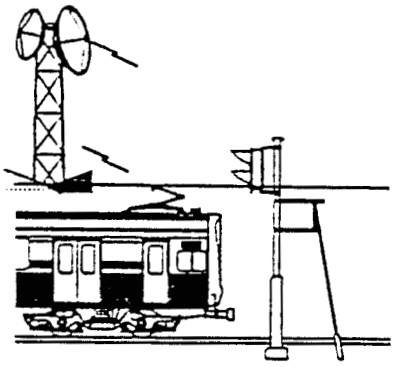

MELBOURNE'S METROPOLITAN RADIO SYSTEM

EQUIPMENT & NETWORKING

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PUBLIC TRANSPORT CORPORATION

TRAIN RADIO SYSTEM

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I.R.S.E. Technical Meeting - Melbourne

March 13 - March 15, 1992.

BACKGROUND

In July 1990, the Public Transport Corporation in Victoria awarded a turn-key contract to Motorola Communications Australia to provide a computer based radio despatch system. To meet the operational, frequency and coverage requirements of the PTC, Motorola Australia supplied a Trunked Mobile Radio Network that incorporated a Despatch Computer supplied by Westinghouse Brake and Signal.

INTRODUCTION

The system will give radio communication for the complete electrified urban railway network of Melbourne and will provide effective communications for drivers, guards, maintenance crews, supervisors, area and train controllers.

The PTC have structured the railway network into five geographical areas, where each area covers several rail lines with its own Train and Area controller. The Controller positions, consisting of a combination of customised touch screen VDU's, audio headset and handset, will be located at the main control centre in Melbourne. From each of these operating positions , private and group communication is possible to the 1300 portable and mobile radio units of the users, throughout the Trunked Radio Network. The network consists of eighteen base sites comprising fifty six base stations and using this network, many conversations can proceed at the one time.

INFRASTRUCTURE HARDWARE

The system required careful integration of three main elements comprising the Trunked Radio Network, the Despatch Computer and the Subscriber equipment including handheld portable radios.

1. TRUNKED RADIO NETWORK

The Trunked Radio network consists of a Motorola Starnet MPT-1327 Trunked Radio system, which is a fully automatic message Trunked radio system using 1200 baud Fast Frequency Shift Keying (FFSK) signalling for control. The Starnet infrastructure includes eighteen base station sites which are controlled by five Trunked System Controllers (TSC). The TSC's are linked by a central data base and audio routing unit called a Master Switch Controller (MSC). To complete the main system hardware, a VME based Despatch Computer, configured with 11 touch screen VDU's, directly integrates with both the TSC's and the MSC. The connection between the MSC and each TSC is via a number of four wire audio lines and an X.25 data link operating at 9600 bps. The link from the Despatch Computer to each TSC and the MSC is also via an X.25 data link operating at 9600 bps. The protocol used by the Starnet system is PSS.

The TSC's are computer based equipment in which the main processor is an Intel Multibus backplane and cardcage configured with an SBC 286/12 containing an 80286 16 bit microprocessor, 4 MByte RAM and 128K PROM. Each TSC comprises of two cabinets: Base Station Interface Rack and the Control Rack.

The base station rack is used to control up to 30 base stations spread over a maximum of four sites. Each base station is connected to the TSC via a four wire line, and in the PTC system both Telecom and private landlines, along with Microwave links have been utilised to provide these links. Communication to the base station equipment is done in the duplex mode, whilst the radio units operate in the two frequency simplex mode of push-to-talk and release to listen.

The Control Rack contains the various computer control cards along with the wired user ports. In the PTC system, ten of these wired user ports are used to provide audio to the Headsets of the five area and five Train controllers. The remaining ports are used for PABX connections and Hard Wired User Handsets of the Driver and Guard Supervisor and the Fleet Maintenance Controller. Communication to wired users is configured for two wire audio with either DTMF or E&M signalling.

The TSC is designed to accommodate four base sites and as the PTC system uses eighteen base sites, five TSC's are required. It is possible that a radio unit on a site on one TSC may need to call a radio unit at a site on another TSC, and this can only be performed with the use of an MSC. The MSC performs the interconnection of Trunking system controllers to provide a larger Radio system thereby facilitating calls between radio units in different TSC coverage areas. The MSC also maintains a database for all subscribers, which is updated with the current location of a radio unit as it moves from one site to another. The MSC provides the networking in a large multisite system.

