RECOMMENDATION ITU-R M.1036-2

Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications-2000 (IMT-2000) in the bands* 806-960 MHz**, 1 710-2 025 MHz, 2 110-2 200 MHz and 2 500-2 690 MHz

(Question ITU-R 229/8)

(1994-1999-2003)

1 Introduction

International Mobile Telecommunications-2000 (IMT-2000) are third generation mobile systems which provide access to a wide range of telecommunications services, supported by the fixed telecommunications networks (e.g. PSTN/ISDN/IP), and to other services that are specific to mobile users.

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;

– small terminal suitable for worldwide use;

– worldwide roaming capability;

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

The capabilities of IMT-2000 systems are being continuously enhanced in line with market and technology trends.

IMT-2000 will operate in the frequency bands identified in the Radio Regulations (RR) as intended for use on a worldwide basis by administrations wishing to implement IMT-2000, as follows:

WARC-92 identified the bands:

– 1 885-2 025 MHz

– 2 110-2 200 MHz

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

** The whole band 806-960 MHz is not identified on a global basis for IMT-2000 due to variation in the primary mobile service allocations and uses across the three ITU Regions.

and WRC-2000 identified the bands:

– 806-960 MHz**

– 1 710-1 885 MHz

– 2 500-2 690 MHz

for possible use by IMT-2000 systems, noting (in accordance with RR No. 5.388) that identification of these bands does not establish priority in the RR and does not preclude use of the bands for any other services to which these bands are allocated. Also, some administrations may deploy IMT-2000 systems in bands other than those identified in the RR.

2 Scope

The scope of this Recommendation is to provide guidance on the selection of frequency arrangements for the terrestrial component of IMT-2000 systems as well as the arrangements themselves, with a view to assisting administrations on spectrum-related technical issues relevant to the implementation and use of the terrestrial component of IMT-2000 in the bands identified in the RR. The frequency arrangements are recommended from the point of view of enabling the most effective and efficient use of the spectrum to deliver IMT-2000 services – while minimizing the impact on other systems or services in these bands – and facilitating the growth of IMT-2000 systems.

3 Objectives

In planning the implementation of IMT-2000, the following objectives are desirable:

– to facilitate the deployment of IMT-2000, subject to market considerations and to facilitate the development and growth of IMT-2000;

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

– to facilitate worldwide roaming of IMT-2000 terminals;

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

– to optimize the efficiency of spectrum utilization within the bands identified for IMT-2000;

– to enable the possibility of competition;

– to facilitate the deployment and use of IMT-2000, including fixed and other special applications in developing countries and in sparsely populated areas;

– to accommodate various types of traffic and traffic mixes;

– to facilitate the continuing worldwide development of equipment standards;

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

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

– to facilitate the evolution of pre-IMT-2000 systems to any member of the IMT-2000 family as specified in Recommendation ITU-R M.1457.

4 Related Recommendations

The existing IMT-2000 Recommendations that are considered to be of importance for this particular Recommendation are as follows:

Recommendation ITU-R M.687:	International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.816:	Framework for services supported on International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.818:	Satellite operation within International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.819:	International Mobile Telecommunications-2000 (IMT-2000) for developing countries
Recommendation ITU-R M.1033:	Technical and operational characteristics of cordless telephones and cordless telecommunication systems
Recommendation ITU-R M.1034:	Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.1035:	Framework for the radio interface(s) and radio sub-system functionality for International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.1073:	Digital cellular land mobile telecommunication systems
Recommendation ITU-R M.1167:	Framework for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.1224:	Vocabulary of terms for International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.1308:	Evolution of land mobile systems towards IMT-2000
Recommendation ITU-R M.1390:	Methodology for the calculation of IMT-2000 terrestrial spectrum requirements
Recommendation ITU-R M.1457:	Detailed specifications of the radio interfaces of International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R SM.329:	Unwanted emissions in the spurious domain

5 Considerations

In order to determine the principles and practical use of the spectrum for IMT-2000 systems it is considered:

Regarding spectrum band/frequency usage

a) that the RR identify the bands 806-960 MHz**, 1 710-2 025 MHz, 2 110-2 200 MHz and 2 500-2 690 MHz as intended for use on a worldwide basis by administrations wishing to implement IMT-2000, as indicated in RR Nos. 5.388, 5.384A and 5.317A and in

Resolutions 212 (Rev.WRC-97), 223 (WRC-2000), 224 (WRC-2000) and 225 (WRC-2000); by taking these provisions and Resolutions into account, flexibility should be afforded to administrations to decide on using these bands at the national level according to each administration's evolution/migration plan;

b) that in some countries, other services are in operation in the bands identified for IMT-2000 as indicated in Resolution 225 (WRC-2000), RR Nos. 5.389A, 5.389C, 5.389D, 5.389E and Recommendations ITU-R M.1073 and ITU-R M.1033;

c) that a minimized number of globally harmonized frequency arrangements in the bands identified for IMT-2000 by one or more conferences will:

– facilitate worldwide compatibility;

– facilitate international roaming;

