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ABSTRACT

Bi-directional cable TV (CATV) systems that are being installed today may not be well suited for computer communications. Older CATV systems are being modified to bi-directional transmission and most new systems are being built with bi-directional capability included. The extreme bandwidth requirement for carrying 20 or more TV channels on a frequence-division multiplexed (FDM) basis requires cables to be equalized and provided with repeaters for operation at comparatively high frequencies. The latest CATV systems provide down stream, to-the-subscriber transmission between 50-300 MHz, and up stream from-the-subscriber transmissions between 5-30 MHz. This system design is adequate for TV. However very little data communications experience has been accumulated on CATV; and because of system noise and the absence of system redundancy, reliability in computer communications on CATV may become a major problem. (Author/MG)

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THE CABLE TELEVISION SYSTEM AS A COMPUTER COMMUNICATIONS NETWORK

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Abstract:-

Broad band communications networks already exist or will soon be installed in many cities to provide television reception by co-axial cable. Older systems can be modified to bi-directional transmission and most new systems are being built with bi-directional capability included. Cable television systems are optimized for their television service function which is primarily the provision of multi-channel television service to private homes. The extreme bandwidth requirement for carrying 20 or more television channels on an FDM basis requires cables to be equalized and provided with repeaters for operation at comparatively high frequencies. The latest cable TV systems provide transmission in the "forward" direction for frequencies between 50 and 300 MHz. Reverse transmission paths are provided by filters which provide a 5 to 30 MHz "return path" or by provision of a second co-axial cable.

The basic characteristics of cable television systems are described for those computer communications engineers who might not be familiar with them. Very little data communications experience has been accumulated on cable television systems and advantages and problems are presently only hypotheses. Reliability may turn out to be the major problem in computer communications on cable TV systems.

PRESENT SYSTEMS

Cable television systems in use today are, for the most part, tree-structured, uni-directional networks of co-axial cables installed for the distribution of broadcast type television signals from a master television receiving antenna to home type television receivers. (Fig. 1) Multiple television signals, which may be received at a central site or relayed over long distances by microwave systems, are processed at a central "head end" and mixed together onto a single co-axial cable for distribution. Co-axial cables now in use are universally 75 ohm impedance types, usually of seamless aluminum sheathed construction, foam polyethylene dielectric, and solid copper or copper clad aluminum centre conductor. The co-axial cables range in size from 3/4" outer diameter for "main trunk cables", through a 1/2" size down to a .412" size for "local distribution". The service drop lines are usually flexible cables of about 1/4" diameter. The useful frequency range covers the VHF television band, 54 - 216 MHz and broadband transistorized amplifiers are installed with equalizers to compensate for cable losses. Practical systems are aligned to be unity gain networks between 50 and 220 MHz with amplifiers spaced about 20 db apart at 220 MHz.

Cable losses range from about 1 db/100' at 220 MHz for the 3/4" size cables to about 5 db/100' for the flexible service drop cables. Power division at cable branches, and "taps" into subscribers homes are accomplished through hybrid directional couplers. All system components are carefully matched to 75 ohms to minimize internal signal reflections within the system.

System amplifiers are subject to rigorous linearity specifications. Amplifier overloads manifest themselves as very objectionable cross modulations between channels and as undesired second and third order intermodulation and harmonic products. Amplifier operating levels are bounded on the lower side by system signal to noise ratio objectives which are about 40 db for reasonably acceptable performance as a television distribution system. A typical system will have amplifier inputs at about +10 dbmv and maximum output at about +30 dbmv. System operating levels are rigorously controlled by pilot carriers and thermal compensation systems.

More recent cable systems have been built using a "hub" principal in which tree-structured networks originate from a number of "hubs" throughout the community serviced (Fig. 2). The "hubs" may contain equipment for more elaborate control of signal levels and it may be possible to perform some special switching functions such as the interconnection of sub-trunks for special purposes, but this "hub" system is still far from a true "space diversity"system.

Some recent systems and most new systems under construction have expanded the capacity of the system for forward television distribution by tightening the linearity specifications on the amplifiers and extending the useful frequency spectrum up toward 300 MHz. The improved linearity, usually achieved through "push-pull" amplifier circuitry reduces 2nd and 3rd order intermodulation problems and allows higher TV channel loading. Capacity of such systems is increased to 30 channels or more, requiring use of a special converter with each TV set to receive these "non-standard" TV channels. These are still uni-directional tree-structured systems.

