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The SECOM II Communications System

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Introduction

The SECOM II (SEcurity COMmunications) system is a High Frequency (HF) system which provides two-way digital communications between a central controller and vehicles carrying nuclear weapons and special nuclear material anywhere in the contiguous 48 states. The system operates on four HF frequencies in the 3-12 Mhz range. While the primary mode of operation is digital, a voice capability is also provided for unusual situations where additional information must be communicated. Initial system operation began in April, 1976 and the system became fully operational in March, 1977.

The system consists of mobile terminals installed in vehicles which communicate with five relay stations. The relay stations are connected with the control center by leased telephone lines as shown in Figure 1. This document will describe the operation of the system and the equipment installed in the vehicles, relay stations, and the control center.

System Operation

When a digital message is sent from a vehicle, it is automatically transmitted twice over each of the four HF frequencies in sequence. Depending on propagation conditions existing at the time, the message should be received at one or more relay stations on one or more frequencies. No propagation prediction is required for digital messages since the frequency band is covered in each transmission sequence and all five relay stations are listening on all frequencies continuously. Error-free messages received by the relay stations are forwarded to the SECOM Control Center (SCC) along with information on the HF channel and antenna which received the message best. The SCC computer then compares the inputs from all relay stations and determines the best station, channel, and antenna for that particular message. The information is presented to the SCC controller, and a computer-generated digital "acknowledge" message is automatically sent to the vehicle over the best station, channel, and antenna. When the acknowledge message is received by the vehicle, the sequence is complete and the vehicle equipment resets. If the vehicle does not receive an acknowledge in 30 to 40 seconds, the equipment will automatically repeat the vehicle message transmission sequence. A maximum of five attempts will be made before signaling the vehicle operator that two-way communication was not accomplished.

In addition to monitoring the incoming messages from vehicles, the SCC controller can initiate digital messages to any vehicle in the fleet when necessary. He can also configure the system for voice operation and talk to vehicle personnel anywhere in the country. The basic features of the SECOM II system are shown in Figure 2. Details of the operations are covered in the following discussions of the equipment involved.

Vehicle Equipment

The equipment installed in the vehicles consists of a vehicle control box (VCB), a vehicle interface box (VIB), and a transceiver and antenna coupler (Figure 3). The transceiver is an all solid-state design which has four fixed-tuned receiver channels and a selectable, four-frequency, 100 watt transmitter. The transceiver and coupler both utilize relay switching for fast, reliable channel selection. On vehicles utilizing the center-loaded whip antenna, the coupler is replaced by a small switching box. The VIB contains all of the electronics and controls that do not require access during a trip.

The VCB is the control unit for the vehicle system and provides the man/machine interface. A front view of the VCB is shown in Figure 4. In addition to the normal control functions (ON/OFF, DIGITAL/VOICE SELECT, etc.), the unit has a calculator-type keyboard for entering digits into the system. To initiate a message, the operator must enter nine digits via the keyboard. As each key is depressed, the digit is displayed in the numeric display above the keyboard. An operator will first enter four digits to represent vehicle location and they will appear in displays 1-4. The next three digits (5-7) are authenticators. The last two digits (8-9) are a 10-code type message using a specially defined vocabulary. When the nine digits have been entered and visually verified by the operator, depressing the transmit switch (XMIT) begins the automatic sequence. The system will format a 100-bit (25 digit) message incorporating the nine operator-inserted digits, the vehicle identification digits, a message type digit, three auxiliary digits (for future growth), a preamble, and an error-detecting cyclic redundancy code (CRC). The format of the message is shown in Figure 5. The message is transmitted in bi-phase FSK coding at 300 bits per second utilizing 1300 and 2100 Hz tones. The 100-bit message is transmitted twice on each of the four channels in the sequence shown in Figure 6. In approximately 14 seconds, the "acknowledge" message will be received by the vehicle and a "00" message (defined to mean acknowledge) will be displayed in positions 10 and 11 of the VCB. In addition, the REC (received) light will illuminate, an alerting tone will sound, and the vehicle sequence will stop. However, if the "acknowledge" is not received within 30 to 40 seconds, the system will automatically initiate another transmission sequence. Should propagation conditions be so bad that five attempts have been made without receiving an "acknowledge", the sequence will stop, the N/REC (not received) light will illuminate, and the alerting tone will sound to inform the operator.

The system also contains an "alert" timer to inform the operator when it is time for his scheduled report. The interval can be set by means of the TME thumbwheel switch. Once an interval has been selected, the system will sound an alert tone and illuminate the ALERT light five minutes before the desired interval from his last transmission has elapsed. The operator then has ample time to complete his transmission before his scheduled time elapses.

Should an emergency occur, the operator can initiate a preformatted emergency message by simply lifting the spring-loaded cover in the upper left corner of the VCB and depressing the E (emergency) switch. Additional emergency switches can be located at other positions within the vehicle to allow other crew members to initiate an emergency transmission.

SECOM II equipment has been installed in a variety of DOE vehicles. Two typical examples, a carryall and a semi-tractor, are shown in Figures 7 through 10. After many thousands of miles over the road, the equipment has been proven to be very rugged and reliable.

Relay Stations

The original SECOM relay stations have been modified to the SECOM II configuration. Each station consists of an equipment building or trailer and four or five antennas oriented for optimum coverage. A typical station is shown pictorially in Figure 11. The equipment installed in the station is shown in Figure 12. The functions performed at each of the unmanned stations are shown in Figure 13 and a block diagram of the information flow is shown in Figure 14. Attached to each antenna is a fixed-tuned receiver for each of the four frequencies used in the system. Digital messages received by these receivers and decoded by the tone receivers are fed to a National Semiconductor IMP-16 microcomputer. Since a single vehicle message can be received on more than one antenna and over more than one channel, the IMP is programmed to accept these multiple messages and perform a bit-by-bit majority logic check to arrive at a single message. A cyclic redundancy code check is then made to assure that no messages containing transmission errors are allowed to enter the system. The IMP then attaches received message count data to the vehicle message, generates a new error detecting code, and transmits the combined message over a leased telephone line to the SCC at DOE/ALO.

When the SCC wishes to send a digital message to a vehicle, it is transmitted over the same leased telephone line to the IMP. The IMP passes the control portion of the message to the Relay Station Interface (RSI) which selects the proper 1000 watt transmitter, tunes it to the correct channel, selects the desired antenna, and keys the transmitter. The IMP then supplies the digital message to modulate the transmitter.

A secondary leased telephone line is brought to each station for backup digital or voice operation. If the primary line goes down, the secondary line will be switched in automatically to provide continued digital operation. When voice operation is desired, a controller-initiated control message is sent by the SCC over the primary line to the IMP. As soon as the station is properly configured, the secondary line is enabled to allow the SCC controller to send and receive voice from that station.

A test set is provided at each relay station to provide the SCC controller with a capability of verifying proper station operation. The test set is essentially a vehicle package with its output attenuated 20 db and its ID set to a number assigned permanently to that station. When the test set is interrogated by having the station transmit a request to that ID, the set responds with a standard vehicle transmission sequence. Since the test set is located at the antenna site, the messages are received by the antennas without any propagation uncertainty. Thus, every message sent should be received by every antenna on every frequency. At a four antenna station that is functioning properly, 32 messages should be received during a test (2 messages/channel, 4 channels/antenna, 4 antennas).