– reduce the overall cost of IMT-2000 networks and terminals by providing economies of scale;

d) that when frequency arrangements cannot be harmonized globally, a common base and/or mobile transmit band would facilitate terminal equipment for global roaming. A common base transmit band, in particular, provides the possibility to broadcast to roaming users all information necessary to establish a call;

e) that when developing frequency arrangements possible technological constraints (e.g. cost efficiency, size and complexity of terminals, high speed/low power digital signal processing and the need for compact batteries) should be taken into account;

f) that some administrations may consider the use of the lower UHF land mobile bands, e.g. below 470 MHz, for the deployment of IMT-2000 systems in cases where it is desirable to evolve an existing first or second generation system to IMT-2000 and/or to take advantage of coverage benefits for rural, sparsely-populated or low-traffic density areas;

g) that some administrations are planning to use parts of the bands 698-806 MHz or 2 300-2 400 MHz for IMT-2000;

h) that guardbands for IMT-2000 systems should be minimized to avoid wasting spectrum;

i) that Report ITU-R M.2031 – Compatibility between WCDMA 1800 downlink and GSM 1900 uplink, addresses adjacent band compatibility at 1 850 MHz;

j) that when developing frequency arrangements, current and future technological advances (e.g. multi-mode/multi-band terminals, enhanced filter technology, adaptive antennas, advanced signal processing techniques, variable duplex technology and wireless connectivity peripherals) should be taken into account;

k) that sufficient frequency separation between transmitter and receiver frequencies, such as those outlined in Annex 3, must exist in a frequency division duplex system;

l) that certain compatibility studies have been undertaken to consider coexistence between services and between systems in frequency bands identified for IMT-2000, for instance, on sharing and adjacent band compatibility with the satellite component of IMT-2000 in the 2 GHz and 2.2 GHz ranges as outlined in Annex 1;

Regarding traffic aspects

m) that individual subscriber traffic in IMT-2000 systems is expected to be dynamically asymmetric where the direction of asymmetry can vary rapidly within short (ms) time-frames;

n) that per cell level traffic for IMT-2000 systems is expected to be dynamically asymmetric where the direction of asymmetry will vary based on the aggregate subscriber traffic;

o) that IMT-2000 network traffic may change in asymmetry over the longer term;

Regarding technology aspects

p) that the IMT-2000 radio interfaces are detailed in Recommendation ITU-R M.1457;

q) that IMT-2000 has two modes of operation – frequency division duplex (FDD) and time division duplex (TDD);

r) that Report ITU-R M.2030 – Coexistence between IMT-2000 time division duplex and frequency division duplex terrestrial radio interface technologies around 2 600 MHz operating in adjacent bands and in the same geographical area, addresses TDD and FDD system installation in adjacent blocks with respect to interference and mitigation techniques;

s) that selectable/variable duplex technology is considered to be one technique that can assist in the use of multiple frequency bands to facilitate global and convergent solutions. Such a technology could bring further flexibility that would enable IMT-2000 terminals to support multiple frequency arrangements;

Regarding other aspects

t) that there may be the need to support the operation of IMT-2000 terminals for self-provided applications[1];

u) that adjacent band compatibility and sharing studies between the terrestrial and satellite components of IMT-2000 for the bands 2 500-2 520 MHz and 2 670-2 690 MHz are under study and might lead to a revision of this Recommendation.

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1 Self-provided applications are expected to develop to complement the services provided by operators and may be provided by businesses or private individuals to cover their own offices or residences, and may stand alone or connect to other networks. A key characteristic of self-provided services, apart from their short range, will be that their availability is not guaranteed because they will operate in spectrum shared with other similar users. An example could be a museum that installs a system to provide communications between staff, and to provide guided tours and souvenir shopping to visitors. Self-provided applications are expected to develop to operate at lower powers, in self-coordinating mode.

6 Recommendations

6.1 Frequency arrangements

6.1.1 Paired frequency arrangements in the band 806-960 MHz

The recommended frequency arrangements in these bands, taking into consideration existing public mobile systems, can be summarized as shown in Table 1 and in § 6.1.4.1.

TABLE 1

Paired frequency arrangements in the band 806-960 MHz

Frequency arrangements	Mobile station transmitter (MHz)	Centre gap(1) (MHz)	Base station transmitter (MHz)	Duplex separation(2) (MHz)
A1	824-849	20	869-894	45
A2	880-915	10	925-960	45

NOTE 1 – Due to the overlap of base station transmitter and mobile station transmitter bands and the different usage of the bands 806-824 MHz, 849-869 MHz and 902-928 MHz between Regions, there is no common solution possible in the near- and medium-terms.

(1) *Centre gap* – the frequency separation between the upper edge of the lower band and the lower edge of the upper band in an FDD paired frequency arrangement.

(2) *Duplex band frequency separation* – the frequency separation between a reference point in the lower band and the corresponding point in the upper band of an FDD arrangement.

6.1.2 Frequency arrangements in the band 1 710-2 200 MHz[2]

The recommended frequency arrangements in these bands, taking into consideration existing public mobile systems, can be summarized as shown in Table 2 and in § 6.1.4.2.

2 The 2 025-2 110 MHz band is not part of this frequency arrangement.

TABLE 2

Frequency arrangements in the band 1 710-2 200 MHz

Frequency arrangements	Mobile station transmitter (MHz)	Centre gap (MHz)	Base station transmitter (MHz)	Duplex separation (MHz)	Un-paired spectrum (e.g. for TDD) (MHz)
B1	1 920-1 980	130	2 110-2 170	190	1 880-1 920; 2 010-2 025
B2	1 710-1 785	20	1 805-1 880	95	None
B3	1 850-1 910	20	1 930-1 990	80	1 910-1 930
B4 (harmonized with B1 and B2)	1 710-1 785 1 920-1 980	20 130	1 805-1 880 2 110-2 170	95 190	1 900-1 920; 2 010-2 025
B5 (harmonized with B3 and parts of B1 and B2)	1 850-1 910 1 710-1 755 1 755-1 805	20 50 305	1 930-1 990 1 805-1 850 2 110-2 160	80 95 355	1 910-1 930
B6 (harmonized with B3 and parts of B1 and B2)	1 850-1 910 1 710-1 770	20 340	1 930-1 990 2 110-2 170	80 400	1 910-1 930

NOTE 1 – Administrations can implement all or parts of these frequency arrangements.

