TWO-WAY SYSTEM EXPERIENCES

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Cablenet International Corporation and Coaxial Scientific Corporation have been operating a per program pay television business in Columbus, Ohio, since June of 1973, using a two-way cable system. This system utilizes technology developed by Coaxial Scientific Corporation which greatly reduces the home terminal cost, simplifies system maintenance, and increases reliability. In the past two years of operation, CSC and Cablenet have gathered a substantial amount of information on two-way system design, construction, balancing, performance, and maintenance. The practical experience gained in the course of operating the two-way CATV system over the last several years will be discussed. An analysis of signal intrusion, noise accumulation, system hum, and system impulse noise problems and their solutions will be among the topics discussed. In addition, day-to-day operation procedures developed by CSC and Cablenet for two-way systems will be discussed. The experience gained demonstrates that two-way CATV is now economical and practical for not only per program pay television but also other services such as fire, intrusion alarm systems, opinion polling, and interactive data transmission.

Coaxial Scientific Corporation has been operating a two-way Pay Television System in Columbus, Ohio for the past 2 years. This system presently consists of approximately 1,500 subscriber terminals and 200 miles of active two-way cable plant. This system uses a unique data transmission technique which was described in last year's NCTA convention. In brief, the system utilizes Code Operated Switches which are located at each bridger amplifier in the cable system. These switches control the flow of upstream signals into the trunk line from each bridger area. (See Figs. 1 & 2) This approach makes possible an inexpensive frequency division multiplex home terminal unit and significantly reduces RF intrusion problems.

In this paper I will describe the two most significant problems we faced in our two years of operation and their solutions.

The first problem faced by the two-way CATV operator is the level instability of upstream signals. Instability arises not from temperature variations as they do in downstream cable plant, but from poor distribution plant integrity, and more significantly, from poor housedrop integrity. We have found that well over half of our operating problems have been due to level variations caused by corrosion in F type fittings in subscriber housedrops. In order to keep subscriber return levels to within an acceptable range, we have found that several things are required.

1. System Design. It has been the philosophy of CATV system designers that upstream signal levels will fall in line when a system is properly designed for downstream signals, and any variations that may result can be compensated for by providing a home terminal with a variable RF output level. In theory this approach works fine. In practice however, it has serious drawbacks. A CATV system so designed results in variations in upstream levels between home terminals in a bridger area of approximately $\pm$ 8 db. It is no problem to provide a home terminal unit which has a 16 db RF output level range to compensate for this difference. However, since it is possible to compensate for most distribution plant and drop problems by turning up or down the RF level control of the home terminal, many faults are masked. In a large number of cases we have discovered that terminals will suddenly and radically change their level at the headend over time due to poor cable integrity in the plant or the subscriber housedrop.

Therefore, we have determined that it is necessary to establish extremely tight specifications for return levels from subscribers' homes to the cable system headend. Our upstream plant is designed so that a signal inserted at the end of any feeder line will arrive back at the headend within $\pm$ 3 db of a specified reference level. In order to accomplish this, some small sacrifices in VHF system design may be required, and as a result, trunk to feeder ratio may suffer slightly. Our experience is however, that the sacrifice is insignificant.

During the system design phase theoretical upstream losses between amplifiers are calculated and the required upstream gain for each amplifier is calculated and noted on the system map. For upstream plant, it is not practical to label amplifier input and output levels as is typical for downstream plant. This is because several feeder lines converge at one amplifier location and each feeder line will have a different input and output levels. In fact, in some systems, as many as 10 or 12 different input and output levels would have to be recorded at the upstream bridger station. (See Fig. 3) Instead, the loss for each cable segment between each amplifier is noted and the gain of each amplifier is noted. To compute the input and output signal at an amplifier from a particular feeder, the gains and losses from that feeder are added and subtracted by the field technician to arrive at input and output levels.

2. Plant Balancing. The CATV technician balances the upstream plant by using a fixed-tuned 11 mhz field strength meter together with an 11 mhz portable test oscillator (PTO). The PTO is located at the end of the longest feeder and the technician, using his 11 mhz field strength meter, follows the cable back to the bridger, measuring the signal level at end amplifier location. Discrepancies of over 2 db from theoretically calculated gains and losses are noted and problems corrected before proceeding to the next segment. The same procedure is followed on each feeder until the entire bridger area has been completed. The system is then ready for installation of end of line test oscillators. Trunk balancing is done in a similar manner. However, since trunk upstream amplifiers request both level and slope adjustment, balancing is done at 32 mhz as well as 11 mhz.

3. End of Line Test Oscillators. Once the system design has been completed and the system constructed and balanced, small line-powered CW oscillators are installed at the end of each feeder in the system. These oscillators are inexpensive and are placed inside subscriber tap housings. Their output stability is $\pm$ 1/2 db over the temperature ranges encountered in the CATV plant. End of Line Oscillators (ELO) are preset for an output level of + 20 dbmv. A spectrum analyzer is used at the headend to make certain that each of these oscillators arrives back within the specified tolerance. This serves as an immediate check on upstream plant performance.