Central Control Station

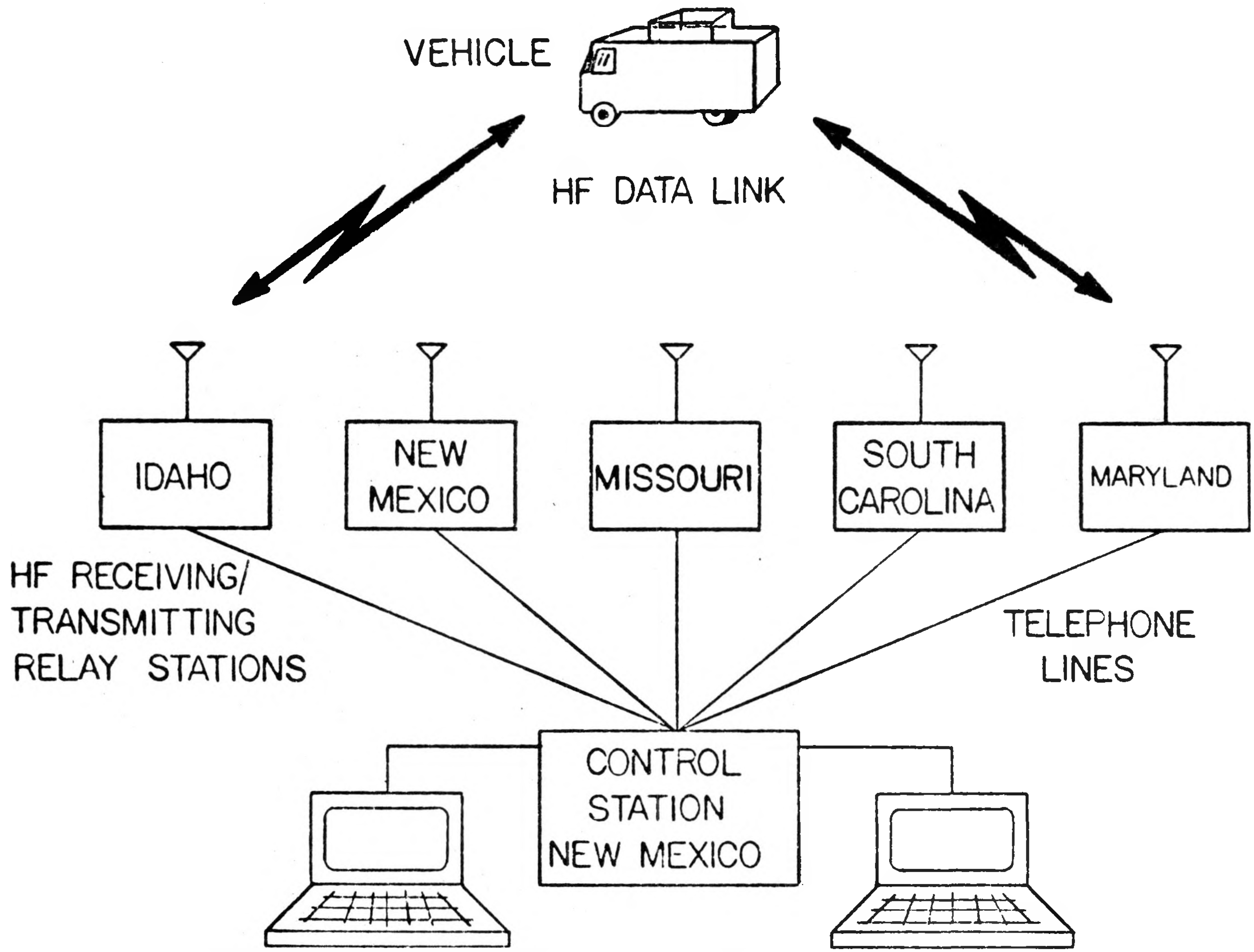
The SCC is the nerve center of the SECOM II system. From here, two controllers receive all incoming messages and control the entire system. A view of one controller station is shown in Figure 15. To assist the controllers, a dual ECLIPSE® computer processes all digital data, performing the functions listed in Figure 16. In addition to merging the messages from up to five relay stations, performing majority logic and CRC code checks, the ECLIPSE analyzes incoming message count data and determines the best station, antenna, and channel for response messages. An "acknowledge" message is then generated automatically and sent to the appropriate station for transmission to the vehicle. (The format for an SCC-initiated message is shown in Figure 17.) The incoming message is

® Registered trademark of Data General Corporation then displayed on the cathode-ray-tube (CRT) and printed on the line printer. At this point, the controller takes over, interpreting the message and determing what action is required, if any. The controller has the capability of initiating a message to any vehicle in the fleet, interrogating any vehicle, conducting relay station self-tests, configuring a relay station for voice operation, and monitoring relay station equipment status. A typical controller CRT display is shown in the upper portion of Figure 18. The information displayed consists of the time of the last message received from each vehicle, the last message contents, and the last message sent to that vehicle. In the event that a vehicle sends an emergency message, a special display is brought up on the lower portion of the screen as shown in the lower view of Figure 18. The emergency display shows the last message received for all vehicles in the convoy from which the emergency was received.

A block diagram of the equipment included in the SCC is shown in Figure 19. To achieve the reliability required, all critical elements in the system are redundant. In addition, if the SCC becomes uninhabitable (due to a fire, etc.), a capability has been provided to operate the system from an alternate control center (ACC) at the New Mexico (Albuquerque) relay station. The configuration of the leased telephone line network for normal and for ACC operation is shown in Figure 20.

Summary

The implementation of the SECOM II system has been completed and all communications between the central control station and vehicles carrying nuclear weapons and special nuclear materials are being handled by the system. DOE has established maintenance depots and personnel have been trained to perform preventive maintenance and equipment repair. A computerized reporting system provides feedback from maintenance groups to the system operators and the equipment designers.



