USE OF HYBRID CARS MICROWAVE/CABLE FOR MULTISITE LOCAL-AREA NETWORKING

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ABSTRACT

In this paper, we first review the new role of CATV coaxial cable systems in supporting point-to-point voice/data networks and their inherent capacity to work as broadband local-area networks for distributed data communications. Then, the use of CATV-compatible AML microwave links to interconnect dispersed LAN systems is discussed.

GENERAL

Coaxial cables have in the past played a major role in providing high-capacity point-to-point communication systems for the transmission of voice, using the frequency-division multiplexing (FDM) technique, all over the country. Subsequently, the use of coaxial-cable systems for the distribution of entertainment video in urban areas saw explosive growth which is still going on. While the application for FDM voice traffic was limited to the base-band method of transmission using only a small portion of the cable spectrum, the CATV industry makes full use of the cable potential of up to 500 MHz of the RF spectrum.

The more cost-effective microwave radio systems practically ended the non-CATV use of cable for the past several years. However, with the explosion of distributed data processing, and advent of affordable workstations, the business world is forcing the communications industry to look into the coaxial-cable-based transmission techniques once again.

Although novel ideas are being introduced in the domain of radio communications technology, the limited available RF spectrum is putting a crunch on many radio users. On the other hand, the unsuitability of existing Telco subscriber loops for higher data transmission rates and the high cost of dedicated "T1" lines have prompted potential users to by-pass the local telephone companies.

The advent of local-area network (LAN) technology to satisfy the growing need for more efficient data transmission networks is another factor that is opening the door to a more novel and challenging use of cable systems to support a large data user population in metropolitan areas.

These facts, plus the widespread proliferation of CATV cable systems in urban/metropolitan areas are actually the driving forces behind the emerging interest in cable systems as alternate communications media for non-video applications.

While the use of coaxial cables for dedicated point-to-point transmission systems is well defined and known to system designers, it is their unique application in a distributed LAN environment, in conjunction with microwave interconnect systems, that is the topic of this paper.

REVIEW OF LAN TECHNOLOGY

There are two broad categories of local-area network systems presently developed to meet the ever increasing need for the transmission of data in a limited geographical area. These are the so called baseband and broadband LAN concepts. While many of the underlying principles of operation are very similar in nature, the two concepts are distinctively different when it comes to their transmission techniques.

The baseband LAN routes the data signals around the network in a modified version of their basic digital form without using a "carrier" signal, thus the name baseband. The broadband LAN, on the other hand, will take the processed digital signals and modulate a "carrier" signal for transmission around the network in the form of an "RF" signal. While a detailed comparison of the two LAN categories is beyond the scope of this paper, it is the broadband version which is fully compatible with the CATV cable technology.

BROADBAND LANs

Figure 1 shows a simplified overview of a broadband (BDB) local-area network. The topology is physically of the inverted-tree configuration which provides a logical bus structure. The system could be a single-cable or dual-cable based network. The single-cable version, being the closest to the majority of existing two-way CATV cable systems, uses a so called head-end frequency translator at the root of the "tree" which is the cable hub.

Figure 2 shows a general allocation concept of the frequency spectrum on a CATV cable system supporting LAN/p-t-p traffic. The BDB-LAN industry has basically opted for the existing CATV channeling plans and their various cable configurations such as sub-split, mid-split, etc. While each vendor allocates the cable spectrum for many services such as video, voice and alarm/security, their main concern is the provision of data communication channels. Depending on their system architecture, several 6 MHz channels in each direction are needed to support an entire Data Terminal Equipment (DTE) population of several thousand.

Based on the required data transmission rate, each 6 MHz channel is subdivided into many narrow-band

