DATA COMMUNICATIONS via CATV SYSTEMS

by

Thomas Chuang
Manager, Advanced Engineering
Vikoa, Inc., Hoboken, New Jersey

I. INTRODUCTION

The need for transmission of data and visual information over telephone networks has been growing very rapidly, especially in the last decade. In these telephone transmission systems the bandwidth being dealt with is usually 3 KHz for voice channels. Recently the introduction of Picturephones has created a requirement for a system with sufficient bandwidth to carry a 6.3 megabits per second signal (1) over long distances for adequate picture resolution. The wide bandwidth available in cable TV systems is attractive for the application of digital communications with the potential of higher speed transmission capability and of more narrow band channels.

This paper describes a method for implementing market survey, alarm monitoring systems, and a method for facsimile system, with relatively inexpensive and simple techniques as a step toward utilizing two-way communications in CATV. These equipments will be of great service to market research organizations, to system operators, and to any industry which has branch offices or which requires to communicate with others within the distribution of the system.

II. TWO-WAY COMMUNICATION SYSTEMS

Two-way transmission is required for data communications. The best two-way communication system is a dual cable system to handle heavy traffic and provide more channels but at the expense of high cost. However, viewed from the requirements of data channels' bandwidth and from the number of channels required per system for local origination, the proposed single cable, bi-directional system (2) shown in Figure 1 is adequate. This requires a relatively simple modification of the existing distribution system. The return direction will cover the frequency range from 5 MHz to 35 MHz. The first 6 MHz band can be reserved for data channels of narrow band, and the next 6 MHz may be allocated for data channels of wide band under time sharing basis. The rest of the channels are allotted for local origination and other public services.

III. CHANNEL MONITORING SYSTEM

One of the simple and useful applications of data communications in CATV is the channel monitoring system. The system is used for continuously sensing the channel setting of any subscriber's TV set and automatically storing or printing out its status information at a central office.

The system block diagram is shown in Figure 2. A control/display unit at a central office or headend sends out an address code data through the cable transmission line to the designated subscriber's transponder at the receiving end. Upon the receipt of a status data from the transponder, via the return path, the control unit will display the information and then send the second signal to request the second subscriber's status information. This is a sequential interrogation process which will continue until the 30th subscriber's status is recorded. The cycle will repeat again for the second group of another 30 sets until the 30th group is interrogated. The carrier frequency chosen for addressing is 73.5 MHz in the guard band and the frequency of 5 MHz is selected for the return carrier. TDM (Time Division Multiplexing) is used for the system and therefore requires synchronization (3).

A. CODING FORMAT

A clock of 60 Hz is used as indicated in Figure 3. Two clock cycles are used for two-word addresses, one for the subscriber's number and the other for sub-group number identification. Each word is represented by five binary digits to which five frequencies are assigned as shown in Figure 3. The channel setting identification code is FSK (frequency-shift-keying) modulated with five bits. Binary "one" is 3.2 KHz and "zero" is 2 KHz. Therefore the system will take 116 millisecond to scan one subscriber, and the basic system consists of 30 (sub-group) x 30 (units) = 900 subscribers. N different sets of frequencies assigned to the five bits of address code yield a system of 900 x N subscribers.

