RECOMMENDATION ITU-R M.687-2

INTERNATIONAL MOBILE TELECOMMUNICATIONS-2000 (IMT-2000)*

(Question ITU-R 39/8)

(1990-1992-1997)

Summary

This Recommendation defines the objectives to be met by IMT-2000 and provides the overall IMT-2000 concepts with particular consideration to achieving worldwide roaming and compatibility.

This Recommendation provides a high level statement on the topics of: services, architecture, network aspects, implementation, sharing and operational characteristics. Guidance is provided, for a limited number of possible scenarios, on spectrum bandwidth and band of operation based on critical technical parameters and traffic estimates.

It forms a foundation for the subject of IMT-2000 and for the subsequent work activities and Recommendations.

The ITU Radiocommunication Assembly,

considering

a) Resolution 212 (Rev.WRC-95);

b) that the frequency bands 1 885-2 025 MHz and 2 110-2 200 MHz are intended for use, on a worldwide basis, by administrations wishing to implement the International Mobile Telecommunications-2000 (IMT-2000);

c) that the cost of radio and very large scale integration (VLSI) technology is continually decreasing, thus making competitive, in a number of cases, the alternative option of a radio approach for accessing voice and non-voice telecommunication services;

d) that different future systems are under study;

e) that system compatibility is necessary for international operation, and that commonality is desirable in any event to ensure that the overall system cost per mobile user is significantly less than it is with present systems;

f) the need for a flexible system structure able to match network investment to revenue growth, to adapt readily to environmental factors and to respond to new developments without restricting innovation;

g) the possible need for common channels or frequency bands to allow regional and/or worldwide operation, particularly with the increasing use of personal (hand-held, portable) terminals;

h) that the use of internationally agreed frequency bands also facilitates the planning of national networks and reduces the risk of harmful interference with other radio services;

j) the increasing importance of the various types of non-voice telecommunication services;

k) the relevant ITU-T Recommendations and on-going studies;

l) that mobile terminals of the IMT-2000 may be used to access mobile satellite systems for use on land, ships and aircraft;

m) that there is a need for mobile terminals to roam between public land mobile telecommunication networks in different countries;

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* IMT-2000 was previously known as Future Public Land Mobile Telecommunications Systems (FPLMTS).

n) that a standardized radio interface would facilitate the roaming of mobile units between networks;

o) that users may want to be able to use the same terminals and procedures as in the fixed networks (public switched telephone network (PSTN), public data network (PDN) and integrated services digital network (ISDN)) to access similar telecommunication services in IMT-2000;

p) that the application of cellular type mobile radiocommunication systems for use as fixed systems and their adaptation to the needs of developing countries is under study;

q) that the description of IMT-2000 will comprise a number of Recommendations for which this one is the key;

r) that IMT-2000 are expected to be used by a large proportion of the general public,

recommends

that IMT-2000 intended for regional and/or worldwide use should conform to the following objectives and characteristics.

1 Objectives

1.1 General objectives

IMT-2000 aim to achieve the following primary general objectives:

1.1.1 to make available to users who are on the move or whose location may change (mobile users), irrespective of their location (i.e. national and international roaming), a wide range of telecommunication services (voice and non-voice), allowing communication between mobile users and other mobile users, users of the fixed public networks (PSTN, PDNs and ISDN) or other telecommunication networks as appropriate;

1.1.2 to provide these services over a wide range of user densities and geographic coverage areas;

1.1.3 to make efficient and economical use of the radio spectrum consistent with providing service at an acceptable cost;

1.1.4 to provide, as far as practical, services with a quality of service comparable to the fixed networks;

1.1.5 to provide for the continuing flexible extension of service provision, subject to the constraints of radio transmission, spectrum efficiency and system economics;

1.1.6 to adopt a phased approach for the definition of IMT-2000. The first phase (Phase 1) includes those services supported by user bit rates up to approximately 2 Mbit/s. Phase 2 is envisaged as augmenting Phase 1 with new services, some of which may require higher bit rates;

1.1.7 to permit the use of the IMT-2000 for the purpose of providing its services to fixed users, under conditions approved by the appropriate national or regional authority, either permanently or temporarily, either in rural or urban areas;

1.1.8 to accommodate a variety of mobile terminals ranging from those which are small enough to be easily carried on the person (the personal pocket radio) to those which are mounted in a vehicle;

1.1.9 to admit the provision of service by more than one network in any area of coverage;

1.1.10 to provide an open architecture which will permit the easy introduction of technology advancements, as well as different applications;

1.1.11 to allow the coexistence with, and interconnection with, mobile systems which use direct satellite links taking into consideration ITU-T Recommendation E.171;

1.1.12 to provide a modular structure which will allow the system to start from as small and simple configuration as possible and grow as needed, both in size and complexity within practical limits.

1.2 Technical objectives

IMT-2000 aim to achieve the following primary technical objectives:

1.2.1 to support integrated communication and signalling;

1.2.2 to establish signalling interface standards, taking into account the principles established by ITU-T Recommendation X.200, and based on the relevant ITU-T signalling Recommendations.

IMT-2000 aim to achieve the following secondary technical objectives:

1.2.3 to provide for additional levels of security (for voice and data services) compared to that contained in § 1.1.4. In addition, to allow for the provision of end-to-end encryption for voice and data services;

1.2.4 to provide service flexibility which permits the optional integration of services such as mobile telephone, dispatch, paging and data communication, or any combination thereof;

1.2.5 to support terminal equipment interfaces (and procedures) defined for the fixed public networks which allow the alternative use of terminal equipment in the fixed public networks;

1.2.6 to support equipment and component design that can withstand typical rural conditions (rough roads, dusty environment, extreme temperatures and humidity, etc.);

1.2.7 to accommodate the use of repeaters for covering long distances between terminals and base stations, providing this does not constrain the specification of the radio interfaces;

1.2.8 to allow the connection of PABXs or small rural exchanges to mobile stations;

1.2.9 procedures used in IMT-2000 should be based on the unique identification of the entities (e.g. service providers, network operators, etc.) involved.

1.3 Operational objectives

IMT-2000 aim to achieve the following primary operational objectives:

1.3.1 to provide for the required user authentication and billing functions;

1.3.2 to provide for unique user identification and numbering in accordance with appropriate ITU-T Recommendations;

1.3.3 to provide for a unique equipment identification scheme;

1.3.4 to enable each mobile user to request particular services, and initiate and receive calls, as desired. These calls for a given mobile user, incoming or outgoing at the same mobile termination, may be simultaneously multiple and associated to different services (i.e., advanced voice and data services including multimedia);

1.3.5 to ensure that the opportunity for fraud in IMT-2000 is minimized, e.g. by restricting services such as multiple call forwarding which are prone to fraud;

1.3.6 to ensure that the theft of IMT-2000 mobile stations is minimized, e.g. by maintaining a list of stolen mobile station identities and monitoring traffic for their use;

1.3.7 to minimize theft, fraud and also abuse of the emergency service by malicious calls, by having available relevant information for use by the appropriate authorities;

1.3.8 to aid the emergency services by providing additional emergency call information as far as possible, e.g. user identity, location information, and other information that may be required by national or local authorities.

