REPORT ITU-R F.2060

Fixed service use in the IMT-2000 transport network

(Question ITU-R 221/9)

(2005)

1 Introduction

Recently, as traffic demands for mobile communications represented by IMT-2000 are increasing, fixed service (FS) use in the transport network in the mobile infrastructure is becoming an important application.

The IMT-2000 transport network supports the connections between the different base stations of the network, as well as the connections of one base station to other stations of the IMT-2000 infrastructure, in order to interconnect the IMT-2000 network to other telecommunication networks.

2 Scope

The aim of this Report is to show how the FS could be used at different hierarchical levels of the transport network of IMT-2000, in order to ensure the connections between base stations, and between base stations and higher-level stations within this transport network. This Report provides an example of the use of the FS in the transport network of IMT-2000.

FS use is necessary to support the operation of IMT-2000 networks in the transport network. Depending on the evolution of IMT-2000 and the required transmission capacities at different levels of the transport network, different FS frequency bands could be employed.

This Report gives possible structures of IMT-2000 transport networks including the outline of the needs of 3G cellular systems (IMT-2000). The Report also examines the possible use of already allocated FS spectrum. Regardless of the transmission network capacity, the choice of frequency bands depends on the local situation of the various countries (existing deployment of the frequency bands, number of mobile (IMT-2000) operators, etc.).

3 References

The reader will find additional guidance in the references listed below:

Recommendation ITU-R F.746:	Radio-frequency arrangements for fixed service systems
Recommendation ITU-R F.758:	Considerations in the development of criteria for sharing between the terrestrial fixed service and other services
Recommendation ITU-R F.1245:	Mathematical model of average radiation patterns for line-of-sight point-to-point radio-relay system antennas for use in certain coordination studies and interference assessment in the frequency range from 1 to about 70 GHz
Recommendation ITU-R F.1399:	Vocabulary of terms for wireless access
Recommendation ITU-R M.1224:	Vocabulary of terms for International Mobile Telecommunications-2000 (IMT-2000)

Recommendation ITU-R M.1390:	Methodology for the calculation of IMT-2000 terrestrial spectrum requirements
Recommendation ITU-R P.530:	Propagation data and prediction methods required for the design of terrestrial line-of-sight systems
Recommendation ITU-R P.676:	Attenuation by atmospheric gases
Recommendation ITU-R P.837:	Characteristics of precipitation for propagation modelling
Handbook on Deployment of IMT-2000 systems:	http://www.itu.int/itudoc/qs/imt2000/84207.html
ECC Report 003:	Fixed service in Europe current use and future trends post-2002

4 List of acronyms

2G	2nd Generation Mobile System
3G	3rd Generation Mobile System (IMT-2000)
AAL	ATM adaptation layer (i.e. AAL 0, AAL 2, AAL 5,...)
ATM	Asynchronous transfer mode
ATPC	Automatic transmission power control
BER	Bit error ratio
BS	Base station
BSC	Base station controller
BTS	Base transceiver station
CBD	Central business district
CBR	Constant bit rate
CCDP	Co-channel dual polarized
CS	Central station (or Central base station)
C/I	Carrier-to-interference ratio
DSL	Digital subscriber line
FDCA	Fast dynamic capacity allocation
FL	Feeder loss
FM	Fade margin
FS	Fixed dervice
FSK	Frequency-shift keying
IMT-2000	International Mobile Telecommunication System-2000
IP	Internet protocol
LOS	Line-of-sight
MM	Multimedia
MSC	Mobile switching centre (2G or 3G)
OBQ	Offered bit quantity
PDH	Plesiosynchronous digital hierarchy

P-P	Point-to-point
P-MP	Point-to-multipoint
POP	Point of presence (of a fibre optical operator)
PSK	Phase shift keying
QAM	Quadrature amplitude modulation
RF	Radio frequency
RPE	Radiation pattern envelope (of an antenna)
SAP	Service access point
SDH	Synchronous digital hierarchy
STM	Synchronous transfer mode
Sub-CS	Sub-central station (or sub-central base station)
XPD	Cross-polarization discrimination
XPIC	Crosspolar interference canceller

5 Structure of IMT-2000 transport network

5.1 Example of the hierarchical levels in IMT-2000 transport network

The transport network of IMT-2000 consists of different transport hierarchical levels to support the transmission interfaces of the IMT-2000 network.

In principle, the IMT-2000 network hierarchy consists of different hierarchical levels and network nodes. In this Report these nodes are defined as follows, using the terms given in Recommendations ITU-R M.1224 and ITU-R F.1399:

– MSC: mobile switching centres in the IMT-2000 network organizing the overall traffic flow as well as representing the interconnection to the fixed network;

– SAP: service access point – The basic node within the network with switching functions for the subordinate base stations in the IMT-2000;

– CS: central station (or central base station) – A base station where several or more links are converging in P-P or P-MP mode to connect the surrounding base stations;

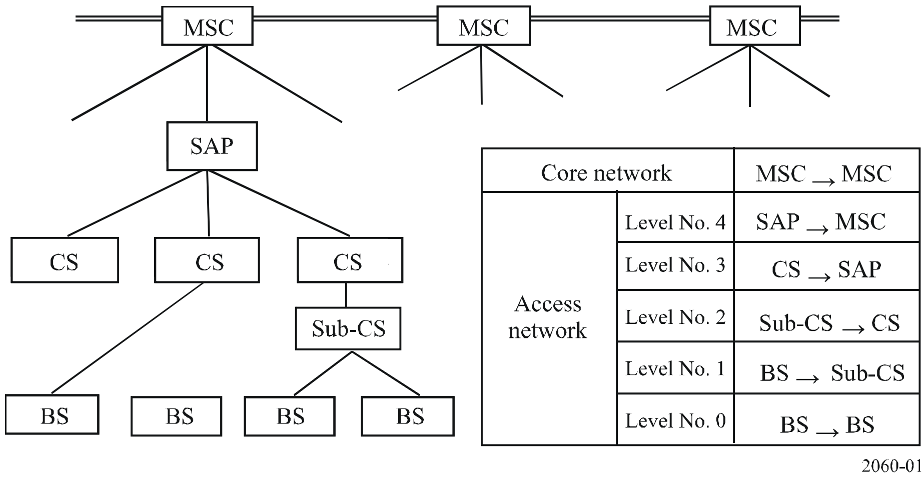
– Sub-CS; sub-central station (or sub-central base station) – A base station having intermediate function of traffic transport between CS and other base stations, and

– BS: base station, except for those categorized as the above nodes, BS is a node forming an end of the transport network.

The general topology of the transport network in IMT-2000 is given in Fig. 1. The hierarchical levels each identifying the connection links used for several hierarchy in the transport network will be considered in the later sections from the viewpoint of use of the fixed service.

FIGURE 1

Example of hierarchical levels of the IMT-2000 transport networks



In the start up phase, most of the connections are likely to be provided by fixed wireless links. As IMT-2000 networks mature other high capacity connections (i.e. fibre optics) may be substituted.

Examples of detailed topology of the IMT-2000 transport network hierarchical levels are described in Annex 1.

5.2 Capacity and hop length requirements in the transport network

A large variety of interconnections in terms of hop length and transport capacity are necessary to operate the IMT-2000 networks. In particular the transport capacity depends on the user's needs for mobile telecommunication services for which Recommendation ITU-R M.1390 provides a methodology for their estimation.

In Table 1 the expected transport capacities are given for the interconnections between the different layers. Detailed consideration on how to derive such expectations are provided in Annex 2. The evolution of the networks has been considered in that respect, expected capacities are given for both short term and long term.

Table 2 illustrates a variety of hop lengths in different operational environments (rural and urban) of the cellular network. Information on capacity and hop length leads to the media which would best serve the requirements of the different layers of the IMT-2000 networks.

TABLE 1

Expected link capacities for interconnecting the different hierarchical levels of IMT-2000 networks

Hierarchical level(1)	Short term	Long term
Hierarchical level No. 0	4-8 Mbit/s	4-34 Mbit/s
Hierarchical level No. 1	8-34 Mbit/s	8 Mbit/s – STM-1
Hierarchical level No. 2	34 Mbit/s – STM-1	$n \times$ 34 Mbit/s – *n* STM-1
Hierarchical level No. 3	34 Mbit/s – 2 STM-1	*n* STM-1 – *n* STM 16
Hierarchical level No. 4	*n* STM-1	*n* STM1 – *n* STM-16

(1) See Fig. 1 for definitions

TABLE 2

Hop lengths for interconnecting the different hierarchical levels of IMT-2000 networks

Hierarchical level(1)	Urban (km)	Rural (km)
Hierarchical level No. 0	0.5-1.4	5-16
Hierarchical level No. 1	0.5-2.5	5-20
Hierarchical level No. 2	2.0-5.0	5.0-20
Hierarchical level No. 3	5-10	5.0-50
Hierarchical level No. 4	0-20	0-20

(1) See Fig. 1 for definitions

5.3 Transportation media used in the transport network

Not all of these connections within the IMT-2000 network are necessarily radio equipment, depending on:

– the network layer under consideration;

– technical facilities of a certain network operator; and

– economic framework.

A certain percentage of the interconnections within the IMT-2000 networks may be operated on cables (e.g. DSL systems) or fibre optics.

The different network levels have different requirements concerning telecommunication capacity and availability targets due to their function within the network. These levels will build a five hierarchical levels transport network, which may be accommodated by different transport media:

– hierarchical levels No. 0, No. 1 and No. 2 (connections between BSs, access from BS to Sub-CS and/or CS) operated mainly by P-P and/or P-MP fixed wireless links or cable;

– hierarchical level No. 3 (interconnection of CS and SAP) operated by P-P fixed wireless links and fibre optics;

– hierarchical level No. 4 (interconnection between SAPs, MSCs and possibly point of presence (PoP) to fibre optic networks) operated mainly by fibre optics; and

– core net (interconnection between MSC) operated mainly by fibre optics.

Scenarios where an interconnection of a certain hierarchical level within the transport network carries traffic of lower transport network layers are possible as well.

6 FS applications within IMT-2000 transport networks

In this section, the fixed service frequency bands and their appropriateness/usability for use in the IMT-2000 are reviewed. Included in this section are: technically and physically related band characteristics, possible link densities, requirements for systems today and in the future, as well as other factors which influence the appropriateness and usability of certain bands. In addition, a comparison of the topology and band specifics is provided.

6.1 Characteristics of FS bands

In general, all frequency bands available for the fixed service could be used in the IMT-2000 transport networks. In the following sections, technical characteristics of certain fixed service bands such as appropriate transmission capacities, channel spacings, modulation levels, available number of channels and typical link lengths are examined.

6.1.1 Information on possible frequency bands for IMT-2000 transport networks

It should be noted that in some cases national usage can vary from the general characteristics described below. Furthermore, it has to be noted that apart from these technically and physically related characteristics as described in Tables 3 and 4 a number of other factors have to be taken into account that could have a significant impact on the usability of a number of bands. These factors are described in § 6.4 where the requirements for wireless links resulting from the IMT-2000 network topology are compared with the band specifics.

Since the structure and the density of the IMT-2000 transport network requires a large number of frequencies, especially for short hops in the range of a few kilometres up to some tens of kilometres, most of the frequency bands of interest, especially for densely populated areas, are located in the frequency range above 11 GHz, although bands below 11 GHz may also be used for certain links in more scarcely populated areas within the IMT-2000 infrastructure network. However, it should be recognized that fixed service bands below 3.4 GHz are required to serve more remote communities, where it is necessary to have long-hop lengths in order to minimize the number of sites. This is an important aspect in providing economical network access in remote areas.

TABLE 3

Characteristics of frequency bands above 3.4 GHz for P-P and P-MP systems

Band (GHz)	Recommendation ITU-R F.	Typical link length in temperate climatic areas (km)
3.6	1488	5-15 (P-MP)
4	382 635	20-80
5	746 1099	20-80
Lower 6	383	20-80
Upper 6	384	20-80
7	385	20-80
8	386	20-80
10	747	10-50
11	387	10-50
13	497	5-35
14	746	5-35
15	636	5-30
18	595	4-25

TABLE 3 (*end*)

Band (GHz)	**Recommendation ITU-R F.**	**Typical link length in temperate climatic areas (km)**
23	637	3-20
27	748	2-12
32	1520	1-10
38	749	1-6
52	1496	<2
57	1497	<2

More information on Table 3 can be found in Recommendation ITU-R F.746, which includes channel separation for each of these frequency bands.