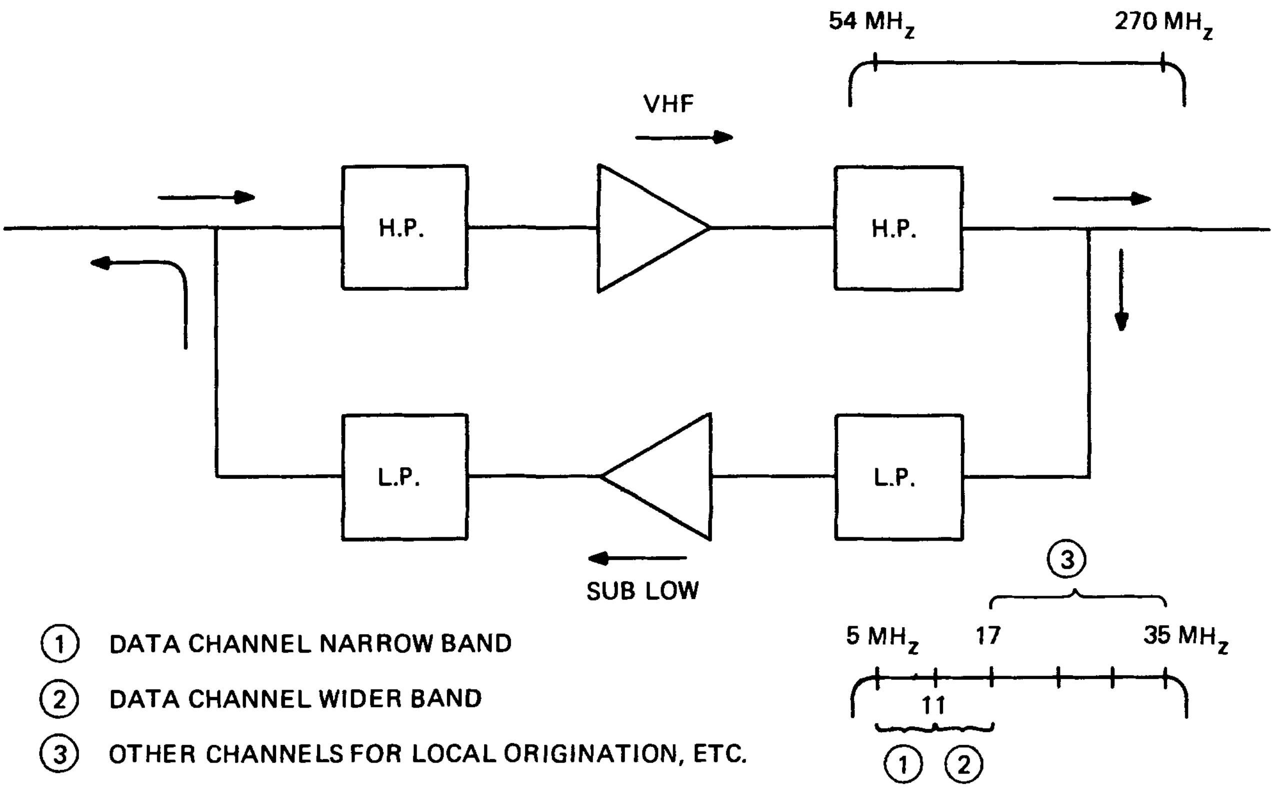


FIGURE 1. FREQUENCY DIVISION MULTIPLEX BI-DIRECTIONAL SYSTEM

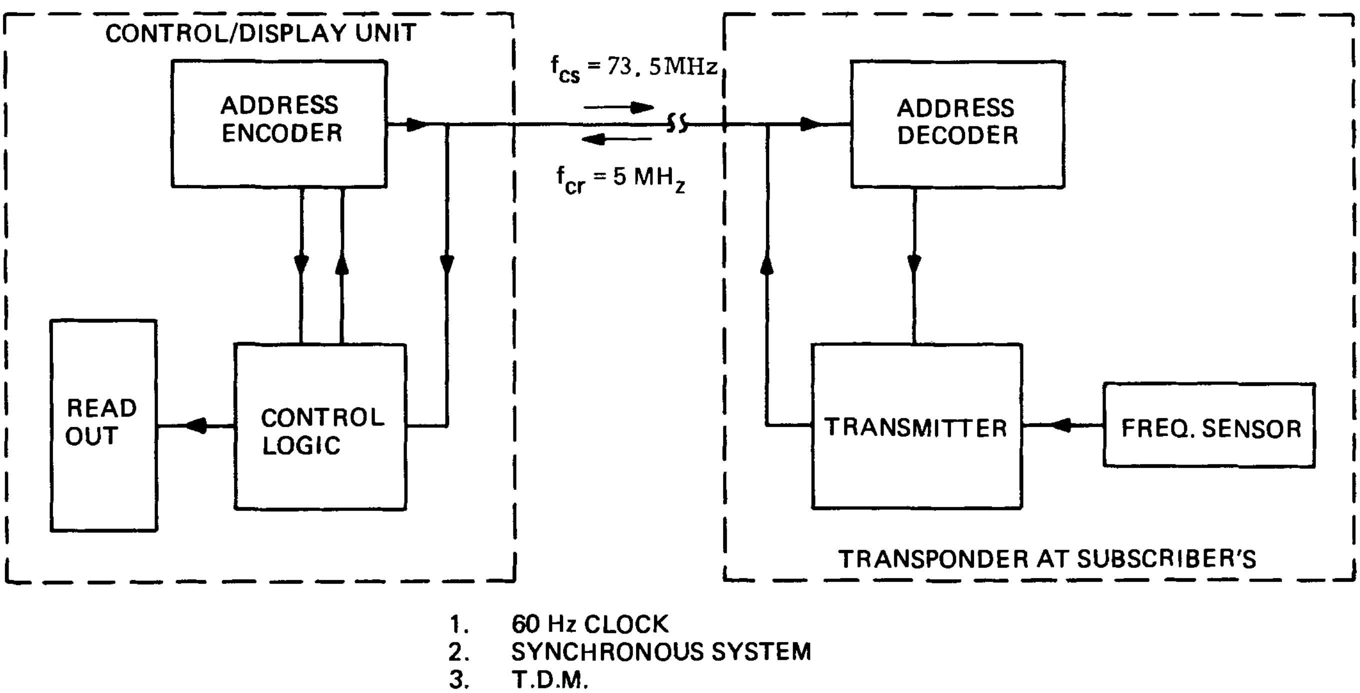
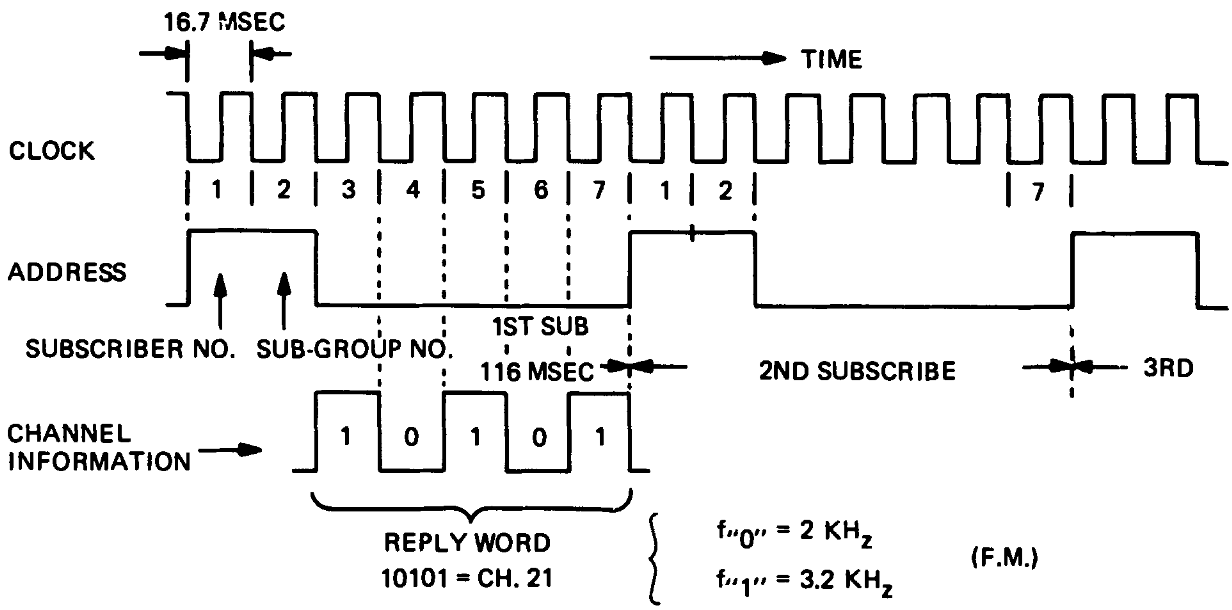


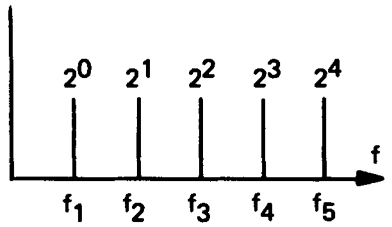
FIGURE 2. BLOCK DIAGRAM OF CHANNEL MONITORING SYSTEM



- 1ST ADDRESS CODE: (AM), f_T = 73.5 MHz

  IDENTIFY

  SUBSCRIBER'S NO. IN A SUB-GROUP



1ST BIT = f_1 = 600 Hz
2ND BIT = f_2 = 1.0 KHz
3RD BIT = f_3 = 1.4 KHz
4TH BIT = f_4 = 1.8 K. KHz
5TH BIT = f_5 = 2.2 KHz

- 2ND ADDRESS CODE

  TO IDENTIFY GROUP NO.

- BASIC SYSTEM CONSISTS 30(SUB-GROUP) x 30(UNIT) = 900 SUBSCRIBERS

- N DIFFERENT SETS OF FREQUENCIES ASSIGNED TO THE 5 BITS YIELD A SYSTEM OF 900 x N SUBSCRIBERS

- M DIFFERENT CARRIER FREQUENCY ASSIGNMENT ⟶ 900 x N x M SUBSCRIBERS

FIGURE 3. TIMING DIAGRAM

Furthermore, if M additional frequencies are assigned to the return carrier (frequency division) one will have a system of 900 x N x M subscribers.

B. ADDRESS ENCODER

Figure 4 illustrates the block diagram of the Control Unit while the encoder circuit diagram is shown in Figure 5. The ring counter counts the 60 Hz clock pulses one through eight and at every eighth count, one pulse is delivered to Counter Module 30 whose function is to perform 30 counts. The first incoming pulse which corresponds to the pulse for address code will be registered as 00001 (a code # for subscriber #1) and only f_1 is turned on. A carrier modulated with the f_1 is then transmitted. The next incoming pulse causes the register to shift into 00010 (subscriber #2) and turn on only the oscillator f_2.

