No. 6
Report from the UMTS Forum

UMTS/IMT-2000 Spectrum

UMTS Forum, December 1998

This report is produced by the UMTS Forum, an association of telecommunications operators, manufacturers and regulators who are active both in Europe and other parts of the world and who share the vision of UMTS. UMTS will be a member of the IMT-2000 family of standards. UMTS will move mobile communications forward from where we are today into the Information Society of third generation services, and will deliver speech, data, pictures, graphics, video communication and other wideband information direct to people on the move.

The work to write the report has mainly been done in the Spectrum Aspects Group, a subgroup of the Forum. The main conclusions and recommendations in the report are supported by all operators and manufacturers of the UMTS Forum. The National Administrations that are members of the Forum have actively supported the development of the report. However, the Administrations cannot be bound by the detailed recommendations contained in the report.

The report is a major input towards the preparations for the World Radio Conference WRC-2000 and the decision making process on spectrum allocations for UMTS/IMT-2000 in a number of countries world-wide. It represents the consensus view on UMTS spectrum issues of the Forum members. It has been carefully developed and expanded over the past two year's life of the Forum and considers the spectrum vision and the spectrum demand. The report is written to be of interest to parties world-wide involved in the future development of the mobile telecommunications industry.

This report follows on from the first report of the UMTS Forum which dealt with a regulatory framework and spectrum aspects for UMTS /1/. Other outputs from the Forum cover areas of technical aspects /2/, economic conditions /4/, and licensing issues /5/. In order to help regulators with the implementation of UMTS spectrum licensing, the Forum has issued a report on minimum spectrum demand /6/.

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0.1 EXECUTIVE SUMMARY

Adequate access to spectrum is a key requirement for the development of the Universal Mobile Telecommunications System, UMTS. The purpose of this report is to give a more detailed analysis of the spectrum issues and express the Forum views regarding spectrum aspects. The Forum has already in its Report #1 /1/ made a number of recommendations regarding spectrum for UMTS, and this work is now pursued by the publication of this report.

The UMTS Forum is an open and independent association of telecommunications operators, manufacturers and regulators (over 150 members) active both in Europe and other parts of the world and who share the vision of UMTS. The preparation of the report has mainly been done in the Spectrum Aspects Group (SAG), a subgroup of the Forum.

UMTS, the Universal Mobile Telecommunication System, as a member of IMT-2000 family, is recognised as the main opportunity to provide mobile multimedia services for the future mass market. UMTS will offer user bit rates up to 2 Mbps.

It should be noted that this report generally focuses on spectrum for a global UMTS/IMT-2000 market. A number of different environments were taken into a generic traffic model, that can be seen as being usable for many countries in the world with varying demographical and economical data. Actually the parameters used in the terrestrial spectrum calculations are derived from a market forecast for the EU15 states for the years 2005 and 2010. The spectrum estimates are valid for countries with environments, which are similar to those in the EU15 states. For satellite services, the spectrum estimates were based on global market studies.

Recommendations:

1. The frequency spectrum as identified for UMTS/IMT-2000 in the ITU Radio Regulations, both for terrestrial and satellite services, should be made available by the year 2002 according to market demand.

2. To meet the market forecast for the terrestrial mobile services a total spectrum amount of 582 MHz was calculated. Therefore, a minimum additional frequency spectrum of 187 MHz is required for terrestrial services in urban areas by the year 2010 in EU15 states. This additional spectrum includes the requirements of public networks and non-public (license exempt) applications.

3. To meet the UMTS market forecast for satellite services a total spectrum amount of 2*123 MHz by the year 2005 and 2*145 MHz by the year 2010 is needed with a lower requirement in Europe. Therefore, additional 2*8 MHz is required globally by the year 2005. In the year 2010 additional 2*30 MHz is required in global hot-spots with lower requirements in EU15.

4. There is a need to designate spectrum for non-public (license exempt) UMTS applications. This will be required from the beginning to help build the market for mobile multimedia terminals and to stimulate a demand for public UMTS access. The amount of spectrum and location will be further investigated by UMTS Forum.

5. The preferred minimum spectrum per operator as defined in /6/ is 2*15 MHz (paired) + 5 MHz (unpaired). Care should be taken that operators have enough spectrum if the additional spectrum is not available by the year 2005.

6. The UMTS Forum recommends to study further the flexible use of TDD and FDD techniques, with the aim of improving the efficient use of spectrum.

7. A logical radio control channel (RCC) is recommended as an appropriate solution for the purpose of multimode terminal operation and global roaming. Identification of a specific physical global radio control channel in the Radio Regulations is not recommended.

0.2 RÉSUMÉ

Ce rapport a été rédigé par l'UMTS-Forum, une association regroupant des opérateurs de télécommunication, des équipementiers et des régulateurs, actifs à la fois en Europe et dans d'autres parties du monde, qui partagent la même vision de l'UMTS. Ce dernier sera un membre de la famille IMT-2000 de standarts. L'UMTS conduira les communications mobiles d'aujourd'hui dans la société de l'information avec des services de troisième génération et fournira voix, données, images, graphiques, vidéocommunication et autres informations « large bande » directement aux personnes en déplacement.

La préparation de ce rapport a principalement été menée dans le SAG, un groupe de travail du Forum sur les aspects Fréquences. Les conclusions et recommandations principales du rapport ont le soutien de tous les opérateurs et équipementiers de l'UMTS-Forum. Ces administrations nationales qui sont membres du Forum, ont activement contribué à ce rapport. Cependant, elle ne peuvent pas être considérées comme liées par les recommandations détaillées contenues dans ce rapport.

Ce rapport est une contribution importante pour la préparation de la Conférence Mondiale des Radiocommunications de l'an 2000 (CMR - 2000) et pour le processus de décision sur l'allocation de spectre pour l'UMTS/SMSMT-2000 dans un grand nombre de pays du monde. Il représente le point de vue consensuel des membres du Forum sur les problèmes de spectre. Il a été établi avec soin et développé pendant les deux années de la vie du Forum qu'il traite des aspects « vision » et « demande de spectre ». Ce rapport intéresse, au niveau mondial, les entités qui sont impliquées dans le développement futur du secteur des télécommunications mobiles.

Ce rapport fait suite au premier rapport de l'UMTS-Forum qui traite du cadre réglementaire et des aspects liés au spectre pour l'UMTS/1/. D'autres documents du Forum traitent des domaines : aspects techniques/2/, conditions économiques /4/ et

attribution des licences /5/. Pour aider les régulateurs dans la réalisation de la phase d'attribution de bandes de fréquence pour l'UMTS , le Forum vient d'éditer un rapport sur le besoin minimum de spectre /6/.

Accéder à une quantité de spectre adéquate est une exigence-clé pour le développement du Système de Télécommunication Mobile Universel (UMTS). L'objet de ce rapport est de donner une analyse plus détaillée des problèmes de spectre et d'exprimer l'opinion du Forum sur ces aspects de fréquences. Le Forum a déjà fait un certain nombre de recommandations concernant le spectre pour l'UMTS dans son rapport # 1 /1/ et ce travail se poursuit maintenant par la publication du présent rapport.

L'UMTS Forum est une association ouverte et indépendante d'opérateurs de télécommunications, d'équipementiers et de régulateurs (plus de 150 membres), actifs à la fois en Europe et dans d'autres parties du monde, qui partagent la même vision de l'UMTS. La préparation de ce rapport a principalement été menée dans le SAG (Spectrum Aspects Group), un groupe de travail du Forum sur les aspects Fréquences.

L'UMTS, Système de Télécommunications Mobiles Universel, comme membre de la famille IMT-2000, est reconnu comme la principale opportunité pour offrir des services multimédia mobiles, à l'avenir, pour le marché grand public. L'UMTS offrira des débits jusqu'à 2 Mbps.

Il faut noter que ce rapport met l'accent d'une manière générale sur le marché global de l'UMTS/SMT-2000. Un certain nombre d'environnements différents ont été intégrés dans un modèle de trafic générique, qui peut être considéré comme utilisable dans beaucoup de pays du monde, avec des données démographiques et économiques variables. Dans le cas présent, les paramètres utilisés dans les calculs de spectre pour les besoins terrestres sont issus d'une prévision de marché pour les 15 états de l'Union Européènne, en 2005 et 2010. Les estimations de spectre sont valables pour des pays avec des environnements qui sont semblables à ceux de l'Union Européènne précités. Pour les services par satellites, les estimations de spectre sont basées sur des études de marché globales.

Recommandations **:**

1. Les bandes de fréquences identifiées à le Règlement Radio de l'UIT pour l'UMTS/IMT - 2000, tant pour lesservices terrestres que par satellites, doivent être rendues disponibles en 2002, selon les besoins du marché.

2. Un total de 582 Mhz a été calculé pour faire face à la prévision de marché pour les services mobiles terrestres. En conséquence, un spectre supplémentaire de 187 Mhz est nécessaire dans les zones urbaines de l'Union Européènne (15 états membres) en 2010. Ce spectre supplémentaire comprend les besoins des applications de réseaux publics et non publics (sans licence).

3. Pour satisfaire la prévision de marché UMTS pour les services par satellites, en total de 2 x 123 Mhz en 2005 et de 2 x 145 Mhz en 2010 est nécessaire, le besoin en Europe étant plus faible. En conséquence, 2 x 8 Mhz de plus sont nécessaires en

2005, de manière globale. En 2010, 2 x 30 Mhz de plus sont nécessaires de manière globale pour les zones de très forte densité, avec un moindre besoin en Europe.

4. Il est nécessaire d'allouer du spectre pour les applications UMTS non publiques (sans licence). Ce besoin existe dès le début pour aider à développer le marché de terminaux multimédia mobiles et pour une demande d'accès public UMTS. La bande de fréquences nécessaire et sa localisation dans le spectre sera étudiée ultérieurement par l'UMTS-Forum.

5. Le spectre minimum par opérateur, comme défini dans /6/ est, de préférence, 2 x 15 Mhz (affairé) + 5 Mhz (non affairé). Il faut faire attention que les opérateurs aient suffisamment de spectre si les fréquences supplémentaires n'étaient pas disponibles en 2005.

6. L'UMTS-Forum recommande d'étudier plus en détail l'utilisation flexible des techniques TDD et FDD, dans le but d'augmenter l'usage efficace du spectre.

7. Il est recommandé d'utiliser un canal logique de contrôle, comme solution appropriée concernant l'exploitation de terminaux multimodes et l'itinérance globale. L'identification d'un canal physique de contrôle dans le Règlement Radio n'est pas recommandé.

0.3 RESUMEN EJECUTIVO

Este informe ha sido elaborado por el UMTS Forum, una asociación de operadores, fabricantes y reguladores que trabajan de forma activa en Europa y en el resto del mundo y que comparten la visión sobre el UMTS. El UMTS será un miembro de la familia de estándares IMT-2000. El UMTS desarrollará las comunicaciones desde el momento en el que nos encontramos hasta adentrarnos en la Sociedad de la Información de los servicios de tercera generación y proporcionará de forma directa servicios de voz, datos, imágenes, gráficos, comunicaciones de video y otras informaciones de banda ancha a todas las personas con necesidad de movilidad.

La tarea de escribir este informe se ha realizado fundamentalmente en el Grupo de Aspectos del Espectro (SAG – Spectrum Aspects Group), un subgrupo del Forum. Todos los operadores y fabricantes del UMTS Forum apoyan las conclusiones más importantes del informe. Las Administraciones Nacionales que son miembros del Forum han contribuido activamente al desarrollo de este documento. No obstante, las recomendaciones que contiene este informe no pueden ser vinculantes para las Administraciones.

El informe es una contribución fundamental en la preparación de la Conferencia Mundial de Radiocomunicaciones CMR-2000 y en el proceso de toma de decisiones en la asignación de espectro para el UMTS / IMT-2000 en un número de países en todo el mundo. Representa la visión consensuada de los miembros del Forum sobre los aspectos de espectro para el UMTS. Dicho informe se ha elaborado y desarrollado cuidadosamente durante los últimos dos años de vida del Forum y considera la visión y la demanda de espectro. El informe se ha escrito para que interese a todas las partes implicadas en el desarrollo futuro de la industria de las telecomunicaciones móviles en el mundo.

Este informe continúa desde donde se quedó el primer informe del UMTS Forum que trataba sobre el marco regulatorio y los aspectos sobre espectro para el UMTS [1]. Otros trabajos del Forum cubren áreas de aspectos técnicos [2], condiciones económicas [4], y asuntos sobre licencias [5]. Para poder ayudar a los reguladores en la puesta en marcha de la licitación del espectro para el UMTS, el Forum ha publicado un informe que trata sobre la demanda mínima de espectro [6].

Un requisito básico para el desarrollo del UMTS (Universal Mobile Telecommunications System) es tener un acceso apropiado al espectro radioeléctrico. El objetivo de este informe es dar un análisis más detallado sobre los temas relacionados con el espectro radioeléctrico y dar el punto de vista del Forum sobre los aspectos acerca de dicho espectro.

El UMTS Forum es una asociación libre e independiente, compuesta por operadores, fabricantes y reguladores del sector de las telecomunicaciones (más de 150 miembros), que están trabajando activamente tanto en Europa como en el resto del mundo y que comparten la misma visión sobre el UMTS. Este informe lo ha preparado el Grupo de Aspectos del Espectro (SAG – Spectrum Aspects Group), un subgrupo dentro del Forum.

UMTS, el Sistema de Telecomunicaciones Móviles Universal (Universal Mobile Telecommunications System), como miembro de la familia IMT-2000, se le reconoce como la principal oportunidad de proporcionar servicios multimedia móviles para el futuro mercado de masas. El UMTS ofrecerá velocidades de transmisión de hasta 2 Mbps.

Debe tenerse en cuenta que este informe se centra generalmente en el espectro para un mercado UMTS / IMT-2000 global. Se utilizaron diversos entornos en un modelo de tráfico genérico, que podría ser aplicado a múltiples países del mundo sin más que variar datos demográficos y económicos. Realmente, los parámetros utilizados en los calculos de espectro radioeléctrico para el sistema terrestre se han extraido de un estudio de mercado para los 15 estados miembros de la UE para los años 2005 al 2010. Las estimaciones de espectro son válidas para países con entornos similares a los de los 15 estados miembros de la UE. Para los servicios por satélite, las estimaciones de espectro se basaron en estudios de mercado globales.

Recomendaciones:

1. El espectro radioeléctrico asignado al UMTS/IMT-2000 en las UIT Regulaciones de Radio, tanto para servicios terrestres y vía satélite, debería estar disponible en el año 2002 de acuerdo a la demanda del mercado.

2. Para poder cubrir la demanda de mercado prevista para los sistemas móviles terrestres, se ha calculado que serán necesarios un total de 582 MHz de espectro

total. Por tanto, se requiere un mínimo de 187 MHz de espectro radioeléctico adicional para servicios terrestres en áreas urbanas en el año 2010 en los 15 países miembros de la UE. Este espectro adicional incluye los requisitos de solicitudes para redes públicas y no-públicas (libres de licencia).

3. Para cubrir la demanda de mercado para los servicios por satélite, se necesitarán 2*123 MHz en el año 2005 y 2*145 MHz en el año 2010, con una necesidad algo más baja en Europa. Por tanto, se requieren 2*8 MHz adicionales de espectro radioeléctico de forma global para el año 2005. En el año 2010 se requerirán 2*30 MHz adicionales de espectro en las zonas críticas ("hot-spots), de manera global, siendo el requisito menor en los 15 estados miembros de la UE.

4. Se necesita designar espectro para solicitudes de UMTS no-públicas (libres de licencia). Este requisito será necesario desde el principio para ayudar a la construcción del mercado de los terminales móviles multimedia y para estimular la demanda para el acceso público al UMTS. La cantidad de espectro necesaria y su situación se investigarán con más detalle en el UMTS Forum.

5. El espectro mínimo recomendado por operador, tal y como se define en [6] es 2*15 MHz (pareado) + 5 MHz (no pareado). Deberá vigilarse que los operadores tienen suficiente espectro incluso si el espectro adicional no está disponible en el año 2005.

6. El UMTS Forum recomienda estudiar en más detalle el uso flexible de las técnicas TDD (Time Division Duplex, o Dúplex por División en Tiempo) y FDD (Frequency Division Duplex, o Dúplex por División en Frecuencia), con el objeto de optimizar el uso eficiente del espectro.

7. Se recomienda el uso de un canal de control de radio lógico (RCC, Radio Control Channel) como una solución adecuada a la operación de terminales multimodo y del roaming global. No se recomienda la identificación en las Regulaciones de Radio de un canal de control de radio global físico específico.

1 Introduction

1.1 Background and Objectives

Adequate access to spectrum is a key requirement for the development of the Universal Mobile Telecommunications System, UMTS. The purpose of this report is to give a more detailed analysis of the spectrum issues and express the Forum views regarding spectrum aspects. The Forum has already in its Report #1 /1/ made a number of recommendations regarding spectrum for UMTS, and this work is now pursued by the publication of this report.

The UMTS Forum is an open and independent association of telecommunications operators, manufacturers and regulators (over 150 members) active both in Europe and other parts of the world and who share the vision of UMTS. The preparation of the report has mainly been done in the Spectrum Aspects Group (SAG), a subgroup of the Forum.

The Forum's members share a vision of UMTS /2/ as a system that will offer:

- New and better services, i.e. multimedia and high-speed data services that are easy to use, and customisable in order to address individual users' needs and preferences.
- Terminals and other "customer facing" equipment which allows fast and easy access to these services.
- User costs, which are low enough to ensure a global mass market - prices which are competitive.
- Similarly, a wide range of available terminals, with prices low enough to be affordable to the mass market, while supporting the advanced capabilities of UMTS.
- Coverage in all environments through both terrestrial and satellite components, and through a radio technology with high spectral efficiency and service quality, allowing global and seamless roaming.

To make all this possible, sufficient spectrum for UMTS/IMT-2000 should be made available globally. UMTS will be a member of the ITU IMT-2000 family of standards. One of the main targets in the investigations of the UMTS Forum was to come to reasonable estimates for spectrum demand. The views of the Forum in this respect are supported by a number of contributions /e.g. 8/ to the work in ITU-R TG 8/1.

Estimates, which have guided to WARC-92 allocation were based on the assumption that FPLMTS will be a world-wide system with a low bit rate. The idea of multimedia services has appeared later on and the WARC-92 allocation is not sufficient any more. Thus, it was necessary to base new estimates on intensive market analysis work, on a reasonable traffic model and a proven methodology. In light of the uncertainty over the market split between 2nd generation and 3rd generation systems, all mobile services were taken into account. In a second step, the amount of spectrum currently identified for the above services, was deducted to identify the additional spectrum demand.

The following objectives were envisaged in this report:

- To establish a traffic model based upon the market analysis made in /3/;
- To develop spectrum calculation methodologies;
- To determine the level and nature of world-wide spectrum demand for all mobile services, 2nd and 3rd generation;
- To determine the additional spectrum requirements beyond the ITU allocations from WARC 92 for the years 2005 and 2010;
- To define the spectrum vision for spectrum expansion.

For terrestrial services the specific emphasis of the traffic model on the EU15 states deals with the market analysis based on the example of Europe. However, it is the UMTS Forums view that these projections are indicative of the world-wide demand for UMTS/IMT-2000 services because the same dense city environments that determine the European peak spectrum requirements are to be found in similar cities in most countries of the world.

1.2 UMTS/ IMT-2000 for the User

UMTS has been conceived from the outset to be a global system, comprising both national terrestrial and global satellite components. Through multi-mode, multi-band terminals it can use 2nd generation systems to extend its coverage for basic services. The first goal is to achieve truly personal communications, with terminals able to roam from a private cordless or fixed network, into a pico cellular / micro cellular public network, then into a wide area macro cellular network (which may actually be a 2nd generation network) and then to a satellite mobile network, in each case with a minimal break in communication. The second goal is to achieve this with a consistent delivery of the ‚look and feel‘ of services via the so-called "virtual home environment" (VHE).

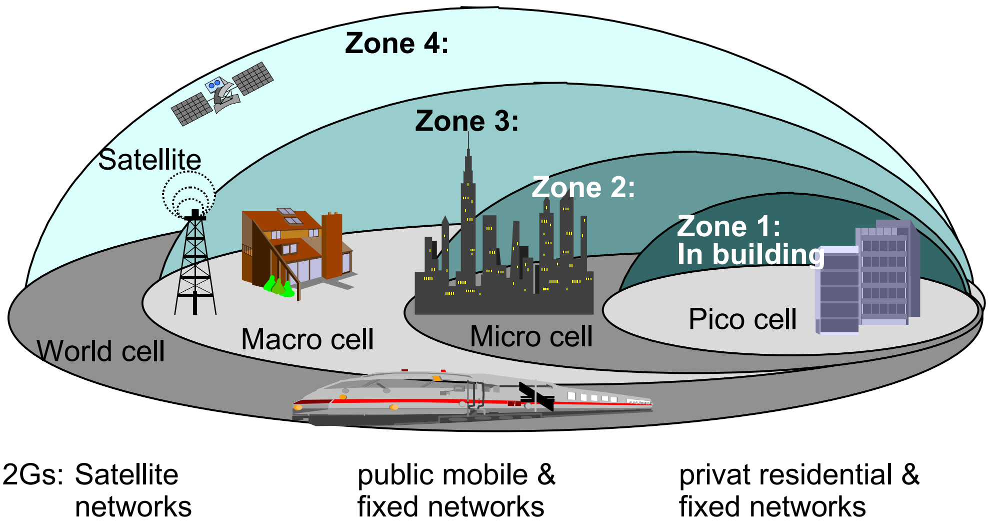

Figure 1.1: UMTS coverage is universal

Radio technology for all environments

The terrestrial UMTS radio access system UTRA /10/ will support operation with high spectral efficiency and service quality in all the physical environments in which wireless and mobile communication take place. Today's users live in a multi-dimensional world, moving between indoor, outdoor urban and outdoor rural environments with a degree of mobility ranging from essentially stationary through pedestrian up to very high vehicular speeds. There are also different user density environments, including three dimensional situations in high rise buildings. UTRA has been specified for all these environments.

Satellite technology can readily provide global coverage and service and so it is expected to play an important complementary role in the completion of UMTS coverage on a world-wide basis.

1.3 UMTS/IMT-2000 Development

IMT-2000 is the ITU concept for 3rd generation systems. Within the ITU-R Task Group 8/1 work is going on to identify members of the IMT-2000 family of standards according to the timetable in Table 1:1

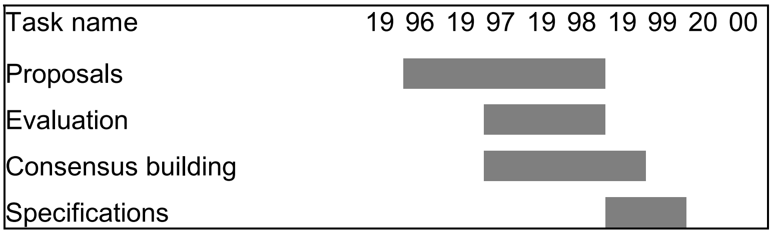

Table 1.1: IMT-2000 development schedule in ITU-R

Plans for the deployment of IMT-2000 systems are already in progress in many parts of the world. The WARC-92 identified 230 MHz for IMT-2000. In preparation for the World Radio Conference (WRC) -2000 a number of preparatory groups in all regions of the world are discussing spectrum demand for IMT-2000. preparing the way forward to the network deployment.

1.3.1 Europe´

In Europe, CEPT ERC decided in the year 1997 to designate the frequency bands for UMTS according to the ITU-R Radio Regulations (RR). The Council and the European Parliament have recently approved a decision on the co-ordinated introduction of a third-generation mobile and wireless communications system (UMTS) in the Community. The aim of this decision is to facilitate the rapid and co-ordinated introduction of compatible UMTS networks and services in the Community in the basis of internal market principles and in accordance with commercial demand.

The discussed schedule for UMTS deployment is shown in Table 1.2. A number of European countries will start licensing in the year 1999.

