RECOMMENDATION ITU-R M.1225

GUIDELINES FOR EVALUATION OF RADIO TRANSMISSION TECHNOLOGIES FOR IMT-2000

(Question ITU-R 39/8)

(1997)

CONTENTS

Page

1 Introduction

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

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

Key features of IMT-2000 are:

– high degree of commonality of design worldwide,

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

– high quality,

– use of a small pocket terminal with worldwide roaming capability.

IMT-2000 will operate worldwide in bands identified by Radio Regulations provision No. S5.388 (1 885-2 025 and 2 110-2 200 MHz, with the satellite component limited to 1 980-2 010 and 2 170-2 200 MHz). IMT-2000 are defined by a set of interdependent ITU Recommendations, of which this Recommendation is a member.

It is a design objective of IMT-2000 that the number of radio interfaces should be minimal and, if more than one interface is required, that there should be a high degree of commonality between them. These radio interfaces will serve the radio operating environments as nominated in Recommendation ITU-R M.1034. A number of sets of radio transmission technologies (SRTTs) may meet the requirements for the radio interfaces. This Recommendation contains the procedure and criteria that will be used to evaluate candidate radio transmission technologies (RTTs).

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

2 Scope

This Recommendation provides guidelines for both the procedure and the criteria to be used in evaluating RTTs for a number of test environments. These test environments, defined herein, are chosen to simulate closely the more stringent radio operating environments. The evaluation procedure is designed in such a way that the impact of the candidate RTTs on the overall performance and economics of IMT-2000 may be fairly and equally assessed on a technical basis. It ensures that the overall IMT-2000 objectives are met.

The Recommendation provides, for proponents and developers of RTTs, the common bases for the submission and evaluation of RTTs and system aspects impacting the radio performance.

This Recommendation allows a degree of freedom so as to encompass new technologies.

The actual selection of the RTTs for IMT-2000 is outside the scope of this Recommendation. It deals only with the methodology for the technical evaluations that should be performed. The results of the evaluation are to be documented in an evaluation report and submitted to the ITU-R.

3 Structure of the Recommendation

Section 5 outlines the RTT considerations and identifies the transmission dependent part of the radio interface considered in the evaluation procedure. Section 6 defines the criteria for evaluating the RTTs and § 7 references the tests environments under which the candidate RTTs are evaluated. Section 8 outlines the overall procedure for evaluating the RTTs. Section 9 gives details on evaluation methodology.

The following Annexes form part of this Recommendation:

Annex 1: Radio transmission technologies description template

Annex 2: Test environments and deployment models

Annex 3: Detailed evaluation procedures

4 Related Documents

Recommendation ITU-R M.687	International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.816	Framework for services supported on International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.818	Satellite operation within International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.819	International Mobile Telecommunications-2000 (IMT-2000) for developing countries
Recommendation ITU-R M.1034	Requirements for the radio interface(s) for International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.1035	Framework for the radio interfaces and radio subsystem functionality for International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.1036	Spectrum considerations for implementation of International Mobile Telecommunications-2000 (IMT-2000) in the bands 1 885-2 025 MHz and 2 110-2 200 MHz
Recommendation ITU-R M.1079	Speech and voiceband data performance requirements for International Mobile Telecommunications-2000 (IMT-2000)
Recommendation ITU-R M.1224.	Vocabulary of terms for International Mobile Telecommunications-2000 (IMT-2000)
ITU-T Recommendation G.174	Transmission performance objectives for terrestrial digital wireless systems using portable terminals to access the PSTN
ITU-T Recommendation F.115	Service objectives and principles for Future Public Land Mobile Telecommunication Systems (FPLMTS)
Recommendation ITU-R M.1167	Framework for the satellite component of International Mobile Telecommunications-2000 (IMT-2000)
ITU-T Recommendation E.770	Land mobile and fixed network interconnection traffic grade of service concept
ITU-T Recommendation E.771	Network grade of service parameters and target values for circuit-switched public land mobile services

5 Radio transmission technology considerations

Within a telecommunication system (see Fig. 1), a RTT reflects the combination of technical choices and concepts that allow for the provision of a radio subsystem. The evaluation process for candidate IMT-2000 RTTs will involve maximizing the transmission independent aspects and minimizing the differences between the remaining transmission dependent parts in the various IMT-2000 operating environments from an implementation perspective.

FIGURE 1

Radio transmission technologies as part of a total telecommunication system

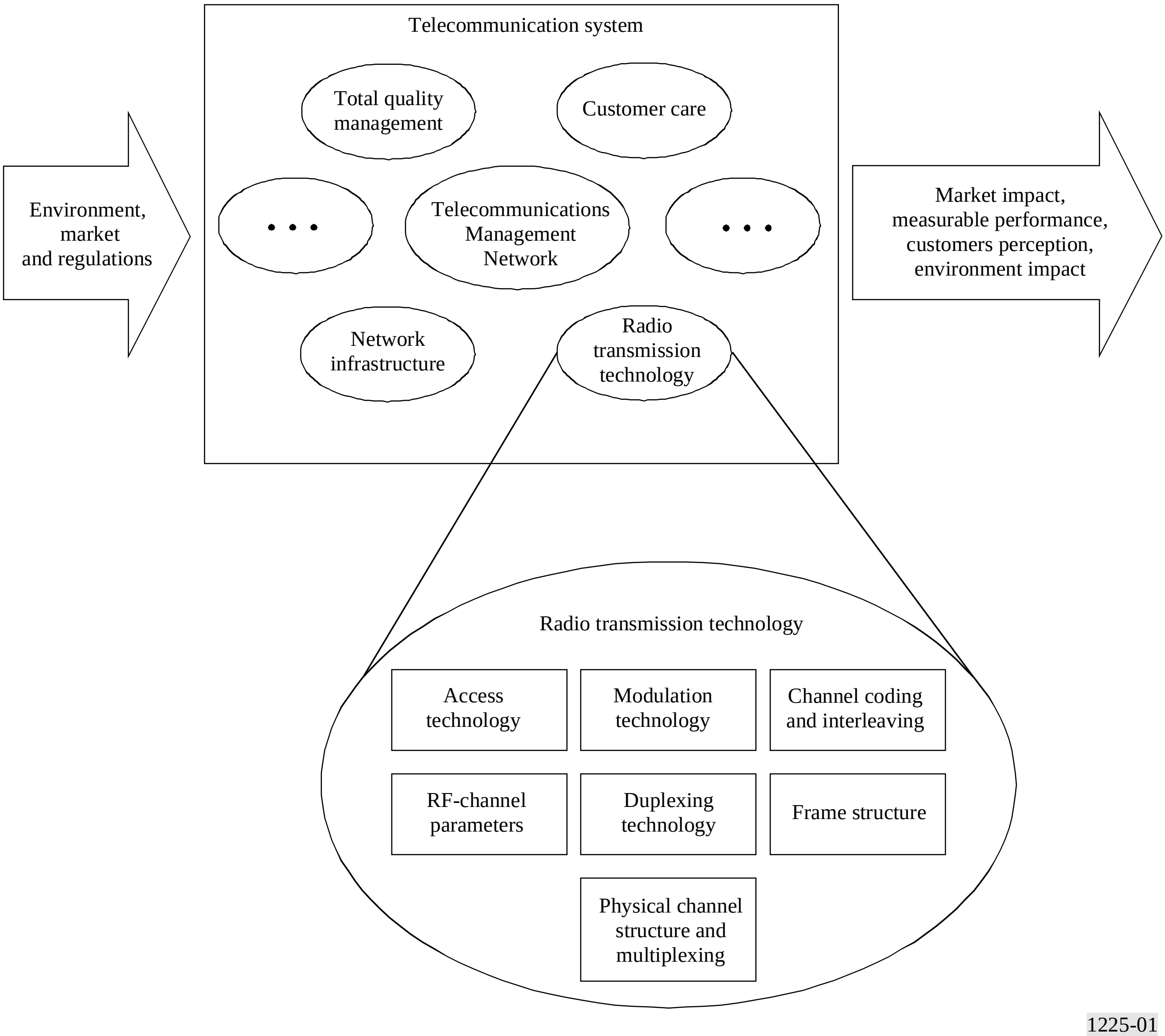
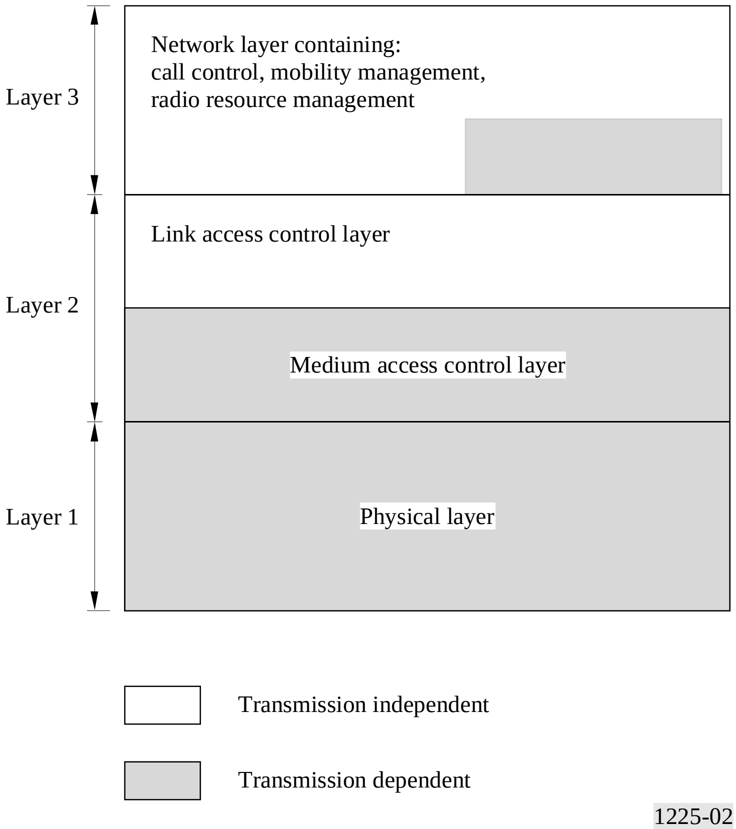


Figure 2 presents an example of a layered structure of radio interface.

FIGURE 2

Example of a layered structure of radio interface



As shown in Fig. 3, the transmission dependent part of the radio interface may be considered as a set of functional blocks. It should be noted that all these functional blocks are not necessarily transmission dependent in their entirety. The functional blocks identified here are the following:

– multiple access technology,

– modulation technology,

– channel coding and interleaving,

– RF-channel parameters such as bandwidth, allocation and channel spacing,

– duplexing technology,

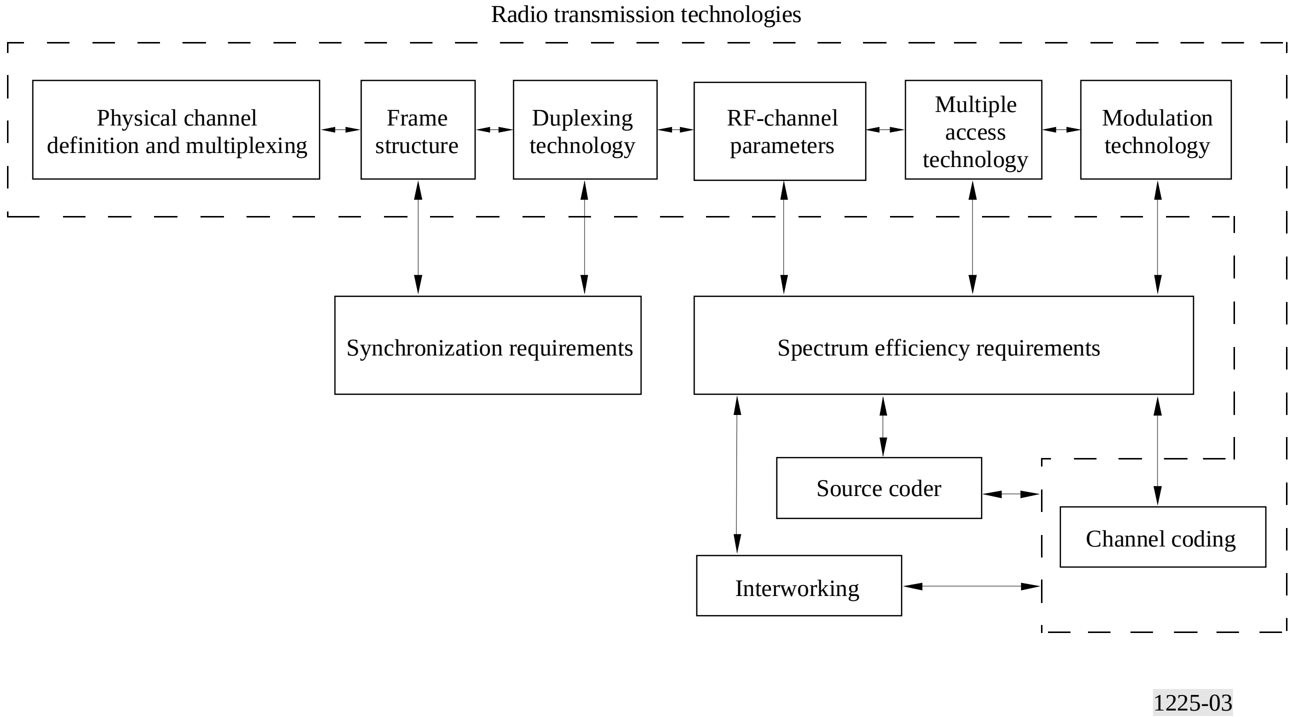
– frame structure,

– physical channel structure and multiplexing.

In the process of making design choices, the dependencies between the above functional blocks have to be considered. Some of the interdependencies are shown in Fig. 3 and are further described in § 5.1.

FIGURE 3

Functional blocks and their interdependencies



5.1 Radio transmission technologies functional blocks

5.1.1 Multiple access technology

The choice of the multiple access technology has major impact on the design of the radio interface.

5.1.2 Modulation technology

The choice of the modulation technology depends mainly on radio environment and the spectrum efficiency requirements.

5.1.3 Channel coding and interleaving

The choice of channel coding depends on the propagation environment and spectrum efficiency and quality requirements of the various services. Applications of large cells, especially in case of satellite component, usually require more powerful channel coding, while microcellular systems, used in a pedestrian environment, may allow less complex channel coding. For the choice of the channel coding with or without interleaving, it may be desirable to have multiple choices; each optimized to the appropriate service environment.

5.1.4 Duplexing technology

The choice of the duplexing technology mainly affects the choices of the RF-channel bandwidth and the frame length. Duplexing technology may be independent of the access technology since for example either frequency division duplex (FDD) or time division duplex (TDD) may be used with either TDMA or CDMA systems.

5.1.5 Physical channel structure and multiplexing

The physical channel is a specified portion of one or more radio frequency channels as defined in frequency, time and code domain.

5.1.6 Frame structure

The frame structure depends mainly on the multiple access technology (e.g. FDMA, TDMA, CDMA) and the duplexing technology (e.g. FDD, TDD). Commonality should be maximised by maintaining the same frame structure whenever possible. That is, data fields identifying physical and logical channels, as well as the frame length should be maintained when possible.

5.1.7 RF channel parameters

RF channel parameters include parameters such as bandwidth, allocation and channel spacing.

5.2 Other functional blocks

5.2.1 Source coder

The choice of the source coder may generally be made independently of the access method.

5.2.2 Interworking

The interworking function (IWF) converts standard data services to the rates used internally by the radio transmission subsystem. The IWF feeds into the channel coder on the transmit side and is fed from the channel decoder on the receiver side.

6 Technical characteristics chosen for evaluation

As a radio interface is only one part of a system, the choice of a specific RTT (see Fig. 1), for the provision of a radio interface for IMT-2000, requires consideration of the broad technical characteristics so as to cover the most important aspects that may impact the economics and performance of the system.

For practical reasons, a limited set of these technical characteristics has been chosen. It by no means implies that other (technical and non-technical) criteria are not relevant or significant. It is however believed that those essential system aspects which are impacted by the RTTs are fairly covered with the selected technical characteristics.

Given the difficulties of predicting the future, in particular when dealing with technology, sufficient provision is also made for a fair technical evaluation for all possible technologies, particularly new technologies. This is accomplished by making sure that it is not only the technology itself which is evaluated but also its impact on the system performance and economics.

6.1 Criteria for evaluation of radio transmission technologies

Each of the technical characteristics defined hereafter will be used as evaluation criterion and is further defined in the specific technical attributes in Annex 3. The RTTs description template is given in Annex 1.

Some of the criteria such as coverage or spectrum efficiency are measurable and may be numerically evaluated. Specific test scenarios are given in Annex 2 so as to enable the proponents and evaluators to calculate and verify the required figures on a common and fair basis.

Other criteria such as flexibility are of a more subjective nature and need to be assessed qualitatively. Advantages and drawbacks of the proposed technologies are to be given and commented on by the proponents and evaluators considering the technical parameters that are judged relevant to the criterion. A list of technical parameters that will be considered for each evaluation criterion, is given in Annex 3.

6.1.1 Spectrum efficiency

Optimum use of the radio spectrum is of great importance to IMT-2000 radio interfaces. In general the more telecommunications traffic that can be handled at a given quality, for a given frequency band, the more efficiently the spectrum is used. Evaluation of voice traffic capacity and information capacity should take into account frequency reuse and signalling overhead, among other parameters, as noted in Annex 2.

6.1.2 Technology complexity – Effect on cost of installation and operation

This criterion expresses the impact of a given RTT on complexity (and hence on cost) of implementation (equipment, infrastructure, installation, etc.) i.e., the less complex the better. In order to achieve the minimum cost and best reliability of equipment, the technologies selected should have a level of complexity consistent with the state of technology, the desired service objectives and the radio environment. Some technologies have several possible methods of implementation which allow a compromise between complexity/cost and performance.

The installed and ongoing cost of IMT-2000 is influenced by both the transmission technology and the level of quality and reliability. At a given quality level, it is impacted by the complexity of the radio hardware, the other necessary network infrastructures, and the ongoing operational aspects of IMT-2000.

6.1.3 Quality

Most of the quality parameters which are dealt with in other Recommendations are minimum requirements which must be met and are not to be treated in the evaluation process. RTTs will be evaluated on the impact of transmission processing delay on the end-to-end delay, expected average bit error ratio (BER) under the stated test conditions, on their maximum supportable bit rate under specified conditions and their overall ability to minimise circuit disruption during handover. In addition, they will be evaluated on their ability to sustain quality under certain extreme conditions such as system overload, hardware failures, interference, etc.

6.1.4 Flexibility of radio technologies

This criterion is of utmost importance for IMT-2000 operators. IMT-2000 systems will have to be flexible in terms of deployment, service provision, resource planning and spectrum sharing. Among the items that need to be considered are:

– ability to balance capacity versus RF signal quality as long as minimum performance requirements are met;

– adaptability of system(s) to different and/or time-varying propagation and traffic environments;

– ease of radio resource management;

– ability to accommodate fixed wireless access (FWA) architecture;

– ease of service provision including variable bit rate capability, packet data mode transmission and simultaneous transmission of voice and non-voice services;

and for terrestrial considerations:

– ability to accommodate mixed-cell (pico, micro, macro, and mega) architecture;

– suitability for multiple operators in the same/overlapping service areas. RTTs will be compared based on their ability to:

  – efficiently share a common spectrum allocation;

  – share network infrastructures (for example in areas of low subscriber density);

  – provide for handover between systems run by different operators.

6.1.5 Implication on network interface

It is desirable to minimise the impact of the radio subsystems on fixed network interfaces. The choice of RTTs may affect both the actual network interfaces required in IMT-2000 for multi-environment operation and the information passed over them. The need for synchronization between base stations (BSs) and between systems sharing common location and spectrum may be different. The requirements placed on the networks by the handover procedure may be different. Cross-environment operation, e.g. PSTN to wireless PBX call transfer, may require additional PSTN functionality. In particular, the number of signalling messages, the actual switching requirements, and the transmission capacity from BSs to switches may be different. RTTs should be evaluated based on the implications they impose on fixed network interfaces.