TABLE 4

Capacity of fixed wireless links according to bandwidth and modulation

Bandwidth (MHz)	**Capacity (Mbit/s)**						
	2 × 2	**8**	**2 × 8**	**34**	**51**	**155**	**2 x 155**
3.5	4 states	16 states					
7		4 states	16 states				
13.75, 14			4 states	16 states	32 states		
27.5, 28, 29.65				4 states	16 states	128 states	128 states (CCDP)
40						64 states	64 states (CCDP)
55, 56						16 states	16 states (CCDP)

NOTE 1 – CCDP operation with cross-polarization cancellation is used up to 13 GHz and may also be used in the near future in higher bands. This mode of operation allows to double the capacity per channel by transmitting simultaneously on two orthogonal polarizations (H and V) within the same channel.

NOTE 2 – Modulations are referred by their number of digital states; for instance 4-PSK modulation is a 4 states modulation.

6.1.2 Impact of rain

The aim of this section is to provide some guidance on how climatic conditions could affect the choice of frequency bands for FS in the IMT-2000 transport network.

The choice of the most relevant band for mobile networks FS infrastructure depends on several parameters being either regulatory (e.g. bands opened or not for FS, licence of the operator limiting access to certain bands) or technical. As far as the latter is concerned, the impact of rain on these parameters, and thus on the choice of the band, should be considered.

It is obvious that this choice will be highly dependent of the geographic zone where the FS networks are deployed.

Therefore a comparison of the use of the 18, 23 and 38 GHz bands has been made with respect to their ability to comply with the requirements of capillary FS networks. In particular, studies on the maximum hop lengths for these frequency bands, according to some geographic rain zones, have been led. For the purpose of these studies, Recommendation ITU-R P.837-1 was used.

As a result of these studies, it appears that in rain climatic zones M, N, P and Q, which apply in several areas under tropical or equatorial climatic conditions, the characteristics of 18 GHz band in terms of maximum hop length are very similar to those of the bands 23 or 38 GHz in the rain climatic zone E, which applies to several other geographical areas with different climatic conditions, for instance in Europe. The distance values provided in Table 3 are no more valid for rain climatic zones M, N, P and Q.

The bands 23 GHz and 38 GHz, which in the climatic conditions of Europe are perfectly fitted for use in the transport network of mobile systems, may not present the same potential in other areas with increased rain precipitation characteristics. They may for instance be limited to very short links in densely populated areas.

Consequently, it is expected that in the areas belonging to rain climatic zones M, N, P and Q, the band 18 GHz could play an important role in the transport network of mobile systems, similar to the role of the bands 23 and 38 GHz in Europe.

More detailed information on the Mobile transport networks in Europe and the results of calculations for the bands 18 GHz, 23 GHz and 38 GHz are provided in Annex 3.

6.2 Technical requirements for P-P and P-MP systems

The technical requirements for either P-P systems or P-MP systems depend on which part of the IMT-2000 network structure and which link density is being considered.

6.2.1 Maximizing spectrum utilization

Both P-P and P-MP systems may be used for IMT-2000 transport network.

In some cases, due to economic reasons, only P-P systems may be deployed in rural areas. In urban and dense urban areas, both P-P and P-MP may be deployed. The choice between these two technologies in urban and dense urban areas may be driven by factors such as capacity requirements at access nodes, traffic management, hop length, availability target and urban limitations.

The efficient use of the spectrum is a basic requirement to allow all interested network operators to deploy their own network using the limited frequency bands.

It is important to note that the application of ATPC, XPIC (for SDH systems where practicable) and antennas with good RPE and improved XPD could improve the efficient use of the spectrum.

6.2.1.1 Benefits of using a combination of low and high modulation schemes in P-P networks

Both low level (e.g., 4 states) and high level (e.g., 16 states or higher) modulation systems are needed in a fixed wireless network.

A combination of low and high levels modulation systems optimises the trade-off between cost and spectrum efficiency, in a typical IMT-2000 network, as there is no definitive single solution satisfying each scenario:

– equipments using higher modulation systems are more costly and more sensitive to impairments (e.g. multipath propagation) than those with lower modulation systems;

– nevertheless the higher states modulation systems are most efficiently used in higher capacity systems (typically SDH systems) to reduce required spectrum or to fit into restricted channel bandwidths, or, for all types of systems, in parts of the network with existing or expected shortage of spectrum.

In addition, adaptive modulation schemes can optimize traffic throughput of P-MP systems by using the highest order modulation scheme supported at any instant depending on the link conditions (i.e. influence of propagation conditions) and traffic demands at the time of communication. When combined with other specific factors of P-MP systems, such as statistical multiplexing gains, useful increases in spectrum utilization can be realized. Adaptive modulation schemes are being considered as a standard feature in the fixed broadband wireless access air interface standards developed by some standards organizations. Interest in this technique is emerging for P-P systems also.

6.2.2 Traffic handling capability

For P-P systems, the interfaces necessary for the Transport equipment are defined by the transport capacity between BS and SAP: up to 4 × 2 Mbit/s or 34 Mbit/s, or between SAPs (requiring higher transport capacities): 34 Mbit/s, 2 × 34 Mbit/s or *n* × STM-1.

For P-MP systems the issue of capacity is complicated further by the area coverage considerations. Many P-MP hubs can transport up to 130 Mbit/s/28 MHz in any sectored coverage area per channel of operation. Multiplexing gains would increase the potential to allocate this resource to a number of nodes within the coverage area.

Even if data traffic is increasing, having symmetrical and asymmetrical characteristics, the voice traffic will still be important. Thus the equipment has to transport different types of information efficiently by providing the possibility to transport the maximal capacity needed in time for the connection considered with the appropriate grade of service.

However, the nature of traffic will change during the course of the IMT-2000 development. A change from predominant voice services to data services is possible which may impact the nature of the traffic to be transported, for instance in terms of traffic asymmetry between uplink and downlink directions. P-MP systems should have the flexibility to cater for these changing requirements by either adapting the uplink/downlink modulation scheme or the ratio of the transmission time resource between uplink and downlink.

6.2.3 Transport mechanism

Some transport mechanisms are based on ATM. The transmission interfaces are mainly based on well-known PDH and SDH-Interfaces, such as 2 Mbit/s, 34 Mbit/s, STM-0 and STM-1, taking more or less the benefits from the ATM – Adaptation Layers (AAL 1 for CBR 2G traffic, AAL 2 and AAL 5).

With future IMT-2000 evolutions, other interfaces may become more prevalent.

6.2.4 Availability and quality

Traditionally, operators have deployed their mobile backhaul networks based on a combination of P-P fixed wireless and wired leased lines. The main deciding factor in the choice between fixed wireless links and leased lines is the individual operator’s needs in terms of network control and transmission quality.

In networks with a high penetration of fixed wireless links, connections between the mobile base stations and the switch site are dimensioned for 99.95% availability or higher, corresponding to four unavailable hours per year. The use of efficient coding techniques could guarantee a quasi error-free operation during the periods of availability.

In these conditions, fixed wireless links are suitable for ATM and IP transport. In conclusion, the availability of a network based on fixed wireless links is very much a planning issue.

6.2.5 Protection

The end-users traffic is the most important asset for the operator. If the service delivered is not reliable, end-users will change their service provider. High quality equipment complemented with additional protection mechanisms provide the operator with the means necessary to deliver high-quality services.

A fixed wireless product includes facilities to implement as necessary protection towards equipment failure as well as towards radio propagation anomalies. A part of the hardware is duplicated to support the protected configurations on either or both of the two sides of the radio connection. The transmitting equipment can be configured either for hot stand-by transmission mode or as independent stand-by transmission mode: (1 + 1) or (N + 1) frequency diversity.

A smart aggregation node combined with an adequate architecture of the transport network adds yet another level of protection i.e. network protection. This functionality enables the operator to build reliable ring structures based on any fixed wireless capacity up to 155 Mbit/s. The ring protection mechanisms works on primary level, and it allows protection of all or pinpointed primary affluents within the total payload.

6.3 Density of P-P links in the IMT-2000 transport network

In general highly directional antennas should be used to increase the density of P-P links in the transport network. Therefore in dense networks, antenna pattern based on Recommendation ITU-R F.1245 should be favoured.

Making use of different polarizations significantly increases the density of terminals (taking into account the cross polarization of the antenna, but also that due to unequal atmospheric precipitations propagation losses, the use of the horizontal polarization at higher frequencies (for instance 38 GHz) is restricted to very short links.).

To derive more realistic results, other features such as ATPCs or parameters like influence of adjacent or nearby channels should be taken into account.

In some cases, in order to increase the density of terminals in dense network deployment, higher threshold degradation could be accepted (e.g. for dense network deployment), if performance and availability objectives can still be met and increased degradation can be compensated in the link budget.

6.4 Comparison of the topology and the band characteristics

This section highlights how the network topologies can be implemented taking into account the band characteristics as well as other influencing factors in order to allow for a dedication of frequency bands to specific parts of the IMT-2000 transport network.

Information on network topologies is available in § 5.2 and in Annex 1. The band characteristics and other influencing factors are described in § 6.1 and 6.4.2 respectively.

6.4.1 Comparison of the topology and band characteristics described in § 6.1 (without taking into account other factors)

Tables 5 and 6 provide lists of possible frequency bands for P-P and P-MP systems in relation to the network layers, respectively. This information only takes into account the band characteristics, the existence of Recommendations and standards for equipment for these bands. It does not take into account any other factors (e.g. specific uses of the spectrum in a particular country) which could have significant impacts on the availability and appropriateness of the bands.

TABLE 5

Possible frequency bands for P-P systems in relation to different hierarchical levels of IMT-2000 network

Hierarchical level(1)	Frequency bands (GHz)	Suitable frequency bands for shorter haul (GHz)	Suitable frequency bands for longer haul (GHz)
Hierarchical level No. 0	11-64	27-32-38-52-57	11-13-15-18-23-27-32
Hierarchical level No. 1	11-57	27-32-38-52-57	11-13-15-18-23-27-32
Hierarchical level No. 2	11-38	27-32-38	11-13-18-23-27-32
Hierarchical level No. 3	4-32	13-18-23-27-32	4-L6-U6-7.5-11-13-18
Hierarchical level No. 4	< 18	13-18	<18

(1) See Fig. 1 for definitions

TABLE 6

Possible frequency bands for P-MP systems in relation to different hierarchical levels of IMT-2000 network

Hierarchical level(1)	Possible frequency bands (GHz)
Hierarchical level No. 0	26-28-32-38
Hierarchical level No. 1	26-28-32-38
Hierarchical level No. 2	3.5
Hierarchical level No. 3	3.5
Hierarchical level No. 4	Cannot be addressed by P-MP

(1) See Fig. 1 for definitions

6.4.2 Other factors to be taken into account when considering bands for the IMT-2000 infrastructure

When considering bands for the IMT-2000 infrastructure, many other factors have to be taken into account such as:

– sharing issues with other radio services;

– spectrum congestion due to existing national assignments; and

– national regulation issues.

6.5 Upgrade of existing 2G links into 3G links

The introduction of 3G is likely to be supported on existing networks when available. Therefore the increased capacity requirements as compared with 2G generation including advanced applications that is typically offered today within the 2G will necessitate an upgrade of current P-P links that support these networks.

Following the practical difficulties considered to upgrade existing PDH links to SDH with the associated increased propagation availability requirement (typically from 99.99% to 99.995%) , a possible way for upgrading is described in details with particular emphasis on the spectrum allocation requirements that could result.

6.5.1 Evolution of 3G networks

Current 2G networks have been heavily reliant on P-P radio infrastructure to link up the MSC – BSC – BTS. The vast majority of links are PDH with capacities of 2-34 Mbit/s and in many cases the frequency bands 23 and 38 GHz have been used. These bands support hop lengths between <1-20 km.

To support the services of 3G it is anticipated that the data traffic capacity will increase to the extent that cannot be carried by the current 2G infrastructure, particularly in the urban areas of the network. For PDH links that are currently carrying a capacity of 16-34 Mbit/s it is anticipated that a high proportion of these links will migrate up to SDH capacities, particularly STM-1. It should also be noted that PDH links deployed were planned with a propagation availability of 99.99%. For SDH links the availability will increase to a minimum of 99.995%.

The mobile traffic on which the above estimation is based includes high-quality speech, high-speed packet and medium/high multimedia signal transport. In 2010 it is assumed that required capacity to an individual station will increase about four times compared to that for the 2G system in terms of 90% cumulative value. A capacity of 30-50 Mbit/s may be necessary to meet most of the capacity demand for the 3G systems.

6.5.2 Technology limitations

Current technology limits the overall system gain of SDH STM-1 as compared to an existing PDH capacity. This will impact on the maximum achievable link length for a P-P link in a particular frequency band. Ideally the operator preference is to upgrade a PDH link to SDH in the same frequency band. However where the current PDH link has been deployed towards the maximum achievable link length for the band, it is sometimes not possible to remain in the same band for the upgraded SDH link.