SECOM II SYSTEM

FIGURE 1

SECOM II FEATURES

HF NETWORK OF FIVE UNMANNED RELAY STATIONS

RELAY STATIONS LINKED TO CONTROL STATION VIA LEASED TELEPHONE LINES

TWO-WAY DIGITAL MESSAGES WITH EMERGENCY VOICE OPTION

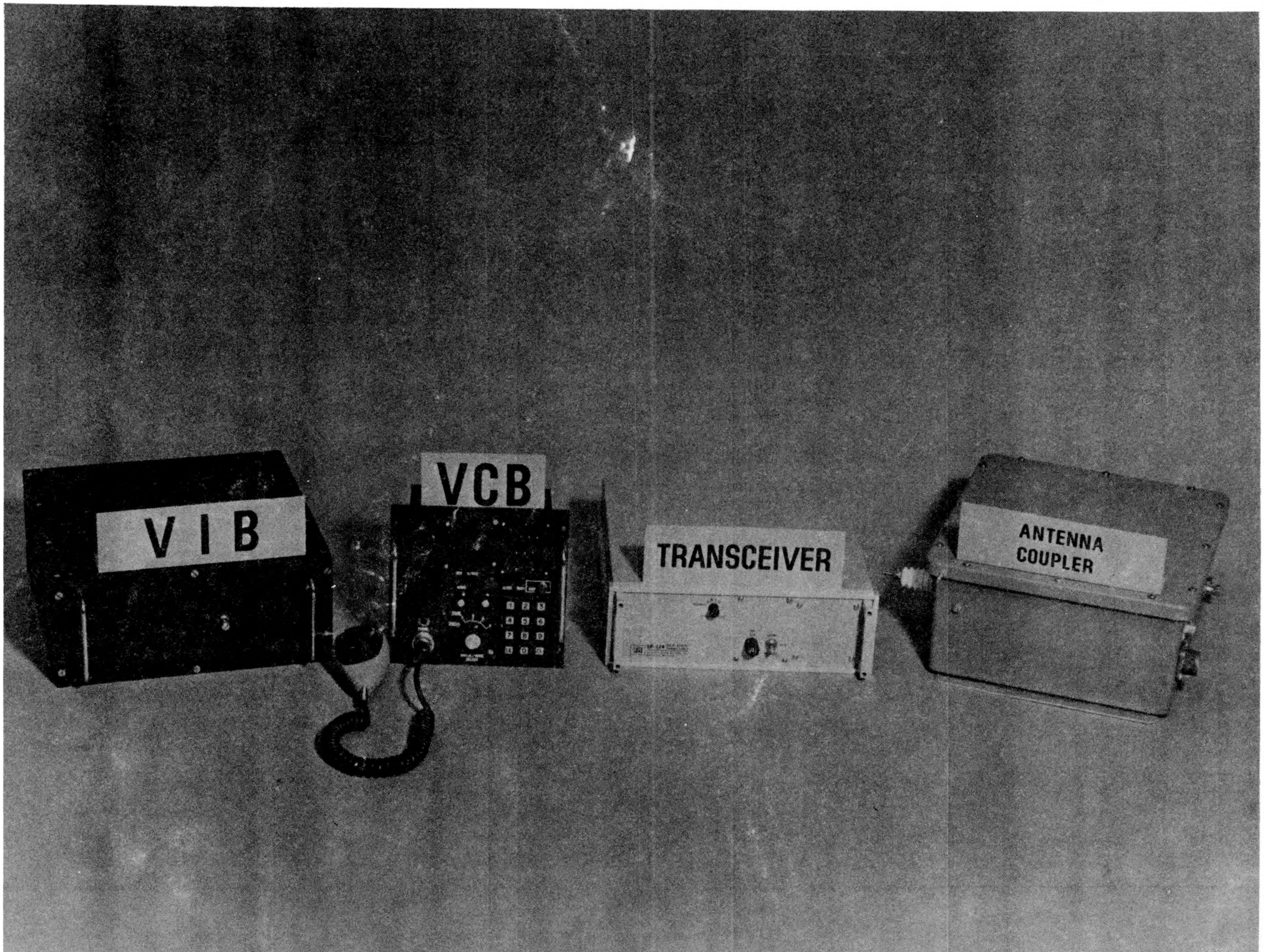
VEHICLE MESSAGES AUTOMATICALLY SENT OVER FOUR HF FREQUENCIES

CONTROL CENTER RESPONSE MESSAGES SENT OVER "BEST" RELAY STATION, ANTENNA, AND CHANNEL ONLY

EACH VEHICLE MESSAGE "ACKNOWLEDGED" BY CONTROL CENTER

AUTOMATIC RETRANSMISSION OF VEHICLE MESSAGE IF NOT "ACKNOWLEDGED" (UP TO 5 ATTEMPTS)

FIGURE 2



VIB
VCB
TRANSCEIVER
ANTENNA
COUPLER

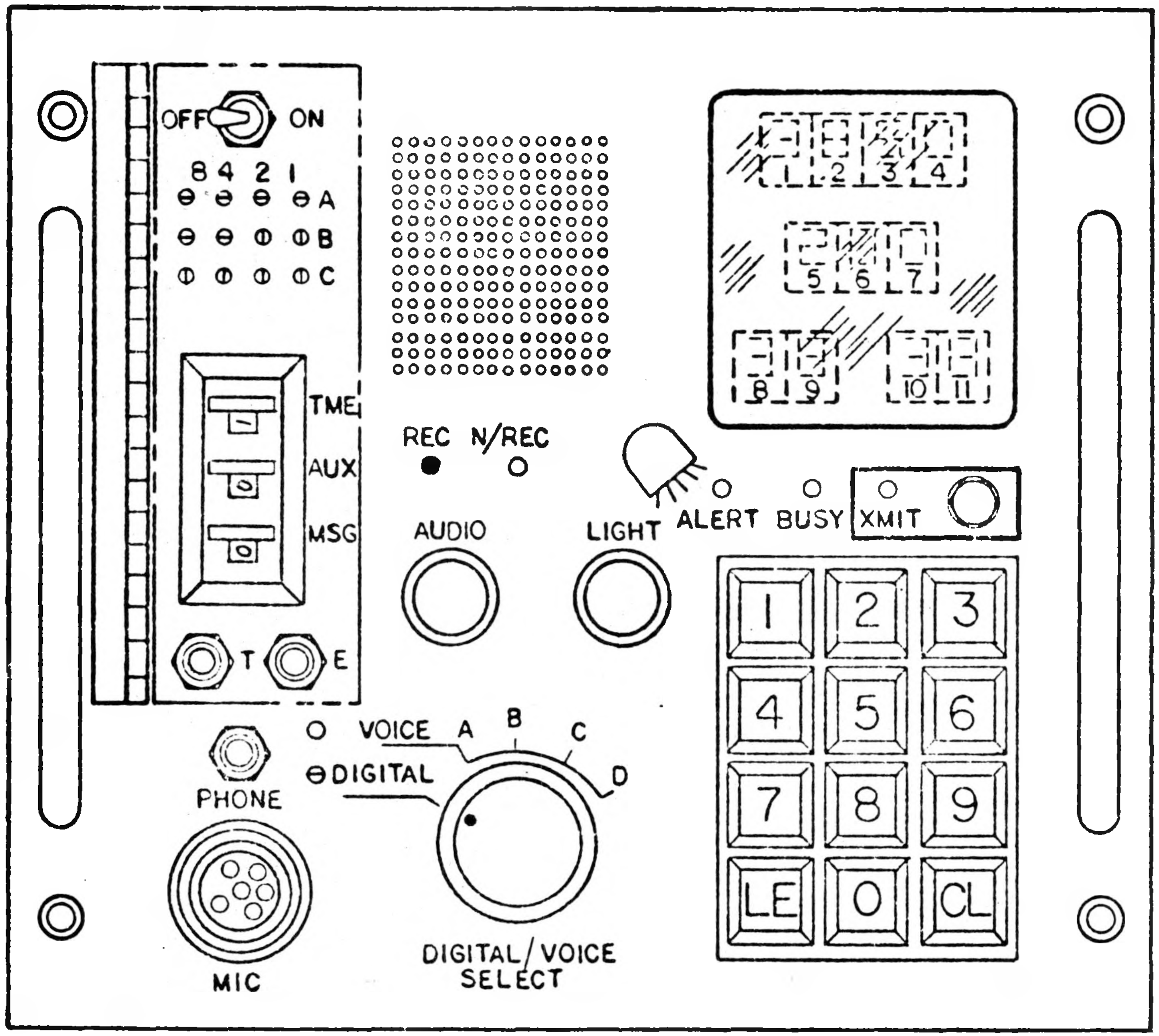

OFF
ON
8 4 2 1
A
B
C
TME
AUX
MSG
T
E
REC N/REC
AUDIO
LIGHT
ALERT
BUSY
XMIT
1
2
3
4
5
6
7
8
9
10
11
1 2 3
4 5 6
7 8 9
LE 0 CL
VOICE
DIGITAL
A
B
C
D
PHONE
MIC
DIGITAL/VOICE SELECT

FIGURE 4

VEHICLE TRANSMITTED MESSAGE - 100 BITS

PREAMBLE (20)	DATA (64)	CRC (16)

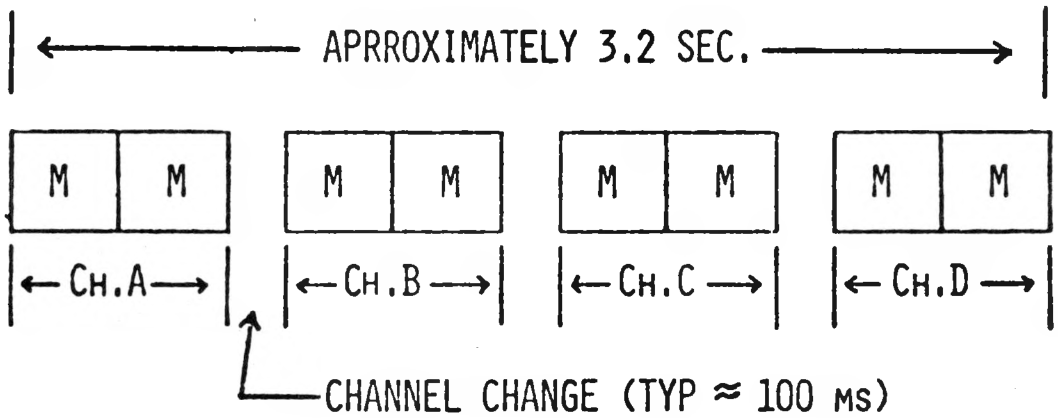
BI-PHASE DIGITAL CODING

DATA RATE = 300 BPS

FSK FREQUENCY = 1300 & 2100 Hz

FIGURE 5

VEHICLE MESSAGE SEQUENCE:



