THE MICROWAVE SYSTEM OF THE MICHIGAN-WISCONSIN PIPELINE COMPANY

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Introduction

It is perhaps unnecessary to point out to the reader that in the design of a communication network, such as the Michigan-Wisconsin Pipeline microwave-VHF system, which includes 60 microwave stations, the incorporation of the desired operating features into the system is often a more complex and demanding engineering task than the design of the basic circuit elements. The provision of maximum flexibility and utility as desired by the customer, introduces engineering problems which are not easily solved by laboratory methods and which must, therefore, be anticipated and solved by analysis, and proven only in the final installation. The microwave-VHF communication system described in this paper required, before its completion, the solution of many complex system problems. The description of the system facilities will, therefore, occupy most of this paper and only a brief description of the apparatus used will be included.

The sixty microwave stations, including several spurs are distributed over nine states. They operate on carrier frequencies between 1800 and 2000 megacycles. Pulse time modulation is used. Interworking with these microwave stations are 22 VHF base stations operating on a frequency of approximately 49 Mc. A map of this system is shown in Figure 1.

RF and Multiplexing Equipment

The basic microwave RF equipment, consists of a transmitter, receiver, duplexing filter, antenna with transmission line, power supply and metering panel.

Two sets of RF equipment are used at terminal stations providing full standby service. Three sets of RF equipment are installed at repeater stations, one for each direction of transmission and one standby set. The standby equipment is automatically switched in when either a transmitter, receiver, or RF power supply fails, and an alarm is initiated to indicate the abnormal condition at a distant alarm receiver.

The microwave transmitter includes a tuned cavity oscillator modulated by direct keying. A lighthouse type tube provides a peak power output of 40 watts. Improvement in the signal-to-noise ratio is accomplished by a catalyzer consisting of a low power continuous wave oscillator coupled to the transmitter cavity to control the start of the transmitting oscillator when it is keyed.

The microwave receiver includes a cavity oscillator similar to the type used in the transmitter, and a crystal mixer. An incoming signal enters the mixer, is converted to a 30-megacycle intermediate frequency, amplified,

demodulated, and again amplified supplying a video frequency output.

In order to use one antenna for both transmitting and receiving in the same direction, a duplex RF filter is connected between the receiver, transmitter, and antenna. The antenna system includes a dipole type antenna with a parabolic reflector. Coaxial transmission line connects the duplexing filter to the antenna.

The radio transmitter is modulated by a group of pulses consisting of a "marker" or synchronizing pulse, and up to 23 individual channel pulses, as required. In the Michigan Wisconsin Pipeline System, eight channels are provided. The pulse train recurs at an eight kilocycle rate. Each channel pulse is time-modulated with respect to the marker by the voice frequency energy. Supervision and signaling is accomplished by shifting the pulse from its center position towards the marker. A typical transmitted pulse train is shown in Figure 2.

The pulse train is generated at a terminal station, and transmitted. At the repeater stations the signal is received, demodulated to a video frequency, and then retransmitted on a new carrier frequency.

When a telephone at a repeater station is off hook, however, the individual received channel pulse is blanked out of the pulse train and demodulated to audio. A new channel pulse is inserted into the transmitted pulse train and is modulated by both the repeater station telephone and the audio of the blanked pulse.

The equipment performing this function, drop and insert, or D&I equipment is inserted between the microwave receiver and transmitter. Since every station has at least two channels dropped, a D&I unit is provided at each station. Should the D&I fail, a monitor circuit switches the receiver output directly to the transmitter input thus maintaining thru service.

Channel Facilities

Eight two-way channels are provided. Three channels are dialing channels for general use, one channel is semi-selective for dispatching only, two channels are provided for maintenance purposes, and two channels are used for a VHF remote selector system. The facilities of a portion of the system, from Detroit, Michigan to C-9, New Windsor, Illinois are shown in Figure 3.

Each of the dial telephones located along the pipeline is equipped with a push button type keybox. The keybox has pickup keys to connect the telephone set as required to the party line channels, the VHF local for direct operation of a base station, the VHF remote for distant operation of a base station via the microwave, or an intercommunication circuit between buildings. Also included in the keybox are lamps to indicate busy channels and a lamp to indicate that the VHF transmitter at the station is on the air.