6.5.3 System gain

The effect of "lost" system gain is detailed in Tables 7 and 8 by using parameters of state of the art fixed wireless systems operating in the frequency bands 23 GHz and 38 GHz.

TABLE 7

System gain at 23 GHz

Capacity/bandwidth	Typical O/P power (dBm)	System gain(1) (dB)	"lost" system gain (dB)
16 Mbit/s/14 MHz	+17	94.5	–
34 Mbit/s/28 MHz	+17	91.5	–3
STM-1/28 MHz	+17	79	–15.5
STM-1/56 MHz	+18	84.5	–10

(1) Referenced to a BER of 10^{-6}, assuming non-protected systems

TABLE 8

System gain at 38 GHz

Capacity/bandwidth	Typical O/P power (dBm)	System gain[(1)] (dB)	"lost" system gain (dB)
16 Mbit/s/14 MHz	+16	89.5	–
34 Mbit/s/28 MHz	+16	86.5	–3
STM-1/28 MHz	+15.5	74	–15.5
STM-1/56 MHz	+15	77.5	–12

(1) Referenced to a BER of 10^{-6}, assuming non-protected systems

The loss of system gain can be measured in terms of maximum distance achievable for a given capacity and a given frequency band. In the higher frequency bands the loss of system gain has a profound effect on the maximum hop length that can be achieved for higher capacity systems.

Increasing the antenna dish size is an engineering solution to recover some of the "lost" system gain, however there is an environmental impact to larger dish sizes that may not be tolerated by local planning committees. In addition, there is the possibility that current tower structures cannot support the additional antenna size due to wind loading constraints.

It should be noted that this measure could impact on other FS link assignments as well as on compatibility with other services sharing the same band, such as the passive services and would therefore have to be taken into account in link planning.

At the initial stage of the IMT-2000 deployment, it is efficient, economical and environmental to use the same site with the 2G system. This means that 3G base stations are overlaid to those of the 2G systems utilizing the same locations. Also in such cases, required capacity for radio access network will be notably increased by conversion from the 2G system to the 3G system.

It is apparent that, in order to allow existing PDH links to upgrade over the same path, other frequency bands need to be considered. 3G networks will evolve from existing 2G networks and so it is impractical to expect a total redesign of the network in the initial stages of development.

6.5.4 Location sharing

As higher layer links can transport lower network traffic, an MSC station can accommodate SAPs. The same relation could apply to SAP and CS. Location sharing by Node facilities with different layers brings about advantage of efficient maintenance and operation.

In a wide and high-density metropolitan area, several MSCs are needed, SAPs could also be concentrated to the same building as MSCs. Thus, on account of the reduced hierarchy, configuration of the networks will be simplified.

6.6 Infrastructure sharing between 3G operators

Where allowed or encouraged by the frequency management authorities, sharing of their infrastructure by mobile operators would be advantageous. Information on infrastructure sharing can be found in the Handbook on "Deployment of IMT-2000 systems".

7 Frequency assignment aspects

7.1 Use of 2G assignments/conversion of assignments into 3G

Existing FS link assignments for the use in 2G mobile infrastructure networks could be used for a combined 2G/3G infrastructure network. Nevertheless, a direct use by the IMT-2000 transport network of existing 2G assignments could be very difficult (sometimes even impossible) due to the increase in capacity demands and spectrum congestion.

This implies that there is a need for new spectrum to accommodate combined 2G/3G networks. In a medium (long) term process, an upgrade of the old assignments towards the needed higher capacity demands is possible in lower bands. Depending on the national situation, a complete successive shift of the assignments to higher bands at least in the dense areas might be favourable for upgrading 2G to a combined 2G/3G network by making more spectrum available in lower bands. The gained spectrum in these lower bands might be available for the use of other high capacity applications, that could not be accommodated in higher bands due to the system gain loss.

Nevertheless, operators should have the option to apply new link-by-link frequency assignments in rural areas, and to have the option to reuse existing fixed wireless equipment.

7.1.1 Possible changes in core network frequency requirements

Lower 6 GHz band: the L6 GHz band will continue to be heavily used for regional SDH loops. Part of the links will be established using optical fibre but, locally, it will be necessary to use additional channels in other frequency bands such as the U6 GHz or 4 GHz bands.

13 GHz band: the assignment in Fig. 3 in § 7.2.2.2 has a certain similarity with that used for transport networks requiring higher capacity. The spectrum illustrated in the dotted line in Fig. 3 indicates an interleaved arrangement with 40 MHz spacing, which could be used for up to STM-1 transmission. Thus, harmonized spectrum management could be possible between base station back-haul links and long/short-haul transport networks.

A very large number of 34 Mbit/s links within the 13 GHz band will become saturated. In order to cope with this increase in traffic, it will be important to use other frequency band with equivalent conditions of propagation (such as the 11 GHz band), or to upgrade these links to SDH capacity, pending national allowance of SDH links within 28 MHz channels, which will allow the bit rate of many existing links to be quadrupled.

18 GHz band: the 18 GHz band is quite important for urban SDH links and connecting sites to the optical loop in rural areas. This band is also very important for medium bit rate (PDH) links. Furthermore, the 18 GHz band will be used to relieve the 13 GHz band and absorb part of the predicted increase in traffic on the 23 GHz band.

7.1.2 Possible changes in access network frequency requirements

The bit rates required in the access network will quickly increase with the arrival of new high capacity mobile services. The resulting frequency requirements can be estimated by means of network simulation assuming different volumes of traffic per base station in an urban area.

Several solutions are envisaged for coping with this increase in capacity of the local loop:

– the use of more efficient modulation such as 16-QAM, since the reduction in the maximum allowable hop distance remains acceptable in densely populated urban areas;

– the use of increased bandwidths (14 MHz, or even 28 MHz) in the existing 23 GHz and 38 GHz frequency bands;

– the use of new frequency bands between 23 GHz and 38 GHz, since due to the current occupancy of the 23 GHz and 38 GHz bands, it will be difficult to accommodate the additional frequency requirements in these two bands. The minimum frequency needs within the frequency bands between 23 GHz and 38 GHz can reasonably be estimated at 2 × 112 MHz per operator;

– the use of new frequency bands above 50 GHz for very short links between pico-cells, such as the 52 GHz or 57 GHz.

7.2 Block assignments/Inter-operator protection measures

The necessary base station density in metropolitan areas determines the spectrum requirement of fixed service links for IMT-2000. In the first years of IMT-2000 deployment there is likely to be a significant requirement of BSs mainly in dense areas. For instance, in Germany for 50% population coverage (8.5% of the area) around 10 000 BS are required per operator. This network rollout should be finished as soon as possible. Beyond these first years of IMT-2000 deployment, a further 10 000 to 20 000 BS will be required in order to extend coverage to certain rural areas and upgrade capacity rollout in dense areas. In order to support the demand for a quick rollout of BS and FS infrastructure, a fast assignment procedure is required. This can be achieved by various means:

– computerized link-by-link assignment with quick response from the regulator;

– block assignment; and

– combination of the above-mentioned methods.

The majority of fixed wireless links for BS connection is characterized as low and medium capacity with short hop distances. Taking into account the large number of links that will be required, block assignment procedures seem to be a quick and viable way for administrations with limited resources. Due to the characteristics of such links, block assignments can be more favourable than other methods, depending on the national availability and frequency planning procedures.

It is expected that administrations wishing to implement block assignment take into account the possibility of establishing proper width and aggregation amount of each block to be assigned.

7.2.1 Advantages and disadvantages of block assignments

To allow a fast and easy rollout, block assignments to operators could be considered at least for base station connections.

Advantages of block assignments are:

– fast rollout to achieve the licence conditions;

– spectrum efficient planning on the basis of typical system parameters;

– spectrum efficient planning by acceptance of possible interference from own systems;

– cost effectiveness in regard to spare part handling and contracting; and

– technology independent (P-P and P-MP could equally be used).

Beside the above-mentioned advantages also risks and disadvantages may appear, e.g.:

– high/low conflicts (leading to possible need for inter-operator coordination);

– unused guardbands (leading to spectrum inefficiency); and

– unused block allocations (leading to spectrum inefficiency).

7.2.2 Inter-operator protection measures in block assignment scenarios

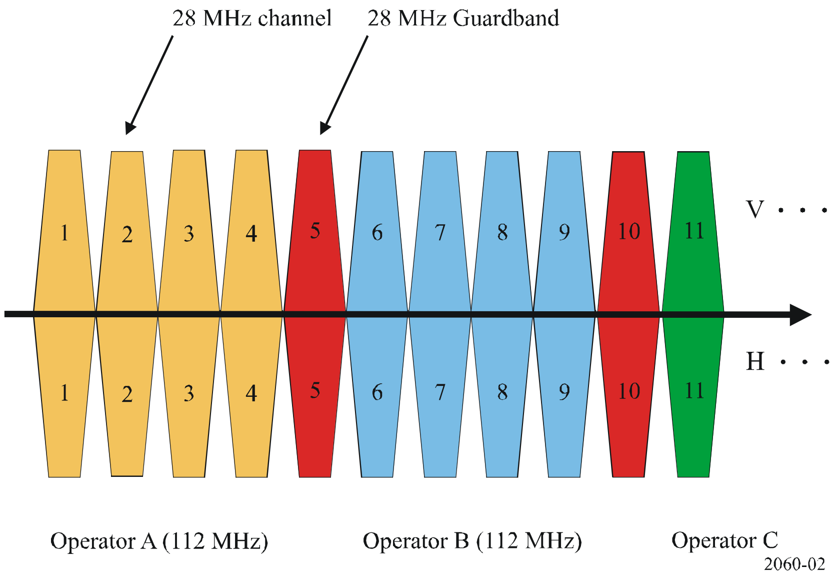
7.2.2.1 Assignment scenario with guardband

If block assignment procedures are applied, guardbands should separate these spectrum assignments to avoid interference between the different operators. Within the assigned blocks the operators can freely choose polarization and channel bandwidth up to maximum usable bandwidth (i.e. 28 MHz).

An example of such assignment scenario with guardband is given in Fig. 2.

FIGURE 2

Example of block and guardband assignment



To avoid the risks mentioned in § 7.2.1 certain measures have to be applied to avoid an inefficient use of spectrum. Such measures would be required in particular in the case that different operators share the location of their base stations.

To avoid high/low conflicts, at least for hubsites in star configurations, a certain sub-band may be defined in advance according to P-MP usage (i.e. Sub-CS with more than three links per band). In conjunction with sufficient guardbands, less conflicts may appear, and several of them be avoided if the positions of big hubsites are exchanged between two frequency neighbours. From experience in 2G networks, different operators often have close relationships and are informed about important nodes of each other.

In an example in Fig. 2, in order to minimize the guardbands, the block size should be adequate and should not be below 56 MHz within a band. Block sizes of 84 MHz or 112 MHz are more suitable but may be difficult to achieve. Since the guardband should be in the size of the maximum usable channel bandwidth, the maximum useable channel bandwidth for the operators has to be limited, at least at the edges of a block. After the main rollout is finished, the guardbands could be used by the operators for optimization purposes if frequency planning is applied between the operators. In this respect the guardbands are not wasted, the use is just delayed behind the major roll-out, this might be even possible in the case of P-MP. Nevertheless at the border of P-MP and P-P usage, the chances to find a suitable solution are relatively small.

To secure an efficient use of the bands and to avoid unused spectrum for each link (P-P), respective central station (P-MP) information should be sent to the authority by means of e.g. monthly or yearly reports. Unused or rarely used spectrum could be made available for other operators or applications later on.

7.2.2.2 Assignment scenario without guardband

An example assignment scenario without the use of guardbands is given in Fig. 3.

