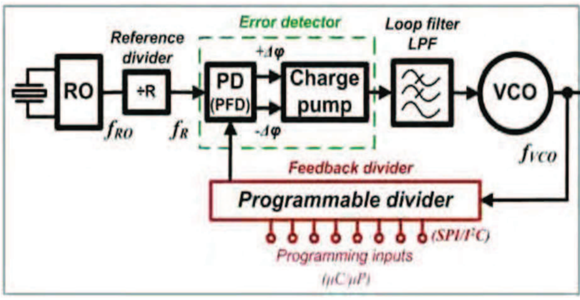

Figure 1. PLL block diagram

2. Problems Leading to Instability of the Oscillator Frequencies

As it is of significant importance to maintain the carrier frequencies constant in time (lack of detuning until the operator decided to change them), it is required to show, analyze and research the problems, which can lead to their instability.

The causes, which can lead to detuning of the carrier frequency/-ies and are not dependent on the kind of the signals (analogue or digital), which a certain module processes, modulates and converts by frequency. They can be connected with different factors, but their influence is only in the frequency determining, and converting elements: integral circuits, capacitors, diodes, inductances, resistors, quartz resonators and etc., which build VCO; Mixer; divider; PD; RO, and 1 even $\mu P/\mu C$ as well as SMPS.

One of the main reasons, which can cause the unwanted alternation of the carrier frequencies is the so called "cold solder", since all elements are being soldered to a printed circuit board (PCB). Furthermore, in the multilayer PCD with bad metallization of the openings or breaking of a track on the PCB again some frequency determining circuits will not work at all or partially. Other reasons are the manufacturing tolerances of the parameters of the elements, which appear after a certain period of operation of the modules, temperature dependencies, and damage in the very frequency determining elements, change of power voltages and etc.

The above mentioned reasons affect, however, differently the modules for analog and digital signals. In the present paper are researched the influences of the adjacent lower (n-1) and upper (n+1) channels in the testing channel (n). In the most channel converters (UpC) the receipt of the channel frequency is done by the upper setting of the oscillation frequency:

$$f_{out} = f_{ch} = f_{osc} - IF, [MHz]. \quad (1)$$

This way, for example, for AM-VSB modulator (Figure 2) a synchronization with PLL occurs only with the second sound intermediate frequency ($IF_{sc,2}$) , which for B/G standard is 5, 5MHz, while for D/K it is 6, 5MHz. However, the oscillator frequency

IF_{pc} 38, 9MHz, through which is obtained the first sound intermediate frequency IF_{sc} (B/G→33,4MHz and D/K→32,4MHz), does not synchronize. By change of the oscillator frequency with $\pm\Delta IF_{pc}$, also IF_{sc} changes and after a frequency convertion can be caused an unfavorable influence (disturbance) in the adjacent upper channel (*n*), (Figure 3).

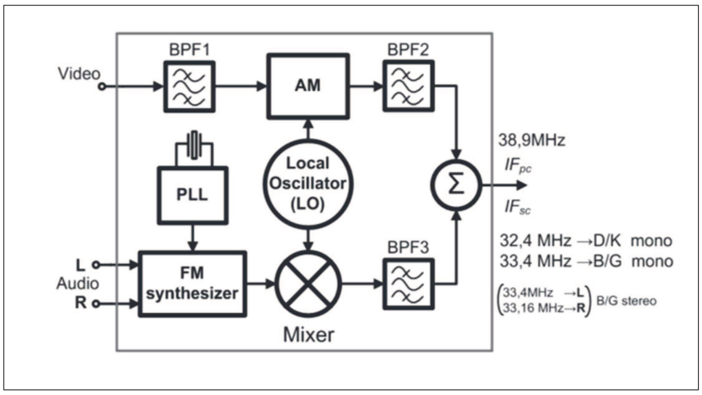

Figure 2. Simplified AM-VSB modulator block diagram

$$IF_{sc} = f_{osc} - IF_{sc,2}, [MHz] \quad (2)$$

$$IF_{sc} = (f_{osc} \pm \Delta f_{osc}) - (IF_{sc,2} \pm \Delta IF_{sc,2}), [MHz] \quad (3)$$