After the 30th count, all registers become Logic "1" and the gate X opens and delivers one pulse. This pulse performs two functions --one, to clear the Counter so that another sequence of 30 counts will start; two, to be used for another group of 30 counts by the other Counter Module 30 (B) as shown in Figure 5. This module stores a group code so long as the acquisition of data from a group of 30 sets is still being undertaken. However, it rolls out the code data only at and during the presence of the pulse entered (gated) by the ring counter. This then forms two successive address codes for each interrogation. See also timing diagram in Figure 5b.

C. TRANSPONDER

The block and circuit diagrams of a transponder at the subscriber's set are shown in Figures 6 and 7 respectively.

The requirements on the sensor depend on the interface of a subscriber's TV set. If no converter is used, leakage from the local oscillator of a TV set may be sensed. However, with today's increasing demand of a system for more than 12 channel capability, perhaps a VHF-VHF converter will be mostly used for this purpose. The sensor depicted in Figure 7 takes the frequency from a V-V converter and feeds into a limiter for a constant amplitude and then its frequency is converted into voltage. The voltage is converted by analog-to-digital converter into 5 bits in parallel at 3.2 KHz clock rate.

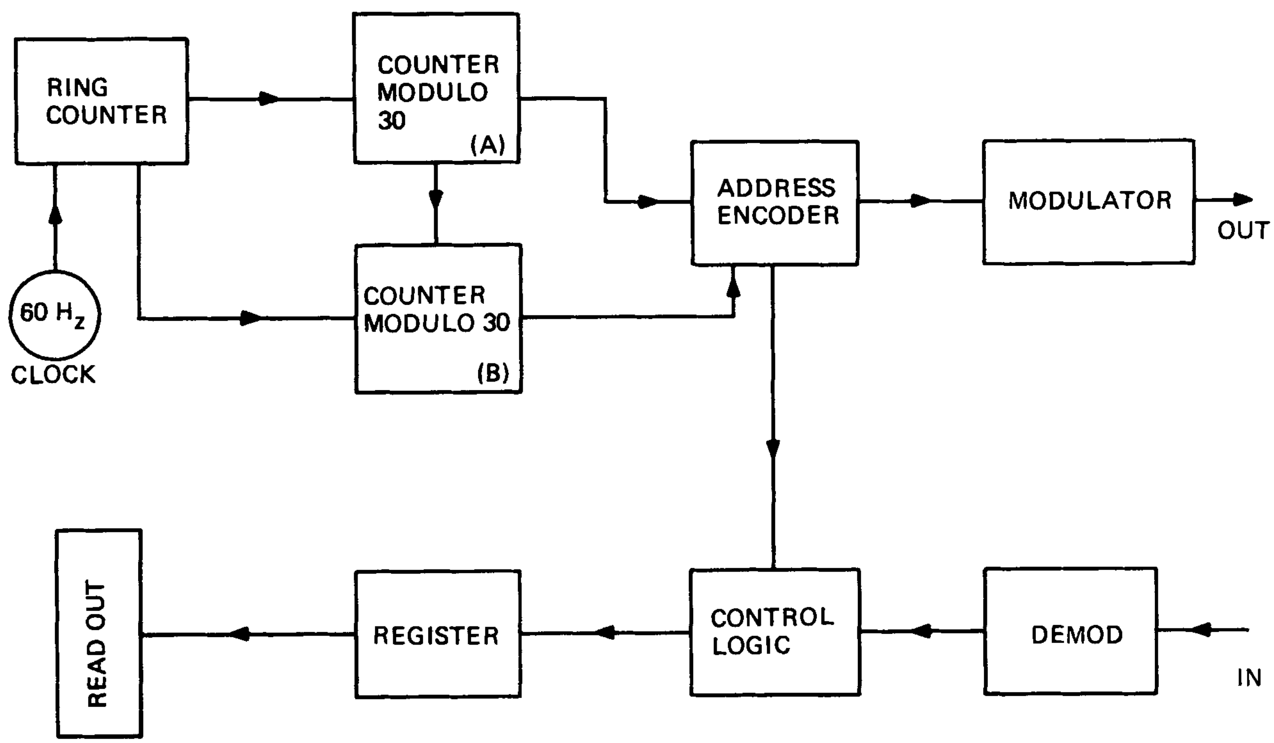


FIGURE 4. BLOCK DIAGRAM OF CONTROL UNIT

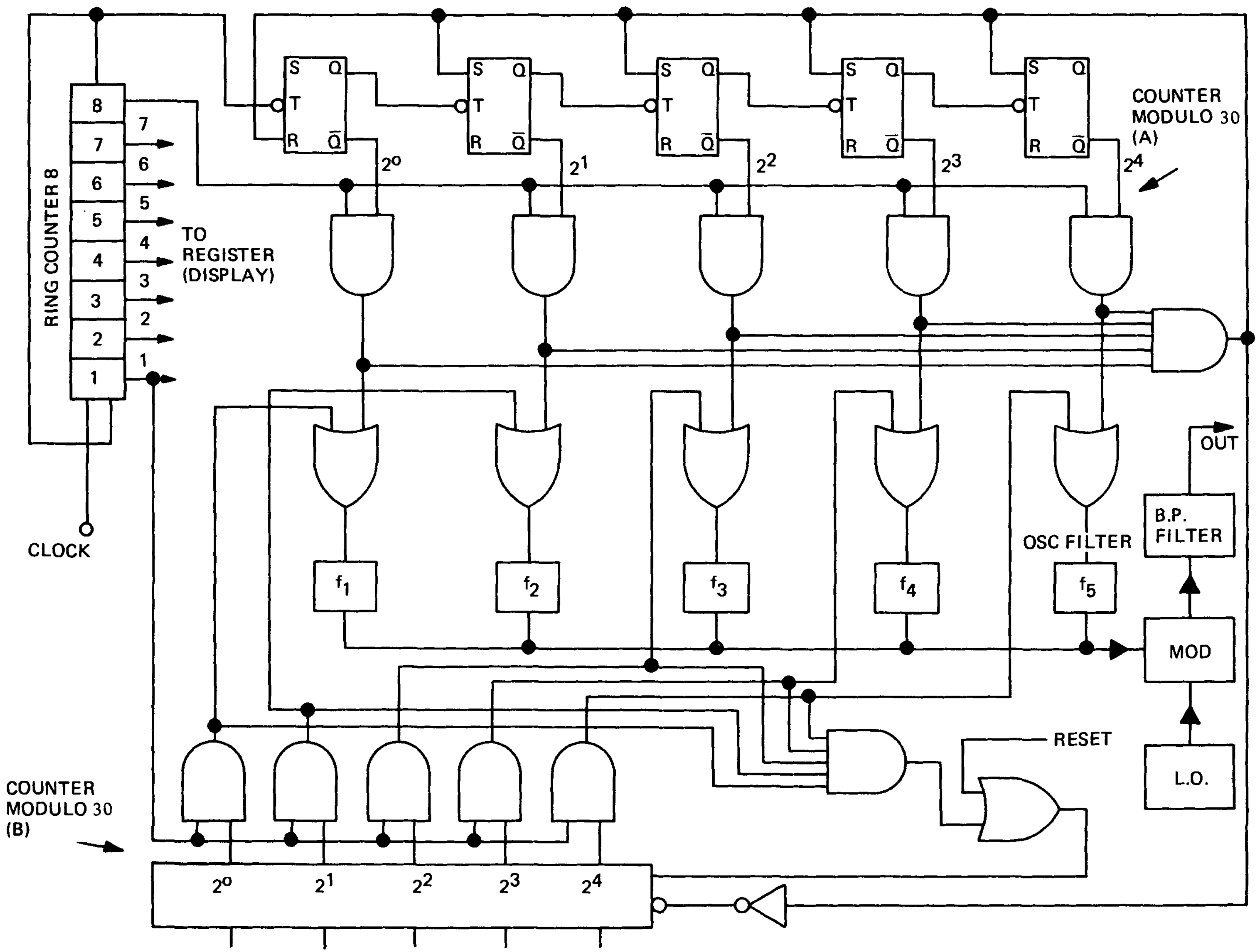


FIGURE 5A. DIAGRAM OF ADDRESS ENCODER LOGIC

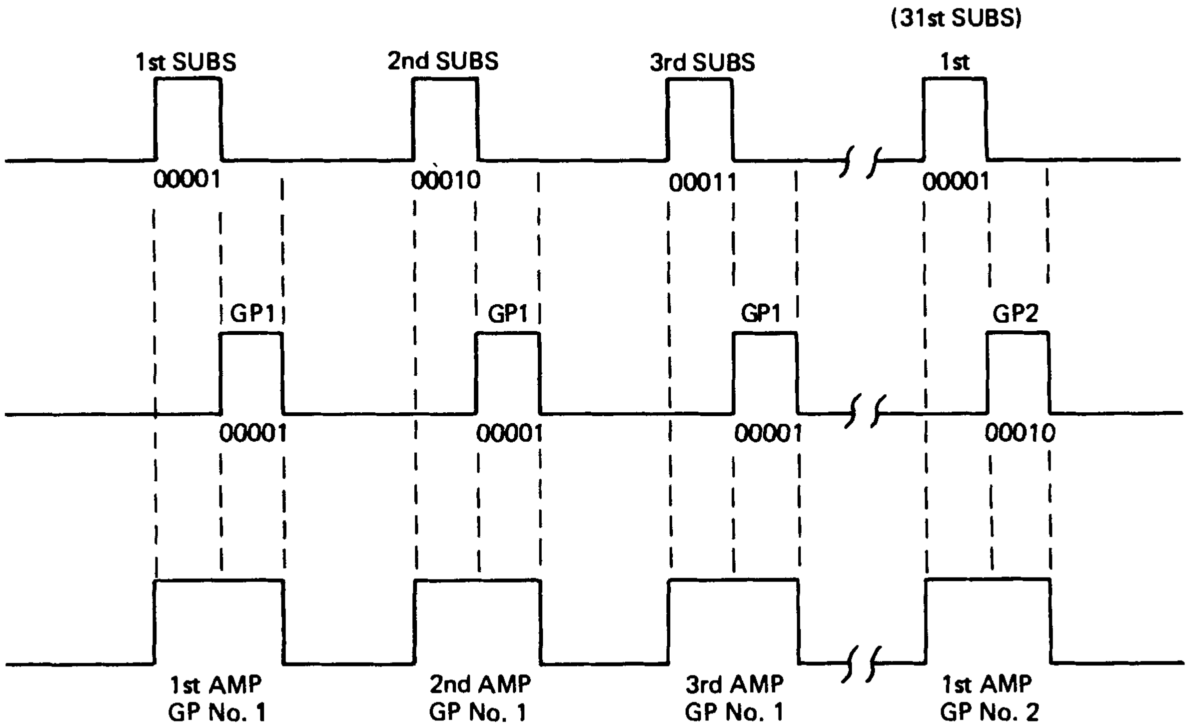


FIGURE 5B. TIMING DIAGRAM, OUTPUT OF ADDRESS ENCODER

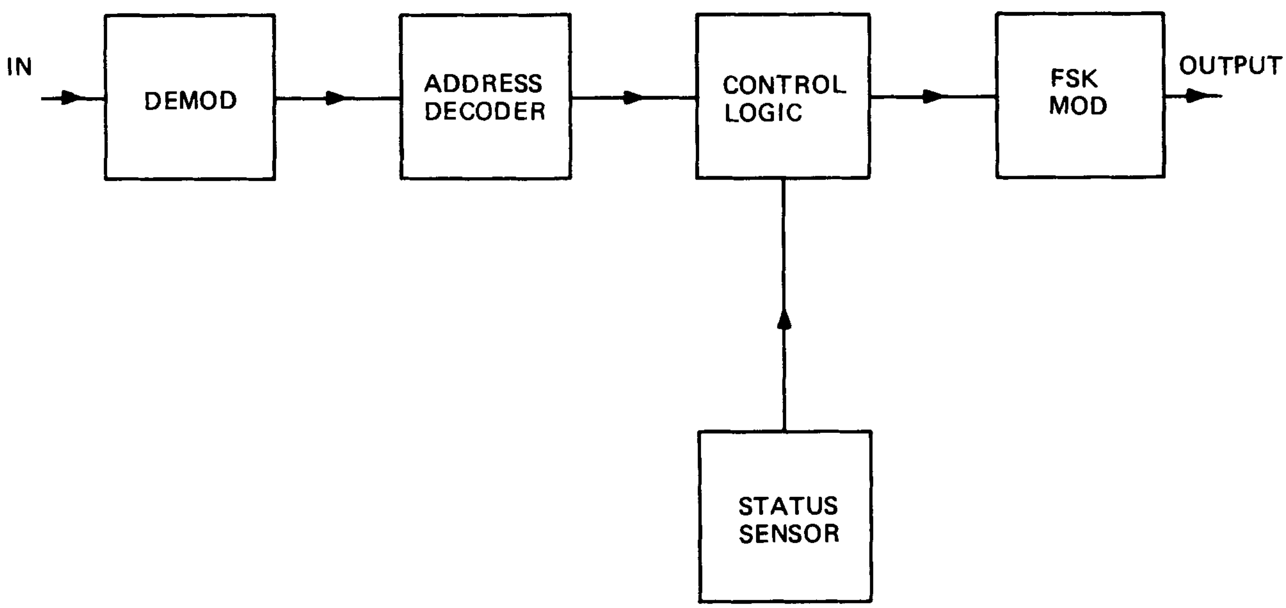


FIGURE 6. TRANSPONDER AT SUBSCRIBER'S

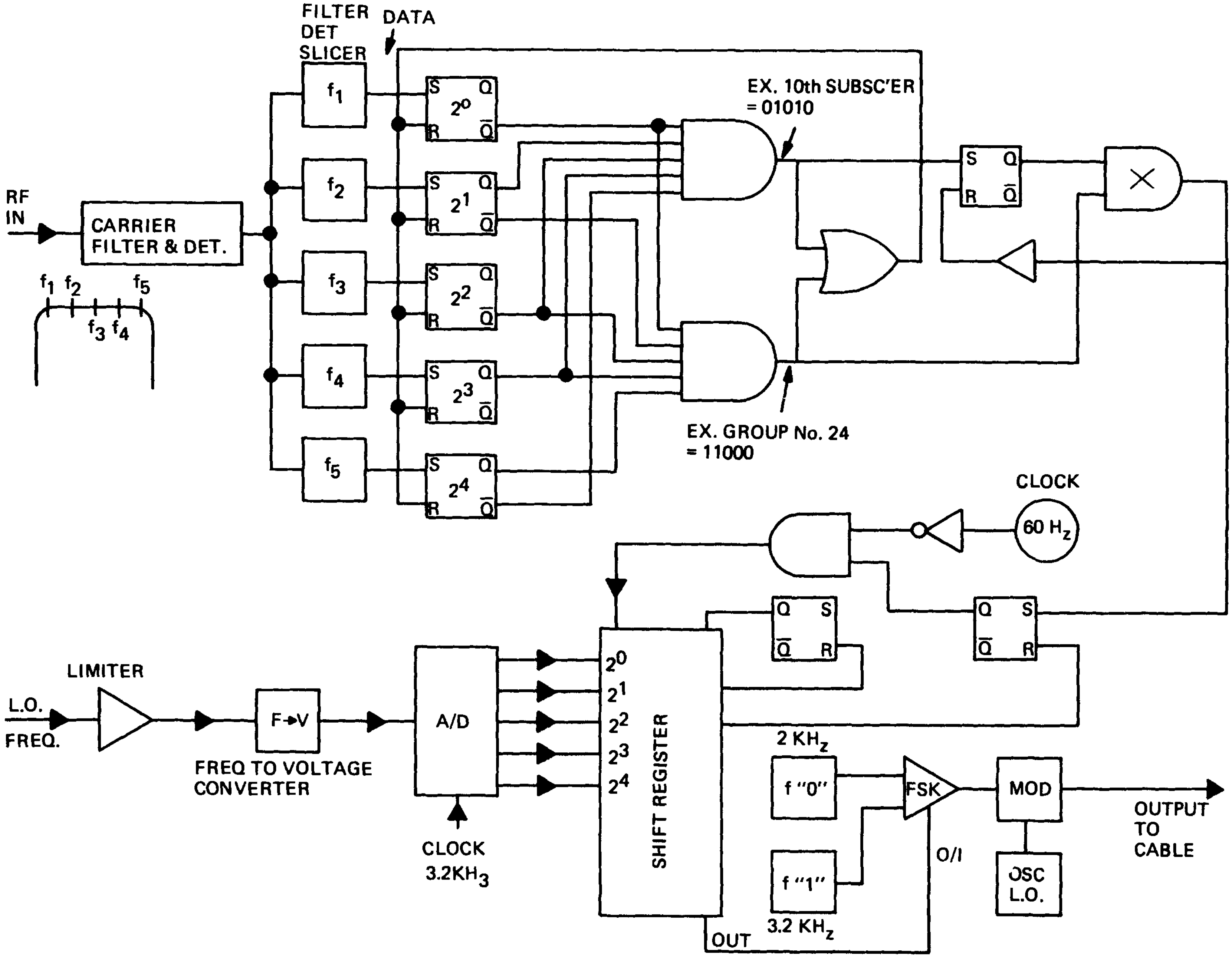


FIGURE 7. TRANSPONDER