"TWO-WAY" SYSTEMS

Uni-directional cable networks can serve only very limited computer communications functions. It is certainly possible to make use of forward spectrum space for conventional computer data transmission systems. Almost any data transmission system could be used provided that it is modulated onto an RF carrier passed by the system. Loading characteristics would probably be similar to loading expected in conventional carrier technology, roughly equating one TV channel to a 960 or 1200 voice channel carrier system. CATV systems will be found to be highly linear by almost any communications engineering standard and a system designed to carry 20 TV channels with high quality will probably stand additional data loading with little strain. The problem is that uni-directional systems will probably have little utility. One could perhaps imagine some applications that would require data capacity in one direction that could not be provided by conventional telephone systems, but for which conventional phone lines would serve as a return link. Some high resolution, high speed facsimile systems might fall into this category.

Such use of cable television systems will be limited by the tree-structured, "party line" nature of cable TV systems and by the finite spectrum space available. Some experiments have been conducted with 1 megabit data transmission rates on cable systems. These occupy almost 6 MHz of spectrum. When launched into the system, this 6 MHz data channel is occupied throughout the system even though this 6 MHz channel really serves only two of the thousands of possible terminal locations on the system. A system built to provide multi-channel television distribution will not have very many 6 MHz channels available for data communications.

If the cable systems must be used for communications between terminals in both directions, some kind of return path must be provided. Cable systems are already making use of limited return path capability for their own internal purposes. Many cable systems have provided some two-way capability in order to permit some video transmission for local programme origination. The first approaches to provision of "two-way" have been by the use of "two-way" amplifier stations using frequency division of E-W and W-E paths.

The use of hybrids to separate E-W and W-E signals has had only limited success in cable TV systems. The use of a single amplifier for both E-W and W-E signal amplification has also not been used because of the complexity of the filters required and the desire to minimize amplifier loading. Most present "two-way" systems use the configuration in Figure 3. Filters at each end of the station separate low and high frequencies and direct them to E-W and W-E amplifiers, usually referred to as "downstream" and "upstream" amplifiers. The frequency cross-over is usually at about 40 MHz. The downstream spectrum is usually 50 - 270 MHz and the upstream spectrum about 5 - 30 MHz. This permits full TV VHF spectrum utilization in the downstream direction and makes available about 25 MHz of upstream spectrum for data and/or video channels.

Some problems are experienced with group delay at the edges of the cross-over. This group delay distortion could affect the performance of video channels near the cross-over. The usual tolerance is no more than 100 nanoseconds between luminance and chrominance carriers and this can be exceeded in cascade of 50 or more such filters. Filters also add some ripple to the pass-bands and level control is so critical in large cable television systems that the ripple from these cross-over filters may be intolerable. Some cable equipment manufacturers are recommending against the use of "two-way" amplifers in large, high quality system and are proposing the use of a separate upstream cable or a second cable on which a wider cross-over area can be provided. There is so little practical experience with these two-way systems that the questions raised have not been definitively answered. The ripple and group delay problems which have been raised are serious for critical video transmission but would probably not affect narrower band data systems or data systems using less critical modulation techniques.

A number of possible "two-way" configurations are shown in Figures 4,5,6,7 and 8. (Courtesy Jerrold Electronics Corporation).

The final choice between single cable/two-way, multi-cable/ two-way, and multi-cable without two-way filters will probably be made on the basis of video transmission requirements. The potential user for computer communications will still be faced by what is essentially a tree-structured system with rather limited bandwidth.

SYSTEM CHARACTERISTICS AFFECTING COMPUTER COMMUNICATIONS

Available Spectrum:- It is doubtful for economic reasons, whether a downstream cable dedicated to data will be available. Computer communications users will have to share a cable with television. Some space is available below Channel 2. The lower edge of television Channe 2 is 54 MHz. Some cable systems will try and squeeze an extra TV channel into the space 48 - 54 MHz. In a two-way cable this will probably encounter serious group delay problems as it approaches the filter cross-over. This space in a "two-way" cable would probably be available for data transmission. The space between Channel 4 and 5 (72 - 76 MHz) might be used for low level data signals. High signal levels in this area could cause harmful picture interference on some TV sets. Data transmission will generally have to be fitted into space not being used for TV channels or for system pilot purposes. Cable system engineers will prefer that data transmission operate at low signal levels and with strictly controlled spectrum characteristics. Data transmission systems will probably have to be strictly filtered to be sure that there is no appreciable energy outside the band assigned to them. TV picture channels are extremely succeptible to interference from spurious signals. Specification will probably be that no spurious signal from a data channel shall be more than -57 db relative to any affected TV picture carrier.