IMT-2000 aim to achieve the following secondary operational objectives:

1.3.9 to provide an indication to the paying party of eventual added call charges, e.g. due to roaming;

1.3.10 to allow the system to be configured for special conditions where mobility between cells, or even within a cell, is not required; or where a high traffic per user is required;

1.3.11 to take account of the communications requirements for road traffic management and control systems;

1.3.12 to allow for extension of the cell size in rural or remote areas, providing this does not constrain the specification of the radio interfaces.

2 Services

2.1 General

2.1.1 IMT-2000 should offer the services available in the fixed public networks (PSTN, ISDN and PDNs), as far as possible, bearing in mind the differences in the characteristics of the fixed networks and mobile radio environment.

2.1.2 IMT-2000 may also offer additional services, taking into account the special nature of mobile communications.

2.1.3 IMT-2000 should be designed in such a way that the calling subscriber does not have to know the location of the mobile.

2.1.4 It should be possible for stations in IMT-2000 to be used in the maritime and aeronautical environment, to the extent permitted by national or international regulatory authorities.

2.1.5 It should be possible for IMT-2000 to be used as a temporary or permanent substitute to fixed networks where fixed network facilities are limited or not available, or more generally where reasons of convenience or economics make this desirable. The system should then be capable of adaptation to these conditions (i.e. higher traffic per subscriber, no mobility between cells or even within a cell).

2.1.6 To support user mobility by registration on different terminals (e.g. by the use of a user identity module – UIM).

2.1.7 To support an open market place for the independent purchase of subscriptions and mobile terminals (e.g. by the use of a UIM).

2.1.8 IMT-2000 should be designed to allow international operation and automatic roaming of mobile subscribers and stations. (The degree to which the roaming facility between networks or countries shall be automatic is for further study).

2.1.9 IMT-2000 should be designed so that under favourable circumstances services requiring high information rates can be provided.

2.1.10 IMT-2000 should be capable of providing service to a variety of mobile terminals ranging from those which are small enough to be easily carried on the person to those which are mounted in a vehicle.

2.1.11 Recommendation ITU-R M.816 contains the framework for the definition of the services to be supported in IMT-2000.

3 Frequency band considerations

3.1 General considerations

Considerations on spectrum should take into account the estimated traffic, the available and foreseeable techniques, the propagation characteristics and time scale for meeting the users' needs to the greatest possible extent.

Considerations on frequency matters should take into account that the traffic generated by mobile systems, as well as the number and diversity of services, will continue to grow.

3.2 Traffic considerations

Any estimation of the traffic should take into consideration that in the future, non-voice traffic will constitute an increasing proportion of the total traffic and that traffic will be generated outdoors as well as indoors by mobile and personal stations.

Annex 1 contains an estimation for traffic in IMT-2000 which is based on the current understanding of the nature of personal telecommunications.

3.3 Spectrum requirements

To comply with IMT-2000 service requirements, namely the concept of regional and/or worldwide roaming, inclusion at least partly of worldwide common frequency should be considered as the first choice to enable universal access particularly for personal stations.

3.3.1 Worldwide compatibility

The primary focus for worldwide compatibility, including common frequency band, is for the personal station where the benefits of worldwide compatibility have most impact. With respect to the mobile station, worldwide compatibility is desirable, but regional/international compatibility may be sufficient in a number of respects.

While a complete common frequency band is preferred, this may not be immediately feasible. A degree of commonality can be obtained through regional/international compatibility with a common signalling band and sufficient overlap of the traffic bands to ensure compatibility for roaming.

Common signalling and numbering standards are also essential.

Multiple standards hamper implementation in smaller markets and developing countries, resulting in poor spectrum utilization and higher costs.

3.3.1.1 Roaming requirements

Some users of IMT-2000 will require the ability for regional and/or international roaming using their own terminals.

In order to provide worldwide roaming capability, particularly for personal indoor and outdoor stations, it is preferred that full compatibility be maintained worldwide. One important requirement is that the band used for worldwide operation be within the frequency agility of the personal stations.

3.3.2 Satellite communications

IMT-2000 include a mobile-satellite component. Recommendation ITU-R M.818 describes this component. Figure 2 shows some configuration examples.

The use of spectrum in accordance with Resolution 212 (Rev.WRC-95) could enable a single equipment to use both terrestrial mobile and mobile satellite communications.

The satellite components may also support:

– a satellite paging function which could reduce the amount of location registration data to be transferred;

– paging terrestrial mobile users beyond the range of the terrestrial system. The equipment required for this one-way function is simpler than that for two-way mobile satellite function;

– linking remote base stations or where temporary (e.g. emergency) system extension is needed.

3.3.3 Duplex techniques

Frequency division duplex (FDD) and time division duplex (TDD) techniques are available. The choice of duplex technique does not affect the total amount of spectrum which is required for IMT-2000 traffic, but could affect frequency planning.

3.3.4 Propagation

Propagation in the 1 to 3 GHz band has been studied in outdoor and indoor conditions. As the frequency increases, the outdoor path attenuation increases. The multipath propagation effects increase with frequency. The outdoor delay time does not vary significantly over the range 1 to 3 GHz.

Measurements have shown that in a building the attenuation between floors increases with frequency; therefore, the frequency re-use in very small cells in buildings is made easier.

3.3.5 RF technology

The cost and power efficiency of the RF technology available to implement IMT-2000 hardware are both adversely affected as the frequency band of operation is increased. It is not currently clear what frequency limit there will be for integrated circuit technology, which will yield adequate performance in high volumes and low cost, in the late 1990s.

3.4 State of techniques

Estimation of spectrum needs should take into account the design of a system carrying traffic with high spectrum efficiency. To that effect speech and data transmissions should include good quality codecs associated with channel coding, modulation and equalization, multiple access techniques and adaptive techniques.

Traffic management techniques such as queueing should also be considered since they may be very effective in smoothing the offered traffic load, and hence substantially increase spectrum utilization efficiency, particularly when services with differing characteristics including significant non-voice traffic are integrated into a common radio system.

