Dial a Program—an HF Remote Selection Cable Television System

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Abstract—A new concept in cable television systems is described in which the general form of the network is similar to the local distribution network of a telephone system. Each television set is provided with an individual connection to a program exchange where the subscriber may select, by means of a remotely operated switch, the program of his choice from the unlimited number of programs available at the exchange. The system is based on the technology of HF multipair cable television systems extensively used in Great Britain. The system is flexible in use and the facilities for two-way transmission, subscription TV, audience rating, etc., are explained.

THE need for the distribution of an ever increasing number of channels has stretched the conventional technology of broad-band VHF distribution operating with conventional television receivers to the point where either two coaxial cables must be employed or every television set must be provided with an additional tuner unit or set top converter. In these circumstances a radically different approach is worth considering. As the number of channels increases, the cost of delivering all channels to all homes and selecting the desired channel by apparatus in the home rises to the point where it breaks even with the alternative possibility of delivering only the desired channel to the home with the selection process carried out at some central "program exchange" by remote control. The break-even point will rise as the density of television sets per unit area increases and this density will be affected, not only by the average distance as the cable runs between one home and the next, but also by the number of television sets in each home. The break-even point will also be greatly affected by the extent to which the cost of a single 5-MHz channel can be reduced in comparison with the cost of a wide-band VHF connection.

The techniques which have been developed by Rediffusion International Limited in Great Britain for their HF multipair cable television systems, now serving over three-quarters of a million subscribers, offer some attractive possibilities of meeting the requirements of a remote selection system [1]. In the multipair cables, instead of each separate pair being dedicated to the distribution of a separate program, each pair is dedicated to a separate subscriber to connect him to the program exchange, as shown in Fig. 1, where he may select, by means of a telephone type dial, the program of his choice from the unlimited number which may be made available there.

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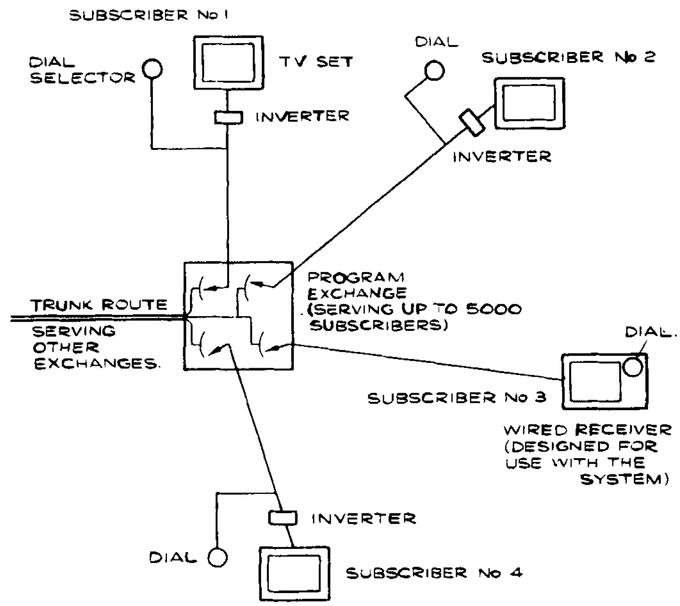

Fig. 1. HF remote selection. General arrangement.

I. The Choice of Frequency

The frequency band chosen for the distribution system must be high enough to avoid complications when demodulating the signals but otherwise should be as low as possible. Thus, all programs are transmitted on the same carrier at a frequency of 7.94 MHz with the upper sideband suppressed; and with the chrominance, therefore, falling at 4.36 MHz and the FM sound at 3.44 MHz. The fact that all programs are on the same carrier means that there can be no beats between the carrier of one program and the carrier of whatever programs happen to be carried by neighboring pairs in the cable; thus, the cross talk or "crossview" performance required is no greater than that required between two video frequency circuits, i.e., about 45 dB. Although there can be no beats between the luminance carriers, the possibility remains of beats between the chrominance carriers because National Television System Commission (NTSC) standards unfortunately allow a tolerance of ± 10 hertz in the luminance–chrominance spacing of 3.58 MHz as opposed to ± 1 hertz which is accepted in Europe. At the limits of the NTSC tolerance a higher crossview performance is required to eliminate the effects of interchrominance beating. For this reason, the upper sideband of the signal is suppressed bringing the chrominance signals

Fig. 2.