NOTE 2 – In the band 1 710-2 025 and 2 110-2 200 MHz three basic frequency arrangements (B1, B2 and B3) are already in use by public mobile cellular systems including IMT-2000. Based on these three arrangements, different combinations of arrangements are recommended as described in B4, B5 and B6. The B1 arrangement and the B2 arrangement are fully complementary, whereas the B3 arrangement partly overlaps with the B1 and B2 arrangements.

For countries having implemented the B1 arrangement, B4 enables optimization of the use of spectrum for paired IMT-2000 operation.

For countries having implemented the B3 arrangement, the B1 arrangement can be combined with the B2 arrangement. Two different arrangements (B5 and B6) are therefore recommended to optimize the use of the spectrum:

– B5 would implement the B2 arrangement to harmonize parts of the extension bands globally. B5 enables the use of spectrum to be maximized for paired IMT-2000 operation in countries where B3 is implemented and where the whole band 1 710-1 850 MHz is available.

– B6 enables the use of spectrum to be maximized for IMT-2000 in countries where B3 is implemented and where the band 1 770-1 850 MHz is not available in the initial phase of deployment of IMT-2000 in this frequency band.

NOTE 3 – TDD may be introduced in unpaired bands and also under certain conditions in the uplink bands of paired frequency arrangements and/or in the centre gap between paired bands.

NOTE 4 – If selectable/variable duplex technology is implemented within terminals as the most efficient way to manage different frequency arrangements, the fact that neighbouring countries could select either option B5 or B6 will have no impact on the complexity of the terminal. Further studies are necessary.

6.1.3 Scenarios for frequency arrangements in the band 2 500-2 690 MHz

For the band 2 500-2 690 MHz three basic arrangements or combinations of them, as shown in § 6.1.4.3, are recommended for consideration by administrations in order to meet the demand for additional traffic; the aggregate asymmetry is as yet unknown but is assumed to be biased towards the downlink:

– FDD uplink and downlink operation[3];

– FDD downlink operation[4];

– TDD operation.

The following section describes a generic principle for the use of the band 2 500-2 690 MHz which embraces currently viable options. It gives flexibility for further evolution depending on the available technologies and the future traffic characteristics.

– The frequency arrangements mentioned above can be combined in the band 2 500-2 690 MHz by subdividing it into segments. Several different scenarios are possible, of which seven are shown in § 6.1.4.3.

– The size of the segments may be unequal, and in some scenarios, one or more could disappear (i.e. zero width).

– It is considered to be premature to decide the order and the sizes of the segments at this moment.

– It should be noted that the edges of segments at the lower and upper end of the band may be influenced by the use of the bands 2 500-2 520 MHz and 2 670-2 690 MHz by the satellite component of IMT-2000 (see *resolves* 2 of Resolution 225 (WRC-2000)).

Since only limited experience with IMT-2000 services has been gained, there are a number of open issues:

– the size of the segments;

– the arrangement of the segments (e.g. the FDD uplink and downlink direction);

– the traffic characteristics;

– the availability of technology;

– the extent of the use of the bands 2 500-2 520 MHz and 2 670-2 690 MHz by the satellite component of IMT-2000. (NOTE – The proposed basic arrangements and combinations (scenarios) in this subsection are temporarily recommended until completion of the sharing studies between satellite and terrestrial IMT-2000 components, taking into account the two conditions of the possible use of the 2 500-2 520 MHz and 2 670-2 690 MHz allocated to the mobile-satellite service, by the IMT-2000 terrestrial component.)