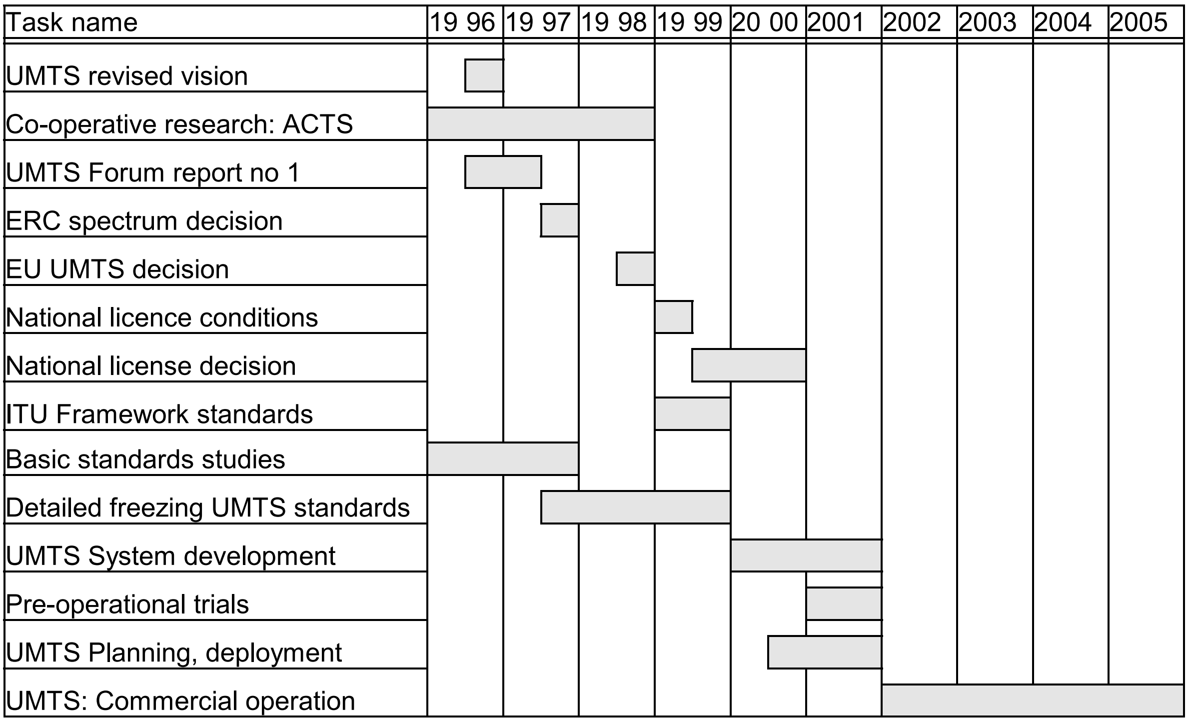

Table 1.2: UMTS Schedule for Europe

1.3.2 The Americas

FCC in the USA had issued a Public Notice for consultation on IMT-2000 services with closing date 30 September 1998. Any specific spectrum for IMT-2000 is not yet allocated, and the main part of the IMT-2000 terrestrial spectrum has already been allocated to 2nd generation PCS systems.

In Canada licenses for IMT-2000 testbeds has been issued. In Latin America the discussions about 3rd generation systems are still in very early stages.

1.3.3 Asia and Oceania

Japan has very advanced plans to introduce IMT-2000 systems by the year 2001. The licensing procedures will start in the year 1999.

New Zealand intends also to start licensing in the year 1999, while Korea is planning to start licensing in the year 2000.

The situation in China and other countries in the region is that firm deployment plans are not yet decided.

1.4 Impacts from Licensing

The Forum has examined the regulatory framework that will be required to allow UMTS/IMT-2000 licensing to meet the necessary and demanding time-scales. This is set out in the UMTS Forum Report # 4 /5/.

The co-ordinated introduction of UMTS/IMT-2000 in the regions is influenced by the occupancy of the IMT-2000 bands as identified by WARC-92. The UMTS Forum encourages administrations to make the complete bands for UMTS/IMT-2000 available as soon as possible. Experimental licensing should also be considered for use before the year 2002 to enable manufacturers to test their equipment and confirm UMTS/IMT-2000 operators to test both commercial and technical options.

- Terrestrial Networks:
  The number of licenses to be awarded is closely related to the spectrum needed per operator – especially in the initial phase of UMTS/IMT-2000. SAG has studied this issue in its Report /6/.
  In addition the spectrum requirement for non-public (license-exempt) use needs to be calculated.

- Satellite Networks:
  These networks play an important role offering a global coverage in the areas where terrestrial UMTS/IMT-2000 is not provided for economical reasons. There is a need for a harmonised approach to frequency management for the satellite component on at least a regional basis. A milestone procedure (e.g. CEPT/ERC/DEC/(97)03) to support satellite due diligence should be extended beyond Europe and to include compliance with IMT-2000 objectives, see /4/.

For the total spectrum estimates for UMTS/IMT-2000, packaging of spectrum and the number of operator licenses per country including non-public (license-exempt) applications play a role by determining guard bands and trunking overheads.

1.5 World-wide Spectrum Allocation

WARC-92 designated the frequency bands 1885 – 2025 MHz and 2110 – 2200 MHz for FPLMTS (the name was changed to IMT-2000 in WRC-97), from which the bands 1980 – 2010 MHz (1980 - 2025 MHz in Region 2) and 2170 – 2200 MHz (2160 – 2200 MHz in Region 2) to be used for the satellite component.

The spectrum available for operators is - for most of the world-wide regions and areas - the spectrum identified for IMT-2000 at WARC-92 according to the ITU RR. Figure 1.2 shows the IMT-2000 spectrum situation in some regions and countries.

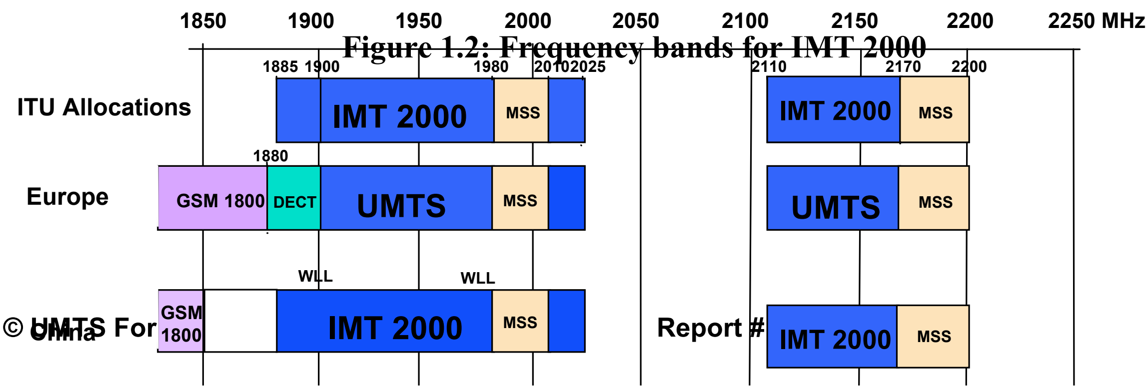

Figure 1.2: Frequency bands for IMT 2000

1.5.1 Europe

In CEPT countries, in general, all UMTS/IMT-2000 spectrum identified in ITU RR, except 15 MHz which is already used for DECT, is designated for UMTS/IMT-2000, as can be seen in ERC Report 25 /11/. The bands for terrestrial UMTS are 1900 - 1980 MHz, 2010 - 2025 MHz, and 2110 - 2170 MHz. This gives 155 MHz in total. The MSS allocations at 2 GHz frequency band that are identified for UMTS/IMT-2000 satellite component are 1980 – 2010 MHz and 2170 – 2200 MHz, which gives 60 MHz in all for UMTS/IMT-2000 satellite services.

The European spectrum designation is confirmed in the ERC Decision CEPT/ERC/DEC/(97)07 on the introduction of UMTS /9/. A total of 15 CEPT countries have already signed up to this ERC Decision (by 10 Oct. 1998). It is anticipated that more countries will sign the decision in the future. According to the ERC decision at least 2 * 40 MHz should be made available to operators by the beginning of year 2002 and all 155 MHz could be made available for terrestrial UMTS/IMT-2000 up to year 2005 subject to market demand.

1.5.2 African and Arabian States

The African and Arabian states are following the ITU discussions and the developments in the other countries and regions. Active participation in conferences dealing with spectrum indicates their high interest in being involved in the future preparations on spectrum issues.

1.5.3 North America

North America has a different scenario: the introduction of PCS services and the auctioning led to a split into licenses of 2 * 15 MHz and 2 * 5 MHz in the frequency bands 1850 – 1990 MHz. This differing spectrum utilisation leads to questions of how radio equipment could be harmonised with IMT-2000 services in Europe, Japan and in the rest of the world.

As can be seen in Figure 1.2, in North America only 5 or 15 MHz frequency blocks can be used in the PCS bands. Therefore the 5 MHz minimum bandwidth per operator is an important requirement for the standard; it has also to include the necessary guard bands. The upper part of the UMTS/IMT-2000 spectrum from 2110 - 2160 MHz is not in PCS use and could therefore possibly be used for UMTS/IMT-2000.

Canada has kept the C and E frequency blocks as a reserve for future allocations. The spectrum policy will be reviewed at the end of 1998. This means, that Canada could license 2 * 15 MHz and 2 * 5 MHz = 40 MHz for 3rd generation services on a national basis.

1.5.4 South America

The South American spectrum situation is presently fragmented and differs in many ways from that in North America and the future plans for 3rd generation mobile systems are not yet known.

1.5.5 Asia/Pacific

Asian Pacific countries are likely to follow the ITU-spectrum allocations. Most of the countries are expected to make paired and unpaired bands available for IMT-2000..

In Japan the Ministry of Post and Telecommunications (MPT) is planning to designate the WARC-92 IMT-2000 spectrum for 3rd generation systems in the same way as the Europeans with the difference, that the frequency band 1893.5 - 1919.6 MHz is already allocated to PHS services. Japan could reserve for IMT-2000 2 * 60 MHz + 15 MHz = 135 MHz in total. MPT announced its IMT-2000 guidelines in order to collect the public comments and decide their IMT-1000 licence policy by around mid-1999. MPT indicated in its IMT-2000 guidelines, that they will decide upon three public terrestrial operators for IMT-2000. The bands 1920 -1980 MHz and 2110 – 2170 MHz will be allocated and each operator will get 2 * 20 MHz paired spectrum to start the service by year 2001. Japan is expected to be one of the first countries to assign spectrum for IMT-2000.

Korea already indicated spectrum allocations for IMT-2000 in line with spectrum identified for IMT-2000 in the ITU RR, which is in total 170 MHz for terrestrial and 60 MHz for satellite services.

The recent discussion of the UMTS Forum in China reflects that the assignments for IMT-2000 are still being studied. It may be assumed that the major part of the IMT-2000 bands identified in ITU RR could be made available, however, there is no detailed plan or decision made yet. There are some reservations presently made for cordless and wireless local loop applications.

1.5.6 Rest of the World

UMTS Forum does not have any detailed information of the availability of the IMT-2000 spectrum in the rest of the world.

1.6 Standardisation

Standardisation is, and will remain, a key factor in providing quality services at an affordable cost and enable roaming between systems, and its success depends upon the flexibility of interfaces and the capacity to evolve in parallel with technological development. Continued close co-operation between operators, manufacturers and regulators in the standardisation of UMTS/IMT-2000 is crucial for successful harmonisation of standardisation proposals.

UMTS is seen as part of the ITU IMT-2000 family. IMT-2000 has been understood by the ITU as an open international standard for high capacity, high data rate mobile telecommunications systems incorporating both terrestrial radio and satellite components. UMTS has been initiated by the European Telecommunications Standards Institute (ETSI) in the IMT-2000 framework and is being standardised in co-operation with other regional and national standardisation bodies around the world to produce the detailed standards to satisfy growing market needs for global roaming and service availability. This work will be done in the ‚3rd Generation Partnership Project' and is known by the acronym ‚3GPP'. 3GPP will provide globally applicable technical specifications for 3rd generation mobile systems based on evolved GSM core networks and the radio access technologies studied in ETSI as UTRA /10/ and in ARIB as W-CDMA (both with FDD and TDD modes) to be transposed by relevant standardisation bodies into appropriate deliverables (e.g. standards) for the initial phase. UTRA will provide high spectral efficiency in two operational modes: FDD mode for the use of paired frequency bands, TDD mode for the use of unpaired frequency bands. On the satellite side, standardisation work continues as part of the work programme within the ITU and the regional/national standardisation bodies.

2 Market

2.1 Terrestrial Mobile Services Market

It is clear, that the spectrum demand for UMTS/IMT-2000 is significantly dependent on the number of users, the quantity of traffic flow and its distribution. In order to identify this critical impact, a market analysis and forecasts need to be made. This study was done by Analysis/Intercai /3/ commissioned by DG XIII of the European Commission. The study has been carried out under guidance of and with contributions from the Market Aspects Group (MAG) in the UMTS Forum.

The total market for mobility in the public and non-public (license-exempt) domains was considered. The study has not considered the market for the delivery of services to fixed terminals.

The major focus of the study, in particular the scenario analysis and market forecasts, has been on the European market, defined as the 15 EU member states: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the UK. Assessment has been made of developments and market growth in the rest of the world – in particular North America and Japan, but not to the same degree of details as for Europe.

A fundamental hypothesis that underpins the market analysis in this study is that the evolution of the market for mobile multimedia services will be strongly influenced by the site and nature of the market for networked multimedia services provided e.g. by Internet and Intranet.

The following process was adopted for the market study:

- Identify the societal and technological trends which are likely to have an impact on the future market for mobile services.
- Investigate various scenarios for the market evolution and produce market forecasts
- Define the traffic model for spectrum calculations in relation to the potential user environments

2.1.1 World market

The world market for mobile services including multimedia was projected on the basis of the current status of market development compared to the European Union (EU), GNP[1] per head and the expected sophistication of the telecoms market in each country or region. The results of this forecast show that markets outside the EU, North America and Japan will dominate the world market by the year 2005 and probably beyond.

Table 2.1 shows the world-wide market forecast for the physical users of terrestrial mobile services including multimedia.

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[1] *GNP = Gross National Product*

Physical users in millions at year end	2000	2005	2010
Europe, EU15	113	200	260
North America	127	190	220
Asia Pacific[2]	149	400	850
Rest of the world	37	150	400
Total	426	940	1730

Table 2.1: World-wide Mobile Market Forecast (Source: UMTS Forum Report # 1 /1/)

Europe, Japan and North America are regions that will most likely face market saturation in terms of physical users by the year 2010. However, there is likely to be additional market potential by machine to machine communications and multiple subscriptions of individuals (e.g. one paid for by the employing company, the other one by the user himself) in order to separate business and private use. Many countries in Asia Pacific/Africa and South America are expected still to be far from reaching saturation in terms of mobile users in the year 2010.

2.1.2 Europe

Europe is considered here in more detailed because it is used as a basis of the traffic model for the spectrum calculations. The spectrum estimate is aligned with the predicted growth of the amount of mobile subscribers within the 15 EU countries. Table 2.2 shows the market forecasts for the number of physical users of mobile services and, out of them, the number of physical users of mobile multimedia (MM) services and their assumed penetration rates.

Year	Population in millions	Physical users in millions	Penetration	Thereof physical users of MM service in millions	Penetration
2005	385	200	0.52	32 (from which 20 use High MM)	0.08 (0.05 for High MM)
2010	387	260	0.67	90	0.23

Table 2.2: Population of EU 15 and the Penetration of Future Mobile Services

Note: Corresponding penetration values for physical users of mobile services used in the spectrum calculations is 0.6 for the year 2005 and finally 0.75 for the year 2010. The slightly higher penetration values used in the spectrum estimation for mobile services, compared to the figures in table 2.2, are due to the fact that the figures in table 2.2 are average values and some countries (e.g. in Scandinavia) have higher penetration figures. The same penetration values have been used in all operational environments. (See Annex 3, section A3 3.2, Tables A3.D and A3.E: speech service representing the physical user penetration value)

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2 *thereoff Japan Segment acc. To ARIB 1/98 year 2000: 60-70 mio; year 2010: 90-100 mio*

For spectrum calculations, a detailed market model needed to be developed. Based upon the forecast figures from /3/ SAG and MAG decided for the market model, which relates to the EU15 forecasts. For this region, the following figures were taken from the study for the year 2005:

a) **Total mobile market:**

Users:	200 million
Service revenues:	104 billion ECU per year
Traffic:	6320 million Mbytes/month
	32 Mbytes/user/month

b) **For the mobile multimedia segment:**

Users:	32 million
Service revenues:	24 billion ECU + 10 billion for terminal revenues
Traffic:	3800 million Mbytes/month
	119 Mbytes/user/month

Note: Detailed traffic model figures including the year 2010 are shown in Chapter 3 and the Annexes.

The UMTS Forum therefore believes that the annual market revenues in Europe for mobile multimedia will be at least 34 billion EURO (services and terminals) by the year 2005 with at least 32 million physical users using mobile multimedia services. In these figures the uses of enhanced 2nd generation mobile services are included.

It becomes visible, that mobile multimedia will be noticeably emerging and already representing 16% of the users and 23% of the revenues in the year 2005. Traffic requirements of that sector will represent 60% of the total, despite many users in many countries being restricted to low data rate services derived from present GSM technology, offering restricted multimedia services. Every multimedia user will generate significantly more traffic than today's mobile user, but they cannot be expected to pay an equivalent multiple of current tariffs, which implies that tariffs will not be proportional to the traffic volume or to the used spectrum. This highlights the need for an order of magnitude capacity improvement with infrastructure costs maintained at no more than current 2nd generation levels. Significantly reduced equipment costs would help to support the higher bit-rate services. This will be a major challenge for the communications and computing industries, but one which seems feasible to meet in the given time frame.

2.1.3 Additional Market Areas

The demand for mobile multimedia services and cellular type mobile services is not the whole market for services and spectrum. In particular, there are other areas where IMT-2000 services are likely to be used.

- Systems with limited mobility primarily used as a more flexible alternative to wired access. This will be the case especially in areas with low population density or difficult topography, or where low mobility is required.

- Private/corporate markets, ranging from home applications to wireless PBXs, to emergency wide area systems and even cordless systems with local mobility. The overlap between these services and more traditional wide area mobile services may increase over the next five years with, for instance, dual-mode and multi-mode handsets, pico cells and changes to tariffing systems. The impact of these changes will need further study.

2.2 Mobile Satellite Services Market

Current expectations are that less than 20% of the world's land area will be covered by terrestrial cellular networks within the envisaged timescales of UMTS/IMT-2000. Satellite systems, which provide world wide service on day one of operation, are therefore important to UMTS/IMT-2000 to provide complete coverage. In turn, this is expected to spur further demand for terrestrially based UMTS/IMT-2000 services. On the other hand, in EU15 more than 80% of the population can be expected to be covered by terrestrial UMTS/IMT-2000 in 2010. Price differences between terrestrial and satellite services will play an important role in the usage of these services. This difference in price is not likely to significantly change in the future.

The forecasts included in this Report distinguished between 12 traffic environments, which are listed in Annex 4. It should also be noted that the forecasts deal only with *mobile* satellite services, i.e., those services supplied from either moving terminals or portable/transportable terminals capable being moved easily. Fixed Satellite Service (FSS) systems (those systems providing services >~ 1Mbit/s to fixed installations) are specifically excluded, as these systems are assumed to be outside the bounds of UMTS/IMT-2000.

2.2.1 Traffic Forecasts

The spectrum calculations in this Report are based on global market forecasts. As part of these forecasts the EU15 market has been projected. Similarly to the terrestrial case, the forecasts represent the market for all mobile satellite services (MSS). However, the study also includes an estimate of the portion of the total MSS market which is UMTS/IMT-2000 compliant.

Forecasts for World-wide and European satellite UMTS/IMT-2000 users have been segmented into non-multimedia users (those requiring non-multimedia services only) and multimedia users. These forecasts have been derived from forecasting the total MSS demand with UMTS/IMT-2000 forming a part of this. It is expected that all the forecast MSS multimedia users will be UMTS/IMT-2000 compliant while only a portion of the MSS non-multimedia users will be UMTS/IMT-2000 compliant.

For non-multimedia users, services extend only to basic speech services (but at high quality - 8/16 kbit/s) and low speed data (9.6/16 kbit/s). For multimedia users the requirements are for a variety of different services and applications. These are described in Annex 4. Based on forecast usage patterns, the MSS and UMTS/IMT-2000 traffic figures (in Million MB's) were derived.

The forecasts are summarised in Table 2.3. The demand for UMTS/IMT-2000 satellite services differs from region to region and depends, *inter alia*, on population density and developed terrestrial infrastructure. In the EU15, the demand may decrease in the long term, as countries complete their terrestrial UMTS/IMT-2000 coverage and combine with 2nd generation cellular systems. This effect is not taken into account in traffic figures for 2010 for EU15, where it can be expected that UMTS coverage will be high. Therefore, the demand for 2010 in EU15 may be considered as overestimated.

	Worldwide		EU	
Year	**2005**	**2010**	**2005**	**2010**
MSS Subscribers (000s)				
Non-Multimedia	4,875	7,500	609	938
Multimedia	6,585	10,975	395	659
	11,460	18,475	1,004	1,596
Average Usage per subscriber (kBs per month)				
Non-Multimedia				
Voice	8,709	8,491	8,709	8,491
Low Speed Data	6,208	5,587	6,208	5,587
Multimedia				
Voice	1,194	1,561	1,194	1,561
Low Speed Data	2,584	3,380	2,584	3,380
Asymmetric	26,154	34,247	26,154	34,247
Interactive	1,781	2,334	1,781	2,334
Total Annual Traffic (Million MB's)				
Non-Multimedia				
Voice	509	764	64	96
Low Speed Data	491	736	45	63
Multimedia				
Voice	94	206	6	12
Low Speed Data	204	445	12	27
Asymmetric	2,067	4,510	124	271
Interactive	141	307	8	18
Total	3,506	6,968	259	486
Annual Traffic (Mill. MB's) - excluding non UMTS/IMT-2000 compliant traffic				
Non-Multimedia				
Voice	34	123	4	15
Low Speed Data	33	119	3	10
Multimedia				
Voice	94	206	6	12
Low Speed Data	204	445	12	27
Asymmetric	2,067	4,510	124	271
Interactive	141	307	8	18
Total	2,573	5,710	158	354

Table 2.3: Worldwide satellite market*

* *For Non-Multimedia, the UMTS/IMT-2000 segment forms a small element of the overall MSS market due to the assumption taken that most handheld speech based systems will not be compliant with UMTS/IMT-2000 (previously it was assumed to be a much higher element). Some indications (from handheld speech based satellite systems) are that the portion compliant will be higher than shown here, due to systems achieving compliance when it was assumed they would not. If this were the case then the forecast for EU would be higher as well.*

3 UMTS/IMT-2000 Spectrum

3.1 General Remarks and Assumptions

The calculations of frequency spectrum requirements for UMTS/IMT-2000 cannot be limited to multimedia services and high speed data services. A number of the foreseen UMTS/IMT-2000 services, such as speech and low speed data services, are today delivered by 2nd generation systems and this will be the case also when UMTS/IMT-2000 has been introduced, at least during a transitional period. In the satellite field, UMTS/IMT-2000 compliant systems and other MSS systems will share to a certain extent the same market.

Therefore, the calculations of frequency spectrum requirement have been made by taking account of future market for mobile services up to the year 2010 covering all services, public (licensed) and non-public (license-exempt), including those provided currently by 2nd generation systems. The terrestrial spectrum calculations are based on the European scenario. As expected, the spectrum demand is predominantly determined by the situation in the dense urban areas. As these areas are similar in many parts of the world it is expected that this scenario can be applied to other regions as well.

The following main assumptions were made:

- In order to adopt multimedia applications sufficiently and to save spectrum resources, both circuit and packet switched radio access are assumed. The traffic calculations consider both transmission principles.

- Asymmetric traffic distributions may influence the spectrum demand on the uplink and downlink.

- For the calculation of spectrum efficiency figures of terrestrial systems a mixture of 2nd generation and 3rd generation systems is assumed. GSM is considered as a 2nd generation reference system. An improvement factor over the system capability of GSM is used for 3rd generation systems.

- For satellite systems a gradual improvement in the spectrum efficiency is assumed.

3.2 Terrestrial UMTS/IMT-2000 Spectrum Demand

The methodology used in this report has been endorsed (with slight refinements to the traffic modelling) by CEPT ERC TG1 /12/ in Europe and globally by ITU-R TG8/1 /13/ as a basis to calculate UMTS/IMT-2000 additional spectrum in preparation for the next World Radio Conference, WRC-2000. ERC TG1 and ITU-R TG8/1 have used partly different assumptions and parameters, but the final results are of the same magnitude as those presented here.

It is anticipated that some of the traffic destined for the UMTS/IMT2000 service will be carried on 2nd generation systems. It will be difficult to differentiate traffic between 2nd

and 3rd generation applications but, in general, we can anticipate that spectrum already available for 2nd generation systems can be deducted from total spectrum requirement to give a reasonable estimate of the new spectrum required. For instance in Europe the spectrum used for today's 2nd generation networks consists of 2*35 MHz for GSM 900, 2*75 MHz for GSM1800, and 20 MHz for DECT, totalling 240 MHz. Thus in the year 2005 a total calculated requirement of 403 MHz can be satisfied by combining the 240 MHz of 2nd generation spectrum, 155 MHz of spectrum currently identified for UMTS/IMT2000 and 8 MHz of new spectrum; similarly by the year 2010 a total calculated requirement of 582 MHz can be satisfied with 240 MHz of 2nd generation spectrum, 155 MHz of established UMTS/IMT2000 spectrum and 187 MHz of new spectrum.

