A VIDEO-OVER-VIDEO MULTIPLEXER FOR MULTI-HOP MICROWAVE RADIO SYSTEMS

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Introduction

Microwave radio relay equipment capable of carrying up to 1800 FDM telephone channels on one RF carrier over 4000-mile routes are presently being manufactured in North America. Plans call for capacities of 2100 or 2400 channels in the near future. Radio systems with capacities of 2700 channels are now being operated in Europe.

The baseband of a typical 1800 channel microwave radio link extends from 300 kHz to 8.2 MHz. To transmit this traffic load with minimum distortion, the useable bandwidth of such a radio will extend to over 12 MHz.

The standard 525 line video signal has frequency components that extend up to approximately 4.2 MHz. Thus a radio designed for 1800-channel operation has excess baseband capacity when carrying one video signal. It would seem reasonable that this excessive capacity could be used to carry additional telephone channels or an additional video signal, if a suitable multiplexer was available. This paper describes such a multiplexer, the GTE Lenkurt 46V.

46V Video Multiplexer

The 46V Video Multiplexer is designed and manufactured by Siemens AG for use on long distance coaxial cable carrier systems and is marketed in the USA by GTE Lenkurt.

This equipment translates a video signal, using a vestigial sideband amplitude modulation process, to a frequency band on the cable between 6.3 and 12.3 MHz. The cable system on which this multiplexer has been used has a nominal capacity of 2700 voice channels, or 1200 voice channels plus one video signal.

Coaxial cable systems using this video multiplexing technique are in use in a number of locations around the world.

Ref. 2 describes a 600-mile system in Australia that can carry 1200 telephone circuits and one television channel. This system, between Perth and Carnarvon, uses 0.375 inch coaxial cable and repeater spacing of 5000 yards. Ref. 3 describes the video test results that were obtained for a 308-mile section. These tests indicate that the system was capable of delivering a high quality video signal. The attenuation distortion was less than 0.2 dB, the delay distortion was less than ±25 ns, and the differential gain and phase were less than 1% and 0.7 degree, respectively. A weighted S/N of 61.2 dB and a S/hum of 45 dB were obtained.

The baseband frequency allocations for this system is shown in Figure 1C.

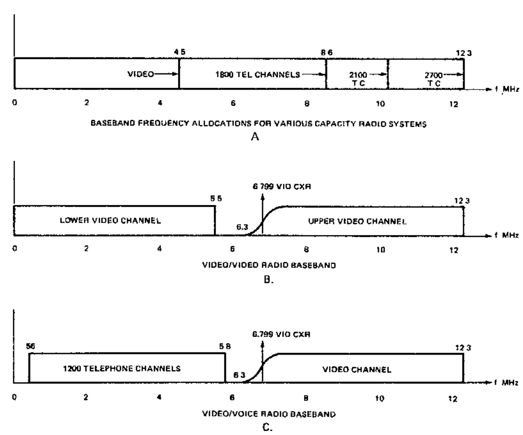

Figure 1. Radio Baseband Frequency Allocation

Figure 1A shows the baseband frequency allocation for various capacity radio systems. Figure 1B shows the frequency allocations for the video-over-video multiplexing configuration. Here, the 1200 voice channels of Figure 1C were replaced with 1 video signal.

VSB-AM was used to permit the transmission of the low-frequency components of the video signal with minimum distortion using minimum bandwidth. This technique (discussed in Reference 1) has been used on coaxial cable systems in this county by AT&T.

A carrier frequency of 6.799 MHz is employed to minimize the effects of any intermodulation products on the 4 kHz-spaced telephone channels.

A modulation index exceeding 100% is used to maximize the amount of information in the sidebands, in order to minimize the loading on the cable repeaters. The modulated signal envelope is shown in Figure 2. When 100% modulation is exceeded, it is more convenient to use the term "excess carrier ratio" (ECR) to describe the modulation index. ECR is the ratio of the peak carrier amplitude to the peak-to-peak modulation available. An ECR of 1.0 corresponds to 100% modulation, as shown in Figure 2.

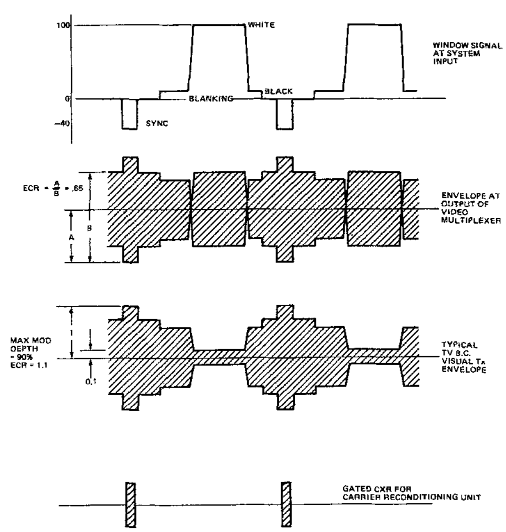

Figure 2. Modulation Envelopes

The modulation envelope of a typical broadcast transmitter is shown in Figure 2 for reference. Here, the maximum modulation depth is 90%, with an ECR of 1.1.

