REMOTE BASEBAND SWITCHING FOR VIDEO MICROWAVE SYSTEMS

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The capability to remotely insert both full field and inservice VITS video test signals at a microwave headend is a highly valuable maintenance tool to the microwave system and CATV operator. A video routing system also allows video program material to be switched to alternate microwave channels on the occasion of a microwave failure downstream from the switcher or during routine maintenance.

Design concepts of such a remotely controlled switching system, including "touchtone" remote control via wire or radio, are described here. Status monitoring and other refinements are included for the operator who desires a more versatile, more sophisticated switching system.

If you have ever operated a microwave system and wished that you could test it on an inservice basis, locate a fault without visiting every site, or route your signals around an outage, then perhaps what you should consider is a remotely controlled switching system. These types of problems prompted United Cable Television Corporation to install such a system on a combination Business Band-CARS Band microwave system which it operates in Wyoming. The microwave system brings Denver television signals to CATV systems in Wheatland, Torrington, Rawlins, Glenrock and Casper, Wyoming on a cost-sharing basis.

THE CONTROL SYSTEM

The very basics of such a system are outlined in Figure 1, titled "Remote Video Switching System - Simplified Block Diagram". At the heart of the system is the video switcher. The switcher without remote control capability is of little use to the microwave operator. The encoder, signaling path and decoder permit control of the switcher, often located at a remote unattended microwave headend, from other points in the system. Normally the end terminal of the system is a logical control point since this site is usually manned and results of the switcher operation can readily be observed. It is desirable, however, to implement a control system which allows control from any microwave site for maintenance purposes.

Reliability, simplicity, versatility and the capability to expand, in that order, were considered the most important requirements for the switching system. Several types of control methods were considered, including dual-tone pulsing, single tone on-off keying, frequency shift keying, carrier keying and dual tone multifrequency (DTMF) which is the technical term for AT&T's registered trademark Touchtone. DTMF signaling was selected because of its reliability, high immunity to voice and noise signals, and proven track record in the telephone industry. Touchtone consists of eight (8) discrete (individual) tone frequencies, ranging from 697 Hz. to 1633 Hz., arranged in two groups of four tones each (a high group and a low group). Sixteen (16) digits can then be represented by the combination of one tone from the high group and one from the low. The normal home phone uses seven of these tones and, therefore, has only twelve digits. The signaling path need only be a "voice grade" circuit for successful transmission of DTMF signals. In a two way or duplex microwave system the most obvious signaling path is the microwave radio itself using subcarriers to carry the audio control signals. Since most microwave systems in video use are not duplex, some alternatives must be considered. In the Wyoming case, all microwave sites were linked by an existing 150 MHz. two-way radio system and DTMF signals from the control point encoder are transmitted over this radio system to the decoders at the microwave headends. If phone lines are available, they could be used instead of or in addition to radio. Control by both wire and radio would add to the system's versatility.

The normal DTMF decoder has sixteen (16) parallel output lines. These sixteen functions are all that are required in switching systems containing up to fourteen (14) inputs and fourteen (14) outputs. Expansion beyond this size is easily done by adding logic which recognized two, three or more digit combinations. The handling of multiple switchers in the system, each located at a different site, only slightly complicates the control methods. If a microwave radio using a different frequency subcarrier for each switcher location or a phone line control system is used, there is no need to encode signals which allow differentiation between stations since this is accomplished by the selection of a subcarrier frequency or a phone number. In a system using the same subcarrier or two way radio frequency or the same wire pair for all stations, then an "on line" condition exists. It is then necessary to assign an address to each station and place an additional address decoder at each site. Typically a two or three digit number is assigned to each station and this number encoded in DTMF format must first be received by the address decoder before the DTMF selector with its sixteen outputs is enabled to receive switcher control signals. A timer in the address decoder keeps the selector enabled for five seconds after which a reset occurs and access to the selector can only be regained by encoding the station address. The decoder can also be reset manually by sending the DTMF pound digit (#). A four digit command is normally used to control the switcher and consists of a CLEAR command (DTMF asterik digit - *) and input selection (DTMF digits 1-14), an output selection (DTMF digits 1-14) and a TAKE command (DTMF pound digit - #). Five seconds is adequate time for the operator to encode these digits and the pound digit (#) not only serves as a TAKE command for the switcher, but also resets the address decoder. An almost unlimited number of switching sites may be controlled by this method which uses a seven digit number similar to your telephone number.

