REPORT ITU-R M.742-4*

PUBLIC LAND MOBILE TELEPHONE SYSTEMS

(Questions ITU-R 37/8 and ITU-R 39/8)

(1978-1982-1986-1990-1995)

1 Introduction

Public land mobile telephone systems are defined as land mobile systems for public correspondence via radio stations connected to the public switched telephone network (PSTN).

Part A of this Report deals with the general principles of public land mobile telephone systems (both conventional and cellular) and, in particular, with system parameters and technical characteristics which are important for international operation. The basic concept of the cellular techniques is outlined in Report ITU-R M.740.

Part B of this Report considers the implementation of international systems.

The major characteristics of some existing or imminent public land mobile telephone systems are given in Part C of this Report, together with brief descriptive material on the status of these systems and other unique aspects of their design.

PART A

GENERAL PRINCIPLES OF PUBLIC LAND MOBILE TELEPHONE SYSTEMS

1 Operational aspects

The following general operational aspects should apply:

– automatic setting up and charging of calls to and from the mobile station;
– for international systems, the ability to set up calls between the mobile stations and any fixed telephone subscriber or any other mobile telephone subscriber within the system;
– costs should be charged in a manner consistent with charging principles in the public switched telephone network;
– the introduction of the system should not necessitate any significant changes in the fixed telephone networks;
– blocking probability should be kept within limits similar to that of the PSTN services at all stages of development;
– continuous control of call quality should be maintained, with automatic hand-over between base stations if needed.

Any specific system must have at least two well-defined interfaces:

– the radio interface between the land-based system and the mobiles it serves; and
– the wire-line interface to the public switched telephone network.

Other internal interfaces may also be defined such as:

– the billing system;
– the interface between controllers for the handling of roamers;
– the methodology for communicating between base sites and controllers; and
– the man-machine interface for operational purposes including maintenance.

* This Report should be brought to the attention of the Telecommunication Standardization Bureau.

2 Interworking with the PSTN

ITU-T Recommendation Q.70 specifies the necessary interworking requirements between the PSTN and the mobile network.

3 Numbering plan and routing

A difficult problem in a fully automated mobile service is to select a numbering plan for the mobile subscribers which is compatible with the established fixed network. A numbering plan based on the conventions built up in the land network may impose severe limitations on mobile routing especially since the subscriber number in a mobile system no longer is referred to the location of the subscriber.

One solution is to allocate a special access number to the mobile service, in which case all dialling to the mobile network is handled free from the routing routines of the telephone service.

Since national numbering plans vary in their capability to manage long numbers and to allocate codes to special services, an international numbering plan needs to be established. ITU-T Recommendations E.212 and E.213 deal with this subject.

4 Roaming

To be able to automatically set up calls between the mobile stations and any fixed telephone subscriber regardless of country, a fully automatic roaming facility is necessary. The mobile system has to be informed of the location of the mobile subscriber as he moves from one location to another.

Further studies are required before adequate technical and operational roaming procedures can be defined. For this reason Recommendation ITU-R M.624 has been written.

Roaming also requires compatibility in frequency bands, channel spacing, and operational signalling protocols and codes.

5 Charging

The principle for charging in mobile networks varies in different national networks.

The question of charging therefore needs to be studied by the ITU-T to achieve international agreement.

6 Radio-frequency considerations

Current systems use the 450 MHz band, the 800-900 MHz band, and other bands according to existing possibilities.

Conventional trunked systems can use only a small number of channels, but cellular systems are only efficient when a larger allocation (e.g. 300 channels) is available since the allocation must be divided into sub-sets in order to implement the cellular plan. Further studies may be necessary before the choice of a radio-frequency band for an international public mobile telephone service can be made.

7 Signalling

The system functions which are required in an automatic public mobile telephone system require a fairly complicated signalling system. The mobility of the subscribers creates a need for information transfer of a kind that has no equivalence in the fixed telephone network. This applies both to the updating procedure, performed when the mobile station enters a new location area, and to the hand-over procedure when a call in progress is switched from one base station to another.

Signalling errors in the radio channel may result in loss of control and the inability to establish a traffic channel between mobile and base stations. The reliability with which a traffic channel may be obtained should be adequately high, since:

– radio channels correspond to lines in the public-switched telephone network, and the signalling and supervision reliability should be as good as in that network;

– to fail to establish and maintain a traffic channel means that the base station loses control of the mobile station. The probability of failure therefore should be made as small as possible;

– billing accuracy is of high importance.

The reliability of control channels can be improved by (for example) diversity, error-control coding, message exchange protocols and simulcast (see Reports ITU-R M.903 and 1022 and Question ITU-R 67/8).

Attempts to seize a channel may fail due to simultaneous requests by two or more mobile stations. The problem can be reduced by a polling technique, but in a high-capacity system it is more efficient to mark the busy/idle status of the channel [Fluhr and Porter, 1979; Okasaka, 1978].

8 Reduction of ineffective air-time

In all public radiotelephone systems, including cellular, a significant delay resulting from dialling, switching and ringing time occurs between the initiation of a call and the start of the conversation. Some cellular systems store the dialled digits in the mobile unit prior to transmission (called "pre-origination dialling") which significantly reduces the ineffective air-time.

The traffic capacity can be increased by assigning traffic radio channels only when both parties are ready to speak [Tridgell, 1977], or by queueing calls on a first-come-first-served basis until they materialize and a free traffic channel becomes available.

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PART B

CONSIDERATIONS FOR THE DEVELOPMENT OF INTERNATIONAL SYSTEMS

1 General

This part identifies considerations that are appropriate for the development of international public land mobile telephone systems and services that may be adopted by many countries around the world. Systems that provide common services amongst a few nearby countries have been implemented.

2 Implementation of international systems

To allow for the implementation of international systems, it would be ideal to select a common band of frequencies with common worldwide service and technical standards. As the development of these agreements could take a long time, it may be necessary to choose methods involving interim stages which immediately take advantage of some of the benefits of international compatibility. Such implementations may be possible by the addition of agreed narrow-band or wideband systems [Murtonen, 1985].

Narrow-band systems may be added with channels directly adjacent to those of existing systems, or in the case of some existing systems, by interleaving the channels of both systems. In both cases there would be systematic expansion of new channels into existing system channel assignments as over time older systems are retired.

Similarly, wideband systems (spread spectrum, TDMA, etc.) may be added using new or cleared spectrum adjacent to the channels of existing systems. Expansion of new systems is possible when the older systems are retired.

Additionally, it may be possible to overlay some spread-spectrum systems onto existing assignments and to simultaneously operate both the new and the existing systems; however the overlay of spread-spectrum systems requires further study, especially in the case of a heavy concentration of users of these systems.

3 Factors needed international agreement

– Channel allocations and spacing;

– class of emission;

– modulation characteristics;

– transmitter and receiver standards;

– signal processing techniques, such as companding;

– use of diversity reception;

– signalling and supervision methods and protocols.

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PART C

SYSTEMS BEING INSTALLED OR PLANNED IN THE NEAR FUTURE

1 High-capacity cellular public mobile telephone services

1.1 Introduction

High-capacity cellular systems have been developed in the United States, in Canada, in the United Kingdom, in the Nordic countries, in Japan, in the Federal Republic of Germany and in Italy to provide a high-quality, nationwide-compatible radiotelephone service.

Systems are now in operation or being installed in the United States and Canada, where 666 channels split into two sub-bands and allocated to two systems per city, have been set aside. These consist of a varying number of cells, depending on the area to be served. The system capacity can be expanded to meet the anticipated subscriber demands which are expected to be more than 100 000 in larger cities. Annex 1 provides more details on the general characteristics of these systems.

