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MOBILE RADIO SYSTEMS IN POWER UTILITIES

Working Group 02

Of Study Committee 35

(Power System Communication and Telecontrol)

February 1994

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SECTION 1 FOREWORD

CIGRE Study Committee 35 (SC35) published its first Guide on Mobile Radio in power utilities in 1985 [1]. Since that time many new mobile radio systems have been introduced or are planned.

At the meeting of Study Committee 35 in 1989, Working Group 35.02 was given the task of preparing a report to update the 1985 Guide so that planners and designers of systems in the mid 1990's would have a complete reference to the choice of systems available for power utilities.

In this report, care is taken not to repeat the earlier work, and therefore readers should refer back to the original guide on matters of principle, and for details and descriptions of basic and conventional systems.

During work on this report, Working Group 35.02 also prepared a report on Telecommunications Network Management [2]. Since there is a merging of the technologies of the complete telecommunications field, some aspects of network management of mobile radio systems are more fully addressed in the companion report.

The preparation of this report represented a significant effort through the questionnaire and the detailed drafting process, and the members of the Working Group (identified in Appendix G) are to be commended.

Explanatory Notes

1. A glossary of terms is contained in Appendix A2 which explains technical phrases and terms used in this Report.

2. References denoted by [1], [2] etc. are contained in Section 11.

3. Mobile Radio Systems in this Report may be abbreviated in the text to MRS.

4. Power utilities in this Report may be abbreviated in the text to PU.

SECTION 2 SCOPE

The specific charter given the Working Group was to prepare a report on the present use and future requirements for mobile radio systems in power utilities, and that it should include:

- the description of existing mobile systems in power utilities based on a questionnaire

- reasons and requirements for new mobile radio systems

- descriptions of main system solutions and future trends of mobile radio systems

- differentiating factors between systems when considering selection criteria and the applicability of particular systems to power utilities needs.

It was further laid down that special attention should be paid to modern mobile radio systems as part of the total telecommunications networks of power utilities including:

- connections between networks

- network management aspects, etc.

During the period of work on this report the discipline of mobile radio has advanced at a rate beyond all expectation. After being a relatively stable technology for many years, the very rapid evolution of public mobile services has brought a new dimension to communication to and from the vehicle and the person in the street.

Furthermore the current introduction of digital transmission techniques to the mobile arena of radio transmission has brought the promise of better quality, higher speed data transfer, and a wide scope of new functions.

In particular, it was continually necessary to address the comparison between networks available for construction and operation by power utilities themselves, and the variety of offerings from public telecommunications companies and other entrepreneurs.

Whilst avoiding as much as possible repeating the work of the 1985 Guide [1], this report details systems currently considered as state-of-the-art and draws comparisons with current public networks. It then attempts to foresee both in the private and public domains what might be the direction for the future. A future that is almost certainly going to continue to produce rapid change for a number of years to come.

SECTION 3 SUMMARY

3.1 Method Adopted in Preparing this Report

To obtain basic data required to prepare this report the Working Group prepared and distributed an extensive survey seeking power utility practices in existing mobile radio design, construction, operation and maintenance, and forecasts on future plans and requirements.

58 responses were received from a wide spread of countries.

The data so collected was processed and analysed and then used by the Working Group authors to draft the various sections of the report.

Each author had extensive background knowledge in the subject matter and was further supported by access to experts in his own and other utilities/countries.

3.2 Content Summary

Section 4 describes the role of the mobile radio system as a part of the total telecommunications network of a power utility in fulfilling its telecommunications needs where mobility is a requirement. The need for connections between different networks and network management aspects are described. Specific problems of mobile radio network interconnections to digitalised fixed infrastructure are introduced. Also the vital role of mobile radio systems in the changing organisational environment of power utilities is stressed.

Deregulation and liberalisation in telecommunications offer opportunities for power utilities to sell capacity or services to other parties and the consequences in respect of mobile radio networks are also discussed in Section 4. The influence of deregulation to the technical requirements of the networks is introduced in Section 5.

In Section 5 the basic requirements for mobile radio systems are presented. The starting point is to list the application areas where mobile radios will be used. Also the description of different operational situations is listed. The outcome of this analysis is a list of services and facilities which the mobile radio system has to offer. Additional requirements for availability, capacity, coverage and connections to other networks are presented. Methods of increasing the availability are described. Also practical advice is given for dimensioning the networks for sufficient capacity. In describing environmental requirements reference is made to existing standards.

There is a trend of growing complexity for new mobile systems. Therefore the requirements for network management and maintenance as well as for training are becoming more important. Because it is difficult to accurately estimate the growth of traffic when dimensioning new systems, the requirements for system flexibility are essential.

In Section 6 following a brief history of mobile radio systems in power utilities the basic types of present mobile radio systems are introduced from conventional private systems to public trunked and cellular systems. The basic differentiating factors between systems from the power utility point of view are presented. Also reference is made to Appendix B which, on the basis of questionnaire analysis, includes descriptions of existing private mobile radio systems in power utilities, usage of public mobile systems and plans for replacement of old systems.

Section 7 details new mobile radio standards relevant to power utilities. The basic characteristics, services and facilities of each system are described, including the main change in standard systems from analogue to digital techniques.

Section 8 describes the evaluation and suitability of different, new or emerging standards. The criteria used in the evaluation is based on the answers to the questionnaire and on the requirements listed in Section 5. Choice between standardised and proprietary systems, private and public systems is also discussed.

Conclusions on the issues treated in this report are contained in Section 9. The main conclusion is that the operational needs of power utilities can only be fulfilled by private radio systems. The chosen solution for power utilities mobile communications can be a balanced combination of both private and public services.

After acknowledgements and references in Sections 10 and 11 there are Appendices including the list of services required for mobile systems, results of questionnaire analysis and examples of typical mobile radio systems used in power utilities. In Appendix D some existing standards of trunked systems are described which are at present in practical use and represent improvements in efficiency and services when compared with conventional private radio systems. As an example of a technical solution in equipment level having generic value in emerging systems, Appendix E introduces the techniques of amplifier linearisation.

An example of modern network design methods is shown in Appendix F and the list of WG35.02 Members is contained in Appendix G.

SECTION 4 MOBILE RADIO SYSTEM AS PART OF THE TELECOMMUNICATIONS NETWORK

4.1 Network Aspects

Modern power utilities require fast and reliable ways of obtaining information from the main activities in the power systems. These needs are of course dependent on the type of activity, i.e. production, transmission and/or distribution. In general the reliability and availablity requirements for these telecommunication networks are higher than can be provided by the public carrier. Power utilities have therefore exploited their privately owned telecommunication networks for many years.

Power utilities need telecommunication facilities for a variety of operational and general business reasons. These are:

- Management of the power system
  - network operation and control
  - general operation and control
  - load management
  - energy accounting
  - analysis of power system faults
  - protection of the power system
- Power system operator communication (voice and data)
- Business voice and data communication
- Customer contacts

The required telecommunication facilities are realised by the following telecommunication systems:

- data communication network for operational purposes
- operational telephone system
- mobile radio system
- corporate telephone network
- corporate data network (LAN's and WAN)
- paging network
- video network

The basis for telecommunication systems in power utilities privately owned telecommunication transmission media are:

- Copper cables are still extensively used. While originally using the copper conductors, many cables are provided with analogue and digital multiplex equipment increasing the capacity of the cables and prolonging the economical life time.

- Radio links are generally in use for more than 40 years and can be analogue or digital. Digital radio links will remain an integral part of the telecommunication network.

- Power line carrier (PLC) is still used extensively with its limited capacity. The existing analogue systems can be replaced by digital ones. In new circuits PLC is replaced by optical systems.

- Optical fibre cables have been introduced in the last decade and are a very suitable and economical solution for power utilities, either buried with high voltage cables in the same trench, or suspended in, on or under transmision line conductors. Mostly digital multiplexing is applied on optical cables. Because of the physical characteristics of the optical fibres the capacity is almost unlimited and exceeds many times the needs of power utilities.

Telecommunication systems were set up in the past as dedicated systems, having a separate system for each function. With the increasing demand for telecommunication facilities, the use of common information, technical developments like the introduction of computer controlled systems and digitalisation, telecommunication systems were integrated to establish corporate communication networks. An example is the interconnection of the telephone systems (operational, PABX and public) and the mobile radio system. Another example is a Wide Area Network used for operational and administrative data. Mobile radio systems are not only used for voice communication (operational and administrative), but also for data communication (operational, control and administrative).

The trend in telecommunication applications of power utilities is towards more flexible and efficient use of the telecommunication infrastructure. Liberalisation makes offering of telecommunication services to third parties possible. As a consequence power utilities have to operate new high performance and complex networks. This sets demanding requirements to the telecommunication network management. Working Group 02 of Study Committee 35 has prepared a specific report on this subject [2].

Mobile radio has been established in power utilities for more than 50 years. Early radio networks were small, localised and stand-alone, with few functions. There were no real systems by todays standard and only used for voice transmission. Modern systems, however, are an integral and important part of the telecommunication system. A number of system functions especially for power utilities has been developed by the mobile radio suppliers.

Mobile radio is usually the only front-line communications medium for people in the field during major power failures, bad weather conditions and other disasters.

Operational radio traffic takes place between control centres and personnel working in the field equipped with mobile radios and/or handsets. The demand for provision of an efficient customer service and short cut off times in the power supply can easily be achieved with the use of mobile radio systems. Data communication over radio will be widely used, not only for operational purposes but also for customer support.

4.2 Organisation and Management in Power Utilities

In many countries the former state owned power utilities are re-organising and splitting up their generating, transmission and distribution activities into different companies. At the same time the companies are sold off with ownership changing to private, industrial or municipal responsibility. There is, however, a need to create a more business like management with respect to customer support, efficiency and costs. This all leads to re-organisation on a large scale in power utilities with requirements to achieve:

- reduction in costs
- better customer oriented relations
- more flexibility
- broader functions

Mobile radio systems will play an important role in achieving this goal. Mobility will be a future key word, not only for operational purposes but also for management with increasing customer contacts and requirements of an efficient service organisation. There will also be a need for integrated telecommunications solutions at reasonable cost. As mentioned earlier MRS will be a fully integrated part of a telecommunication network. This development will be more important in the new customer oriented world.

Not only for traditional private mobile radio systems, but also, as an addition, the public mobile systems will take a share of the needs for mobile communications in power utilities. For management and customer oriented functions, a public mobile phone is more appropriate.

The management of the telecommunication activities of a power utility will change from being technically oriented, towards the requirement of a separate business unit. This is due to the influence of the fast growing integrated services, a more customer oriented approach, internal cost-budgeting and opportunities on the external market due to deregulation.

4.3 Influence of Deregulation

The telecommunication monopolies of the Public Telecommunications Operators are generally being broken down. The social and political trends are towards deregulation, liberalisation, privatisation, standardisation and Open Network Provision. Also the technology and the market is changing rapidly with the penetration of optical cables, the introduction of digital networks and the fast growing market for mobile communications.

In most countries power utilities have their own private telecommunication networks, operated by their own telecommunication experts. These networks are regional or country wide. Optical cable systems utilising the infrastructure of the power transmission network are an economical solution for existing and future needs, sometimes in combination with public networks. As the capacity of the optical cables is very high and exceeds the needs of the power utilities many times, it can be worthwhile to exploit the spare capacity on a commercial basis and deregulation makes this possible.

The introduction of Telecommunications Network Management will support this development.

All these developments make it possible for power utilities to be considered as possible telecommunication service providers. These services can be:

- lease of spare network capacity
- lease data communication
- provision of telecommunication services.

With regard to mobile communications the market is changing rapidly. In several countries second operators are competing with public operators who are going to build the new GSM network. In other countries public mobile systems are being liberalised. Private trunked networks may be exploited commercially.

For power utilities these developments can give the following options:

- lease data communication lines and antenna/housing facilities to a second public mobile operator

- spare capacity in the private mobile network may be available for leasing to a third party

These new services can be considered as a complement to the prime activities. A minimum investment can therefore be very profitable.

As telecommunications is now a prime facility to the activities of a power utility, its role will change drastically when operating on a commercial basis. There will be consequences in:

- dimensioning of the network, including the necessary investments
- grade of service
- management of the network
- cost calculation of the services
- co-operation between power utilities to provide a nationwide and/or international service
- standardisation of the network components and interfaces.

More technical consequences are contained in Section 5.20.

Although the challenges are large in the market, the risks may be even higher in cases where a telecommunication department is not prepared to operate on a commercial basis. The most sensible approach can be described as 'THINK BIG BUT ACT SMALL'.

The following steps can be taken:

- Create a separate Telecommunications business unit within the PU with the utility as the prime customer
- Develop an internal tariff structure
- Specify the grade of service
- Explore the internal market
- Train the employees and reshape the organisation
- Prepare a "Business and Marketing Plan" and act accordingly
- Seek co-operation with other utilities
- Try to get pilot customers with a limited risk and, if successful, a further penetration of the market can be considered after the necessary investments in infrastructure.

SECTION 5 REQUIREMENTS FOR MOBILE RADIO SYSTEMS

5.1 Field of Application

Mobile radio equipment used by power utilities is an important tool for operational management. Its main use is for communications between personnel engaged in the following activities:

- construction and maintenance of distribution networks
- construction and maintenance of power stations
- operation of power networks

An important service for many power utilities is the use of mobile radio systems for remote control. This function includes normal use of the system for operation of circuit breakers and switches, metering and obtaining status information from substation equipment. The use of mobile radio systems for telecontrol systems is particularly efficient when disturbed situations occur such as during short cut-off periods in the power supply. In some utilities radio networks are also used for administrative traffic and other services.

Results from the questionnaire, see Appendix B, have highlighted the important values of a power utility radio system. These include the demands for availability and radio coverage over the utility distribution area. Today many utilities are establishing coverage area with systems based on strategically located repeater stations, whilst some utilities are using public mobile telephone networks to complement their own mobile radio networks.

5.2 Frequency and Coverage Demands

Often there is a requirement for radio coverage over large areas and because of this the decision of frequency band is an important factor. In most countries the frequency allocation authorities well understand the requirements for full radio coverage in their working area. The frequency allocations for power utilities are in the VHF bands, 80 or 160 MHz.

Designs need to allow for future traffic growth, and frequency allocation administrators need to be pressured to reserve appropriate frequencies to allow for this growth. In some countries, however, frequency resources are scarce and such reservation may not be permissible or even possible. Power utilities must then resort to techniques which will make more efficient use of the available spectrum, to enter into sharing agreements with other major users, and/or use public mobile telephone systems for all or part of their requirements.

5.3 Description of Functions and Facilities

Manufacturers of modern mobile radio equipment can offer systems with a great number of facilities. However, it is not possible to produce a standard system with services and applications required by all types of PU's let alone all types of MRS users generally. Accordingly, it is still necessary to specify the functional requirements of each particular system. The most important system functions and facilities in modern radio systems are listed in Appendix A.

To maintain consistency, these descriptions of services and functions are based on those contained in the emerging TETRA Standard [3].

5.4 Normal Operational Conditions

For most of the time, MRS are used to support the normal daily operations of the power utilities. Traffic load may be small and variable dealing with the needs of distribution system workers, or with predictable morning and evening peaks typical of work patterns in construction and maintenance activites. For either case, the design parameters of the system are rarely extended, since much more demanding criteria evolve from the needs arising in abnormal operating conditions. Access to fixed telephone networks can be permitted during normal conditions since the higher holding times are not normally an embarrassment to the system. This leads to the recommendation of closed traffic mode for normal traffic, see also Section 5.10.3.

5.5 Abnormal Operational Conditions

Disturbances to the power distribution network through climatic conditions, plant failure or other cause, will always produce an abnormal demand on the MRS. Existing systems are expected to carry highly increased traffic loads and some channels may be required for specialised service needs. Open traffic mode (group call or open channel) is the preferred traffic mode at these times, see also Section 5.10.1. Experience also shows that often when abnormal pressure is being applied to PU MRS systems, similar pressure is evident in systems of other authorities and the networks of public operators, such that little relief can be gained by using other facilities.

During such abnormal conditions, not only is there substantially increased traffic, but message handling is of a more critical nature. Furthermore, the mobile system may be the only available system to carry traffic if other facilities have been interrupted or damaged. However, all systems have a finite capacity and it is not always possible to avoid blocking or longer than desirable waiting times. Systems designs must take these issues into account and may need to provide priority access, curtailment of administrative traffic, queuing, call duration limiting, barring of telephone network access, and/or conversion to open channel operation.

Some of the MRS functions in the power utilities are created just for abnormal conditions only. Activities during disturbances are different depending on how the radio is used. In many cases there is a requirement to change organisational instructions without delay.

Also, there is often a necessity to join operations with other groups inside and outside their own mobile networks. Because of this the system must permit flexibility.

5.6 Specific Requirements on Local Level

In general, power utilities have established radio networks for mobile communication with system facilities in practical use over its total working area, but there are cases of specific requirements for local use in smaller areas. For some groups in the field, or in certain selective environments, these can be different from the requirements in the main system.

Communication on a local level is usually carried out in simplex mode (direct call) or in some cases in local repeater mode, but due to the traffic load and the risk of disturbances from other groups, simplex channels are normally preferred.

5.6.1 Communications in Small Distribution Areas

In a number of power utilities, personnel working in small distribution areas, such as parts of a city, are the main users of the mobile radio network, and some utilities have established local systems for this purpose. Alternatively, this function may be seen as the main purpose of the primary system and no other system is deemed to be necessary. During disturbances in the power system, there may be a need for local systems to work independently, to have connectivity to the main system, and/or to have interconnect facilities to the telephone network.

5.6.2 Communication for Indoor Use

Local networks are sometimes established for indoor use. For example local networks are established in confined environments in power stations and substations in remote areas. The main requirement is for cordless telephone applications, but all other requirements for the local power utility communications can be included too. Often there are a number of other technical or environmental solutions which can be utilised for indoor use. For instance accessories for communication in noisy environments or radiating cables can be used. The indoor systems can be seen as a complement to the local telephone systems.

5.6.3 Other Special Local Communication Systems

Paging systems can be seen as local networks also. Here of course the primary operational requirement is for full radio coverage to all parts of the construction plant, or the power station area. Paging systems are often integrated into the local system but can be isolated for working on separate channels outside the mobile network. The paging system can be open voice, selective tone alert, or alpha-numeric message based.

5.7 Specific Requirements on Regional Level

Certain groups of personnel within the administrative region of a PU require to communicate throughout the whole region, from control centres to each mobile. The size of this region may vary for different PU's but however, the main communications facilities should be suitable for use throughout the whole working area.

For operational situations there is a need to communicate over long distances within the region and most utilities establish contact over separate fixed circuits, for example over channels in either public or private networks, terminating at base or repeater stations. Modern systems may use roaming functions for automatic long distance calls. In addition, alarms from remote sites need to be transmitted to regional control centres for supervisory purposes. Important services such as group and broadcast calls, may have to be routed via several base station sites.

5.8 Specific Requirements on National Level (or MRS interconnection)

In a power utility there are sometimes groups working in the power system all over the country. There are contacts inside the utility but communication with colleagues in other utilities in joint operation can also be required. Long distance communication therefore must be created over fixed circuits in the same way as for the long distance calls inside the region.

In some cases the mobile radio system can be shared by several utilities. In situations of that kind there are requirements to carry out joint specifications and numbering facilities for calling and solutions are often based on interconnected exchanges and utilisation of fixed networks.

Some utilities have need to establish communications between mobile units located hundreds of kilometres away from each other and this can only be solved by usage of public or own fixed transmission systems.

5.9 Availability Requirements

5.9.1 General Aspects Concerning the System Availability

System availability is one of the most important requirements of the PU telecommunications networks. There are several methods to design and construct high availability systems. In any case requirements for the Mobile Radio System components are affected strongly by the system structure. If the system intelligence is totally distributed and there are no critical devices in the system the availability requirements for different components can be minimised. In practice conventional systems are a good example of this. In this kind of MRS the system components are normally connected in parallel for reliability.

In a trunked system the intelligence and gateways may be concentrated in a Mobile Exchange (MX). Also many system components are functionally connected in series. This means that the reliability demand of system components is very high. In this Section most effort has concentrated on exchange based and trunked systems.

It is very important to note that high availability requirements lead to quite expensive system costs. In practice there are several ways to increase the system availability:

- hot or cold stand-by devices
- overlapping in base station coverage
- duplicated lines to base station by alternate routes

- duplicated gateways from MX to fixed telephone network
- improved fault diagnostic
- fast repairing response in fault cases, short mean time to repair (MTTR)
- in designing and manufacturing system components special attention can be paid on reliability etc.
- dynamic channel allocation

Normal definition of the availability (A):

$$A = \text{total available time/measured time} = \frac{MTBF}{MTBF + MTTR}$$

MTBF = Mean time between failures

The recommended availability for modern mobile radio system is at least 99.9%. The system availability here is defined as that if more than 95% of system functions and connections are available the whole system is available.

5.9.2 Availability Requirements for Mobile Exchange (MX)

Structure of a mobile exchange is such that the total availability of an exchange is in the order of 99.5% - 99.9% and the availability of a single base station interface or external data/voice interface (channel) is 99-99.5%.

Some technical solutions to reach very high MX availability are:

- totally duplicated exchange (very expensive)
- partially duplicated exchange structure (expensive):
  * at least the control part and switching matrix of exchange is duplicated
  * line interfaces are distributed on different modules (cards)
- very high performance fault detection and isolation system and very fast response on repairing
- line interface shall operate independently with minimum central control
- exchange software is constructed so that it can handle fault situations and can stand up and reboot without any help from the operator
- use of high quality components

5.9.3 Availability Requirements for Base/Repeater Station (BS)

Availability of base/repeater station unit shall be in the order of 99.0% - 99.5%. There are some technical solutions which can increase base station availability:

- careful component selection in design process
- microcomputer control and fault detection
- fault messages between base station and management system
- loop mixer between receiver and transmitter to test receiver and transmitter functions
- line fault indication system between BS and MX
- local repeater function in fault cases
- selection of high quality antenna and antenna cable
- selection of high quality combiner units to prevent intermodulation problems
- end to end testing using special test radio units
- devices are classified for right environmental conditions
- several base station units/site

5.9.4 Availability Requirements for Mobile Station (MS)

The availability of a MS is in the order of 99%-99.5% but strictly depending upon the service level of the maintenance organisation. The availability of mobile station can be increased using careful component selection and wide or over dimensioned temperature range of components (e.g. -25°C-+55°C) in designing process.

Easy fault detection can be achieved using microcomputer based systems. Extra care needs to be put into antenna and cable selection. Location of vehicle antenna is best placed in the middle of the roof area.

5.9.5 Availability Requirement for Handportable Station (PS)

The handportable shall have the same availability figures as for mobile station. Special care is required in selecting radios for very robust conditions, e.g. mechanical strength against dropping on hard surfaces and also resistant to water ingress. Also it is important to use very high quality antennas.

5.9.6 Availability Requirements for the System Software

System software has a very strong influence on system availability. The software has to be designed and programmed very carefully and it is very highly recommended to use modular structured programming. Also special attention has to be paid to software testing. The system software has to support system fault detection and to limit fault influence on operations. In practice the system software has to put a redundant unit or connections into operation if faults are to be located. It is also very important to give statistical and fault information to operators and/or to management network, see also Section 5.14.

5.10 Capacity Requirements

5.10.1 Traffic Density in Open System

In an open system the users can listen to all traffic on the air. In that kind of system the maximum number of active mobiles and handportables stations operating on one channel is between 40-80, so the amount of channels chosen has to ensure that this figure is not exceeded. An open channel can transmit a variety of traffic loads. For this reason the open channel can more easily carry the traffic which is required during abnormal power network operational conditions.

5.10.2 Traffic Density in Semi-open System

In a semi-open system the audio path in mobile radio (MS or PS) is normally closed and the signalling is used to connect the speech path. In certain operational conditions the mobile subscriber can connect a speech path using push button command. A call from a mobile radio to the fixed telephone network is built up using special signalling. For these reasons semi-open channels cannot handle as many mobile radios per channel as an open one, and therefore, the maximum number of radios operating on semi-open channel can be limited to between 30-50.

This figure can be larger if the trunking effect is utilised.

5.10.3 Traffic Density in Closed System

In a closed system the audio path of a mobile is connected only by selective signalling. The network structure and the average call duration both have substantial effects on the traffic capability of a closed system.

If the system can be constructed so that there are several base station channels on one site the trunking effect can be utilised, see figure 5.1. For example on a ten channel base station site the traffic transit capability per channel is 2.6 times compared with two channels per site.

Power utility networks are often a combination of open and closed parts. The use of open channels will diminish the need to dimension the closed part according to the traffic peaks, and a larger number of mobiles, per channel, can be handled.

In an intermediate system where average call duration is 1-2 minutes, the following values can be used:

- on one channel site 15-25 mobile radios per channel
- on two channel site 25-35 mobile radios per channel
- for other values the engineer has to calculate on an individual basis

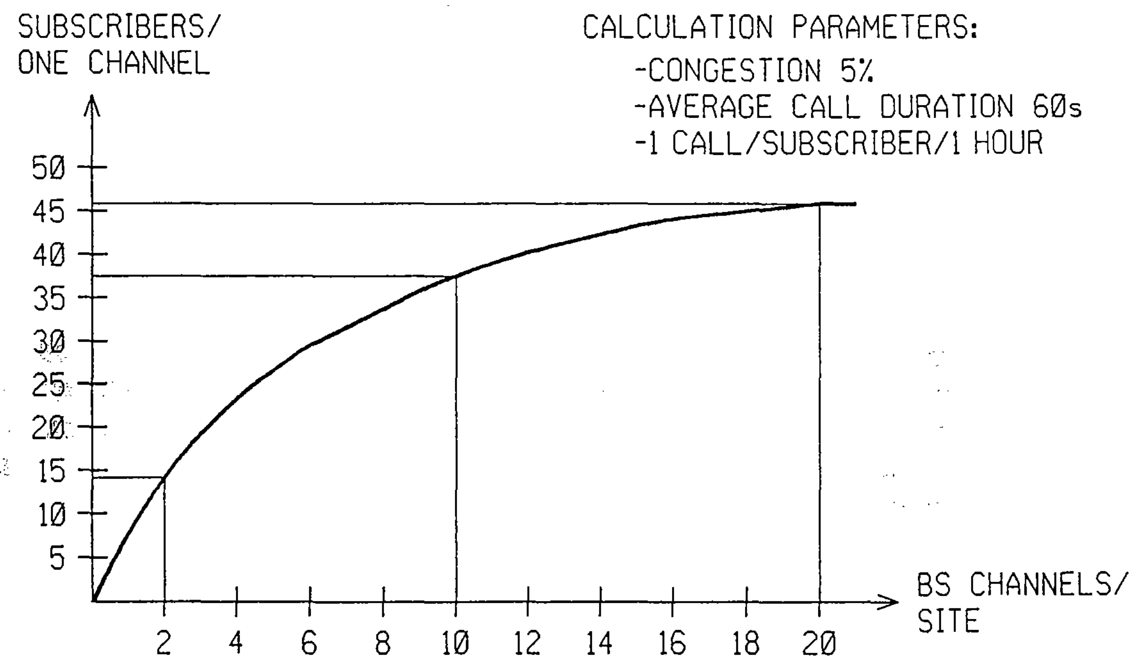

Figure 5.1 The trunking effect

5.10.4 Traffic Density in Abnormal Operational Conditions

In abnormal operational conditions the traffic density is much higher than in so called normal conditions. For that reason the system must be able to accept this increasing traffic. There is no problem in open and semi-open systems because one can operate in open mode. The problem is in closed systems and there have been several solutions developed to overcome this problem such as:

- special "open channel or broadcast call" which has high priority
- selective access to ongoing call (access priority)
- special duplex or simplex channel for operational traffic in open mode

5.10.5 Traffic Transit Capacity of the Mobile Exchange

Traffic transit capability of the mobile exchange has to be dimensioned so that there is no capacity limits between the fixed network and the mobile exchange. One good solution is to make the number of channels for PABX or PSTN as large as the number of base station channels which are allowed to access to the fixed network.

The switching matrix and the registers (state variables of processors) of the exchange have to carry all the traffic which is offered via interface ports.

5.11 Coverage Requirements

5.11.1 Coverage Requirement for the System Service

The basic requirement for the system coverage is that it has to cover the whole service area of the utility. In some cases a larger coverage area is needed and in nationwide utilities this means large numbers of base station sites.

5.11.2 Coverage Area Requirement for a Call Set-Up

There are different methods used to find the location of a called party in large systems. In some systems there are specific calling area structures for the call routing purposes. The preferred solution is that the calling area is physically same as the system service area and there is no need to know the location of mobile radios. This leads to mobile registration procedure and to exchanging roaming information between mobile exchanges in large systems.

5.11.3 Requested Field Strength Values for Base Station Service Area

Normally dimensioning of base station service area is achieved using either CCIR field strength curves [4] or propagation loss models [11]. In any case the engineer has to decide the lowest acceptable field strength value at certain probability level and protection ratio against co-channel interference in the system.

Estimated values for the lowest acceptable field strengths (average values) for power utility systems are listed in Table 5.1. Power levels (dBm) measured in mobile radio antenna ports, and equivalent field strength values for half wave dipole antenna are presented. The values are based on experiences in typical power utility environments.

The protection ratio against unwanted co-channel interference is 8 dB in conventional analogue mobile radio systems [5].

	Operating Surroundings		
Frequency band (MHz)	Power station/ substation (dBm/uV/m)	Urban area (dBm/uV/m)	Open rural area (dBm/uV/m)
80	-95/8	-100/5	-110/2
160	-98/10	-103/6	-110/3
450	-98/32	-102/20	-108/10
900	-100/50	-102/40	-105/30

Table 5.1 Estimated acceptable antenna power levels and field strength for mobile radios in MRS of power utility

5.11.4 Typical Coverage Area of Base Station in Different Frequency Bands

The radio coverage area of a base station is strongly affected by several parameters:

- system type (analogue/digital)
- maximum deviation/modulation
- used RF-power
- base station antenna height and radiation pattern
- terrain profile
- frequency band
- requested service level (field strength)
- mobile radio type (handportable or mobile station)
- operating surroundings (power station, urban, open area etc.)

For the analogue systems the basic design information can be obtained from CCIR Recommendations 370-5[4] and 567-4[6].

The estimated service areas of base stations are listed in Table 5.2, values are based on the following assumptions:

- analogue system, channel spacing 12.5kHz
- maximum deviation $\pm$ 2.5kHz
- used RF-power levels in base station and mobile station is 20W (10W) and in hand portable 2.5W (1W), the values in the parenthesis are for 450 and 900MHz.
- base station antenna height 70m above ground
- medium terrain profile
- requested field strength from Table 5.1 (urban area)
- hand portable and mobile station

- urban area
- medium man made noise
- omnidirectional base station coverage

Frequency band	Service Radius for Handportable	Service Radius for Mobile Station
80 MHz	16km	30km
160 MHz	14km	28km
450 MHz	10km	22km
900 MHz	8km	18km

Table 5.2 Estimated values for the base station service radius in the analogue system

5.12 Connections to External Systems

5.12.1 Connections to Fixed Telephone Systems

It is desirable to have connections from MRS to other fixed telephone systems. Normally these connections are built up to make gateways between the mobile exchange and exchanges in the fixed telephone network. Typical systems to be interconnected to MRS are power utilities operational telephone system, PABX and some direct lines to the public telephone network. In some cases there are direct extensions (control points) for the operational staff in the control centre of the power utility.

Technically the gateways between MRS and the fixed telephone systems are built up using analogue 2 or 4 line connections. Normally there are several parallel lines in one gateway to make it possible to have numerous connections at the same time. In practice the high capability gateways can be constructed using subscriber extension lines or several trunk lines.