3.2.1 Methodology

The spectrum requirement calculated for terrestrial UMTS/IMT2000 is based on several factors:

- Market forecast and penetration
- Potential user density
- Service and traffic characteristics
- Infrastructure and technical characteristics

The calculation methodology is explained in detail in Annex 3. Therefore in the following only a short overview of the methodology is given. The flowchart of the methodology is given in Figure 3.1.

The spectrum requirement for each service: speech, simple messaging, switched data, medium multimedia, high multimedia and high interactive multimedia are considered in each of the six geographical operating environments: CBD (Central Business District), Suburban, Home, Urban pedestrian, Urban Vehicular and Rural, see detailed explanations in Annex 3. So including the uplink and downlink there are 2*6*6=72 cases to consider. The spectrum requirement calculation takes place independently for each case, with a final summation giving the total spectrum requirement.

The first stage in the calculation is to derive the total amount of users per km^2 for each of the six service classes. This can be readily derived by multiplying the population density by the service penetration.

Each service in each environment generates a particular call rate (calls/hour) and particular call duration (s) and a particular bit rate (kbit/s). Further multiplication generates the bit requirement (kbit/hour/km^2). The bit requirement must be increased to take account of a coding factor (Table A3.I in Annex 3), overhead for signalling and packet retries (Tables A3.J, A3.K, A3.L and A3.M) and blocking for circuit switched services (Tables A3.N, A3.O, A3.P and A3.Q) This gives the figure for the *Offered Bit Quantity (kbit/hour/km^2.).*

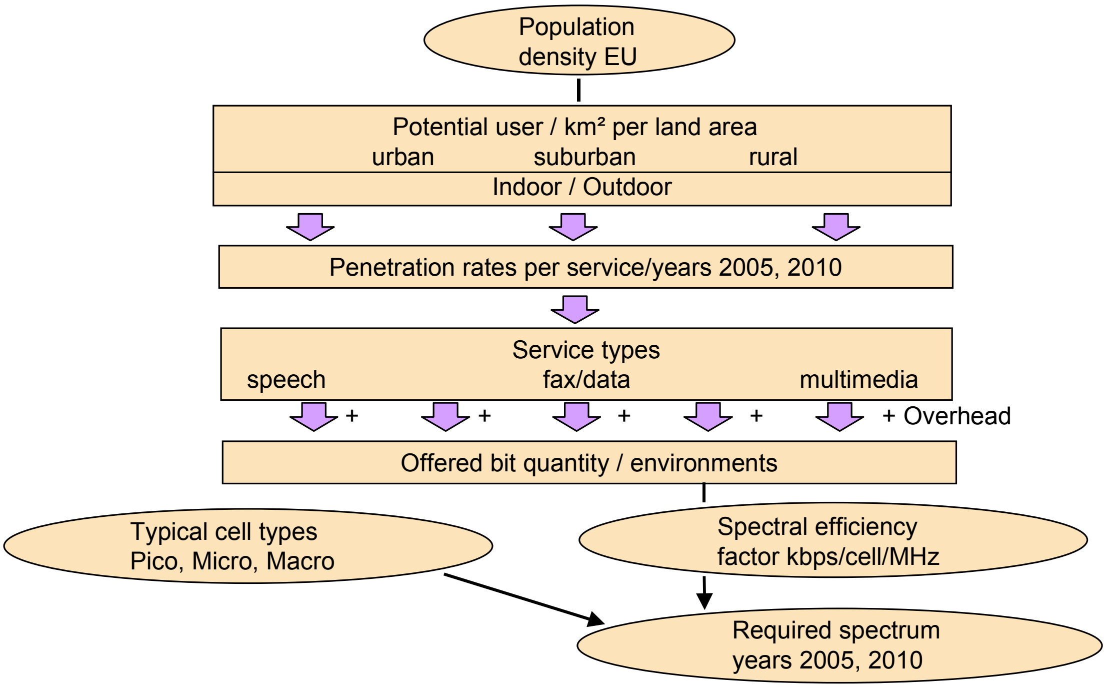


Figure 3.1: Calculation Method for UMTS Spectrum

GSM system capability is used to derive the system capability used in the spectrum calculations in this report. It is reasonable to assume that the UMTS/IMT-2000 system capability will be at least equivalent to that of a GSM based system. Appendix 1 of Annex 3 describes the derivation of GSM capability of 339 Mbit/hour/cell/MHz. This generalised capability is called the *Carried Traffic.*

From 2010 a factor has been included to allow for improvements in system capability as UMTS/IMT-2000 evolves towards more sophisticated technology (Table A3.Q). A figure of 1.1 represents the average improvement in system capability achievable by 2005 and 1.35 by 2010.

Dividing the *Offered Bit Quantity* by the *Carried Traffic* we can get a general figure for the cell utilisation

$$\frac{OfferedBitQuantity}{CarriedTraffic} =$$

$$\frac{kbit / busy\ hour / km^2}{kbit / hour / cell / MHz} = \frac{kbit / (busy\ hour \times km^2)}{kbit / (hour \times cell \times MHz)} = \frac{cell \times MHz}{km^2} \qquad (3.1)$$

The spectrum requirement is given by

$$Spectrum / \ MHz = \frac{OfferedTraffic}{CarriedTraffic} * \frac{km^2}{cell} \qquad (3.2)$$

So for each service and environment the spectrum requirement may be calculated.

The factor $\frac{km^2}{cell}$ is previously established as the cell area described in Table A3.C.

The complete process is shown step by step in Annex 3 Tables A3.B to A3.W.

The spectrum requirement for home cells has been calculated using a simplified methodology. Each pico-cell is assumed to serve one customer. There is therefore no requirement to allow for Erlang blocking, see chapter A3 4.2.4.

To obtain the total spectrum requirement the uplink and downlink spectrum is summed for all services in the three urban environments: CBD/Urban (in building), Urban (Pedestrian) and Urban (Vehicular) and an increase of 10% (5% from 2010) is applied to allow for spectrum partitioning and guard bands. The final calculated spectrum requirement is 403 MHz for the year 2005 and 582 MHz for the year 2010.

3.2.2 Potential User Density

The potential user density per operational environment is based on /16/ and can be seen in Table 3.1.

Operational environments	**Density of potential users/km^2**
1) CBD/Urban (in building)	**180 000**
2) Suburban (in building or on street)	7 200
3) Home (in building)	380
4) Urban pedestrian	**108 000**
5) Urban vehicular	**2 780**
6) Rural in- & out-door	36

Table 3.1: Potential User Density

Only three of the operational environments (marked in bold in Table 3.1) contribute to the maximum total amount of spectrum required. This is because they coexist in the same geographical area. In urban areas all spectrum is assumed to be needed for mobile services and applications like WLL (Wireless Local Loop) have to be accommodated in other frequency bands. The spectrum requirements for these applications are therefore not included in the estimates of this report.

3.2.3 Service Characteristics

The definitions of the services are based on same definitions as in the market forecast /3/. Table 3.2 shows the service characteristics.

The speech service corresponds to a GSM speech codec. The channel coding gives rise to an overhead of 1.75 times the user net bit rate of the codec. Speech is a symmetric service with the same amount of information in the up link (UL) as in the down link (DL). The effective call duration is based on an average call duration equal to 120 seconds multiplied with an occupancy factor of 0.5. This finally ends up with an effective call duration of 60 seconds as shown in table 3.2. The usage of the occupancy factor implies that the system should be able to handle the discontinuous transmission mode.

The simple messaging service is the evolution of the GSM SMS (Short Message Service). The user net bit rate of the simple messaging service is based on the assumption that the typical size of a simple message is 40 kbyte and an acceptable delay for this service is assumed to be 30 seconds (user net bit rate 10.67 kbit/s. The final user net bit rate is derived by dividing the obtained relation between the file size and the acceptable delay to get an equivalent continuos user net bit rate. Further on an assumption is made of a packet efficiency factor of 0.75. The packet efficiency factor is based on consideration of practical packet networks and includes the effects of re-transmission of unsuccessful packets.

The same type of calculations are made in order to find out the user net bit rate for the medium and high MM services. The services are similar to evolved WWW types of services. The typical amount of data that needs to be transmitted for the medium MM service is 0.5 Mbytes during 14 seconds (user net bit rate 286 kbit/s) while the same figures for the high MM service are 10 Mbytes and 53 seconds (user net bit rate 1.51 Mbit/s). Further on the MM services are assumed to be asymmetrical.

The interactive MM service is assumed to be based on a 128 kb/s symmetrical connection. The duration of this service is 180 seconds with an assumed occupancy factor of 0.8 resulting in an effective call duration of 144 seconds. The switched data is a 14.4 kb/s circuit switched service type similar to existing data services within GSM.

The signalling overhead, training sequences etc. for the radio interface for all type of services is 20%.

The above figures indicate representative delays that might be acceptable for the packet switched services. In reality a range of delay constraints will be appropriate depending on the nature of the application being supported over the radio interface.

The delays represent a user net bit rate that is slightly lower than the nominal rate. However, the assumption made in the calculations is that the traffic carried for packet switched applications will include session control overheads (not to be confused with the air-interface signalling overheads), including set-up and clear-down control messages. These overheads will be invisible to the user, but will occupy the apparent delay time of the channel. In the absence of detailed applications information it is assumed that the gross traffic bit rate offered to the air interface is equal to the nominal user bit-rate. The nominal bit rates are therefore used in the spectrum calculations.

Services	**User nominal bit rate [kbit/s]**	**Effective call duration [s]**	**User net bit rate [kbit/s]**	**Coding factor**	**Asymmetry factor**	**Service bandwidth* [kbit/s]**
High interactive MM	128	144	128	2	1/1	256/256
High MM	2000	53	1509	2	0.005/1	15/3200
Medium MM	384	14	286	2	0.026/1	15/572
Switched data	14	156	14.4	3	1/1	43/43
Simple messaging	14	30	10.67	2	1/1	22/22
Speech	16	60	16	1,75	1/1	28/28

* The service bandwidth is the product of user nominal bit rate, coding factor and asymmetry factor.

Table 3.2: Service Characteristics

3.2.4 Service penetration

In order to estimate the usage of different services in varying environments, the following penetration values for the UMTS services are assumed. It is expected that users in many cases will subscribe to multiple services and hence use more than one service in that environment.

Note, that in the calculations it is assumed that service penetration is similar throughout all environments.

a) 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	0.01	0.005	0.005	0.005	0.005	0.005
High MM	0.05	0.047	0.047	0.047	0.047	0.047
Medium MM	0.08	0.047	0.047	0.077	0.077	0.047
Switched Data	0.10	0.10	0.10	0.10	0.10	0.10
Simple Messaging	0.25	0.25	0.25	0.25	0.25	0.25
Speech	0.60	0.60	0.60	0.60	0.60	0.60

b) 2010 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	0.050	0.053	0.053	0.053	0.053	0.053
High MM	0.180	0.180	0.180	0.180	0.180	0.180
Medium MM	0.180	0.180	0.180	0.180	0.180	0.180
Switched data	0.100	0.100	0.100	0.100	0.100	0.100
Simple messaging	0.400	0.400	0.400	0.400	0.400	0.400
Voice	0.750	0.750	0.750	0.750	0.750	0.750

Table 3.3: Service Penetration a) in the Year 2005, b) in the Year 2010.

3.2.5 Traffic Characteristics

The 'busy hour call attempt' (BHCA) in Table 3.4 defines an important part of the traffic characteristics in the spectrum estimation model. The BHCA is here defined as the ratio between the total number of connected calls and the total number of subscribers in the considered area, measured during the busy hour. This traffic characteristic is hard to predict especially for the MM type of services. New services will have different temporal characteristics so that the relative spectrum balance between speech and other services varies through the day. Further on, differentiated tariffs during the day would change the traffic characteristics entirely.

	2005			2010		
Services	**CBD in building**	**Urban pedestrian**	**Urban vehicular**	**CBD in building**	**Urban pedestrian**	**Urban vehicular**
High interactive MM	0.12	0.06	0.004	0.24	0.12	0.008
High MM	0.12	0.06	0.004	0.12	0.06	0.004
Medium MM	0.12	0.06	0.004	0.12	0.06	0.004
Switched data	0.06	0.03	0.002	0.06	0.03	0.002
Simple messaging	0.06	0.03	0.002	0.06	0.03	0.002
Speech	1	0.6	0.6	1	0.85	0.85

Table 3.4: Busy Hour Call Attempts (BHCA)

Further more the assumed BHCA values for the MM services lack of good comparison material due to the fact that similar charged services do not exist in public use today.

The interactive MM service, the switched data and the speech services are all circuit switched services with an assumed blocking rate of 0.02. Apart from the 20 % signalling overhead and the packet efficiency factor of 0.75, no additional resources are added to the packet based services (e.g. according to the Erlang B formula) in order to handle situations similar to the blocking.

3.2.6 Cell Sizes

The averaged cell radius for the central business district (CBD) is assumed to be 75 m during for both the years 2005 and 2010. The averaged cell radius for the other two operational environments of significance, (the urban pedestrian and vehicular) is around 700 m for the year 2005 and will decrease to around 600 m for the year 2010. An average cell radius of 700 m describes an environment where the cell sizes vary from 400 m to 1 km. Similarly an average cell radius of 600 m corresponds to cell radius between 300 m to 900 m.

3.2.7 Results and Discussion

Table 3.5 and Figure 3.2 show the spectrum required per service in the busy hour for the years 2005 and 2010. Detailed calculation is described in Annex 3.

The conclusion is that about 582 MHz will be required in the year 2010. The requirement includes the bands currently designated for second generation systems and the UMTS/IMT-2000 core bands, plus new spectrum fully and flexibly exploited. This leaves a requirement of 187 MHz for additional spectrum in Europe.

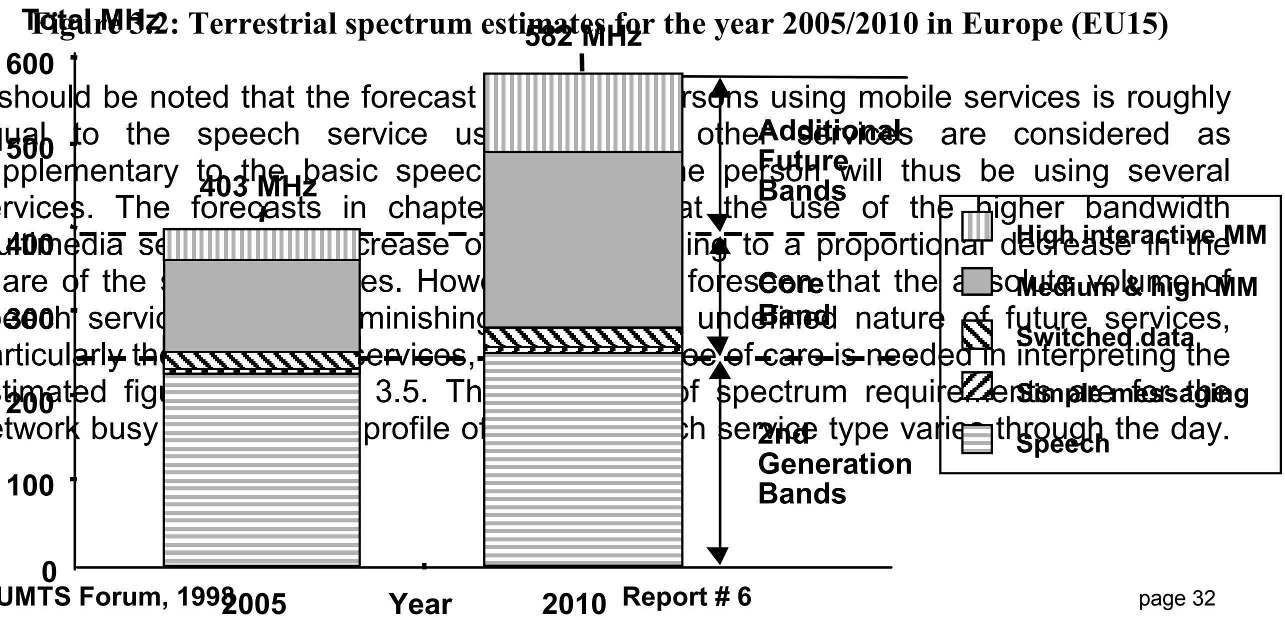
For the more distant future, i.e. after the year 2010, the general increase in penetration may not be as significant. However, the use of services requiring wider bandwidths may still increase. This might then lead to increasing spectrum demand. Further designation of frequency bands to cover such spectrum demand should be considered as early as possible when experience has been obtained from the implementation of UMTS/IMT-2000.

Services	Year 2005	Year 2010
High interactive MM	35 MHz	85 MHz
Medium & high MM	102 MHz	227 MHz
Switched data	14 MHz	10 MHz
Simple messaging	2 MHz	2 MHz
Speech	214 MHz	230 MHz
Total	366 MHz [1]	554 MHz [1]
Total(allowing for spectrum division)[2]	403 MHz	582 MHz

Notes:
1 Includes existing 2nd generation spectrum.
2 Trunking inefficiency and guard bands must be allowed for, due to multiple operators, and public/private and service category segmentation. This is assumed to improve from 10 % in the year 2005 to 5 % in the year 2010.

Table 3.5: Result of Terrestrial Spectrum Requirement Calculations.

Figure 3.2: Terrestrial spectrum estimates for the year 2005/2010 in Europe (EU15)



It should be noted that the forecast [illegible] rsons using mobile services is roughly equal to the speech service us[illegible] other services are considered as supplementary to the basic speec[illegible]e person will thus be using several services. The forecasts in chapte[illegible]at the use of the higher bandwidth multimedia se[illegible]crease o[illegible]ing to a proportional decrease in the share of the s[illegible]es. How[illegible] foreseen that the absolute volume of speech servic[illegible]minishing[illegible] undefined nature of future services, particularly th[illegible]services, [illegible] of care is needed in interpreting the estimated fig[illegible] 3.5. Th[illegible]f spectrum requirements are for the network busy [illegible] profile o[illegible]ch service type varies through the day.

The future mix of services should result in spectrum being utilised more evenly than the present, particularly through the use of delay in high volume data applications.

Factors that are not treated in the calculations and which may further increase the required spectrum include higher traffic rates, higher penetration and user density variations. Nor are factors that might reduce the spectrum requirements, such as half rate speech codecs, low rate video codecs, adaptive and/or distributed antennas, efficient statistical multiplexing and overall improved C/I performance, considered in the performed calculations.

Improvements in technology will lead to improvements in system capability. However, this potential may be partially reduced if improved quality is chosen, which is expected to be a market requirement. In addition, cellular radio operators have a practical difficulty in finding cell sites in optimal locations. The cellular grid will become more irregular as the nominal cell size is reduced with a consequential impact on cell capacity.

3.3 Satellite UMTS/IMT-2000 Spectrum Demand

3.3.1 Description of Service categories

As in the terrestrial case, traffic predictions were made for a number of service types in each of a variety of geographical environments. As detailed in Annex 4, 12 such environments were considered, ranging from ‚deep sea maritime' to ‚terrestrial fill-in'.

Distinction was also made between the following four types of services:

1. Speech - quality basic speech at 8/16 kbit/s
2. Low-speed data - predominantly messaging and e-mail (without attachments) type services at 9.6/16 kbit/s
3. Asymmetric services - this includes the predominantly one way services including file transfer, database/LAN access, Intranet/Internet WWW, E-mail (with attachments), image transfer etc. Rates of transmission will be up to around 144 kbit/s. This corresponds approximately to the Medium (and High) Multimedia services defined for terrestrial UMTS/IMT-2000
4. Interactive Multimedia - predominantly relating to videoconferencing and videotelephony at data speeds of around 144 kbit/s. This corresponds approximately to the High interactive Multimedia services as defined for terrestrial UMTS/IMT-2000.

3.3.2 Methodology

The methodology used to calculate the satellite spectrum requirements has been agreed in ITU-R Task Group 8/1 and was recently adopted by ITU-R Study Group 8 as Recommendation ITU-R M.[doc. 8/BL/13]. A flow-chart illustrating the methodology is given in Figure 3.3.

The calculation of spectrum requirements proceeds as follows:

The starting point is the yearly traffic demand in million Mbytes. For each type of service and each environment the traffic is converted to the average bit rate in the busy hour.

$$R_b = \frac{C_y \cdot 8 \cdot 10^6 \cdot f_B}{365 \cdot 3600} \qquad (3.3)$$

where
C_y is the total yearly traffic in million Mbytes;
f_B is the portion of the diurnal traffic occurring at busy hour;
R_b is the busy hour traffic in Mbit/s.

Applying the busy hour offset factor gives the bit rate for each service and environment in the overall busy hour:

$$R_b' = R_b \cdot f_{BO} \qquad (3.4)$$

where R_b' is the corrected busy hour traffic in Mbits/s;

Next, the number of carriers required to carry this traffic is calculated:

$$n_c = \frac{R_b' \cdot 1000}{R_c \cdot f_D \cdot f_C} \qquad (3.5)$$

where
R_c is the carrier information bit rate in kbit/s assumed to be 144 kbps;
f_D is the reduction in capacity which can be tolerated due to delay;
f_C is the number of satellite beam clusters covering the area.

The frequency bandwidth requirement becomes:

$$B = \frac{n_c \cdot B_c}{1000} \qquad (3.6)$$

where B_c is the bandwidth of the carriers in kHz

The total spectrum requirement may be calculated by summing over all relevant services and environments:

$$B = \sum_i B_i \qquad (3.7)$$

These calculation steps are shown in Figure 3.3 for a single service type and traffic environment.

Adjustments may have to be applied to account for:
1) inefficiencies due to spectrum being divided up between several operators;
2) granularity due to minimum spectrum requirements per operator.

To determine the peak spectrum requirement in a region, geographic peaking factors may also have to be applied, depending on the resolution of the input traffic data.

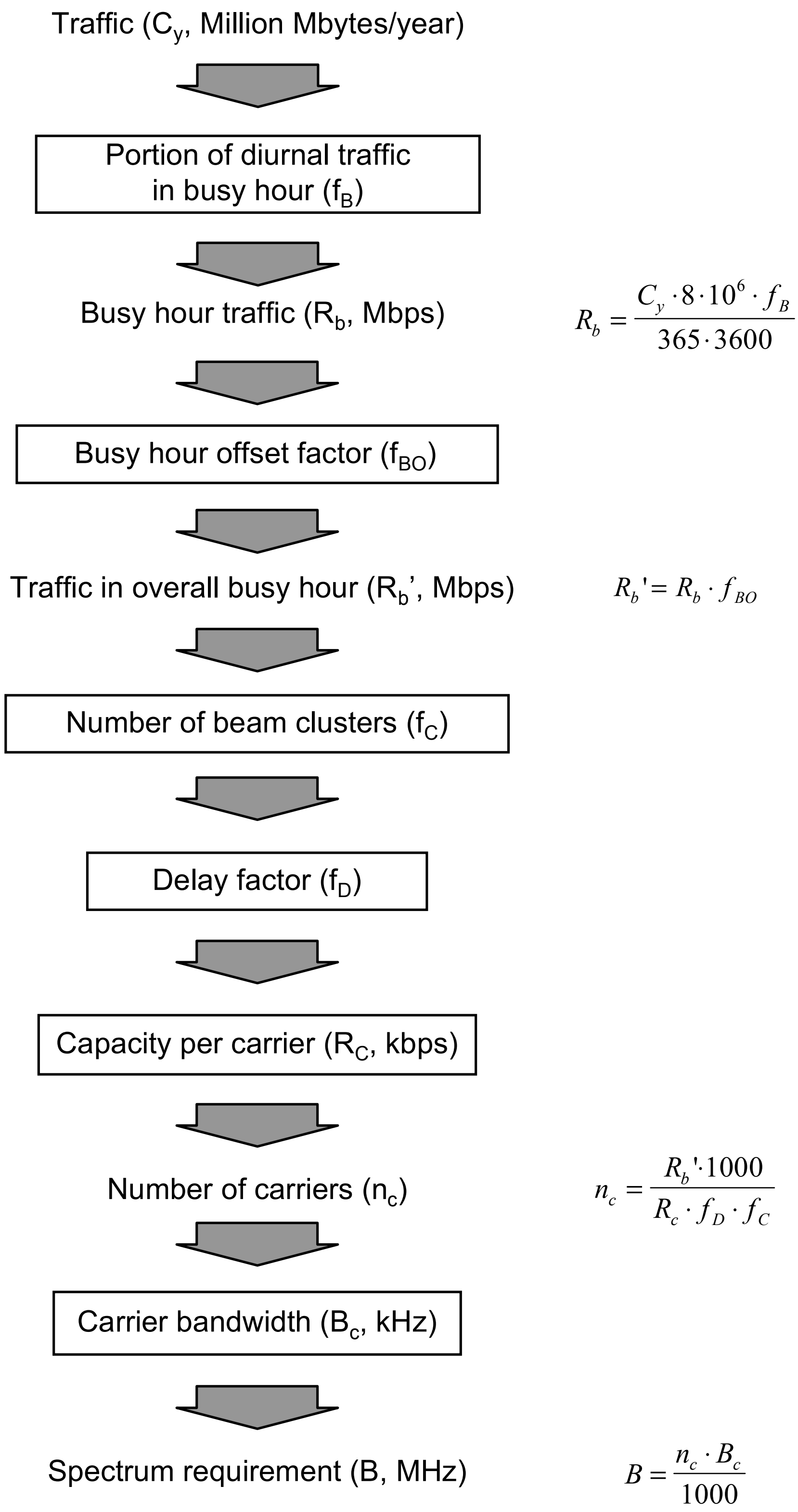


Figure 3.3: Calculation method for satellite spectrum requirements

3.3.3 Assumptions

The assumptions used in the calculation of satellite spectrum requirements are detailed in Annex 4. In simplified terms, two types of terminals are expected to provide mobile satellite services: hand-held terminals providing speech and low-rate data services and somewhat bulkier terminals providing multimedia services. The predicted market demand for these satellite services is given in chapter 2 and further detailed in Annex 4.