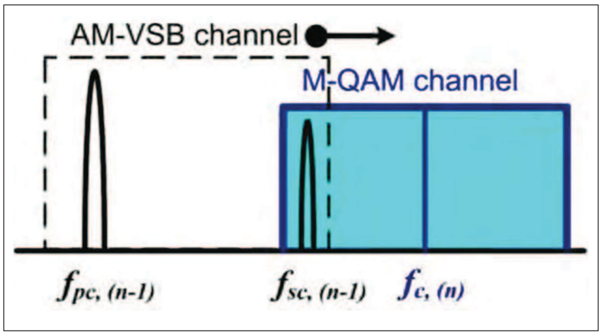

Figure 3. Unfavorable influence in the adjacent upper channel (n)

The synchronization of IF_{pc}, respectively f_{pc}, is performed with bi-circular chain PLL in UpC (Figure 4), as through first circle of the PLL, IF_{pc} and the programmable synthesizer stabilize the frequency of VCO. Through the second circle, the program able synthesizer, the VCO, Mixer 1 and BPF form f_{pc} for the corresponding channel, but for f_{sc} its stability is not support in UpC. In a given moment f_{sc} increases (i.e. $f_{sc} > 5, 5$MHz or $f_{sc} > 6, 5$MHz) or decreases (i.e. $f_{sc} < 5, 5$MHz or $f_{sc} < 6, 5$MHz). In the first case, the distortion influences negatively the upper (*n*) channel (Figure 3) and in the second case – the effect is reflected in the channel itself (*n*-1), as the sound does not reproduce itself or reproduces with distortions.

$$f_{ch} = f_{VCO} - (IF \pm \Delta IF), [MHz] \quad (4)$$

$$f_{ch} = (f_{VCO} \pm \Delta f_{VCO}) - (IF \pm \Delta IF), [MHz] \quad (5)$$

By stable IF_{pc} and IF_{sc} in the modulator, but unstable f_{pc} (i.e. decrease f_{pc} of with $-\Delta f_{pc}$ or increase of f_{pc} with $+\Delta f_{pc}$) is negatively influenced over the lower (Figure 5) or upper (Figure 3) channel (n).

The synchronization of IF_c = 36MHz in QAM modulators (Figure 6) and f_c in the channel convertors (UpC), respectively –

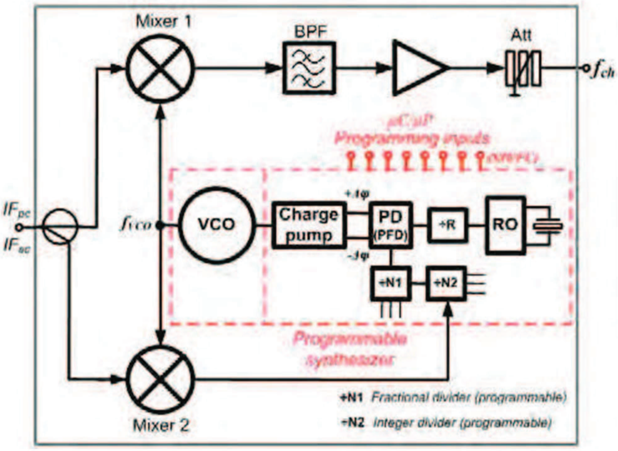

Figure 4. Up converter block diagram

transmodulators, is being performed mainly with the one circular chain PLL. Some manufacturers [8] use infradyne conversion (with two frequency converters), as the second intermediate frequency is out (upper) of the operating frequency range (Figure 7). In such case are used two of each: VCO, Mixer, converter (UpC, DwC), PLL (not tuning, tuning). VCO1 works with one frequency >>862MHz (in this case f_{VCO1} = 1244MHz). The management and the settings are performed by μC (MICOM). The stability of the frequencies depends on the foregoing factors, while the influence of the detuning $\pm\Delta IF_c$ and $\pm\Delta f_c$ is illustrated on Figure 8 and Figure 9 with adjacent to the testing channel (n) disturbing channels (n-1) and (n+1), which are also digital with QAM modulation.