Figure 5.2 is an illustrated example of the gateways of MRS to the fixed telephone networks.

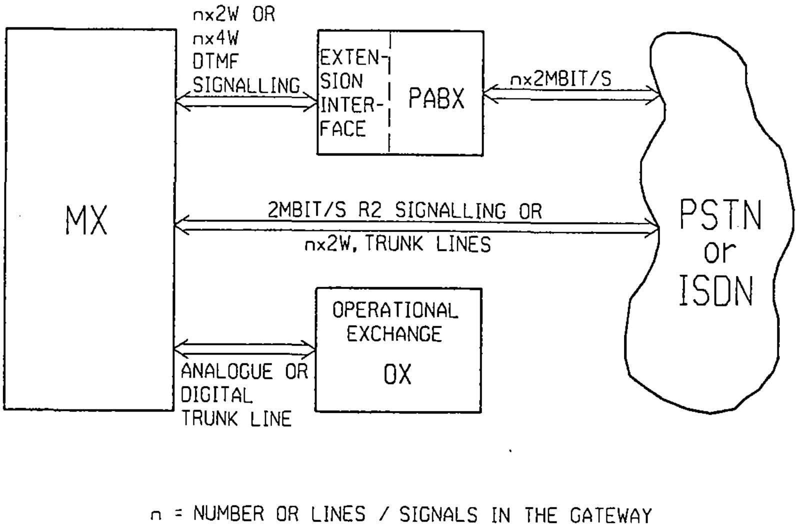

Figure 5.2 Example of MRS gateways to the fixed telephone network

In a digital gateway it is possible to use full 2 Mbit/s [7] connection or part of it. Also the gateway can be carried out using ISDN basic rate user-network interface [8] or ISDN primary rate user-network interface [9].

Section 5.10.5 specifies one recommendation for channel capacity needed between the mobile exchange and the fixed network, and in Section 5.19.1 there is more information regarding interfaces between exchanges.

5.12.2 Connections to Data Systems

Advanced mobile radio systems can have connections to data networks like public or private packet data network, LAN or WAN, direct computer connections etc.

There are two possible ways to carry data in MRS:

1. using external modems (normal or error corrective)

2. or using system internal signalling (internal modems) and special message format and interface protocols.

In alternative 1, there is no need for special protocols and it is necessary for external devices to handle the protocol. Care should be taken in the choice of the modem to avoid corruption on both radio and data channel signalling. It is highly recommended in analogue systems to use advanced modulation methods in data modems e.g. FFSK.

Normal speed of data in analogue systems varies from 300 bit/s to 4800 bit/s. Modem connections are usually serial type V.24/V.28. In error correcting modems even higher bit rates are usable.

In fully digital systems data can be coded and directly transferred (modulated) by the system. The data speed can be up to 32 kbit/s, see also Section 5.18.1.

5.13 Environmental Requirements

5.13.1 General Aspects

Power utility MRS environments can vary between complicated nuclear power station sites to normal vehicle installations. In many cases the MRS operating in a hostile environment can receive either RF interference or power system disturbances (EMI) from a power station or substation complex, which results in a poor S/N ratio on the telecommunications system. It is essential to shield telecommunications signal lines and power supply lines with high speed overvoltage protection devices.

The system engineer can also utilise standards and recommendations in installation design e.g. CCITT K. series recommendations. CEPT recommendation T/TRO2-02 for power supply application, IEC standards 65 and 801 for EMI and EMC application and ETS 300 019 for environmental conditions.

Only the installation environment is handled in this section although standards also support transportation and storage of equipment.

5.13.2 Environmental Requirements for Mobile Exchange

The installation environment of the MX is normally fully or partly temperature controlled at weather-protected locations (ETS 300 019-2-3: Class T3.1 or T3.2). Typical facilities for this kind of location are:

- climate-controlled system or
- air conditioning system
- heating and cooling equipment
- forced ventilation system

5.13.3 Environmental Requirements for Base Station

The base station installation environment can vary from temperature controlled locations to almost unsheltered locations. Relative humidity and temperature can vary in large scale. Typical ETSI classes are ETS 300019-2-3: Classes from T3.1 to T3.5 or ETS 300019-2-4: Class T4.1. Class T4.1 specifies non-weather protected locations.

5.13.4 Environmental Requirements for Mobile Station

Mobile stations are typically installed inside vehicles where stations are sheltered against water, animals, sand and rough dust. Temperature variations and mechanical shocks need a special design. A typical classification is ETS 300019-2-5: classes T5.1 and T5.2.

5.13.5 Environmental Requirements for Portable Station

The operating environment of PS can also largely vary. The location can be weather-protected or not, therefore temperature and humidity can vary significantly. A typical classification is ETS 300 019-2-7: Classes from T7.1 to T7.4.

In power utility applications it is also important to check the ability of a PS to withstand disturbing electromagnetic fields. A good rule of thumb is that a PS has to withstand fields in a 400kV switchyard and near a high power (over 200MW) generator.

5.14 Management Requirements

5.14.1 General Aspects

New revision of CCITT Recommendation M3010 deals with management levels in the following way:

1. Business management
2. Service management
3. Network management
4. Network element management

Business management includes managing of economical and business strategical objects in a telecommunications company, that can also be needed when considering MRS in a power utility.

Service management concerns the service level of one client or company. Service level means the total availability and quality of client services. This level can also produce the basic information e.g. for the accounting process. This level can be required for MRS in the power utility.

Some mobile radio systems are integrated into the high level Telecommunications Management Network. The advantage is that one can concentrate management expertise in one location and the maintenance information can be obtained in a uniform way from different systems. Thus the operational and educational costs can be minimised and the risk that the fault information is misunderstood can be radically reduced. See [2] for more information.

In the network management level the operator is managing the whole network or part of it. The influence of the managing operation is not restricted to one device e.g. on one MX. This level is needed in large trunked systems in power utilities.

The network element level is the most attractive for a power utility as maintenance personnel of the power utility can handle system parametering and fault management from one location. Typical management services can be:

- Configuration management
- Fault management
- Performance management
- Security or access management
- Traffic density analysis
- Accounting management (in some MRS)

5.14.2 Conventional Systems

In a conventional system there is usually no integrated management system. The parametering operations are achieved by the device programming (changing programmable memories or turning micro-switches). In some systems device alarms can be concentrated e.g. from base station to the despatcher control unit or external alarming system but it is not real TMN.

5.14.3 Advanced Systems

In an advanced system the TMN has built in devices, or the MRS exchanges and base stations have interfaces to separate TMN and the MRS software can support the TMN in the functional level. Often these kind of systems are trunking systems which can carry traffic from several utilities.

5.15 Maintenance Requirements

5.15.1 Basic Features

Maintenance of an MRS must be as easy and straightforward as possible. This can be achieved using modular design in software and hardware. Also fault detection has to be integrated into the system so that the operators can have as much fault information as possible concerning the system via the maintenance interface. Typical maintenance equipment can be for example O&M-terminal, logging printer, TMN system interface.

In advanced systems the users can have some special information in case the system has some limited capability to carry traffic due to a fault in the system. The best way to give that kind of information is a recorded message to users. In the systems which have high availability demands it is highly recommended to use hot standby spare units to carry critical functions in fault situations. To minimise mean time to repair (MTTR) the spare parts have to be available in a very short time period. For this reason power utilities often buy their own spare parts. It is important to consider if there is a need for a PU to have its own personnel to repair MRS. Usually utilities have their own staff but the alternative solution is that the utility buys services from the manufacturer or from the dealer. It is equally important that if the choice of the utility is to contract maintenance to a third party, that a very tightly worded service level agreement is established with clear responsibilities laid down for both parties and appropriate penalties set for non compliance. If the choice of the utility is own maintenance, it is also very important to have excellent system documentation to support the maintenance work.

5.15.2 Setting System Parameters

The system parameters have special components which concern the whole system or most part of it. In the following there are listed some possible system parameters:

- calling area structures
- base station frequency settings
- base station output RF-power
- state of interface units (in operation/in service)
- level settings of analogue interface units
- interface signalling type and parameters
- numbering schemes in gateways
- number tables for routing purposes

- maximum call duration times in different types of calls
- system alarm settings
- operational configuration of the system etc.

In conventional networks, the system parameters are fixed in the execution of the hardware, or in non-erasable memories.

In advanced systems all the functions and services are based on programmable devices and often numerous devices and services can be adjusted using different parameters. Using a modern TMN-system the setting of parameters can be undertaken from one point i.e. from MRS control centre or telecommunications system control centre. It is also very highly recommended that those parameters can be changed on line (no rebooting is needed).

5.15.3 Setting Subscriber Parameters

There are numerous parameters of a subscriber which can be adjusted in modern MRS.

- subscriber number/numbers
- priority/category group
- basic right to access to other systems and public networks
- channel frequencies
- basic type to access into channel; open, semi-open or selective
- transmitter power levels
- field strength and squelch settings
- pre-programmable short dialling

5.15.4 Fault Detection and Automatic Fault Isolation

The fault and error detection built into equipment is very useful in many cases. There can be several types of fault and error detection:

- user error or other error detection which means that the system or device has tried to operate in a wrong way.

- fault detection in devices, normally this is done with special software routines when the device is started or after some time periods.

- fault detection between different devices and systems. For example a fault in a base station line can be detected or faulty units in PABX gateway can be blocked.

In any case the automatic isolation process is very useful in fault situations. Normally detected fault information is printed by the logging printer or the information is transferred to separate TMN system.

5.15.5 Traffic Monitoring

In large systems it is very useful for operators and system designers to collect traffic information. Using this information and special statistics system personnel can ascertain how the system is used and how the traffic is distributed over the system. After that it is easy to put more capacity into the bottleneck points of the system etc.

In a trunked mobile system there is often a need to divide the system operating costs to users or even to different utilities. In that case also the accounting programs are needed in MRS or in separate management system.

5.16 Requirements for System Improvements

There are several basic requirements for system improvements for a power utilities MRS.

- system should be capable of expansion
- system should be capable to adopt new user groups
- system should be capable to expand its traffic
- new functions should be able to be installed on the system
- the service areas can be modified
- new interfaces and signalling protocols could be included
- suitability for multi vendor policy

5.16.1 Ability to Expand

Mobile radio system should be capable for expanding physically in several ways. Typical functions for expansion are:

- number of mobile exchanges in the system
- number of gateways to fixed telephone networks
- interface units into one gateway to the fixed telephone network
- interface units to data systems
- number of base station sites or units in one exchange or in the whole system
- the system numbering shall be capable of enlargement

5.16.2 Ability to Adopt New User Groups

In many systems there is a need to add new user groups after commissioning. This demand is often met in trunked systems which are operated with several companies or utilities. In extreme cases the MRS has to accept new utilities where there can be hundreds or even thousands of new users.

5.16.3 Ability to Accept Growing Traffic

Traffic can grow due to new user groups or due to growing call length or even increasing amount of calls per one subscriber. The system has to accept this new traffic to keep the service level high enough.

In many cases this means increasing the amount of interfaces, size of the switching matrix or even processing capability of the mobile exchange.

5.16.4 Ability to Add Functions to the System

Only software based systems can easily be extended and functions must be capable of being changed or added.

As mentioned in Section 5.15.1 the system software should be programmed in modular form. In modular structured systems it is easy to install and test new software based functions without replacing the whole software.

5.16.5 Ability to Modify the Service Area

The service area of the system may require modification. In many cases, the system coverage area is small. After some period of system usage there will be new demands to enlarge or modify the coverage area. Therefore, it should be possible to add base station unit and interfaces. Also there must be enough capacity in the system data base for these extensions.

The structure of the system software should support these modifications so that there is no need to re-organise the whole system. The basic frequency plan of the system should also have reserve for future extensions to minimise difficult modifications.

5.16.6 New Interfaces and Signalling Protocols

As mentioned in Sections 5.16.1 and 5.16.5 it should be possible to add new interfaces to the system. It should also be possible to take into account new signalling protocols in these interfaces because the equipment which is connected to the system could be changed.

5.16.7 Multi Vendor Policy

The system specification should be based on standards or widely accepted specifications to accept as many vendors as possible and in addition signalling protocols should be of a standard type (e.g. CCIR, FFSK etc.).

The minimum demand is that the protocols should be open so that the client has the right to give the information to competing manufacturers. In practice the multi vendor policy means that the system documentation should be comprehensive and cover all protocol levels.

5.17 Training Requirements

5.17.1 System Documentation

As mentioned in Section 5.15.1 it is very important to have high quality documentation for maintenance purposes.

The documentation should include the following:

- description of general system
- detailed system arrangement
- hardware (electrical and mechanical) documentation of equipment
- software documentation:
  * functional descriptions
  * structure descriptions of the operation system, application software and databases
  * source codes of software if needed
  * signalling protocol description etc.

For operational purposes one must have at least the following handbooks or manual:

- MX operational handbook
- BS operational handbook (if needed, depends on the system structure)
- operational manuals for MS and PS
- operational manual for control point or direct extensions
- operation in abnormal conditions (if needed)

For fluent operation of an MRS a good integrated telephone directory is essential.

5.17.2 Training of System Experts

A modern MRS normally has quite a complicated structure and is based on micro-computer control. Also, on the other hand in PU's the staff which can be involved with MRS maintenance is restricted.

From this point of view it is a necessity to train these experts.

The tasks for these system experts are typically:

- construction of the system (if it is done by PU)
- maintenance of the system
- repairing of the system devices (if it is done by PU)
- end user training
- to give operational advice to the end users
- further development of the system

There are several possibilities to educate the system experts for these tasks:

- on courses offered by the manufacturer
- on courses delivered by technical education establisments
- by another PU
- by some telecommunication operator or consultant

5.17.3 Training of the End Users

In modern multi-functional MRS, efficient training is most important. A rule of thumb is to put several per cent of investment cost into training. Most of these costs have to be put towards end user training. In many cases the number of end users to be educated is so large that the basic project staff cannot successfully handle it themselves in a reasonable time schedule. One solution is to first train the system experts who are then responsible for the end user training.

5.18 Additional Future Requirements

5.18.1 Data Applications

Data communication over radio will be more widely used for new applications in the future. Some applictions can only be solved technically in digital radio systems. These may require very efficient protocols and coding, or simultaneous data and speech transmission.

Typical applications are:

- Telecontrol to stations not served by fixed links
- Printed directions from control centres to mobiles
- Mobile access to operational and administrative central data bases

5.18.2 New Functions and Services

Numerous new functions and facilities have been introduced in trunked systems and even more can be included in new digital ones. The most interesting functions from a power utility point of view are different types of group and broadcast calls. One facility which is possible in digital systems is that a mobile unit can at the same time receive speech, data and signalling. This makes it possible to design very attractive and complicated call structures for example "call in call" or "temporarily visit to an other call" etc. More information about digital MRS functions can be found from new standards for example ETSI RES6 TETRA standard.

5.18.3 Smaller Subscriber Devices

Many users find present PMR mobile stations too large to be installed into cars or especially hand-portable stations too heavy and bulky to carry. Typical environments where small handportables are needed are power line construction and maintenance and operation and maintenance of power plants. Modern mobile phones in cellular networks are a very compact size compared with "old design" PMR radios. For these reasons it can be expected that PMR mobiles and portables will become smaller as technology advances.

5.19 Total System Integration in PU Networks

5.19.1 Connections Between Different Exchanges

In present telecommunication switching systems in PU mobile exchange, operational exchange and private automatic branch exchange are different devices. In most cases MX is an analogue device but operational exchanges and PABX can be digital. Different devices have to be equipped with similar interfaces to carry out gateways between exchanges. These interfaces can be divided into two parts:

- hardware specification of interface: signalling media, signal levels, impedances etc.

- signalling protocol: signal coding, hand shaking, error detection, retransmission, control of timing parameters etc.

Typical signalling systems used in analogue gateways systems are:

- 2-wire telephone extension signalling with pulse or DTMF dialling
- 2-wire and 4-wire E&M signalling
- MFC R2 signalling in analogue lines etc.

Here are some examples of digital signalling systems which are based on 2 Mbit/s lines:

- digital E&M
- digital R2
- DPNSS
- ISDN primary rate user-network interface
- ECMA Q.SIG

If it is impossible to equip devices with a common signalling interface an extra signalling transducer must be used. It can either be normal multiplexing equipment or special device.

See also Section 5.12.1 Connections to Fixed Telephone Systems.

5.19.2 Integration of Separate Exchanges into One Device

It may be theoretically possible to build an exchange that combines PABX, operational and mobile functions into one switch. However, for a PU the possibility of a single mode failure causing loss of all communication is an intolerable risk.

5.19.3 Integration of Mobile Radio System into Telecontrol System

In many countries the mobile radio systems are connected to telecontrol-systems for remote control substations and other electrical equipment in the power systems. For such solutions the mobile telecommunication network is integrated into the utility data based power control system. The mobile radio system is working normally only as a transparent four wire connection.

In future standard data interfaces are available, for example X25 syncronous interface etc.

5.19.4 TMN Integration

It is an advantage to have uniform TMN system interface in all telecommunication devices and in future when CCITT Q3 interface specification is completed this can be possible. See more about TMN integration from [2].

5.20 PU as a MRS Public Operator

In future it is possible that a power utility becomes a MRS public operator. In that case there are several additional requirements for MRS:

- MRS has to be capable to handle closed user groups
- MRS has to be dimensioned so that it can carry the extra traffic
- MRS has to be equipped with two way gateway to the PSTN
- Mobile and handportable stations have to be addressable directly from the PSTN without any supplementary dialling
- no dialling limitations from MS to the PSTN
- common numbering plan
- selectable dialling restrictions for different user groups
- duplex traffic is often required
- power utility has to specify and carry out an accurate response time for network fault isolation and repairing so that a PU can provide good quality of service
- there has to be in MRS a very efficient management system for customer and network management
- in many cases the MRS has to be equipped with a separate accounting or integrated accounting system to enable it to collect fees.
- it is highly recommended that the statistical information of the traffic is available for system improvements.
- operating costs of MRS have to be minimised.

SECTION 6 PRESENT MOBILE RADIO SYSTEMS

6.1 Historical Development

Mobile radio has been in practical use in power utilities in many countries for more than 50 years. In the beginning the radio networks were small with strongly limited functions. Quite often the radio networks were established as backup for their own wire connections or unreliable public telephone connections at various areas when constructing new distribution systems.

Power utilities found mobile radio a very efficient communication tool for a number of applications.

Mobile radio networks grew rapidly and created important complements to fixed telecommunications for power utilities.

In some areas local networks were connected to control centres. They could from that time be seen as part of the regional control systems. Later on the networks became better designed. In the 1960's and 1970's the new systems were built with several traffic channels. In many systems repeater stations were introduced working in semi-duplex or full duplex mode.

New technically advanced communication systems have been developed having a great number of services. It has been possible due to the fact that new technical applications are making use of microprocessors. Equipment for todays market are all designed by software and operated by programmable memories.

System planning, network design and construction with computers using topographical data bases and propagation models are now considered very useful tools. Over the years new applications have been developed. In the present situation mobile radio systems are very often complemented with local radio networks, for example in mountains or substations situated in concrete buildings.

In many countries there are country wide public mobile telephone networks. From the questionnaire the power utilities have stated that the public mobile system never can replace their own system for the main tasks in operation and maintenance. The reason is the limited number of functions in the public services and the requirement of unblocked communications during disturbed situations in society. As a matter of fact the public mobile systems in many cases are important complements to the total capacity in the demand for communication channels.

Among new system solutions for more efficient use in the power industry there are technical applications with digital signalling trunked systems, implementing radio networks in small or larger cells. Small cell techniques were first introduced in public mobile telephone systems.

As the world is now more computerised some new mobile systems are designed for co-operation directly with computer based register or other systems with information in digital form.

6.2 Conventional Systems

These systems represent 69% of the responses obtained from the questionnaire on mobile radios.

6.2.1 Simplex Systems

These networks, mentioned here just as a matter of interest, are the oldest and simplest networks. They are made up of stations which are all technically identical and use only one frequency on which one station speaks and the others listen. These rather rudimentary networks do not require an infrastructure. As a result they are cheap, but connections are only possible as far as distance and the surrounding environment permit. Their range is still limited even with reasonably powerful stations. This type of system is generally reserved for very localised networks using portable sets.

6.2.2 Own Conventional Systems

Any system capable of covering a fairly large area is based on an infrastructure.

The simplest and most commonly used system consists of a fleet of mobile stations revolving around a well positioned repeater (relay). The repeater re-transmits on an f_2 frequency, which is the receiving frequency for mobile stations, and receives on an f_1 frequency, the mobile transmitting frequency.

This forms a basic network featuring the area being served, linked to a dedicated dual frequency channel. Each station can be equipped with a selective call coder-decoder, which makes individual calls possible, but the network is, by its very nature, open. This "open network" feature is more difficult to obtain with more sophisticated networks.

The equipment available from manufacturers is tried and tested and does not vary much between manufacturers.

The selective calls are fairly standard e.g. CCIR, ZVEI [1] and the power of the stations does not vary greatly between suppliers. Inter-network connecting systems are generally available in order to join up several basic networks with the aim of extending the area covered, whether on a permanent basis or on request.

The channels should be arranged in geometric patterns in order to avoid interference. This means that the channel of a network which is at rest cannot be used, even though a neighbouring network may be overloaded. This type of network, therefore, is only intended for users capable of exercising a certain amount of discipline.

In addition, it can only accommodate about 50 mobile stations per channel, as mutual aid between the channels is impossible. Some networks operate a call distribution system whereby scanning of the mobile stations enables traffic to be shared between several relays. There is no standardisation for this type of function.

The network owner is in control of the network. Nevertheless, using fixed resources, he may find the channels are very severely overloaded in times of crisis on the power network.

The cost of the network is quite reasonable, compared to other more elaborate systems, particularly for low capacity stations.

6.2.3 Shared Conventional Systems

It is quite possible for either the channel on its own or the infrastructure equipment and the channel together to be shared between several users. Where only the channel is shared, the infrastructures should be combined. Using equipment originating from the simple systems, a network may be prevented from accessing when the channel is in use. The usual way of undertaking this is by adding a carrier detector which prevents transmission. This obviously results in less traffic time being available on each network. All the other network features are virtually the same. Although this form of operation is common for small to medium sized business communications systems, it is unusual to find PU's using this shared arrangement because of the demand access usually required by the users.

6.3 Trunked Systems (See figure 6.1)

These systems represent 31% of those listed in the questionnaire. One third relate to public networks and two thirds to private networks. These figures are evaluated based on the number of systems. However the number of mobiles would give a particular emphasis to private systems.

The shortage of frequencies and a real need to increase their spectral efficiency led to the introduction of trunk systems. Systems were originally designed to service a single site, but manufacturers were rapidly encouraged to develop systems grouping several sites together around a central control unit and linking them to the centre by telephone lines. Pooling the channels and infrastructure equipment in this way requires the system, in order to function properly itself, to operate the fundamental "roaming" function. This function also benefits network users who no longer have to worry about the location of the mobile station they have called.

A special channel, the control channel, via which control signalling information can be exchanged, provides a virtually permanent link between subscribers and the infrastructure. As a general rule, this channel should be taken into account when evaluating spectral efficiency (dedicated channel or not).

Communication between subscribers takes place mainly on an individual basis. Numerous telephone-type functions are available, see Appendix A. Paradoxically, it is more difficult for the system to function like a conventional radio network.

6.3.1 Own Trunked System

The infrastructure here belongs to the user. In view of the cost of such a system, it can only be justified by having a large fleet of mobiles. The cost of inter-site links, which are sometimes provided by public operators, should in particular be taken into consideration. Moreover, the high technological level of these networks often makes them less robust than conventional systems. By using different protection schemes (duplication of critical parts, fall back methods etc.) the availability can be guaranteed. A general benefit of trunked systems is increased reliability in a sense that one channel failure in a multi-channel base means only a temporary decrease in system capacity.

6.3.2 Shared Private Trunked Systems

These networks, which are identical in type to the preceding ones, enable several closed user groups to be formed. Standardisation makes this separation possible. This arrangement is particularly beneficial where the users' needs, taken on an individual basis, do not by themselves justify the existence of a trunked system. Sharing channels improves the overall efficiency of the system.

6.3.3 Public Trunked System

These networks are set up by a public operator or by a delegated private operator acting on behalf of the public operator. Users of this type of network are customers who just use the services provided, without having any direct influence on operating conditions.

The service provided is paid for by subscription, or an equivalent method. This arrangement means that the user can plan his operating budget fairly accurately. Cover is usually obtained on a regional basis and only applies to economically profitably regions.

6.4 <u>Public Cellular Systems</u>

Public cellular networks form the natural mobile extension of the switched telephone network, generally providing all the functions made available by telephone. Bar exceptions, they ensure continuity of communication during the changeover between cells (handover) and, by their very nature, they provide the possibility of obtaining any subscriber in the general network, whereas with the systems described above this is not the primary objective and in some cases not possible.

Cellular networks have the typical characteristics of any public network. Their performance is good in normal circumstances but during busy hours, in areas of high economic activity or during special events, they may quickly become saturated. They provide virtually complete cover, however, some sparsely populated areas may not always be covered. Power engineers need to carry out some of their work in deserted areas, so incompatibilities may arise for public radio-telephone users.

Operations are always duplex, so with some technical adjustments to terminals, it should be possible to provide all the applications presently available on the PSTN, such as fax, teletext etc. (full duplex operations).

Public radio-telephone use is always charged per call. These operating charges vary considerably from one country to another. Costs of mobile terminals are generally on a downward trend.

6.5 Mobile Data Systems

A clear distinction must be made between different modes of data transmission. An analogue radio network, capable of transmitting phone signals, is capable of transmitting audio frequency signals coming from a modem, providing that the spectrum of this signal is compatible with the bandwidth of the radio channel used.

This is not the most effective data transmission. Computer equipment connected to the modems manages the transmission (error detection and correction); transmission speeds remain slow (less than 2400 bit/s).

New types of networks using appropriate modulation techniques enable data to be transmitted at a much higher bit rate on a dedicated channel (> 10kbit/s). It should be possible to use this type of network to interconnect complex digital systems. A second feature worth noting is that these networks can transmit digitalised speech via a codec. No fixed standard is presently available for these networks.

These systems constitute the mobile extension of existing fixed networks (e.g. the X25) and optimise the spectrum, in comparison with analogue networks, by providing fast digital transmission along with an improved co-channel protection ratio. This permits greater re-use of channels.

6.6 Paging Systems

This system enables a single message (ranging from a simple beep to a 100-character alpha-numeric message) to be transmitted to a portable set. The systems presently available vary considerably. The simplest ones are private and local. They are usually linked to a PABX and only serve a very localised fleet of receivers. The more extensive one belong to the public service and cover a national area.

The transmitting infrastructures are either dedicated, or consist of a network of broadcasting transmitters, with the paging function linked to a sub-carrier transmitted simultaneously. In this case listening to the radio gives a good indication of the cover produced by the system.

6.7 Further Conclusions for Existing Systems

The majority of the existing systems is simple and sometimes based on "old fashioned" technology, which could be considered as the second generation since power utilities started using radio systems.

This apparent conservatism is probably due to the fact that mobile radio is often heavily used under emergency conditions. Therefore such systems have to be reliable and thoroughly proven.

Pioneers remain careful and avoid putting all 'eggs into one basket'. Recent successes should however encourage the more conservative, which seems to be supported by the answers to the questionnaire.

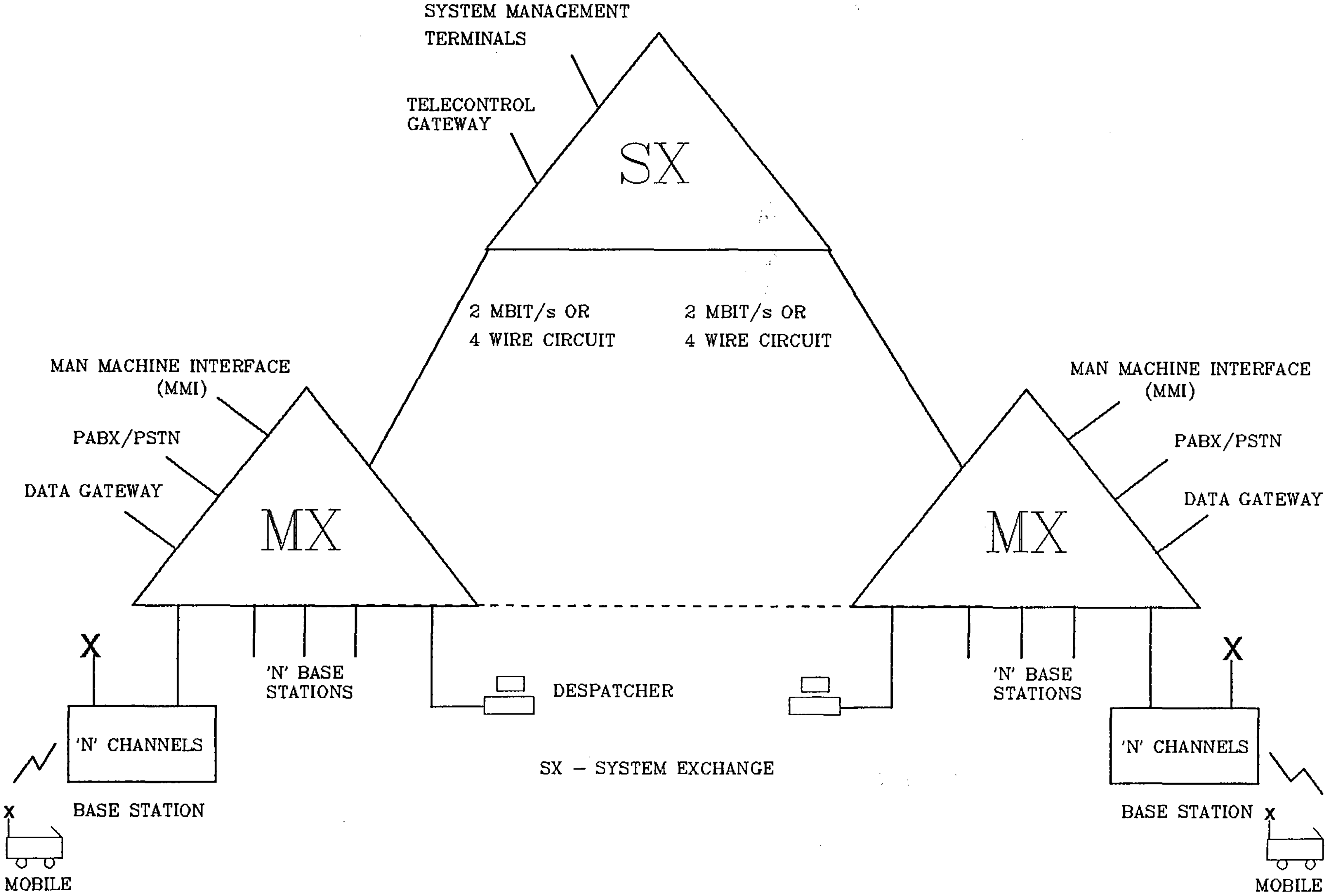

Figure 6.1 Typical trunked mobile radio network

SECTION 7 FUTURE DEVELOPMENTS IN MOBILE RADIO SYSTEMS

7.1 General

This Section deals with future standards and developments for Mobile Radio Systems. The growth of public cellular systems has been very fast. Because of the volume of the market, public cellular systems are the main driving force to the technical development of mobile radio systems and equipment. This reflects also to the technical solutions and standardisation of private mobile radio systems.

