HEADEND TECHNIQUES FOR REDUCING DISTORTION IN DISTRIBUTION SYSTEMS

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The rate of increase in distribution system bandwidth and signal loading has exceeded the rate at which amplifier noise and distortion performance has been improved. This has resulted in some dependance upon headend based techniques, such as harmonically related coherent picture carriers. The continuation of this trend demands additional techniques to supplement the development of improved amplifier technology.

A headend system capable of coherent carrier, sync suppression and synchronized video operation was constructed. The hardware implementation of each method is described. A representative distribution cascade was used to determine the effect of each headend technique on system distortion performance. Both subjective and measureable effects were investigated, with the various techniques were evaluated individually and in combination.

INTRODUCTION

Since the development of distribution systems with 400 MHz bandwidth, the demand for system channel capacity has tended to increase more rapidly than basic amplifier distortion performance. It appears to be fundamental to the nature of the amplifying devices that distortion performance deteriorates as frequency increases. This implies that the conflict between increased bandwidth and distortion performance will worsen.

Where system distortion performance is insufficient, an alternative is to employ special headend signal processing techniques which cause the subjective visibility of distortion to decrease. Coherent carrier headend systems represent one such technique. Specific implementation of this technique, such as Harmonically Related Carriers, are already widely accepted as a basis for expanded bandwidth distribution system design. The improvement in apparent amplifier distortion performance permitted the design of practical systems with capacitance of 50 or more channels per cable. Since the development of systems with 500 MHz or greater bandwidth appears inevitable, new techniques are required to allow the transmission of 75 or more channels per cable.

Two headend signal processing techniques which could permit increased system loading are all channel sync suppression and all channel video synchronization. The hardware to implement these techniques already exists so the assessment of their value for distortion reduction becomes an entirely practical matter.

THE AMPLIFIER CASCADE

The results reported herein were obtained from the traditional method that is used to evaluate the effect on system performance of any change in circuit or system design, or change in environmental or signal conditions; that is, the impairment to high quality video signals is determined by observing changes in picture quality after the signal has passed through a representative amplifier cascade. The actual cascade consists of sixteen trunk amplifiers with equal cable spacing, followed by a distribution line consisting of a bridger and two line extender amplifiers.

HEADEND SYSTEM DESIGN

A headend system used for such an investigation has to perform the usual function of producing a combined RF output of up to 65 channels suitable for driving a distribution trunkline. In addition, several unconventional features are required. These include the ability to switch rapidly between Harmonically Related Carrier (HRC) operation and non-coherent operation; the means to switch instantly from synchronized to non-synchronized video modulation and a facility to select horizontal sync suppression and vertical sync suppression independently in any combination, including no suppression.

The system was constructed from standard headend products to minimize construction time. The hardware is organized into three sections for flexibility in program switching and special function control. A block diagram of the complete test headend system is shown in Figures 1, 2 and 3.

The Video Source Section

It is assumed, when simulating the signal conditions of a distribution system, that video program content is not repeated. Since it is not practical, in the laboratory, to produce a separate video program for each RF channel, it was decided that 20 programs, where no program would appear on more than 3 channels, was an acceptable compromise between system complexity and realistic conclusions. The number of programs cannot be reduced arbitrarily because the subjective visibility of distortion products is affected by video duplication.

The required 20 video program sources consist of 10 satellite receivers, 9 off-air demodulators and an EIA standard color bar generator. The video output of each source unit is applied to a video synchronizer so that all 20 video signals can be synchronized when required. The color bar video standard is supplied to all of the synchronizers as a timing reference. By disconnecting the reference video the synchronizers switch automatically to bypass mode and non-synchronized operation results. The synchronizer outputs are applied to a video patch panel.

The Video to I.F. Section

This section includes standard modulators with I.F. output and Scrambled Service Encoders to provide for suppressed sync operation. The standard encoder was modified to permit independent selection of horizontal or vertical sync suppression. The scrambling system normally increases the peak carrier level by 3 dB during scrambled operation, so this mode was made programmable as well. When all channels are scrambled, the 3 dB boost is equivalent to raising the headend system output level by 3 dB.

Therefore, this feature was deactivated throughout this test series. The addition of a simple interface allows external control of the sync suppression mode of all 20 intermediate frequency (I.F.) sources from a single switch. The output of each modulator is split 3 ways and connected to an I.F. patch panel. The patch panel connections determine the channelization of the 20 sources.