At the executive offices in Detroit, the telephones are connected to a 50-line step-by-step type private automatic exchange, or PAX. Each of the three party dialing channels is terminated in a PAX entrance panel.

A person on the party line calling a Detroit office first dials the PAX entrance number to get dial tone from the PAX. The office extension number is then dialed. Likewise, a person in the Detroit office may dial an entrance number to the desired microwave channel, then dial the station. A restricted service feature has been incorporated into the PAX to prevent unauthorized personnel from using the microwave channels.

One of three different entrance numbers allows access to each of the three microwave dialing channels. One channel is termed the pipeline channel. All pipeline offices and warehouses along the line have telephones on this channel. The second is the compressor channel and all compressor stations have telephones on this channel. The third is the executive channel, and only major operating points and division offices have extensions on this channel. To obtain the greatest amount of use of the compressor and pipeline channels, these are sectionalized and provided with dial operated section patches. For example, up to five conversations may take place simultaneously on the compressor channel, providing that each call is between stations within the same section. A person who makes a call from one section to another section first dials the section patch numbers and then the extension number desired. The sections are 200 to 400 miles in length. Normally, independent conversations can take place on the compressor channel from Austin to Detroit, from C-13 to C-10, and C-9 to a station down the line. If a person at C-9 wishes to call Detroit for example, he must first dial the patch number at C-10, then the patch number at Austin, the PAX entrance number to get dial tone and then the office extension number. Suppose a person in Detroit wishes to call Kewanee. First he must dial the entrance number to the pipeline channel, then the patch number at C-10, and then the call number at Kewanee. From these examples, it can be seen that although the channels are divided into independent sections, a call from any telephone in one section can be completed to a telephone in any other section on the same channel.

Since the pipeline and compressor channels are party line channels, any party may cut in on a busy line. He cannot, however, interfere with dialing in progress. He may dial on a busy line after a 30-second time interval. Facilities are provided for dialing through stations with a receiver off hook.

The executive channel is not sectionalized since there are relatively few telephones connected to this circuit. A lockout feature is provided on this channel to afford privacy on the line. When a call is initiated on this line, only the calling party and the called party are connected to the circuit. All other telephones are automatically locked out. When the line is idle, any telephone on the line may use the circuit.

With the type of party line dialing used on this system, each station has an all-relay selector unit to operate the telephone ringer upon receipt of the correct call number. This differs from the usual telephone practice of providing central office equipment common to a group of subscriber lines. Microwave channels closely resemble trunk circuits and the procedures used in switching on this system are similar to those used in toll switching.

Since the dispatch channel must be under complete control of the dispatcher, this channel is semi-selective; that is, the dispatcher at Detroit

may dial any compressor station on the system or dial all stations at once with a conference call number. The compressor stations are provided with a manual type telephone equipped with a push button for ringing the Detroit dispatcher only. This provides rapid calling of the dispatcher. No sectionalizing is used on this channel.

The two channels provided for maintenance purposes are the alarm channel and the service channel. The alarm channel is used for alarm signals only, and is sectionalized, with an alarm receiver located in each section. An alarm transmitter is provided at each microwave station along the main line to indicate fault conditions, such as standby equipment in service, tower light conditions, emergency power plant in operation (power failure), and illegal entry. The alarm transmitter sends a series of pulses identifying the fault and the station at which the fault has occurred. Notice in Figure 3 that the alarm transmitters from Detroit to C-11 send the alarms to the receiver at Austin. The first repeater west of C-11 to C-9, as well as the entire Wisconsin branch send the alarms to the receiver at C-10. At the distant alarm receiver, panel lamps indicate the condition to the operator on duty. The operator at the alarm receiver may interrogate the alarm section and each station in succession will then report the alarms standing or an all clear if no alarm condition is present. If the equipment is found to be in standby at one or more stations, the operator at the alarm receiver, by means of a key, may restore to normal all of the standby equipment within the alarm section for a second try of the normal equipment. The alarm channel is the maintainer's most useful tool for localizing trouble within the system. The service channel is a through party line channel which drops at every microwave station in the system. Operation of two signaling keys at a station will operate buzzers at all other stations in the system. This provides intercommunication between all microwave sites.