6.1.6 Handportable performance optimization capability

Handportable IMT-2000 terminals will be used in a broad range of user environments and applications which are defined in Recommendation ITU-R M.1034 and other IMT-2000 Recommendations. As with previous generation wireless systems, the capability for handportable voice and personal data applications will impact the market acceptance and success of IMT-2000.

The following should be considered when evaluating the RTTs for either individual or multiple operating IMT-2000 environments:

– transmit power requirements,

– transmitter and receiver linearity requirements,

– size and weight as a function of application,

– intermittent reception capability,

– circuit clock rate,

– overall complexity.

6.1.7 Coverage/power efficiency

In terrestrial systems, the minimum number of BSs per square kilometre for a given frequency assignment to offer a certain amount of traffic with the required coverage is an important figure, at low traffic levels. At low loading, the system will be noise limited and the number of base stations constrained by the maximum range achievable by the technology.

At low loading, range and coverage efficiency are the major considerations, while at high loading, capacity and spectrum efficiency are more important.

Technologies providing the desired level of coverage with fewer base sites for a specific test environment are defined as having higher coverage efficiency.

The coverage efficiency as defined above is not applicable to satellite systems for this evaluation criterion.

In satellite systems the DC power available for conversion into usable RF power is limited and fixed for any given satellite. It is important that this power is used efficiently and yields the maximum number of traffic channels of a given quality. The power efficiency as defined here is not applicable to terrestrial systems.

7 Selected test environments for evaluation

The test environments for evaluation are discussed in Annex 2. The selected test operating environments are the following:

– indoor office,

– outdoor to indoor and pedestrian,

– vehicular,

– mixed-cell pedestrian/vehicular,

– satellite.

8 Guidelines for evaluating the radio transmission technologies by independent evaluation groups

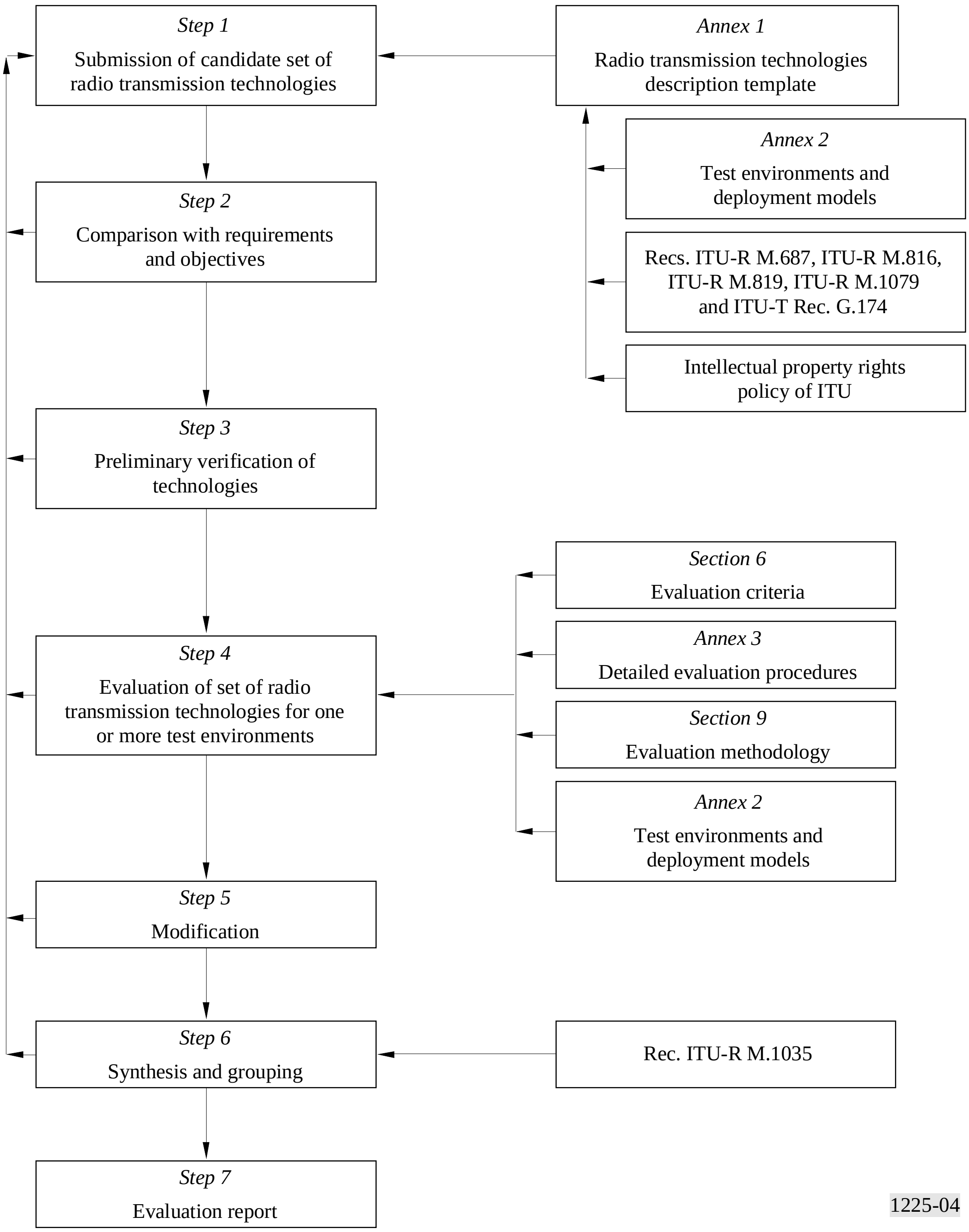
This section gives guidelines for evaluating candidate RTTs, or candidate SRTTs, for the IMT-2000 radio interface. This procedure evaluates the candidate SRTTs as a whole as it is difficult to evaluate transmission technologies independently of each other.

This procedure deals only with evaluating radio transmission aspects. It is not intended for evaluating system aspects (including those for satellite system aspects). Nevertheless, some combinations of RTTs may have an impact on the network side, and this is taken into consideration in the evaluation procedure (Step 4).

Figure 4 presents in a schematic way the different steps involved in the evaluation procedure.

The results will then be submitted to the ITU-R in the form of an evaluation report.

FIGURE 4



Evaluation guidelines

The evaluation procedure is based on the following steps.

Step 1 – Submission of candidate radio transmission technologies

Candidate RTTs are submitted with a technical description which should be formatted according to the template in Annex 1 to facilitate their comparison. In order to evaluate performance aspects of proposed RTTs, such as traffic capacity and others, it is necessary to assume appropriate conditions that include propagation models, traffic conditions and objective performances. Annex 2 provides the test environments and deployment models which should be assumed by all proponents.

Proposed RTTs should also be capable of meeting IMT-2000 objectives and requirements as defined in existing IMT-2000 Recommendations (see § 4). Also the intellectual property right (IPR) category should be stated as noted in Annex 1.

The level of detail in the Annex 1 template is sufficient to allow an accurate evaluation of the overall performance of the proposed RTT. In the case of new proposed technologies, it may need further refinements and more information may be added or requested.

It is also recognized that the Annex 1 template is only a list of radio related technical parameters. Other aspects, which would be essential for the choice of a commercial system, may not be taken into account.

Step 2 – Comparison with requirements and objectives

Candidate RTTs are compared against the technical requirements and objectives given in IMT-2000 Recommendations.

Step 3 – Preliminary verification of technology

Proponents may be asked to submit additional information, including perhaps results of software or simulation tests, or hardware tests, to verify key elements of their candidate technologies.

Step 4 – Evaluation of RTTs

Candidate RTTs are evaluated through use of analysis and simulation by comparing them against the set of criteria defined in § 6 for test environments given in Annex 2. Each RTT is then evaluated according to the procedure given in Annex 3.

Step 5 – Modification

The candidate RTTs may be modified by their proponents through additional iteration of the evaluation procedure returning back to Step 1.

Step 6 – Synthesis and grouping

Based on the results of Steps 4 and 5, proponents are requested to form an "optimum" group of RTTs for serving all IMT-2000 test environments. The grouping process should also take into account high commonality of the RTTs within the group to serve all environments. Recommendation ITU-R M.1035 provides guidelines to be considered in this step to obtain high commonality in the group of RTTs.

Step 7 – Evaluation report

An evaluation report should be prepared for consideration by the ITU-R and should include:

– technologies description as per Annex 1,

– evaluation based on the application of Annexes 2 and 3,

– applicable information.

9 Evaluation methodology

After the candidate RTT has been compared against the technical requirements and objectives and a preliminary verification of the technology has been made (Steps 2 and 3 in § 8), a technical evaluation of the candidate RTT is made against each evaluation criterion given in § 6.1. This evaluation will be made in the appropriate test environments using the deployment models described in Annex 2. Candidate RTTs will be evaluated based on technical descriptions that are submitted using the technologies description template contained in Annex 1. The detailed evaluation procedures are given in Annex 3, which lists technical attributes that should be considered for the evaluation of RTTs against each of the evaluation criteria.

The evaluation criteria can be sub-divided into objective and subjective criteria. Objective criteria contain technical attributes that can be assessed on a quantitative basis; subjective criteria contain a mixture of technical attributes that can be assessed on a quantitative basis and technical attributes that can be assessed on a qualitative basis.

Objective criteria	Subjective criteria
– Spectrum efficiency – Coverage/power efficiency	– Technology complexity - Effect on cost of installation and operation – Quality – Flexibility of radio technologies – Implication on network interfaces – Handportable performance optimization capability

9.1 Objective criteria

For these criteria, the evaluation is made based on the quantitative information submitted for each technical attribute. The independent evaluation groups may comment on the results and request further information or new calculations to further validate the given figures (e.g. by requesting simulation results when only theoretical analyses have been performed). The proponent is allowed to reply to these comments within a given deadline. Final conclusions or comments are then issued by the evaluators, and a summary evaluation for the criteria, as described in § 9.4, is then given taking into account all the results.

9.2 Subjective criteria

For these criteria, a numerical evaluation is difficult as the information submitted for a technical attribute may be qualitative instead of quantitative. However, a technical-based evaluation is still feasible and beneficial if a summary criteria evaluation approach is taken so as to understand the relative merits and drawbacks of each candidate RTT. In doing so, the most important technical information for decision-makers is then given as a result of this technical evaluation process. As with objective criteria, the evaluators may comment on the results and request additional information to further validate the RTT submission. The proponent is allowed to reply to these comments within a given deadline. Final conclusions or comments are then issued by the evaluators, and a summary evaluation for the criteria, as described in § 9.4, is then given taking into account all the results.

9.3 Evaluation spreadsheet

The following spreadsheet should be used as a guideline for the submission of the evaluation information to the ITU-R. It includes an example for information.

SPREADSHEET FOR RTT A CRITERION 1

Criterion e.g. flexibility	Proponent comments	Evaluator comments
1st technical attribute E.g. variable user bit rate capabilities	E.g. how well the RTT performs with respect to this attribute; how relevant this technical attribute is for the proposed RTT	E.g. request for clarification, disagreement, etc.; indication of relative importance of this attribute to others within this criterion
2nd technical attribute	This is not relevant as our technology does not use that particular feature, ...	
3rd technical attribute E.g. maximum tolerable Doppler shift	Required figures xxx Comments (e.g. it has been obtained using the following assumptions)	E.g., comments on the validity of the results; request for further hardware verification
…		
Comment sections	General comments from the proponents (e.g. new relevant technical parameters to take into account, etc.)	General comments from the evaluators (e.g. request for clarification, missing points, etc.)
2nd step comments	Reply to the evaluator’s comments	*Summary criterion evaluation*, including information about how the summary evaluation was achieved and the relative importance placed on the technical attributes and other considerations

9.4 Summary evaluations

In order to compare multiple RTTs, it is useful to have criteria evaluation summaries for each RTT. A criterion evaluation summary may be difficult to make when both qualitative and quantitative attributes must be considered, and when each technical attribute may have different relative importance with the overall evaluation criteria.

To facilitate such a criterion evaluation summary, Annex 3 identifies the importance or relative ranking of the various technical attributes within each of the evaluation criteria. These rankings are based upon current anticipated market needs within some countries. It is recognized that market needs may differ in various countries and may change over time. It is also recognized that some new technical attributes or important considerations may be identified during the evaluation procedure that would impact on any summary. As such, Annex 3 provides that evaluation groups may, if appropriate, modify the group of technical attributes, or add new attributes or considerations, in determining a criterion evaluation summary.

All evaluation groups are requested to include in the evaluation reports, information on the criterion evaluation summaries including the relative importance which was placed on each technical attribute and any other consideration that affected the summaries.

9.4.1 Methodology for criteria evaluation summaries

Some evaluation groups may wish to use a methodology to determine the criterion evaluation summaries. This section contains one example of a possible numerical methodology; however, other numerical or non-numerical methodologies may be used for criterion evaluation summaries provided adequate documentation is provided in the evaluation report as to how they were done.

The technical attributes given in Annex 3 are grouped relative to their overall impact on a specific evaluation criterion. Each group can be assigned a relative weight based upon their perceived importance or impact for each criterion. This allows the inclusion of both qualitative and quantitatively defined attributes to be simultaneously and objectively evaluated when comparing proposed RTTs.

RTT performance comparisons are done attribute by attribute for a given evaluation criterion. Relative attribute performance for different RTTs are quantified into four performance bins: poor, fair, good, and excellent. Attribute performance not supporting IMT-2000 objectives is graded poor and exceeding objectives as excellent.

Considering the relative attribute characterization noted above, a differential grade is determined based upon how attribute performances compare. After completion of the attribute performance comparisons, the attribute grading differentials are multiplied by the agreed upon weightings and aggregated to determine an overall RTT performance differential grade for that criterion.

ANNEX 1

Radio transmission technologies description template

Description of the radio transmission technology

The RTT has to be described in a detailed form to get an overview and an understanding of the functionalities of the technical approach. This Annex provides a template to aid in the technical description of the characteristics of a candidate RTT.

The following technical parameters, the relevant templates given in Annex 2 and any additionally useful information, should be provided for each test environment for which the candidate RTT is proposed to operate. This can be done by preparing:

– a separate template submission for each test environment; or

– a single submission that includes multiple answers for those technical parameters impacted by a test environment.

In addition to the detailed technical description described below, proponents should assure that their submission meets the overall IMT-2000 objectives as defined in existing Recommendations (see § 4). Submittors should also state if the current ITU policy for IPR is met for their RTT proposals.

The following table describes the technical parameters needed to characterise a proposal. Proponents should feel free to add any new information if required for a better assessment of their proposal.

IMT-2000 may serve both mobile users as well as fixed wireless users sharing common geographical locations and frequency bands. As a result, certain parameters may be designed for one or the other type of user in combination. To account for fixed wireless use of a candidate RTT, the description given in the template should indicate when a parameter has been designed for dual use.

TABLE OF CONTENTS

A1.1	Test environment support
A1.1.1	In what test environments will the RTT operate?
A1.1.2	If the RTT supports more than one test environment, what test environment does this technology description template address?
A1.1.3	Does the RTT include any features in support of FWA application? Provide detail about the impact of those features on the technical parameters provided in this template, stating whether the technical parameters provided apply for mobile as well as for FWA applications.
A1.2	Technical parameters NOTE 1 – Parameters for both forward link and reverse link should be described separately, if necessary.
A1.2.1	What is the minimum frequency band required to deploy the system (MHz)?
A1.2.2	What is the duplex method: TDD or FDD?
A1.2.2.1	What is the minimum up/down frequency separation for FDD?
A1.2.2.2	What is requirement of transmit/receive isolation? Does the proposal require a duplexer in either the mobile station (MS) or BS?
A1.2.3	Does the RTT allow asymmetric transmission to use the available spectrum? Characterize.
A1.2.4	What is the RF channel spacing (kHz)? In addition, does the RTT use an interleaved frequency plan? NOTE 1 – The use of the second adjacent channel instead of the adjacent channel at a neighbouring cluster cell is called “interleaved frequency planning”. If a proponent is going to employ an interleaved frequency plan, the proponent should state so in § A1.2.4 and complete § A1.2.15 with the protection ratio for both the adjacent and second adjacent channel.

A1.2.5	What is the bandwidth per duplex RF channel (MHz) measured at the 3 dB down points? It is given by (bandwidth per RF channel) × (1 for TDD and 2 for FDD). Provide detail.
A1.2.5.1	Does the proposal offer multiple or variable RF channel bandwidth capability? If so, are multiple bandwidths or variable bandwidths provided for the purposes of compensating the transmission medium for impairments but intended to be feature transparent to the end user?
A1.2.6	What is the RF channel bit rate (kbit/s)? NOTE 1 – The maximum modulation rate of RF (after channel encoding, adding of in-band control signalling and any overhead signalling) possible to transmit carrier over an RF channel, i.e. independent of access technology and of modulation schemes.
A1.2.7	*Frame structure*: describe the frame structure to give sufficient information such as: – frame length, – the number of time slots per frame, – guard time or the number of guard bits, – user information bit rate for each time slot, – channel bit rate (after channel coding), – channel symbol rate (after modulation), – associated control channel (ACCH) bit rate, – power control bit rate. NOTE 1 – Channel coding may include forward error correction (FEC), cyclic redundancy checking (CRC), ACCH, power control bits and guard bits. Provide detail. NOTE 2 – Describe the frame structure for forward link and reverse link, respectively. NOTE 3 – Describe the frame structure for each user information rate.
A1.2.8	Does the RTT use frequency hopping? If so, characterize and explain particularly the impact (e.g. improvements) on system performance.
A1.2.8.1	What is the hopping rate?
A1.2.8.2	What is the number of the hopping frequency sets?
A1.2.8.3	Are BSs synchronized or non-synchronized?
A1.2.9	Does the RTT use a spreading scheme?
A1.2.9.1	What is the chip rate (Mchip/s)? Rate at input to modulator.
A1.2.9.2	What is the processing gain? 10 log (chip rate/information rate).
A1.2.9.3	Explain the uplink and downlink code structures and provide the details about the types (e.g. personal numbering (PN) code, Walsh code) and purposes (e.g. spreading, identification, etc.) of the codes.
A1.2.10	Which access technology does the proposal use: TDMA, FDMA, CDMA, hybrid, or a new technology? In the case of CDMA, which type of CDMA is used: frequency hopping (FH) or direct sequence (DS) or hybrid? Characterize.
A1.2.11	What is the baseband modulation technique? If both the data modulation and spreading modulation are required, describe in detail. What is the peak to average power ratio after baseband filtering (dB)?
A1.2.12	What are the channel coding (error handling) rate and form for both the forward and reverse links? E.g., does the RTT adopt: – FEC or other schemes? – Unequal error protection? Provide details. – Soft decision decoding or hard decision decoding? Provide details. – Iterative decoding (e.g. turbo codes)? Provide details. – Other schemes?
A1.2.13	What is the bit interleaving scheme? Provide detailed description for both uplink and downlink.
A1.2.14	Describe the approach taken for the receivers (MS and BS) to cope with multipath propagation effects (e.g. via equalizer, Rake receiver, etc.).

