Voice Messaging for Definity® System Customers Around the World — the Definity Audix® Voice Mail System

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The Definity Audix® voice mail system, introduced in 1992, provides service superior to the previous generation of Audix voice mail systems at a cost well below that of competing systems. Based on a multifunction circuit board that is installed in the port carrier of the Definity® switch, the Definity Audix system is low in cost, easily installed and serviced, and tightly integrated with its host switch. It has been designed for worldwide sales, and is quickly gaining acceptance in the nearly 80 countries in which the Definity switch is currently sold. This paper describes how the Definity Audix voice mail system was integrated with the Definity switch and designed to meet the needs of a global environment.

Introduction

The voice-messaging market is growing significantly as voice mail vendors use new technology to lower the cost of products for the global marketplace. The Definity Audix voice mail system, introduced in 1992, brings significant improvements to the feature-rich Audix Release 1 system at a cost well below comparably sized competing systems (see Figure 1). The system is based on a powerful, multifunction circuit board that fits into a Definity port carrier and connects directly to the Definity time-division multiplexing (TDM) bus. It is low in cost, highly manufacturable, closely integrated with Definity private branch exchanges (PBXs), expandable to include new features, and simple to install, service, and maintain. (See Panel 1 for definitions of abbreviations, acronyms, and terms used in this paper.) The Intuity™ Audix voice mail system, announced in January 1994, uses the same voice mail software and speech-encoding algorithm as the Definity Audix system. It represents the evolution of the Audix system into larger port sizes, advanced multimedia messaging, and non-Definity switch support.

This paper describes how the Audix system was integrated with the Definity switch. The first half of the paper details the system's electrical and physical design, and the second half of the paper describes switch integration methods, user interface improvements, and global adaptability.

Background

Release 1 of the Audix system, introduced in 1984, achieved a strong position in the marketplace. When the Definity Audix voice mail system was introduced, the sixth set of enhancements to Release 1 of the Audix system was already being planned. Audix Release 1 offered the best integration with AT&T PBXs in the industry using an X.25 control link and proprietary protocol. The touch-tone-oriented user interface had gained wide acceptance among customers and users. Expandable from 2 to 32 ports per system, it also offered strong support for sending voice messages between Audix systems in a corporate Audix network. When interconnected with other Audix or Intuity Audix systems through Audix digital networking, a larger "virtual" system becomes available to the user from the perspective of addressing, sending, and receiving voice mail messages. In addition, Audix Release 1 can be integrated with a long list of PBX and central office switches.

The hardware design of the Audix Release 1 system, consisting of a minimum of 17 special-purpose circuit cards and several system buses, had not significantly changed, however, in the seven-plus years

of the product's life. Market analysis showed a need for a lower-cost system that would attract small customers, and for more advanced speech-encoding technology to improve the system's voice quality. AT&T also envisioned a global marketplace for the voice mail system, with multimedia applications in the future.

With its globally adaptable design, multilingual capabilities, and multimedia processing potential, the Definity Audix system is well equipped to meet the messaging needs of Definity customers around the world.

Panel 1. Abbreviations, Acronyms, and Terms

ALB — disk/alarm board
ASCII — American Standard Code for Information Interchange
CPU — central processing unit
DMA — direct memory access
DRAM — dynamic random-access memory
DSP — digital signal processor
DTMF — dual-tone multifrequency (touch-tone)
G3-MA — G3-Management Applications
LAN — local-area network
LED — light-emitting diode
LWC — leave word calling
MFB — multifunction board
MW — message waiting
MWI — message waiting indicator
PBX — private branch exchange
port — the physical connection point in a voice communications path that gives a caller access to the voice-messaging system. For example, a 16-port system gives 16 callers simultaneous access to the messaging system and can handle the voice-messaging needs of several hundred subscribers.
port carrier — a cabinet or shelf in a switching system into which port cards are inserted. A port card may contain circuitry for several ports.
RAM — random-access memory
SCI — Switch Communications Interface
SCSI — small computer system interface
TDM — time-division multiplexed
TDM bus — an electronic bus that can carry multiple voice or data connections simultaneously
VLSI — very-large-scale integration

Electrical Design

The Definity Audix voice mail system contains two circuit boards that are installed in a port carrier of a Definity switch. The multifunction board (MFB) and the disk/alarm board (ALB) are electrically and mechanically connected, forming a "sandwich" that can be inserted into the port carrier of a host switch while the switch is processing calls. Both circuits offer much functionality in a compact form by means of the highly dense placement of very-large-scale integrated (VLSI) components on both sides of each circuit board. Figure 2 shows a block diagram of the two circuits.

