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COVER ILLUSTRATION — THE C O N U S (CONtinental United States) AUTOVON (AUTOmatic VOice Network) comprises more than 70 switches in the U.S. and Canada. This installation is one of the Canadian Forces Switched Network sites, linked with the U.S. Government's Automatic Voice Network for defense communications in North America. Situated near Vancouver, British Columbia, this switching system was produced and installed by Automatic Electric (Canada) Ltd. and is owned and maintained by the British Columbia Telephone Company, a subsidiary of General Telephone & Electronics Corporation.

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MODIFICATION of Overseas AUTOVON for CONUS AUTOVON

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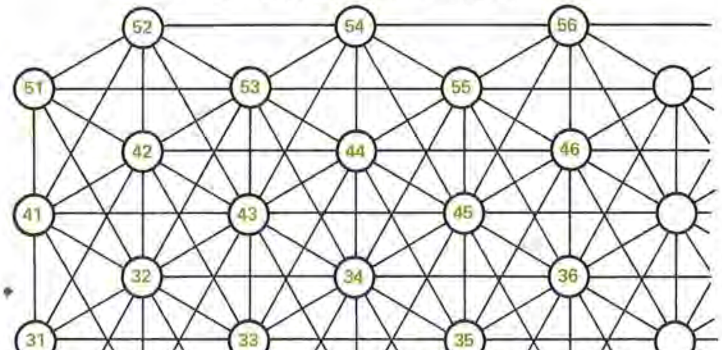
Overseas AUTOVON (AUTOmatic VOice Network) provides speed, flexibility, and survivability to suit the requirements of modern-day worldwide military communications. Such requirements become more stringent when applied to the CONUS (CONtinental United States) AUTOVON Network. The Overseas AUTOVON System comprises about 20 switches, while the CONUS AUTOVON System is composed of slightly more than 70 switches. The larger number of CONUS AUTOVON switches and the complexity of the Network necessitate a more sophisticated and flexible routing philosophy to insure survivability of the Network. This article outlines the major features of the CONUS AUTOVON switch.

The Overseas AUTOVON switch is a telephone switching system in the overseas portion of the AUTOmatic VOice Network (AUTOVON). AUTOVON is a worldwide communications network capable of handling end-to-end circuit-switched communications for the Department of Defense and certain nongovernmental subscribers; it is a portion of the Defense Communications System. The Overseas AUTOVON switch employs electronic control to provide a variety of features and services normally not available in telephone switching systems. Switching is performed under high speed electronic control by electromagnetic elements that complete a metallic path between the calling and called stations for subsequent signaling and voice or graphic transmission. Reliability and maintainability are assured by heavy derating of components, by duplication of markers, and triplication of common control elements.

Figure 1. Basic polygrid network structure of CONUS.



The instructions stored in the translator's memory comprise the program required for system switching; this program may be changed simply by altering the stored information: new number assignments, new classes of service, new routes, etc. are made by punching a new deck of computer cards and feeding them through the card reader.

Some of the services provided by the Overseas AUTOVON switch include Touch Calling, abbreviated dialing, conference service, dial service assistance, off-hook service, five levels of precedence to indicate the urgency of the call, and capability of preempting lower-precedence calls by higher-precedence calls. Numerous class marks and restrictions are also provided.

Switching is accomplished on a space-division basis, employing electromagnetic elements ("correeds") in a nonblocking crosspoint-matrix configuration. The basic electronic controls operate on a time-division basis employing high speed scanning and memory techniques. Control is performed by a translator and route selector that supplies "instructions" for the switching of each call from an electrically alterable magnetic core memory. The entire switching operation is completed within ⅓ second after receipt of the last digit of the telephone number keyed by a calling subscriber.

The CONUS AUTOVON (CONtinental United States AUTOmatic VOice Network) constitutes the remaining portions of the Automatic Voice Network and encompasses telephone switching centers in the United States and Canada. CONUS and Overseas AUTOVON numbering plans and network structures are quite different—additional features are incorporated into the CONUS machine. To provide these features most easily, Automatic Electric has designed and manufactured a separate package which, when added to the Overseas switch, converts it into a CONUS switch. This conversion requires minimal hardware modifications.