Two nationwide systems (TACS), similar to those in North America but based on channels spaced at 25 rather than 30 kHz have been developed in the United Kingdom, and were brought into use in January, 1985. Each system will offer coverage to at least 90% of United Kingdom inhabitants by 1990. In November, 1985, the total number of subscribers on the two systems exceeded 35 000. Annex 5 provides more details on the general characteristics of the system.

The Japanese system MCS-L1 now provides nationwide service to more than about 70% of all Japanese cities, using nine mobile telephone switching centres connected to the common channel inter-office signalling network. The numbers of subscribers in the Tokyo metropolitan and Osaka areas are expected to reach the MCS-L1's maximum capacity in the near future. To meet demands, such as handling capacity increase, lower rates and upgraded services, the new 900 MHz band high capacity land mobile communications system (MCS-L2) has been introduced. The system handling capacity is expanded to about 100 000 subscribers in the large cities, by improving spectral efficiency to about three times the present system. Annex 2 provides more details on the general characteristics of the systems.

The Nordic mobile telephone system (NMT-450) was put into operation in the participating countries, Denmark, Finland, Norway and Sweden during the end of 1981 and the beginning of 1982 with country-wide continuous coverage and full roaming capability. During the last year, cell splitting has been introduced in the big cities in order to cover the traffic demand. Cells as small as 1.0 km radius are used. In October, 1985, the number of subscribers exceeded 200 000 corresponding to 0.9% of the population. During 1986, this system will be expanded to Iceland with full roaming capability between all the countries. The system will be expanded into the 900 MHz band in late 1986 and is designed for 2 000 channels including the utilization of interleaving. At start-up, 799 channels were used (NMT-900). Annex 3 provides more details on the general characteristics of the system.

In Belgium, the Netherlands and Luxembourg, a cellular system providing international roaming is in operation. This system is an NMT-450 system with modifications such as 20 kHz channel spacing and the use of a syllabic compandor.

The C450 network in the Federal Republic of Germany was brought into service in 1985. It provides a complete coverage of the Federal Republic of Germany. The ultimate subscriber capacity is estimated to be at least 200 000. Specific features are: off-air call set-up and queueing operation. Annex 4 provides more details on the general characteristics of the system.

The Italian second-generation mobile telephone system operating in the 450 MHz frequency band was brought into service in the Rome and Milan areas beginning in September, 1985. It is expected to provide a complete coverage of the Italian territory by 1988. Annex 6 provides more details on the general characteristics of the system.

1.2 System features

The following system features are common to all described systems unless stated:

– cellular structure in both base-to-mobile and mobile-to-base directions with frequency reuse and inter-cell hand-over (switching call-in progress);

– automatic, two-way, direct-dial operation;

– full duplex communications;

– voice channel supervision via continuous tone (North American and United Kingdom systems, NMT system, Italian system), or digital control channel (C450, MCS-L2 system);

– automatic roaming;

– dedicated control channels used for call set-up (North American and United Kingdom system, Japanese system, C450 system, Italian system);

– pre-seizure dialling;

– cell splitting during system growth.

1.3 Conclusions

Cellular radiotelephone systems using the parameters and features described above have been installed or are planned for the near future. There is a large demand for a land-mobile radiotelephone service in many parts of the world, and it is considered that systems with the above characteristics are capable of meeting that demand.

2 Hybrid systems combining public mobile telephone system and dispatching type networks

2.1 In 1985 France opened a system with the main characteristics described below:

2.1.1 General characteristics

- Dispatch type operation for half-duplex private network application offering the following links:
  - base-to-mobile or fleet (or sub-fleet);
  - mobile-to-base;
  - mobile-to-mobile or fleet (or sub-fleet);
  - access for certain mobiles to the PSTN;
- duplex public radiotelephone operation; a unique number is used to call the mobile wherever it is located;
- cellular structure covering a wide geographical area with automatic roaming using medium-sized cells (15 to 20 km radius); cell splitting possible during system growth;
- digital data transmission is under study;
- the system provides for priority subscribers;
- hand-over is under study.

Annex 7 provides more details on the general characteristics of the system.

TABLE 1

General system specifications

Feature	North American systems		Japanese system MCS-L1	Japanese system MCS-L2	NMT-450 system	NMT-900 system	C450 system	United Kingdom system - TACS	Italian 450 MHz system	French system RADICOM 2000
	AMPS	Narrow-band N-								
Class of emission	Voice 40K0G3E Control 40K0G1D	Voice 17K4F9W Control 40K0F1D	Voice 16K0G3E Control 16K0F1D	Voice 8K50G3E Control 8K50F1D	Voice 16K0G3E Signalling 16K0G2D	Voice 16K0G3E Signalling 16K0G2D	Voice 14K0G3E Control 14K0F1D	Voice 32K0G3E Control 32K0F1D	16K0G3E	Voice 11K0G3E
Transmit frequency bands (MHz) – base stations – mobile stations	 869-894 824-849	 869--894 824-849	 870 - 885 925 - 940	 870 - 885 925 - 940	 463 - 467.5 453 - 457.5	 935 - 960 890 - 915	 461.3 - 465.74 451.3 - 455.74	 935 - 950 890 - 905	 460 - 465 450 - 455	{202.7 – 207.5 {207.5 – 215.5 {424.8 – 427.9 {194.7 – 199.5 {215.5 – 223.5 {414.8 – 417.9
Duplex separation (MHz)	45	45	55	55	10	45	10	45	10	8 10
Channel spacing (kHz)	30	10	25	12.5	25	12.5	20 (10)	25	25	12.5 12.5
Total number of duplex channels	832 (416 in each of two sub-bands, including 21 signalling channels)	2 499	600	1 200	180	1 999	222	600 (300 in each of two sub-bands, including 21 signalling channels)	196	1 024 256
Maximum base station ERP (W)	100(1)	100(1)	50	20	50	100	100 (adaptive control)	100	25/2.5	25 to 70
Nominal mobile station transmitter power (W)	3	3	5	1		15	15 (+3 dB antenna gain adaptive control)	7 - class 1 mobile	10/1	11
Typical cell radius (km)	2-20	2-20	3 (urban area) (2) 10 (suburban area) (2)	3 (urban area) (2) 10 (suburban area) (2)	1 - 40	0.5 - 20	2 - 30	2 - 20	5 - 20	20
Voice signals – type of modulation	 PM	 PM	 PM	 PM	 PM	 PM	 PM	 PM	 PM (FM, if the band inverter is used)	 PM
– peak deviation (kHz)	±12	±5 ±1.5 average	±5	±2.5	±5	±5 (including supervisory signal)	±4	±9.5	±5	±2.5
– processing	2:1 syllabic compandor	2:1 syllabic compandor	2:1 syllabic compandor	2:1 syllabic compandor	-	2:1 syllabic compandor (CCITT Rec. G.162)	2:1 syllabic compandor	2:1 syllabic compandor	2:1 syllabic compandor (CCITT Rec. G.162)	Syllabic compandor base to mobile