3.5 Estimation of spectrum needs

Annex 1 contains an estimation of the spectrum needs for some of the Phase 1 services of IMT-2000 based on traffic estimations in urban areas. The results obtained show that the bandwidth needed for voice services totals 162 MHz and, based only on limited data services, that the bandwidth needed for non-voice services totals 65 MHz; these figures should be considered minimum values.

As noted in Annex 1, this estimate does not include any provision for spectrum for traffic carried by satellites.

3.6 Consideration of sharing possibilities

Studies have been made of possibilities for IMT-2000 to share with other services. The results are given in Annex 2.

From these studies, IMT-2000 may be able to share band allocations with fixed and possibly other services only where there is suitable geographic separation between services, or where neither service requires the total allocated bandwidth. The economic cost associated with sharing has not been included in these considerations. The IMT-2000 with adaptive channel assignment will greatly facilitate sharing and will simplify the introduction of IMT-2000 into bands currently used by other services. The relative geographic separation required for the alternative IMT-2000 access techniques such as frequency division multiple access (FDMA), time division multiple access (TDMA) and code division multiple access (CDMA) will depend on detailed system parameters. However, it is emphasized that co-channel sharing between the fixed service and IMT-2000 requires adequate geographic separation.

It is also concluded that sharing is not feasible between R1 and R2 interfaces (see Fig. 1) of the IMT-2000 and the space research service (SRS), space operation service (SOS) and Earth exploration satellite service (EESS) in the 2 025-2 110 MHz and 2 200-2 290 MHz bands.

IMT-2000 should be an advanced system where control of the equipment will allow for adapting to various situations. In particular, dynamic power control and frequency agility would aid conformance with planning criteria and should be further investigated. Frequency sharing or coexistence with other radio services may be studied in more detail by developing suitable algorithms and models.

4 Technical characteristics

In order to provide for regional and/or worldwide station compatibility, uniformity of main characteristics including architecture, channel structure, control procedures, access techniques, modulation methods and data rates, should be applied.

4.1 System architecture

Recommendation ITU-R M.817 contains the functional network architectures and some of the resulting network configurations which are possible for IMT-2000.

4.2 Radio interfaces

The family of radio interfaces is:

R1: radio interface between a mobile station (MS) and the base station (BS);

R2: radio interface between a personal station (PS) and the personal base station (CS);

R3: radio interface between the satellite and the mobile earth station (MES). IMT-2000 may also allow for the automatic routing of traffic between terrestrial and mobile satellite systems;

R4: an additional radio interface used for alerting (e.g. paging) in the case of a call terminated at an IMT-2000 terminal.

It should be noted that it is not necessarily a complete list of all the radio interfaces.

A possible scenario for the evolution and implementation of personal communications within IMT-2000 is given in Figs. 1 and 2.

Taking into account the characteristics of areas where IMT-2000 is introduced, the system structure should be optimized according to the geographical coverage areas and traffic conditions. Therefore, plural air interfaces should be allowed in the design of systems.

The radio interface should be designed to allow different applications to use the same interface where this can be shown to be technically and economically feasible. If the same radio interface cannot be used for all applications then the individual interfaces should have maximum commonality to allow interworking with the minimum extra complexity.

4.2.1 Radio coverage of the service area

The aims of IMT-2000 should be:

4.2.1.1 to accommodate the possibility of more than one base station in a service area;

4.2.1.2 to allow handover from one channel to another between cells, and in the same cell, if necessary;

4.2.1.3 to allow for implementation of small cell sizes taking account of the need for rapid handover for moving users;

4.2.1.4 to allow re-use of the same channel assignment simultaneously by more than one cell and for more than one communication;

4.2.1.5 to be able to start with the fewest cells necessary to meet subscriber demands and grow as necessary, with the possibility of increasing the availability of equipment for interconnection along the different system interfaces;

4.2.1.6 to provide for adequate coverage to include portable units outdoors and in buildings, both single-storey and multi-storey;

4.2.1.7 to minimize the complexity of any radio network planning, taking into consideration radio propagation variations in different environments and locations.

4.2.2 Signalling functional structure of mobile terminals (MS/PS/MES/PES)

Among the logical signalling functions, either integrated or separated, the following should be provided by IMT-2000:

– call control,

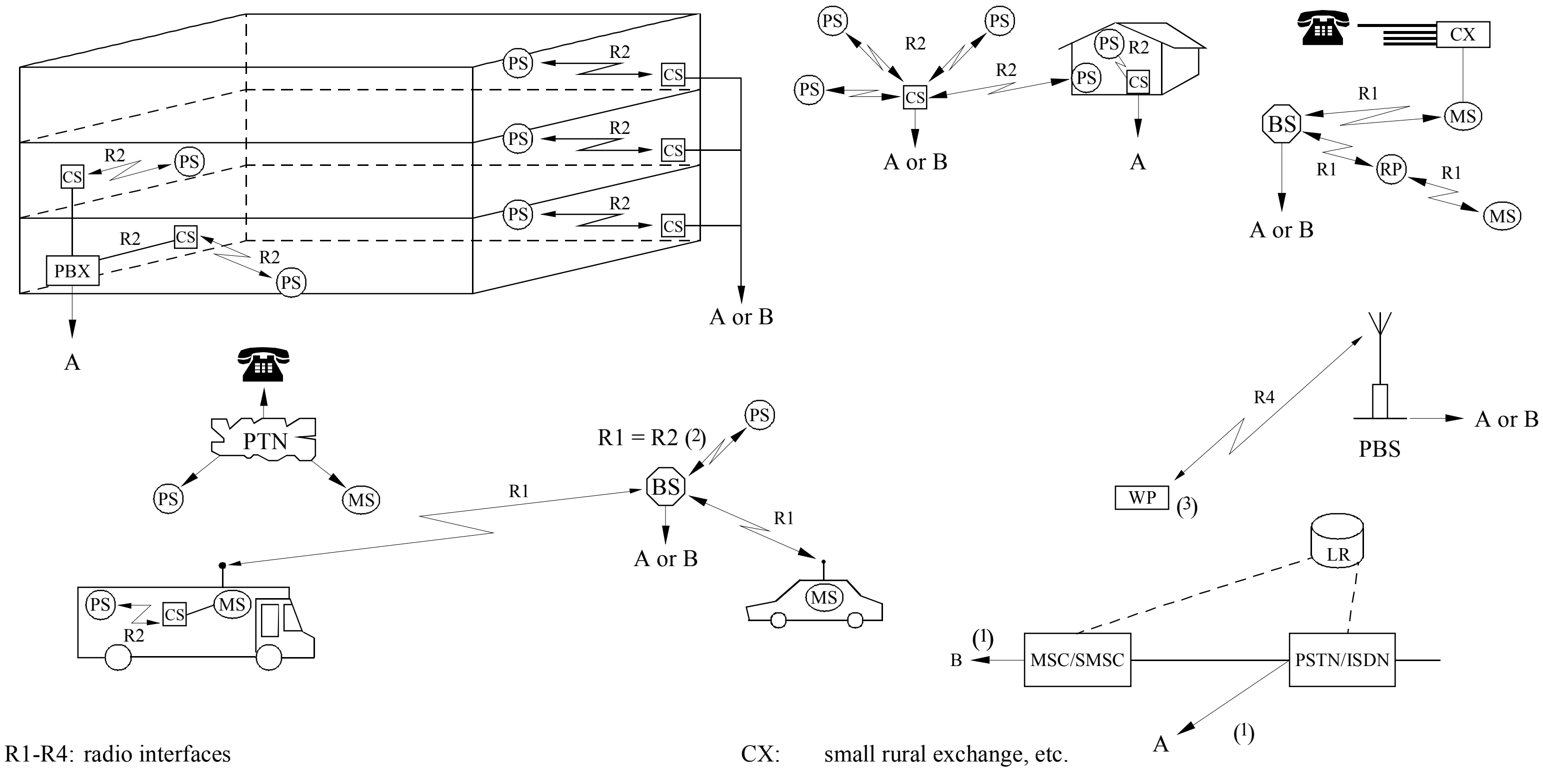
– IMT-2000 call control adaptation,

– mobility management,

– channel and RF transmission management.

FIGURE 1

Scenario for personal communications within IMT-2000 (terrestrial component)



R1-R4: radio interfaces
PS: personal station (R2)
CS: personal base station (cell site for PSs)
MS: mobile station (R1)
BS: base station (for MSs)
MSC: mobile services switching centre
SMSC: satellite mobile services switching centre
LR: location register

CX: small rural exchange, etc.
PBX: private exchange
RP: repeater
PTM: personal telecommunications number service
PBS: paging base station
WP: wide area pager (R4)
☎ telephone

(1) Access to and the scope of the location registration functions will vary with system evolution and network operator requirements. This is reflected in network interfaces A and B.
(2) In some implementation scenarios R1 may equal R2.
(3) Can be co-located/integrated with the PS.

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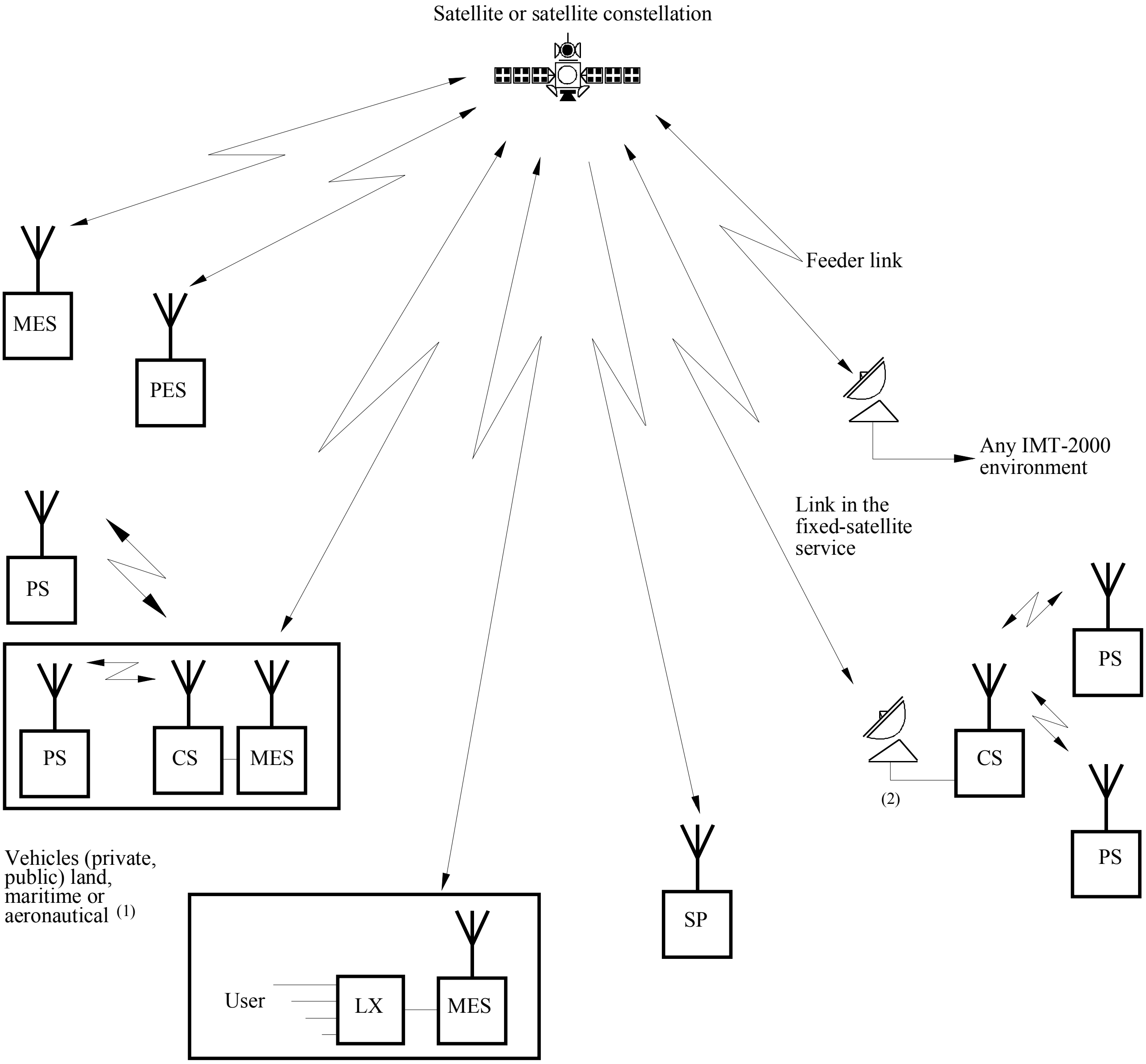
FIGURE 2

Some configuration examples for the satellite component of IMT-2000



PES: personal earth station (hand held)
MES: mobile earth station
SP: satellite pager
CS: cell station
LX: local exchange
PS: personal station

(1) The use of IMT-2000 stations aboard an aircraft may not be allowed because of potential harmful interference to the aircraft electronic systems.

(2) Fixed earth station.