The I.F. to Channel Section

This section contains 58 standard phaselocked capable I.F. to channel converter modules and associated I.F. phaselocked circuitry. Switching facilities allow the replacement of the normal I.F. input of any converter with an unmodulated carrier and the elimination of any channel from the combined output. HRC operation is obtained by phaselocking all converters to a common reference comb. Non-coherent operation is obtained by disconnecting the reference comb signal whereupon the converters switch automatically to crystal controlled operation. The converter module R.F. outputs are combined with 8-way couplers as in a typical CATV headend to provide an output to the cascade under test.

A Review of Coherent Carriers

Coherent carrier techniques, exemplified by HRC, are already used widely with systems designed with a capacity of 50 or more channels. Although HRC is not considered herein as a new method, it will be seen that the effect of the new techniques being investigated can differ from HRC to non-HRC conditions. In reviewing the principle of HRC, we recall that the intermodulation products of two or more picture carriers are caused to be coherent with any given picture carrier. This makes the carrier intermodulation products subjectively invisible and leaves the associated modulation sidebands as visible interference. It is generally held that this results in a subjective reduction of distortion levels of 10 decibels and allows amplifier output levels to be increased by up to 5 decibels.

ALL CHANNEL SYNC SUPPRESSION

The cascades under study are limited in output level by third order intermodulation distortion. When the system is without the benefit of special headend techniques, and the amplifier level is raised to produce visible degradation, the familiar "composite triple beat" effect is seen. This appears as a generally random noise-like pattern with horizontal streaking. At times local concentrations, usually in the form of sliding bars, will be seen. These are associated with energy peaks of the carriers that are generating the triple beats. The energy peaks occur during the synchronizing pulses of the video signals that are modulating the distortion producing carriers. When these peaks coincide in time for several carriers, a worst case concentration occurrs which determines the threshold for perceptable distortion.

When all-channel sync suppression or scrambling is activated, the carrier levels are reduced by 6 dB during horizontal and vertical sync intervals. This eliminates the energy peaks described above and results in a more uniform and random triple beat pattern. This suggests a reduction in the worst case perceptability of this distortion and an attendant increase in amplifier output level.

When the headend system is switched to HRC mode the carrier triple beats are no longer seen. As the system level is increased, the video modulation components of the distortion producing carriers become visible. Typically, the most perceptable aspects of this form of distortion are sliding vertical or horizontal bars associated with the synchronizing information of the video waveform.

When all-channel sync suppression is employed under HRC conditions, the perceptability of the sync bars is reduced such that they do not predominate. Major picture elements in the distortion producing channels, such as a row of large white characters, are seen to be as visible as the sync bars. The constant horizontal or vertical sliding of these frames continues to increase visibility. Again, this suggests that some increase in amplifier level should be possible for just perceptable distortions.

VIDEO SYNCHRONIZATION

Activating video synchronization causes the synchronizing information in the video waveforms of all channels to be time coincident. This means that any elements of distortion that are associated with the sync pulses of the distortion producing channels will occurr during the horizontal and vertical blanking portions of the picture being viewed and will not be visible. The sliding frame effects are also eliminated by synchronization. This combination of two beneficial effects suggests that synchronization may be subjectively more beneficial than sync suppression.

In the non-HRC situation the subjective result is generally similar to that obtained with all-channel sync suppression: the composite triple beat pattern appears to be uniform without the bar-like concentrations.

Under HRC conditions the vertical and horizontal "sync bars" are not seen and the only background motion is that caused by moving elements in a particular distortion producing channel.

TEST RESULTS

Initially, the distribution portion of the cascade was operated with bridger and line extender output levels, relative to the trunk amplifier output levels, at typical system values. It was found, however, that when system levels were raised above the perceptible distortion threshold with the above techniques used together that the system no longer exhibited "linear" behaivour. Direct measurement of third order distortion showed that the incremental ratio of distortion to signal level was about 5 to 1 rather than the 3 to 1 ratio expected from a normally behaved system. Under practical conditions this would not occur because no system would be designed to operate with perceptible distortion. Instead, a typical system might operate 3 dB below this point.

Since it is necessary to produce visible distortions in order to make subjective judgements, it was decided to reduce the distribution signal level enough to obtain perceptible distortion under all conditions without producing amplifier compression. The bridger amplifier gain was reduced to produce a distribution level of 8 dB above trunk level. The average trunk level at which distortion was just perceptible on channel 51H was 35.5 dBmV, corresponding to 44 dBmV distribution level.

