APPENDIX S:
IVSAWS IMPLEMENTATION ANALYSIS

This appendix identifies commercial off-the-shelf (COTS) hardware and software available to implement the IVSAWS Operations Center (IOC) functions.

1.0 Introduction

This report identifies commercial off-the-shelf (COTS) hardware and software available to implement the IVSAWS Operations Center (IOC) functions. When implemented, the IOC functions may initially exist as a stand alone system, however, the long-term goal will be to add the IOC system to a larger IVHS system in the form of a software applique. The IOC functions include collection of hazard and advisory event information, and IVSAWS message generation, storage, look-up, verification and dissemination.

This report provides a sampling of the existing systems, the expected hardware and software necessary to create a new system, and the COTS hardware and software costs for both the existing system and the new system. Software development costs for an IVSAWS-unique applique are not included. The cost associated with providing a standard messaging capability, however, are provided for both the new and existing systems.

1.1 Architecture Review

The IVSAWS System Architecture Analysis (Task C, Subtask 1; documented in ENB C-1-1) yielded two promising system architectures which can implement IVSAWS at different levels of cost and functionality. System Architecture #1 employs a new narrowband communication link operating in the 220-222 MHz band supported by Global Positioning System (GPS) area of coverage (AOC) control. Figure 1.1-1 shows a block diagram of the narrowband-GPS architecture. System Architecture #2 utilizes existing FM radio stations to broadcast IVSAWS alerts via the Radio Broadcast Data System (RBDS). GPS or other geolocation systems (e.g., Position Information Navigation System (PINS)) can be used to control the AOC. Figure 1.1-2 shows a block diagram of the RBDS architecture.

At the IOC level, both architectures are the same. In fact, both systems share the same architecture with respect to implementation of the following functions: 1) hazard and advisory event detection and verification, 2) collection of hazard and advisory event information, and 3) IVSAWS message generation. As described above, the latter two functions are to be embedded in an IOC. Message dissemination, another IOC function, is implemented differently by the two architectures.

The scope of this implementation analysis focuses on the IOC for the following reasons: 1) except for an antenna performance analysis and in-vehicle retrofit analysis, the definition of an in-vehicle implementation (Task F) has been deleted from the scope of this contract and 2) information flow from the hazard or advisory site to the IOC uses channels which have already implemented (except Iridium, which is analyzed in ENB C-1-1).

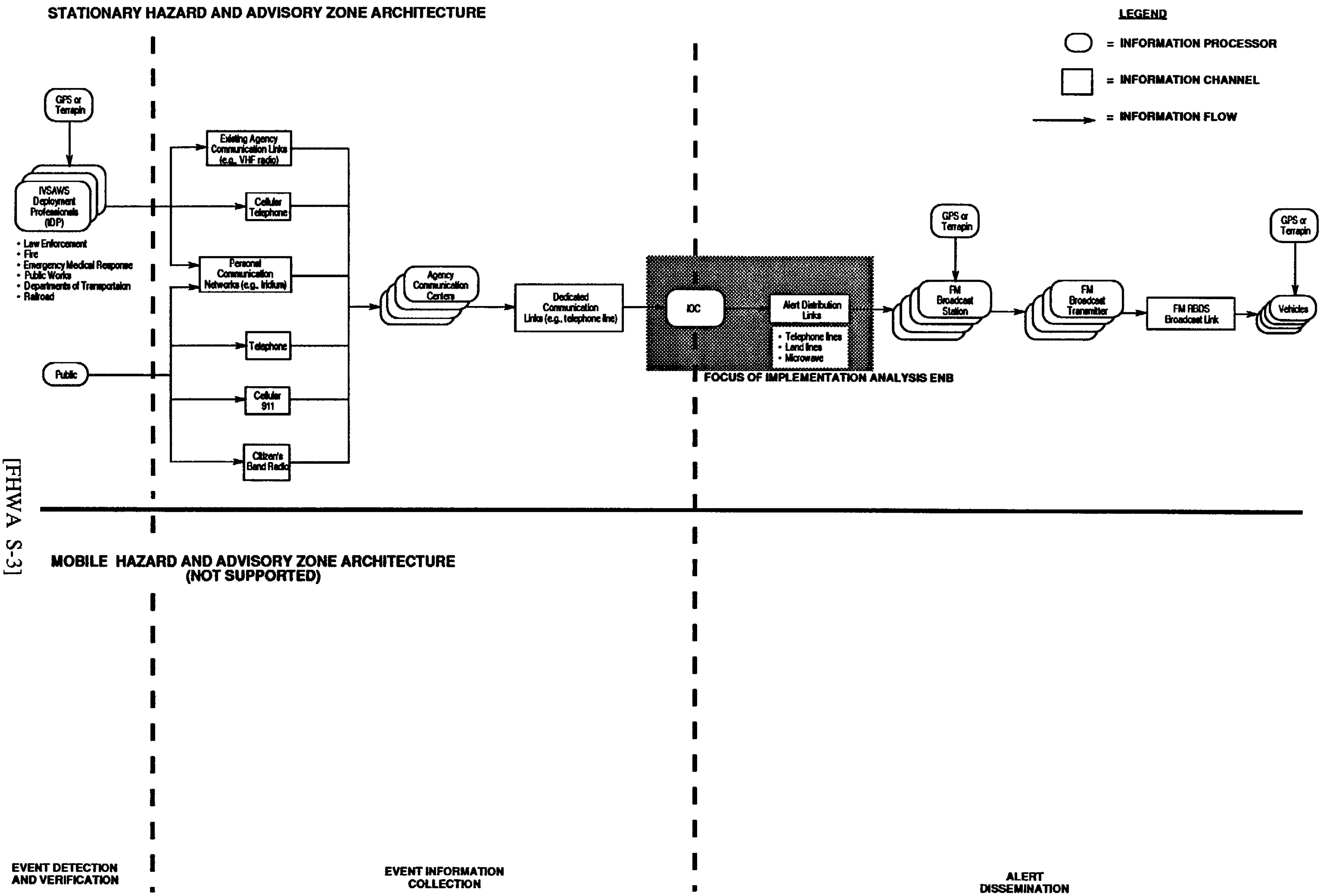
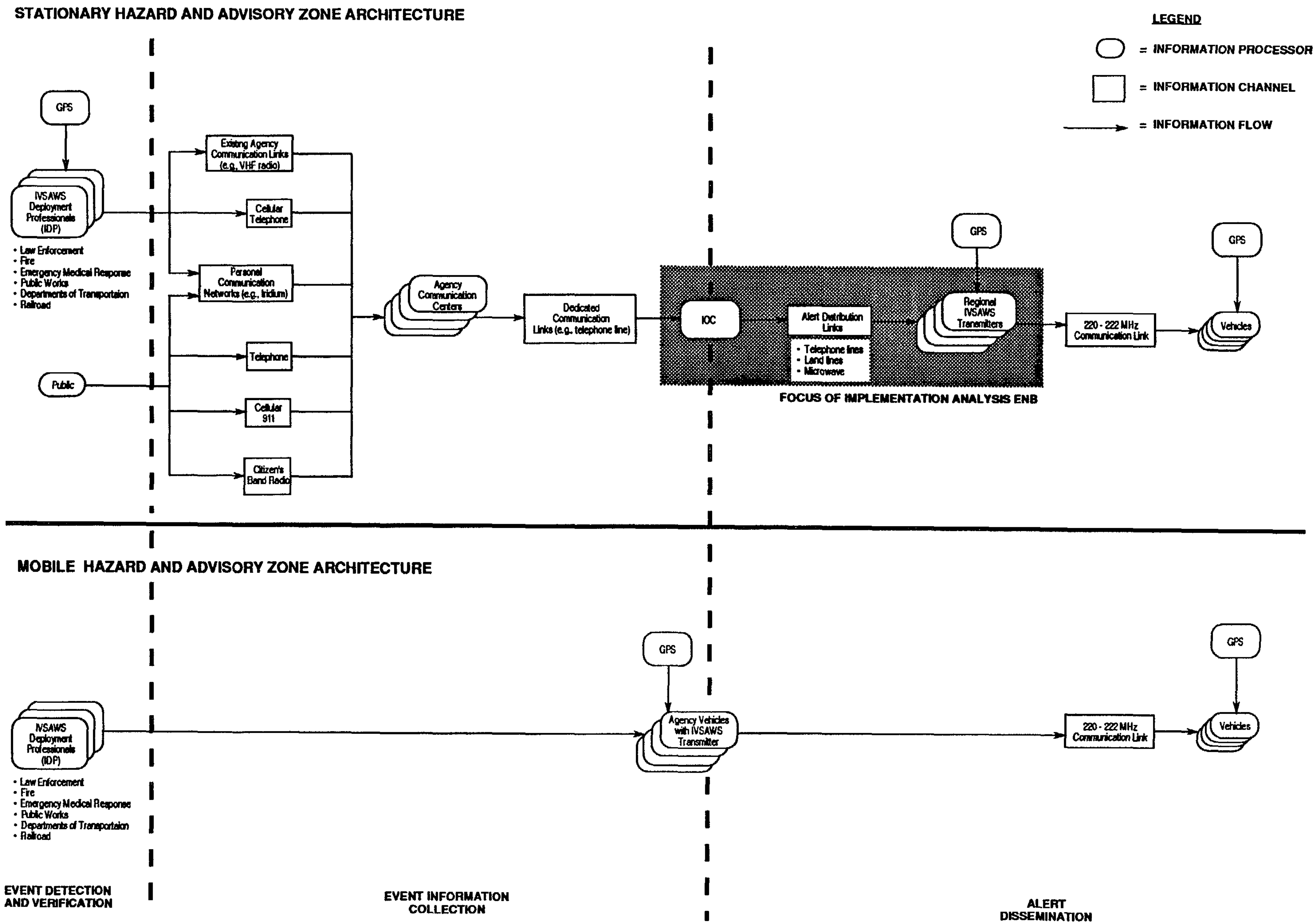


Figure 1.1-2. RBDS - GPS/Terrapin AOC control system architecture.

[FHWA S-3]



[FHWA S-4]

Figure 1.1-1. Narrowband communication - GPS AOC control system architecture.

2.0 Existing Systems Available for Adaptation within an IOC

The IOC system may be implemented by modifications to an existing fleet management system. The identified fleet management systems will need modifications to provide the IOC capability. This method of generating an IOC will be the shortest time to completion, however, it will lock the IVSAWS into a specific manufacturer due to the proprietary nature of the messaging protocols.

There are several fleet management systems available which provide two-way messaging. These systems provide both an integrated workstation and an integrated in-vehicle unit. There are also manufactures which make dumb terminal displays for the in-vehicle application. The existing systems are designed to communicate via conventional and trunked data radio and cellular telephone. The existing systems provide an interface for a GPS receiver to append vehicle location to automatic responses and in-vehicle generated messages.

Fleet management systems are provided to accommodate efficient use of company vehicle resources. The central controller typically provides a status display of the fleet assets under control. Messages are generated and sent to a specific vehicle instructing the operator to take a specific action. Broadcast, or all-call, capabilities are provided for each vehicle on a particular conventional or trunked data radio channel. The in-vehicle unit provides the location information to the central controller with each acknowledgment of message receipt and with each status message generated.

The messaging systems provide guaranteed delivery using some network, OSI Level 3, protocol. This protocol will retransmit all unacknowledged messages and request retransmission of all messages received in error. Forward error correction may be provided in the more expensive systems.

For the IOC application, the existing fleet management systems provide a model. Modification of the existing systems is not recommended due to the cost associated with modifications. As an alternative, the existing systems should be studied and the best features identified. Message formats should be identified, communication protocols defined, and communication medium selected. Finally, a system specification for the IOC should be developed and each of the fleet management system providers should be asked to provide a competitive bid to meet the IOC requirements and schedule. This approach will accomplish two goals. First, all manufacturers will be competing to build a specified system which will be universal. Second, competition for the IVSAWS business will ensure a low cost system for both the IOC and the in-vehicle unit(s).

The following table lists the manufacturers of fleet management systems, the fleet management system name and the communication service used. The range in price for the fleet management system central controller software, communication hardware, and development system software is from $3,000 to $10,000. The range in price for the in-vehicle communication unit and display unit is $750 to $1,300.

Manufacturer	Product	System
Mentor Engineering	Express Mobile Data Terminal (MDT)	Conventional/ Trunked Radio
DINET, Inc.	DATA-MATE 1000 MDT	Conventional/ Trunked Radio
Sigtone, Inc.	mobi-SCRIPT	Conventional/ Trunked Radio
Arrowsmith Shelburne, Inc.	MX5-Tracker System	Conventional/ Trunked Radio and Cellular
Titan Linkabit	PositCOMM	Conventional/ Trunked Radio
Millidyne	STX-4000 MDT	Conventional/ Trunked Radio and Cellular
PacTel Teletrac	Fleet Director	Conventional/ Trunked Radio, Cellular and Paging
Granite Communications	Granite Links	Conventional/ Trunked Radio, Cellular and Satellite
DATARADIO Corporation	Vehicular Information Series	Conventional/ Trunked Radio and Cellular

Table 2.0-1 - Fleet Management Systems

3.0 IOC Development

The IOC task will be developed using either an existing system or designed from the ground up. The above mentioned systems will be investigated to determine there applicability to the IOC task. Also, the ability to transport the software to a UNIX workstation will be investigated. A block diagram of the IOC is shown in Figure 3.04.

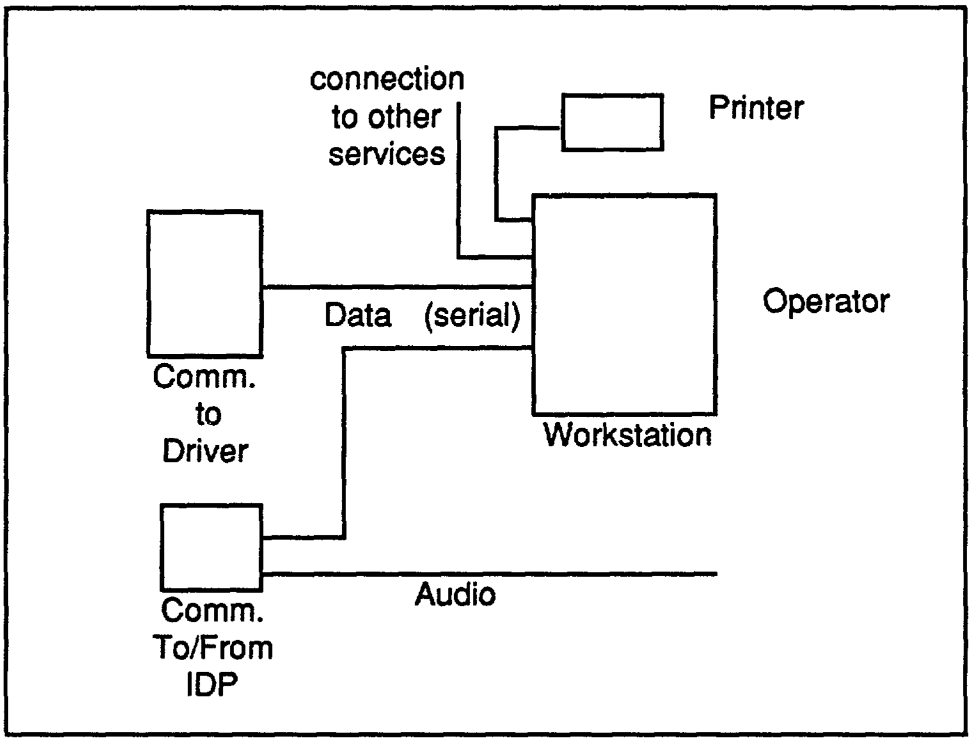


Figure 3.0-1 - IOC Block Diagram

If a third party's management package cannot be modified to work in the IVSAWS environment then a system will need to be developed. The IVSAWS management program will need to be a stand-alone program that can run on an IBM PC/Compatible 80386 SX @ 33MHz (see Table 4.0-1), or a UNIX workstation (see Table 4.0-2). The interfacing program should be windows based and written in a high level language, the primary IVSAWS message handler will be a database system programmed to provide for manipulation and storage all of the message data. Since there are several platforms available for IVSAWS (PCs and workstations primarily) it is recommended that a database package that is cross platform compatible be selected, Foxpro, dBase IV, and Oracle7 are three such packages (Foxpro should have their UNIX based product out by the fourth quarter of 1993). The database packages provide a development environment to set up the operator interface.

The costs involved with developing an IVSAWS interface will be the purchase of the development software, a database software package, along with the costs incurred during the development of the IVSAWS management program. A one time purchase of a developers kit or compiler (depending on the software product purchasing) will allow for the customized IVSAWS database application to be run at any site without having to purchase a separate site license. The software costs are shown in Table 3.0-1.

Operating System	Cost (PC)	Cost (workstation)
Dos 6.0	~$50	n/a
Workstation OS	n/a	$500 - 1000
Database Software		
Foxpro 2.5	~$350	*
developers kit	~$495	*
dBase IV	~$500	$900 - tbd
compiler kit	~$495	tbd
Oracle 7 (+ developers kit)	~2300 - $3500	~$14,000
C++		
	$200 - $800	$950 - $4500

* - not available until fourth quarter of 1993

Table 3.0-1 - Development Software Costs

Automapping, to provide coordinates for phoned in incident locations, may need to be purchased. The scope of the coverage, however, is a limiting factor in that most cities are currently mapped but most rural maps have not been generated. The highway performance analysis branch for the Federal Highway Administration's (FHWA) office of planning and environment in Washington, D.C. should have national highway planning network map scaled to 1:100,000. The FHWA map could provide a source for an IVSAWS database. Third party vendors supply geopositional software that utilizes digital maps and provides Lat./Long. equivalents to locations selected via mouse positioning or address selection. Currently there is no mile marker overlays that can be used with a software system, however, the FHWA database may provide the mile marker information. Software systems cost $3,000 (approx.) with the mapping database varying per county from $5,000 (for Imperial County CA) to $15,000 (for Los Angeles, Orange, Ventura, and San Bernadino counties - one package).

3.1 IVSAWS Application Software

The IVSAWS applique will coordinate incoming information from the IDP, alert broadcasts to drivers, interim IVSAWS information management (the incident message database). The IVSAWS management program should be menu driven with selections to allow for communication parameters to be established and modified, data to be backed-up to a tape drive, reports to be generated, preplanned incidents to be entered using a calendar application, and the execution of the incident message subprocess. The management program is the primary message handler that aids the operator in generating, sending and storing IVSAWS messages.

Communications Interface

The communications interface selection will bring the operator into a subprocess that will allow for the setting up and modification of the communication links. The links consist of the data interface to the IVSAWS Deployment Personnel (IDP) hardware, and the data interface to the hardware used for getting incident information out to the driver. The subprocess will provide a summary table indicating the current status of each interface.

Data Back-up

Data will be automatically collected and stored within the internal hard drive. The data back-up subprocess will provide for the backing up of the data onto a magnetic tape.

Report Generation

Data reduction and or report generation will be provided for all of the stored message information (data message traffic and incident messages generated within the incident message subprocess). The parameters for reduction will include: messages to and from the IDP, messages sent to the drivers, incident type ID, date range, time range, by IDP ID, priority, incident message number, area, and roadway location. The subprocess will provide for both on or off-line reduction. Reports will be stored on disk, with the option to print as part of the menu selections.