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4.3 Quality of service

IMT-2000 should provide a level of service quality comparable to the PSTN/ISDN within the limitations set by the radio channel. Determination of the quality of a telecommunication service should include consideration of the following:

– transmission quality:
  – *S*/*N* and *S*/*I*,
  – service area reliability,
– blocking probability,
– cut off probability, such as cut off probability due to handover blocking,
– channel assignment strategies and call control thresholds,
– handover,
– initial connection delay,
– system reliability.

4.3.1 Speech quality

IMT-2000 should be planned on the basis of digital speech coders and error control schemes of high quality and low delay with performance equivalent to 32 kbit/s adaptative differential pulse-code modulation (ADPCM) operated in the fixed network.

IMT-2000 system planning should be based on the use of speech coders meeting this requirement, supported by appropriate radio coverage.

Flexibility should be included in IMT-2000 to exploit lower bit rate speech coders of this quality when available.

4.4 Security

IMT-2000 should provide a level of security comparable to that of the fixed public networks (PSTN, ISDN and PDNs).

If required, additional levels of encryption of user information could be offered. Any such facility should not have a significant influence on the costs of those parts of the system used by mobile subscribers who do not require such facility.

It should be possible for the subscribers themselves to provide end-to-end encryption, subject to the technical limitations of the network.

Protection should be provided to prevent unauthorized access to the system (authentication).

Location information regarding mobile units should be subject to special safeguards. See also § 5.3 and Recommendation ITU-R M.816.

4.5 Radio transmission considerations

In order to improve performance, systems may adapt such parameters as channel bit rate, bandwidth, frequency/time/coding arrangements, diversity techniques, and multipath equalization to actual propagation, interference and traffic conditions, subject to cost and power consumption considerations.

4.5.1 Multiple access techniques

Voice and data services will be a basic part of IMT-2000 and a flexible multiple access scheme is desirable to handle the wide range of traffic densities and services offered.

4.5.2 Modulation techniques

When considered with frequency re-use factors, the modulation techniques should achieve efficient use of the spectrum. Technologies having transmission efficiencies greater than 1 bit/s/Hz should be used for IMT-2000.

4.5.3 Source and channel coding

In order to maximize spectrum efficiency and transmission quality, channel coding should be utilized.

Speech coding and radio channels characteristics together determine the protection needed.

The system should be designed to ensure that an ordinary user will not experience an unacceptable channel delay.

4.6 Network aspects

4.6.1 The identification plan

In accordance with the appropriate ITU-T Recommendations.

4.6.2 The numbering plan

In accordance with the appropriate ITU-T Recommendations.

4.6.3 Routing and billing rates

System design should permit different charging and billing rates to be used in different networks.

4.6.4 Interconnection signalling system

ITU-T Signalling System No. 7 should be used for interconnection signalling system in IMT-2000.

5 Operational characteristics

5.1 Call handling

The following system functions which should take into account efficient use of the radio channel should apply to IMT-2000:

– channel assignment and set-up control procedures;

– channel release at the completion and/or dropping of the call.

5.2 Supervision

IMT-2000 should perform those functions necessary to supervise channel status and to maintain the necessary quality.

5.3 Location registration

In accordance with the principles laid down in Recommendation ITU-R M.624 and ITU-T Recommendations Q.1003 and Q.1004.

5.4 Network interworking

IMT-2000 should interwork with PSTN and ISDN in accordance with the principles laid down in ITU-T Recommendations Q.1031 and Q.1032, and with PDNs in accordance with the principles laid down in ITU-T Recommendation X.300.

ANNEX 1

Traffic considerations and estimation of spectrum needs

1 Traffic estimation

The maximum demand for "personal" telecommunication services is in large cities where different categories of traffic can be found, i.e. that generated by mobile stations (MS), vehicle-mounted or portable, and personal stations (PS), outdoor and indoor. The number of customers in these different cases may be estimated, with some variations, according to the nature of cities.

The traffic generated by the paging service in IMT-2000 has not yet been estimated in this Annex, but is considered to have negligible impact on spectrum requirements.

The traffic of the mobile-satellite services has not been estimated in this Annex.

1.1 Voice traffic

It is estimated that in a traffic jam the number of vehicles per km of street lines is around 600 if they are stationary or 350 if they are moving slowly. Assuming a mean value of 400 vehicles per km of street length 50% of the vehicles equipped with a mobile station, each generating 0.1 E, the traffic density will be 20 E/km of street length leading to 300 E/km^2 based on a typical urban street density. Adding about the same amount of traffic for portable mobile stations carried by pedestrians, the combined traffic, for MS, would be around 500 E/km^2 in the more dense city areas.

The peak traffic for personal stations is estimated at 1 500 E/km^2, assuming 3 000 pedestrians per km of street length, 80% penetrations of the personal station and 0.04 E/station.

It is estimated that the peak to mean ratio of traffic for pedestrians in busy streets of large cities has a value around 3.

For PS indoors the traffic may increase by a factor of 10 or more in a multi-storey office building. An estimation is one station per 10 m^2 active floor area with a traffic of 0.2 E/station. This corresponds to 20 000 E/km^2/floor.

1.2 Non-voice traffic

In the future, non-voice services will constitute an increasing proportion of total traffic. Some data services need more transmission capacity than a duplex voice channel, increasing the necessary spectrum. On the other hand, some non-voiced services can be handled by using queueing procedures, which improve the spectrum utilization.

1.2.1 Mobile stations

Circuit-switched services are considered as being relevant mainly for vehicle-mounted MS. Telefax is an example of such a service. Assuming 3 000 terminals/km^2, of which 15% are equipped with a Telefax unit, a call holding time of 6 min/h, per terminal; the estimated traffic amounts to 45 E/km^2.

Interactive data services are likely to employ packet transmission. The assumption is a cumulative channel occupancy of 15 s/h for a hand portable (10 page/h with 8 kbit/page, at a transmission rate of 4.8 kbit/s) and 30 s/h occupancy for a vehicle mobile (4.5 and 9 mE respectively). Assuming 5 000 terminals per km^2 (3 000 vehicular and 2 000 portables), the estimated traffic amounts to 37 E/km^2.

1.2.2 Personal stations outdoor

Traffic generated by circuit-switched data services, e.g. Telefax, has been considered insignificant. Therefore, only short-message interactive data communications are considered in the present case.

The assumption is a cumulative channel occupancy of 5 s/h (10 page/h with 8 kbit/page at a transmission rate of 16 kbit/s) corresponding to 1.4 mE/station.

Assuming 2 400 station/km^2 of street length (37 500 station/km^2), as in the case of voice, the amount of traffic would be 50 E/km^2. To account for other data services, this estimation is increased by a factor of 3 to 150 E/km^2. The non-voice traffic is then 10% of the voice traffic.

