RECOMMENDATION ITU-R M.1036-1

SPECTRUM CONSIDERATIONS FOR IMPLEMENTATION OF INTERNATIONAL MOBILE TELECOMMUNICATIONS-2000 (IMT-2000) IN THE BANDS 1 885-2 025 MHz AND 2 110-2 200 MHz[1]

(Question ITU-R 39/8)

(1994-1999)

Introduction

International Mobile Telecommunications-2000 (IMT-2000) are third generation mobile systems which are scheduled to start service around the year 2000 subject to market considerations. They will provide access, by means of one or more radio links, to a wide range of telecommunication services supported by the fixed telecommunication networks (e.g. PSTN/ISDN), and to other services which are specific to mobile users.

A range of mobile terminal types is encompassed, linking to terrestrial and/or satellite based networks, and the terminals may be designed for mobile or fixed use.

Key features of IMT-2000 are:

– high degree of commonality of design worldwide,

– compatibility of services within IMT-2000 and with the fixed networks,

– high quality,

– use of a small pocket-terminal with worldwide roaming capability,

– capability for multimedia applications and a wide range of services.

IMT-2000 are defined by a set of interdependent ITU Recommendations of which this one is a member.

This Recommendation forms part of the process of specifying the radio interface(s) of IMT-2000. IMT-2000 will operate in the frequency bands 1 885-2 025 and 2 110-2 200 MHz which are identified in the Radio Regulations (RR) as intended for use on a worldwide basis by administrations wishing to implement IMT-2000.

The subject matter of IMT-2000 is complex and its representation in the form of Recommendations is evolving. To maintain the pace of progress on the subject it is necessary to produce a sequence of Recommendations on a variety of aspects. The Recommendations strive to avoid apparent conflicts between themselves. Future Recommendations, or revisions, will be used to resolve any discrepancies.

Scope

The scope of this Recommendation is to provide principles to guide administrations on spectrum related technical issues relevant to the implementation and use of IMT-2000 in the bands identified in the RR, while minimizing the impact on other systems and services in the bands and facilitating IMT-2000 growth as countries require it.

Many of the technical characteristics of IMT-2000 will be the subject of future Recommendations in the IMT-2000 series and a flexible treatment is necessary to accommodate this and the development of the IMT-2000 standards.

This Recommendation addresses the principles covering the use of the relevant bands by IMT-2000 which can assist administrations to plan their future use of these bands to enable the most effective and efficient use of the spectrum to deliver IMT-2000 services.

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1 Some administrations may exploit or deploy IMT-2000 systems in bands other than those identified here.

The ITU Radiocommunication Assembly,

considering

a) that the RR identify the bands 1 885-2 025 MHz and 2 110-2 200 MHz as intended for use on a worldwide basis by administrations wishing to implement IMT-2000, as indicated in RR S5.388, and Resolution 212 (Rev.WRC-97);

b) that the RR also allocate within these bands the portions 1 980-2 010 MHz and 2 170-2 200 MHz to the mobile-satellite service (MSS) on a worldwide basis, potentially for use by the satellite component of IMT-2000, under the provisions of RR S5.389A;

c) that the RR also allocate 2 010-2 025 MHz and 2 160-2 170 MHz in Region 2 to the MSS under the provisions of RR S5.389C, S5.389D and S5.389E;

d) that the different allocations to the MSS impacts upon the common spectrum available worldwide for the terrestrial component of IMT-2000, if frequency sharing with the satellite component is to be avoided;

e) that in some countries, within the lower part of the 1 885-2 025 MHz IMT-2000 band, digital enhanced cordless telecommunications (DECT) operates at 1 880-1 900 MHz, and personal handyphone system (PHS) at 1 893.5-1 919.6 MHz. Also, in some countries personal communication systems (PCS) systems based on North American standards employ 80 MHz duplex separation within the band 1 850-1 990 MHz;

f) that the bands identified for the implementation of IMT-2000 (1 885-2 025 MHz and 2 110-2 200 MHz) are used by terrestrial fixed services;

g) that the initial implementations of IMT-2000 are expected to commence around the year 2000, subject to market considerations;

h) that the simultaneous availability of both the terrestrial and satellite components of IMT-2000 would improve the overall implementation and attractiveness of IMT-2000 to both developed and developing countries;

j) that the bands identified in § a) above are shared with other systems of the mobile, fixed and mobile-satellite services and a portion with the space research service, many of these systems are in use now;

k) that these bands are used differently in various countries;