This assignment has the following advantageous features:

– four RF channels are accommodated within 80 MHz bandwidth assigned to one operator;

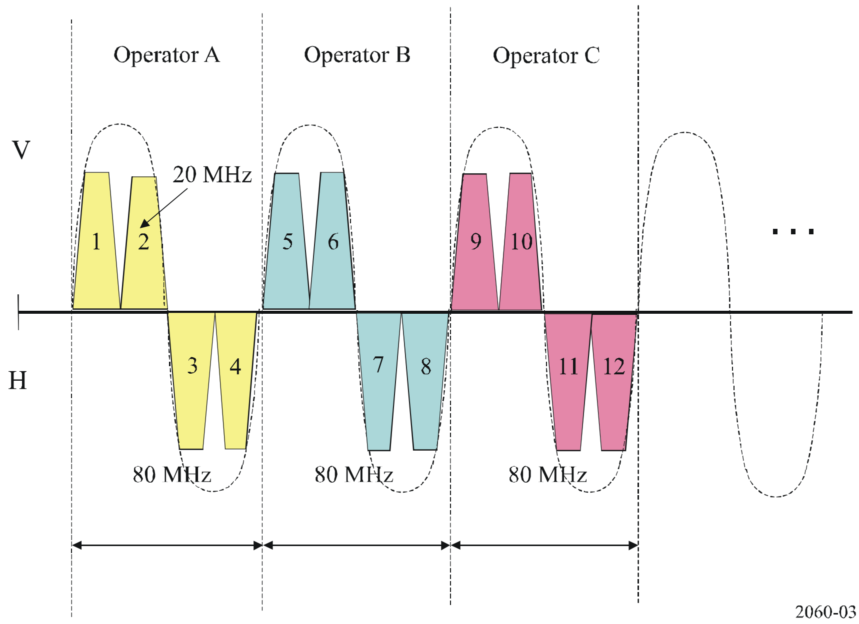
– adjacent RF channels between two operators (e.g. channels No. 4 and No. 5) are arranged in different polarizations, and this will contribute to reduction of the inter-operator interference; and

– one operator could use its channels from the lower frequency (e.g. channels No. 1 and No. 2) utilizing a single polarization antenna, then afterwards increase the link capacity by employing either the opposite polarization feeder or separate antenna with the opposite polarization.

The assignment in Fig. 3 has certain similarity with that used for transport networks requiring higher capacity. The spectrum illustrated in the dotted line in Fig. 3 indicates an interleaved arrangement with 40 MHz spacing, which could be used for up to STM-1 transmission. Thus, harmonized spectrum management is possible between base station back-haul links and long/short-haul transport networks.

FIGURE 3

Example of interleaved assignment without guardband



7.2.3 Examples of assignment methods

Examples of assignment methods in some countries are provided in Annex 4.

7.2.4 Summary of assignment aspects

It should be noted that other than a totally exclusive use of block assignments and a link-by-link assignment, there are various possible solutions. A block assignment procedure can be useful for the lower layer of the infrastructure network in frequency bands above around 20 GHz. Furthermore, it may be favourable to allow the exclusive use of the relevant part of the spectrum only for a certain timeframe until the major network rollout is completed and have a reconsideration afterwards.

For the upper part of the network layers where less links with high capacity demands (STM-1 and more) will be likely, a link-by-link assignment seems to be more appropriate.

8 Overall summary

Due to different national requirements, it is not possible to provide a single number for the amount of spectrum required or in which bands spectrum for this purpose may be provided.

This decision has to be made on a national basis. However, some principles could be taken into account:

– The required total bandwidth of FS for IMT-2000 infrastructure networks will be determined in the long term primarily by the development of IMT-2000. The actual requirements should be oriented towards a medium term solution, that allows sufficient planning security for service providers in terms of economical aspects and fast roll out of the IMT-2000 network, but also takes into account spectrum efficiency and requirements of other services and applications.
– Although the required amount of spectrum and the absolute numbers of fixed wireless links will vary by country and operator, the link densities in the urban areas will determine the required fixed service spectrum for infrastructure networks of IMT-2000. With this background, the required fixed service spectrum can be estimated for the different layers of the IMT-2000 infrastructure network for an operator (the numerical estimations are provided for an operator with 2-3 IMT-2000 frequency blocks of 5 MHz each, i.e. with a whole amount of IMT-2000 spectrum of 10-15 MHz). The requirements can be adopted by the various administrations based on their national needs in terms of:
  – number of operators;
  – scenarios for the evolution of users needs;
  – future density of the fixed wireless part of the infrastructure networks;
  – use of alternative networks to provide infrastructure (e.g. cable or fiber optics);
  – climatic and topographic situation; and
  – regulation policy.
– When considering FS bands for IMT-2000 infrastructure, the following factors may also be taken into account:
  – technical characteristics in terms of achievable data rates, hop length, etc.;
  – sharing issues and/or split of the band and/or priorities given to various radio services (relevant ITU-Recommendations to be applied); and
  – spectrum congestion due to existing assignments.
– With regard to the frequency assignment by the national authorities, a fast and flexible roll out of the infrastructure network has to be considered requiring the:
  – provision of spectrum for P-P and P-MP systems with an appropriate assignment strategy;

– incorporation/upgrade of existing infrastructure networks (e.g. 2G into 3G) if appropriate and possible; and
– possible sharing of infrastructure (e.g. between 2G and 3G infrastructures of an operator, or between different mobile operators) if appropriate and possible.

Annex 1

Detailed topology of the IMT-2000 transport network

1 Connection between BS and CS stations

If large numbers of BS stations need to be served by the SAP, subnetworks should be built in order to have additional nodal interconnection concentration in the network. This additional concentration is ensured by including CS stations with ATM switching functions in the transport network, as can be seen in Fig. 1. The connections between BS and CS stations can be achieved either by P-P, P-MP architectures, or a combination of both.

1.1 P-P Applications

P-P fixed service wireless links are a very important transportation media in the architecture of the Radio-Access-Network within IMT-2000. The interconnection between base stations and the switching centres within the network is one of the main fields for these applications. P-P may dominate the access from the cell implementations to the network. Depending on the requirements including:

– hop length;
– required capacity;
– availability target,

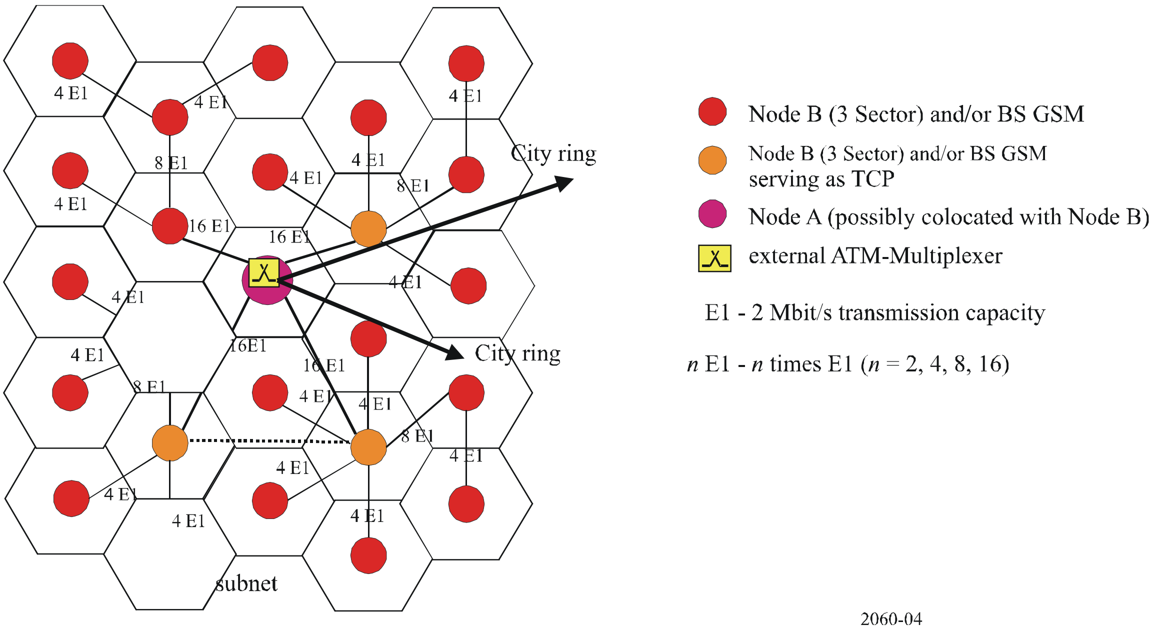
suitable frequency bands for wireless link operation may be found.

However, direct access to the BS of a certain cell may lead to a hop length that would require installation of big antennas. This may cause severe problems with installation, especially at the big concentration points (CS) within the network. Thus, chains of P-P links, instead of direct interconnections, should be used, including aggregation of capacities along the chain of links between cell BS and switching centre especially in suburban and rural environment.

In urban and dense urban environments, BS density allows the effective use of star and sub-star networks with pre-concentration or at least collection functionality by introducing a SUB-CS. Nevertheless conventional structure may still be a possible solution, since the driving force in mobile networks is always the radio coverage of the mobile system, not optimal transport network conditions. This fact will always require certain flexibility by the transport network, resulting sometimes in higher spectrum demands. Fig. 4 illustrates a possible sub-star network structure including chains of P-P links.

FIGURE 4

An example of a subnetwork structure for BS access using sub-star and chains of FS links



In this architecture based on P-P fixed links, each CS is equipped with directional antennas, each of them pointing in the direction of a specific BS. Also BSs are equipped with directional antennas pointing towards either a CS station, or another BS with which it constitutes a sub-star or chain of FS links.

This solution has the advantages of:

– limited number of link installations for a certain location;

– short hop lengths;

– small antennas due to high frequencies used;

– reducing an extreme aggregation of capacities along chains; and

– flexibility with respect to changes/increases of required transport capacities and addition of further BSs.

An example of estimation of spectrum needs for the subnetwork described in Fig. 4 can be found in Annex 2.

Where the situation allows, a direct access method to construct links from the CS (ATM-switch) to as many surrounding BSs as possible has following advantages:

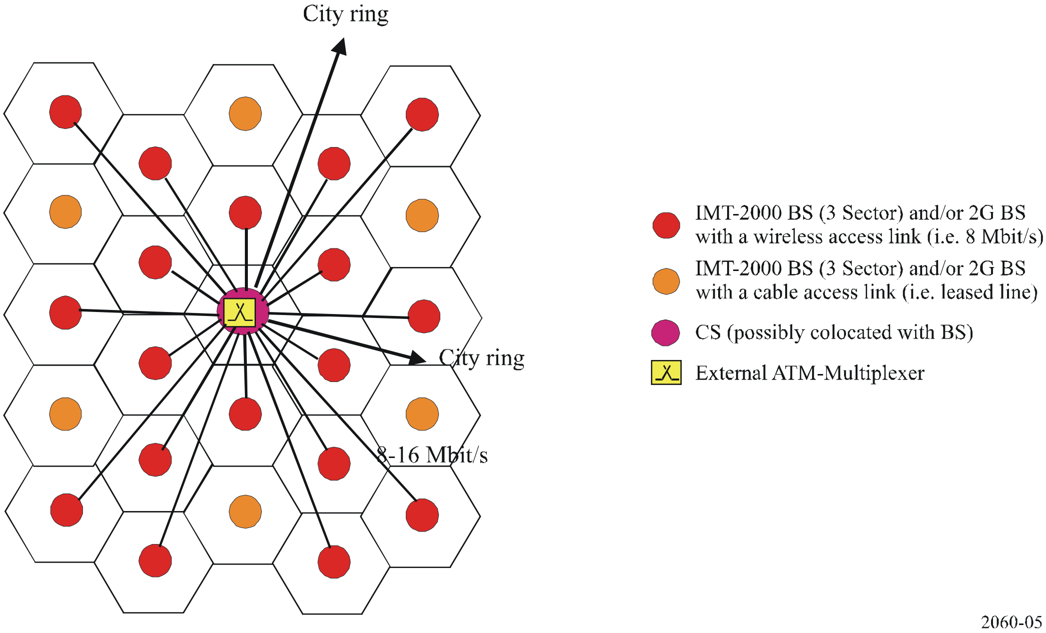
– payload division or interconnection to another radio access system at the base station is not necessary; and

– line-of-sight condition to many base stations may be easily obtained if the CS has a high tower.

Figure 5 illustrates an example of direct access link deployment to the BSs from the CS station.

FIGURE 5

An example of direct link structure for BSs access



In this architecture based on P-P fixed links, each CS is equipped with directional antennas, each of them pointing in the direction of a specific BS. Also BSs are equipped with directional antennas pointing towards a CS.

In two deployment scenarios of access links to base stations (BS), i.e. Fig. 4 and Fig. 5, existence of LoS condition between stations should be carefully considered. Appendix 1 to Annex 1 presents examples of investigations of LoS probability from CS to the surrounding BS, and between BSs.