The MSC, like the TSC, has as the main processor an Intel Multibus backplane and cardcage configured with an SBC 286/16 containing an 80286 16 bit microprocessor, 4 MByte RAM and 128K PROM. The MSC comprises of one cabinet which houses the computer control cards along with the audio switching ports required to route calls from one TSC to another.

Further features of the MSC and TSC's are the system management functions which can be exercised from an RS232 terminal which plugs directly into the TSC or MSC. From this terminal many functions can be performed including adding or deleting radio units from the system, barring radio access to the system, adjusting call limit times, forcing items of equipment out of service etc.

The Base station sites are strategically positioned throughout Metropolitan Melbourne to maximise the radio coverage area. Only twenty-four frequencies have been used in the system and the frequencies have been reused at many sites. Each base site consists of base stations, multicoupling and antennae systems and power supplies. An active base site consists of at least two base stations: a control channel and a traffic channel. Each channel consists of two frequencies, a Transmit frequency for transmission from the Starnet Infrastructure to the radio unit and a receive frequency for transmission from the radio unit to the Starnet infrastructure. The signalling to set up the call is exchanged on the control channel, resulting in the parties being directed to a traffic channel. Further Traffic channels may be added , allowing several conversations to proceed at the one time, and all PTC sites have a minimum of two active traffic channels. The switching of channel frequencies is performed automatically by the radio unit under the direction of the TSC's and the MSC.

Full system operation relies on all equipment operating correctly, however in the event of a failure, redundancy has been provided. The TSC's can operate as a standalone component and therefore if the path to the MSC is broken, radio units will still be able to access other radio units on sites controlled by that TSC. If a control channel base at a site loses its link to the TSC or breaks down, the first traffic channel will be directed by the TSC to become the control channel and the site will continue operation. If the link is lost to all the base stations at the site, the site will go into 'Fallback' mode, whereby the control channel will allow all radio units on that site to talk only to other radio units on that site.

2. *DESPATCH COMPUTER*

The computer control system is known as the "Despatch Computer". The computer system despatches calls to portable radios via the Motorola Trunked Radio Network.

The system is able to accept operator inputs to set up calls between the operator and a portable radios. The portable radios are held by train crew, namely guards, drivers and roving inspectors. The train crew is also able to request calls to the controllers at Metrol.There are three different types of controllers with access to the train radio system. These are :-

- five area controllers (signalmen)
- five train controllers (operations)
- one radio fleet maintenance controller

Each of the area and train controllers control a specific region of the suburban railway system defined by the line sections emanating from the Melbourne CBD. These areas are :-

- Burnley (BLY) Lilydale, Belgrave, Alamein, Glen Waverley
- Northern (NTH) Broadmeadows, Werribee, Williamstown, St Albans
- Clifton Hill (CHL) Epping, Hurstbridge
- Caulfield (CFD) Packenham, Frankston
- Sandringham (SHM) Sandringham

The fleet maintenance controller has the special area defined as maintenance.

Controller Terminals

The train and area controller terminals each comprise of an IBM PS/2 Model 30 personal computers. These are connected via a token ring local area network to the central computer.

Each of these PC's is fitted with a 14 inch colour monitor with a capacitive touch screen overlay and a mouse. All controller input is entered by the use of the touch screen or the mouse with the keyboard completely disabled.

Central Computer

The interface to the Trunked Radio system is implemented using VMEbus modules for the central processing as well as Westinghouse proprietary hardware to implement a hot standby system.

The Trunked Radio system interface is via six X.25 links with information packets being transmitted at 9600 baud. The protocol used by the Despatch Computer is Telenet with Restart Request.