The MFB contains four major subcircuits:

- A 386 processor complex with 16 megabytes of dynamic random-access memory (DRAM),
- An array of six 50-megahertz (MHz) AT&T DSP-32C digital signal processors (DSPs),
- The Definity switch TDM and packet bus interface circuits, and
- An alarm monitoring processor.

The 386 processor complex supports the UNIX System V, Release 4 operating system, two synchronous/asynchronous RS-232 ports, and a small computer system interface (SCSI) to mass storage devices. (UNIX is a registered trademark of UNIX System Laboratories, Inc.) A SCSI tape drive and hard drive are mounted on the ALB, which also provides an Ethernet connection for the MFB's 386 processor, and an on-board modem for remote alarm notification and remote maintenance. For countries in which the on-board modem does not comply with local telephony standards, the ALB provides an RS-232 port for an external modem. The ALB's controller implements a secondary level of sanity checking and maintenance control over the MFB. This helps guarantee that a nonfunctional system will be able to notify remote service centers, and can be remotely diagnosed and brought back into service.

All nine processors on the MFB and the processor on the ALB are reprogrammable or downloadable to accommodate feature growth, a wide variety of applications, and software "bug" fixes. Nonvolatile, reprogrammable flash memories are used to store the 386 boot code, and for the alarm monitoring/reporting processors on the MFB and ALB. Firmware for these

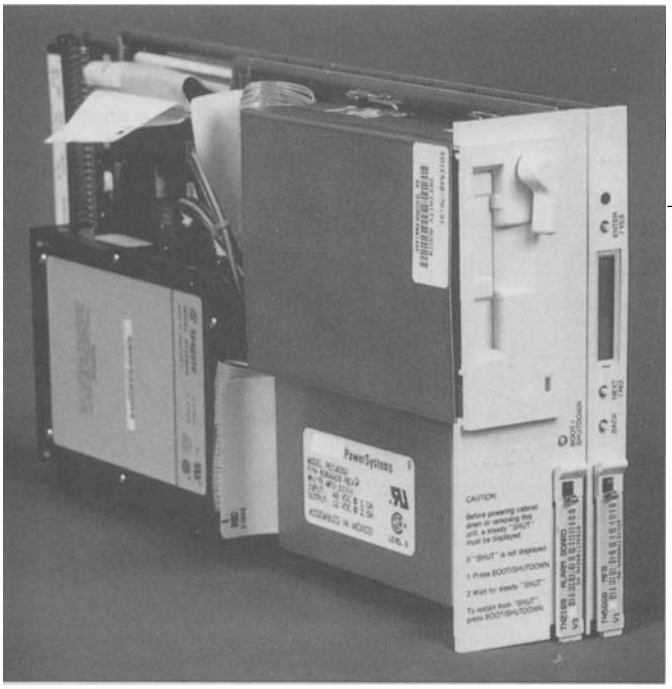

Figure 1. The Definity Audix voice mail system.

processors and software for all circuit subsystems have become part of the Definity Audix system software. This eliminates the need to change hardware to upgrade firmware functionality or to match firmware versions to software packages. The system software resides on a single 160-megabyte cassette tape, and is loaded onto the system hard drive when installations or upgrades are performed.