Twelve viewers participated in the subjective tests. Each viewer used his own interpretation of "just perceptible". The actual trunk system level at which "just perceptible" degradation was seen was recorded for each headend operating mode. The group was retested on four occasions to allow for program related variations and human consistancy and the total data was averaged. The averaged results were then normalized to a zero value for standard conditions. The resulting numbers represent the change in system level, compared to standard conditions, that produced equally perceptible distortion for each of the three headend techniques individually and in combination:

SYNC SUPPRESS	VIDEO SYNCH	STANDARD	HRC
OFF	OFF	0.0 (REF)	+5.1 dB
ON	OFF	+1.6 dB	+6.7 dB
OFF	ON	+1.2 dB	+7.2 dB
ON	ON	+1.7 dB	+7.6 dB

Additional observations were made on channels 4, 18, 11 and 38 to make certain that the channel 51 results above were not anomalous. The absolute levels at which distortions were seen increased, as expected, with decreasing frequency, but the relative effect of the various headend techniques was essentially the same as seen at channel 51.

A LIMITATION OF CLASS 1 CHANNELS

Current FCC regulations prohibit the scrambling of class 1 broadcast channels. Leaving these channels unscrambled would reduce the subjective benefit of the full system sync suppression technique. This compromise might be minimized by placing such channels at the system's lowest frequency assignments. On the assumption that 12 class 1 channels would be typical for a large system, the practicality of this approach was tested by reconfiguring the headend system such that lowband channels 2 through 6 and highband channels 7 through 13 were never sync suppressed, but could be video synchronized. The remaining 46 channels were operated as described above. The average threshold for "just perceptible" triple beats with twelve viewers was 35.6 dBmV, vertually the same as the first configuration. After normalization, as above, the following results were obtained:

SYNC SUPPRESS	VIDEO SYNCH	STANDARD	HRC
OFF	ON	0.0 (REF)	+5.6 dB
ON	OFF	+0.9 dB	+6.6 dB
OFF	ON	+1.2 dB	+7.5 dB
ON	ON	+1.7 dB	+8.1 dB

These results are sufficiently similar to those obtained with full sync suppression to suggest that such a compromise could be made and still obtain most of the benefit of that technique.

SUMMARY AND CONCLUSIONS

Harmonically related carrier headends have provided a practical method for increasing system capacity by making the triple beat products of the picture carriers subjectively invisible. Under HRC conditions, the limitation to amplifier output levels is the subjective visibility of the video modulation sidebands of the third order distortion products. This suggests that further increases in system capacity could be obtained from additional headend techniques that would reduce the perceptibility of the distortion sidebands. All channel scrambling and video synchronization are two techniques which should provide this form of improvement. These techniques were evaluated subjectively by a limited group of expert viewers using a test headend system that could be switched between standard, HRC, all-channel scrambling and synchronized video modes. Operating the system in HRC mode alone allowed a 5.1 dB increase in amplifier level, a value that is consistent with earlier results. All-channel scrambling permitted an average increase in system levels of 1.6 dB above that enabled by HRC. Video synchronization produced an increase of 2.1 dB beyond that of HRC. Both techniques operating simultaneously allow a level of 2.5 dB above HRC. If the use of scrambling was excluded from class I channels, indications are that most of the distortion benefit would still be obtained, provided that the Class I programs are assigned to channels at the low end of the system spectrum. Video synchronization provides a greater reduction in distortion visibility, but has a very high hardware cost. The synchronizers used for these tests cost about 8900 dollars. The cost of this equipment has dropped from over 25,000 dollars in the last three years and would certainly continue to drop if the synchronization technique were used on a large scale.

Since the data presented herein represents only a single system configuration and was obtained from a limited number of expert viewers, the results presented must be considered preliminary. However, the results serve as useful indicators of the relative merit of each technique.

