MODULATION PRACTICE USED IN SATELLITE TELEVISION TRANSMISSION

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ABSTRACT

In the absence of federally mandated standards for video transmission on the cable television satellites, the industry has been forced to develop it's own procedure and standards. This paper describes both the history and the current practice for modulation parameters currently used by the major program suppliers. Also described is the NCTA attempt to develop uniform standards and the reasons this has been unsuccessful. A brief description of the techniques used for additional subcarriers and stereo sound is also included.

INTRODUCTION

The advent of satellite transmission to the cable television community required the development of standards for the video transmission and for the associated program audio. In particular, the video and audio deviation parameters need to be specified. There were some guidelines created by Intelsat and others, however the equipment and needs of international transmission are different than those for domestic cable television usage. Therefore, a technology and practice evolved specifically for the cable industry.

After the initial group of programers initiated service on the Satcom system, the NCTA through the NCTA engineering committee determined it was in the best interest of the industry to develop a standard for video, program audio, and subcarrier deviations so as to create uniformity among the various satellite signals. This was considered desirable as it aided receiver manufacturers to design products that would function equally well on any transponder. Also, switching from transponder to transponder with a single receiver (Cherry picking) was common. Without uniform video and audio deviation parameters there would be objectional differences in brightness and audio levels.

For many reasons it was not possible to create a standard which everyone agreed to follow. Therefore a NCTA document was written and issued as a "Good Engineering Practice Bulletin" rather than a standard. This bulletin was subsequently withdrawn and is being replaced with a document entitled "Present Practices and Recommendations for Satellite Uplink to Cable Systems."

HISTORY

The original deviation parameters are believed to have been created as a joint effort between RCA and Scientific Atlanta. RCA was the common carrier desiring to transmit satellite video services to cable television systems and Scientific Atlanta was the manufacturer of the transmitting and receiving equipment involved in these early tests and implementations. At that time the video deviation chosen was 21.5 mHz for 100% modulation (Sync tip to reference white).

It was determined that the audio should be transmited on a separate subcarrier instead of a composite signal as is done for broadcast television. The technique chosen is identical to what is in common use on terrestrial microwave systems; in fact, terrestrial microwave subcarrier equipment was used and still is in use in many applications.

The terrestrial microwave modulators were commonly available with subcarrier frequencies of 5.8, 6.2, 6.8, and 7.2 mHz. Several of the early programers used the 6.2 mHz frequency, others used the 6.8 mHz frequency with the 6.8 mHz eventually emerging as a standard. The deviation of the main carrier by the subcarrier was chosen to be 2.0 mHz. (one side peak for 100% modulation), the same as used on terrestrial microwave.

The nominal peak deviation of the subcarrier by the audio is +-75 kHz for average program level or 0 dbm. It is broadcast practice to allow 10 db. of headroom for peaks, so this equates to a peak deviation of 237 kHz. The original satellite services such as HBO and WTCG (now WTBS) used these modulation parameters.

Unfortunately, some manufacturers did not understand the above parameters. They were never really "official", but only conveyed verbally. It was discovered that many receiver manufacturers beleived the 75 kHz to be a peak value rather than an average value and products were designed accordingly.

Most program material that is video taped does not have the 10 db peaks above average level, in fact seldom would a peak approach 6 db. (This equates to 150 kHz peak deviation). When the value of transponder space became apparent and additional subcarriers began to appear, various transponder users limited the peaks to 6 db or less by installing limiters in the transmit system. This allowed a greater number of additional subcarriers to be safely placed on the transponder.

Simultaneously, other transponder users began implementing plans to broadcast music or other audio material that required the full 10 db of headroom and the resultant 237 kHz deviation. It was with this conflict of requirements that prohibited a uniform standard from being followed.

EFFECTS ON RECEIVERS

It has not been practical to date to build a low cost satellite receiver to function optimally with the various audio deviations now in use. If a receiver is manufactured that is optimized for a peak deviation of 150 kHz, clipping will result on a signal with 237 kHz peaks. The noticeable result is distortion of letters such a "s" and "t". Conversely, a receiver optimized for higher deviations will exhibit a poor S/N when used on a lower deviation signal.

Most manufacturers attempt to build a compromise receiver, which is not optomized for either the 150 or the 237 kHz deviation. The result is that the cable operator will not obtain optimum performance. This may not be of serious importance to many cable operators as these effects are hidden by the low bandwidth of the television sound and the noise generated within the cable plant. However, some operators are now modulating the aural channel onto the FM band which has a full 15 kHz bandwidth. The effects of a non-optimized receiver can be very noticeable in this application.