Each of the six DSPs on the MFB has private, high-speed random-access memory (RAM) that is downloaded by the 386 using a high-speed direct memory access (DMA) controller. The DSPs can be programmed to handle a variety of multimedia messaging and networking tasks. The *DMA controller* is a dynamically reprogrammable gate array that provides a flexible interface between the 386 complex and the parallel port of each DSP. The six DSPs also connect to a 4-megabit/second serial "concentration highway," which has 32 full-duplex channels that can be used either between the DSPs or as connections to the TDM bus of the host switch.

The system maintenance software constantly monitors the multiple thermal sensors on the two circuit packs, and +5 volt (V), -5V, +12V, and -48V sensors.

Physical Design

The voice mail system hardware consists of four replaceable parts: a hard disk, a tape drive, and two circuit boards. The parts can be assembled and disassembled quickly and easily. Connection to the system's administrative terminal port, maintenance terminal port, remote alarm notification and maintenance port, and Ethernet port are all made through the 25-pair amphenol connectors that are available behind every port slot in the Definity switch's port carrier.

Because the Definity Audix system resides within a port carrier, it must be compact. The circuit density was maximized by using a totally surface-mount design with VLSI components on both sides of the circuit boards. This product was the first at the AT&T Denver Works to use a bottom-side-reflow, top-side-reflow assembly sequence. The totally surface-mount design allowed the system disk and tape drives to be directly attached to one of the circuits, thereby eliminating bulky and costly brackets.

Bottom-side integrated circuit (IC) placement yields significant advantages by minimizing the length of critical electrical paths. For example, the static RAM of each 50-MHz DSP-32C is located directly beneath the processor on the opposite side of the circuit board, resulting in simpler routing of wide, high-speed data and address buses and reductions in electromagnetic radiation. Similar advantages were obtained by placing the 386 processor's DRAM on both sides of the board, with one-half of the memory mirroring the layout of the memory directly beneath it.

The MFB faceplate (see Figure 3) contains a 10-character alphanumeric display and three control buttons. The pushbuttons and display provide an interactive status indicator that allows service personnel to check the MFB's state and its environment. The display indicates when an MFB can be removed from service without corrupting the database file.

Call Flow Integration

For each call that a switch presents to a voice mail system, the switch can also provide information about the calling and called parties. With this information, the voice mail system is able to play the greeting of the person that the caller intended to reach. It can also use this information to light a message-waiting lamp on the voice mail subscriber's telephone. In the voice-messaging industry, two methods exist for transmitting this call-related information to the voice mail system:

- In-band method — Transmits tones over the voice path.
- Control link method — Sends information using data transmission methods. The control link implements a protocol for switch-to-adjunct system communication, such as the standard Simplified Message Set Interface.