The central computer also interfaces to other peripheral devices including :-

- PTC Train Describer
  This interface was defined by the PTC. The PTC supplied source code for the implementation of this interface so that train describer number changes could by input directly into the train radio system.
- System Faults Printer
- Controller Screen Dump Printer
- PTC Standard Time generator
- Audio Voice Switch Matrix

Controller Functions

Each controller has a base screen from which the various functions may be selected. Selection of all functions from the terminal is window based and can be selected by either touch screen of mouse pointing device. Any selection will cause user friendly windows to be displayed from which either actions are initiated or further windows are displayed. The functions available from the base screen are described below.

1. Help
   This function is available at all times and provides on-line context sensitive help about any window or sub-window.

2. Call
   This function is used by the controller to place calls to a number of different parties. controllers may place calls to a train, a portable radio, a single line, a group of single lines or the whole train fleet. Priority calls are able to be made to trains and to portables. A call to a train may be placed by touching only two positions on the screen, making the calling process very rapid.

3. Screen
   This function will generate a screen dump of the terminal which then prints on a printer on the operations floor. This is used to enable a hardcopy record of the screen display to be obtained.

4. Answer
   This function enables the controller to answer an incoming call from train crew. Selection of answer will initiate the call answering sequence. The facility exists to display up to six queued calls waiting to be answered on the screen at once. The controller has the option of answering the calls in the time order they were requested or in an order which the controller selects. Emergency calls are colour coded and flash on the display. A distinctive audible beep is also sounded.

5 Night
   This function enables controller positions to be night switched to other positions in the event of low traffic periods. Train controller positions may be night switched to other train controller positions and area controllers may be night switched to other area controllers.

6. Report (train and fleet controller only)
   This function provides a number of on screen reports to train controllers. These reports provide information on :-

   - Train List: displays a list of the radios currently associated with a particular train describer number.

   - Faults: displays currents faults detected by the despatch computer.

   - Time On: displays the time that train describer numbers were registered by the despatch computer.

   - Down Time: displays the time at which faults were detected.

   - Call Log: displays a chronological list of the calls registered by the despatch computer since the start of day.

7. Monitor (train controller only)
This function enables a train controller to monitor the audio of their respective area controller. This enables the train controller to listen in to both sides of a conversation in which an area controller is involved.

8. Survey (fleet maintenance controller only)
This function is used to key up any of the radio system traffic channels which then allows the keyed signal to be monitored at different geographical locations to determine signal strength.

3. *SUBSCRIBER UNITS*

Over 1300 Motorola Trunked portable radios will be issued to drivers, guards and other system users. These portables, with their integrated Keypad will allow the user to initiate calls directly to other portables, calls directly to the PABX, and calls to the Despatch Computer based controllers. Each portable has its own individual identification programmed in it, and it may receive dynamic group idents from the Starnet system. These dynamic groups remain inside the portable until power is disconnected to it.

The portable has a screen display, an integrated keypad, a press to talk button, a normal call button, an Emergency call button, a rotary switch selector and an on/off volume control switch.

The keypad is used for entering Train Describer numbers and dialling idents. The normal call button is used in conjunction with the rotary switch selector to send short data messages relevant to the switch position. For example, to send a call to the Train controller, the selector switch should be in position 2, and by pressing the call button, a short data message will be sent to the Starnet system, which passes it to the Despatch Computer, and the request is routed to the relevant Train controllers screen. This enables easy system operation. There are six selector switch positions used currently in the system.

The Emergency call button also sends a short data message to the Despatch Computer via the Starnet system. Again the request will be routed to the relevant controller.

The portable radios used in the Trunking system are the same portables the PTC have used in the interim conventional system. A straightforward modification allows these portables to be converted into a Trunked portable radio.

SYSTEM OPERATION

The system can operate in two formats:

i) A standard Trunked radio system whereby only the Trunked radio network and not the Despatch Computer is used. In this format, the keypad on the portables is used to dial the individual idents to call other portables directly, as well as PABX numbers.

ii) Train describer Number based despatch system whereby the complete integrated Trunked Radio and Despatch Computer infrastructure is used, and this allows more flexibility of calls.

Upon switch-on, the portable will scan through a predetermined list of control channels and it will lock on to the strongest one. The Starnet system will pass this registration information to the Despatch Computer, which will then issue a dynamic group which corresponds to that site back to the portable via the Starnet system. As the portable moves around the system, the control channel signal will become weak and the portable will again scan and capture a new control channel. The dynamic group ident is updated, and the new location of the portable is recorded.