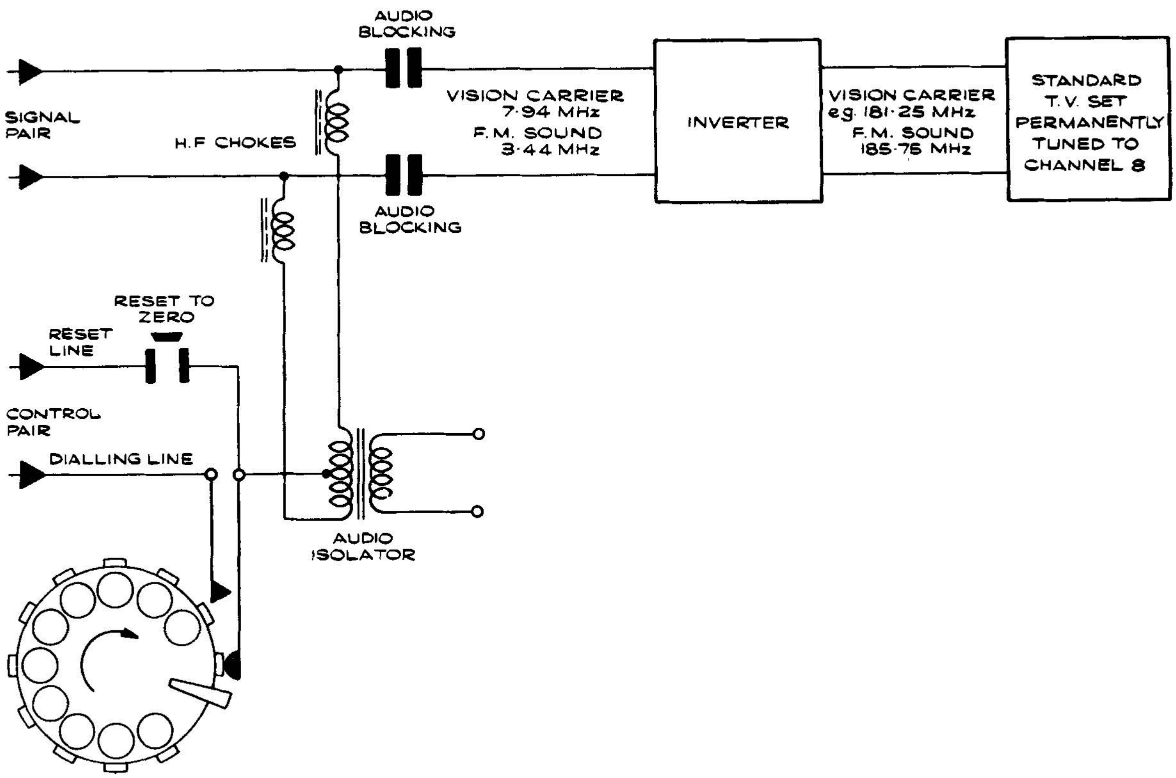

Fig. 3. HF remote selection.

to a lower frequency where the crossview performance of the cables is better.

Operation at frequencies only just above the video band has advantages in simplicity and reduced cable attenuation but introduces other difficulties which may be mitigated by careful choice of the exact frequency. For example, the second harmonic at 6.88 MHz of the FM sound carrier, which may result from nonlinearity in the repeaters or in the receiving equipment, will beat with the luminance carrier at 7.94 MHz. However, if the frequency of the luminance carrier is correctly chosen, this interference will occur at a frequency offset from the luminance carrier by a multiple of one-third of the line frequency and its visibility will be much reduced [2].

For the operation of the simplified "wired" receivers which may be used with the system, the sound is also transmitted at audio frequency.

II. Equipment in the Home

In the ordinary case, the equipment will consist of a standard television receiver connected to the cable through a small unit containing a telephone-type dial for program selection and a frequency conversion unit known as an *inverter*. The inverter unit contains a single transistor and three semiconductor diodes. It has no controls and requires no attention: its function is to change the signals on the cable to a channel in the VHF high band which is free of interference from local broadcasting stations. The television receiver is left permanently tuned to this channel—programs being selected by the dial. See Fig. 2 and Fig. 3.

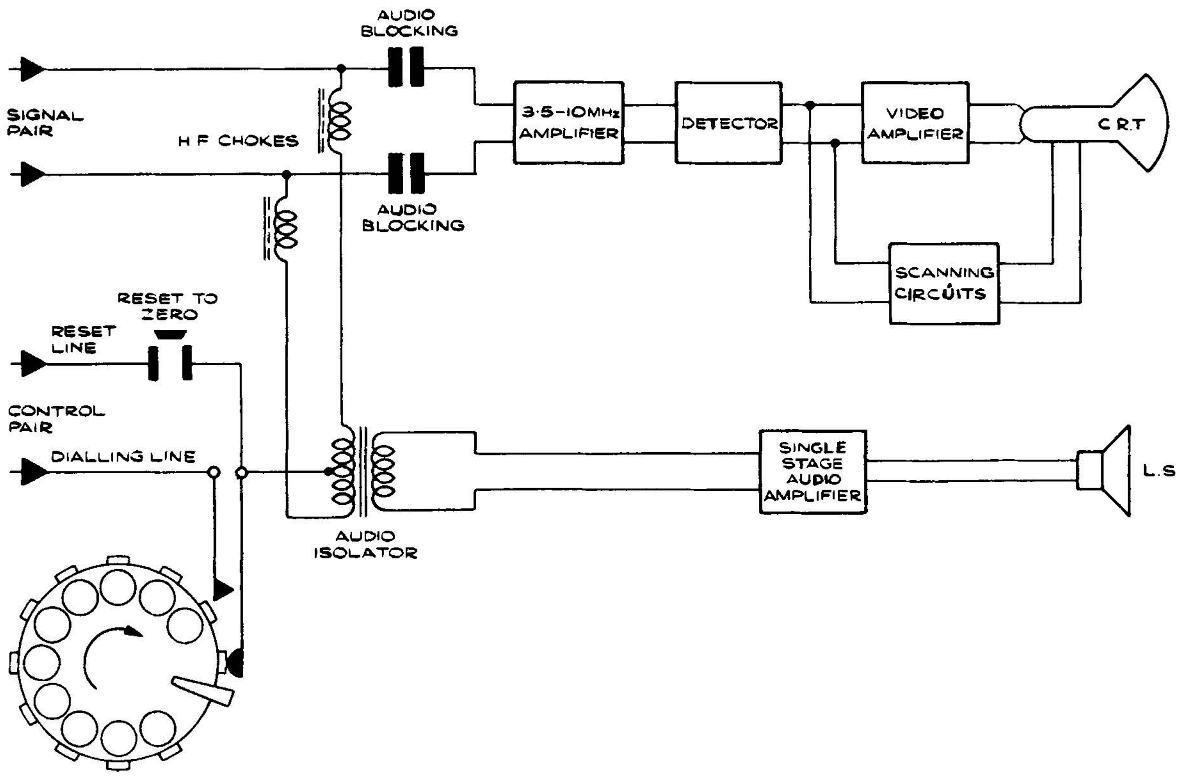

Fig. 4. HF remote selection.