Calendar

The calendar selection will allow the operator to generate a message for a pre-planned event such as road closures, road work, parades, etc.. The message will be built ahead of time with the operator manually entering the AOC information. The operator can then assign a date and time that the message is to be transmitted. The operator will have the power to set the reminder flag or suppress it at any time. The selection will allow the operator to view all pre-planned event messages by week, and by month. Once a message has been entered and a date and time associated with it, the operator will be automatically notified when it is time to send the message. The message will be pulled out of the database and displayed allowing the operator a chance to modify the message as well as to suppress transmission if the event is not to take place.

Incident Message

The IVSAWS system will constantly monitor the IDP communication interface so as to notify an operator of an incoming incident. Notification will include a audible sound and the incident message subprocess is automatically started. If an incident is called in over the phone, the operator will be able to manually start the incident message subprocess. The incident message subprocess will prompt the operator for fields, such as alert status, priority, type information, etc. as defined in the functional requirements document, in order to complete an advisory message. Data collected from the IDP: AOC coordinates and shape, IDP zone identification, zone location, data quality, and community segment will be automatically fed in from communication lines. If the data is not sent in via the communication links, the operator should have the capability to manually enter in all data. System time and date should also be automatically attached to each incoming IDP message and each outgoing message to the drivers. Incident messages, the textual portion of an IVSAWS message report, will be stored, each with a unique message ID number associated with it. The operator can select an incident message using the associated ID number or a key word search. If more data is required with a message (e.g. how long is the incident expected to last) the program shall prompt the operator for input.

4.0 IOC Hardware Configuration and Cost

The IOC requires a minimum hardware suite to perform its function. The IOC will be loaded with communication, database, operating system and windows software as a minimum. As functions are added to the IVHS the IOC may be joined with a larger system or functions will be added to the IOC hardware. The IOC hardware should be selected with the final IVHS configuration having been considered. A stand-alone IOC implementation will require the following minimum configuration for a PC Based system, Table 4.0-1, and for a UNIX Workstation based system, Table 4.0-2. Figure 4.0-1 shows the configuration of the IOC hardware station. Finally, Table 4.0-3 shows the expected communication connections.

PC Hardware Description	cost
IBM PC/Compatible 80386 DX 33MHz w/256k Cache, Math Co-Processor Socket, 4 MB of RAM, 100 MB Hard Disk (250 MB Recommended), 1.2 and 1.44 MB Floppy Disk Drives, 2 Serial and 1 Parallel Ports, Super VGA Card with 1 MB RAM, Super VGA .28 dp Monitor, 101 Key Enhanced Keyboard, Mini Tower Case w/230W Power Supply Microsoft Compatible Mouse, MS-DOS 5.0, Windows 3.0	$ 1200.00
250 MB Tape Backup System with Tape Cartridge	$ 250.00
HPIIP Laser Printer or equivalent	$ 750.00
Ethernet Interface Card (16 Bit)	$ 150.00
9600 bps Modems (IDP & FM)	$ 300.00
Total Cost	$ 2650.00

Table 4.0-l PC Based IOC Hardware Cost

UNIX Workstation Hardware Description	cost
Workstation 33 - 40 MHz Processor, 16" -19" Monitor, 16 MB RAM, 425 MB hard disk, 1.44 MB drive, Ethernet/ 2 serial/l parallel	$10,000,000 $17,000.00
Tape Drive (for workstation)	$2000.00 $3000.00
HPIIP Laser Printer or equivalent	$ 750.00
9600 bps Modems (IDP & FM)	$ 300.00
Total Cost	$ 13050.00 $21 050.00

Table 4.0-2 UNIX Workstation Based IOC Hardware Cost

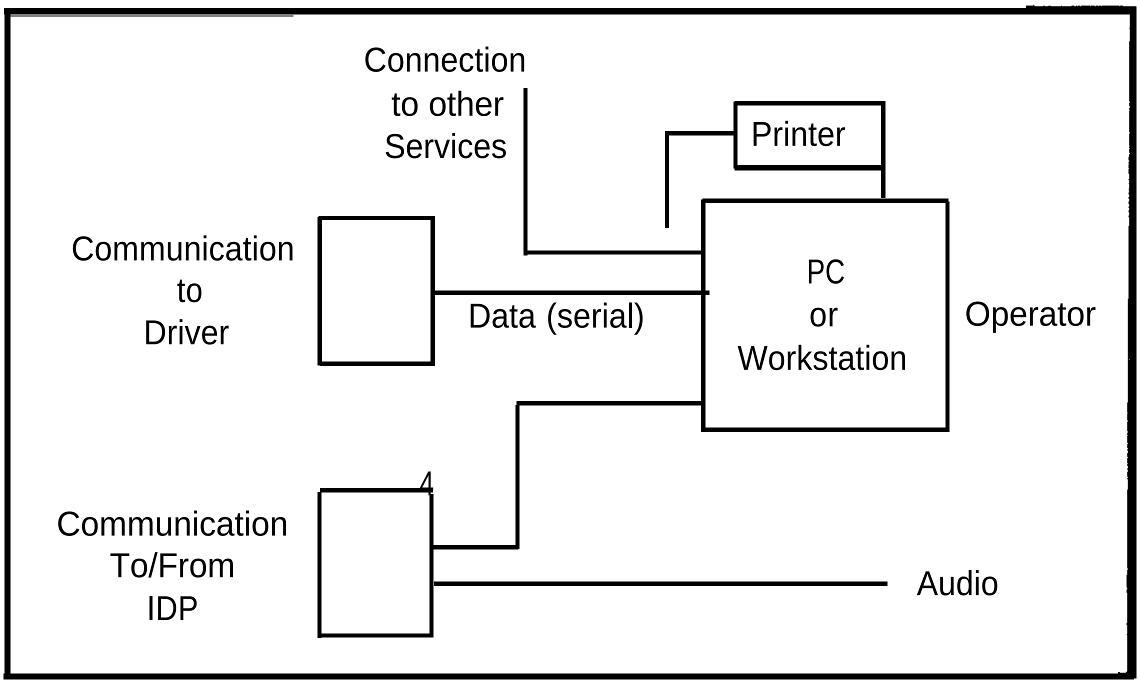


Figure 4.0-I IOC Hardware Diagram

Equipment/Application	Connections	Qty	Notes
Operator Workstation			
Printer	Parallel	1	
IDP communication	RS-232/RS-422	1	modem
Driver communication	RS-232/RS-422	1	if not using RBDS/SCA -
RBDS communication	RJ-11 from modem	1	requires **a** modem (internal or external)
SCA communication	RJ-11	1	requires special line from local phone co.
SAP communication	RJ-11	1	see SCA
Voice Communication			
Phone station w/headset and speaker option	RJ-11	1	phone connection for operator (2 - 4 lines)

Table 4.0-3 IOC Communication Connections

5.0 IDP-IOC Interface

Two options exist for the implementation of IDP-IOC communicatit 1) direct IDP-IOC communication and 2) IDP-IOC communications rout, through existing agency communication centers (e.g., police dispatch). A present, Option #1 appears to be most promising due to observations made during the IVSAWS Deployment Community Interviews; at present, a direct IDP-IOC communication implementation has a cost and coverage disadvantage. With respect to cost, the postulated rural deployment agencies utilize of wide range of communication equipment (e.g., low-band VHF, hi-band VHF, trunked systems, cellular telephone). Inter-agency communication is almost nonexistent. If direct IDP-IOC communication is to be supported with current agency equipment, the IOC will require a diverse, and therefore expensive, communication suite. Alternatively, a standardized IDP-IOC communication interface implementation will reduce IOC costs at the expense of IVSAWS deployment agencies which will need to purchase the standardized communication hardware. Coverage is also an issue; unless the standardized implementation utilizes an existing communication system backbone with adequate coverage, (e.g., repeater network), additional costs will be incurred to provide or expand coverage to regions of the rural transportation environment which can receive the most benefit from the application of IVSAWS.

If direct IDP-IOC communication is implemented, the IDPs will call in information, voice or data, to the IOC. When the IDP is using data, the controller will allow message generation prior to call-in. The IDP will then call-in and transmit the data to the IOC. There is no need for the IDP to speak with the IOC operator in this configuration. The IDP will also have a voice connection to the IOC operator. The IDP may place a voice call to the IOC operator when the situation to be reported is not completely supported by the pre-arranged incident report forms. The IOC operator will also be capable of reaching all IDP's via voice for clarification of incident reports. Therefore, it is expected that there will be two communication lines to each IOC operator station, one voice line and one data line (directly to the computer). When operational, Iridium (see END C-1-1) will be an attractive implementation of direct IOC-IDP communication due to its global coverage and low infrastructure costs (satellites already in place). However, initial channel leasing and end-user equipment costs may be prohibitive to most deployment agencies.

6.0 IVSAWS Transmitter

System Architecture #1 (Narrowband - GPS)

The Narrowband-GPS architecture requires the construction of new 220-222 MHz base stations to provide coverage for IVSAWS broadcasts. Base stations located at or near a regional IOC could be tied to the center by wire or optic fiber. When IOC-base station separation prohibits the use of a direct connection, dedicated telephone service could be used to link the station and IOC provided the desired base station site has access to the service. However, in many instances, it will be desirable to locate base stations on mountaintops or at other geographically advantageous locations in order to maximize coverage and minimize the number of base stations required to provide acceptable IVSAWS service. In these instances, co-locating IVSAWS base stations with microwave repeater sites appears attractive for the following reasons: 1) the repeater sites are usually selected to maximize coverage and will therefore provide good IVSAWS coverage, 2) power is available, and 3) the microwave links can be used to link the IOC and base station. Figure 6.0-l shows an architecture using microwave links.

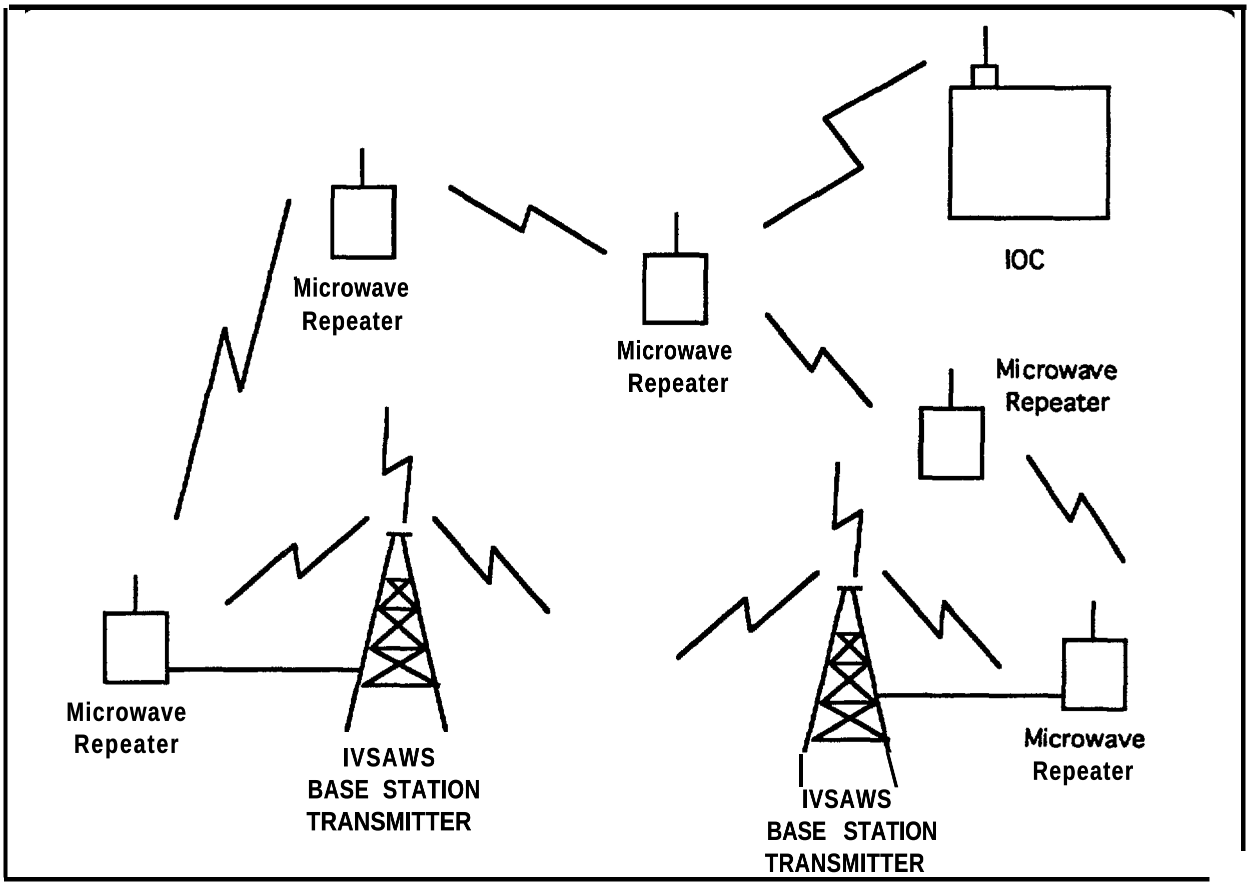


Figure 6.0-1 IOC-base station transmitter links using microwave repeaters.

The cost of each base station can be subdivided into the following elements:

- Equipment
- Installation
- Maintenance

Equipment costs are summarized in Table 6.0-l. It should be noted that the costs listed are for unit quantity. Significant cos reductions (>50%) can be expected with large quantity purchases.

Base Station Component	cost
8-Channe; GPS Receiver with antenna and Cables	**$40,000**
200W 220-222 MHz Power Amplifier	**$20,000**
B/4 - Shifted Differential QPSK Modulator	**$27,000**
Antenna	**$10,000**
Controller (80386 PC)	**$ 2,000**
Accessories	**$ 2,000**
Total Cost	**$101,000**

Table 4.0-2 Base Station Hardware costs

The cost of installation and checkout of the equipment at the sites is estimated to be $30,000 per site. Maintenance is estimated to cost $5,000 per site per year.

System Architecture #2 (RBDS-PINSIGPS)

The FM transmitters will be receiving their IVSAWS drive from the RBDS sideband sent from an FM station. The FM station houses the RBDS encoder that will put the message on the sideband of the signal. The encoder receives the information for transmission directly from the IOC system. To prevent large time delays, a direct phone line connection from the IOC system to each of the FM stations will be required (no delays will be added due to setting up a connection via the regular dialing technique).

APPENDIX T:
IVSAWS RETROFIT ANALYSIS

This appendix identifies commercial off-the-shelf (COTS) hardware and software available to conduct retrofit operations for IVSAWS implementation.

1.0 Introduction

The purpose of this report is to identify the requirements to retrofit a vehicle with hardware that will provide the In-Vehicle IVSAWS functionality. This analysis includes the new vehicle and retrofit vehicle configurations, cost data for the individual components, and issues which will be decided at a future date.

1.1 Architecture Review

The IVSAWS System Architecture Analysis (Task C, Subtask 1; documented in ENB C-l-l) yielded two promising system architectures which can implement IVSAWS at different levels of cost and functionality. System Architecture #l employs a new narrowband communication link operating in the 220-222 MHz band supported by Global Positioning System (GPS) area of coverage (AOC) control. System Architecture #2 utilizes existing FM radio stations to broadcast IVSAWS alerts via the Radio Broadcast Data System (RBDS). GPS or other geolocation systems (e.g., Position Information Navigation System (PINS)) can be used to control the AOC.

Of the two architectures, the RBDS system is most ammenable to a vehicular retrofit for the following reasons:

1) When utilizing PINS AOC control, the retrofit unit will require, minimally, two external connections - a FM signal input from the existing car radio antenna, and prime power (possibly from a cigarette lighter adapter)

2) RBDS is a standard

3) RBDS radios are presently being manufactured (European versions)

Two of the three retrofit options presented in this ENB are derivatives of the RBDS system architecture.

2.0 Integrated System - RBDS-PINS

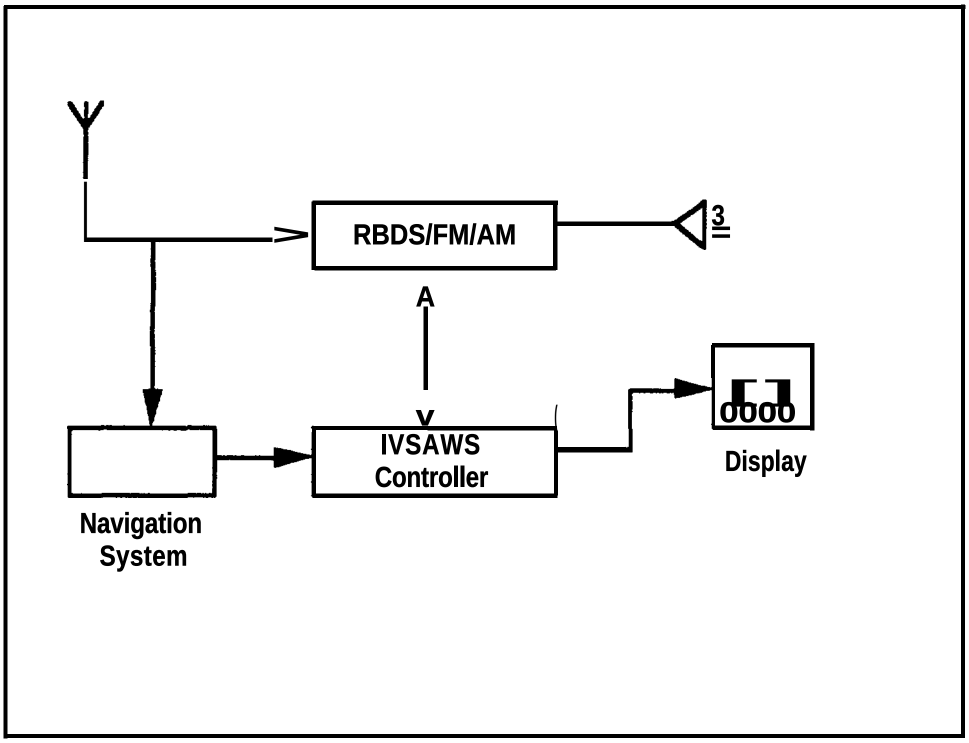


Figure 1 - In-Vehicle Block Diagram

The hardware components for the baseline non-retrofit RBDS system, shown in Figure 1, are anticipated to consist of an RBDS/AM/FM receiver, a navigation system, a display unit and an IVSAWS controller. The location of the hardware will be vehicle dependent, however, the receiver, controller, and display unit shall be located within the drivers compartment. The display unit should be positioned within an acceptable human factors range of the driver. The navigation system need not be accessed by the driver, therefore, its location within the vehicle is not a critical factor. The In-Vehicle IVSAWS hardware positioning shall be left as design decisions for the vehicle engineers.