Modification for Polygrid Network Routing

Network Structure

Unlike Overseas AUTOVON [1] where the "originating office control" principle is employed in a hierarchical network, the CONUS configuration is a polygrid. The polygrid network routing principle applied here provides for maximum network survivability. The basic network structure using this routing principle [2] is illustrated in Figure 1. Most switches will have direct trunk groups to six adjacent centers, and additional trunk groups to the next closest surrounding switches. Thus, a basic grid configuration termed "Home Grid" is formed as illustrated in Figure 2. Each center in Figure 1 will have its own "Home Grid" of switching centers; however, the "Home Grid" pattern may not be full for the peripherally located centers. Each center is of equal rank and has full capability for alternate routing.

Routing Procedure

In the Overseas switch a maximum of 18 trunk groups form six basic routes for any destination code (Figure 3).

In CONUS, there are 10 possible trunk groups to a destination outside a "Home Grid". These groups include the direct trunk group, most direct triple, best alternate triple, and second best alternate triple. The direct and most direct triples represent forward routes, while the last two triples represent lateral routes which do not advance the call any closer to its destination. Within a "Home Grid" there are seven possible trunk groups to a destination; these include the direct trunk group, best alternate triple, and second best alternate triple (Figure 4).

Numbering Plan

The Overseas AUTOVON switch employs for intertoll transmission numbering plan P-R-NYX-NNX-XXXX, wherein P is the precedence level, R is the route digit, and NYX-NNX-XXXX is the directory number (Figure 5).

In contrast, the CONUS numbering plan uses P-R-RC-NYX-NNX-XXXX for intertoll transmission. The decimal digit RC is used to distinguish forward routing or lateral routing on a call, and to exercise route control in the polygrid network. Specifically, the RC digit exercises control over alternate routing at the next switching center to prevent "shuttle" and "ring-around-the-rosie,"[1] and assists in limiting the number of intertoll trunk links used on a call. The functions of the route control digit are illustrated in Figure 4.

Trunk Group Hunting Sequence

The Overseas switch employs a hunting sequence in which all 18 possible trunk groups are first searched in a sequential manner for an idle

1. These terms refer to the situation wherein a call goes from one office to another and returns to offices which already had handled the call. The call may eventually reach its destination with unnecessary additional equipment attached, or the call may never reach its destination owing to lack of idle equipment.

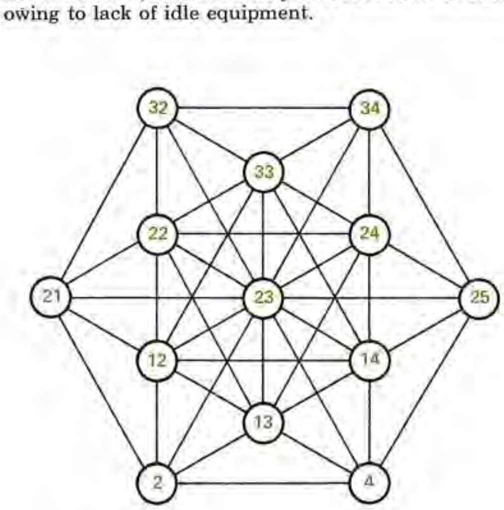


Figure 2. Basic "Home Grid" configuration.

trunk (Figure 3). If no idle trunk exists, a "preempt search" is made to locate the first lowest-precedence call that exists among the same 18 trunk groups. If the precedence of the call thus found is equal to or higher than the precedence level of the call being processed, the call will be routed to a tone or announcement trunk. No trunk group rotation in the hunting sequence for precedence calls is employed in any route.

The trunk group hunting sequence in CONUS is controlled by the received RC digit, the precedence level of the call, and the destination code—which may be outside the "Home Grid," inside the "Home Grid," or a "Dual Homed" PBX code (Figures 4 and 6). The trunk group hunting sequence for a P = 0 to 3 (nonroutine) call starts with a friendly search for an idle trunk to the direct and the most direct triple. Failure to select an idle trunk on this search will cause a preempt search to be initiated. In this search, the trunk groups are tested one by one to determine if there are any idle trunks in the groups. If there are no idle trunks, then the lowest precedence call that exists having a precedence lower than the call being processed is preempted. Failing to select a trunk in one trunk group, the preempt search advances to the next trunk group until all 10 groups have been tested for all valid search levels as dictated by the incoming RC digit. Complete failure in the search will route the call to a recorded announcement.