A1.2.14.1	Describe the robustness to intersymbol interference and the specific delay spread profiles that are best or worst for the proposal.
A1.2.14.2	Can rapidly changing delay spread profile be accommodated? Describe.
A1.2.15	What is the adjacent channel protection ratio? NOTE 1 – In order to maintain robustness to adjacent channel interference, the RTT should have some receiver characteristics that can withstand higher power adjacent channel interference. Specify the maximum allowed relative level of adjacent RF channel power (dBc). Provide detail how this figure is assumed.
A1.2.16	Power classes
A1.2.16.1	*Mobile terminal emitted power*: what is the radiated antenna power measured at the antenna? For terrestrial component, give (dBm). For satellite component, the mobile terminal emitted power should be given in e.i.r.p. (effective isotropic radiated power) (dBm).
A1.2.16.1.1	What is the maximum peak power transmitted while in active or busy state?
A1.2.16.1.2	What is the time average power transmitted while in active or busy state? Provide detailed explanation used to calculate this time average power.
A1.2.16.2	Base station transmit power per RF carrier for terrestrial component
A1.2.16.2.1	What is the maximum peak transmitted power per RF carrier radiated from antenna?
A1.2.16.2.2	What is the average transmitted power per RF carrier radiated from antenna?
A1.2.17	What is the maximum number of voice channels available per RF channel that can be supported at one BS with 1 RF channel (TDD systems) or 1 duplex RF channel pair (FDD systems), while still meeting ITU-T Recommendation G.726 performance requirements?
A1.2.18	*Variable bit rate capabilities*: describe the ways the proposal is able to handle variable baseband transmission rates. For example, does the RTT use: – adaptive source and channel coding as a function of RF signal quality? – Variable data rate as a function of user application? – Variable voice/data channel utilization as a function of traffic mix requirements? Characterize how the bit rate modification is performed. In addition, what are the advantages of your system proposal associated with variable bit rate capabilities?
A1.2.18.1	What are the user information bit rates in each variable bit rate mode?
A1.2.19	What kind of voice coding scheme or codec is assumed to be used in proposed RTT? If the existing specific voice coding scheme or codec is to be used, give the name of it. If a special voice coding scheme or codec (e.g. those not standardized in standardization bodies such as ITU) is indispensable for the proposed RTT, provide detail, e.g. scheme, algorithm, coding rates, coding delays and the number of stochastic code books.
A1.2.19.1	Does the proposal offer multiple voice coding rate capability? Provide detail.
A1.2.20	*Data services*: are there particular aspects of the proposed technologies which are applicable for the provision of circuit-switched, packet-switched or other data services like asymmetric data services? For each service class (A, B, C and D) a description of RTT services should be provided, at least in terms of bit rate, delay and BER/frame error rate (FER). NOTE 1 – See Recommendation ITU-R M.1224 for the definition of: – “circuit transfer mode”, – “packet transfer mode”, – “connectionless service”, and for the aid of understanding “circuit switched” and “packet switched” data services. NOTE 2 – See ITU-T Recommendation I.362 for details about the service classes A, B, C and D.
A1.2.20.1	For delay constrained, connection oriented (Class A).
A1.2.20.2	For delay constrained, connection oriented, variable bit rate (Class B).
A1.2.20.3	For delay unconstrained, connection oriented (Class C).
A1.2.20.4	For delay unconstrained, connectionless (Class D).

A1.2.21	Simultaneous voice/data services: is the proposal capable of providing multiple user services simultaneously with appropriate channel capacity assignment? NOTE 1 – The following describes the different techniques that are inherent or improve to a great extent the technology described above to be presented. Description for both BS and MS are required in attributes from § A1.2.22 through § A1.2.23.2.
A1.2.22	*Power control characteristics*: is a power control scheme included in the proposal? Characterize the impact (e.g. improvements) of supported power control schemes on system performance.
A1.2.22.1	What is the power control step size (dB)?
A1.2.22.2	What are the number of power control cycles per second?
A1.2.22.3	What is the power control dynamic range (dB)?
A1.2.22.4	What is the minimum transmit power level with power control?
A1.2.22.5	What is the residual power variation after power control when RTT is operating? Provide details about the circumstances (e.g. in terms of system characteristics, environment, deployment, MS-speed, etc.) under which this residual power variation appears and which impact it has on the system performance.
A1.2.23	*Diversity combining in MS and BS*: are diversity combining schemes incorporated in the design of the RTT?
A1.2.23.1	Describe the diversity techniques applied in the MS and at the BS, including micro diversity and macro diversity, characterizing the type of diversity used, for example: – time diversity: repetition, Rake-receiver, etc., – space diversity: multiple sectors, multiple satellite, etc., – frequency diversity: FH, wideband transmission, etc., – code diversity: multiple PN codes, multiple FH code, etc., – other scheme. Characterize the diversity combining algorithm, for example, switch diversity, maximal ratio combining, equal gain combining. Additionally, provide supporting values for the number of receivers (or demodulators) per cell per mobile user. State the dB of performance improvement introduced by the use of diversity. For the MS: what is the minimum number of RF receivers (or demodulators) per mobile unit and what is the minimum number of antennas per mobile unit required for the purpose of diversity reception? These numbers should be consistent to that assumed in the link budget template of Annex 2 and that assumed in the calculation of the "capacity" defined at § A1.3.1.5.
A1.2.23.2	What is the degree of improvement expected (dB)? Also indicate the assumed conditions such as BER and FER.
A1.2.24	*Handover/automatic radio link transfer (ALT)*: do the radio transmission technologies support handover? Characterize the type of handover strategy (or strategies) which may be supported, e.g. MS assisted handover. Give explanations on potential advantages, e.g. possible choice of handover algorithms. Provide evidence whenever possible.
A1.2.24.1	What is the break duration (s) when a handover is executed? In this evaluation, a detailed description of the impact of the handover on the service performance should also be given. Explain how the estimate was derived.
A1.2.24.2	For the proposed RTT, can handover cope with rapid decrease in signal strength (e.g. street corner effect)? Give a detailed description of: – the way the handover detected, initiated and executed, – how long each of this action lasts (minimum/maximum time (ms)), – the time-out periods for these actions.
A1.2.25	Characterize how the proposed RTT reacts to the system deployment (e.g. necessity to add new cells and/or new carriers) particularly in terms of frequency planning.
A1.2.26	*Sharing frequency band capabilities*: to what degree is the proposal able to deal with spectrum sharing among IMT-2000 systems as well as with all other systems: – spectrum sharing between operators, – spectrum sharing between terrestrial and satellite IMT-2000 systems, – spectrum sharing between IMT-2000 and non-IMT-2000 systems, – other sharing schemes.
A1.2.27	*Dynamic channel allocation*: characterize the dynamic channel allocation (DCA) schemes which may be supported and characterize their impact on system performance (e.g. in terms of adaptability to varying interference conditions, adaptability to varying traffic conditions, capability to avoid frequency planning, impact on the reuse distance, etc.).

A1.2.28	*Mixed cell architecture*: how well does the RTT accommodate mixed cell architectures (pico, micro and macrocells)? Does the proposal provide pico, micro and macro cell user service in a single licensed spectrum assignment, with handoff as required between them? (terrestrial component only). NOTE 1 – Cell definitions are as follows: – pico – cell hex radius: $r < 100$ m – micro: 100 m $< r <$ 1 000 m – macro: $r >$ 1 000 m.
A1.2.29	Describe any battery saver/intermittent reception capability.
A1.2.29.1	*Ability of the MS to conserve standby battery power*: provide details about how the proposal conserves standby battery power.
A1.2.30	*Signalling transmission scheme*: if the proposed system will use RTTs for signalling transmission different from those for user data transmission, describe the details of the signalling transmission scheme over the radio interface between terminals and base (satellite) stations.
A1.2.30.1	Describe the different signalling transfer schemes which may be supported, e.g. in connection with a call, outside a call. Does the RTT support: – new techniques? Characterize. – Signalling enhancements for the delivery of multimedia services? Characterize.
A1.2.31	Does the RTT support a bandwidth on demand (BOD) capability? BOD refers specifically to the ability of an end-user to request multi-bearer services. Typically, this is given as the capacity in the form of bits per second of throughput. Multi-bearer services can be implemented by using such technologies as multi-carrier, multi-time slot or multi-codes. If so, characterize these capabilities. NOTE 1 – BOD does not refer to the self-adaptive feature of the radio channel to cope with changes in the transmission quality (see § A1.2.5.1).
A1.2.32	Does the RTT support channel aggregation capability to achieve higher user bit rates?
A1.3	Expected performances.
A1.3.1	For terrestrial test environment only.
A1.3.1.1	What is the achievable BER floor level (for voice)? NOTE 1 – The BER floor level is evaluated under the BER measuring conditions defined in Annex 2 using the data rates indicated in § 1 of Annex 2.
A1.3.1.2	What is the achievable BER floor level (for data)? NOTE 1 – The BER floor level is evaluated under the measuring conditions defined in Annex 2 using the data rates indicated in § 1 of Annex 2.
A1.3.1.3	What is the maximum tolerable delay spread (ns) to maintain the voice and data service quality requirements? NOTE 1 – The BER is an error floor level measured with the Doppler shift given in the BER measuring conditions of Annex 2.
A1.3.1.4	What is the maximum tolerable Doppler shift (Hz) to maintain the voice and data service quality requirements? NOTE 1 – The BER is an error floor level measured with the delay spread given in the BER measuring conditions of Annex 2.
A1.3.1.5	*Capacity*: the capacity of the radio transmission technology has to be evaluated assuming the deployment models described in Annex 2 and technical parameters from § A1.2.22 through § A1.2.23.2.
A1.3.1.5.1	What is the voice traffic capacity per cell (not per sector): provide the total traffic that can be supported by a single cell (E/MHz/cell) in a total available assigned non-contiguous bandwidth of 30 MHz (15 MHz forward/15 MHz reverse) for FDD mode or contiguous bandwidth of 30 MHz for TDD mode. Provide capacities for all penetration values defined in the deployment model for the test environment in Annex 2. The procedure to obtain this value is described in Annex 2. The capacity supported by not a standalone cell but a single cell within contiguous service area should be obtained here.
A1.3.1.5.2	What is the information capacity per cell (not per sector): provide the total number of user-channel information bits which can be supported by a single cell (Mbit/s/MHz/cell) in a total available assigned non-contiguous bandwidth of 30 MHz (15 MHz forward/15 MHz reverse) for FDD mode or contiguous bandwidth of 30 MHz for TDD mode. Provide capacities for all penetration values defined in the deployment model for the test environment in Annex 2. The procedure to obtain this value is described in Annex 2. The capacity supported by not a standalone cell but a single cell within contiguous service area should be obtained here.

A1.3.1.6	Does the RTT support sectorization? If yes, provide for each sectorization scheme and the total number of user-channel information bits which can be supported by a single site (Mbit/s/MHz) (and the number of sectors) in a total available assigned non-contiguous bandwidth of 30 MHz (15 MHz forward/15 MHz reverse) in FDD mode or contiguous bandwidth of 30 MHz in TDD mode.
A1.3.1.7	*Coverage efficiency*: the coverage efficiency of the radio transmission technology has to be evaluated assuming the deployment models described in Annex 2.
A1.3.1.7.1	What is the base site coverage efficiency (km^2/site) for the lowest traffic loading in the voice only deployment model? Lowest traffic loading means the lowest penetration case described in Annex 2.
A1.3.1.7.2	What is the base site coverage efficiency (km^2/site) for the lowest traffic loading in the data only deployment model? Lowest traffic loading means the lowest penetration case described in Annex 2.
A1.3.2	For satellite test environment only
A1.3.2.1	What is the required C/N_0 to achieve objective performance defined in Annex 2?
A1.3.2.2	What are the Doppler compensation method and residual Doppler shift after compensation?
A1.3.2.3	*Capacity*: the spectrum efficiency of the radio transmission technology has to be evaluated assuming the deployment models described in Annex 2.
A1.3.2.3.1	What is the voice information capacity per required RF bandwidth (bit/s/Hz)?
A1.3.2.3.2	What is the voice plus data information capacity per required RF bandwidth (bit/s/Hz)?
A1.3.2.4	*Normalized power efficiency*: the power efficiency of the radio transmission technology has to be evaluated assuming the deployment models described in Annex 2.
A1.3.2.4.1	What is the supported information bit rate per required carrier power-to-noise density ratio for the given channel performance under the given interference conditions for voice?
A1.3.2.4.2	What is the supported information bit rate per required carrier power-to-noise density ratio for the given channel performance under the given interference conditions for voice plus data?
A1.3.3	*Maximum user bit rate (for data)*: specify the maximum user bit rate (kbit/s) available in the deployment models described in Annex 2.
A1.3.4	What is the maximum range (m) between a user terminal and a BS (prior to hand-off, relay, etc.) under nominal traffic loading and link impairments as defined in Annex 2?
A1.3.5	Describe the capability for the use of repeaters.
A1.3.6	*Antenna systems*: fully describe the antenna systems that can be used and/or have to be used; characterize their impacts on systems performance, (terrestrial only); e.g., does the RTT have the capability for the use of: – remote antennas: describe whether and how remote antenna systems can be used to extend coverage to low traffic density areas; – distributed antennas: describe whether and how distributed antenna designs are used, and in which IMT-2000 test environments; – Smart antennas (e.g., switched beam, adaptive, etc.): describe how smart antennas can be used and what is their impact on system performance; – other antenna systems.
A1.3.7	Delay (for voice)
A1.3.7.1	What is the radio transmission processing delay due to the overall process of channel coding, bit interleaving, framing, etc., not including source coding? This is given as transmitter delay from the input of the channel coder to the antenna plus the receiver delay from the antenna to the output of the channel decoder. Provide this information for each service being provided. In addition, a detailed description of how this parameter was calculated is required for both the uplink and the downlink.
A1.3.7.2	What is the total estimated round trip delay (ms) to include both the processing delay, propagation delay (terrestrial only) and vocoder delay? Give the estimated delay associated with each of the key attributes described in Fig. 6 that make up the total delay provided.
A1.3.7.3	Does the proposed RTT need echo control?

A1.3.8	What is the MOS level for the proposed codec for the relevant test environments given in Annex 2? Specify its absolute MOS value and its relative value with respect to the MOS value of ITU-T Recommendation G.711 (64 k PCM) and ITU-T Recommendation G.726 (32 k ADPCM). NOTE 1 – If a special voice coding algorithm is indispensable for the proposed RTT, the proponent should declare detail with its performance of the codec such as MOS level. (See § A1.2.19)
A1.3.9	Description of the ability to sustain quality under certain extreme conditions.
A1.3.9.1	*System overload (terrestrial only)*: characterize system behaviour and performance in such conditions for each test services in Annex 2, including potential impact on adjacent cells. Describe the effect on system performance in terms of blocking grade of service for the cases that the load on a particular cell is 125%, 150%, 175%, and 200% of full load. Also describe the effect of blocking on the immediate adjacent cells. Voice service is to be considered here. Full load means a traffic loading which results in 1% call blocking with the BER of 1×10^{-3} maintained.
A1.3.9.2	*Hardware failures*: characterize system behaviour and performance in such conditions. Provide detailed explanation on any calculation.
A1.3.9.3	*Interference immunity*: characterize system immunity or protection mechanisms against interference. What is the interference detection method? What is the interference avoidance method?
A1.3.10	Characterize the adaptability of the proposed RTT to different and/or time-varying conditions (e.g. propagation, traffic, etc.) that are not considered in the above attributes of § A1.3.
A1.4	Technology design constraints
A1.4.1	*Frequency stability*: provide transmission frequency stability (not oscillator stability) requirements of the carrier (include long term – 1 year – frequency stability requirements (ppm)).
A1.4.1.1	For BS transmission (terrestrial component only).
A1.4.1.2	For MS transmission.
A1.4.2	*Out-of-band and spurious emissions*: specify the expected levels of base or satellite and mobile transmitter emissions outside the operating channel, as a function of frequency offset.
A1.4.3	*Synchronisation requirements*: describe RTT's timing requirements, e.g. – Is BS-to-BS or satellite land earth station (LES)-to-LES synchronisation required? Provide precise information, the type of synchronisation, i.e., synchronisation of carrier frequency, bit clock, spreading code or frame, and their accuracy. – Is BS-to-network synchronisation required? (terrestrial only). – State short-term frequency and timing accuracy of BS (or LES) transmit signal. – State source of external system reference and the accuracy required, if used at BS (or LES) (for example: derived from wireline network, or GPS receiver). – State free run accuracy of MS frequency and timing reference clock. – State base-to-base bit time alignment requirement over a 24 h period (μs).
A1.4.4	*Timing jitter*: for BS (or LES) and MS give: – the maximum jitter on the transmit signal, – the maximum jitter tolerated on the received signal. Timing jitter is defined as r.m.s. value of the time variance normalized by symbol duration.
A1.4.5	*Frequency synthesizer*: what is the required step size, switched speed and frequency range of the frequency synthesizer of MSs?
A1.4.6	Does the proposed system require capabilities of fixed networks not generally available today?
A1.4.6.1	Describe the special requirements on the fixed networks for the handover procedure. Provide handover procedure to be employed in proposed RTT in detail.
A1.4.7	Fixed network feature transparency
A1.4.7.1	Which service(s) of the standard set of ISDN bearer services can the proposed RTT pass to users without fixed network modification.
A1.4.8	Characterize any radio resource control capabilities that exist for the provision of roaming between a private (e.g., closed user group) and a public IMT-2000 operating environment.

A1.4.9	Describe the estimated fixed signalling overhead (e.g., broadcast control channel, power control messaging). Express this information as a percentage of the spectrum which is used for fixed signalling. Provide detailed explanation on your calculations.
A1.4.10	Characterize the linear and broadband transmitter requirements for BS and MS (terrestrial only).
A1.4.11	Are linear receivers required? Characterize the linearity requirements for the receivers for BS and MS (terrestrial only).
A1.4.12	Specify the required dynamic range of receiver (terrestrial only).
A1.4.13	What are the signal processing estimates for both the handportable and the BS? – MOPS (millions of operations per second) value of parts processed by DSP (digital signal processing), – gate counts excluding DSP, – ROM size requirements for DSP and gate counts (kbytes), – RAM size requirements for DSP and gate counts (kbytes). NOTE 1 – At a minimum the evaluation should review the signal processing estimates (MOPS, memory requirements, gate counts) required for demodulation, equalization, channel coding, error correction, diversity processing (including Rake receivers), adaptive antenna array processing, modulation, A-D and D-A converters and multiplexing as well as some IF and baseband filtering. For new technologies, there may be additional or alternative requirements (such as FFTs etc.). NOTE 2 – The signal processing estimates should be declared with the estimated condition such as assumed services, user bit rate and etc.
A1.4.14	*Dropped calls*: describe how the RTT handles dropped calls. Does the proposed RTT utilize a transparent reconnect procedure – that is, the same as that employed for handoff?
A1.4.15	Characterize the frequency planning requirements: – frequency reuse pattern: given the required *C*/*I* and the proposed technologies, specify the frequency cell reuse pattern (e.g. 3-cell, 7-cell, etc.) and, for terrestrial systems, the sectorization schemes assumed; – characterize the frequency management between different cell layers; – does the RTT use an interleaved frequency plan? – are there any frequency channels with particular planning requirements? – all other relevant requirements. NOTE 1 – The use of the second adjacent channel instead of the adjacent channel at a neighbouring cluster cell is called "interleaved frequency planning". If a proponent is going to employ an interleaved frequency plan, the proponent should state so in § A1.2.4 and complete § A1.2.15 with the protection ratio for both the adjacent and second adjacent channel.
A1.4.16	Describe the capability of the proposed RTT to facilitate the evolution of existing radio transmission technologies used in mobile telecommunication systems migrate toward this RTT. Provide detail any impact and constraint on evolution.
A1.4.17	Are there any special requirements for base site implementation? Are there any features which simplify implementation of base sites? (terrestrial only)
A1.5	Information required for terrestrial link budget template Proponents should fulfil the link budget template given in Table 6 and answer the following questions.
A1.5.1	What is the BS noise figure (dB)?
A1.5.2	What is the MS noise figure (dB)?
A1.5.3	What is the BS antenna gain (dBi)?
A1.5.4	What is the MS antenna gain (dBi)?
A1.5.5	What is the cable, connector and combiner losses (dB)?
A1.5.6	What are the number of traffic channels per RF carrier?
A1.5.7	What is the RTT operating point (BER/FER) for the required E_b/N_0 in the link budget template?
A1.5.8	What is the ratio of intra-sector interference to sum of intra-sector interference and inter-sector interference within a cell (dB)?
A1.5.9	What is the ratio of in-cell interference to total interference (dB)?
A1.5.10	What is the occupied bandwidth (99%) (Hz)?

A1.5.11	What is the information rate (dBHz)?
A1.6	*Satellite system configuration* (applicable to satellite component only): Configuration details in this subsection are not to be considered as variables. They are for information only.
A1.6.1	Configuration of satellite constellation
A1.6.1.1	GSO, HEO, MEO, LEO or combination?
A1.6.1.2	What is the range of height where satellites are in active communication?
A1.6.1.3	What is the orbit inclination angle?
A1.6.1.4	What are the number of orbit planes?
A1.6.1.5	What are the number of satellites per orbit plane?
A1.6.2	What is the configuration of spot beams/cell layout pattern?
A1.6.3	What is the frequency reuse plan among spot beams?
A1.6.4	What is the service link G/T of satellite beam (average, minimum)?
A1.6.5	What is the service link saturation e.i.r.p. of each beam (average, minimum), when configured to support 'hot spot'?
A1.6.6	What is the service link total saturation e.i.r.p. per satellite?
A1.6.7	Satellite e.i.r.p. per RF carrier for satellite component.
A1.6.7.1	What is the maximum peak e.i.r.p. transmitted per RF carrier?
A1.6.7.2	What is the average e.i.r.p. transmitted per RF carrier?
A1.6.8	What is the feeder link information?
A1.6.9	What is the slot timing adjustment method (mainly applicable to TDMA system)?
A1.6.10	What is the satellite diversity method, if applicable?