IF ACKNOWLEDGE NOT RECEIVED,
REPEATED IN 30-40 SECONDS (5 ATTEMPTS MAXIMUM)

FIGURE 6

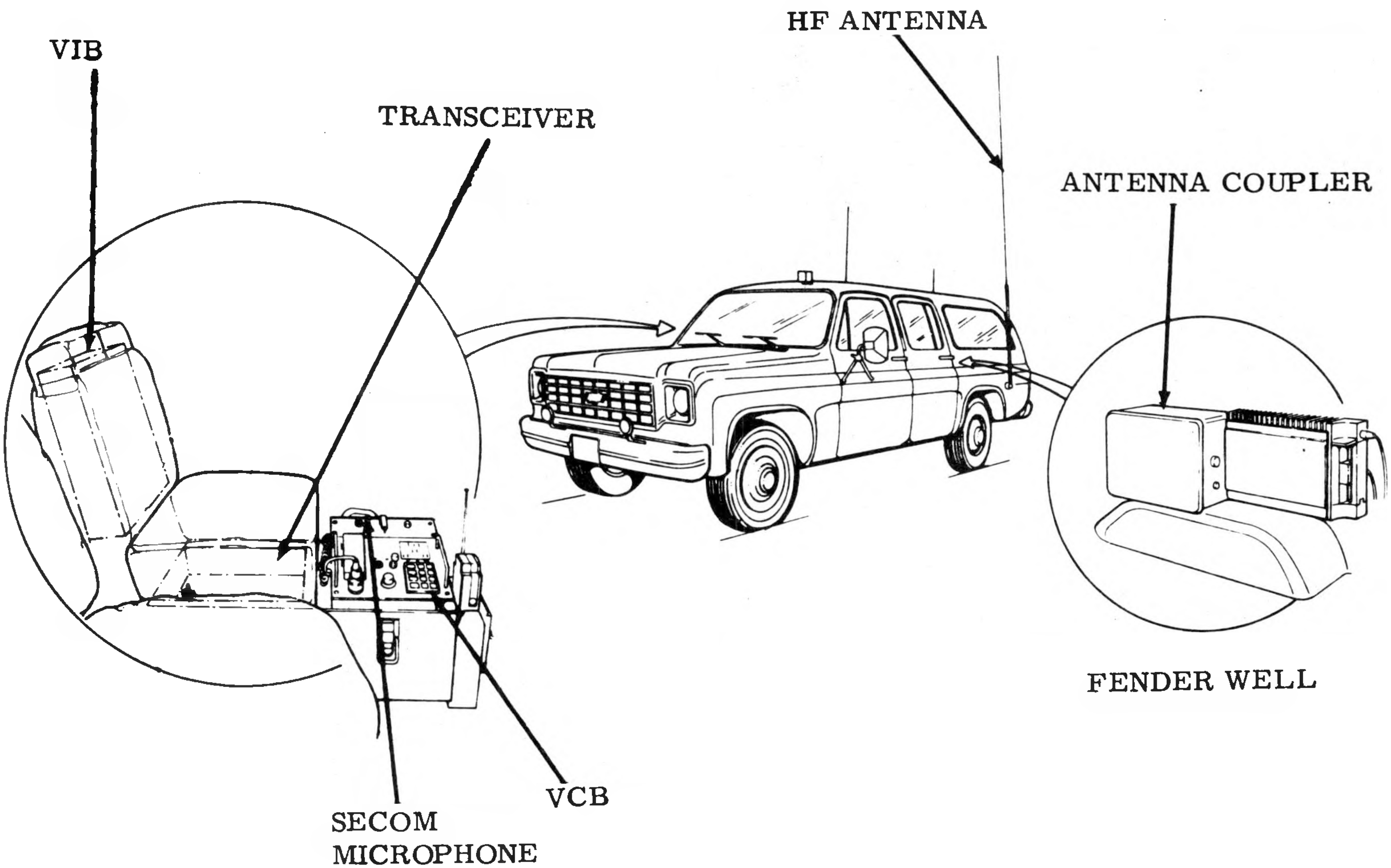
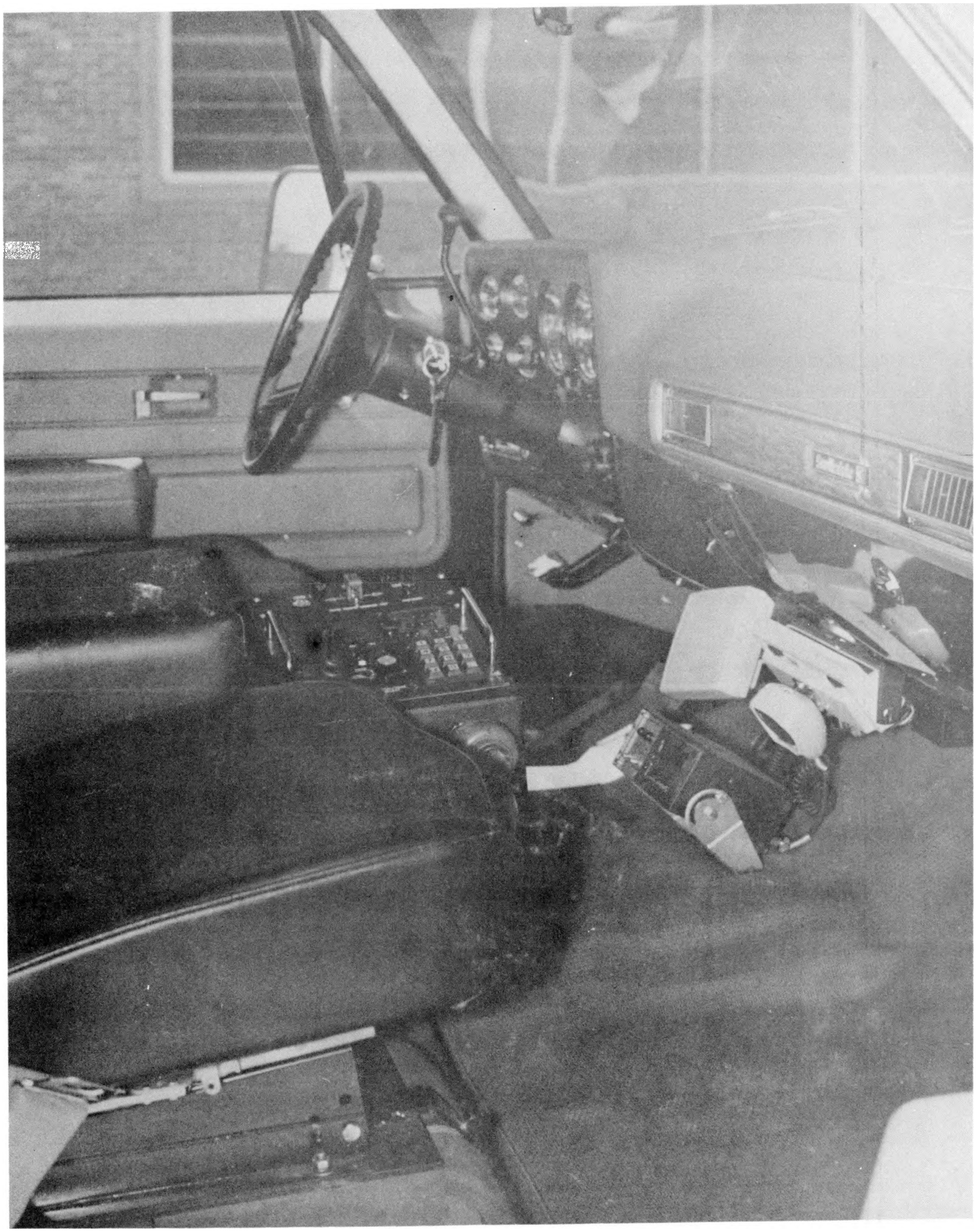