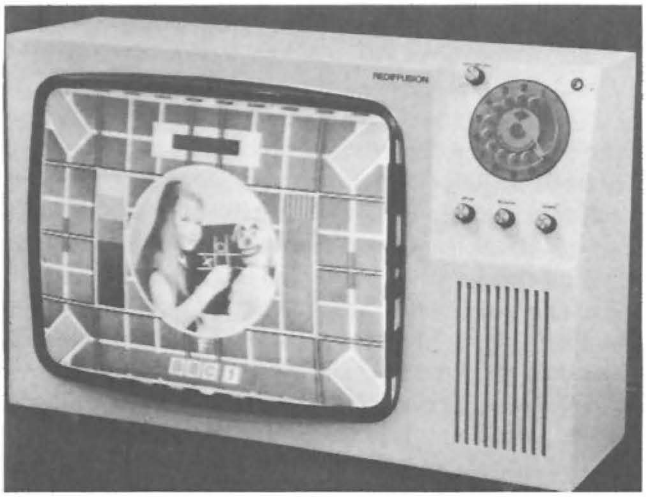

Fig. 5. Monochrome dial receiver.

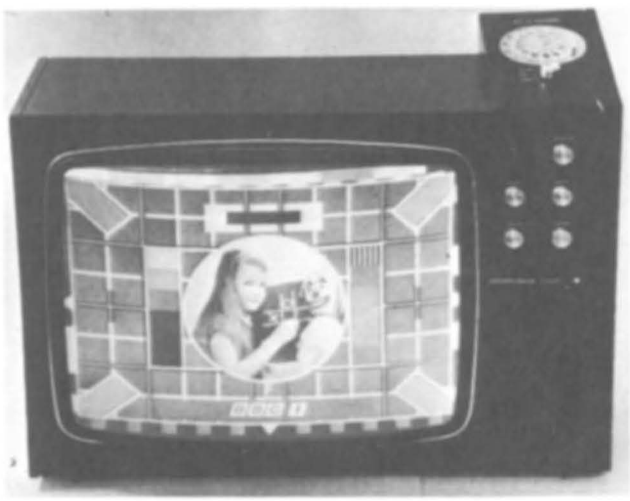

Fig. 6. Color dial receiver.

If the home or other establishment is not already equipped with television receivers, they may purchase a simplified and cheaper receiver designed for use with the system. This contains a straight amplifier for the vision signals and has no tuner. It does not respond to the FM sound signals but accepts instead the audio frequency signal from the cable which is applied through a single stage amplifier to the loudspeaker. The only controls are volume, brightness, and the program selection dial, which in this case forms an integral part of the receiver. A block schematic is shown in Fig. 4. A monochrome wired receiver with dial incorporated is shown in Fig. 5 and a color version is shown in Fig. 6.

The transmission of the sound at audio frequency to these wired receivers has several advantages; it reduces their cost, provides a very high quality signal, and enables them to accept a sound program unaccompanied by a vision signal. It also means that if, on certain programs, the FM sound is not transmitted, the sound trap in these receivers can be switched out of circuit; therefore, a very wide-band vision signal can be reproduced. Such a facility might be useful for displaying alpha-numeric information or high quality color pictures, perhaps for medical purposes.

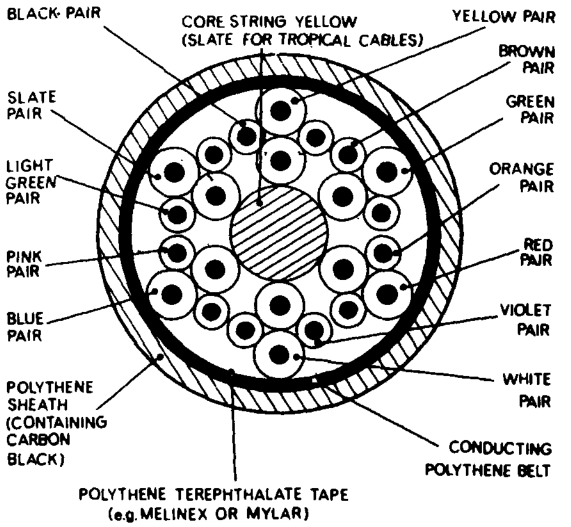

Fig. 7. Twelve-pair (6 Qwist) cable.