VHF Facilities

The VHF channel provides means for communication between the microwave system and any mobile radio in the vicinity of a VHF base station connected to the microwave system.

The VHF remote channel, like the pipeline and compressor channels, is sectionalized in order to obtain the greatest use. A special thru channel known as the VHF express channel may be connected to any of the VHF remote sections by means of a dial operated patch. This permits persons in Detroit, who have special push-to-talk telephones, to operate a base station in any section for emergency orders. Figure 4 is a block diagram of a portion of the VHF selector system.

The dial selectors attached to the VHF remote channel are arranged so that all calls coming in over any base station within the section will be heard throughout the section over monitor speakers on the channel, since the base station receivers are normally connected to the microwave system. When the operator on duty at a station answers a call from a vehicle, he may connect the base station on local. This disconnects the base station receiver from the microwave channel and permits the use of the base station directly with no dialing necessary. If a local operator does not answer, a distant operator may answer by dialing the number assigned to the desired base station, thus connecting the base station transmitter to the microwave

system, then operating the push-to-talk button. The push-to-talk button applies a burst of 1800 cycle tone to key the VHF transmitter on the air and inserts a normal pulse on the channel to serve as a carrier for the speech and a means for holding the transmitter on the air. The presence of the pulse also disconnects all other base station receivers from the channel to prevent other calls from coming in on the microwave channel while the push-to-talk button is depressed and to prevent any possibilities of lock-up. In order to prevent the system from lock-up due to a possibility of equipment failure, a timer is employed which disconnects the base station transmitter from the air at the end of 55 seconds after the push-to-talk button has been pressed. To keep the transmitter on for a longer period, the push-to-talk button must be released and again depressed.

An operator may initiate a call over any base station within the remote section by dialing the number assigned to the base. To operate a base station from the Detroit office, the party must first dial the patch from the VHF express channel to the desired VHF remote section and then the base station number. This VHF scheme provides communication between a telephone at Detroit and a vehicle within the range of any base station on the system.

The system has been designed to handle as much traffic as possible, yet regulate the traffic within specific divisions, to provide communication from a telephone to a mobile unit on the system as well as to other telephones within the system, to provide circuits for convenient maintenance and rapid localizing of trouble along the line as well as providing automatic standby equipment and emergency power generators to enable the system to remain in operation when a failure occurs. As much flexibility as possible has been incorporated to make the system a most useful equipment for the customer's pipeline operations.