1.2.3 Personal stations indoor

For Telefax application: assuming 25% of stations having a Telefax and 6 min call holding time per hour, per Telefax terminal; the estimated traffic is 25 mE/station i.e. one-eighth of the voice traffic, or 2 500 E/km^2.

For interactive application: considering all stations are using this application and assuming 20 interactive sessions per hour, with a cumulative channel occupancy of approximately 2 s per station, we arrive at 0.01 E/station, equivalent to 1 000 E/km^2. In order to take account of contention due to packet transmission, a factor of 2 is assumed, leading to 2 000 E/km^2.

In total, taking into account batch data application, data base retrievals (10% overhead) a total amount of 5 000 E/km^2 is assumed for non-voiced services indoor.

2 Estimation of spectrum needs

Using the traffic estimation of § 1, the minimum spectrum bandwidth required for voice and non-voice services is approximately 230 MHz. The key parameters on which these estimations are based are given in Tables 1 and 2. The total requirement per radio interface is 167 MHz for R1 (mobile station) and 60 MHz for R2 (personal station).

A speech coding rate of 8 kbit/s was assumed for mobile station use in Tables 1 and 2, since speech coders with lower bit rates, quality and transmission delay comparable to those of the PSTN may not be available in the foreseeable future. Higher rate speech coders have been assumed for use in inexpensive personal stations. It should be noted that current fixed networks use coders with bit rates of 64 kbit/s and mobile applications range from 32 down to approximately 10 kbit/s.

It is believed that the choice of access scheme (FDMA, TDMA, or CDMA) does not substantially affect the overall estimation.

The estimations in Tables 1 and 2 are for dense metropolitan areas.

The following were recognized, but not considered in the estimates of Tables 1 and 2:

– additional signalling traffic for system operation is expected to be significant in IMT-2000 because of system complexity and quality objectives;

– road traffic management and control applications may generate additional non-voice traffic;

– sharing of spectrum between several operators may result in less efficient use of spectrum;

– there are further quality of service considerations that may increase the amount of spectrum needed.

Considering the above, the estimate of about 230 MHz for IMT-2000 should be regarded as a lower bound.

TABLE 1

General characteristics of personal communications (high density area) voice service traffic demands and spectrum requirement

Specifications	MS outdoor interface R1	PS outdoor interface R2	PS indoor interface R2
Radio coverage (%)	90	> 90	99
Base station antenna height (m)	50	< 10	< 3[(1)]
Base station installed: Indoor/outdoor	No/Yes	Yes/Yes[(2)]	Yes/Yes[(2)]
Traffic density (E/km^2)	500	1 500	20 000[(1)]
Cell area (km^2)	0.94	0.016	0.0006
Blocking probability (%)	2	1	0.5
Cluster size (cell sites × sectors/site)	9	16	21 (3 floors)
Duplex bandwidth per channel (kHz)	25	50	50
Traffic per cell (E)	470	24	12
Number of channels per cell	493	34	23
Bandwidth (MHz)	111	27	24
Station[(3)]:	Vehicle mounted or portable		
Volume (cm^3)		< 200	< 220
Weight (g)		< 200	< 200
Highest power	5 W	50 mW	10 mW

(1) Per floor.

(2) Usual case.

(3) A range of terminal types will be available to suit operational and user requirements.

TABLE 2

Spectrum estimation for non-voice services

	MS outdoor interface R1		PS outdoor interface R2		PS indoor interface R2	
	Circuit switched	Packet switched	Circuit switched	Packet switched	Circuit switched	Packet switched
Traffic density (E/km^2)	45	37	[(1)]	150	2 000[(2)]	2 500[(2)]
Duplex bandwidth per channel (kHz)	100	50	50	50	50	50
Bandwidth (MHz)	56		3		6	

(1) Insignificant.

(2) Per floor.

ANNEX 2

Sharing considerations

1 General

Sharing conditions should be such that one service does not cause interference to the other in excess of the limits recommended by the ITU-R.

2 Basic parameters

The basic parameters for sharing with IMT-2000 are the power flux-density (PFD) and the minimum carrier to total noise plus interference which is required.

The PFD is derived from the number of terminals per km^2 and power for each category of stations.

The following estimates have been made as shown in Table 3:

TABLE 3

Power flux-densities for IMT-2000 in an urban area

Stations	Base and mobile	Personal
e.i.r.p.	10 W (base) 1 W (mobile)	3 mW (indoor) 20 mW (outdoor)
Traffic density (E/km^2)	582	25 000 (indoor)[(1)] 1 650 (outdoor)
Assumed bandwidth (MHz)	167	60
Estimated PFD	38 $\mu W/km^2/Hz$ –68 $dB(W/m^2/4\ kHz)$	1,5 $\mu W/km^2/Hz$ –82 $dB(W/m^2/4\ kHz)$

(1) This takes into account the vertical frequency re-use of IMT-2000 in buildings.

3 Estimate of permissible level of interference to IMT-2000

The level of interference to IMT-2000 which can be tolerated, has been estimated using a link budget which shows that personal mobile systems are expected to be interference limited, rather than noise limited. To facilitate sharing, an allocation of 10% of the total interference budget to external interference sources is assumed. For one example studied, this corresponds to a level of –117 dBm for indoor personal stations and –119 dBm for outdoor personal stations. These are the maximum permissible aggregate interference power levels that can be received by the personal stations without significantly degrading the quality of service provided.

4 Sharing with specific services

4.1 Sharing between IMT-2000 and the fixed service

The analysis of sharing between the fixed service and the terrestrial segment of IMT-2000 indicates that such sharing is feasible with a geographic separation or for overlapping band allocations.

With geographic separation, the fixed service and IMT-2000 can share spectrum outside of a safe contour.

The calculation of the safe contour should take account of the statistical nature of the mutual interference between fixed stations and IMT-2000 mobile stations. This method for determining the parameters for sharing should reflect the respective performance objectives to which the fixed systems and IMT-2000 are designed.

The unrestricted introduction of IMT-2000 using the same frequencies as the fixed service and in areas close to the fixed service beam will cause unacceptable degradation of performance to the fixed service. The IMT-2000 will also experience a degradation in performance when it operates in these areas.

The relative inter-service sharing merits of the alternative IMT-2000 access techniques such as FDMA, TDMA and CDMA will depend on the detailed individual system parameters.

Co-channel sharing between the fixed service and IMT-2000 using any of these access techniques will cause difficult sharing conditions, without sufficient geographic separation. The degree of geographic separation will depend on the system characteristics of the IMT-2000 and the fixed service, but should be made sufficient to limit the degradation of the fixed service receiver threshold to 1 dB.