Various satellite receiver manufacturers will provide audio demodulators optimized for specific services. Alternately, one can use external demodulators tailored to the specific application.

COMMON MODULATION PRACTICES

The information delineated in Table 1 was compiled from information provided by program suppliers, uplink operators, and equipment suppliers. This list is not complete, but is intended to show the various practices now being used. However, in numerous instances, it has been observed that the parameters defined by a program suppliers engineering department are not necessarily followed by the uplink operators.

The deviation parameters given in Table 1 are for the nominal test tone input level. This is complicated by the practice of many transponder users who implement various forms of audio processing. The effect is to make the effective average level to be somewhat higher than the nominal level. The peaks are generally reduced using dynamic compression techniques rather than limiting by clipping.

TABLE 1

VIDEO AND AUDIO DEVIATION

SERVICE	VIDEO	AUDIO AVERAGE	AUDIO PEAK
HBO	10.75	75	237
WGN	8.46	75	150
WTBS	9.1	75	150
USA	10.75	75	237
MTV	10.75	75	237
SHOWTIME	10.75	75	237
CNN	10.75	75	237
NCN	9.1	75	150

TABLE2

SATCOM IIIR TRANSPONDER 3

CHANNEL NUMBER	SERVICE TYPE	CENTER FREQUENCY mHz	CARRIER DEVIATION mHz
--	VIDEO	N/A	8.460
--	ENERGY DISP.	N/A	1.000
01	15 kHZ audio	5.40	.972
02	15 kHz audio	5.58	1.004
03	15 kHz audio	5.76	1.037
04	15 kHz audio	5.94	1.069
05	15 kHz audio	6.12	1.102
06	15 khz audio	6.30	1.008
07	15 kHz audio	6.48	1.037
08	15 kHz audio	6.80	2.000
09	Audio FSK	7.237	.941
10	15 kHz audio	7.38	1.328
11	15 kHz audio	7.56	1.361
12	7.5 kHz audio	7.695	1.000
13	7.5 kHz audio	7.785	1.012
14	15 kHz audio	7.920	1.426
15	7.5 kHz audio	8.055	1.047
16	7.5 kHz audio	8.145	1.059

Courtesy United Video Inc.

ADDITIONAL SUBCARRIERS

As transponder space increases in value, there has been extensive engineering effort to fully utilize the bandwidth available. Numerous subcarriers have been added to transmit stereo program audio, separate monural and stereo programing, data services, and slow scan video. Tables 2 and 3 demonstrate the usage of additional subcarriers on Satcom IIIR Transponders 3 and 6 repectively. These two transponders are the most heavily loaded with added subcarriers. There is very little commonality in the techniques used for these additional services.

TABLE 3

SATCOM IIIR TRANSPONDER 6

CHANNEL NUMBER	SERVICE TYPE	CENTER FREQUENCY mHz	CARRIER DEVIATION mHz
--	VIDEO	N/A	9.100
--	ENERGY DISP.	N/A	1.000
01	15 kHZ audio	5.40	.972
02	15 kHz audio	5.58	1.004
03	15 kHz audio	5.76	1.037
04	15 kHz audio	5.94	1.069
05	15 kHz audio	6.12	1.102
06	7.5 khz audio	6.225	.800
07	7.5 kHz audio	6.345	.810
08	7.5 kHz audio	6.435	.820
09	15 kHz audio	6.80	2.000
10	15 kHz audio	7.38	1.328
11	15 kHz audio	7.56	1.361
12	7.5 kHz audio	7.695	.980
13	7.5 kHz audio	7.785	.990

Courtesy Southern Satellite Systems

TECHNICAL CONSIDERATIONS

It has been shown that several additional subcarriers can be added with little or no effect on the video performance. When a large number of subcarriers are added, it is necessary to reduce video deviation, which effectively slightly degrades performance. From Table 1 it can be seen that the video deviations on the WGN, WTBS, and NCN transponders is lower than on several other transponders.

With respect to bandwidth, Carson's Rule is generally assumed to apply. Stated mathematically it is:

$$BW = 2 \left(F_{comp} + f_{max} \right)$$

where f_{max} is the instantaneous modulating frequency. It is considered good engineering practice to keep the bandwidth within the rated emission designator of the transmission system being used. The emmission designator of the present satellite system transponders is 36000F9, or 36 mHz bandwidth.

In the absence of rigorous theoretical analysis, one model commonly used to calculate the total deviation of multiple subcarriers is the Root Sum Square method. In this method the deviation of each component is squared; all squares are added and a square root taken on the total. The result approximates the composite peak deviation of the carrier.