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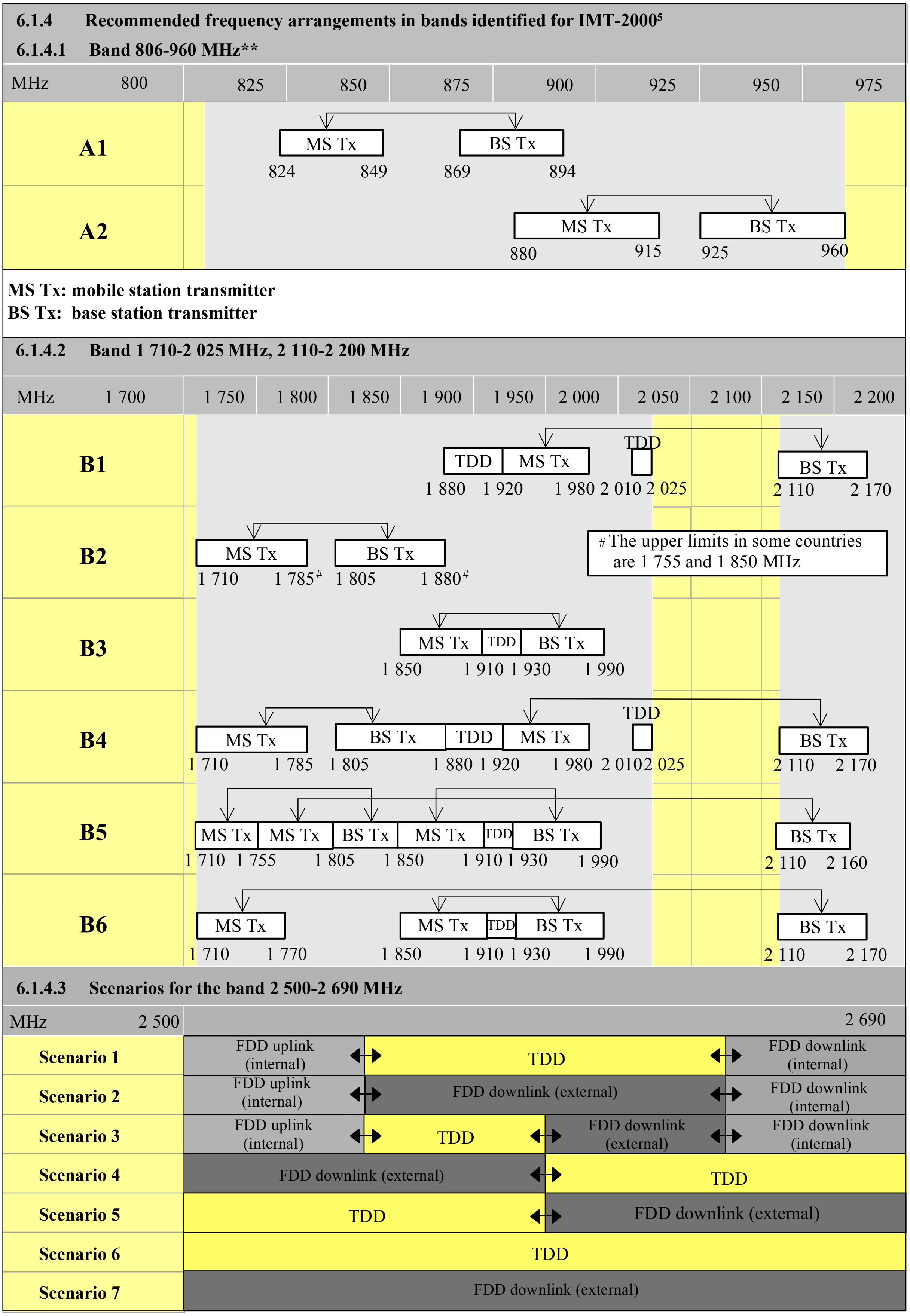
[3] The centre gap may optionally be used for TDD.

[4] This FDD downlink operation is independent, i.e. can be combined with any FDD pairing e.g. with IMT-2000 WARC-92 bands.



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[5] Administrations can implement all or parts of these frequency arrangements.

6.2 Traffic asymmetry implications

It is recommended that administrations and operators consider asymmetric traffic requirements when assigning spectrum or implementing systems, and consider the techniques in Annex 2.

6.3 Segmentation of the spectrum

It is recommended that the frequency arrangements not be segmented for different IMT-2000 radio interfaces or services except where necessary for technical and regulatory reasons.

It is recommended that the frequency arrangements should, to maintain flexibility of deployment, be available for use in either FDD mode, TDD mode, or both, and should not, ideally, be segmented between FDD and TDD modes in paired spectrum except where necessary for technical and regulatory reasons.

It is noted that in the initial phase of IMT-2000 deployment, the TDD and FDD modes will be used in separate bands.

6.4 Duplex arrangement and separation

It is recommended that for the bands below 2.2 GHz, IMT-2000 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. Studies have shown that this use is preferable when considering compatibility with MSS (see Annex 1) and with non-IMT-2000 terrestrial services, the development of dual mode satellite/terrestrial terminals, differences in propagation loss (resulting in changes in battery life and/or cell size), and the impact on global roaming.

It is recommended that for administrations wishing to implement only part of an IMT-2000 frequency arrangement, the channel pairing[6] should be consistent with the duplex frequency separations of the full frequency arrangement.

It is noted that the technical impacts relating to centre gaps are examined in Annex 3.

6.5 Frequency availability

It is recommended that administrations make available the necessary frequencies for IMT-2000 system development in a timely manner.

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[6] Duplex channel frequency separation: the frequency separation between a specific channel carrier in the lower band and its paired channel carrier in the upper band of an FDD arrangement.

Annex 1

Satellite component sharing issues

The following conclusions are derived from studies undertaken for the bands identified for IMT-2000 at WARC-92. Further studies for the frequency range 2 500-2 520 MHz and 2 670-2 690 MHz are planned; in particular, sharing and adjacent band compatibility studies are being developed for these bands as carried out in the past for the bands below 2.2 GHz.

In the MSS uplink band (around 2 GHz), considering the e.i.r.p. of terrestrial IMT-2000 transmitters at high elevation angles and the number of terrestrial IMT-2000 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 (around 2.2 GHz), 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.

Annex 2

Technology solutions to support traffic asymmetry

1 Background

Radio interfaces for IMT-2000 systems and systems beyond IMT-2000 may support different traffic capabilities on the uplink and downlink. The radio interface could be designed to cope with special conditions that exist on the uplink and downlink as well as different asymmetry ratios.

In order to utilize the scarce spectrum resources most efficiently, technical aspects and market considerations must be taken into account. The interrelation between them will influence costs.