ANNEX 2

Test environments and deployment models

This Annex describes the reference scenarios (test environments and deployment models) and propagation models necessary to elaborate the performance figures of candidate terrestrial and satellite RTTs for IMT-2000. The terrestrial and the satellite component are subdivided in Parts 1 and 2, respectively.

PART 1

Terrestrial component

1 Test environments

This section will provide the reference model for each test operating environment. These test environments are intended to cover the range of IMT-2000 operating environments. The necessary parameters to identify the reference models include the test propagation environments, traffic conditions, user information rate for prototype voice and data services, and the objective performance criteria for each test operating environment.

The test operating environments are considered as a basic factor in the evaluation process of the RTTs. The reference models are used to estimate the critical aspects, such as the spectrum, coverage and power efficiencies. This estimation will be based on system-level calculations and link-level software simulations using propagation and traffic models.

Critical aspects of RTTs, such as spectrum and coverage efficiencies, cannot be fairly estimated independently of appropriate IMT-2000 services. These IMT-2000 services are, as minimum, characterised by:

– ranges of supported data rates,

– BER requirements,

– one way delay requirements,

– activity factor,

– traffic models.

Table 1 provides a list of test data rates for evaluation purposes.

TABLE 1

List of test data rates for evaluation purposes

Test environments	Indoor office	Outdoor to indoor and pedestrian	Vehicular
Test services	Bit rates (values) BER Channel activity	Bit rates (values) BER Channel activity	Bit rates (values) BER Channel activity
Representative low delay data bearer for speech(1)	8-16-32 kbit/s $\leq 1 \times 10^{-3}$ 50%	8-16-32 kbit/s $\leq 1 \times 10^{-3}$ 50%	8-16-32 kbit/s $\leq 1 \times 10^{-3}$ 50%
Data (circuit-switched, low delay)(1)	64-**144**-384-512- 1 024-2 048 kbit/s $\leq 1 \times 10^{-6}$ 100%	**64**-144 kbit/s $\leq 1 \times 10^{-6}$ 100%	16-**32**-64 kbit/s $\leq 1 \times 10^{-6}$ 100%
Data (circuit-switched, long delay constrained)(1)	64-**144**-384-512- 1 024-2 048 kbit/s $\leq 1 \times 10^{-6}$ 100%	**64**-144 kbit/s $\leq 1 \times 10^{-6}$ 100%	16-**32**-64 kbit/s $\leq 1 \times 10^{-6}$ 100%
Data (packet)(1)	64-**144**-384-512 - 1 024-2 048 kbit/s $\leq 1 \times 10^{-6}$ Poisson arrivals(2)	**64**-144 kbit/s $\leq 1 \times 10^{-6}$ Poisson arrivals(2)	16-**32**-64 kbit/s $\leq 1 \times 10^{-6}$ Poisson arrivals(2)

(1) Proponents must indicate the achieved one-way delay (excluding propagation delay and processing delay of voice channel coding) for all the test services.

(2) For packet data service an interarrival process with Poisson distribution has to be considered. Packet block size is of exponential length.

NOTE 1 – The delay values for various services are to be derived from service (e.g. speech) requirements which may vary from one test environment to another. Coordination between different evaluations is encouraged in order to achieve comparable evaluation results.

In the coverage and spectrum efficiencies evaluation procedure, proponents shall use:

– "speech" – one among the data rates given in Table 1;

– data – for each service the evaluation of RTTs or SRTTs shall be performed for at least the following two data rates from Table 1:

  – one data rate equal to the proposed value indicated in bold;

  – the maximum data rate of the proposed RTT or SRTT.

It is open to the proponent of an RTT (or SRTT) to give performance for more than two data rates to show advantages of the proposed technology.

1.1 Test environment descriptions

A central factor of mobile radio propagation environments is multi-path propagation causing fading and channel time dispersion. The fading characteristics vary with the propagation environment and its impact on the communication quality (i.e. bit error patterns) is highly dependent on the speed of the mobile station relative to the serving base station. These environments are described in Recommendation ITU-R M.1034.

The purpose of the test environments is to challenge the RTTs. Instead of constructing propagation models for all possible IMT-2000 operating environments, a smaller set of test environments is defined which adequately span the overall range of possible environments. The descriptions of these test environments may therefore not correspond with those of the actual operating environments.

This section will identify the propagation model for each test operating environment listed below. For practical reasons, these test operating environments are an appropriate subset of the IMT-2000 operating environments described in Recommendation ITU-R M.1034. While simple models are adequate to evaluate the performance of individual radio links, more complex models are needed to evaluate the overall system-level reliability and suitability of specific technologies. For narrowband technologies, time delay spread may be characterized by its r.m.s. value alone; for wideband technologies, however, the number, strength, and relative time delay of the many signal components become important. For some technologies (e.g. those employing power control) these models must include coupling between all co-channel propagation links to achieve maximum accuracy. Also, in some cases, the large-scale (shadow fading) temporal variations of the environment must be modelled.

The key parameters to describe each propagation model would include:

– time delay-spread, its structure, and its statistical variability (e.g. probability distribution of time delay spread);

– geometrical path loss rule (e.g. R^{-4}) and excess path loss;

– shadow fading;

– multipath fading characteristics (e.g. Doppler spectrum, Rician vs. Rayleigh) for the envelope of channels;

– operating radio frequency.

Statistical models are proposed in § 1.2 to generate path losses and time delay structures for paths in each test environment.

It should be noted that IMT-2000 will be a world-wide standard. Therefore, the models proposed for evaluation of RTTs should consider a broad range of environment characteristics, e.g. large and small cities, tropical, rural, and desert areas.

The following sections provide a brief description of the conditions that might be expected in the identified environments. The specific channel parameters are found in the appropriate parts of § 1.2.

IMT-2000 may include both mobile wireless and fixed wireless applications. It should be noted that for the purpose of evaluation, operation in the fixed environment is considered to be covered by the mobile test environments. Generally, the fixed wireless channel model will be less complex due to lack of mobility. As a result, there is a trade-off possible between fixed and mobile users which should be considered while evaluating RTTs.

1.1.1 Indoor office test environment

This environment is also characterized by small cells and low transmit powers. Both base stations and pedestrian users are located indoors. Section 1.2.2 describes the channel impulse response model and its parameters. The path loss rule varies due to scatter and attenuation by walls, floors, and metallic structures such as partitions and filing cabinets. These objects also produce shadowing effects. A log-normal shadow fading standard deviation of 12 dB can be expected. Fading ranges from Rician to Rayleigh, with Doppler frequency offsets set by walking speeds.

1.1.2 Outdoor to indoor and pedestrian test environment

This environment is characterized by small cells and low transmit power. Base stations with low antenna heights are located outdoors; pedestrian users are located on streets and inside buildings and residences. Section 1.2.2 describes the channel impulse response model. A geometrical path loss rule of R^{-4} is appropriate, but a wider range should be considered. If the path is a line of sight on a canyon-like street, for example, the path loss follows a R^{-2} rule where there is Fresnel zone clearance. For the region where there is no longer Fresnel zone clearance, a path loss rule of R^{-4} is appropriate but a range up to R^{-6} may be encountered due to trees and other obstructions along the path. Log-normal shadow fading with a standard deviation of 10 dB is reasonable for outdoors and 12 dB for indoor. Building penetration loss averages 12 dB with a standard deviation of 8 dB. Rayleigh and/or Rician fading rates are generally set by walking speeds, but faster fading due to reflections from moving vehicles is occasionally seen.

1.1.3 Vehicular test environment

This environment is characterized by larger cells and higher transmit power. Assuming limited spectrum, higher cell capacity will be important. Section 1.2.2 describes the channel impulse response model and its parameters. A geometrical path loss rule of R^{-4} and log-normal shadow fading with 10 dB standard deviation are appropriate in urban and suburban areas. In rural areas with flat terrain the path loss is lower than that of urban and suburban areas. In mountainous areas, if path blockage are avoided by choosing base station locations, a path loss rule closer to R^{-2} may be appropriate. Rayleigh fading rates are set by vehicle speeds. Lower fading rates are appropriate for applications employing stationary terminals.

1.1.4 Mixed test environment

It is not sufficient for a RTT to have good performance in only one of the specified test environments defined in this section. The RTT should also have a good performance in a mixed environment, see Recommendation ITU-R M.1035, § 10. For example, it can be a “vehicular test environment” (macro cells) and an “outdoor to indoor test environment” (micro cells) in the same geographical area. In this area fast moving terminals (vehicles) should probably be connected to the macro cells to reduce the handoff rate (number of hand-offs per minute) and slow moving terminals (pedestrians) should be connected to the micro cells to achieve high capacity.

1.2 Propagation models

The following sections provide both path loss models and channel impulse response models for the terrestrial component.

For the terrestrial environments, the propagation effects are divided into three distinct types of model. These are mean path loss, slow variation about the mean due to shadowing and scattering, and the rapid variation in the signal due to multipath effects. Equations are given for mean path loss for each of the three terrestrial environments. The slow variation is considered to be log-normally distributed. This is described by the standard deviation (given in the deployment model section).

Finally, the rapid variation is characterized by the channel impulse response. Channel impulse response is modelled using a tapped delay line implementation. The characteristics of the tap variability is characterized by the Doppler spectrum. A detailed treatment of the propagation models is found in Appendix 1.

1.2.1 Path loss models

Equations are given for mean path loss as a function of distance for each of the terrestrial environments except the mixed-cell test environment. The slow variation is considered to be log-normally distributed. This is described by the standard deviation (dB) and the decorrelation length of this long-term fading for the vehicular test environment.

1.2.1.1 Path loss model for indoor office test environment

The indoor path loss model (dB) is in the following simplified form, which is derived from the COST 231 indoor model presented in Appendix 1. This low increase of path loss versus distance is a worst-case from the interference point of view:

$$L = 37 + 30 \log_{10} R + 18.3\, n^{\left(\frac{n+2}{n+1} - 0.46\right)}$$

where:

R: transmitter-receiver separation (m)

n: number of floors in the path.

NOTE 1 – L shall in no circumstances be less than free space loss. A log-normal shadow fading standard deviation of 12 dB can be expected.

1.2.1.2 Path loss model for outdoor to indoor and pedestrian test environment

The following model should be used for the outdoor to indoor and pedestrian test environment:

$$L = 40 \log_{10} R + 30 \log_{10} f + 49$$

where:

R: base station – mobile station separation (km)

f: carrier frequency of 2 000 MHz for IMT-2000 band application.

NOTE 1– L shall in no circumstances be less than free space loss. This model is valid for non-line-of-sight (NLOS) case only and describes worse case propagation. Log-normal shadow fading with a standard deviation of 10 dB for outdoor users and 12 dB for indoor users is assumed. The average building penetration loss is 12 dB with a standard deviation of 8 dB.

1.2.1.3 Path loss model for vehicular test environment

This model, based on the same general format as in § 1.2.1.2, is applicable for the test scenarios in urban and suburban areas outside the high rise core where the buildings are of nearly uniform height:

$$L = 40 (1 - 4 \times 10^{-3} \Delta h_b) \log_{10} R - 18 \log_{10} \Delta h_b + 21 \log_{10} f + 80 \qquad \text{dB}$$

where:

R: base station – mobile station separation (km)

f: carrier frequency of 2 000 MHz

Δh_b: base station antenna height (m), measured from the average rooftop level.

To quantitatively evaluate each RTT, the base station antenna height is fixed at 15 m above the average rooftop (Δh_b = 15 m). Each proponent has an option to specify an alternate base station antenna height to optimize coverage and spectrum efficiency in their proposal.

NOTE 1 – L shall in no circumstances be less than free space loss. This model is valid for NLOS case only and describes worse case propagation. Log-normal shadow fading with 10 dB standard deviation are assumed in both urban and suburban areas.

NOTE 2 – The path loss model is valid for a range of Δh_b from 0 to 50 m.

1.2.1.4 Decorrelation length of the long-term fading

The long-term (log-normal) fading in the logarithmic scale around the mean path loss L (dB) is characterized by a Gaussian distribution with zero mean and standard deviation. Due to the slow fading process versus distance Δx, adjacent fading values are correlated. Its normalized autocorrelation function $R(\Delta x)$ can be described with sufficient accuracy by an exponential function (Gudmundson, M. [7 November, 1991] Correlation Model for Shadow Fading in Mobile Radio Systems. *Electron. Lett.*, Vol. 27, **23**, 2145-2146):

$$R(\Delta x) = e^{-\frac{|\Delta x|}{d_{cor}} \ln 2}$$

with the decorrelation length d_{cor}, which is dependent on the environment. This concept can be applied in the vehicular test environment with a decorrelation length of 20 m.

1.2.2 Channel impulse response model

For each terrestrial test environment, a channel impulse response model based on a tapped-delay line model is given. The model is characterized by the number of taps, the time delay relative to the first tap, the average power relative to the strongest tap, and the Doppler spectrum of each tap. A majority of the time, r.m.s. delay spreads are relatively small, but occasionally, there are “worst case” multipath characteristics that lead to much larger r.m.s. delay spreads. Measurements in outdoor environments show that r.m.s. delay spread can vary over an order of magnitude, within the same environment. Although large delay spreads occur relatively infrequently, they can have a major impact on system performance. To accurately evaluate the relative performance of candidate RTTs, it is desirable to model the variability of delay spread as well as the “worst case” locations where delay spread is relatively large.

As this delay spread variability cannot be captured using a single tapped delay line, up to two multipath channels are defined for each test environment. Within one test environment channel A is the low delay spread case that occurs frequently, channel B is the median delay spread case that also occurs frequently. Each of these two channels is expected to be encountered for some percentage of time in a given test environment. Table 2 gives percentage of time the particular channel may be encountered with the associated r.m.s. average delay spread for channel A and channel B for each terrestrial test environment.

TABLE 2

Parameters for channel impulse response model

Test environment	Channel A		Channel B	
	r.m.s. (ns)	*P* (%)	r.m.s. (ns)	*P* (%)
Indoor office	35	50	100	45
Outdoor to indoor and pedestrian	45	40	750	55
Vehicular – high antenna	370	40	4 000	55

Tables 3 to 5 describe the tapped-delay-line parameters for each of the terrestrial test environments. For each tap of the channels three parameters are given: the time delay relative to the first tap, the average power relative to the strongest tap, and the Doppler spectrum of each tap. A small variation, ±3%, in the relative time delay is allowed so that the channel sampling rate can be made to match some multiple of the link simulation sample rate.

TABLE 3

Indoor office test environment tapped-delay-line parameters

Tap	Channel A		Channel B		Doppler spectrum
	Relative delay (ns)	Average power (dB)	Relative delay (ns)	Average power (dB)	
1	0	0	0	0	Flat
2	50	–3.0	100	–3.6	Flat
3	110	–10.0	200	–7.2	Flat
4	170	–18.0	300	–10.8	Flat
5	290	–26.0	500	–18.0	Flat
6	310	–32.0	700	–25.2	Flat

TABLE 4

Outdoor to indoor and pedestrian test environment tapped-delay-line parameters

Tap	Channel A		Channel B		Doppler spectrum
	Relative delay (ns)	Average power (dB)	Relative delay (ns)	Average power (dB)	
1	0	0	0	0	Classic
2	110	–9.7	200	–0.9	Classic
3	190	–19.2	800	–4.9	Classic
4	410	–22.8	1 200	–8.0	Classic
5	–	–	2 300	–7.8	Classic
6	–	–	3 700	–23.9	Classic

TABLE 5

Vehicular test environment, high antenna, tapped-delay-line parameters

Tap	Channel A		Channel B		Doppler spectrum
	Relative delay (ns)	Average power (dB)	Relative delay (ns)	Average power (dB)	
1	0	0.0	0	–2.5	Classic
2	310	–1.0	300	0	Classic
3	710	–9.0	8.900	–12.8	Classic
4	1 090	–10.0	12 900	–10.0	Classic
5	1 730	–15.0	17 100	–25.2	Classic
6	2 510	–20.0	20 000	–16.0	Classic

1.3 Link budget template and deployment models

In the sections that follow a link budget template and deployment models are proposed to be used for evaluation in each of the terrestrial test environments. The proponent must use the terrestrial link budget corresponding to channel impulse response model channels A and B. For calculations of coverage and spectrum efficiencies the worst case among channels A and B has to be assumed.

For the terrestrial RTTs, the deployment models are used to extract critical parameters, such as coverage efficiency and spectrum efficiency. They also give a general idea of the amount of infrastructure required to provide service to the specified model deployment area.

The spectrum efficiency is defined as the number of E/MHz/cell for speech and Mbit/s/cell for data. Spectrum efficiency is calculated for the higher offered traffic levels and for the given spectrum allocation. Spectrum efficiency is dependent on the frequency bandwidth allocation and is not linearly scaleable between different bandwidth allocations. For the purpose of evaluation, a duplex bandwidth of 30 MHz is assumed and is to be divided between forward and reverse link as required by the RTT implementation. An indication of the guardband needed between operators using the same RTT should be given by the RTT proponent.

The coverage efficiency is defined as the total number of cell sites per square kilometre required to meet the coverage requirements specified for each test environment. Coverage efficiency is to be calculated at low traffic levels (as specified in deployment tables) since the system will most probably be interference limited at high traffic load.

A link budget template for the terrestrial RTTs is given in Table 6. The link budget template is to be completed for each test environment and each test case service in Table 1. Link level simulations based on channel B of the impulse response models are used to determine the required $E_b/(N_0 + I_0)$ and hence the required C/I of their RTT to meet the performance criteria given in Table 1. Path loss formulas are then used to determine the maximum range and the coverage area. In case of hexagonal deployment of sectored cells, the area covered by one sector is defined as $S = R^2 \cdot \sqrt{3/4}$, where R is the range obtained in the link budget. This means that the sectors are hexagonal with base stations placed in the corners of the hexagons.

An infrastructure is determined by the proponent to meet the service objectives and coverage requirements for the deployment. Calculation of coverage efficiency is done based on the proposed deployment for the given low traffic levels.

Implementation independent parameters (ii) are fixed in the link budget template to avoid divergence not directly related to radio technology differences. The proponents must provide coverage efficiency values using these fixed ii values.

A specific deployment scenario is given for each terrestrial test environment. This contains information on market requirements including grade of service, traffic level, coverage requirements and subscriber penetration. Also given for each deployment scenario are the physical parameters of that environment which includes: area to cover, population density, and mobile terminal velocity (for Doppler frequency).

Along with a link budget template for each terrestrial test environment a deployment model results matrix is to be completed for each specified traffic. The results matrix is found in Table 11. The simulations used to complete the link budget template are required to complete the model deployment for each test environment. Each system proponent must use only the propagation models given in § 1.2.

System proponents will assume a centre frequency of 2.0 GHz when completing the deployment models.

1.3.1 Terrestrial link budget templates

The link budget template shall be completed for both the forward and reverse links for each deployment environment and each test case service. In the case of the mixed environment, the link budget template should be completed for the pedestrian and vehicular test environments. Implementation dependent and independent link budget items are indicated by id and ii in the template. The link budget template should not be considered as a tool for planning since essential parts are missing such as body loss, penetration loss into cars etc. To facilitate comparable results RTT independent parameters are pre-set.