Stated mathematically:

$$F_{comp} = \sqrt{F_v^2 + F_e^2 + F_{s1}^2 + \cdots F_{sn}^2}$$

where:

F_{comp} = the composite deviation of the carrier.

F_v = the peak deviation of the video signal.

F_e = the peak deviation of the energy dispersal waveform.

F_{s1} = the peak deviation of the carrier by the first subcarrier.

F_{sn} = the peak deviation of the carrier by the nth subcarrier.

It has been determined experimentally that the RSS method is not totally accurate. For subcarriers below 7.50 mHz it appears that greater deviation is possible than would result from the calculation. For subcarrier frequencies above 7.50 mHz it appears less deviation is possible than the equation indicates. The optimum deviations are generally determined experimentally using the above equations as guidelines.

STEREO SYSTEMS

The largest single use of additional subcarriers is to provide stereo sound, either for the program audio or for discrete additional services. There are basically four types of systems in use, however there are variations in the application of a system to fit individual applications. A description of each system with pertinent parameters follows.

1. Composite Stereo System.

This was the first system in use for satellite stereo and is still used today by several program suppliers although most programers have changed to more efficient technology. The system is virtually identical to the broadcast FM stereo system, utilizing a left plus right main channel and a left minus right difference channel centered at 38kHz above the sum channel. This system produces S/N performance of 65 to 68 db on a five meter dish and midband stereo separation of 35 db.

The biggest disadvantage is the large occupied bandwidth and deviations required to obtain the above S/N performance. Deviation of the main carrier is +/- 4 mHz. Typical audio deviations are 405 kHz peak with an occupied bandwidth of approximately 900 kHz. One programer has reduced the peak deviation to 237 kHz which reduces the S/N to approximately 63 db. A second disadvantage is that the stereo separation drops significantly at band edges.

At the present time this system is being used by Home Theatre Network (HTN), and Bravo cable services.

2. Warner-amex System.

In this system, first used by Warner Amex for The Music Channel, the left plus right channel is transmitted on one subcarrier and the left minus right is transmitted on a second subcarrier. Typically, average audio deviations of +-75 kHz and peak deviations of 237 kHz are used. Deviation of the main carrier is typically +/- 2 mHz. A S/N of 70 db or greater is possible with a 5 meter dish and midband stereo seperation of 40 db is possible with bandedge separation of 35 db. This type of system can provide excellent performance if properly mantained and adjusted. The major problem is the need to maintain the phase and amplitude characteristics of the two channels as identical as possible. Failure to do so results in loss of stereo separation.

At present this system is being used by The Music Channel (MTV), The Movie Channel, and The Disney Channel.

3. Times Mirror System.

In this stereo system the sum left plus right signal is transmitted on the normal 6.8 mHz subcarrier. In addition, the left channel is transmitted at 5.8 mHz and the right subcarrier is transmitted at 6.2 mHz. Deviations of +-75 kHz average and 237 kHz peak are used. S/N is typically 65 to 68 db and stereo seperation is almost unlimited. This system provides the best performance, but is also the most wasteful of bandwidth and transponder power.

This system is used by the ARTS and SPOTLIGHT programing services.

4. Wegener Communications System

The Wegener Communications System(WCI) is unique in that it utilizes low deviation narrow band subcarriers. To compensate for the lower S/N which one may expect from the low deviations, a compounding system is utilized. The system is similar to Dolby except that the preemphasis starts as low as 50 Hz and extends over the entire frequency spectrum. The result is a highly efficient transponder usage. Tables 2 and 3 demonstrate the use of this system for all except the 6.8 mHz program audio.

In this system, separate left and right channels are transmitted on separate subcarriers. The typical occupied bandwidth for a 15 kHz channel is only 130 kHz instead of 500 Khz for any of the above methods. Also, the main carrier deviation is nominaly 1.0 mHz instead of 2.0 used for the other systems. S/N performance of 68 to 70 db results along with unlimited stereo separation. In practice, the stereo separation is about 30 db. due to the conversion to the standard broadcast FM format for transmission over the cable system.

At the present time this system is used by Southern Satellite Systems (WTBS), United video (WGN), National Christan Network, and PTL.

CONCLUSIONS

There are some differences in the parameters used for the transmission of the program associated audio. Although adequate performance can be obtained with a general purpose receiver, optimum performance requires a receiver tailored to the specific service desired. The reception of subcarriers requires special equipment in all cases as there is a wide variety of systems and techniques in use.