Control signal – type of modulation – peak deviation (kHz) – code form – transmission bit rate (kbit/s) – effective information transmission rate (kbit/s) (depends on message type) Control signal for in-service – type of modulation – peak deaviation (kHz) – code form – transmission bit rate (kbit/s) – effective information transmission rate (kbit/s) (depends on message type)	FSK ±8 Manchester 10 0.27 - 1.2	FSK ±8 Manchester 10 Voice channel signalling sub-audible 100 bit/sec Manchester 200 bit/sec NRZ sub-audible supervisory signalling	FSK ±4.5 Manchester 0.3 0.12 - 0.18	FSK ±2.0 Manchester 2.4 1.3 - 1.64 FSK ±0.6 Manchester 0.1 0.04	FFSK ±3.5 NRZ 1.2 About 0.46	FFSK ±3.5 NRZ 1.2 About 0.46	FSK ±2.5 NRZ 5.28 1.82	FSK ±6.4 Manchester 8 0.22 - 0.96	FSK ±4 Multifrequency (two of seven) (3) About 0.1	FFSK ±1.7 NRZ 1.2 0.46
Error protection coding Control signal – base-to-mobile – mobile-to-base Control signal for in-service – base-to-mobile – mobile-to-base	Shortened (63:51) BCH repeated (4) (40:28) BCH (48:36) BCH	Reverse control channel BCH (48,36;5) Forward control channel BCH (63,51;5)	Shortened (63:51) BCH; shortened (23:12) BCH (43:31) BCH (43:31) BCH-access; (23:12) BCH-paging	Shortened (63:51) BCH; (40:28) BCH (40:28) BCH (23:12) BCH (23:12) BCH	Type B1 burst error-correcting convolutional code (Hagelbarger)	Type B1 burst error-correcting convolutional code (Hagelbarger)	(15:7) BCH	Shortened (63:51) BCH repeated (4) (40:28) BCH (40:36) BCH		Hagelbarger code (6:19)
Error detection	Min 11 Max 89 } per 200 bits	Min 11 Max 89 } per 200 bits	Min. 3	Min. 3			Min. 40 per 150 bits	Min 11 Max 89 } per 200 bits		
Error correction	Min 5 Max 83 } per 200 bits	Min 5 Max 83 } per 200 bits	1 error	1 error for 2.4 kb/s 2 error for 0.1 kb/s	Min. 6 with 19 bit guard space	Min. 6 with 19 bit guard space	Min. 20 per 150 bits	Min. 5 per 200 bits		Min. 6
Message protection	Recycled control signal transmissions: repeated control signal transmissions with bit-by-bit majority voting	5 repeat/majority vote	Recycled control signal transmissions; simultaneous transmissions from the base stations in a control zone	Recyled control signal transmission; simultaneous transmissions from the base stations in a control zone	Frame acceptance procedure depending on message category	Frame acceptance procedure depending on message category	Adaptive message repetition in case of error	Recycled control signal transmissions; repeated control signal transmissions with bit-by-bit majority voting	Autocorrelation control of the encoded message with repetition, depending on message type, in case of error	Frame repetition

(1) Exceptions may be allowed, depending on circumstances.

(2) A control zone covers about 10 cells.

(3) The modulation rate is 50 ms/character.

(4) Repeated 5 to 11 times, depending on message type, with bit-by-bit majority voting. In addition, to achieve decorrelation, two message streams are interleaved on the common paging channel.

ANNEX 1

North American system

PART 1

GENERAL DESCRIPTION

1 Operational and system characteristics

1.1 Purpose

The land mobile telephone system is designed to permit an automatic exchange of traffic with the public switched telephone network (PSTN) and offers a service, from the user's point-of-view, similar to that of land-line calls: high voice quality, high reliability, low blocking, and relatively low cost.

1.2 Cellular properties

– Growth from large cells at start-up to small cells at maturity, with a mix of several sizes, is permitted.

– Hand-off is allowed, up to at least one call per minute.

– For spectrum efficiency (channel reuse), small values for the number of channel sets are used: appropriate to the multipath (Rayleigh) fading typical of urban mobile channels, the terrain variability, the antenna patterns selected and the RF quality desired. A local median *C/I* target of 17 dB at the 90th percentile is suggested. (If the standard deviation is 8 dB, this is equivalent to a median of *C/I* of 27 dB, at the nominal boundary of the cell.) Other quality objectives are of course permissible.

1.3 Signal processing

– The widest deviation and receiver predetection bandwidth appropriate to the cellular concept (which permits separation of the spectrum into channels by both frequency division and spatial separation) are used.

– Voice processing using a 2:1 compressor/expandor is employed to enhance the perceived quality of the received signal.

– The coding of digital signalling uses burst-error detection and correction.

– Design for a peak-to-r.m.s. ratio of between 6 dB and 20 dB for the demodulated voice signal at the receiver is possible; that is, a range of quality comparable to land-line service should be accommodated.

1.4 Service protection

– A transmitted serial number prohibits the use of stolen units or use by unauthorized callers.

– The introduction of means to ensure privacy of communication is not precluded by the design.

– Means for preventing intelligible crosstalk is included in the system design.

– The successful completion of the entire call takes place on at least 99% of the calls on which an initial two-way connection was established between calling and called parties.

1.5 Services offered

– Voice message telephone service with automatic calling to and from the PSTN.

– Data services.

– Vehicular-mounted equipment.

– Hand-held equipment.

– Other enhancements consistent with mobile services: call forwarding, repertory dialling, message waiting, etc.

2 Signalling formats and codes

See Part 2.

3 RF equipment

3.1 The RF equipment allows full duplex operation.

3.2 Frequency tolerance: base station - 1 part in 10^6; mobile - 2.5 parts in 10^6.

3.3 RF power limit: 100 W ERP; more when adjacent systems are not expected.

3.4 Power tolerance: ±2 dB.

3.5 Mobiles are tuneable to each of the allocated channels.

3.6 Receiver sensitivity: -116 dBm from a 50 Ω source applied to the antenna terminals should produce a 12 dB SINAD (C-message weighting).

3.7 Diversity: optional at mobile; also optional, but highly recommended, at base station.

3.8 Antenna height: 30 to 45 m, higher when adjacent systems are not expected to interfere. With careful design, according to local practice, greater heights may be used.

4 Land-based control equipment

4.1 Connection to the PSTN is accommodated on a fully automatic basis.

4.2 Mobile-to-land, land-to-mobile, and mobile-to-mobile calls are permitted.

4.3 Hand-off of mobiles is a feature of the system plan (see § 1.2).

4.4 Supervision of the radio channel is sufficiently robust so that accurate billing timing can be expected (accurate to ±5 s); billing to the proper number takes place with more than 0.9999 probability.

4.5 The system can provide for automatic roaming within an administration's territory.

4.6 The system is designed for blocking objectives similar to the PSTN.

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PART 2

COMPATIBILITY SPECIFICATION FOR CELLULAR CODES, FORMATS, AND PROTOCOLS*

1 Modulation interface

1.1 Voice

– 2:1 syllabic compandor (3 ms attack time, 13.5 ms recovery time).
– Pre-emphasis: 6 dB per octave, from 300 to 3 000 Hz.
– Deviation limiter: ±12 kHz.
– r.m.s. deviation: ±2.9 kHz.

1.2 Control

– Manchester bit encoding.
– Deviation: ±8 kHz for digital signalling: ±2.0 kHz for continuous out-of-band supervision.

2 Baseband interface

2.1 Unique mobile identification

– Mobile unit identification number: 10 decimal digits coded into 34 bits, via specified algorithm.
– Serial number (not changeable): 32 bits, intended as an anti-fraud, anti-theft means.

2.2 System-specific memory

– Station class.
– Access method.
– First paging channel to use.
– Home system identification: 15 bits.
– Preferred system. The overall plan allows for one or two separate systems (A, B) in any city, and the unit must remember its assignment.