Spectrum between 108 and 118 MHz might be available for low level data channels. There is still discussion going on as to whether this band should be used within a cable system because of danger of interference to aircraft navigation in case of signal leakage out of the cable.

A data channel launched into the system appears throughout the system unless special measures are taken to trap it out of specific portions of the system. This may be practical in "hub" type systems and may make it possible to use same spectrum for different users in different parts of the system. System designers will want to consider whether it is more practical to serve a large number of potential data users by time division multiplexing of a high speed channel, or by providing frequency division multiplexing to provide each link with a unique frequency assignment in the system. TDM system should consider the significant propagation time within the system. Multiple users multiplexing into and out of a high speed data stream on a time-division basis can be separated by some tens of microseconds in propagation time. Terminals can, however, be synchronized relatively easily by a master clock distributed throughout the cable system.

The hybrid devices used in new cable systems are usually specified only down to 5 MHz and frequency response falls off rapidly below 5 MHz.

System Operating Levels:- Individual cable television amplifiers usually have a noise figure of about 10 db. Effect of cascading amplifiers can increase effective system noise figure to 30 db. or more. System loading considerations limit television carrier levels to about +30 or +32 dbmv. Data channel operators will probably want to limit data channel carriers to a level of 10 to 20 db below TV operating levels in order to minimize additional loading due to the data channel carriers. The cable operator, at least for the time being, is making his living by providing a maximum number of downstream television channels and will accept data channels only on a "non-interfering" basis.

System power:- Cable system amplifiers are powered by low voltage 60 Hz power through the co-axial cable. This power may be as high as 60 volts (RMS) and currents may run to 10 amperes (RMS) with peak currents even higher. There are significant harmonics of the power line frequencies present. Some amplifiers use switching mode power supplies with switching frequencies in 10 - 20 KHz range. "Hash" from these switching regulators also finds its way into the cable. This limits the use of very low frequency data or data carriers.

System Reliability:- There is virtually no redundancy in cable systems. Most present systems do not even have stand by primary power. Alternate routings are not available in case of system "catastrophy". Data users will find cable system reliability quite poor when compared with common carrier facilities that they are used to. Not much is being done about this and it will take considerable pressure by cable system users of all kinds to get cable operators to improve reliability.

Noise in "Two-Way" Systems:- Most two-way systems are being developed with an "up-stream" channel designed to permit input from virtually any location in the network. We end up with a large number of noise sources being fed up-stream toward a common source. The practical limitations of this noise problem are not yet fully understood nor is there enough direct experience to guide system designers. All potential and actual terminals are connected to both upstream and downstream systems and any malfunction or excessive noise in any of them gets into the system and can seriously affect many other terminals not directly concerned with the faulty terminal.

Another unwelcome source of system "noise" is leakage into the system. Cable and equipment radiation problems are reciprocal. The most common "leaks" in a system are poorly made cable splices and connections. Cable connections often loosen under influence of vibration and the cold-flow property of aluminum. Strong RF sources such as nearby mobile radio transmitters, amateur radio transmitters, AM and short wave broadcasting stations, and miscellaneous EMI sources leak into both upstream and downstream cables and interfere with the low level television and data carriers. Most "two-way" cable systems now in use suffer from this problem and we have seen demonstrations of data transmission on cable systems seriously affected by RF leakages into the cable. Loose connections and cracked cable sheaths also cause intermittent transmission conditions, and the momentary "disconnects" which would cause only minor "flashes" on a TV picture constitute major data drop outs in a high speed data circuit.

Privacy:- Upstream and downstream channels are essentially big "party-lines" amd everyone has access to all the data moving in the system. Privacy will be difficult to provide. Private cryptographic systems will probably be required to provide reasonable assurance of privacy. Since data transmission systems will probably be mostly digital these cryptographic protections will probably be easy to provide but will entail some cost and may somewhat penalize data transmission rates and capabilities.

Ubiquity:- Cable systems are being installed primarily for distribution of entertainment type television. The basic cable network may not be extended to all locations to which computer communications users may want access. The economic of computer communications on cable has not yet been established and we do not know yet whether it will pay to extend broad band cable into industrial areas strictly for computer communications.