Most systems use one of these methods. The Definity

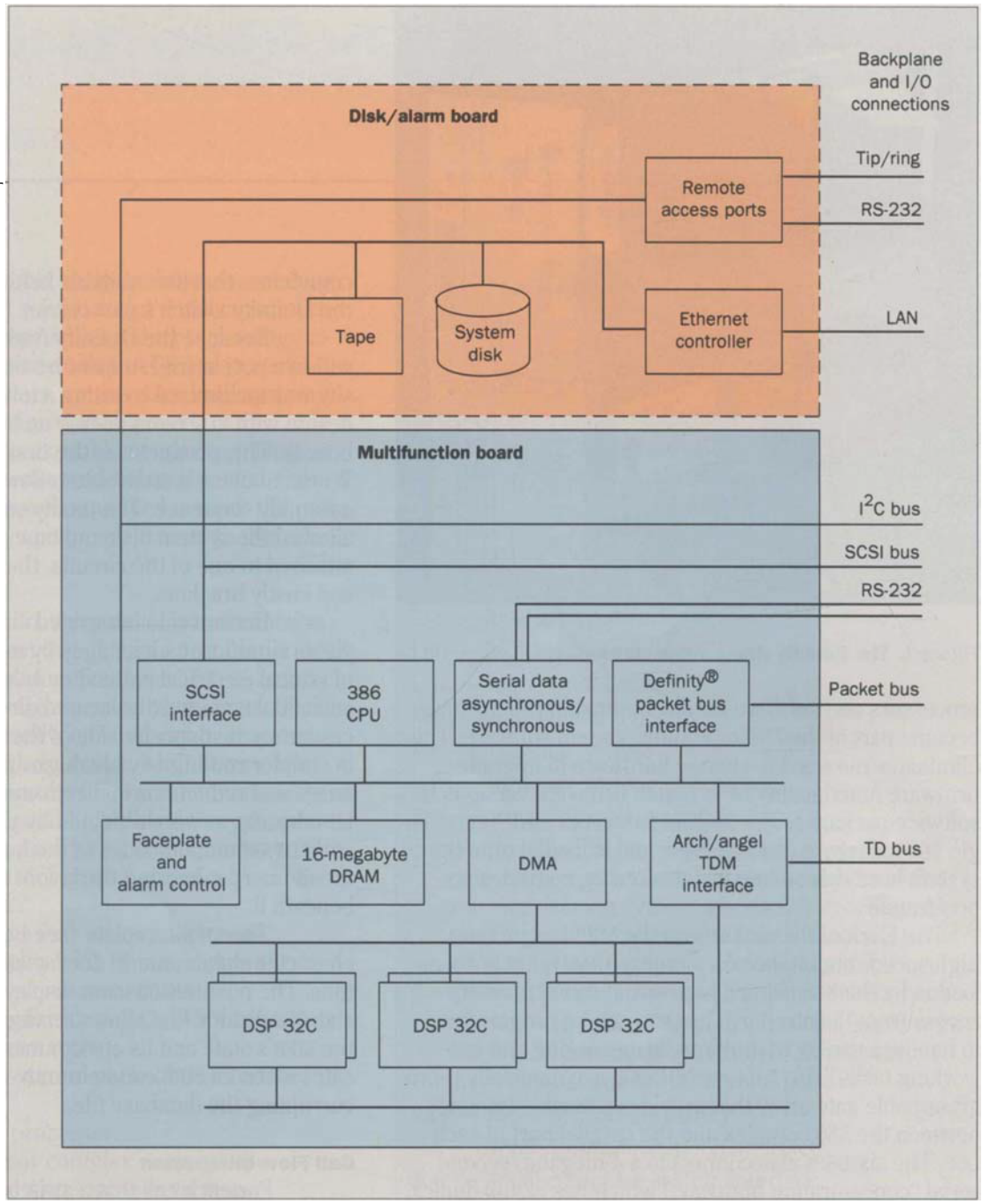

Figure 2. MFB and ALB block diagram.

Audix voice mail system supports the control link method, and also introduces a third switch-integration method, called digital port emulation.

Digital Port Emulation. The Definity Audix system takes advantage of direct access to the Definity TDM bus by using digital port emulation (see Figure 4). Each time a call arrives at a Definity Audix port, the MFB receives the same information that the Definity call processor would send to a digital port that is connected to a digital display telephone. At a low cost, digital emulation provides:

- Voice connectivity with the caller,
- Call control capabilities (answer, transfer, hang up, etc.),
- Information about the calling and called parties,
- Information about the previous routing of the call, and
- Control of the message-waiting lamps on subscriber phones.

Call control. The digital port emulation allows the Definity Audix system to perform the following call control functions:

- Detect an incoming call (i.e., a ringing port),
- Answer a call on any port and establish a voice connection with the caller,
- Detect that the calling party has disconnected (i.e., hung up),
- Disconnect a call on any port,