Minimum hardware components required for the baseline IVSAWS controller:

microprocessor (286 or better)
D/A converter
12 VDC power supply
3 serial ports
audio out (Left and Right)

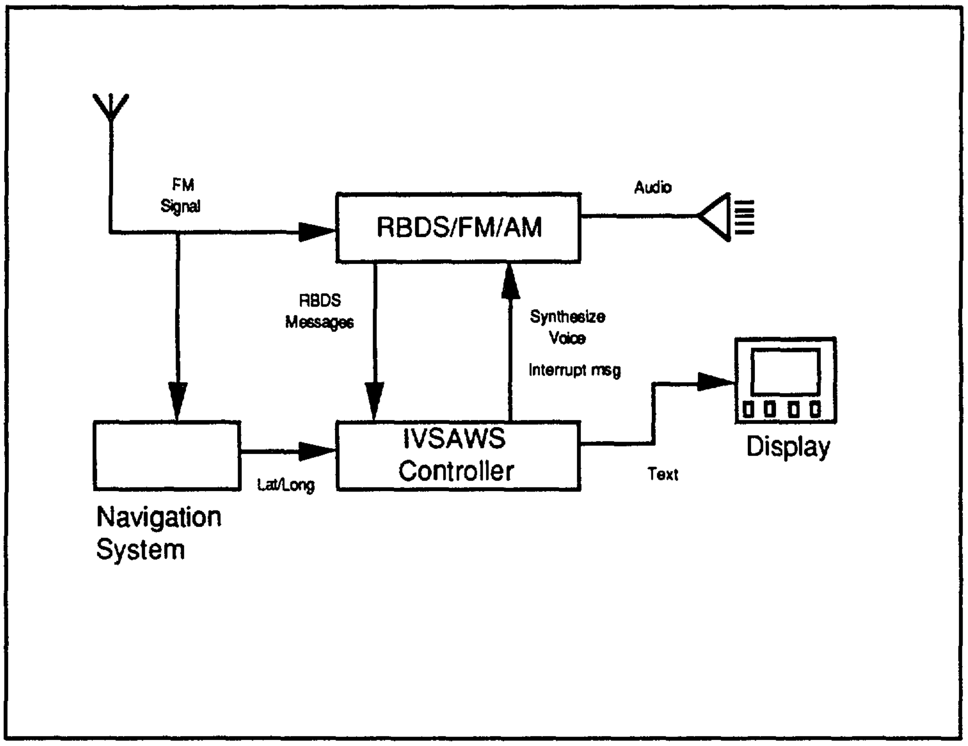


Figure 2 - In-Vehicle Information Flow

Data flow between the In-Vehicle system units shall be as shown in Figure 2. The incident information will be received by the RBDS receiver (see IVSAWS architectural trade-off study) which shall forward the message information to the IVSAWS controller. The RBDS receiver shall not compromise its regular functions and continue to display non-IVSAWS information being sent to it by the FM station. The navigational system determines the location of the vehicle by means of FM triangulation (see the IVSAWS architectural trade-off study) and sends position information to the controller. The controller determines when the driver should be notified based on driver inputs (button selections made from the display unit), message type, and vehicle location. Once it is determined that the driver should receive the incident alert, the controller shall forward an interrupt, and voice to the RBDS receiver.

The incident message shall be sent as synthesized voice to the RBDS receiver and as text to the display unit. The RBDS receiver should be equipped with an auxiliary port to accommodate the voice information from the controller. An assumption has been made that the RBDS receiver comes equipped with a serial port. The RBDS receiver serial port is expected to send the RBDS message data to the IVSAWS controller. The RBDS receiver serial port is expected to receive start and stop interrupts from the IVSAWS controller to indicate that audio information is available for broadcast on the speaker system.

The driver interaction with the IVSAWS consists of defining the information to be heard and displayed, hearing the audio information, and viewing the information on the display screen. The display unit shall provide keys to allow the driver to make Driver Alert Warning Subsystem (DAWS) selections. The commands to be implemented by the DAWS are beyond the scope of this IVSAWS contract.

3.0 Retrofit Systems - System Architecture #2 (RBDS)

Drivers who would like to have IVSAWS capabilities can outfit their vehicle with only a slight modification to the complete RBDS architecure. Figures 3 and 4 show a compromise to the intergrated RBDS approach which can be made for retrofit installations without the need for a RBDS capable receiver. There are at least two retrofit options to consider. One option is to have a separate controller, display and navigational unit, the other option is to have the functional capabilities of the display and the navigational unit incorporated within the IVSAWS controller unit.

3.1 Retrofit Option 1

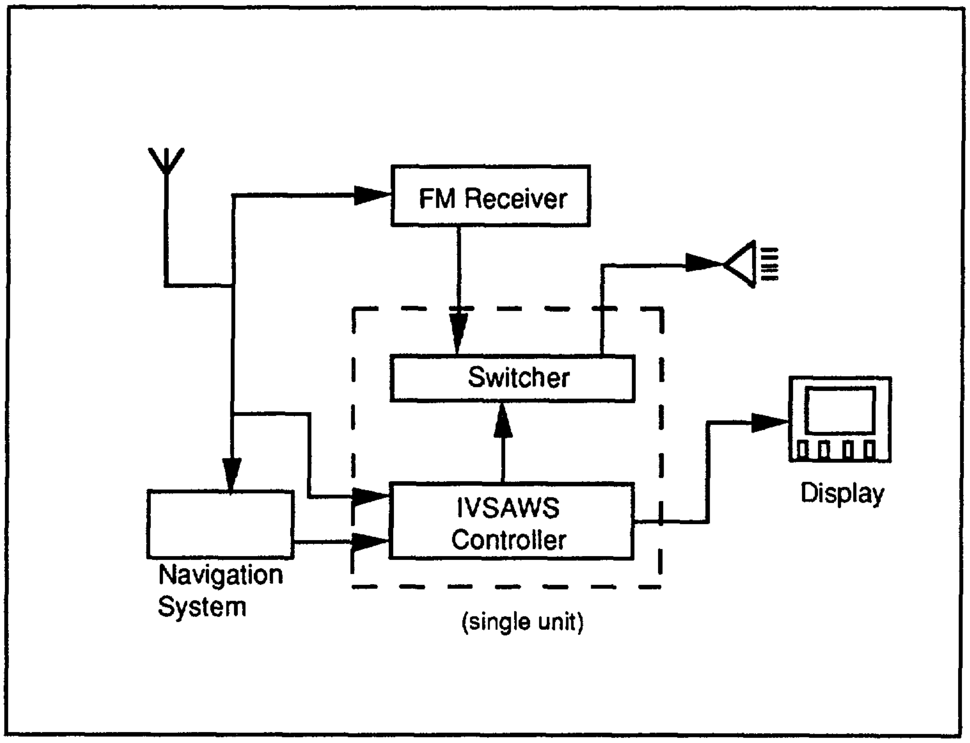


Figure 3 - In-Vehicle Retrofit Diagram
Option 1

The first option is to have separate pieces of hardware for the navigational unit (PINS or GPS), the display and the IVSAWS controller. Figure 3 shows the IVSAWS retrofit installation requirements. The IVSAWS controller should be manufactured to contain an FM receiver with RBDS scanning capabilities. The controller would be spliced into the existing antenna cable to allow monitoring of the RBDS subcarrier(s) for IVSAWS data. A switcher, located within the controller, shall provide entertainment output suppression while alert information from the IVSAWS is being broadcast to the driver.

The hardware required for an IVSAWS retrofit system (option 1) is as follows:

- FM (or AM/FM) receiver
- IVSAWS controller (with scanning RBDS/FM receiver) unit
- Switcher (part of the IVSAWS controller unit)
- Navigational unit
  The PINS system should be marketed as part of the system due to its reasonable cost and the ease in installation (no external antenna required)
- Display Unit (after market)
  Selection buttons located on the front of the unit

For vehicles which have a geopositional location device (such as GPS) already installed, the PINS navigation system would not need to be purchased. The communication cable between the IVSAWS controller and the navigation unit, however, will still be required. Design of the IVSAWS controller should accommodate position information from several navigation systems, for example, GPS and PINS. This will allow the IVSAWS to accept position information from different manufacturers equipment in different formats.

For vehicles with both front and rear speakers, the switcher shall have control of the front speakers for broadcast of the IVSAWS alert information. The switcher shall not control the rear speakers unless they are the only speakers available in the vehicle, a warning should be included to accommodate the many varieties of amplifiers on the market. There will be a slight loss in audibility of the IVSAWS information being delivered to the driver. The broadcast entertainment, still playing on the rear speakers, is not expected to lessen the impact of the IVSAWS information. Coincident with the audio broadcast will be a textual information display of the IVSAWS information broadcast to the driver. This will allow the driver to read the broadcast IVSAWS alert information which allows more than one opportunity to comprehend the alert.

Minimum hardware components required for the IVSAWS controller (retrofit option 1) are as follows:

microprocessor (286 or better)

FM receiver scanning and RBDS capable

D/A converter

12 VDC power supply

audio switching components

2 serial ports
audio in (Left and Right)
audio out (Left and Right)
coaxial connection

3.2 Retrofit Option 2

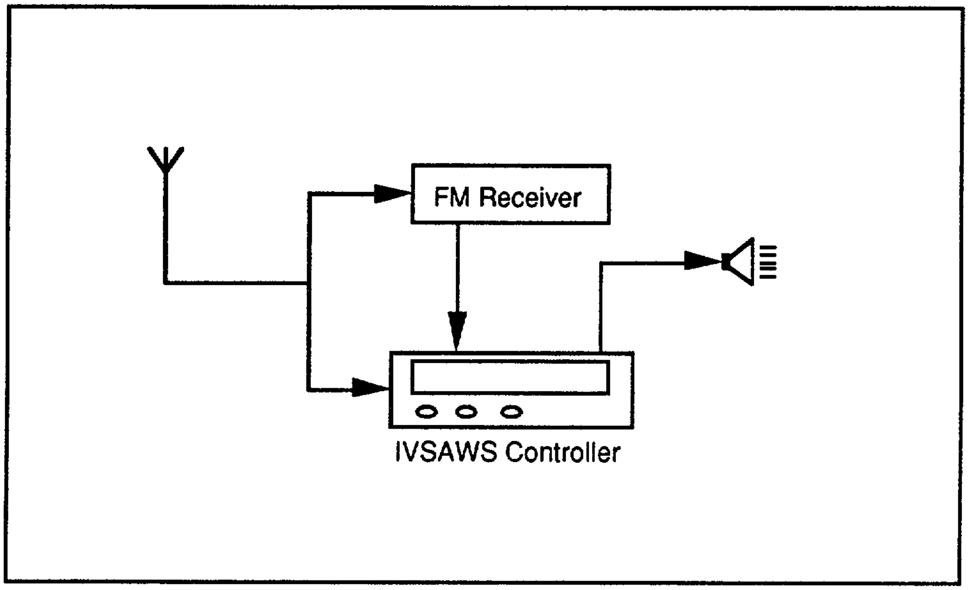


Figure 4 - In-Vehicle Retrofit Diagram
Option 2

Another retrofit option is to have a single IVSAWS controller unit which would contain the display and the navigational capabilities. The controller unit would have the same FM/RBDS scanning capabilities, and entertainment interrupt as the controller in option 1. The navigational source and display unit, however, would be contained within the unit instead of externally as they are for retrofit option 1. Another added component to the controller would be an internal speaker for transmitting IVSAWS messages to the driver. The hardware required for an IVSAWS retrofit system option 2 is an FM (or AM/FM) receiver, and an IVSAWS controller unit.

Minimum hardware components required for the IVSAWS controller (retrofit option 2) are as follows:

- microprocessor (286 or better)
- FM receiver scanning and RBDS capable
- D/A converter
- 12 VDC power supply

- navigational unit (PINS)
- operator entry buttons/keys
- audio switching components
- speaker
- display - two lines of up to 16 characters a line
- 1 serial port
- audio in (Left and Right)
- audio out (Left and Right)
- coaxial connection

3.3 Installation - RDBS System Architecture

The installation of the retrofit components will assume an AM, FM, or AM/FM receiver exists in the vehicle. The components to be installed will consist of the IVSAWS controller, the display unit, and the navigation system. All components shall be powered by the 12 VDC car battery. The navigation system should be installed in location similar to that used by remote CD changer. The IVSAWS controller and display unit are to be located in the main passenger compartment of the vehicle. For retrofit option 1, the controller unit need not be accessed by the driver so it should be mounted under the dash, or in some other out of the way location. The display unit should be mounted on top of the dash within the drivers forward field of vision. The distance should not be more than that for the car stereo for two reasons; the driver must be able to read the text data and must be able to reach the selection buttons located on the unit. The IVSAWS controller, for retrofit option 2, contains the display so the location of the unit should be in a similar location as the display unit for the retrofit option 1 configuration.

Tables 1 and 2 indicate the type of connections which are anticipated for the in-vehicle installation. The vehicle antenna will be spliced into and routed off to the navigation system, and the IVSAWS controller, for reception of FM signals. The audio output from the current entertainment system will be routed to the controller unit (containing the switcher) and from there routed to the front (if there are front and rear speakers) speaker lines. For retrofit option 1, there shall be communication cables routed between the navigation system and the controller. The display unit shall have its own cable (terminated inside the unit so as to prevent accidental disconnects) that will need to be connected to the controller unit. Retrofit option 2 contains both the display and the navigational components, however, connections shall be available should an external connections be desired.

UNIT	CABLE	CONNECTOR
Navigation System (from Antenna)	Coaxial	BNC
Navigation System (to Controller)	Shielded 8-pair 20 AWG	RS-232 (DB-15 pin)
Controller (from Antenna)	Coaxial	BNC
Controller (switcher) (to FM receiver)	Speaker Wire	TBD
Controller (switcher) (to Speakers)	Speaker Wire	N/A
Display Unit (to Controller)	Shielded 8-pair 20 AWG	RS-232 (DB- 15 pin)

Table 1 - Cables and Connections Retrofit Option 1

UNIT	CABLE	CONNECTOR
Controller (from Antenna)	Coaxial	BNC
Controller (to FM receiver)	Speaker Wire	TBD
Controller (to Speakers)	Speaker Wire	N/A

Table 2 - Cables and Connections Retrofit Option 2

3.4 Cost - RDBS System Architecture

The cost of the IVSAWS shall be determined by the manufacturers of the system components. The required components for the baseline system and their estimated costs are listed in Table 3 - Baseline Equipment Costs. The cost of the hardware and the installation of the retrofit system is listed in Tables 4 and 5. The cost of the installation was estimated by obtaining quotes from installers based on the similarity that exists between the installation of the IVSAWS system and an installation of a cellular radio or a multi-compact disk changer, receiver, and amplifier.

Equipment	cost
RBDS	TBD
IVSAWS Controller	TBD
Display Unit	$50.
Cables	$30.
Total Cost	TBD

Table 3 - Baseline Equipment Costs

Equipment	Cost
IVSAWS Controller + switcher	$
Display Unit	$50.
Cables	$30.
Navigational Unit (PINS)	$200.
Installation	$50. - $80.
Total Cost	TBD

Table 4 - Retrofit Equipment and Installation Costs
Option 1

Equipment	cost
IVSAWS Controller	TBD
Cables	$10.
Installation	$50.
Total Cost	TBD

Table 4 - Retrofit Equipment and Installation Costs
Option 2

3.5 Issues - RDBS System Architecture

There are some issues that should be mentioned, assumptions made and future possibilities for the in-vehicle system considered. First, the RBDS receiver can only receive RBDS information when tuned to a FM station that is broadcasting data on the sideband. Second, the RBDS radios may not have a means for 2-way communication. Third, the RDS-TMC (Radio Data System - Traffic Message Channel protocol) technology is developed and has been tested in Europe. The RDS-TMC will be tested in the United States soon and should be considered as an IVSAWS standard. Finally, the amount of noise expected within a vehicle could warrant the use of RS-422 vice RS-232.

When the driver is tuned to a station not transmitting the IVSAWS information, the IVSAWS information will not be received by the driver. Option one, consideration should be given to the RBDS receiver scanning the FM band for IVSAWS information. Received IVSAWS information could then be sent to the IVSAWS controller to determine the information importance to this driver. Option two, consideration should also be given to providing the RBDS/FM receiver within the IVSAWS controller. The second option allows a single IVSAWS controller to be manufactured for both the new and retrofit vehicles which should provide a lower cost IVSAWS controller to be developed.

The IVSAWS controller with RBDS/scanning and switcher 2-way communication is only possible if the RBDS radio provides a means of 2-way communication. For the Michigan DOT DIRECT project, the three automobile manufacturers are partners, and part of the criteria for their vehicles' RBDS receivers is that they have an RS-232 connection (for data transfer) and an auxiliary port for the audio. It is unknown, however, if this configuration is planned for radios marketed to the masses. If the RBDS receivers do not have a standard 2-way communication interface, then communication with the radio would be impaired and there may be no way to indicate to the radio that there is external information that must be passed through. Once again this points to building an IVSAWS controller with the FM/RBDS receiving capabilities built in.

Attention should be given to using the RDS-TMC (The "Alert C" document) standard for the IVSAWS messages. This would circumvent the need to generate a new alert message and utilize the technology already generated by radio manufacturers. There are currently manufacturers of RDS ("RBDS" is the United States standard for the same technology) radios that have integrated synthesized voice and external displays for the explicit use of the TMC (Traffic Message Channel) sub process capability within the RBDS system. These systems have been used in the European community's advanced traffic testing - the DRIVE (Dedicated Road Infrastructure for Vehicle safety in Europe). Bosch and Phillips, for example, installed synthesized voice, excluding text, into their receivers used in the BEVEI and Rhine corridor projects, each part of the ACCEPT project (Germany and the Netherlands). The Minnesota Department of Transportation (MnDOT) "Trilogy Project" is testing the first TMC transmissions, in the United States, utilizing a RDS receiver from Delco. Also tested will be RDS-TMC systems from Volvo and Indikta Display Systems, Ltd., in the United Kingdom. The Indikta radio is equipped with an external display unit as is envisioned for the IVSAWS system. Manufacturers of RDS capable receivers are known to consist of Delco, Phillips, Bosch, Sony, Panasonic and others.

It is anticipated that there will be quite a bit of noise in the vehicle environment, therefore, cable shielding is required. Shielded twisted pair cable used with EIA RS-422 would be better suited to the noisy environment, however, the navigation system comes equipped with an EIA RS-232 interface. The cost of providing a converter from EIA RS-232 to EIA RS-422 could be prohibitive. Another option to circumventing the noise problem is to have the navigation system send the position message two or three times in a row.

All options should be considered for reduced cost and ease of implementation.

6.0 Retrofit Systems - System Architecture #1 (Narrowband-GPS)

Though less ammenable to a retrofit, the narrowband-GPS system architecture could be integrated into a dashboard-mount device. In order to be affordable, a highly integrated unit will be required, possibly fabricated with semiconductor technology using Application Specific Integrated Circuits (ASICs) When the market is measured in millions of units, the large volume of units to be produced makes the non-recurring investment to develop the semiconductor masks and processes reasonable.

If the vehicle to be retrofit is equipped with a GPS subsystem that can export latitude/longitude data and once-per-second GPS timeticks, an IVSAWS receiver with display, control buttons, and tone generator should be producable at a $250 (approx.) cost to the cosumer. The price is based upon a comparison of the IVSAWS receiver to the projected price of emerging digital cellular telephones (DCT) ($450 after two years on market). The IVSAWS receiver and DCT receiver are of similar complexity. However, as a unit, the IVSAWS retrofit "box" should cost less since no transmitter is required, processing tasks are considerably less complex, and no voice interface is required (i.e, no microphone, D/A coverter, or A/D converter).

If the vehicle to be retrofit is not equipped with a GPS subsystem, a GPS receiver will need to be incorporated into the integrated IVSAWS dashboard-mount device. The cost of such a unit is estimated to be $450.

APPENDIX U:
IVSAWS ANTENNA PERFORMANCE ANALYSIS

This appendix describes the performance of several antenna architectures that are capable of supporting IVSAWS narrowband communications and GPS coverage control in accordance with IVSAWS waveform design #l.

ANTENNA PERFORMANCE ANALYSIS

The proposed IVSAWS architecture will add two electromagnetic links to a modern vehicle containing several simultaneous, wireless systems. It will be necessary then to significantly reduce the size of any added antenna or to share these new links with the existing vehicle antennas. Focusing on this issue including cost and performance of the new links is the purpose of this analysis. A vehicle antenna may represent a personal ornament so its general appearance must not be neglected. Radomes and mounting hardware fall into this category. It is out of the scope of this analysis to determine the public acceptance of each design although the success of an antenna may be determined more from its esthetics than from its engineering performance.