TABLE 6

Link budget template

id/ii	Item	Forward link	Reverse link
	Test environment		
	Test service		
	Multipath channel class	A, B	A, B
ii/id	(a0) Average transmitter power per traffic channel (NOTE 1)	dBm	dBm
id	(a1) Maximum transmitter power per traffic channel	dBm	dBm
id	(a2) Maximum total transmitter power	dBm	dBm
ii	(b) Cable, connector, and combiner losses (enumerate sources)	2 dB	0 dB
ii	(c) Transmitter antenna gain	13 dBi (vehicular) 10 dBi (pedestrian) 2 dBi (indoor)	0 dBi
id	(d1) **Transmitter e.i.r.p. per traffic channel = (a1 – b + c)**	dBm	dBm
id	(d2) **Total transmitter e.i.r.p. = (a2 – b + c)**	dBm	dBm
ii	(e) Receiver antenna gain	0 dBi	13 dBi (vehicular) 10 dBi (pedestrian) 2 dBi (indoor)
ii	(f) Cable and connector losses	0 dB	2 dB
ii	(g) Receiver noise figure	5 dB	5 dB
ii	(h) Thermal noise density (H) (linear units)	–174 dBm/Hz 3.98×10^{-18} mW/Hz	–174 dBm/Hz 3.98×10^{-18} mW/Hz
id	(i) Receiver interference density (NOTE 2) (I) (linear units)	dBm/Hz mW/Hz	dBm/Hz mW/Hz
id	(j) **Total effective noise plus interference density** **= 10 log ($10^{((g + h)/10)}$ + I)**	dBm/Hz	dBm/Hz
ii	(k) Information rate (10 log (R_b))	dB(Hz)	dB(Hz)
id	(l) Required $E_b/(N_0 + I_0)$	dB	dB
id	(m) **Receiver sensitivity = (j + k + l)**		
id	(n) Hand-off gain	dB	dB
id	(o) Explicit diversity gain	dB	dB
id	(o′) Other gain	dB	dB
id	(p) Log-normal fade margin	dB	dB
id	(q) **Maximum path loss** **= {d1 – m + (e – f) + o + n + o′ – p}**	dB	dB
id	(r) Maximum range	m	m

NOTES to Table 6:

NOTE 1 – Proponents must provide coverage and spectrum efficiencies values using the following proposed average transmitter power per traffic channel. However they should provide additional values based on optimized transmitter power for their proposed RTT.

	Forward link	Reverse link
(a0) Average transmitter power per traffic channel	30 dBm vehicular 20 dBm pedestrian 10 dBm indoor	24 dBm vehicular 14 dBm pedestrian 04 dBm indoor

NOTE 2 – Since the significance and method of calculating this value will vary from RTT to RTT, the proponent must give a detailed explanation of their method for calculating this value and its significance in determining capacity and coverage of the RTT. In particular, the proponent must state explicitly what frequency reuse ratio and traffic loading per sector are assumed in determining this quantity. Interference has to be evaluated for the specified low traffic level given for each test environment.

The following sections provide descriptions of the individual link budget template items. Descriptions apply to both forward and reverse links unless specifically stated otherwise. For the forward link the base station is the transmitter and the mobile station the receiver. For the reverse link the mobile station is the transmitter and the base station the receiver.

(a0) Average transmitter power per traffic channel (dBm)

The average transmitter power per traffic channel is defined as the mean of the total transmitted power over an entire transmission cycle with maximum transmitted power when transmitting.

(a1) Maximum transmitter power per traffic channel (dBm)

Maximum transmitter power per traffic channel is defined as the total power at the transmitter output for a single traffic channel. A traffic channel is defined as a communication path between a mobile station and a base station used for user and signalling traffic. The term traffic channel implies a forward traffic channel and reverse traffic channel pair.

(a2) Maximum total transmitter power (dBm)

Maximum total transmit power is the aggregate maximum transmit power of all channels.

(b) Cable, connector, and combiner losses (transmitter) (dB)

These are the combined losses of all transmission system components between the transmitter output and the antenna input (all losses in positive dB values). The value is fixed in the template.

(c) Transmitter antenna gain (dBi)

Transmitter antenna gain is the maximum gain of the transmitter antenna in the horizontal plane (specified as dB relative to an isotropic radiator). The value is fixed in the template.

(d1) Transmitter e.i.r.p. per traffic channel (dBm)

This is the summation of transmitter power output per traffic channel (dBm), transmission system losses (–dB), and the transmitter antenna gain (dBi), in the direction of maximum radiation.

d2) Transmitter e.i.r.p. (dBm)

This is the summation of the total transmitter power (dBm), transmission system losses (–dB), and the transmitter antenna gain (dBi).

(e) Receiver antenna gain (dBi)

Receiver antenna gain is the maximum gain of the receiver antenna in the horizontal plane (specified as dB relative to an isotropic radiator).

(f) Cable, connector, and splitter losses (receiver) (dB)

These are the combined losses of all transmission system components between the receiving antenna output and the receiver input (all losses in positive dB values). The value is fixed in the template.

(g) Receiver noise figure (dB)

Receiver noise figure is the noise figure of the receiving system referenced to the receiver input. The value is fixed in the template.

(h), (H) Thermal noise density, N_0 (dB(m/Hz))

Thermal noise density, N_0, is defined as the noise power per Hertz at the receiver input. Note that (h) is logarithmic units and (H) is linear units. The value is fixed in the template.

(i), (I) Receiver interference density I_0 (dBm/Hz)

Receiver interference density is the interference power per Hertz at the receiver front end. This is the in-band interference power divided by the system bandwidth. The in-band interference power consists of both co-channel interference as well as adjacent channel interference. Thus, the receiver and transmitter spectrum masks must be taken into account. Note that (i) is logarithmic units and (I) is linear units. Receiver interference density I_0 for forward link is the interference power per Hertz at the mobile station receiver located at the edge of coverage, in an interior cell.

(j) Total effective noise plus interference density (dBm/Hz)

Total effective noise plus interference density (dBm/Hz) is the logarithmic sum of the receiver noise density and the receiver noise figure and the arithmetic sum with the receiver interference density, i.e:

$$j = 10 \log (10^{((g + h)/10)} + I)$$

(k) Information rate (10 log R_b) (dB(Hz))

Information rate is the channel bit rate in (dB(Hz)); the choice of R_b must be consistent with the E_b assumptions.

(l) Required $E_b/(N_0 + I_0)$ (dB)

The ratio between the received energy per information bit to the total effective noise and interference power density needed to satisfy the quality objectives specified in Table 1 under condition of § 1.2.2 channel model. Power control should not exceed the ceiling established by the sum of the log-normal fade margin plus hand-off gain. Diversity gains included in the $E_b/(N_0 + I_0)$ requirement should be specified here to avoid double counting. The translation of the threshold error performance to $E_b/(N_0 + I_0)$ performance depends on the particular multipath conditions assumed.

(m) Receiver sensitivity (j + k + l) (dBm)

This is the signal level needed at the receiver input that just satisfies the required $E_b/(N_0 + I_0)$.

(n) Hand-off gain/loss (dB)

This is the gain/loss factor (+ or –) brought by hand-off to maintain specified reliability at the boundary. Assume equal average loss to each of the two cells. The hand-off gain/loss shall be calculated for 50% shadowing correlation. The proponent must state explicitly the other assumptions made about hand-off in determining the hand-off gain.

(o) Explicit diversity gain (dB)

This is the effective gain achieved using diversity techniques. It should be assumed that the correlation coefficient is zero between received paths. Note that the diversity gain should not be double counted. For example, if the diversity gain is included in the $E_b/(N_0 + I_0)$ specification, it should not be included here.

(o′) Other gain (dB)

An additional gain may be achieved due to future technologies. For instance, space diversity multiple access (SDMA) may provide an excess antenna gain. Assumptions made to derive this gain must be given by the proponent.

(p) Log-normal fade margin (dB)

The log-normal fade margin is defined at the cell boundary for isolated cells. This is the margin required to provide a specified coverage availability over the individual cells.

(q) Maximum path loss (dB)

This is the maximum loss that permits minimum RTT performance at the cell boundary:

$$\text{Maximum path loss} = d1 - m + (e - f) + o + o' + n - p$$

(r) Maximum range (km)

The maximum range is computed for each deployment scenario. Maximum range, R_{max}, is given by the range associated with the maximum path loss. The equations to determine path loss are given in § 1.2.

1.3.2 Deployment model

In spectrum efficiency computation, the offered traffic level has to be adjusted to reach the grade of service and coverage criteria as defined in Tables 7 to 10. The offered traffic is calculated as:

$$\text{offered traffic} = \text{user density} \times (\text{bhca/sub/3600}) \times \text{call duration}$$

where:

bhca: busy hour call attempts

sub: subscriber.

1.3.2.1 Indoor office test environment deployment model

This deployment scenario describes conditions relevant to the operation of a IMT-2000 system that might be found in the indoor office test environment. The test service requirements for the indoor office environment are listed in Table 1. General assumptions about market requirements are summarized in Table 7a.

TABLE 7a

Indoor office deployment model market requirements

Grade of service	Traffic level (bhca/sub)[(1)]	Coverage[(2)]	Subscriber penetration (% of potential users)
1% blocking	3 for speech 3 for data	95%	50 for spectrum efficiency 5 for coverage efficiency

(1) bhca: busy hour call attempts e.g., assuming a call duration of 2 min (speech) and 2 min (data).

(2) Let "A" be the declared geographical area over which the service is planned. It is required that good operating conditions (for the receivers) be maintained over X% (95%), of the area "A" during Y% (95%) of the time. Further definition of "A" is needed.

For this indoor deployment scenario a model office environment is specified below and consists of a large office building with an open floor plan layout. Office cubicles are separated by conducting moveable partitions. These partitions create a large degree in signal variation as is borne out in the log-normal standard deviation given in Table 7a. Traffic levels are given in Erlangs per floor. In this scenario users in elevators and stairwells are not considered though realistically they would have to be accounted for.

The specific assumptions about the indoor physical deployment environment are summarized in Table 7b.

TABLE 7b

Indoor office deployment model physical environment

Area per floor (m^2)	Potential users per floor	Number of floors	Log-normal standard deviation (dB)	Mobile velocity (km/h)
10 000	1 000	10	12	3

1.3.2.2 Outdoor to indoor and pedestrian deployment model

Note that the physical environment description includes both indoor and outdoor users. The indoor coverage is to be provided by the outdoor base stations. This requires that the additional loss due to building penetration be accommodated in the link budget. The test service requirements for the outdoor to indoor pedestrian environment are listed in Table 1.

TABLE 8a

Outdoor to indoor and pedestrian deployment model market requirements

Grade of service	Traffic level (bhca/sub)[(1)]	Coverage[(2)]	Subscriber penetration (% of potential users)
1% blocking	1.2 for speech 1.2 for data	95%	10 for spectrum efficiency 0.1 for coverage efficiency

(1), (2) See Table 7a.

The specific assumptions about the outdoor physical deployment environment are summarized in Table 8b.

TABLE 8b

Deployment model physical environment

Type	Area (km^2)	Potential users per km^2	Building penetration loss/standard deviation (dB)	Log-normal standard deviation (dB)	Mobile velocity (km/h)
Outdoor	40	9 000	Not applicable	10	3
Indoor	25	12 000	12/8	12	3

1.3.2.3 Vehicular environment deployment model

The test service requirements for the vehicular environment are listed in Table 1. General assumptions about market requirements are summarized in Table 9a. The base station antenna height must be above the average roof top height of 12 m.

TABLE 9a

Vehicular deployment model market requirements

Grade of service	Traffic level (bhca/sub) (1)	Coverage (2)	Subscriber penetration (% of potential users)
1% blocking	0.75 for speech 0.75 for data	95%	10 for spectrum efficiency 0.1 for coverage efficiency

(1), (2) See Table 7a.

The specific assumptions about the vehicular physical deployment environment are summarized in Table 9b.

TABLE 9b

Vehicular deployment model physical environment

Area (km^2)	Potential users per km^2	Log-normal standard deviation (dB)	Mobile velocity (km/h)
150	3 500	10	120

In addition, proponents should provide information on how high speed up to 500 km/h can be handled.

1.3.2.4 Mixed-cell pedestrian/vehicular test environment deployment model

This deployment scenario describes conditions relevant to the operation of a IMT-2000 system that might be found in the mixed test environment. The test service requirements for the mixed-cell environment are listed in Table 1. The general assumptions about market requirements are summarized in Table 10a. The link budget uses the pedestrian and vehicular ones which have been calculated before. The interference from the large cells to the small cells and *vice versa* should be accounted for, if necessary.

TABLE 10a

Mixed test deployment model market requirements

Grade of service	Traffic level (bhca/sub) (1)	Coverage (2)	Subscriber penetration (% of potential users)
1% blocking	1 for speech	95%	10 for spectrum efficiency
	1 for data		0.1 for coverage efficiency

(1), (2) See Table 7a.

The specific assumptions about the outdoor and vehicular physical deployment environment are summarized in Table 10b.

TABLE 10b

Mixed test deployment model physical environment

Path loss type	Area (km^2)	Log-normal standard deviation (dB)	Mobile velocity (km/h)	% users
Pedestrian (outdoor)	4	10	3	60
Vehicular	150	10	120	40

1.3.3 Deployment model result matrix

Results from the system deployment model are to be tabulated as specified in Table 11.

TABLE 11

Deployment model result matrix

Input assumptions				
Test environment				
Test service				
Base station antenna height (m)				
Any other assumptions made by the proponent (e.g. antenna pattern, sectorization etc.)				
Deployment results				
Total number of cell sites	Total number of RF channels	Number of voice channels per RF channel	Coverage efficiency (km^2/site)	Spectrum efficiency (E/MHz/cell) for speech (Mbit/s/cell) for data

PART 2

Satellite component

The satellite component is of specific nature and cannot be evaluated in the same way as for the terrestrial component. Recommendation ITU-R M.1167, Framework for Satellite Component of International Mobile Telecommunications-2000 (IMT-2000), provides details about this subject.

2.1 Propagation models

Satellite propagation normally includes a line of sight component and diffused/reflected multipath components, and hence tends to be Rician distributed with fading rates set by user and satellite motions; however, Rayleigh fading occurs when the line of sight path is obstructed. Time delay spreads are likely no more than a few tens or hundreds of nanoseconds and the levels of delayed components are low so that fading may be considered as flat in frequency for a channel with a bandwidth less than about 2 MHz.

Doppler offsets and rates of change are dependent upon relative motion between user and satellite. Gross Doppler shift in the carrier is a function of satellite velocity while Doppler spreading is dependent on the motion of the mobile station.

For satellite applications in general a Rician fading model should be used to assess the performance of the RTT. Further, the aspects of multipath propagation and the maximum Doppler shifts are taken into account. The gross Doppler shift in the carrier frequency due to the motion of the satellite and the mobile terminals should be included in the link level simulation.

2.1.1 Narrowband model

In the narrowband case the Rician model is characterized by the sum of the direct path component and the diffused/reflected multipath components. When the direct path component is diminished due to shadowing, it becomes the Rayleigh fading.

If $z(t)$ and $w(t)$ denote the complex low pass representation of the channel input and output, then:

$$w(t) = \sqrt{P_0}\; z(t) + \sqrt{P_1}\; g_1(t)\; z(t)$$

where:

- P_0 : strength of the direct component
- P_1 : strength of the multipath component
- $g_1(t)$: complex Gaussian process weighting the multipath component.

The general amplitude distribution of the Rician channel is characterized by (probability density-function, pdf):

$$pdf\,(a) = 2\frac{a}{P_1} \cdot e^{-\frac{a^2+P_0}{P_1}} \cdot I_0\left(\frac{2a\sqrt{P_0}}{P_1}\right)$$

The ratio c of P_0 and P_1 is the direct-to-multipath signal power ratio and is called the Rician factor, K, usually expressed in dB value as:

$$K = 10 \log (P_0/P_1) = 10 \log c$$

The Doppler spectrum of $g(t)$ is described by the Rician case in § 2.1.3.

The special case when $P_0 = 0$, i.e. $K = -\infty$ is called the Rayleigh fading channel and its amplitude distribution is characterized by:

$$pdf\,(a) = 2\frac{a}{P_1} \cdot e^{-\frac{a^2}{P_1}}$$

with P_1 as the mean received power. The Doppler spectrum of $g(t)$ is described here by the classical case in § 2.1.3.

Rician factor values in Table 12 should be considered. Note that the attenuation of the direct path component due to shadowing should also be considered as indicated in this Table.

TABLE 12

Rician factors for satellite environment

Rician factor, K (dB)	Direct path component, P_0	Multipath component, P_1
10	1.0	0.1
7	0.5	0.1
3	0.2	0.1
–∞	0.0	0.1

2.1.2 Wideband model

Satellite cell wideband propagation models for the 2 GHz band are proposed to represent the different environments:

– rural,

– suburban,

– urban,

which are based on extensive measurement campaigns. These models are typical in the elevation angles ranging from 15° to 55°. In addition to the narrowband description echoes due to multipath signals (near echoes) have to be taken into account according to:

$$w(t) = \sqrt{P_0}\; z(t) + \sqrt{P_1}\; g_1(t)\; z(t) + \sum_{i=2}^{M} \sqrt{P_i}\; g_i(t)\; z(t - \tau_i)$$

This model corresponds to a tapped-delay line structure with a fixed number M of taps with a direct path and $M - 1$ echoes with tap delays τ_i and randomly time varying tap amplitudes. Each tap is described by its:

– complex time varying amplitude $\sqrt{P_i}\; g_i(t)$ with variance P_i relative to free space propagation;

– delay τ_i relative to the first path;

– Rayleigh amplitude distribution of $\sqrt{P_i}\; g_i(t)$ (with $i > 1$);

– Doppler spectrum.

2.1.3 Description of Doppler spectra

With respect to the LOS and NLOS situations of the direct component and the Rayleigh amplitude distribution of the delayed components two types of Doppler spectra were chosen. The power spectrum of $g_i(t)$ with $i > 0$ is called the Doppler spectrum and is modelled by:

– Classic Doppler power density spectrum:

$$G_i(\upsilon) = G(\upsilon) = \frac{1}{\pi \cdot \upsilon_{max} \sqrt{1 - \left(\dfrac{\upsilon - \upsilon_{sat}}{\upsilon_{max}}\right)^2}} \qquad \text{for } \upsilon_{sat} - \upsilon_{max} \le \upsilon \le \upsilon_{sat} + \upsilon_{max}$$

υ_{max} is related to the speed V of the mobile terminal:

$$\upsilon_{max} = \frac{V}{\lambda}$$

where:

V: velocity of the mobile

λ: wavelength at the carrier frequency.

Two values of V, 3 km/h for pedestrian and 70 km/h for vehicle environment, should be considered.

In the satellite environment, there is a gross shift υ_{sat} in the carrier frequency due to the relative motion of the satellite relative to the Earth surface (see Appendix 2) and the mobile terminal. This gross Doppler shift in the carrier is a function of the satellite orbital velocity $V_{orbital}$ and its position relative to the mobile and λ is the wave length of the carrier frequency.

$$\upsilon_{sat} = \frac{V_{orbital}}{\lambda}$$

The satellite orbital velocity is a function of the orbital elevation (see Appendix 2). Some satellite RTTs can compensate for gross Doppler shift. If there is any residual Doppler shift experienced by the receiver, this must be included in the link level simulation.

– Rice: classical Doppler power density spectrum plus discrete spectral line:

$$G(\upsilon) = \frac{1/c}{\pi \cdot \upsilon_{max}\sqrt{1 - \left(\frac{\upsilon - \upsilon_{sat}}{\upsilon_{max}}\right)^2}} + \delta(\upsilon - \upsilon_{sat}) \qquad \text{for } \upsilon_{sat} - \upsilon_{max} \leq \upsilon \leq \upsilon_{sat} + \upsilon_{max}$$

2.1.4 Parameters of the wideband models

Tables 13 to 15 give the parameters proposed for channel A, B and C. These channels represent the 10% (channel A), 50% (channel B) and 90% (channel C) quantities of the delay spread values.

Both LOS and NLOS cases are included in these tables. LOS cases of channel models A, B and C correspond to the cases of Rician factor 10, 7 and 3 dB of the narrow band model, respectively, and the NLOS cases correspond to the case of Rician factor –∞.

The impact of these additional taps may be insignificant depending on the bandwidth of the RTT and the carrier-to-noise ratio.