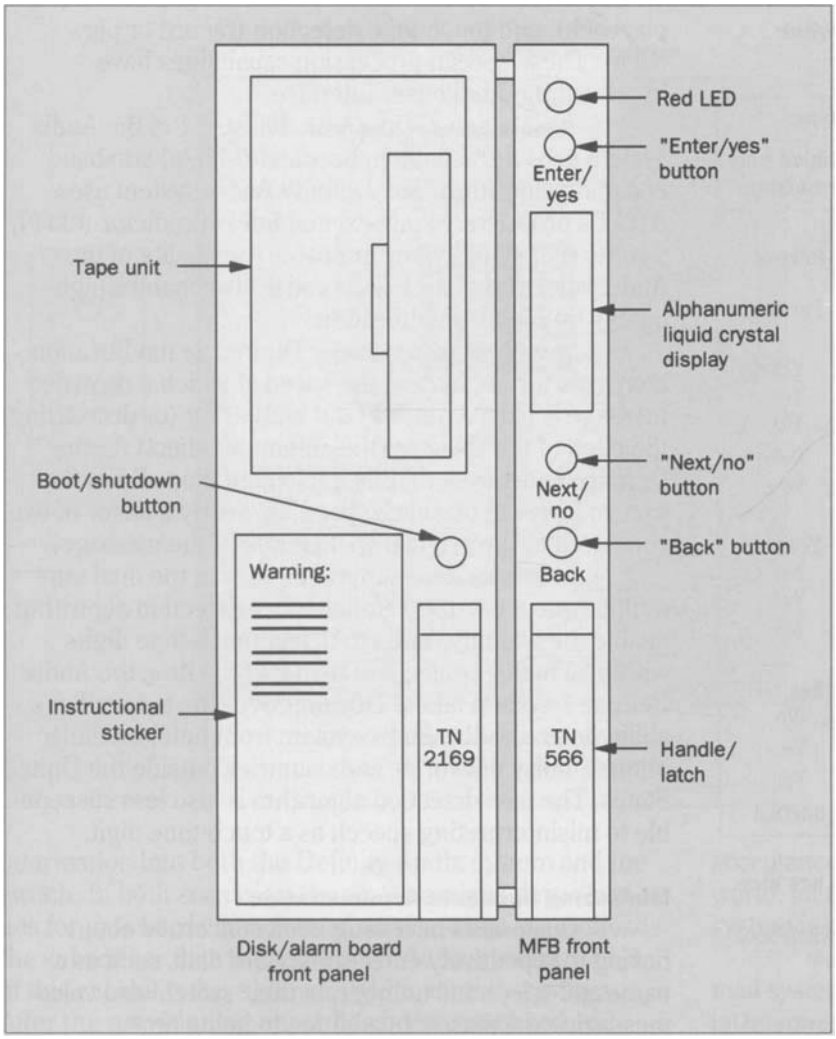

Figure 3. Front view of the sandwich assembly.

- Disable any port to prevent it from receiving incoming calls,
- Originate outgoing calls,
- Query the switch's directory of its users,
- Query the switch for the current time and date, and
- Transfer a call to any extension in the host switch's dial plan.

Call-history information. Each call to the Definity Audix system arrives with call-history information. This is the same information that appears on the display of a digital display set. The Definity Audix system interprets the ASCII display information sent to the port board to identify the extensions of the called and calling parties (if available), and the reason for the call (e.g., direct or redirected). With digital port emulation, the arrival of incomplete or invalid call-history information will cause the Definity Audix system to answer a call in stand-alone mode. In this mode, the Definity Audix system prompts the caller for the extension of the person for whom they wish to leave a message. This emulation operates with AT&T's System 75 (Release 1, Version 3, and later), and Definity G1 and G3 switches.

Control Link. As an alternative, the Definity Audix system also supports the highly functional Switch Communications Interface (SCI) control link for integration with the AT&T System 75 (Release 1, Version 3, or later), and Definity G1 and G3 switches. This X.25-based link, also used with the Intuity Audix system and the

Table I. Functionality Provided by Definity Audix Switch Integrations

Functions	Integration types	
	Control link	Digital port emulation
Physical connection		
Type(s)	RS-232 (X.25)	Internal
Data rate (bit/s)	9600	Parallel
Call-history information:		
Reason for call	Yes	Yes
Calling party ID	Yes	Yes
Called party ID	Yes	Yes
Integrated MW notification	Yes	No
Disconnect message	Yes	Yes
MW status information:		
Updated on activity	Yes	Yes [1]
Audit of each mailbox	Yes	No
Refresh of all mailboxes	Yes	Yes
Store LWC messages	Yes	No
Call transfer out:		
Basic (switch-hook flash)	Yes	Yes [2]
Enhanced (control message)	Yes	No
Audix control of port availability	Yes	Yes
Time synchronization	Yes	Yes
Maintenance information for link	Yes	Internal

Notes:
1. Message-waiting (MW) indicator will light only when first new message is received.
2. Emulation of telephone set "transfer" button instead of switch-hook flash.