Once a control channel has been captured, the Train Describer Number (TDN) can now be entered. The TDN have all been predetermined and have been allocated to every scheduled train route. Once accepted by the system, the number will be displayed on the portable, as well as on the relevant controllers screen. The five operating areas of the PTC have TDN's allocated to them and the portable will be routed to the relevant Area and Train controllers' screen. As the number is displayed on the Controllers terminal, selection of that number will reveal the portables idents registered with that TDN. The Despatch Computer will allocate dynamic groups to the Portable via the Starnet for TDN and Line Group.

On any train run, the Driver and Guard must enter the TDN, and proper system usage will see at least two portables with the same TDN.

The portables can now request calls and depending on the rotary selector switch position, they will be processed. When requesting a call to a controller, the call is placed in a queue on the controllers VDU. Calls are answered by the controller by selecting the call on the queue. The Despatch Computer then sends the appropriate commands via the data network to the TSC which locates the portable units, assigns a traffic channel and connects the audio paths. The call can either be an individual portable call or it may be a group call to the portables with a certain TDN.

If the call set-up is a group call, ONLY those portables with the correct group ident will take part in the call. Two short beeps are sounded by the portable to signify the start of the call. If the call set-up is an individual portable call, ONLY that portable will take part in the call. The portable will ring like a telephone until the driver or guard answers. As a result, the portables will not be involved in calls they are not required to be in, and the driver or guard will not be affected by excess radio traffic.

From the portable, the use of the normal call button in conjunction with the rotary selector switch will enable the user to setup some six call types:

1. A train call including only those portables registered with the same TDN.

2. A call request to a Train controller, who in turn will set-up a group call to those portables with the same TDN.

3. A call request to an area Controller, who in turn will set-up a group call to those portables with the same TDN.

4. An individual call to the driver supervisor.

5. An individual call to the guard supervisor.

6. A group call that will involve all portables that are registered on the same base site.

In addition to these calls, the portable user has the ability to make an Emergency call which is handled as a special case in this system. Once an Emergency call has been requested by pressing the emergency button on the portable, the relevant controllers terminal will sound an alerting beep and the call request will flash in bright red on the screen. The call is handled as a priority, and upon setup, the TSC will clear the portable out of any call it may be in and set the Emergency call up.

In effect, the portable users can initiate calls to other parties by simply pressing the call buttons thereby making the interface simplistic and very user friendly.

The eleven controllers can also initiate calls to portables that have not requested calls. The touch screen interface allows the controllers to setup calls to TDN groups and individual portables. As well, the controllers can patch portables through to PABX numbers, including the V-Line country train section. The controller has the ability to set up calls to all portables on a particular train line, group of train lines and even the whole fleet of trains.

In addition to the call features of the system, the controller has access to a variety of reports. At the completion of every call, the TSC sends log information to the Despatch Computer which then processes the information into various reports. The controller can obtain immediately a call record, any faults in the system, number of calls made per hour and other related information. Using this information, the performance of the system can be readily monitored.

One of the main design criteria adopted by Motorola has been ease of operation at the controllers screen and the portables. The press of one button can automatically set a call up within seconds to portables located anywhere in the system.

ON TRAIN EQUIPMENT

As a further part of the contract, Motorola supplied a system to enable drivers and guards to make public address announcements over speakers in the passenger compartments of the trains.

The drivers compartment is equipped with a Motorola Mobile Vehicular Adaptor (MVA) which will hold the drivers portable radio. A footswitch and microphone allows the driver to talk through the system, whilst the guards compartment will contain a fist microphone only. The remaining equipment, including a Motorola amplifier, transformer, Westinghouse designed PA Interface Module, and Motorola power supply will be housed in a special equipment box.

The PTC trains are configured using three car consists. In this configuration, there are 2 driver and 2 guard compartments which are situated at the ends of the consist or train. A PA module exists at both ends of the train whilst an amplifier resides at only one end. An announcement can be made from either end of the train and will be heard on all the speakers. Similarly, if two 3 car consists are coupled together, a PA announcement made in the first consist will be heard through the speakers in both of the consists.