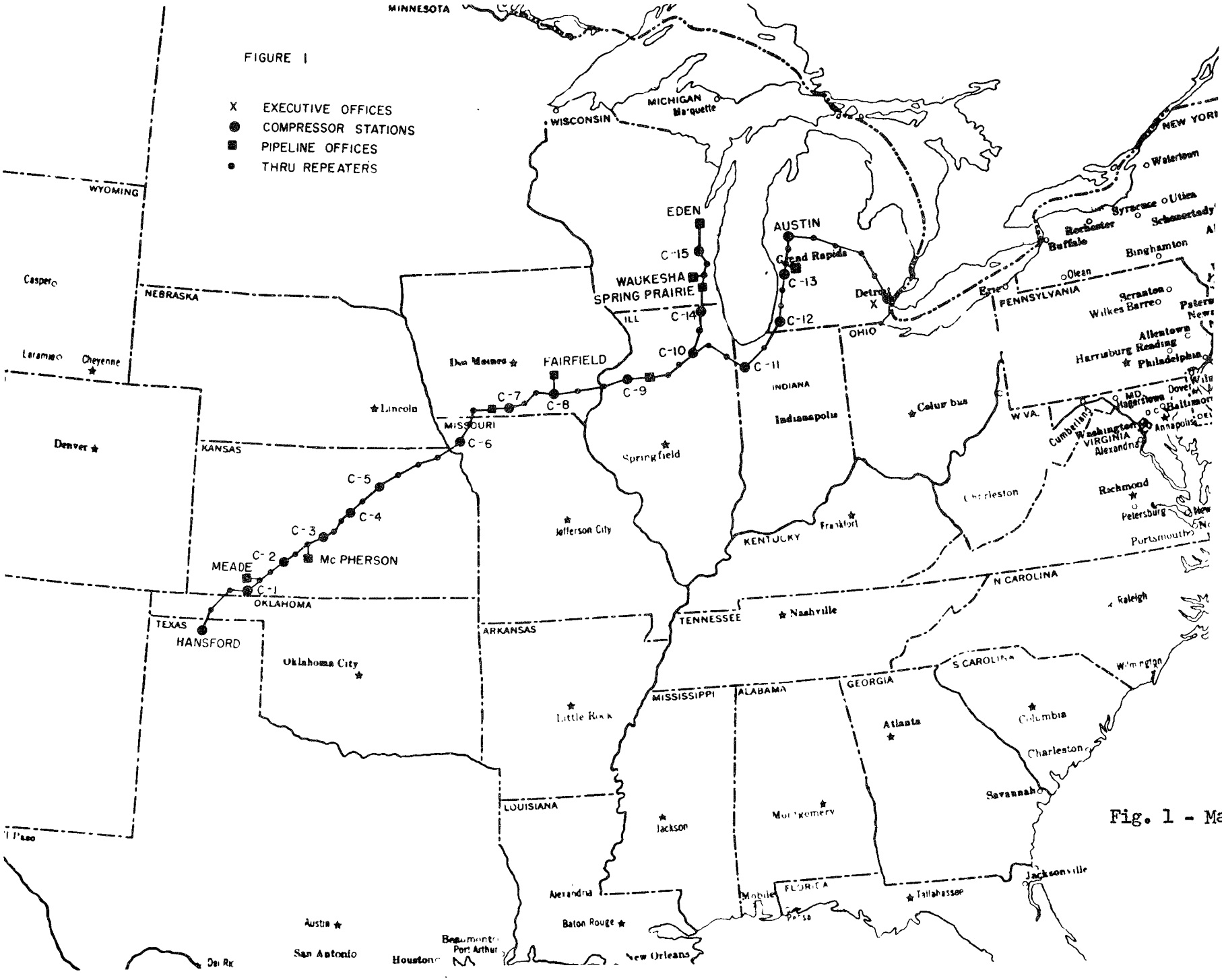
FIGURE 1
X EXECUTIVE OFFICES
COMPRESSOR STATIONS
PIPELINE OFFICES
THRU REPEATERS
MINNESOTA
WISCONSIN
MICHIGAN
Ma'quette
WYOMING
Casper
NEBRASKA
Laramie
Cheyenne
Denver
KANSAS
Lincoln
Des Moines
MISSOURI
Springfield
Jefferson City
Oklahoma City
OKLAHOMA
TEXAS
Little Rock
ARKANSAS
Jackson
MISSISSIPPI
LOUISIANA
Alexandria
Baton Rouge
New Orleans
Houston
Austin
San Antonio
El Paso
Montgomery
ALABAMA
Mobile
FLORIDA
Tallahassee
Atlanta
GEORGIA
Columbia
S CAROLINA
Charleston
Savannah
Jacksonville
Wilmington
Raleigh
N CAROLINA
Nashville
TENNESSEE
Frankfort
KENTUCKY
Charleston
W VA.
Columbus
Indianapolis
INDIANA
Chicago
ILL
Detroit
OHIO
Erie
PENNSYLVANIA
Buffalo
Rochester
Syracuse
Utica
Binghamton
Scranton
Wilkes Barre
Harrisburg
Reading
Allentown
Philadelphia
Baltimore
Annapolis
Washington
Alexandria
VIRGINIA
Richmond
Petersburg
Portsmouth
Cumberland
Hagerstown
MD
Dover
EDEN
AUSTIN
WAUKESHA
SPRING PRAIRIE
FAIRFIELD
MEADE
Mc PHERSON
HANSFORD
C-1
C-2
C-3
C-4
C-5
C-6
C-7
C-8
C-9
C-10
C-11
C-12
C-13
C-14
C-15
Grand Rapids

Fig. 1 - Map.