III. The Cables

It is not always realised that, for a given attenuation, an unscreened twisted pair will have a smaller overall diameter than a coaxial cable and will cost a great deal less. So, if a multipair cable can be made to operate in the 5-MHz to 10-MHz range with adequate isolation between one pair and its neighbors, it will represent the best engineering solution. A range of multipair cables for the Rediffusion International Limited HF system has been developed over the last 20 years and has now reached a highly developed state in which a very high degree of balance can be regularly maintained in production. A particular form of these cables is known as *Qwist* and is shown in cross section in Fig. 7 [3]. This cable, with an outside diameter of 0.41 inch, contains six larger pairs, comprising conductors of 0.018 inch, which are used to carry the vision signal. In the interstices of each of these vision pairs an additional smaller 0.016 inch pair is laid and twisted together with the vision pair. These additional pairs were originally included to provide circuits for six sound-only radio programs in the standard Rediffusion International Limited HF system but it was found that they led to a marked improvement in the crossview performance of the cable. This is due partly to an improvement in dimensional stability as the sheath is extruded over the pairs and partly to some screening effect. When these cables are used for a remote selection system this improvement in performance is very welcome since the crossview conditions are unusually severe. This is because one must design for the worst case, which arises when five subscribers served by the same cable choose the same program and the sixth chooses another. It is for this reason, and because of the simplification which is possible in the control circuits in the home and the exchange, that these extra conductors are included. Also, since they are used only during dialing, these circuits are available at all other times for other communication needs such as fire or burglar alarms or for talk-back in closed circuit systems for education and so on. Conceivably, in new housing construction, they could be used for telephone service but the saving in cable cost does not seem likely to outweigh the extra costs involved in the diversion of the normal telephone cable route, the relays required to distinguish the telephone and television system conditions, and the extra fault liability for both services.

The *Qwist* cables radiating from the exchange are terminated at junction boxes where a straight-through connection is made to six separate two-pair cables which carry the signals on to the individual television sets.

IV. Network Plan

Normally, no repeater amplifiers are used between the program exchange and the television receiver so that the length of cable is limited by the permissible attenuation and the tolerable level of crossview from the adjacent pairs in the cable which will be carrying different programs. The limit set by these two considerations is about 400 yards map distance (500 yards actual cable route) between the program exchange and the junction box with up to a further 100 yards of cable from the junction box to the television receiver. Although these lengths can be used within the limits of the performance specification, economic consideration may dictate a smaller area. As the cables approach the exchange their number builds up and, in an exchange serving say 2400 sets, one might have 100 cables leaving in one direction.

The cost per yard of this part of the network will obviously be high and it might cost less if the area were served by two exchanges instead of one. Any such saving will be offset by an increase in the cost of the trunk route serving the exchanges and the cost of this will increase with the number of programs carried. Another offsetting factor is the cost of obtaining suitable sites for the exchanges—two separate sites being likely to cost more than twice one larger site; although, in serving a series of apartment blocks, a small exchange in the basement of each block might well be the best arrangement. An unfortunate but inescapable consequence of removing the tuners from the home is that one must find space for their equivalent elsewhere.

The distance between the junction box and the receiver can be extended to about five miles if required, for example, to feed remote subscribers in country districts by the use of single channel transistorised repeater amplifiers powered over the cable and spaced every three-quarters of a mile. These repeaters and the screened two-pair cable are inexpensive and they make it possible to serve remote subscribers at a cost which would not compare too unfavorably with the cost of a telephone connection. See Fig. 8.

In general, when planning the network for a city and for the distribution of 20 to 40 programs, a reasonable compromise between the conflicting factors is obtained if the area is split up into units of about one-tenth square mile which might contain from say 300 to 3500 homes and, allowing for a second set in every other home, some 450 to 5000 television receivers. A program exchange is set up at the center of each one-tenth square mile area and the multipair cables are taken through the streets overhead or via under-