The drivers equipment will enable communication to both the Trunked radio system and the trains public address system. For Trunked radio operation, the driver activates the footswitch and speaks into the microphone. The MVA generates the Press to Talk (PTT) and the correct level of audio via the connector on top of the portable. The Radio Frequency signal is sent through the top connector also and then via the RF cable internal to the MVA which is connected to the external antenna on the trains roof. The received audio is heard through the portables speaker. Using this system, the driver can achieve hands free operation.

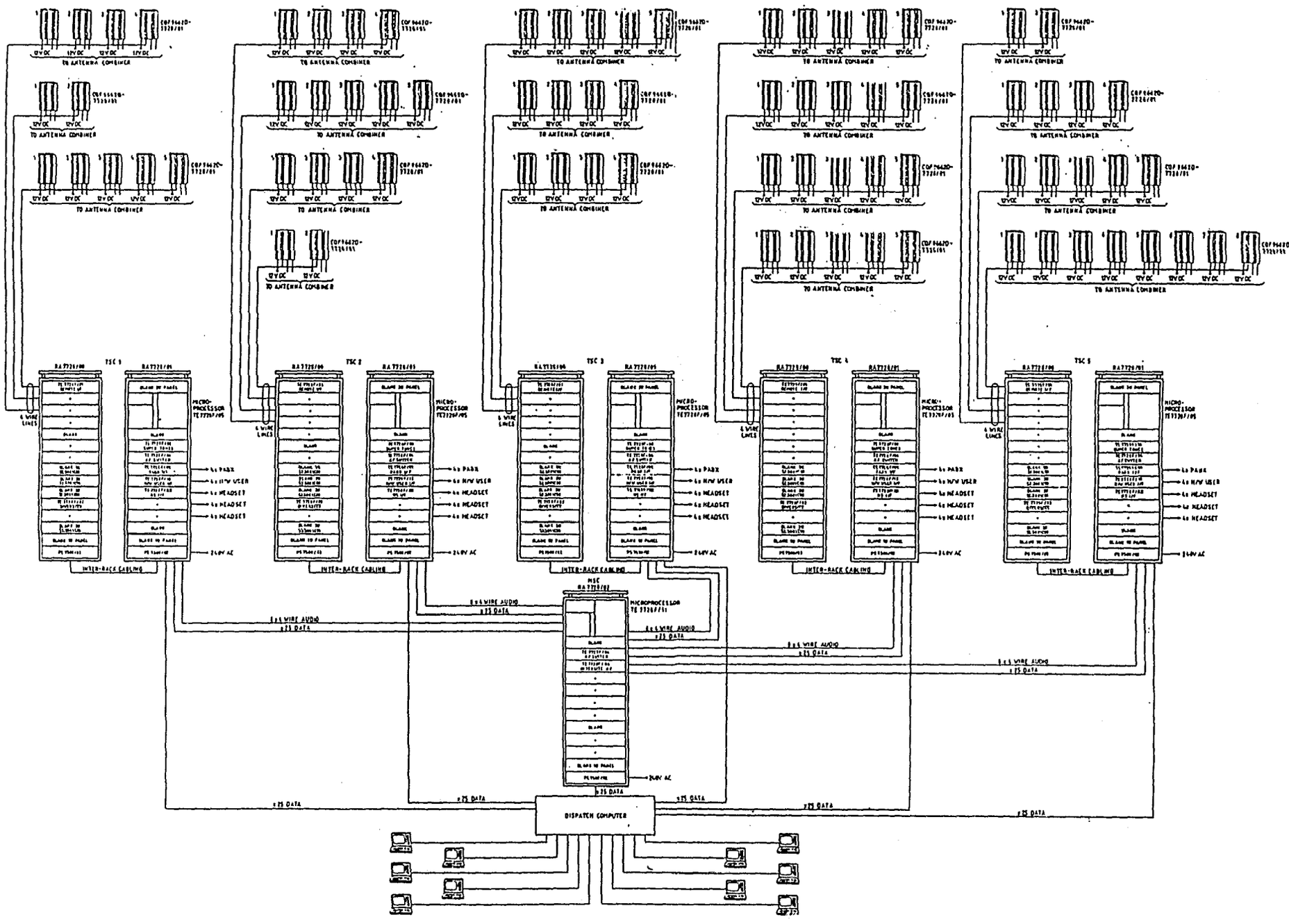
For PA system operation, the driver presses the button on the MVA and speaks into the microphone. The MVA generates PA PTT and pre amplified compressed audio on a 600 ohm balanced output which is then fed to the PA interface module. For the guard to use the PA system, the PTT button on the fist microphone is pressed. The audio is pre amplified inside the fist microphone and fed to the PA interface module together with the PTT signal.