TABLE 13

Channel model A
(10% delay spread values)

Tap number	Relative tap delay value (ns)	Tap amplitude distribution	Parameter of amplitude distribution (dB)	Average amplitude with respect to free space propagation	Rice factor (dB)	Doppler spectrum
1	0	LOS: Rice NLOS: Rayleigh	10 log c 10 log P_m	0.0 –7.3	10 –	Rice Classic
2	100	Rayleigh	10 log P_m	–23.6	–	Classic
3	180	Rayleigh	10 log P_m	–28.1	–	Classic

TABLE 14

Channel model B
(50% delay spread values)

Tap number	Relative tap delay value (ns)	Tap amplitude distribution	Parameter of amplitude distribution (dB)	Average amplitude with respect to free space propagation	Rice factor (dB)	Doppler spectrum
1	0	LOS: Rice NLOS: Rayleigh	10 log c 10 log P_m	0.0 –9.5	7 –	Rice Classic
2	100	Rayleigh	10 log P_m	–24.1	–	Classic
3	250	Rayleigh	10 log P_m	–25.1	–	Classic

TABLE 15

Channel model C
(90% delay spread values)

Tap number	Relative tap delay value (ns)	Tap amplitude distribution	Parameter of amplitude distribution (dB)	Average amplitude with respect to free space propagation	Rice factor (dB)	Doppler spectrum
1	0	LOS: Rice NLOS: Rayleigh	10 log c 10 log P_m	0.0 –12.1	3 –	Rice Classic
2	60	Rayleigh	10 log P_m	–17.0	–	Classic
3	100	Rayleigh	10 log P_m	–18.3	–	Classic
4	130	Rayleigh	10 log P_m	–19.1	–	Classic
5	250	Rayleigh	10 log P_m	–22.1	–	Classic

2.2 Satellite test scenarios: link budget and deployment model

Unlike the terrestrial component, the satellite power is precious and therefore the power efficiency of the RTTs is the most critical parameter for the satellite component. The power efficiency of the RTT can be defined as the supported information capacity per required satellite power. The required satellite power can be normalized as the required carrier power-to-noise power density ratio at the receiver input port. Then the normalized power efficiency can be defined as the supported information bit rate per required carrier power-to-noise density ratio, which is actually equal to the reciprocal of the required E_b/N_0 for the RTT. The spectrum efficiency is also important and it can be defined as the supported information bit rate per required RF bandwidth.

Link models for the satellite RTTs are given in § 2.2.1 to extract the power and spectrum efficiency in the presence of fading and interference. The results of the link level simulation or measurements will give required E_b/N_0 for the given channel performance under the given interference. The performance requirements including information bit rate and bit error ratio performance found in Table 16 should be used for the evaluation. The resulting power and spectrum efficiencies should be summarized in the output results matrix for voice only and the voice and data mix results matrix. For the voice and data mix case, combination of 80% voice and 20% data should be assumed.

Since the overall capacity and the coverage are mostly determined by the configuration of the constellation including the type and altitude of the orbit, number of satellites, configuration of the spot beams, etc. the deployment models in terms of the user density, the traffic level, etc. are not needed for the evaluation of the satellite RTTs.

2.2.1 Satellite RTT link model

The link models for the performance evaluation of the satellite RTTs are given in Fig. 5a for the return link and in Fig. 5b for the forward link. In both cases, the carrier and noise powers are normalized as those values at the input port of the receiver (demodulator), and thus the link loss or gain for the desired signal is assumed to be 0 dB except for the excess loss due to the fading.

2.2.1.1 Return link model

For the return link model shown in Fig. 5a, the desired output signal, with average power of C, from the desired MES is first suffered by the fading and Doppler frequency shift and then mixed with various interfering signals at the satellite, such as:

– co-channel signals from other MESs sharing the same frequency channel (notably for CDMA case),

– adjacent frequency signals from other MESs using the adjacent frequency channels,

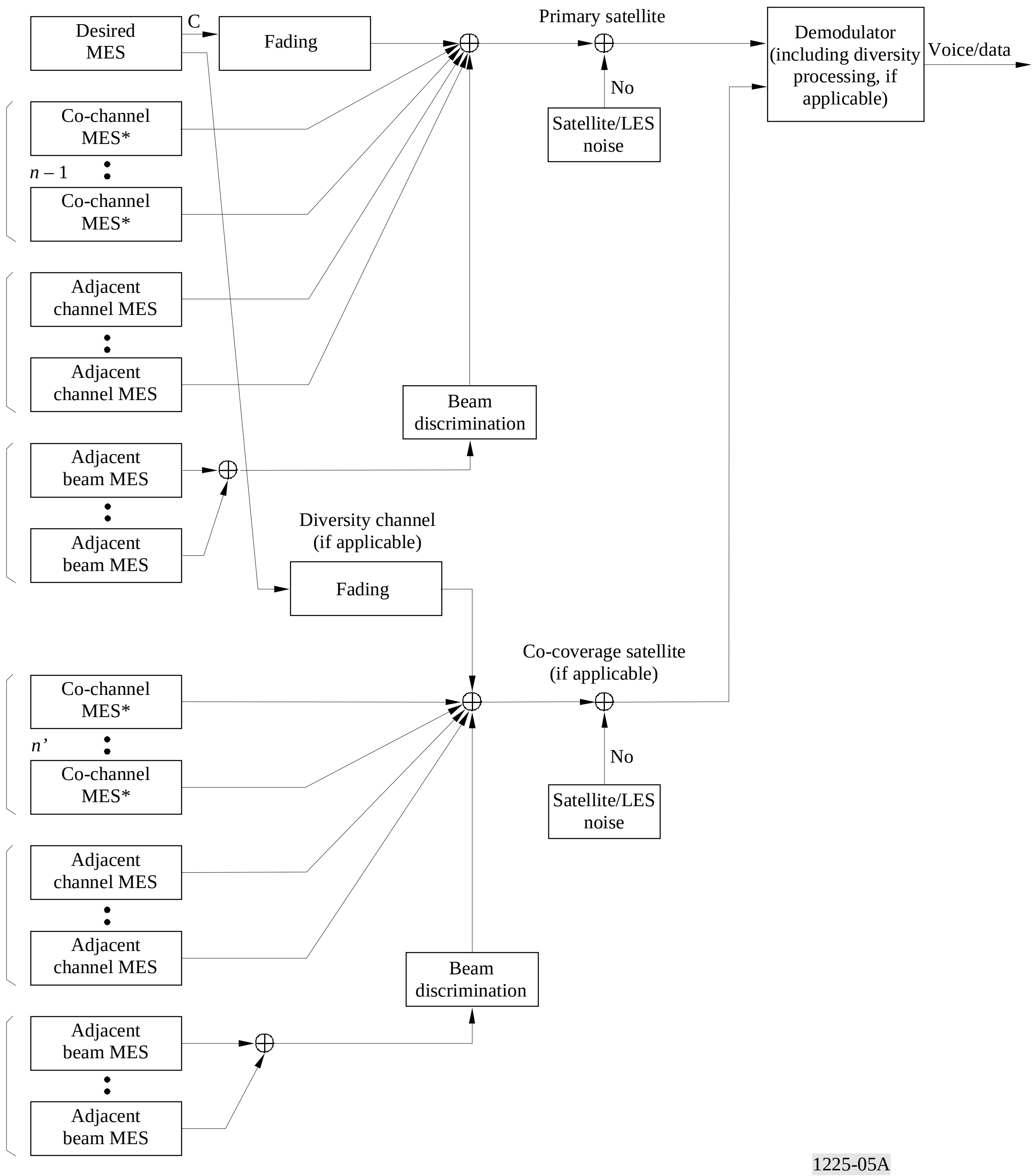
– co-channel signals from other MESs sharing the same frequency channel using the different spot beams, of which levels are attenuated by the satellite antenna discrimination.

It can be assumed safely that these interference signals are free from fading. Then the Gaussian noise with power spectrum density of N_0 is added before the signal is processed by the receiver (demodulator) at the LES.

If co-coverage satellite(s) are available, there is a possibility that the diversity is employed so that the signal from the desired MES is also transmitted through the co-coverage satellite(s). This diversity signal suffers by the fading and Doppler frequency shift and then mixed with interfering signals similarly as the primary satellite signal. Then the Gaussian noise is added and processed by the receiver with diversity processing at the LES.

FIGURE 5a

Return link model



* In case of CDMA.

2.2.1.2 Forward link model

For the forward link model shown in Fig. 5b, the desired output signal, with average power of C, from the primary satellite is first mixed with various interfering signals at the satellite, such as:

– co-channel signals to other MESs sharing the same frequency channel (notably for CDMA case):

– adjacent frequency signals to other MESs using the adjacent frequency channels;

– co-channel signals to other MESs sharing the same frequency channel using the different spot beams, of which levels are attenuated by the satellite antenna discrimination.

Then the mixed signals suffer by the fading and Doppler frequency shift. Then the Gaussian noise with power spectrum density of N_0 is added before the signal is processed by the receiver (demodulator) of the MES.

If co-coverage satellite(s) are available, there is a possibility that the diversity is employed so that the signal to the desired MES is also transmitted through the co-coverage satellite(s). This diversity signal suffers by the fading and Doppler shift after it is mixed with interfering signals similarly as the primary satellite signal. Then both the primary and co-coverage signals including the interference are mixed at the MES and processed by the receiver with diversity processing at the MES.

2.2.1.3 Inter-beam interference

For the interference from the other spot beams sharing the same frequency band, the following assumptions can be adequate for both return and forward links:

– for TDMA: 4 cell frequency reuse pattern and average beam discrimination of 20 dB should be assumed;

– for CDMA: full frequency reuse and average beam discrimination of 10 dB should be assumed.

Other sources of noise and interference are not taken into account for the sake of simplicity.

2.2.1.4 Derivation of power and spectrum efficiency

Then by using computer simulations and/or experimental measurements based on this model, the proponent should derive the minimum required value of C/N_0 to achieve the objective performance in terms of frame and/or bit error ratio under the designed full load condition. For the return link, the effect of the non-linearity of the HPA of the MESs should be taken into account in the adjacent channel interference and demodulator performance.

In TDMA case, if the carrier supports *n* channels of user voice or data information of *b* bit/s, the power efficiency can be derived as:

$$\textit{Power efficiency} = n \times b \,/\, (C/N_0) = 1 \,/\, (E_b/N_0)$$

and the spectrum efficiency can be derived as:

$$\textit{Spectrum efficiency} = r\, n\, b \,/\, B$$

where *B* is the required RF bandwidth for the carrier including half of the guard bands of both sides between the adjacent frequency channels, and *r* is the frequency reuse factor between spot beams which is assumed to be 0.25 for TDMA case.

Similarly in case of CDMA, if for return link up to *n* MESs within the coverage of a spot beam can transmit the signal simultaneously in the same frequency channel as the desired MES signal, or for forward link up to *n* signals can be transmitted from a spot beam simultaneously in the same frequency channel, and still the required performance can be achieved, the power efficiency can be derived as:

$$\textit{Power efficiency} = b \,/\, (C/N_0) = 1 \,/\, (E_b/N_0)$$

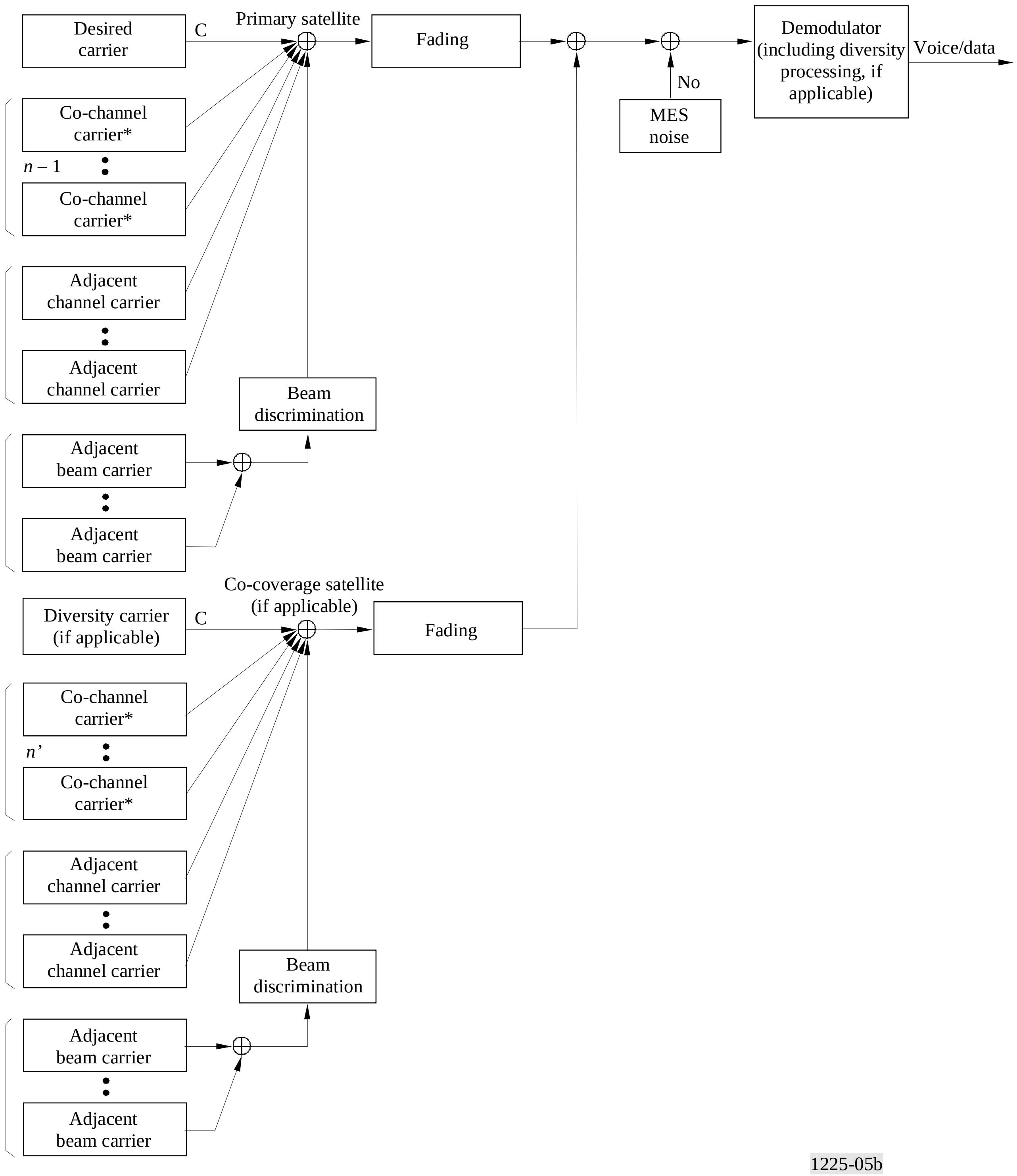
and the spectrum efficiency can be derived as:

$$\textit{Spectrum efficiency} = r\, n\, b \,/\, B$$

where *r* is the frequency reuse factor which is assumed to be 1.0 for CDMA case. If there are co-coverage satellites, total number of signals transmitted simultaneously in the same frequency channel from all co-coverage satellites to the direction of the MES with effectively the same strength should be counted as *n* in the above formula for forward link.

FIGURE 5b

Forward link model



* In case of CDMA.

2.2.1.5 Consideration of diversity

If the diversity is proposed to be employed so that the same information is transmitted through *k* satellite paths, the power and spectrum efficiencies should be adjusted as follows:

Case a): different frequency and/or different time slot (e.g. TDMA)

– power efficiency (return and forward link): $1/k$

– spectrum efficiency (return and forward link): $1/k$.

Case b) : same frequency and same time slot (e.g. CDMA)

– power efficiency for forward link: $1/k$

– power efficiency for return link: 1

– spectrum efficiency for forward link: $1/k$

– spectrum efficiency for return link: 1.

2.2.1.6 Other conditions for evaluation

If the power control is proposed to be employed, the residual power variation after the power control should be taken into account. Following values should be assumed as the standard deviation of the residual power variation: 0 dB, 2 dB, 4 dB and 10 dB.

The following values should be assumed as the maximum values of the residual gross Doppler frequency shift of the carrier experienced by the receiver after compensation by automatic frequency control (AFC) schemes: 0.5 kHz and 5 kHz.

If the voice activation of transmitted carriers is proposed to be employed, voice activity factor of 50% should be assumed.

2.2.2 Output result matrix

Results from the RTT link simulation or measurements are to be tabulated in Table 16. The two most important results are the spectrum efficiency and the power efficiency.

The spectrum efficiency is defined as the number of user information bit rate per unit bandwidth supported by the RTT.

The power efficiency is defined as the reciprocal of the minimum required E_b/N_0 for the RTT to obtain the required performance of FER for voice and BER for data under the given fading and interference conditions with full loading of the user traffic.

TABLE 16

Satellite results matrix

	Low bit rate, low delay data (speech)				Data mix (80% speech, 20% data)			
Information rate	2.4 kbit/s				2.4 kbit/s (speech)/9.6 kbit/s (data)			
Objective performance	1×10^{-2} (FER)				1×10^{-2} (FER/1×10^{-6} (BER)			
Fading model	Power efficiency		Spectrum efficiency		Power efficiency		Spectrum efficiency	
	Forward link	Reverse link	Forward link	Reverse link	Forward link	Reverse link	Forward link	Reverse link
Rician $K = 10$ dB								
Rician $K = 7$ dB								
Rician $K = 3$ dB								
Rayleigh $K = -\infty$								

APPENDIX 1

TO ANNEX 2

Propagation models

1 Propagation models

The following sections provide a more detailed treatment of both the path loss models, where more detail is available, and the channel impulse response models. The personal antenna height of 1.5 m is used in developing the propagation models for all test environments.

1.1 Path loss models

1.1.1 Path loss model for indoor office test environment

The indoor office path loss is based on the COST 231 model (to be published in 1997, Final Report COST 231. Digital Mobile Radio: View on the Evolution towards Third Generation Systems. Commission of the European Communities) which is defined as follows:

$$L = L_{fs} + L_c + \sum k_{wi} \; L_{wi} + n^{\left(\frac{n+2}{n+1} - b\right)} \times L_f$$

where:

L_{fs}: free space loss between transmitter and receiver

L_c: constant loss

k_{wi}: number of penetrated walls of type i

n: number of penetrated floors

L_{wi}: loss of wall type i

L_f: loss between adjacent floors

b: empirical parameters.

NOTE 1 – L_c normally is set to 37 dB.

NOTE 2 – $n = 4$ is an average for indoor office environment. For capacity calculations in moderately pessimistic environments, the model can be modified to $n = 3$.

TABLE 17

Weighted average for loss categories

Loss category	Description	Factor (dB)
L_f	Typical floor structures (i.e. offices) – hollow pot tiles – reinforced concrete – thickness type < 30 cm	18.3
L_{w1}	Light internal walls – plasterboard – walls with large numbers of holes (e.g. windows)	3.4
L_{w2}	Internal walls – concrete, brick – minimum number of holes	6.9

Under the simplifying assumptions of the office environment the indoor path loss model has the following form:

$$L = 37 + 30 \log_{10} R + 18.3 \times n^{\left(\frac{n+2}{n+1} - 0.46\right)}$$

where:

R : transmitter-receiver separation

n : number of floors in the path.

1.1.2 Path loss model for outdoor to indoor and pedestrian test environment

The following model is intended for the outdoor to indoor and pedestrian test environment. In the general model for outdoor transmission loss, the total transmission loss L (dB) between isotropic antennas is expressed as the sum of free space loss, L_{fs}, the diffraction loss from rooftop to the street, L_{rts}, and the reduction due to multiple screen diffraction past rows of buildings, L_{msd}. In this model, L_{fs} and L_{rts} are independent of the base station antenna height, while L_{msd} is dependent on whether the base station antenna is at, below or above building heights. In general the model is given as:

$$L(R) = L_{fs} + L_{rts} + L_{msd}$$

Given a mobile-to-base separation R, the free space loss between them is given by:

$$L_{fs} = -10 \log_{10}\left(\frac{\lambda}{4\pi R}\right)^2$$

The diffraction from the rooftop down to the street level gives the excess loss to the mobile station:

$$L_{rts} = -10 \log_{10}\left[\frac{\lambda}{2\pi^2 r}\left(\frac{1}{\theta} - \frac{1}{2\pi + \theta}\right)^2\right]$$

where:

$$\theta = \tan^{-1}\left(\frac{|\Delta h_m|}{x}\right)$$

$$r = \sqrt{(\Delta h_m)^2 + x^2}$$

Δh_m is the difference between the mean building height and the mobile antenna height; x is the horizontal distance between the mobile and the diffracting edges.