2 What is asymmetry?

In this context, asymmetry means that the basic amount of traffic may differ between the uplink and the downlink direction. As a possible consequence, the amount of resources needed for the downlink may differ from that of the uplink.

There are at least four aspects of traffic asymmetry:

– at the personal area level: the degree of asymmetry for traffic between devices of a personal area network (PAN);

– at the user access level: the degree of asymmetry for the traffic between a specific user and the network for a specific service;

– at the cell level: the degree of total traffic asymmetry in a specific cell;

– at the network level: the degree of total traffic asymmetry in the entire network.

All definitions have their justification when considering different levels of detail in the system.

The speed of change over time in the degree of traffic asymmetry depends on which view is taken. For each individual user (at the user access level) the degree of asymmetry may change quickly. But the degree of total asymmetry over a cell (at the cell level) and even more over the entire network (at the network level), will change much slower due to aggregation of individual services on the one hand and changing mix of services on the other hand.

3 Service mix in IMT-2000 systems

In IMT-2000 networks or systems beyond IMT-2000, there will be a mix of symmetric applications as well as predominately downstream or predominately upstream applications using different data rates. The most recent estimates for a mix of traffic are described in Report ITU-R M.2023. An analysis of these estimates indicates that the total traffic asymmetry in a specific cell or the entire network from IMT-2000 users would have the same "down load" characteristics as in the fixed network, i.e. it is predominately downstream. However, it should be noted that the traffic characteristics and the degree of traffic asymmetry between a specific user and the network for some IMT-2000 specific services may be different. It is expected that new applications, such as picture and video clips, as well as peer-to-peer traffic, which would generate traffic from terminals or servers connected over wireless, will affect the IMT-2000 traffic mix.

4 Technical aspects

Radio interface support for asymmetric traffic can be achieved by different means:

– By asymmetric resource allocation, e.g. asymmetric frequency allocation in case of FDD operation or asymmetric time-slot allocation in case of TDD operation.

– By symmetric uplink/downlink frequency allocation in the case of FDD or symmetric uplink/downlink time slot allocation in the case of TDD with only partial use of the available capacity in one of the two directions.

– By applying different capacity-enhancing technologies to uplink and downlink, regardless of the resource allocation. These technologies are typically independent of the duplex scheme.

4.1 Frequency band asymmetry

FDD is a duplex technique where uplink and downlink traffic takes place on different carriers, i.e. downlink and uplink channels are separated in the frequency domain (Figs. 1a and 1b). Both links can be used simultaneously. In general, a different amount of uplink and downlink spectrum may be allocated for the respective direction.

Three cases can be distinguished:

– In the first case the uplink and downlink carrier are of equal bandwidth. However, more carriers are allocated for the downlink compared to the uplink (or vice verse) in order to provide more overall downlink capacity compared to the uplink capacity (or vice versa, Fig. 1a). In general, each uplink and downlink carrier can be shared between multiple users.

– In the second case the downlink carrier bandwidth is larger than the uplink carrier bandwidth (or vice verse) (Fig. 1b).

– In the third case, the same technology is used, in both directions, but well-known multiple access techniques are used to share the uplink channel while continuing with a dedicated downlink channel (Fig. 1c).

FIGURE 1a

FDD concept, variable duplex (assuming larger downlink capacity requirements)

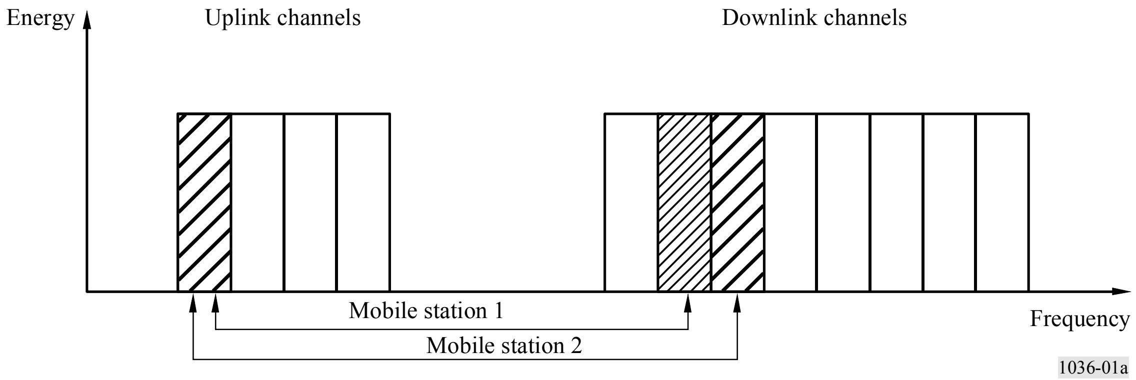


FIGURE 1b

FDD concept, variable bandwidth (assuming larger downlink capacity requirements)