The interface module compresses the guards audio and modulates any audio onto the train wires (speaker wires) and autocoupler wires (which link one three car consist to another) using 60 KHz frequency modulation. Modulated audio is received by all interface modules which generate PTT and demodulated audio for the PA amplifier if present. The interface module also generates PA active signal whenever it detects carrier and this signal is fed to the MVA to light the indicator on the PA pushbutton signify that the system is busy and thereby locking out other users of the PA system while an announcement is being made. Modulated FM carrier is also fed through from the train wires to auto coupler wires or vice versa depending upon the source. The public address amplifier then amplifies the demodulated audio to a 50 watt maximum in a 3 car consist and this 50 watt audio is matched to the train wires via the matching transformer. The matching transformer is used to match the 11 ohm output of the amplifier to either the 290 ohm or 190 ohm train wires depending upon the train type.

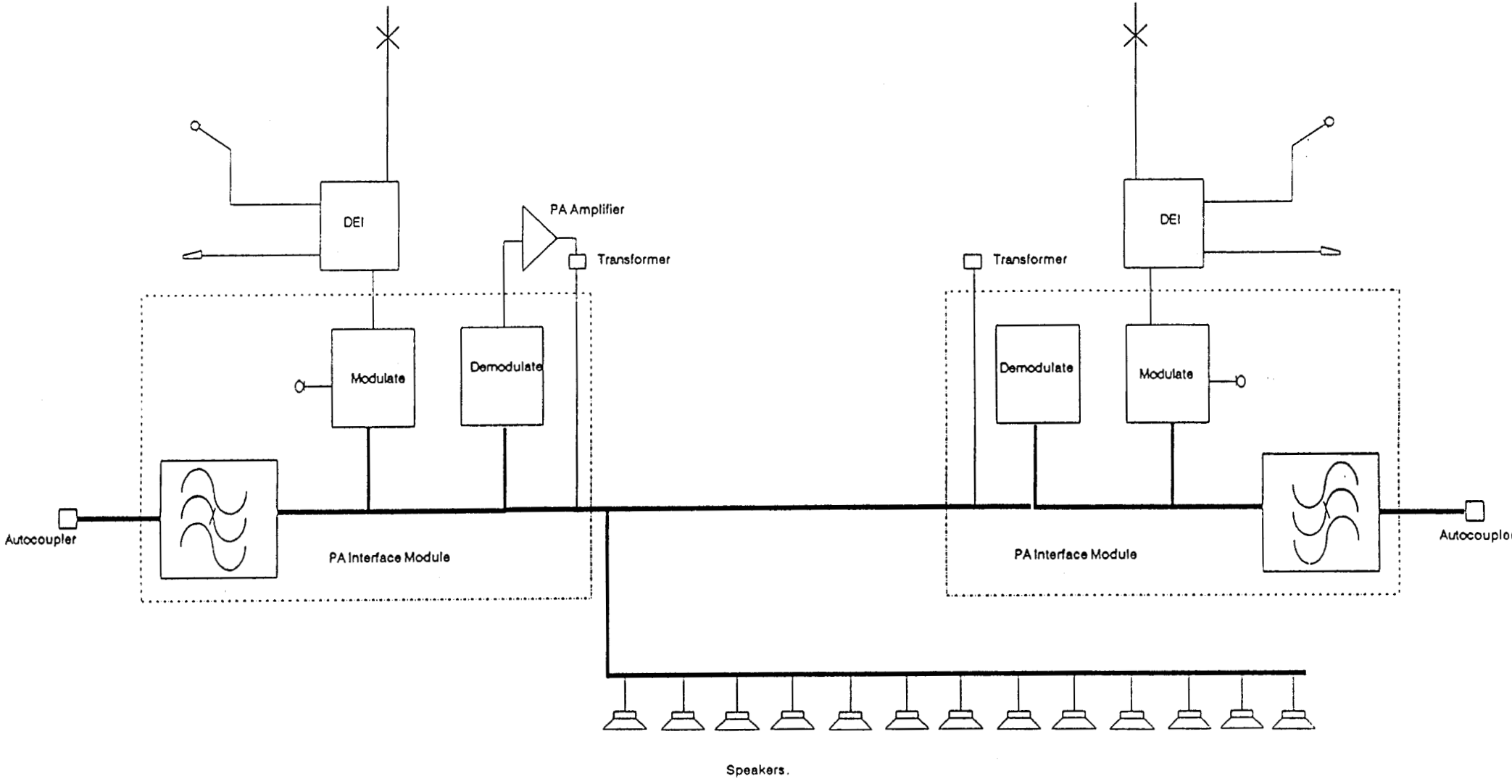
The feature of the PA system is the integration of equipment into both the existing equipment on the trains and into the Trunked radio system.

