MICROWAVE DATA TRANSMISSION USING AML TECHNIQUES

A. H. Sonnenschein P.E, I. Rabowsky, and W. C. Margiotta

HUGHES AIRCRAFT COMPANY
MICROWAVE COMMUNICATIONS PRODUCTS

This paper discusses the characteristics and relative merits of some of the alternate signal modulation methods which are employed to transmit various forms of data and voice over AML microwave systems.

AML systems have during the past 10 years become widely accepted as the dominant means for the local distribution of multiple video signals in the CATV industry. The reasons for this extensive use of more than 20,000 video channel paths worldwide are tabulated in Figures 1 and 2. In a nutshell, these reasons are that AML systems are more cost effective, spectrum efficient, and reliable than any of the available alternatives.

- ECONOMICAL FOR MULTIPLE CHANNELS
- SPECTRUM EFFICIENT – HIGH CHANNEL CAPACITY
- CABLE COMPATIBLE – VHF IN/OUT
- GOOD PERFORMANCE
- HIGH RELIABILITY

1. Why AML?

- INCREASED CHANNEL CAPACITY REQUIREMENTS & DUAL CABLE SYSTEMS
- SHORTER AMPLIFIER CASCADES (MORE HUBS)
- ESCALATING COST OF HEADENDS
- FREQUENCY RE-USE TECHNIQUES
- ACCELERATING CASH FLOW BY LEAPFROGGING TO PROFITABLE AREAS

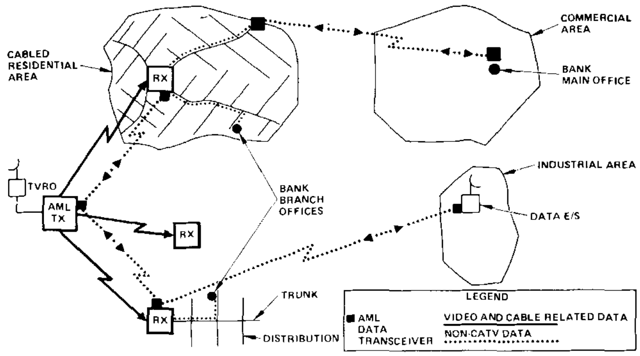
2. Further reasons for recent proliferation of AML in major urban markets.

The trend towards the use of AML hub distribution systems has further accelerated in recent years, as a direct consequence of the dramatic increase of channel capacity of major market franchises. This increase in channel loading has the following effects: 1 - A shortening of permissible amplifier cascades, 2 - A major increase in the cost of sophisticated headends to an extent that the cost of duplicating headends at various hubs becomes prohibitive, and 3 - A further strain on limited frequency allocations. All the factors have intensified the necessity for the use of AML systems in suburban as well as rural areas. Channel capacities as high as 160 channels are frequently necessary to accommodate all upstream as well as downstream transmission requirements.

More recently, various forms of data transmission requirements have been added to the prior video and FM broadcast traffic requirements. Some of these new requirements are CATV related, for instance security alarm signals, subscriber addressable control signals, interactive service signals, etc. An even larger growth area however is represented by opportunities for carrying signals for unrelated non-CATV entities on a leased channel basis. Potential customers include various kinds of institutions as well as commercial and industrial establishments.

Thus there are two major reasons why we have had to implement the data transmission capabilities of AML systems. First is the obvious fact that where the AML system forms the backbone of a CATV system, it must be capable of transmitting all required cable related as well as all leased channel data traffic. More importantly however is the fact that many potential commercial and industrial customers for data transmission services are in non-residential areas that are not cabled now, and that will be the last to be cabled - if they are ever cabled. Thus, a hybrid transmission system, as illustrated in Figure 3 is the only practical means of serving such potential data transmission customers. As the illustrations indicate, microwave relays are used to complement the CATV system, extending service to uncabled areas.

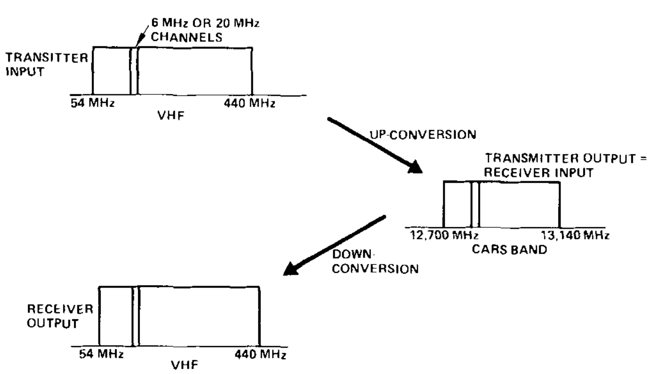
Before proceeding on to the various different data modulation methods, it is useful to briefly summarize the principle of operation of an AML system, from a broader perspective than is common in normal CATV video usage (see Figure 4). It can be seen that the AML system is essentially a frequency translating device. It simply upconverts any signals that lie in the VHF band to the 12 GHz band, transmits these signals from one place to