On the other side deregulation and liberalisation in telecommunications environment offer new opportunities to power utilities to act as a network operator for public mobile services. Therefore it is also of interest to power utilities to follow the development and standardisation of public mobile radio systems in addition to the private systems.

Future developments in mobile radio systems will be studied here in the light of standardisation. Examples will be taken mainly from European activities, but the systems introduced are representative to give an idea of the development in the global perspective.

7.2 Standards

The description of standards is divided here into three groups. In the first group are standards which will be used in private systems. Included here are:

- Digital Short Range Radio (DSRR)
- Binary Interchange of Information and Signalling at 1200 bit/s (BIIS 1200)
- Project 25 of the Association of Public Safety Communications Officers (APCO25)

The second group of standards are those which will be used in public systems.

- Global System for Mobile Communications (GSM)
- European Radio Message System (ERMES)
- Future Public Land Mobile Telecommunications System (FPLMTS)

The third group of standards include those which can be used both in private and public systems:

- Trans European Trunked Radio (TETRA)
- Digital European Cordless Telecommunications (DECT)
- Satellite based standards, like:
    - Project 21 of INMARSAT

7.2.1 DSRR

This system is the normal evolution of the actual Citizen Band radio applications, with an option to use repeater and radio relay. An important aspect of this system is to have a reserved frequency band with no operator. In fact it will be a very low cost product with few facilities, convenient for all those who need simple radio communication and are often on the move. DSRR will have possible use for public events like football matches, demonstrations, fairs, etc.

The system is based on a low power radio transceiver with a multi-channel trunking modes system (scanning terminal) in the 900MHz band.

Radio communications will use a direct digital modulation of the carrier, for the transmission and reception of voice and data at a total bit rate of 16 kbit/s.

DSRR terminals will be equipped with an automatic multi-channel access technique without the assistance of a central controller, and may be required to operate both in a single frequency simplex mode, and in a two frequency semi-duplex mode.

The simplex mode is planned in the frequency band 933-935 MHz and the semi-duplex mode in the frequency band 933-935, paired with 888-890 MHz. There are 76 traffic channels in each mode of operation, which are administered by 4 control channels in the semi-duplex mode, and by 2 control channels in the simplex mode.

To set up a call, the calling terminal has to locate a free channel by self scanning. The terminal switches automatically to another control channel if spurious signals are present on the previous one for more than 5 seconds.

The system will provide the following main services (See Appendix A for definitions):

- Individual call
- Group call
- Time limitation (1 minute)

7.2.2 BIIS 1200

This standard is the evolution of conventional private MRS. Its new features compared to the conventional ones are:

- Digital signalling, which ensures more efficient services
- Integration of speech and data facilities

BIIS 1200 is the adaptation of MPT 1327 standard to the non trunked applications.

The possibility to form a very wide network and to have a global management are attractive for users who have a low to medium number of subscribers per cell and need all private MRS facilities like open channel for emergency.

BIIS 1200 standard was studied by the ETSI Sub-Technical Commitee RES2, and describes a binary signalling system for private mobile radio equipment operating at 1200 bit/s. It applies to systems operating on either shared or exclusive control channel. The binary signalling procedure described in this standard is an alternative to existing signalling systems such as single tone, multitone and sub-audio tones. The standard defines fields which are reserved for future expansion and shall not be used, and fields which are free for custom specific applications.

Some specific characteristics of the system BIIS 1200 are the following:

All units of the system (mobile stations, base stations, repeaters) have one or several addresses. In a normal address mode 4096 addresses are provided but more of them can be provided for specific systems.

The binary data transmission is based on a sub-carrier FFSK modulation at 1200 bit/s.

The possible channel spacings are 12.5kHz, 20kHz and 25kHz.

This standard provides high level procedures for system management like the processing of busy channel access (Immediate access with priority or waiting for free channel with queuing mode).

The BIIS 1200 provides, among others, the following services and facilities for speech communications (See Appendix A for definitions):

- Individual call
- Group call
- Broadcast call
- Priority call
- Emergency call
- Automatic acknowledgement
- Emergency acknowledgement
- Informative acknowledgement in:
    - Called user busy
    - Called user unavailable
    - Invalid call
- Manual response
- Call cancellation
- Emergency reset
- Repeater access
- Telephone access (PABX and PSTN)
- Request to call back
- Channel control
- Mobile control

- Status transmission (up to 16 status messages can be transmitted):
    - Status request
    - Status transfer

For data transmission two methods are provided within the signalling system whereby data can be exchanged between system users, without the need to enter into speech communications: Short data transmission and Packet mode data transmission. The data compression may be possible, and the system terminal interface is studied and provided in the standard.

There are some special services and facilities such as:

- System control
- Short data transfer
- Dialogue data transfer
- Go to channel
- Vote now
- Status
- Mobile enable/disable

7.2.3 APCO25

APCO is an organisation withing the public-safety segment in North America but there are also members outside this region.

In order to study advanced technology for land mobile radio APCO Project 25 was started in 1989. It is co-chaired by APCO and the National Association of State Telecommunications Directors and along with manufacturers who are members of this project. The goal is the development of recommendations for standards for a new generation of digital mobile communications for public safety applications. Some objectives are spectrum efficiency, new additional operational features compared with APCO 16 (see Appendix D2), forward and backward compatibility, interoperability, vendor multi-sourcing and introduction of technology innovations.

Up to now the emphasis has been on the common air interface, but during 1992 work has been carried out in order to define a general system model, host and data network interfaces, interface between mobile/portable and data peripherals, management interface and statement of requirements.

For basic digital radio communication the common air interface describes the following items:

- Channel bandwidth
- Channel access method
- Modulation techniques
- Channel bit rate
- Voice coder
- Data frame structure (including codes for error detection and correction)

During 1991 the APCO Steering Committee has established FDMA as access method, and 12.5kHz as channel bandwidth. They have also recommended QPSK-C as modulation method and a data rate of 9.6kbit/s. However, the agreements about Intellectual Property Rights have not yet been fully completed. A general Memorandum of Understanding has been signed.

Later in 1991 APCO 25 charged Telecommunications Industry Association with the specification and selection of a voice coder. The test of the voice coders was held in December 1991 and four candidates participated. The selected voice coding technique was so called "Improved Multi Band Excitation".

The current goal is to establish the common air interface by Summer 1993.

7.2.4 GSM

GSM network will be a fully digital (signalling and traffic) public cellular land mobile network. The system, also called European digital cellular telecommunications system, is being developed by ETSI.

The main objectives of GSM are:

- To provide users with wide range of services and facilities, both voice and non voice, that are compatible with those offered by fixed networks (PSTN, ISDN, PDN) through standardised accesses between networks.

- To offer compatibility of access to the GSM network for any mobile subscriber in any country of the CEPT who operates the GSM system.

The major characteristics of the GSM system are:

- Access method: TDMA, 8-16 channels.
- Carrier spacing: 200kHz.
- Data rate: Up to 9.6 kbit/s.
- The signalling channel can be implemented as:
  - Broadcast channel
  - Common channel
  - Stand alone dedicated channel
  - Associated channel
- Signalling system: Specific at layers 1, 2 and 3 for radio path,
  CCITT Signalling System No. 7 for the rest
- Frequency band: 900Mhz

The GSM will support, as basic services, the following bearer services and teleservices:

Bearer services:

- Audio at 3.1kHz, transparent (T)
- Audio at 3.1kHz, non transparent (NT)
- Circuit mode data duplex asynchronous 300-9600 bit/s (T/NT)

- Circuit mode data duplex synchronous 1200-9600 bit/s (T/NT)
- Packet mode data duplex synchronous 2400-9600 bit/s (T/NT)
- PAD access circuit asynchronous 300-9600 bit/s (T/NT)
- Alternate speech/unrestricted digital at 12 kbit/s
- Speech followed by data
- 12 kbit/s unrestricted digital

- Teleservices:

  - Telephony
  - Short message mobile originated/terminated (point to point)
  - Short message cell broadcast
  - Videotex access profile 1, 2 and 3
  - Facsimile group 3

For these Bearer services and Teleservices, there are the following Supplementary services (See Appendix A for definitions):

- Number identification
- Malicious call identification
- Call forwarding
- Call transfer
- Mobile access hunting
- Call waiting
- Call hold
- Completion of calls to busy subscriber
- Three party service
- Conference calling
- Closed user group
- Advice of charge
- Freephone services
- Reverse charging
- User to user signalling
- Call restrictions

A proposal for a digital mobile system operating at 1800 MHz frequency range was made in UK in 1989. Initially, the system was called Personal Communications Network. In 1990 it was decided by ETSI that the system will be based on GSM standards, so that this system can be considered now as a version of the whole GSM, which is called Digital Cellular System at 1800 MHz (DCS 1800).

7.2.5 ERMES

The aim of the ERMES system is to offer a public paging service which will allow any European subscriber to travel through any European city and receive messages from any other part of Europe using his/her own receiver. The frequencies are in the 160 MHz band.

ERMES will have a greater capacity than current paging systems and will provide new services and facilities.

There will be four paging categories:

- Tone only	8 types of tones
- Numeric	20 digits
- Alpha-numeric	400 characters
- Transparent data	4000 bits

Some services and facilities offered by the ERMES system will include:

- Individual call
- Group call
- Narrow casting/Radio distribution calls
- International roaming
- Call restrictions
- Closed user group
- Protection against message loss
- Repetition of messages
- Enumeration of messages
- Storing and retrieval
- Priority call (3 priority levels)
- Encryption of messages
- Authentication
- Advice of charge
- Reverse charge

7.2.6 FPLMTS

This future system is strongly foreseen for use in the next century. It is a global approach that can be considered as the third generation of mobile radio systems and tries to combine as many wireless applications as possible.

This system will also use satellites which have a "pan global" coverage.

The system will consist of:

- A personal station, for example, a pocket size portable, with a variety of usages; within buildings, inside a moving vehicle or outdoors.

- A mobile station, for example, vehicle mounted, operating within defined coverage areas (urban, suburban, rural) at a rate of motion of up to high speed trains.

- A satellite network plus a terrestrial infrastructure.

About the main functionalities, FPLMTS will offer voice and non voice services available in the PSTN/ISDN and other public networks and accesses to these networks. It should be possible for terminals in FPLMTS to be used also in maritime and aeronautical environment and to be also utilised as temporary or permanent links substituting the fixed networks where convenience or economies makes it desirable.

This will be a digital cellular system incorporating messaging and paging facilities.

The first technical assumptions are:-

- Speech codecs of approximately 8 kbit/s or more
- 230 MHz of spectrum space (minimum requirement)
- Frequency about between 1 and 3 GHz

In Europe, a research project managed by the European Community and called "Research into Advanced Communications in Europe" (RACE) has the sub-project "RACE mobile" which is studying how to offer possible future broadband services to mobile and portable terminals. This concept is known as Universal Mobile Telecommunication System (UMTS). ETSI is studying such a system for standardisation purposes within Europe and has determined that FPLMTS and UMTS should have the same aims and preferably the same solution.

7.2.7 TETRA

TETRA is the future standard for digital trunked mobile radio systems. It is studied by ETSI Sub Technical Committee RES6.

Modern features of TETRA compared to existing analogue systems are:

- Data services
- Higher data rate on the signalling channel
- Better spectrum efficiency

It is expected that the standard will be applicable and appropriate for both public and private systems.

The standard will cover two main applications:

- Digital speech and data services with optional connection to public and private fixed networks

- Data only services

The field for the basic applications of TETRA are regional coverage, with the ability to form national to international network of heterogenerous networks (different suppliers).

The scheduling is:

End 1991 Marketing and services definition

End 1992 First draft of the air interface

End 1995 Is the first assumption to get the equipment available but 1996/1997 seems to be a more realistic date.

The access method is TDMA with four time slot channels. Carrier spacing is 25kHz and the gross bit rate is 36 kbit/s per carrier. The traffic channels (slots) can be shared between voice and data services. In addition a narrower band version with 12.5kHz carrier spacing and two time slot channels could be standardised.

For the performance figures of the TETRA system, the following assumptions have been stated:

Typical system size	1000 to 100,000 subscribers/system
Typical coverage	$50km^2$ to national
Typical user density	0.1 user/km^2 to 70 user/km^2
Average speech call duration	30 sec
Message length	Short 100 bytes, long 10 kbytes
Messages/h/subscriber	Short 20/h, long 0,5/h
Call set up time	< 300 ms
Grade of service	5%
Net bit rate	Up to 19.2kbit/s

In Europe strong demand for a common frequency band for TETRA has been made to the CEPT. The preferred frequencies are in the 400 MHz range. 2 x 5 MHz are required in 1995, and 2 x 20 MHz in 2000. European Radio Committee has decided on the basis of CEPT recommendation to reserve frequencies to TETRA systems. These frequencies should be made available in parts of one or more of the following bands:

380-390/390-400 MHz
410-420/420-430 MHz
450-460/460-470 MHz
870-888/915-933 MHz

TETRA may require to be interfaced with public networks (PSTN, PDN, ISDN) and also with private networks.

TETRA will support four data bearer services and one speech bearer service:

- Connectionless packet data
- Connectionless broadcast packet data
- Connection oriented packet data
- Circuit switched data
- Circuit switched speech

The Teleservices and Supplementary Services that the system will support are the following (see Appendix A for definitions):

- Individual call
- Group call
- Acknowledged group call
- Broadcast message
- Telephone access
- Connectionless data message
- Connection oriented data message
- Open channel
- Search group call
- Include call
- Call diversion
- Call authorised by dispatcher
- Call restrictions
- Call me back
- Call waiting
- Number identification
- Selection of confirmation
- Automatic redial
- Automatic call back
- Short number addressing
- Priority call
- Pre-emptive priority call
- Access priority
- Mail box
- Advice of charge
- Discreet monitoring
- Ambience listening

Services to the Operator:

- Authentication
- Network configuration
- Registration/De-registration
- Centralisation for network management
- Information broadcast
- Log in/Log out
- Communication recording
- Call statistics

The possible particular applications of TETRA will not be standardised by RES6. Any application may be developed/supported by the available telecommunications services, according to user/operator demand. The following applications have been identified:

- Secure speech
- Secure data
- Road transport informatics

- Interactive word processing
- File transfer
- Fixed image
- Access to data bases
- Fleet management (computer aided)
- Approximate vehicle location
- Automatic vehicle location
- Facsimile transmission
- Message handling systems
- Key management

7.2.8 DECT (Digital European Cordless Telecommunications)

DECT is a pan-European standard for cordless telephone systems. It is a low-power radio access between portables and infrastructure at ranges up to several hundred meters and offers to the user speech services and circuit switched and packet data services of private and public networks. The standard defines only the radio interface.

DECT has three major applications:

- business communications (cordless PABX, cordless LAN)
- public access
- residential cordless telephone

Common feature of speech services is that access to PSTN or ISDN can be substituted with a cordless extension. Speech is ADPCM coded to 32kbit/s. In addition to speech services possible other services are data transmission and encryption of user data.

DECT specification makes provision for small and large business systems in a flexible manner where the required capacity and service provision can be optimised depending on the needs of the customer in terms of cost and the offered service.

The range of systems can vary from single cell systems, with 20 or less extensions and limited service facilities, to complex PABX systems offering features which are normally incorporated in an enhanced wired PABX.

A secure authentication of a handset is a basic feature in all environments as well as the indication of an inaccessible handset. Cordless specific enhanced services such as secure validation of a handset user or a message service are examples of features which are relatively easy to implement.

Systems can also be connected enabling roaming to find a person for incoming and outgoing calls within the nominated communication area.

The specification also makes provision for undisturbed handovers during a call even with a very high user densities.

Data services of DECT fall into two categories:

- primarily static, using DECT as a cordless drop-line bearer to a high speed back-bone of the LAN. Application areas and requirements are related to those anticipated for general network terminal usage.

- primarily portable for applications such as
  - portable multi-media (e.g. voice and fax) mail termination
  - portable access to personal and corporate data bases

To support other teleservices, DECT will have appropriate bearer capabilities over which external processes can offer teleservices. Remote terminal protocols such as X-terminal protocol and OSI VT, batch file services such as File Transfer Access Mode and real-time access for CCITT X.400 protocol, will be examples to be supported. The maximum transmission speed is 256 kbit/s. Other technical details of the system are shown on the Table in Section 7.3.

7.2.9 INMARSAT Project 21

Present analogue and the new digital land mobile radio standards will satisfy the demand for mobile communications to a large extent, but towards the end of this decade, satellite based systems will be able to fill the gaps that remain outside the cellular service areas. A global system would be especially attractive to organisations such as power utilities and companies with communications needs in areas where other telecommunications systems are poor or non-existent.

One possible solution with great potential for global communications is INMARSAT Project 21. The target is to provide world spanning, hand held satellite telephone services at consumer affordable prices by the end of the year 2000.

Service features

- voice service quality as good as cellular
- cellular extension: compatibility and interconnectability with cellular services
- global roaming with single number access regardless of location
- integral pager for standby call alerting
- in-built position determination and reporting facilities
- fax, data and memory storage capabilities

Satellite system

A number of different proposals are currently being considered by INMARSAT. Among the options under evaluation are:

- geostationary earth orbit satellite system
- a low earth orbit satellite system overlay
- an intermediate circular orbit satellite system overlay
- combination of these constellations

After describing the future oriented plan of INMARSAT it is worthwhile to mention the existing land mobile satellite service INMARSAT-C which provides a broad range of data messaging services to portable, briefcase form terminals. An interim phase to Project 21 will be INMARSAT-M. Like in INMARSAT-C, briefcase-sized terminals will be used, but in addition to data, direct dial two-way telephone services will be provided.

7.2.10 GPS

The Global Positioning System (GPS) is a satellite-based navigation and positioning system developed by the US Department of Defense. It will provide a continuous, global high accuracy service to military and civilian users. Authorised users will have access to the Precise Positioning Service, which will provide accuracies of 10 to 20 metres. Civilian users will have access to the Standard Positioning service, which will provide 100 metre accuracy.

The system consists of a constellation of 21 satellites and 3 spares which orbit the earth twice a day.

Each GPS satellite continuously transmits direct-sequence, spread-spectrum signals at 1,5 GHz and 1,2 GHz frequencies on which receivers can perform ranging measurements.

User receivers employ signals from a number of satellites simultaneously or sequentially to determine their positions.

Accuracy of the Standard Positioning Service is controlled for security reasons through a program called Selective Availability. The way this can be compensated in local use is a technique known as differential GPS, where a fixed reference receiver is used to enhance the accuracy. Position accuracies of 3 metres are possible.

In fleet management applications the position information from vehicle mounted receivers will be sent via terrestrial mobile radio network to the dispatcher for automatic vehicle location purposes.

7.3 Comparison of System Parameters and Allocation of Spectrum (CEPT Countries)

Private systems	DSRR	BIIS 1200	TETRA
Frequencies (As applied in Europe)	888-890 MHz	not allocated, conventional PMR frequency ranges VHF-UHF	400MHz
Allocated bandwidth	2 x 2 MHz	not allocated	2x20 MHz
Access method	FDMA	FDMA	TDMA
Carrier spacing	25 kHz	12, 5kHz 20 kHz/25 kHz	25 kHz
Number of channels	76		4 within 25 kHz
Codec	16 kbit/s		4.8 kbit/s
Radius of cells	from 3 km to 6 km	depending on frequency band and national limitations	several tens of km
Emitted output power of terminal	4W		several tens of watts

Public systems	DECT	DCS1800	GSM
Frequencies	1,88-1,9 GHz	1710-1785MHz 1805-1880MHz	890-915MHz 935-960MHz
Allocated bandwidth	20 MHz	150 MHz	50MHz
Access method	TDMA	TDMA	TDMA
Carrier spacing	1,728 MHz	200kHz	200 kHz
Number of channels	12/carrier	8 or 16/ carrier	8 or 16/ carrier
Codec	32 kbit/s	13 kbit/s	13 kbit/s
Radius of cells	30-200 metres	0,4-6km	0,5-35km
Emitted output power of terminal	250 mW max	variable	0,6-10W

7.4 WARC '92

WARC is the forum with the International Telecommunications Union, where the Regulations of Radiocommunications are revised and modified, specially its table of allocations of frequency bands for the existing and planned radiocommunication services.

The WARC of 1992, has been an important landmark because of the special circumstances now concerning the radiocommunications, such as:-

- The trend towards liberalisation and de-regulation.
- The spread of radio based telecom services, which are increasingly moving from national to international services.
- The rise of the demand of mobile radio services.
- The new satellite systems now emerging, like INMARSAT Project 21.

The agenda of the WARC'92 included the following subjects:

- FPLMTS
- New land mobile applications
- Two way communications with low earth orbit satellites
- Direct ground to aircraft communications for public in flight telephone
- Broadcast satellite service
- Digital audio broadcasting

The most significant results of WARC'92 in the field of the mobile radio systems are the following:

- Spectrum allocation for mobile services in the range 1700-2450 MHz, that indicates a very strong support for the developments of DCS 1800 and DECT systems.

- Allocation of the bands 1885-2025 MHz and 2110-2200 MHz for the terrestrial components of FPLMTS, jointly with the bands 1980-2010 MHz and 2170-2200 MHz for its satellite components.

- For the mobile satellite services operating above 1 GHz, allocations have been made, including primary and secondary allocations, in bands near 1.5, 1.6 and 2 GHz, to the maritime, land and aeronautical services.

- For in flight telephone systems, in Europe, the bands 1593-1594 MHz and 1625,5-1626,5 MHz plus 1670-1675 MHz and 1800-1805 MHz have been reserved.

- Allocations for low earth orbit satellites with one or two way data communications and position location: 137-137.025 MHz, 137.175-137.825 MHz and 148-149.9 MHz, 400.15-401 MHz.

7.5 Mobile Data Applications

One of the trends in mobile radio applications is the growing use of data services. This becomes clear from the questionnaire sent to power utilities (See Appendix B). In modern networks data services can be offered simultaneously with speech services. However when the data communication is the only mode of operation, it might be better to use networks which are optimised for data traffic.

Today there are a limited number of data only systems such as:

- Mobitex
- MDI
- Cognito system

For future applications, RES6 defines a TETRA data only standard. This standard will have the following characteristics:

The data only standard will support packet mode services divided into two categories:

- connection oriented services
- connectionless services

Two alternative points of attachment are defined for both services:

- fixed port attachment
- mobile port attachment

Connection oriented service

- X.25 access
- outage recovery; when disruption of communication due to natural causes
- handover; when the call is disrupted due to a transfer on a new radio base station
- internetworking to X.25

Connectionless services

- point to point, non confirmed
- point to point, confirmed
- point to multipoint, confirmed
- message stores, automatic delayed delivery of messages if destination is unavailable
- mailbox

Standardised management services to the operator

- authentication
- registration/deregistration
- information broadcast
- log in - log out

Non standardised management services to the operator

- network configuration
- centralisation
- communication recording
- call statistics

7.6 Management of Mobile Radio Systems

The normal management of mobile radio networks is the O & M functions which are located in exchanges of mobile networks; whereas transmission systems between base stations and exchanges have their own dedicated management systems. The future trend is towards more integrated management. In longer term the CCITT recommendations on TMN (Telecommunications Management Network), M.3000 series, will be taken into account in new products and they will include standardised interfaces for management purposes. More detailed description of network management aspects is carried out in CIGRE Publication on Telecommunications Network Management in Power Utilities [2].

SECTION 8 EVALUATION OF EMERGING SYSTEMS

8.1 General

After introducing the new mobile radio standards in Section 7, the power utility radio systems planner has many alternatives when choosing suitable solutions for their mobile telecommunications needs.

As a starting point for evaluation of the suitability of different standards, the following criteria from Section 5 and Appendix B are the main considerations for mobile radio systems.

- availability
- coverage area
- own management and control
- services and facilities
- total cost

These are the major reasons for having private systems. In evaluating emerging systems, considerations must also be given to new public systems in order to check if the conclusion after evaluating the characteristics of new systems on the basis of the above criteria is still to have own private systems. When public systems are considered as an addition to the basic private services offered by own networks, different criteria will be applied in evaluating public services.

8.2 Standardised or Proprietary System

PMR technology has been characterised by a significant lack of standardisation, which has meant that only the very simplest terminals from different manufacturers were compatible. Some national standards, or the availability of the specifications of some large customer's networks, have made it possible in some cases for users to obtain a competitive offering for terminal equipment after the initial network had been purchased but, in general, users were locked to their system supplier for the lifetime of the system once the initial order had been placed.

The effect of standardisation is clearly visible in the range of mobile terminals being offered. Improved quality, size, reliability and lower costs have attracted users from proprietary systems to move to standardised systems. The user has benefitted from these trends. The owners of private systems will also benefit from the advantages of having several suppliers bidding for the initial supply with a uniform specification and perhaps even more importantly, ensuring a competitive supply of terminal equipment over the total life of the system. The owner of a standards based system also has the opportunity to benefit from the large and competitive development effort justified by the larger installed base and future markets for standardised systems.

According to the questionnaire, many power utilities have plans to sell capacity to other parties. It is natural, that a standards based system is most attractive to those utilities being network operators and running a public service, as the competitive offering of terminal equipment is a very important part of the marketing effort for any mobile telephone service.

8.3 Private or Public System

Despite the differences between private system solutions, and among countries in the development of public systems, we can establish some generic differences between public and private systems for the most important evaluation criteria used by the power utilities. The following Table shows these generic differences,

Table 8.1
Comparison table of public cellular and trunked mobile radio systems vs. private mobile radio systems for power utilities

CRITERIA	PUBLIC CELLULAR	PUBLIC TRUNKED	PRIVATE SYSTEM
AVAILABILITY	Generally acceptable, but can decrease considerably in adverse conditions The user can do nothing to increase the system availability	Generally acceptable. In critical situations availability can be technically guaranteed by priority arrangements	The owner can design the system to reach a high availability in any conditions, and can introduce changes in systems already in service to increase his availability.
COVERAGE AREA	In many countries, the coverage area offered by the public systems cannot reach the service area required by the power utilities	Typical coverage for regional services	The system can be designed with a coverage area adjusted to the required service area
OWN MANAGEMENT AND CONTROL	The user cannot gain access to the management or control of the system.	Own management and control not provided	The system can include appropriate tools for the total control and management of the system.
SERVICES AND FACILITIES	- No emergency call - No group call - No despatcher call facilities	Private type services available	A private system can include any required call facility.

When comparing public trunked systems and private systems, the following comments can be added:

A public trunked network offers the user the following advantages over a private network:

- connection to the network is simple, so it is much easier to start up radio operations than with a private network

- the user organisation does not need to invest in its own fixed network or provide itself with the necessary operating and maintenance resources

- a trunking network provides more advanced functions and services than could be economically implemented into a private conventional network

- a trunking network built by a service provider will, in many cases, cover a much larger area than could be economically covered by a private network

- because trunking networks operate in accordance with accepted signalling standards there will be a much wider range of subscriber equipment available than for a private network.

8.4 <u>Evaluation of Standards</u>

After comparing the generic differentiating factors of private and public systems we continue by making a closer evaluation of systems introduced in Section 7.

8.4.1 TETRA

The most interesting system for power utilities is TETRA. The standard is intended for professional users who need voice and data services for fleet and group operations. Clearly power utilities belong to this category. The standard can be applied to small and large networks. Interoperability between different TETRA networks is possible. The standard is suitable for private networks as well as to public networks. Special features of interest are

- optimised dispatcher facilities
- versatile group call facilities
- call priorities
- flexible data transmission facilities
- fast call set-up
- open channel mode
- direct mode operation

Benefits of digital techniques are
- spectrum efficiency
- improved data facilities
- speech quality better than in analogue systems
- speech encryption, when needed, is easier than in analogue systems
- connections to the power utility's other digital telecommunications networks is easier than in analogue mobile radio networks

Improved data capability is of special interest, because according to the questionnaire the trend is to use more data applications in future. In fleet management operations combining voice and data communication can improve the efficiency of operations, compared with the voice only traffic mode.

The choice of the modulation method makes possible the co-existence of TETRA systems in the same frequency bands as for analogue systems using 25 kHz frequency. In very low-traffic networks the 12.5 kHz option of TETRA can be a good solution.

Compared with FDMA based solutions TETRA offers

- cheaper base stations
- flexible capacity allocation between voice and data
- flexible control channel arrangements

The services listed in Appendix A1 as required by PU can all be offered by TETRA systems. Traffic peaks in abnormal operating conditions can be handled e.g. using open channel and direct mode of operation. The interoperability via a standardised interface between different TETRA networks gives various possibilities for co-operation between different PU's.

There are many variations for public use of TETRA networks. Power utilities can share a common network between different authority organisations. The operator of the network might be PTT or other second operator. The facilities offered by the standard make this kind of multi-user operation possible. Each organisation sees the network as their own virtual private network.

The third possibility is that the PU will use services from a public trunked system operated by a separate organisation like a PTT. The benefits especially to smaller utilities are listed in Section 8.3.

8.4.2 GSM

The growth of public cellular systems has been explosive and the need of more spectrum efficient systems has led to digital standards. Because PU are not isolated from what happens in larger public telecommunications environment, it is quite natural to examine what might be the role of new digital public cellular networks in PU telecommunications. As a representative of public digital systems the features of GSM will be evaluated against TETRA.

The differentiation between TETRA with respect to GSM is clear from the following Table 8.2, where some key PMR features and their implementation possibilities in TETRA and GSM are listed.

It can be concluded, that PU cannot rely on GSM in critical operations. However, GSM can be a useful complement offering services for non-critical operations, administrative traffic and for customer contacts.

8.4.3 Comparison of Other Standards

In addition to TETRA, BIIS 1200 is also suitable for operational use. Many essential services are possible by using this signalling standard, also offering many data services.

DSRR can be used in local operations and is easy to use since no infrastructure is needed. DSRR communications can be extended to areas where no base station coverage exists.

DECT is applicable as a cordless telephone extension to PU PABX-networks for example in substations where local communications is required. LAN applications are also of interest for PU's.

Public paging services offered by ERMES type of systems can be applied e.g. in new construction sites where own telecommunication infrastructure is still missing. Public paging is also useful for personnel in cases when they have left the car and have no hand portable radios.

In evaluating PCN and FPLMTS, reference can be made to GSM. These systems will be planned to offer wireless extensions to public telephone and data networks. Due to the higher frequencies the coverage area will follow the density of population and not necessarily the operating areas of PU. However, as in the case of GSM, these systems can offer complementary non critical services to PU's.

Mobile satellite systems like INMARSAT Project 21 can be considered as filling the gaps of public cellular systems coverage areas. These systems can be useful in rural areas providing services to remote locations when the installation of the organisation's own infrastructure is too expensive.

Table 8.2
Key PMR Features and their implementation possibilities for TETRA and GSM

Feature	TETRA	GSM
Direct control of the system	full availability in emergency situations	overloading possible in critical situations
Efficient group- calls - broadcast call - open channel	based on efficient semi-duplex mode	semi-duplex not possible, full-duplex not spectrum efficient
Direct mode operation	additional direct simplex-calls between mobiles (essential requirement in authority networks)	not possible
Efficient despatcher type services	optimised for this kind of operation	not possible
Fast access time for calls	< 300 ms	inferior to TETRA
Priority calls	available	not defined
Closed user groups - multiuser operation	available	possible but not defined in GSM
Queuing of mobiles	available	possible but not defined in GSM
Call duration limitations	available	not possible
Call restrictions	available	available
Dynamic channel allocation e.g. in emergency situations	available	not basic feature of GSM, response time
Price of system	planned for regional coverage cheaper infra-structure compared to GSM	heavy infra- structure expensive for small networks
Data services:		
- fast transfer of connectionless packet transmission	available in TETRA	GSM offers circuit switched data 300-9,600 bit/s. Possibilities to include packet data is under consideration within ETSI.
- special data services	technical realisation in TETRA simpler than in GSM	Short message service
- pure data networks	considerably cheaper in TETRA than in GSM	GSM optimised for speech services

SECTION 9 CONCLUSIONS

Mobile radios have proven their usefulness in many applications in power utilities. They are used in normal operational situations of generation and distribution of power, in emergency situations for power systems and in maintenance and construction of power stations and lines. The requirements for reliable communications during critical situations has been one of the main reasons for power utilities to have their own mobile radio systems. Many power utilities are now in the process of modernising their mobile radio networks, or replacing them with new systems. The reasons include new service requirements, growing traffic and extension of networks.