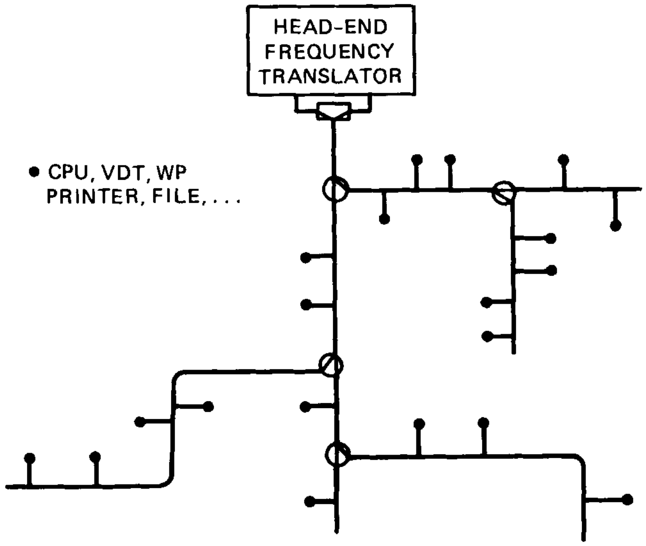

Fig. 1: Broadband LAN Topology

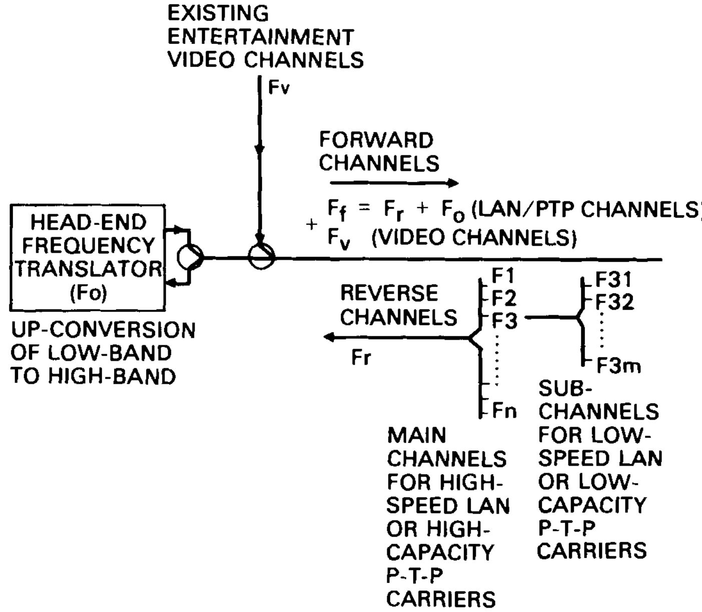

Fig. 2: CATV Plus LAN/p-t-p Channeling Concept

channels (10-300 kHz for example). Several systems in the market use the 300 kHz basic channeling scheme; thus providing 20 RF data carriers in a 6 MHz (TV) channel. Each 300 kHz carrier is capable of carrying a minimum of 128 kbps of digital information using the simple FSK modulation technique. This basic capacity of each carrier could be shared among many lower speed (e.g. 9.6 kbps) DTEs on a virtual-connection basis. The maximum number of DTEs sharing a given RF carrier is basically determined by their traffic rates and patterns and the medium-access mechanism of the LAN system. The most popular CSMA/CD (Carrier Sense Multiple Access with Collision Detection) method can provide system throughputs as high as 96 percent of the total available capacity. A thorough data communication traffic study must be done to determine the optimum number of shared users on any given RF carrier in order to meet the required system response time and/or grade of service.

INTEGRATION OF DISPERSED LANs

Many of the available broadband LAN systems on the market are specified to support as many as 65000 DTEs on 60 300 kHz wide RF carriers, occupying a total of 18 MHz of cable spectrum in each direction of transmission. Such an inherent huge capacity of BDB LANs is far beyond the normal need of any single organization, particularly if confined within a very limited geographical area that a "local" area network is designed to support. For this reason, BDB LAN's are generally highly underutilized in private business applications.

One way to increase the utilization factor of a given LAN system is to integrate several dispersed "mini" LANs into a larger network. In real life, these could, for example, be the various buildings or plants of a large corporation scattered in a 20 mile radius as shown in Figure 3. The problem is to expand the basic LAN tree to reach every facility in the network. In urban areas this becomes almost an impossible task if one had to run dedicated coaxial cables across town.

This is where the existing CATV cable systems prove their value. Being designed to serve a large community, the cable systems can easily function as a real LAN tree if many of the existing or new subscribers require data communications services. It also pays to interconnect large isolated users to the main cable tree through dedicated "branches".

CARS-MICROWAVE INTERCONNECT SYSTEMS

The problem of integration of widely dispersed cable systems, or large customers not passed by cable, into a comprehensive LAN system can easily be achieved through dedicated CARS microwave radio links. Just as video channels have been distributed from a program origination point to several cable hub locations, the cable compatible Hughes AML^{R} microwave concept can be used to extend or interconnect several "mini" LANs into one large network.

The AML concept that is so well known to the CATV industry is based on the heterodyning principle where any given VHF carrier, with whatever type of modulation, can be up or down-converted to another frequency when properly mixed with a locally-generated signal. This process is basically independent of the modulation content of the desired carrier; analog AM, FM or digital FSK, QPSK, etc.