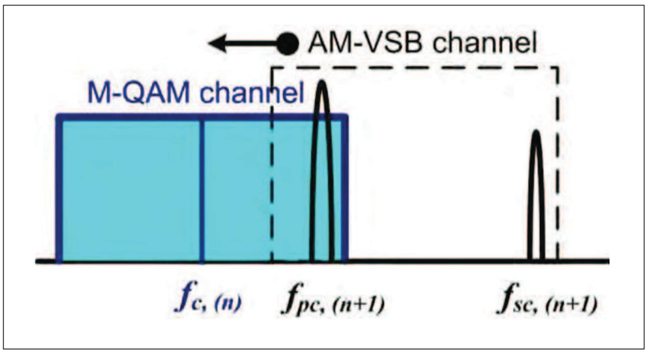

Figure 5. Unfavorable influence in the adjacent lower channel (n)

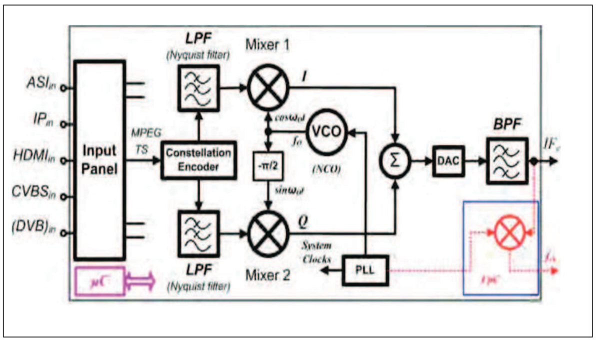

Figure 6. Simplified QAM modulator block diagram

$$IF_c = f_o \pm \Delta f_o, [MHz] \quad (6)$$

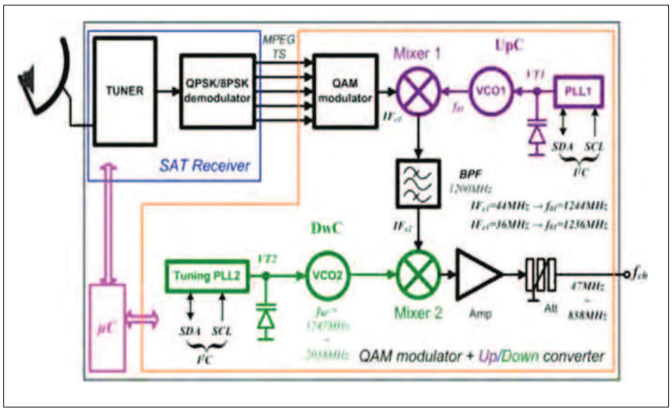

Figure 7. QPSK/8PSK-QAM transmodulator block diagram

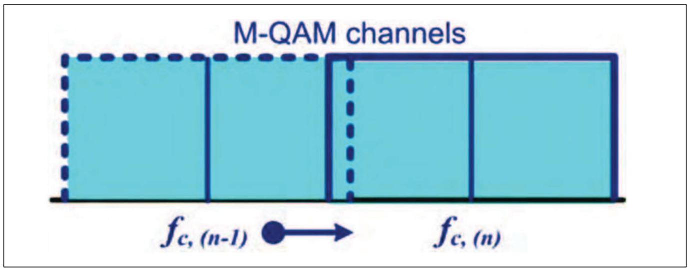

Figure 8. Unfavorable influence in the adjacent upper channel (n)

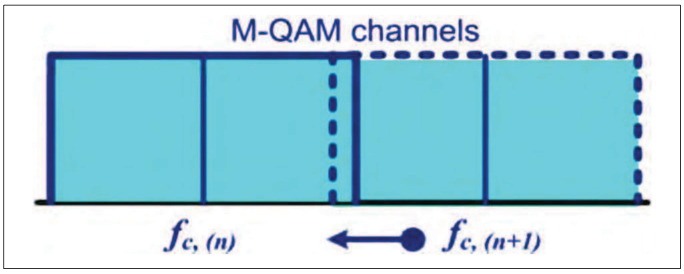

Figure 9. Unfavorable influence in the adjacent lower channel (n)

By all detuning $\pm\Delta f$ $(\pm\Delta IF)$ no matter if the signals are analog or digital is produced an overlap of the channels, which leads to worsening of signal parameters and channels. For the analog, CSO, CTB, C/N, respectively S/N worsens, while for the digital: BER, MER, C/N and etc.

3. Experimental Results

Here are presented the results of the researches about the influence of changes in the oscillation frequencies in the modulators and channel converters in a Head End for cable TV. The test channel (n) is the standard channel 46 from the UHF range of B/G standard. The signals, which are transmitted in it are digital with 64-QAM, symbol rate 6900ks/s, $f_{ch} = f_c = 674$MHz, channel level $U_{46} = 8$ 0dBmV. Lower disturbing channel (n-1) is the standard channel 45: analog with AM-VSB modulation; $f_{pc} = 663, 25$MHz; $f_{sc} = 668,75$MHz; level of the channel with sound carrier f_{sc} is $U_{45,sc} = 60$dBmV. The upper disturbing channel (n+1) is the standard channel 47: analog with AM-VSB modulation; $f_{pc} = 679, 25$MHz, $f_{sc} = 684, 75$MHz; channel level with picture carrier f_{pc} is

$U_{47,\,pc}$ = 70dBmV.