CONCLUSION

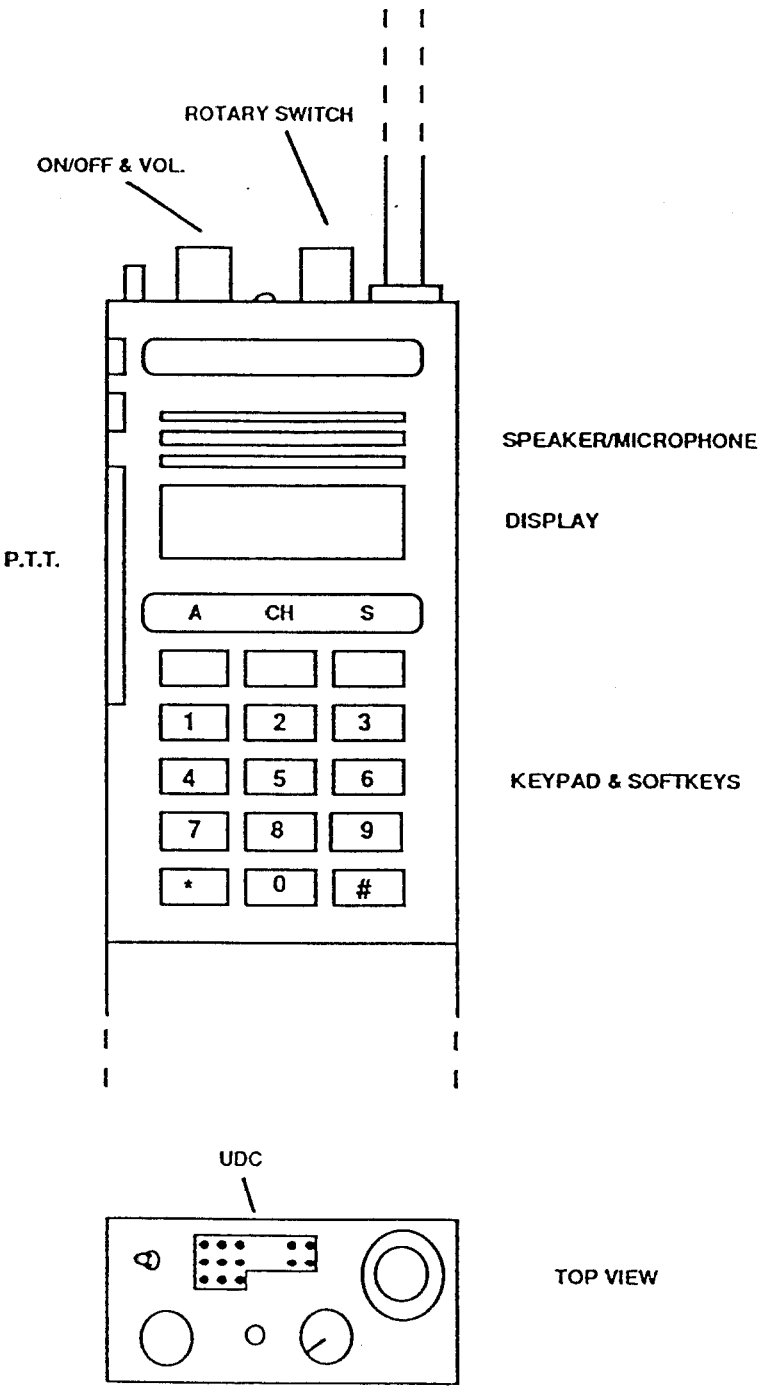
The computer based radio despatch system will provide the PTC with a user friendly and comprehensive communication network. Drivers, guards, controllers and other system users will have a reliable mode of communication allowing private, group and fleet calls.