Audix Release 1 system, offers a slightly wider range of functionality (see Table I) and better responsiveness to the caller. The primary benefits of control link integration are an enhanced form of call transfer and operation across a network of Definity switches.

Digital Signal Processing in the User Interface

Currently, the DSPs of the MFB perform only voice processing and networking functions; they can, however, be programmed for a variety of multimedia applications. The voice-messaging application requires multiple functions on the same port, including speech encoding (record), speech decoding (playback), automatic gain control (record), power limiting (playback), time-scale modification (accelerated or decelerated playback), and touch-tone detection (record or playback). These speech-processing capabilities have improved the Audix user interface.

Speech Encoder/Decoder. Release 1 of the Audix system uses a 16-kilobit-per-second (kbit/s) sub-band encoding algorithm. The Definity Audix system uses AT&T's proprietary code-excited linear predictor (CELP), a coder that significantly improves the quality of the Audix voice recordings. This coder also enables high-quality time-scale modification.

Time-Scale Modification. Time-scale modification increases (or decreases) the speed at which a recorded message is played out, without increasing (or decreasing) the pitch of the speaker (the chipmunk effect). In the Definity Audix system, this implementation allows the user to increase playback speed, by nearly a factor of two, compared to the original spoken rate of the message.

DTMF Detection. Improvements in the dual-tone multifrequency (DTMF) (touch-tone) detection algorithm enable the Definity Audix to detect touch-tone digits within 25 milliseconds, less than half the time the Audix Release 1 system takes. This improves the subscriber's ability to access the Audix system from hotels, cellular phones, noisy networks, and countries outside the United States. The new detection algorithm is also less susceptible to misinterpreting speech as a touch-tone digit.

Minimizing Duplicate Administration

Customers have long been concerned about having to repetitively enter subscriber data, such as a name and telephone number, in their switch- and voice-messaging databases. In addition to being time-consuming, the duplication of processes exposes the databases to potential error. The G3-Management Applications (G3-MA) product offers tools that the customer can use to administer subscribers at provisioning time (when Definity Audix is first installed), and during day-to-day operations. The provisioning tools support both scenarios for installing the Definity Audix system. In the first scenario, where the Definity Audix system is added to an already existing switch installation, the G3-MA "copies" the subscriber information from the switch into the Definity Audix system. In the second scenario, where the Definity Audix system and the switch are newly installed together, subscriber information is entered into the G3-MA directly, and then the G3-MA "copies" the