The progress in mobile radio technology has been very fast and new radios offer versatile call facilities to users. At the same time the complexity of the systems has grown to a level where automation is necessary in order to make the operation easy.

Frequency spectrum congestion is a severe problem nowadays. The effective use of spectrum requires co-ordinated planning of different power utility mobile networks.

In order to improve the spectrum efficiency trunked mobile radio systems have been introduced. Large organisations can install their own private systems. For smaller companies a more economical solution might be to use services from shared or public trunked networks.

Private mobile radio systems have a long history when compared with public cellular mobile telephone systems. As opposed to the more stable markets of private systems the growth of public cellular market has been explosive. The lack of frequencies has resulted in a search for more spectrum efficient solutions. New systems based on digital standards offer the solution to this problem in public cellular markets.

Despite advances in public systems, the basic solution for power utilities in the future is for them to install their own mobile radio networks. The most important reasons for power utilities to rely on their own private mobile radio system are the following: High availability of the system, good coverage, in house management and control of the network. The best solution for power utility mobile communications can be a balanced combination of both private and public services.

PMR technology has been characterised by a significant lack of standardisation, which has meant that only the very simplest terminals from different manufacturers were compatible. A general advantage of standardised solutions is cheaper equipment due to large markets. An example of a successful standard for analogue systems is MPT 1327 (See Appendix D). The next phase in private mobile radio networks is digitalisation, following the evolution happening in public cellular systems. In Europe ETSI has started the standardisation of a digital trunked mobile radio system (TETRA). The standard is intended for professional users who need voice and data services for fleet and group operations.

Among the features of digital private mobile systems are spectrum efficiency and flexible data services. Especially the improved data capability is of interest because, according to the questionnaire, the trend is to use more data applications in future. For fleet management operations combined voice and data communication can improve the efficiency of operations compared with the voice only traffic mode.

In the general climate of deregulation and liberalisation of the telecommunications environment, many power utilities have plans to sell spare capacity, or services, to other parties. It is natural therefore that a standard based system is most attractive to those utilities being network operators and running a public service, as the competitive offering of terminal equipment is a very important part of the marketing effort for any mobile telephone service.

In many countries the former state owned power utilities are re-organising and separating their generating, transmission and distribution activities and forming different companies. The aim is to improve the efficiency of operations and reduction of costs. The mobile radio systems will play an important role in achieving these goals. Mobility will be a future key word, not only for operational purposes but also for management with increasing customer contacts and requirements of an efficient service organisation. There will be a need for integration in telecommunications networks. Mobile radio systems will form an important part in this integrated network. This development will be more important in the new customer oriented world.

SECTION 10 ACKNOWLEDGEMENTS

The Members of CIGRE Working Group SC35.02 would like to record their grateful thanks and appreciation to all those who have assisted in the preparation of this MRS Report. They would also like to express their appreciation to those who responded to the Questionnaire on Mobile Radio Systems.

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APPENDIX A

A1 LIST OF SERVICES AND FACILITIES FOR MOBILE RADIO SYSTEMS

A1.1 General

Service Facility	Description
- Acknowledged group call	Group call with check of called parties in presence. It is an operator option whether the called parties presence are checked before setting up the multipoint call or during the call after the call set up.
- Authentication	The act of positively verifying that the true identity of a user is the same as the claimed identity.
- Broadcast call	A multipoint call in which the same information is transmitted simultaneously by the calling party to all available parties.
- Broadcast message	One way point to multipoint communication between a calling party and several called parties. It is assumed that the called parties cannot respond on the information.
- Call re-establisment	See "Handover".
- Category groups	Users joined in each priority level of a system.
- Circuit switched data	A service that uses a circuit-switched connection to transfer data between data terminal equipments.
- Communication recording	Registration of the communications of a party in a tape recorder.
- Connectionless packet data service	A service which transfers a single packet of data from one source node to one or more destination nodes in a single phase (i.e. without establishing a logical connection or virtual circuit).
- Connection oriented packet data service	A service that transfers data from one source node to one destination node using a multi-phase protocol that establishes and releases logical connections or virtual circuits between end users that are then used to transferring packet data.

- Direct call	A mode of simplex operation where mobile subscriber radio units may communicate using radio frequencies which are outside the control of the network and without intervention of any base station.
- Direct mode	See "Direct call".
- Emergency call	Priority call, usually with the highest priority level, to a pre-determined party, for example, an emergency centre.
- Encryption	Use of coding methods to keep the message content secret.
- Group call	Two way point to multipoint communication between a calling party and one or more called parties. All the called parties must be previously defined.
- Handover	Automatic transference of a call in progress, from a cell or base station site to another, by the system.
- Individual call	A two way point to point communication between one calling party and one called party.
- Message trunking	A method of traffic channel organisation where each traffic channel is permanently allocated for the complete duration of the call, which may include several separate call transactions (several pressel activiations by separate terminals). The channel is only de-allocated if the call is (explicitly) released or if a timeout expires.
- Mobile access hunting	See "Roaming".
- Mobile repeater	Special duplex mobile radio equipment that can operate as a repeater station.
- Open channel	A dedicated traffic channel that is reserved for exclusive use of a user group.
- Pseudo open channel	A method of assigning traffic channels to a user group such that the group appears to have exclusive use of a dedicated traffic channel.

- Queueing	A system in which a certain number of calls are stored, in order of arrival, for subsequent completion in a desired sequence.
- Roaming	The act of a subscriber terminal changing its point of attachment within one mobile radio system.
- Selective call	A system whereby the transmission of a signal code from a station enables another pre-determined station or group of stations to be called exclusively.
- Slow handover	See "Handover".
- Status call	Call originated by any system equipment, for supervision/alarm purposes.
- Telephone access	Possibility of interconnection between a party from a Mobile Radio System, and a party from any fixed telephone network.
- Transmission trunking	A method of traffic channel organisation where each traffic channel is individually allocated for each call transaction. The channel is immediately de-allocated at the end of the call transaction (subject to unavoidable protocol delays).

A1.2 Supplementary Services

Service	Description
- Abbreviated dialling	This service allows a subscriber to call to pre-determined subscribers, using short dial codes, instead of the full numbers.
- Access priority	A service that can give certain subscribers preferential access to the system. There will be levels of access priority.
- Advice of charge	A service allowing the user paying for a call to be informed of usage-based charging information. The charging information may be given at the end of the call, during the call or at call set up.

- Ambiance listening	This service makes it possible for a mobile user to initiate, usually in an emergency situation, a mode of operation such that the transmitter of the mobile is keyed. Normally, a speech path is set up to a dispatcher although the destination could be any addressable terminal.
- Area selection	This service allows a subscriber to select a geographical area(s) or service area, in which the call is to be set up. The calling party may define the selected area for the call in the set up message and the system will set up the call in those areas. Alternatively, the selected areas for the call may be stored in the users profile within the infrastructure and the system will set up the call accordingly after referring to the database.
- Automatic call back	See "Completion of calls to busy subscriber".
- Autiomatic redial	See "Completion of calls to busy subscriber"
- Call authorised by dispatcher	A user may decide that direct calls between certain categories of subscribers are not allowed. They have to be authorised by a dispatcher. This can for example mean that direct calls from mobile to PSTN/PABX are not allowed.
- Call diversion	See "Call forwarding".
- Call forwarding (busy, no reply, unconditional or on mobile subscriber not reachable)	This service allows a party that their incoming calls (on busy, on no reply, on any condition or on mobile subscriber not reachable) may be diverted by the system to another party, previously defined by the user served.
- Call hold	This service allows a party to interrupt communications on an existing call, connect to a waiting call and subsequently re-establish communication to the first call if desired.
- Call me back	See "Call report".
- Call report	This service provides the ability for the calling party to leave his identity to the called party for subsequent call back.

- Call restrictions	This service allows the possibility for a TETRA internal user to have barring of certain categories of outgoing and/or imcoming calls.
- Call waiting	Possibility for a party to be notified of an incoming call whilst her termination is in the busy state.
- Completion of calls to busy subscriber	This service allows a calling party encountering a busy called party, to have the call automatically re-initiated by the system, when the called party becomes free.
- Conference call	A call established between three or more stations in such a manner that each of the stations is able to carry on a communication with all the others.
- Discreet monitoring	A supplementaty service that makes it possible for an authorised user (for example a dispatcher) to listen in on any call. When listening in on a call, the dispatcher can enter into the conversation and/or if he so wishes to terminate the call.
- Forced release	Release of a call in progress forced by an intruding party.
- Include call	See "Three party call".
- Intrusion	Intervention of an authorised subscriber in a call in progress.
- List search call	See "Search group call".
- Number identification	This service can provide: Connected number identification presentation/restriction, and Calling number identification presentation/restriction.
- Pre-emptive priority call	A call that has pre-emptive priority will always have resources allocated, even if this means that other calls will be disconnected.
- Priority call	The priority call service allows the infrastructure to give preferential treatment to calls which have been sent with priority status. A priority call can be sent to any addressable terminal. There could be several priority levels.

- Request to call back — See "Call report".
- Search group call — Sequential call forwarding for subscribers previously included in a list. Some criteria can be attached to each address such as time schedule, area constraints or state such as busy.
- Short number addressing — See "Abbreviated dialling".
- Talking party identification — This service provides the ability for the connected parties to obtain information relating to the transmitting unit.
- Three party call — Permits a party, whilst holding an existing call, to make a call to a third party. The following possibilities are then available:

  - Ability to switch between the two calls, with secrecy between them (Shuttle).
  - Connection of the other two parties (Transfer).
  - Introduction of a common speech path between the three parties (Add-On).

A2 GLOSSARY OF TERMS

Automatic exchange — An exchange in which the inter-connections are effected by means of automatic apparatus.

Base station — Radio equipment installed in a fixed position, for communication with mobile stations.

Base station site — Place where one or more base stations are located.

Bearer service — A type of telecommunication service that provides the capability for the transmission of signals between user-network interfaces.

Call receiver — Portable radio equipment with receiver functions only.

Called party — The party (subscriber, user, station) required by the calling party.

Calling channel — See "Signalling channel".

Calling party — The party (subscriber, user, station) who originates a call.

Channel	A means of one-way transmission.
Channel spacing	Frequency diference between the carriers of two adjacent radio channels.
Common channel signalling	Signalling method that utilises a single channel for the signalling information of several traffic channels.
Control channel	See "Signalling channel".
Duplex	A method of operation whereby transmission is possible simultaneously in both directions.
Duplex spacing	Frequency difference between the carriers of the two associated radio channels of a duplex radio communication.
Exchange	A switching centre for inter-connecting the lines which terminate therein.
Frequency Division Multiple Access	One frequency slot of a wide channel is allocated to each user for the whole duration of the call.
Mobile exchange	A specialised exchange utilised in some trunked mobile radio systems, with control and interface functions.
Mobile station	Radio equipment to be utilised in move, or while stayed in undeterminated places, for communications with another mobile or base stations.
Portable station	Mobile station which is intended to be carried by the user.
Private automatic branch exchange	An automatic exchange which is usually installed on the premises of a subscriber and which is connected to a public exchange, by one or more lines.
Radio channel	A channel provided by means of a radio transmitter and radio receiver.
Repeater station	Base station in which the received signals are fed directly to transmitter.

Semiduplex operation	Method of operation simplex in a telecommunication circuit end, and duplex in the other.
Signalling channel	The radio channel used for the signalling, in a trunked mobile radio system with common channel signalling.
Simplex operation	A method of operation whereby transmission is possible in both directions, but not simultaneously.
Supplementary service	A supplementary service modifies or supplements a bearer service or a teleservice. It cannot be offered to a customer as a stand alone service. It must be offered in combination with a bearer service or a teleservice.
Teleservice	A type of telecommunications service that provides the complete capability, including terminal equipment functions, for communication between user according to agreed protocols.
Time Division Multiple Access	One time slot of a high rate channel is allocated to each user for the whole duration of the call.
Trunking	Automatic sharing of several communication channels by a number of users.
Voting	The act of selecting, to carry a call, the channels that have the better signal to noise ratio, between all the possible channels in the system.

A3 LIST OF ABBREVIATIONS

BS	Base station
CCIR	International Radio Consultative Committee
CCITT	International Telegraph and Telephone Consultative Committee
CEPT	European Conference of Postal and Telecommunications Administrations
C/I	Carrier to Interference ratio
DECT	Digital European Cordless Telecommunications
DPNSS	Digital Private Network Signalling System
DQPSK	Differential Quadrature Phase Shift Keying
DSP	Digital Signal Processing
DTMF	Dual Tone in Multi-Frequency Signalling
EC	European Community
ECMA	European Computer Manufacturers Association
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ERMES	European Radio Messaging System
ETSI	European Telecommunications Standards Institute
FFSK	Fast Frequency Shift Keying
FSK	Frequency Shift Keying
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
FPLMTS	Future Public Land Mobile Telecommunication System
GSM	Global System for Mobile Communications
IEC	International Electrotechnical Committee
INMARSAT	International Maritime Satellite Organisation

ISDN	Integrated Services Digital Network
ITU	International Telecommunication Union
JRC	Joint Radio Commitee of the Fuel and Power Industries (UK)
LAN	Local Area Network
MRS	Mobile Radio System
MTTR	Mean Time To Repair
MTBF	Mean Time Between Failures
MX	Mobile Exchange
NMT	Nordic Mobile Telephone
O & M	Operation and Maintenance
OX	Operational Exchange
PABX	Private Automatic Branch Exchange
PC	Personal Computer
PCN	Personal Communications Network
PDN	Public Data Network
PLC	Power Line Carrier
PM	Phase Modulation
PMR	Private Mobile Radio
PS	Portable Station
PSTN	Public Switched Telephone Network
PTO	Public Telecommunication Operator
PTT	Post Telephone and Telegraph, used as a generic term, for various telecommunication Administrations and/or PTO's
PU	Power Utility
QPSK	Quadrature Phase Shift Keying
RES	Radio Equipment and Systems (ETSI Committees)

RF	Radio Frequency
SCADA	Supervisory, Control and Data Acquisition
SNR	Signal to Noise Ratio
TDMA	Time Division Multiple Access
TETRA	Trans European Trunked Radio
TMS	Telecommunication Management System
TNM	Telecommunication Network Management
VDU	Visual Display Unit
WAN	Wide Area Network
WARC	World Administrative Radio Conference

APPENDIX B

RESULTS OF MRS QUESTIONNAIRE
(Based on paper 35-102 presented at Paris 92 CIGRE Conference)[14]

Summary

At the meeting of CIGRE SC35 in Minsk in 1989, Working Group 02 was given the task of preparing a report on "Mobile Radio Systems in Power Utilities", which the working group is to complete in 1993.

In order to get information required for the report, WGO2 has decided to commence this work by distributing a questionnaire to get an overview of the present situation and what plans different power utilities have for the future. This questionnaire was sent out to the 24 SC35 member countries, 58 answers were received. The answers have been analysed and are presented in this report. The answers contain general information about the power utilities involved, the usage of public mobile systems, descriptions of their existing private mobile radio systems, replacement plan of old systems and trends in future private mobile radio systems.

Keywords: Mobile radio systems, radio, mobile(s), trunked systems, future trends.

B1. Introduction

CIGRE Study Committee 35 has published the "Guide on Mobile Radio for the Electricity Utilities" in 1985[1]. Since that time many new mobile radio systems have been or will be introduced.

The new report with this earlier published guide is intended to provide information to mobile radio system planners when designing new systems.

The report will include a description of present use and future requirements for mobile radio systems in power utilities based on a questionnaire. The answers have been analysed and will be presented in this report. The general conclusions from the answers will also be included in the main report on "Mobile Radio Systems in Power Utilities".

Mobile radio has been in practical use in power utilities in many countries for more than 40 years. Mobile radio systems are growing rapidly in size and complexity. In many countries the systems have been developed technically to provide advanced communication media with a great number of services. Different answers on the questionnaire clearly show this development.

The development and introduction of country wide public mobile telephone networks is spectacular. One of the purposes of the questionnaire was to investigate the acceptance of public mobile networks for power utilities.

New developments and detailed descriptions of both private and public mobile radio systems will be included in the above mentioned main report.

B2. General Comments to the Questionnaire

The questionnaire has two parts. Part 1 describes the existing situation whilst Part 2 addresses the future situation. The purpose of the questions of Part 2 is to get an overview of the future trends of mobile radio systems in power utilities. Although the questions in Part 2 are quite detailed, the answers could be given as a "good guess", if the utility does not have detailed plans for the future.

In total 58 answers were received from 19 countries. 44 answers were given to Part 2. As was expected the power utilities, which have answered, are of varying sizes, which can be seen from the following figures.

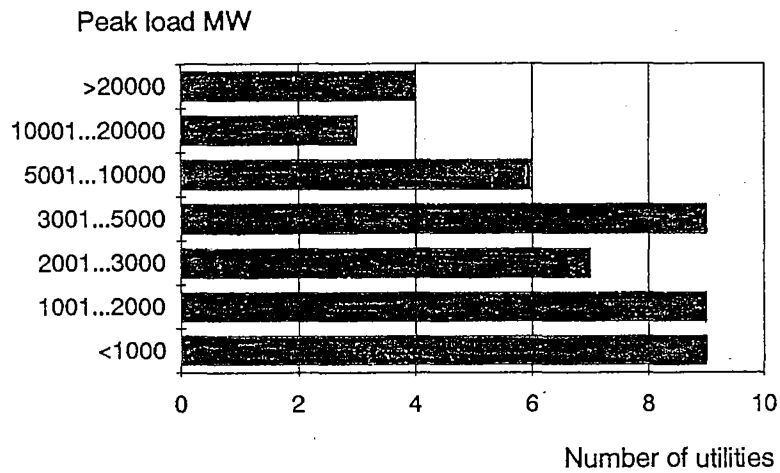


Figure B1 Number of utilities versus peak load

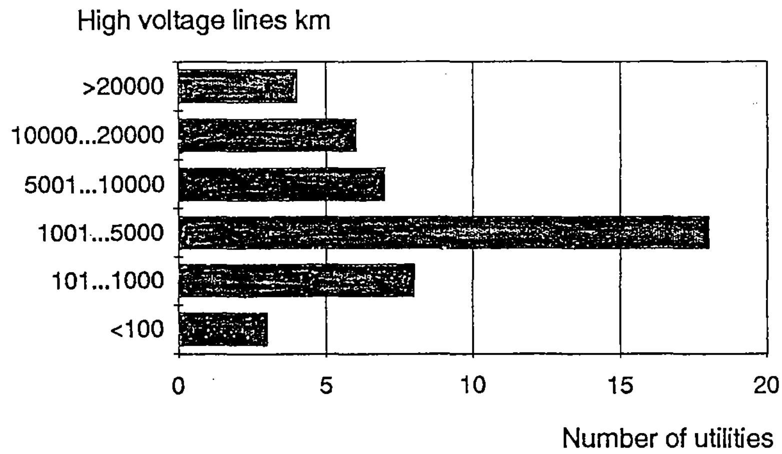


Figure B2 Number of utilities versus length of high voltage lines

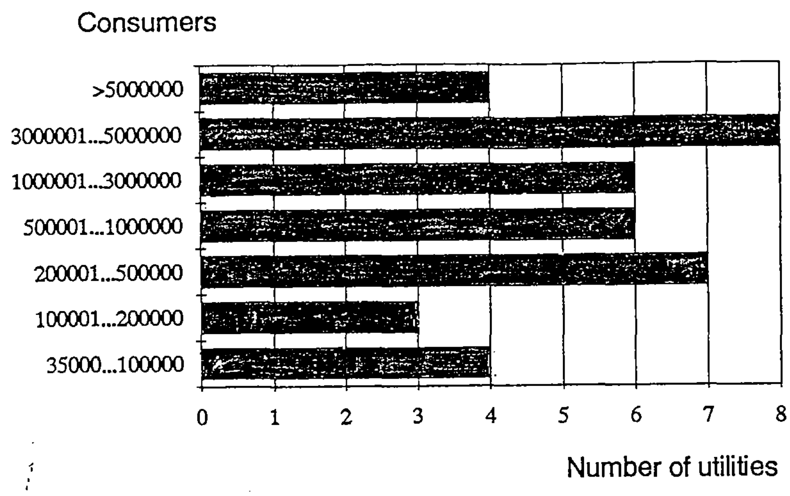


Figure B3 Number of utilities versus consumers

8 Utilities have less than 100 customers and 12 utilities did not answer to the consumer question.

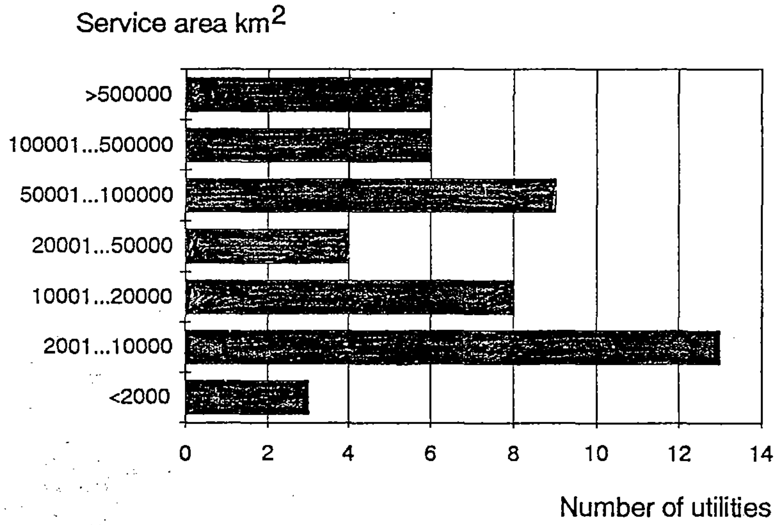


Figure B4 Number of utilities versus service area

The number of answers from the different countries are:

Australia	5	Netherlands	5
Austria	6	New Zealand	1
Brazil	3	Norway	2
Denmark	2	Portugal	1
Finland	7	Spain	2
France	1	Sweden	3
India	3	Switzerland	2
Ireland	1	UK	5
Italy	1	USA	1
Japan	7		

The power utilities involved vary from relatively small local distribution companies to regional distribution companies with transmission lines and up to national power utilities with generating capacity. In general, there is a relationship between the number of mobiles and mobile systems and length of high voltage lines, the size of service area and the number of consumers. The answers can therefore be considered representative for this analysis. Because the questionnaire and the answers are worked out by technical people, views on the subject are mainly technical.

The total number of systems involved in the questionnaire is 145.

B3. Public Versus Private Mobile Systems

In Fig. B5 the division between public and private systems is shown, now and in the future. A substantial amount of systems are public. Almost all public systems are of the cellular type.

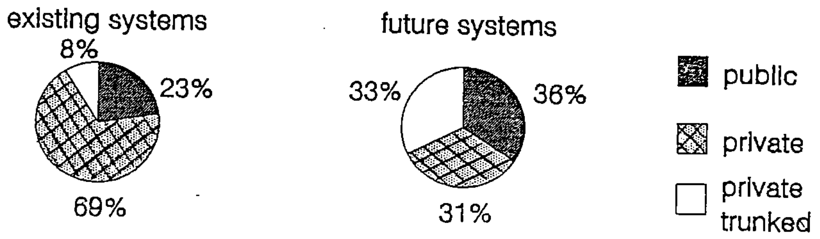


Figure B5 Division between public and private systems

As can be seen in Fig. B6 the number of mobiles, used in the different systems, show a totally different division.

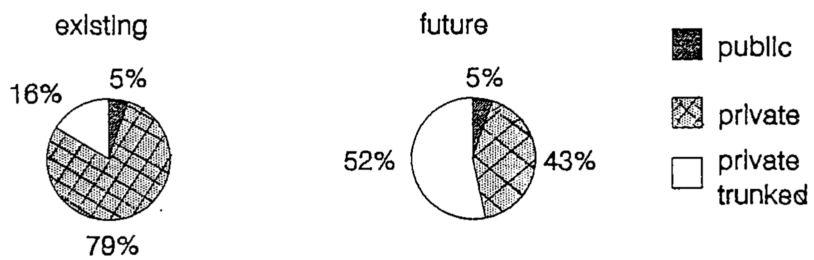


Figure B6 Division between mobiles in different systems

The following conclusions can be drawn from these answers.

- 23% of the systems are public ones now, and for the future 36%

- the number of mobiles used in public systems represent only 5% of the total amount of mobiles, now and for the future

- in private systems there will be a break-through in favour of trunked systems.

The major reasons for using private systems are shown in Fig. B7. The figures for each item represent the average value of the answers (5 = very important, 1 = no importance).

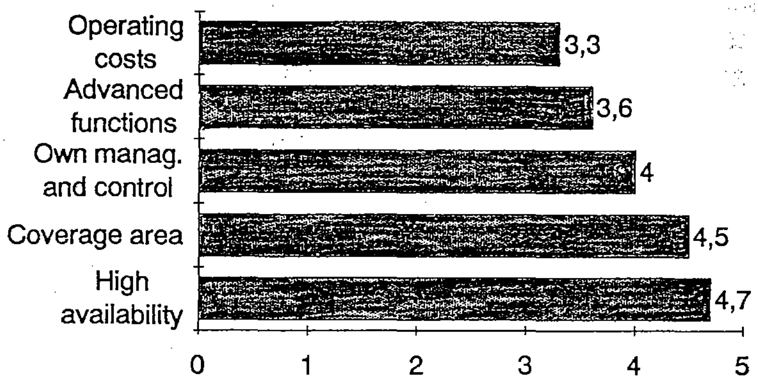


Figure B7 Major reasons for using private systems

B4. <u>Existing Private Systems</u>

B4.1 System Types

In order to give a better background for the subsequent sections various existing solutions for mobile systems are described.

Simplex systems

These networks are the oldest and simplest. They are made up of stations which are all technically identical and use only one frequency on which one station speaks and the others listen. They don't require an infrastructure and are reserved for very local networks using portable sets.

Private conventional systems

The simplest and most commonly used system consists of a fleet of mobile stations around a well positioned repeater (relay). The repeater re-transmits on a frequency f2, which is the receiving frequency of the mobiles, and receives on a frequency f1, the mobile transmitting frequency. By its nature the network is open. The "open network" feature is more difficult to obtain with more sophisticated networks.

Features like selective calling can be added. It is also possible to join several repeaters in a network. The network can also be connected to a PABX (Private Automatic Branch Exchange) or PSTN (Public Switched Telephone Network).

Trunked systems

The shortage of frequencies and a real need to increase spectral efficiency led to the introduction of trunked systems, grouping several sites together around a central control unit and linking them to the centre. Pooling the channels and infrastructure equipment in this way requires the system, in order to function properly, to operate in the fundamental "roaming" mode. This function also benefits network users who no longer have to worry about the location of the mobile station they have called. Signalling between the mobiles and the control centre can be done on a dedicated channel. Communication between subscribers takes place on an individual basis. Numerous telephone-like functions are available. The system can be used either by a single utility or it can be shared by several utilities.

B4.2 Size of Private Systems

The number of different private mobile radio systems existing in the power utilities is shown in Fig. B8. The total number of private systems involved in the questionnaire is 111.

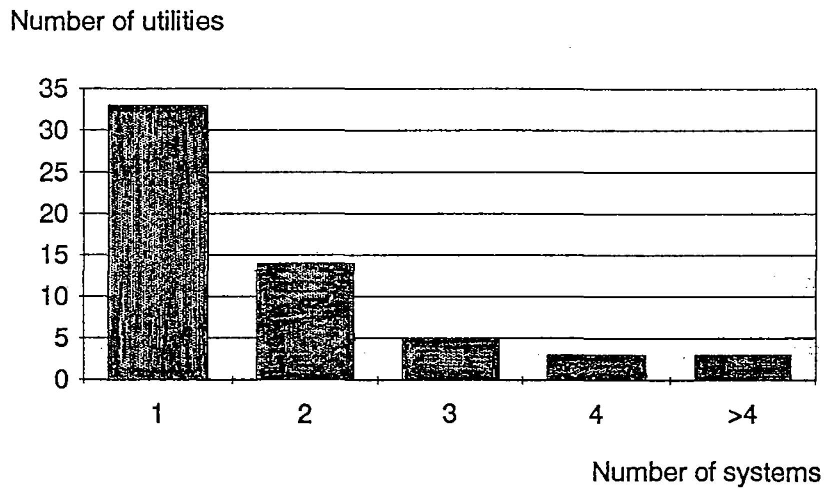


Figure B8 Number of different private mobile radio systems in power utilities

In addition public mobile radio services are used in 31 utilities.

The number of mobile radios in power utilities is shown in Fig. B9. It should be noticed that absolute values between present and future systems cannot be compared because there are fewer answers to future system description.

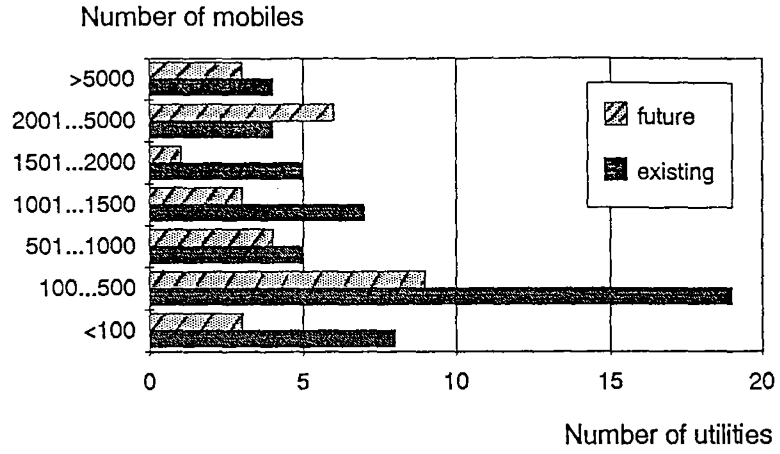


Figure B9 Number of mobile radios in utilities

The following figures give statistics of the size of the mobile radio systems in power utilities.

Number of	Min	Average	Max
Mobiles related to 100 employees in utility	5	25	87
Mobiles related to 100 vehicles in utility	24	125	343
Mobiles per base station site	6	38	240
Base station sites in 63 systems	1	77	700
Mobiles in vehicles in 60 systems	31	1152	20000
Transportable phones in 27 systems	5	337	4000
Handportable phones in 48 systems	10	587	8500
Call receivers in 28 systems	20	740	13000
Tone pagers in 18 systems	10	960	13000
Voice pagers in 9 systems	4	34	160

Number of data pagers is 35,500, 1000 and 3800 in 4 systems
Number of data terminals is 1,2,2,4,51 and 110 in 6 systems

B4.3 Links in Fixed Networks

The links between the base station and mobile exchange(s) are routed mainly through the utilities own telecommunication network. Only 20% of the links are leased. The quality of the links is generally voice grade. Only in 10% of the links is the quality high grade (group delay equalised).

Type of links

2-wire	11%
4-wire	56%
digital 4-wire	13%
multichannel	20%

Data links were used in 23 systems. In 19 systems the data links are using fixed lines; in 2 systems the data links are circuit switched; in the remaining 2 systems the data links are using a packet switched network.