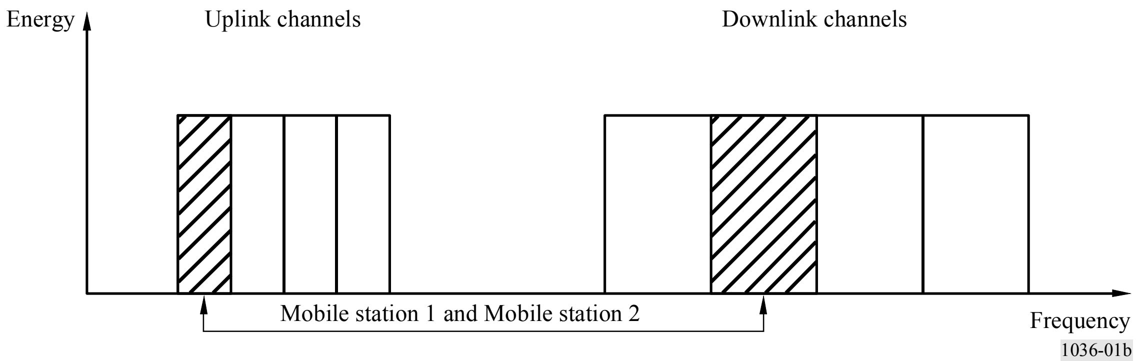
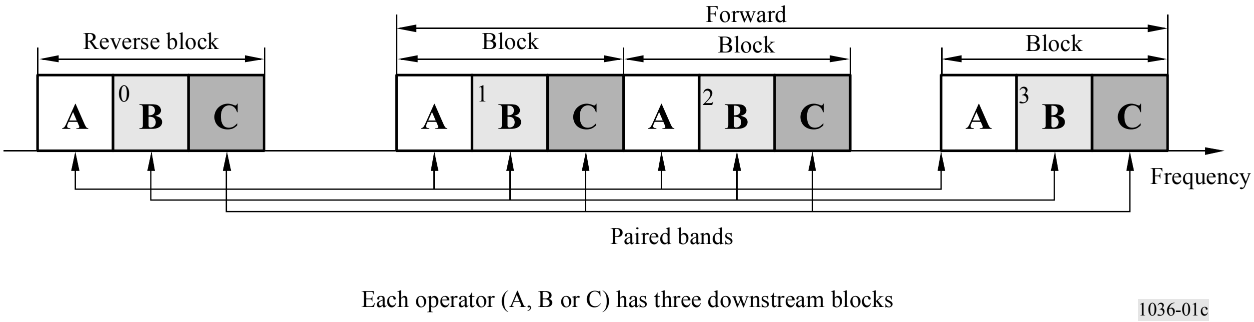


FIGURE 1c

FDD concept, multiple blocks (assuming larger downlink capacity requirements)



The above cases require a reasonable *a priori* estimate of the expected asymmetry for a spectrum efficient frequency allocation and spectrum usage.

FDD systems do not limit the service range in one link when allocating more resources in the other link to achieve asymmetric capacity, but more bandwidth is needed. The operators do not need to coordinate their networks and thus may have different degrees of asymmetry in order to support different business plans.

In order to support flexible asymmetric capacity by means of frequency band asymmetry using the two methods above the equipment needs to have the capability for variable duplex distance. The following method does not require that capability of the equipment and could be crucial for an evolutionary rather than revolutionary deployment.

With the method illustrated in Fig. 1c the same technology is used in both directions, but well-known multiple access techniques – e.g. statistical multiplexing or packet multiplexing – are employed to share the return-link channel while continuing with a dedicated forward-link channel. The operator is allocated a single block of spectrum (say Y MHz) on the reverse-link and three equal blocks of spectrum (Y MHz each) on the forward-link. With this method, blocks 0 and 1 can provide conventional symmetric operation and some asymmetric operation (by changing modulation technologies for example), while blocks 2 and 3 provide support for asymmetric operation. Thus the same equipment is common to all operators using conventional technology in all bands.

Opening up blocks 2 and 3 can be timed as enhanced band equipment becomes available. Note that there is no requirement for the blocks (e.g. 2 and 3) to be adjacent to each other. This could be overlaid on existing 3G or 2G technologies, where symmetric bands 0 and 1 are already deployed.

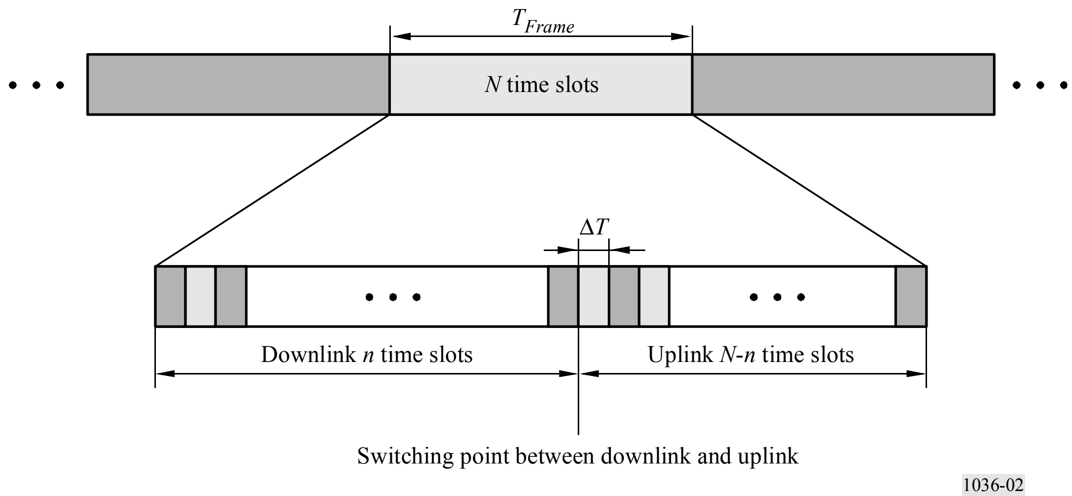
FDD implementations based on this method of block allocations have some built-in future proofing since additional spectrum blocks needed to support future asymmetric traffic can be added when the traffic patterns are determined.