The use of this modulation technique complicates the demodulation process at the receiving end of the system. When the modulation depth of an AM signal exceeds 100%, the phase of the carrier is reversed and is therefore unsuitable as a reference for the local carrier at the demodulator. If the local carrier in a product detector is not inserted in the proper phase relationship with the incoming signal, the detector output will contain quadrature distortion terms.

The 46V demodulator overcomes this problem by sampling the receive signal when sync information is present, as shown in Figure 2. During this time, the modulation index is low, and the carrier has a constant phase. The carrier sample is filtered and used to phase-lock the receiver local oscillator, thus minimizing the effects of quadrature distortion.

These design features, which make the 46V useful in a coaxial cable system, also make it attractive for applications with microwave radio as the transmission medium. In summary, their advantages are:

1. The VSB modulation requires a minimum of bandwidth for low-distortion transmission.

2. The high-modulation index minimizes the carrier content, and thus the system loading.

3. Two video signals can be modulated on one carrier, which doubles the capacity of the radio.

4. The system is capable of high-quality transmission.

The video multiplexer is shown in Figure 3. Two 6 MHz HP/LP filters are used to both combine and separate the HF multiplexer line signal from the lower video signal. A phase correction network is used to equalize the phase characteristics of the HP side of these two filters. Not shown on the diagram is a phase equalizer that was used to correct the characteristics of the low-pass section of the two filters.

These factors were taken into account during feasability tests with the 46V modulator connected to a microwave system. Because the two video signals to be multiplexed are complex, it was thought easier to set up the equipment and make empirical measurements rather than depend on a theoretical analysis. We felt that one of the major problems to be encountered would be intermodulation products generated between

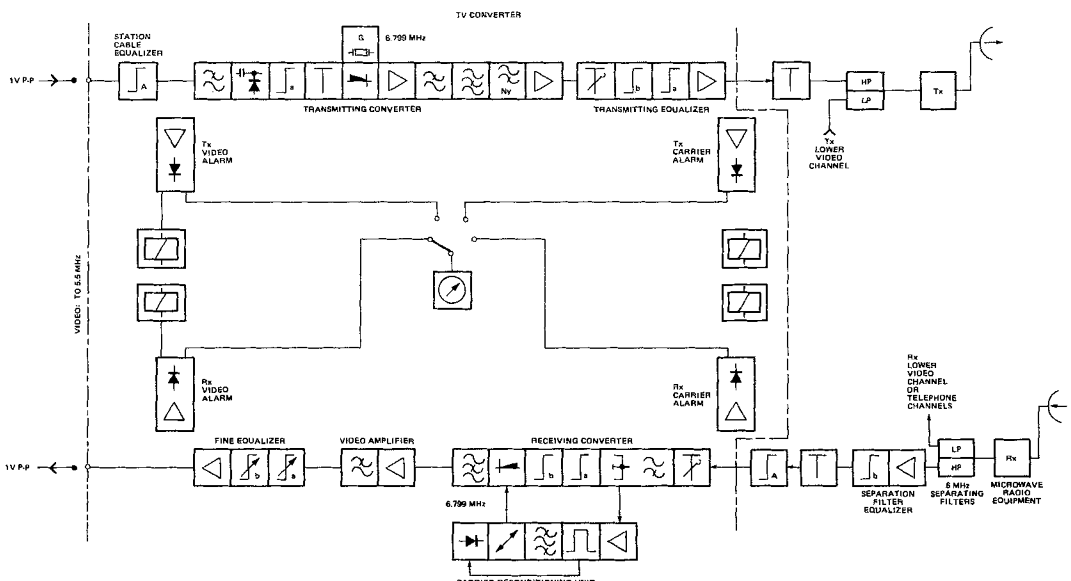

Figure 3. 46V Video Multiplexer

Video Multiplexer on Radio Considerations

Microwave radio and coaxial cable are two vastly different transmission mediums. The former is subject to propagation fading and its bandwith is limited (usually by regulatory agencies, rather than by design). It has a few pluses, however. Fading can be counteracted by space or frequency diversity switching technique; there are fewer parts to malfunction, and it is less expensive to install and maintain.

the two video signals, and that subjective testing was the best method of determining their effects.

Consequently, the 46V video modulator was connectea to two hops of radio in the laboratory, with the path loss being simulated by suitable RF attenuators.

Two independent, nonsynchronous video signals were used to drive the system. A number of tests were made to determine the quality of transmission of each signal path, and the amount of interaction between the two signals. Tests were also conducted with the LP channel carrying white noise, simulating various telephone channel loadings. The results of the video-over-video tests are discussed below.