B4.4 Usage of Mobile Systems

The type of usage of the mobile radio systems is shown in the following table

		Amount of utilities in %	
		Present	Future
1.	Maintenance of power lines	93%	91%
2.	Operational traffic (local)	84%	77%
3.	Maintenance of power plants	83%	75%
4.	Operational traffic (regional)	81%	84%
5.	Construction of power lines	74%	80%
6.	Construction of power plants	62%	64%
7.	Vehicle management (local)	60%	66%
8.	Vehicle management (regional)	53%	57%
9.	Administrative traffic	47%	66%
10.	Telecontrol	38%	52%
11.	Other use	16%	
12.	Plans to sell capacity		18%

It can be concluded that private mobile radio systems are mainly used for operational purposes.

Significant differences in usage between the present situation and the future are:

- the increase of administrative traffic
- the increase of usage for telecontrol
- the plans to sell capacity to a third party

B4.5 Traffic Statistics

The traffic distribution (average values) is given in the following table.

Mobile to mobile, single site	20%
Mobile to mobile, multi site	15%
Mobile to mobile, regional	14%
Mobile to mobile, national	0.2%
Mobile to/from dispatcher	28%
Mobile to PABX	10%
PABX to mobile	9%
Mobile to PSTN	3%
PSTN to mobile	1%

About 80% of the traffic is between mobiles and between mobiles and a dispatcher. Only a small amount of traffic (23%) is directed to and from fixed networks. National traffic between mobiles is negligible. Statistics of the calls are as follows:

	Min	Average	Max
Average number of calls in busy hour	7	79	400
Average call duration in busy hour (sec)	10	71	300
Average call set-up duration (sec)		0.3	2.4 10

The distribution of average call duration in different systems is shown in Fig. B10.

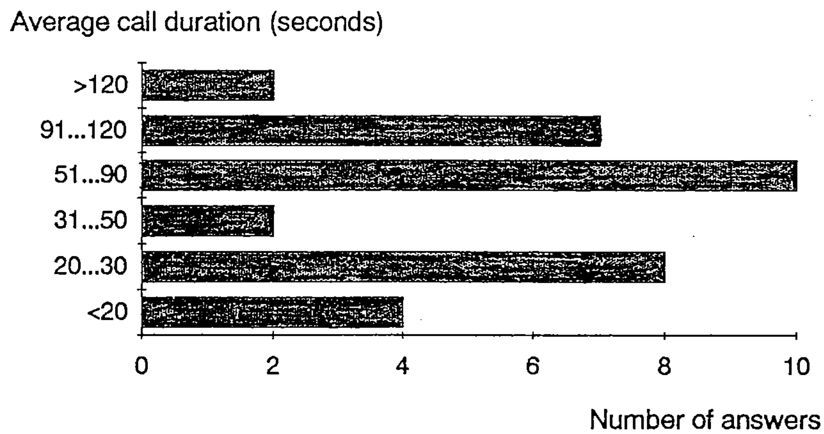


Figure B10 Distribution of average call duration in busy hour

B4.6 Facilities

In the following table different functions and facilities used in the different systems are listed in order of highest percentage of present systems.

	Amount of utilities in % Present	Future
Individual call to radio	71%	70%
Group call to radios	64%	66%
Call to PABX	52%	66%
Call from PABX	50%	64%
Call to operational telephone network	50%	64%
Call from operational telephone network	50%	64%
Emergency call	48%	66%
Time limitations in call duration	45%	64%
Broadcasting call	43%	59%
Hardware based functions	38%	41%
Software based functions	38%	50%
Call retransmission to call receiver	34%	57%
Different category groups	29%	50%
Priority calls	28%	66%
O & M terminal	28%	57%
Request to call	26%	52%
Calling party identification	26%	55%
Call to PSTN	24%	52%
Roaming	21%	55%
Statistical information	21%	59%
Selective access to ongoing call	19%	43%
Call from PSTN	17%	45%
Queueing	14%	48%
TNM connected to system	14%	57%
Recorded messages to radios	10%	45%
Handover	5%	41%
Separate calling channel	3%	43%
Encryption	0%	41%

Additional facilities asked for future systems:

Direct connection between radios	68%
Dispatcher facilities	43%
ISDN facilities	39%
Call charging information	36%

When interpreting this table it is important to remember that 89% of the existing private systems are of the conventional type.

Only 11% of the existing private systems are trunked systems, where more advanced functions are introduced. For the future a major part of the system will be trunked.

The facilities of the radio units are listed below. About 50% of the mobiles are of a very advanced type as can be concluded from the existence of a keypad.

	Amount of Utilities in %	
	Present	Future
Hand microphone	71%	45%
Hand set	60%	68%
Full keypad	47%	50%
Emergency switch	22%	41%
Calls to predefined numbers only	19%	25%
Hands free	12%	43%
Modem connection	10%	41%
RS232 connection	10%	50%

B4.7 Data Transmission Over Radio

38% of the utilities involved in the questionnaire do use data communication. Data communication over radio however is not yet generally used in private mobile radio systems. The different functions are listed below.

	Amount of Utilities in %	
	Present	Future
Vehicle management	17%	39%
Telemetry	17%	43%
Telecontrol	15%	43%
Short messages	15%	52%
Interactive	7%	25%
Telefax	2%	39%
Drawings	2%	25%
Other	5%	-

Some specific applications of data communication are:

- distribution telecontrol purposes
- information on faults of distribution cable
- experimental pole mounted switchgear control
- exchanges of messages related to works on power lines
- telecontrol of substations
- water level telemetry, main/standby repeater changeover
- customer information, operational data
- technical data for maintenance
- printed messages from control centre to mobiles
- mobile terminal for normal asynchronous data transfer between mobile unit and fixed computer network
- pc-terminal connected to RS232
- telesignalling

The data equipment is built into the mobile in only 17% of the systems involved. In future this will be about 50%.

The data speed is:

	Present	Future
300 b/s or below	36%	-
600 b/s	23%	12%
1200 b/s	27%	28%
>1200 b/s	14%	60%

Error protection is now applied in 7 systems and in 18 systems in the future.

B4.8 Technical Details

The frequency bands used in private mobile systems are mainly the 80 and 160 MHz band.

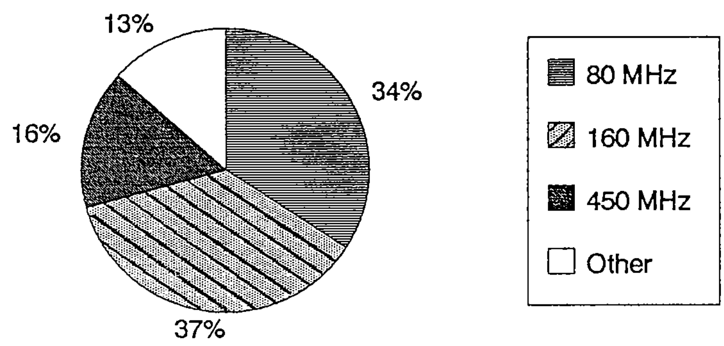


Figure B11 Operating frequencies

Phase/frequency modulation is mainly used (92%) compared to amplitude modulation (8%).

The channel spacing is mainly 25kHz (60%).

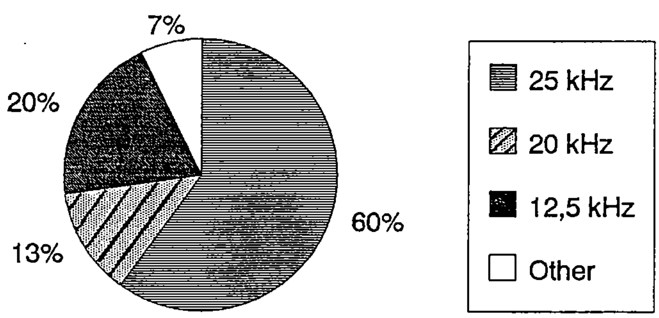


Figure B12 Channel spacing

In the following table the number of simplex, semi-duplex and full-duplex channels in the different systems is given.

	Number of systems		
	Simplex	Semi-duplex	Full-duplex
1 channel	19	5	1
2-4 channels	15	5	4
5-10 channels	15	19	5
> 10 channels	9	10	4

The frequency range of transmit channels are shown in Fig. B13.

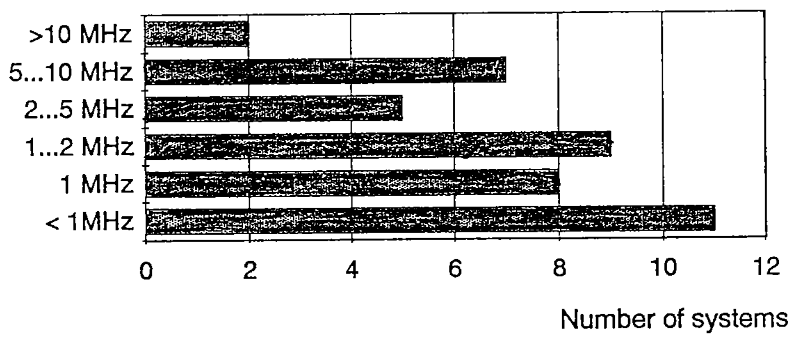


Figure B13 Frequency range of transmit channels in different systems

The duplex spacing is shown in Fig. B14

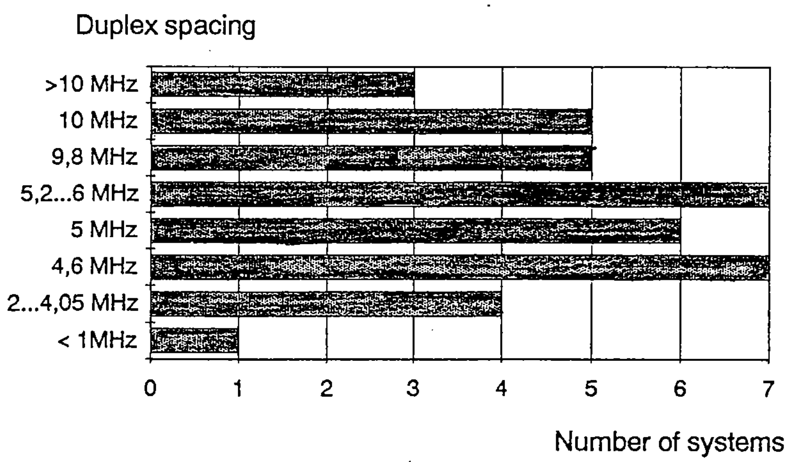


Figure B14 Duplex spacing in different systems

The typical channel reuse distance is shown in Fig. B15

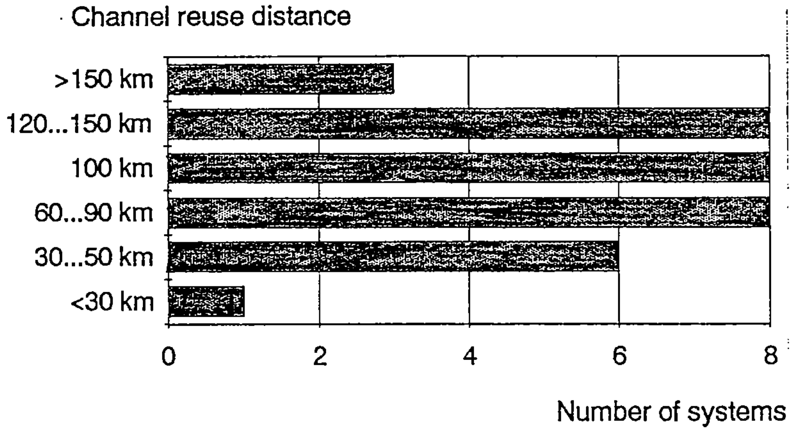


Figure B15 Channel reuse distance

The method of calling on channels is:

	Number of systems: Simplex	(Semi) Duplex
Speech call	33	10
Selective and speech call	8	11
Selective call	5	16

Selective calling can be done using one of the following signalling methods

CCIR	25 systems
ZWEI	9 systems
DTMF	8 systems
FSK	6 systems
FFSK	1 system
Other	4 systems
No signalling	15 systems

Error detection and correction code in signalling and the re-transmission of failed blocks is seldom used.

B4.9 Operation and Maintenance

Most of the power utilities involved in this questionnaire have their own maintenance organisation. The maintenance organisation is mostly local with a small central staff. System and fault management are also distributed over the local/regional and central organisation.

The average number of maintenance people per 100 mobiles is 0.9 with a maximum number of 1.9.

The level of maintenance is given below.

	Number of utilities System	Mobiles
Change of faulty unit	32	29
Minor repairs	30	29
Major repairs	20	22

In 8 cases the management system is integrated into the mobile radio system. In 9 cases there is a separate management system and in 12 cases the management system is integrated into another telecommunication management system.

The required availability of the mobile system excluding mobile radios is between 90 and 99.9%, with an average of 98%.

B5. Replacement of Old Mobile Systems

B5.1 Age to Replace Systems

The average age of mobiles and base/repeater stations is shown in Fig. B16

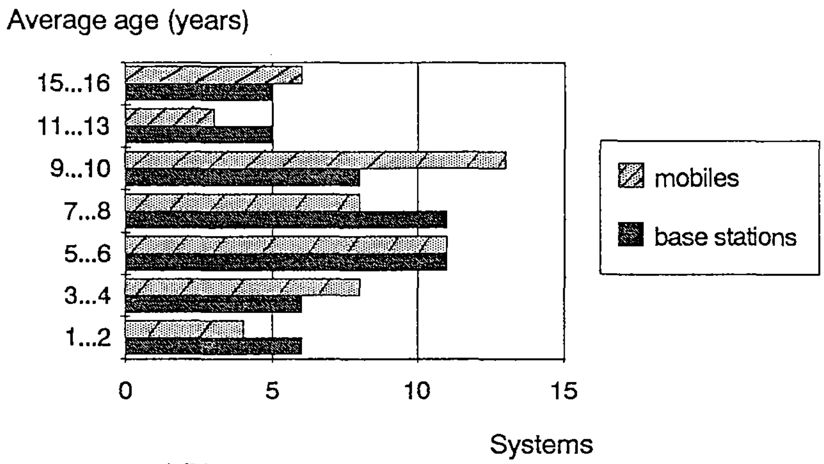


Figure B16 Average age of mobiles and base stations

The utilities will replace the mobiles and the base/repeater stations at the following age in years.

	Min	Average	Max
Mobiles	8	12.5	25
Base/repeater stations	8	13.5	20

The target year to install a new system is shown in Fig. B17

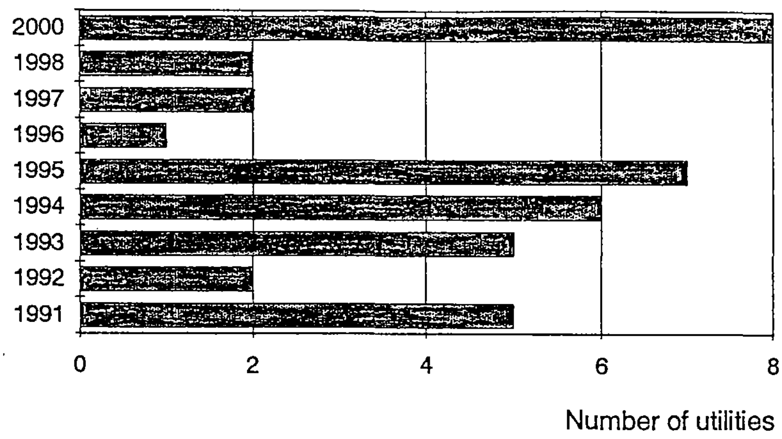


Figure B17 Target year to install a new system

The estimated average life time of future systems is 13.5 years.

B5.2 Reasons to Buy a New System

The main reasons for the utilities to buy a new system are shown in Fig. B18.

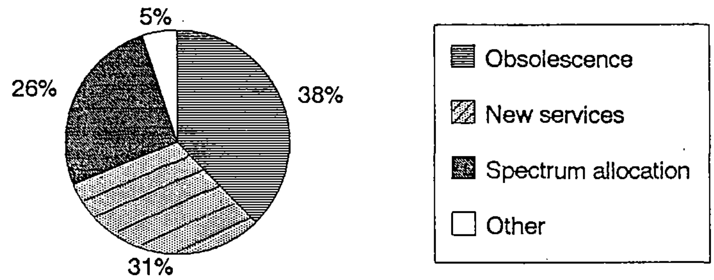


Figure B18 Main reasons to buy a new system

The criteria in selecting a new system can be seen in the following table (average figures with 5 = very important, 1 = not important).

High availability	4,8
Coverage area	4,4
Own management and control	4,0
Wide area operation	3,8
Call facilities	3,8
Cost of mobile unit	3,8
Operating costs	3,8
Radio unit facilities	3,7
Cost of fixed equipment	3,6
O & M facilities	3,6
Spectrum efficiency	3,5
Suitability for handportables	3,5
Cost of links	3,3
International standard signalling	3.3
Multi vendor policy	3,2
Access to public network	3,1

B6. Future Private Mobile Systems

B6.1 Trends

The questions in Part 2 of the questionnaire are quite detailed. Not all the power utilities involved have answered Part 2. The answers could be given as a "good guess" and may not be accurate. These are the reasons why in this section for future systems only trends are given.

The trends of the development of private mobile radio systems are:

- in many cases conventional systems will be replaced by trunked systems together with the introduction of new facilities

- these trunked systems will have more connections to the PSTN

- in private mobile radio systems handportable phones will be in common use

- data communication over radio will be more widely used for several applications

- next to the 80 and 160 MHz band, the 450 MHz band will be used for private mobile radio systems together with the reduction of the channel spacing to 12.5 kHz, the introduction of digital signalling and modulation and the application of error detection/correction.

B7. Conclusions

The power utilities involved in the questionnaire vary from relatively small local distribution companies to regional distribution companies with transmission lines and up to national power utilities with generating capacity. The answers can therefore be considered representative for this analysis. The answers to the questionnaire are very detailed and technically oriented. Care should be taken in drawing exact conclusions from this questionnaire. However it is possible to state some general conclusions.

Although public systems are used by a reasonable number of power utilities the relative portion of public mobiles is and will be very small and can be considered a complement to their own private mobile radio network.

The major reasons for power utilities to own a private mobile radio system are high availability of the system, good coverage area and own management and control. There are also important reasons to ensure the services required for operational purposes, even in peak hours and during power breakdowns.

In future a major part of private mobile radio systems will be of the trunked type with binary signalling and special facilities. There will be more connections to the PABX and to the PSTN.

Data communication over radio will be more widely used for applications like printed messages, telecontrol and remote terminals.

There is an interest to sell capacity to third parties.

APPENDIX C

EXAMPLES OF POWER UTILITY MOBILE RADIO SYSTEMS

C1 Description of existing mobile radio system of Vattenfall

C1.1 Demands

The state owned Vattenfall generates half of all the electricity in Sweden. Vattenfall operates approximately 70 hydro power stations spread throughout the country and seven nuclear units as well as a few oil-fired and coal-fired condensing power stations.

The high voltage power is transmitted between different parts of the country over the national grid, but also over regional and local transmission networks.

For maintenance and operation of the power systems there is a great demand for fast and reliable telecommunications. Vattenfall utilises different systems that work together supplying information to national, regional and local control centres. Normally this is carried out by power line carrier (PLC) or single or multichannel radio links.

Mobile radio has been used as an important tool for more than 40 years. From the beginning there was a number of small systems and the use basically was for voice communication on local and regional level with people in the field working with the operation, maintenance and construction of networks.

Todays countrywide mobile system was completed around 1985. The system at Vattenfall consists of 120 repeater stations, 250 base stations, 2000 mobiles and 1400 hand portable units.

As a result of demands formed by a working group with users the system has to meet the following requirements:

- easy to handle
- emergency buttons on mobiles and portables
- connections to public and own operational telephone network
- automatic channel selection
- application of the mobile units working in local repeater mode
- printed messages from control centres to mobiles
- ability to transmit identity and status messages
- remote control of electrical equipments in substations by digital transmission
- ability for joint operation with other mobile networks

C1.2 System Layout

The Mobilradio 80-system is based on strategically located autonomous multi-channel repeater stations which pass the traffic between base stations and mobiles (Figure C1). The repeater and base stations are connected to the public and sometimes also the Vattenfall operational telephone system.

The system works on frequencies in the mid VHF band, 70-80MHz, and uses seven two-frequency repeater channels with 5 MHz separation. There is also one mobile repeater channel and two one-frequency channels for communication directly between base stations, mobiles and handportables.

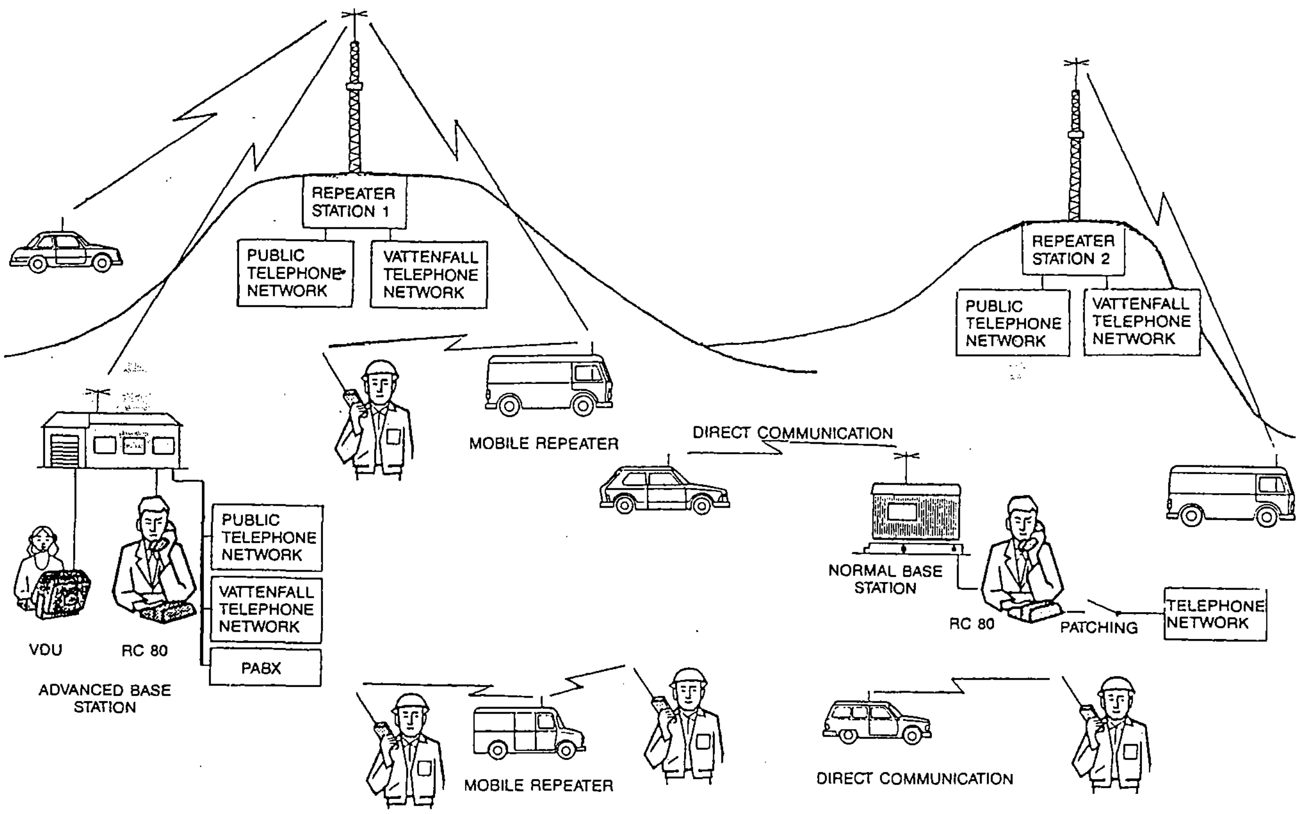


Figure C1.1 System layout with main traffic routes

C1.2.1 Units in the system

Repeater station - dynamic channel selection

Each of the repeater stations consists of a microprocessor controlled radio exchange and two duplex multichannel transmitters/receivers in order to carry out two simultaneous connections. They are equipped with all seven repeater channels. In order to make optimal use of the radio channels in disturbance situations the system is working with automatic dynamic channel selection. This means that when a base or mobile station addressed a certain repeater station on a channel which the calling station thinks is free, (first hand channel), the repeater station first monitors the surrounding areas and then answers a "yes" or "no". The channel might be busy with another repeater station. If the answer is "no" the calling unit will automatically try the next channel and this continues until a suitable channel is found.

It is possible to connect a service terminal as well as a logging terminal to the radio exchanges.

Base Station

Base stations are normally located on working sites, local offices and control centres. There are two different types of base stations, normal and advanced. The normal base station consists of a 15 channel radio unit and one or more control units which also displays queues for incoming speech requests and alarm calls including supervision of the repeater sites.

The radio unit scans all channels and the additional channels (besides Vattenfalls own) which are used for communication with units belonging to other radio systems such as other power utilities, transport organisations and fire-brigades in connection with joint operations.

The advanced base station consists of up to four of the radio units mentioned previously, connected to a radio exchange. Video display units are used as control units in concert with the control units. By the use of a radio exchange it is very easy to increase the number of despatchers and connections by simply adding additional modules.

Mobile radio station (mobile repeater)

All mobile radio units are of the mobile repeater type. This is multi-channel microprocessor controlled radio which works both in simplex and duplex mode. There is a removable code plug which also contains information about channels, scanning, identity and authority to access the public telephone network.

The mobile radio unit normally installed in vehicles may be completed by installing a charging cassette for a portable handheld station. When the portable is removed from the cassette the mobile unit automatically transfers to a mobile repeater station. This paves the way for distance calls to and from portables via the repeater station and the mobile radio station working in repeater mode but also locally extending the coverage between handportables.

The mobile unit may be installed together with batteries in a carrying case for use as a portable local repeater station since there are many sites which cannot be reached by a vehicle.

The mobile repeater (relay mobile function) is described in Section C1.2.5.

Hand station (portable)

The portable handheld station is used in two versions, one mainly in connection with the mobile as repeater and the other more advanced with the same features as a mobile except the repeater mode.

The handheld station is a multi-channel microprocessor controlled radio equipped with a display and a keyset. From the portable it is possible to release pre-programmed calls in the mobile repeater.

C1.2.2 Signalling

Signalling system

All signalling on radio channels is carried out by sequential tones according to the CCIR standard extended with a few special tones.

CCIR 5- and 7- tones signalling is used for all calls on the radio channels with the exception from the repeater stations, which are using 11-tones signalling. The exceptions to this are also printed messages which are realised by 1200 bit/s FFSK.

When signalling to and from the operational telephone network decadal dialing is used.

Either decadal dialing or key dialing (DTMF according to the Swedish Telecom standard) can be used when signalling towards the public telephone network.

From the public telephone network DTMF standard is used. Emergency call is signalled to the County Alarm Centre by using DTMF according to special specifications.

All calls in the system over radio vias are established through a handshaking procedure.

The radio stations in the system are identified by using 5-tones CCIR.

Busy marking when blocked

In all traffic cases busy marking is given when base stations, repeater stations selected channels, telephone lines are engaged. Busy marking is given visually or by tones.

Limited duration call

All established calls are monitored for maximum duration of call and for maximum absent of carrier. Those timed are eligible.

Automatic disconnection

In the case of maximum duration of call or maximum absence of carrier the calls will automatically be disconnected. When transmitting text, status or VHS (calling party) the automatic disconnection will not be done before all signalling has been carried out.

Listening and breaking into an engaged channel

When there is an on-going traffic on a selected channel, it is possible to go to a listening mode. In this mode it is possible to break in, either openly or by using tone signalling.

The break-in function is encoded in the mobile station.

C1.2.3 Channel scanning

For the mobile station and base station the following is valid:

The mobile station is scanning all channels used, looking for a group and individual call. The station can also be set to look for carrier wave on a preselected channel. If there is no carrier wave on the pre-selected channel, all the remaining channels are cyclically scanned selectively. Maximum of 12 channels can be scanned.

For the hand stations the following is valid:

The advanced hand station is scanning all channels as the mobile station. The other hand station is mainly working in combination with the mobile station looking for carrier wave on the pre-selected channel.

C1.2.4 Traffic modes

Traffic on the direct channels is carried out in the one frequency simplex mode.

The mode for repeater traffic between mobile stations or base station and mobile stations is two frequencies simplex (semi-duplex).

Full duplex mode is used for telephone traffic with base and mobile stations. Traffic in mobile repeater mode is simplex using two frequencies.

C1.2.5 Functions

Text transmission

In some areas the mobile units are supplied with a printer. It is possible for a despatcher at the advanced base station site to edit a message on his VDU and then transfer it to the mobile printer. It doesn't matter if the mobile is unmanned at that time. The digital transmission is carried out by 1200 bit/s FFSK-signalling, 1200/1800 Hz. The transmission format of the message is specially designed by the manufacturer for the frequencies and the disturbances on the radio channels in use. The text is coded in several steps and split into blocks before transmission. At the receiving end each block is decoded and error corrected.

The text will not be printed out unless the whole text has been received correctly.

Emergency alarm function

All mobiles and portables are equipped with emergency push buttons. When releasing the alarm the mobile (which may also be in the repeater mode) calls the repeater station that was used last. If all channels are busy the mobile tries to use a busy channel and make an intrusion. If the mobile is still not successful it will automatically try to establish contact with other more distant stations.

When a repeater station receives an emergency alarm it automatically calls the corresponding County Alarm Centre by using the public telephone network and a hand-shaking procedure which includes information about the mobile reporting an emergency. When the call is established, two-way voice communication between the mobile or portable and the County Alarm Centre is possible.

Telephone traffic

Both the repeater and the advanced base stations are connected to the public as well as Vattenfall's own operational telephone network. The advanced base stations are also often connected to a local PABX. This means that a mobile may automatically reach any subscriber in the different telephone networks and vice versa. However, to be able to reach a mobile from a public telephone the subscriber has to dial a DTMF access code.

Limiting of the possibility to telephone traffic is individually encoded in the mobile station.

At all base stations it is also possible for a despatcher to manually patch a mobile to the different networks.

In the repeater stations there are also up to ten of pre-programmed telephone numbers which may be accessed by any mobile.

The connection to the public telephone network is done with a two-wire subscriber's line using ring-in and loop-out.

The connection to the operational telephone network is done with loop-loop interface using separate four-wire tone frequency transmission.

Relay mobile function (mobile repeater)

The mobile stations can operate as local relay stations (relay mobile stations, mobile repeaters). The functions are as follows

Every vehicle equipped with a mobile radio station can also be equipped with a hand station placed in a charging support. The mobile station will automatically switch over to the relay mobile mode when the hand station is removed from its support or the corresponding code is keyed on the mobile station.

From the hand station it is possible to use the public telephone or the operational network or to reach base or mobile stations via the relay mobile function in the vehicle.

Furthermore, traffic between hand stations can be transmitted via the relay mobile function in the vehicle. This function is extending the range for works locally in the power systems.

Verbal calls to the relay mobile station are transmitted to the hand station. When calling on direct channels no connections can be established.

The relay mobile function is also available from mobile stations in carrier trunks or permanently mounted.

Who has called?

When a despatcher calls an unmanned mobile he may use the "who has called" function (VHS). This means he transfers his own identity to a special queue in the mobile; the queue has space for the ten most recent calls. It is also possible for mobiles/hand-stations to transfer their own identity to control units and VDUs at base stations or to other mobiles.

Status-messages

Frequently mobiles want to transmit a standard message. It is possible to transfer two-digit status messages from mobiles/hand stations to control units and VDUs at base stations.