l) that the traffic and service mix carried by IMT-2000 networks may vary from country to country, and also within countries. In some parts of the world, additional spectrum may be required[2] whilst in other parts of the world less than 230 MHz could be adequate to meet IMT-2000 services present and future demands;

m) the need to support the operation of IMT-2000 terminals in different regulatory environments including unlicensed and licensed applications;

n) that the various radio access technologies that may be appropriate for IMT-2000 may have different channel bandwidth requirements, and hence varying impact on the basic frequency usage possibilities;

o) that traffic handled by mobile systems as well as the number and diversity of services will continue to grow;

p) that worldwide compatibility will facilitate international roaming;

q) that future systems may include the use of a range of cell types from indoor cells to satellite cells, which must be able to coexist in a given location;

r) that IMT-2000 will offer wider-bandwidth services than earlier systems in order to meet increasing customer demands, and this could create a demand for additional spectrum beyond that earlier estimated;

s) that efficiency of spectrum use requires consideration of the balances between IMT-2000 system costs and bandwidth needed,

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2 Studies are already under way to assess and quantify the potential requirement for additional spectrum.

recommends

1 Implementation of IMT-2000

that administrations, in planning the implementation of IMT-2000 do so on the basis of the following objectives:

1.1 to facilitate introduction of IMT-2000 around the year 2000, subject to market considerations and to facilitate the development and growth of IMT-2000;

1.2 to minimize the impact on other systems and services within, and adjacent to, the IMT-2000 bands;

1.3 to preserve flexibility of system implementation until the Recommendations for the IMT-2000 radio interface(s) have been adopted by the ITU;

1.4 to facilitate worldwide roaming of IMT-2000 terminals;

1.5 to integrate efficiently the terrestrial and satellite components of IMT-2000;

1.6 to optimize the efficiency of spectrum utilization within the IMT-2000 bands;

1.7 to allow the possibility for competition;

1.8 to facilitate the use of IMT-2000 technologies for fixed and other special applications such as those of developing countries;

1.9 to accommodate various types of traffic and traffic mixes;

1.10 to facilitate worldwide equipment standards;

1.11 to facilitate access to services globally within the framework of IMT-2000;

1.12 to minimize terminal costs, size and power consumption, where appropriate and consistent with other requirements;

2 Traffic requirements

that consideration should be given to the impact of possible asymmetric traffic requirements, noting that IMT-2000 traffic requirements may in some instances be asymmetric in direction while in other instances the traffic may be symmetric. Until commercial IMT-2000 services commence it is difficult to predict the level of asymmetry of the traffic;

3 Segmentation of the spectrum

that in order to make most effective and efficient use of the bands to deliver IMT-2000 services and facilitate the growth and development of IMT-2000, the IMT-2000 bands:

3.1 should not, ideally, be segmented for different IMT-2000 radio interfaces or services except where necessary for technical and regulatory reasons;

3.2 should, to maintain flexibility of deployment, be available for use in either frequency division duplex (FDD) mode, time division duplex (TDD) mode, or both, and should not, ideally, be segmented between FDD and TDD modes except where necessary for technical and regulatory reasons,

noting that

a) it is likely that some IMT-2000 environments will require FDD;

b) TDD may help to prevent asymmetric traffic demands from decreasing the efficiency of spectrum use;

c) it is likely that in some IMT-2000 terrestrial environments, TDD will be used either by itself or in combination with FDD;

4 Duplex direction and separation

4.1 that terrestrial systems, when operating in FDD mode, should maintain the conventional duplex direction, with mobile terminal transmit within the lower band and base station transmit within the upper band, following studies as summarized in Annex 2, which have shown that this use is preferable when considering:

i) compatibility with MSS operating in the bands given in *considerings* b) and c) above;

ii) compatibility with non IMT-2000 terrestrial services;

iii) the development of dual mode satellite/terrestrial terminals;

iv) differences in propagation loss (resulting in changes in battery life and/or cell size);

v) the impact on global roaming;

4.2 that any frequency separations between uplink and downlink allocations should be allowed to permit independent management of uplink and downlink resources;

4.3 that complexity implications are for further study;

5 Global roaming

that bands required for global roaming should be made available from within the bands identified for IMT-2000 in *considering* a);

6 Spectrum efficiency

that methods should be employed to ensure efficient use of the spectrum, such as the following:

6.1 radio transceiver technology and access protocols, including access technology, modulation and coding, adaptive interference management, diversity techniques, and smart antenna technology;