Even in systems having only one switcher, it is desirable to include an address decoder because of the additional security provided against unauthorized control of the switcher and false triggering of the DTMF selector by noise and voice signals. Two way radio systems equipped with continuous tone coded squelch systems (CTCSS), known by such brand names as Motorola's "Private Line" and General Electrics's "Channel Guard", are relatively immune to false triggering since audio from the radio receiver is not available at the DTMF selector input unless the two way radio signal contains a sub-audiable tone capable of operating the CTCSS decoder in the radio receiver.

A sixteen digit DTMF encoder can be permanently installed at the microwave end terminal and a portable decoder allows control of the switching system from any microwave site or other locations linked to the microwave headends by radio or wire, depending upon the signaling path chosen for control. DTMF encoders, decoders, selectors, and accessories are available from Speedcall, Solid State Communications, Secode, Bramco and others. Encoder costs range from $100 to $300 and each station of decoding equipment, which includes a decoder, selector, power supply and card cage or other mounting hardware, can be expected to cost between $600 and $900.

THE VIDEO SWITCHER

A multiple input, multiple output video switcher takes the form of an X-Y matrix when represented by a drawing. The columns being the inputs and the rows the outputs. Each point at which an input line or bus meets an output line or bus is designated a crosspoint (X) and is a potential input to output connection within the switcher. Figure 2, "Video Switcher - Simplified Diagram", shows a matrix type switcher with an n x k configuration where n is the number of inputs and k is the number of outputs. Usually integral to the control systems of this type of switcher are provisions to preclude more than one input at a time on a single output line. On the other hand, it is possible to feed all outputs from a single input line. These large matrix type switchers are often called routing switchers and in addition to the video only type used for this application combination video-audio units are available for studios where "audio follow video" applications are frequent. Vertical Interval switchers are also made which switch only during the vertical interval to prevent any noticable interruption of the picture. The video inputs to such a switcher must share a common sync source for no interruption of the picture using vertical interval switching. In a CATV microwave headend, it is highly unlikely that the video sources will have a common sync source. This expensive feature is, therefore, not needed, besides, the millisecond switching time of these switchers is so fast that even without vertical interval switching the switch itself will not be noticeable. Tally outputs which indicate which crosspoints are energized within the switcher can provide both local and remote monitoring of the switching status of the switcher. This is a highly desireable feature of any large switcher when you consider the myriad of possible input to output combinations. The status monitoring feature of this system is discussed later in the paper.

When selecting a switcher, do not forget to use the same care and criteria which you used in selecting the microwave or any other device in the baseband video path. These switchers are active devices and are not without distortion although a good switcher is practically "transparent". Differential gain, differential phase, envelope delay, transient response, frequency response, signal to noise, input and output return loss, gain, hum and crosstalk are all important considerations.

Most of these switchers use a mainframe or motherboard which may contain control electronics, power supplies and interconnecting wiring including input and output wiring. The actual switches or crosspoints and video amplifiers are usually on separate circuit boards which are either hard wired or plugged into the mainframe. The mainframe will have a maximum capacity of n x k (inputs x outputs) and the actual crosspoints come in smaller units such as 4 x 1, 12 x 1, 1 x 4 or 1 x 8. In the 12 x 8 switcher featured in Figure 5, the mainframe capacity is 20 x 8. Crosspoints are available in 1 x 4 increments for plug in installation, so it takes twenty-four (24) of these 1 x 4 boards to implement a 12 x 8 switcher.

The mainframe costs are major and may range from $1,500 to $3,500 with each crosspoint costing up to an additional $50.00 each. Each manufacturer will approach the mainframe-crosspoint board problem in a different manner. The engineer designing the remote video switching system may realize significant savings by matching his current and future size requirements to the particular switcher which meets his needs without providing excessive mainframe or crosspoint board capacity. As an example, suppose the switcher in Figure 5 need only be a 6 x 5 unit with no provisions for future expansion. First, the use of a 20 x 8 mainframe is an overpowering of the situation. Secondly, since crosspoint boards come in 1 x 4 units, the fifth output requirement would require purchasing six (6) additional boards which would expand the switcher to a 6 x 8 size. A 6 x 3 portion of the switcher containing eighteen (18) crosspoints would go unused. If a smaller mainframe with 6 x 10 capacity would cost $1,000 less than the 20 x 8 unit and 6 x 1 crosspoint boards were available which would exactly fit our 6 x 5 requirement a savings of $1,900 would result if crosspoints cost $50.00 each.

All of the criteria used in switcher selection above are overshadowed by the control electronics which interface the DTMF selector and the switcher. Local control methods offered by switcher manufacturers include thumbwheel and pushbutton schemes and remote control options include BCD Keyboard, X-Y coordinate, computer BCD control and others. Use of the DTMF selector sixteen parallel lines in a serial decimal format to control the switcher is a special application.