Upon receipt of address code from the control unit, the demodulator attenuates noise and interference outside the band of interest and recovers the baseband wave. The recovered data then enters into an address decoder. If the code is in coincidence with the gate set for that code, the 60 Hz clock will be switched to the shift register to cause the five bits of channel-setting reply code to roll out serially. An integrated circuitry, gated, dual input amplifier is used for binary frequency modulation. With Logic "1" from the shift register, the input gate for 3.2 KHz signal will be open and with Logic "0", 2 KHz signal will appear at its output.

D. SYSTEM CONSIDERATIONS AND PERFORMANCE.

A synchronous system was chosen in order to reduce the complexity of the equipment, furthermore, a clock of 60 Hz is chosen to reduce the cost. Still the system can be operated to cover a distance of about 1000 miles, from a signal delay viewpoint, without getting into synchronization problems. The system performs the monitoring at the rate of 116 milliseconds per subscriber or one minute and fifty-six seconds for 1000 subscribers. By using amplitude modulation of parallel date for a reply code, this speed will be reduced by a factor of 2.3 to 1.

The bandwidth required for a transmission channel is a function of the number of subscriber sets to be monitored. The basic system of 900 subscriber monitoring requires a bandwidth of 4.5 KHz. For N=10, i.e., 9000-subscriber system, 10 sets of frequency allocation for f_1 through f_5 with 400 Hz spacing necessitates the bandwidth of system to be raised to 40 KHz which is still a very narrow band for a CATV system.

The cost of the system is largely dependent on the cost of the transponder. This is estimated to be under $30 per subscriber, based on the use of commercially available digital integrated circuits.

IV. ALARM MONITORING SYSTEM