6.2 applications and services technology, including the use of packet transmission, asymmetry management, compression techniques and agent technology;

6.3 radio channel access management, i.e. the management of instantaneous access to spectrum, to reduce the probability of idle channels during peak traffic hours;

7 System development

that the necessary frequencies should be made available for IMT-2000 system development in a timely manner, as appropriate;

8 Sharing and compatibility

8.1 that due consideration is given to the spectrum sharing and compatibility issues arising from the implementation of IMT-2000, the need to identify services in adjacent frequency bands that may be affected by the implementation of IMT-2000 and to perform studies as necessary to ensure co-existence of these services and the need to consider sharing issues such as that between terrestrial and satellite components of IMT-2000 or between IMT-2000 and such services that may presently be operating in the bands identified for IMT-2000;

8.2 that due consideration is given to the results of certain compatibility studies that have been undertaken to consider co-existence between services and between systems in these frequency bands, for instance on sharing with the satellite component of IMT-2000. The conclusions of these compatibility studies are outlined in Annex 1;

8.3 that due consideration is given to these issues to ensure that the implementation of IMT-2000 on a global basis does not result in unacceptable interference to existing services in the IMT-2000 spectrum or those operating in adjacent spectrum, whilst considering that a wide range of services and systems are variously deployed in these bands around the world.

ANNEX 1

Satellite component sharing issues

1 Sharing with the fixed service

Sharing between systems in the MSS and fixed service (FS) was extensively studied by ITU-R in preparation for WRC-95. The conclusions of the studies, which are summarized in the CPM Report to WRC-95, were:

– the aggregate interference from multiple FS transmitters in densely used parts of the MSS uplink band into MSS satellites would be unacceptable; however, in the early years when MSS traffic is low MSS operators may be able to avoid interference by using lightly used parts of the band;

– detailed coordination of MSS downlinks may be feasible in the short-to-medium term; however, as MSS traffic levels increase over time it will become increasingly difficult to share.

These conclusions led WRC-95 to adopt Resolution 716 which urges administrations to implement any new 2 GHz FS systems outside the 2 GHz MSS bands and calls for the gradual transition of FS systems away from the 2 GHz MSS bands.

Also based on these conclusions and further work conducted after WRC-95, the coordination thresholds and procedures of Recommendations ITU-R M.1141, M.1142, M.1143, M.1319 and Resolution 46 (Rev.WRC-97) have been developed.

2 Sharing with the IMT-2000 terrestrial component

Sharing between the satellite and terrestrial components of IMT-2000 is in many ways similar to sharing between MSS and the FS.

In the MSS uplink band, considering that the e.i.r.p. of terrestrial IMT-2000 transmitters at high elevation angles will be similar to FS e.i.r.p. levels, and that the number of terrestrial IMT-2000 stations will greatly exceed the number of FS stations, the aggregate interference from this large number of terrestrial IMT-2000 stations will be unacceptable to MSS satellite receivers.

In the MSS downlink band, sharing could lead to a decrease in cell size and/or capacity for the terrestrial IMT-2000 component.

In both the MSS uplink band and the MSS downlink band the interference between mobile earth stations and terrestrial IMT-2000 stations would impose significant limitations on satellite and/or terrestrial service areas and require complicated coordination.

For these reasons, it is clear that co-coverage, co-frequency sharing between the terrestrial and satellite components of IMT-2000 is not feasible.

3 Sharing between satellite systems

Sharing between MSS systems was studied by ITU-R in preparation for WRC-95, and studies have continued also after WRC-95. The CPM Report for WRC-95 states that:

– Sharing on a co-frequency co-coverage basis between MSS networks employing time division multiple access (TDMA) or frequency division multiple access (FDMA) techniques is not feasible.

– With potentially severe constraints on system capacity, limited co-frequency, co-coverage sharing may be possible between MSS networks using FDMA or TDMA and networks using CDMA.

– MSS networks using CDMA can share on a co-frequency, co-coverage basis; the attendant capacity constraints increase with the number of such co-frequency networks.

These results are confirmed by the studies conducted for WRC-97. The CPM Report for WRC-97 states that:

– An analysis has been performed on uplink parameters which impact on sharing between global non-GSO MSS systems using different access technologies (FDMA/TDMA and CDMA) under a codirectional, co-frequency, co-coverage scenario. It was shown that it would not be possible to modify these parameters in such a way as to acceptably control the intersystem interference between an FDMA/TDMA MSS system and a CDMA-based system serving the same area with the same frequencies.