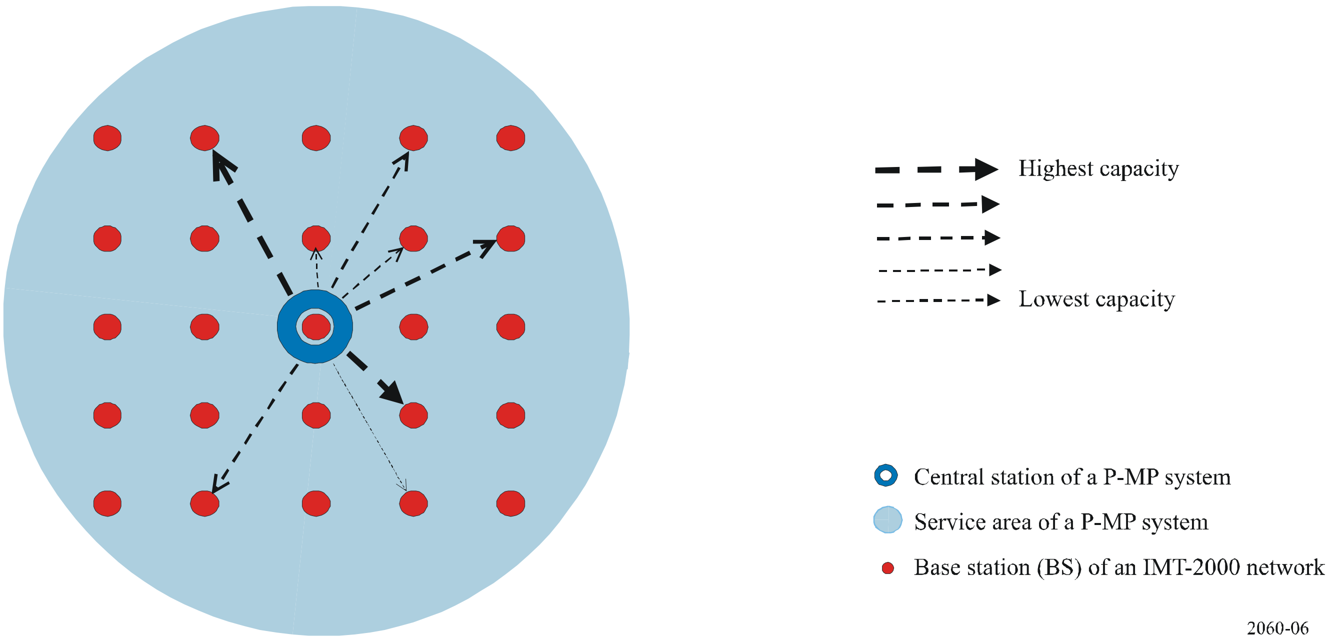
1.2 P-MP applications

In areas of high density of cells within IMT-2000, the use of P-MP fixed service applications might be a solution for accommodating the capacity requirements of interconnecting the cell base stations (BS) with the switching centre. P-MP applications could have the ability to serve large numbers of cells, especially if P-MP systems using sectored antennas are operated.

The structure of such a P-MP network is given in Fig. 6. According to the individual requirements of each BS, different transport capacities can be provided to serve the CSs of the P-MP system.

FIGURE 6

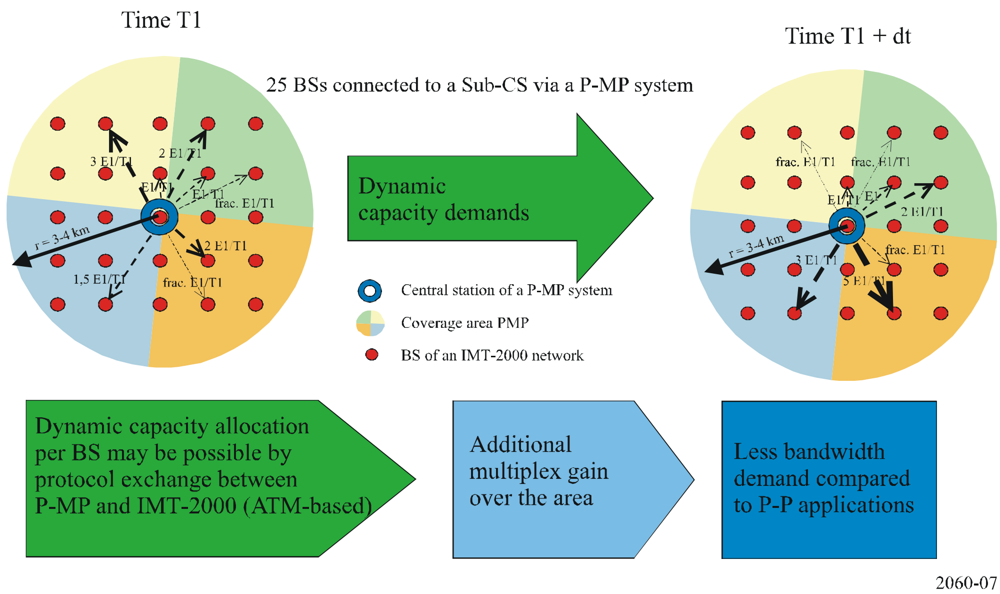
An example of a fixed service P-MP network structure



Furthermore, dynamic capacity allocation within the P-MP system is possible and could increase the efficiency of this system. The dynamic behaviour of the P-MP Systems should adapt to the current traffic demands of the served BS. The reaction time is typically below 1 s. The principles of the dynamic capacity allocation are shown in Fig. 7 .

FIGURE 7

Dynamic capacity allocation in fixed service P-MP systems



P-MP systems may be more efficient by using:

– ATM granularity gain;

– FDCA (fast dynamic capacity allocation) and

– ATM multiplexing.

In addition P-MP systems may provide an advantage by minimizing the visual impact.

1.3 Combined P-MP/P-P solutions

There are several reasons for P-P link applications, considering limitations of networks with significant P-MP deployment:

– no LoS of the BS to the central station of the P-MP system;

– worse *C*/*I* condition at some BSs connected to the P-MP system;

– singular BS with constant high capacity demands; and

– trunk links to connect the P-MP central station to the SAP.

ATM aggregation via P-MP is typically more suitable in the large hubs where the number of connected BSs is high and spectrum efficiency is a must (as it determines the operator frequency assignment requirement).

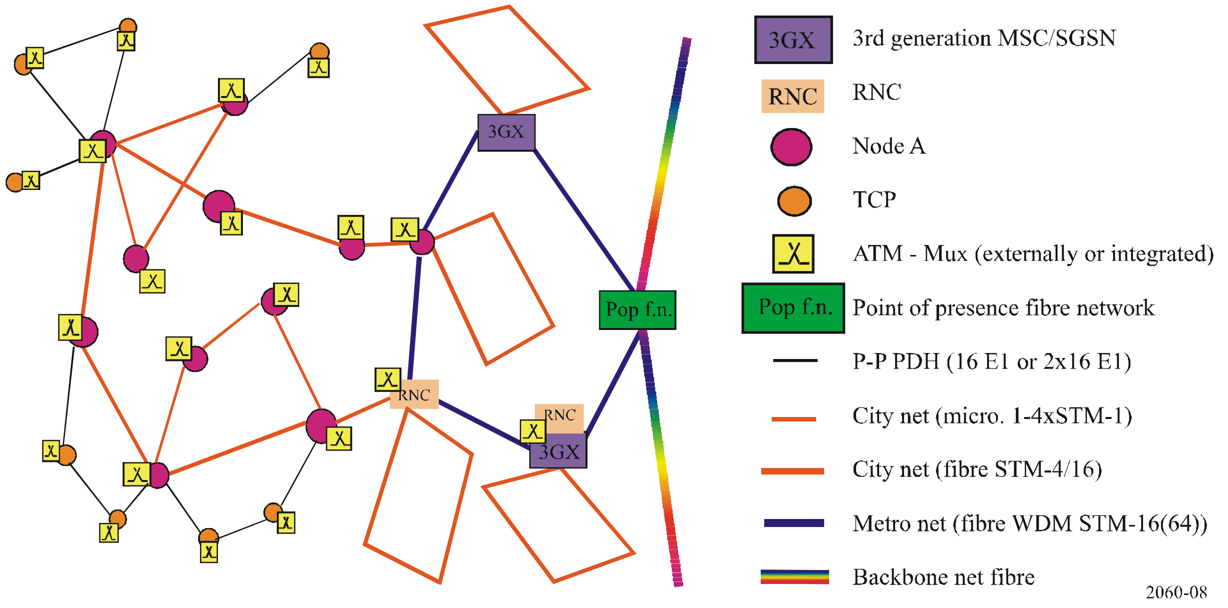
2 Transport network structures between the CS and the core network

The transport network above CS and SAP within the IMT-2000 has the task to organize and operate the concentration of information in the direction of the SAP and further to the core network (MSC), see Fig. 1 in the main body of the Report. A possible structure of this part of the network is given in Fig. 8.

A certain number of CSs could be connected via a ring structure towards the next SAP location. Within the hierarchical level No. 3 structures, at least in the first years of utilization of the network, a reasonable number of P-P SDH links can be expected. Furthermore, only a few SAP locations may be used, since traffic concentration has already applied at the concentration points by ATM-multiplexing/switching functionality. The traffic concentration at the SAP is negligible. Above the SAP, P-P SDH links may be applied as well, but fibre optical connections may be preferred from the beginning.

FIGURE 8

Possible structure of the higher order transport network for IMT-2000



Appendix 1
to Annex 1

LoS probability simulations between node stations in the sub-network structure

In Annex 1 Section 1 two example structures using P-P links are shown in Fig. 4 and Fig. 5, i.e. respectively:

– sub-star and chain structure (Fig. 4) and,

– direct access structure (Fig. 5).

Table 9 shows that average probability of LoS from CS stations to surrounding base stations within 5 km is about 92%. This indicates that direct access link could be constructed to a number of base stations from CS with an antenna height greater than 40 m.

TABLE 9

Example of LoS probability between CS and BS

CS (antenna height)	Number of BSs within 5 km	LoS probability to BSs within 5 km (%)
No. 1 (82 m)	52	96.2
No. 2 (98 m)	71	83.1
No. 3 (71 m)	63	90.5
No. 4 (99 m)	60	93.3
No. 5 (49 m)	38	97.4
No. 6 (54 m)	24	95.8
No. 7 (43 m)	26	100
No. 8 (43 m)	31	87.1
No. 9 (96 m)	31	93.6
Average (70 m)	44.5	92

On the other hand, following the BS access structure based on Fig. 4, another investigation of the LoS probability between BS stations has been conducted. The result is given as an example in Table 10, which shows that, even for low antenna heights (20 -40 m), high LoS probability could be obtained.

TABLE 10

Example of LoS probability between BS stations

	Antenna height (m)	Number of sample stations	Average LoS probability to 5 nearest stations (%)	Average distance to the 5 nearest stations (m)
Low antenna group	20-40	35	94	1 294
Medium antenna group	40-60	52	95	1 067
High antenna group	Higher than 60	13	97	944

Annex 2

Examples for estimation of FS spectrum requirements for IMT-2000 networks in urban areas

1 Glossary of notation and acronyms

Symbol	**Unit**	Description
A_M	km^2	Area per micro cell
B_A	$Mbit/s/km^2$	Bit rate per unit area and per operator
B_{AN}	$Mbit/s/km^2$	Bit rate per unit area for N_O operators
$ß_B$	Mbit/s	Theoretical required gross bit rate per cell site
B_B	Mbit/s	Reduced gross bit rate to standard PDH hierarchy
B_Q	$kbit/h/km^2$	Total offered bit quantity downlink
B_S	Mbit/s	Bit rate per cell site
B_T	MHz	Total bandwidth of required frequency spectrum
B_U	MHz	Unit bandwidth
C_M	---	Number of carriers per micro cell
D	km	Hop length
D_S	Mbit/s	Data rate per sector
N_C	---	Total number of required RF channels at the node
N_O	---	Total number of operators
O_A	---	ATM overhead
O_H	---	Overhead for soft hand-over
O_S	---	Overhead for signalling
O_T	---	Accumulated overhead
R_M	M	Micro cell radius
S_M	---	Number of sectors per micro cell

2 Introduction

This Annex provides some guidelines for the estimation of FS spectrum requirements for IMT-2000 transmission networks forming interconnections between cell sites (BS) and Sub-CSs.

It describes the input data set, some assumptions and the procedure for calculation of the cell radius which was used for the design of a cell cluster. Based on these estimations, in § 6 different layouts of transmission networks were chosen for the evaluation of required spectrum especially in the 38 GHz band. The results may be applicable to other bands e.g. 27 GHz, 32 GHz as well. The main focus was dedicated to urban areas and micro cells.

Layout of every transmission network example is documented by:

– situation of interconnections within the cell cluster;

– proposal for frequency plan; and

– main characteristics.

Technical performance of available transmission equipment was considered and calculation of interference levels were made for verification. Finally all versions are compared with regard to bandwidth requirement and the spectrum available. A ratio between the worst and the best case were found somewhere between a factor 2 to 3.