The technique described above for channel monitoring can be directly applied for an alarm monitoring system. The alarm system is a means of detecting failures and pinpointing the failure's location in the CATV system. The need for an alarm system is justified for system maintenance for the following reasons:

A. CATV amplifiers and instruments must be in continuous operation (24 hours a day) and therefore, will occasionally fail.

B. They are usually installed outdoors and subjected to changes in temperature, weather, etc.

C. It is difficult to quickly find a failure location because the system is widely distributed.

Thus an alarm system should meet the following requirements:

A. Indication of the failure mode

B. Identification of the failure location

C. Indication of elapsed time and subsequent status change.

The channel monitoring system satisfies the above requirements with some minor modifications. Figure 8 shows an error detector in place of the aforementioned frequency sensor. The first bit of data indicates a trunk amplifier gain status, the 2nd bit indicates an amplifier tilt status, etc.

An address code identifies a status location and its timing plus a clock printer will continuously print out all events and the time of occurrence of any event.

Some features of this monitoring method over a conventional are:

A. Regardless of how many status changes occur simultaneously, the receipt of all signals is assured due to TDM technique.

B. A single channel is used.

C. The data is in a format convenient for data processing.

V. GRAPHIC DATA COMMUNICATIONS VIA CATV SYSTEMS

Thus far, systems of very low transmission speeds have been described for their particular applications. When communication of visual information between locations becomes necessary, higher data rates (for fast transmission speeds) becomes essential to reduce signal traffic and to save time.

