

A Network Control System for Television Distribution by Satellite

By J. KINIK and F. J. FOX

The Canadian Broadcasting Corp. (CBC) utilizes the Canadian Domestic Satellite System to distribute three television channels throughout Canada via ANIK-1, the world's first synchronous-orbit domestic satellite, and a network of 33 earth stations. A Network Control System has been developed to provide the CBC with centralized remote control over the routing of channels to specific areas of the country or the accessing of satellite channels by different transmitting stations. With dual identical control centers — in Toronto (English Network) and Montreal (French Network) — either control center is able to control any earth station in the network to feed regions or specific locations with the desired channel, to control the audio/video output feeds to given regions or communities at the beginning and end of the broadcast day (or to blank out commercial messages), and to control the origination point of the program for any given satellite channel by turning transmitters on and off.

PART 1: OPERATION

1.1. Introduction

In February 1973, the Canadian Broadcasting Corp. (CBC) began transmitting television programs to various parts of Canada via ANIK-1, the world's first synchronous-orbit communications

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satellite used for domestic communications purposes. Today the CBC uses the satellite to distribute four channels of radio and television programming across the country and to the far north. Three channels are used full time and the fourth on a part-time basis.

To complete its requirements, the CBC needed a network control system to provide control over the routing of programs to different parts of the country. The CBC Network Control System required the following features:

(1) Dual identical control centers, one in Toronto for English, and one in

Montreal for French, these operating in a common control mode.

(2) Manual and computer control at each center.

(3) Compatibility with existing CBC studio control system design concepts.

(4) Centralized remote control of television earth station receivers to control audio and video outputs.

(5) Centralized remote switching of TV earth station transmitters to change the video source to the satellite network channels.

Telesat Canada (the corporation established by the Canadian government to build and operate the satellite system) and the CBC designed a control system concept to meet the CBC requirements while staying within a practical and cost-effective design scheme. The design approach utilized:

(1) A one-way control system without status feedback — since the majority of earth stations are receive-only types.

(2) A non-dedicated control channel which is part of the television video-audio baseband.