The switcher in Figure 5 was manufactured by American Data Corporation and they modified their X-Y coordinate control system to be compatible with the DTMF control system. Most manufacturers will provide switcher control electronics to interface with your control system if you furnish them with adequate information. Manufacturers that build video switchers are American Data, Central Dynamics, Grass Valley, Telemation, Telemet, Matrix Systems and others.

Electronic video switchers normally employ digital logic circuits which provide the memory to latch chosen crosspoints until a new command calls for a change in the switcher status. If the power is interrupted for even the shortest time, this memory is lost and when power is restored the previous video paths thru the switcher will no longer exist and it will be necessary to reprogram the switcher locally or remotely using the DTMF control system. It is, therefore, imperative that the system design include a reliable, non interruptible power supply for the switcher. The standby battery supply commonly used in microwave systems is an extremely reliable -24V DC, positive ground, power source. It is likely that the switcher will also require a positive polarity, negative ground, supply. Input voltages may also be much lower than 24 volts. Electronic regulation of 24 volts down to a lower voltage is a relatively simple and straightforward problem, but a polarity change can be much more difficult.

In the Wyoming system, the switcher required -11 VDC and + 11 VDC. Initially DC to DC converters were used to provide +11 VDC and -11 VDC outputs with a -24 VDC input. Not only was a reliability problem encountered with these units, but the noise on their outputs often interfered with the operation of the digital control electronics. After varying degrees of success with other power supplies, the -11 volts is now supplied by regulating the existing -24 volt microwave battery down to -11 volts and the addition of a high quality 12 volt charger and a battery serves as a positive voltage source.

APPLICATIONS

Now that we have progressed through engineering the DTMF control system and selecting a video switcher, how can it all be put to use ? Figure 3 shows some typical routing paths thru a video switcher. In normal operation a video signal is routed to its corresponding microwave channel as shown in the middle diagram. If your microwave system includes channels which are considered to be more important than others, the switcher may be of help during a failure of one of these primary microwave channels. Until the outage can be corrected, a "primary" video source can be routed to a "secondary" microwave channel. This means, of course, the loss of the lower priority secondary video signal until normal operation can be reinstated.

If you ever wondered whether the distortion you were viewing at a microwave receive terminal was a microwave problem or was coming from a video source such as a demodulator, the switcher offers many alternatives to locating the problem. One solution might be to put the video in question on two or more microwave channels and make a side by side comparison. If the problem is now apparent on all microwave channels carrying the signal, then more than likely the video source is at fault. If the problem is evident only on the original microwave channel, then that particular channel is at fault. A more definitive solution would be to use the full field test signal capacity of a signal generator such as the Tektronix 147A. This is shown in Figure 3 by the diagram on the right. By routing a known to be good test signal down the microwave channel, it is very easy to locate any distortions associated with the microwave. The microwave technician who can control the switcher from each site using the portable DTMF encoder can isolate a problem very quickly. The switcher is almost like having another man available on a twenty four hour basis to change the baseband inputs to the microwave during outages or for testing.

So far the use of the switcher for testing has involved "out of service" conditions. This interruption of service is often untenable and the next step is in-service testing. Figure 3 in the left hand diagram shows how a video signal is routed to allow vertical interval test signals (VITS) to be inserted using a VITS inserter such as the Tektronix 147A. Now you can monitor your system's performance while it is in service. Localizing faults before they become outages becomes a day time job rather than a task done only after hours when the television stations sign off. Those twenty four hour stations are really a problem without inservice testing capability! In a multihop system with switchers and VITS inserters located at intermediate points, even greater possibilities are available. The build up of distortions in the video signal can be monitored at the end terminal of the system by progressively inserting VITS starting at the microwave headend and moving toward the end terminal. Even noise build-up can be measured by using the noise deletion feature of the Tektronix 147A. This strips all noise off a line in the vertical interal of video routed through the 147A. Signal to noise can then be measured in the microwave system downstream from the VITS inserter using instruments such as the Vista Systems Noise Meter or the Tektronix 1430 Noise Measuring Set.