CONCLUSIONS

Cable television is in a primitive state of development. Cable systems are being developed primarily for distribution of television programmes with some data handling capability for internal system uses such as monitoring and control of "Pay TV" systems, monitoring of home fire and burglar alarm systems, and very limited data communications to and from private homes. Wide spread computer communications might be possible if the total requirements for spectrum space are not exceeded by limitations imposed by the "party-line" tree-structure of cable TV systems. There is not yet enough experience with actual computer communications on a large enough scale to recommend any particular approach to the detailed design of communications systems, modems, or operating techniques for computer communications on cable TV systems. With the recent adoption of new rules by the FCC, cable system development will go ahead rapidly in major metropolitan areas. Cable operators developing these systems would, no doubt, welcome specific approaches from computer communications systemd desiring more detailed studies or practical tests on cable television system.

Completely switched systems with useful bandwidths of 6 to 10 MHz are presently too expensive to be considered for community-wide use and cable systems for the next decade or so will be developed on a broadband, tree-structure basis, with very limited space separation possible.

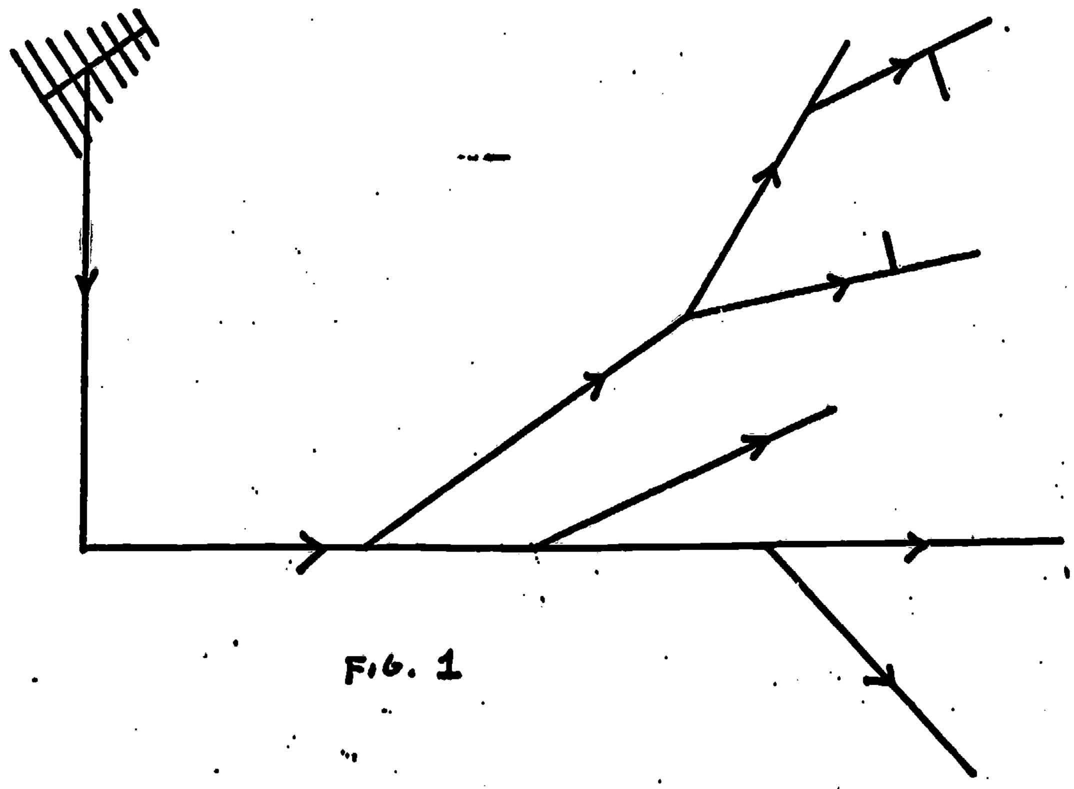

FIG. 1

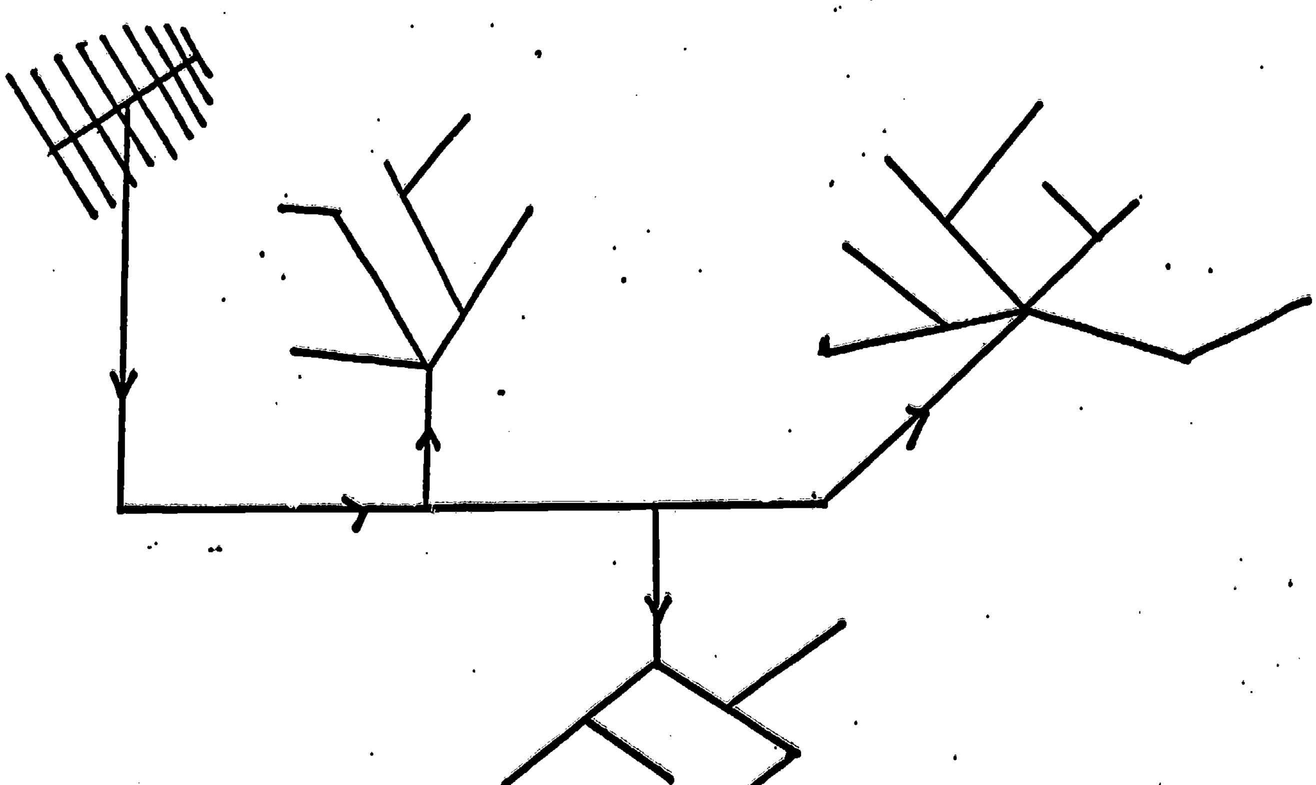

FIG 2.