Expected frequency reuse and modulation techniques of planned MSS systems were taken into account. These parameters assume a gradual improvement in the spectrum efficiency of MSS systems, with several times better spectrum efficiency assumed compared with currently operational systems. See Annex 4 for more details.

3.3.4 Results

The satellite spectrum demand estimates are summarised in Table 3.6 and Figures 3.4 and 3.5. Figures 3.4 and 3.5 also show the existing MSS allocations, which total 229 MHz (2*114.5 MHz). However, in Europe since the bands 2520-2535 MHz and 2655-2670 MHz are not planned to be made available for MSS, the total available MSS spectrum is 199 MHz (2*99.5 MHz). This comparison shows that there is a requirement for additional MSS spectrum of 50-60 MHz by the year 2010 (with the lower requirements in Europe).

	EU15		*Global Hot Spot*	
	Year 2005	**Year 2010**	**Year 2005**	**Year 2010**
Non-IMT-2000 MSS	2x93 MHz	2x79 MHz	2x93 MHz	2x79 MHz
IMT-2000 MSS	2x19 MHz	2x44 MHz	2x30 MHz	2x66 MHz
Total	**2x112 MHz**	**2x123 MHz**	**2x123 MHz**	**2x145 MHz**

Table 3.6: MSS spectrum demand

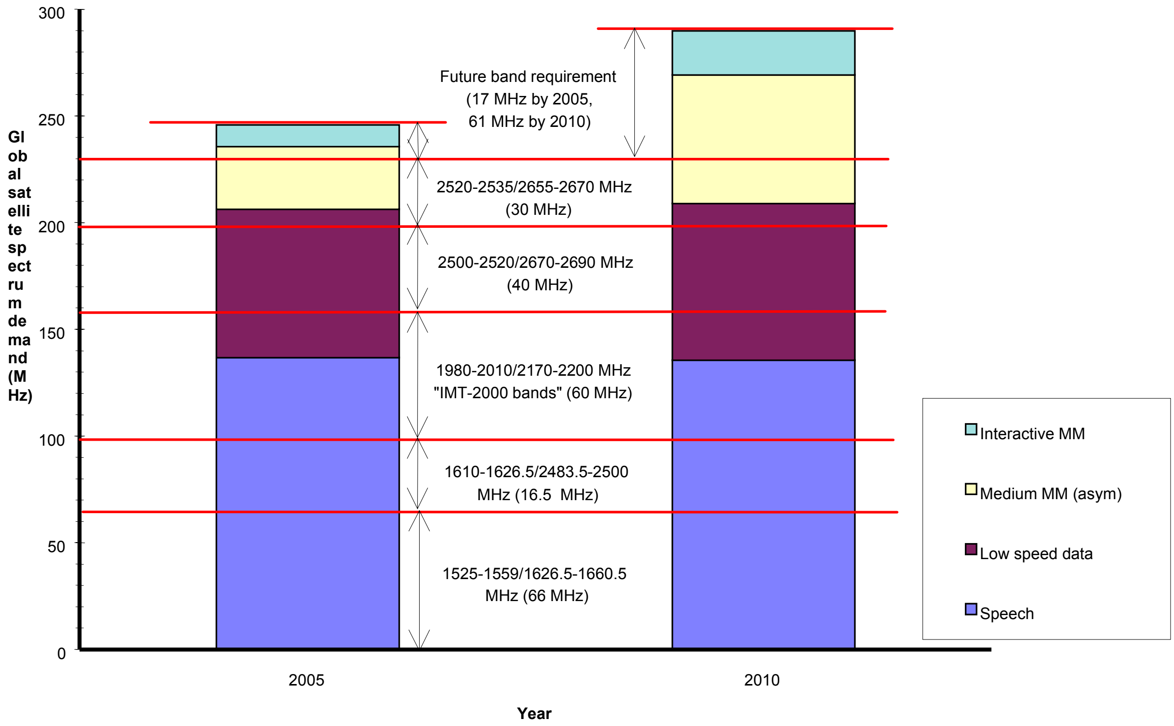


Figure 3.4: Satellite spectrum estimate for the years 2005/2010 (global hot spot)*

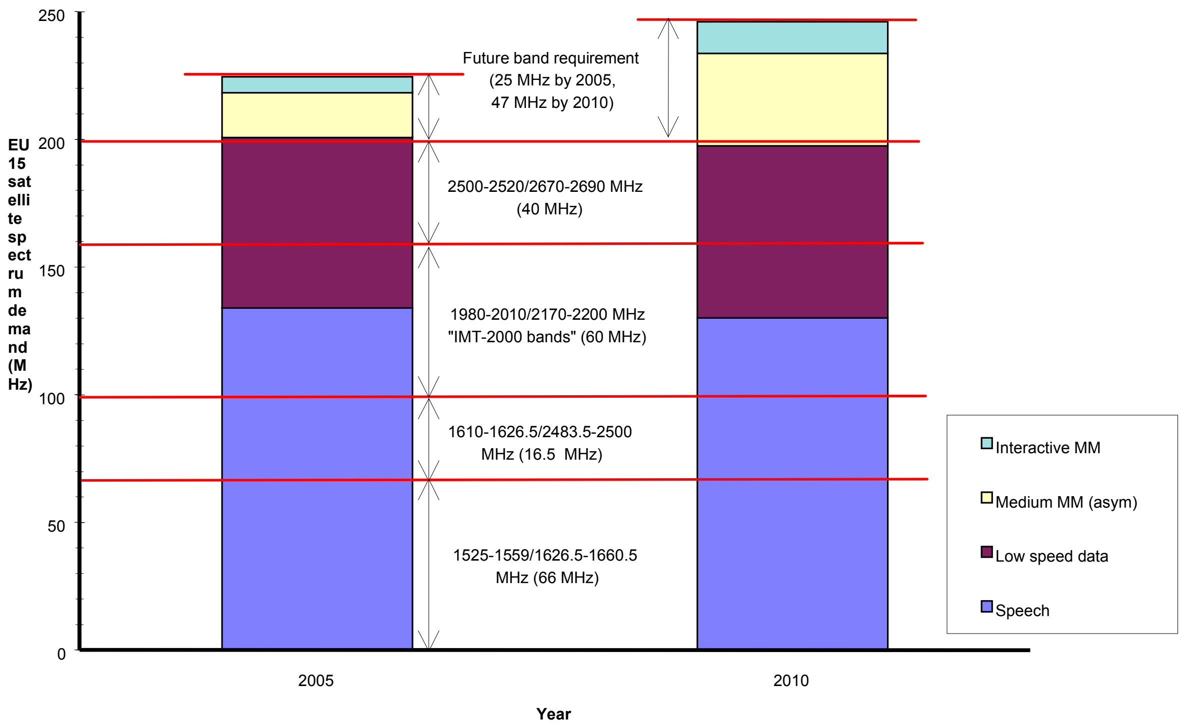


Figure 3.5: Satellite spectrum estimate for the years 2005/2010 in Europe (EU15)*

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* *Please note that this figure only compares the amount of MSS spectrum required to the amount available and does not indicate which services will be implemented in which frequency bands.*

3.4 Spectrum Plan

Spectrum is a limited and valuable resource that must be used in the most efficient way to satisfy the continuously increasing demand. The spectrum utilisation is different depending on region or country specific situation. Such factors as population density and economic development are very important considerations which may influence the overall spectrum demand including UMTS/IMT-2000 needs.

To enable UMTS/IMT-2000 services to be offered globally the Forum confirms that further spectrum should be identified by WRC-2000 on world-wide basis as extension bands 1 and on a regional or/and country specific basis as extension bands 2. These bands should be identified as relatively large blocks, contiguous, if possible, to the core band. The development of equipment that has to operate over fragmented parts of the spectrum might be more complex and expensive. It is of particular importance that the identification of additional bands for UMTS/IMT-2000 serves well the interest of the users world-wide.

The benefits of having frequencies harmonised are undeniable. World-wide harmonisation of extension bands 1 would be highly desirable as it would facilitate roaming and the successful development of a mass market but it will not always be feasible.

Figure 3.6 illustrates a concept that could provide a possible solution for a flexible spectrum designation for UMTS/IMT-2000.

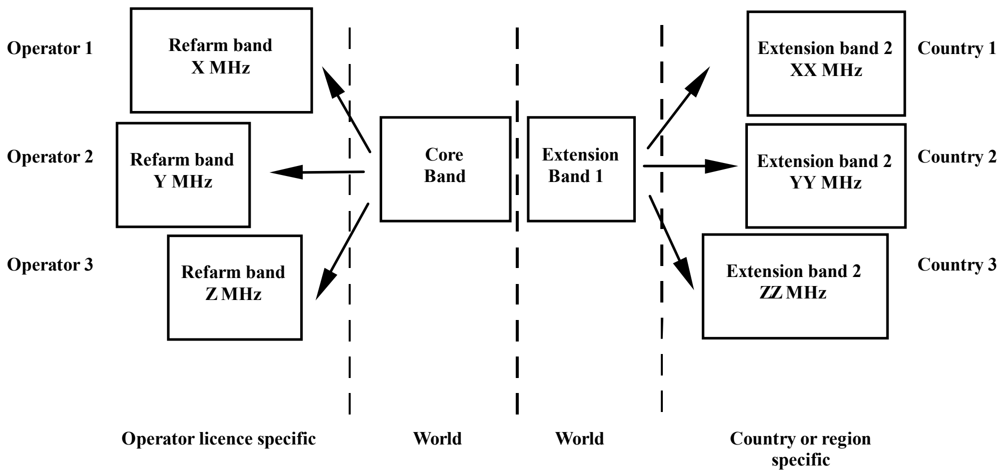

Figure 3.6: Spectrum vision

3.4.1 Core Band

The bands 1885-2025 MHz and 2110-2200 MHz were identified for IMT-2000 by WARC-92 and are now considered to be the core band where UMTS/IMT-2000 should initially be deployed, see figure 3.7. This identification of a world-wide core band gives all administrations wishing the implementation of UMTS/IMT-2000 the best opportunity for deployment of advanced mobile multimedia services on a world-wide basis.

At least part of the core band is expected to be available in most countries world-wide (in Europe the sub-band 1885 – 1900 MHz is not currently available for this purpose). However, the core band is really needed in its entirety around the year 2005 to satisfy the estimated IMT-2000 spectrum demand for full implementation of UMTS/IMT-2000 services globally. The timely availability of the core band in many countries will be a major encouragement to industry to invest time and resources to develop UMTS/IMT-2000 services, and ensure their global success.

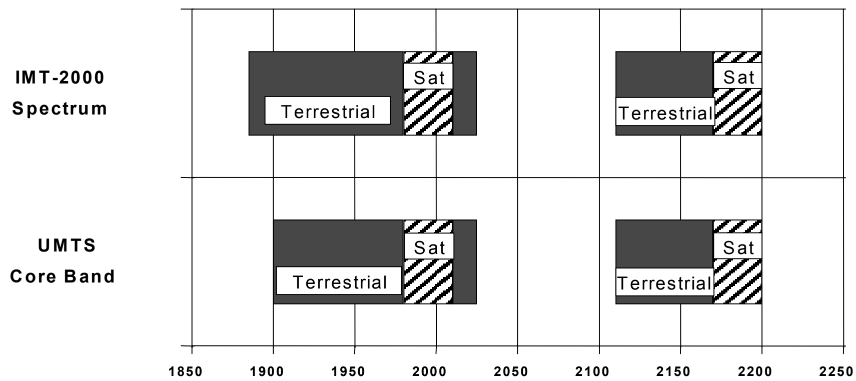

Figure 3.7: UMTS/IMT-2000 Core Band

The first development of UMTS/IMT-2000 will therefore occur in the core band. However, UMTS/IMT-2000 technology should be developed to operate in the core band and any extension bands identified by WRC-2000.

3.4.2 Extension Bands

The importance of having a sufficient spectrum allocation for a successful deployment of UMTS/IMT-2000 is widely recognised and the WRC-2000 is expected to allocate an additional spectrum for UMTS/IMT-2000. The operators' and manufacturers' decision to invest in UMTS/IMT-2000 will depend on initial and future spectrum availability i.e. sufficient amount of spectrum allocated in due time in the appropriate frequency bands.

Spectrum demand identified by UMTS Forum is far beyond the capacity of the core band. The initial WARC-92 designation of 230 MHz will only accommodate predicted traffic levels for the start up phase until about 2005. According to chapter 3.2.7 an additional spectrum of about 185 MHz is needed for the terrestrial UMTS by the year 2010 according to chapter 3.3.4 for the satellite component of UMTS/IMT-2000 the total spectrum demand by the year 2010 has been calculated to 2*66 MHz in global hot spots and 2*44 MHz in EU15. It is not possible to calculate the additional demand for the satellite component, since the bands identified for satellite UMTS/IMT-2000 may also be used by non-UMTS/IMT-2000 MSS systems.

The locations of the possible extension bands for IMT-2000 is the subject of current work. Such studies have been started within CEPT and ITU-R.

Extension Band 1

Extension bands 1 are essential and should be identified as a world-wide band for UMTS/IMT-2000. Propagation at higher frequency ranges, above 3 GHz, would make coverage and mobility more difficult and expensive to achieve. Furthermore equipment design is expected to be more complex at higher frequency bands.

Extension Band 2

Extension bands 2 may differ in frequency range and size on a regional and/or national basis. It will be preferable to allocate the extension band 2 in the frequency bands adjacent to core band or to extension bands 1. Harmonisation within regions will be desirable.

Candidate bands for Extension Band 1

Initial consideration in the UMTS Forum and work done by CEPT/ERC TG 1 (ITU-R/ TG8-1/151-E) has identified possible candidates for UMTS/IMT-2000 extension bands, which should preferably be harmonised on a world-wide basis. These candidates are summarised in Table 3.8.

Frequency bands	European Situation/ UMTS Forum Comments
470 – 862 MHz	This band is mainly used for analogue broadcasting. Replacement by digital television (with better spectrum efficiency) may offer the possibility of part of this spectrum being released for other services in the long term. If this is the case, the highest part of this band i.e. 806 – 862 MHz is of the greatest potential interest for UMTS because it is already allocated to mobile services in Region 2 and it is adjacent to GSM 900 band. Parts of this band are also used by other services (SAB/SAP[2)] and Tactical Relay).
2290 – 2300 MHz	This band is already allocated to mobile services on a co-primary basis. Studies to address protection of stations for deep space research have indicated that large separation distances are required around a very few stations in the world. Nevertheless the Forum sees some potential for this band to provide additional unpaired spectrum, possibly for indoor public or licence exempt applications.
2520 – 2670 MHz[1)]	The UMTS Forum considers this band to be an attractive option because it could contribute a significant proportion of the required additional spectrum. It could become available after phasing out of existing usage (fixed and ENG/OB[3)]). Geographical sharing (urban/rural) is one solution to facilitate the transition.
2700 – 2900 MHz	This band is still under consideration by ERC/TG 1.

1) The bands 2520 – 2535 / 2655 – 2670 MHz are allocated to the MSS on a global basis, limited to regional systems, and subject to agreement under the RR footnote S9.31. In Europe, ERC/TG1 has agreed to reserve these bands for the terrestrial component of IMT-2000. However it is envisaged that the bands may be used for the satellite component of IMT-2000 in other regions, where the demand for satellite services is higher than in Europe.

2) SAB = Service Ancilliary to Broadcasting ; SAP = Service Ancilliary to Program making

3) ENG = Electronic News Gathering ; OB = Outside broadcasting

Table 3.8: Candidate Bands for Extension Band 1.

Future Use of Bands Used by 2nd Generation Mobile Systems

Globally, any spectrum used for 2nd generation mobile systems can be seen as a natural resource for 3rd generation applications. Therefore, spectrum for 2nd generation systems might be migrated to UMTS/IMT-2000 in the longer term. For Europe, this spectrum is indicated in Table 3.9. This spectrum is already taken into account in the UMTS Forum calculations and its migration would not therefore reduce the additional spectrum requirements that have been identified.

Frequency bands	European Situation
880 – 915/925 – 960 MHz	This band is used for second generation mobile system (GSM 900). It could be refarmed progressively in the long term when GSM use decreases.
1710–1785/1805– 1880 MHz	This band is also used for second generation mobile system (GSM 1800). It could be refarmed progressively in the long term when GSM use decreases.
1880 – 1885 MHz	This band forms the lower part of the DECT band. It could be refarmed progressively in the long term when DECT use decreases.

Table 3.9 : Spectrum for 2nd Generation Systems which might be migrated to UMTS/IMT-2000 in the longer term for Europe.

Candidate Bands for the Satellite Component

As a first step towards satisfying the satellite spectrum requirements identified above, the Forum recommends that the currently allocated bands be made fully available for MSS use in a timely manner. Significant progress to this end has already been made in Europe with the adoption of ERC Decisions for the introduction of S-PCS and for transition of fixed services from the 2 GHz MSS bands. It is proposed that similar arrangements be considered for the 2500 - 2520 / 2670 - 2690 MHz MSS allocations. These bands are also possible candidates for extension bands 1 for the satellite component of IMT-2000.

Finding additional MSS spectrum in 1-3 GHz has proved to be very difficult. WRC-2000 are considering, under agenda item 1.9 (Resolutions 213 and 220), the possibility of global allocations in part of the band 1675-1710 MHz (uplink) and an associated downlink, either the band considered under Res. 220 or an alternative band. This could result in 2x8 MHz of spectrum - however, studies to date indicate that an allocation is unlikely.

Although at this time no additional candidate bands have been agreed, the UMTS Forum recommends that in the long-term planning of the 1-3 GHz spectrum, Administrations should seek to find additional MSS spectrum, keeping in mind the special needs of mobile services to operate in spectrum below 3 GHz, due to antenna technology limitations and propagation related advantages.

3.4.3 Refarming

The existing spectrum designated for 2nd generation mobile services may be refarmed and integrated into the UMTS/IMT-2000 allocation in the long term. It is expected that the need for refarming of the existing 2nd generation mobile bands will arise as a result of market forces. It is possible (or even likely) that the need for refarming will be recognised internationally.

It should be for each national Administration, in consultation with operators, to decide how and when to refarm all, or parts of, the 2nd generation bands. However, in some cases, Administrations may already have given individual licensees the right to refarm at a time of their choosing.

Refarming may need to take into consideration the duration of existing licences, the ongoing support of 2nd generation customers and co-existence with other operators.

3.4.4 Minimum Spectrum Demand for Public Operators

Based on certain assumptions and projected demand of 3rd generation services in Europe, the UMTS Forum report No. 5, Minimum spectrum demand per public terrestrial UMTS operator in the initial phase /6/, recommends 2 * 15 MHz (paired) plus 5 MHz (unpaired) as the preferred minimum spectrum requirement per public operator. However depending on country specific situations other spectrum assignments may be more appropriate. /6/ gives a full analysis of the range of spectrum options considered and for situations where unpaired spectrum is not available options to use the paired spectrum only are given.

The calculation methodology of /6/ includes the multi-operator scenario and takes account of a layered physical network architecture, which leads to a slightly different cell sizes compared to this report. However, the average cell sizes of the corresponding cell layer in the same environment in /6/ and this report are of the same magnitude. Some assumptions have also been made about how the existing 2nd generation networks and licence-exempt systems carry part of the expected traffic.

The UMTS/IMT-2000 operators may need to work with the initially assigned channels for a number of years beyond 2005. There is uncertainty as to when more spectrum will be available for UMTS/IMT-2000 and this has to be taken into account for the spectrum requirement per operator in such a way, that the operator gets an adequate spectrum for traffic demand until the additional spectrum will be available.

3.4.5 Spectrum for License-exempt Applications

There is a need to designate spectrum for non-public (license exempt) UMTS applications. This will be required from the beginning to help build the market for mobile multimedia terminals and to stimulate a demand for public UMTS access. The amount of spectrum and location will be further investigated by UMTS Forum.

3.5 Efficient Use of Spectrum

A significant element of the UMTS vision is the need to achieve a major improvement in the efficient use of spectrum compared to that already being achieved for 2nd generation mobile systems. Furthermore, IMT-2000 is required to support a wide range of traffic types including mobile multimedia. Current traffic and spectrum estimates range far to and beyond the year 2010. The characteristics of mobile multimedia services are not well known yet and may vary over such a long time period.

To cope with the above mentioned requirements and uncertainties it seems to be necessary that the standard must be designed so that all parameters are optimised in a balanced way, i.e. a good compromise has to be reached between short term and long term requirements as well as between technical factors like terminal costs, spectrum efficiency and the ability to coexist with other services.

The following issues have been identified as possibly affecting the above mentioned goals and will be studied in more detail by the Forum.

3.5.1 UMTS/IMT-2000 System Capabilities

The system capabilities are determined to a great extent by technical parameters from the standard and even more important by the relationship between all technical parameters in optimising the overall performance of the standard. Main influencing factors are:

- *radio transceiver technology*, including access technology, modulation and coding, adaptive interference management;
- *applications and services technology*, including the use of packet transmission, asymmetry management, compression techniques and agent technology;
- *radio channel access management*, i. e. the management of instantaneous access to the spectrum, to reduce the probability of idle channels during peak traffic hours.
- *traffic management*, especially via the use of delay management and tariffs to manage peak-to-mean traffic ratios.

Based on the available technical information the UMTS Forum has chosen, for the terrestrial calculations, a technical improvement factor of 1.25 for the year 2005 and 1.35 for the year 2010, see Annex 3.

3.5.2 Further Technical Improvements

The introduction of further technical improvements to the standard depends very much on the ability, flexibility and the build-in provisions to allow the later introduction of further improvements. Promising examples for such technical improvements are diversity techniques and smart antenna technology. These technological improvements are just emerging on the market and still in an early stage of development. The actual usefulness and the possible improvements that can be reached are therefore uncertain. However, in the current work of standardisation care has to be taken, that the standard admits that these improvements and enhancements can be introduced at a later stage.

Another improvement could possibly be reached by introducing a more flexible usage of TDD and FDD transmission. As for terrestrial wide-area, full mobility systems the use of paired bands and FDD (Frequency Division Duplex) transmission can be advantageous, while short-range, low mobility systems and TDD (Time Division Duplex) transmission in unpaired bands may be advantageous to handle asymmetric traffic. If further technical investigations show that TDD transmission can be combined with FDD-transmission in order to handle the asymmetric traffic in an optimised way this could improve the efficient use of spectrum significantly.

3.5.3 Spectrum Sharing

3.5.3.1 Spectrum Sharing with Other Services

The extension bands are currently used for other applications than UMTS/IMT-2000. The calculations developed in this report show that the totality of extension bands is needed in urban areas, but the need in rural areas might be less stringent, and sharing might be possible on a geographical basis. This could be a means of gaining access for UMTS/IMT-2000 to some bands in earlier stages. It should ,however, be noted that particular attention should be given to the sharing criteria, in order to avoid difficulties in the co-ordination process.

3.5.3.2 Sharing of Terrestrial UMTS/IMT-2000 Spectrum between Different Operators

It has been suggested that the sharing of a common pool of spectrum by operators might be a method to significantly improve spectrum efficiency and thereby minimising the overall demands for spectrum for UMTS/IMT-2000. Sharing the same spectrum between several operators could result in a higher trunking efficiency and savings in guard bands. However, these savings do not take into account the airtime overheads that arise during call set-up, clear-down, handover, etc. The problems associated with operator spectrum sharing are likely to be significant and could reduce competition between operators.

Furthermore, to build a business case, UMTS/IMT-2000 operators must be certain about the spectrum to which they have uninhibited access. Operators may be reluctant to invest in the spectrum if it is not certain that the additional channels would be available when needed. The commercial drivers may lead to unwanted network developments, such as increasing transmitter power levels, which will then decrease the spectrum efficiency.