Television sound is usually carried on a 4.5 MHz. subcarrier on a video microwave system. Other subcarriers above 4.5 MHz. carry FM broadcast program material and service channels for microwave maintenance. The VITS inserters currently available are designed for use on video only lines as found in television broadcast studios. Deletion of incoming VITS at a field rate (60 Hz.) is done by the VITS inserter before inserting its own VITS. This deletion feature also "chops holes" in the subcarriers with 60 Hz. frequency. In the Wyoming system, which is in use, this problem is solved on the most important subcarrier, the 4.5 MHz. sound, by bypassing it around the VITS inserter. A Jerrold CST-4.5 is used to separate the subcarrier from the video on the input line to the VITS inserter. A 10 dB amplifier is then used for the 4.5 MHz. signal to compensate for the insertion loss of the "video and sound" to "sound only" path of the CST-4.5. A Jerrold SCC-4.5 is used on the output line of the VITS inserter to recombine the 4.5 MHz. sound with the video. The variable gain feature of the Tektronix 147A is used to provide unity gain in the video path between the CST-4.5 "video and sound input" to the SCC-4.5 "video and sound output". Bypassing the other subcarriers above 4.5 MHz. could probably be done in a similar manner although it has not been tried in the Wyoming system yet. Care must be exercised in inserting numerous high-Q traps in the video line since frequency response and group delay problems are the likely result.

STATUS MONITORING AND OTHER REFINEMENTS

With the many possible routing combinations in a large matrix type switcher and the use of multiple switchers, it becomes almost a necessity to have a status monitoring system. Such a system should provide the control operator not only a real time indication of all energized crosspoints in each switcher, but will confirm that his encoded commands have been properly received by the decoder and executed by the switcher. Both local and remote status indicators are useful. Only a duplex control system can offer "real time" status monitoring, so whether the control signaling path is wire or radio, the microwave system itself is useful in returning status data to the control point. The DTMF decoder system in one manufacturer's configuration can also be used to encode the tally outputs of the switcher into a DTMF format for transmission via subcarriers to the control point for decoding into a visual display. Figure 4 shows a block diagram of a typical video switching system with full status monitoring. At this time, the monitoring system is still in the conceptual stages. A simpler system has actually been implemented. By using the tally outputs of all crosspoints normally energized, as inputs to an AND gate, a normal condition causes the output of the gate to remain "high". Any "not normal" routing causes the gate output to go "low" which is used to drive a number five (#5) alarm on an existing eleven (11) point alarm system on the microwave. At the control point reception of a number five (#5) alarm from a particular station reminds the operator that the switcher at that site is no longer in a normal routing condition. This system works well, but it is more limited than the more extensive system shown in Figure 4.

Another accessory to the switcher now under development is the use of a read only memory (ROM) to provide automatic programming of a switcher's many normally energized crosspoints when the power returns to the switcher control electronics after a power supply failure. A single command signal from the control point could also be used to reset the entire switcher to a normal condition or any other preprogrammed routing scheme.

A digital counter is used with a single input from the DTMF control system to sequence the Tektronix 147A signal generator through its available full field outputs, including Flat Field, Noise, Field Square Wave, Window, Sin^2 Pulse and Bar, Composite, Linearity and Multiburst.

The DTMF control system could also be used to control standby generator exercising, charger output failure simulations, battery equalization charges and a host of other functions.

CONCLUSIONS AND RECOMMENDATIONS

A remote baseband switching system as described in this paper has been implemented in a microwave system serving CATV systems and in daily use it has proven its value and capability in allowing bypassing of microwave outages and in both routine and emergency maintenance. As an instrument in testing a microwave system, it has saved engineers and technicians alike valuable time by allowing problems to be localized by switching from the control point rather than sending technicians to remote sites to try and track down a problem. The inservice testing capability it offers is an extremly valuable tool in performing routine maintenance on a microwave system.

The major limitation to the use of such a system is its cost. A 12 x 8 matrix switcher and the DTMF control system may cost up to $7,000. The microwave system operator must balance this cost against the projected cost savings in labor and reduced downtime which the switcher may reasonably be expected to produce.

Another disadvantage from an engineering viewpoint is the addition of another active device in the video signal path. A total failure of the switcher is one of the only events which can cause an outage on all channels. This is a catastropic failure. Although the reliability of the switcher itself in the Wyoming system has been quite good with only two single channel failures in over two years of operation, outages caused by power supply failures during the first year of operation occurred four times. The power supply problem has since been rectified by using separate battery systems for both negative and positive supplies. A needed feature of video routing switchers is provision for automatic bypassing during a failure.

The entire remote switcher concept could be further developed by work in the area of higher reliability power sources, computer control for automatic channel switching and status monitoring, and the use of a switcher in a multichannel microwave system to implement automatic inservice monitoring of video quality.