VIB
TRANSCEIVER
HF ANTENNA
ANTENNA COUPLER
FENDER WELL
VCB
SECOM
MICROPHONE

FIGURE 7



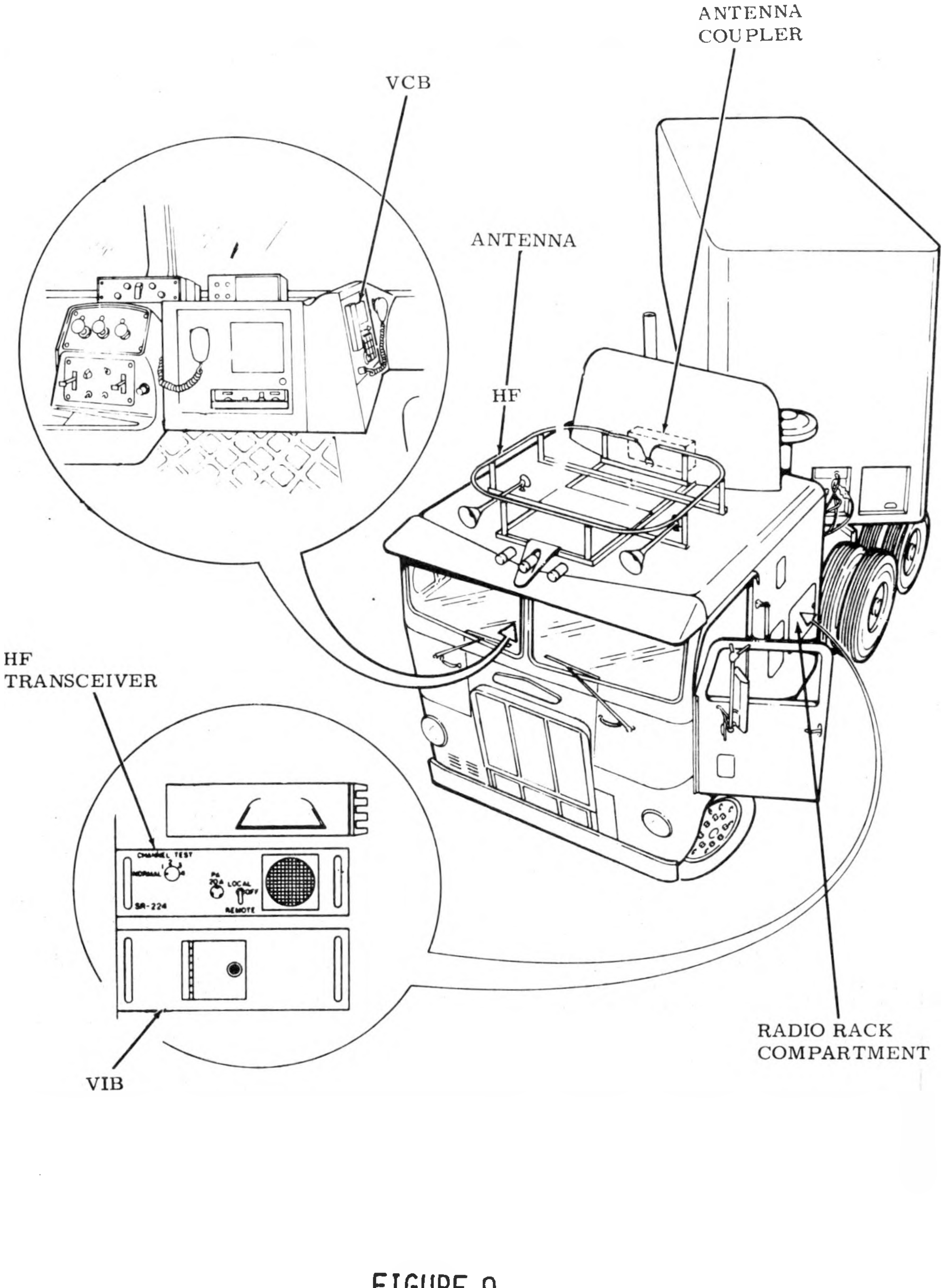
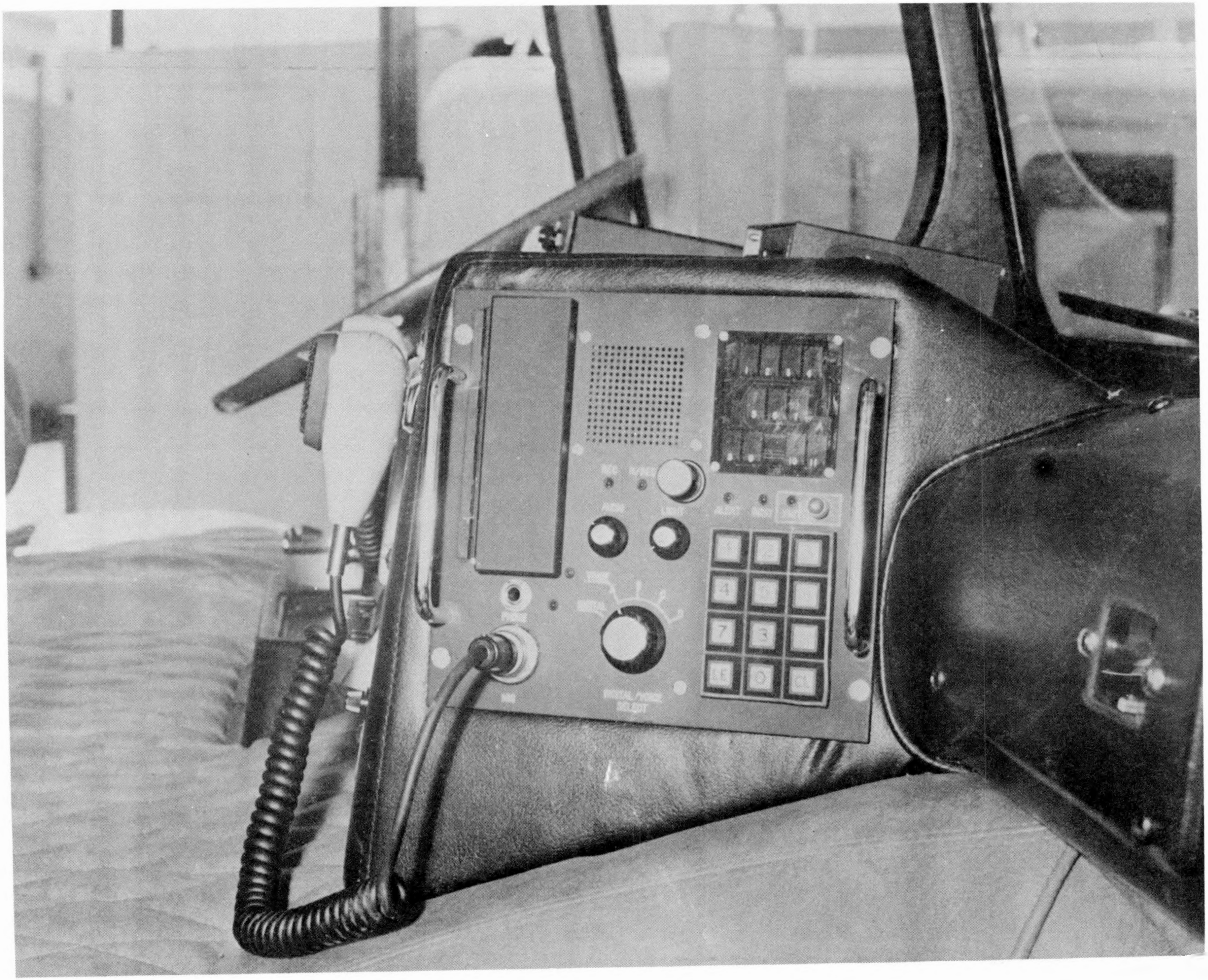