2.3 Supervision

Voice channels use a continuous supervisory audio tone (SAT); control channels and digital signals on the voice channels use a digital equivalent call "colour code".

– SAT frequencies: 5 970, 6 000, 6 030 Hz.
– Digital "colour code": 2 bits coded into 7 bits, using a (7:4) Hamming code; used to identify the base station to which the message is intended.

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* These standards are specified in precise detail in the United States Federal Communications Commission Document OST-53 and in the Canadian Department of Communications Document RSS-118, Annex A, dated October 1983, respectively; these are both compatible with EIA Interim Standard CIS-3A, available from the Electronic Industries Association, Engineering Dept., 2001 I (Eye) Street, Washington DC 20006. This specification describes a minimum capability; manufacturers and system providers have also written enhanced versions of this specification to describe capabilities above and beyond this minimum capability. This document comprises about 60 pages; in lieu of publishing that specification in its entirety, this Part 2 summarizes its major points, as they relate to codes, formats, and protocols.

In addition to these supervisory signals, a 10 kHz tone (deviation: ±8 kHz) is used to indicate "on-hook".

2.4 Malfunction

Each mobile has a timer running independent of other logic functions, which will shut down the mobile transmitter within 60 s if the main logic ceases to function.

2.5 Call processing

Several primary tasks are specified; most important of these are (in order):

- d.c. power start-up and initialization;
- idle;
- activation:
  - origination;
  - paging response;
  - order response;
  - autonomous registration;
- conversation;
- release.

Other tasks, called secondary, are performed concurrent with, and controlled by, these primary tasks; these include:

- control data transmission and reception;
- control channel scanning;
- RF power control;
- response to system control messages;
- user interface management.

The primary tasks can be described briefly:

Initialization: when the unit is first turned on, the logic is made to enter the proper sequence; the memory and other mobile functional units can optionally be audited, and then the potential control channels are scanned, using a logarithmic measurement of signal strength, to find out which one will be able to tell the unit about its current proximity. Depending on whether the unit is "home" or "roaming", it may register its existence with the land system. It should also determine a control channel over which it can be paged if it receives a call.

Idle: without radiating, the unit receives and decodes the continuous stream of system control ("over-head") and paging messages, using the error-detecting and error-correcting algorithms available. During this time, it also monitors signal strength and reinitializes itself if the signal becomes unusable.

Activation: if the unit receives a call or gets a command from the user interface to place a call, the control channels should be rescanned, the idle state of the selected control channel determined, and a seizure of the system attempted. The unit then identifies itself to the system and a voice channel assignment will be given to it by the land system.

Conversation: if the mobile is being called, a ringing sequence is initiated; otherwise, the conversation state begins immediately. During the call, "blank-and-burst" messages (comprising a brief blanking of the voice signal and a burst of control data) may be received, instructing the mobile to change power and/or channel. Supervision via the out-of-band and SAT continues.

Release: when the call is ended normally, the transmitter is turned off and the unit is made to revert to the idle task again. If channel conditions of trouble or low-signal are encountered, release should also take place, so that positive system integrity is maintained.

2.6 Signalling

A variety of messages are required to administer the system; these are:

TABLE 2

Channel	Types of messages
Base transmit:	
Control channels	Paging messages Channel assignments Overhead information Filler text
Voice channels	Hand-offs Orders
Mobile transmit:	
Control channels	Page responses mobile address serial number Origination mobile address serial number called number Orders Order confirmation
Voice channels	Order confirmation Called numbers

The fundamental signalling format used is a shortened (63:51) BCH word in which the first 28 or 36 bits are the message and the final 12 bits are parity check bits calculated from the message bits. Of the message bits, the first four serve a control or "book-keeping" function and the rest form the specific messages. 28 information bits are used in the base-transmit direction and 36 in the mobile-transmit direction, so that the resulting codes are (40:28) BCH and (48:36) BCH, respectively.

A second level of redundancy - message repetition when transmitting and bit-by-bit majority voting when detecting - is layered on top of the basic block coding. Interleaving of two message streams adds further decorrelation of bit-error probability, where this is possible. Messages are typically repeated five times, except on the base-to-mobile voice channel when hand-off messages are sent; in this case, the message is repeated eleven times.

Bit synchronization is augmented by providing a long 101010... sequence before each message. Word synchronization employs an 11-bit Barker sequence (11100010010), which possesses unique minimum distance properties.

2.7 Seizure

The effects of collisions during control channel contention are mitigated by two devices:

– between each 10 bits on the base-to-mobile control channel, an eleventh bit is inserted; its state informs the mobiles of the busy/idle status of the control channel, and its change relative to the timing of a seizure attempt tells the mobile logic whether or not its seizure was clean;

– a precursor of 48 bits is added to the mobile's asynchronous seizure attempt on the mobile-to-base control channel to:
  – provide bit and word synchronization and
  – signify the base station to which the attempt is directed.

This latter scheme lowers false seizures caused by co-channel interference.

3 Other

– Power classes:

Class I: +6 dBW max.

Class II: +2 dBW.

Class III: -2 dBW.

– Power control: 7 steps, 4 dB per step.
– Other specifications: typically state-of-the-art.

ANNEX 2

General description of the Japanese system

PART I

MCS-L1

1 Radio link design objectives

1.1 Service quality

– Blocking probability: Radio channels are allotted to make the radio path blocking probability less than 3%.
– Speech quality: The design objective of the speech quality is to realize more than 80% sound articulation score, which can produce 100% sentence intelligibility, in the service area.

1.2 Radio zone configuration

Coverage reliability of 80% sound articulation score in more than 90% of the service area. To get this reliability:

– Maximum cell size is determined so that 90% of the sites at the zone boundary provide reliable reception. Median C/N = 17 dB.
– Channel reuse is determined so that 90% of the sites at the zone boundary provide a reliable wanted/unwanted signal ratio. Median wanted/unwanted (W/U) = 15 dB.

2 Control channel configuration

2.1 Control channel allotment

The control channels are dedicated and divided into subsets of the following two channels:

– paging channel: mobile stations always seize this channel and receive the paging signal, location data and access channel data;

– access channel: a mobile station randomly originating calls is controlled with this channel. To prevent double seizures, the base stations detect the access signal from mobile stations and broadcast the busy status on this channel and then prevent the signals from other mobile stations (ISMA: idle signal multiple access).

2.2 Multi-cell control technique

A control channel is assigned to cover a group of adjacent traffic cells, and simultaneously transmitted from each base station in the control area.

2.3 Seizure

The busy/idle status in the control channel is used to mitigate the effects of collisions during control channel contention.

2.4 Reduction of co-channel interference

In order to prevent co-channel interference, control zones and radio zones using the same frequencies are discriminated by J-code and K-code, respectively.

3 Control sequence

3.1 Mobile origination

The features required in a mobile origination call are:

– numbering from the mobile station that uses the same format as the PSTN;

– locations of mobile stations are detected at base stations by the field strength of access signals received from mobile stations;

– speech channels are assigned by the access channel and a loop check signal is exchanged on the assigned speech channel between mobile station and base station;

– dialling signals are sent through the speech channel after the speech channel is set up.

3.2 Mobile termination

– Numbering for the mobile station is as follows:

  0 +A0 + (7 digits subscriber number), where A is charging class code and 3 or 4 is selected for it.