An attractive application of visual communication on CATV systems is Facsimile. At this time this type of service is restricted

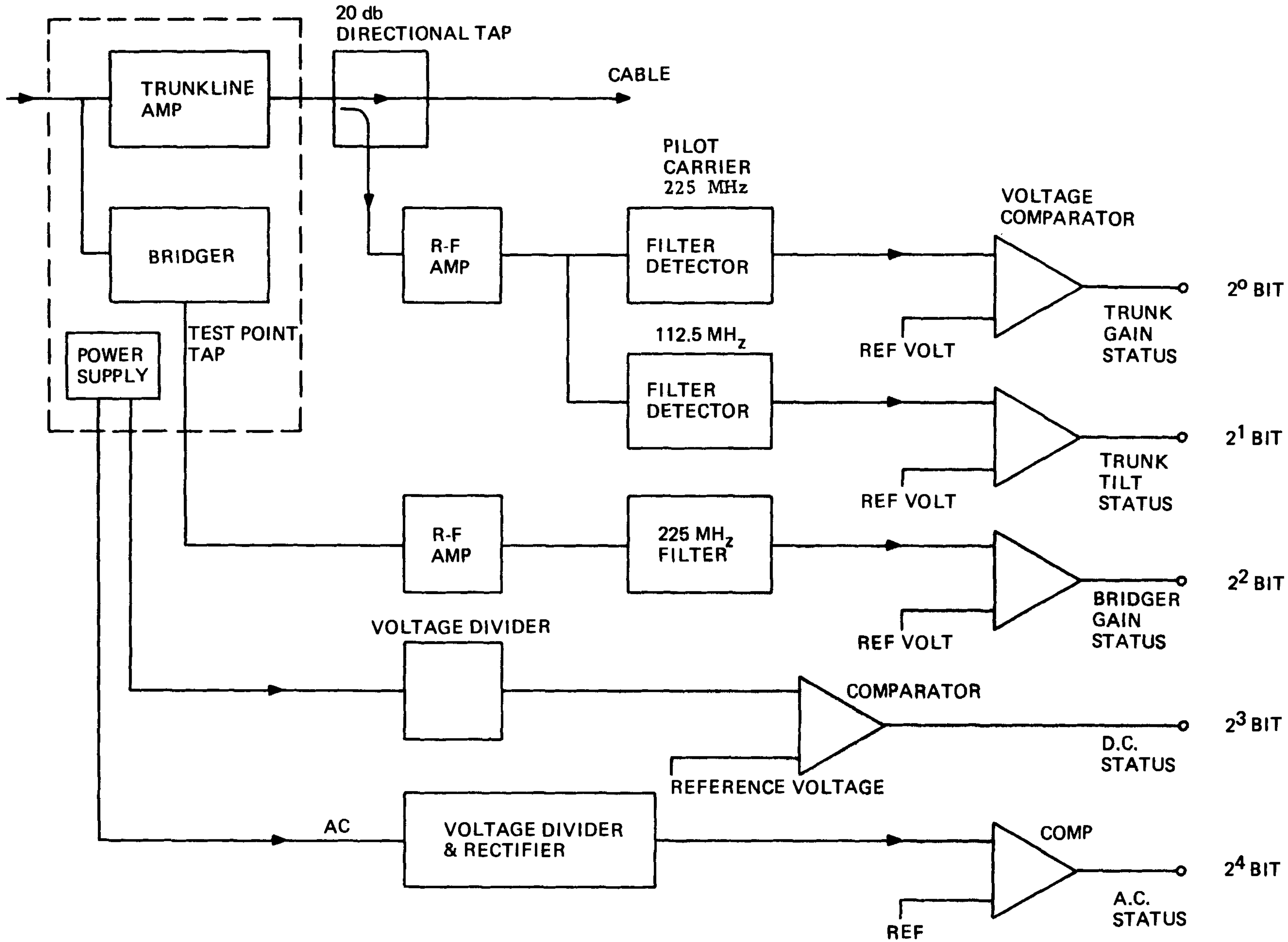


FIGURE 8. BLOCK DIAGRAM OF ERROR DETECTOR

usually for industrial or office use. However, as long as the number of installations are limited the implementation can be carried out at reasonable cost since the more sophisticated equipments which would allow TDM techniques to be utilized need not be used during this initial phase. For example a 6 MHz channel without TDM techniques could only support 20 subscribers for this type of service.

A. TRANSCEIVER EQUIPMENT

Most existing facsimile systems are designed for transmission over telephone lines, and the highest speed obtainable is 60 seconds for an average document of 8-1/2" x 11". The equipment to be described here is designed to use a flying-spot scanner and photo multiplier for image pick up and to use a CRT for display. If desired, a printing process can be added to obtain hard-copy printouts in about 10 seconds from the CRT display terminal. The basic technique used is one of "redundancy elimination" by sending video information at the two edges of an image (4) and by variable scan speed.

1. TRANSMITTER

The transmitter block diagram is shown in Figure 9. The horizontal scanning starts from left to right on the text onto which a "beam spot" from the CRT is focused. The line scanning is from top to bottom and is accomplished by means of a vertical stair-case generator. The space in time between horizontal sync pulses is analog, set by a voltage reference at the voltage comparator. When the spot travels horizontally and enters the edge of an image, a pulse of duration t is generated, i.e., a bit of information is generated to indicate the start of video. As the spot is on the verge of leaving the image, another pulse of t duration is generated to indicate the stop of video. The output is therefore a series of pulses of equal duration.

Legibility is a function of resolution. For a standard resolution of 100 scan lines per inch, one picture element = 0.01 inch. In order for a video-start-and-stop pulse t not to cause any spot positioning distortion on the CRT faceplate at the receiver, the time t should be less than the time required to scan one element. Suppose 150 KHz is used as tone signal as shown in Figure 11, thus t = 6.65 microsecond, then the bandwidth of the system $= \frac{2.2}{t} = 330$ KHz. Total number of picture elements $= 100^2 \times 8 \times 11\text{-}1/2 \times 1/0.75 =$ 1,250,000 elements per page. To scan the image at a rate of 9 microsecond per element and white area at 3 microsecond per element results in:

Total transmission time per page for all black = 11.4 sec, all white = 3.9 sec, average page = 7.5 sec.

Which includes retrace 0.1 ms x 1470 lines = 1.47 sec.

2. RECEIVER

The receiver is similar to the transmitter except that a CRT is used to reproduce the exact text. It is "slaved" to the transmitter, The sync pulses are separated to drive its internal sweep generators.

The leading edges of video demodulated signals are sliced to form video pulses (Figure 10). A high persistence CRT or storage tube is used instead of using memory storage to refresh the frame. The latter may cause "jitter".

3. RESULTS AND FEATURES

a. High speed 75 kbits/sec is achieved. An average text of 8-1/2" x 11" can be transmitted in 7.5 sec. in contrast to 60 sec. of today's modern facsimile machines.

b. High resolution: 100 scan lines/in. horizontal; and 120 lines/in. vertical.

c. The latest print out equipment can be incorporated for hard copy.

B. COMMUNICATION LINK

The next immediate question is how data communications can be carried via the CATV system. A modem is built into each transceiver, to which a set of two carrier frequencies are assigned, (one for sending (f_s), the other for receiving (f_r)). A switching network is also included so that a tone signal can be transmitted to the headend for request and reply.

1. PRIVATE LINE

Referring to Figure 12, a converter with the frequency f_{12} is assigned to the two parties permanently, so that communications between the two are always at their disposal.