A second trunk group hunting sequence termed "Immediate Preempt" (IMP), omits the friendly search in the direct and most direct triple, and enters the preempt search immediately. Calls which have the capability of utilizing a precedence higher than routine may be programmed to use the IMP feature (Figure 7).

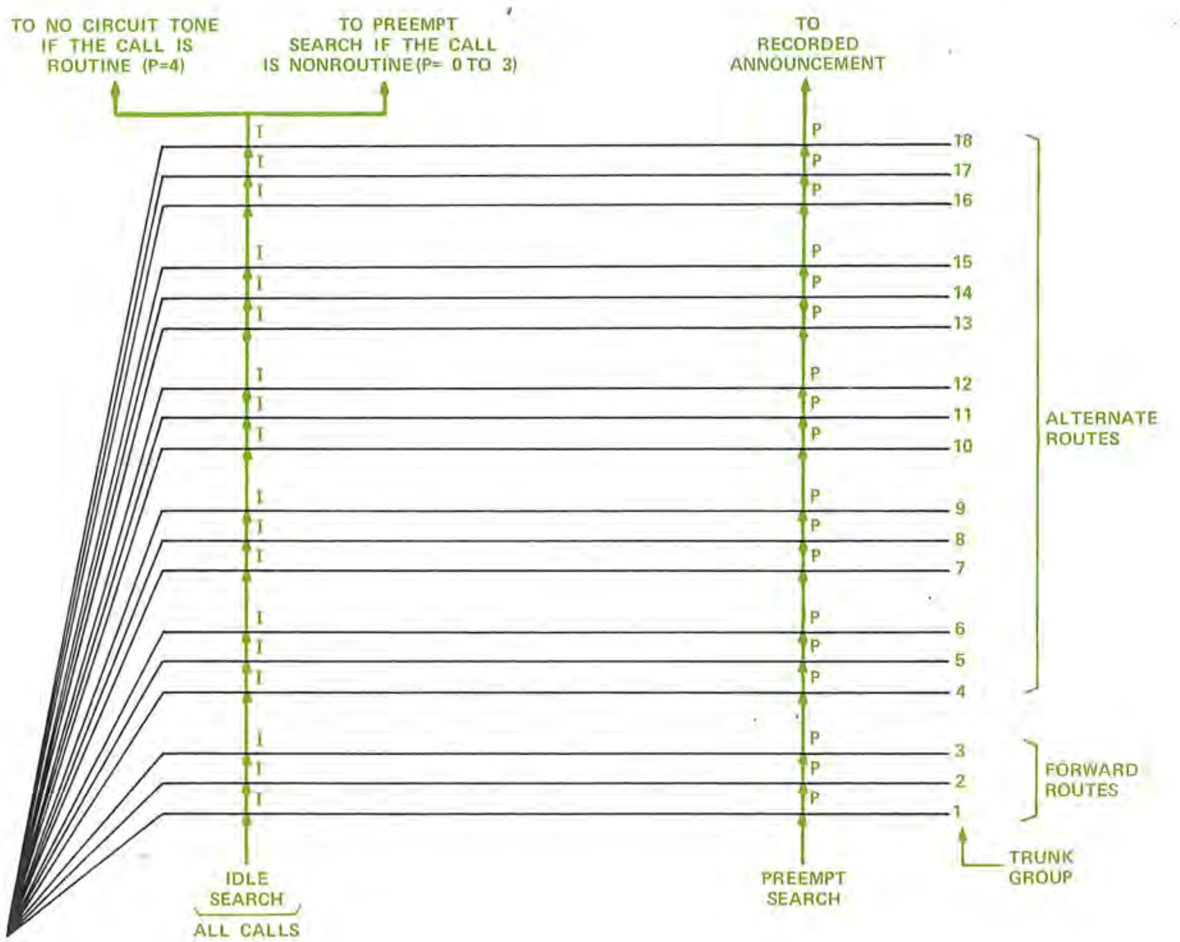


Figure 3. Overseas AUTOVON trunk selection.

Another new feature employed by the CONUS AUTOVON route selection process is that of trunk group rotation. This scheme prescribes that the three trunks within the particular triple be searched in the sequence prescribed by the Trunk Group Rotation Count (Table 1).

Trunk group rotation in the triples is only employed in handling nonroutine calls. Each new nonroutine call will enter a different trunk group among a triple whenever this triple is searched.