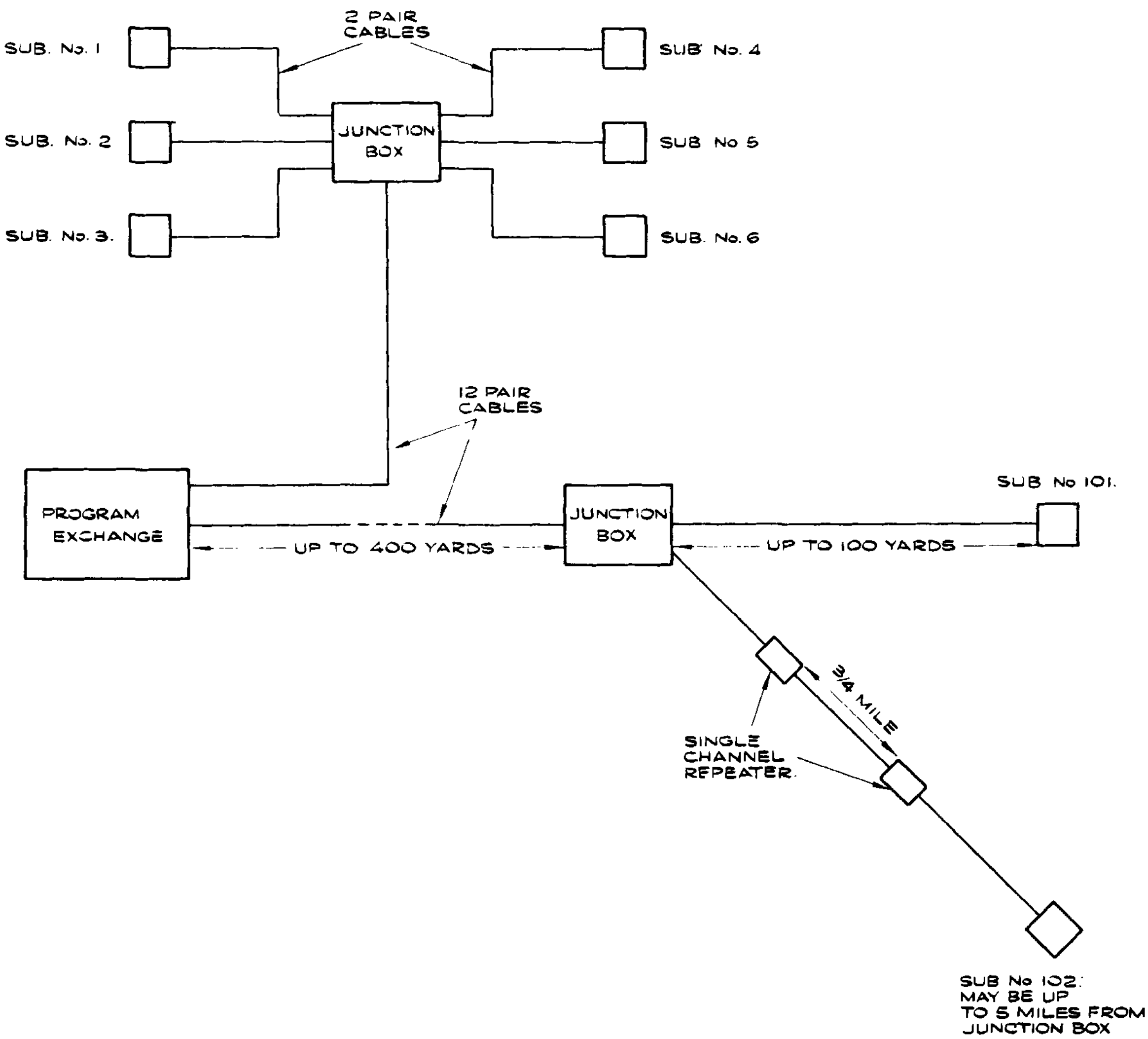

Fig. 8. HF remote selection network plan.

ground ducts of similar construction to telephone ducts. If spare telephone ducts are available they may be used without any fear of causing or suffering interference from the telephone system. The operation of the television system itself depends upon a very high degree of electrical isolation between the pairs in its cables and this ensures an even higher degree of isolation from other cables which may be nearby.

V. The Program Exchange

The program signals are delivered to the exchange by means of a primary distribution or trunk network and are amplified by single-channel repeaters and separate amplifiers for the audio signals. The audio and television signals for each program for these amplifiers are in the unbalanced mode and are combined and applied to a screened bus-bar system in the form of printed circuit conductors. Each alternate conductor is grounded and the printed circuit is backed by a continuous aluminium sheet which is also grounded. The remaining conductors, the bus-bars, carry the signals, and form transmission lines of very low impedance, 12 ohms, and distribute the signals to the subscribers' selector switches which may be plugged in and out by means of edge connectors. The bus-bar system is split up into four sections of different voltage level with the sections being connected together by step-down hybrid transformers. The most distant subscribers are served by the section carrying the highest voltage (0.75 volts) with the other sections serving groups of subscribers which are progressively nearer the exchange. The object in dividing the bus-bar exchange in this way is to ensure that the signal levels in any one Qwist cable are approximately the same so that a difference in level does not add to the crossview protection required in the cables. An outline of the circuit arrangement is shown in Fig. 9.

The selector switches make use of reed relays operated by a permanent magnet mounted on a rotating arm which is stepped round by impulses from the subscriber's dial. A prototype switch is illustrated in Fig. 10 and is shown without the cover shield which normally lies between the rotating magnet and the reeds. The main criteria in the design of the selectors is an adequate crossview performance and an ab-

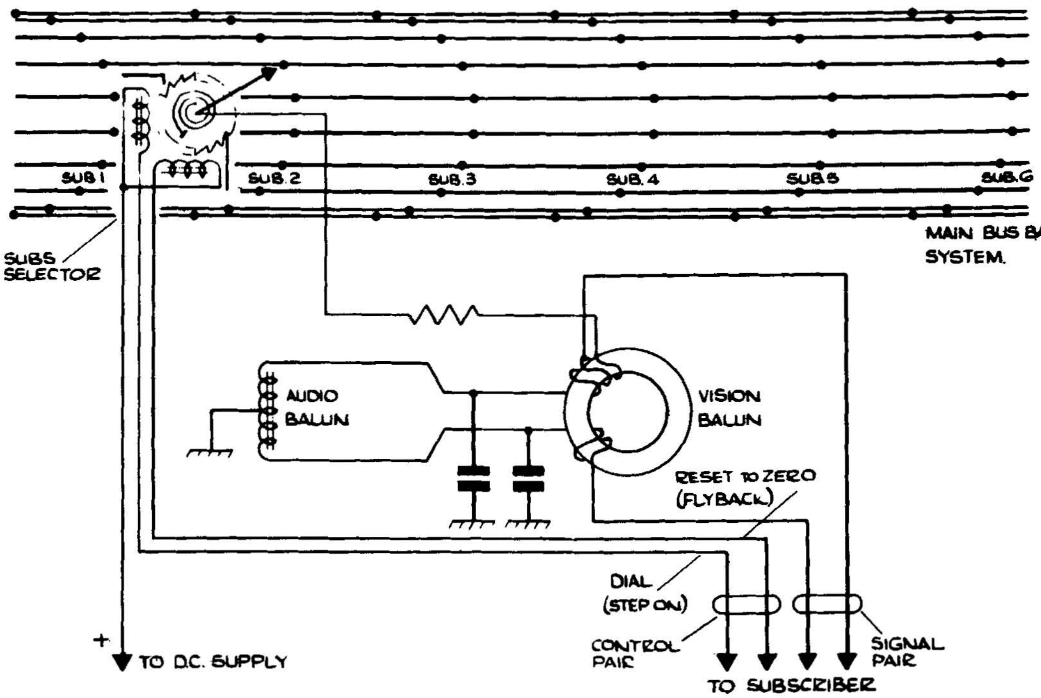

Fig. 9. HF remote selection. Subscriber program exchange (10 or more channels).