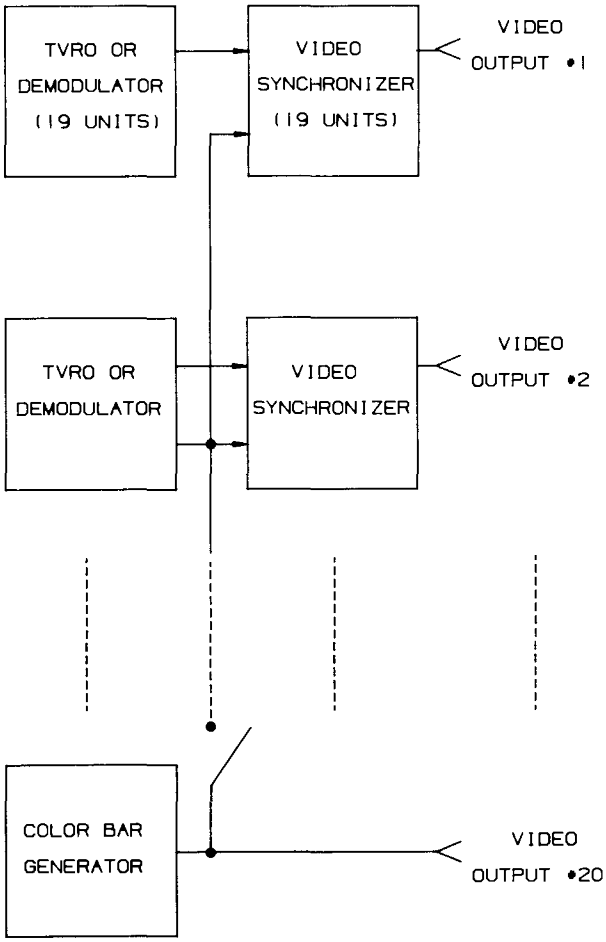

FIGURE 1.

VIDEO SECTION

TEST HEADEND SYSTEM

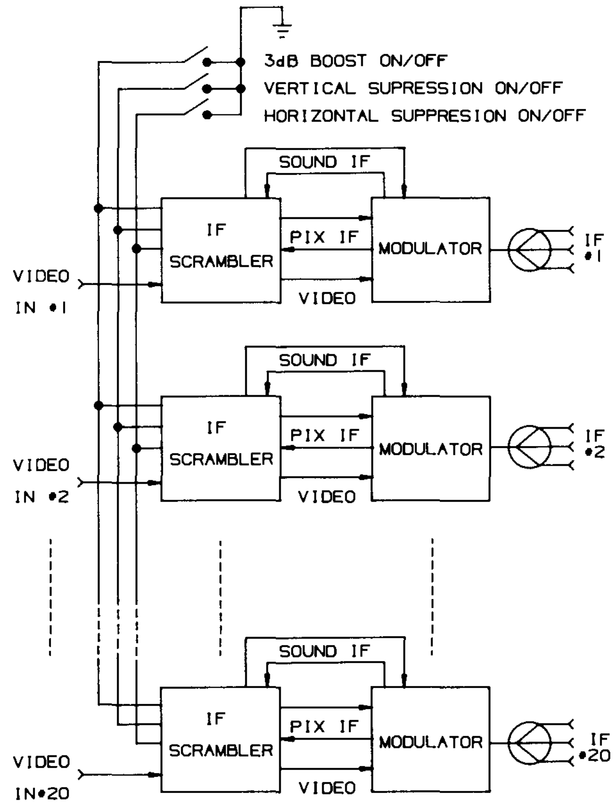

FIGURE 2. VIDEO/I.F. SECTION

TEST HEADEND SYSTEM

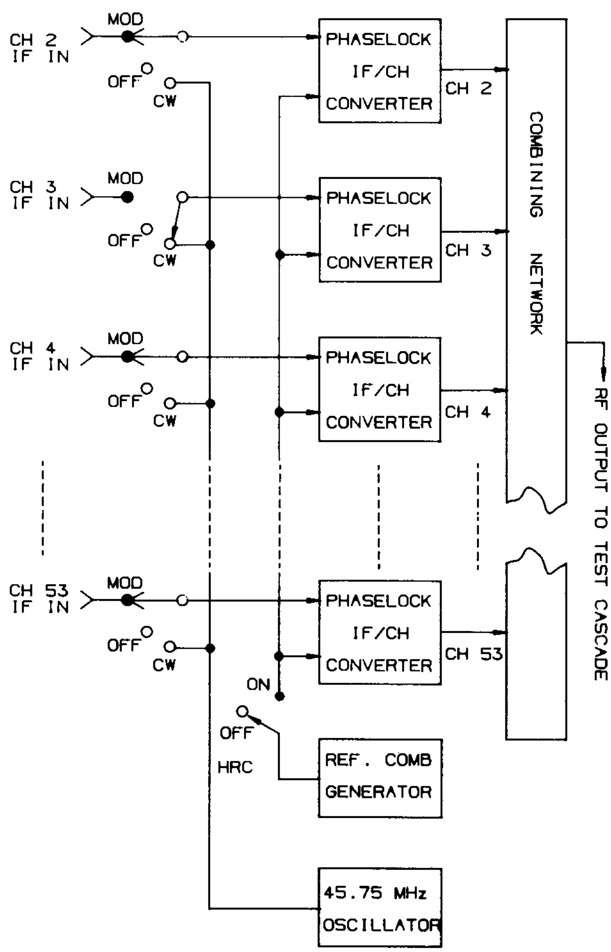

FIGURE 3.

IF/RF SECTION
TEST HEADEND SYSTEM