– A paging signal which is checked with the subscriber data at the home memory office, is then simulcast from each base station in the control zone. If there is an answer from the mobile station, the next process is similar to the mobile origination. When there is no answer, i.e. if the mobile station is off-power or out of the service area, the originating subscriber will get a service announcement of the situation from the exchange (MSC).

3.3 Hand-over

A new speech channel is reassigned to mobile stations crossing a zone boundary:

– the base station detects *S/N* deterioration from the speech channel and asks the control station for hand-over;

– the control station orders an *S/N* check of the mobile to the original and neighbouring base stations;

– the control station selects a new zone and a new speech channel, after comparing the signals from the ordered base stations, and then assigns a new channel to the mobile station. In order to shorten disconnection time during this procedure (less than 500 ms), the land-line is reserved. If the mobile station cannot change to a new speech channel successfully, it returns to the previous speech channel.

4 Signalling code

Signalling code includes the following characteristics:

– telephone number: 7 decimal digits coded into 24 bits binary;
– serial number (not changeable);
– station class;
– first paging channel to use;
– home area identification: 2 decimal digits.

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PART II

MCS-L2

1 Introduction

The second generation mobile telephone system (MCS-L2) that operates in the same 900 MHz band as the MCS-L1 has been developed in Japan. It is intensively aimed to expand the system handling capacity, to reduce the system cost and to diversify the various services.

The handling capacity is expanded to about 100 000 subscribers in the large cities by techniques of 12.5 kHz channelling analogue FM transmission, diversity reception, intra/inter-zone channel reassignment, adaptive transmitting power control and semi-off-air call set-up.

Full detailed specifications for the system and their components are given in the reference list. The following are the additional features and specifications, compared with the MCS-L1.

2 Radio link design objectives

See Part I, § 2.

3 Radio-frequency interface

3.1 Traffic channel

Maximum frequency deviation is limited to 2.5 kHz for 12.5 channel spacing.

3.2 Radio channel control

Radio channel control utilizes both 2 400 bit/s signalling and 100 bit/s channel-associated control signalling. The 100 bit/s data channel that transmits various signals between a base station (BS) and a mobile station (MS), such as *C/I* and *C/N* information from MS, hand-over information from the BS, etc., is transmitted at sub-audio frequency, maintaining overall radio spectrum compactness for 12.5 kHz channel spacing.

4 Control channel configuration

4.1 Control channel allotment

The control channels are dedicated and divided into sub-sets of the two channels, paging channel and access channel.

– Paging channel: A new transmission method, Multi-transmitter Simul/Sequential-Casting (MSSC), is used. Signals common to all radio zones in a control zone, such as mobile terminated call information, are simultaneously broadcast from multiple base stations. Signals peculiar to each radio zone, such as each radio zone's access channel number, are broadcast sequentially.

– Access channel: The idle signal-Casting Multiple Access with Data-slot Reservation (ICMA-DR) scheme is used in multiple-access radio channels. A data-slot reservation packet is sent first from a terminal through the upward radio channel. Then, the MS sends the information packet after it has received an information request signal from the BS. This method shortens the period of wasted transmission caused by packet collision, and can improve random access channel efficiency.

MSSC transmission secures advantages of wide area paging by simulcasting, more accurate location by sequential broadcasting to allocate exclusively access channels to individual radio zones.

4.2 Control zone configuration

The basic unit is the radio zone. This corresponds to an access zone. Several such radio zones together form a paging zone which corresponds to a registration zone. Several paging areas are combined in one switching zone.

5 Switching and control system

5.1 Signalling

Common Channel Signalling System No. 7 is adopted between the mobile control centres (MCCs) and between the MCC and the PSTN. A dedicated common signalling system has been used between the MCC and the BS.

5.2 Roaming

As in the MCS-L1, the MCS-L2 system maintains connectability from/to the PSTN wherever the subscribers go. The MCS-L2 system can also provide the roaming capability to the MCS-L1 system.

5.3 Dialling method

See Part I, § 3.2.

5.4 Speech channel supervision

The quality of an ongoing call is continuously supervised by the BS and MS using measurements of RF signal level, BER of 100 bit/s in-service control data signal and desired and undesired signal level ratio.

5.5 Hand-over procedure

A new speech channel is reassigned quickly and noiselessly to mobile stations in the following three conditions:

– the BS or MS detects *C/I* deterioration and the BS asks to the control stations for intra-zone hand-over;

– the base station detects *C/N* deterioration or excess *C/N* and the BS asks to the control stations for inter-zone hand-over.

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ANNEX 3

General description of the Nordic mobile telephone system (NMT)

1 Introduction

The development and specifications of the international Nordic mobile telephone system (NMT) has been carried out by cooperation between Denmark, Finland, Norway and Sweden. The international aspects of the system were taken into account from the very beginning, making the system a true international public land mobile network from the start, e.g. roaming between countries and full access to the international public switched telephone network and its services.

The rapid growth of the number of subscribers in the NMT-450 system in Nordic countries has led to the need for expanding the system into the 900 MHz band (NMT-900). Therefore, a new specification has been brought forward, taking the experiences for the NMT-450 into account.

Full detailed specifications for the system and their components are given in the reference list.

2 Technical characteristics

2.1 RF equipment requirements

In accordance with Recommendation ITU-R M.478, the adjacent-channel selectivity requirement and adjacent-channel power requirement are met at 25 kHz channel spacing.

2.2 Cell structure and channel reuse

It is possible to use large cells (20 - 40 km radius) in rural areas as well as small cells (down to 0.5 km radius) in urban areas. The base station receiver sensitivity can be adjusted for symmetry in coverage range for the two propagation directions taking base station (BS) and mobile station (MS) ERPs and (MS) receiver sensitivity into account.

In peak traffic density areas (e.g. city centres) it is possible to use a "sector" cell structure with directional antennas and a channel concentration at the centre of the traffic peak area.

2.3 Control signals

The use of 1 200 bit/s FFSK signalling enables generation and detection of the FFSK signal at the mobile service switching centre (MSC) and the use of ordinary telephone network circuits to convey the FFSK baseband signal. At the base stations, the FFSK baseband signal is processed by the ordinary audio signal circuits (including pre- and de-emphasis). The same signalling is used to control BS channel equipment.

The capacity of the control signal is large enough to handle the traffic of at least 25 000 mobile stations per location area (LA) with a traffic load of 0.015 erlang per mobile station.

3 Operational characteristics

3.1 Channel search procedure

All channels may be used as calling channels (CC) or traffic channels (TC). The CC of a base station is used mainly to page the mobile stations on calls from the PSTN while the TCs are used to handle the calls and for the call set-up procedure for calls from a mobile station.

The channel search procedure of a mobile station is carried out in order to find either a new CC (current CC may be changed either because current base station has chosen a new CC or when entering a new cell) or to find an idle TC on call set-up.

The channel locking criteria is set in accordance with the frequency planning criteria. The scan of the band is performed at three receiver sensitivity levels.

3.2 Location registration (roaming)

The mobile station initiates the location registration procedure when necessary. Full automatic roaming is implemented between mobile service switching centres (MSC) and between countries in accordance with Recommen- dation ITU-R M.624.

3.3 Call set-up procedure to MS

The MS is locked to a CC of a base station in the LA where it was last updated in the system. A paging call is transmitted on the CC of all base stations in the area location. On reception of the call, the MS transmits an acknowledgement on the return frequency of the CC of the current base station. On reception of this signal, the MSC sends a channel switching order to an idle TC on that base station and the call is established on that channel.