4. Home Terminal Installation. When home terminals are installed the same procedure is used. Each home terminal has been preset to + 36 dbmv output level and must be received at the headend within $\pm$ 5 db of the reference. If it is not, a technician is dispatched to troubleshoot the subscriber's housedrop. If the terminal is within the $\pm$ 5 db range, its RF output level is adjusted by the installer to the system reference level at the headend.

A computer program is used to automatically scan each of the ELO levels and each of the home terminal levels and to report significant variations from normal. By taking care that levels are carefully set up prior to the installation of home terminals, system maintenance and fault location become substantially easier.

The second major problem area in operating a two-way cable television plant is that of radio frequency intrusion or RFI. The sources of RFI are many; international short-wave broadcasts, amateur radio operators, citizens band operators, and harmonics from various electrical devices such as neon lights and industrial machinery. These signals enter the coaxial cable through many points. From our experience, the greatest problems are encountered with intrusion into improperly tightened connectors and broken cable sheaths. Intrusion has also been noted into subscriber drops, but in general, the intrusion levels are well below those caused by distribution system faults.

As mentioned above, the use of Code Operated Switches in the cable system greatly reduces the intrusion problem. This is for two reasons. First, only a small section of the cable plant is contributing intrusion to the system at any given time since only one Code Operated Switch is in use at a time. And secondly, when intrusion does reach intolerable levels the COS allows the operator to localize the sources of the intrusion to a relatively small section of cable plant. The first step in localizing intrusion, therefore, is to enable each COS and note the area or areas where intrusion increases.

RF intrusion is very difficult to measure in absolute terms. This is because the sources of the intrusion are of varying intensity. It is not practical to generate a standard intrusion source since intrusion will vary with frequency and distance of the source from the cable plant. In addition, no frequencies are presently authorized by the FCC for such use. Therefore, the task of tracking down such intrusion can be a difficult one.

Prior to attempting to use a cable plant for two-way, we have found it necessary to have our technicians go through each area of the plant checking each connector for corrosion and proper tightening. This step is not necessary if adequate safeguards are provided in the specifications to the cable system contractor and if the system has been well maintained for signal intrusion since construction. However, in dealing with even a well constructed cable plant, we found that a connector-by-connector check in this system prior to any attempt to balance the upstream plant or document upstream levels is worthwhile.

We have devised two techniques which make the process of locating intrusion easier. We have discovered that intrusion of signals at VHF frequencies generally correlate with intrusion at subband frequencies. The relationship is not 1 to 1 but an increase in the intrusion of a VHF signal will correlate to an increase in subband intrusion. Therefore, when our CATV plant is first balanced and made ready for two-way operation, the intrusion of a strong local FM radio station carrier is measured at the end of each feeder line and entered in the system documentation. Typically, the FM signal would be 40 to 50 db below the lowband video carrier levels for a properly operating cable plant. Should that level rise significantly it is an indication that there is a cable sheath or loose connector problem in that segment of plant. In order to use this technique, the technician simply goes to the COS area where the intrusion problem exists, then goes to the end of each feeder within that COS area (usually there are a fewer than 10 feeder ends per COS area) and measures the FM carrier at each feeder and compares it to the documented level. When an intrusion level is found to be incorrect, the technician works backwards toward the bridger until the level is again normal. He has then isolated the problem to a single amplifier span. A connector-by-connector check of that span of cable then reveals the source of the intrusion.

The second technique which simplifies the tracking down of intrusion is based on the fact that loose fittings or broken cable sheaths result in VSWR problems. At VHF frequencies the problems may have little or no effect on signal levels. However, in a subband range where cable losses are low, a poor match can result in a large effect on upstream levels received from subscribers' terminals or End of Line Test Oscillators. As mentioned previously, we install End of Line Oscillators at the end of each active feeder. These devices provide a reference at the headend for proper operation of the cable plant. When a signal intrusion problem is noted, the level at each ELO within that COS area is measured. Generally, one or more of the ELOs will be incorrect in level due to the reflection set up by the mismatch at the point of intrusion. A technician is then dispatched to the area or areas where these level variations are noted and the intrusion entry point is tracked down as described above.

Using these two methods we have been able to successfully and quickly track down all the intrusion problems that have cropped up in our system.

Through the use of the COS approach and using the techniques described in this paper, we have been able to make the job of two-way plant maintenance practical and inexpensive.