(3) A highly secure encoding/decoding

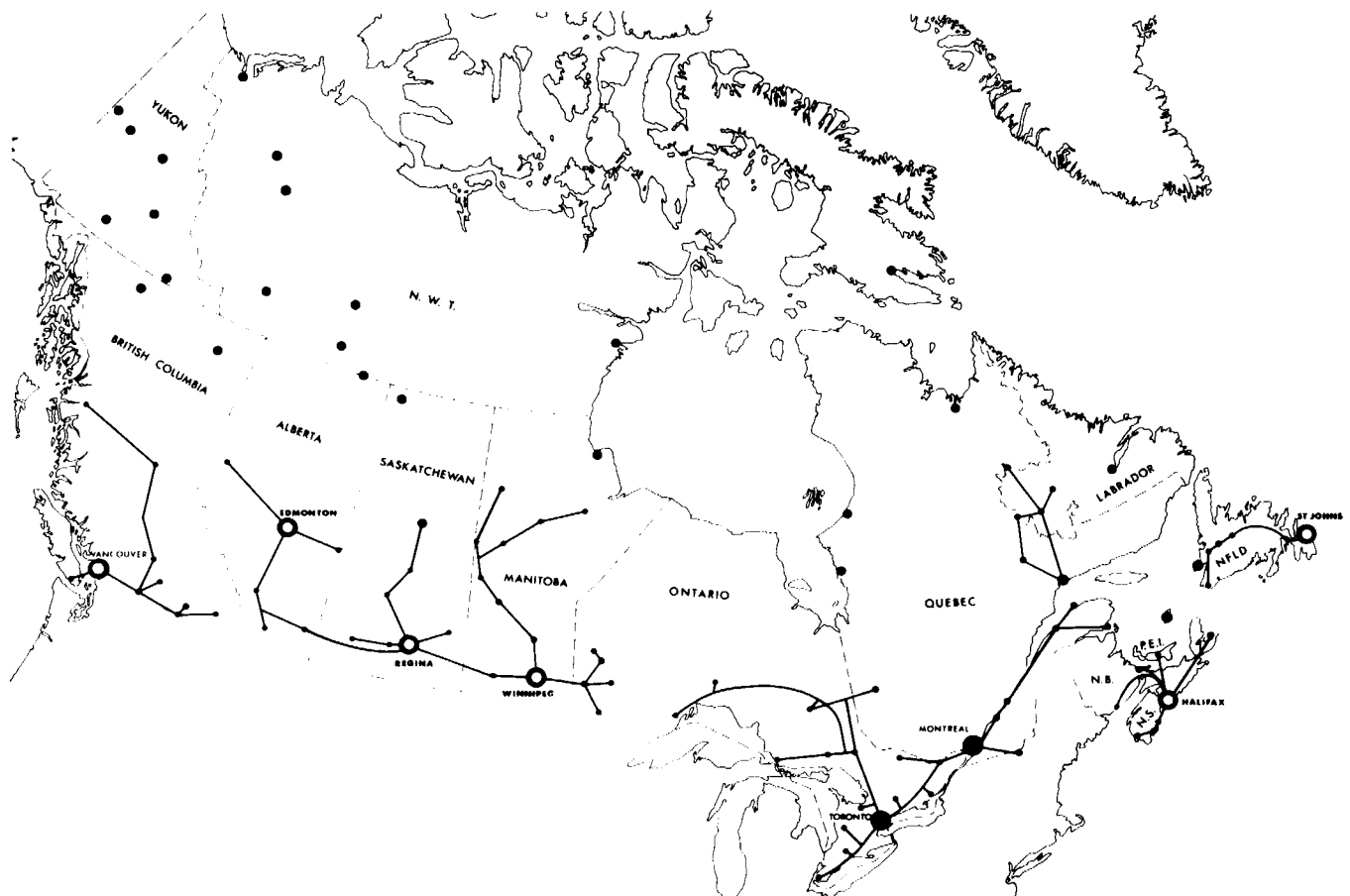


Fig. 1. CBC distribution plan including satellite links: ● Network TV station, main transmit-receive; ○ Network TV station, transmit receive; ● Earth station, receive only; — Television station connected by terrestrial link.

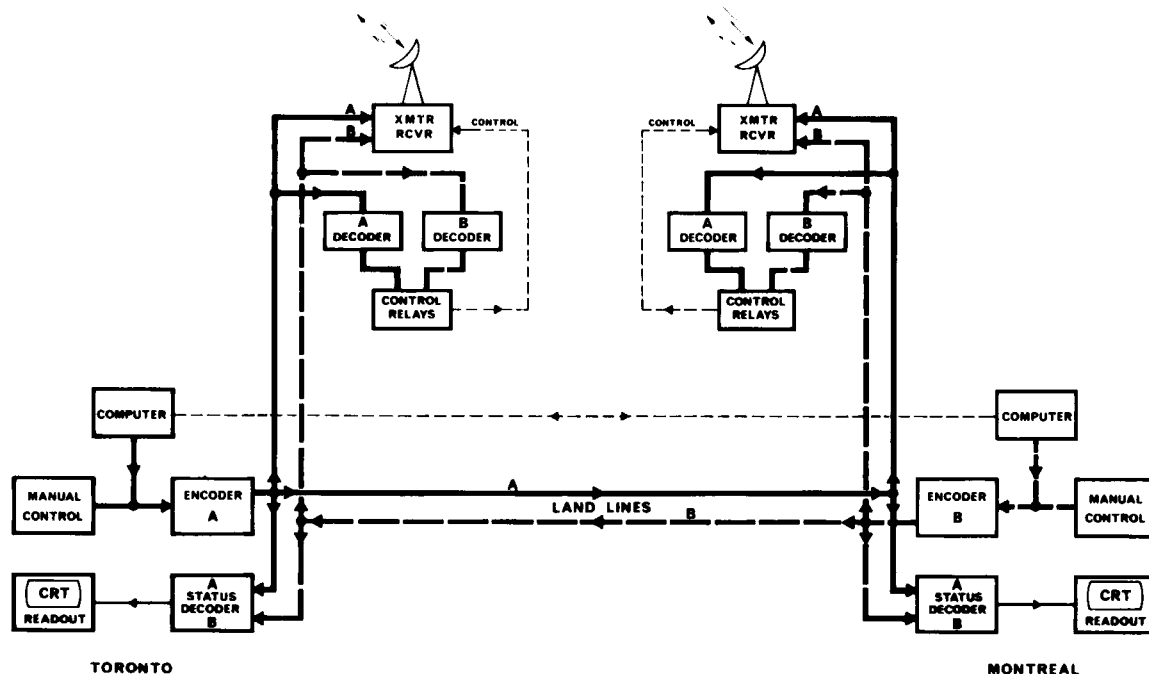


Fig. 2. Cue/control system for main network centers at Toronto and Montreal.

system to ensure reliable execution of commands.