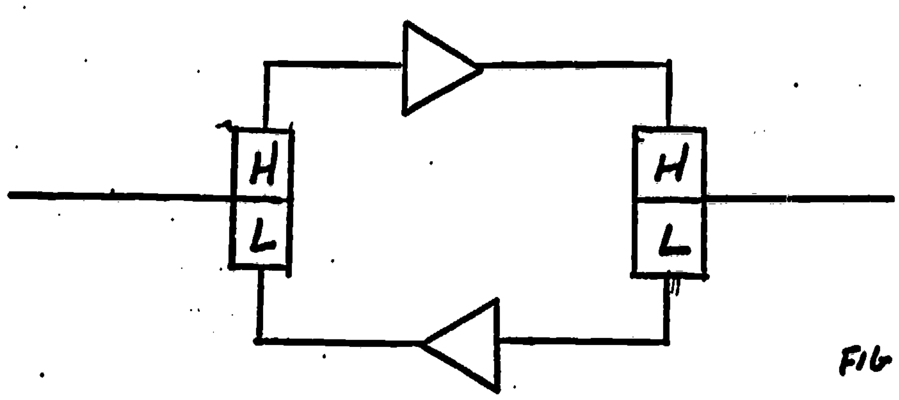

FIG 3

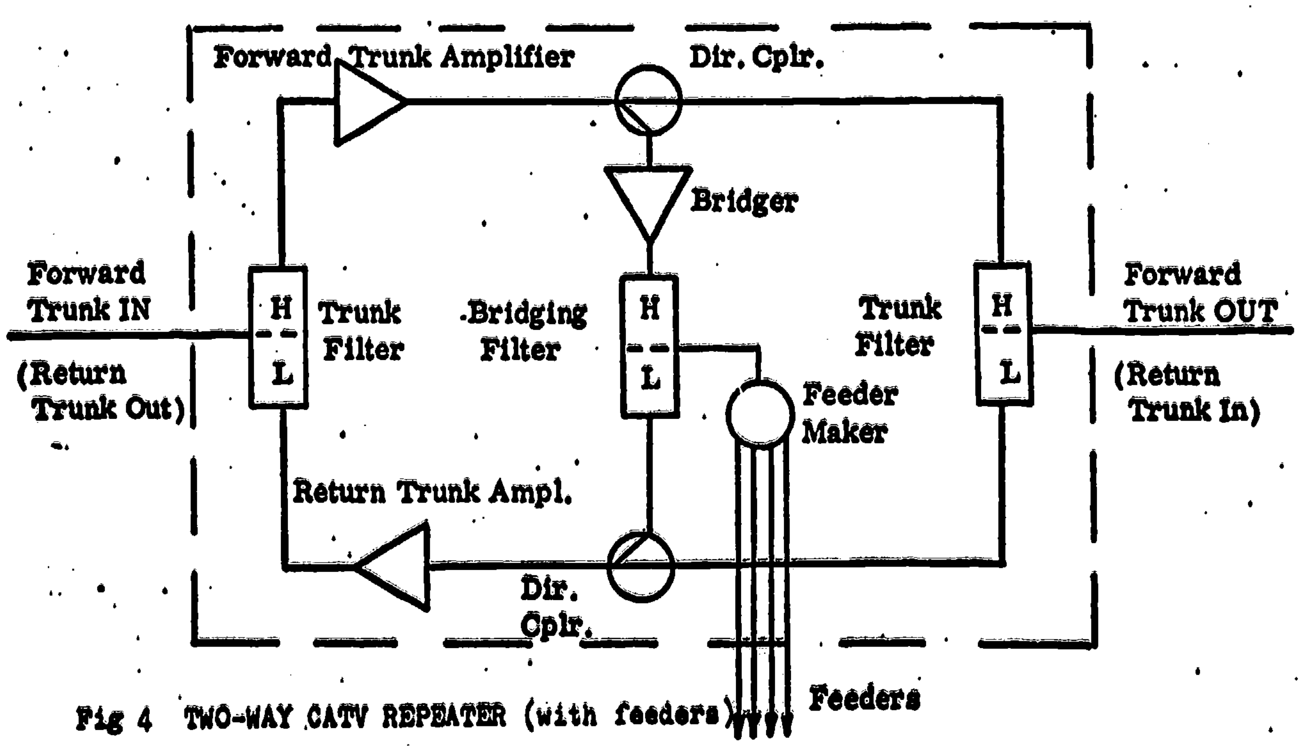

Fig 4 TWO-WAY CATV REPEATER (with feeders)