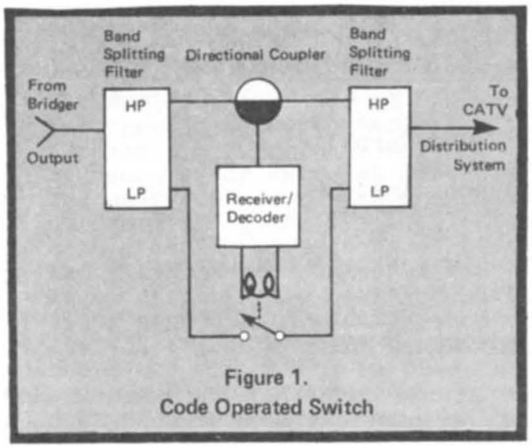

Figure 1.
Code Operated Switch

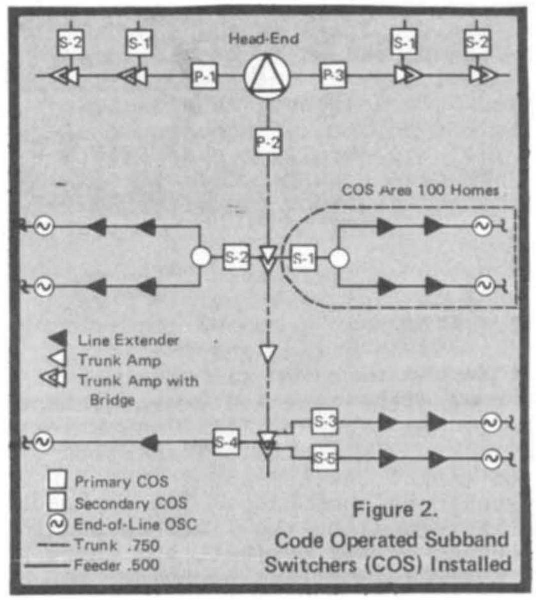

Figure 2.
Code Operated Subband Switchers (COS) Installed

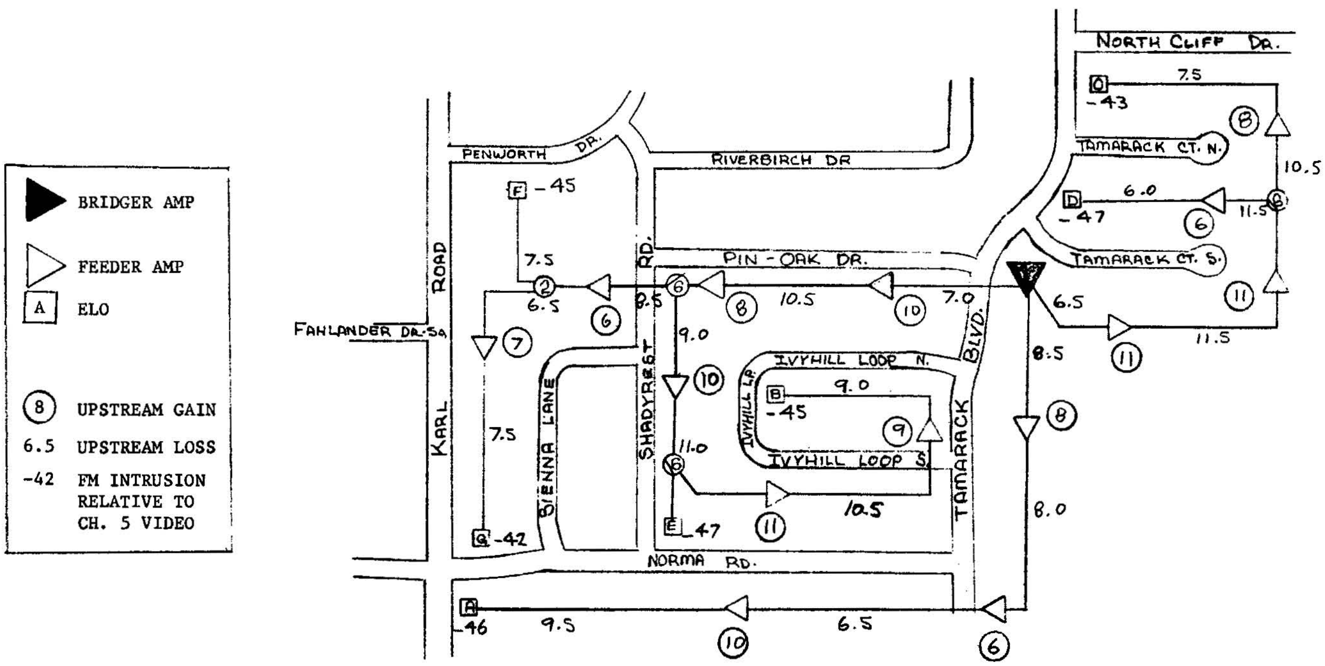

FIGURE 3. TYPICAL UPSTREAM DOCUMENTATION