TECHNICAL CONSIDERATIONS IN THE DESIGN AND OPERATION OF A TWO-WAY CATV SYSTEM IN A MAJOR MARKET AREA

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ABSTRACT

The design and operation of a two-way CATV system in a major metropolitan market area involves a number of unique problems. Following a review of development in past years, the current design parameters are discussed and the author's recommendations are presented for the specification, design and operation of a contemporary two-way broadband communications system.

SIGNAL TRANSMISSION REQUIREMENTS:

The nature of the two-way CATV system is essentially defined by the characteristics of the signal transmission requirements. In contemporary systems serving major metropolitan centers the following signal transmission requirements are considered essential:

1. Thirty (30), or more, downstream television channels available to all subscribers with very high quality video reception,

2. Twenty (20) F. M. radio channels in the normal F. M. radio frequency band (88-108 MHz), with spacing for stereo modulation,

3. Twelve (12) to Twenty (20) additional television channels available to limited areas for distribution of limited access nonentertainment television programs (municipal, medical, educational, industrial, etc.),

4. 5 to 30 MHz reverse (upstream) non-television transmission facilities from all residential subscribers to a central data collection center,

5. Five (5), minimum, reverse (upstream) television channels of high quality. F. M. video modulated channels may be required in order to attain sufficient fidelity as to permit re-transmission without noticeable video degradation.

The downstream distribution requirements are generally known to CATV system engineers and present no new or difficult problems. However, the upstream transmission system represents a new technology that has not been fully demonstrated on an extensive system. In addition, there are certain avoidable problems associated with the possible interference between the upstream and downstream transmissions which should be considered in the system design.

ORIGINAL DESIGNS AND DEVELOPMENT:

There are several basic designs for two-way systems which have been field tested and the advantages and limitations reported in the trade press and technical seminars. Early systems used a separate coaxial cable from each origination location to the "headend". To minimize noise build-up a low frequency (below Channel 2) video carrier was used so that amplifiers could be spaced farther apart in the "return line". This "sub-VHF" band (5.75 to 47.75 MHz) was generally converted to the VHF high band (174 to 216 MHz) for reception and the channels were assigned appropriate numerical designation (T-7, T-8,.....T-13).

A natural development occurred in the early 70's wherein the "sub-VHF" band was diplexed onto the CATV system in the reverse (upstream) direction. The complimentary filters which provided the isolation between the upstream "sub-VHF" and the downstream "VHF" transmissions were the subject of intensive research and development. The early "sub-split" systems were designed to provide downstream transmission from 54 to approximately 250 MHz and upstream transmission from 5 to 30 MHz. These early two-way (on a single coaxial cable) systems exhibited several severe limitations, although most "blue sky" system operators chose to ignore them.

It is, however, generally recognized today that such sub-low band frequency division two-way multiplexed systems are not suitable for major market system use because:

1. Phase delay, due to the cascade of large

numbers of the complimentary filters, causes intolerable video distortion in the higher frequency "sub-VHF" channels and in the lower frequency VHF channels.

2. Noise and ingress interference is excessive due to the branching nature of the system.

3. Upstream transmission bandwidth, of 5 to 30 MHz does not provide space for sufficient video channels.

SFDT SYSTEM: (See Fig. Nos. 1 & 2)

As a consequence, a system was developed to provide the two-way facilities without these limitations. This system is generally referred to as the "Single-Feeder, Dual Trunk" (SFDT) design.

The essential components of the SFDT system are:

(a) Two independent trunk cables ("A" and "B") with complete physical separation to achieve maximum isolation. Trunk "A" provides conventional CATV multi-channel downstream only distribution (50 - 300 MHz). Trunk "B" operates as a "mid-split" two-way transmission system with downstream distribution (174 - 300 MHz) and upstream transmission (5 - 110 MHz).

(b) Two-way distribution, or feeder, with downstream supplied from the "A" trunk (50-300 MHz) and the upstream signals of 5 to 30 MHz diplexed through the line extender amplifiers from each subscriber drop to the bridging or distribution amplifier.

(c) The sub VHF (5-30 MHz) upstream signals are separated from the downstream signals by highpass/lowpass filters at the bridging or distribution amplifier and are coupled through a "seventh port" to the "B" cable reverse amplifier. This "seventh port" amplifier is unique inasmuch as the conventional downstream only amplifier housing has only six (6) ports: input and output trunk ports plus four (4) distribution ports.