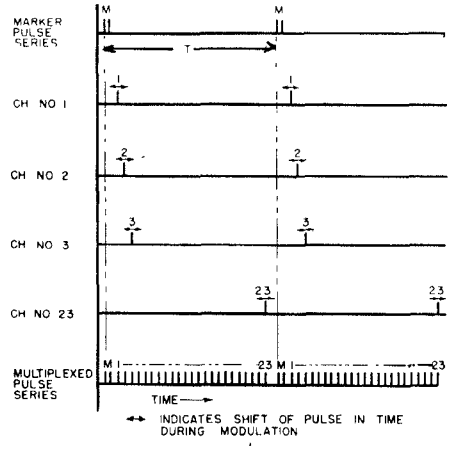

Fig. 2 - Multiplex pulse train.

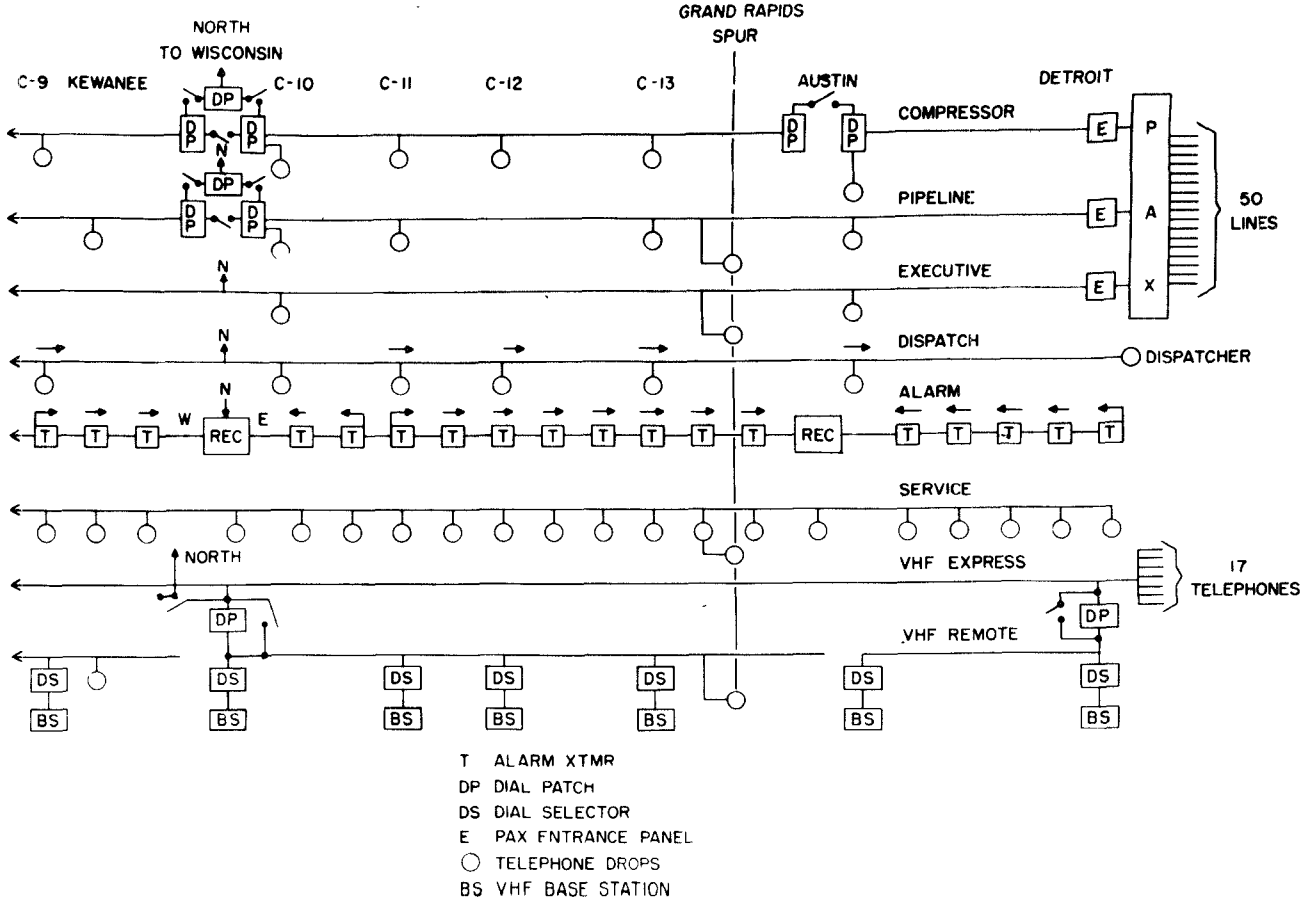

Fig. 3 - Facilities of a portion of the system, from Detroit, Michigan to C-9, New Windsor, Illinois.