When an outgoing trunk is selected, an outgoing RC digit will be generated. This digit generation is a function of the incoming RC digit, the destination code where a set of "stored RC digits" for the 10 trunk groups has been kept, and the trunk group that was selected (Table 2).

Modification for Special Features

(1) Alternate-Subscriber Line Selection and Termination.

Because it was not included in the specification, this feature was not provided in the Overseas switch. In CONUS, provision may be made so that when a subscriber cannot be reached by a call because of a line busy, an unpreemptable, or a maintenance busy condition, the call will be automatically routed to an alternate-address subscriber, who may be located in the same switch or at a distant switch.

(2) Community of Interest Networks.

According to the specification, three communities of interest were provided in the Overseas switch, whereas 15 communities of interest were provided in CONUS. A "Community of Interest" network may be confined to one geographical area or may be worldwide. Members may be restricted to calling through worldwide AUTOVON. The normal AUTOVON subscriber may be prevented from calling into the network, or be capable of entering the network only with precedence calls. Designated subscribers may be included as members of two or more special networks. All members of a "Community of Interest" will be capable of using a level of precedence within their network higher than that allowed to them on the worldwide AUTOVON.

(3) Precedence Digit Insertion.

If a subscriber does not key in a precedence digit in the Overseas switch, the call is automatically treated by the machine as a routine call.

In CONUS, certain designated subscribers can have the precedence digit assigned by the machine even if it is not keyed in.

(4) Precedence Call PABX Line Hunting.