For navigation a GPS satellite link is easy to implement on a vehicle. Flat planar elements are becoming readily available from a variety of manufactures. This antenna should be a dedicated element mounted on the rooftop as in Figure 1. The technology that provides a small profile is the microstrip patch. The antenna has omnidirectional patterns in azimuth with peak gain directed away from the earth. The polarization is right hand circular operating from 1565 to 1585 MHz. Table 1 lists the specifications of a typical Ball Communication System Division GPS antenna. Eventually, automobiles may come equipped with a GPS antenna; so that, its cost would become negligible.

The other link, VHF band, 220-222 MHz, will need a larger antenna if high efficiency and low costs are desired. Typically quarter wave monopoles are simple to build and their radiation resistance is compatible with most RF systems. An existing FM vehicle antenna is this type. It would seem possible to share the FM antenna with the IVSAWS VHF band. At 220 MHz the antenna would be close to a half wavelength nominally 30". But an existing FM antenna would vary in its actual length from vehicle to vehicle due to retractable elements and manufacturing tolerances. Given that the length might vary from as little as 15", a -6 dB impedance mismatch degradation in gain would be expected. Figure 2 shows a plot of loss length variations given a 30 " monopole antenna matched at 220 MHz. Added loss can also be attributed to scattering and de-polarization from the roof; window supports or any nearby metallic surroundings. FM band losses are reduced by high power circular polarized transmissions. Similar solutions for the IVSAWS could be adopted. Another approach might be to share an existing cellular telephone antenna. This antenna is less likely to vary in length and since cellular antennas are generally mounted on the roof, better performance results.

The same antenna can be used for dual frequency operation. This is done by a diplexer. A filter arrangement makes it possible for two radios to channel energy through a single radiating structure without interfering with each other. Simply hooking the two radios in parallel would cause random loss. The diplexer isolates the radios thus improving radiation efficiency. An impedance matching circuit would also help improve performance. The antenna impedance for the dual band monopole will be matched at its nominal frequency, but at 220 MHz the radiation resistance will be reactive and not necessarily 50 ohms. A matching circuit would be included with the diplexer as in Figure 3.

A small discreet antenna is another option for the VHF band. A miniature self matched antenna would remove the diplexer and the uncertainty of sharing an unknown antenna with the system. The main disadvantages include engineering development, performance and material costs. The antenna department has experience designing small antennas. Specifically a dielectric disc loaded monopole could be used. The disc profile is planar like the GPS antenna so the two could be packaged together. The patterns are omni in azimuth and a GPS antenna mounted on top would not interfere with performance. The disc diameter is proportional to the operating wavelength. It can be reduced significantly by shorting inductive posts symmetrically at the substrate edge or by increasing the relative dielectric constant of the substrate between the discs. Currently ceramic substrates are available with high dielectric. It should be possible to make a disc less than 4 inches in diameter. However, the cost of the ceramic makes this approach less desirable. A lower cost and lower dielectric substrate, several layers of fiberglass circuit board, yields disc diameters of 8 inches. Also, cheaper substrate is less efficient because of the higher loss tangent and ohmic heating. Heating is overcome by increasing the plate separation to l/2 inch or greater. The cost of the disc antenna in Table 1 is based upon substrate only, additional manufacturing cost cannot be forcasted. The challenge in using a disc loaded monopole is finding a low cost, low loss, high dielectric substrate.

The complement of the electric monopole, is the magnetic monopole or loop antenna. Specifically a ferrite loaded coil can be useful for mobile communication. The advantages are the same as the disc. The drawback, like the disc, is heating loss. With the small size heating losses compete with the radiation resistance. By adding more turns the radiation resistance can be increased. At RF frequencies the effectiveness of many turns reaches a limit when displacement current flows between the windings instead of through the inductance. The radiation efficiency of a loop antenna can only be further increased by introducing a ferrite rod into the coil. The ferrite will also absorb heat so this antenna is not very efficient. The ferrite loop antenna’s main feature is its small size and low cost. The actual size, loss and cost of the antenna depend on the geometry of the coil. Measurements will be needed to research the ferrite loop further.

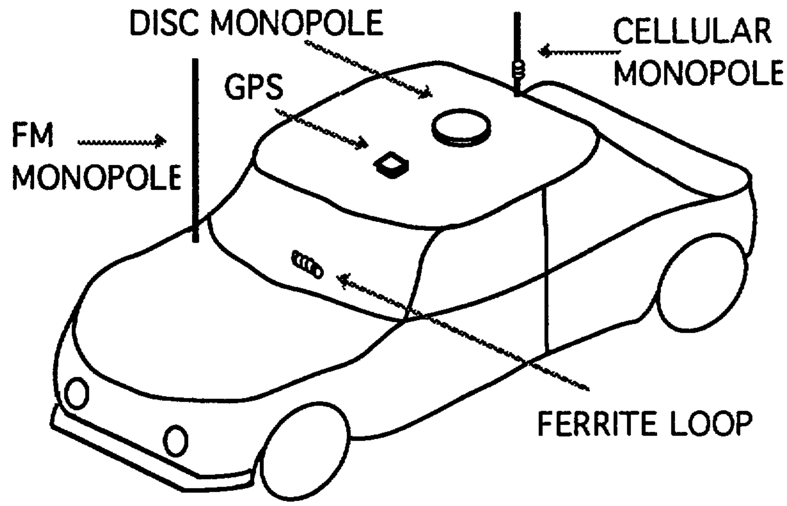
The determination of the antenna radiation patterns depends on the antenna type plus the mount location and model of the vehicle. This is most true for antennas mounted on the front or rear hoods. A +/- 5dB degradation in azimuth gain can be expected for hood mounts. The GPS antenna will be less concerned with this degradation because its gain will peak at zenith. Vertical monopoles will not necessarily peak on the horizon given a fixed length and ground plane size. The Bardeen Mitre Integral Equation method can be used to estimate the elevation pattern of a half wave monopole. It shows that the FM monopole candidate will peak near the horizon at 220 Mhz as in Figure 4. The monopole’s azimuth pattern cannot accurately be calculated subject to local geometry of the vehicle, however it will approach omnidirectional. The cellular monopole is difficult to calculate because of its loading coil near the base of the antenna. Elevation pattern measurements at 250 MHz give a good indication, Figure 5 that the cellular telephone antenna will perform well. The disc loaded monopole will also have these characteristics. The ferrite loop, a magnetic monopole, will have a complement pattern, omni in elevation and similar to Figures 4 and 5 in azimuth.

Two antenna links have been studied, GPS and VHF with the results summerized in Table 1. It suggests that many options of performance, size, and cost are available with existing technology. The cost is only an estimate using vendor quotes on materials or units in quantities over 10,000. The less costly choice is the ferrite loop antenna. Its cost can be justified only when built together on the same circuit board with the RF components. Special mounting hardware, connectors, cable, and cosmetic costs will be additional for an external mount. The best performance antennas are the dual band monopoles. The FM monopole may not be a consistent radiator because of length variation (-6 dB) and its azimuth uncertainty for hood mount +/-5 dB). The FM gain given in Table 1 of -1 dBi is for the best case only; -12 dBi is possible in many cases. This uncertainty is reduced using the cellular monopole because it is less likely to vary in length and because it can be mounted unobstructed on the roof. By adding a dipexer, the cellular user simply connects his antenna port to the IVSAWS radio in turn connected to the antenna. The GPS antenna should also be mounted on the roof for the best performance. The possibility of packaging a GPS antenna with the VHF band is promising, using the disc loaded monopole. Both planer antennas might be manufactured for less cost, as one piece, than two individual components. The final antenna choice should be weighed against the system parameters.

TABLE 1. SUMMARY OF ANTENNA CANDIDATES

TYPE	BAND MHz	GAIN dBi	SIZE inch	COST each
FM MONOPOLE DIPLEXER & connectors	88 - 108 220 - 222	-1 to -12 -1 to -12	30 x 0.1 dia	$6
CELLULAR MONOPOLE DIPLEXER & connectors	220 - 222 870 - 890	-1 4	10 x 0.1 dia	$6
DISC LOADED MONOPOLE	220 - 222	<-3	0.5 x 8 dia	$15 (POLY CLAD PCL FR204)
FERRITE LOOP & matching ckt.	220 - 222	<-10	4 x 0.4 dia	$4 (FAIR-RITE No 68 Nickel Zinc)
MICROSTRIP PATCH GPS	1573 -1577	5 dBic	2 x 2 x 0.1	$15 (BALL AN496A)

FIGURE 1 IVSAWS VEHICLE ANTENNA CANDIDATES



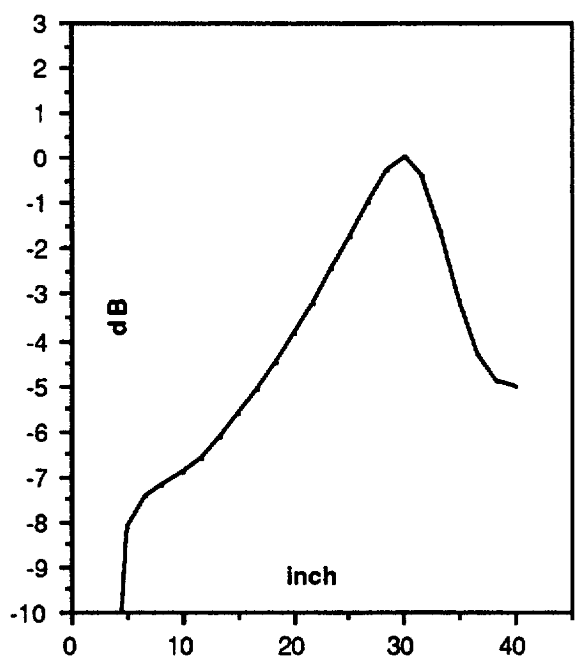


FIGURE 2 GAIN DEGRADATION OF A 30" MONOPOLE TUNED TO 220 MHz AS A FUNCTION OF LENGTH VARIATION

FIGURE 3 VHF UHF DIPLEXER AND GPS LINK

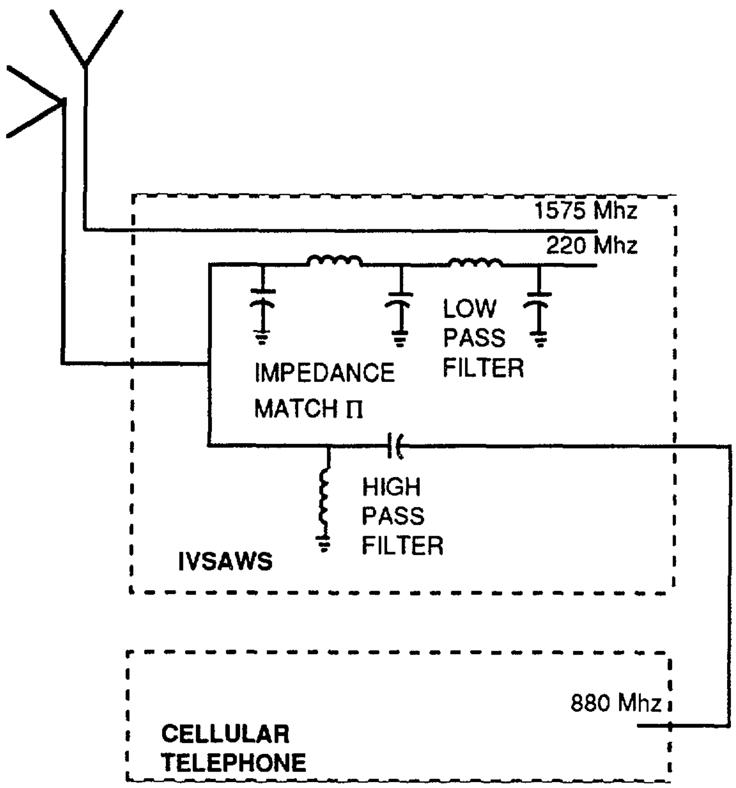


FIGURE 4 CALCULATED ELEVATION PATTERN OF A FM MONOPOLE @ 220 MHz

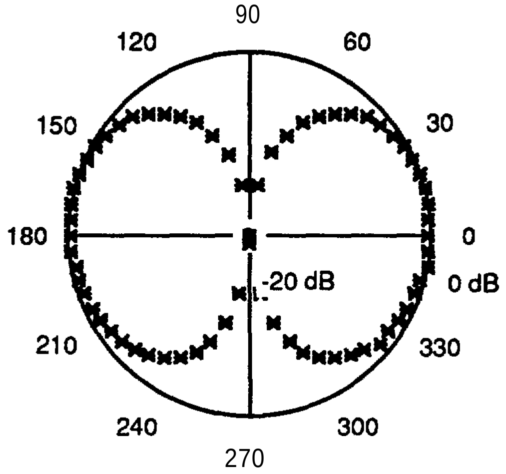
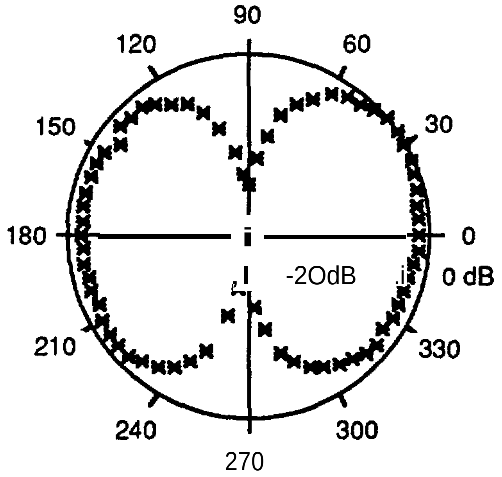


FIGURE 5 MEASURED ELEVATION PATTERN OF A CELLULAR MONOPOLE @ 250 MHz



APPENDIX V:
DESIGN CONCEPT FOR AN INVEHICLE SAFETY ADVISORY AND WARNING SYSTEM (IVSAWS)

This appendix provides a top-level functional system specification of a communication system between hazard transmitters and hazard receivers in sufficient detail to completely characterize an Invehicle Safety Advisory and Warning System (IVSA WS) in accordance with task H of the IVSAWS study effort. The IVSAWS functional system specification includes a system architecture, waveform design, and candidate IVSAWS invehicle and infrastructure implementations.

1. INTRODUCTION

The In-Vehicle Safety Advisory and Warning System (IVSAWS) is a Federal Highway Administration program developing a nationwide vehicular information system that provides drivers with advance, supplemental notification of dangerous road conditions. These warnings will occur at a point sufficiently upstream from the hazard to enable the driver to take appropriate action. The goal is to ameliorate the severity of scenarios which are particularly hazardous and have remained hazardous despite traditional crash reduction techniques such as additional mechanical signing. Primary emphasis is given to scenarios for rural settings, though most scenarios are equally valid for both urban and rural conditions.

As part of the program, a system concept for a nationwide IVSAWS was developed. The model includes one-way communication links from a network of IVSAWS transmitters to private vehicles equipped with receiver systems which can demodulate the warning broadcasts and then alert drivers. The transmitter network operates over two separate channels, one supporting advisories relevant to stationary hazard scenarios, the other warning drivers of mobile hazards. Stationary hazard broadcasts are disseminated via base station transmitters tied into regional network control stations, or IVSAWS Operation Centers (IOC). Support for mobile hazards is provided through the use of low-power transmitters installed in emergency vehicles, trains, school buses, hazardous material transports, and other high-priority vehicles.

Thus, the IVSAWS is comprised of the following major subsystems:

- IVSAWS Operations Centers
- Base station transmitter network
- Mobile transmitter network
- In-vehicle receiver systems

The following sections describe 1) subsystem architectures, 2) the operation of NSAWS, and 3) the communication protocols for the stationary and mobile hazard channels.

2. BASICS OF OPERATION

IVSAWS operation is based upon the concept of virtual warning zones established in the vicinity of roadway hazards. The zones are “virtual” in the sense that they can only be realized through the use of IVSAWS. Figure 1 depicts a virtual warning zone established around an accident site. The size, shape, and location of a virtual warning zone is broadcast from an IVSAWS transmitter (base station or mobile), received by in-vehicle IVSAWS receiver systems, and stored in receiver systems’ memory. Each in-vehicle receiver system periodically compares vehicle location to the set of virtual warning zones stored in memory. When an IVSAWS-equipped vehicle zone penetrates a zone, a driver alert sequence is initiated.

The comparison of zone location to vehicle position implies the use of a geolocation system. The proposed IVSAWS uses the Global Positioning System (GPS) to establish spatial relationships. GPS is a multi-satellite system which provides navigation and position location service to users equipped with GPS receivers. Thus, each in-vehicle receiver system employs a GPS receiver.

Under normal conditions, users of GPS can expect position measurements accuracies better than 100 meters. In many urban settings, this accuracy would not be sufficient to resolve vehicle position to a particular street. Virtual warning zone definitions would be equally vague. Thus, drivers on routes not intersecting the accident location would be warned, thereby creating annoying irrelevant alerts. In order to preserve system integrity, a differential GPS technique has been selected which can improve user accuracy to better than 10 meters (two-dimensional root-mean-squared error). Differential GPS corrects for local system errors through the use of a high-quality GPS receiver placed at a reference site which has been precisely surveyed.

Intuitively, differential GPS (DPGS) involves the comparison of position calculations derived through the GPS reference receiver with the receiver’s known position. The difference between the calculated and true position is then transmitted from the reference site over a communication link to all local GPS users. Since GPS system errors tend to be correlated for receivers separated over ranges of 200 miles or more, users could correct for position errors simply by subtracting the offset from position measurements generated by the users’ GPS receivers.