– For the case between two FDMA/TDMA MSS systems the result will be the same as for different technologies. For example, the possibility of increasing the received signal power in order to overcome the intersystem interference was considered. In this case it was shown that all of the techniques available to increase the desired signal receive power would also increase the interfering signal receive power.

– However, for systems which are both using CDMA access technologies, depending on the parameters chosen, sharing is possible. The basis for such sharing is found in Recommendation ITU-R M.1186, "Technical considerations for the coordination between MSS networks utilizing code division multiple access (CDMA) and other special spectrum technologies in the 1-3 GHz band".

ANNEX 2

Summary of conclusions relating to the duplex direction

1 Compatibility with existing and future services

1.1 Compatibility with MSS allocations including IMT-2000 satellite component

1.1.1 Interference to and from satellites

The results of theoretical calculations show that the normal assignment which assigns the lower band to the uplink (from mobile station to base station) is preferable to the reverse assignment. These results also show that the base station-to-satellite and satellite-to-base station interference is larger than the mobile station-to-satellite and satellite-to-mobile station interference, respectively.

1.1.2 Interference to mobile earth stations (MESs)

Studies have shown that the interference to the MESs of the satellite component of IMT-2000 would be increased also if the duplex direction is reversed.

1.1.3 Conclusions

Reversing the duplex direction would create considerable compatibility problems on a worldwide basis with satellites and MESs in the satellite component of IMT-2000. It would increase the need for greater guardbands and cause a corresponding loss in overall spectral efficiency. This may have a considerable impact on the spectrum requirements of IMT-2000. Considering these results the conclusion is that the terrestrial bands should employ the traditional duplex direction.

1.2 Compatibility with PCS

PCS1900, ANSI IS-136 and ANSI IS-95 are different systems that have been implemented in some countries to provide PCS.

It has been shown that the guardbands necessary between PCS1900 and IMT-2000 can be reduced if the duplex direction is reversed.

However, results with power control on the downlink and conventional duplex direction show that this guardband is of the same level of magnitude as the one necessary between two uncoordinated IMT-2000 terrestrial operators.

It should be noted that power control may not always be used by the base station in PCS1900 (for BCCH carriers for instance), IS136 and IS95 systems. If power control is not used on the closest carriers, the required guardbands are larger.

1.3 Compatibility with other terrestrial allocations

The choice of the duplex direction would not affect some existing terrestrial land mobile systems operating in adjacent bands such as DCS1800 and DECT. However, interference to PHS is increased if the duplex direction is reversed.

1.4 Compatibility between TDD and FDD blocks

Some studies have shown that interference with systems operating in TDD mode is increased if the base station operating in FDD mode transmits in adjacent bands.

2 Dual mode satellite/terrestrial terminals

2.1 Sharing common RF circuitry

The degree of sharing of radio frequency (RF) circuitry between the two modes is not considered to be of significance when examining the terrestrial duplex direction. The coupling between the two modes and the requirement for simultaneous transmission are considered much more important.

2.2 Simultaneous operation

When considering the effect of terrestrial duplex direction on dual mode terminals, the requirement for simultaneous operation of both the terrestrial and satellite components should be considered, along with the potential constraints that terrestrial duplex direction may place on such operation.

Situations where simultaneous operation may be used include:

– Terminal in standby mode (i.e. carrying no user traffic, only signalling traffic): the terminal is logged-on to both the terrestrial and satellite networks (or parts of the network). With simultaneous operation, the loss or gain of one mode, due to loss or gain of coverage for example, would not prevent the alternate mode from operating normally. Without simultaneous operation this would not be the case; for example, consider the transition between satellite and terrestrial modes at the edge of terrestrial coverage:

  – Transition from the terrestrial mode to the satellite mode may be possible using an appropriate time-out before connection to the satellite component is initiated. However, this is not desirable since it implies that the user is out of all coverage from some duration.

  – Transition from the satellite mode to the terrestrial mode is much more complex; the terminal will not be aware that terrestrial coverage is available in order to initiate connection to the terrestrial component.

– Terminal in use (i.e. carrying user and signalling traffic): one mode of a terminal is carrying a call, whilst the second mode is logged-on to the alternate component. Without simultaneous operation any future possibility of developing handover between satellite and terrestrial components would be excluded. Also, simultaneous operation permits the delivery of additional services via the alternate component, e.g. paging, short messaging services.

