Transmitting coherent carrier frequencies in modern CATV/HFC systems

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Abstract – **In this paper are presented the researches made on the effort to improve the parameters of modern CATV/HFC systems for Downstream. Mathematical equations are drawn and an algorithm for calculation of the digital carrier in HRC/IRC systems for the standards B/G and D/K is proposed. In a table matter are also presented the values of the digital carrier for standard and coherent distribution, as well as the values of BER, MER and SNR.**

Keywords – **CATV/ HFC, HRC, IRC, DVB-C.**

I. Introduction

This paper is a scientific development for allocation of television channels for the standards B/G and D/K by using DVB-C in modern CATV/HFC systems. The digital carriers are coherent synchronized, which improves the BER, MER, SNR and other parameters. The transmission of coherent digital carrier is realized with the methods of harmonically related carrier/coherent (HRC) and incrementally related carrier/coherent (IRC). Those methods ensure improvement of the parameters of 20% to 80% depending on the number of channels, the modulation, the frequency spectrum and the frequency allocation of the channels [1], [2], [3], [4]. In North America those methods have already found an application in a number of cable operators. Some of the main manufacturers have designed and are manufacturing television sets [5], [6], [7], [8] which can receive channels from both the standard distribution (STD), and the HRC and IRC distribution (Fig.1). The modulation of the analog carriers is AM-VSB and 8VSB/16VSB/m-QAM of the digital carriers [9], [10], [11]. These channel allocations are made for the FCC: standards ITU-T/J.83B/J.112, CEA-542-B, meanwhile for B/G and D/K there are none. Because in [3] are considered and presented the relations for HRC and IRC transmitting of analogue carriers, in this publication will be presented the mathematical relations and the results for digital carries for the standards B/G and D/K by DVB-C.

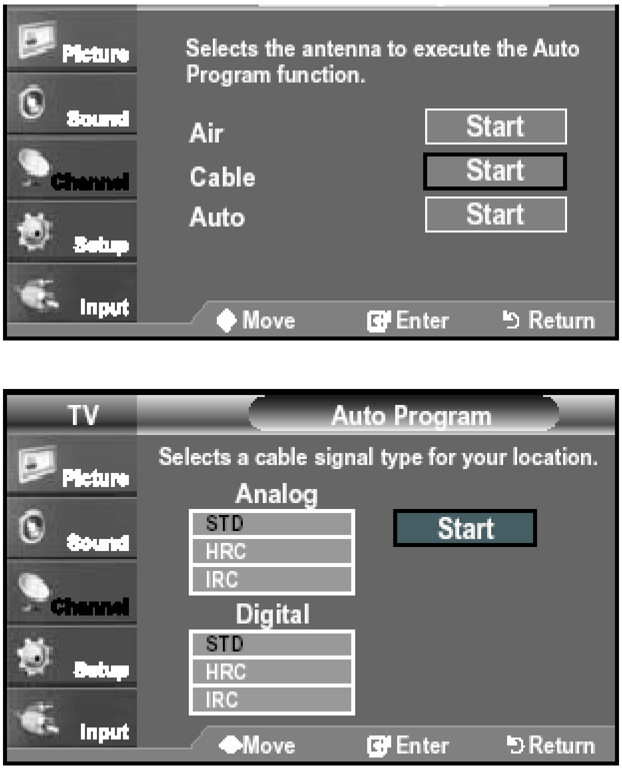

Fig.1. Menu tuning channels

II. Structural schematics of a Head End with coherent carriers

The method of transmittion with coherent carriers consists of the usage of modified schemas for allocation of the carrier frequencies, which leads to the elimination of some components of the composite three-component beat.

In the Head End the oscillators in the modulators, the converters and the transmodulators are synchronised by a separate circuit from a Main oscillator, where by the synchronizing signal is feed by a shirmed/coaxial cable, and it's frequency f_R is in the range of megahertz, mostly 1MHz. The unstability of the generated signals must not be worst then 10^{-6}.

Structural schematic of a Head End with coherent carriers is presented on Fig.2, where the generator for synchronisation is a quartz generator and the step f_0 is defined by the type of the synchronization (HRC or IRC), whereby $f_o \leq f_R$.