ANTENNA
COUPLER
VCB
ANTENNA
HF
HF
TRANSCEIVER
CHANNEL TEST
NORMAL
LOCAL
OFF
REMOTE
SR-224
RADIO RACK
COMPARTMENT
VIB

FIGURE 9



SECOM RELAY STATION

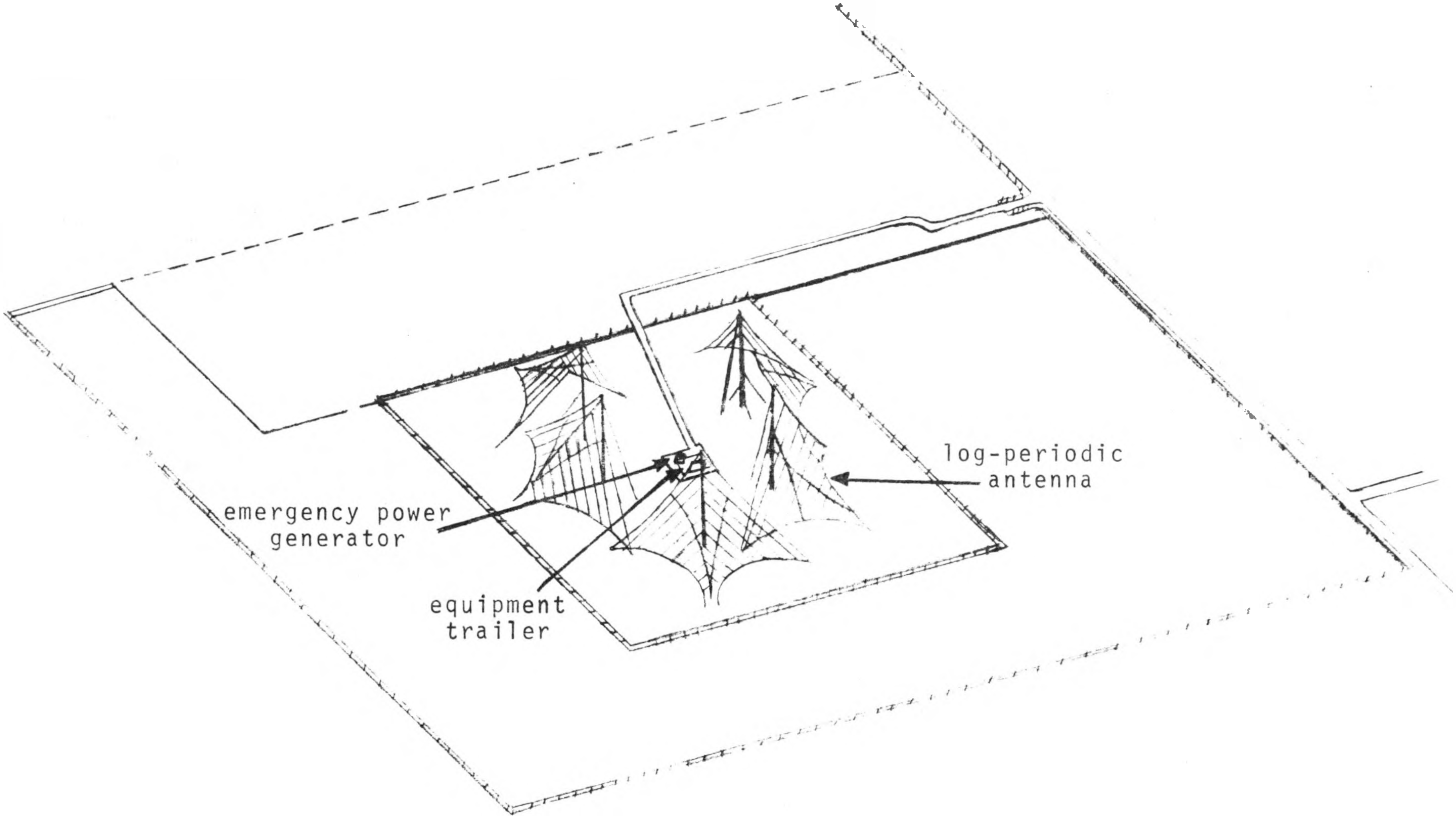
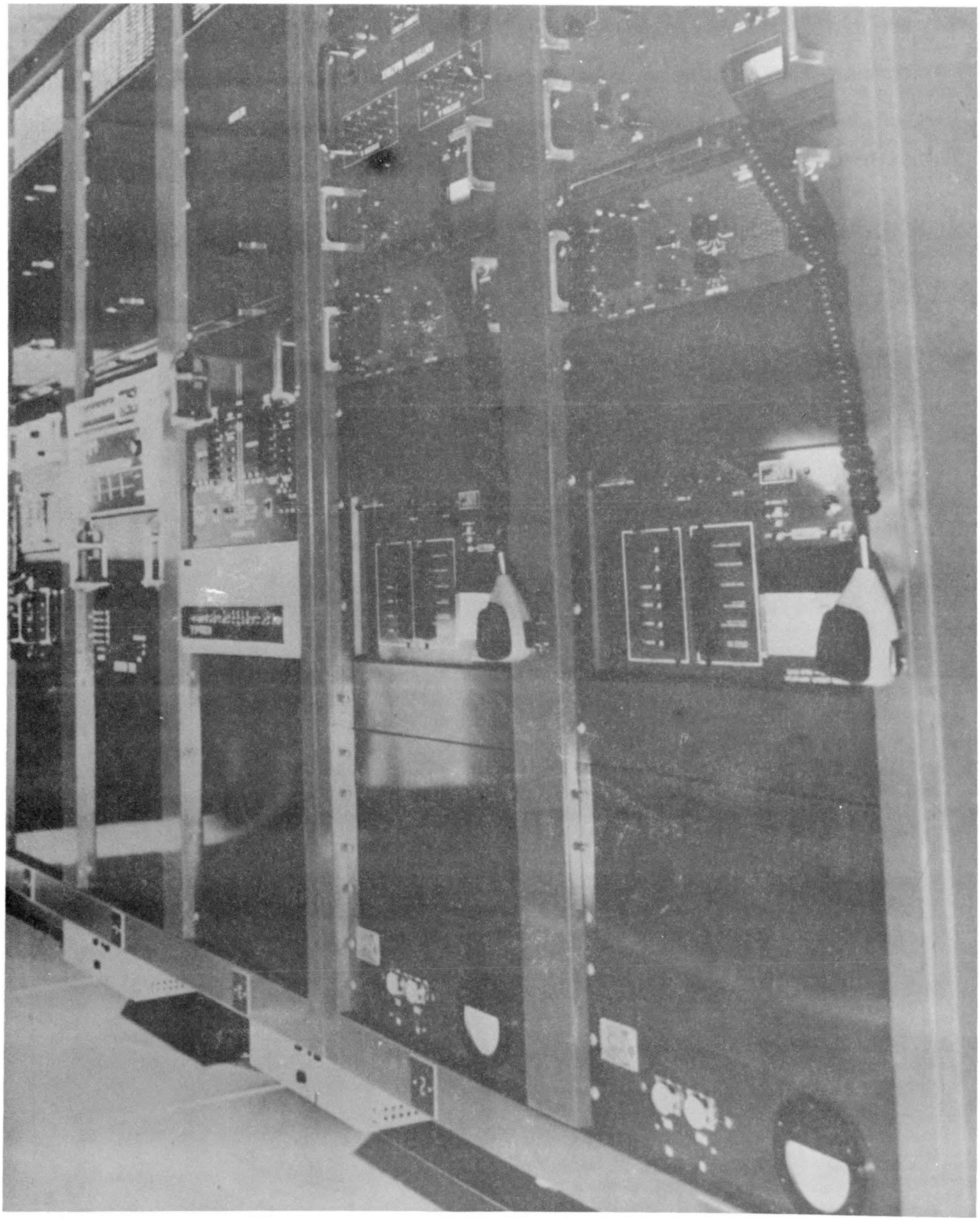


FIGURE 11



RELAY STATION PROCESSING

- BIT-BY-BIT MAJORITY LOGIC OF ALL RECEIVED MESSAGES.
- ERROR DETECTING CODE CHECK OF MAJORITY MESSAGE.
- ATTACH RECEIVED MESSAGE COUNT DATA TO MAJORITY MESSAGE
- GENERATE NEW ERROR DETECTING CODE.
- TRANSMIT MESSAGE THREE CONSECUTIVE TIMES AT 1200 BPS OVER PHONE LINE TO SCC.