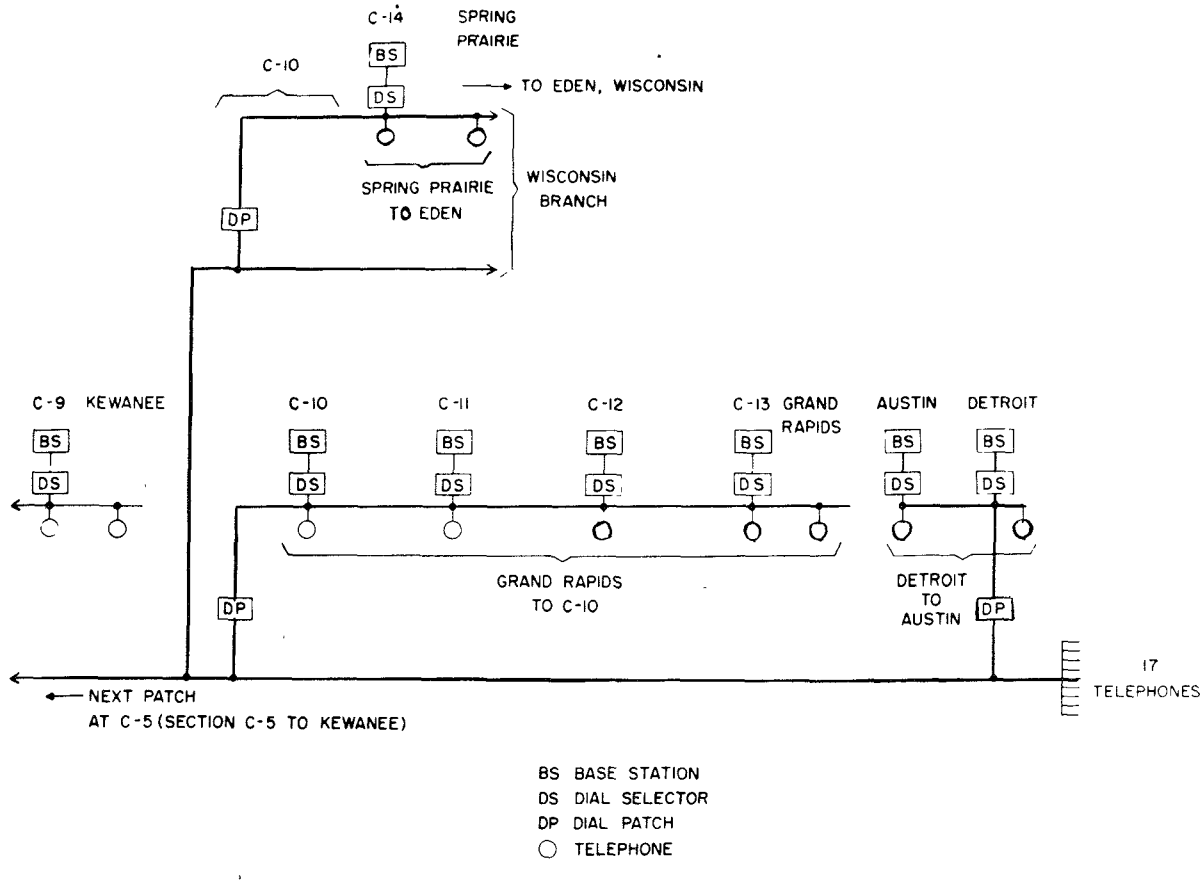

Fig. 4 - Block diagram of a portion of the vhf selector system.