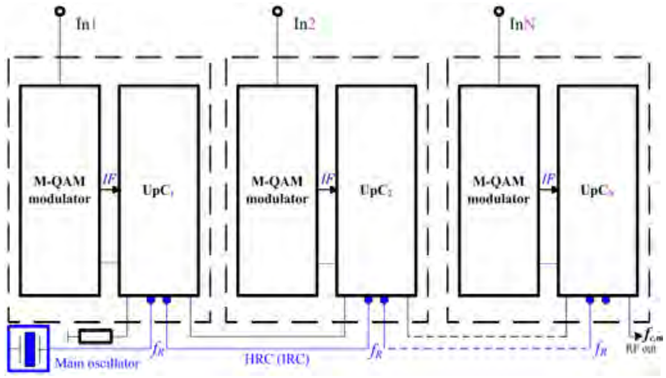

Fig.2. Structural schematic of Head End with coherent carriers

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The influence of coherent synchronisation on the CATV/HFC system's spectrum when transmitting "channel to channel" is shown on Fig.3a, for decrease (Fig.3b) of the Main oscillator's frequency, as well as for its increase (Fig.3c). In this case the overlaping of the neighbouring channels with eachother (which is possible for noncoherent carriers) is lacking, because by frequency alternation (increase or decrease), the whole spectrum is being shifted to the left/right with the value of unstability of the Main oscillator. This way the neighbouring channels cannot overlap with eachother and respectively cannot get a throbbing between them, and hence also nonlinear distortions.

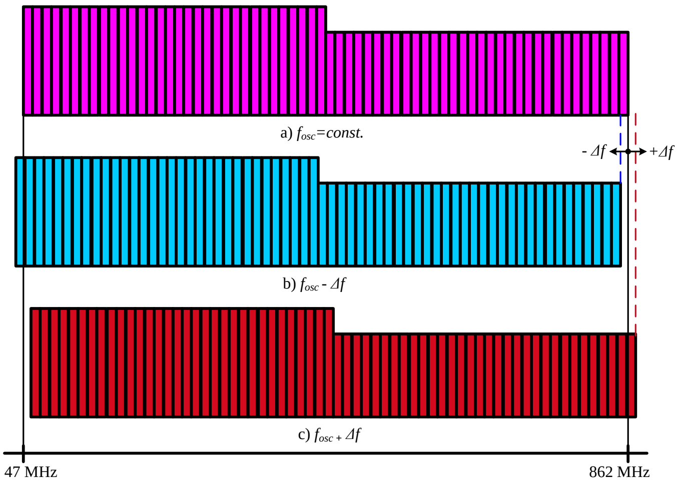

Fig.3. CATV/HFC system's spectrum

III. Transmission of Harmonically Related Carriers

By this method the carring frequencies synchronise with the phase of the harmonics of the generator with comb-spectrum, whose main frequency is chosen with value equal to the bandwidth of the channel for the relevant standard.

Since for the standard B/G in VHF range the bandwidth of every channel is 7MHz, and for UHF range 8MHz, the application of the HRC method is impossible. By D/K standard the bandwidth of every channel is 8MHz for both ranges. Because of those reasons are presented below the mathematical expressions for the standard D/K by DVB-C. The carrier frequency of each channel is described by the following formula:

$$f_{c,n} = (k + \mu)\, f_0 \text{, where} \tag{1}$$

n=RI, RII,…, SR1,…, RVI,…, SR11,…, SR21,…, 21,…, 69;
k=1, 2, 3,…, 102 is channel destination (Ch. Des.);
μ=5; f_o=8MHz.

<u>*The advantages of this method are:*</u>

- coherence of emerging beats of second and third order with $f_{c,n}$, in which no essential distortions and worsening of *BER*, *MER*, and *C/N* happen;
- Decrease of the transitional (interchannel) distortions;
- Use of one Main oscillator and others.

<u>*Disadvantages*</u>

- Low flexibility;
- Difference in the values of digital carrier to the standard distribution (STD) - central frequency of the channel;
- The signals of NMS, pilot signals and other do not synchronize by phase.

IV. Transmission of Incrementally Related Carriers

By the IRC method most of the disadvantages of the HRC method are prevented. The principle of obtaining the digital carrier is the same as with the HRC method, but the step is different.

Here the step of synchronization is part/increment of the frequency of the synchronization signal, respectively of the width of the channel, as the value of f_o is an integer much smaller than them. Frequently f_o=100kHz, 125kHz, 250kHz.

As a disadvantage can be considered the uncoherence of the products of second order with digital carriers, respectively with picture carriers.

By the derivation of the mathematical dependencies will be considered the value of the synchronization step of the carrier frequencies and the parameters of the channels: width, quantity, order number and etc., which determine the number of the harmonic according to f_o.