In the Overseas switch, no differentiation is made

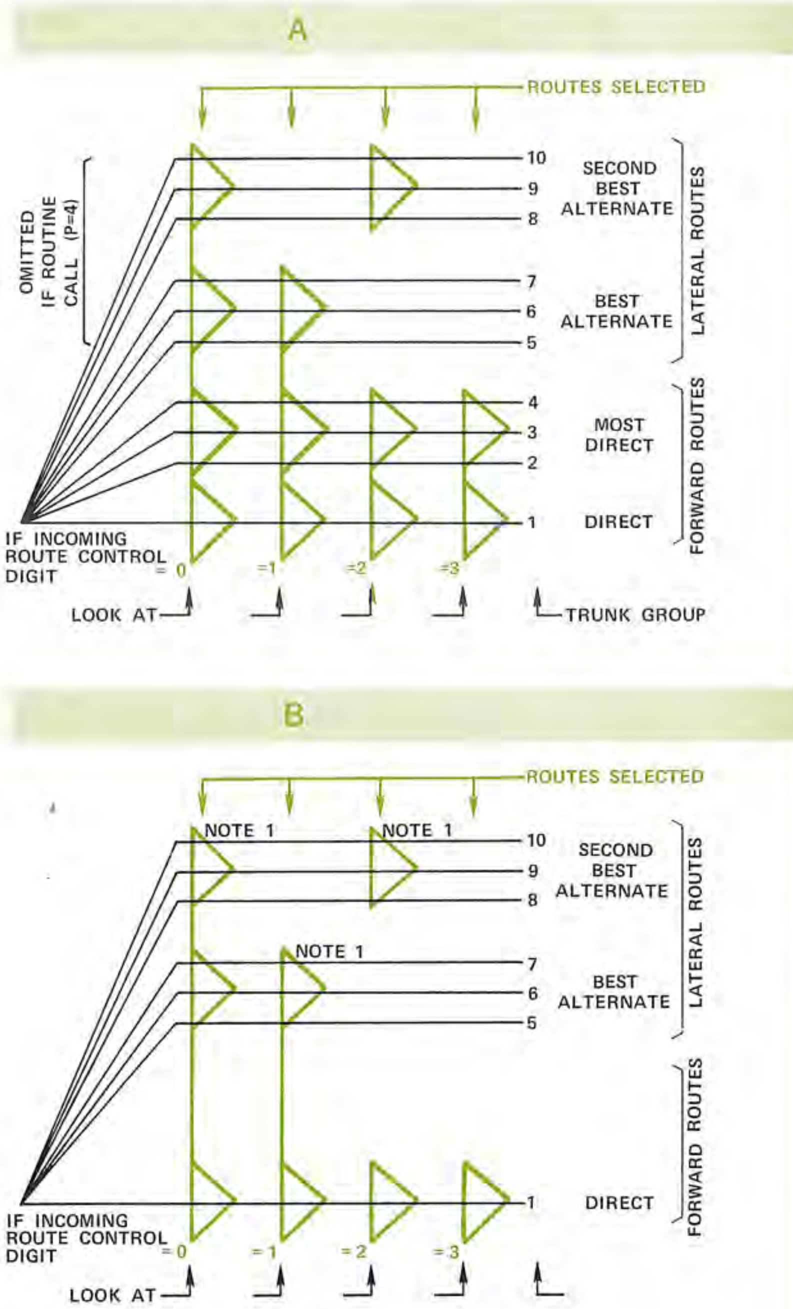


Figure 4. CONUS AUTOVON route selection. A: Outside "Home Grid"; B: inside "Home Grid."

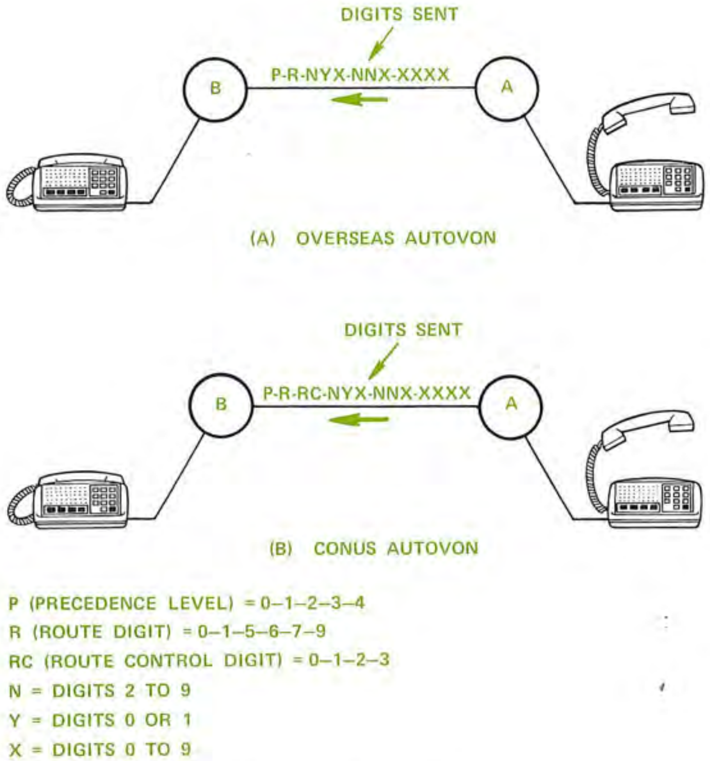


Figure 5. Intertoll numbering plan.

Table 1. Trunk Group Rotation.

Trunk Group Rotation Count	0	1	2	3
Trunk Group Selection	No Trunk Group Rotation Allowed	Select TGA TGB TGC	Select TGB TGC TGA	Select TGC TGA TGB

between routine and precedence calls in trunk group hunting sequences to a PABX.

In CONUS, a precedence call will test preemptable trunk groups first. This is accomplished by using an idle search and then a preempt search. Failing to find a suitable trunk in these trunk groups, the hunting is then advanced to the nonpreemptable trunk groups for an idle search. Failure to select a trunk will route the call to a recorded announcement. A routine call will test the nonpreemptable groups first, then test the preemptable trunk groups. Failing to select an idle trunk, the call will be routed to a "no circuit" tone.

The following modifications were also incorporated in the CONUS machine:

Table 2. CONUS AUTOVON Route Control Digit Selection.

DIRECT

	INCOMING RCD	0				1				2				3			
TG1	STORED RCD	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
	OUTGOING RCD	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3

MOST DIRECT TRIPLE

	INCOMING RCD	0				1				2				3			
TG2	STORED RCD	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
TG3	STORED RCD	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
TG4	STORED RCD	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
	OUTGOING RCD	0	1	2	3	0	3	3	3	0	3	3	3	0	3	3	3

BEST ALTERNATE TRIPLE

	INCOMING RCD	0				1				2				3			
TG5	STORED RCD	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
TG6	STORED RCD	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
TG7	STORED RCD	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
	OUTGOING RCD	0	1	2	3	0	3	3	3	X	X	X	X	X	X	X	X

SECOND BEST ALTERNATE TRIPLE

	INCOMING RCD	0				1				2				3			
TG8	STORED RCD	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
TG9	STORED RCD	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
TG10	STORED RCD	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
	OUTGOING RCD	0	1	2	3	X	X	X	X	0	3	3	3	X	X	X	X

X—Not applicable for this incoming RCD

(a) Separate route sequence hunting for voice and data grade calls by the same NNX code.