3.4 Call set-up procedure from MS

MS searches for a free-marked TC (NMT-450 and NMT-900) or an access channel (NMT-900). The channel is seized by transmitting a call set-up request on that channel.

3.5 Speech channel supervision

During a call, one out of four supervisory tones with a frequency of about 4 000 Hz and a deviation of ±300 Hz is inserted by the BS together with the voice signal. This tone is looped by the MS and the quality of the tone after looping is evaluated by the BS.

3.6 Hand-over procedure

The quality of an ongoing call is continuously supervised by the BS using measurements of RF signal level (NMT-900) and supervisory tone quality (NMT-450 and NMT-900). Should the quality fall below a preset level, the mobile service switching centre (MSC) is informed. The MSC will order neighbouring base stations (up to 16) to measure the signal quality on the used TC of the old BS, using a special measuring receiver, tuneable to all channels. The measuring results from all neighbouring base stations is evaluated by the MSC. If one of the neighbouring base stations provides better reception than the current one, the MSC will allocate a free TC on the new BS for the call, send a channel switch order to the MS on the TC in use for the call on the old BS and reroute the call to the allocated TC on the new BS. Hand-over can also be carried out between base stations in adjacent location areas.

3.7 Call release procedure

Calls are released immediately upon reception of clearing signal from the mobile station. If the PSTN party hangs up but not the mobile station, the normal time-out function of the PSTN clears the call. Forced call clearing is carried out if the signal quality at the base station falls below a preset level for more than 20 s and hand-over is impossible. In the mobile station, there is an autonomous time-out, switching the transmitter off when the RF signal level is below a certain level for more than 30 s.

3.8 Numbering plan

In accordance with ITU-T Recommendation E.213, the mobile station is identified in the public land mobile network (PLMN) by a unique seven-digit mobile subscriber number. In NMT-900 the mobile subscriber number is extended with a secret three-digit password.

3.9 Signalling between MSCs and PSTN interface

ITU-T Signalling System No. 7, permitting hand-over between MSCs by use of mobile use part (MUP), or ITU-T Signalling System R2.

The PSTN interface is in accordance with ITU-T Recommendation Q.70. The differences between various national PSTNs are covered by the MSC. Connection to the PSTN is made on trunk exchange level. MSC and trunk exchange can be integrated.

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	3	Technical specification for the mobile station, NMT Document 3
	4	Technical specification for the base station equipment, NMT Document 3
NMT-900	1	System description, NMT Document 900-1
	2	Technical specification for the mobile telephone exchange, NMT Document 900-2
	3	Technical specification for Signalling System No. 7 mobile user part, NMT Document 900-2, Annex 3
	4	Technical specification for the mobile station, NMT Document 900-3
	5	Technical specification for the base station equipment, NMT Document 900-4
	6	Technical specification for the system simulator, NMT Document 900-5

Available at any of the Telecommunications Administrations of Denmark, Finland, Norway and Sweden.

ANNEX 4

General description of the C450 system

1 Summary

The C450 system design combines optimum transmission quality and high capacity with very efficient utilization of the frequency spectrum. This is achieved by adaptive power control, distance measurements for cell assignment and hand-over and special switching capabilities like off-air call set-up and queueing operation. All relevant ITU-R and ITU-T Recommendations are met.

2 Radio-frequency interface

The radio-frequency interface is consistent with Recommendation ITU-R M.478. The system is designed for 20 kHz channel spacing and adjacent channels can be operated at one base station. Channel addresses for 25 kHz spacing are also provided in the equipment, as well as for 10 kHz and 12.5 kHz interleaved channels.

3 Permanent control of connection

Traffic channels have a permanent digital sub-channel control for continuous identification, power and signal quality control, etc. The power of base and mobile transmitters is adaptively controlled with 8 steps over a range of 35 dB.

Field strength and signal-to-noise ratio (phase jitter) are monitored for transmission quality assessment, both from the mobile and base station. As soon as the quality tolerances are violated, an intra-cell hand-over to another channel will be initiated.

During connection, the distance of a mobile station is continuously determined from its base station, and this information is transmitted on the digital sub-channel. By means of a special scanning receiver, each base station observes field strength and distance information of mobile stations in neighbouring base station areas as these approach the boundary of its own cell. In this way, the hand-over is prepared, and will be effected when the boundary is passed. The use of a channel is thus restricted to the defined base station area, which improves channel reuse and spectrum utilization.

A permanent exchange of identifications between mobile and base station prohibits another mobile station from accidentally entering into the connection.

The digital sub-channel is provided by time compression of speech signals, leaving 1.14 ms for the data burst within a period of 12.5 ms. Time compression has no perceptible influence on speech quality.

4 TDMA common control channel

All base stations of the C450 system operate on a common time-shared control channel, so that the mobile station can compare signals of the surrounding cells. The right base station is selected, either by comparison of relative distance (delay) - which is the preferred mode of selection - or by field-strength measurement. Each base station uses 1 time slot out of 32. In areas with high traffic, additional frequency channels can be added for common control (roaming), up to a total number of eight. The switch-over from the first common control channel, which is used in the whole service area, to another control channel is initiated by command from the relevant base station.

The TDMA frame with 2.4 s duration consists of 32 time slots, each containing 396 bits.

If a base station is in the status "blocked waiting queue", the mobile stations will check surrounding cells to determine whether support is possible.

5 Identification of mobile and base station

Mobile station:

–	nationality	3 bits
–	home mobile switching centre	5 bits
–	remaining digits of subscriber number	16 bits

Base station:

–	nationality	3 bits
–	number of mobile switching centre	5 bits
–	remaining digits	16 bits

Up to 16 decimal digits are transmitted in one message.

6 Location registers

Location registration is consistent with Recommendation ITU-R M.624. There are three types of location registers.

The home mobile switching centre (MSC) has a file of all subscribers assigned to its area, with the following features: class of mobile station, priority status, roaming location, etc.

The visited mobile switching centre keeps a file of the active mobile stations including those originating from other MSCs.

The base station contains a register of active mobile stations within its cell boundaries. On average once in every 4 min, the mobile stations are polled and requested to answer to the base station. This updating procedure discovers the switched-off mobile stations and avoids "dead" entries in the file.

7 Security

Personal subscriber identification cards are used to allow operation of different mobile stations by the same subscriber. The call charge is assigned to the holder of the card. A special security code prohibits the use of lost cards by unauthorized users.

Privacy is provided by means of inversion of the audio-frequency band. For data transmission, this band inversion can be switched off at the mobile station.

The mobile station has a built-in monitoring function which will shut down the transmitter when a severe malfunction occurs.

8 Switching capabilities

ITU-T Signalling System No. 7 is used between base station and mobile switching centre. The numbering plan is in accordance with ITU-T Recommendation E.213. The PSTN interface complies with ITU-T Recommendation Q.70.

The time slot capacity of the common control channel is designed for a minimum percentage of access collisions. All other message dialogues are performed under control of the base station.

Optimum utilization of the speech channels is obtained by queueing and off-air call set-up during traffic peaks.

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ANNEX 5

General description of the total access communication system (TACS)

1 Operational and system characteristics

1.1 Purpose

The public land mobile network (PLMN) is designed to permit an automatic exchange of traffic with the public switched telephone network (PSTN) and offers service, from the user's point-of-view, similar to that of land-line calls: high voice quality, high reliability, low blocking, relatively low cost.

1.2 Cellular properties

– Growth from large cells at start-up to small cells at maturity, with a mix of several sizes, is permitted.

– Hand-over is allowed, up to at least one per call per minute.