(4) A capability for easy expansion to include many additional earth stations and a fourth television channel.

The CBC Network Control System went into operation in October 1973, and in May 1974 was expanded to include a fourth television channel, which is presently used on a part-time basis by the CBC.

1.2. System Description

The program distribution system using four satellite channels, selected terrestrial networks and individual receiving stations requires a control system which on command performs numerous remote switching functions to give a high degree of system versatility with regard to transmission source, destination, selection and direction. The system is complex and sophisticated and represents a major development in the methodology to control the direction of complex multi-path simultaneous program services.

The system will on command:

- (a) select the transmit and receive channels at all network-quality earth stations (NTV);
- (b) select receive channels at all remote quality earth stations (RTV);
- (c) mute audio and/or video at RTVs;
- (d) perform rapid transfer of up-link transmission between earth stations; and
- (e) provide internal teletype service.

Figure 1 shows the areas in Canada where earth stations are located. Provincial terrestrial networks are also shown. The transmit/receive earth stations are located in the southern part of the country with the two central

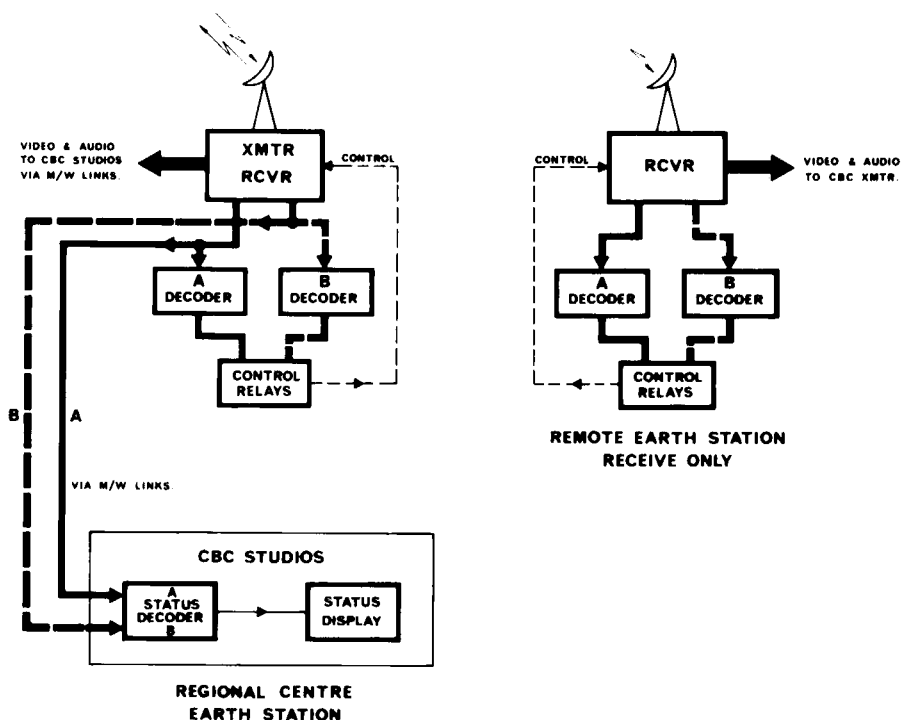


Fig. 3. Cue/control system for regional and remote stations.

transmit/receive stations located at Montreal and Toronto.

Because Montreal is the originating center for French programming and Toronto for English programming, these two locations were chosen as the centers for control of the network.

All centers have identical control panels to allow independent control of any or all of the stations comprising the entire network. These main centers are tied together by duplex land lines to allow data and commands from both centers to be transmitted over the satellite simul-

taneously from earth stations connected to these centers.

Each satellite channel, in addition to carrying the audio and video information, contains a 3.2-KHz cue/control channel used for carrying the earth station switching control information and teletype information. Commands originating from the two centers are carried in separate channels within the cue/control channel. A dual decoder system is provided at each earth station, with one decoder dedicated to each of the sub-channels within the cue/control channel.