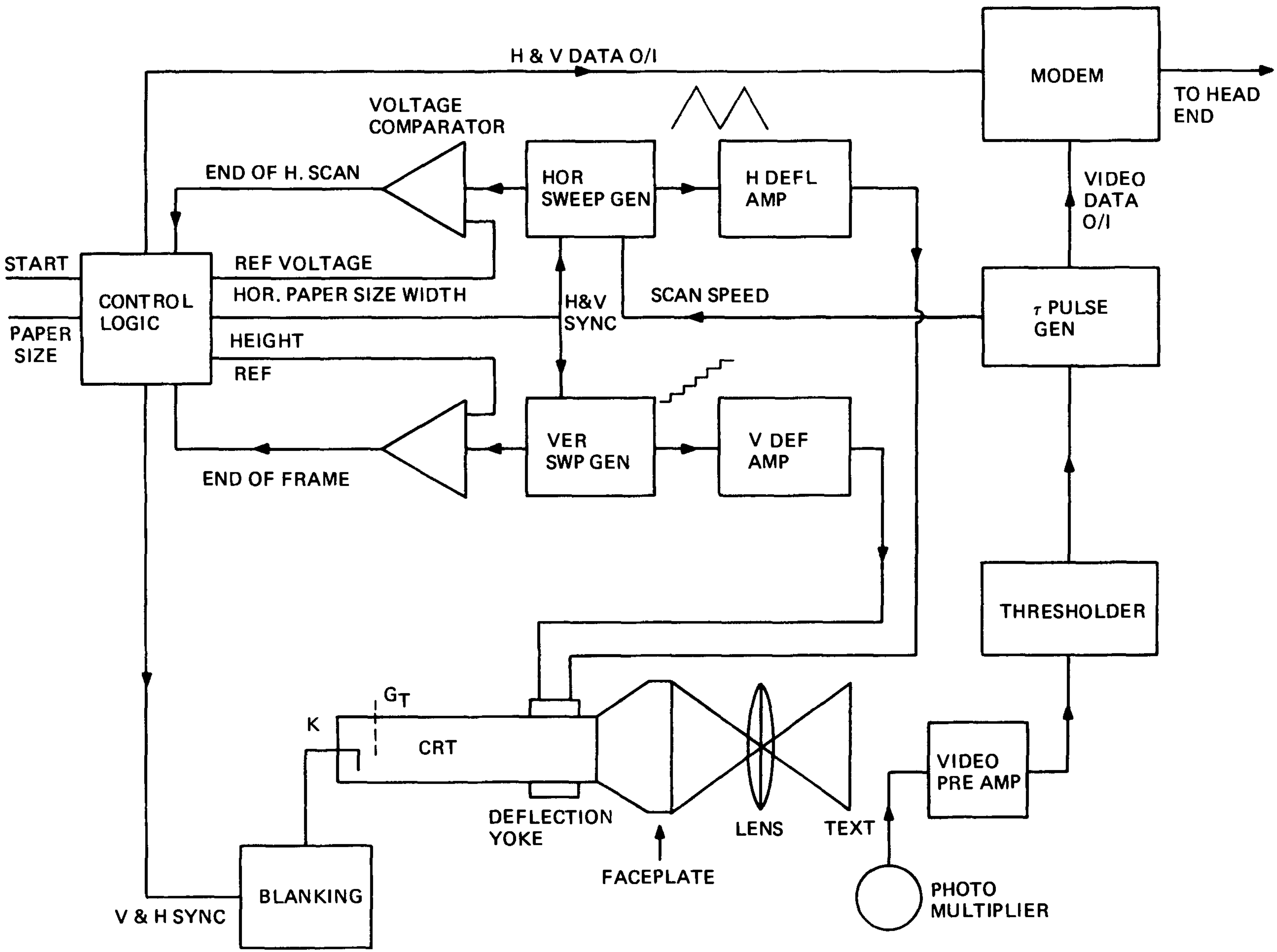


FIGURE 9. BLOCK DIAGRAM FACSIMILE TRANSMITTER

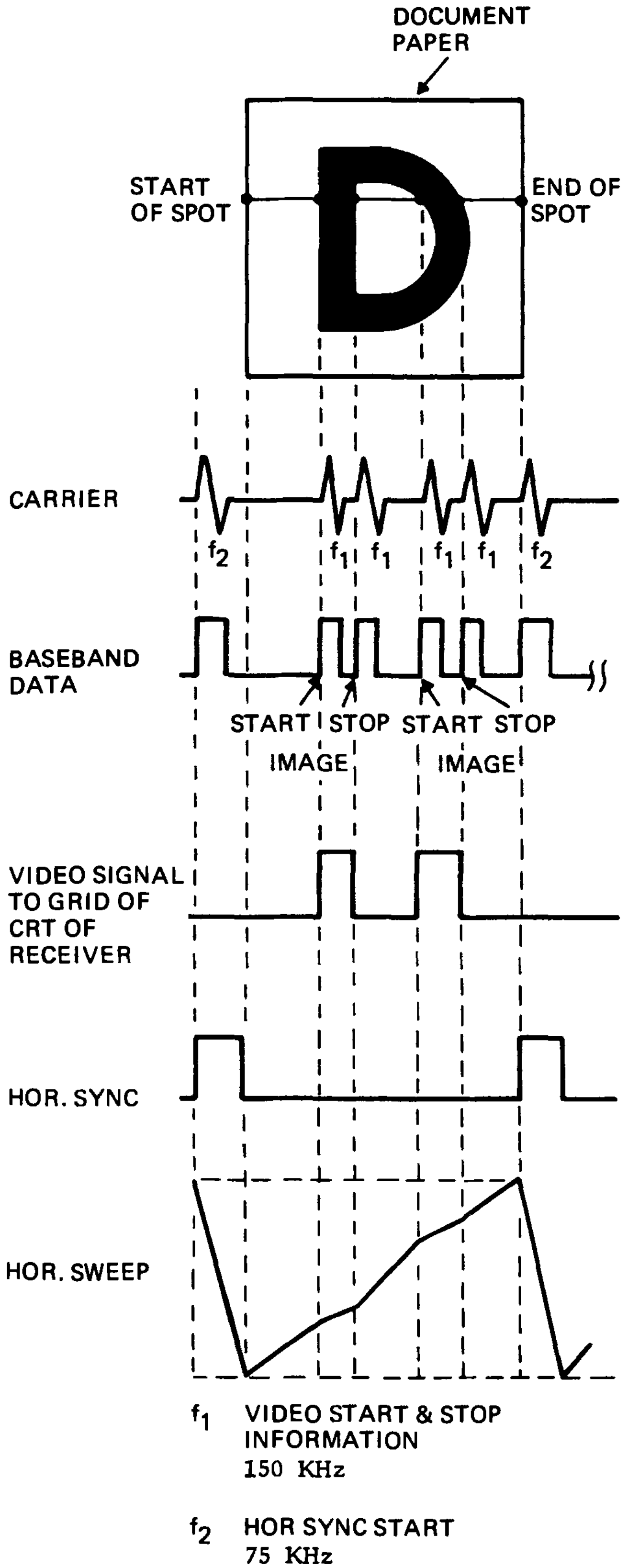


FIGURE 10. TIMING DIAGRAM TRANSCEIVER

2. PRIVATE PUBLIC LINE

As shown in Figure 13. Each subscriber can dial to any other subscriber by sending the "address code" of the party desired to the headend. If the party is free, the appropriate converter will be turned on, in the meantime, a code is returned to the addressor to activate his gate. If the party is busy, the gate remains closed.

3. PARTY LINE

Two or three subscribers can share the same set of two carrier frequencies, but each has a different code to modulate the same carrier. Additional logic is required to inhibit other parties while one of them is in the operating mode.