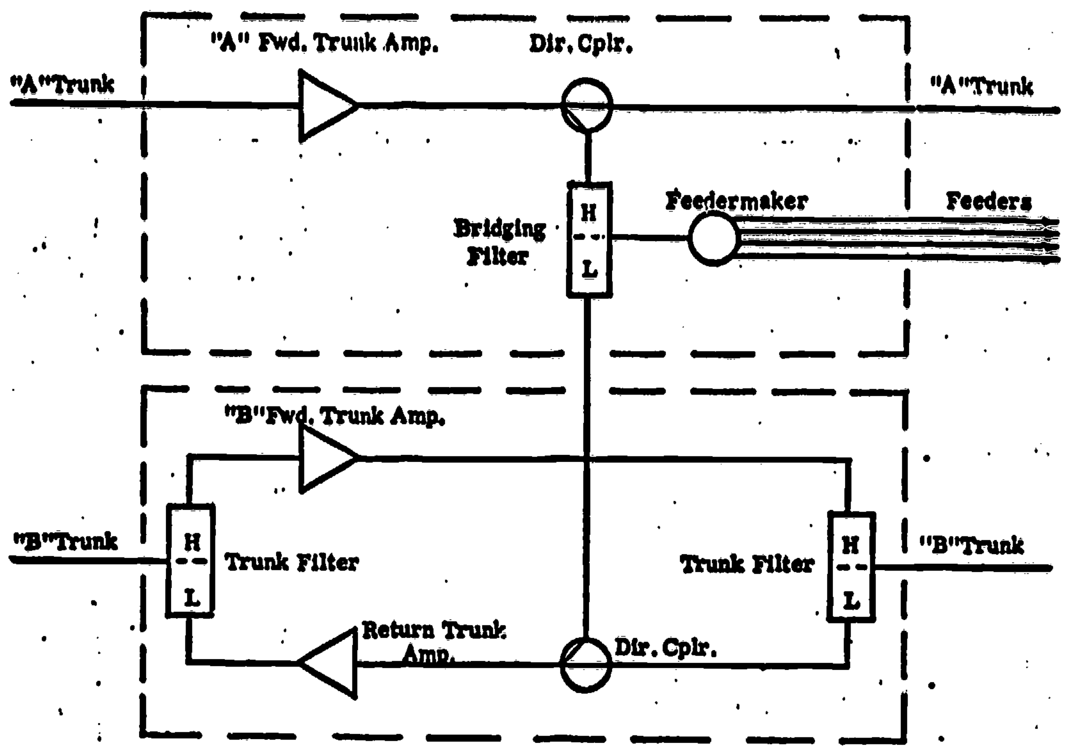

Fig 5 Dual Trunk/Single Feeder Station

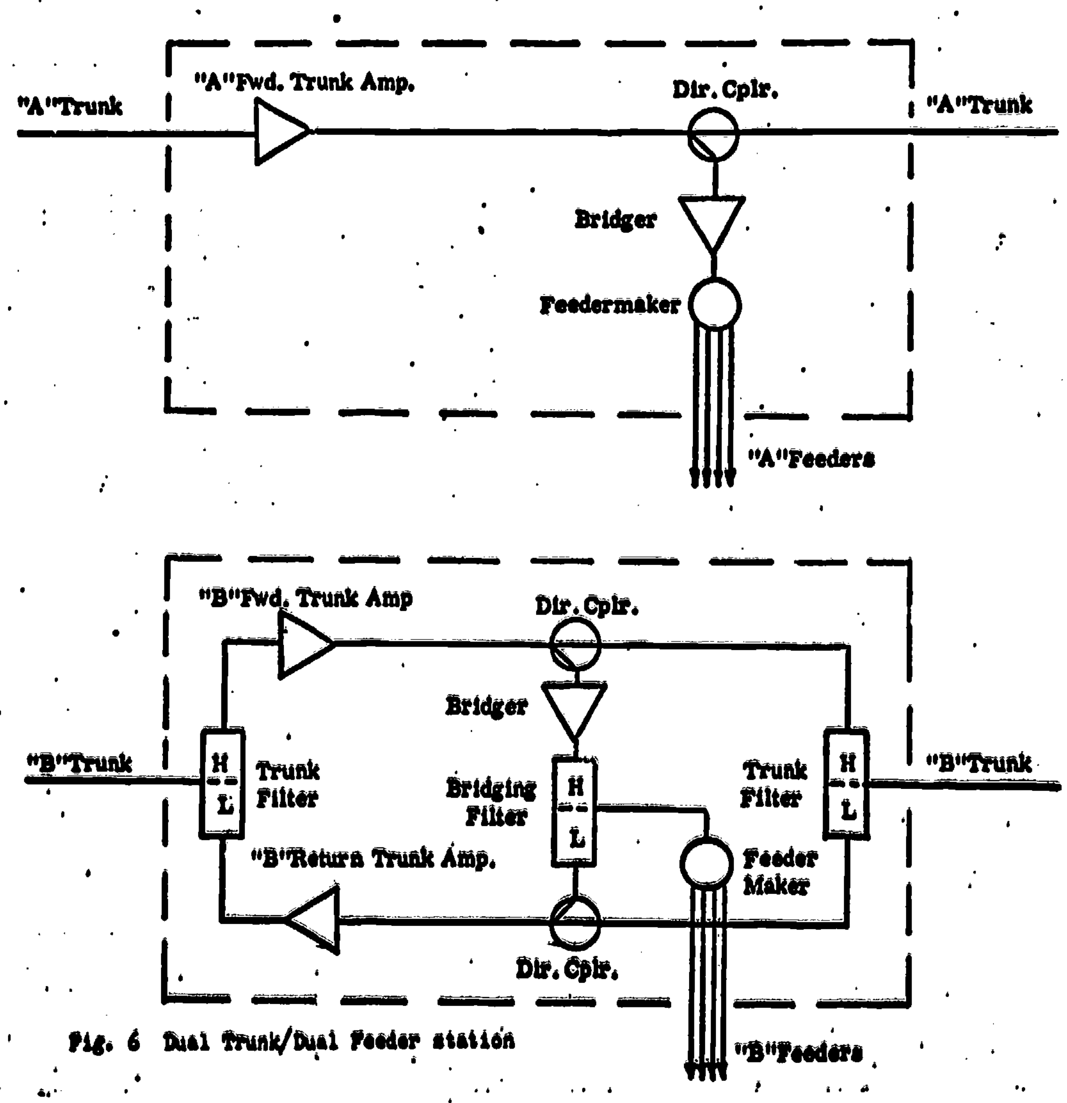