(b) Echo suppressor control.

(c) Precedence network in-dialing service to PABX.

(d) "Ready to receive" signal indicator.

(e) Abbreviated dialing translation.

(f) Accept route (R) digit from dial pulse subscriber.

(g) Overflow of voice traffic to data trunks or links and/or overflow of data traffic into voice links if their respective links are busy.

(h) Dual homed PBX routing.

A detailed explanation of these features is beyond the scope of this paper.

Implementation Considerations

Since the Overseas switch is a wired logic machine, any logic changes would normally involve wiring program modifications. However, a decision was made to implement the CONUS features without changing the wiring program, if possible, in the Overseas switch. A retrofit (field conversion) package concept was introduced to achieve this objective. All logic hardware required to implement the CONUS features was designed into this package, and then interfaced with the Overseas switch by "shorting cards" which make electrical connections when installed.

In the design phase of the retrofit package, a careful analysis and detailed examination and evaluation of the overall Overseas switch operation was made. Each subsystem's functions were analyzed to insure that the integration of the retrofit package into the Overseas switch would be economically and technically feasible.

Once the functions were assigned to a subsystem, the designers examined the cause and effect of the additional logic introduced. This process usually included the following:

(a) Examine existing logic for usable signals and loading considerations.

(b) Examine logic timing propagation.

(c) Implement the new logic.

(d) Disable existing functions that apply only to the Overseas switch.

Ultimately, most of the CONUS features were implemented in the translator, the route selector, and the register-sender subsystems. Memory usage in these subsystems was reassigned or added to establish new translation tables, digit registration, and controls. As a result of the new translation tables, the encoding instructions for the Overseas switch were modified. Most of the CONUS features were programable.