– For spectrum efficiency (channel reuse), small values for the number of channel sets are used, appropriate to the multipath (Rayleigh) fading typical of mobile channels, the terrain variability, the antenna patterns selected, and the RF quality desired. A local median *C/I* target of 17 dB at the 90th percentile is suggested. (If the standard deviation is 8 dB, this is equivalent to a median *C/I* of 27 dB, at the nominal boundary of the cell.) Other quality objectives are of course permissible.

– Enhanced mobile station registration techniques are employed to allow automatic roaming both nationally and internationally.

1.3 Signal processing

– The widest deviation and receiver predetection bandwidth appropriate to the cellular concept (which permits separation of the spectrum into channels by both frequency division and spatial separation) are used.

– Voice processing using a 2:1 compressor/expandor is employed to enhance the perceived quality of the received signal.

– The coding of digital signalling uses burst-error detection and correction.

– Design for a peak-to-r.m.s. ratio of between 6 dB and 20 dB for the demodulated voice signal at the receiver is possible; that is, a range of quality comparable to land-line service should be accommodated.

1.4 Service protection

– A transmitted serial number prohibits the use of stolen units or use by unauthorized callers.

– The introduction of means to ensure privacy of communication is not precluded by the design.

– Means for preventing intelligible cross-talk is included in the system design.

– The successful completion of the entire call takes place on at least 99% of the calls on which an initial two-way connection was established between calling and called parties.

1.5 Services offered

– Voice message telephone service with automatic calling to and from the PSTN and other mobile users.

– Data services.

– Vehicular-mounted equipment.

– Transportable equipment.

– Hand-held equipment.

– Other enhancements consistent with mobile service: call forwarding, repertory dialling, message waiting, etc.

– Charging information transmitted during a call to allow direct display of call charges: coin-box mobiles, taxi phones, etc. are thus facilitated.

2 RF parameters

The major RF parameters of the system are detailed in Table I of Part C of this Report.

Other specific RF parameters are as follows:

2.1 Modulation characteristics

The peak FM deviation is around twice that normally associated with 25 kHz channel spacing. This has the major advantage of an improved resistance to co-channel interference, the minimum usable mean carrier-to-interference (*C/I*) ratio being around 10 dB rather than 15 dB. This means that for the voice quality, a shorter frequency reuse distance, and hence a smaller frequency reuse pattern, can be employed. There is the effect, however, that adjacent channels cannot be used in the same cell, but this is not a problem for cellular radio systems because only a small proportion of the available channels (typically 1/7th) is used in any one cell.

2.2 Total number of channels - up to 1 000

2.3 Control channels

In order to allow for more than one system operator in a given location, two sets of dedicated control channels are identified. There are 21 control channels in each set and each block of control channels is contiguous.

The dedicated control channels for system A are channels 23 to 43.

The dedicated control channels for system B are channels 323 to 343.

2.4 Mobile station power

There are four classes of mobile stations corresponding to the following powers:

TABLE 3

Class of station	Type of mobile station	Nominal ERP (W)
1	Very high power mobile	10
2	High power mobile	4
3	Mid-range power hand portable	1.6
4	Low power hand portable	0.6

Adaptive power control is employed with 7 steps of 4/8 dB.

2.5 Supervisory tones

Supervisory audio tones (SAT) are sent by the system over an assigned voice channel and transponded by the mobile station on the duplex voice channel forming a closed identification loop.

SAT frequencies - 5 970 Hz; 6 000 Hz; 6 030 Hz.

Signalling tone (ST) is an 8 kHz tone transmitted on the assigned voice channel from mobile to base station. It is sent to indicate the status of the mobile handset:

– handset on hook – tone sent;

– handset off hook – tone not sent.

3 Signalling code and format

Signalling occurs in both directions on control channels and voice channels to ensure that the mobile station is always under system control. All data is generated at an 8 kbit/s rate.

Each of the four signalling paths carry different types of information and their operational conditions differ, this would require many compromises if a common signalling format were adopted. Each path is therefore treated independently.

Synchronization (sync.) sequences are chosen to minimize the risk of a random appearance within the data, and to provide sufficient time for the mobile/base station equipment to achieve sync. With the exception of the forward control channel (FOCC), used by the base station, transmission occurs as a burst of data when required.

All channels are subject to fading and interference. To give adequate error protection, each data word is transmitted a number of times and incorporates forward error correction bits to ensure integrity. At the receiving end, the repeats are stored sequentially and a majority decision made bit-by-bit on five stored words (the eleven repeats sent on the forward voice channel ensure that at least five will be received by the mobile station).

A BCH code generator is used to produce 12 bits of parity which are added to the end of the data to produce the overall data word. The forward channels (FOCC; FVC) use 28 information bits and 12 parity bits per word, the reverse channels (RECC; RVC) have 36 information bits and 12 parity bits per word. This code structure is capable of correcting 1 bit error and detecting 4 bit errors.

Transmission of control data over the voice channels (FVC; RVC) is accomplished by muting the audio paths while transmitting the data burst. This is a very short duration activity not noticeable to the user.

Before FSK transmission, the data is Manchester encoded. This ensures that sufficient data transitions occur to permit accurate bit synchronization within the signal. This is particularly necessary for synchronizing sequences with large strings of zeros and ones.

The data words are complex packets of information subdivided into groups of bits or single bits each defining a system parameter: serial number, dialled digit, etc. The exact format within a word is dependent on the type of channel in use and the type of message.

4 International mobile station identity

A 34 bit binary mobile identification number is derived from the 10 digit international mobile station identity which comprises a 3-digit mobile counting code, a 1-digit mobile network code and a 6-digit mobile station identification number (see ITU-T Recommendation E.212).

A unique 32 bit binary serial number is assigned to each mobile station. The number is non-changeable and is intended as an anti-fraud, anti-theft means.

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ANNEX 6

General description of the Italian 450 MHz system

1 System structure

The Italian territory is subdivided into ten calling areas. A calling area is characterized by a single calling channel; calls to mobile stations present in that area are transmitted in a simulcast mode by all the base stations included in that area. Adjacent calling areas use different calling channels. The same calling channel is reused in distant calling areas.

Calls directed to mobile stations are routed through the main mobile control centre (MMCC) of the calling area where the mobile station is present.

When a mobile station crosses the border between two calling areas, it automatically informs the MMCC of the new calling area of its presence. This MMCC will update the location registration of all the other MMCCs, so that each MMCC knows the calling area in which each subscriber is present.

A calling area may either be coincident with a conversation area or subdivided in some conversation areas. A conversation area is characterized by the fact that mobile station originated calls enter the telephone network directly in the satellite mobile control centre (SMCC) of the conversation area, apart from the conversation area where the MMCC is located. The hand-over procedure is only possible within a conversation area. Each conversation area will include several base stations in order to cover the most populated areas and the main roads.

The Italian territory will be subdivided into 16 conversation areas; the average size of a conversation area will be about 20 000 km^2.

The MMCCs and the SMCCs will be connected to the tertiary centres of the telephone network.

2 Radio-frequency characteristics

2.1 Frequency band

The system is planned to operate in the 450 MHz band. There are 200 duplex channels, the highest four channels are utilized as unidirectional calling channels.

2.2 Base stations and channel grouping

Each base station will be equipped with a redundant calling transmitter, two monitor receivers utilized for the hand-over procedure and a number of traffic transceivers dependent on the traffic expected in the coverage area of the base station.