FIGURE 13

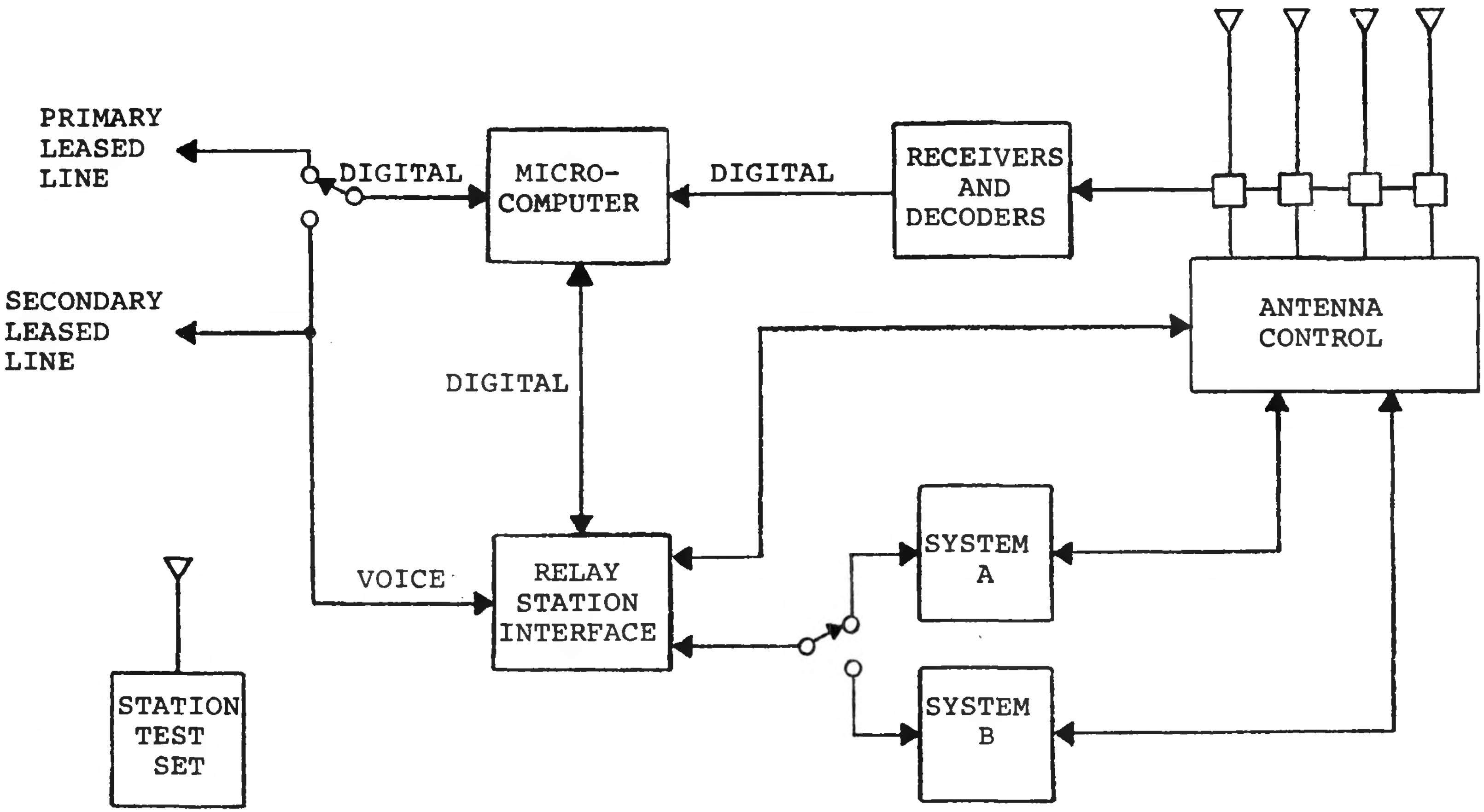


FIGURE 14

RELAY STATION BLOCK DIAGRAM


PRIMARY
BACKUP
NATIONAL
ALERT

SECOM CONTROL CENTER PROCESSING

- RECEIVE MESSAGES FROM UP TO FIVE STATIONS.
- PERFORM MAJORITY LOGIC AND CRC CODE CHECKS.
- DETERMINE BEST STATION, ANTENNA AND CHANNEL FOR RESPONSE.
- GENERATE AND TRANSMIT AUTO-ACKNOWLEDGE THROUGH SELECTED RELAY STATIONS.
- SEND MESSAGES TO CRT, PRINTER AND DISK FILE.

FIGURE 16

SCC INITIATED MESSAGE

TRANSMITTED FROM RELAY STATION - 60 BITS

PREAMBLE (20)	DATA (32)	CRC (8)

BI-PHASE DIGITAL CODING

DATA RATE = 75 BPS

FSK FREQUENCY = 1300 AND 1700 Hz.

TRANSMITTED THREE CONSECUTIVE TIMES ON COMPUTER-SELECTED BEST STATION, ANTENNA AND CHANNEL

FIGURE 17

TYPICAL OPERATOR DISPLAY

VEH	TIME 12:19	CKPT	AUTH	RECV	AUX	XMIT
101	11:26	2546	464	3	000	0
102	12:01	3081	010	3	000	0
121	12:14	1141	368	3	000	0
122	11:19	2419	816	3	000	0
123	10:45	3734	581	3	000	0
124	11:37	1729	391	3	000	0
134	12:13	1111	111	51	000	0
135	11:57	2027	642	3	000	0
145	12:00	1732	305	38	000	4
146	11:50	1227	773	3	000	0
147	10:01	3566	910	3	000	0
161	9:50	1394	179	3	000	0
162	11:59	3591	256	37	000	4
163	9:55	1406	604	3	000	0
235	12:12	1206	054	3	000	0

VEH	TIME	CKPT	AUTH	RECV	AUX	XMIT
236	12:05	3014	158	3	000	0
311	12:10	1111	111	51	000	0
312	12:10	1111	111	51	030	78
313	12:10	1111	111	51	000	0