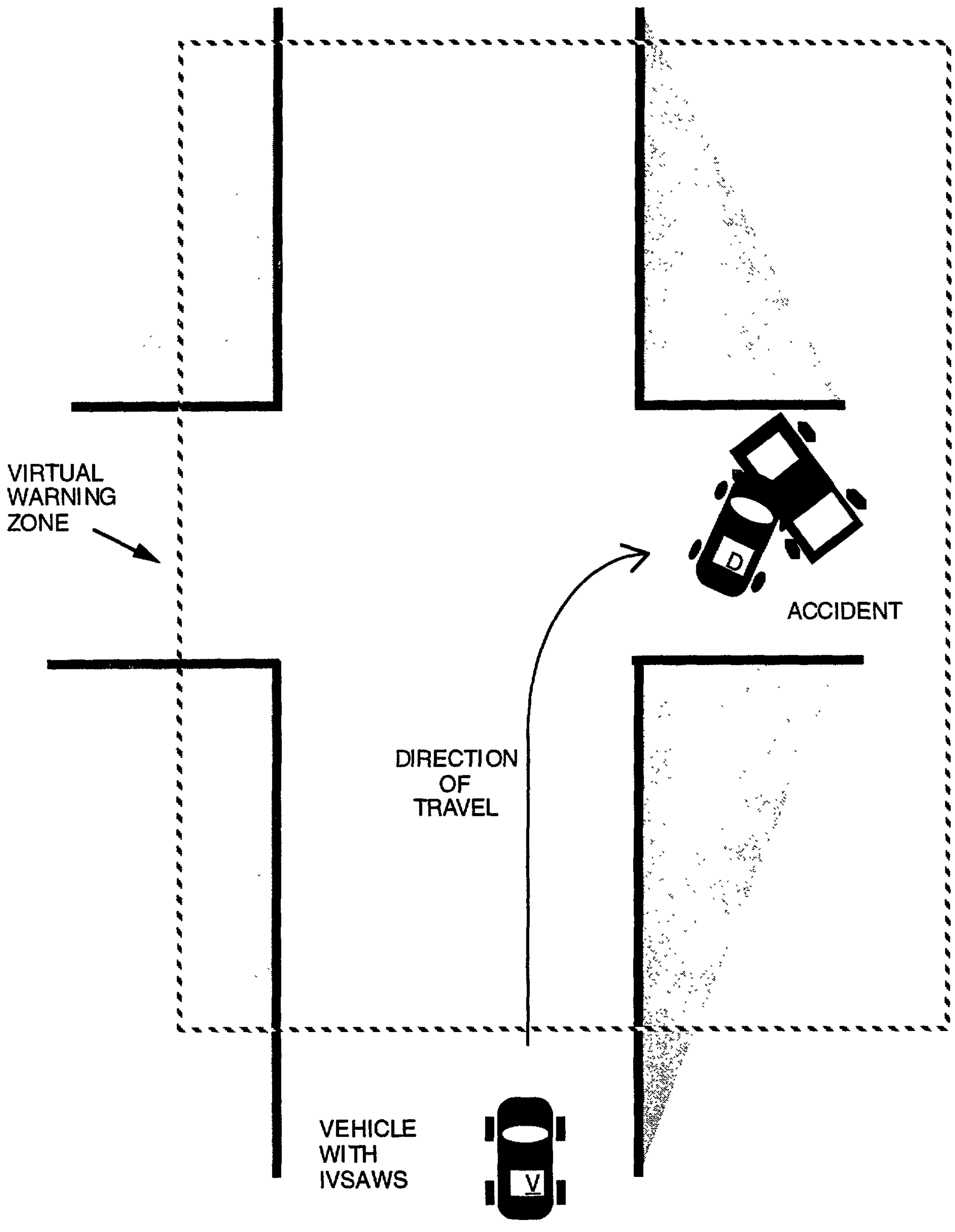


FIGURE 1. IVSAWS VIRTUAL WARNING ZONE PROJECTED AROUND AN ACCIDENT SITE.

The method described above has its limitations since it assumes that all user GPS sets utilize the same satellites as the reference receiver to make position calculation. If this condition is not met, large errors will result. Since tall buildings or mountains might block a user's view of a given satellite (especially when the receiver is installed in a vehicle), this method is not recommended for IVSAWS.

IVSAWS uses an alternate DGPS method in which statistics about each satellites' apparent range (pseudorange) and range-rate are compared to the same statistics generated using the receiver's known position. The pseudorange and range-rate corrections for each satellite in view of the reference station are broadcast periodically to all GPS users. The user systems select and apply the corrections only for the satellites used to make the local position measurement. If the reference receiver is positioned such that all satellites which can possibly be seen by user GPS systems are within view, the method will be valid.

Each IVSAWS base station transmitter includes a DGPS reference unit. The base stations transmit pseudorange and range-rate correction data interleaved with roadway hazard alert messages. Since the base stations are usually positioned at highest possible elevation in order to maximize communication range, it is probable the DGPS reference units can acquire all satellites in view of IVSAWS-equipped vehicles within the area of coverage.

3. STATIONARY CHANNEL BROADCASTS

Consider an accident site along a rural section of interstate highway. The generation of a virtual warning zone around the accident could entail the following sequence of events:

a) A motorist passing the accident site contacts a local law enforcement agency using telephone, citizen's band radio, or cellular 911 (roadside callbox or in-vehicle). The motorist informs the call-taker of the nature of the accident and provides a general description of the accident location, such as "Northbound Interstate 10 between Gila Bend and Chandler."

b) The call-taker dispatches a patrol car to the accident site. Furthermore, a telephone call is placed to the regional IVSAWS Operations Center (TOC), possibly located within a highway patrol dispatch office. The dispatch officer logs the available accident data and constructs an IVSAWS message using a computer-driver expert system. The message includes a brief description of the scenario, identifies the fact that the accident is reported, not confirmed, and defines a warning zone large enough to ensure that all drivers who might encounter the accident site are warned. In this case, the warning zone might include the entire 30mile stretch of Interstate 10 between Gila Bend and Chandler including feeder roads within 5 miles of the interstate.

c) The IVSAWS message, now a data stream stored in computer memory, is relayed to one or more IVSAWS base stations using land lines and/or radio frequency communication links. The selection of base station transmitter(s) is made by the computer-based expert system without operator intervention. When received, the message is downloaded to base station computer memory and transmission of the message begins over the stationary hazard channel. Drivers are warned of the hazard.

d) The dispatched patrol car arrives at the accident scene. Using the two-way radio within the vehicle, the officer informs his agency dispatch office of the nature of the accident, and provides a more precise accident location, possibly obtained from a GPS receiver. The officer departs the patrol car to attend to accident victims. This process takes less than 15 seconds.

e) The dispatch office informs the IOC of the refined accident location. A new message is generated which identifies that the accident is confirmed. Furthermore, the size of the virtual warning zone is condensed to a two-mile section of northbound Interstate 10 just prior to the accident site.

f) A command is issued which deletes the old warning message from the affected base station transmitter databases. Two new messages are downloaded to the base station memory, one which contains the updated accident information and one which instructs in-vehicle receiver systems to delete the old message from their database. Transmission of the new messages begins over the stationary hazard channel.

g) The accident scene is cleared. All relevant messages are deleted from base station and vehicular databases.

Thus, the generation of a virtual warning involves the following processes:

- event detection.
- notification.
- message generation.
- message transmission.
- message reception.
- event verification.
- message refinement.
- event closure.

Event verification and message refinement would not be required if the original message was the result of a report from a law enforcement officer.

A total of four communication links is required to establish a virtual warning zone around a stationary hazard:

- accident site to agency-specific communications center (e.g., police station dispatch)
- agency-specific communications cen the IOC
- IOC to base station transmitters
- base station transmitter to in-vehicle receiver system

Figure 2 shows a block diagram of the communications architecture which supports broadcasts over the stationary hazard channel.

IVSAWS has been designed to minimize infrastructure costs to municipal and county governments whose participation and support is vital to the success of the system. No supplemental communications equipment is required by field personnel, within response vehicles, or within agency communication suites. All IVSAWS-related information travels over *existing* communication links, namely VHF/UHF radios and telephone lines. Providing field personnel with GPS receivers will greatly enhance system performance, but is not required for system operation.

In order to minimize system costs, IVSAWS should also maximize use of existing communication channels to support IOC to base station transmitter communication. In urban areas, dedicated phone lines or land lines may be most cost effective, provided the IOC and transmitters are within reasonable distance of each other. However, in rural areas the separation between the IOC and transmitters could be large, necessitating the use of RF communications. Again, IVSAWS should utilize existing links if possible. For example, the Idaho Bureau of Communications maintains a network of microwave repeaters which provides state agencies with point-to-point voice communication capability over 98 percent of the state. Collocating IVSAWS transmitters with these repeaters could, in concept, enable statewide IVSAWS coverage from a single IOC provided the repeaters are equipped with modems which allow base station transmitter access to the repeater communication links.

Finally, communication from the base station transmitters to in-vehicle receiver systems is realized by a new communication link which is described in the final section of this document.

3.1 IVSAWS OPERATIONS CENTER (IOC)

The IOC is the heart of any regional IVSAWS network. The network configuration and area of coverage served by a single IOC will depend upon regional demographics. In states with relatively small populations, a single IOC may be able to support a single state-wide IVSAWS network. Conversely, states like California will likely require multiple IOCs to handle the required message traffic.

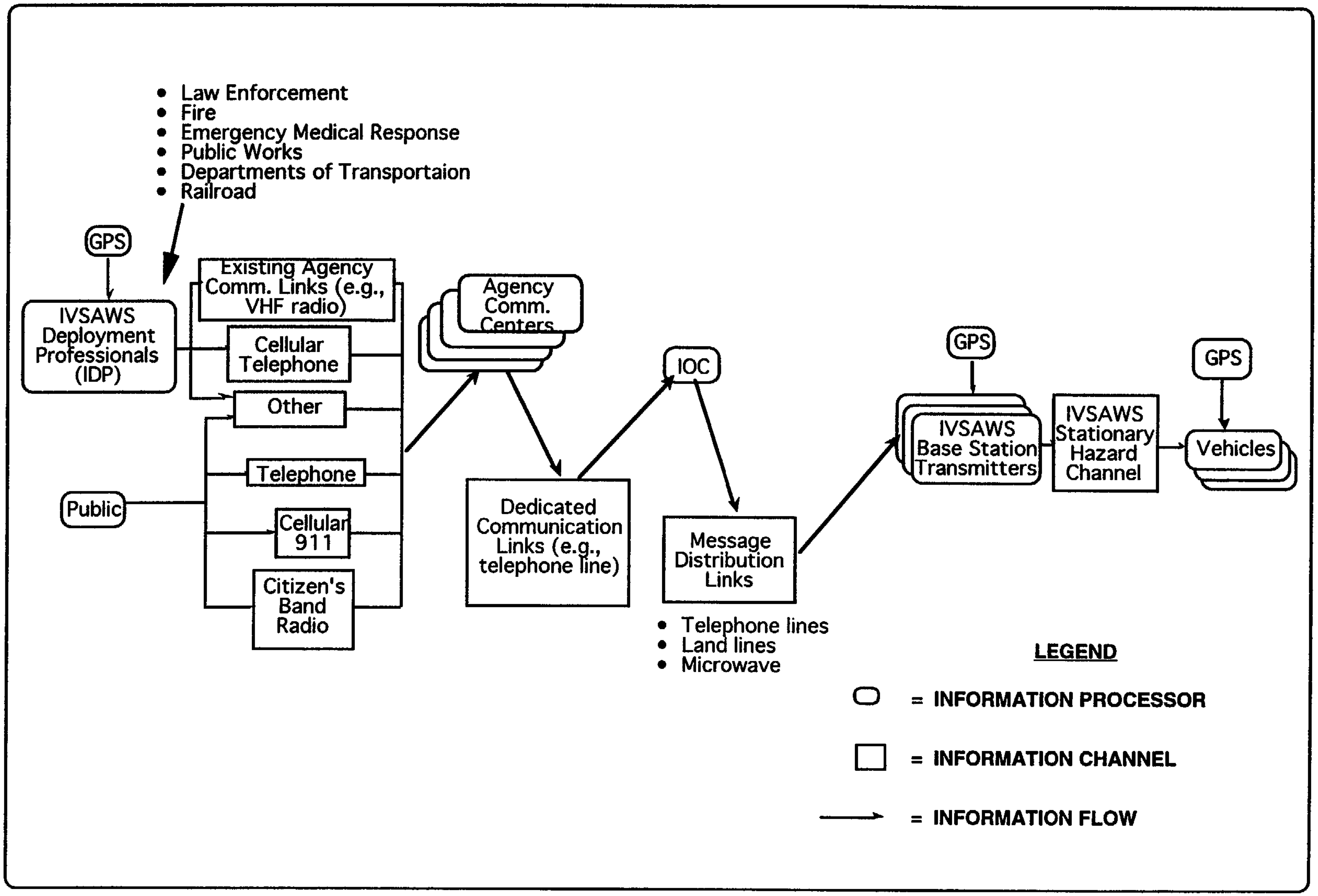


FIGURE 2. IVSAWS STATIONARY HAZARD CHANNEL ARCHITECTURE.

The IOC requires a minimum hardware suite to perform its function. As part of a larger Intelligent Vehicle Highway System (IVHS), the IOC may be joined with a larger system, (e.g., an urban traffic operations center) or non-IVSAWS functions may be added to the IOC hardware. The IOC hardware should be selected with the final IVHS configuration having been considered. A stand-alone IOC implementation will require, at minimum, a computer system based upon a high-end PC architecture. Figure 3 shows the configuration of the IOC hardware stat on.

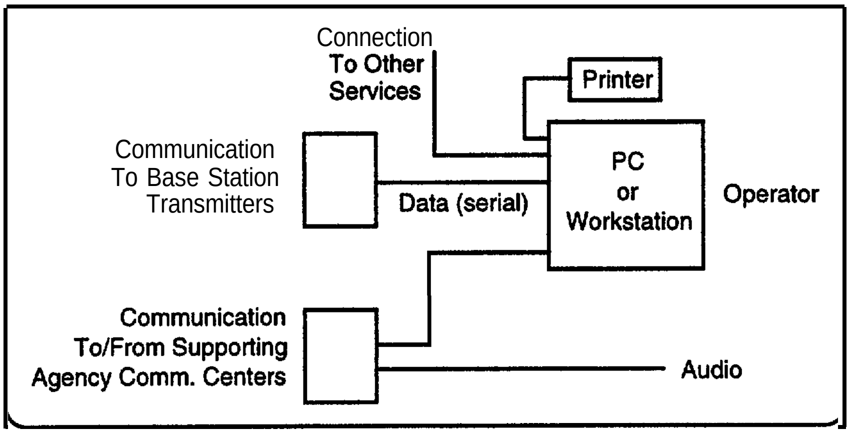


FIGURE 3. IOC WORKSTATION ARCHITECTURE.

The IOC will be loaded with communication, database, operating system and windows software. The IVSAWS applique will coordinate incoming information from the supported agency-specific communication centers, alert broadcasts to drivers, and interim IVSAWS information management (the incident message database). The IVSAWS management program should be menu driven with selections to allow for communication parameters to be established and modified, data to be backed-up to a tape drive, reports to be generated, preplanned incidents to be entered using a calendar application, and the execution of the incident message subprocess. The management program is the primary message handler that aids the operator in generating, sending and storing IVSAWS messages.

***Communications** Interface.* The communications interface selection will bring the operator into a subprocess that will allow for the setting up and modification of the communication links. The links consist of the data interface to the supported agency (e.g., municipal police departments), communication hardware, and the data interface to the hardware used for getting incident information out to the driver. The subprocess will provide a summary table indicating the current status of each interface.

Data Back-up. Data will be automatically collected and stored within the internal hard drive. The data back-up subprocess will provide for the backing up of the data onto a magnetic tape.

Report Generation. Data reduction and report generation will be provided for all of the stored message information (data message traffic and incident messages generated within the incident message subprocess). The parameters for reduction will include: messages to and from the supported agencies, messages sent to the drivers, incident type ID, date range, time range, priority, incident message number, area, and roadway location. The subprocess will provide for both on and off-line reduction. Reports will be stored on disk, with the option to print as part of the menu selections.

Calendar. The calendar selection will allow the operator to generate a message for a pre-planned event such as road closures, road work, parades, etc.. The message will be built ahead of time with the operator manually entering the area-of-coverage (AOC) information. The operator can then assign a date and time that the message is to be transmitted. The operator will have the power to set the reminder flag or suppress it at any time. The selection will allow the operator to view all pre-planned event messages by week, and by month. Once a message has been entered and a date and time associated with it, the operator will be automatically notified when it is time to send the message. The message will be pulled out of the database and displayed allowing the operator a chance to modify the message as well as to suppress transmission if the event is not to take place.

Incident Message. The IVSAWS system will constantly monitor the communication interfaces so as to notify an operator of an incoming incident. Notification will include a audible sound and the incident message subprocess is automatically started. If an incident is called in over the phone, the operator will be able to manually start the incident message subprocess. The incident message subprocess will prompt the operator for fields, such as alert status, priority, type information, etc., in order to complete an advisory message. Preferably, data collected, (AOC coordinates and shape, zone-type identification (e.g, accident site, roadway maintenance), zone location, and data quality) will be automatically fed in from communication lines. If the data is not sent in via data communication links, the operator should have the capability to manually enter in all data. System time and date should also be automatically attached to each incoming message and each outgoing message to the drivers. Incident messages, the textual portion of an IVSAWS message report, will be stored, each with a unique message ID number associated with it. The operator can select an incident message using the associated ID number or a key word search. If more data is required with a message (e.g. how long is the incident expected to last) the program shall prompt the operator for input.

Automapping. Automapping, to provide coordinates for phoned in incident locations, may need to be purchased. The scope of the coverage, however, is a limiting factor in that most cities are currently mapped but most rural maps have not been generated. The highway performance analysis branch for the Federal Highway Administration's (FHWA) office of planning and environment in Washington, DC should have national highway planning network map scaled to 1: 100,000. The FHWA map could provide a source for an IVSAWS database. Third party vendors supply geopositional software that utilizes digital maps and provides Lat./Long. equivalents to locations selected via mouse positioning or address selection. Currently there is no mile marker overlays that can be used with a software system, however, the FHWA database may provide the mile marker information.

3.2 BASE STATION TRANSMITTERS

IVSAWS requires the construction of new 220-222 MHz base stations to provide coverage for message broadcasts. Base stations located at or near a regional IOC could be tied to the center by wire or optic fiber. When IOC-base station separation prohibits the use of a direct connection, dedicated telephone service could be used to link the station and IOC provided the desired base station site has access to the service. However, in many instances, it will be desirable to locate base stations on mountaintops or at other geographically advantageous locations in order to maximize coverage and minimize the number of base stations required to provide acceptable IVSAWS service. In these instances, co-locating IVSAWS base stations with microwave repeater sites appears attractive for the following reasons: 1) the repeater sites are usually selected to maximize coverage and will therefore provide good IVSAWS coverage, 2) power is available, and 3) the microwave links can be used to link the IOC and base station. Figure 4 depicts a regional base station transmitter network.

Figure 5 shows a block diagram of a base station transmitter. Major components include a 220-222 MHz band transmitter with antenna, a GPS reference unit, and computer with modem. Each base station incorporates a differential GPS reference receiver in order to provide pseudo-range and range-rate corrections to vehicles equipped with IVSAWS in-vehicle receiver systems. Section 2 describes differential GPS as it applies to IVSAWS. The corrections are broadcast periodically, interleaved with other IVSAWS message broadcasts. The base station computer accepts commands and data from an IOC via a modem connected to an IOC-to-base station communication link. The link may be RF or wired (e.g., telephone, land line, optical fiber). Messages to be broadcast are stored in a circular buffer, and are transmitted periodically according to a message priority scheme.