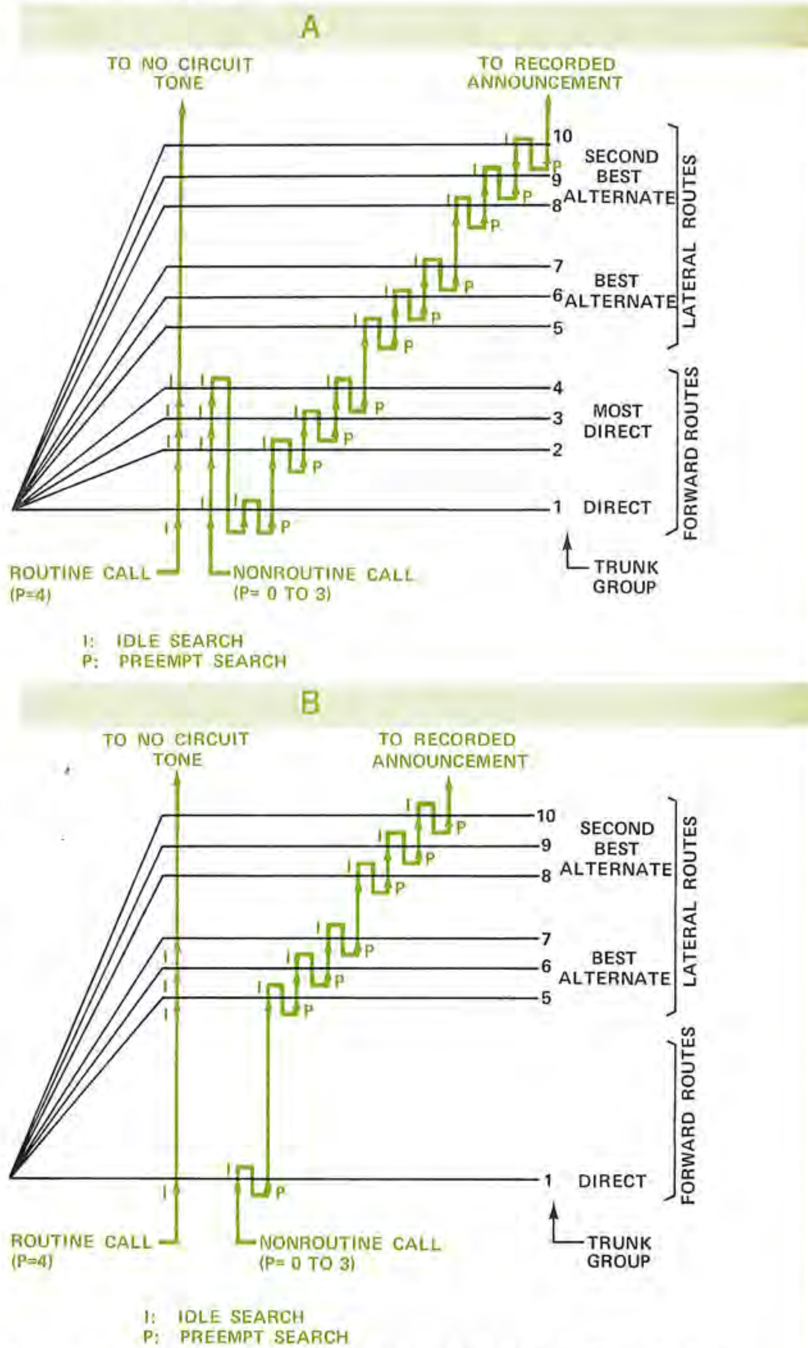


Figure 6. CONUS AUTOVON trunk selection. A: Exterior to "Home Grid"; B: inside "Home Grid."

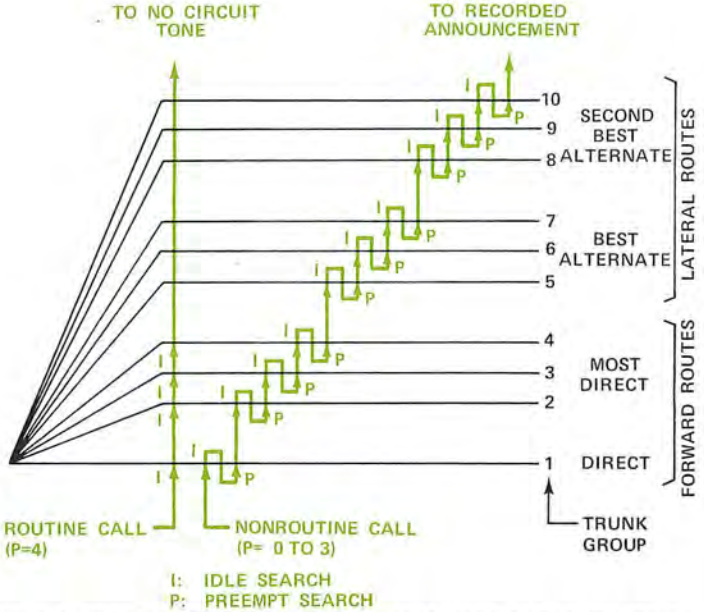


Figure 7. CONUS AUTOVON immediate preempt search (outside the "Home Grid").

Summary

With limited hardware modifications, the Overseas AUTOVON switch was adapted to the requirements of the polygrid CONUS network. Most of the differences between Overseas AUTOVON and CONUS were treated as software changes and minimal control logic changes were necessary. All the features covered in this paper have been successfully tested and meet the CONUS AUTOVON requirements.

Acknowledgements

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DON N. WONG joined Automatic Electric Laboratories in 1963. He received the BS degree in engineering science from Pratt Institute in 1960 and the MSEE degree from the Illinois Institute of Technology in 1964 while working at Automatic Electric Laboratories. In 1967, after a series of assignments, he engaged in the design of Retrofit Package #1 to convert the Overseas AUTOVON switch into a CONUS switch. Currently, Mr. Wong is engaged in the design of the Common Control portion of a Centralized Automatic Message Accounting (CAMA) Machine. He is a member of IEEE.

RAFAEL A. SANABRIA was graduated from the University of Illinois in 1967 receiving the Bachelor of Science degree in electrical engineering. That same year, he joined the Advanced Switching Laboratory at Automatic Electric taking part in the prototype evaluation of the CONUS AUTOVON Retrofit Package #1. After this, Mr. Sanabria was assigned to the prototype and paper evaluation of the Traffic Measurement System, which was to be incorporated into the CONUS AUTOVON Switch as Retrofit Package #2. Currently, he is working in the preliminary design stage of the proposed CAMA Ticketing System. He is a member of IEEE.