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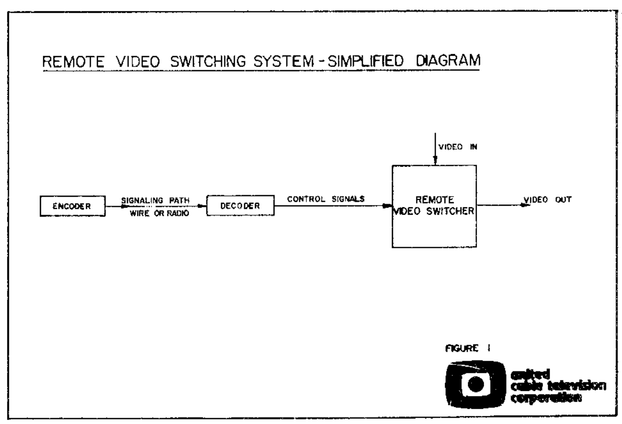

FIGURE 1

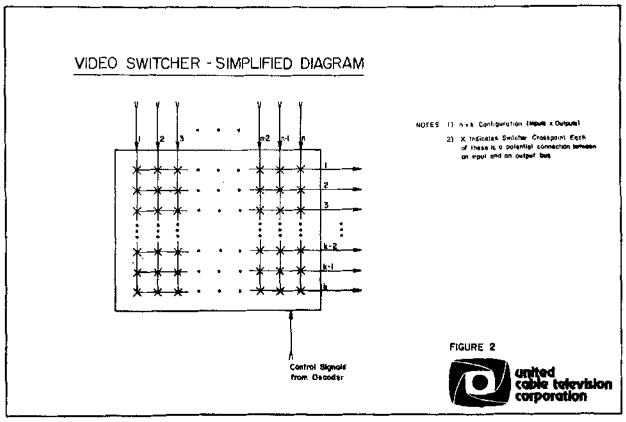

FIGURE 2

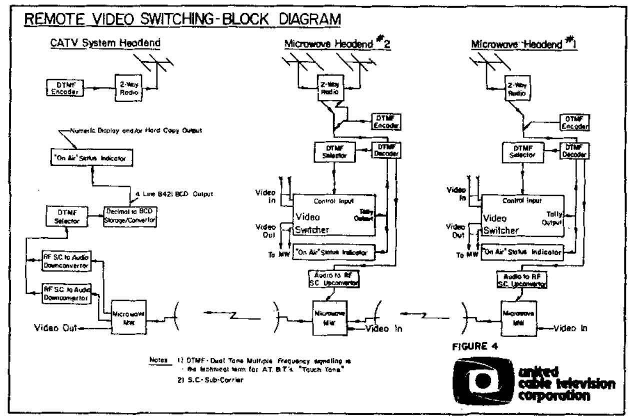

FIGURE 4

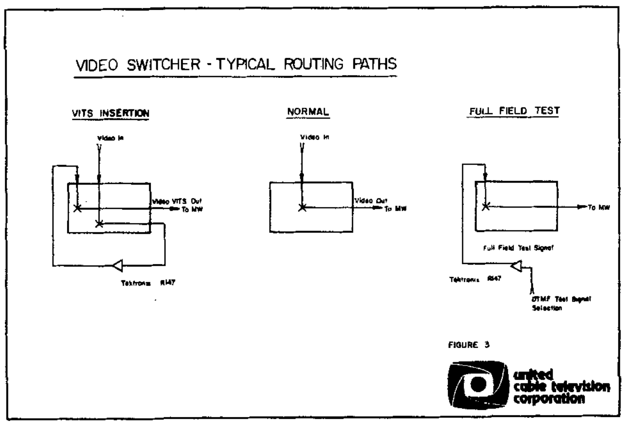

FIGURE 3

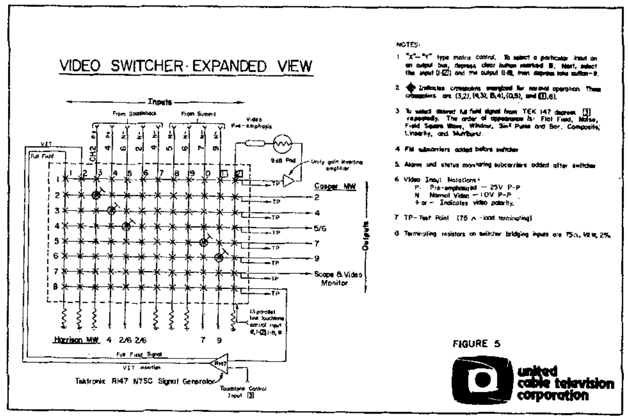

FIGURE 5