Another form of status signalling is information about supervision alarms from repeater stations. Also these messages are in two-digit status signalling. The base station operator may call a mobile and request its current two digit status without disturbing the driver.

Communication tests

The operator in the mobile station can check if he is within the range of the pre-selected repeater station. The simple test can be carried out from the mobile without occupying channels too long. The repeater acknowledges the call at which the mobile station gives a voice frequency pulse in the loudspeaker.

The same test will be carried out automatically from the mobile station when the hand station is taken out from its cassette.

C1.3 Experiences

The field people are pleased with the system and have found that it complies with their demands according to the original specifications. Especially the functions emergency alarm with access to the County Alarm Centres and connection to the public telephone networks are popular in usergroups working alone in the power systems.

Due to the high complexity of the system there was a must to create resources for training courses in maintenance of the system. Some courses were ordered from the system supplier.

The experiences from operation have pointed out the importance of good user training.

This part of the education has been realised with teachers from Vattenfall.

C1.4 Developments

There is always an interest to improve the functions and also create new functions designed to change operational requirements. For the time being the Vattenfall technical responsible people are discussing new solutions in the emergency alarm concept using the GPS systems as a complement.

Roaming is another function of interest for some groups in the future.

There will be an increasing demand of new digital services to and from people in the field in the future.

C2 Description of the mobile radio network of Red Electrica De Espana (REE)

The mobile radio service of REE is mainly used for maintenance tasks for HV lines and substations. Co-ordination of the works is done from each area head centre.

The coverage required extends from the head centres along the HV lines, roads close to them, and to the substations of this region. The number of mobile radios is relatively small, as compared to the number of repeaters needed, and traffic in the network is relatively small in normal operational conditions.

Based on these requirements, a mobile radio system was specified and developed in 1988. This system is based on a radial structure, the branches of which come out of the head centre. Each branch includes several repeaters, low-frequency inter-linked by standard analogue channels (300-3,400Hz).

Among the facilities offered to the user are the following:

- Selective call with identification codes through CCIR tones
- Capability to cancel a selective call by means of an external control (non privacy)
- Audible confirmation of called set answer (if it is within coverage area)
- Transmission inhibition on channel busy
- Emergency call (intrusion in network with channel busy)
- Time-delay closing of the network after finishing conversation
- Scanner
- Display of calling number

In an initial stage, the mobile radio network includes 83 repeaters and 9 head centres.

Construction was started in 1989, and the first stage is to finish in 1992. The installation rate was about 20 repeaters per year.

A second stage will be started in 1993, main objectives of which are:

- Extension of coverage, through increase in number of repeaters
- Connection of the mobile radio network to the operational telephone network

Figure C.2.1 shows a sketch of the repeaters in the mobile radio system that will be working by the end of 1992.

Figure C.2.2 shows the typical network structure of an area centre.

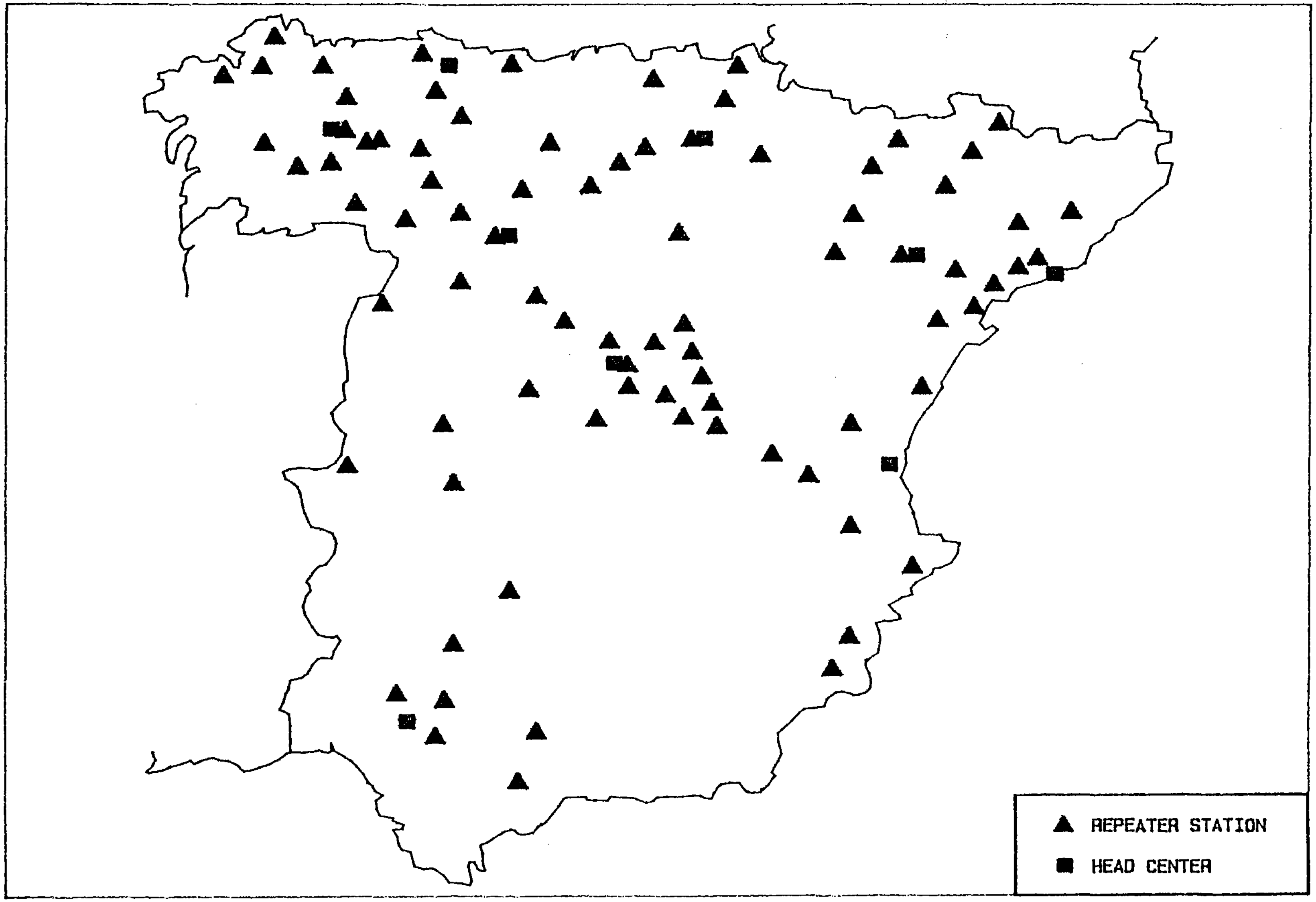


Figure C2.1 - REE Mobile Radio System. Situation of Repeaters and Head Centers.

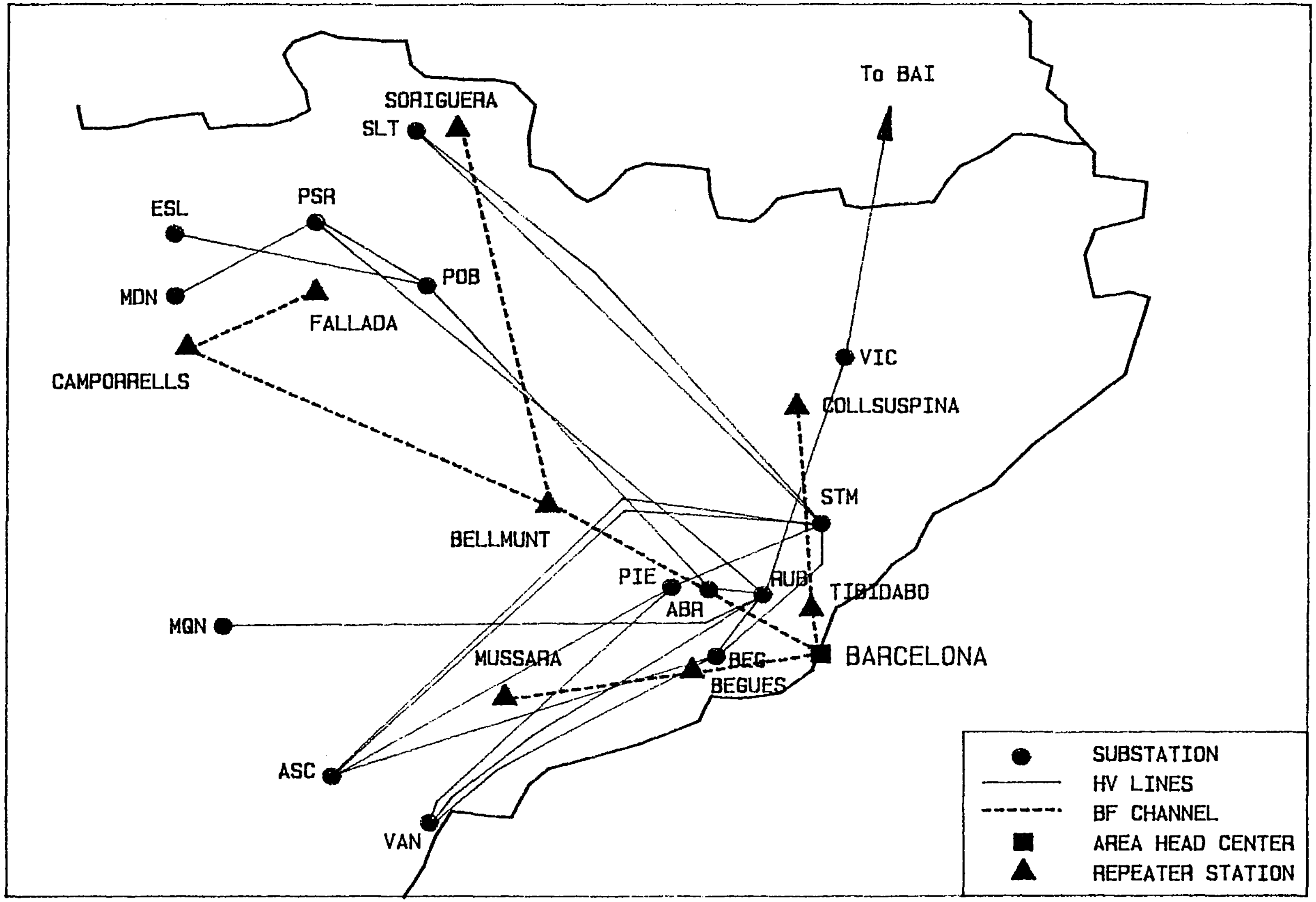


Figure C2.2 - REE Mobile Radio System. Network Structure of an Area.

C3 Electricity supply industry (England and Wales) trunked private mobile radio system as used by East Midlands Electricity plc

C3.1 Introduction

In April of 1987 it was decided to take a corporate approach to procure a replacement mobile radio system. By October 1988 a firm decision had been made to go for a Trunked Private Mobile Radio system. A contract was finally awarded for the MRS in December 1989. With the majority of the UK power utilities procuring the same system, this allows the National Grid Company (NGC) to use their mobile radios over the whole of the UK and therefore provide interworking between NGC and the Regional Operating Companies in England and Wales.

The system used MPT 1327 and modified MPT 1343 trunking protocols. The system was based on a 9 cell repeat pattern, each cell having 4 primary radio channels (1 control and 3 traffic). There can be up to 6 base stations within a cell all using the same "polled" control channel, whilst the traffic channels are assigned, on call set up, to a particular base station for the duration of the call. All base station radio equipment is frequency dynamic to provide the frequency assignment flexibility required.

This meets the general traffic requirements, however in large urban areas where the traffic density is higher these primary channels can be supplemented by the use of low power "inset" channels which can be re-used from nearby cells. The normal re-use distance, for primary channels, is 80km between cell boundaries and for inset channels is 40km. The radio planning calls for a system that will provide good frequency re-use and, at the same time, provide acceptable performance characteristics against co-channel interference.

C3.2 East Midlands Electricity System

East Midlands Electricity operations area is shown in figure C.3.1 with the cell structure overlaid; cell bending techniques have been used to cater for geographic and traffic requirements. The system will support a total of 51 simultaneous mobile radio calls, this will be required to serve a total fleet of some 1500 - 1800 mobiles with 60 wired despatchers.

There are 13 cells in the area, serving a total of 46, 4 channel base stations. These are broken down into 4 areas, each area being served by a Local System Controller (LSC); a LSC serves approximately 3 cells with 12 base stations. The LSC provides the following access features.

Wired dispatchers
PABX access
PSTN access
System interconnect access

The whole system is centrally managed from ports off the Regional System Controller (RSC) which also holds the system data base, this data base includes mobile location (last base station and hence LSC that was in contact with a mobile). Also available from the RSC is real time system re-configuration, equipment and circuit monitoring and testing, plus full statistical usage reports. The RSC also utilises an X25 switch which provides data access to the LSCs and will be used for data traffic access after further developments. Figure C.3.2 shows the system architecture as described above.

C3.3 Implementation

The system is to be introduced in 3 phases, commencing September 1992. The whole East Midlands Electricity system will be operational by January 1994. As this is a significant change from the existing open channel radio system a great deal of training will be required to ensure a successful changeover.

Initially the system will be voice only however it is anticipated that extensive use of data will be required in the near future. In the two transmission line control and out of hours communication centres additional integrated radio and voice system switches are being procured to allow engineers to make, receive and interconnect calls from telephony and radio systems via a touch screen.

EAST MIDLANDS ELECTRICITY DISTORTED CELL STRUCTURE

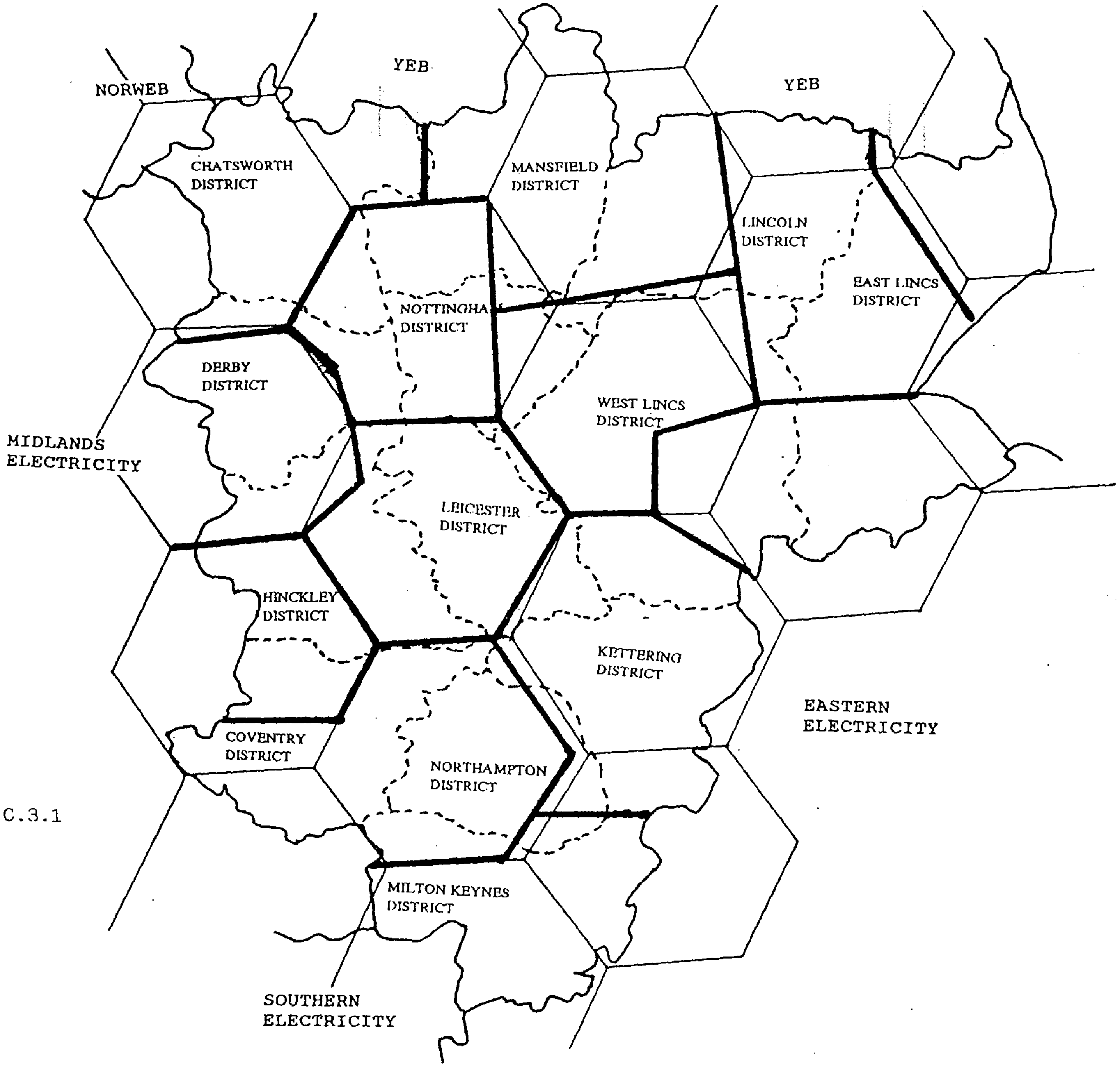


FIGURE C.3.1

SCHEMATIC OVERVIEW EAST MIDLANDS TRUNKED PMR SYSTEM

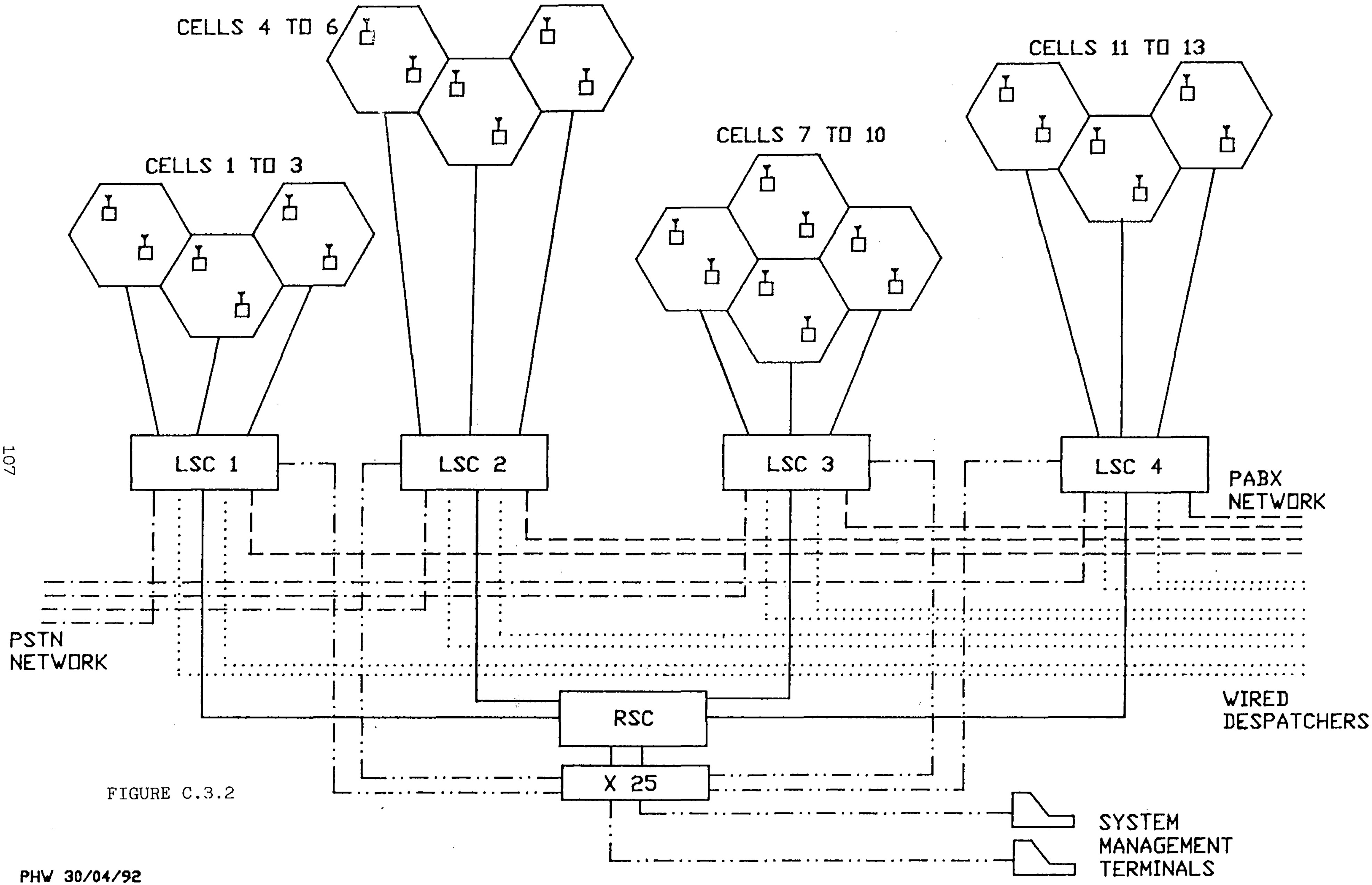


FIGURE C.3.2

PHW 30/04/92

C4 Countrywide trunked mobile radio system of Finnish Power Utilities

C4.1 Introduction

The Finnish state-owned power companies, viz. Imatran Voima Oy (IVO), Oulujoki Oy and Kemijoki Oy, put the new mobile radio system into operation in December 1987. The system, called VY 85, is designed especially for power utilities and distributors of electric energy.

Why own system

The main reasons for designing and constructing a special system are:

* power utilities and distributors of electric energy needing different functions and facilities than public mobile networks can support.

* total cost of a trunked system was less than the cost of using public systems.

* easy to ensure the radio communication in abnormal circumstances, so high availability of the own system.

* Finnish power utilities own a very wide and modern telecommunication transmission system as well as numerous radio masts.

* Finnish power utilities have special staff and equipment to design, install, commission and maintain modern radio systems

* possibility to communicate directly between radios of power utilities and radios of distributors although companies have different systems (co-operational channel of electricity distributors in Finland)

The system design and construction

The system design was started by finding out the functional demands of different user groups and the desired combinations of telecommunication connections between mobile radios and subscribers of fixed telephone networks (operational telephone network (DIXI), PABX, public network.

After that the structure of the system and the connections to other systems was specified.

Information was put in the form of a system specification which was found to be a very useful document when arranging the permission from the telecommunication authorities and calling for tenders.

The next step was to locate base station sites and to make the final frequency plan of the network. Two main principles were used in locating the base stations. First, the system must serve areas where the major user groups are operating, and second, IVO tried to use its own masts in as many cases as possible. For coverage reasons, almost the whole country had to be covered. For base station sites and service areas of base stations, see Figure C.4.1.

Because the design of the system was totally new, numerous tests had to be done. In factory tests, it has been checked that the basic principle of the system was working. Also, signalling on the radio path as well as between mobile exchanges and fixed telephone exchanges was tested.

The supplier and the power utilities installed the mobile exchanges (8 pcs) in co-operation. The base stations (130 pcs. in the first phase) were installed and the system commissioning was done mainly by the staff of power utilities.

The owners and the users of the system

The system is used by the state-owned power companies and by five local distributors of electrical energy. The user organisations can be characterised by the following functions:

* producing electric energy and district heat
* delivering electric energy and district heat
* maintenance of power plants
* construction and maintenance of power lines
* transportation

The system is also used for special purposes, such as sending control data to electrical substations and disconnectors along lines.

The system is owned as follows:

* roaming information handler and mobile exchanges are owned by IVO
* base stations are owned by the state power utilities
* mobile phones are owned by each company

C4.2 The Structure of the System

Elements of the system

The number of system elements is (6/1992):

* 1 roaming information handler (RIH) database
* 8 mobile exchanges (MX), one in each operational area
* 162 base station channels (BS) in ca. 135 base station sites (BSS)
* 710 mobile stations (MS)
* 300 handportable stations (PS)
* 140 call receivers (PR)
* about 400 single frequency simplex mobiles and portables; these are devices from the old system
* 120 telecontrolled disconnector stations
* 4 control points (CP)

Connections of the system elements

Each BS is connected to one MX via a 4-wire connection. These connections are mainly made by using ordinary radio link channels. In special cases, BS can operate without any connection to MX: this is called fault repeater function.

Up to 10 telephone exchanges (PABX) can be connected to one MX. In this case, either a 2-wire or a 4-wire connection is used, depending on whether the MX and the PABXs are at the same physical place or not. Each gateway between MX and PABX can use several parallel lines so that several calls can be transmitted at the same time.

In addition, each MX is connected to IVO's private operational telephone network (DIXI). The operational telephone network is based on 15 digital exchanges and has all function and facilities which are available in advanced PABX-networks.

Control points (CP) can be connected to MX. By using CPs it is possible to get special dispatcher services.

For the principal structure of the VY 85 network, see Figure C.4.2.

Area structures of VY 85 system

There are several different area structures in the VY 85 systems. Some of them are physical structures and some are based on system software:

- the system service area: total coverage of base stations
- operational area: IVO has 8 operational districts, each district has an MX
- calling areas which are used to set up different types of calls to mobile phones
- system calling area: whole country (individual call)
- MX-calling area: one operational district (individual call, group call, general call)
- sub-calling area: one or several base station sites (individual call and directed general call)
- radio area: service area of one base station (in the VY 85 network typically a circle with a diameter of about 60km)

Frequency band and channels of the system

The system operates mainly in 80 MHz band, where the system has 12 semi-duplex channels (system channels) and 6 simplex channels. In addition, there are channels for sub-systems in power plants using 450 MHz band. In this case, the number of semi-duplex channels is 4 and that of simplex channels is 5.

C4.3 The Main System Functions and Facilities

Basic features

The VY 85 system is designed especially for power utility applications. The system has a cellular configuration and many progressive functions. The VY 85 is a trunked radio system - it can be shared by several user groups or companies.

Functions and facilities

- the system is fully automatic, including call set-up as well as channel selection and roaming facilities
- basic functions are easy to use
- micro-computer-controlled devices (RIH, MX, BS, MS and PS)
- traffic can be divided into two parts:
  - traffic via MX, which is called system traffic
  - direct traffic between two or more mobile phones (MS or PS)
- system traffic is totally closed
- direct traffic is totally open
- connections to PABXs makes it possible to set up a call:
  - directly to a subscriber of PABX
  - to the operator of PABX or to the PSTN
- connections to the DIXI-network makes it possible to set up a call:
  - from a mobile phone to DIXI-subscribers
  - between mobile phones which are located in different operational areas (automatic routing using roaming)
- selective mobile calls makes it possible to set up an:
  - individual call
  - a group call
  - a general call
  - a directed general call
- in the previous alternatives, a subscriber of the fixed telephone network can be as an A-subscriber, in an individual call as a B-subscriber as well
- an emergency call to the public emergency centre
- a general call and an emergency call have an intrusion right so that these calls can be activated on an occupied channel
- request to call, call requests can be sent to mobile phones from other mobiles, from DIXI-network, from PABXs and from the PSTN
- MX has different calling methods to build up different types of mobile calls, the co-operational channel of the Finnish electricity distributors makes it possible to build up a connection between mobiles, which operate in different systems
- the system has a roaming function which operates over whole country
- mobile phones are equipped with field strength measuring circuits and can select the best available free channel
- the MX has a special gateway to telecontrol systems to send messages to substations or disconnectors along lines

- base station lines are supervised: if BS detects a fault on its BS-line, BS goes into fault repeat mode and BS can repeat mobile calls within its service area
- the system uses extended CCIR-signalling on the radio path
- every BS-channel can be used for speech transmission or signalling
- statistical information of the traffic:
- MX outputs call information via special serial data interface after the call has been disconnected
- by collecting and analysing the information with a PC, one can get 15 different types of statistics, e.g. how the system is used, etc.
- tape recorder connection: messages can either be sent to mobile phones via a certain BS or the traffic can be recorded
- O & M computers and software in MXs make it easy to find faults and to maintain the system
- some examples of the system parameters which the maintenance staff can easily change:
  - category groups
  - maximum call durations
- all MX O&M computers are connected to IVO's telecommunication maintenance system (TIEVA); using TIEVA it is possible to collect and analyse fault information from the system and set MX parameters etc., see Figure C.4.3.
- the control of all main system elements is based on microcomputers; therefore, it is easy to change and add functions

Special functions of mobile phones

- user programmable abbreviated dialling numbers using 51 memory locations
- some of these also have special functions:

0:	the last-dialled number
40-46:	call requests
47:	an automatic alarm call
48:	a programmable group call number
49:	a programmable call receiver number
50:	a programmable MX-area lock number

- mobile phone can be locked on a specified system channel
- mobile phone can stand in a queue and wait until one of the occupied channels is released
- mobile phone can retransmit an individual call to a call receiver
- mobile phone has available connections for an extra loudpeaker, hands-free equipment, an extra control unit, etc.
- some users can have special priority over the others and they have an intrusion right
- mobile phones can receive and send a call on system channels although direct channel is selected by the user (channel scanning)

- maintenance staff can easily change numerous programmable mobile parameters:
- the MS is light enough to be used as a transportable station
- the MS transmitter output RF power can be selected when it is used as a transportable station: normal power 2.5W and high power 25W.

C4.4 Operating Experiences of the System

Generally, the users have been very satisfied with the system. The users have been satisfied especially with the connections, which have been greatly improved. Also, the coverage of the system is very good when compared with the old system which had only 32 one frequency simplex base stations.

According to the system manager, the programmable devices seem to be excellent. Further development of the system is easy if the needs of the users or the technology related to the MX changes.

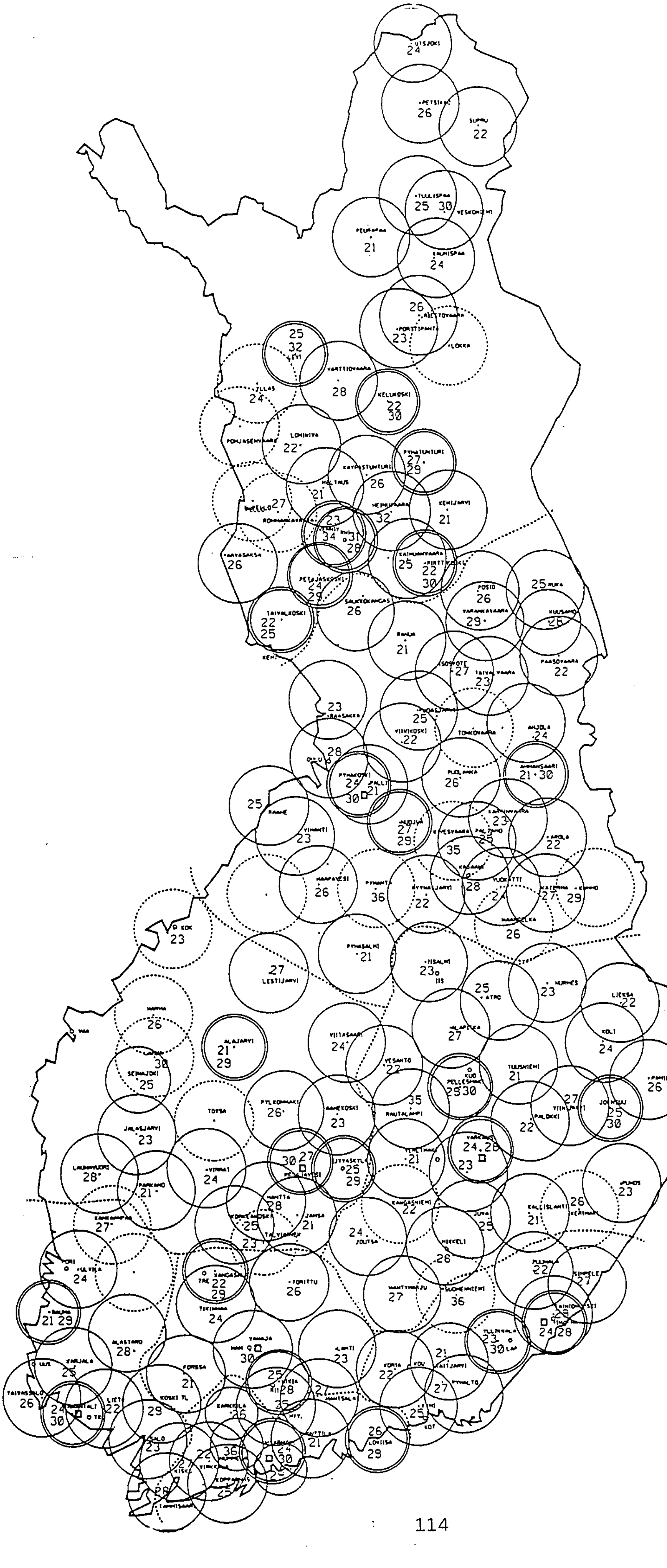
Also the maintenance of the system has been very easy due to the fact the reliability of the MX and the BS have been extremely high.