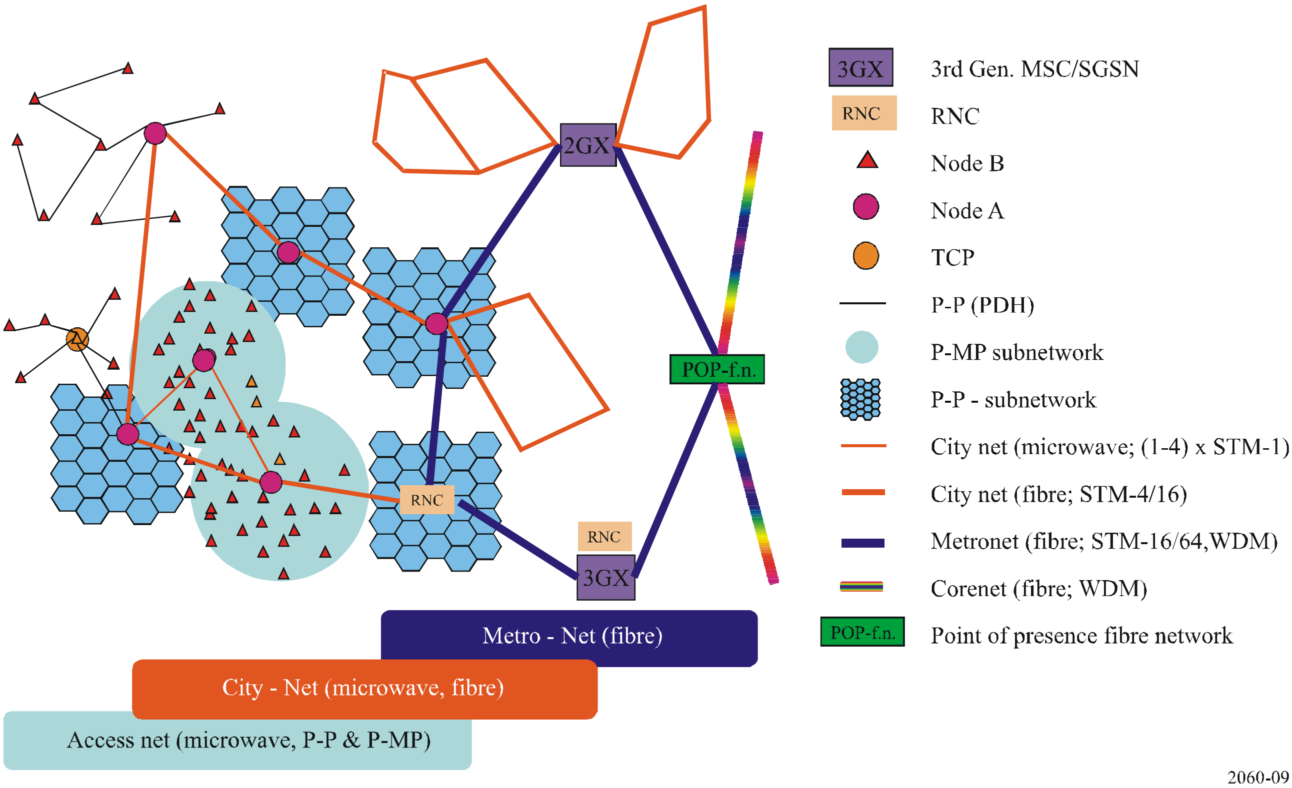
3 General overview of an IMT-2000 network

The IMT-2000 transport network represents the interconnection between the mobile user and the core network. This mobile infrastructure needs to be supported by a transport network, which organizes the transport of information between the mobile users concentrated at the BSs and the interconnection to the fixed network as well.

A general overview of an IMT-2000 network is given in Fig. 9. The interconnections between the radio access network and the transport network, as well as the interfaces within the transport network itself dictate the requirements concerning capacities and transportation media used for interconnecting all levels of the network hierarchy.

FIGURE 9

General overview of an IMT-2000 network



4 Estimation of the micro cell radius

First, the size of a cell is estimated. Table 11 shows an example of an estimated calculation within CEPT for the Total Offered Bit Quantity Down Link (kbit/h/km^2) for the year 2005.

TABLE 11

Total offered bit quantity (OBQ) downlink (kbit/h/km^2) for the year 2005

Services	CBD/Urban (in building)	Suburban (in building or on street)	Home (in building)	Urban (pedestrian)	Urban (vehicular)	Rural in- & out-door
High interactive MM	3.78×10^8	4.73×10^5	5.37×10^3	8.69×10^6	2.17×10^6	1.66×10^4
High MM	2.76×10^8	5.24×10^6	2.77×10^5	7.86×10^7	1.35×10^5	1.72×10^3
Medium MM	2.21×10^7	2.62×10^5	1.38×10^4	6.42×10^6	1.10×10^4	8.62×10^1
Switched data	9.58×10^7	2.99×10^5	9.22×10^3	4.76×10^6	3.66×10^5	5.61×10^3
Simple messaging	2.76×10^6	5.53×10^4	2.92×10^3	8.29×10^5	1.42×10^3	1.82×10^1
Speech	3.52×10^8	1.29×10^6	5.98×10^4	8.20×10^7	3.56×10^6	3.46×10^4
Total	1.13×10^9	7.62×10^6	3.68×10^5	1.81×10^8	6.24×10^6	5.86×10^4

Comparison of results in the line "Total" shows that only two services are of interest for further estimations in respect to FS system transport capacity:

– Central Business District (CBD), which requires a total of 1.13×10^9 kbit/h/km^2; and
– Urban (pedestrian) with a total of 1.81×10^8 kbit/h/km^2.

All other categories are far below the totals as mentioned and therefore they are negligible for estimation of required transport capacity. Totals of OBQ Up Link, was not considered because of lower values, on the other hand, load of fixed wireless links is normally balanced in forward and back direction.

The total OBQ in CBD environment is ten times higher than for the Urban (pedestrian) environment, but, as it would mainly be served by pico cells, it is not considered for the estimation of the micro cell radius.

TABLE 12

Assumptions for further calculations

Subject	Notation	Value	Unit	Remark
Total OBQ downlink	B_Q	1.81×10^8	kbit/h/km^2	From Table 11
Total number of operators	N_O	4	---	Driven by evolution scenarios
Number of carriers per micro cell	C_M	2	---	Assumed
Number of sectors per micro cell	S_M	2	---	Assumed
Data rate per sector	D_S	0.9	Mbit/s	Assumed

TABLE 13

Derivation of micro cell radius considering values of Table 11

Subject	Notation	Calculation	Result	Unit
Bit rate per micro cell site, net	B_S	$C_M \times S_M \times D_S$	3.6	Mbit/s per cell site
Bit rate for N_O operators per unit area (rounded)	B_{AN}	$B_Q/3600$	52	Mbit/s/km^2
Bit rate per operator and per unit area	B_A	B_{AN}/N_O	13	Mbit/s/km^2
Area per micro cell	A_M	B_S/B_A	0.277	km^2
Micro cell radius (rounded)	R_M	$620 \times A_M^{1/2}$	**330**	M

5 Cluster model

5.1 General

Considerations:

– only micro cells are used in the first run;

– FS P-P links are used to interconnect the cell site to a node. An additional overhead is taken into account for the determination of the transport capacity on the P-P link, e.g. as presented in the Table 14;

– focus is set to urban area primary – if the results for the required frequency spectrum for the FS P-P links fits to frequency spectrum available then there will be no shortage for sub-urban and rural areas.

FIGURE 10

Dimensions of the micro cell

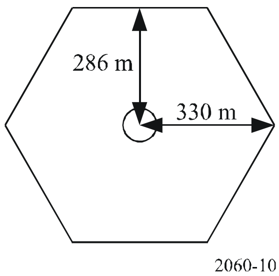


TABLE 14

Determination of the required transport capacity per micro cell site for the fixed wireless link

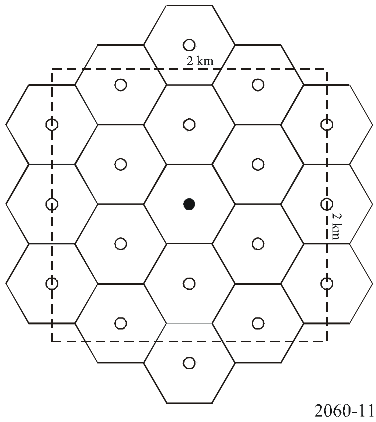
Subject	Notation	Calculation	Value	Unit
Bit rate per micro cell site, net	B_S	$C_M \times S_M \times d_S$	3.6	Mbit/s per cell site
Overhead for signalling	O_S		1.15	---
Overhead for soft hand-over	O_H		1.40	---
ATM overhead, ranging from 20% up to 70%, depending on service	O_A		1.45	---
Accumulated overhead	O_T	$O_S \times O_H \times O_A$	2.33	---
Required transport capacity (gross bit rate per micro cell site)	$ß_B$	$O_T \times B_S$	8.4	Mbit/s per cell site
Reduced gross bit rate adapted to standard PDH hierarchy	B_B		8	Mbit/s per cell site

5.2 Cluster design

In this context, a cluster is formed by a number of equal sized micro cells (as shown in Fig. 10) and they are arranged such that a quadratic area is covered (Fig. 11). All respective BSs are connected to one SUB-CS by P-P links.

FIGURE 11

Layout for a cluster of 2 × 2 km with one sub-CS at the centre



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Transmission networks under investigation are defined in Table 15.

TABLE 15

Considered parameters for transmission calculations

Parameter	Transmission network
Micro cell radius (m)	330
Carriers per micro cell	2
Sectors per micro cell	2
Cluster size	2 × 2 km
No. of micro cells/cluster approx.	14
FS links per cluster	13
Layout details	§ 6.3
Summary of results	§ 6.4

6 Layout of a transmission network

6.1 General

Different structures of transmission network layout are evaluated by interconnecting micro cells to one cluster node. Estimation of total required frequency spectrum is based on interference calculations. For simulation of several configurations, the characteristics of real equipment (radio equipment and antenna) have been used.

6.2 Some definitions for simulation work

6.2.1 Unit bandwidth B_U

The unit bandwidth indicator B_U was introduced to have a measure for the occupied frequency spectrum depending on required gross bit rate per link (or transport capacity). This value is based on 4-level modulation scheme (4-FSK or 4-QAM) and it represents also in special cases the channelling of the respective frequency plan. If different transport capacities are used B_U is set to the smallest value.

TABLE 16

Transport capacity versus unit bandwidth (B_U)

Transport capacity (Mbit/s)	B_U (MHz)
4 × 2 or 8	7
2 × 8	14
16 × 2 or 34	28

6.2.2 Bandwidth of required frequency spectrum B_T

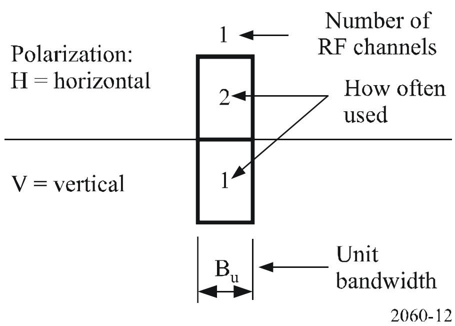
Bandwidth of total required frequency spectrum depends on layout of the interconnection network, it is defined for realization of one cluster (and for one operator) as:

$$B_T = N_C \times B_U$$

where N_C represents the number of consecutive RF channels at the SUB-CS(s) including "guard" channels (if necessary to meet a predefined *C*/*I*-value). Therefore only N_C has to be evaluated for each type of transport network layout. Adjacent clusters with different layout have a small impact on cluster under consideration.

FIGURE 12

Frequency plan (example)



6.2.3 Frequency band

The assignment of the frequency band is, where applicable, selected depending on hop length *d*.

TABLE 17

Frequency band versus hop length *d* (example)

Hop length *d* (km)	Frequency band (GHz)
up to 0.7	52 or 56 or 58
up to 5	38

6.2.4 Level at receiver input

In any case the level at the receiver input shall be –40 dBm within a tolerance of ±1 dB. Therefore:

– output power of the corresponding transmitter shall be adjusted accordingly; and/or

– antennas shall be chosen properly.

6.2.5 *C*/*I* requirements

Selection of a RF channel is based on results of interference calculation and $C/I \geq 55$ dB.

6.2.6 Polarization

Horizontal or vertical polarization is used depending on hop length (or to improve decoupling).