One method of spectrum sharing is to allow users access to several or all of the operators in the same region. In this way, the users share the spectrum instead of the operators. While this method avoids some of the commercial problems of other sharing methods, some other technical and commercial problems remain. The user terminals have to ensure that the spectrum is efficiently utilised, which might increase the airtime overheads, and operators have to compete for users on a call-by-call basis. It is not yet clear if a stable market situation with investment incentives can be achieved in this situation.

3.5.3.3 Spectrum Sharing between Terrestrial UMTS and MSS

The co-channel sharing of spectrum between terrestrial and satellite UMTS/IMT-2000 networks does not seem to be currently feasible, due to the expected wide differences in received power flux density and transmitted power levels between the terminals operating in these systems. Therefore, it is currently necessary to make separate spectrum allocations for terrestrial and satellite UMTS/IMT-2000 networks */15/*.

It has also been determined that the additional attenuation afforded by building loss would be inadequate to allow sharing between indoor (non-public, license exempted) terminals and satellite UMTS. Further investigations in this field will be appreciated.

3.5.4 Duplex Direction

In ITU recommendation considering spectrum for IMT-2000 /14/ it is stated 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.

UMTS/IMT-2000 is required to support a wide range of traffic types including mobile multimedia. The characteristics of mobile multimedia services differ from speech service, because the demand for bandwidth varies over time for speed of transfer, length of transmission streams and symmetry of bi-directional transmission.

3.5.5 Global Radio Control Channel RCC

Several concepts are under discussion – physical versus logical control channel. A voluntary logical channel within all IMT-2000 public networks will avoid the need for any additional network or physical radio resources or spectrum.

The RCC logical channel is used to broadcast all necessary frequency (and other associated) information for all IMT-2000 countries/regions so that a user terminal may retain an up-to-date reference to facilitate its own roaming into other areas.
The information would be broadcast via a bulletin board type of logical channels (e.g. a channel named BBCH - bulletin board channel), with such broadcasts being made at suitable intervals during non-peak traffic to avoid adding to spectrum or traffic loads.

If, when a user is not in the home network, the terminal in its attempts to roam finds that it cannot readily identify a service channel, the terminal is able to request the user to indicate the country and/or region (if this is not automatically provided in the future by some positioning function). The terminal can then either speed its search to access the local networks (assuming it has the necessary functionality and band coverage) or alternatively, the terminal can simply indicate it is not equipped to operate in that area. Users would also be able to check before roaming if their terminal will be able to operate in the visited area.

The overriding objectives of this recommendation are to establish a preferred solution to the real roaming requirement and one which does not demand any significant cost or investment on the part of network operators, regulators, and terminal manufacturers.

4 Conclusions

This report summarises the UMTS Forum view about spectrum aspects related to UMTS/IMT-2000 including a detailed analysis of the spectrum demand for public mobile networks beyond year 2010. The main results of earlier UMTS Forum reports, especially /1/, /4/ and /6/ are repeated (and updated, if necessary) in this report in order to get a complete picture about the UMTS/IMT-2000 spectrum aspects.

The spectrum demand for terrestrial mobile services was calculated for 2nd and 3rd generation networks together because it was felt impossible to divide the traffic between different technologies. On the other hand the used approach may give a more reliable result and the situation varies in different countries in any case. It was clearly noted that the main reason for additional frequencies is the high bit rate multimedia services.

The total calculated spectrum requirement for terrestrial services in the year 2005 is 403 MHz and 582 MHz in the year 2010. The total calculated spectrum demand for satellite services in the global hot-spot is 2*123 MHz by the year 2005 and 2*144 MHz by the year 2010.

The 3rd generation frequency bands as identified by WARC-92 are sufficient for mobile multimedia services up to the year 2005. If all the 2nd and 3rd generation spectrum is made available for the operators, additional spectrum will be required between the years 2005 – 2010. The calculated additional spectrum demand is:

+187 MHz for terrestrial services in EU15
+ up to 60 MHz for satellite services depending on region

The Forum also estimated the minimum required spectrum per terrestrial UMTS operator in /6/. The preferred option is 2*15 MHz (paired) plus 5 MHz (unpaired) but some other options may be better in certain countries. It was noted, however, that the UMTS/IMT-2000 operators may need to work with the initially assigned channels for a number of years beyond 2005. There is uncertainty as to when more spectrum will be available for UMTS/IMT-2000 and this has to be taken into account for the spectrum requirement per operator in such a way, that the operator gets an adequate spectrum for traffic demand until the additional spectrum will be available.

Recommendations:

1. The frequency spectrum as identified for UMTS/IMT-2000 in the ITU Radio Regulations, both for terrestrial and satellite services, should be made available by the year 2002 according to market demand.

2. To meet the market forecast for the terrestrial mobile services a total spectrum amount of 582 MHz was calculated. Therefore, a minimum additional frequency spectrum of 187 MHz is required for terrestrial services in urban areas by the year 2010 in EU15 states. This additional spectrum includes the requirements of public networks and non-public (license exempt) applications.

3. To meet the UMTS market forecast for satellite services a total spectrum amount of 2*123 MHz by the year 2005 and 2*145 MHz by the year 2010 is needed with a lower requirement in Europe. Therefore, additional 2*8 MHz is required globally by the year 2005. In the year 2010 additional 2*30 MHz is required in global hot-spots with lower requirements in EU15.

4. There is a need to designate spectrum for non-public (license exempt) UMTS applications. This will be required from the beginning to help build the market for mobile multimedia terminals and to stimulate a demand for public UMTS access. The amount of spectrum and location will be further investigated by UMTS Forum.

5. The preferred minimum spectrum per operator as defined in /6/ is 2*15 MHz (paired) + 5 MHz (unpaired). Care should be taken that operators have enough spectrum if the additional spectrum is not available by the year 2005.

6. The UMTS Forum recommends to study further the flexible use of TDD and FDD techniques, with the aim of improving the efficient use of spectrum.

7. A logical radio control channel (RCC) is recommended as an appropriate solution for the purpose of multimode terminal operation and global roaming. Identification of a specific physical global radio control channel in the Radio Regulations is not recommended.

5 References

/1/ UMTS Forum Report No. 1 'A Regulatory Framework for UMTS', 25 June 1997

/2/ UMTSF Report No. 2: 'The Technical Vision', Sept. 1998

/3/ 'UMTS Market Forecast Study', Final Report for EC DG XIII, Analysis/Intercai Report Number 97043,12 February 1997

/4/ UMTSF Report No.3: 'Cost Impacts', Sept. 1998

/5/ UMTSF Report No. 4: 'Licensing Conditions for UMTS', Sept. 1998

/6/ UMTSF Report No. 5: 'Minimum Spectrum demand per public terrestrial UMTS operator in the initial phase', Sept. 1998

/7/ 'ERO Report on UMTS'. Sep 1996, European Radio Communications Office

/8/ ITU-R TG8/1 Contributions:

Doc 8-1/xx: Terrestrial Spectrum Requirement for IMT-2000, Source: Finland, endorsed by CEPT ERC TG1

Doc 8D/73-E and Attachment Doc 8-1/62: Report of the Satellite Spectrum Expert Meeting, Chairman Task Group 8/1, 28. April 1998

Doc 8-1/66-E: Spectrum Calculation for Terrestrial UMTS, Source: Finland, 21. April 1998

Doc 8-1/74-E: Text for Draft New Recommendation, ITU-R M. [IMT-SPEC] Spectrum Requirements for IMT-2000, Source: United States of America, 21. April 1998

/9/ ERC Decision CEPT/ERC/DEC/(97)07on the Introduction of UMTS

/10/ ETSI SMG "Consensus Decision on the UTRA concept to be defined by ETSI SMG2", Tdoc SMG 39/98, SMG #24bis, 28 – 29 January 1998

/11/ ERC Report 25: Frequency Range 29.7 MHz to 105 GHz and Associated European table of Frequency Allocations and Utilisations.

/12/ Doc. ERC TG1(98)59: Spectrum Calculation for Terrestrial IMT-2000/UMTS.

/13/ Draft new Rec. M.[IMT-MTER] - Methodology for the calculation of IMT-2000 terrestrial spectrum requirements.

/14/ Recommendation ITU-R M.1035: Framework for the radio interface(s) and radio sub-system functionality for International Mobile Telecommunications-2000 (IMT-2000)

/15/ Recommendation ITU-R M.1036: Spectrum considerations for implementation of International Mobile Telecommunications-2000 (IMT-2000) in the bands 1885-2025 MHz and 2110- 2200 MHz

/16/ CEC deliverable R2066/SESA/GA2/DS/P/030/b1, 'Result of traffic modelling for UMTS'

List of Annexes

Annex 1

Milestones for UMTS/IMT-2000, Work plan from SAG

1 October 1997	ERC Decision on UMTS Core band.
30 November 1997	IMT-2000 additional frequency spectrum demand put on the agenda of WRC 2000.
	Suggestions for UMTS regulatory framework from the EC.
First quarter 1998	ETSI freezing of basic UMTS parameters.
June 2000	WRC 2000 Identification of IMT-2000 Extension bands.
Year 2001	Pre-operational UMTS/IMT-2000 trials.
Year 2002	Availability of UMTS/IMT-2000 Core band.
	Commercial UMTS/IMT-2000 operation.
Years 2008 - 2010	Availability of UMTS/IMT-2000 Extension bands

Annex 2

Vocabulary of Terms

Accounting A function which apportions the revenue obtained by the service providers to network operators in line with commercial arrangements.

Adaptive terminal Terminal equipment with the capability of adapting to more than one type of network.

NOTE – Adapting to different networks could be accomplished by using a combination of techniques such as analogue-to-digital/digital-to-analogue conversion, multi-band antennas and/or software radio architectures.

Air interface The common boundary between the mobile station and the radio equipment in the network, defined by functional characteristics, common radio (physical) interconnection characteristics, and other characteristics, as appropriate.

NOTE – An interface standard specifies the bi-directional interconnection between both sides of the interface at once. The specification includes the type, quantity and function of the interconnecting means and the type, form and sequencing order of the signals to be interchanged by those means.

Air interface protocol The protocol used across the air interface (usually a collection of protocols supporting various layers of the protocol reference model).

Authentication The process of verifying the identity of a user, terminal, or service provider.

Base station (BS) The common name for all the radio equipment located at one and the same place used for serving one or several cells.

Base station area The area covered by all the cells served by a base station.

Bearer service A type of telecommunication service that provides the capability for the transmission of information between user-network interfaces.

Billing A function whereby charging information generated by the charging function is transformed into bills requiring payment. Billing also includes collecting payments from the subscribers.

Broadcasting service A service where the same message (voice, text, pictures, video or data) is transmitted simultaneously to all users within the radio coverage of the broadcasting transmitter(s) or to a group of several users via wire or cable.

Call The use, or possible use, of one or more connections set-up between two or more users and/or services.

Capability The ability of an item to meet a service demand of given quantitative characteristics under given internal conditions.

Cell The radio coverage area of a satellite spot beam or a base station, or of a subsystem (e.g. sector antenna) of that base station corresponding to a specific logical identification on the radio path, whichever is smaller.

NOTE – Every mobile station in a cell may be reached by the corresponding radio equipment. The radio coverage area of a satellite spot beam or a base station, or of a subsystem (e.g. sector antenna) of that base station corresponding to a specific logical identification on the radio path, whichever is smaller.

Charging A function, whereby information is gathered, recorded or transferred in order to make it possible to determine and to collate usage for which the subscriber may be billed.

Circuit transfer mode A transfer mode in which transmission and switching functions are achieved by permanent or quasi-permanent allocation of channels, bandwidth or codes between identified points of a connection. See also Packet transfer mode.

Compatibility A degree of transparency sufficient to support an acceptable grade of service with respect to a connection between system entities. Full compatibility implies full transparency.

Connectionless service A service which allows the transfer of information among users without the need for end-to-end call establishment procedures. Connectionless services may be used to support both interactive and distribution services.

Earth station A station located on the Earth's surface intended for communication with a satellite system.

Emergency service	A telecommunication service, which is used to access a public emergency centre, characterised by a locally significant access number, high priority, and distinctive feature interactions.
Encryption	A function used to transform data so as to hide its information content to prevent its unauthorised use.
ETSI	European Telecommunications Standards Institute. The body charged with developing the UMTS standard.
Evolution	A process of change and development of a mobile radio system towards enhanced capabilities.
Fixed network service	A service with a set of capabilities that allows service profile management but not any type of mobility.
FPLMTS / IMT-2000	Those systems that conform to the corresponding series of ITU Recommendations and Radio Regulations.
Freephone	A supplementary service which allows a subscriber to offer a call free of charge to a caller at the subscriber's expense for that call.
Full mobility	mobility for local and wide areas (vehicular and pedestrian)
Handover	The action of switching a call in progress from one cell to another (intercell) or between radio channels in the same cell (intracell) without interruption of the call.

NOTE – Handover is used to allow established calls to continue when mobile stations move from one cell to another (or as a method to minimise co-channel interference).

IMT- 2000	International Mobile Telecommunications-2000. A global standard for 3rd generation mobile telecommunications systems, promoting a high degree of commonality of design world-wide while incorporating a variety of systems. Previously known as FPLMTS.
Integration	The act or process or an instance of forming, co-ordinating, or blending into a functioning or unified whole.
Intelligent network (IN)	A telecommunication network based on an architecture that provides flexibility for facilitating the introduction of new capabilities and services, including those under customer control.
Interactive service	A service which provides the means for the bi-directional

exchange of information between users or between users and hosts.

NOTE – Interactive services are subdivided into three classes of services: conversational services, messaging services and retrieval services.

Interoperability The ability of multiple entities in different networks or systems to operate together without the need for additional conversion or mapping of states and protocols.

Interworking The means of supporting communications and interactions between entities in different networks or systems.

Location service A particular mobility service in which location information can be provided to authorised users or to relevant authorities in case of emergency calls or for vehicular traffic management.

Macro cells Cells with a large cell radius, typically several tens of km.

NOTES:
- The radius of a cell can be extended by the use of directional antennas.
- Macro cells are characterised by low-to-medium traffic density, support for moderate mobile station speeds and narrow band services.
- A typical macro cell may be situated in a rural or suburban environment, with moderate building blockage, and, depending on terrain, significant foliage blockage.

Mega (satellite) cells Cells which provide coverage to large areas and are particularly useful for remote areas with low traffic density. Due to their size, mega cells will provide coverage in many kinds of environment, from remote to urban, in areas without access to terrestrial telecommunications networks and in developing countries (even in urban areas) where this may be the only cell type available.

NOTE – Currently, satellites can only practically provide mega cell coverage (the term "satellite cell" is sometimes used interchangeably with mega cell); however, it may be possible in the future for satellites to provide macro cell coverage.

Messaging service An interactive service which offers user-to-user communication between individual users via storage units with store-and-forward, mailbox and/or message handling (e.g. information editing, processing and conversation) functions.

Micro cells Cells with low antenna sites, predominantly in urban areas, with a typical cell radius of up to 1 km.

NOTES:
- Micro cells are characterised by medium-to-high traffic density, low mobile station speeds and narrow band services.
- Blockage by man-made structures may be significant in a micro cell environment.

Migration	Movement of users and/or service delivery from existing telecommunication networks to new networks.
Mobile Satellite Service (MSS)	A radiocommunication service: - between mobile earth stations and one or more satellites, or between satellites used by this service; or - between mobile earth stations by means of one or more satellites. This service may also include feeder links necessary for its operation.
Mobile service	A service with a set of capabilities that allows some combination of terminal mobility and service profile management.
Mobile station (MS)	A station in the mobile service intended to be used while in motion or during halts at unspecified points.
Mobility	low speed (pedestrian) mobility
Mobility manager	A repository of information and its associated processes accessed by personal mobility management or terminal mobility management.

NOTE – A mobility manager is used for location management, terminal registration and personal registration. A mobility manager is a functional concept which may be implemented in different ways, for example, as a database or in a signalling transfer point.

Multi-band terminal	Terminal equipment with the capability of accessing services using different frequency bands.
Multimedia service	A service in which the interchanged information consists of more than one type (e.g. video, data, voice, graphics). Multimedia services have multivalued attributes which distinguish them from traditional telecommunication services such as voice or data. A multimedia service may involve multiple parties, multiple connections, the addition/deletion of resources and user's within a single communication session.
Multi-mode terminal	Terminal equipment with the capability of accessing

services using different radio interfaces and/or techniques.

Network A set of nodes and links that provides connections between two or more defined points to facilitate telecommunication between them.

Network architecture A network configuration which identifies and defines physical entities and physical interfaces between these physical entities.

Network operators A provider of network capabilities needed to support the services offered to subscribers.

Non-fixed access A terminal access to a network in which there is no set relationship between the terminal and the access interface. The access interface and the terminal each have their own separate "identifiers". The terminal may be moved from one access interface to another while maintaining its unique identity.

Packet transfer mode A transfer mode in which the transmission and switching functions are achieved by packet oriented techniques, so as to dynamically share network transmission and switching resources between a multiplicity of connections. See also Circuit transfer mode.

PCS system A collection of facilities which provide some combination of terminal mobility, personal mobility, and service profile management.

NOTE – The term facilities should be understood to include hardware, software, and network components, such as transmission, switching and signalling facilities, databases, etc.

Personal communications service (PCS) A service with a set of capabilities that allows some combination of terminal mobility, personal mobility, and service profile management.

NOTE – The acronym PCS should be taken to refer to personal communication services.

Personal mobility The ability of a user to access telecommunication services at any terminal on the basis of a personal telecommunication identifier, and the capability of the network to provide those services according to the user’s service profile.

NOTES:

– Personal mobility involves the network capability to locate the terminal

associated with the user for the purposes of addressing, routing, and charging of the user's calls.
– The word "access" is intended to convey the concepts of both originating and terminating services.
- Management of the service profile by the user is not part of personal mobility.

Pico cells Small cells with a typical cell radius of less than 100 m that are predominantly situated indoors.

NOTE – Pico cells are characterised by medium to high traffic density support for mobile low speed stations and wide band services.

Privacy The right of individuals to control or influence what information related to them may be collected and stored and by whom and to whom that information may be disclosed.

NOTE – National laws may apply in matters dealing with the protection of privacy.

Private service provider A service provider which offers services to a closed group of subscribers, i.e. not to the general public.

Public An attribute for services and networks accessible to everyone that wants to subscribe.

Public land mobile network (PLMN) A network established and operated by an administration or Recognised Operating Agency (ROA) for the specific purpose of providing land mobile telecommunication services to the public. A PLMN may be regarded as an extension of a fixed network (e.g. PSTN) or as an integral part of the PSTN.

NOTE – PLMN may comprise terrestrial cells or a combination of terrestrial and satellite cells.

Public network operator A provider of the network capabilities needed to support the services offered to the general public.

Public service provider A service provider which offers services to the general public.

Quality of service (QoS) The collective effect of service performances which determine the degree of satisfaction of a user of a service. It is characterised by the combined aspects of performance factors applicable to all services, such as:

– service operability performance;
– service accessibility performance;
– service retainability performance;
– service integrity performance; and

– other factors specific to each service.

Radio frequency (RF) channel A specified portion of the RF spectrum with a defined bandwidth and a carrier frequency and is capable of carrying information over the radio interface.
mission and reception of signals over the radio interface.

Radio resource A radio resource is a portion of spectrum available in a limited geographical area (cell). This portion of spectrum can be further divided into radio frequency channels.

Robustness The ability to withstand random errors, burst errors and high bit error ratios over the whole service area.

NOTES:
- Robustness of a system is an important attribute.
- The ranking of potential speech/channel codec combinations may be different under good and marginal conditions.

Roaming The ability of a user to access wireless telecommunication services in areas other than the one(s) where the user is subscribed.

Satellite network A satellite system and its co-operating earth stations.

Satellite system A space system using one or more artificial satellites.

Security The protection of information availability, integrity and confidentiality.

Service A set of functions offered to a user by an organisation.

Service profile A record containing information related to a user in order to provide that user with a defined set of services.

Service provider A person or another entity that has the overall responsibility for the provision of a service or a set of services to the users and for negotiating network capabilities associated with the service(s) he/she provides.

Subscriber A person or other entity that has a contractual relationship with a service provider on behalf of one or more users. (A subscriber is responsible for the payment of charges due to that service provider.)

System A regularly interacting or interdependent group of items forming a unified whole technology.

System integrity	The property (in the context of security) that data and the methods of handling the data cannot be altered or destroyed in an unauthorised manner.
Telephone service	A public telecommunication service primarily intended for the exchange of information in the form of speech, whereby users can communicate directly and temporarily between themselves in conversational mode, and should be provided in accordance with the International Telecommunication Regulations, and the relevant ITU-T Recommendations. Sometimes referred to as POTS.

NOTE – The telephone service can also support a number of non-voice services such as facsimile and data transmission.

Terminal	The equipment which interfaces the end user with a network.
Terminal equipment	A device or functionality which provides the capabilities for user applications, e.g. telephony, including the user interface.
Terminal mobility	The ability of a terminal to access telecommunications services from different locations and while in motion, and the capability of the network to identify and locate that terminal or the associated user.

NOTE – This ability implies the availability of telecommunication services, ideally, in all areas and at all times. Terminal mobility may be provided according to the mobile terminal’s or the user’s service profile.

Terminal roaming	The movement of a terminal (associated with at least one user) from one cell, location area, area served by one visitor location database, exchange area, sub network or network to another, respectively, while the network keeps track of the terminal's location.
Universal mobile telecommunications system (UMTS)	Future multi-function mobile system with wideband multimedia capabilities as well as present narrowband capabilities. UMTS is the planned European member of the ITU IMT-2000 family concept. UMTS will probably consist of a family of interworking networks, delivering the same new and innovative personal communication services to users regardless of used networks.
UMTS Access network	Future multi-function mobile access network with wideband multimedia capabilities (presently under standardisation within ETSI) that will interface with several different core networks.

UMTS services	A set of services accessible through the UMTS access network. UMTS services will probably be limited to services that require transmission speeds less than 2 Mbit/s.
Universal personal telecommunications (UPT) service	A service which provides personal mobility and service profile management.

NOTE – This involves the network capability of uniquely identifying a UPT user by means of a UPT number.

User	A person or other entity authorised by a subscriber to use some or all of the services subscribed to by that subscriber.
Value added service provider	A service provider which offers services that add value to other (primitive) services. (A value added service cannot be used alone, i.e. with another primitive service.)
Wireless access	A terminal access to the network which uses wireless technology.
Wireless terminal	A general term used for any mobile station, mobile terminal, personal station or personal terminal, with which non-fixed access to the network is used.
Wireline access	A terminal access to the network which uses wireline technology.

NOTE - For example conventional telephone sets and subscriber lines are means of access to the wireline network.

Annex 3

Spectrum Calculations for Terrestrial Mobile Services

A3 1. Introduction

The methodology and parameters for spectrum calculations in this Annex are done by the UMTS Forum Spectrum Aspects Group (SAG) in conjunction with the Market Aspects Group (MAG).

A3 1.1 Purpose of This Annex

This Annex describes in detail the method of estimating the amount of spectrum required for the terrestrial mobile services. All figures needed to repeat the calculations are presented and the process used is explained.

A3 1.2 How to read this Annex

This Annex starts with an introduction in section 1 and an overview of the method used in section 2. This is followed in section 3 by a detailed calculation of the total amount of data (OBQ = Offered Bit Quantity) to be transferred across the UMTS Air Interface. This section includes all figures in the various environments necessary to repeat the OBQ calculation. In section 4, the required frequency spectrum is calculated, and in section 5 some conclusions are drawn. Section 6 contains the references. In the Appendix the capacity of a GSM system is calculated.

A3 1.3 Market figures

In the market analysis made by the UMTS Forum in the year 1997 for future terrestrial high density mobile services the total number of mobile users was estimated for various market scenarios. No split was made between 2nd and 3rd generation services nor between public and private markets. The spectrum calculations done by the Spectrum Aspects Group (SAG) are based on this market analysis. Thus the spectrum estimates in this document are consistent with the market forecasts. To make these calculations possible, additional effort was spent to get the amount of data (offered bit quantity) for the service classes, which were identified in the market analysis as being relevant for UMTS. The data inside this Annex may be used for further considerations on e.g.

- how much spectrum is needed for 2nd generation mobile systems (e.g. mainly speech, low rate data, GPRS)
- how much spectrum is needed for 3rd generation mobile systems (multimedia)
- how much spectrum is needed for unlicensed use (all services)
- partitioning of spectrum to cover traffic asymmetries
- how to use unpaired and paired frequency bands in a complementary arrangement

The list is probably not complete, but it indicates that some further work will be necessary to enable the regulator and operator to allocate spectrum in the most efficient way.

A3 2. Overview

The calculations used to estimate the frequency requirements are straightforward. Basically, for each UMTS service, the offered bit quantity (OBQ) during the busy hour for a given area is calculated based on certain assumptions. OBQ is the total throughput of bits per km^2 in the busy hour.