For the general model, the multiple screen diffraction loss from the base antennas due to propagation past rows of buildings is:

$$L_{msd} = -10 \log_{10} Q_M^2$$

where Q_M is a factor dependent on the relative height of the base station antenna as being either at, below or above the mean building heights (see Note 2).

In this case the base-station antenna height is near mean rooftop level, then:

$$Q_M = d/R$$

where d is the average separation between rows of buildings.

The total transmission loss for the near rooftop case then becomes:

$$L = -10 \log_{10}\left(\frac{\lambda}{2\sqrt{2\pi R}}\right)^2 - 10 \log_{10}\left[\frac{\lambda}{2\pi^2 r}\left(\frac{1}{\theta} - \frac{1}{2\pi + \theta}\right)^2\right] - 10 \log_{10}(d/R)^2$$

When Δh_m = 10.5 m, x = 15 m , and d = 80 m, as typical in an urban and suburban environment, the above path loss expression reduces to a simple function of the transmitter to receiver distance R (km) and frequency f (MHz),

$$L = 40 \log_{10} R + 30 \log_{10} f + 49$$

NOTE 1 – L shall in no circumstances be less than free space loss.

NOTE 2 – XIA, H.H. and BERTONI, H.L. [February, 1992] Diffraction of Cylindrical and Plane Waves By an Array of Absorbing Half Screens. *IEEE Trans*. *Ant. Prop*., Vol. 40, **2**, 170-177.

MACIEL, L.R., BERTONI, H.L. and XIA, H.H [February, 1993] Unified Approach to Prediction of Propagation Over Buildings for All Ranges of Base Station Antenna Height. *IEEE Trans. Vehic. Techn.*, Vol. 42, **1**, 41-45.

1.1.3 Path loss model for vehicular test environment

This model, based on the same general format as in § 1.2.2, is applicable for the test scenarios in urban and suburban areas outside the high rise core where the buildings are of nearly uniform height.

In this case the base station antenna height is above rooftop level and:

$$Q_M = 2.35 \left(\frac{\Delta h_b}{R} \sqrt{\frac{d}{\lambda}} \right)^{0.9}$$

where:

Δh_b: height difference between the base-station antenna and the mean building rooftop height

d: average separation between rows of buildings.

The total transmission loss for the above rooftop case then becomes:

$$L = -10 \log_{10}\left[\left(\frac{\lambda}{4\pi R}\right)^2\right] - 10 \log_{10}\left[\frac{\lambda}{2\pi^2 r}\left(\frac{1}{\theta} - \frac{1}{2\pi + \theta}\right)^2\right] - 10 \log_{10}\left[(2.35)^2 \left(\frac{\Delta h_b}{R} \sqrt{\frac{d}{\lambda}}\right)^{1.8}\right]$$

Measurements in building environments (see NOTE 3) showed that the path loss slope is approximately a linear function of the base station antenna height relative to average rooftop Δh_b. The above path loss equation can then be modified as:

$$L = -10 \log_{10}\left[\left(\frac{\lambda}{4\pi R}\right)^2\right] - 10 \log_{10}\left[\frac{\lambda}{2\pi^2 r}\left(\frac{1}{\theta} - \frac{1}{2\pi + \theta}\right)^2\right] - 10 \log_{10}\left[(2.35)^2 \left(\Delta h_b \sqrt{\frac{d}{\lambda}}\right)^{1.8} \Big/ R^{2(1-4\times 10^{-3}\Delta h_b)}\right]$$

where:

$$\theta = \tan^{-1}\left(\frac{|\Delta h_m|}{x}\right)$$

$$r = \sqrt{(\Delta h_m)^2 + x^2}$$

where:

Δh_m: difference between the mean building height and the mobile antenna height

x: horizontal distance between the mobile and the diffracting edges.

When Δh_m = 10.5 m, x = 15 m and d = 80 m, as typical in an urban and suburban environment with average buildings of four storey height, the above path loss expression reduces to a simple function of the transmitter to receiver distance R (km), the base station antenna height measured from the average rooftop Δh_b (m), and frequency f (MHz):

$$L = \left[40(1 - 4 \times 10^{-3} \Delta h_b)\right] \log_{10} R - 18 \log_{10} \Delta h_b + 21 \log_{10} f + 80 \qquad \text{dB}$$

NOTE 1 – L shall in no circumstances be less than free space loss.

NOTE 2 – The path loss model is valid for a range of Δh_b from 0 to 50 m.

NOTE 3 – XIA, H.H. *et al*. [August, 1994] Microcellular Propagation Characteristics for Personal Communications in Urban and Suburban Environments. *IEEE Trans. Vehic. Techn.*, Vol. 43, **3**, 743-752.

1.2 Channel impulse response model

The channel model to be used for simulation is a discrete wide sense stationary uncorrelated scattering (WSSUS) channel model for which the received signal is represented by the sum of delayed replicas of the input signal weighted by independent zero-mean complex Gaussian time variant processes. Specifically, if $z(t)$, $w(t)$ denote the complex low pass representations of the channel input and output, respectively, then:

$$w(t) = \sum_{n=1}^{N} \sqrt{p_n} \; g_n(t) \; z(t - \tau_n)$$

where p_n is the strength of the nth weight, and $g_n(t)$ is the complex Gaussian process weighting the nth replica.

The power spectrum of $g_n(t)$, called the Doppler spectrum of the nth path, controls the rate of fading due to the nth path. To completely define this channel model requires only a specification of the Doppler spectra of the tap weights $\{P_n(\upsilon);\, n = 1, \ldots, N\}$, the tap delays $\{\tau_n;\, n = 1, \ldots, N\}$, and the tap weight strengths $\{p_n;\, n = 1, \ldots, N\}$.

The process $g_n(t)$ is to be interpreted as modelling the superposition of unresolved multipath components arriving from different angles and in the vicinity of the delay interval:

$$\tau_n - \frac{1}{2W} < \tau < \tau_n + \frac{1}{2W}$$

where W is the bandwidth of the transmitted signal.

Each ray, in general, has a different Doppler shift corresponding to a different value of the cosine of the angle between the ray direction and the velocity vector. In the interests of simplicity the following assumptions are made:

a) For outdoor channels a very large number of receive rays arrive uniformly distributed in azimuth at the mobile station and at zero elevation for each delay interval. Also, the antenna pattern is assumed to be uniform in the azimuthal direction. At the base station in general the received rays arrive in a limited range in azimuth.

b) For indoor channels a very large number of receive rays arrive uniformly distributed in elevation and azimuth for each delay interval at the base station. Also, the antenna is assumed to be either a short or half-wave vertical dipole.

Assumption a) is identical to that used by Clarke and Jakes (see NOTE 1) in narrow band channel modelling. Thus the same Doppler spectrum will result, i.e.:

$$P_n(\upsilon) = P(\upsilon) = \frac{1}{\pi} \frac{1}{\sqrt{(V/\lambda)^2 - \upsilon^2}} \qquad \text{for } |\upsilon| < V/\lambda$$

where V is the velocity of the mobile and λ is the wavelength at the carrier frequency. The term classic is used to identify this Doppler spectrum.

Assumption b) results in a Doppler spectrum that is nearly flat, and the choice of a flat spectrum has been made, i.e.:

$$P_n(\upsilon) = P(\upsilon) = \frac{\lambda}{2V} \qquad \text{for } |\upsilon| < V/\lambda$$

Hence, this Doppler spectrum is referred to as “flat”.

NOTE 1 – CLARK, R.H. [1968] A Statistical Theory of Mobile Reception. *BSJT*, Vol. 49, 957-1000.

JAKES, W.C. (Editor) [1974] Microwave Mobile Communications. John Wiley & Sons.

APPENDIX 2

TO ANNEX 2

Computation of Doppler shift for satellites

In this Appendix, the Doppler shift caused by the motion of (non-geostationary) satellites in circular orbits is derived. Exemplary numerical results are given in Table 18.

TABLE 18

Maximum LEO and MEO Doppler shift values (*i* = 45°, *B* = 0°)

Type of orbit	Minimum elevation (degrees)	Maximum Doppler shift max ($f_{D, Sat}(t)$) (kHz)	Maximum Doppler rate max ($df_{D, Sat}(t)/dt$) (Hz/s)
LEO (800 km)	10	41.4	–371
LEO (800 km)	40	32.2	–371
MEO (10 354 km)	10	9.92	– 4
MEO (10 354 km)	40	7.91	– 4

The time-dependent position of the satellite can be expressed in sidereal Cartesian coordinates x, y, and z, originating at the Earth's centre. The x-axis is directed to the ascending node and the z-axis is northbound. We adopt the following designations:

T_S : orbit period of the satellite

ω_S : angular rotation of the satellite
= $2\pi/T_S$

ω_E : angular rotation of the Earth
= 2π / 23 h 56 min = 7.29×10^{-5}/s

R_E : Earth radius
= 6 378 km

h : orbit height (km)
= $331.25 \, (T_S / 60)^{2/3} - R_E$

a : orbit radius
= $R_E + h$

i : orbit inclination

u_0 : satellite orbit angle at $t = 0$.

f_c : carrier frequency.

With the orbit angle $\theta_S(t) = u_0 + \omega_S(t)$, the satellite coordinates are given by:

$$x_S(t) = a \cos \theta_S(t)$$

$$y_S(t) = a \cos i \sin \theta_S(t) \qquad (1)$$

$$z_S(t) = a \sin i \sin \theta_S(t)$$

The coordinates of the user are determined by his/her latitude B and longitude L. Assuming that at time $t = 0$ longitude 0° coincides with the ascending node, the time-varying longitude angle of the user is $\theta_E(t) = L + \omega_E(t)$, and the user coordinates are:

$$\begin{aligned} x_E(t) &= R_E \cos B \cos \theta_E(t) \\ y_E(t) &= R_E \cos B \sin \theta_E(t) \\ z_E(t) &= R_E \sin B \end{aligned} \tag{2}$$

The slant range as a function of time is:

$$s(t) = \left|\vec{x}_S(t) - \vec{x}_E(t)\right| = \sqrt{a^2 + R_E^2 - 2a\, R_E \cos \varphi(t)} \tag{3}$$

with φ designating the angle between $\vec{x}_S$ and $\vec{x}_E$, and

$$\cos \varphi(t) = \cos B \cos \theta_S(t) \cos \theta_E(t) + \cos i \cos B \sin \theta_S(t) \sin \theta_E(t) + \sin i \sin B \sin \theta_S(t) \tag{4}$$

The time-varying Doppler shift is determined by:

$$\begin{aligned} \upsilon_{sat} &= -\frac{f_c}{c} \cdot \frac{\mathrm{d}s(t)}{\mathrm{d}t} \\ &= \frac{f_c}{c} \cdot \frac{a\, R_E}{s(t)} \big[(\omega_E \cos i - \omega_S) \cos B \cos \theta_S(t) + \\ &\quad + (\omega_S \cos i - \omega_E) \cos B \cos \theta_S(t) \sin \theta_E(t) + \omega_S \sin i \sin B \cos \theta_S(t)\big] \end{aligned} \tag{5}$$

The time-varying elevation angle is given by:

$$\varepsilon(t) = \arcsin\left(\frac{\vec{x}_E(t) \cdot \left(\vec{x}_S(t) - \vec{x}_E(t)\right)}{R_E \cdot s(t)}\right) = \arcsin\left(\frac{a \cos \varphi(t) - R_E}{s(t)}\right) \tag{6}$$

In the following, we consider a situation where the satellite directly passes over the user position (the passing occurs at $t = 0$). This should be a rather good approximation for the worst-case with regard to Doppler shift. The user latitude can be chosen within $-B_{max} \le B \le B_{max}$, with:

$$B_{max} = \min\{i,\ 180° - i\} \tag{7}$$

In order to have the overpass occurring at $t = 0$, the initial phases $u_{0,1}$ for the ascending overpass and $u_{0,2}$ for the descending overpass are:

$$\begin{aligned} u_{0,1} &= \arcsin\left(\frac{\sin B}{\sin i}\right) \\ u_{0,2} &= \pi - u_{0,1} \end{aligned} \tag{8}$$

and the respective user longitudes are:

$$\begin{aligned} L_1 &= \arcsin\left(\frac{\tan B}{\tan i}\right) \\ L_2 &= \begin{cases} 180° - L_1 & \text{for } i \le 90° \\ -180° - L_1 & \text{for } i > 90° \end{cases} \end{aligned} \tag{9}$$

The slant range, Doppler shift, and elevation can now be evaluated from (3), (5) and (6). At the moment of the overpass we have $\varphi = 0$, $s = h$, $f_{D,\,Sat} = 0$ and $\varepsilon = 90°$.

To a good approximation, the maximum Doppler shift occurs when the satellite appears at minimum elevation angle ε_{min}. The Doppler shift is almost independent from the user latitude B.

ANNEX 3

Detailed evaluation procedures

Introduction

This Annex lists technical attributes which should be considered for the evaluation of RTTs against each of the criteria and gives indication on what possible impact they may have upon the different criteria. Other information submitted based on the template in Annex 1, or additionally relevant information, may be considered during the evaluation. The evaluation described in this Annex shall be done on the basis of the deployment models in Annex 2. RTT performance evaluation is to be based on a common set of verifiable parameter assumptions for all evaluation criteria for each test environment; if conditions change the technology descriptions should explain it. This Annex identifies which attributes can be described qualitatively (q) and quantitatively (Q).

When more than one candidate RTT is evaluated, it is useful to provide evaluation summaries for each evaluation criteria. A criteria evaluation summary may be difficult to make when both qualitative and quantitative attributes must be considered and when each technical attribute may have different relative importance with the overall evaluation criteria.

To facilitate such criteria evaluation summaries, this Annex identifies the importance or relative ranking of the various technical attributes within each evaluation criteria by giving a grouping G1 (most important), G2, G3, G4 (least important). Ranking of some attributes may be different for different test environments, in particular for the satellite environment. These rankings are based upon current anticipated market needs within some countries. It is recognized that the market needs may differ in the various countries in which IMT-2000 may be deployed and that they may also change during the time in which RTTs are being evaluated. It is also recognized that some new technical attributes or important considerations may be identified during the evaluation procedure that could impact any evaluation criteria summary. As such, evaluation groups may, if appropriate, modify the groupings of technical attributes, or add new attributes or considerations, in determining a criteria evaluation summary. Therefore, all evaluation groups are requested to include in their evaluation reports, information of the criteria evaluation summaries including the relative importance which was placed on each technical attribute and any other considerations that affected the summaries.

The evaluation methodology is discussed in § 9.

Index	Criteria and attributes	Q or q	Gn	Related attributes in Annex 1
A3.1	Spectrum efficiency The following entries are considered in the evaluation of spectrum efficiency:			
A3.1.1	For terrestrial environment			
A3.1.1.1	Voice traffic capacity (E/MHz/cell) in a total available assigned non-contiguous bandwidth of 30 MHz (15 MHz forward/15 MHz reverse) for FDD mode or contiguous bandwidth of 30 MHz for TDD mode. This metric must be used for a common generic continuous voice bearer with characteristics 8 kbit/s data rate and an average BER 1×10^{-3} as well as any other voice bearer included in the proposal which meets the quality requirements (assuming 50% voice activity detection (VAD) if it is used). For comparison purposes, all measures should assume the use of the deployment models in Annex 2, including a 1% call blocking. The descriptions should be consistent with the descriptions under criterion § 6.1.7 – Coverage/power efficiency. Any other assumptions and the background for the calculation should be provided, including details of any optional speech codecs being considered.	Q and q	G1	A1.3.1.5.1

A3.1.1.2	Information capacity (Mbit/s/MHz/cell) in a total available assigned non-contiguous bandwidth of 30 MHz (15 MHz forward/15 MHz reverse) for FDD mode or contiguous bandwidth of 30 MHz for TDD mode. The information capacity is to be calculated for each test service or traffic mix for the appropriate test environments. This is the only measure that would be used in the case of multimedia, or for classes of services using multiple speech coding bit rates. Information capacity is the instantaneous aggregate user bit rate of all active users over all channels within the system on a per cell basis. If the user traffic (voice and/or data) is asymmetric and the system can take advantage of this characteristic to increase capacity, it should be described qualitatively for the purposes of evaluation.	Q and q	G1	A1.3.1.5.2
A3.1.2	For satellite environment These values (§ A3.1.2.1 and A3.1.2.2) assume the use of the simulation conditions in Annex 2. The first definition is valuable for comparing systems with identical user channel rates. The second definition is valuable for comparing systems with different voice and data channel rates.			
A3.1.2.1	Voice information capacity per required RF bandwidth (bit/s/Hz)	Q	G1	A1.3.2.3.1
A3.1.2.2	Voice plus data information capacity per required RF bandwidth (bit/s/Hz)	Q	G1	A1.3.2.3.2
A3.2	Technology complexity – Effect on cost of installation and operation The considerations under criterion § 6.1.2 – Technology complexity apply only to the infrastructure, including BSs (the handportable performance is considered elsewhere).			
A3.2.1	Need for echo control The need for echo control is affected by the round trip delay, which is calculated as shown in Fig. 6. Referring to Fig. 6, consider the round trip delay with the vocoder (D1, ms) and also without that contributed by the vocoder (D2, ms). NOTE 1 – The delay of the codec should be that specified by ITU-T for the common generic voice bearer and if there are any proposals for optional codecs include the information about those also.	Q	G4	A1.3.7.2 A1.3.7.3
A3.2.2	Transmitter power and system linearity requirements NOTE 1 – Satellite e.i.r.p. is not suitable for evaluation and comparison of RTTs because it depends very much on satellite orbit. The RTT attributes in this section impact system cost and complexity, with the resultant desirable effects of improving overall performance in other evaluation criteria. They are as follows.			
A3.2.2.1	Peak transmitter/carrier (P_b) power (not applicable to satellite) Peak transmitter power for the BS should be considered because lower peak power contributes to lower cost. Note that P_b may vary with test environment application. This is the same peak transmitter power assumed in Annex 2, link budget template (Table 6).	Q	G1	A1.2.16.2.1
A3.2.2.2	Broadband power amplifier (PA) (not applicable to satellite) Is a broadband power amplifier used or required? If so, what are the peak and average transmitted power requirements into the antenna as measured in watts.	Q	G1	A1.4.10 A1.2.16.2.1 A1.2.16.2.2 A1.5.5 A1.2.5
A3.2.2.3	Linear base transmitter and broadband amplifier requirements (not applicable to satellite)			

A3.2.2.3.1	Adjacent channel splatter/emission and intermodulation affect system capacity and performance. Describe these requirements and the linearity and filtering of the base transmitter and broadband PA required to achieve them.	q	G3	A1.4.2 A1.4.10
A3.2.2.3.2	Also state the base transmitter and broadband PA (if one is used) peak to average transmitter output power, as a higher ratio requires greater linearity, heat dissipation and cost.	Q and q	G2	A1.4.10 A1.2.16.2.1 A1.2.16.2.2
A3.2.2.4	Receiver linearity requirements (not applicable to satellite) Is BS receiver linearity required? If so, state the receiver dynamic range required and the impact of signal input variation exceeding this range, e.g., loss of sensitivity and blocking.	q	G4	A1.4.11 A1.4.12
A3.2.3	Power control characteristics (not applicable to satellite) Does the proposed RTT utilize transmitter power control? If so, is it used in both forward and reverse links? State the power control range, step size (dB) and required accuracy, number of possible step sizes and number of power controls per second, which are concerned with BS technology complexity.	Q and q	G4	A1.2.22 A1.2.22.1 A1.2.22.2 A1.2.22.3 A1.2.22.4 A1.2.22.5
A3.2.4	Transmitter/receiver isolation requirement (not applicable to satellite) If FDD is used, specify the noted requirement and how it is achieved.	q	G3	A1.2.2 A1.2.2.2 A1.2.2.1
A3.2.5	Digital signal processing requirements			
A3.2.5.1	Digital signal processing can be a significant proportion of the hardware for some radio interface proposals. It can contribute to the cost, size, weight and power consumption of the BS and influence secondary factors such as heat management and reliability. Any digital circuitry associated with the network interfaces should not be included. However any special requirements for interfacing with these functions should be included. This section of the evaluation should analyse the detailed description of the digital signal processing requirements, including performance characteristics, architecture and algorithms, in order to estimate the impact on complexity of the BSs. At a minimum the evaluation should review the signal processing estimates (MOPS, memory requirements, gate counts) required for demodulation, equalization, channel coding, error correction, diversity processing (including Rake receivers), adaptive antenna array processing, modulation, A-D and D-A converters and multiplexing as well as some IF and baseband filtering. For new technologies, there may be additional or alternative requirements (such as FFTs). Although specific implementations are likely to vary, good sample descriptions should allow the relative cost, complexity and power consumption to be compared for the candidate RTTs, as well as the size and the weight of the circuitry. The descriptions should allow the evaluators to verify the signal processing requirement metrics, such as MOPS, memory and gate count, provided by the RTT proponent.	Q and q	G2	A1.4.13