6.3 Layout of a transmission network

For a cluster size of 2 × 2 km different layouts of the transport network are evaluated. For each of the following structures 2 versions are investigated:

– Version x.1 – All links operate in the same frequency band (e.g. 38 GHz);

– Version x.2 – All links with length d < 0.7 km are chosen from a band > 38 GHz (e.g. 58 GHz);

where x refers to the rank of the structures, according to the subsections 6.3.1 to 6.3.3 (e.g. x = 1 for Structure 1).

6.3.1 Structure 1

For this structure the SUB-CS is placed approximately in the centre of the cluster and each BS is connected by an individual P-P link (Fig. 13).

Main characteristics:

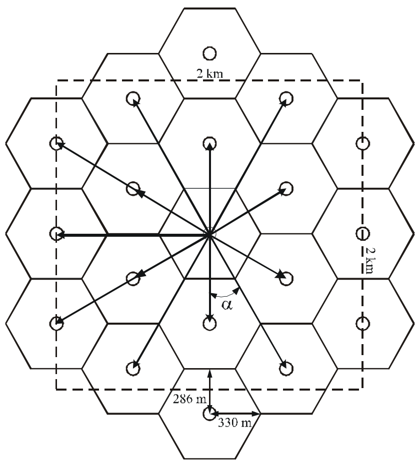
– minimum hop length is approx. 0.6 km;

– maximum hop length is approx. 1.2 km; and

– capacity per FS link is 8 Mbit/s ($B_U = 7$ MHz).

FIGURE 13

Layout of interconnections for Structure 1



2060-13

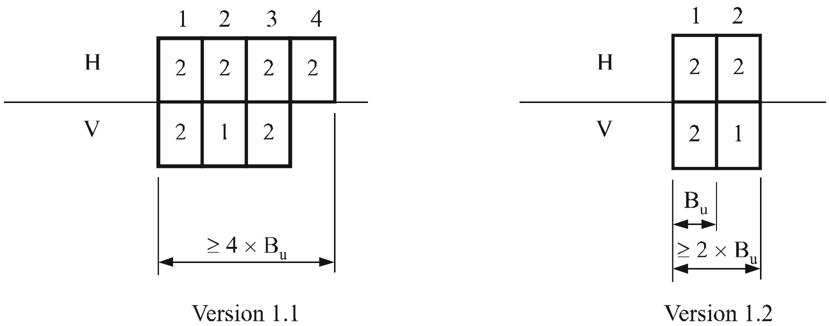
TABLE 18

Main characteristics of Structure 1

Version	Frequency band (GHz)	Number of links	RF channels required	Hop length *d* (km)
1.1	38	13	$N_C \geq 4$	> 0.6
1.2	38	7	$N_C \geq 2$	> 1
	58	6	$N_C \geq 2$	< 0.7

FIGURE 14

38 GHz frequency plans for Structure 1



6.3.2 Structure 2

In this case up to three cells are connected in series to the node. Hop length of all links is in the same order of approx. 0.6 km. Angle between neighbouring connections is mostly higher than in Structure 1 since fewer connections are led to the SUB-CS.

FIGURE 15

Layout of interconnections for Structure 2

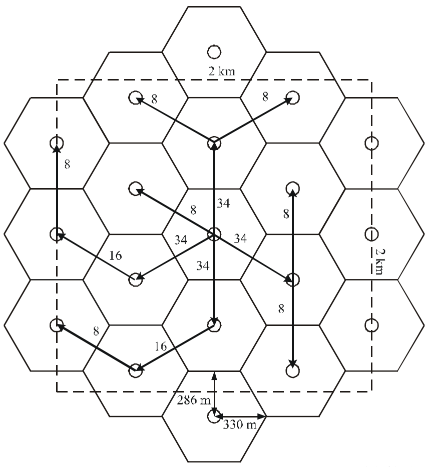


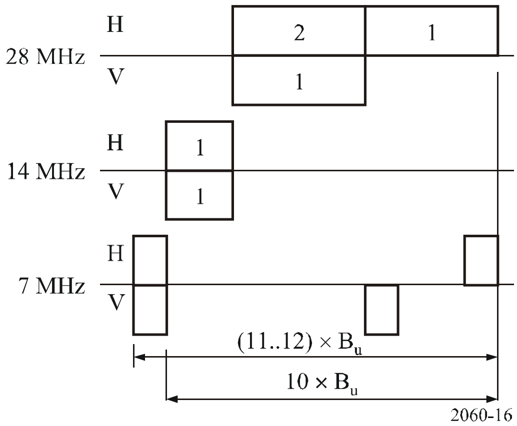
TABLE 19

Main characteristics of Structure 2

Transport capacity Mbit/s	Frequency band (GHz)	Modulation	Channel spacing (MHz)	Number links
8	38	4 FSK, 4-QAM	7	7
16	38	4 FSK, 4-QAM	14	2
34	38	4 FSK, 4-QAM	28	4

FIGURE 16

38 GHz frequency plan for Structure 2



If all links operate in the 38 GHz band the required bandwidth is (11..12) × B_U (Version 2.1), if all 8 Mbit/s-links operate in the 58 GHz band the required bandwidth is 10 × B_U (Version 2.2).

6.3.3 Structure 3

This case is a variation of Structure 1. The SUB-CS is shifted from the centre to one edge of the cluster. Each cell is connected by a separated link. This structure is often used in Switzerland.

This configuration is characterized by:

– total enclosed angle is of about 90°;

– mean angle between two adjacent links is $\alpha \geq 7°$;

– min. hop length *d* is approx. 0.6 km;

– max. hop length *d* is approx. 2.1 km; and

– capacity per FS link is 8 Mbit/s (B_U = 7 MHz).

FIGURE 17

Layout of interconnections for Structure 3

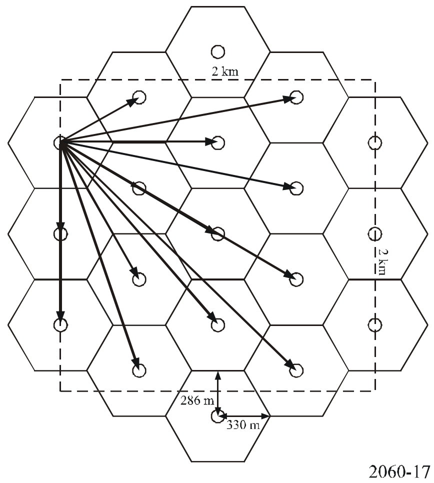


TABLE 20

Main characteristics of Structure 3

Version	Frequency band (GHz)	Number of links	RF channels required	hop length *d* (km)
3.1	38	13	$N_C \geq 11..13$	> 0.6
3.2	38	10	$N_C \geq 6$	> 0.7
	58	3	$N_C \geq 2$	< 0.7

Version 3.1 contains some links in parallel. Version 3.2 avoids, in almost all cases, the presence of links working in parallel by operating all links with hop length of less than 0.7 km in the 58 GHz band.

6.4 Summary of the different structures

In Table 21 the main characteristics and results for the different structures and versions under investigation are compared.

TABLE 21

Comparison for different structures of a transmission network

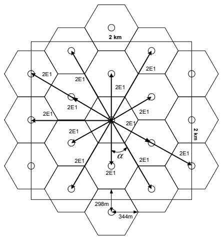
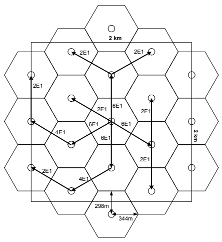
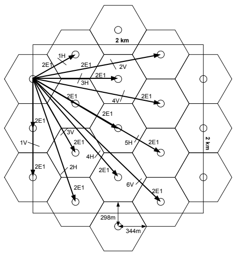
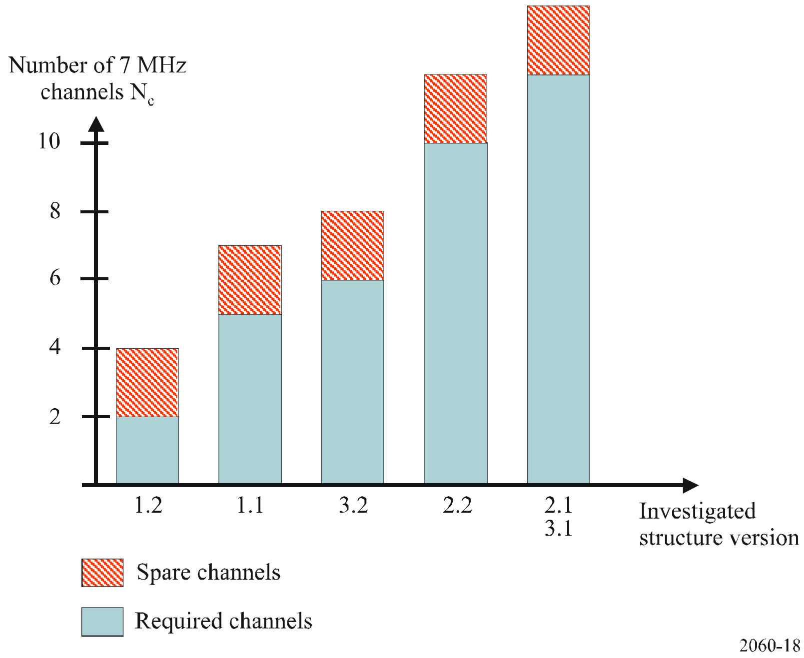
Structure of transmission network		**Version**	**Total bandwidth required B_T**	**"Parallel" links to the node**	**Different transport capacity**	**58 GHz for links of *d* < 1 km**
Fig. 13		1.1	$\geq 4 \times B_U$	Yes	No	No
		1.2	$\geq 2 \times B_U$	No	No	Yes
Fig. 15		2.1	$\geq (11...12) \times B_U$	No	Yes	No
		2.2	$\geq 10 \times B_U$	No	Yes	Yes
Fig. 17		3.1	$\geq (11...13) \times B_U$	Yes	No	No
		3.2	$\geq 6 \times B_U$	No	No	Yes

Figure 18 gives a graphical overview to the estimated FS spectrum requirements. For every structure and version of the transmission network the required bandwidth in the 38 GHz-band is compared.

As a result of this study, the frequency demand per operator may be estimated to be approximately 70 MHz, i.e. in the 38 GHz band. An additional demand of two 7 MHz channels should be added to each spectrum requirement. These spare channels are necessary to minimize interference between adjacent clusters, including a reservation of 7 MHz made for the interconnection of pico cells.

FIGURE 18

Requirements for total bandwidth in the frequency band 38 GHz; "urban"



Annex 3

Impact of rain on the IMT-2000 transport network

This Annex presents the results of a study on the impact of rain on the IMT-2000 transport network. This study focuses on frequency bands largely used in Europe, namely the 18 GHz, 23 GHz and 38 GHz bands.

The results of this study suggest that the choice of the frequency bands for the IMT-2000 transport network may be strongly affected by the climatic conditions encountered in a given area. This is illustrated by an example derived from the experience of a French operator in areas with very different climatic characteristics.

1 Mobile transport networks in Europe

In February 2002, ECC Report 003 on "Fixed service in Europe, current use and future trends post-2002" was published. The studies, carried out by a number of administrations, show that the 23 and 38 GHz bands are the two main bands used in Europe for FS infrastructure networks. The number of links for these bands, together with those for the 18 and 24.5-26.5 GHz bands, are given in Table 22.

TABLE 22

Number of FS links in Europe in 2001 in various bands

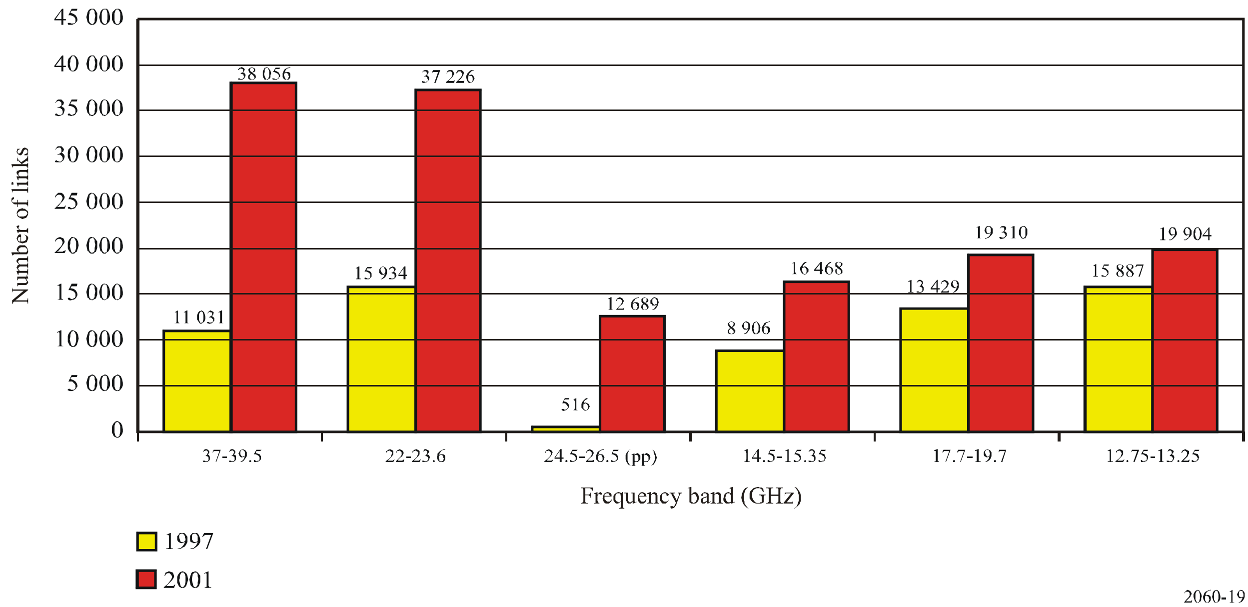
Frequency band (GHz)	Number of links within Europe
17.7-19.7	19 310
22-23.6	37 226
24.5-26.5 (note)	12 689
37-39.5	38 056

NOTE – This band is one of the bands referred as "27 GHz bands" in Table 3.