Operational sharing of an allocation common to the fixed service and IMT-2000 can be accomplished through a number of techniques that are discussed in § 4.5. A consequence of band allocation sharing is that IMT-2000 can only use part of the spectrum within the safe contour, without degrading the fixed service. In a low density traffic area or during the introductory phase of IMT-2000 there could be sufficient spectrum available to permit sharing on a geographical separation basis. Where the fixed service is utilizing the full allocated bandwidth in a geographic area, IMT-2000 could not be used, and *vice versa*.

4.2 Sharing between IMT-2000 stations and mobile-satellite services

Studies which are at an early stage show that there is a potential risk of degradation of the *C/N* ratio at the satellite station receiver when simultaneous emissions occur on uplink frequencies used by both IMT-2000 and a satellite system. At a satellite receiver, the cumulative effect of IMT-2000 interface R2 stations (personal outdoor and indoor) although their individual power is low, must be considered over the large geographic area of the mobile-satellite spacecraft antenna coverage. For the R1 interface this interference may also be unacceptable.

On downlink frequencies, the interference from IMT-2000 to an aircraft mobile earth station receiver could also be unacceptable. Interference from IMT-2000 to land mobile earth stations would be limited to acceptable values by geographic separation of the order of 3 km for interface R2 or greater for interface R1. Sharing of frequencies, if any, might be arranged for stations participating in a dynamic frequency assignment (partitioning) so that terrestrial services would have greater spectrum access in areas where their demand is very high and mobile-satellite services would have greater spectrum access in areas of lesser demand or lower availability of terrestrial services.

Simultaneous use of frequencies by both IMT-2000 and an earth-station receiver in a fixed location might be envisaged, particularly for IMT-2000 R2 interface when sufficient geographic separation between IMT-2000 stations and the fixed terrestrial stations is provided so that the path loss due to spherical earth diffraction and terrain gives sufficient protection. IMT-2000 could restrict its emissions in zones designated in advance.

Nevertheless, due to the low level of power received by the earth stations, the high gain (10 dB or more) of its antenna and possible low elevation angle, further study is necessary to determine if the path loss attenuation would provide sufficient protection, and if sufficient usable spectrum is available to permit operations of IMT-2000. Interferences caused by space communications to IMT-2000 are not likely to cause major difficulties to IMT-2000.

Mobile-satellite communications would produce an interfering power which could be below the tolerated limit of IMT-2000 stations. Land and aircraft mobile earth stations would produce harmful interference to IMT-2000 which could, however, be limited to the channels in use. Further studies on interference from space communications to IMT-2000 also appear to be necessary.

4.3 IMT-2000 sharing with SRS, SOS, and EESS in the 2 025-2 110 MHz and 2 200-2 290 MHz bands

The use of the 2 025-2 110 MHz and 2 200-2 290 MHz bands by the SR, SO and EES services provides the main tracking, telemetry and telecommand (TT&C) links for manned and unmanned space exploitation and exploration. Two distinct types of networks are used, as shown in Fig. 3. The ground network, as indicated on the left, consists of an earth station communicating with an application satellite which may be in any type of orbit (low-Earth orbit – LEO, elliptical, geostationary – GSO, etc.). The space network, as indicated on the right, consists of a geostationary data relay satellite (DRS) communicating with the applications satellites. The data relay network exchanges signals with manned or unmanned space vehicles (user vehicles) in low, medium or high orbits having various inclinations. These geostationary data relay satellite networks are capable of communicating with the user vehicles at practically any point of their orbit. It follows that the elements of the DRS network can be interfered with by signals transmitted from any point on the visible part of the Earth.

An important characteristic of the ground and DRS network is their efficient use of the spectrum, obtained by the use of common frequency bands. The 2 025-2 110 MHz band is used for transmissions to the application satellite from either the earth station (link 1 of Fig. 3) or the DRS (link 9 of Fig. 3). Similarly transmissions from the application satellite in the 2 200-2 290 MHz band can be sent to the earth station (link 3 of Fig. 3) or the DRS (link 7 of Fig. 3).

Studies evaluating the feasibility of the R1 and R2 interfaces of the IMT-2000 sharing with the SRS, SOS and EESS have been performed. These studies assumed parameters of the IMT-2000 consistent with those contained in Table 3 which lists the characteristics associated with R1 and R2 interfaces. These studies evaluated the interference to LEO and GSO satellites operating in the 2 025-2 110 MHz and 2 200-2 290 MHz bands due to emissions from R1 and R2 elements of the IMT-2000. They also evaluated the interference to R1 and R2 interfaces caused by emissions from SOS, SRS and EESS earth stations.

The results of all studies can be summarized as follows:

– *2 025-2 110 MHz band*

Interference excess values for spacecraft receivers vary widely depending mainly on type of space service, orbit height, antenna patterns and IMT-2000 characteristics. Typical interference excess values are between 13 and 65 dB. Coordination distances with earth stations operating in the ground network are several hundred kilometres and practical separation distances taking into account diffraction loss and site shielding range between 75 and 110 km. It must be emphasized that while R1 and R2 may receive interference from earth stations (i.e. link 6 of Fig. 3) they themselves simultaneously cause unacceptable interference to the space network (i.e. link 2 of Fig. 3).

– *2 200-2 290 MHz band*

Interference excess values for spacecraft receivers range between 27 and 59 dB. Coordination distances are several hundred kilometres and practical separation distances taking into account diffraction loss and site shielding range between 35 and 80 km for a single IMT-2000 unit. It must be emphasized that the R1 and R2 emissions which interfere with the ground network (i.e. link 4 of Fig. 3) simultaneously cause unacceptable interference to the space network (i.e. link 8 of Fig. 3).