While the use of AML in VSB-AM transmission of video signals is well defined, its new application in interconnecting cable systems supporting LAN networks, or point-to-point voice/data traffic, needs redefining. The standard 6 MHz VSB-AM channel carried by each AML transmitter is characterized by the video, color and audio carriers in a well defined relationship. The new LAN or p-t-p carriers are as yet not standardized in terms of bandwidth, modulation type, their sensitivity to system non-linearities, frequency shifts, and a host of other parameters. For example, the low-speed 300 kHz wide RF carriers of a CSMA/CD LAN network using FSK modulation can only tolerate a frequency shift of 10 kHz when going through any interconnect link. Their threshold response of 10^{-6} BER requires certain minimum values of

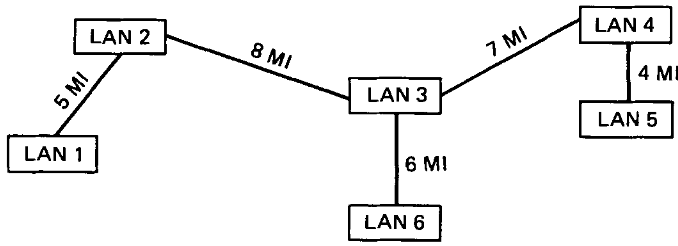

Fig. 3: Integration of Dispersed Mini LANs Into One Network

carrier-to-noise or carrier-to-intermod noise ratios. Their sensitivity against carrier level variations is another point that must be considered. The number of RF carriers and their relative levels in any given bandwidth also directly affects the system I.M. performance.

With LAN systems, even when we have perfect transmission channels, the actual transmission delay experienced by the carriers in going from the farthest user terminal to the head-end translator and back will affect the overall LAN system throughput. So, the location of the head-end translator and the maximum length of the LAN tree branches becomes critical in the context of the LAN performance constraints. It is interesting to note that the transmission delays introduced by the AML link is about one tenth that of a coaxial cable of comparable length.

With all the above in mind, every AML-LAN interconnect system must be carefully tailored to meet the performance requirements of a given LAN or p-t-p system if true transparency on the part of the AML equipment is to be achieved.

TYPICAL APPLICATION

Figure 4 shows the simplified block diagram of a typical AML microwave LAN interconnect where two independent LANs are to be integrated into one system. In this example all the users on LAN 2 are to become part of the population of LAN 1.

To implement such an integration, the coax cable of LAN 1 is tapped through a standard directional tap at a convenient point closest to the location where the AML microwave equipment is to be housed. The choice of this location is dictated by the need to have line-of-sight transmission between the two sites of LAN 1 and LAN 2. At the other end, the AML radio equipment is directly interfaced with the LAN 2 coax cable at its head point.

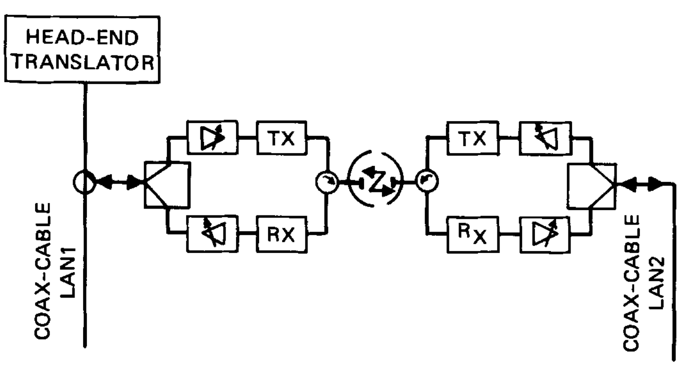

Fig. 4: AML-LAN Interconnect

With the connections so made, the coax cable of LAN 2 becomes a major "branch" of the system "tree" under LAN 1 and the two-way communications among the users of LAN 2 themselves and the other users on LAN 1 take place as if all the users were connected by a single network. The flow of signals to/from LAN 2 take place in the following manner.

The channel carriers within a given window, up to 20 MHz, transmitted by the cable modems of the users on LAN 2 will arrive at the AML equipment. They first pass through a diplexer filter which separates the "forward" and "reverse" frequency bands in order to be compatible with the single-cable mid-split system. The carriers then go to an amplifier where their level is adjusted to the optimum value required by the transmitter (TX) unit. The TX unit upconverts the carriers to the designated microwave band for onward transmission. At the other end, the microwave signals are picked up by the antenna and passed to the microwave receiver unit (RX) where they are downconverted to their original VHF frequencies. They will then pass through an amplifier that sets their levels to the optimum value for injection onto the LAN 1 coax cable.