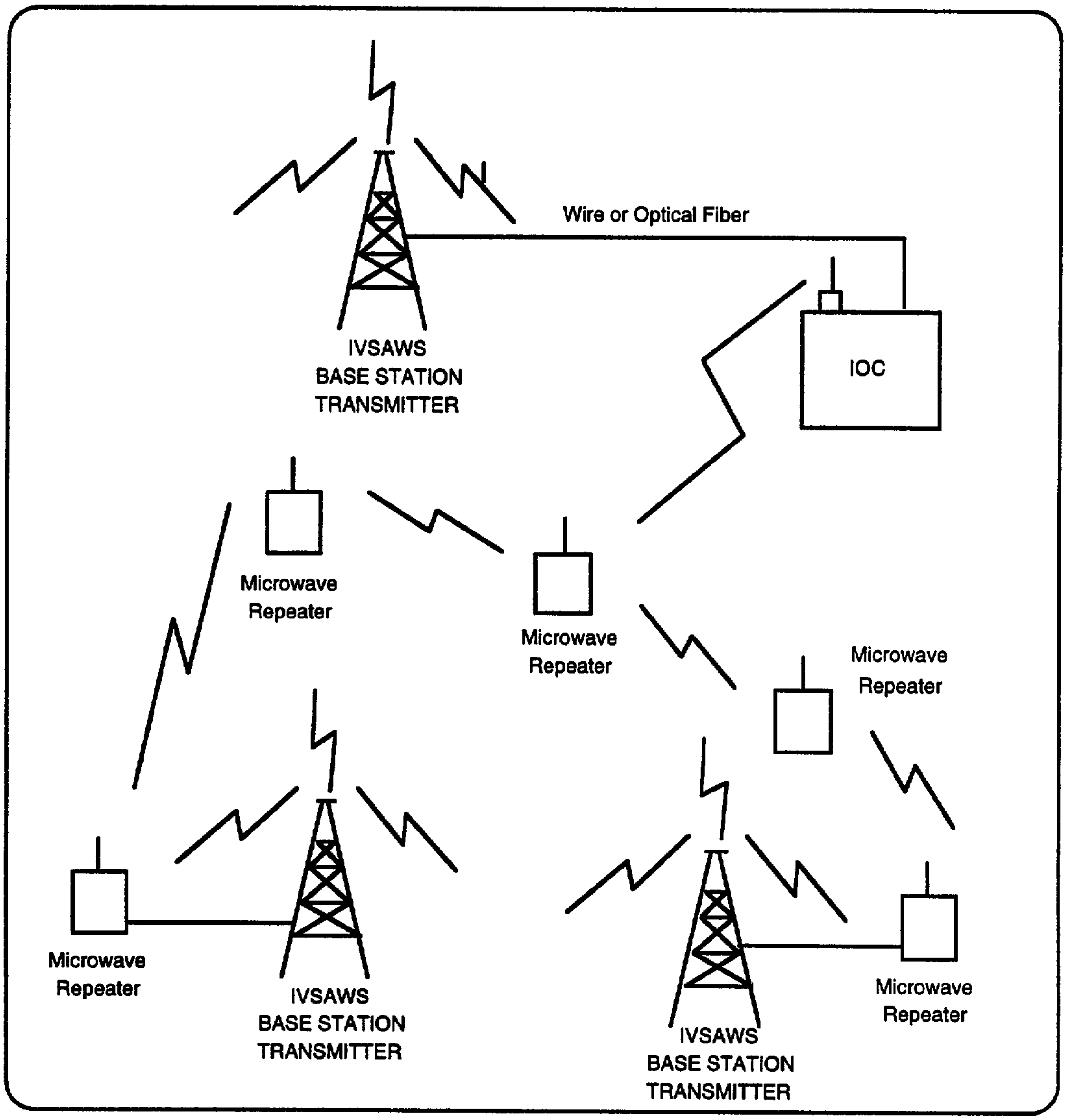


FIGURE 4. REGIONAL BASE STATION TRANSMITTER NETWORK EXAMPLE.

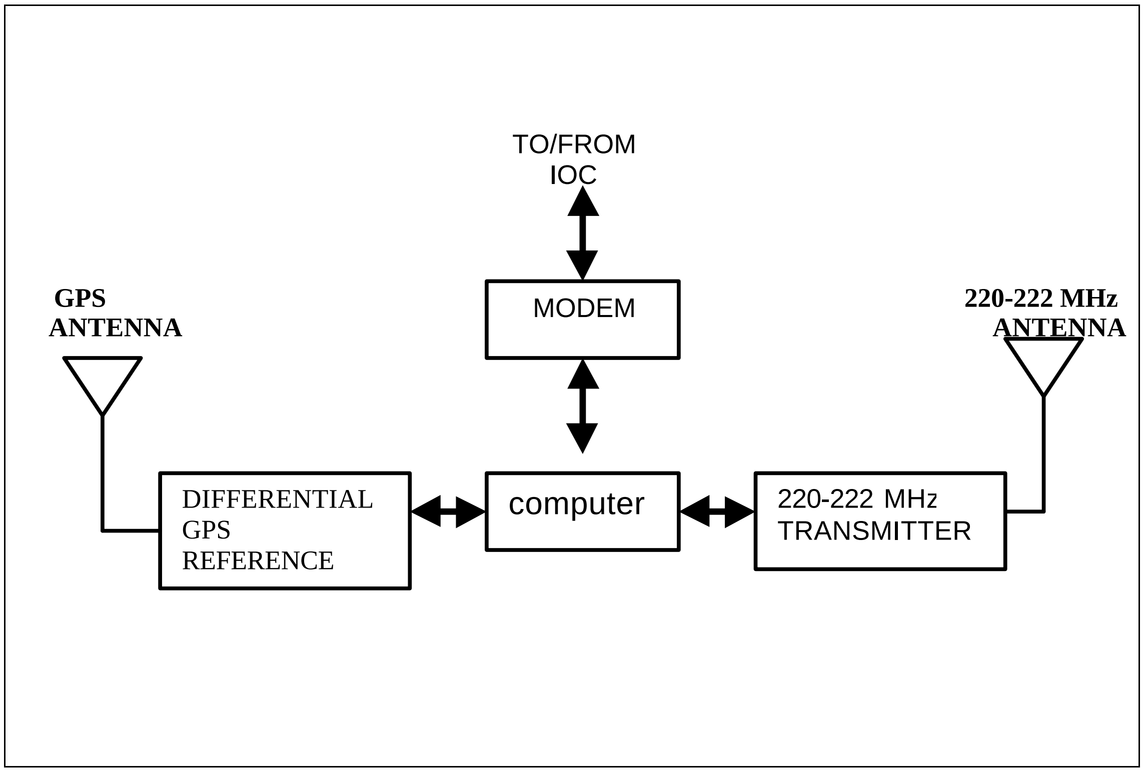


FIGURE 5. BASE STATION BLOCK DIAGRAM

4. MOBILE CHANNEL BROADCASTS

The coordinates of a virtual warning zone projected around an emergency vehicle or other mobile hazard will need to be updated as the vehicle travels. Otherwise, an excessively large warning zone would be required to ensure all drivers who might encounter the vehicle are warned, resulting in untimely driver alerts. This task will require an on-board computer to monitor the vehicle's position, speed and direction of travel and adjust the size and placement of the warning zone envelope. Thus, the in-vehicle IVSAWS transceiver systems are composed of a GPS receiver, a computer, and an IVSAWS transmitter-receiver pair as shown in figure 6. The IVSAWS receiver is used to obtain GPS pseudo-range and range-rate corrections from a base station transmitter.

When activated, the mobile transmitters broadcast an IVSAWS message once every two seconds using a slotted ALOHA time-division multiple-access (TDMA) protocol (see 6.4.2). Activation of the vehicular units should be automatic (possibly tied to the emergency lights switch) with controls provided for manual activation and deactivation. Prior to each broadcast, the computer updates the ***AOC dimensions, zone (vehicle) locution*** and ***direction indicators*** fields (see 6.3.2) to compensate for any vehicle movement since the last broadcast. The ***alert duration*** should be set to 10 seconds.

When vehicles equipped with IVSAWS in-vehicle receiver systems (see section 5) receive mobile broadcasts, their IVSAWS database will become active due to the frequency of transmissions from a single source. The database should be maintained such that only the last message received from a mobile source is retained. This is accomplished by comparing the ***alert*** ID field, which is static and unique for a given mobile transmitter. As an option, in-vehicle receiver systems can maintain mobile transmitter position and speed tracks to improve driver alert timeliness and reliability (i.e., minimize irrelevant alerts). As with stationary channel broadcasts, when an IVSAWS-equipped vehicle penetrates a mobile transmitter's area of coverage, the distance and closing rate between the vehicle and mobile hazard is monitored such that the driver is alerted between six and ten seconds in advance of the encounter.

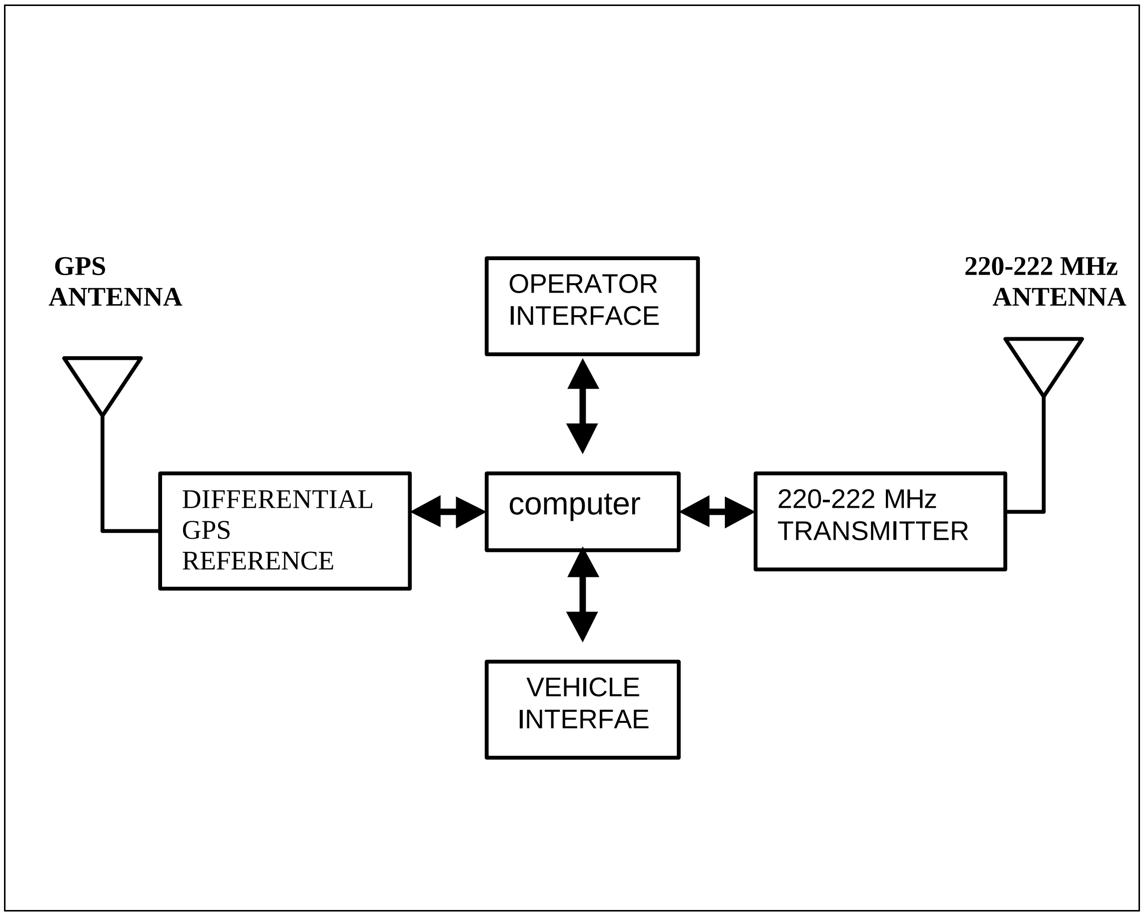


FIGURE 6. MOBILE TRANSCEIVER BLOCK DIAGRAM

5. IN-VEHICLE RECEIVER SYSTEM

The previous sections have proposed architectures for the IVSAWS operations centers, base station transmitter network, and mobile transmitter network. The in-vehicle receiver system has only been described briefly. Two options exist for implementation of the in-vehicle systems, 1) integration with existing or proposed driver information systems, and 2) manufacture of a stand-alone vehicular IVSAWS receiver.

5.1 IVSAWS-DRIVER INFORMATION SYSTEM OPTION

In its most elegant implementation, the IVSAWS in-vehicle receiver system will be available as a software option to a multi-function driver information system (DIS) integrated into the dash of an automobile. Sold as an option to a new vehicle purchase, the DIS would be composed of a display, controls, central processing unit (CPU), mass data storage device (e.g., hard disk drive and CD-ROM drive) for data and applications, multiband transceiver, and multiband antenna. Figure 7 shows a block diagram of a DIS.

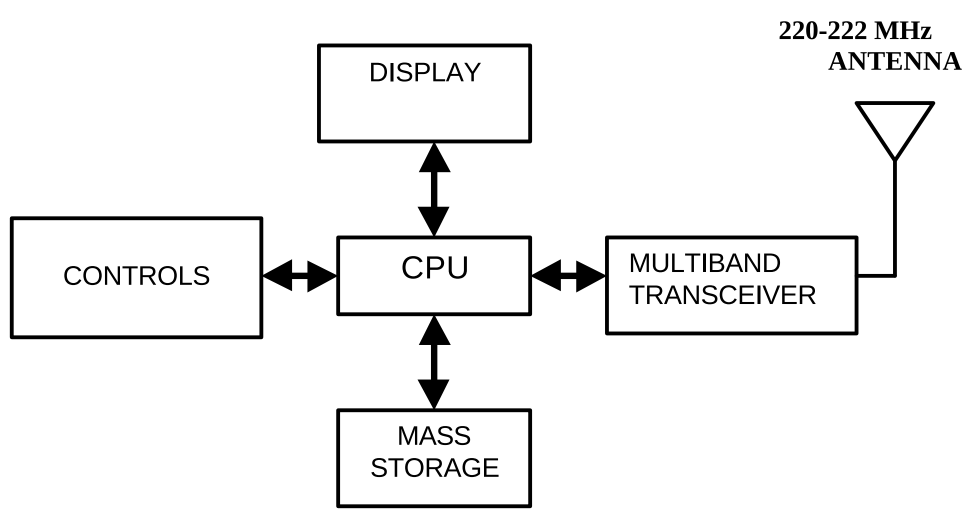


FIGURE 7. DRIVER INFORMATION SYSTEM @IS) BLOCK DIAGRAM

The DIS would be capable of supporting several applications, including the following:

- Driver navigation aide, including electronic maps showing vehicle location.
- Cellular telephone, including 9 11 access.

- AM/FM radio.
- Electronic toll collection.
- Roadway information, including hotel/motel vacancy status and room rates.
- IVSAWS.

Although the cost of a DIS is likely to be significant, when amortized across the available functions the DIS should provide a more capable and cost-effective approach than installing separate components, each of which support a single function. IVSAWS would likely operate in conjunction with a driver navigation aide, showing the hazard location on a displayed roadway map. The driver could retrieve detailed information about the hazard, if available, using the DIS controls.

5.2 STAND-ALONE IVSAWS IN-VEHICLE RECEIVER SYSTEM

Even after integrated driver information systems become widespread, demand for an aftermarket IVSAWS receiver system may be high. Some drivers may wish to equip older vehicles that do not have a DIS with an IVSAWS capability. Others may chose not purchase a DIS with a new vehicle, but still want an IVSAWS receiver system.

All IVSAWS receiver functions can be integrated into a dashboard-mount device. However, in order to be affordable, a highly integrated unit will be required, possibly fabricated with semiconductor technology using Application Specific Integrated Circuits (ASICs). When the market is measured in millions of units, the large volume of units to be produced makes the non-recurring investment to develop the semiconductor masks and processes reasonable.

If the vehicle to be retrofit is equipped with a GPS subsystem that can export latitude/longitude data and once-per-second GPS timeticks, an IVSAWS receiver with alphanumeric display, control buttons, and tone generator should be producible at a $250 (approx.) cost to the consumer. The price is based upon a comparison of the IVSAWS receiver to the projected price of emerging digital cellular telephones (DCT) ($450 after two years on market). The IVSAWS receiver and DCT receiver are of similar complexity. However, as a unit, the IVSAWS retrofit “box” should cost less since no transmitter is required, processing tasks are considerably less complex, and no voice interface is required (i.e, no microphone or speech processor).

If the vehicle to be retrofit is not equipped with a GPS subsystem, a GPS receiver will need to be incorporated into the integrated IVSAWS dashboard-mount device. The cost of such a unit is estimated to be $450.

6. COMMUNCATIONS

The proposed modulation and data format to be used for the communication of IVSAWS messages to vehicles equipped with IVSAWS receiver systems is described below.

6.1 MODULATION

The modulation method used is $\frac{\pi}{4}$ - shifted, differentially encoded quadrature phase shift keying ($\frac{\pi}{4}$ - shifted DQPSK). Figure 8 shows the block diagram of an IVSAWS modulator. The binary data stream entering the modulator, b_m, is converted into two separate binary streams, M_k and N_k, via a convolutional encoder. The encoder is a 1/2 rate constraint length seven (k = 7) convolutional encoder.

A block diagram of the rate 1/2, k=7 encoder is shown in Figure 9. The generating functions, denoted as GO and G1, are 1111001 (binary) and 1011011, respectively. At each b_m bit input, the data stream is convolved with the generating functions to produce two codewords, M_k and N_k.

The codewords M_k and N_k are written into an interleaving matrix, row-wise, as shown in Figure 10. The codewords are read by columns, two at a time, to produce the binary data sequences X_k and Y_k. The binary data sequences X_k and Y_k are differentially encoded onto I_k and Q_k according to:

$$I_k = I_{k-1} \cos[\Delta\Phi(X_k,Y_k)] - Q_{k-1} \sin[\Delta\Phi(X_k,Y_k)]$$
$$Q_k = I_{k-1} \sin[\Delta\Phi(X_k,Y_k)] + Q_{k-1} \cos[\Delta\Phi(X_k,Y_k)]$$

where I_{k-1}, Q_{k-1} are the amplitudes at the previous pulse time. The phase change $\Delta\Phi$ is determined according to Table 1.

TABLE 1. DIFFERENTIAL PHASE CODE.

X_k	Y_k	$\Delta\Phi$
0	0	$\pi/4$
0	1	$3\pi/4$
1	0	$-\pi/4$
1	1	$-3\pi/4$

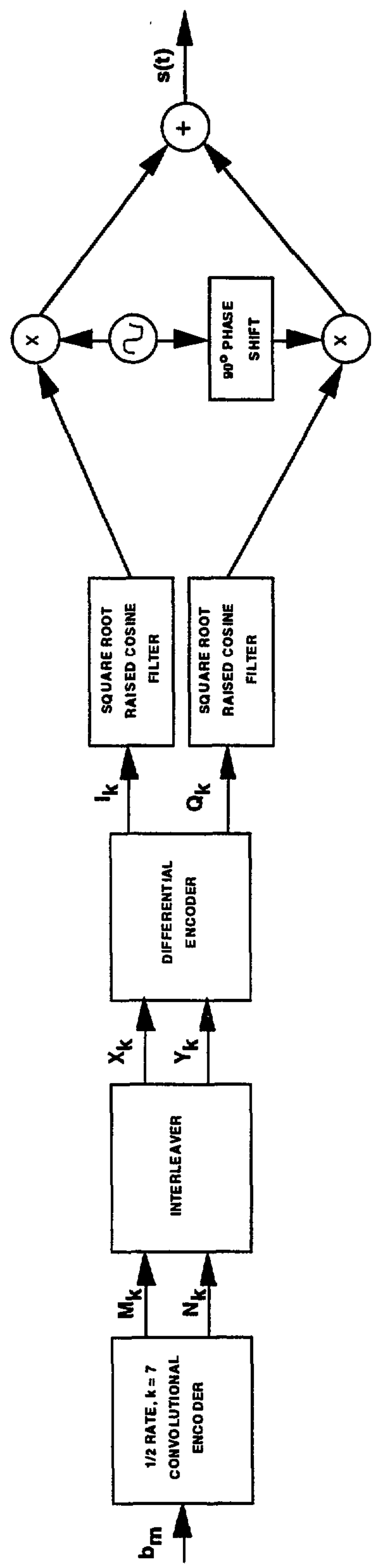


FIGURE 8. IVSAWS MODULATOR BLOCK DIAGRAM.