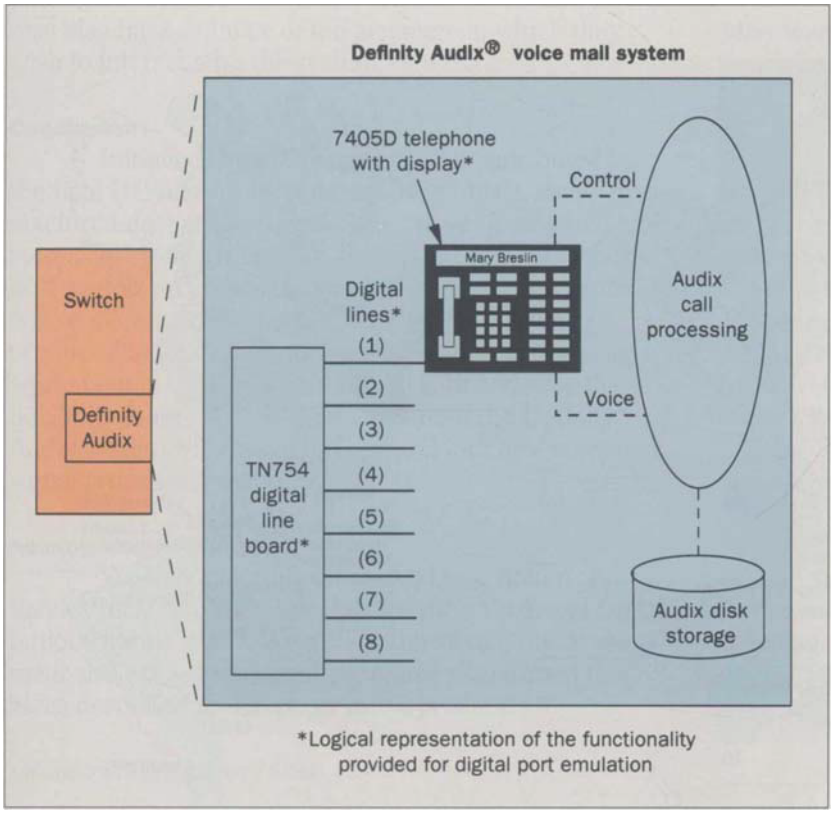

Figure 4. Definity Audix integration via digital port emulation.

information into both the Definity Audix system and the switch. In both scenarios, the G3-MA assigns default values for passwords and class of service when it downloads the subscriber data to the Definity Audix system. Trials of this capability have shown significant time savings. After the provisioning phase has been completed and the magnitude of new subscribers has subsided, the customer can add new subscribers by entering the data once into G3-MA, which then downloads the data into both systems.

A Global Product

In less than two years, the Definity Audix voice mail system has been accepted in 40 countries. Riding on the Definity switch's coattails, the Definity Audix system will eventually be available in all 80 countries in which the Definity switch is now being sold. Because the host switch provides the network interfaces, as well as the power supply and distribution infrastructure, acceptance of the Definity Audix system quickly follows acceptance of the switch. Figure 5 shows a map of the world, identifying countries in which the Definity Audix system is currently available.

Multilingual Features. A globally successful voice mail system requires more than an adaptable network interface and certification, by numerous governmental authorities, to local telephony and safety standards; it also requires a flexible user interface that can accommodate varied language needs. Critical to the international viability of the Definity Audix system was the development of a language-independent software architecture.

System software plays announcements (voice prompts) to the user that may consist of multiple fragments. A fragment is a recording that may be a single word, a complete sentence, or multiple sentences. Each announcement is one complete semantic thought. The construction of fragments to compose an announcement will, of course, vary by language. For instance, in the United States when we give the date, we concatenate two fragments, one for the month and one for the day of the