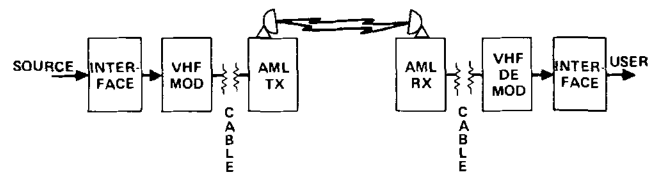
3. Hybrid data network.

another and then downconverts the received signals back to VHF again. In this process, it fully preserves all incoming modulation forms and spectral relationships. Thus the acronym AML no longer only denotes an "Amplitude Modulated Link" for VSBAM video signals, but rather a faithful and transparent microwave transmission system for any or all modulation forms, be they digital or analog. It has only half jokingly been suggested that AML really means "Any Modulation Link" and it is with this broadened scope that we wish to deal with here, bearing in mind that all the previously mentioned cost and bandwidth saving attributes of AML systems recognized for video traffic apply equally well to data transmission.

As illustrated in Figure 5 a typical block diagram of an AML one-way data link consists of an appropriate interface with the transmitting data equipment followed by a modulator which provides a modulated VHF carrier at its output. The VHF modulator output is connected to the input of an AML transmitter which then upconverts the VHF signal to the authorized microwave frequency. The signal received at a remote site by the AML receiver is downconverted to VHF and fed to a VHF demodulator. The output of the demodulator provides the appropriate interface with the receiving data communications equipment. Two-way communications is obtained by duplicating the equipment shown, with the exception of the antenna systems, at each data



4. AML - principle of operation.



5. Block diagram.

communications site and by providing frequency distinction between the upstream and downstream paths.

The modulators and demodulators may be remote from the AML equipment, being interconnected with standard CATV cable links.

There are a number of standard data communications interfaces which may be required to interconnect the data equipment to the modulator-demodulator (modem) equipment. Data processing standard interfaces such as RS-232C, RS422 and V.35 are readily available. Bell standard interfaces such as DS1, DS2 are also available.

There are five modulation methods that are being widely used for transmission of voice and data. They are tabulated in Figure 6. As you can see from the table, the familiar VSB and FM modulation methods can be used for either video or data transmission.

Each form of modulation has its own particular advantages and disadvantages to be considered when designing a data communications system for a particular application and for transmission through a broadband cable system.

Figures 7, 8, 9, 10 and 11 tabulate some of the characteristics of VSB, FM, SSB, FSK and QPSK modulation in relationship to the transmission of voice and data. These charts describe the applications and relative merits of the various modulation methods for different types of message traffic requirements.

MODULATION	TECHNIQUE	APPLICATION
VSB	VESTIGIAL SIDEBAND AM	VIDEO/DATA
FM	FREQUENCY MODULATION	VIDEO/VOICE & DATA
SSB	SINGLE SIDEBAND SUPRESSED CARRIER AM	VOICE & DATA
FSK	FREQUENCY SHIFT KEYING	VOICE & DATA
QPSK	QUADRATURE PHASE SHIFT KEYING	VOICE & DATA

6. Modulation techniques for data transmission.

APPLICATIONS	SIGNAL RANGE	ADVANTAGES	DISADVANTAGES
• VIDEO & PROGRAM AUDIO	NTSC STANDARD COMPOSITE VIDEO 6 MHz BANDWIDTH	• SPECTRUM EFFICIENT • CABLE COMPATIBLE • ECONOMICAL	NO FM IMPROVEMENT
• LOW SPEED DATA	3 CHANNELS 600 b/sec	• INEXPENSIVE	VERY LOW DATA RATE
• LINE SYNC MULTIPLEX	ANY COMBINATION OF NTSC VIDEO, OR DATA TO A TOTAL OF 6.3 Mb/sec	• POTENTIALLY LOW COST IN LARGE VOLUME • TDMA • FREQUENCY SHARED • TELETEXT COMPATIBLE	NOT YET COMMERCIALLY AVAILABLE