C4.5 Further System Development

Some new private power utilities will become network users.

The amount of base stations will be increased.

FIGURE C.4.1
BASE STATION
SITES 1992



◻ : OHJAUSKESKUS = MX
⊙ : TUKIASEMA = BS
⁘ : TUKIASEMA OPTIO

Figure C.4.2

MOBILE RADIO SYSTEM VY-85
PRINCIPAL STRUCTURE

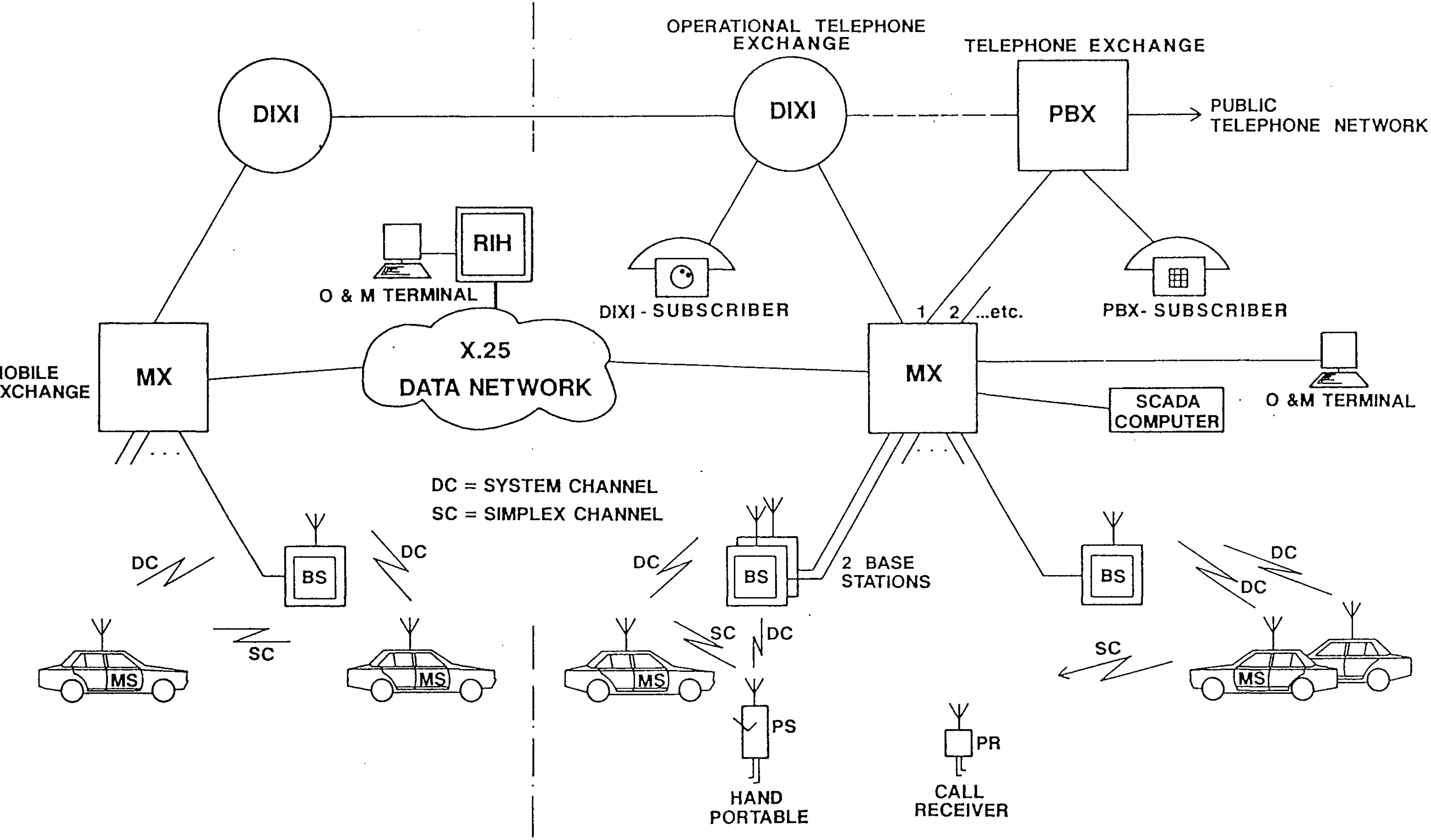
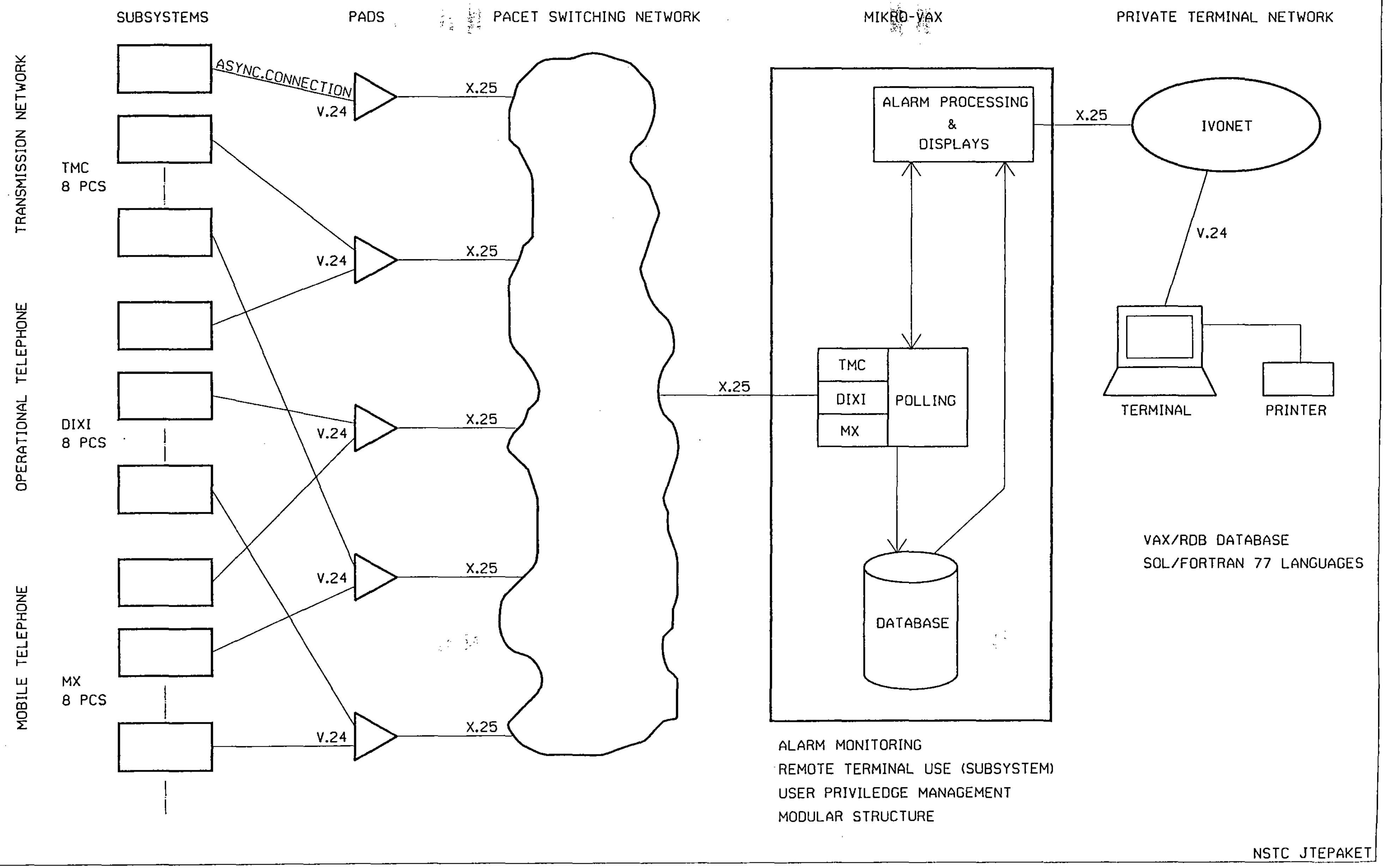


Figure C.4.3.

TELECOMMUNICATIONS NETWORK MANAGEMENT SYSTEM



C5 A typical private mobile system used by NV Energie Bedrijf Ijsselmij in the Netherlands

C5.1 History

The history of mobiles used by power utilities in the Netherlands dates from about 1950 with systems working in the 35- 40MHz band.

In the first generation the mobiles were equipped with radio tubes. The second generation was produced on special specifications written for power utilities (1966). The Dutch power utilities bought the same system. The system could be used as an open system, but in normal service individual call was used (ZVEI 5-tone). The mobiles were protected against disturbances from other mobiles by a tone slot.

The development of the system was co-ordinated by a joint working group "Mobile Systems", formed by members of the utilities and KEMA. The working group also negotiated with the PTT about frequencies and licences and played an important role when changing to the 158 - 162 MHz band. In 1978 the working group formulated new specifications and started the negotiations about frequencies. The power utilities were allocated 14 exclusive channels and a simplex frequency. The working group is due to advise about the employment of the frequencies. The working group is still in service to investigate new technical developments.

C5.2 Technical Description

Some details are given of mobile systems installation used by the three power utilities in the north eastern part of the Netherlands. These utilities did the investigations, negotiations with the manufacturer, buying and installing together to save time and money. IJsselmij was one of them.

The system is in use since 1981; it is a full automatic computer-based scanning system with semi-duplex traffic, see figure C.5.1.

The installation consists of:

base station:	9
mobiles:	223 (375 in future)
pagers:	223

Seven frequencies are available and the simplex frequency.

The simplex frequency can be used by direct mobile-mobile traffic, even between two cars of different energy boards. So good communication is possible at the borders of the energy companies. Maximum distance between the mobiles is about 8km. The simplex frequency is also used for data transmission for measurements at protection relays in adjacent substations of the high voltage networks.

C5.3 Roaming Function

Every 2.5 seconds a base station sends a free tone of 2980 Hz superimposed on the base frequency.

All the mobiles measure the incoming signal strengths and lock to the best received base station. When a base station is occupied, the next best station is chosen.

To call a mobile, the free base stations send a code of the EEA 9 tone system. The other mobiles are not disturbed. In this system 85% of the calls are successful, including the influence of holidays, illness etc. when the mobile is not in service at all.

The systems facilities are:

- direct traffic between mobiles (simplex frequency) is open;

- system traffic is closed, even between mobiles;

- a subscriber of the public telephone network can be connected to a mobile by the operator;

- direct calling is possible in the cases:

  subscriber PABX to mobile
  mobile to public network
  mobile to subscriber PABX
  mobile to mobile

The facilities of the mobiles are

- recall last chosen number
- paging
- abbreviated dialling
- automatic recall (within 15 min.); when a mobile doesn't answer, a caller can program his number in the mobile's memory; the mobile-operator can call back by pushing a special button
- handsfree operation
- system display

System facilities are:

- call all mobiles
- group calling
- conference conversation of a PABX-subscriber to a maximum of four mobiles
- back-up system to hand operation is installed
- management system is in service
- data transmission
- transmission of facsimile messages

C5.4 Experience

Some years ago the power utilities were transferred to energy distribution companies of gas, electricity, water, heat and cable television. So the need of mobile communication is increasing. The system is now daily occupied by 300 to 400 calls. To avoid congestion when traffic is high, the length of the speechtime had to be limited to 3 minutes.

Because of the layout and the many possibilities a lot of the complaints about the systems are caused by bad handling of mobiles. So good manuals and education of the users are a necessity. For information a video-clip is made.

To analyse the performance a management-system is of course indispensable. By the TMS all significant data are registered: time of a call, numbers of mobiles or PABX-subscribers, speech time, user features and so on.

C5.5 Future Use

Facsimile apparatus will be installed in cars.
Investigations have started on the subjects:

- dynamic limiting of speechtime (high traffic short, low traffic speechtime longer)

- use of a trunking system

A power utility can use public communication systems in normal conditions, but in emergency situations there could be congestions in the networks. So it will remain very important to have a private mobile system.

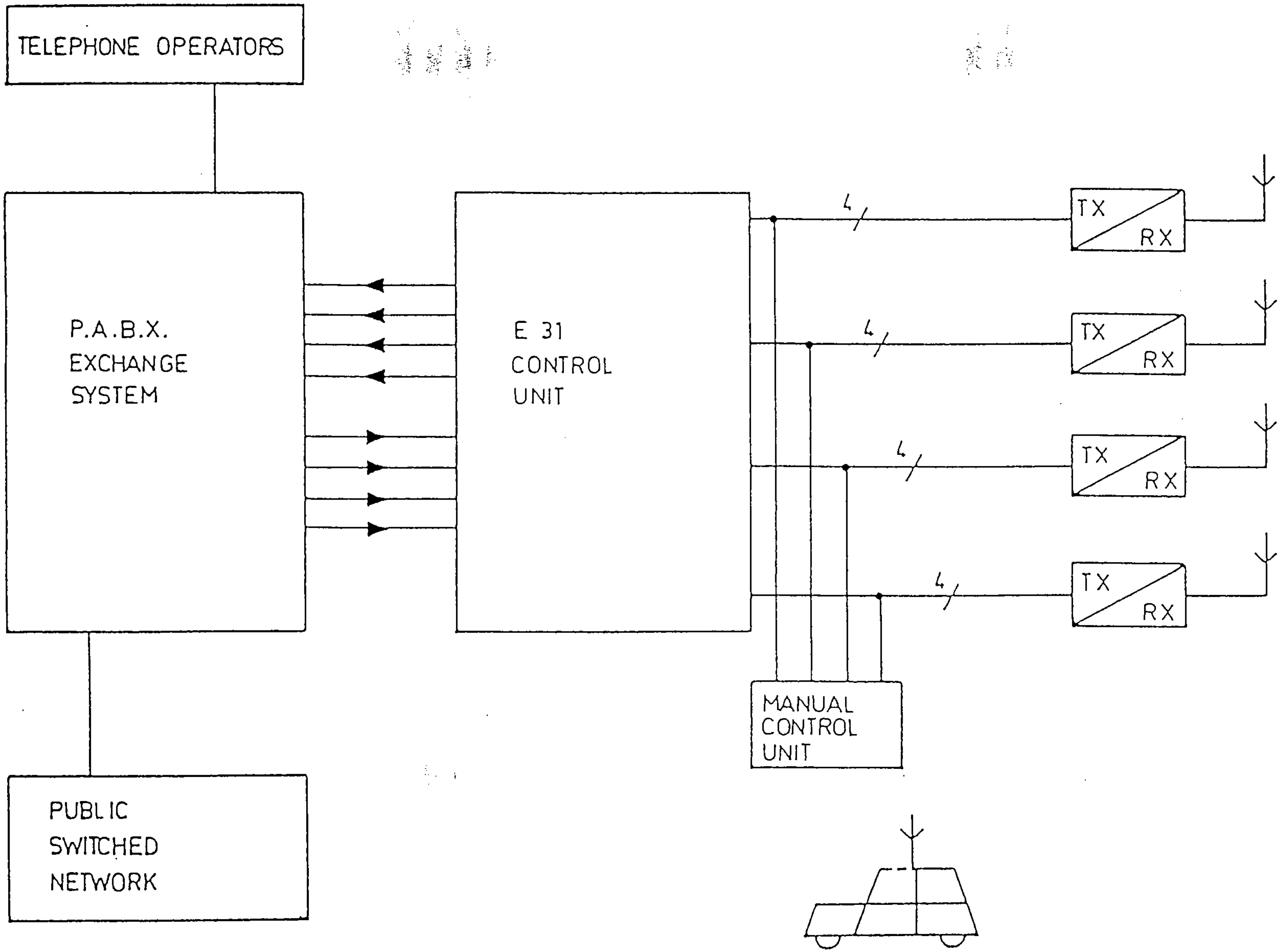

TELEPHONE OPERATORS
P.A.B.X.
EXCHANGE
SYSTEM
E 31
CONTROL
UNIT
4
TX
RX
MANUAL
CONTROL
UNIT
PUBLIC
SWITCHED
NETWORK

FIGURE C.5.1

APPENDIX D

TYPICAL EXISTING STANDARDS

D1 Standard for trunking system MPT 1327

Taken from document of the Department of Trade and Industry Radiocommunication Division, United Kingdom and from document of User Access Definition Group (D1.8)

Protocall 1327 is a family of standards which defines a trunking system for Private Mobile Radio.

These standards were first adopted in the UK in 1987. Since then, they have been in successful operation in public and private trunking systems in an increasing number of countries worldwide.

A conventional PMR service offers the user a single channel. When the user wishes to make a call, this channel may well be occupied by another user. The prospective user must wait until the end of the conversation and then compete with others to obtain the vacant channel.

In a trunking system, a set of channels shares the communication demands of the users. If no channel is free at the time a user makes a call, the call will be placed on hold for a few seconds until any channel becomes available. As a result, the user has less time to wait and enjoys a better quality of service.

D1.1 Why was it developed

Trunking was developed because radio spectrum throughout the World is becoming congested. Dynamic growth in mobile communications has made channel availability very difficult and the increasing consumer demand for the benefits of mobile communications means that more and more users need to be given access to the same number of channels, without any loss of quality of service.

At the same time, users are demanding a wider geographical area of use than is economically viable with most conventional private radio systems.

Advances in technology have allowed trunking techniques, previously only associated with hard wire communications, to be applied to radio networks. These allow more efficient use of spectrum.

D1.2 How does it work

Each radio station transmits a control signal on a radio channel. It also has a number of 'traffic' channels at its disposal on which user of radio units communicate. When not in use, the radio unit is automatically tuned to the control signal and the unit's microprocessor can communicate with the system computer on this channel at any time.

When the user wishes to make a call, the unit transmits the request in the form of a data signal to the system computer. The computer finds the caller's desired correspondent and, by means of the control channel, checks for willingness to receive a call. When both called and calling parties are ready to communicate, the computer allocates the first available 'traffic' channel.

When the call is terminated by either party, the radio unit sends a data signal releasing the channel. Radio stations may be interconnected to increase the service area to provide any size of network, up to a national or international level.

Calls may also be made into other fixed line networks such as telephone systems.

D1.3 Worldwide Application

- Protocall 1327 is proven technology. The UK experience is evidence of the success of these standards.

- Their widespread adoption will provide great opportunities for manufacturers by establishing a worldwide market for their products.

- Systems can be set up quickly since network and user systems already exist. There need be no troublesome delays while standards are devised and equipment is designed and produced.

- Because the Protocall 1327 standards are flexible, they can be easily implemented to suit specific requirements.

- When universally adopted, the transfer of radio units conforming to similar frequencies between networks and countries will no longer be a problem.

- Of course, users will benefit too. The larger the market and economies of scale, the less expensive the subscriber equipment.

D1.4 User Features

- Two-way conversation with a variety of types of call.

- Data transmission of:

- status message instruction
- short text messages
- bulk data print-out

- Conference calls

- Call transfer

- Automatic call holding until a channel becomes available

- Priority and urgent calls

- Ability to call:

  - individual radio units
  - a group of units
  - all the units on the systems

  - User can call PABX or PSTN numbers

  - 'Call me back' facility when unit is unattended

  - Allows the user to roam across boundaries

D1.5 System Features

- Protocall capacity:
  - one million addresses per system code

- 3 channel types:
  - dedicated control channel
  - floating control channel
  - traffic channel

- Traffic jam prevention controls

- Interference prevention

- Automatic user location and registration

- Automatic release of traffic channels at call termination

- Periodic checking of serial numbers for subscriber security

- Standards designed to support any size of system, from local to international networks.

D1.6 Facilities

Registration:

- to identify and locate the unit in the network. Enables multi-site working with full or restricted roaming.

Speech call request:

- individual calls to other radio units, line connected users (e.g. despatchers), telephone networks, etc.

- full off air call set-up.

- group calls, announcement or conference facility.

- include calls to allow further parties into a conversation.

Priority call facility:

- priority over other mobiles queuing for channels.

Urgent call requests:

- to any defined destination or to a pre-defined destination with a special status message.

Status call requests:

- simple (maximum 32 states) data messages for signalling a radio user's operational status. Sent on the control channel.

Short data messages:

- short text and numeric messages sent on the control channel - 184 bit.

Data call transmission:

- on traffic channels using data signalling. Presently non-prescribed data may be sent. Used for sending text messages between mobile terminals and despatch base.

Comprehensive numbering scheme
Serial number security facility

D1.7 Outline Technical Specifications

Codewords:
64 bit word containing 48 data bits, 15 CRC bits and 1 bit parity.

Signalling rate:
1200 bit/s FFSK

Dynamic Slotted Aloha:
- 2 codewords per slot
- up to 32 slots per frame

Radio unit signalling:
- synchronisation sequence plus one codeword sent in one slot.
- one random attempt per frame.

Addressing:
- up to 32,000 system codes
- one million addresses per system code

D1.8 Mobile Terminal Data Interface Protocol MAP27[15]

The MAP 27 standard has been prepared and published by the User Access Definition Group which includes radio equipment manufacturers, network operators, terminal manufacturers and application designers. The MAP 27 is intended to be an open standard in addition to the MPT 1327.

The MAP 27 (Mobile Access Protocol for MPT 1327 standard) protocol specifies an interface between a mobile radio and a data terminal equipment using an RS-232 connection (CCITT V.24/V.28). This interface gives access to and defines network layer procedures for call set-up and data transfer as specified in MPT 1327 and MPT 1343 or derivations thereof. The MPT 1327 and MPT 1343 standards define rules for communication between radio units and trunking system controllers operating in land mobile radio systems.

The new MAP 27 standard supports the following call functions:

- status messages
- short and extended data messages
- modem data connections
- voice connections
- call diversion control

The supported call functions are sufficient to satisfy the growing user need for data communications such as:

- acknowledged messaging
- mailbox
- file transfer
- interactive terminal sessions
- modem calls
- automated speech call control

D2 North American Specifications of Mobile Radio Function Requirements (APCO)

APCO stands for Associated Public-Safety Communications Officers and is an organisation within the public-safety segment in North America but there are also members outside this region. Regarding the radio communication field APCO became more well known outside the USA through its study Project 16. This project started in 1979 and had in view to define minimum functional requirements for public-safety trunked systems in the 800 MHz band. It was based on a combination of both operational capabilities and technical possibilities at that time. It took advantage of the opportunities inherent in the digital signalling (addressing, data etc.) but still used analogue voice. Group communication was of great importance as well as call set-up time, emergency and status transmissions, priority levels, privacy, reliability, flexible command and control and such like.

The APCO 16 defined mandatory minimum system performance requirements but it should be noted that the digital signalling concept used was at the discretion of the system designer. During the 1980's systems based on APCO 16 were launched.

APPENDIX E

AMPLIFIER LINEARISATION

The present generation of RF amplifiers in general operate in the Class C mode to provide maximum transfer efficiency and minimum power consumption requirements. As this amplifier is non linear high levels of intermodulation products are produced if the amplifier module is subject to an amplitude modulated input. The unwanted products cause serious interference with adjacent channels in mobile radio systems. Additionally at the base station the method of combining a number of high power r.f. channels together through high loss combining units is costly and inefficient and also provides a further source for creating intermodulation distortion.

At the University of Bristol (UK), Centre for Communication Research has been investigating the feasibility of producing a broadband linearised power amplifier based on feed forward techniques operating over 30MHz at UHF with extremely low levels of intermodulation products [10].

The use of wideband linear RF amplifiers could have a significant impact in the design of new radio systems since the combining of systems can be applied at low level overcoming the complex problems when combining high level signals. This also offers significant flexibility to the system operator for the introduction of new modulation techniques whilst allowing a smooth transition from existing to new modulation systems.

The basic performance of a prototype feedforward amplifier is shown in Figs. E1 and E2 where a class AB (60W) commercially available power amplifier is fed with three tones, 1MHz frequency separation between each tone. Fig. E1 depicts the performance of the main amplifier over a 30MHz bandwidth at high band UHF without feedforward correction, whereas Fig. E2 shows the performance of a feedforward amplifer over the same MHz bandwidth incorporating the correction circuitry and the same three-tone input. Whilst it is relatively easy to construct a feedforward amplifier, it is extremely difficult to build such an amplifier which will operate within specification with the accepted changes that occur in temperature and component tolerances, etc.

The deficiencies of the Class C amplifier for mobile radio operation have now been overcome by the development of a **linearised** Class C amplifier (with a 100KHz bandwidth) using Cartesian and digital control loop techniques, offering very low levels of intermodulation distortion, yet retaining the efficiency of the Class C device as shown in Fig. E3.

Digital signal processing (DSP) is a further development which is revolutionising both the public and private mobile radio networks. The DSP being a software organised device, offers many new opportunities and facilities for the system designer since the system can now be configured to provide any modulation type available at present such as continuous envelope (FM PM), Digital, Quadrature Amplitude Modulation, narrow band channel and also cater for future modulation types provided from a single radio equipment by means of a software change.

The narrow band system operating within 5kHz channel spacing offers a very high degree of spectrum efficiency. The system operating with Transparent Tone-in-Band along with Feed Forward Signal Regeneration provides not only a high quality voice channel but also a data channel capable of transmitting a true 9,600 bit/s information in the Rayleigh fading environment [10]. Many organisations have shown this type of linear modulation to be highly spectrum efficient i.e. the USA 220MHz band. A UK specification for narrow band 5kHz channelling (MPT 1376) is in the final stages of preparation.

Another need for linear amplification is in new digital mobile radio systems where complex modulation methods will be used in order to achieve good spectrum efficiency. An example is TETRA which has $\pi/4$ - DQPSK modulation method.

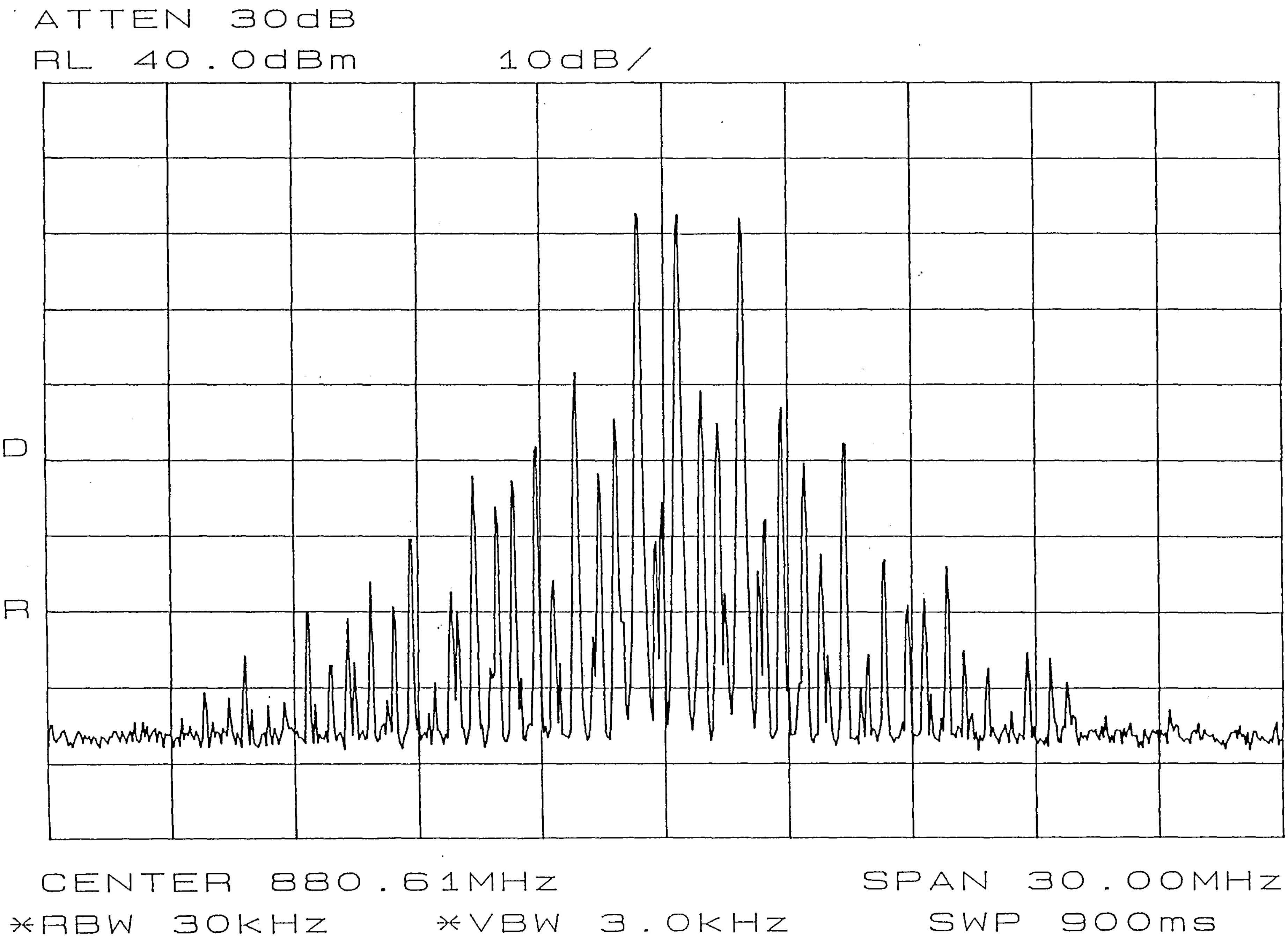

ATTEN 30dB
RL 40.0dBm
10dB/
D
R
CENTER 880.61MHz
SPAN 30.00MHz
*RBW 30kHz
*VBW 3.0kHz
SWP 900ms