Fig. 6 Dual Trunk/Dual Feeder station

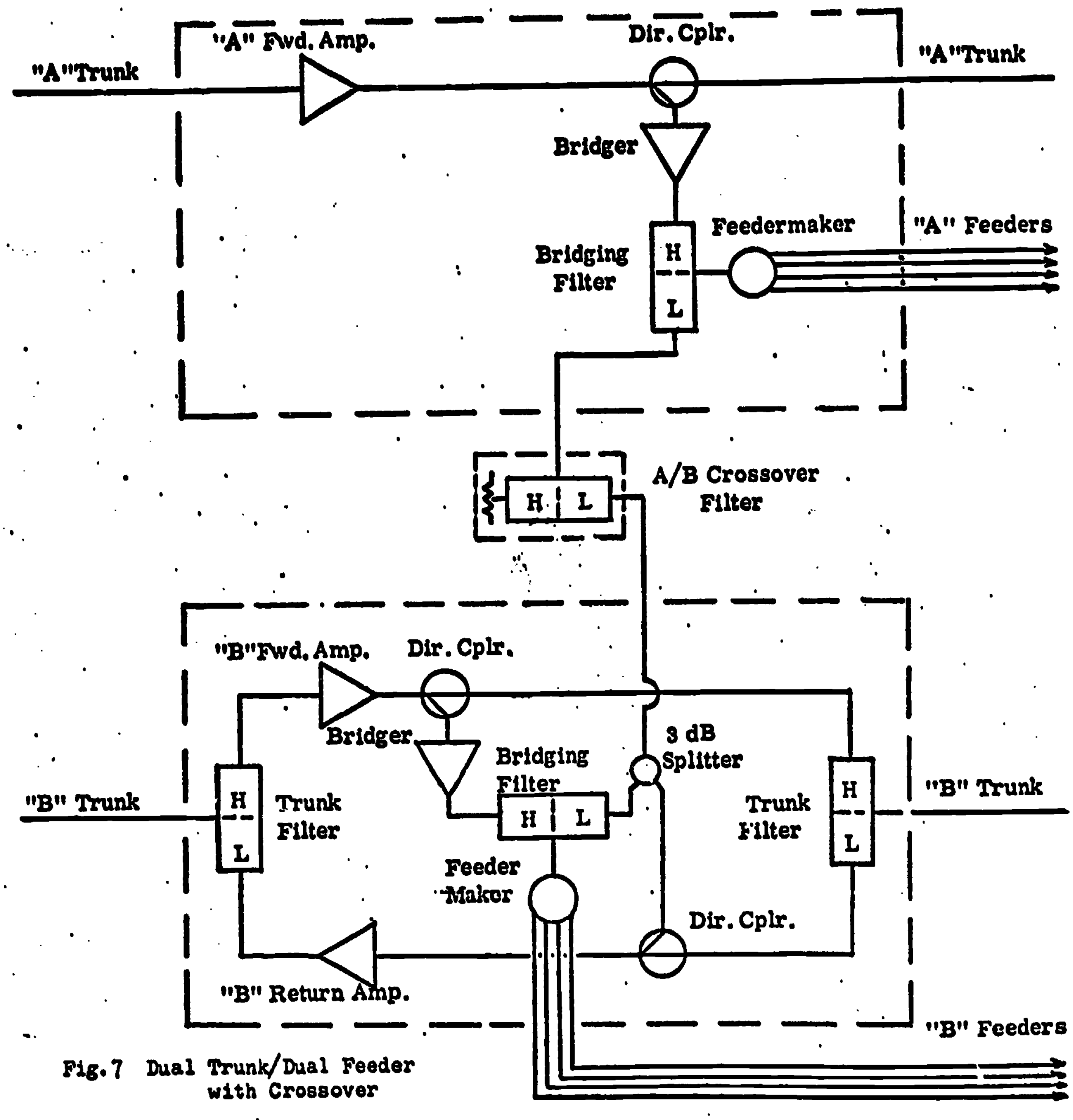

Fig. 7 Dual Trunk/Dual Feeder with Crossover