With a conventional terrestrial duplex direction, simultaneous operation of both modes is straightforward to achieve, as there is sufficient spectral separation for practical filtering to be employed to protect the receiver(s). However, with a reversed terrestrial duplex direction, adequate filtering may be difficult to achieve. Simultaneous operation of both modes may be achievable if the timing of each component can be coordinated in some way (e.g. by use of staggered timeslots). However, due to the possible variety of radio transmission technologies (RTTs) (even within a component) and the differing requirements of the components, it is unlikely that coordination could be achieved.

Therefore, when considering the impact on dual mode terrestrial/satellite IMT-2000 terminals, it is apparent that the reversing the terrestrial duplex direction is not desirable and it is recommended to remain with the conventional terrestrial duplex direction.

3 Propagation loss

There is around 1 dB path loss difference between the two bands identified for IMT-2000. There are two options to handle this increase in the path loss if the duplex direction were reversed. The first option consists in keeping the same cell size and having a loss in battery life. However, this is not always possible to keep the same cell size, especially for high bit rate services and for rural environments, because the maximum mobile transmitter power is limited. Therefore, a second consequence would be a reduction of the cell size.

3.1 Reduction of battery life

An analysis of battery life assuming constant cell size for conventional and reversed duplex directions has been performed.

The method is based upon power consumption during both talktime and standby time. The parameters used for the battery life calculation are listed in Table 1.

TABLE 1

Parameters used by the battery life calculation

Parameter	Value
Mobile nominal transmit power	23 dBm (200 mW)
Mobile antenna gain	0 dBi
Mobile antenna height	1.5 m
Mobile power control dynamic range	50 dB
Mobile power control step size	1 dB
Base sensitivity	–118 dBm
Base antenna gain	14.5 dBi
Base antenna height	30 m
Base power control margin	10 dB
System cell radius	2-3 km
Path loss model	Modified Hata without fading
Battery energy	10 kJoules
Percentage of time that is talktime	0%-100%
Percentage of time that is standby time	0%-100%
Average power consumption during talktime	dependant upon cell size
Average power consumption during standby time	5 mWatt

A circular cell is defined with the base station positioned at the centre. The average mobile transmit power is calculated based upon link budget calculations across the cell.

The average mobile transmit power does not determine battery life on its own. In addition, the power consumption during the time that the mobile is in standby must be considered. Equation 1 is used to calculate battery life.

$$\text{Battery Life} = \frac{\text{Battery Energy}}{\dfrac{(\%T_{idle} \times P_{idle})}{100} + \dfrac{(\%T_{talk} \times P_{talk})}{100}} \qquad (1)$$

Where:

– $\%T_{idle}$ is the percentage of time that an average mobile is in standby;

– P_{idle} is the average power consumption of a mobile while in standby;

– $\%T_{talk}$ is the percentage of talk time of an average mobile;

– P_{talk} is the average power consumption of a mobile during talktime.

3.1.1 Results

The first stage of the analysis is to determine the average mobile transmit power during talktime. This is dependant upon the cell size due to power control. It has been assumed that power control is not used during standby time. Table 2 provides the average transmit powers that have been computed for a range of cell sizes.