The OBQ is then compared to the system capability of a reference system, which in this case is a GSM system. By comparing OBQ and GSM system capability it is possible to estimate how much bandwidth is needed to support the UMTS traffic. Corrections are made for estimates of the likely improvement in spectral efficiency of UMTS over GSM due to technological improvements.

A3 2.1 Market sectors considered in the calculations

The market for UMTS comprises a wide area of applications (examples are shown in appendix 2). These are converted into six main service classes for this analysis. These are as follows /9/:

Speech (S): (symmetric)
- Simple one to one and one to many voice (teleconferencing) services
- Voicemail

Simple Messaging (SM): (asymmetric)
- SMS (short message delivery) and paging
- Email delivery
- Broadcast and public information messaging
- Ordering/payment (for simple electronic commerce)

Switched Data (SD): (symmetric)
- Low speed dial-up LAN access
- Internet/Intranet access
- Fax

Legacy services - mainly using radio modems such as PCMCIA cards, are not expected to be very significant by 2005.

Medium Multimedia (MMM): Asymmetric services which tend to be ‘bursty’ in nature, require moderate data rates, and are characterised by a typical file size of

(asymmetric)

0.5 Mbytes, with a tolerance to a range of delays. They are classed as packet switched services.

- LAN and Intranet/Internet access
- application sharing (collaborative working)
- interactive games
- lottery and betting services
- sophisticated broadcast and public information messaging
- simple online shopping and banking (electronic commerce) services

High Multimedia (HMM): (asymmetric)

Asymmetric services which also tend to be 'bursty' in nature, require high bit rates. These are characterised by a typical file size of 10 Mbytes, with a tolerance to a range of delays. They are classed as packet switched services.
Applications include:

- fast LAN and Intranet/Internet access
- video clips on demand
- audio clips on demand
- online shopping

High Interactive Multimedia (HIMM): (symmetric)

Symmetric services which require reasonably continuous and high-speed data rates with a minimum of delay.
Applications include:

- video telephony and video conferencing
- collaborative working and telepresence

The first three services are seen as logical extensions of 2nd generation mobile market and the last three are addressing the new mobile multimedia market.

The bit rates, asymmetry factors and the switching modes (circuit / packet switched) of the six service classes are derived from the market analysis /9/ in Table A3.A:

		Bit rate	**Asymm. Factor**	**Switch Mode**
HIMM	High Interactive Multimedia	128 kbps	1/1	circuit
HMM	High Multimedia	2000	0,005/1	packet
MMM	Medium Multimedia	384	0,026/1	packet
SD	Switched Data	14	1/1	circuit
SM	Simple Messaging	14	1/1	packet
S	Speech	16	1/1	circuit

Table A3.A: Some Service Characteristics.

A3 2.2. Offered Bit Quantity (OBQ) Assumptions and Calculation

This chapter describes the calculation of OBQ with the help of Figure A3.B. OBQ is based on the *population density* in the EU 15 countries. The *population density* is divided into three environments: urban, suburban and rural.

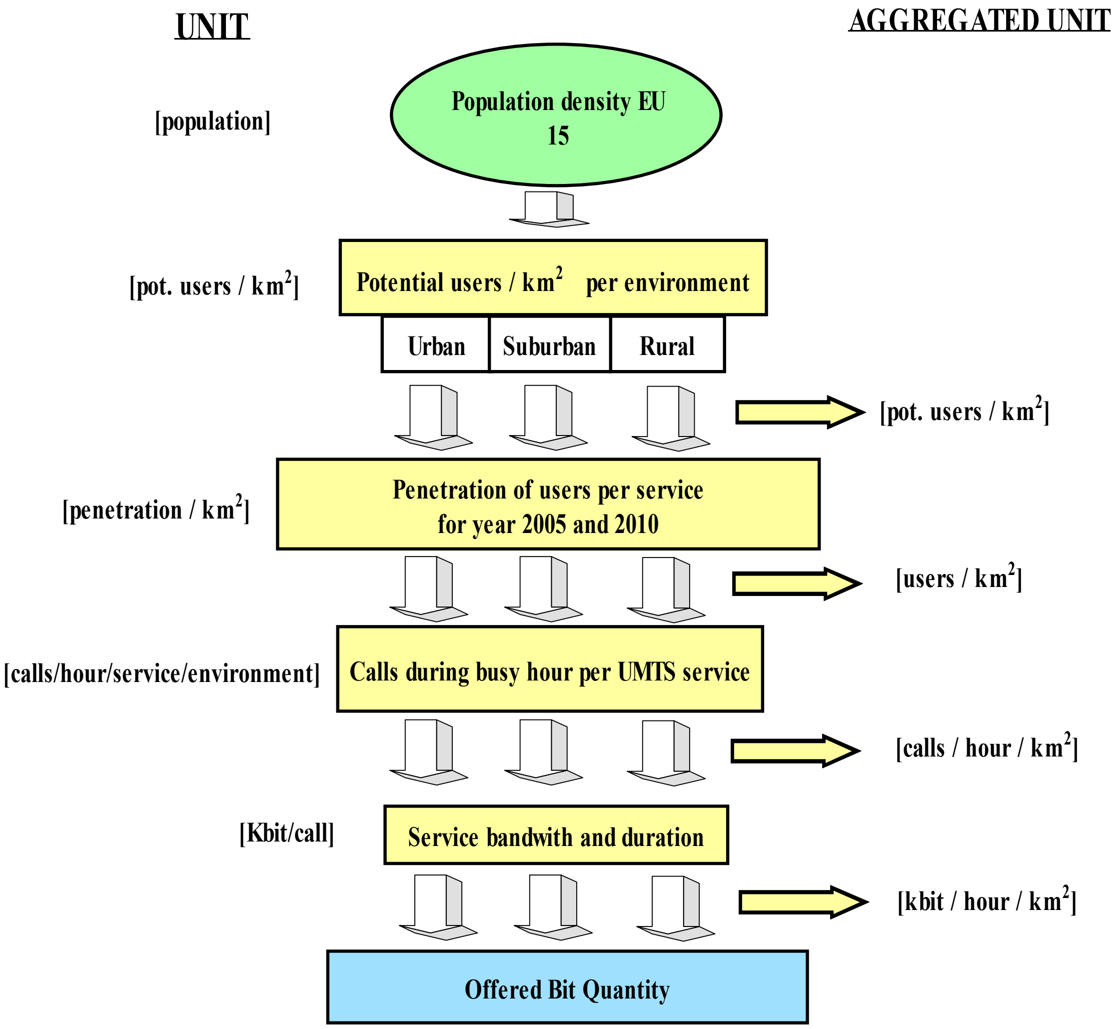

Figure A3.A: How to Calculate the Offered Bit Quantity (OBQ).

The *potential users per km²* (see Table A3:B for more details) is estimated for each environment. Then the *penetration rate of users per service* (Tables A3.D and A3.E) is multiplied with the *potential number of users per km²* which gives the *actual number of users per service per km²*.

The users will not use the service all the time and therefore we have to define *busy hour call attempts* (Tables A3.G and A3.H). This means that we look at the busiest hour of the day and estimate the average number of calls per user in that hour. Therefore the *busy hour call attempts* is multiplied with the *actual number of users per service per km²*, which gives the equivalent number of *active users during the busy hour* for one km².

The throughput or *service bandwidth* (Table A3.I) in kb/s is multiplied by the *active users during the busy hour* and the *effective call duration* (the duration of the call, see Table **A3.**able A3.E), which gives the o*ffered bit quantity OBQ* (Tables A3.J, A3.K and A3.M) during the busy hour. This is also explained by equation (A3.1)

OBQ = busy hour call attempts × penetration× (pot. users/km²)× service bandwidth× effective call duration (A3.1)

where pot. users/km^2 is potential users/km^2.

A3 2.3. Translation of OBQ into Spectrum Requirements

This chapter describes the calculation of the required bandwidth based on the calculated OBQ, see Figure A3.B.

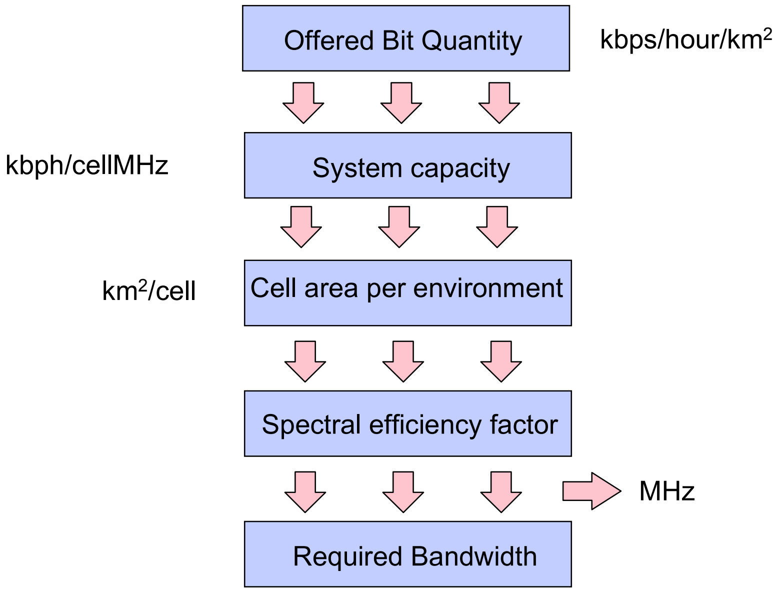

Figure A3.B: How to Calculate Spectrum Requirements.

The OBQ will have a unit of *kbit/busy hour/km²*

This quantity is then divided by the capability figure of the radio interface for one hour according to the A3 Appendix 1. With this capability figure of 339 kbit/hour/cell/MHz we get a *offered versus carried figure (OCF)*. By doing a unit analysis OCF will get the following unit:

$$\frac{kbit \,/\, busy\ hour \,/\, km^2}{kbit \,/\, hour \,/\, cell \,/\, MHz} = \frac{kbit \,/\, (busy\ hour \times km^2)}{kbit \,/\, (hour \times cell \times MHz)} = \frac{cell \times MHz}{km^2}$$

where $cell/km^2$ corresponds to the number of cells in a square kilometre and *MHz* to the bandwidth. If, for example, the OCF is equal to one (1) then a system with one cell every square kilometre and a bandwidth of one (1) MHz is enough to handle the traffic. A system with two cells every square kilometre and a bandwidth of 0.5 MHz would also be able to handle the traffic since 2 $cell/km^2 \times 0.5\ MHz = 1\ cell{\times}MHz/km^2$. This leads to the following equation

$$OCF = cells/km^2 \times required\,bandwidth\,/\,cell \qquad (A3.2)$$

The unit of *OCF* is $\frac{cell}{km^2} \times MHz$.

But

$$cell\,/\,km^2 = \frac{1}{cell\,area\,in\,km^2} \qquad (A3.3)$$

and therefore equation (A3.2) can be written as

$$required\,bandwidth = OCF \times cell\,area\,in\,km^2 \qquad (A3.4)$$

A *spectral efficiency factor* is then included to make allowances for the improved system capability. The spectral efficiency factor is the improvement of the system capability in relation to the GSM system capability figure given in A3 Appendix 1
(339 kbit/hour/cell/MHz).

$$required\,bandwidth = \frac{OCF \times cell\,area\,in\,km^2}{spectral\,efficiency\,factor} \qquad (A3.5)$$

The equation (A3.5) is the final equation used to calculate the required bandwidth (see Tables A3.S, A3.T, A3.U and A3.V).

A3 3. Calculation of the Required Information Capacity, Equal to OBQ

A3 3.1. Operating Environments and Equivalent User Densities

As OBQ is calculated per unit area, the area of the cell needs to be considered. Equation (A3.5) shows the relationship between cell radius, number of sectors and unit area. Table A3.B shows the operating environments, corresponding estimation of potential users per land area and cell type. Table A3.C shows cell dimensions as they are sectors per a base, cell radius and sectored hexagon cell area. The sectored hexagon cell area is calculated according to

$$Area = \frac{3}{2}\sqrt{3}\,R^2/S \qquad (A3.6)$$

where R is the cell radius and S is the number of sectors per a base. A simplified model for the hexagonal cell is used instead of a three sector model in which each sector is a hexagon. This is shown in Figure A3.C.

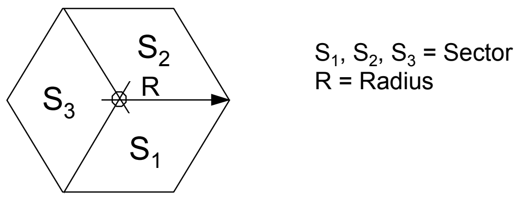

Figure A3.C: Simplified Sector Cells.

Operational environments	Density of potential users/km2	Cell Type
1.) CBD/Urban(in building)	180 000	Micro/pico
2.) Suburban (in building or on street)	7 200	Macro
3.) Home (in building)	380	Pico
4.) Urban (pedestrian)	108 000	Macro/micro
5.) Urban (vehicular)	2 780	Macro/micro
6.) Rural in- & out-door	36	Macro

Table A3.B: Density of Users per Operating Environment and the Corresponding Cell Types

It should be noted that the model assumes that no user occupies two operational environments at the same time. Additional operating environments such as aeronautical (telecommunication to subscribers who are passengers on board a moving aircraft), vehicles with mobile base stations (telecommunications to pedestrian subscribers in a bus or a train) and all satellite environments, are left out in this estimation.

It is assumed that services are deployed, at least initially, on a platform based on the existing DECT and GSM systems. The system capability of UMTS will be higher than for GSM, but it is also dependent on service bit rates / classes and low / high mobility use.

Operational environments	Sectors per base	Cell radius (km) [2005]	Sectored Hexagon Cell Area (km2) [2005]	Cell radius (km) [2010]	Sectored Hexagon Cell Area (km2) [2010]
1.) CBD/Urban(in building)	3	0.075	0.005	0.075	0.005
2.) Suburban (in building or on street)	3	3	7.79	2.0	3.46
3.) Home (in building)	1	0.02	0.001	0.02	0.001
4.) Urban (pedestrian)	3	0.7	0.424	0.6	0.312
5.) Urban (vehicular)	3	0.7	0.424	0.6	0.312
6.) Rural in- & out-door	3	8	55.43	8	55.4

Table A3.C: Cell Dimensions per Operating Environment

For the frequency requirement estimations, only three operational environments contribute, namely those which coexist in the highest traffic area:

- Central Business District (CBD)/Urban(in building)
- Urban (pedestrian)
- Urban (vehicular)

By 2010 the cell radii are on the minimum limit, and further reductions may not be economically feasible. However, system capability improvement is expected to satisfy further capacity requirements.

A3 3.2 Services and Penetration

The penetration figures in the following tables for year 2005 (Table A3.D) and year 2010 (Table A3.E) are presented for each service in each operating environment. These figures are based on extensive market research within Europe /9/ and represent the fraction of the density of potential users given in Table A3.B.

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	0.01	0.005	0.005	0.005	0.005	0.005
High MM	0.05	0.047	0.047	0.047	0.047	0.047
Medium MM	0.08	0.047	0.047	0.077	0.077	0.047
Switched Data	0.10	0.10	0.10	0.10	0.10	0.10
Simple Messaging	0.25	0.25	0.25	0.25	0.25	0.25
Speech	0.60	0.60	0.60	0.60	0.60	0.60

Table A3.D: Penetration Rate per Operating Environment and Service, 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	0.050	0.053	0.053	0.053	0.053	0.053
High MM	0.180	0.180	0.180	0.180	0.180	0.180

Medium MM	0.180	0.180	0.180	0.180	0.180	0.180
Switched Data	0.100	0.100	0.100	0.100	0.100	0.100
Simple Messaging	0.400	0.400	0.400	0.400	0.400	0.400
Speech	0.750	0.750	0.750	0.750	0.750	0.750

Table A3.E: Penetration Rate per Operating Environment and Service, Year 2010

It should be noted that the use of each service is not exclusive. Each penetration figure refers to the penetration of this service as a proportion of the total potential user base. Since users can use more than one service it is possible for the *total* penetration in an environment (across all services) to exceed one (100%) if a high proportion of users are using more than one service.

The CBD (Central Business District) environment is assumed to be the only environment with offices. This means that the penetration in CBD area comes primarily from people in those offices.

A3 3.3 Effective Call Duration and Busy Hour Call Attempts (BHCA)

UMTS will provide both packet switched and circuit switched services. Therefore a calculation model for spectrum estimates that deals with a detailed consideration of the different transmission schemes becomes difficult and requires a number of assumptions to be made relating to traffic characteristics, as well as the UMTS air interface. In light of the uncertainties associated with the radio interface and the detailed multimedia traffic characteristics, the following assumptions for packet type traffic were used:

1. The end user initialises a session and sets up a virtual connection with the server or vice versa. The session time is not considered in the calculations of spectrum demand, as long as no data are transferred.
2. Services like High/Medium Multimedia have bursty traffic characteristics. If data in bursts are transferred during the session over the radio interface, a “call duration” is defined reflecting the *active* data transfer time.

The following considerations include the UMTS services as analysed by the market study of the UMTS Forum /9/.

The effective call duration per service according to occupancy and average call duration is given in Table A3.F.

Services	Occupancy	Average call duration [s]	Effective call duration[s]
High Interactive MM	0.8	180	144
High MM	1	53.3	53.3
Medium MM	1	13.9	13.9
Switched Data	1	156	156
Simple Messaging	1	30	30
Speech	0.5	120	60

Table A3.F: Effective Call Duration, Applicable to Both the Years 2005 and 2010

The occupancy indicates if and how much, on average, the activity of the service will vary. This is highlighted by the discontinuous transmission for a speech service.

The call duration of a service corresponds to how long, on average, the service is connected.

The call duration and the occupancy are not suitable to characterise packet switched services. However, an estimation of effective call duration and finally the equivalent offered bit quantity the packet services will generate, could be based on calculations that consider the busy hour calls and an acceptable throughput and delay for the packet services. The effective call duration for the packet based services should be interpreted as the acceptable delay. See also service bandwidth for further estimations.

The busy hour call attempts (BHCA) for each service in each operating environment are estimated as below (Table A3.3.G for year 2005 and Table A3.H for year 2010).

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	0,12	0,06	0,06	0,06	0,004	0,004
High MM	0,12	0,06	0,06	0,06	0,004	0,004
Medium MM	0,12	0,06	0,06	0,06	0,004	0,004
Switched Data	0,06	0,03	0,03	0,03	0,002	0,002
Simple Messaging	0,06	0,03	0,03	0,03	0,002	0,002
Speech	1	0,13	0,13	0,6	0,6	0,5

Table A3.G: Busy Hour Call Attempts 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	0,24	0,12	0,12	0,12	0,008	0,008
High MM	0,12	0,12	0,12	0,06	0,008	0,008
Medium MM	0,12	0,12	0,12	0,06	0,008	0,008
Switched Data	0,06	0,03	0,03	0,03	0,002	0,002
Simple Messaging	0,06	0,03	0,03	0,03	0,002	0,002
Speech	1	0,13	0,13	0,85	0,85	0,5

Table A3.H: Busy Hour Call Attempts for the Year 2010

A3 3.4 Service Bandwidth

The service bandwidth according to throughput, coding factor and symmetry is given in Table A3.I. In addition the blocking factor for circuit switched services is defined. The blocking factor is relevant for all environments except for the home environment.

Services	Throughput [kbps]	Coding factor	UL factor	DL factor	UL Service bandwidth [kbps]	DL Service bandwidth [kbps]	Blocking factor
High Interactive MM	128	2	1	1	256	256	0,02
High MM	2000	2	0.005	1	20	4000	-
Medium MM	384	2	0.026	1	20	768	-
Switched Data	14	3	1	1	43	43	0,02
Simple Messaging	14	2	1	1	28	28	-
Speech	16	1.75	1	1	28	28	0,02

Table A3.I: Service Bandwidth, for the Years 2005 and 2010.

The throughput corresponds to the output bit rate from the source without any kind of error protection.

The coding factor is a generalised measure of the degree of coding required to transport the service to the required quality. This is separate from the signalling requirements.

High and medium multimedia and simple messaging services correspond to packet based services such as WWW. It is assumed that these services will have a different service bandwidth in the uplink (UL) and downlink (DL) except for simple messaging.

A3 3.5 Offered Bit Quantity (OBQ) During the Busy Hour

The formula to get OBQ for each service in the different operation environments during the busy hour is given by equation (A3.1)

It is necessary to calculate one OBQ for downlink and one for uplink due to the service bandwidth differences in uplink and downlink for high and medium multimedia.

This section presents an example of how to calculate OBQ for years 2005 and 2010.

The tables below show the uplink and downlink OBQ per km^2 for the operating environments and services for the years 2005 and 2010.

At this point an overhead, covering such as signalling and packet retries, is added to OBQ.

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	9.56×10^{6}	1.02×10^{5}	5.37×10^{3}	1.53×10^{6}	2.62×10^{3}	3.34×10^{1}
High MM	1.38×10^{6}	2.62×10^{4}	1.38×10^{3}	3.93×10^{5}	6.75×10^{2}	8.62
Medium MM	5.75×10^{5}	6.82×10^{3}	3.60×10^{2}	1.67×10^{5}	2.86×10^{2}	2.24
Switched Data	8.73×10^{6}	1.75×10^{5}	9.22×10^{3}	2.62×10^{6}	4.50×10^{3}	5.74×10^{1}
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	2.18×10^{8}	1.13×10^{6}	5.98×10^{4}	7.84×10^{7}	2.02×10^{6}	2.15×10^{4}

Table A3.J: OBQ for All Operating Environments and Services *(kbit/h/km^2)*, Uplink and with 20% Overhead. 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	9.56×10^{6}	1.02×10^{5}	5.37×10^{3}	1.53×10^{6}	2.62×10^{3}	3.34×10^{1}
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	8.73×10^{6}	1.75×10^{5}	9.22×10^{3}	2.62×10^{6}	4.50×10^{3}	5.74×10^{1}
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	2.18×10^{8}	1.13×10^{6}	5.98×10^{4}	7.84×10^{7}	2.02×10^{6}	2.15×10^{4}

Table A3.K: OBQ for All Operating Environments and Services *(kbit/h/km^2)*, Downlink and with 20% Overhead. 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	9.56×10^{7}	2.03×10^{6}	1.07×10^{5}	3.05×10^{7}	5.24×10^{4}	6.69×10^{2}
High MM	4.98×10^{6}	1.99×10^{5}	1.05×10^{4}	1.49×10^{6}	5.12×10^{3}	6.54×10^{1}
Medium MM	1.31×10^{6}	5.26×10^{4}	2.27×10^{3}	3.94×10^{5}	1.35×10^{3}	1.73×10^{1}
Switched Data	8.73×10^{6}	1.75×10^{5}	9.22×10^{3}	2.62×10^{6}	4.50×10^{3}	5.74×10^{1}
Simple Messaging	4.42×10^{6}	8.85×10^{4}	4.67×10^{3}	1.33×10^{6}	2.28×10^{3}	2.91×10^{1}
Speech	2.72×10^{8}	1.42×10^{6}	7.47×10^{4}	1.39×10^{8}	3.57×10^{6}	2.68×10^{4}

Table A3.L: OBQ for All Operating Environments and Services *(kbit/h/km^2)* Uplink and with 20% Overhead. Year 2010.

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	9.56×10^{7}	2.03×10^{6}	1.07×10^{5}	3.05×10^{7}	5.24×10^{4}	6.69×10^{2}
High MM	9.95×10^{8}	3.98×10^{7}	2.10×10^{6}	2.99×10^{8}	1.02×10^{6}	1.31×10^{4}
Medium MM	4.98×10^{7}	1.99×10^{6}	1.05×10^{5}	1.49×10^{7}	5.12×10^{4}	6.54×10^{2}
Switched Data	8.73×10^{6}	1.75×10^{5}	9.22×10^{3}	2.62×10^{6}	4.50×10^{3}	5.74×10^{1}
Simple Messaging	4.42×10^{6}	8.85×10^{4}	4.67×10^{3}	1.33×10^{6}	2.28×10^{3}	2.91×10^{1}
Speech	2.72×10^{8}	1.42×10^{6}	7.47×10^{4}	1.39×10^{8}	3.57×10^{6}	2.68×10^{4}

Table A3.M: OBQ for All Operating Environments and Services *(kbit/h/km^2)*, Downlink and with 20% Overhead. Year 2010.

A3 3.6 Adjustment for Blocking on Circuit Switched Services

A method has been devised to allow for the impact of blocking in *circuit switched services* (i.e. high interactive MM, switched data and speech). By increasing the number of resources necessary to carry the traffic with the required blocking factor an adjusted OBQ can be calculated. This allows the OBQ of every service/environment to be considered in a consistent manner in regard to their spectrum requirements.