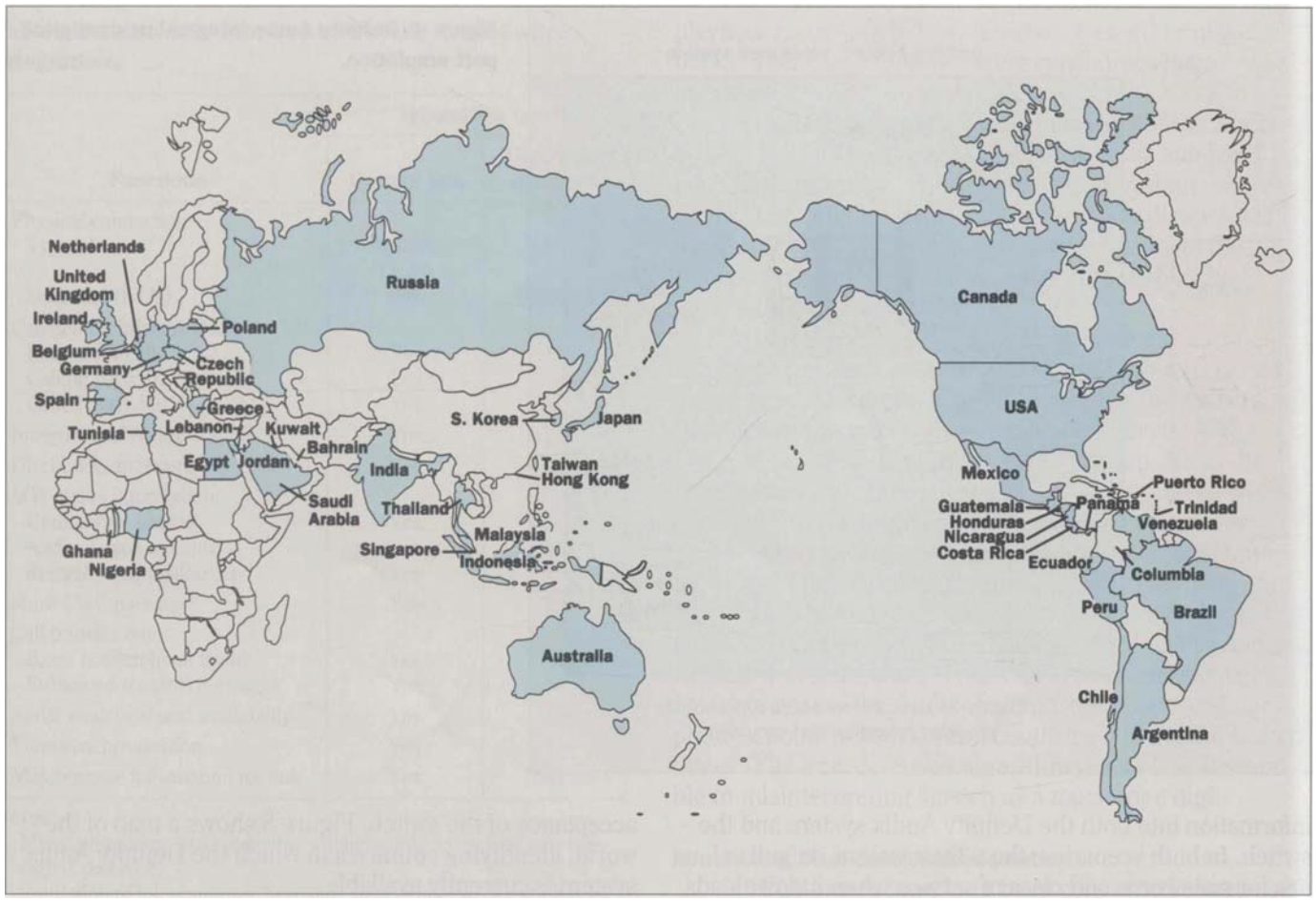

Figure 5. A map of the world, identifying countries in which the Definity Audix voice mail system is currently available.

month, as in "March fifteenth"; in France, however, the day precedes the month. Hence, the fragments are reversed, as in "quinzieme Mars." Nuances of sentence construction and grammatical syntax particular to each language could have been built into the system software, but doing so would have resulted in software that is difficult to change. The introduction of new voice mail features and new languages would have been more expensive and time-consuming.

Language Tapes. Definity Audix languages are available on a tape separate from the system software tape. Each tape provides all the recorded voice fragments for the language, as well as semantic rules that are used by the system software as a guide in constructing each announcement.

Language tapes are currently available in American–English, British–English, Latin–Spanish, Canadian–French, German, and Portuguese. Soon, Dutch, Japanese, Euro–French, and Italian tapes will also be available. Others will follow.

In addition to enhancing the development and delivery of new languages, the Definity Audix announcement strategy allows the system to support a multilingual user interface. Outside the United States, the simultaneous support of multiple languages is an important voice mail feature. As many as nine languages can co-exist on the Definity Audix system, enabling system subscribers to interact with the voice mail system in the language of their choice. Callers that leave messages on the system

may also have a choice of the language in which they wish to interact with the system.

Conclusion

Initiatives in several areas have contributed to the final Definity Audix product. Its compact, easily manufactured design has reduced the cost of goods sold and increased system reliability. Strong integration with the host switch, an improved user and administrative interface, and enhanced language support have created a product that leads the way for AT&T voice processing equipment in the global marketplace. In addition, the flexibility inherent in the architecture of the Definity Audix system will enable it to expand into new voice and signal processing markets.

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