As shown by the histogram in Fig. 19, the bands 37-39.5 GHz and 22-23.6 GHz are clearly the two bands primarily used for infrastructure networks in Europe.

FIGURE 19

Comparison of the use of the various frequency bands in Europe in 1997 and 2001 (extract from ECC Report 003)



2 Comparison of the impact of rain on the use of FS

To enable the comparison of the impact of rain on the use of FS in various bands, the available fade margin has been computed in different geographical rain zones for the bands 18, 23 and 38 GHz, as a function of the length of the link.

2.1 Calculation of the margin as a function of the hop length

The calculation is based on Recommendations ITU-R P.530, with an availability of 99.99% minimum, and ITU-R P.676. The FS systems considered are P-P and their characteristics are taken from Recommendation ITU-R F.758. In some cases, characteristics of systems currently in operation in certain countries with temperate or tropical climates have been used.

The fade margin FM is calculated as follow:

$$FM = P_r - P_{r,min}$$

or:

$$FM = G_e + G_r + P_e - L_T(p) - FL - P_{r,min}$$

where:

FM: fade margin

P_e: input power at the emission (transmitter power) (dBm)

$L_T(p)$: total loss (rain at p%, gas, diffraction) (dB)

FL: feeder loss (total: at the emission and reception) (dB)

$P_{r,min}$: minimum level at the reception (usually for BER of 10^{-6}) (dBm)

G_e: antenna gain at the emission (transmitter) (dBi)

G_r: antenna gain at the reception (receiver) (dBi).

NOTE 1 – Since only P-P FS systems are considered, in the following calculation $G_e = G_r = G$.

2.2 Results of the calculations in Zones E, M, N, P and Q

In all cases, the elevation is 0° and $p = 0.01\%$.

A direct comparison between the available range of hop lengths in the bands 18 GHz in Zone Q, 23 and 38 GHz in Zone E, is proposed below, based on calculations presented in § 2.1.

The characteristics in Table 23 have been used:

TABLE 23

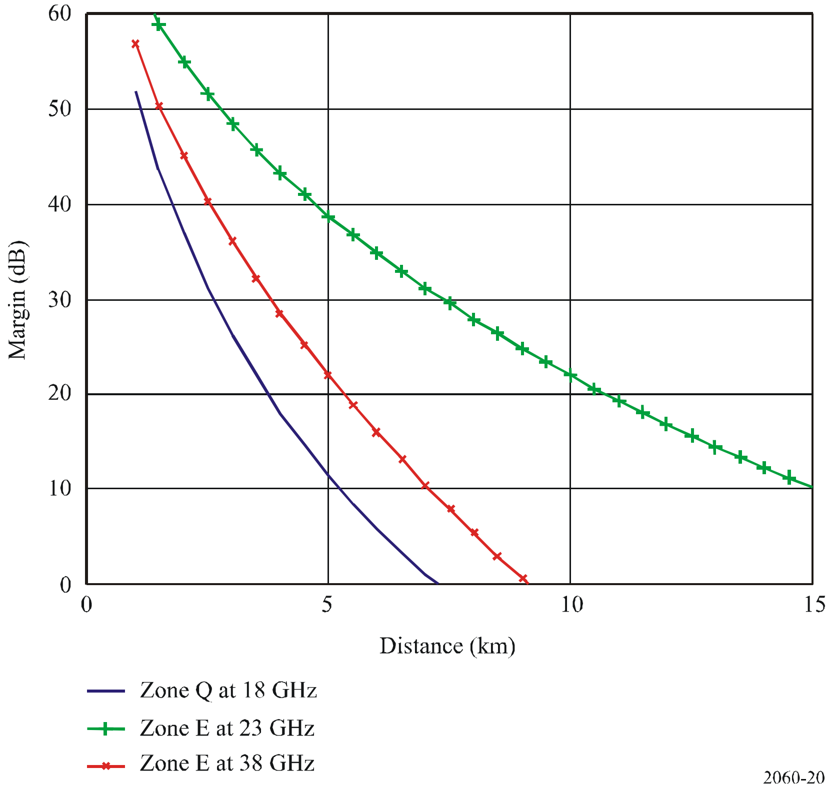
System characteristics for the calculations presented in Fig. 20

Frequency (GHz)	18	23	38
FL (dB)	3	4	4
P_e (dBm)	+25	–25	–25
G (dBi)	45	46	46
$P_{r,min}$ (dBm)	–72.4	–78	–78

The results of this comparison are shown in Fig. 20. It appears that there is a large similarity between the range of hop lengths provided by the 38 GHz band in the climatic Zone E and with that provided by the 18 GHz band in the climatic Zone Q. In this Zone, the 18 GHz band plays the same role (namely, for the infrastructure network) rather than the 38 GHz band in the climatic zone.

FIGURE 20

Comparison between the available range of hop lengths in the bands 18 GHz in Zone Q, 23 and 38 GHz in Zone E



3 Existing case in the French overseas departments

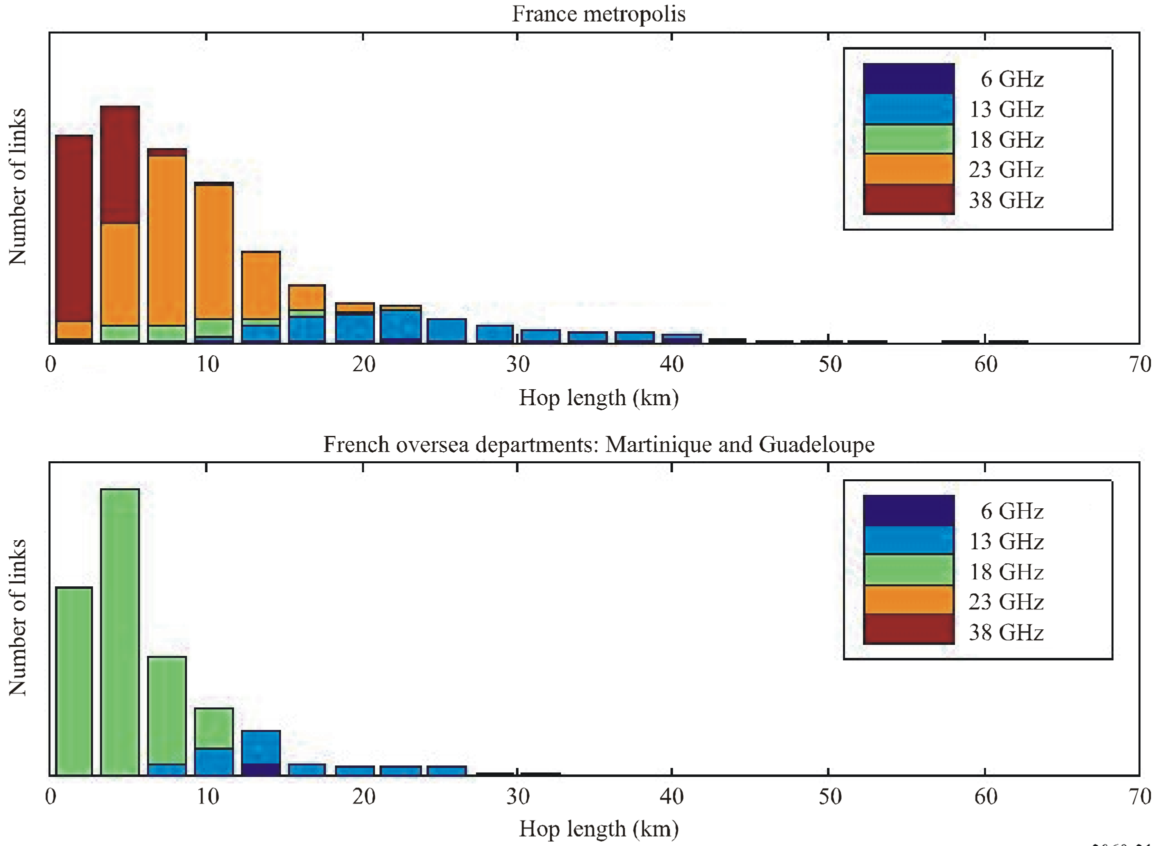
A French operator does not use the 23 and 38 GHz bands in the Caribbean French overseas departments Guadeloupe and Martinique because of rain attenuation. The highest frequency band used for FS in support of IMT-2000 infrastructure network is the 18 GHz band.

Figure 21 provides a comparison of the distribution of the frequency bands as a function of the hop length for the French metropolis and for the French overseas departments Martinique and Guadeloupe.

NOTE 1 – For information, the total number of links considered in the following histogram are: 5 460 in French metropolitan departments and 241 in French overseas departments.

FIGURE 21

Distribution of the links for mobile networks infrastructure in France including its overseas departments



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Annex 4

Examples of frequency assignments in some countries

1 Block assignment method in Norway

In Norway, frequency blocks have been allocated in the 23, 24.5-26.5 GHz, and 38 GHz bands. Because of the large demand and the limited resources of the licensing authority, frequency blocks were allowed to the operators on a "first-come, first-served" basis. In addition, these blocks were licensed to new operators with the following conditions:

– The licenses are given without very strict technical regulations. The operators are responsible for any interference caused by their systems. If a conflict should occur between two operators, the operator, who put his system into service first, has the priority.

– At the end of each year, the operators must send to the licensing authority detailed information of the links that have been established.

– At any time, the utilization of the spectrum allocated to an operator may be evaluated. If the authority considers that there is no need for a whole frequency block, the license for the block may be withdrawn, and replaced by individual licenses.

2 Link by link assignment procedure in the United Kingdom

The fixed link assignment system, a noise limited system that has been developed by the UK Radiocommunications Agency (RA), now merged into the Office of Communications (OFCOM), is efficient in meeting the demands of customers. Each fixed service frequency band administrated by the OFCOM, assignment system is updated with the relevant frequency assignment criteria (for instance, minimum hop length, authorized antenna classes, etc.). All assignments via the assignment system are then made on a link by link basis.

In the license application, the customer provides details of the preferred sites as well as technical characteristics of the required link e.g. equipment, polarization, availability. In most cases, with the exception of the 57-59 GHz band which is licence exempt, and 64-66 GHz band, which is licensed with a registration process, channels are assigned in the highest frequency band compatible in order to meet the customer's requirements.

Prior to assigning the link, the application is validated by the system, which checks whether:

– sites are identifiable or known, create new sites if required;
– Hi/Lo Configuration and LoS;
– antennas used are approved for the band according to manufacturers' specifications;
– approval of equipment for the band; and
– link lengths are appropriate.

If the application is valid, further technical checks are carried out including:

– correct antenna elevations and azimuths; and
– whether the required availability is greater than 99.99%.

After this verification process, the assignment routine identifies the terrain type around and in between link ends e.g. rural, urban, water, wood, etc; the Fresnel Zone clearance, fade margin and the required EIRPs are calculated.

The assignment process next identifies all links in the same band within the coordination zone. A channel/range of channels are then selected by the assignment engineer from all the channels available. All interference signals from and to every other user within the coordination zone are calculated and assessed for interference potential. The first available interference free channel is then assigned. This system can be manually overridden for special cases.

Frequencies for each link are assigned provisionally, following coordination with existing fixed (P-P) terrestrial links and other services. Notification of provisional frequencies does not give authority to operate the fixed (P-P) terrestrial link but is provided to assist the applicant with early equipment procurement and configuration. The licence is only formally issued when all clearances have been received with confirmations from all interested parties.