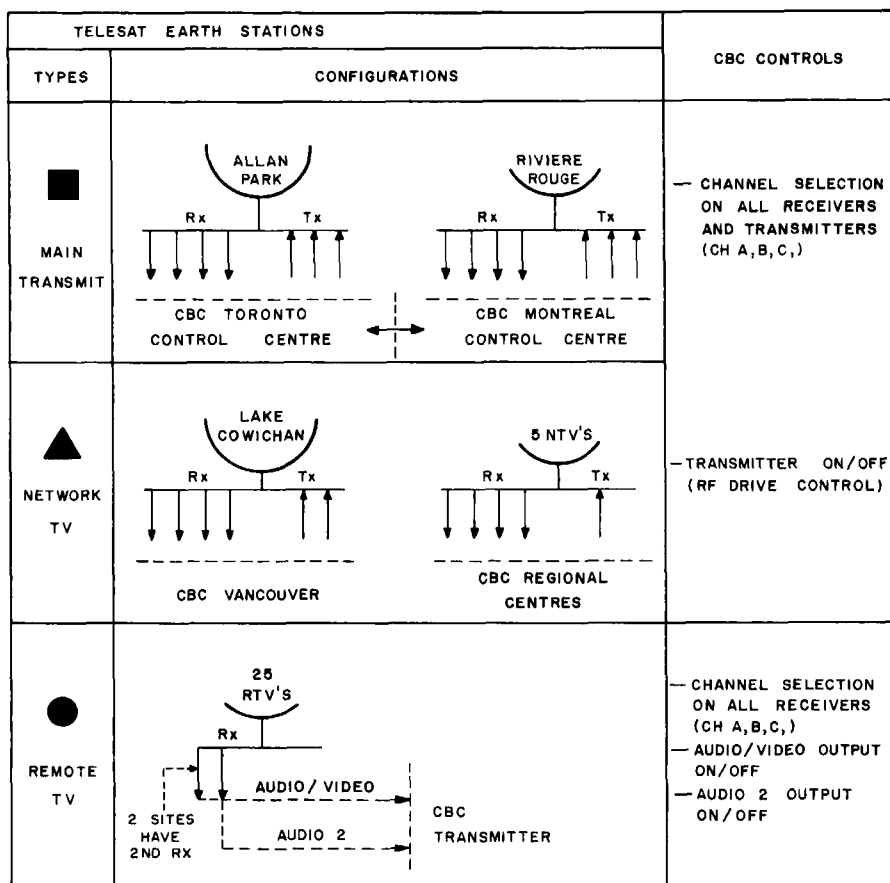


Fig. 4. Telesat earth station configurations and CBC controls.

Thus normally each earth station can receive commands from either of the main centers over independent sub-channels of the cue/control channel.

Figure 2 shows the control systems at Toronto and Montreal in simplified diagram form. Commands from the two control centers are carried by different center frequencies within the 3.2-KHz cue/control channel and thus are independent from each other. Status indication is provided at each network control center, via CRT readout, of channel assignment of each earth station. This includes existing conditions and next preset conditions.

Computer control is provided in both centers to alleviate the repetitive manual switching operations. Switching data for the entire day is entered into the computer via cassette. The computers at both control centers are connected via land lines to ensure proper status update and to avoid conflicting commands.

Figure 3 shows a typical regional center receive/transmit station and a northern remote receive station. The cue/control information from both centers is received and routed to two separate decoders. The decoders both operate the same set of interface relays which in turn perform the necessary switching action. The dual control centers/dual decoder system allows for complete independent control of the entire network of stations and provides redundancy in the case of

failure of either center. At CBC Regional Centres status information is also provided in the form of a status panel showing status at the associated earth station.

1.3. Operational Features

Program/Execute Concept: The control system operates within a "program/execute" concept. All commands are first entered (transmitted to the addressed earth stations and stored) then executed with one common "take" command. This feature allows many switching actions to be sent prior to the required "take" time.

Transmit Transfer: One of the most versatile features of the control system is the capability to control transmitter turn-on and turn-off for the purposes of news gathering from Regional Centres. A rapid transfer of the source of transmission is possible with a maximum break in signal of 50 milliseconds. This feature is used daily to gather the latest news from across the country for use on the CBC's National News Program.

Central Control Restrictions: Because the two originating control points are at Montreal and Toronto, loss of the ability to transmit cue/control information from both centers would mean the complete loss of control of the entire network. Because the control system has the ability to assign the transmit function on any of the four channels to any regional center,

a built-in inhibit feature was incorporated to ensure that one channel was always transmitting from either one of the two control centers. If the operator attempts to transfer the last operating transmitter away from Toronto or Montreal, the command is inhibited and an alarm indication is given. In the same manner, he is prevented from isolating any Network TV Earth Station from Central Control by improperly assigning receivers to satellite channels.