The increased amount of resources to prevent blocking is calculated according to the Erlang B formula. The use of the Erlang B formula has been adopted for the time being, because there is no more precise method available for the estimation of blocking effects on multimedia services. However, of the three circuit switched services mentioned, speech has the dominant impact on total spectrum requirements. The Erlang B formula is valid for the speech services and thus the spectrum requirement for circuit switched services will be reasonably accurate.

The average impact of the use of the Erlang B formula on the spectrum for speech services is about 5 to 10 percent. The Erlang B corrections for switched data and interactive multimedia services are higher but they do not significantly influence the total spectrum requirement.

In applying the Erlang B formula, we have to transform OBQ into Erlang/cell. OBQ is the offered bit quantity during one hour from an area of one square kilometre. By dividing the OBQ with 3600 seconds we get the OBQ during one second from an area of one square kilometre. Further on, we multiply the OBQ with the cell area and get OBQ in one cell during one second. Finally we divide the OBQ with the service bandwidth (resource bit rate) and get Erlang/cell.

To get the *number of resources necessary* to carry the traffic at the required 2 % blocking factor (see Table A3.I) the following procedure may be used:

1 Set number of resources = 0
2 Increase number of resources by one

3 Calculate blocking = Erlang B(Erlang/cell, number of resources)
4 Compare blocking with *required blocking factor*. If blocking is greater than *required blocking factor* then go to 2, else go to 5
5 *number of resources necessary* = number of resources

The home (in building) environment is a special case, within which one user per a home cell is assumed. The use of the Erlang B formula is not relevant in this case as there will be no blocking and the values from the Tables A3.J, A3.K, A3.L and A3.M for this special case remain unchanged.

OBQ after the circuit switched services have been adjusted for blocking according to Erlang B formula is shown in Tables A3.N and A3.O for the year 2005 and in Tables A3.P and A3.Q for the year 2010.

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	1.38×10^6	2.62×10^4	1.38×10^3	3.93×10^5	6.75×10^2	8.62
Medium MM	5.75×10^5	6.82×10^3	3.60×10^2	1.67×10^5	2.86×10^2	2.24
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

Table A3.N: OBQ UL *(kbit/h/km^2)* after Adjustment for Blocking, 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

Table A3.O: OBQ DL *(kbit/h/km^2)* after Adjustment for Blocking, 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	5.68×10^{8}	3.72×10^{6}	1.07×10^{5}	5.03×10^{7}	2.96×10^{6}	3.33×10^{4}
High MM	4.98×10^{6}	1.99×10^{5}	1.05×10^{4}	1.49×10^{6}	9.12×10^{3}	6.54×10^{1}
Medium MM	1.31×10^{6}	5.26×10^{4}	2.27×10^{3}	3.94×10^{5}	1.35×10^{3}	1.73×10^{1}
Switched Data	9.58×10^{7}	4.04×10^{5}	9.22×10^{3}	5.49×10^{6}	4.99×10^{5}	5.61´x10^{3}
Simple Messaging	4.42×10^{6}	8.85×10^{4}	4.67×10^{3}	1.33×10^{6}	2.28×10^{3}	2.91×10^{1}
Speech	4.14×10^{8}	1.68×10^{6}	7.47×10^{4}	1.44×10^{8}	5.82×10^{6}	4.00×10^{4}

Table A3.P: OBQ UL *(kbit/h/km^2)* after Adjustment for Blocking, Year 2010.

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	5.68×10^{8}	3.72×10^{6}	1.07×10^{5}	5.03×10^{7}	2.96×10^{6}	3.33×10^{4}
High MM	9.95×10^{8}	3.98×10^{7}	2.10×10^{6}	2.99×10^{8}	1.02×10^{6}	1.31×10^{4}
Medium MM	4.98×10^{7}	1.99×10^{6}	1.05×10^{5}	1.49×10^{7}	5.12×10^{4}	6.54×10^{2}
Switched Data	9.58×10^{7}	4.04×10^{5}	9.22×10^{3}	5.49×10^{6}	4.99×10^{5}	5.61×10^{3}
Simple Messaging	4.42×10^{6}	8.85×10^{4}	4.67×10^{3}	1.33×10^{6}	2.28×10^{3}	2.91×10^{1}
Speech	4.14×10^{8}	1.72×10^{6}	7.47×10^{4}	1.44×10^{8}	5.82×10^{6}	4.00×10^{4}

Table A3.Q: OBQ DL *(kbit/h/km^2)* after adjustment for blocking, year 2010.

A3 4. Calculation of Required Spectrum

By dividing OBQ during the busy hour with the system capability of a generalised GSM system during one hour (calculated to be 339 Mbit/cell/MHz in A3 Appendix 1), it is possible to generate a ratio between offered and carried traffic (*OCF*). This ratio should become *one* if the system were able to handle the offered traffic, see chapter A3 2.3.

Assuming hexagon cells, the required bandwidth is according to (A3.5):

$$required\,bandwidth = \frac{OCF \times Hexagon cell area in km^2}{Spectral efficiency\, factor}$$

where *Hexagon cell area in km^2* is given in Table A3.C and *spectral efficiency factor* is the improvement in system capability over GSM. Shown in Table A3.R.

Services	2005	2010
High Interactive MM	1.1	1.35
High MM	1.1	1.35
Medium MM	1.1	1.35
Switched Data	1.1	1.35
Simple Messaging	1.1	1.35
Speech	1.05	1.25

Table A3.R: Assumed Spectral Efficiency Factor improvements over GSM for Each Service.

The approach adopted in the calculations has been to describe the cellular network by a nominal cell radius and re-use factor. These parameters have the most impact as their changes have an approximately square law effect on the spectrum estimate. In comparison, reductions in bandwidth, occupancy factor, etc. are essentially pro rata. The way in which the future technology improvement factor will build up is difficult to predict but the basic system capability figure of 339 Mb/h/cell/MHz seems to be of the correct order for spectrum estimation purposes.

The improvement factor in Table A3.R has to be understood as the average figure for a service, which may be offered in UMTS as well as in 2nd generation radio networks.

A3 4.1 Spectrum Calculations for the Home (In-building Coverage) Environment for UMTS

The home (in-building) environment for UMTS reflects the use of home cells, or single-user base stations, which allow the use of UMTS terminals and services in the residential and small office / home office domains. In terms of spectrum requirements this is a special case because there will be down to one single user per a base station (in this context a ‘user’ could include all members of a single family). The homes can be considered to be single isolated cells (Figure A3.D), and the cell boundaries will be those of the building (a cell radius of 20 m is therefore assumed) and it is considered that the same frequencies can be re-used in each cell, i.e. a re-use factor of 1.

The market data suggests a potential user density of 380/km^2. In this environment this translates into 380 cells/km^2. With a cell radius of 20 m the cell area will be approximately 0.001 km^2.

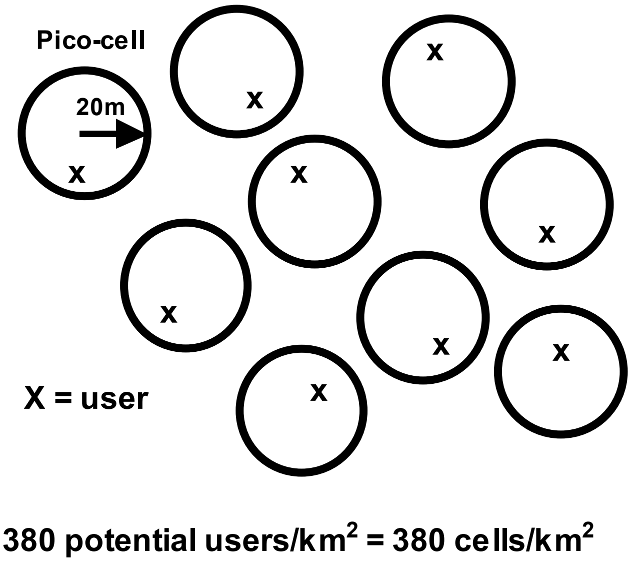

Figure A3.D: Single User Cells in the Home (In-building) Environment.

The spectrum demand of a home cell will be dependent of the number of services and the bit rates required for those services. Given that the use of UMTS in the home environment will include private, social, entertainment and educational purposes as well as business/professional work at home, it is considered that all UMTS services should be available via the home cell.

It can therefore be assumed that the following services will be required from the network:

a) *Packet switched services*: The assumption for home applications is a nominal of 384 kbit/s service. Allowing for acceptable packet delays and typical call durations it gives a net bit rate of around 330 kit/s.

b) *Circuit switched services*: The home cell should offer a minimum of one high interactive multimedia channel (128 kbit/s), 1 speech channel (16 kbit/s) and one circuit switched data channel of 14 kbit/s. Because these services may be required simultaneously, the bit rates must be aggregated to give 379 kbit/s (with appropriate coding). The circuit switched services are deemed to be symmetrical, and intolerant of significant delay. If these services are to be available simultaneously with the packet switched services then a separate RF channel will probably be required. If the minimum UMTS channel is 5 MHz, then this amount of additional spectrum will be required on the uplink and the downlink. It may therefore be possible to accommodate additional speech/data channels at no additional spectrum cost.

If the home (in-building) environment is to be realised with the TDD mode with a dynamic asymmetry capability, the packet services could possibly be realised within a single 5 MHz channel.

The calculated spectrum requirement is the minimum required to provide the stated services within the home cell. Unlike the equivalent figures for the other market environments, the spectrum requirement for the home cells is independent of busy hour call attempts and blocking factors.

The total spectrum requirement cannot be determined more precisely until the full performance and guard-band requirements of the UMTS FDD and TDD elements of the UTRA radio interface are determined. It should be noted that there will be a trade off between the efficiency of carrying the traffic over a dynamic TDD system and the guard bands required between the TDD system and the adjacent channels/services.

A3 4.2 Calculation of Spectrum Requirements for the Home (In-building) Environment

A3 4.2.1 OBQ Calculation

a) Packet switched services

The assumption is a nominal bit rate of 384 kit/s, which is converted to net bit rate of 330 kit/s.

Channel throughput x coding factor x overhead =

= 330 kbit/s x 2 x 1.2 = 792 kbit/s

b) Circuit switched services

Channel throughput x coding factor x overhead =

= (128 + 14 + 16 kbit/s) x 2 x 1.2 = 379 kbit/s

A3 4.2.2 Spectral efficiency factor

The same figure is used for the year 2005 and the year 2010. The spectral efficiency includes coding overhead.

Spectral efficiency (Home cell) = 128 kbit/s/cell/MHz

A3 4.2.3 Spectrum Requirement

a) Packet switched services

$$\text{Required bandwidth} = \frac{OBQ/cell}{\text{Spectral efficiency}} = \frac{792\ kbit/s/cell}{128\ kbit/s/MHz/cell} =$$

= 6.2 MHz (DL)

UL = 10% ➜ UL = 0.6 MHz

b) Circuit switched services

$$\text{Required bandwidth} = \frac{OBQ/cell}{\text{Spectral efficiency}} = \frac{379\ kbit/s/cell}{128\ kbit/s/MHz/cell} =$$

= 3 MHz (DL)

UL = DL ➜ UL = 3 MHz

A3 4.2.4 Total Spectrum Demand

UL: 0.6 + 3 MHz = 3.6 MHz
DL: 6.2 + 3 MHz = 9.2 MHz.

A3 4.3 Calculation Results for All Environments

Tables A3.S and A3.T present the required bandwidths for each operating environment and service for the year 2005, Tables A3.U and A3.V for the year 2010. In the Tables rounded figures are shown.

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	4.94	9.89	2.4	9.89	2.47	2.47
High MM	0.02	0.55	0.6	0.45	0.0	0.0
Medium MM	0.008	0.14	incl.	0.19	0.0	0.0
Switched Data	1.25	6.26	0.3	5.42	0.42	0.83
Simple Messaging	0.04	1.16	incl.	0.94	0.0	0.0
Speech	4.82	28.3	0.3	97.7	4.25	5.38
Total per env. (MHz)	11.1	46.3	3.6	114.6	7.14	8.69

Table A3.S: Uplink for the Year 2005: The Required Spectrum for Each Operating Environment *(MHz*).

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	4.94	9.89	2.4	9.89	2.47	2.47
High MM	3.61	109.6	6.2	89.5	0.15	0.26
Medium MM	0.29	5.48	incl.	7.3	0.01	0.01
Switched Data	1.25	6.26	0.3	5.42	0.42	0.83
Simple Messaging	0.04	1.16	incl.	0.94	0.0	0.0
Speech	4.82	28.33	0.3	97.7	4.25	5.38
Total per env. (MHz)	14.9	160.7	9.2	210.8	7.3	8.96

Table A3.T: Downlink for the Year 2005: The Required Spectrum for Each Operating Environment *(MHz*).

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	6.04	28.2	2.4	34.2	2.0	4.0
High MM	0.05	1.51	0.6	1.02	0.0	0.01
Medium MM	0.01	0.4	incl.	0.27	0.0	0.0
Switched Data	1.02	3.06	0.3	3.74	0.34	0.68
Simple Messaging	0.05	0.67	incl.	0.9	0.0	0.0
Speech	4.76	14.04	0.3	105.6	4.28	5.23
Total per env. *(MHz)*	11.94	47.87	3.6	145	6.6	9.96

Table A3.U: Uplink for the Year 2010: The Required Spectrum for Each Operating Environment *(MHz*).

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	6.04	28.2	2.4	34.2	2.0	4.0
High MM	10.6	301.45	6.2	203.5	0.7	1.6
Medium MM	0.53	15.07	incl.	10.17	0.03	0.08
Switched Data	1.02	3.06	0.3	3.74	0.34	0.68
Simple Messaging	0.05	0.67	incl.	0.9	0.0	0.0
Speech	4.76	14.04	0.3	105.7	4.28	5.23
Total per env. (MHz)	23.0	362.5	9.2	358.2	7.37	11.6

Table A3.V: Downlink for the Year 2010: The Required Spectrum for Each Operating Environment (MHz).

A3 4.3 Calculation Results for the Relevant Environments - Values for Spectrum Estimation

The three operational environments that determine the maximum spectrum requirements are CBD/Urban (in building), Urban (pedestrian) and Urban (vehicular) as described in section 3.1. To get the final spectrum requirement per service we add the uplink and downlink for these three operational environments. The amount of required spectrum for the year 2010 can be calculated in the same way. The results for each service are given in Table A3.W.

	Year 2005			**Year 2010**		
Services	**Uplink**	**Downlink**	**Total**	**Uplink**	**Downlink**	**Total**
High Interactive MM	17.3	17.3	**35**	42.3	42.3	**85**
High MM	0.47	93.3	**94**	1.07	214.8	**216**
Medium MM	0.3	7.6	**8**	0.28	10.7	**11**
Switched Data	7.1	7.1	**14**	5.1	5.1	**10**
Simple Messaging	0.98	0.98	**2**	0.95	0.95	**2**
Speech	106.8	106.8	**214**	114.7	114.7	**230**
Sum (rounded)	132.8	233.1	**366**	164.4	389	**554**
Total (allowing for spectrum partitioning)[3]			**403**			**582**

Table A3.W: Result of the Terrestrial Spectrum Requirement Calculation *(MHz)*.

Example of calculation for the year 2005:
Medium MM UL= 0.08+0,19+0.0=0.27 MHz, rounded=0.3 MHz
Medium MM DL= 0.29+7.3+0.01=7.6 MHz
Total MM** = 0.3+7.6=, rounded=**8 MHz

3 *Trunking inefficiency and guard bands must be allowed for, due to multiple operators, and public/private and service category segmentation. This is assumed to improve from 10 % in 2005 to 5 % in 2010.*

A3 5. Conclusions

This document describes the calculation of the frequency requirements for terrestrial high density mobile markets. The parameter assumptions are based on the market model and forecasts for the EU15 states for the years 2005 and 2010. All services from speech to multimedia are included from 2nd generation to 3rd generation mobile systems. The estimation is based on assumptions from /1/ and /7]/ and on calculations of the GSM system capability but with a modifier for improvements in UMTS spectral efficiency.

The estimated spectrum demand ends up with the figures of 403 MHz for the year 2005 and 582 MHz for the year 2010. As it was realised in doing the calculations, a deviation in the parameter assumption may change considerably the calculation results. A comparison with earlier estimations showed, that the figures are reasonable and can be approved.

As there are in Europe (EU 15 states) 240 MHz already identified for 2nd generation systems and 155 MHz as the UMTS core band, the additional total spectrum requirement for the terrestrial services in the EU15 states will be

for the year 2005: ca. 10 MHz
for the year 2010: ca. 185 MHz.

A3 6. References

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[4] H. Olofsson, J. Näslund, J. Sköld, "Interference Diversity Gain in Frequency Hopping GSM", *Proceedings in IEEE Vehicular Technology Conference*, Chicago, 1995

[5] ITU-R, *"Guidelines for evaluation of radio transmission technologies for FPLMTS"*, ITU-R 39/8, 26 April 1996

[6] *"UMTS Task Force Report"*, Brussels, 1st March 1996.

[7] CEC deliverable R2066/SESA/GA2/DS/P/030/b1, *"Result of traffic modelling for UMTS"*

[8] ”A Regulatory Framework for UMTS” Report No 1 from the UMTS Forum, 25 June 1997.

[9] ”UMTS Market Forecast study” Final Report for EC DG XIII, Analysys/Intercai Report No 97043, 12 February 1997.

[10] „On the spectrum efficiency of third generation mobile systems“ Marco Mastroforti, CSELT, Stockholm, 11 Sept. 1997; a contribution to the Spectrum Aspects Group Annex SAG #10/12

APPENDIX 1 TO ANNEX 3

A3 A1. Carried Traffic in a Generalised GSM System

In this section we try to estimate the information capacity of the GSM system. It should be noted that capacity is a very complex issue based on various assumptions. These calculations are not intended to give an all true solution about the question of the GSM capacity, but more or less some sort of reference to compare the previous results to. The following calculations are also compared with other independent capacity simulations and calculations /2 to 4].

A3 A1.1 Information Capacity

In a general TDMA system the number of RF-carriers per cell can be defined as:

$$N_{CARR} = \left\lfloor \frac{W_{TOT} - W_G}{F \times W_C} \right\rfloor \quad [carriers / cell]$$

where W_{TOT} is the total available bandwidth, F is the carrier reuse factor, W_C is the carrier spacing and W_G is the part of the spectrum that can not be used due to guard band requirements. The number of user traffic channels per cell can now be defined as:

$$N_{UTS} = \frac{1}{n} \times \left(N_{CARR} \times N_{TS} - N_C \right) \quad [user\,traffic\,channels / cell]$$

where N_{TS} is the total number of time slots per TDMA-carrier, N_C is the number of control signalling time slots per cell and n is the number of required time slots per frame and user for the service in question. For a full rate *13* kbps speech codec, $n=1$ and for the half rate codec $n=0.5$ is used.

The parameter N_{UTS} can now be used in various capacity measures. We will here focus on the information capacity (*IC*). For a given channel and quality of service (BER), the Information Capacity is defined as:

$$IC = \frac{N_{UTS} \times R_b}{W_{TOT}} \quad [kbit / s / cell / MHz]$$

where R_b is the information bit-rate per channel.

A3 A1.2 Assumptions and Calculations

First we assume a total bandwidth of 5.8 MHz allocated for the GSM system operator with one divided carrier as guard band due to out-of-bound interference restrictions. A common assumption seems to be a site reuse factor of 3, with 3 sector antennas /2/, which in this example will give a reuse factor of 9. Finally the GSM carrier separation of 200 kHz is used. To summarise the parameters are:

$$W_{TOT} = 5.8\,MHz$$
$$W_G = 200\,kHz$$
$$F = 9$$
$$W_C = 200\,kHz$$

which gives

$$N_{CARR} = \left\lfloor \frac{5.8 - 0.2}{9 \times 0.2} \right\rfloor = 3\,carriers\,/\,cell$$

The GSM frame structure gives 8 time slots per carrier. The overhead (control signalling) is not considered here. This makes it possible to calculate the number of user traffic channels per cell as

$$N_{TS} = 8\,time\,slots\,/\,carrier$$
$$N_c = 0\;time\,slot$$

$$N_{UTS} = \frac{1}{1} \times (3 \times 8 - 0) = 24\;user\,traffic\,channels\,/\,cell$$

The full rate speech codec in the GSM system is specified for 13 kbps which finally gives the information capacity

$$R_b = 13\,kbit\,/\,s$$

$$IC = \frac{24 \times 13}{5.8} \approx 53.8\,kbit\,/\,s\,/\,cell\,/\,MHz$$

Note that we will achieve the same information capacity if we make the same calculations for the half rate codec. This is easy to understand if you remember that we basically have the same system as before, we just multiplex a double amount of users each one with half of the bit rate. The number of user traffic channels per cell is however doubled, increasing the cell traffic capacity.

Also note, that this information capacity does **not** consider any blocking. According to Erlang B a cell with 24 user traffic channels and a quality of service grade of 2% blocking required, only is dimensioned on average for about 15 users.

In /3 and 4] the GSM capacity is simulated and calculated. A recalculation of these results gives an information capacity of 56 kbit/s/cell/MHz, with a 3/9 reuse. Similar capacity figures (57 kbit/s/cell/MHz) are given in /2/ where the GSM system is compared to the North American AMPS analogue cellular system. This indicates that the above given assumptions was a little bit pessimistic, but we like to point out that the results are very dependent on the assumptions done in the calculations. The important thing is that the results are of the same magnitude.

A3 A1.3 System Capability - Carried Bits During One Hour

In order to find out how many bits that the generalised GSM system could carry per cell and MHz during one hour, the following formula is used:

Carried bits/cell/MHz=information capacity×coding factor× hour factor.

The information capacity corresponds to the above given 53.8 kbit/s/cell/MHz. The coding factor is estimated to 1.75 according to the unequal error protection in GSM. The total amount of *carried bits/cell/MHz* in a generalised GSM system is therefore 339 Mbit/hour/cell/MHz (339 Mbph/cell/MHz).

Reference /10/

APPENDIX 2 TO ANNEX 3

The UMTS services

Services on demand will be common in UMTS. High quality entertainment services, down-loading of large files or on-line surfing are possible services in this context. In addition to the provision of multimedia, the user's needs for the present telecommunication services will also be satisfied inside UMTS.

Below are examples of new or enhanced services and applications which should be supported by UMTS. Some of these mass market services have already been applied in the fixed network or in GSM and will be improved with the advent of GSM based General Packet Radio Service (GPRS)[4] and High Speed Circuit Switched Data (HSCSD)[5], but UMTS will offer significant improvements both in service provision and delivery performance.

Information
Public information services such as
- Browsing the WWW
- Interactive shopping
- On-line equivalents of printed media
- On-line translations
- Location based broadcasting services
- Intelligent search and filtering facilities

Education
- Virtual school
- On-line science labs
- On-line library
- On-line language labs
- Training

Entertainment
- Audio on demand (as an alternative to CDs, tapes or radio)
- Games on demand
- Video clips
- Virtual sightseeing

Community services
- Emergency services
- Government procedures

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4 *GPRS is a GSM service that will use the GSM radio channel in an optimal way for delivery of packet data services. A maximum data rate of 115 kb/s is foreseen for the service.*

5 *HSCSD is a GSM service that will combine two or more time-slots in the GSM radio channel to deliver a circuit switched data service of up to 64 kb/s or more.*

Business information
- Mobile office
- Narrowcast business TV
- Virtual work-groups

Communication services
Person-to-person services such as
- Video telephony
- Video conferencing
- Voice response and recognition
- Personal location

Business and financial services
- Virtual banking
- On-line billing
- Universal SIM-card and Credit card

Road transport telematics
- Toll ticket
- Fleet management
- Car security

Annex 4

Spectrum Calculations for MSS

A4.1 Introduction

The spectrum forecasts presented in this Annex are based on market forecasts for MSS. In addition, an assessment was made of the portion of these requirements that applies to systems forming part of UMTS/IMT-2000.

It is expected that in the time frame covered by these forecasts, there will still be MSS systems in operation which could be called 1st generation systems. However, the traffic carried by these systems is likely to be comparatively small and is therefore ignored.

Section A4.2 gives an overview of the traffic forecasts (further details are given in the main part of this Report). The spectrum calculations are presented in section A4.3. Calculations are shown for the spectrum requirements in a global hot spot in the years 2005 and 2010. Similar calculations, not shown in this Annex, were also performed for the EU15 requirements. The results of these calculations are also given. Conclusions are given in section A4.4.

A4.2 Traffic Forecasts

The assessment of UMTS/IMT-2000 market demand, commissioned by the UMTS Forum under responsibility of the Market Aspects Group in 1996, which was conducted by Analysys Ltd. (see [2]), did not include in its scope the demand for Satellite UMTS/IMT-2000. As a result, the traffic forecasts have been built up from market study data provided by Inmarsat and from other industry studies. The traffic forecasts distinguished between two types of user terminals: terminals providing a full range of multimedia services and terminals limited to speech and low-speed data services (non-multimedia terminals). The projections show that 6% of the multimedia traffic and 12% of the non-multimedia traffic will be over the 15 EU countries. World-wide, the highest multimedia traffic region will take 10% of the total multimedia traffic in an area of approximately 3 million km^2. For non-multimedia traffic, EU15 is foreseen to be one of the global hot-spots.