(d) The seventh port in the "B" cable amplifier provides a means to couple the 5 to 30 MHz signals to the 5 to 110 MHz upstream system such that:

(i) An automatic switch opens to block the insertion of noise and interference when actual sub-low signals are not being transmitted,

(ii) Amplifier response, and lowpass filters, prevent noise and interference from the subscriber drops and "A" cable distribution system from appearing on the "B" cable -- particularly in the 45 to 110 MHz bandwidth. This frequency band is reserved for "preferred" reverse video transmission.

It can, therefore, easily be seen that the SFDT system provides all of the signal transmission requirements which are considered essential for service in contemporary systems serving major metropolitan areas. Such systems have been extensively field tested and are available from all major equipment manufacturers. There are, nevertheless, certain precautions that should be taken to avoid crosstalk and interference/noise problems.

THE REVERSE SYSTEM "NOISE TREE":

Although "thermal" noise contributed by the reverse amplifiers in the upstream transmission system can be a significant problem, and can severely limit the quality of video channels which are carried, the interference from r.f. ingress leakage is of greater concern. C.B. radio and foreign radio stations can be very "active" in the sub-VHF frequency band and can easily enter the upstream system through the unshielded 300-Ohm twin lead on the customer's side of the matching transformer or through inadequately shielded drop cables. The preferred reverse video band (45 - 110 MHz) is subject to interference from lowband television and FM radio transmission and other radio frequency interference and must be well isolated.

If the subscriber drop is, therefore, assumed to be a potential source of noise and interference which will be amplified and combined in the upstream transmission, it is apparant that a filter which excludes all unnecessary interference should be used in the 5 to 30 MHz upstream circuit. Further, a squelched or switched upstream amplifier would provide additional isolation from such interference. The relative merits of a squelched reverse amplifier vs. a code-operated switch may be debated, and may vary with the state-of-the-art, but one or the other would seem to be imperative in a contemporary system for two-way service.

It has been demonstrated [1] that data error rates on reverse transmissions within two-

(1) Reliability Engineering Report No. 75-06, February 9, 1975, Jerrold Electronics Corporation by S. Allen (Unpublished)

way frequency division multiplexed systems extending only twelve (12) amplifiers away from the headend exceed tolerable rates. The use of time sharing techniques to control the effect of noise-contributed errors has been shown to be adequate for such sensitive applications as home security system communication requirements.[2]

COMPONENT SELECTION:

One of the lessons which was learned through early two-way system design, construction and operation was the requirement to fully consider the sub-low frequency band in the selection of system components. Passive devices must be carefully selected to assure the desired reverse attenuation vs. frequency characteristics. Drop cable, connectors and equipment housings must exhibit high resistance to signal leakage, particularly in the sub-low band frequencies. Cable and electronic equipment which was designed and tested for use at 50 MHz and higher frequencies should NOT be assumed to be adequate for sub-VHF frequency use. Likewise, dual cable forward only transmission system equipment and design techniques should not be assumed to be adequate for forward-reverse system operation with common frequency use such as the SFDT system. The isolation required in the two-way system is considerably greater than that required in a dual cable downstream only distribution system. This may be attributed to the branched design of CATV systems; and to the consequent addition of all noise and interference at the central hub or headend vs. the single upstream signal.

SYSTEM DESIGN AND CONSTRUCTION:

It is therefore obvious that system test points should not be constructed so as to violate this high isolation requirement -- with lengths of parallel drop cable down the pole. Significant r. f. currents will exist on the outer surface of solid aluminum sheath coaxial cable with a wall thickness of less than 8 mils and a high level 5 MHz signal impressed thereon. Conventional 40% to 50% braid coverage drop cable provides too little shielding at any frequency.

The a.c. powering is also critical as a potential problem in isolation. Separate ferroresonant regulating transformers and diplex couplers are recommended. In some cases it has been necessary to cascade the a.c. power couplers in order to obtain the high isolation required.

Separate trunk amplifier housings, preferably mounted "back-to-back", are recommended. These housings should demonstrate effective r.f. shielding at all frequencies within the 5 to 300 MHz bandwidth.

(2) "The Quiet Way to Link Upstream" by Cecil C. Ho , TOCOM, Inc. (Unpublished)

Although the conventional amplitude modulation used for television video transmission may at first appear to be a "worst-case" situation, it should be remembered that the upstream data signals may be pulse code modulated and contain relatively high level harmonic components. Cross talk from such signals can have a devastating effect upon the video signals.[3]

As a final precaution to be observed in the design of a CATV system within a major market area the system maps should be on a scale of 100 ft./inch instead of the conventional 200 ft./inch scale. The increased system complexity, together with the usually higher dwelling density in major market areas, will require more spacious system layout for legibility.