The change of the corresponding carrier frequency is with a step $\pm\Delta f$ = 250kHz, as for channel (n-1) sound carrier increases(f_{sc} + $k.\Delta f$) and for channel (n+1) picture carrier decreases ($f_{pc}k. \Delta f$). Here k is the serial number of the step, such as its maximal value in the researches is determined by the value of postBER. When postBER reaches values $\geq 10^{-4}$, the research is terminated.

The results presented, in Table 1, are for the influence of channel (n-1), and in Table 2, are for the influence of channel (n+1). Figure 10 is constellation diagram of the signal with absence of disturbance, and Fig.11a and Fig.11b are constellation diagrams of the signal with existence of disturbance (with maximal number of the step, respectively k = 8 and k = 7). The levels of the signals are in accordance to the nominal output levels of the modulators, channel converters and transmodulators, as for the disturbing channels are also accounted the influences of varicaps tunable bandpass (BPF) filters over the levels of the signals, whose frequency is outside of passband $B_{0,7}$.

k	$f_{sc}+k.\Delta f$ MHz	▶BER (preBER)	BER▶ (postBER)	MER dB	C/N dB
0	668.75	4.9E-4	1.2E-9	25	31
1	669	1.0E-3	1.2E-9	25	31
2	669.25	9.8E-4	1.2E-9	25	31
3	669.5	1.0E-3	1.2E-9	25	31
4	669.75	1.0E-3	2.4E-9	25	31
5	670	1.0E-3	1.2E-9	25	31
6	670.25	1.5E-3	4.5E-8	24	31
7	670.5	3.7E-3	1.8E-4	23	31
8	670.75	4.0E-3	4.0E-3	23	31

Table 1. Values of BER, MER, C/N at the Influence of the Channel (N-1)

k	$f_{pc}-k.\Delta f$ MHz	▶BER (preBER)	BER▶ (postBER)	MER dB	C/N dB
0	679.25	1.1E-3	6E-9	25	31
1	679	1.3E-3	2E-8	24	31
2	678.75	1.2E-3	1E-8	24	31
3	678.5	1.2E-3	1.6E-8	24	29
4	678.25	1.2E-3	1.2E-8	24	21
5	678	1.2E-3	1.4E-8	24	21
6	677.75	3E-3	3.2E-4	23	25
7	677.5	>4E-3	>4E-3	24	28

Table 2. Values of BER, MER, C/N at the Influence of the Channel (N+1)

Figure 10. Constellation diagram for ch.46 with absence of disturbance

a) from ch.45

b) from ch.47

Figure 11. Constellation diagram for ch.46 with disturbance

4. Conclusion

The results for the standard B/G can successfully refer also to the 46th channel of the D/K standard [9]. The picture carrier for both standards is the same, so the influence of the (n+1) channel on the channel (n) by decrease of its value(respectively the oscillator frequency) is the same as thepresent case. Differently stays the case of the influence of the (n-1) channel onto the (n)

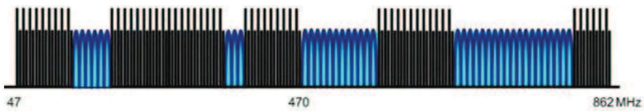

Figure 12. Non standard (mixed) frequency plan of CATV/HFC system

channel, because the sound carrier at the D/K is closer with 1MHz to the next upper channel. In this case, smaller alterations in the sound carrier lead to overlapping with the (n) channel and deterioration of BER, MER and C/N. The applied approach for channel 46 can be applied for every digital (QAM) DVB-C channel, which is adjacent to an analogue (AM-VSB) channel, where the number of the channel depends on the frequency plan [10], [11] of the corresponding cable provider. By a standard (classical) frequency plan an overlaping of the examined type: channel (n-1) with the channel (n) is possible only between the last analogue channel and the first digital channel, whereas when other conditions are equal, the non-standard (mixed) frequency plan (Figure 12) ensures lower level of nonlinear products from the cross modulation.

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