VI. CONCLUSION

Techniques for subscriber and equipment status monitoring systems, and a facsimile system have been discussed as a first step application of data communications on CATV and expansion into new areas of CATV services.

If the speed of facsimile transmission is not a stringent requirement, a modem can be constructed to interface the presently available equipment with CATV transmission facilities for this new service.

The headend switching unit is by no means complex at this initial phase. The same monitoring technique could be utilized in this type of switching network.

Although today's CATV systems are limited to localized distribution, with available technology, it is reasonable to expect that a national network inter-connecting local CATV systems through microwave or satellite link will be established by the end of the decade. It will then mean much more for proposed services, such as, market survey, audience response, home educational TV, transaction, video phone, facsimile mail, etc., to be available on CATV and to have direct access to each subscriber's home. Before a nationwide system is developed, however, it is natural that the first phase will be the application of data communications within local systems, spurred by the CATV industry's trend.

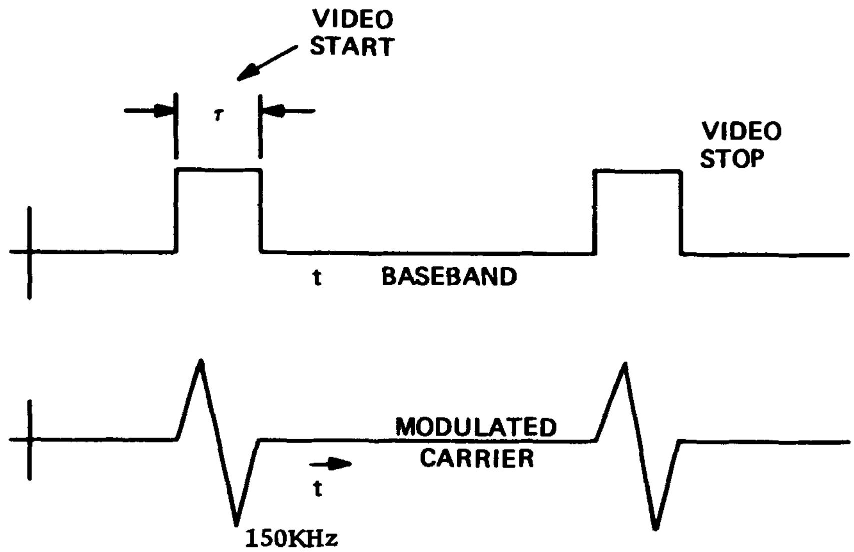


FIGURE 11. VIDEO DATA

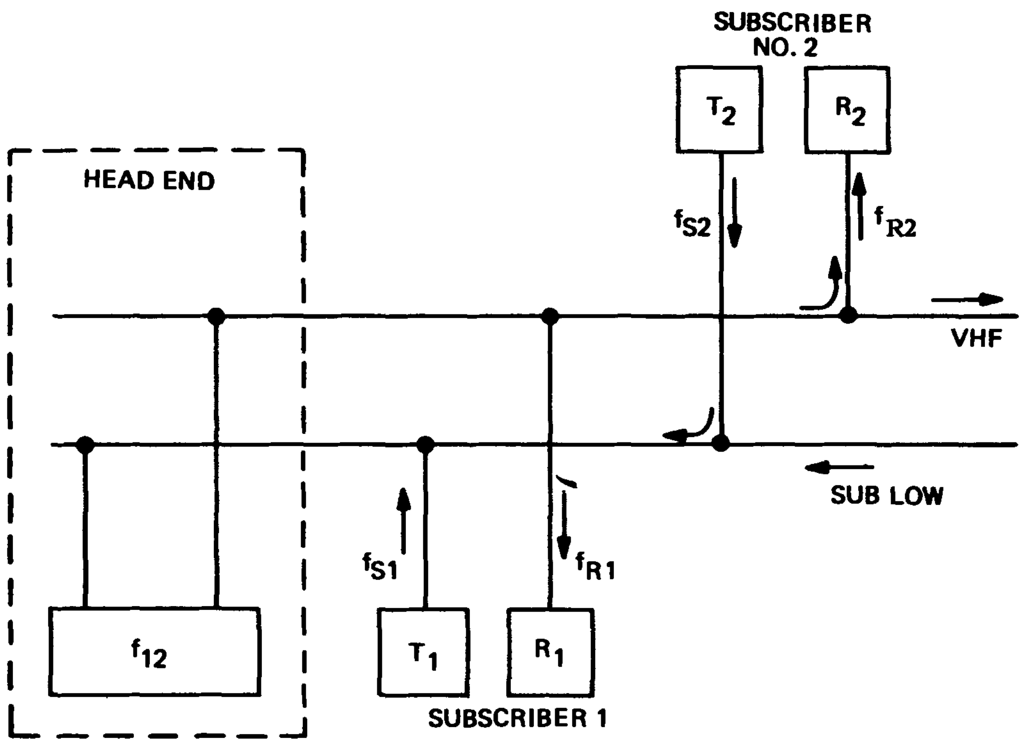
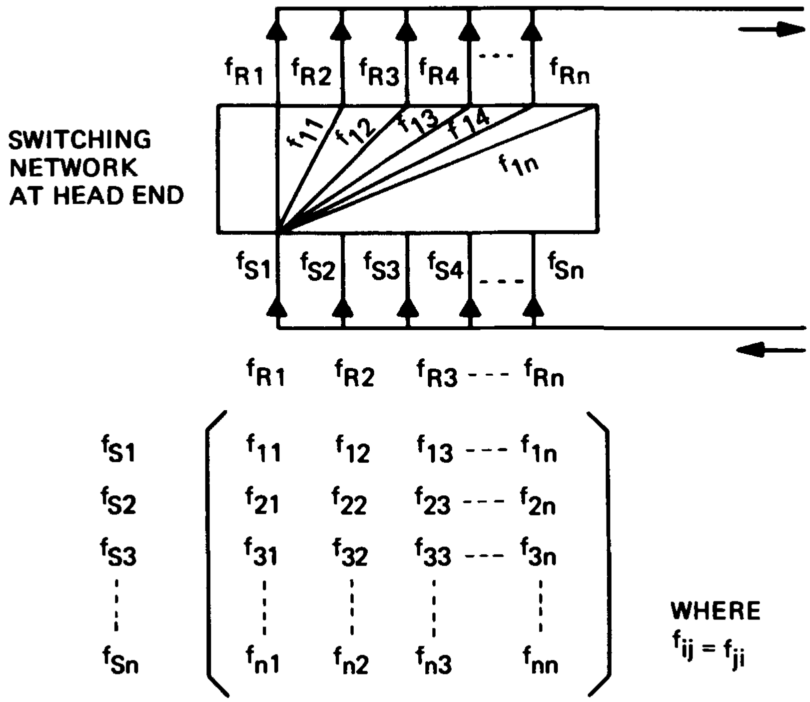


FIGURE 12. PRIVATE LEASE LINE



FOR N SUBSCRIBERS. THERE ARE N + (N-1) CONVERTERS.

FIGURE 13. PUBLIC PRIVATE LINE

ACKNOWLEDGEMENT:

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