CONCLUSION:

In summary, it is suggested that great care be given the design and construction of systems within the major metropolitan areas. Although initially intended only for downstream signal distribution with, perhaps, some widely scattered upstream transmission of locally originated television signals, there are strong indications that complete two-way service will be required before complete depreciation write-off. Some minor design and construction modification, together with careful selection of cable and equipment, can avoid the major expense and confusion of extensive design change and equipment replacement when two-way operation is desired.

REFERENCE LIST

1. Cable Television Technical Advisory Committee's Final Report to the F.C.C., Volume II, Panel 9, pp. 813-826.

2. "Two-Way System Experiences" by D. Stevens McVoy NCTA Technical Transcript of 24th Annual Convention, April 13-16, 1975.

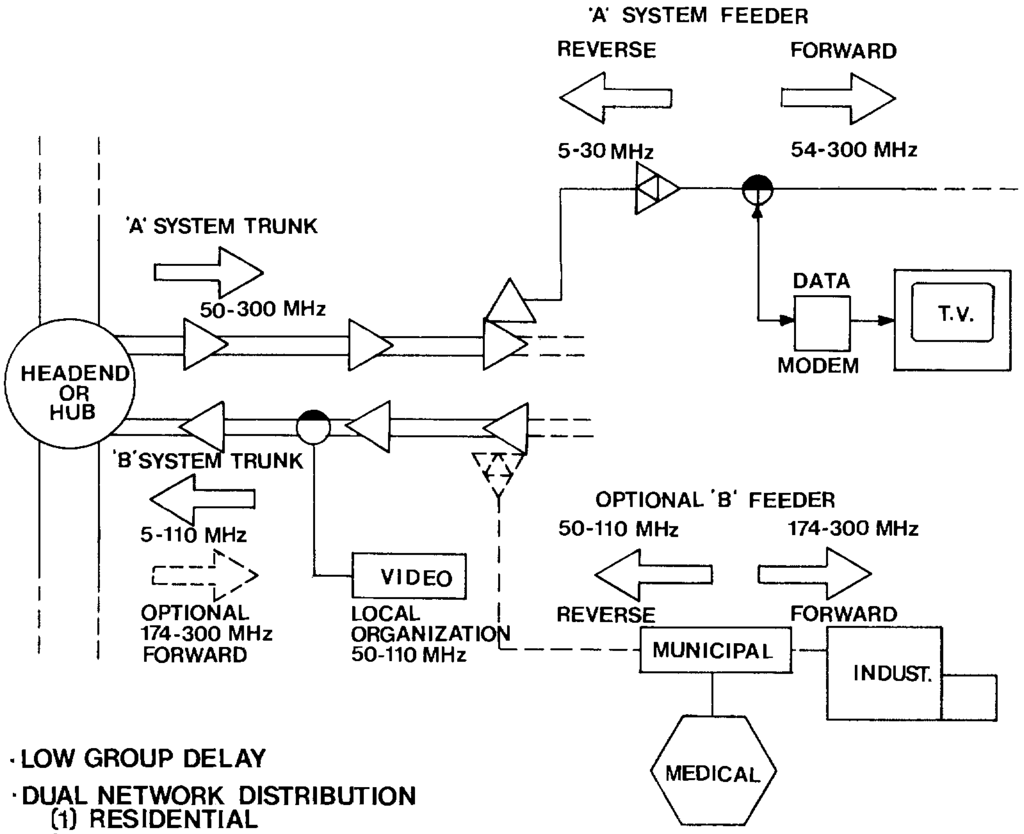
3. "Two-Way is Alive and Well" by Donald T. Rozak, NCTA Technical Transcript of 25th Annual Convention, April 4-7, 1976.

4. "A Study of Aluminum Cable-Connector Interfaces and Their Effect on CATV System RF Ingress" by Eric Winston, NCTA Technical Transcript of 22nd Annual Convention, June 17-20, 1973.

5. "Considerations for Reverse Signals in the Feeder Lines" by Robert Wilson, NCTA Technical Transcript of 22nd Annual Convention, June 17-20, 1973.

(3) "Mutual Interference Effects in Data/CATV Systems" by Charles E. Sampson, NCTA Convention 1973.