The maximum number of duplex channels for each station will be 64; several groups of 64 channels can be used at the same site. Traffic channels utilizing the same antenna system are usually grouped in a self-masking intermodulation arrangement. Normally eight channels with equal spacing of 600 kHz are grouped together; such a spacing allows the utilization of small transmit branching filters.

2.3 Transceiver characteristics

Most transceiver performances are in line with those of equipment utilized in other advanced public mobile systems. However, it seems suitable, from the system point of view, to mention the following characteristics:

– the nominal output power of the base station transmitters is 25 W and that of the mobile transmitter 10 W. A 10 dB reduction of the output power is possible. The power reduction of the mobile station is automatic;

– a syllabic compandor is utilized in both directions of transmission in order to improve speech quality;

– band inverters are provided which can be inserted and deactivated by the mobile subscriber during the conversation.

3 Numbering and call procedures

3.1 Numbering

The national telephone number of a mobile station consists of a service access code "0333" followed by a six digit subscriber number. The first of the six digits is the same for all the subscribers, and is utilized for control purposes, the second and third digits are related to the MMCC to which the subscriber belongs.

Usually the telephone number is the same as the mobile station identification number; however, there is the possibility for about 10% of subscribers to have an identification number different from the mobile station telephone number; this possibility allows a subscriber whose mobile equipment has been stolen, to keep the same telephone number.

3.2 Call to a mobile subscriber

A call to a mobile subscriber is made by dialling his telephone number, including the service code. The service code connects the calling party to the nearest MMCC. This MMCC analyses the mobile station number with regard to validity, subscriber category and location registration. If the mobile station is in another calling area the call is routed to the corresponding MMCC.

The MMCC of the calling area where the mobile station is present, pages it though all the calling transmitters included in that area.

When the mobile station receives its identification, it starts to search for an idle traffic channel with the same procedure as for mobile station originated calls (see § 3.3). When a free traffic channel is found, the mobile station identification and the acknowledgement signal are transmitted. If the MMCC does not receive the acknowledgement within 10 s, it sends a second paging call.

3.3 Mobile station originated calls

The preseizure dialling, or off-air call set-up, is employed in order to reduce the channel occupancy due to dialling information. The mobile station searches for a free traffic channel with the double threshold search; in the first attempt a search is only made for a good quality free traffic channel, in the second attempt a search is made for a channel with only acceptable quality. The double threshold search improves the system quality and reduces the number of hand-over events.

Once a traffic channel is found, the mobile station identification and the dialled number are transmitted. The SMCC or the MMCC analyses the subscriber validity and category and then the call is set up.

4 Hand-over

If during the conversation the quality falls below a given value, the involved base station informs the corresponding SMCC or MMCC which will initiate the hand-over procedure by ordering a field-strength measurement on the relevant traffic channel to the monitoring receivers of adjacent base stations. If one of the base stations offers better transmission quality and at least one traffic channel is free in that station, a command is sent to the mobile station via the previous traffic channel to switch to the new channel.

A confirmation from the mobile station is sent on the new channel and then the switch-over is completed by the control centre.

5 Signalling on the radio path

The main signalling utilized in the radio path is a two-of-seven in band multifrequency code suitable for operation in a mobile service environment. It has been derived from the code already used in the first generation Italian system for which a long field experience has been gained.

A low frequency pilot with amplitude modulation is used for information that is transmitted during conversation, e.g. band inverter insertion and deactivation command, and call charge pulses to the mobile station.

Up to three different audio-frequency pilots can be utilized to identify the same (frequency) channel employed in the three different adjacent clusters.

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ANNEX 7

General description of the French national system

1 Frequency band and class of emission

The system uses blocks of channels (up to 256 per block) with a channel spacing of 12.5 kHz, class of emission 11K0G3E. The frequency bands used in France are the 200 MHz (duplex spacing 8 MHz) and 400 MHz (duplex spacing 10 MHz) bands.

2 Signalling

FFSK modulation at 1 200 bit/s; Hagelbarger coding.

3 Characteristics of the mobile stations

The station may be multi-service or only offer some of the services described in § 2 of Part C of this Report.

The mobile station has access to 256 channels.

4 Characteristics of the base stations

The base station comprises a switching unit connected to the PSTN as a time-division PABX with automatic direct routing capabilities ("direct dialling-in").

The base station may have up to 24 transceivers cavity coupled to two or three antennas. The radio channels are managed by queueing. Off-air call set-up is used.

5 Architecture of the system

The PSTN switching exchanges are connected by PCM links to the relays which are comprised of the relay management unit, the switching and radio units. Remote radio units may be connected to the relays, for instance to cover low density areas.

Information exchange and rerouting are carried out using the PSTN.

6 Capacity of the system

The numbering plan provides for 500 000 subscribers.

7 Frequency efficiency

A block of 256 channels in a cell may service 7 000 public telephone type subscribers, 20 000 dispatch type subscribers or any combination of these two types.

8 Charging

Charging is carried out by the relays, and then retransmitted by 1 200 bit/s links to an operating centre.

9 Commissioning

Operation started at the end of 1985, and the total subscribers were 100 000 at the beginning of 1989 and 150 000 on 1 October 1989.

It is foreseen that 85% of the surface area of metropolitan France will be covered, and 98% of the French population at the end of 1990.

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ANNEX 8

General description of narrow-band North American system (N-AMPS)

1 Introduction

Narrow-band analogue technology was addressed by the United States TIA Standards Subcommittee TR45.1, in 1992. A standard was developed and approved in November, 1992, and published as IS-88. The purpose of the narrow-band standard is to provide a cellular air interface with voice quality comparable to AMPS, but with voice channels occupying 1/3 the bandwidth of AMPS, thereby allowing significant system capacity improvements. The IS-88 standard is based upon the EIA/TIA-553 analogue air interface standard. Extended Protocol, contained in EIA/TIA-553, is used to allow the serving system and the mobile to signal to each other, their ability to support narrow-band voice channels. Two additional enhancements incorporated in IS-88 are 1) MRI, or "mobile reported interference", a technique allowing maintenance of improved audio quality through detection and reporting (by mobile unit) of channel impairments due to interference; and 2) addition of special services such as short message service (14 character text message); and CLI (calling line indicator).

This standard is a "dual-mode" standard. Signalling for access and call setup are accomplished on 30 kHz AMPS control channels, and assignment to narrow-band voice channels is made only if the mobile unit and the serving system, are capable of supporting the narrow-band mode. Therefore, compatibility with exiting AMPS systems and subscriber equipment is maintained.

2 Technical characteristics

Channel parameters (shown with AMPS for comparison)

Parameter	Narrow-band analogue	AMPS
Channel spacing	10 kHz	30 kHz
Frequency stability	1 p.p.m.	2.5 p.p.m.
Supervisory deviation	700 Hz	2 kHz
Peak voice deviation	5 kHz	12 kHz
Average voice deviation	1.5 kHz	2.9 kHz
Paging and access bit rate	100 kbit/s Manchester	10 kbit/s Manchester
Voice channel signalling	100 bit/s Manchester	10 kbit/s Manchester
Supervisory signalling	200 bit/s NRZ (sub-audible)	6 kHz tone
SAR scheme	7 data words	3 tones

3 References

TIA/EIA IS-88 Mobile station-land station compatibility standard for dual mode narrow-band analogue cellular technology.

TIA/EIA IS-89 Recommended minimum standard for 800 MHz, dual mode narrow-band analogue cellular land station.

TIA/EIA IS-90 Recommended minimum standard for 800 MHz, dual mode narrow-band analogue cellular subscriber units.