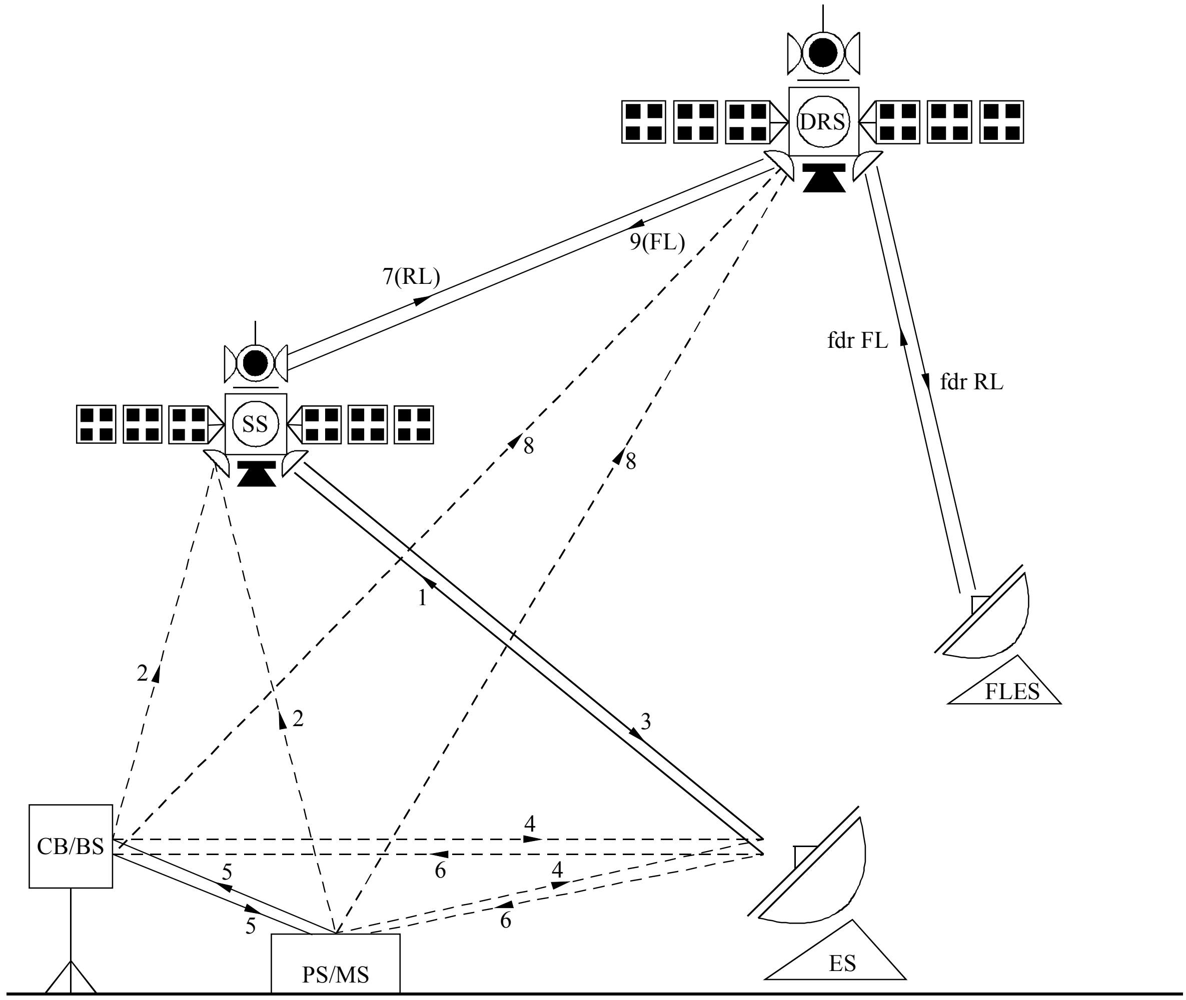
From the results of studies, it is concluded that sharing is not feasible between the R1 and R2 interfaces of the IMT-2000 and the SRS, SOS and EESS in the 2 025-2 110 MHz and 2 200-2 290 MHz bands.

4.4 Sharing with the radioastronomy service (RAS)

IMT-2000 is envisaged as providing worldwide personal telecommunication services through the use of hand-held portable terminals and access to satellite systems. Power flux-densities of the order of –120 dB(W/m^2/Hz) in urban areas, and approximately 30 dB lower in rural areas are commonly considered in the IMT-2000 for the personal station component and roughly 15 dB higher for mobile and base stations. These power flux-density estimates are based on reasonable assumptions for the e.i.r.p. of base and mobile stations (10 W and 1 W, respectively) and personal stations (20 mW outdoors). It is clear that such power flux-densities are many orders of magnitude above the harmful interference levels for the RAS which, in the 500-3 000 MHz frequency range are about –240 dB(W/m^2/Hz) for spectral line observations, and about –250 dB(W/m^2/Hz) for continuous observations. Because of the inherently roaming nature of the personal stations in the IMT-2000, geographical sharing is not possible.

FIGURE 3

Sharing situations for the ground network and the data relay network



BS: mobile base station (R1)
MS: mobile station (R1)
PS: personal station (R2)
CS: cell site personal base station (R2)
DRS: data relay satellite
ES: earth station
SS: spacecraft station
FLES: feeder link earth station
FL: forward link
RL: return link
fdr: DRS feeder links

2 GHz frequency band usage

Frequency (MHz)	Desired signal (solid lines)	Interference (dashed lines)
2 025-2 110	1 5 9	2 6 2
2 200-2 290	3 5 7	4 None(1) 8

(1) IMT-2000 cannot suffer interference in that band, because it is not allocated for uplinks.

Note 1 – Feeder links use frequencies higher than 10 GHz.

Note 2 – Terrestrial services are protected from space station transmitters by pfd limits specified in Article 28 of the Radio Regulations.

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4.5 Conclusions

In some cases there may be services in which the usage is not densely packed or uniform over a geographic area. The largest operational bandwidth requirement for the IMT-2000 will be located in urban areas, while less operational bandwidth will be required in suburban and rural areas. To facilitate optimal use of the allocated spectrum, IMT-2000 could adopt itself to use appropriate channels.

Thus, an essential feature of the IMT-2000 which will facilitate sharing, is that the personal and mobile stations are given knowledge of the local conditions so that sharing conditions are fulfilled. The base station can be designed with knowledge of the local conditions needed for sharing and prevent operation on the other service channel assignments.

Nevertheless in some areas the density of radio links may be such that geography and terrain make sharing based on geographic separation extremely difficult.

In a sharing scenario involving several services, it must be noted that sufficient bandwidth must be available to support the sum of the traffic needs of all services sharing the same band.

The conclusions from these technical considerations are that IMT-2000 may be able to share band allocations with fixed and possibly other services only where there is suitable geographic separation between services, or where neither service requires the total allocated bandwidth. The economic cost associated with sharing has not been included in these considerations. The IMT-2000 with adaptive channel assignment will greatly facilitate sharing and will simplify the introduction of IMT-2000 into bands currently used by other services. The relative geographic separation required for the alternative IMT-2000 access techniques such as FDMA, TDMA and CDMA will depend on detailed system parameters. However, it is emphasized that co-channel sharing between the fixed service and IMT-2000 requires adequate geographic separation.

It is also concluded that sharing is not feasible between R1 and R2 interfaces of the IMT-2000 and the SRS, SOS, and EESS in the 2 025-2 110 MHz and 2 200-2 290 MHz bands.