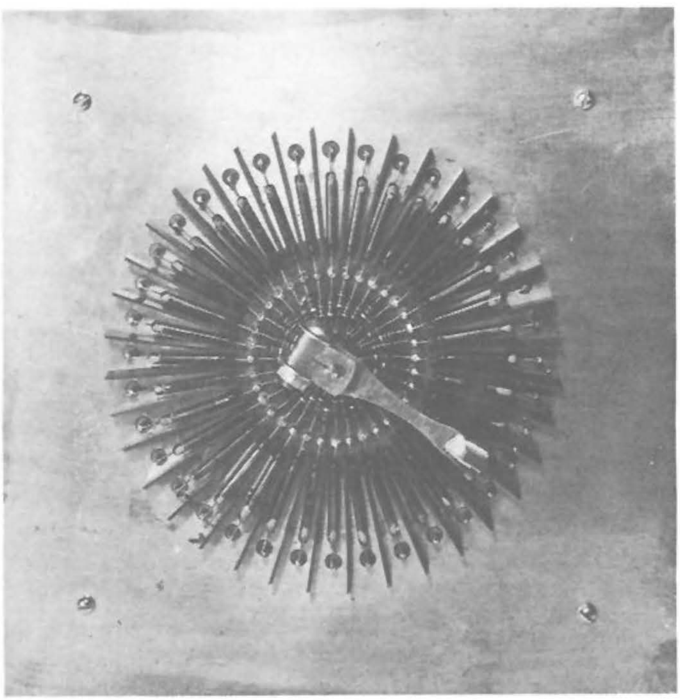

Fig. 10. Prototype selector.

solutely reliable break before make action as the magnet passes from one reed to the next. Both objects are achieved by a screen of transformer iron between one reed and its neighbor which concentrates the magnet field on the chosen reed and is effective electrostatically.

Even so, it remains of first importance that the effect of any residual coupling between neighboring circuits in the exchange should be reduced as far as possible and, for this reason, two different luminance carrier frequencies in one-third line offset relationship to each other are used for programs on alternate bus-bars in the exchange. The two frequencies chosen are 1009 times one-half the line frequency plus and minus one-sixth of the line frequency, that is, 7.935314 MHz and 7.940558 MHz. It will be seen that by choosing the frequencies in this way the condition of one-third line offset for the second harmonic of the FM sound frequency referred to in Section I of this paper is also met [2].

In order to reduce the capital cost of a program exchange, from which initially only a few subscribers may be served, and for ease of maintenance, it is desirable that the selectors should plug in and out of the bus-bar system. As reliable edge connectors are expensive, and in order to reduce the volume of the exchange equipment, the selectors are mounted in pairs on printed circuit boards as shown in Fig. 11.

The simple electromagnetic stepping mechanism is shown in Fig. 12. When the subscriber presses his reset button a catch is released and the mechanism returns to its zero position under the action of a spring. In this zero position the subscriber would, in most applications, receive a dialing directory on his screen of the programs available at that time.

Since a selector switch must be provided for each subscriber, the cost of this item is a matter of first importance in the economy of the system as a whole. It is this which has led to the adoption of an electromechanical design in which a cost of 70 cents per cross point seems well within reach

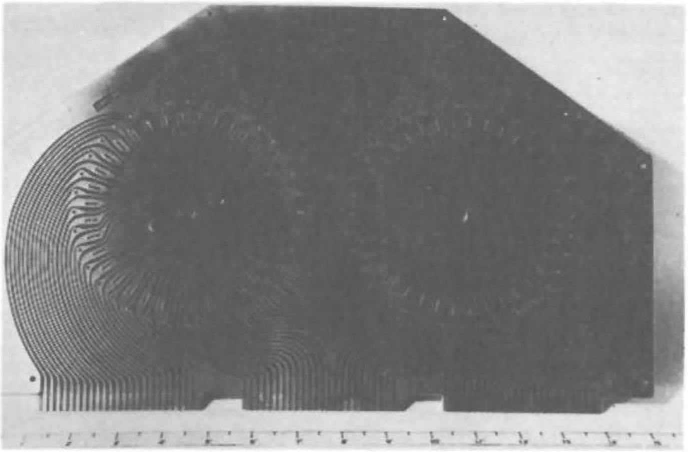

Fig. 11. Twin selector printed circuit.