For standards B/G and D/K formula (1) becomes [3]:

$$f_{c,n} = k_\mu . f_0 \,, \tag{2}$$

where k_μ takes into account the values of k and μ for every carrier frequency in the range 47÷862MHz.

Every digital carrier is made by multiplying a fold integer k_μ by the step.

In such case, the value of every digital carrier is an even number and simultaneously it represents the number of the harmonic according to the step.

Main oscillator can work on another frequency, different from the step and few times larger than it, and the value of the step is produced by division of the oscillation frequency (more often by 4, 8 and 10 by f_{osc}=1MHz).

A) Mathematical relations for the standard D/K

The channel distribution for DVB-C refers to the whole frequency spectrum from 47÷862MHz, where equation (2) changes as follows:

$$f_{c,n} = (A + C.k.B).\, f_0 \text{, where} \tag{3}$$

A=42.C; $C=f_R/f_o$; *k=1…102; B=8MHz;*
n=RI, RII,…, SR1,…, RVI,…, SR11,…, SR21,…, 21,…, 69.

B) Mathematical relations for the standard B/G

Because the channels' bandwidth in the frequency bands VHF and UHF is different (B_{VHF}=7MHz; B_{UHF}=8MHz) equation (3) changes as follows:

$$f_{c,n} = C.[(42 - s) + k.B).\, f_0 \text{, where} \quad (4)$$

s=0; k=1…36; B=7MHz;
s=32; k=37…106; B=8MHz;
n=2,…, S1,…, 5,…, S11,…, S21,…, 21,…, 69.

By comparing equations (3) and (4) we can deduce an aggregate equation for both standards, where when calculating the values for a digital carrier we need to take in a consideration the above mentioned conditions and dependencies for *n, k, B* and f_0.

$$f_{c,n} = C.[\Delta + k.B).\, f_0 \text{, or} \quad (5)$$

$$f_{c,n} = C.[(f_b - B - s) + k.B).\, f_0 \text{, where} \quad (6)$$

$A=\Delta.C$; $\Delta=(f_b-B-s)$ and $f_b=f_{c,RI}$ or $f_b=f_{c,2}$.

Based on the deduced mathematical relationships is composed algorithm (Fig.4) for calculating the digital carrier. The numerical results are presented in Table 1 and Table 2.

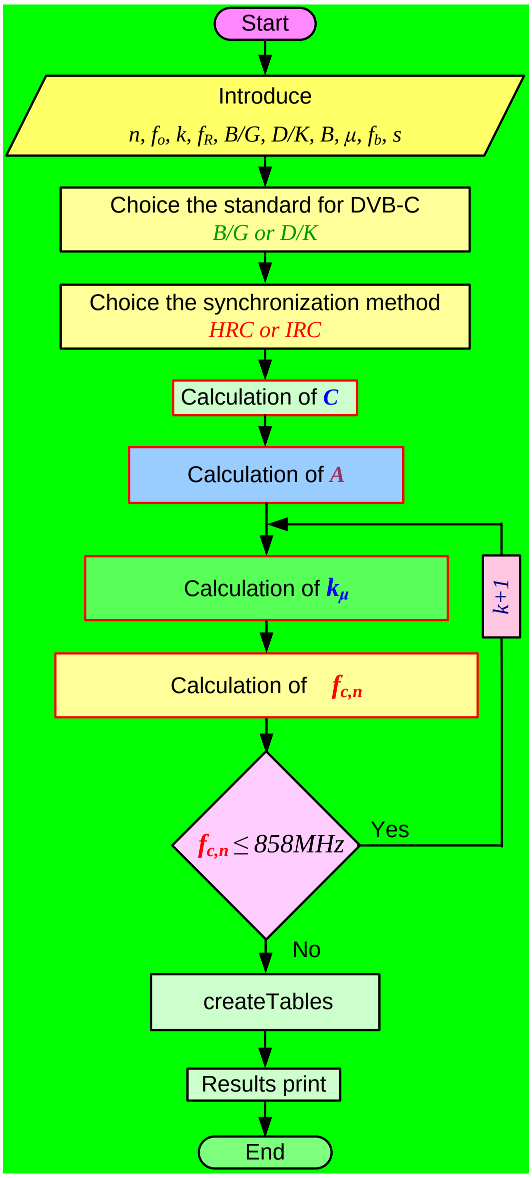

Fig.4. Algorithm for calculating the digital carrier

TABLE I
CHANNEL DISTRIBUTION FOR D/K (STD, HRC, IRC)