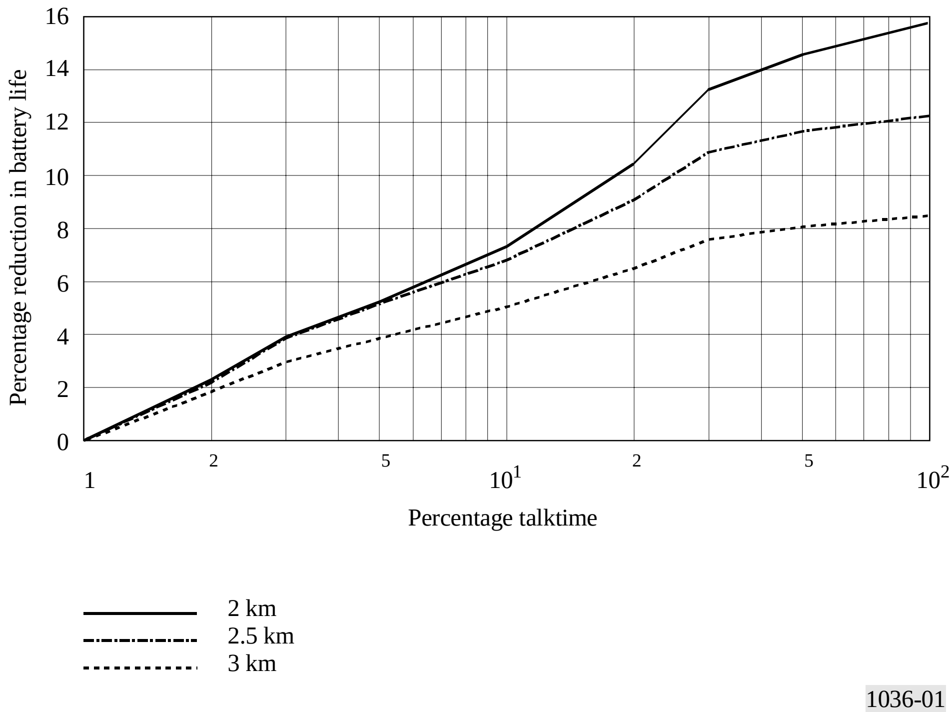
TABLE 2

The average mobile transmit power during talktime

	IMT-2000		GSM	
Cell radius	Mobile transmits on 1 950 MHz	Mobile transmits on 2 140 MHz	Mobile transmits on 1 950 MHz	Mobile transmits on 2 140 MHz
2.0 km	17.9 dBm	18.7 dBm	30.0 dBm	30.5 dBm
2.5 km	19.7 dBm	20.3 dBm	31.1 dBm	31.4 dBm
3.0 km	20.7 dBm	21.1 dBm	31.6 dBm	31.9 dBm

FIGURE 1

Percentage reduction in battery caused by reversing the duplex band



Percentages of talktime and standby time are relative to the time when the mobile is switched on.

At this point, it is difficult to define a “typical” IMT-2000 user profile since services and customers habits are still evolving. Some typical talktimes per day for cellular voice user traffic can range from 5 min/day (very low) to 2 h/day (traders). In the case of data user traffic, it has been stressed that interactive uses can also require much connect time, up to 2 h/day.

The corresponding percentage of talktime and standby time are given in Table 3:

TABLE 3

Percentage of talktime and standby time

	Talktime % | Standby time %		
talktime | switched on time	24 H/day	12 H/day	8 H/day
5 min/day	0.3% | 99.7%	0.7% | 99.3%	1% | 99%
15 min/day	1% | 99%	2% | 98%	3% | 97%
30 min/day	2% | 98%	4% | 96%	6% | 94%
1 h/day	4% | 96%	8% | 92%	12% | 88%
2 h/day	8% | 92%	16% | 84%	24% | 76%

3.1.2 Conclusions

Dependant upon the percentage of talktime relative to the time that the mobile unit is switched on, the percentage loss in battery life varies. For percentage talktimes between 1 and 2 percent the reduction in battery life is below 3%. However, as the percentage talktime increases, the percentage reduction in battery life also increases. A user who has his/her mobile switched on for 12 hours a day and is communicating altogether for 1 hour would incur a percentage battery life loss of between 4 and 7% depending upon cell size. The maximum loss of battery life is about 16% for 100% talktime and large cell sizes.

3.2 Reduction of the cell size

Studies have shown that reversing the duplex direction would have a significant impact as follows:

– Additional sites required for duplex band reversal, of between 6 and 13%.

– Additional cost of extra sites to the operator of the order of at least 6 to 13%.

– The environmental impact of the increased cell site count and the likely negative public reaction.

It is recommended that, with regard to the impact of reversing the duplex direction on the cell sizes, the conventional duplex direction should be maintained and that no change in the reverse and forward direction should be made at this time.

4 Asymmetric traffic

Some marketing studies foresee that the overall IMT-2000 traffic will be asymmetric with a larger traffic on the downlink direction. However, there is still a large uncertainty on the level of asymmetry and it might be difficult to get more accurate figures before IMT-2000 services will be effectively implemented.

The higher traffic expected on downlink could suggest that the lower band of IMT-2000 would be more convenient for the downlink direction than the upper band. It was noted that this situation might change with the extension bands of IMT-2000, which have not been identified yet. However, duplex direction should be chosen considering the already identified IMT-2000 bands. The TDD operation is seen as a convenient way to handle asymmetric traffic in microcells and indoor environments because it can more easily adapt transmission direction split to the actual asymmetry of traffic. However, TDD operation would be less feasible for larger cells.

As a conclusion, the consideration of asymmetric traffic for IMT-2000 is not relevant for the choice of the duplex direction.