Manual Control: Under purely manual control, the operator is able to program and execute a given control function on the control panel easily within 10 seconds. He is also able to program any number of control functions, then execute at the desired time with a single pushbutton.

Computer Control Features: The normal operational mode allows the CBC to enter the day's automatic control commands independently at the two control centers. Any control commands which are in conflict (with the other center) or with network restrictions are automatically identified on the CRT's and can be corrected at the control panel keyboard. Additional commands can also be inserted at any time.

The computer memory is capable of storing up to 250 switching events. Upon execution of an event under computer control, the event executed disappears from the CRT display and the entire display moves up by one event with a new event coming in on the bottom line. The next event to be executed is automatically sent out and stored (preset) at that time. If a new event is inserted into the program by the operator at a time prior to the event previously preset, the latter is cancelled and the new event is preset. All executed events are retained in computer memory and a memory "DUMP" feature is provided to enable erasing of the memory store at the end of the day.

Manual/Automatic Control: The automatic system computer can also be used to enter control functions whose execution time is only approximately known. Thus, typically in a news gathering procedure, a transmit source transfer between two cities can be entered by the computer, which then automatically switches the system to manual control. The transfer is executed at the required time by the operator.

Expansion: The control panel and system software are designed for ease of expansion to additional control functions at each existing earth station as well as to additional earth stations. A fourth channel, for occasional use, became available in the spring of 1974 and the network control system was easily expanded to include it. For the earth stations, equipment has been designed to accept addi-

tional functions per receiver or transmitter as well as additional receivers or transmitters.

PART 2: DESIGN — By J. KINIK

2.1. System Design Features

Network Configuration: The configuration of transmitters and receivers at the three types of earth stations comprising the network is illustrated in Fig. 4 with the required CBC controls indicated. The system design employs a common control channel (cue/control channel) via which commands are transmitted from Toronto and Montreal. The cue/control channel is then multiplexed into the audio portion of the television baseband at each transmitting point in the Telesat system.

Figure 5 illustrates the multiplexing and command distribution scheme. Commands are transmitted through each of the satellite channels at all times.

In order to prevent Network Television Stations from being isolated from central control, an automatic restriction is built into control panel logic to ensure that at least one receiver is tuned to a channel being transmitted by either Toronto or Montreal. Central control over Remote Television Stations (most have only one receiver) is maintained by retransmitting the cue/control channel if a Network Television Station is transmitting.

Transmit Transfer: Because the timing of the transfer is critical the transmitting stations must respond only to commands which have not been retransmitted through the satellite. Thus an identification pilot tone is inserted into the cue/control channel at the main transmit stations. Network Television Stations select only one pilot-identified cue/control channel from their four receiver outputs, and filter out the pilot before retransmission of the cue/control channel, thereby ensuring that no commands are received after more than one hop through the satellite. This also prevents any command from being retransmitted more than once.

The timing of transmission source transfers is controlled by the introduction of bulk delays of 256 ms at Allan Park, the transmitting and receiving site for Toronto, and Rivière Rouge, the transmitting and receiving site for Montreal, to compensate for the nominal one-hop transmission delay (commands go directly to these stations via terrestrial backhaul since no receiver restrictions are permissible), and by a 20-ms delay for a transmitter turn-on command at any transmitting station to compensate for differences in distance between given transmitting stations and the satellite. The 20-ms delay is chosen to compensate for the worst case pair. Thus double-illumination of the satellite channel is prevented and the maximum signal break is less than 50 ms.