Band	Channel	Channel BW MHz	$f_{c,n}$ MHz STD DVB-C	HRC DVB-C all position Ch. Des.	HRC DVB-C	IRC DVB-C
1	2	3	4	5	6	7
Standard *D*						
VHF I	R I	48,5-56,5	52,5	48	48	50
	R II	58-66	62	56	56	58
	R III	76-84	80	64	80	82
VHF II	R IV	84-92	88	72	88	90
	R V	92-100	96	80	96	98
S Low	SR1	110-118	114	88	112	114
	SR2	118-126	122	96	120	122
	SR3	126-134	130	104	128	130
	…..	…..	…..	…..	…..	…..
	SR8*	166-174	170	144	168	170
VHF III	R VI	174-182	178	152	176	178
	…..	……	……	…..	…..	…..
	R XII	222-230	226	200	224	226
S High	SR11	230-238	234	208	232	234
	…..	…..	…..	…..	…..	…..
	SR19	294-302	298	272	296	298
Standard *K*						
S Extended (hyper)	SR21	302-310	306	280	304	306
	…..	…..	…..	…..	…..	…..
	SR30	374-382	378	352	376	378
	…..	…..	…..	…..	…..	…..
	SR41	462-470	466	440	464	466
UHF IV/V	21	470-478	474	448	472	474
	…..	…..	…..	…..	…..	…..
	29	534-542	538	512	536	538
	30	542-550	546	520	544	546
	…..	…..	…..	…..	…..	…..
	39	614-622	618	592	616	618
	40	622-630	626	600	624	626
	…..	…..	…..	…..	…..	…..
	49	694-702	698	672	696	698
	50	702-710	706	680	704	706
	…..	…..	…..	…..	…..	…..
	59	774-782	778	752	776	778
	60	782-790	786	760	784	786
	…..	…..	…..	…..	…..	…..
	69	854-862	858	832	856	858
				840 856		

In Table 3 are presented the data for improving the quality of transmitted signals in a IRC system in accordance to a system for cable television with noncoherent distribution of the channels.

TABLE II
CHANNEL DISTRIBUTION FOR B/G (STD, HRC, IRC)

Band	Channel	Channel BW MHz	$f_{c,n}$ MHz STD DVB-T/C	$f_{c,n}$ MHz IRC DVB-C
1	2	3	4	5
Standard *B*				
VHF I	2 3 4	47-54 54-61 61-68	50,5 57,5 64,5	49 56 63
S Low	S2 ….. S10*	111-118 ….. 167-174	114,5 ….. 170,5	112 ….. 168
VHF III	5 ….. 12	174-181 ….. 223-230	177,5 ….. 226,5	175 ….. 224
S High	S11 ….. S20	230-237 ….. 293-300	233,5 ….. 296,5	231 ….. 294
Standard *G*				
S Extended (hyper)	S21 ….. S30 ….. S41	302-310 ….. 374-382 ….. 462-470	306 ….. 378 ….. 466	306 ….. 378 ….. 466
UHF IV/V	21 ….. 29	470-478 ….. 534-542	474 ….. 538	474 ….. 538
	30 ….. 39	542-550 ….. 614-622	546 ….. 618	546 ….. 618
	40 ….. 49	622-630 ….. 694-702	626 ….. 698	626 ….. 698
	50 ….. 59	702-710 ….. 774-782	706 ….. 778	706 ….. 778
	60 ….. 69	782-790 ….. 854-862	786 ….. 858	786 ….. 858

TABLE III
BER, MER AND SNR

CATV/HFC system	Parameters		
862 MHz 51 channels DVB-C	*BER* *(RS,Viterbi)*	*MER* *dB*	*SNR* *dB*
noncoherent	10^{-8}	36	32
coherent	10^{-12}	44	37

V. CONCLUSION

The results allow concluding that transmitting with HRC synchronization is possible only for the D/K standard, because the bandwidth of each television channels is identical, for both the VHF and UHF bands. The difference in bandwidth of the channels for the B/G standard in VHF and UHF bands do not allow HRC synchronization.

It is possible to use IRC synchronization for both standards by using steps with values divisible by 7MHz, respectively by 8MHz.

The distribution of the channels, the synchronization frequency, the step and the standard are not influenced by the signals' type (SD; HD) and the compression (MPEG-2; MPEG-4).

The coherent methods for synchronizations prevent interference in the channel (n) when a change of the digital carrier in the channel (n-1) and (n+1) occurs - an overlap is absent.

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