The carriers, now being on LAN 1 cable, will be treated like the other in-house carriers. That is, they will be received by the LAN 1 headend translator, converted to the forward frequencies, and injected back onto the cable to go to all users on LAN 1 cable. To go to LAN 2 users, the carriers will enter the AML radio equipment through the directional tap and undergo a similar process as they did in the return direction. In this manner, the LAN 2 system will be fully integrated into LAN 1.

The coverage range of the AML microwave radio system basically depends on the operating microwave frequency, the terrain and climatic conditions of the areas and, of course, the availability of line-of-sight propagation between the two LAN sites to be interconnected. However, for many applications such distances could range up to 20 miles.

Figure 5 shows the detailed block diagram of a fully protected AML-LAN interconnect system as implemented in a single-hop application in a university environment. Here, the two buildings are separated by about 2 miles in a very crowded part of Chicago, where laying of coaxial cable was impractical. The AML link interconnects 18 MHz of the cable spectrum that is supporting about 800 DTEs plus the entire central data processing equipment of the university.

CONCLUSION

Existing or new CATV cable systems are inherently capable of supporting other types of traffic besides traditional entertainment video. Through proper design and allocation of the freqeuncy spectrum they can be used to provide point-to-point transmission channels to the business community as "by-pass" links for their inter-office use. In a more universal role the cable system can be employed as a broadband local-area network supporting thousands of data terminal users.

In all cases, any cable system may have to be extended to cover distant clusters of users in order to be more viable as a LAN or a by-pass. In such cases, proven microwave transmission techniques are available to extend the branches of any cable system for this purpose.

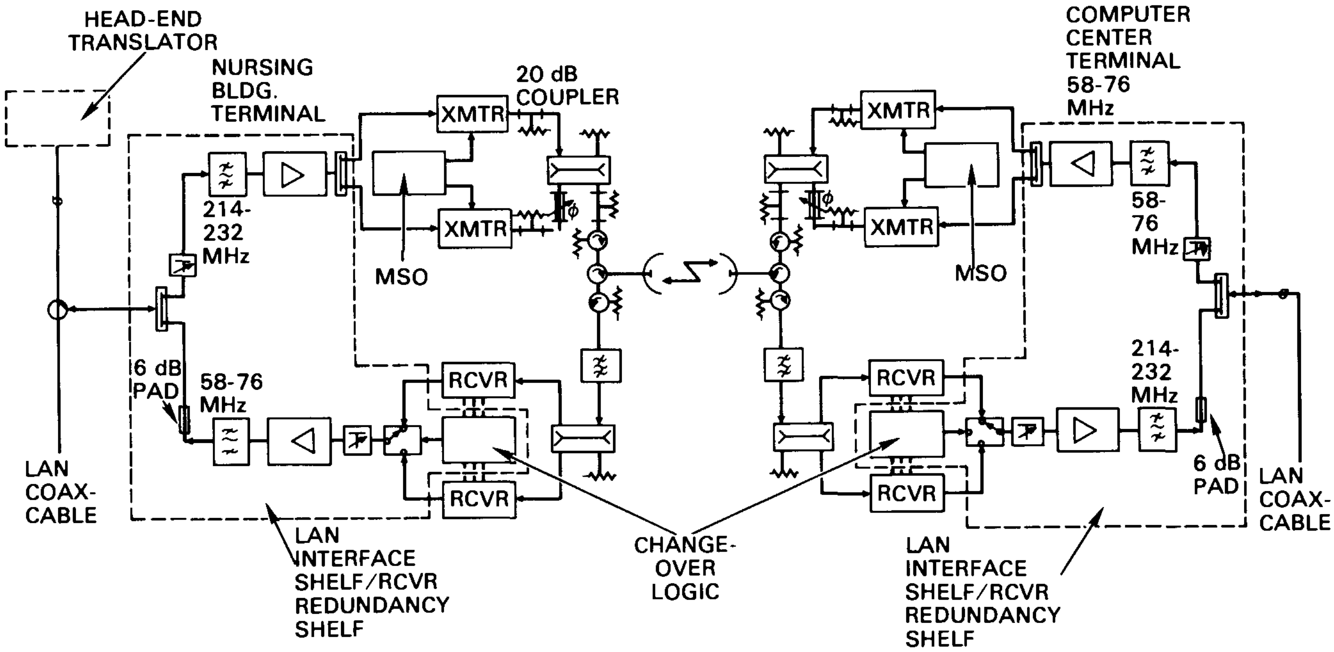

Fig. 5: Fully Protected AML-LAN Interconnect System Block Diagram

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