COMPLETE SYSTEM LAYOUT



ON TRAIN EQUIPMENT BLOCK DIAGRAM



MOTOROLA PORTABLE RADIO

Westinghouse Method of Development: Despatch Comuter

This sub-contract was a development project for Westinghouse, and in line with Westinghouse's commitment to expanding its accreditation to the Quality System AS3901, the project fulfilled many of the requirements of this standard during the development of software.

Following the award of the sub-contract Westinghouse embarked upon a number of steps in development. Upon completion of each stage of design, the relevant design documentation was passed to Motorola for approval.

1. **Functional Specification**

   A functional specification was written in conjunction with both Motorola and PTC in order for Westinghouse to establish the customer requirements precisely. This document is voluminous and covered the following two main areas :-

   system interfaces including
   - controller
   - radio system
   - printer
   - voice switch matrix
   - PTC train describer
   - PTC standard time generator

   functional relationships between these interfaces

   A proposed system hardware design was also included in the functional specification.

2. **System Design**

   The next stage was to design a system which would meet the functionality required. This design was to identify the main system functions and areas.

   There were three sub-system areas identified as VME, PC and Gateway these coincided with relevant area of hardware. The system needed to incorporate hot-stand-by as a major design consideration and to communicate with the peripheral devices via the interfaces defined in the functional specification.
   The interfaces between sub-systems was also defined at this point.

3. **Sub-System Design**

   The sub-system design stage identifies the software packages within each of the sub-systems. This level of design was by far the most important for the project. It was at this level that the detail of the design began to evolve. The interfaces between packages were defined during this level of design.

4. **Package Design**

   This level of design was where the individual functions of the software were identified. Due to the number of packages within each sub-system, the task of package design can be undertaken by many people simultaneously. Computer Aided Software Engineering (CASE) tools were used to assist with this level of design. The interfaces between code functions were defined during this stage of design.

5. Coding

Coding of the functions was completed with the use of a further CASE tool. The tool was a semi automatic code generator tool. The tool enables the software engineer to means the logical function of the code can be determined before the code is entered.

6. Testing

Testing was generally performed at a package level. The primary requirement for testing of a package was that all pathways within a package must be tested. Where pathways were not able to be tested at a package level, the testing was performed at a function level. Test documents and software test stubs were written to assist and document the testing. The results of all the testing performed were recorded and the tests are able to be reproduced at a later time if required.

7. Integration

Once each of the packages had been tested it was available to be integrated into the whole system. Where packages were not yet completed, software package stubs were written to enable integration of the packages into one system to take place. A system integration document was written to enable the integration of the system in a defined and orderly manner.

8. System Test

A system test document was written to enable the system to be methodically tested. This document was based upon the interfaces and functional requirements as defined by the functional specification.

There were two other very important documents which were written to ensure the quality of the development. These were :-

Environment Document - This document describes the storage of all documentation of the system including source files and design documents, file naming conventions and computer file directory structure.

Standards Document - This document described the standards used during the development of the computer system. In particular it describes how to use the CASE tools for both the package and coding stages of design.

Conclusion

In reaching this stage of development of the Despatch Computer system, a great deal of effort has been provided by the staff of all parties involved in the sub-contract. Westinghouse are satisfied that the development of this computer control system has addressed many of the issues to produce computer software and systems of a quality to meet the requirements of the Railway Signalling Industry and AS3901.