7. VSB.

APPLICATION	SIGNAL RANGE	ADVANTAGES	DISADVANTAGES
• VIDEO & PROGRAM AUDIO	STANDARD NTSC VIDEO & AUDIO	FM IMPROVEMENT OF SIGNAL TO NOISE	REQUIRES 20 MHz
• BROADCAST AUDIO FM	16 CHANNELS @ 15 KHz AUDIO @ 75 KHz DEVIATION	LOW COST, FM IMPROVEMENT	REQUIRES 20 MHz
• VOICE-ANALOGUE	600 CHANNELS OF FDM @ 4 KHz EA	MODERATELY HEAVY DENSITY	REQUIRES 20 MHz
• VOICE-DIGITAL	192 VOICE CHANNELS, T1 COMPATIBLE	COMPATIBLE WITH DIGITAL SWITCHING	SPECTRUM INEFFICIENT, COMBINED ON ONE STREAM
• DATA-ANALOGUE	600 FDM CHANNELS EACH CHANNEL 14.4 Kb/s	FM IMPROVEMENT EDP COMPATIBLE	LIMITED DATA RATES, REQUIRES DATA MODEMS
• DATA-DIGITAL	12 Mb/sec IN T1 FORMAT	FM IMPROVEMENT, T1 COMPATIBLE.	EXPENSIVE MULTIPLEXERS, SELECTIVE FADING SENSITIVE

8. FM (20 MHz).

Upon review of a specific application, it should be possible to narrow down the selection of equipment to a preferred choice. For example, if you are to transmit data during daylight hours and entertainment video at night, you would most likely choose VSB and use line sync multiplex equipment to transmit the data. Line sync multiplex equipment is designed to convert standard data formats into teletext format and to transmit up to 525 lines of data at the rate of 9600 BPS for each line.

If the application calls for subdividing a 6 MHz channel into many standard 4 KHz voice channels and thus serve many users of voice and data, then you will use Frequency Division Multiplex (FDM) equipment together with a single sideband modulator.

If the application calls for a data network to connect a few hundred data terminals to a computer center, and if available spectrum on the cable is not in short supply, you will use an economical FSK data communications system.

Finally, if you have a mix of high speed data requirements such as 1.544 MBPS T1 lines for digital telephone switching systems, or 1 MBPS lines for high speed graphics terminals, then you will use the QPSK RF data modems. Because a 1.544 MBPS data modem requires a bandwidth of about 1.1 MHz it is possible to subdivide the 6 MHz channel and by utilizing FDM techniques isolate T1 data streams from one another, thus providing security between applications and preventing intersymbol interference from interrupting the entire data transmission in the channel.

The data communications network designer should become thoroughly familiar with each of the modulation methods listed above, and the wide

APPLICATION	SIGNAL RANGE	ADVANTAGES	DISADVANTAGES
VOICE	≤ 960 CHANNELS OF FDM @ 4 KHz EA	• SPECTRUM EFFICIENT	NO FM IMPROVEMENT
DATA	≤ 960 CHANNELS @ ≤ 14.4 Kb/s	• COMPATIBLE WITH STANDARD EDP INTERFACES. • SPECTRUM EFFICIENT	NO FM IMPROVEMENT

9. SSB (6 MHz BW).

APPLICATION	SIGNAL RANGE	ADVANTAGES	DISADVANTAGES
DATA	≤ 56 CHANNELS @ 56 Kb/s	LOW COST CABLE COMPATIBLE	VERY SPECTRUM INEFFICIENT

10. FSK (frequency shift keying).

variety of interfacing data communications equipment. This information together with the knowledge that the AML microwave link is equivalent to a short length of broadband coaxial cable makes it possible to design cost effective, reliable data communications networks.

In conclusion, we would like to reiterate the following points.

1. Message traffic in general, and data traffic in particular, offer one of the most promising and profitable enhanced service opportunities for CATV operators.

2. Data transmission requirements consist of CATV related traffic (such as interactive services or station monitoring) as well as traffic for institutional, commercial and industrial customers.

3. Such data traffic requires high transmission reliability and spectral utilization efficiency.

4. Commercial and industrial customers are frequently not in cabled areas and can only be reached by hybrid systems combining cable compatible microwave and cable elements.

5. AML microwave techniques offer advantageous means of accommodating virtually any analog or digital signal capable of being carried on conventional cable systems. In such applications, the AML system becomes a virtually transparent link which completely avoids the distortions and other technical and financial costs inherent in microwave systems that require demodulation of the cable-carried signals to baseband and subsequent remodulation to cable compatible formats.

APPLICATION	SIGNAL RANGE	ADVANTAGES	DISADVANTAGES
VOICE	144 T1 COMPATIBLE VOICE CHANNELS	• SPECTRUM EFFICIENT, • CABLE COMPATIBLE • PARTIONABLE USING FDM TECHNIQUES	REQUIRES HIGH C/N RATIOS FOR LOW BER COMPARED TO FM OR FSK
DATA	10 Mb/s IN A 6 MHz BANDWIDTH SLOT	• SPECTRUM EFFICIENT • CABLE COMPATIBLE • PARTIONABLE USING FDM TECHNIQUES	REQUIRES HIGH C/N RATIOS FOR LOW BER COMPARED TO FM OR FSK

11. QPSK (quadrature phase shift keying).