The traffic forecasts are summarised in Table A4.1. These forecasts distinguish 12 traffic environments as follows:

1. Rural pedestrian (handheld, portable, transportable)
2. Rural vehicular (car, truck, train, bus)
3. Rural fixed
4. Remote pedestrian
5. Remote vehicular
6. Remote fixed.
7. Off-shore maritime (yacht, tug boat)
8. Deep sea maritime (freighter, tanker, ocean liners)
9. Personal/Corporate aeronautical
10. Passenger aeronautical

11. Localised base station (a cell covering an indoor area not covered by terrestrial UMTS/IMT-2000, such as a train, bus or building, with an outside repeater to the satellite)
12. Terrestrial fill-in (traffic resulting from coverage of areas which eventually will be covered by terrestrial UMTS/IMT-2000)

	Worldwide		EU	
	2005	2010	2005	2010
MSS (Million MB's)				
Non-Multimedia	1,000	1,500	109	158
Multimedia	2,506	5,468	150	328
Total MSS	3,506	6,968	259	486
UMTS (Million MB's)				
Non-Multimedia	67	242	7	26
Multimedia	2,506	5,468	150	328
Total UMTS	2,573	5,710	158	354

Table A4.1: Summary of MSS traffic projections

No traffic forecasts have been made available for terrestrial fill-in. This could result in some underestimation of the spectrum requirements for the early years of UMTS/IMT-2000 operation. Similarly, traffic forecasts for localised base stations are limited to the non-multimedia case.

Distinction was also made between the following four types of services of which all four will be provided by multimedia systems and the first two by non-multimedia systems:

1. Speech - quality basic speech at 8/16 kbit/s
2. Low-speed data - predominantly messaging and e-mail (without attachments) type services at 9.6/16 kbit/s
3. Asymmetric services - this includes the predominantly one way services including file transfer, database/LAN access, Intranet/Internet WWW, E-mail (with attachments), image transfer etc. Rates of transmission will be up to around 144 kbit/s. This corresponds approximately to the Medium (and High) Multimedia services defined for terrestrial UMTS/IMT-2000
4. Interactive Multimedia - predominantly relating to videoconferencing and videotelephony at data speeds of around 144 kbit/s. This corresponds approximately to the High Multimedia services as defined for terrestrial UMTS/IMT-2000.

The traffic forecasts include maritime and aeronautical traffic. However, since the spectrum estimates have been based on land areas (see below), the maritime traffic and half the aeronautical traffic have been subtracted from the totals to yield the traffic volumes that will originate from the those land areas. The market studies have shown that satellite based asymmetric services can be characterised as having a balanced overall traffic demand in both transmission directions.

A4.3 Spectrum calculation

As stated in section 3.3 of the main Report, the spectrum calculations were carried out using the methodology adopted by Study Group 8 as Recommendation ITU-R M.[8/BL/13]. The calculations are summarised in Tables A4.2 to A4.7. A discussion of the input parameters is given in section A4.3.1. *Note that Tables A4.2 to A4.7 gives the spectrum requirement in each direction.*

Service type	Speech	LSD	
Total traffic (million Mbytes)	475	458	
% in hot spot	12	12	
C_y (MMB)	57	54.96	
f_B (-)	0.15	0.15	
R_b (Mbps)	52.05	50.19	
f_{BO} (-)	87%	86%	
R_b' (Mbps)	45.21	43.24	
f_C (-)	1	1	
f_D (-)	1	2	
R_C (kbps)	144	144	
n_C (-)	313.99	150.14	
B_C (kHz)	200	200	
B (MHz)	62.80	30.03	92.83

Table A4.2:Non-multimedia non-IMT-2000 traffic in the year 2005

Service type	Speech	LSD	
Total traffic (million Mbytes)	34	33	
% in hot spot	12	12	
C_y (MMB)	4.08	3.96	
f_B (-)	0.15	0.15	
R_b (Mbps)	3.73	3.62	
f_{BO} (-)	87%	86%	
R_b' (Mbps)	3.24	3.12	
f_C (-)	2	2	
f_D (-)	1	2	
R_C (kbps)	144	144	
n_C (-)	11.24	5.41	
B_C (kHz)	200	200	
B (MHz)	2.25	1.08	3.33

Table A4.3: Non-multimedia IMT-2000 traffic in the year 2005

	Speech	LSD	Asymm	Interact	
Total traffic (million Mbytes)	94	204	2067	141	
% in hot spot	10	10	10	10	
C_y (MMB)	9.4	20.4	206.7	14.1	
f_B (-)	0.1	0.1	0.1	0.1	
R_b (Mbps)	5.72	12.42	125.84	8.58	
f_{BO} (-)	84%	86%	84%	84%	
R_b' (Mbps)	4.80	10.74	105.60	7.20	
f_C (-)	2	2	2	2	
f_D (-)	1	2	5	1	
R_C (kbps)	144	144	144	144	
n_C (-)	16.68	18.64	73.34	25.01	
B_C (kHz)	200	200	200	200	
B (MHz)	3.34	3.73	14.67	5.00	26.73

Table A4.4: Multimedia IMT-2000 traffic in the year 2005

	Speech	LSD	
Total traffic (million Mbytes)	641	617	
% in hot spot	12	12	
C_y (MMB)	76.92	74.04	
f_B (-)	0.15	0.15	
R_b (Mbps)	70.25	67.62	
f_{BO} (-)	82%	81%	
R_b' (Mbps)	57.56	54.93	
f_C (-)	1.5	1.5	
f_D (-)	1	2	
R_C (kbps)	144	144	
n_C (-)	266.47	127.14	
B_C (kHz)	200	200	
B (MHz)	53.29	25.43	78.72

Table A4.5: Non-multimedia non-IMT-2000 traffic in the year 2010

	Speech	LSD	
Total traffic (million Mbytes)	123	119	
% in hot spot	12	12	
C_y (MMB)	14.76	14.28	
f_B (-)	0.15	0.15	
R_b (Mbps)	13.48	13.04	
f_{BO} (-)	82%	81%	
R_b' (Mbps)	11.04	10.59	
f_C (-)	2	2	
f_D (-)	1	2	
R_C (kbps)	144	144	
n_C (-)	38.35	18.39	
B_C (kHz)	200	200	
B (MHz)	7.67	3.68	11.35

Table A4.6: Non-multimedia IMT-2000 traffic in the year 2010

	Speech	LSD	Asymm	Interact	
Total traffic (million Mbytes)	206	445	4510	307	
% in hot spot	10	10	10	10	
C_y (MMB)	20.6	44.5	451	30.7	
f_B (-)	0.1	0.1	0.1	0.1	
R_b (Mbps)	12.54	27.09	274.58	18.69	
f_{BO} (-)	79%	81%	79%	79%	
R_b' (Mbps)	9.92	22.08	217.23	14.79	
f_C (-)	2	2	2	2	
f_D (-)	1	2	5	1	
R_C (kbps)	144	144	144	144	
n_C (-)	34.45	38.33	150.85	51.34	
B_C (kHz)	200	200	200	200	
B (MHz)	6.89	7.67	30.17	10.27	55.00

Table A4.7: Multimedia IMT-2000 traffic in the year 2010

A4.3.1 Discussion of input parameters

- % in hot spot: The calculations have been carried out for a global "hot spot", which is approximately 3 million km^2 in area. The % of traffic in the hot spot specifies the percentage of the total world-wide traffic which originates from this area as predicted by the market forecast;
- The portion of diurnal traffic occurring in the busy hour (f_B): This is determined by the diurnal traffic distribution. The market forecasts has projected this factor to be 0.1 for multimedia traffic and 0.15 for non-multimedia traffic;

- The busy hour offset factor, f_{BO}: The total traffic would nominally be the sum of the busy hour traffic values from all environments and services. However, the busy hour occurs at different times in different environments. The spectrum calculations are therefore performed for an “overall busy hour”, for which the sum of the traffic from all services and environments reaches its peak. This factor has been calculated by considering the 12 traffic environments (listed in section A4.2) and calculating the weighted average of the busy hour offset factors for these environments as shown in Tables A4.8 and A4.9;
- Number of beam clusters in the area, f_c: This is determined by the frequency reuse pattern together with the average size of the beam footprint. In choosing this value, it has been considered that already planned non-IMT-2000 MSS systems would typically cover the area in question with 1 beam cluster or less. Future MSS systems are expected to provide improved reuse, however it is unlikely that any MSS systems will be able to provide more than 2 beam clusters in the area by the year 2010. For the purpose of these calculations, it has been assumed that IMT-2000 satellites will have 2 beam clusters in the area (f_c=2). This corresponds to, for example, an average beam footprint of around 200,000 km^2 and a frequency reuse pattern of 7. For non-IMT-2000 systems, considering that some already planned such systems being launched before and around 2000 are still expected to be in operation in the year 2010, the assumption taken is f_c=1.5. For non-IMT-2000 MSS systems in the year 2005 f_c has been taken as 1. It should be noted that the significant variations in traffic density within an area as large as 3 million km^2 makes these frequency reuse assumptions very difficult to achieve in practice.
- The choice of the factor f_c has been considered together with the choice of modulation efficiency, i.e. C/W, since neither can be improved without considering the effect on the other. For example, an improved modulation efficiency will require a higher carrier-to-noise ratio, leading to a degradation in reuse. Also, in determining these factors, it was considered that actual frequency reuse can never be perfect, due to geographical variations in traffic volume.
- The delay factor takes account of the fact that for certain services it is possible to save bandwidth by delaying the transmission of data when there is a high demand, particularly during busy hour, thus smoothing out the time variations in traffic. This is not possible for speech and interactive services. Thus, for low-speed data this delay factor has been estimated to 2 and for asymmetric services 5. However, f_D = 1 for the circuit-switched speech and interactive services.
- The capacity per carrier, R_C, is assumed to be 144 kbit/s;
- The carrier bandwidth, B_C, has been taken as 200 kHz;
- The information bit rate of 144 kbit/s plus overhead of approximately 30 kbit/s is thus assumed to be accommodated in a carrier bandwidth of 200 kHz, which can be achieved for example by QPSK modulation with an FEC rate approximately 0.6.

Table A4.10 gives the resulting spectrum requirements for the different cases.

Global Hot Spot	**Year 2005**	**Year 2010**
Non-IMT-2000 MSS	2x93 MHz	2x79 MHz
IMT-2000 MSS	2x30 MHz	2x66 MHz
Total	2x123 MHz	2x145 MHz

Table A4.10: MSS spectrum requirements for a global hot spot.

All the calculations presented above relate to a global hot spot. Separate calculations were also performed according to the same methodology for the EU15 area. For the non-multimedia cases, these calculations are identical to the above. For the multimedia case, the EU15 requirements are projected to be 6% of the total world-wide traffic. The result of that calculation can be seen in Table A4.11.

EU15	**Year 2005**	**Year 2010**
Non-IMT-2000 MSS	2x93 MHz	2x79 MHz
IMT-2000 MSS	2x19 MHz	2x44 MHz
Total	2x112 MHz	2x123 MHz

Table A4.11: MSS spectrum requirements for EU15.

It should be noted that ITU studies have shown much greater spectrum requirements, as stated in the CPM report to WRC-97, section 4.2.6 : "Studies conducted for WRC-97 have estimated that the MSS may require around 2x250 MHz of spectrum at the year 2010 in the 1-3 GHz range."

A4.3.2 MSS allocations status

The estimated spectrum requirements are summarised in Figures A4.1 and A4.2, for a global hot spot and EU15 respectively. The Figures show the breakdown of spectrum requirements by service type alongside the available MSS allocations in the 1-3 GHz range. As shown in Figure A4.2, the bands 2655-2670 / 2520-2535 MHz are not expected to become available for MSS in Europe. The spectrum shortfall for MSS in the year 2010 is thus predicted to be 2x30.5 MHz in the global hot spot and 2x23.5 MHz in EU15. Similarly, the shortfall in the year 2005 would be 2x8.5 MHz in the global hot spot and 2x12.5 MHz in EU15. Of course this assumes that the bands shown in Figures A4.1 and A4.2 are made available for MSS in the given time-frame.

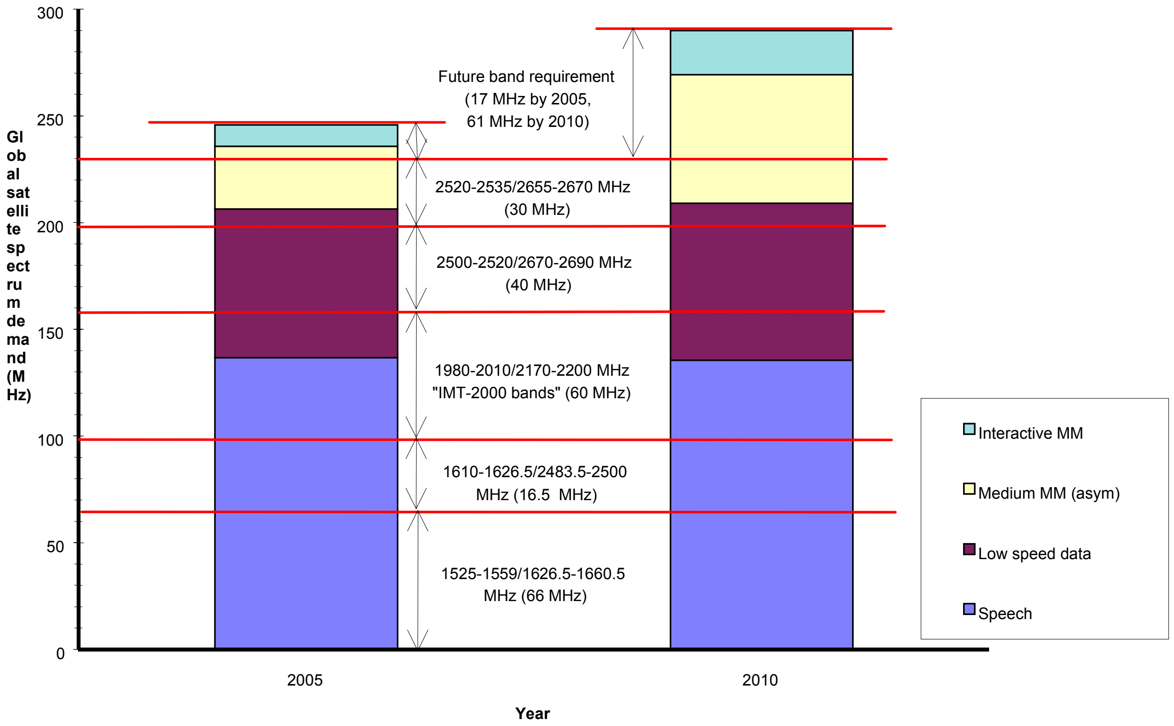

Figure A4.1: MSS spectrum estimates for a global hot spot and comparison with MSS allocations

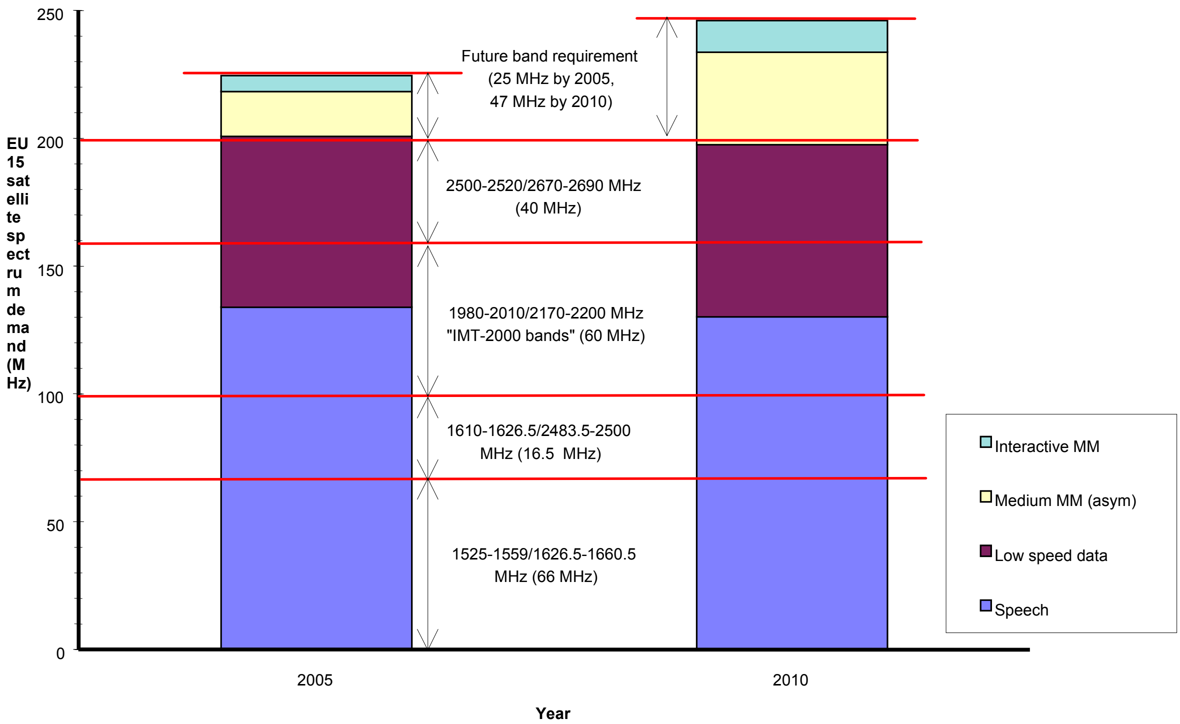

Figure A4.2: MSS spectrum estimates for EU15 and comparison with MSS allocations

A4.4 Conclusion

The MSS spectrum requirements have been estimated to 2x123 MHz in the year 2005 and 2x145 MHz in the year 2010 for a global hot spot, while the available spectrum is assumed to be 2x114.5 MHz. In EU15 the estimates are 2x112 MHz at the year 2005 and 2x123 MHz at the year 2010, while the available MSS spectrum is estimated as 2x99.5 MHz. In other words, the additional MSS spectrum requirements in the 1-3 GHz range for the year 2005 are 25 MHz for EU15 and 17 MHz for the global hot spot. For the year 2010, the additional spectrum requirements are 47 MHz in EU15 and 61 MHz in the global hot spot.

For the satellite component of UMTS/IMT-2000 it is estimated that the spectrum requirements in the global hot spot will be 2x30 = 60 MHz in the year 2005 and 2x66 = 132 MHz in the year 2010, and the EU15 requirements will be 2x19 = 38 MHz by the year 2005 and 2x44 = 88 MHz by the year 2010.

A4.5 References

[1] "A Regulatory Framework for UMTS", Report No 1 from the UMTS Forum, 25 June 1997

[2] "UMTS Market Forecast Study", Final Report for EC DG XIII, Analysis/Intercai Report Number 97043, 12 February 1997

Multimedia traffic in 2005	Percentage of traffic in each environment				% of traffic in overall Busy Hour*	Split across Environment			
	Voice	LSD	Asymmetric	Interactive		Voice	LSD	Asymmetric	Interactive
Rural pedestrian (handheld, portable, transportable)	24%	24%	24%	24%	100%	24%	24%	24%	24%
Rural vehicular (Car, truck, train, bus)	6%	6%	6%	6%	100%	6%	6%	6%	6%
Rural semi-fixed	5%	5%	5%	5%	85%	4%	4%	4%	4%
Remote pedestrian	34%	35%	34%	34%	100%	34%	35%	34%	34%
Remote vehicular	6%	6%	6%	6%	100%	6%	6%	6%	6%
Remote semi-fixed	8%	9%	8%	8%	85%	7%	7%	7%	7%
Off-shore maritime (yacht, tug boat)**	2%	1%	2%	2%	0%	0%	0%	0%	0%
Deep sea maritime (freighter, tanker, ocean liners)**	2%	1%	2%	2%	0%	0%	0%	0%	0%
Personal/Corporate aeronautical ***	5%	5%	5%	5%	60%	1%	2%	1%	1%
Passenger aeronautical ***	8%	8%	8%	8%	40%	2%	2%	2%	2%
Localised base-station ****	0%	0%	0%	0%	0%	0%	0%	0%	0%
Terrestrial fill-in ****	0%	0%	0%	0%	0%	0%	0%	0%	0%
	100%	100%	100%	100%					
			Busy Hour offset factor - Weighted Average			84%	86%	84%	84%

Non-multimedia traffic in 2005	Percentage of traffic in each environment		% of traffic in overall Busy Hour*	Split across Environment	
	Voice	LSD		Voice	LSD
Rural pedestrian (handheld, portable, transportable)	57%	58%	100%	57%	58%
Rural vehicular (Car, truck, train, bus)	2%	2%	100%	2%	2%
Rural semi-fixed	11%	11%	85%	9%	9%
Remote pedestrian	7%	5%	100%	7%	5%
Remote vehicular	4%	4%	100%	4%	4%
Remote semi-fixed	3%	4%	85%	3%	3%
Off-shore maritime (yacht, tug boat)**	1%	1%	0%	0%	0%
Deep sea maritime (freighter, tanker, ocean liners)**	3%	3%	0%	0%	0%
Personal/Corporate aeronautical ***	2%	2%	60%	1%	1%
Passenger aeronautical ***	3%	3%	40%	1%	1%
Localised base-station	7%	8%	50%	4%	4%
Terrestrial fill-in ****	0%	0%	0%	0%	0%
	100%	100%			
			Busy Hour offset factor - Weighted Average	87%	86%

* Includes both Business and Non-Business
** Maritime excluded from busy hour as traffic generated will never be in the "hot spot"
*** Aero traffic in busy hour halved
**** No traffic share for these environments included currently, however total foreacast traffic inlcudes these environments.

Table A4.8: Traffic split across environments and calculation of overall busy hour offset factors - year 2005

Multimedia traffic in 2010	Percentage of traffic in each environment				% of traffic in overall Busy Hour*	Split across Environment			
	Voice	LSD	Asymmetric	Interactive		Voice	LSD	Asymmetric	Interactive
Rural pedestrian (handheld, portable, transportable)	24%	24%	24%	24%	95%	22%	23%	22%	22%
Rural vehicular (Car, truck, train, bus)	6%	6%	6%	6%	95%	6%	6%	6%	6%
Rural semi-fixed	5%	5%	5%	5%	75%	4%	4%	4%	4%
Remote pedestrian	34%	35%	34%	34%	95%	32%	33%	32%	32%
Remote vehicular	6%	6%	6%	6%	95%	6%	6%	6%	6%
Remote semi-fixed	8%	9%	8%	8%	75%	6%	7%	6%	6%
Off-shore maritime (yacht, tug boat)**	2%	1%	2%	2%	0%	0%	0%	0%	0%
Deep sea maritime (freighter, tanker, ocean liners)**	2%	1%	2%	2%	0%	0%	0%	0%	0%
Personal/Corporate aeronautical ***	5%	5%	5%	5%	60%	1%	2%	1%	1%
Passenger aeronautical ***	8%	8%	8%	8%	40%	2%	2%	2%	2%
Localised base-station ****	0%	0%	0%	0%	0%	0%	0%	0%	0%
Terrestrial fill-in ****	0%	0%	0%	0%	0%	0%	0%	0%	0%
	100%	100%	100%	100%					
			Busy Hour offset factor - Weighted Average			79%	81%	79%	79%

Non-multimedia traffic in 2010	Percentage of traffic in each environment		% of traffic in overall Busy Hour*	Split across Environment	
	Voice	LSD		Voice	LSD
Rural pedestrian (handheld, portable, transportable)	57%	58%	95%	54%	55%
Rural vehicular (Car, truck, train, bus)	2%	2%	95%	2%	2%
Rural semi-fixed	11%	11%	75%	8%	8%
Remote pedestrian	7%	5%	95%	7%	5%
Remote vehicular	4%	4%	95%	4%	3%
Remote semi-fixed	3%	4%	75%	3%	3%
Off-shore maritime (yacht, tug boat)**	1%	1%	0%	0%	0%
Deep sea maritime (freighter, tanker, ocean liners)**	3%	3%	0%	0%	0%
Personal/Corporate aeronautical ***	2%	2%	60%	1%	1%
Passenger aeronautical ***	3%	3%	40%	1%	1%
Localised base-station	7%	8%	50%	4%	4%
Terrestrial fill-in ****	0%	0%	0%	0%	0%
	100%	100%			
			Busy Hour offset factor - Weighted Average	82%	81%

* Includes both Business and Non-Business
** Maritime excluded from busy hour as traffic generated will never be in the "hot spot"
*** Aero traffic in busy hour halved
**** No traffic share for these environments included currently, however total foreacast traffic inlcudes these environments.

Table A4.9: Traffic split across environments and calculation of overall busy hour offset factors - year 2010.

Annex 5

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