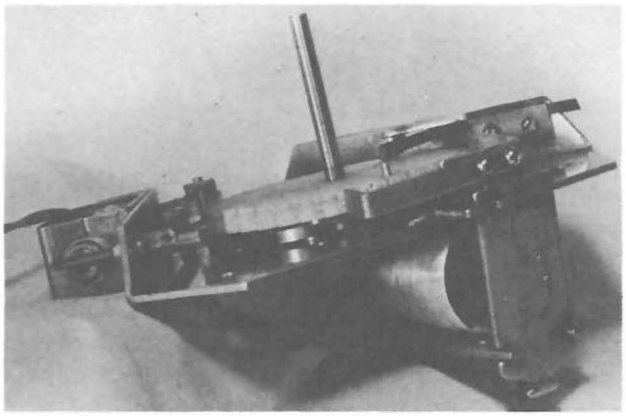

Fig. 12. Selector actuating mechanism.

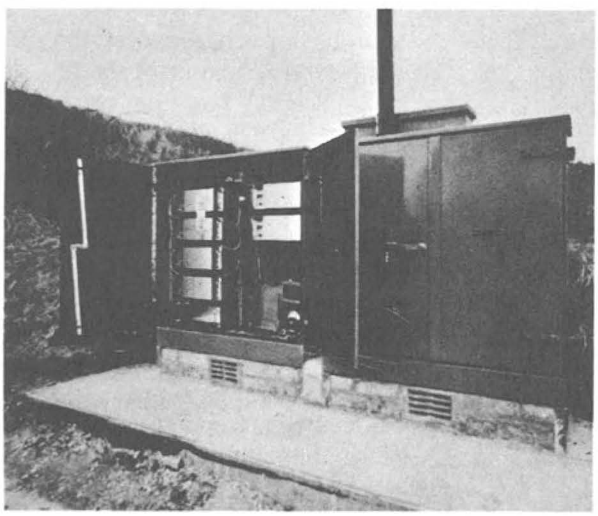

Fig. 13.

for production in reasonable volume. Although no doubt the cost of solid-state switching will fall in the course of time, it does not appear at present that such techniques can approach that figure.

The space occupied by the exchange equipment will, of course, depend on the number of television receivers served and the number of programs available to them; but for example, the equipment required for 330 receivers each having a choice of 36 programs would be contained in a volume of 8 feet by 6 feet by 2 feet. In areas of low housing density the exchange might therefore take the form of a kiosk of the type illustrated in Fig. 13. In areas of high density where the number of receivers might be about 5000, the equipment would be housed on 9-foot high racks in a room 27 feet by 15 feet.

VI. Trunk Network

The programs are delivered to the exchange by means of a primary distribution network which may use any of the conventional methods of transmitting a television signal. For example, in a city where adequate underground duct space is available the maximum simplicity and economy will be obtained by the use of a separate coaxial cable carrying the signal in the same form and on the same channel as that used for the distribution network; in this case, the equipment required in the exchange consists only of amplifiers. An inexpensive coaxial cable, having an outside diameter of 0.312 inch, will have an attenuation of less than 40 dB per mile at the operating frequency, so that a city, together with large parts of its outlying suburbs, can be covered without the use of repeaters between program exchanges. This greatly facilitates two-way transmission on the trunk routes and enables the programs from any source within reach of a program exchange to be made available throughout the network without first being carried back to a distribution center.

If the duct space is insufficient to allow the use of separate cables or if the distance to be covered is many miles, then it may become more convenient to employ a wider frequency spectrum and to carry many programs on a single coaxial cable with frequency changing equipment in the program exchanges. These techniques are, of course, very well developed and in extensive use in the United States and elsewhere for CATV.

A third alternative method is the use of multichannel microwave links between program exchanges. No doubt these three methods and other point-to-point television links that may be developed in the future would find appropriate use in a large system. Also, in a large city the program capacity of the trunk network would vary from one part to another and not all programs would need to be available to all citizens. For example, in the downtown districts many channels would be required for commercial purposes; in other parts, programs for particular ethnic groups could be limited to the areas of their concentration, thus reducing the cost of distribution. Similarly, the broadcasts of political candidates could be confined roughly to their area of concern.

VII. Two-Way Operation

In the ordinary case there is nothing except cable between the subscriber and the program exchange and the cable is therefore available to carry signals in the inward direction from the subscriber to the exchange as well as outward. The channel used for outward transmission is approximately

3.2 MHz to 9.2 MHz and the next channel above this from 9.2 MHz to 15.2 MHz may be used for inward transmission.

At the point where the subscriber's pair enters the exchange the 9.2-MHz to 15.2-MHz channel is diverted by filters to frequency changing equipment and fed to the busbar system and, if desired, also to the trunk network to serve other program exchanges. In this way the originating subscriber may, by dialing in the normal way, monitor his own program exactly as it will appear to other viewers or, if he wishes, he may continue to view some other program which might be from another subscriber with whom he was in conversation. Their connection would be similar to a videophone connection but without privacy.

VIII. Sound Radio Programs

Sound radio programs may be treated in exactly the same way as the sound accompanying a television signal; that is, they may be transmitted at audio frequencies to serve the "wired" receivers and also on an FM carrier at the usual spacing from an unmodulated luminance carrier so that they become available through the loudspeaker of an ordinary television set. Such a system is, however, rather wasteful both of television channels in the exchange and of the life of ordinary television sets. The alternative is to transfer the sound programs to a series of channels at the usual 400 Hz spacing within one of the 3.2-MHz to 9.2-MHz vision channels. In order to receive sound programs, the subscriber would dial for this particular channel and an inverter would lift the frequencies to the usual FM band for reception by a standard FM receiver. An alternative possibility is to use the control pair with a secondary and cheaper type of selector switch in the exchange with audio frequency transmission to simple amplifiers and loudspeakers in the home. This would have the disadvantage that the sound programs would be interrupted when the subscriber dialed for a vision program but would have the countervailing advantage that sound programs could be received in one part of the home and television programs in another without the necessity for two separate connections. Stereo programs could be provided by sending the L+R information at audio frequency and the L−R on the normal 19-kHz carrier for decoding in the home.