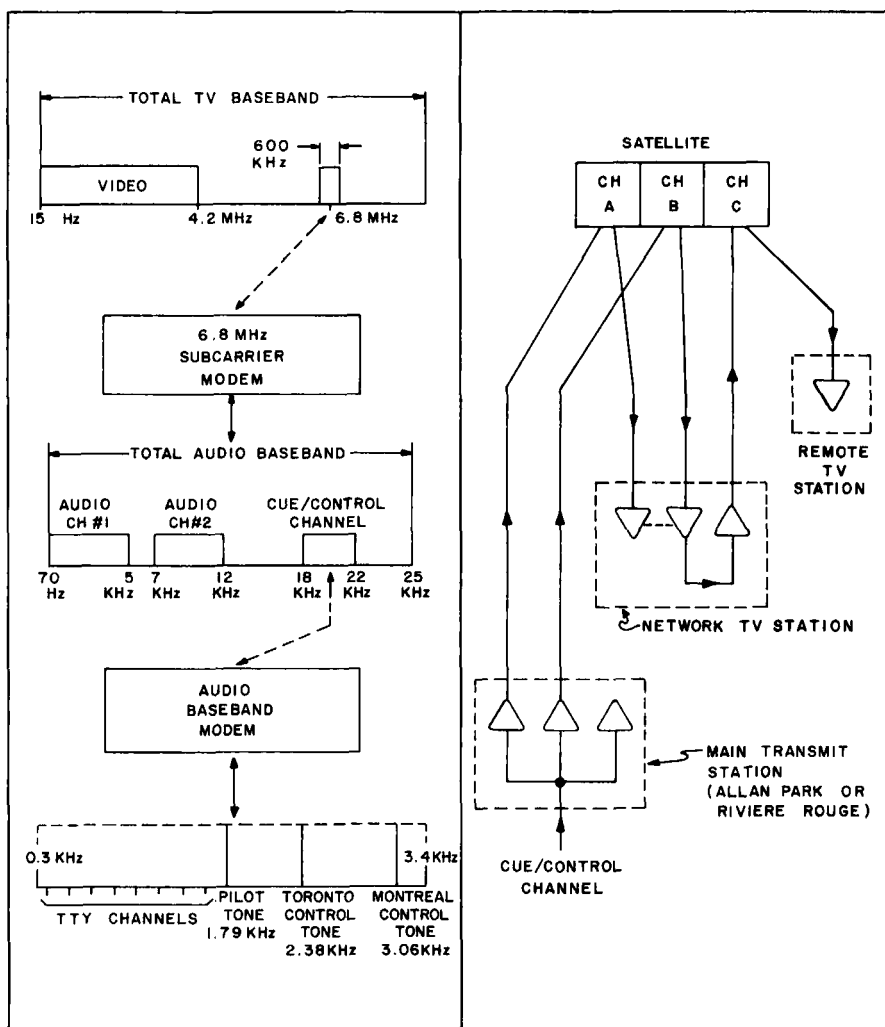


Fig. 5. Multiplexing and command distribution.

Program/Execute Concept: The timing of execution of other commands is not critical but the control system is designed within a "program/execute" concept. This feature allows an execution time which is well within the CBC minimum time interval of one second.

Command Word: The command word structure is a 16-bit word with 7 bits allocated to location address, 5 bits to equipment address, 3 bits to function address and 1 bit to final execution. Frequency shift keying (FSK) modulation is used to encode the control tones which act as command carriers. At each decoder in the network a coding security check is carried out prior to the location address decoding process by means of the Bose-Chaudhuri-Hocquenghem (BCH) principle, utilizing an additional 7 bits as BCH check bits.

Command Execution Security: The high-quality signal-to-noise characteristics of the satellite link (40 dB) plus the coding security provided by the command word structure makes a highly reliable control system possible on a one-way basis. Additional security is derived by transmitting each command word three times. A return-to-zero code is utilized, and at

remote decoders the clock is synchronized after every bit. Command execution security has thus been maximized by trading off against command transmission speed. (A 150-baud transmission speed is utilized for commands.)

2.2. Control Center Design

Control Centers: The design of the control centers is illustrated in Fig. 6. Manual system commands are entered and executed by the operator at the control panel with logic functions carried out by a Data Gen of Canada Nova 1210 Minicomputer. Automatic system commands are entered and executed by a Data Gen Nova 1220 Minicomputer, with switching events entered into the computer by means of magnetic tape cassette (normally at the beginning of a broadcasting day). A hybrid mode is also available to the operator whereby commands can be entered by the Automatic System Computer but executed at a time determined by immediate program requirements.