4.2 Time slot allocation asymmetry

TDD is a duplex technique where both uplink and downlink traffic takes place on the same carrier. Downlink and uplink channels are separated in the time domain by dividing the time-frame into slots (Fig. 2). Each time slot can be allocated to either uplink or downlink traffic. By allocating different numbers of slots for uplink and downlink, asymmetric capacity can be obtained.

FIGURE 2

TDD concept with time-frame structure (assuming larger downlink capacity requirements)



A frame comprises *N* time slots, where *n* time slots are used for the downlink and *N-n* time slots are used for the uplink.

Another option is to use variable-size time slots rather than multiple time slots.

For a TDD system to work properly and achieve good performance a cell should generally avoid having a downlink/uplink configuration different from co-channel or adjacent-channel cells, especially in case of a frequency reuse equal to one. Otherwise, severe base station-to-base station and mobile station-to-mobile station interference will occur. However, this may be mitigated by several methods.

In the single-operator case and with a frequency reuse larger than one, different downlink/uplink configurations in different cells are feasible due to the additional de-coupling by an increased geographical distance between same frequencies. Some degree of frequency planning and coordination would be required.

4.3 FDD or TDD duplex arrangement combined with other technologies

Modulation asymmetry is a general technique, applicable to systems operating with either FDD or TDD, and where different modulation schemes may be used on uplink and downlink channels, respectively, in order to obtain different data rates.

Different modulation formats for uplink and downlink can provide some capability for asymmetric traffic, preferably for more downlink traffic. The maximum level and direction of asymmetry is basically fixed and limited by the equipment design and the modulation formats, which can be implemented in practical systems.

However, higher order modulation schemes or coding with reduced overhead require higher signal/interference-ratios or lower corresponding interference than the scheme in the other link. Therefore, such concepts can only be applied as a trade-off between link capacity and coverage for packet services in a link adaptation mode.

The main reason for having different modulation techniques in the uplink and downlink is to increase the peak data rates for a few users having good radio conditions (reasonably close to the base station) to provide asymmetric traffic in a given frequency allocation. The method is primarily useful for best-effort type of services.

This method could be used to enhance both FDD and TDD systems in future extensions of the IMT-2000 standards and systems beyond IMT-2000. This means that the important regulatory question whether new spectrum should be reserved for TDD or FDD systems does not need to include the consideration of modulation asymmetry.

By implementing additional technologies the handling of asymmetrical traffic could be improved.

An additional method to improve the performance and/or the asymmetric capacity properties is the use of adaptive antennas or more advanced detection schemes to increase the link capacity for one link. This would provide some additional possible asymmetry for a given frequency allocation. These techniques will add capabilities either alone or in combination to both FDD and TDD based systems.

In case of TDD operation, radio-propagation properties, although not in the interference situation, are the same for the uplink and downlink, as uplink and downlink transmission takes place on the same carrier frequency.

From this point of view TDD shows some advantages in the application of adaptive antennas for low mobile speed.

Advanced detection schemes to mitigate the impact of co-channel interference can be applied to both FDD and TDD.

5 Comparison of the various methods to provide asymmetric traffic capability

In general, the duplex scheme is one of many factors that determine the overall spectrum efficiency of a system. In terms of efficient support for asymmetric traffic, both FDD and TDD schemes have inherent advantages and disadvantages.

5.1 FDD scheme with symmetrical spectrum allocation

The maximum available user data rate per link is fixed.

This scheme has the following advantages:

– It allows for continuous (non-bursty) transmission in the uplink and downlink. This also allows for faster signalling of feedback information for, e.g. power control, link adaptation, and fast channel-dependent scheduling.

– For wide area coverage the range is primarily limited only by the system margin.

– No additional particular requirements for adjacent channel isolation or co-planning of systems in adjacent channels compared to TDD.

– Multi-operator co-location of base stations is possible depending on system design and frequency reuse independent of overall spectrum asymmetry.

– No inherent relation between the range of available maximum service data rates and the degree of asymmetric capacity, which is the case for TDD.

– Flexibility, to a certain extent, to traffic asymmetry.

Potential disadvantages to be considered are:

– Symmetric paired spectrum with a minimum duplex distance is required.

– The spectrum efficiency of the arrangement depends on the relation between the symmetric spectrum and the actual network traffic asymmetry.

5.2 FDD scheme with asymmetrical spectrum allocation

The maximum available user data rate per link is fixed.

This duplex scheme has the following advantages in addition to those of § 5.1:

– Flexible pairing of uplink and downlink carriers is possible that allows for asymmetric capacity. The spectrum usage is most efficient if the selected bandwidth ratio for both bands corresponds to the traffic asymmetry. The asymmetric spectrum can be used either as having more carriers in one direction, *or* as having wider carriers in one direction or a combination thereof (Figs. 1a, 1b and 1c).

– The multi-bandwidth alternative allows for higher peak rates in the direction with the wider band.

– Availability of additional unpaired spectrum is sufficient.

Potential disadvantages to be considered are:

– asymmetrical paired spectrum requirement;

– estimation of future spectrum demand per direction is required and may be difficult in advance. An immediate adaptation may be difficult to implement but indications are that more spectrum in both uplink and downlink are needed and later adaptation is then possible;

– the requirement for flexible duplex spacing, for the methods that require it (see Figs. 1a, 1b and 1c), slightly increases the terminal implementation complexity;

– the spectrum efficiency of the arrangement depends on the relation between the degree of actual network traffic asymmetry and the degree of spectrum asymmetry;

– multi-rate, multiple bandwidth capability for channels of different width are required if the uplink and downlink carriers are designed to have different bandwidths.