IX. Subscription Television

It will be clear from the foregoing that the selection of programs offered to particular subscribers may easily be varied and the charges made to them can be varied accordingly. Thus a basic monthly charge might provide all subscribers with all programs carrying advertising. On payment of supplementary charges subscribers could obtain access to additional programs without advertising and thus provide a source of revenue for financing such programs. A scheme of this kind would cost no extra but would not provide subscription television in the full sense that a variable price may be put on particular programs. However, only simple equipment is required to achieve this. The subscription television channels would be connected to the selector switch via reed switches which would be operated over the control pair from each subscriber upon his placing money in a coin box in his home or accepting a debit to his account. The identity of each subscriber being defined in the exchange by his incoming control pair, the recording of the money paid or due from each subscriber amounts to little more than the provision of simple counting equipment attached to each subscriber's pair.

X. Audience Rating

A sample of subscribers is selected by the usual statistical methods and an additional connection made to their control pairs so that a secondary program selection switch operates under the control of the dial selectors in the home. The subscribers in the sample are divided into their socio-economic classes and the secondary selection switches for each class are fed on each program position from a constant voltage source via a recording ammeter. The current taken by each subscriber's circuit is identical so that the total current recorded by the ammeters is a true count of the subscribers in each class connected to each program at any moment. An additional circuit guards against a subscriber being counted if his television receiver is not operating. In this way the sample may be as large as desired, the individuals comprising the sample may be changed from time to time, and, unless they are told, they have no means of knowing that they are included in the sample.

XI. Applications

In addition to ordinary cable television systems for distribution to the home, the system offers a number of advantages in other applications. For example, on a university campus it would be possible to provide every student with a television screen and a dial in his room which would give him access to a new concept of a university library in which the material would be stored in audio visual form. The dial or touch-tone-type control would also enable the student to communicate with the university computer and to receive information back either in alpha-numerical or graphical display on his television screen. Lecture rooms both in the university and possibly at schools in the neighborhood could be similarly equipped at a cost which would be a fraction of that in existing installations of this type based on video frequency distribution over coaxial cable.

Another application in which immediate access is required to large volumes of information is in the financial centers such as Wall Street and the City of London. The system is particularly suitable in these applications because of its open-ended nature with no limitation on the number of separate channels of information which may be offered to subscribers and because of the high technical quality which can be achieved if wired receivers are used exclusively for display. Other possible applications are in military control centers and large fighting ships.

References

[1] R. P. Gabriel, "Wired broadcasting in Great Britain," *IEEE Spectrum*, vol. 4, pp. 97–105, April 1967.
[2] U. S. Patent 3 290 432.
[3] U. S. Patent 3 350 647.

Mr. Lady: Thank you very much, Ralph. We do have time for a few brief questions if we have any. Would you please use the center mike for your questions?

Terry Crawford: Mr. Gabriel, my name is Terry Crawford of the Jerrold Corporation. I wonder if you could give us a brief description of how you compensate for the fact that the loading on any given trunk channel varies with the number of subscribers connected to that channel?

Mr. Gabriel: Yes, each subscriber is stood off the bus bar in the exchange by a number of decibels, but I don't know whether you noticed in the picture of the rotary selector switch each reed is connected through to the central connector by means of a resistor whose value, I'm sorry to say I've forgotten, but the specification to which we work is that the change in level between the condition under which one subscriber has selected a particular program and 100% of the subscribers have selected the same program, shall not exceed 1 dB.

Mr. John Lady: Are there any additional questions?

Question: You had mentioned cross-view talk several times, but you have never mentioned a figure of how far down this cross talk would be and secondly, coming off headends putting multi-channels on, will you have to go to one standard oscillator so everything is phase-locked in so all your carriers seem to keep this cross-talk down at a low level?

Mr. Gabriel: Yes, indeed. All the carriers for every channel are identical and phase-locked. The interference that we are concerned with, therefore, is similar to interference between 2 video signals for which a figure of 45 - 46 dB is generally accepted as adequate and that is the figure to which we work, but there are some things that you can do, in addition, to make cross-view less obvious. We use, for example, precision off-set between the carriers and the adjacent bus bar in the exchange.

Mr. Lady: Thank you very much.

Question: I was curious what the output level is if you are running out of your exchange for handling the 6,000 subscribers out of a common exchange and is there an individual pair run from the subscriber's home to that exchange for each customer? Also, how do you split off internally for your second set connections or multiple set connections on this type of situation?

Mr. Gabriel: There is a separate connection for every television set. The multiple set in the home is a problem and, as I mentioned in my opening remarks, the economy of the system is affected by this. If you want a separate set with separate program selection, it is correct to say that wanting two separate telephones, you must have two separate connections. I have forgotten your first part - -oh, the level, yes. The program exchange is divided into four separate sections. The first section delivers the---carries the highest voltage which with an output of 0.6 volts and is used for feeding the most distant subscribers. Each section then goes down to 6 dB so that the lowest section is used for feeding the nearest subscribers which will, therefore, be at a level of 6.24 dB down or 0.6 volts.