Video-Over-Video Test Results

1. Test Conditions

	HP (Upper Video Chan)	LP (Lower Video Chan)
Modulation	525 Line Video	525 Line Video
Deviation	4 MHz (peak)	4 MHz (peak)
Emphasis	Internal	525 Line CCIR

2. Measured Test Results

	HP Chan	LP Chan
S/N Weighted	66 dB	>70 dB
S/Hum	>73 dB	>73 dB
Receive Signal Level for 37 dB Video S/N	-58 dBm	-70 dBm
Diff. Gain 10-90% APL	1%	1%
Diff. Phase 10-90% APL	0.5°	0.6°
Multiburst Response Variation	5 IRE Units	2 IRE Units
Sin^2 2T Pulse Overshoot	1%	1%
60 Hz Square Wave Tilt	1%	1%(unclamped)

3. Subjective Test Results

Subjective tests were carried out to determine the effects of crosstalk between the HP and LP video channels. No discernable crosstalk was seen on the color picture monitor connected to either of the two channels with a multiburst on the interfering channel, using the above deviation. We noticed that if the LP signal level (deviation) was increased by 5 dB, some discernable interference was visible on the HP channel in the form of horizontal bars. The use of 525 line preemphasis in the LP video channel reduced the effect of interference on the HP video signal.

The 4 MHz peak deviation represents a considerably heavy loading for the radio system. In practice, less deviation would be used in order to stay within the FCC criteria for occupied bandwidth.

The effects of varying receive signal level of the video S/N in the HP and LP video channels for one hop of radio is shown in Figure 4. As expected, the HP channel had a S/N that was 16 dB worse than the LP channel for the same deviation. This was caused by the "triangular" thermal noise spectrum of an FM system, and by the vestigial sideband process used to translate the video. It follows also that the threshold level (or mute point) will be correspondingly reduced for the HP signal.

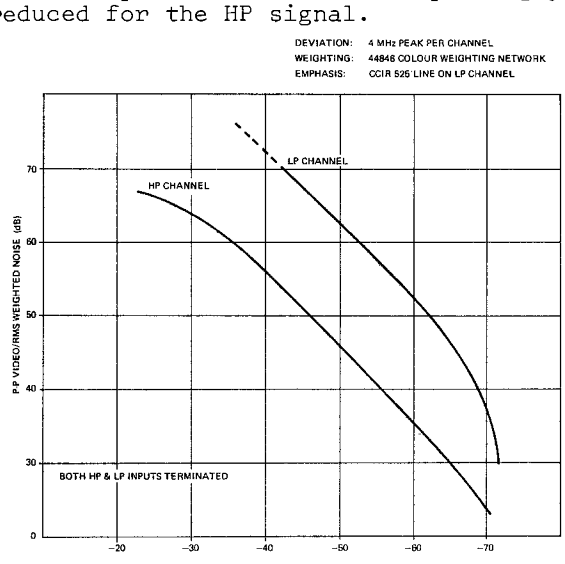

Figure 4. Video S/N vs Receive Signal Level

Radio Deviation Considerations

The tests indicated that both video signals could be sent over the system at full 4 MHz per channel peak deviation, with no noticable intermodulation problems. Maximum deviation will be determined in the USA by FCC criteria for "necessary bandwidth," which is the familiar "Carson's Rule" for FDM-FM radio systems. The expression for FCC necessary bandwidth is:

Bn = 2M+2DK
where Bn = Necessary bandwidth
= 30 MHz in 6 GHz common carrier band
= 40 MHz in 11 GHz common carrier band
M = Maximum modulation frequency
D = Peak deviation
K = A constant, taken as 1 for this case

The peak deviation for both video signals (assuming worst-case coherent addition) will be 8 MHz and the top modulating frequency is 11.1 MHz.

The necessary bandwidth is then 38.2 MHz, which exceeds the FCC limit by 8.2 MHz. To reduce the necessary bandwidth, the deviation of the lower channel was reduced by 16 dB to equalize the S/N in both channels. If the composite deviation is reduced by 0.4 dB, the occupied bandwidth of 30 MHz will be met. Of course the relative deviation of the two signals could be changed, depending on the application. A deviation of 40 MHz is permitted in the 11 GHz common carrier band, which would allow both signals to be applied at 4 MHz peak deviation.

Conclusions

The 46V video multiplexer provides a useful way to multiplex two video signals on a single radio bearer. Tests (not described here) have shown that it is also feasible to combine up to 1200 FDM telephone channels and one video channel on a microwave system. This multiplexer is designed for radio systems having capacities of 1800 telephone channels, or greater. The limitations are associated with the restrictions that licensing agencies place on the occupied bandwidth, which limits the deviation, and thus the thermal S/N. Application of this multiplexer will therefore be limited to those microwave systems having adequate receive signal levels and fade margins. The multiplexer effectively doubles the capacity of a video microwave system, which should be of interest to those concerned with frequency conservation.

References

1. J. W. Riebe, and R. S. Graham; "The L3 Coaxial System, Television Terminals," BSTJ, July 1953.

2. L. A. Jones; "The Perth-Carnarvon Cable Project: Planning Aspects," Telecommunication Journal of Australia, February 1970.

3. W. Von Guttenburg, E. Kugler, and A. Stegmer"; Siemens Review Vol. XXXVIII (1971).