Command verification is carried out only on a "short-loop" basis between each control center and its respective transmitting station. This approach not only checks out the "weakest" portion of

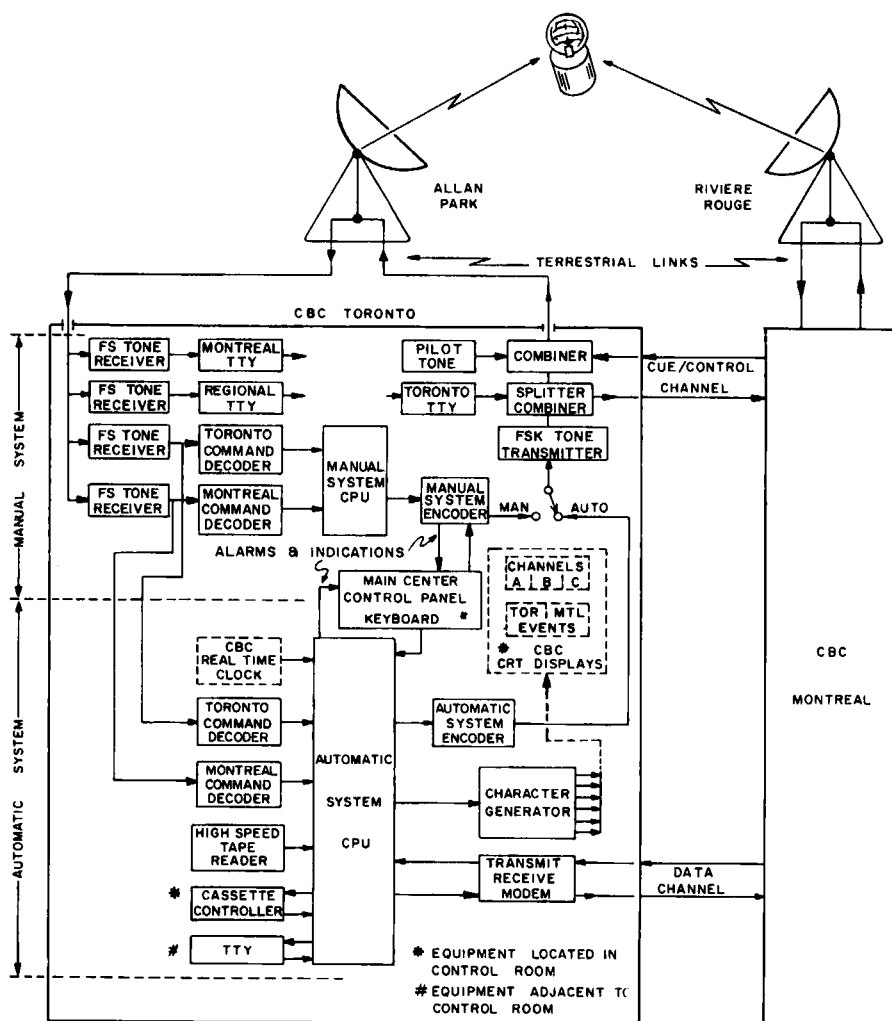


Fig. 6. Block diagram of the design of the main control centers.

the command channel network link, but also provides for the possibility of a full feedback system in the future.

When the command is received back from the station, it is displayed by the Automatic System Computer on the Network Status CRTs, where status is a result of all commands sent out by both centers. For purely automatic control, status CRTs also display the list of up-

coming switching events to be executed from each control center. Since both centers have equal access to the network, the dual-control nature of the design provides a form of redundancy for command execution and information storage. A memory "refresh" feature is provided in the event of failure of either of the automatic system CPUs. Once the computer is put back on-line, its memory can

be updated via the data channel (1200 baud) by means of a pushbutton control on the control panel keyboard.

A teletype terminal at each center acts as an on-line logger of all commands sent out to the network by both control centers, providing a hard-copy printout of all commands entered and executed.

2.3. Future Capabilities

The availability of additional control functions at each earth station allows the possibility of extending channel selection at any receiver beyond the four primary channels. Should any of the channels be converted to dual-channel service (such as in the case of digital TV where two channels could be interleaved into one normal channel) then the selection of one of the sub-channels could easily be effected by means of the presently unused future function.

In addition to the expansion capabilities described previously, the system could be upgraded to a partial feedback system, with status feedback from transmitting stations. Non-satellite links could be used, or the concept could be extended to one in which a dedicated status feedback channel is allocated on the satellite. The latter step would require small transmitters to send back status and additional receivers at earth stations associated with the control centers. A concept using a control channel separate from the audio/video information would involve an additional increase in cost due to the requirement for a dedicated command receiver at each earth station. This could be partly traded off against simplification of manual operation and computer software because the configuration restrictions associated with sending commands along with program information would be removed.

Satellite distribution systems will be utilized widely in the future for domestic communications purposes, particularly for television distribution applications. The concept used for the CBC Network Control System is an attractive approach, providing a cost-effective, reliable control system.