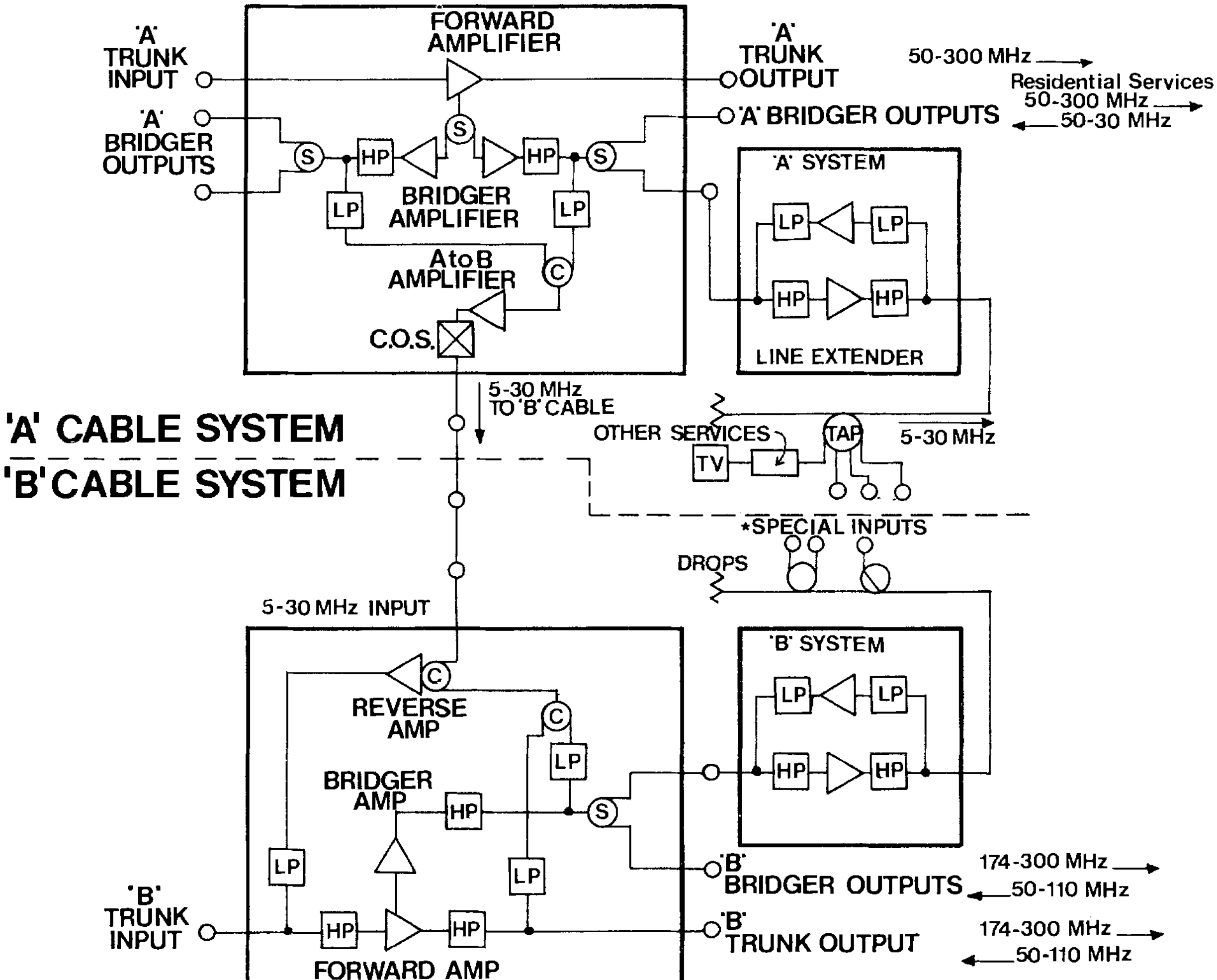
DUAL TRUNK CABLE
SINGLE DISTRIBUTION CABLE



- LOW GROUP DELAY
- DUAL NETWORK DISTRIBUTION
  (1) RESIDENTIAL
  (2) LIMITED ACCESS
- LOW NOISE VIDEO RETURN (50-110 MHz) WITH DATA RETURN (5-30 MHz)
- OPTIONAL ADDITIONAL LIMITED ACCESS FORWARD DISTRIBUTION

FIGURE 1

SYSTEM STATION DIAGRAMS



*SPECIAL LIMITED ACCESS INPUT & DROPS FOR SECURE SERVICES. (POLITICAL, INDUSTRIAL, MEDICAL, EDUCATIONAL, ETC.)

FIGURE 2