* * * * * * * * * E M E R G E N C Y * * * * * * * * *

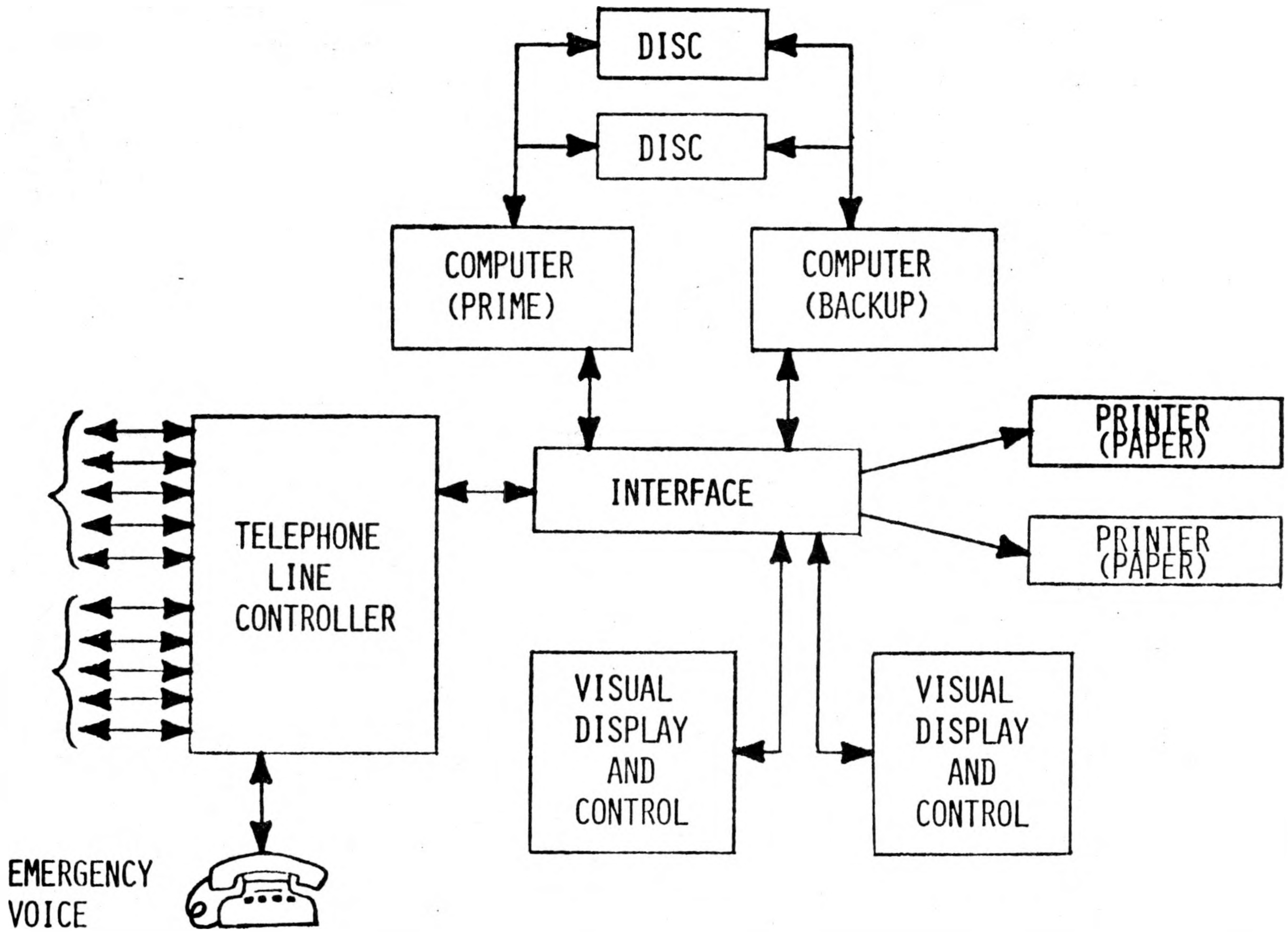
VEH	TIME	CKPT	AUTH	RECV	AUX	XMIT
121	12:14	1141	368	3	000	0
122	12:19	0000	000	33	008	33
123	10:45	3734	581	3	000	0

VEH	TIME	CKPT	AUTH	RECV	AUX	XMIT
124	11:37	1729	391	3	000	0

TYPE RETURN TO CONTINUE

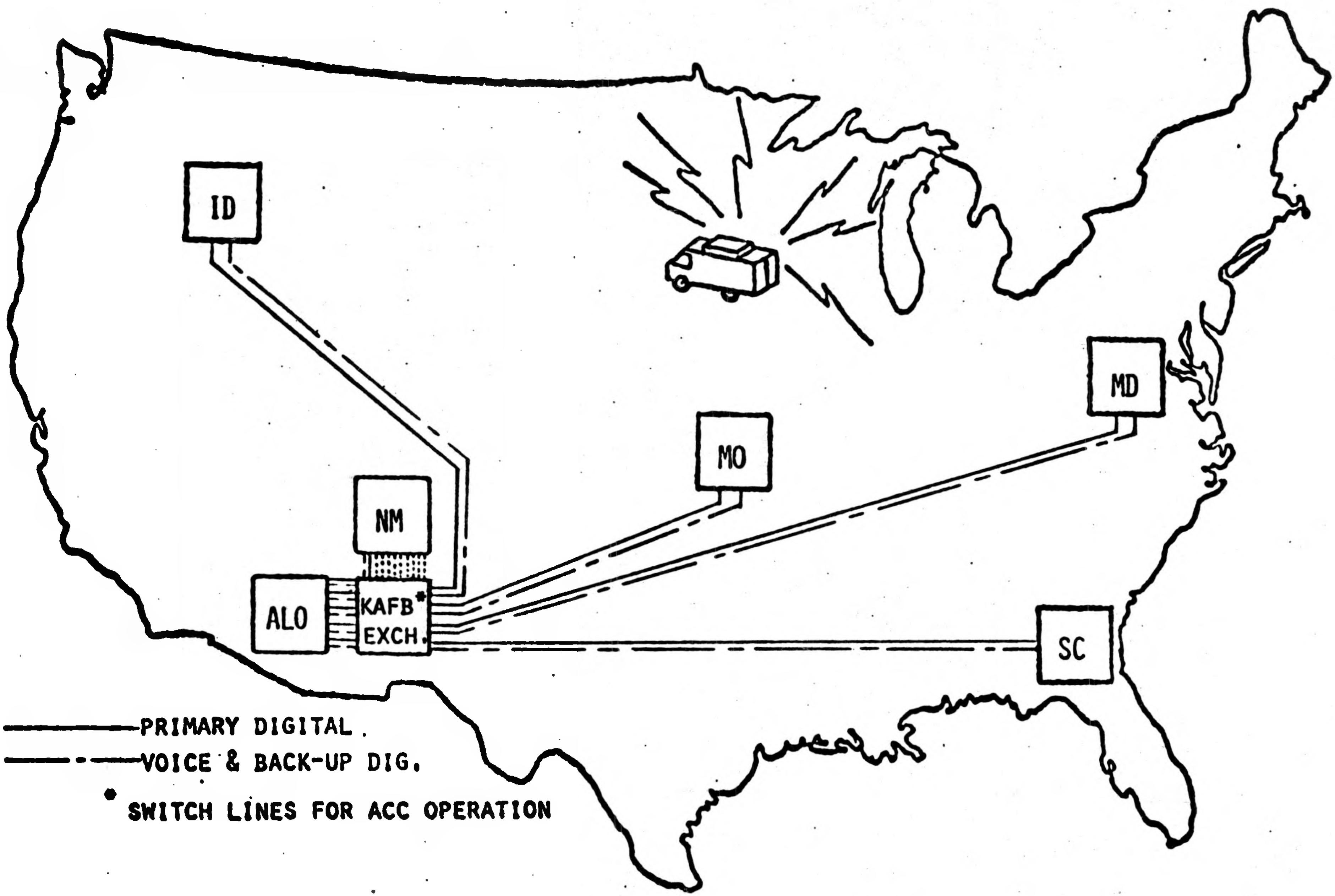
BLINKING

FIGURE 18



CENTRAL CONTROL STATION

FIGURE 19



SECOM II LEASED LINE NETWORK

FIGURE 20

Distribution:

Col. H. M. Dixson, Chairman
Physical Security Equipment Action Group
DDR&E
30 1028 Pentagon
Washington, DC

Lt. Col. D. R. Richards
Nuclear Security Division
DNA Headquarters
Washington, DC 20305

Lt. Col. Greg Lacy
DNA Field Command
Albuquerque, NM

US NRC
Attn: Mr. John Hockert
Nuclear Material/Safeguards & Security
Washington, DC 20555

US DOE
Mr. Burton Newmark
Safeguards & Security
Washington, DC 20545

US DOE
Attn: R. G. Shull, Chief
Nuclear Explosives Safeguards Branch
Washington, DC 20545

DOE/ALO D. P. Dickason, Director
Transportation Safeguards Division

1310	A. A. Lieber
1710	V. E. Blake, Jr.
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1713	J. T. Risse
1714	E. I. Bruce
1716	R. L. Wilde
1730	C. H. Mauney
1750	J. E. Stiegler
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3141	C. A. Pepmueller (Actg) (5)
3151	W. L. Garner (3)
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8266	E. A. Aas
8321	R. L. Rinne
1715	W. D. Olson (15)