5.3 TDD scheme

The maximum available service data rate per link depends on the ratio of asymmetry.

This duplex scheme has the following advantages:

– Availability of unpaired spectrum is sufficient. The identification of single blocks of spectrum may be easier than for paired spectrum.

– Flexibility is available with respect to the degree of traffic asymmetry, depending on the co-channel and adjacent channel interference conditions. The spectrum usage is independent of the location of the switching point between uplink and downlink transmission.

– The spectrum efficiency of the arrangement is less dependent on the actual network traffic asymmetry since TDD can vary the degree of asymmetry within a specified range.

– If the neighbouring cells/systems agree on the same slot configuration, depending on system design and frequency reuse, the range of asymmetry is given by the number of time slots.

– Capacity increase by using adaptive antennas can be further improved by using the reciprocity of the radio channel for low mobile speeds.

Potential disadvantages to be considered are:

– services in adjacent bands must be able to cope with both uplink and downlink interference;

– synchronization and coordination of uplink and downlink of neighbouring cells is required with a small frequency reuse; in the case of a sufficiently large reuse cluster size no coordination is necessary within an operator’s frequency allocation but it is still needed between operators having frequency bands adjacent to each other;

– multi-operator co-location of base stations depends on the system design, the frequency reuse and the frequency separation of co-located operators;

– isolation between adjacent channels is required.

5.4 Comparison of the alternative technologies to provide asymmetric traffic capability

Asymmetric modulation has the following advantages:

- No additional frequency allocations or time slot allocations are required.
- A better throughput for the same channel, however, only for lower range or cases with higher *S*/*N* (link adaptation necessary).
- This method could be used to enhance both TDD and FDD systems in areas with favourable radio conditions.

Potential disadvantages to be considered are:

- influence of direction on system margin;
- only limited possible ratio of asymmetry;
- trade-off between coverage and maximum available data rate;
- link adaptation is required;
- mainly applicable for packet services;
- more complicated planning and implementation;
- if capacity on one link can be improved, the same method does also increase capacity on the other link; therefore, no inherent advantage with regard to improving asymmetric service provision.

Application of additional techniques provides the following advantages:

- Improvements can be applied to both FDD and TDD.
- Improvement of capacity by adaptive antennas in the downlink only by transmit antenna for simple terminals.
- Adaptive transmit antennas more effective for TDD than for FDD.

Potential disadvantages to be considered are:

- More capacity will be needed in the downlink, which would increase terminal receiver complexity compared to the base station for advanced detection schemes.
- These methods would put higher complexity to the terminal than to the base station.

The selection of a suitable duplex arrangement depends on the application (short range, wide area, flexibility, etc.). The duplex scheme is only one of several aspects to be considered (other aspects are, e.g. interference sensitivity, switching point flexibility, etc.).

Annex 3

Factors that impact the size of the centre gap

Certain isolation between transmitter and receiver must exist in an FDD system if normal receiver performance is expected. This depends on:

– maximum allowable transmitted power of both links;

– individual characteristics of the transmitter and receiver which vary with manufacturer and model;

– cost and size of a duplexer with a low insertion loss and acceptable isolation.

The minimum size of the centre gap between downlink and uplink will depend on the maximum allowable transmitted power of both links, in particular, of the uplink, with the mobile terminal transmitting. One of the factors related to the minimum size of the centre gap is the requirements needed from the duplexer (which is one of the major cost/size elements of the mobile terminal). For ceramic filters, the size of the filter is strongly dependent on the duplex gap. New filter technologies, such as film bulk acoustic resonator (FBAR), are likely to improve the situation and minimum centre gaps of 20-30 MHz seem achievable in the future.

Currently, duplex filters in mobile terminals mainly rely on ceramic filter technology. Recently published information introduce advanced filter technologies (e.g. FBAR) or other advanced technologies that may allow duplex filters with smaller size and/or better performance. With the application of new duplex filter technologies in IMT-2000 terminals the minimum duplex gap might no longer be considered a significant limitation for system and terminal implementation for the examples described in Table 3.

Centre gap

The consideration of the centre gap is important because it impacts the design of transmit and receive filters. A small centre gap would require the filters to have a sharper roll-off to prevent them from overlapping.

Table 3 gives information on the situation for the centre gap and duplex separation for some second generation systems and IMT-2000 implemented in the WARC-92 bands.

TABLE 3

Examples	**Frequency bands (MHz)**	**Centre gap (MHz)**	**Duplex separation (MHz)**
WARC-92 bands	1 920-1 980/2 110-2 170	130 (2 110 – 1 980 = 130)	190 (2 110 – 1 920 = 190)
PCS 1900	1 850-1 910/1 930-1 990	20	80
GSM 1800	1 710-1 785/1 805-1 880	20	95
PCS 1800	1 750-1 780/1 840-1 870	60	90
GSM 900	880-915/925-960	10	45
800-cellular	824-849/869-894	20	45

For time differential multiple access type systems like GSM 900 and GSM 1800 it should be noted, however, that in the terminal, transmit and receive intervals are separated in the time domain and transmit/receive separation is usually achieved by a switch and not by a duplex-filter.