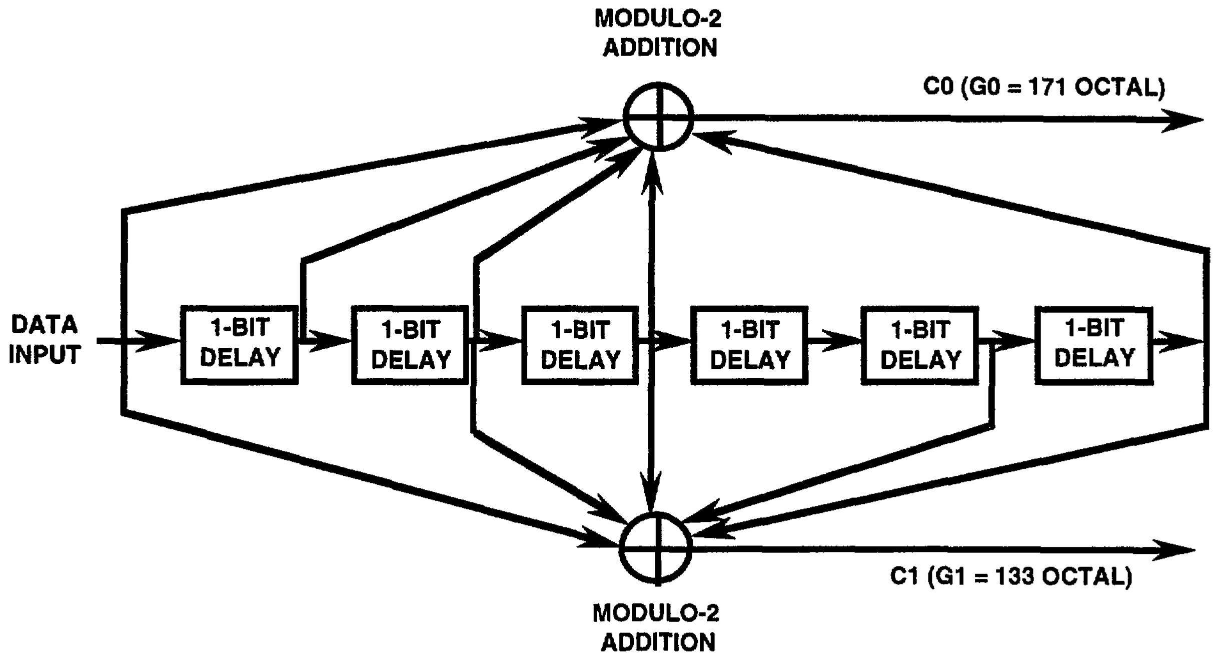


FIGURE 9. CONSTRAINT-LENGTH-7 HALF-RATE CONVOLUTIONAL ENCODER.

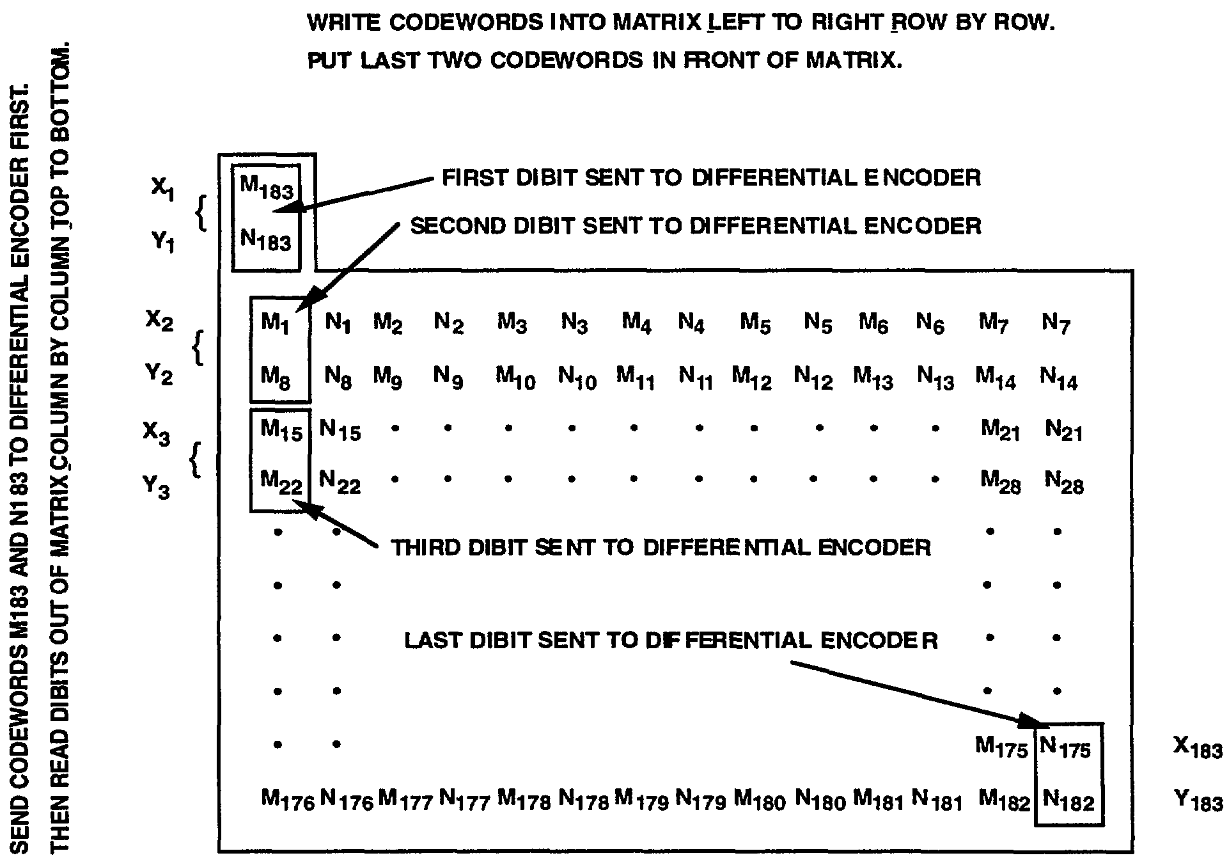


FIGURE 10. CODEWORD INTERLEAVER.

The signals I_k, Q_k at the output of the differential phase encoding block can take one of five values, 0, ±1, $\pm\frac{1}{\sqrt{2}}$, resulting in the constellation shown in Figure 11. Odd (denoted ⊕) and even (denoted ⊗) symbol constellations are offset by $\frac{\pi}{4}$ radians.

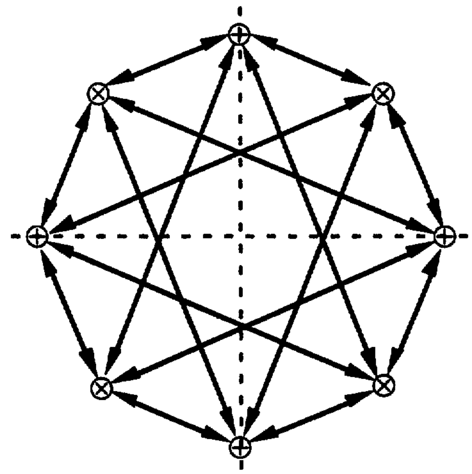


FIGURE 11. $\frac{\Pi}{4}$ SHIFTED, DIFFERENTIALLY ENCODED QPSK CONSTELLATION.

I_k, Q_k are applied to the inputs of the I & Q base-band filters. The base-band filters shall have linear phase and square root raised cosine frequency response of the form:

$$|H(f)| = \begin{cases} 1 & 0 \le f \le \frac{(1-a)}{2T} \\ \sqrt{\frac{1}{2}\left\{1 - \sin\left[\frac{\pi(2fT-1)}{2a}\right]\right\}} & \frac{(1-a)}{2T} \le f \le \frac{(1+a)}{2T} \\ 0 & f > \frac{(1+a)}{2T} \end{cases}$$

where T, the symbol period, is equal to twice the reciprocal of the baseband data rate (6075 bits per second). The roll-of factor, a, determines the width of the transition band, and is 0.35.

Symbols are transmitted as changes in phase rather than absolute phases. The resultant transmitted signal s(t) is given by:

$$s(t) = \sum_n h(t - nT)\cos\Phi_n \cos\omega_c t - \sum_n h(t - nT)\sin\Phi_n \sin\omega_c t$$

where h(t) is the baseband filter impulse response (finite), ω_c is the radian carrier frequency, T is the symbol period, and Φ_n is the absolute phase corresponding to the n^{th} symbol interval. The Φ_n which results from the differential encoding is:

$$\Phi_n = \Phi_{n-1} + \Delta\Phi_n.$$

6.2 TRANSMITTER OUTPUT

IVSAWS is designed to operate using one channel of the 220-222 MHz band. The channel consists of a frequency pair separated by 1 MHz. Table 2 lists the proposed operating frequencies and channel assignment. Frequency tolerance for base stations shall be 0.1 ppm. Frequency tolerance for mobile units shall be 1.5 ppm.

TABLE 2. IVSAWS OPERATING FREQUENCIES IN THE 220-222 MHZ BAND.

Base Station Transmit Frequency	Mobile Transmit Frequency
220.5725 MHz	221.5725 MHz

The required emissions mask shall be as specified in paragraph 102 of the Amendment of Part 90 of the Commission's Rules to Provide for the 220-222 MHz Band by the Private Land Mobile Radio Services. Figure 12 illustrates the specified emissions mask. Power is relative to the maximum effective radiated power (ERP).

Transmitter power shall be as specified in paragraphs 115 and 116 of the Amendment of Part 90 of the Commission's Rules to Provide for the 220-222 MHz Band by the Private Land Mobile Radio Services unless an exception can be obtained which allows higher base station powers. This exception should be permissible since the channel is designated for nationwide use (no co-channel users). However, it will need to be shown that the higher power transmissions do not raise out-of-band interference levels above those specified in the Amendment. The rationale for higher powers is reduced infrastructure cost. In free space, quadrupling the transmit power doubles communication range. Assuming circular base station communication coverage, this would reduce the required base station density by a factor of seven. Since base stations are a major cost element of a nationwide IVSAWS, system infrastructure costs would be reduced significantly.

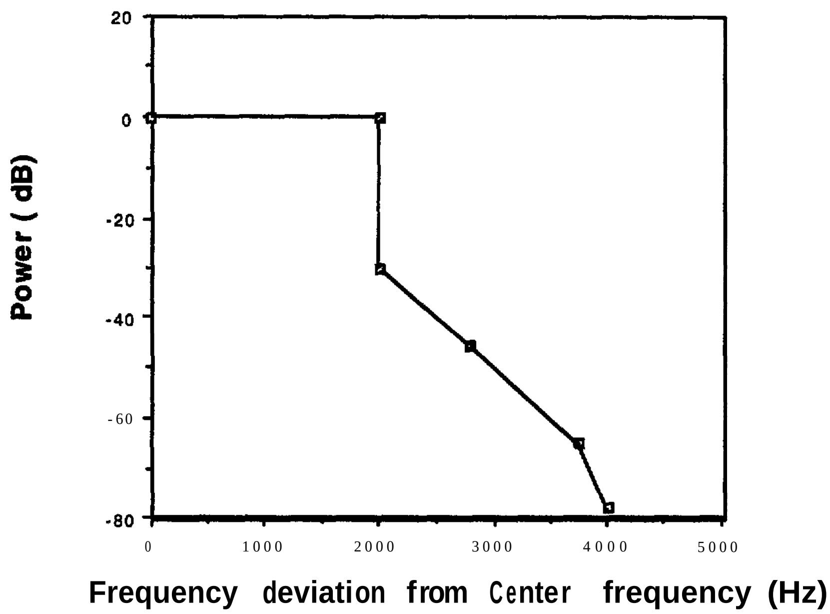


FIGURE 12. IVSAWS EMISSIONS MASK.

6.3 SIGNAL STRUCTURE

This section provides definition of the IVSAWS alert signal structure. Included are: message format and bit structure, coding, framing and synchronization.

The frame structure is shown in figure 13. Each frame is 12150 bit periods in duration, divided into six timeslots designated slot 1 through slot 6. Over-the-air signalling occurs at a rate of 6075 bits per second. Each timeslot is 2025 bit periods in duration. Frames begin on even second counts of the time standard.

The basic alert message consists of 183 bits of information, excluding guard time, transmitter power ramp up time, and synchronization (sync). The 183 bits of information are convolutionally encoded and interleaved into a 366 bit message. Including guard time, transmitter power ramp up time, and sync, the alert message is 405 bit periods in duration. Alert guard is five bit periods in duration. Transmitter power ramp up is six bit periods in duration. In addition to the basic message type, continue, free text, delete, system time and offset, and area of coverage (AOC) extension messages are defined.

The synchronization word is a 14 symbol field used for alert synchronization and equalizer training. The sync word is specified by the following sequence of phase changes in radians:

-B/4 -B/4 -B/4 3B/4 B/4 3B/4 -3B/4 3B/4 -3B/4 -B/4 3B/4 B/4 -B/4 -B/4

Alert type is a 3 bit number which identifies the type of alert message being broadcast. Table 3 identifies the relationship between the contents of alert type and the type of message being broadcast.

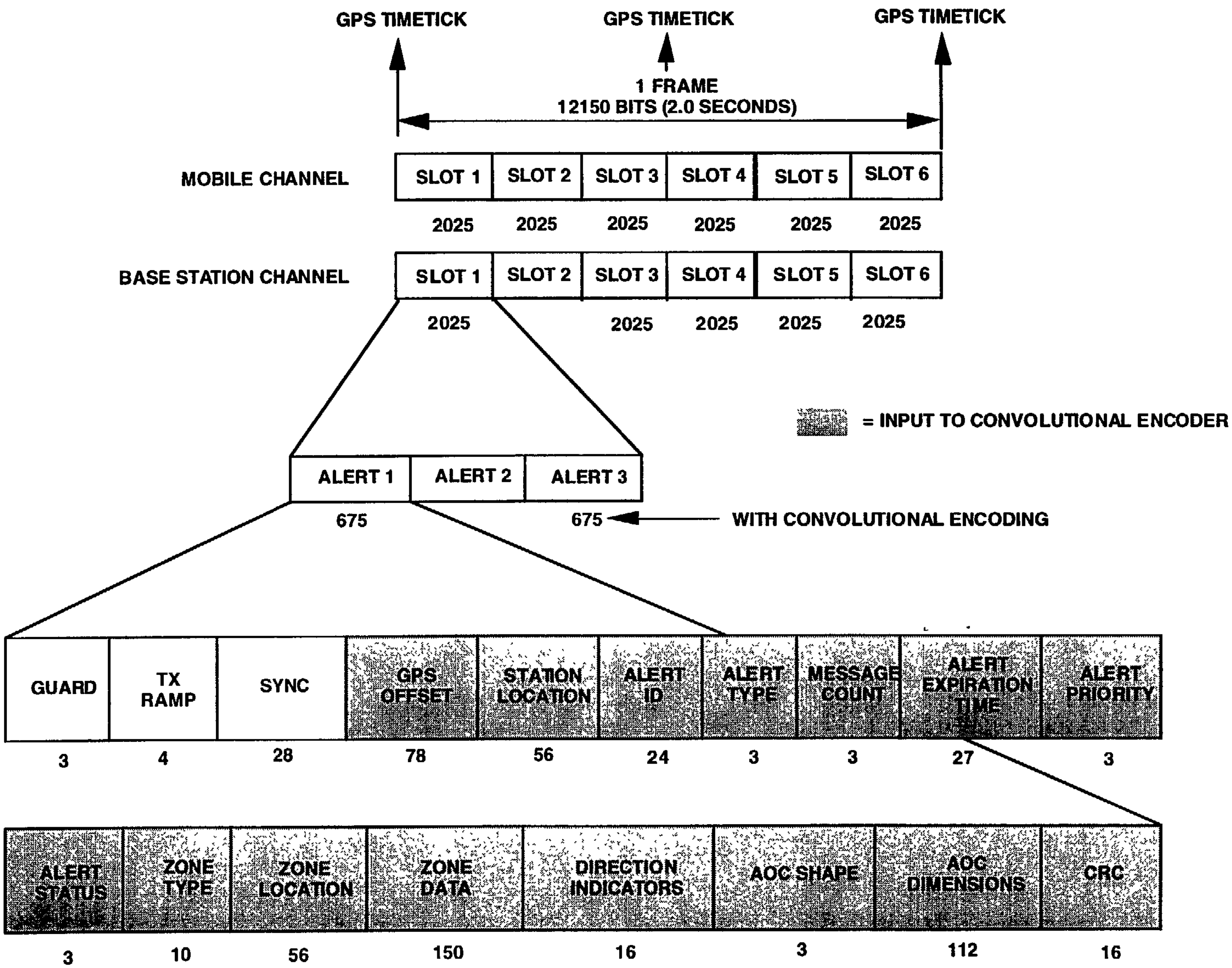


FIGURE 13. FRAME STRUCTURE.

[FHWA V-27]

TABLE 3. ALERT TYPES.

Message type	Alert type value
Basic (stationary alert zone)	0
Basic (mobile alert zone)	1
Continue	2
Delete	3
System time and GPS correction	4
Free text	5
AOC extension	6
Reserved	7

6.3.1 BASIC ALERT MESSAGE

The basic alert message structure is shown in figure 13.

Alert ID is a 28 bit number that uniquely identifies an alert message. IVSAWS can issue 268435,456 alerts without alert ID reuse. Mobile units are assigned a unique alert ID which will be used for all alert broadcasts.

Message count identifies the number of continue, free text, and or AOC extension messages to follow (0 - 7).

Alert duration is a 13 bit field that specifies the time at which an alert is to be deleted from the vehicular alert database. Alert duration is relative to system time (defined below). Table 4 shows the field structure.

TABLE 4. ALLOCATIONS FOR ALERT DURATION.

Segment	Bits
Coarse duration	2
Time offset	11
Total	13

Coarse duration specifies the time reference of the time offset. If coarse duration is 00, time offset is relative to midnight of the current day (0000 hours). Time offset then specifies the alert expiration time in terms of the number of minutes past midnight. When system time equals alert expiration time, the alert is to be removed from the vehicular database. If coarse duration is 0 1, time offset is relative to midnight of the first day of the current month. Time offset then specifies the alert expiration time in terms of the number of hours past midnight of the first day of the current month. Again, when system time equals alert expiration time, the alert is to be removed from the vehicular database. If coarse duration is 10, time offset is to be relative to midnight of the first day of the current year. Time offset then specifies the alert expiration time in terms of the number of days past the first day of the current year. If coarse duration equals 11, the alert can only be removed from the database via the receipt of a delete message (see section 3.3.8).

Alert priority shall is set from 0 to 7 to indicate the relative urgency or severity of the embedded hazard or advisory message. 0 is the lowest priority; 7 is the highest priority (most severe).

Akrt status is set from 0 to 7 to indicate the source or condition of the embedded hazard or advisory message. Table 5 correlates alert status with alert status value.

TABLE 5. ALERT STATUS.

Alert status	Alert status value
Confirmed	0
Unconfirmed	1
Forecast	2
Reserved	3thru7

Zone type is an 1 l-bit pointer to one of 2048 hazard and advisory messages stored within a vehicular IVSAWS database. It identifies a message to be presented to a driver via a display or speech synthesizer. The message list has not been defined.

Zone location is a 44 bit field used to identify the position of a hazard or advisory site. The grid reference system is based on the Universal Transverse Mercator (UTM) projection. As shown in figure 14, the features on the surface of the earth (from 80^{o} S latitude to 84^{o} N latitude) are projected onto a cylinder, and the cylinder is flattened to achieve 6-degree wide zones. A five-element term is used to designate coordinates (e.g., NN A al a2 eeeee nnnnn). The term NN refers to one of the 60 zones and the term A designates one of the 20 latitude bands, labeled C through X, in figure 15.