Figure E1

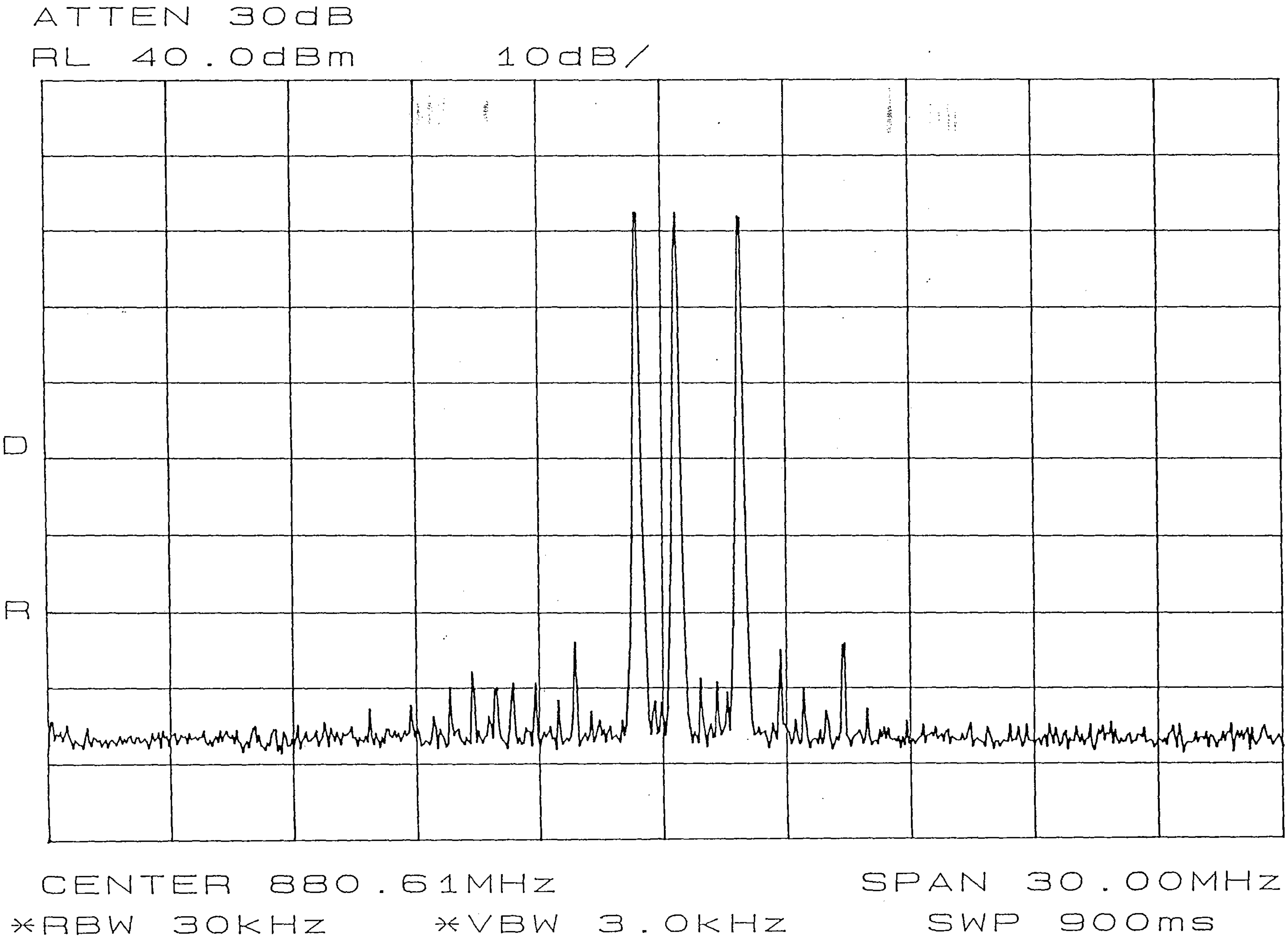

ATTEN 30dB
RL 40.0dBm 10dB/
D
R
CENTER 880.61MHz
SPAN 30.00MHz
*RBW 30kHz
*VBW 3.0kHz
SWP 900ms

Figure E2

Cartesian Feedback Loop

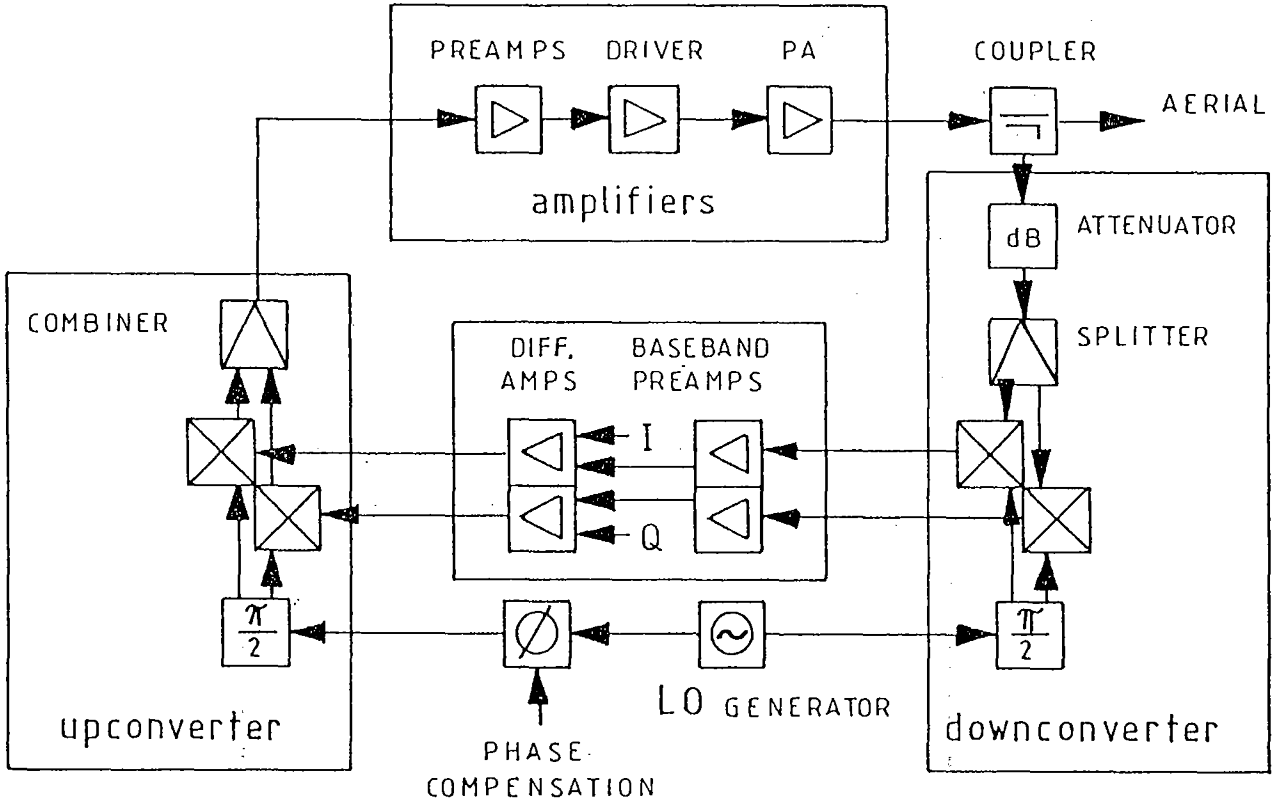


Figure E3

APPENDIX F

NETWORK DESIGN

In conventional planning of mobile radio networks the coverage area of a base station is maximised in order to spare the amount of sites. The systems are noise limited. However, growing traffic and effective use of spectrum with re-use are leading to network planning where the coverage area of base stations are smaller and the systems will be interference limited.

Because of interference and disturbances the amount of useful channels can diminish. New co-ordinated plans for spectrum use are often resulting to changes in operating frequency bands. At the same time the number of allocated channels might be smaller than original due to growing number of users. The effective use of spectrum requires co-ordinated planning of different power utility mobile networks.

F.1 JRC Frequency Plan

As an example of modern system planning the JRC frequency plan in UK will be described.

Increasing frequency congestion coupled with an explosion in entertainment broadcasting and private radio communication brought about a comprehensive reassignment of the radio frequency spectrum at the 1979 World Radio Conference. The result was to shift away by 1995 from the existing bands in use (105-108 MHz and 139-141 MHz) to a much narrower band range assigned for the exclusive use of the gas, electricity and coal industries (139.5-140.5MHz and 148-149 MHz). Consequently, fewer channels became available, thus requiring a system that maximised their efficient use.

To deal with these new operational constraints, the regulatory board responsible for the interests of the electricity, gas and coal industries in the field of radio communications, the Joint Radio Committee (JRC) of the Fuel and Power Industries, opted for a cellular network employing a nine-cell repeating cluster pattern throughout the U.K. Each cell was assigned a maximum of eight operating channels divided up into four for the power utilities and four for gas producers. Of the four assigned channels, one has been assigned for control purposes and three for general traffic.

The following more detailed description of the JRC plan is based on direct extractions from JRC documents [12] [13].

The JRC band consists of 76 channels. Due to growing traffic these must be shared between 565 services estimated. This leads to a channel re-use factor of 7,4.

F.1.1 Co-channel Interference

It is the interference from co-channel systems which limits the degree to which re-use distances can be reduced. In reality the signal level received can fluctuate over a range about the mean value. There are two factors which cause this variation:-

- Multi-path reflections which cause the rapid variation of field strength-often known as Rayleigh fading.

- A slow variation known as shadowing.

Before the C/I values can be established, it is first necessary to determine the minimum usable signal level. Traditionally there has been a tendency to use service areas where signal levels have dropped to a point where the receiver performance has been the limiting factor. Whilst this approach is initially attractive, given the economic of having base stations widely separated, such systems are very susceptible to interference. The interference might arise from a co-channel system or from noise sources such as industrial processes or other vehicles, and have been known to have a very harmful effect.

The CCIR has studied this problem and produced recommendation [5] of minimum usable signal levels taking account of the ambient noise, multipath propagation and man-made noise. Its recommendation for a high quality signal (grade 4) for frequencies in the vicinity of 140-150 MHz suggests a medium field strength of 20 dB (uV/m), which produces a level of approximately 3 uV (pd) at a receiver terminal.

Since the UK radio regulatory authority use this data when co-ordinating the use of frequencies on an international basis, the radio networks in the JRC band will be designed to meet this requirement.

It is important to note that the CCIR criteria for good quality MRS operation is that service is provided at 50% locations for 90% of the time - that is, interference should not occur for more than 10% of the time - and these parameters are used by administrations for international frequency co-ordination work.

When dealing with wanted and unwanted signals using computer modelling, it is convenient to work in terms of similar percentages of time thereby enabling both wanted and unwanted signals to be predicted on the same basis. Many computer models predict median values of field strength which means that the interference levels would also be on a 50% time basis. This would result in too low a value being predicted for interference as it should be considered on a 10% time basis. In order to correct this, 9dB - the difference between the 10% and 50% time curves at 100km - has been added to the planned signal to interference ratio. This enables computer models to be used for the prediction of both wanted and unwanted signals and ensures that the design signal to interference ratio is based on the 10% propagation criteria for interference.

In order to establish the design signal ratio, the performance of a receiver under steady state signal conditions is determined, together with correction factors to allow for fading:-

Basic receiver interference rejection	7 dB
Allowance for Rayleigh fading	3 dB
Allowance for 50% - 10% time curves	9 dB
Design signal to interference ratio	19 dB

F.1.2 Co-channel Separation

It is possible to use the agreed values of minimum field strength and C/I ratio to determine the order of re-use distance needed to meet the targets. In any real situation the nature of the topography between the transmitting and receiving points will have an influence on the actual values, but a number of approaches are possible which enable the solution to be analysed over the national scale.

The CCIR propagation curves allow the effects of antenna heights to be included into the analysis, together with a correction for terrain undulation, if this is known, for the paths being considered. A simpler, but rather more approximate method, which has been used in the analysis of cellular systems is to assume a particular law for the decay of power density with increasing range. The law is simply stated as:

power varies as $1/(\text{distance})^x$

In situations where the transmitter is well elevated with respect to the receiving point, i.e. short ranges x will be near to 2. At longer ranges where the path is grazing x will be near the higher value, i.e. at points in the outage parts of a service area. For much longer paths, typical of interference situations, the effective value of x will exceed 4 since the plane earth losses will generally be increased by scattering effects caused by intervening obstacles.

The above law can be used to produce C/I values if the same value of x is assumed for both paths. If the value of x is chosen to be between that for service area ranges and that for interference ranges, the predicted C/I will be pessimistic because the wanted signal will not decay as rapidly as implied by the x- value and conversely the interference will decay rather more rapidly. If the distances from the wanted and interfering transmitters to a receiving location are R and d, respectively, then

$$C/I = (d/R)^x$$

F.1.3 Basic Cell Structure

The development of the frequency plan based on the regular re-use of channels is most conveniently carried out by using a closely fitting array of hexagons or "cells".

Regular frequency re-use is a major factor by which cellular radio achieves its high traffic intensities, and it is this aspect which will be applied to the JRC band frequency plan.

The principal arguments for using a regular re-use strategy are:-

(a) that higher traffic capacity is available by using cell size coverage areas rather than wide area coverage schemes.

(b) that by having a regular plan, better overall use is made of the spectrum over the whole country.

(c) that channels may be arranged in sets which may be used together without generating interference to themselves and thus more readily permitting trunking systems and hence higher traffic capacities.

(d) where higher traffic densities are foreseen on a long term basis, it is possible to utilise the technique of cell splitting, that is substituting several smaller cells in the place of a larger one and assign frequencies to the new cells according to the cellular plan. The major restraints on the use of this practice is the need to control the interference between large and small cells by the use of directional antennae and by the need for the lower power transmitters in the small cells.

The disadvantages seen are:-

(a) The rigidity of the plan will cause the radio service areas to mismatch with administrative areas, and a more complex control system is required to even allow simple modes of use.

(b) When sites are shared with other users then the rigidity of the plan could clash with the channels operated by the other users.

Choice of Cell Arrangement

In the main, there are two principal conflicting factors which need to be taken into account when evaluating the best cell pattern for the JRC Band. These are:-

i) the need to meet a minimum signal to interference (C/I)
ii) provide an adequate traffic capacity

A solution which favours (i) will lead to the clustering of cells in large groups, which will necessarily spread the available channels rather thinly, which will conflict with (ii). The following sections seek to qualify the factors in numerical terms so that the best compromise might be gauged easily against an operational background.

The C/I ratio was derived from the ratio of distances to wanted and interfering signal sources in a simple equation, which is reproduced for convenience.

$$C/I = (d/R)^x$$

In describing the ability of cell arrangements to meet the target value, we need to change the terminology slightly to conform to that normally used, where D is the distance between co-channel sites. If we regard a receiver near to the periphery of its own cell as being most susceptible to interference, then D = d + R. Thus we have the worst C/I value in a cell arrangement expressed as follows:

$$C/I = (D/R - I)^x$$

There are only certain possible values for the ratio D/R which are set by the need for the arrangement of cells to form a continuous pattern. These arrangements have been extensively studied, and a particular set of cells which forms an acceptable repeating pattern is usually called a cluster. The number of cells (N) forming the cluster will fully describe the arrangement and, in particular, will specify the co-channel separation as:

$$D/R = \sqrt{3N}$$

Not all values of N will give a valid cluster arrangement; the common values used are: (4, 7, 9, 12 and 19). The following table summarises available C/I ratio for these arrangements, for the likely range of propagation law factor x, and assuming omni-directional antennas:

CELLS PER CLUSTER	CHANNELS PER CELL	D/R	C/I (dB) x = 3.0	x = 3.5	x = 4.0
4	19	3.46	11.7	13.7	15.7
7	10	4.58	16.6	19.4	22.2
9	8	5.20	18.7	21.8	24.9
12	6	6.00	21.0	24.5	28.0
19	4	7.55	24.5	28.6	32.6

Taking a value for x of 3.5 to represent average propagation law we see from the table that the 7 cell per cluster just meets the target, and the cases for 9 and 12 cells per cluster give 2.8 and 5.5 dB margin, respectively. In drawing up the table, it has been implicitly assumed that the transmitters are at cell centres.

The choice of the 9 cell cluster from the JRC plan was therefore adopted as representing the most realistic trade-off between maximising the channel count per cell, whilst comfortably meeting the target C/I requirement of 19 dB, and giving some tolerance to variation of transmitter location. The physical layout of the 9 cell cluster is shown in Fig. F.1.

Cell dimension is dictated by finding a satisfactory compromise between:

i) Achieve a national channel repeat of not less than 7-8 times.

ii) Reasonable prospect of achieving a complete cell coverage from one transmitter at a nominal centre position under average terrain conditions.

iii) Avoidance of small cells that would need many extra transmitter sites and possibly introduce the need for "hand-off" procedures.

iv) Recognising that smaller cells give a better chance of aligning the cell boundaries with major administrative boundaries.

v) Small cells also give an improved channel density (ch/km^2).

Some of these overall aims directly conflict, so that the final choice will represent only a partial satisfaction of any particular factor. In analysing these targets a cell size of 40km (across flats) i.e. 46km (across vertices) has emerged as the recommended size. This meets factors (ii), (iii); comfortably exceeds (i), and provides an adequate traffic capacity viewed on the national scale.

F.1.4 Meeting Variable Traffic Densities

Regular re-use of channels makes the most effective use of channels by ensuring that they are all intensively re-used, limited only be interference levels between co-channel cells. In the basic form, regular re-use gives an equal traffic capacity across all cells; however, the traffic demands are not uniform across the country.

Modifications to the cell structure may be necessary to improve the traffic carrying capacity at certain points in a network. Such modification may take the form of the use of an inset cell, cell edge re-alignment or cell sub-division.

The following sections describe a technique of using small cells within the general framework of cells already proposed. The technique exploits certain features of the 9 cell cluster, and may be applied selectively dependent on the traffic needs.

Use of Small Cells

There are two ways in which small cells can be incorporated into the regular re-use patterns, namely:

i) locally superimposed cells

ii) cell splitting over part of a large cluster

These approaches are favoured because it appears possible to produce engineering guidelines which do not depend on the use of antennas having highly directional properties. The example calculations assume an omnidirectional radiation pattern, but the use of VHF antennas having some directional discrimination which are known to exist could give additional margin to the signal to interference values obtained in co-channel systems across the transitional region between small and large cells.

Directional antennas would also appear to have a role to play where transmitters are located in the outer parts of a cell.

Inset Cells

If we examine the channel sets adjacent to any particular cell in the 9 cell cluster there will always be two channel sets which are absent. Some (or all) of the channel sets are candidates for assignment to a small cell located in the cell being examined. This can be repeated for all cells in a cluster and then repeated in different clusters as far as is necessary. Assignment of channel sets to inset cells is shown in Fig. F.2.

Traffic Considerations

It is convenient to examine the traffic capacity of the inset cell principle by referring to the effective channel coverage in terms of area (km^2) per channel (a reciprocal of channel density). Where a superimposed cell is implemented, there is the prospect of using two complete channel sets from non-adjacent cells. The remaining area of the cell would then use the 8 channels normally assigned - this will give an increased channel density in these areas also.

It will be seen that the range of available densities span a range of 8:1 over the basic value resulting from a uniform deployment. We are able to provide at least a doubling of channel density nationally - at the expense of more precise coverage engineering.

The penalty for using this approach are two-fold; the inherent C/I obtained for the 9-cell is eroded, and there is also the need for both operators in the normal cell and the overlay cell to minimise the export of interference by adopting low power/low height base stations.

Cell Sub-division

The frequency plan does allow for cell sub-division, where each normal cell is replaced by three smaller ones. One of these small cells would have the channel set associated with the original cell, and the other two would take channel sets from donors in exactly the same way as the inset cell. Consequently stringent engineering considerations have to be borne in mind when contemplating the adoption of this procedure, since the size of the sub-divided cells will be large compared with the envisaged size of a 'typical' isolated inset cell.

There will be the need for coverage in the donor cells to use comparable engineering techniques, needed in the small cells. This will inevitably increase costs, so that strong justification will be needed.

F.1.5 Cell Orientation

The final parameter for defining completely the JRC frequency plan is the location of the cell outlines over the country as a whole. There are many possible positions which can be arrived at by a combination of shifting and rotating the system of cells.

Among the considerations are:

- Degree of natural alignment with major administrative boundaries.
- The extent to which major population centres are partitioned into two or more cells. This would make available higher traffic capacity without the need to resort to inset cells.

F.1.6 The Basic Approach to Interference Limited Design

It is worth emphasising the way in which the cellular map of the JRC band plan should be understood. It is a map which shows the areas where channels will be protected from co-channel interference, and where those channels can therefore be used to provide service. The service area is designed within the constraints of limiting interference to surrounding co-channel cells. This design on the basis of limiting co-channel interference levels also applies where agreement has been obtained to use inset or split cells.

This regular re-use of spectrum will result in a design process significantly different from that practised in the past. Prime concern was coverage of an area, with the channel being available for re-use subject to the use which had been made of it in a specific design. It is recognised that a more powerful computing tool will be required to assist with the design process.

It is acknowledged that topography and base station siting makes the coverage area of each base station different, so in order to be able to realistically describe the design issues, the CCIR propogation data [6] is used.

Antenna directivity is an additional parameter which can be used, particularly when a base site is considerably off-set from cell centre, to achieve a service area corresponding to both the cells to be served and the limitation of interference to other cells.

As the planning rules are concerned with control of the interference in neighbouring co-channel cells it follows that the positioning of a base station site to provide service within its cell is governed primarily by these rules.

Since there is considerable investment in existing base station sites a first step in the design process is to determine what coverage can be provided by existing sites.

F.1.7 The Changeover

The translation of over 2,000 systems on 84 channels to new systems on 76 channels, over about six years, is a complex problem and some form of computer assistance is clearly necessary.

The objective is to get from the existing middle-band to the JRC cell plan with as few moves as possible. The changeover is not easy because many of the existing middle-band channels are part of wide-area schemes.

The main task is to make channels available in the JRC Band by phasing the discontinuation or decommissioning of existing mid-band services. The usage of the mid-band channels which overlap the JRC Band channels is not equally distributed between the two major users, with the electricity industry occupying many channels which are required for both electricity and gas, and hence there is a particular need for the power industry to plan the release of mid-band channels.

To ease the transitional planning a group of channels above the established JRC section of mid-band have been made available for use for a limited period. These are referred to as 'parking channels' since they are only of use for short duration transitional arrangements in the first years of the change-over. These have been allocated to the JRC Band cellular grouping on the basis of one channel each for gas and power for each cell.

F.2 <u>Control and Traffic Channel Strategies</u>

F.2.1 Control Channels

When building large multi-site networks, different control channel strategies have to be considered.

In each cell, it is necessary to have channel capacity allocated for control purposes as well as for traffic. This capacity will be used by the system for signalling between the exchange and the subscriber equipment. This signalling is mainly for call set-up purposes, but also for operational and maintenance purposes.

Dedicated control channel

Typically in large public mobile radio systems, dedicated channels are allocated in each cell for control channel use. In private systems, having typically only a few channels available, this would often lead to very inefficient use of the frequency spectrum.

An important advantage of using a dedicated control channel is, however, the possibility to offer instant access for prioritised or emergency communications, even when all available channels are occupied.

Non-dedicated control channel

The most economical scheme for control is to use non-dedicated control channels. In this method, all channels may be used for speech traffic. One channel is temporarily allocated for control, and taken into speech use when necessary. Because of this, the available frequencies are used as effectively as possible, and the investment in base station equipment is the lowest possible. The drawback in the scheme, however, is that service cannot be assured for critical purposes.

When all channels are occupied, new call requests may not be communicated to the exchange how urgent or prioritised they may be. Call set-up times including waiting for the calling channel to become available may become rather long and unpredictable.

Time-shared control channel

An alternative combining good frequency economy and good service for critical functions is the time-shared control channel. For an area consisting of up to ten cells, one channel is allocated for control. This channel is used automatically by the system on a time-shared basis as a dedicated control channel.

Investment in base station equipment remains the same as when using full-time dedicated control channel, but different radio channels are not needed for control on adjacent sites. Using this scheme, good service can be provided for critical and prioritised services.

Time sharing a control channel, when compared to employing a dedicated control channel, lowers control channel capacity and increases waiting times during call set-up. Special adaptive and dynamic methods can be used to minimize this effect.

In the JRC plan time shared control channels are used.

In the context of the JRC Band frequency plan some constraints are introduced on the control channels. Firstly, the control channel has to be taken from each cell channel set, so consequently different control channels exist in each of the 9 cells making up a cluster. Within each cell radio coverage will, in general, need more than one radio site; consequently the control channel will need to be shared around the sites allowing access to all mobiles in the cell over a period of time. Thus the most common mode of operation which is emerging is for a time shared control channel in which a mobile has access to the control channel for a period of time - generally of the order of one second or so, after which the control channel is operated from a different site within the cell, and so on until it returns to the original site.

F.2.2 Dynamic Channel Allocation

Ordinarily, frequencies to be used at all base station sites are fixed. Each transmitter/receiver typically operates on a single channel only. Use of channel capacity is therefore statistically allocated and cannot be adapted to changes in traffic distribution. In many situations, advantages can be gained by using dynamic channel allocation. In this scheme, same channels may be shared by different sites. Distribution of channel capacity can be changed according to situation.

Of course, at each site, the number of physical channel units must correspond to the maximum estimated traffic at that site. However, the available radio channels can be used more effectively because a free channel can be taken into use at any site.

Efficient use of dynamic channel allocation requires frequency agile base stations, whose frequency can be remotely controlled.

Frequency planning, unfortunately, may become more difficult with dynamic channel allocation. When a channel is allocated for a certain site, it has to be investigated that the same channel is not being used within a certain radius required to keep down possible mutual interference. If, then, use of a channel is not restricted to a certain location, but shared by several locations, the area suffering from possible interference naturally increases.

F.3 Radio Site Engineering

The growth of radio services has resulted in an increase in the number of radio sites required and in the number of users sharing their facilities.

The radio frequency spectrum is a finite natural resource for which there are many competing demands, therefore radio systems must be designed so that individual systems are very efficient and operate with minimum interference to other systems.

For a proposed service, sites are chosen for their ability to provide coverage of the required service area. Preference is usually given to sites centrally located within the required service area so that maximum coverage is achieved with an omni-directional radiation pattern. In the event that no suitable locations can be found it may be necessary to utilise sites on the periphery of the service area. In these circumstances directional antennas would normally be employed to limit radiation to the desired area.

The use of the highest available site is not always the best decision. As more users occupy the available radio spectrum there is an increasing need to share frequencies. The use of an unnecessarily high site may provide degraded service due to co-channel users. Modern systems are frequently designed on an interference limited, rather than a noise limited criteria.

European Telecommunications Standards Institute has prepared a report "Radio Site Engineering For Radio Equipment And Systems In The Mobile Service"[16].

Whilst this report has been prepared to assist radio system designers to obtain optimum use of radio sites and the radio spectrum, it is also intended for the guidance of those site operators and maintenance organisations who do not have ready access to radio systems engineers.

Accordingly the document sets out methods and design solutions which are achievable without extensive resources.

The report examines the objectives of good design and the effects of common deficiencies. It provides recommendations designed to ensure that users avoid interactions which result in mutual interference, spectrum contamination, or danger to personnel or equipment. References and annexes are provided for further reading by engineers who are new to the field or are encountering the problems which are described for the first time.

F.4 Computer Based Planning Tools

The basis of the cellular frequency plan is the generalised radio propagation model. The base station site planning and more detailed coverage area calculations require the local terrain effects to be taken into account. Computer aided design systems with digital maps can be used for coverage area and interference predictions.

In digital mobile radio systems the threshold effect on the border of the coverage area is stronger than in analogue systems. This leads to requirements of even more accurate predictions in order to estimate the coverage area with sufficient accuracy without too much post-tuning of the network parameters.

The final verification of the coverage area and interference level predictions must be carried out with measurements. Nowadays advanced automated measurement systems have been developed using localisation devices based on receiving signals from navigational satellite systems such as 'Global Positioning System'.

Driving force of the development of computer aided network planning systems and advanced measurement methods are the needs of fast growing public cellular systems. Especially new digital systems like GSM and the needs of microcellular structures set demanding requirements for accurate predictions of coverage area and interference. This development can be directly utilised in planning of power utility radio networks.

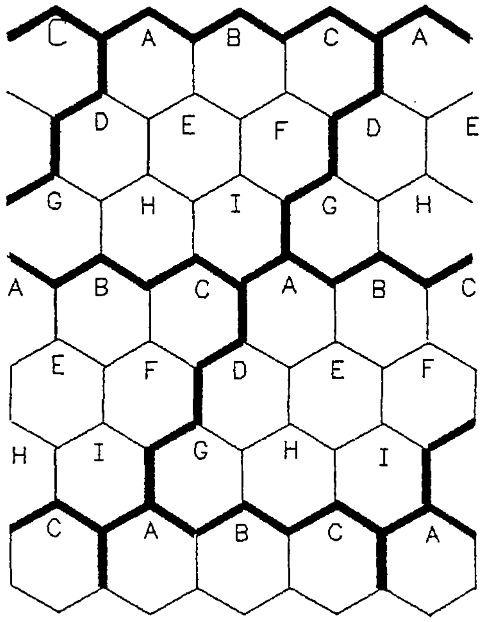


Fig. F.1 General arrangement of 9 – Cell clusters

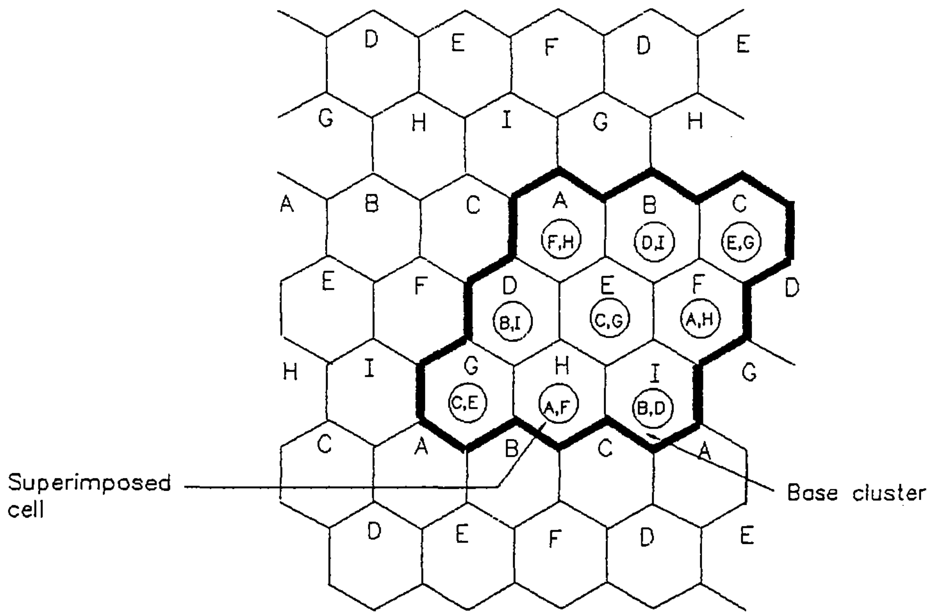


Fig. F.2 Assignment of channel sets to inset cells

APPENDIX G

LIST OF WORKING GROUP MEMBERS

G1 LIST OF WGO2 MEMBERS

P. Somervuo	Chairman WGO2	FINLAND *
A.D. Bartlett	Secretary WGO2	U.K *
G. Vincent	Chairman SC35	AUSTRALIA *
E.K. Salo		FINLAND
T. Greene		IRELAND
S.A.V. Andersson		SWEDEN *
E. Andersen		DENMARK
J. Tervo		FINLAND *
J.P. Bourbigot		FRANCE
F. Gonzalo		SPAIN
O.H. Nordgard		NORWAY
J.P. Pittion		FRANCE *
J.A.N. Aguiar		PORTUGAL
K. Morf		SWITZERLAND
H. Wissen		SWEDEN
B. Toet		NETHERLANDS *
Y. Loussouarn		FRANCE *
G. Endlich		GERMANY
J.M. de la Pena		SPAIN *
J. Melin		SWEDEN *

G2 CORRESPONDING MEMBERS

R. Koskinen	Chairman SC35 (Past)	FINLAND
G. Carlton		U.K. *
E. Pace		ITALY
A. Pollard		SOUTH AFRICA
T. Saxton		U.S.A.
M. Ozaki		JAPAN

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