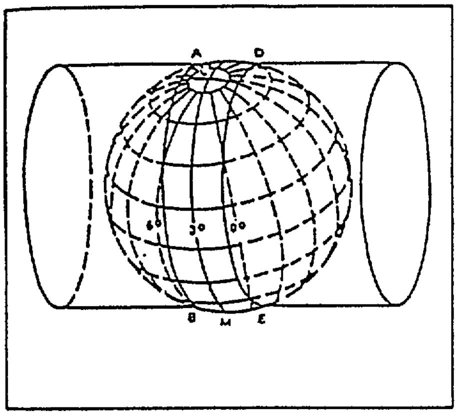


Figure 14. The Traverse Mercator Projection.

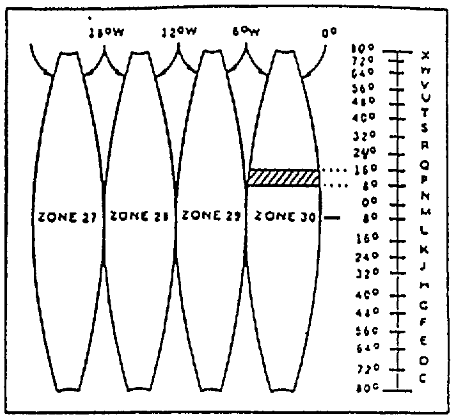


Figure 15. UTM 6°-wide standard zones.

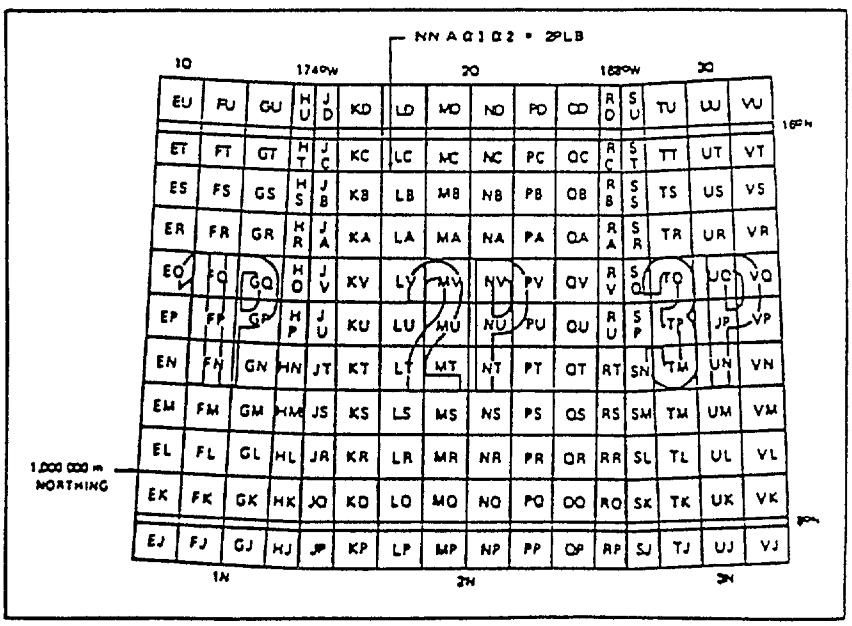


Figure 16. Grid-square designators.

Each UTM zone is divided into a number of 100 km squares, as shown in figure 16. Each of these grid squares has a two-character designator (al a2) known as the alpha pair designator. The al character designates the column a grid square is in and the a2 character designates the row. The alpha pair designators occur in a normal sequence, and repeat approximately every 2,000 km north or south, and every 18 degrees east or west. Within a single grid square, a position can be indicated by two numbers: easting (eeeee), the distance in meters from the west edge of the grid square, and northing (nnnnn), the distance in meters from the south edge of the grid square. Since IVSAWS driver alert distances are small (less than 2 km), the grid zone designator can be dropped and an IVSAWS zone location thus has the form:

al a2 eeeee nnnnn.

Table 6 shows the zone location field structure.

TABLE 6. FIELD ALLOCATIONS FOR ZONE LOCATION.

Station location segment	Bits
Alpha designator - column (al)	5
Alpha designator - row (a2)	5
Easting (eeeee)	17
Northing (nnnnn)	17
Total	44

Direction indicators is a 12 bit field used to limit alert dissemination to vehicles based upon their direction of travel. Each bit covers a 30 degree segment (see figure 17). Setting a bit of this field to a 1 permits alert dissemination to vehicles travelling in the corresponding directional range. Setting a bit of this field to a 0 prohibits alert dissemination to vehicles travelling in the corresponding directional range. For example, setting all bits to 1 enables omnidirectional alert dissemination.

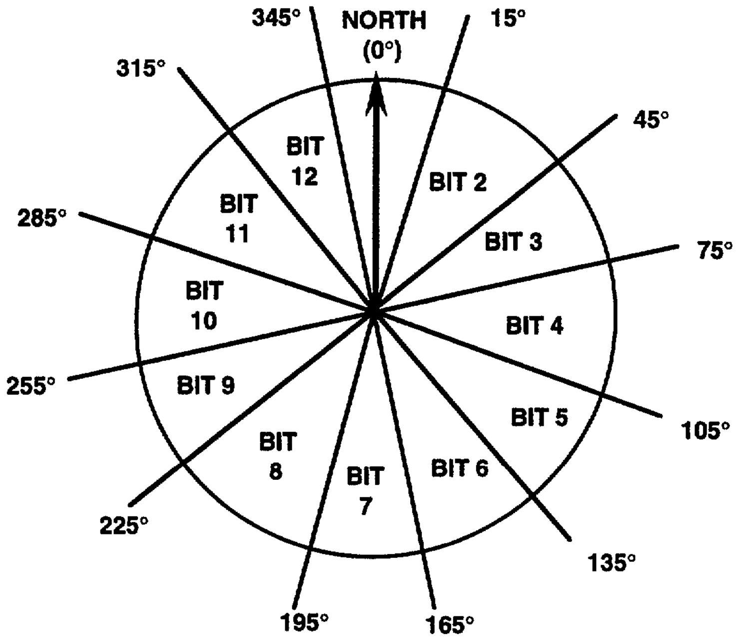


FIGURE 17. DIRECTION INDICATOR BIT ASSIGNMENTS.

AOC shape is a 3 bit field used to define the shape of the intended area of alert coverage. Table 7 identifies valid shapes. If the shape is extended, an AOC extension message follows which defines the AOC dimensions (see 6.3.6).

TABLE 7. AOC SHAPES.

Shape	Value
Box	0
Circle	1
Semicircle	2
Reserved	3 thru 6
Extended	7

AOC dimensions is a 44 bit field used to define the dimensions of the area of alert coverage. The format and content of the field is AOC-shape dependent and has not been defined. If the AOC shape is extended, this field shall be set to all zeros.

6.3.2 CONTINUE MESSAGE

The continue message is used to extend the basic alert message. Figure 18 shows the continue message structure.

Alert ID is set equal to the alert ID of the source basic alert message.

Message count identifies the current continue, free text, or AOC extension message number (1 - 7).

Message extension is subdivided into 13 subfields. Each subfield consists of a two bit header followed by an 11 bit data or pointer segment. The header can assume one of four values and identifies the type of information in the segment, as listed in Table 8. Customized messages can therefore be created by using a combination of “canned” alert message from the database messages together with site-specific data.

TABLE 8. MESSAGE EXTENSION SUBFIELD CONTENTS.

Contents	P/D
Not used	0
Pointer to alert message database	1
Data	2
Reserved	3

6.3.3 FREE TEXT MESSAGE

Figure 19 shows the free text message structure.

Alert ID is set equal to the alert ID of the source basic alert message.

Message count shall identifies the current continue, free text, or AOC extension message number (1 - 7).

Free text is a field used to send site-specific information to the driver. Typically, it could be used to identify the names of roads at which an incident has occurred (e.g. 15 at HIWAY 39).

6.3.4 DELETE MESSAGE

The delete message is used to erase messages from vehicular alert databases. The delete message structure is shown in figure 20.

Alert ID is set equal to the ID of the alert to be erased from the alert database.

6.3.5 SYSTEM TIME AND GPS CORRECTION MESSAGE

Each base station transmits a system time and GPS correction message, once per second, as the first alert (ALERT 1, figure 13) of its assigned slot. The message structure is shown in figure 2 1. Station ID, station health, and Z-count are transmitted with each message and are defined in table 9. A system time or GPS correction field is also incorporated into each message. The correction/time (C/T) control bit identifies the field type. A system time field is broadcast once every three seconds. GPS corrections are transmitted in the remaining broadcasts. For each GPS satellite viewed by the IVSAWS base station, a GPS correction is broadcast. If more than four satellites are in view, alternate messages divide the satellite corrections.

TABLE 9. STATION ID, STATION HEALTH, Z-COUNT, AND C/T FIELD STRUCTURES.

Field	Scale factor and units	Range	Bits
Station ID	1	0 - 65,535	16
Station health		4 states	2
Z- count	6 seconds	l-100,794 s.	17
Correction/time (C/T) control	1		1

GPS pseudorange and range-rate corrections are used to improve the accuracy of hazard and vehicle position measurements utilizing Differential GPS. Table 10 shows the GPS correction field structure. Four subfields are broadcast with each GPS correction message.

TABLE 10. SUBFIELD STRUCTURE FOR GPS CORRECTION.

Segment	Scale factor and units	Range	Bits
Pseudorange correction	0.1 meters	313276.8 m	16
Range-rate correction	0.004 m/sec	+/- 0.5 12 m/s	8
, Satellite ID	1	o-3 1	5
Satellite health		4 states	2
Reserved			
Total			32

System time (date and time of day) incorporates Coordinated Universal Time (UTC) and Modified Julian Day (MJD) in accordance with CCIR Recommendations 457 and 460. A coded local time difference, expressed in multiples of half-hours, is appended to the system time. Table 11 shows the field structure.

TABLE 11. FIELD STRUCTURE FOR SYSTEM TIME.

Segment	Scale factor and units	Range	Bits
Modified Julian Day	1 day	0 - 99999 d.	17
Hour	1 hour	0 - 23 hr	5
Minute	1 minute	0-59 min	6
Local time offset	0.5 hours	+/- 12hr	6
Reserved			94
Total			**128**

6.3.6 AOC EXTENSION MESSAGE

The AOC extension message is used to define irregular areas of coverage. Figure 22 shows the message structure.

Alert ID is set equal to the alert ID of the source basic alert message.

Message count identifies the current AOC extension message number (1 - 7).

The first three bits of the *AOC coordinates* field identifies the number of coordinate pairs (Dx, Dy) that have been incorporated into the current message (1-5). Each coordinate pair defines a vertex of the desired AOC. The coordinate positions are specified relative to the defined zone location (see 3.3.1, BASIC ALERT MESSAGE). Dx and Dy can range from -4095 meters to 4096 meters. A positive Dx (Dy) specifies an abscissa (ordinate) that is north (east) of the zone location. A negative Dx (Dy) specifies an abscissa (ordinate) that is south (west) of the zone location.

Cyclic redundancy check (CRC) is a 16 bit field used for error detection with all messages. The CRC polynomial generator is $X^{16} + X^{15} + X^5 + 1$ (CRC-CCITT).

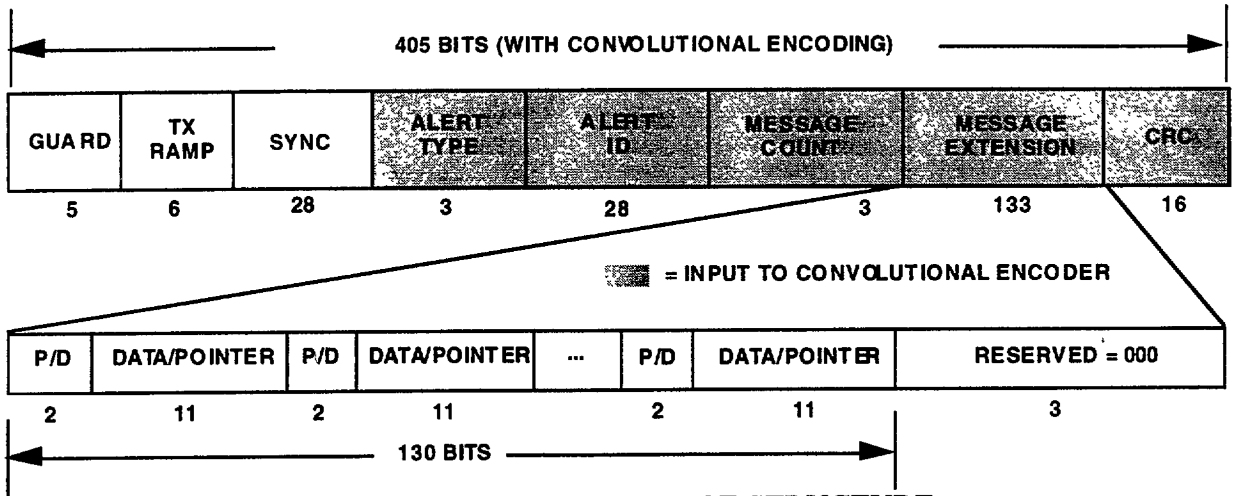


FIGURE 18. CONTINUE MESSAGE STRUCTURE.

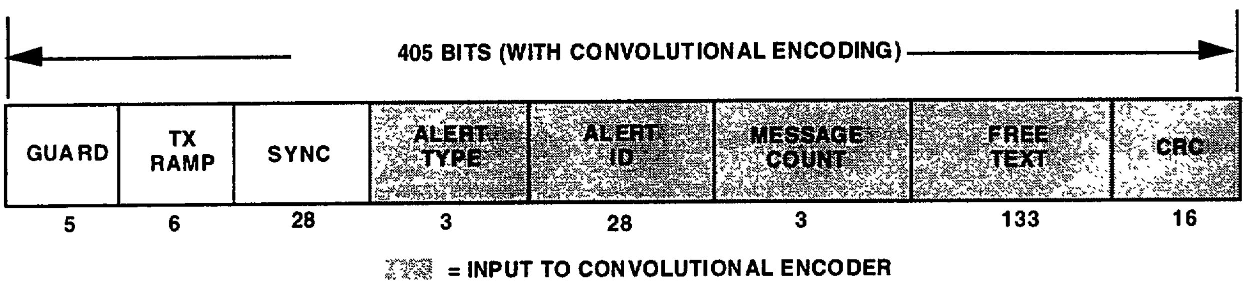


FIGURE 19. FREE TEXT MESSAGE STRUCTURE.

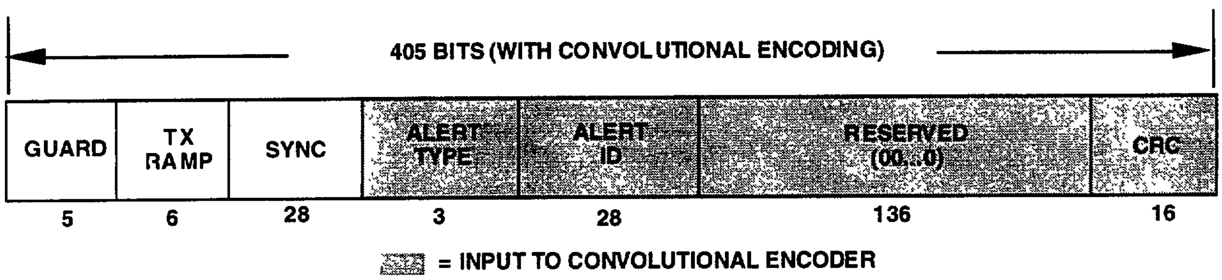


FIGURE 20. DELETE MESSAGE STRUCTURE.

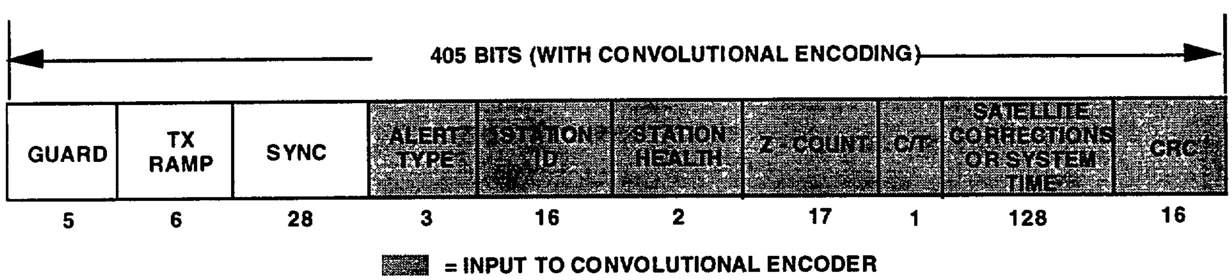


FIGURE 21. SYSTEM TIME/GPS CORRECTION MESSAGE STRUCTURE.

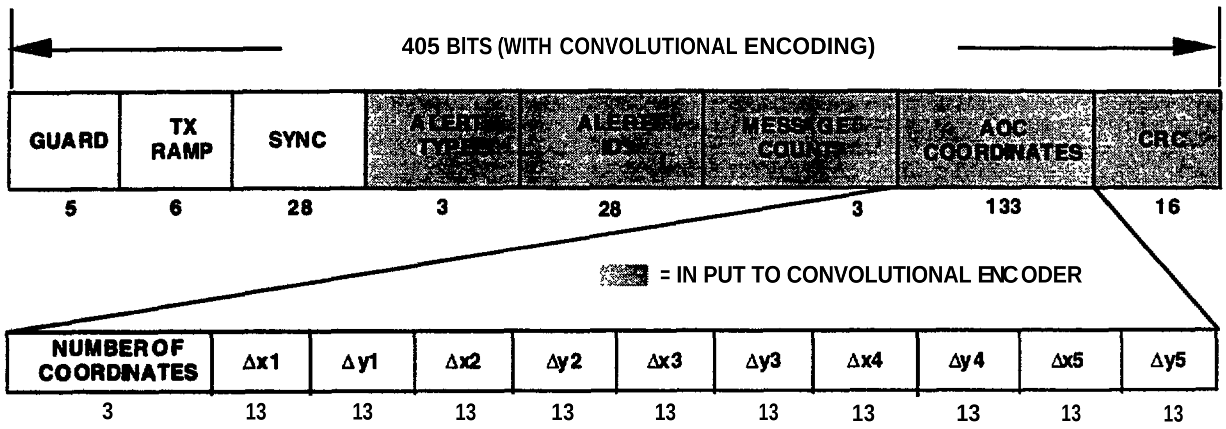


FIGURE 22. AOC EXTENSION MESSAGE.

6.4. SYSTEM TIMING AND DIVERSITY

6.4.1 BASE STATION CHANNEL

Each base station transmits during one and only one of the six available timeslots of each frame (see figure 13). The timeslot is pre-assigned and does not vary during normal system operation. The beginning each frame is aligned with the even-second GPS time ticks.

Each base station transmits a system time and GPS correction message, once per second, as the first alert (ALERT 1, figure 7) of its assigned slot. The remaining two alert positions are available for basic, continue, free text, and delete message broadcasts. Base stations queue all messages to be broadcast into a buffer. The buffer is be transmitted repeatedly in ALERT 2 and ALERT 3 positions. Base stations remove messages from the queue upon command from the system controller (IOC).

6.4.2 MOBILE CHANNEL

When activated, mobile transmitters broadcast one basic alert message every frame. Mobile stations randomly select one of 18 available alert positions (6 timeslots x 3 alert positions/timeslot) for the basic alert broadcast (slotted Aloha protocol). Mobile transmitters do not broadcast delete, free text, continue, or system time and GPS correction messages. The alert ID of the mobile transmitter basic alert message is pre-assigned (e.g., vehicle ID) and remains constant for all broadcasts.