A3.2.5.2	What is the channel coding/error handling for both the forward and reverse links? Provide details and ensure that implementation specifics are described and their impact considered in DSP requirements described in § A3.2.5.1.	q	G4	A1.2.12 A1.4.13
A3.2.6	Antenna systems The implementation of specialized antenna systems while potentially increasing the complexity and cost of the overall system can improve spectrum efficiency (e.g. smart antennas), quality (e.g. diversity), and reduce system deployment costs (e.g. remote antennas, leaky feeder antennas). NOTE 1 – For the satellite component, diversity indicates the number of satellites involved; the other antenna attributes do not apply.			
A3.2.6.1	*Diversity*: describe the diversity schemes applied (including micro and macro diversity schemes). Include in this description the degree of improvement expected, and the number of additional antennas and receivers required to implement the proposed diversity design beyond and omni-directional antenna.	Q	G2	A1.2.23 A1.2.23.1 A1.2.23.2
A3.2.6.2	*Remote antennas*: describe whether and how remote antenna systems can be used to extend coverage to low traffic density areas.	q	G2	A1.3.6
A3.2.6.3	*Distributed antennas*: describe whether and how distributed antenna designs are used.	q	G3	A1.3.6
A3.2.6.4	*Unique antenna*: describe additional antenna systems which are either required or optional for the proposed system, e.g., beam shaping, leaky feeder. Include in the description the advantage or application of the antenna system.	q	G4	A1.3.6
A3.2.7	BS frequency synchronization/time alignment requirements Does the proposed RTT require base transmitter and/or receiver station synchronization or base-to-base bit time alignment? If so, specify the long term (1 year) frequency stability requirements, and also the required bit-to-bit time alignment. Describe the means of achieving this.	Q and q	G3	A1.4.1 A1.4.3
A3.2.8	The number of users per RF carrier/frequency channel that the proposed RTT can support affects overall cost – especially as bearer traffic requirements increase or geographic traffic density varies widely with time. Specify the maximum number of user channels that can be supported while still meeting ITU-T Recommendation G.726 performance requirements for voice traffic.	Q	G1	A1.2.17
A3.2.9	Base site implementation/installation requirements (not applicable to satellite) BS size, mounting, antenna type and height can vary greatly as a function of cell size, RTT design and application environment. Discuss its positive or negative impact on system complexity and cost.	q	G1	A1.4.17
A3.2.10	Handover complexity Consistent with handover quality objectives defined in criterion § 6.1.3, describe how user handover is implemented for both voice and data services and its overall impact on infrastructure cost and complexity.	Q and q	G1	A1.2.24 A1.4.6.1

A3.3	Quality			
A3.3.1	Transparent reconnect procedure for dropped calls Dropped calls can result from shadowing and rapid signal loss. Air interfaces utilizing a transparent reconnect procedure – that is, the same as that employed for hand-off – mitigate against dropped calls whereas RTTs requiring a reconnect procedure significantly different from that used for hand-off do not.	q	G2	A1.4.14
A3.3.2	Round trip delay, D1 (with vocoder (ms)) and D2 (without vocoder (ms)) (See Fig. 6). NOTE 1 – The delay of the codec should be that specified by ITU-T for the common generic voice bearer and if there are any proposals for optional codecs include the information about those also. (For the satellite component, the satellite propagation delay is not included.)	Q	G2	A1.3.7.1 A1.3.7.2
A3.3.3	Handover/ALT quality Intra switch/controller handover directly affects voice service quality. Handover performance, minimum break duration, and average number of handovers are key issues.	Q	G2	A1.2.24 A1.2.24.1 A1.2.24.2 A1.4.6.1
A3.3.4	Handover quality for data There should be a quantitative evaluation of the effect on data performance of handover.	Q	G3	A1.2.24 A1.2.24.1 A1.2.24.2 A1.4.6.1
A3.3.5	Maximum user bit rate for data (bit/s) A higher user bit rate potentially provides higher data service quality (such as high quality video service) from the user's point of view.	Q	G1	A1.3.3
A3.3.6	Channel aggregation to achieve higher user bit There should also be a qualitative evaluation of the method used to aggregate channels to provide higher bit rate services.	q	G4	A1.2.32
A3.3.7	Voice quality Recommendation ITU-R M.1079 specifies that IMT-2000 speech quality without errors should be equivalent to ITU-T Recommendation G.726 (32 kbit/s ADPCM) with desired performance at ITU-T Recommendation G.711 (64 kbit/s PCM). NOTE 1 – Voice quality equivalent to ITU-T Recommendation G.726 error free with no more than a 0.5 degradation in MOS in the presence of 3% frame erasures might be a requirement.	Q and q	G1	A1.2.19 A1.3.8
A3.3.8	System overload performance (not applicable to satellite) Evaluate the effect on system blocking and quality performance on both the primary and adjacent cells during an overload condition, at e.g. 125%, 150%, 175%, 200%. Also evaluate any other effects of an overload condition.	Q and q	G3	A1.3.9.1

A3.4	Flexibility of radio technologies			
A3.4.1	Services aspects			
A3.4.1.1	Variable user bit rate capabilities Variable user bit rate applications can consist of the following: – adaptive signal coding as a function of RF signal quality; – adaptive voice coder rate as a function of traffic loading as long as ITU-T Recommendation G.726 performance is met; – variable data rate as a function of user application; – variable voice/data channel utilization as a function of traffic mix requirements. Some important aspects which should be investigated are as follows: – how is variable bit rate supported? – what are the limitations? Supporting technical information should be provided such as – the range of possible data rates, – the rate of changes (ms).	q and Q	G2	A1.2.18 A1.2.18.1
A3.4.1.2	Maximum tolerable Doppler shift, F_d (Hz) for which voice and data quality requirements are met (terrestrial only) Supporting technical information: F_d	q and Q	G3	A1.3.1.4
A3.4.1.3	Doppler compensation method (satellite component only) What is the Doppler compensation method and residual Doppler shift after compensation?	Q and q	G3	A1.3.2.2
A3.4.1.4	How the maximum tolerable delay spread of the proposed technology impact the flexibility (e.g., ability to cope with very high mobile speed)?	q	G3	A1.3.1.3 A1.2.14 A1.2.14.1 A1.2.14.2 A1.3.10
A3.4.1.5	Maximum user information bit rate, R_u (kbit/s) How flexibly services can be offered to customers ? What is the limitation in number of users for each particular service? (e.g. no more than two simultaneous 2 Mbit/s users)	Q and q	G2	A1.3.3 A1.3.1.5.2 A1.2.31 A1.2.32
A3.4.1.6	Multiple vocoder rate capability – bit rate variability, – delay variability, – error protection variability.	Q and q	G3	A1.2.19 A1.2.19.1 A1.2.7 A1.2.12
A3.4.1.7	Multimedia capabilities The proponents should describe how multimedia services are handled. The following items should be evaluated: – possible limitations (in data rates, number of bearers), – ability to allocate extra bearers during of the communication, – constraints for handover.	Q and q	G1	A1.2.21 A1.2.20 A1.3.1.5.2 A1.2.18 A1.2.24 A1.2.30 A1.2.30.1
A3.4.2	Planning			
A3.4.2.1	Spectrum related matters			

A3.4.2.1.1	Flexibility in the use of the frequency band The proponents should provide the necessary information related to this topic (e.g., allocation of sub-carriers with no constraints, handling of asymmetric services, usage of non-paired band).	q	G1	A1.2.1 A1.2.2 A1.2.2.1 A1.2.3 A1.2.5.1
A3.4.2.1.2	Spectrum sharing capabilities The proponent should indicate how global spectrum allocation can be shared between operators in the same region. The following aspects may be detailed: – means for spectrum sharing between operators in the same region, – guardband between operators in case of fixed sharing.	q and Q	G4	A1.2.26
A3.4.2.1.3	Minimum frequency band necessary to operate the system in good conditions Supporting technical information: – impact of the frequency reuse pattern, – bandwidth necessary to carry high peak data rate.	Q and q	G1	A1.2.1 A1.4.15 A1.2.5
A3.4.2.2	Radio resource planning			
A3.4.2.2.1	Allocation of radio resources The proponents and evaluators should focus on the requirements and constraints imposed by the proposed technology. More particularly, the following aspects should be considered: – what are the methods used to make the allocation and planning of radio resources flexible? – what are the impacts on the network side (e.g. synchronization of BSs, signalling,)? – other aspects. Examples of functions or type of planning required which may be supported by the proposed technology: – DCA, – frequency hopping, – code planning, – time planning, – nterleaved frequency planning. NOTE 1 – The use of the second adjacent channel instead of the adjacent channel at a neighbouring cluster cell is called “interleaved frequency planning”. In some cases, no particular functions are necessary (e.g. frequency reuse = 1).	q	G2	A1.2.25 A1.2.27 A1.4.15
A3.4.2.2.2	Adaptability to adapt to different and/or time varying conditions (e.g., propagation, traffic) How the proposed technology cope with varying propagation and/or traffic conditions? Examples of adaptive functions which may be supported by the proposed technology: – DCA, – link adaptation, – fast power control, – adaptation to large delay spreads. Some adaptivity aspects may be inherent to the RTT.	q	G2	A1.3.10 A1.2.27 A1.2.22 A1.2.14
A3.4.2.3	Mixed cell architecture (not applicable to satellite component)			

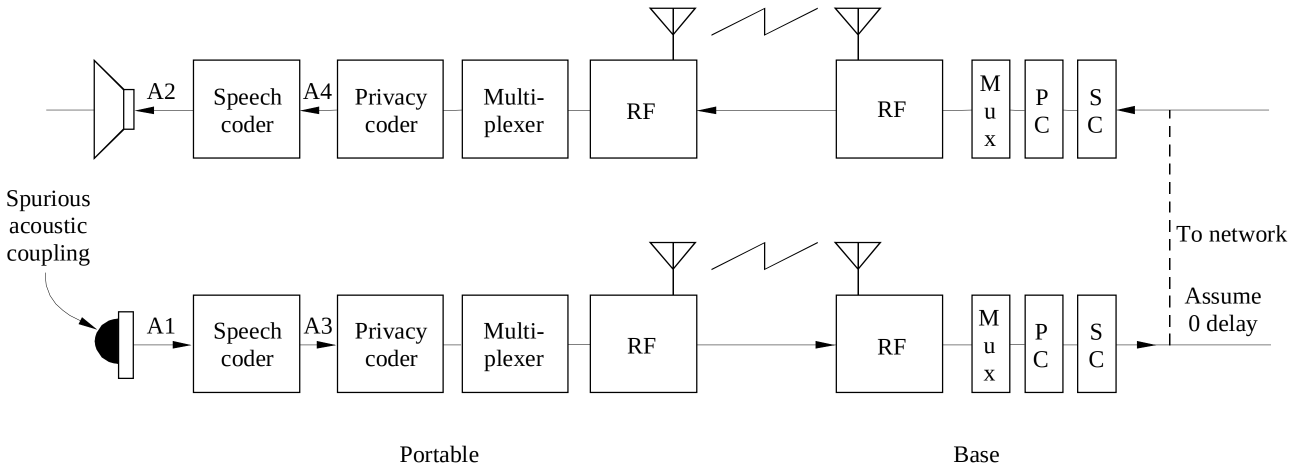
A3.4.2.3.1	Frequency management between different layers What kind of planning is required to manage frequencies between the different layers? e.g. – fixed separation, – dynamic separation, – possibility to use the same frequencies between different layers. Possible supporting technical information: – guard band.	q and Q	G1	A1.2.28 A1.4.15
A3.4.2.3.2	User adaptation to the environment What are the constraints to the management of users between the different cell layers? e.g. – constraints for handover between different layers, – adaptation to the cell layers depending on services, mobile speed, mobile power.	q	G2	A1.2.28 A1.3.10
A3.4.2.4	Fixed-wireless access			
A3.4.2.4.1	The proponents should indicate how well its technology is suited for operation in the fixed wireless access environment. Areas which would need evaluation include (not applicable to satellite component): – ability to deploy small BSs easily, – use of repeaters, – use of large cells, – ability to support fixed and mobile users within a cell, – network and signalling simplification.	q	G4	A1.1.3 A1.3.5 A1.4.17 A1.4.7 A1.4.7.1
A3.4.2.4.2	Possible use of adaptive antennas (how well suited is the technology) (not applicable to satellite component) Is RTT suited to introduce adaptive antennas? Explain the reason if it is.	q	G4	A1.3.6
A3.4.2.4.3	Existing system migration capability	q	G1	A1.4.16
A3.5	Implication on network interface			
A3.5.1	Examine the synchronization requirements with respect to the network interfaces. *Best case* : no special accommodation necessary to provide synchronization. *Worst case* : special accommodation for synchronization is required, e.g. additional equipment at BS or special consideration for facilities.	q	G4	A1.4.3
A3.5.2	Examine the RTTs ability to minimize the network infrastructure involvement in cell handover. *Best case* : neither PSTN/ISDN nor mobile switch involvement in handover. *Worst case* : landline network involvement essential for handover.	q	G3	A1.2.24 A1.4.6.1
A3.5.3	Landline feature transparency			
A3.5.3.1	Examine the network modifications required for the RTT to pass the standard set of ISDN bearer services. *Best case* : no modifications required. *Worst case*: substantial modification required, such as interworking functions.	q	G1	A1.4.7.1

A3.5.3.2	Examine the extent of the PSTN/ISDN involvement in switching functionality. *Best case*: all switching of calls is handled by the PSTN/ISDN. *Worst case*: a separate mobile switch is required.	q	G2	A1.4.6 A1.4.8
A3.5.3.3	Examine the depth and duration of fading that would result in a dropped call to the PSTN/ISDN network. The robustness of an RTTs ability to minimize dropped calls could be provided by techniques such as transparent reconnect.	Q and q	G3	A1.2.24 A1.4.14
A3.5.3.4	Examine the quantity and type of network interfaces necessary for the RTT based on the deployment model used for spectrum and coverage efficiencies. The assessment should include those connections necessary for traffic, signalling and control as well as any special requirements, such as soft handover or simulcast.	Q	G2	A1.2.30 A1.2.30.1 A1.4.9
A3.6	Handportable performance optimization capability			
A3.6.1	Isolation between transmitter and receiver Isolation between transmitter and receiver has an impact on the size and weight of the handportable.	Q	G2	A1.2.2 A1.2.2.1 A1.2.2.2
A3.6.2	Average terminal power output P_0 (mW) Lower power gives longer battery life and greater operating time.	Q	G2	A1.2.16.1.2
A3.6.3	System round trip delay impacts the amount of acoustical isolation required between handportable microphone and speaker components and, as such, the physical size and mechanical design of the subscriber unit. NOTE 1 – The delay of the codec should be that specified by ITU-T for the common generic voice bearer and if there are any proposals for optional codecs include the information about those also. (For the satellite component, the satellite propagation delay is not included.)	Q and q	G2	A1.3.7 A1.3.7.1 A1.3.7.2 A1.3.7.3
A3.6.4	Peak transmission power	Q	G1	A1.2.16.1.1
A3.6.5	Power control characteristics Does the proposed RTT utilize transmitter power control? If so, is it used in both forward and reverse links? State the power control range, step size (dB) and required accuracy, number of possible step sizes and number of power controls per second, which are concerned with mobile station technology complexity.			
A3.6.5.1	Power control dynamic range Larger power control dynamic range gives longer battery life and greater operating time.	Q	G3	A1.2.22 A1.2.22.3 A1.2.22.4
A3.6.5.2	Power control step size, accuracy and speed	Q	G3	A1.2.22 A1.2.22.1 A1.2.22.2 A1.2.22.5
A3.6.6	Linear transmitter requirements	q	G3	A1.4.10
A3.6.7	Linear receiver requirements (not applicable to satellite)	q	G3	A1.4.11
A3.6.8	Dynamic range of receiver The lower the dynamic range requirement, the lower the complexity and ease of design implementation.	Q	G3	A1.4.12
A3.6.9	Diversity schemes Diversity has an impact on handportable complexity and size. If utilized describe the type of diversity and address the following two attributes.	Q and q	G1	A1.2.23 A1.2.23.1 A1.2.23.2

A3.6.10	The number of antennas	Q	G1	A1.2.23.1
A3.6.11	The number of receivers	Q	G1	A1.2.23.1
A3.6.12	Frequency stability Tight frequency stability requirements contribute to handportable complexity.	Q	G3	A1.4.1.2
A3.6.13	The ratio of "off (sleep)" time to "on" time	Q	G1	A1.2.29 A1.2.29.1
A3.6.14	Frequency generator step size, switched speed and frequency range Tight step size, switch speed and wide frequency range contribute to handportable complexity. Conversely, they increase RTT flexibility.	Q	G2	A1.4.5
A3.6.15	Digital signal processing requirements Digital signal processing can be a significant proportion of the hardware for some radio interface proposals. It can contribute to the cost, size, weight and power consumption of the BS and influence secondary factors such as heat management and reliability. Any digital circuitry associated with the network interfaces should not be included. However any special requirements for interfacing with these functions should be included. This section of the evaluation should analyse the detailed description of the digital signal processing requirements, including performance characteristics, architecture and algorithms, in order to estimate the impact on complexity of the BSs. At a minimum the evaluation should review the signal processing estimates (MOPS, memory requirements, gate counts) required for demodulation, equalization, channel coding, error correction, diversity processing (including Rake receivers), adaptive antenna array processing, modulation, A-D and D-A converters and multiplexing as well as some IF and baseband filtering. For new technologies, there may be additional or alternative requirements (such as FFTs). Although specific implementations are likely to vary, good sample descriptions should allow the relative cost, complexity and power consumption to be compared for the candidate RTTs, as well as the size and the weight of the circuitry. The descriptions should allow the evaluators to verify the signal processing requirement metrics, such as MOPS, memory and gate count, provided by the RTT proponent.	Q and q	G1	A1.4.13
A3.7	Coverage/power efficiency			
A3.7.1	Terrestrial Coverage efficiency: – the coverage efficiency is considered for the lowest traffic loadings; – the base site coverage efficiency can be quantitatively determined by addressing coverage limitation and/or by calculating the maximum coverage range for the lowest traffic loading.			
A3.7.1.1	Base site coverage efficiency The number of base sites required to provide coverage at system start-up and ongoing traffic growth significantly impacts cost. From § 1.3.2 of Annex 2, determine the coverage efficiency, *C* (km^2/base sites), for the lowest traffic loadings. Proponent has to indicate the background of the calculation and also to indicate the maximum coverage range.	Q	G1	A1.3.1.7 A1.3.1.7.1 A1.3.1.7.2 A1.3.4

A3.7.1.2	Method to increase the coverage efficiency Proponent describes the technique adopted to increase the coverage efficiency and drawbacks. Remote antenna systems can be used to economically extend vehicular coverage to low traffic density areas. RTT link budget, propagation delay system noise and diversity strategies can be impacted by their use. Distributed antenna designs – similar to remote antenna systems – interconnect multiple antennas to a single radio port via broadband lines. However, their application is not necessary limited to providing coverage, but can also be used to economically provide continuous building coverage for pedestrian applications. System synchronization, delay spread, and noise performance can be impacted by their use.	q	G1	A1.3.5 A1.3.6
A3.7.2	Satellite Normalized power efficiency Supported information bit rate per required carrier power-to-noise density ratio for the given channel performance under the given interference conditions for voice Supported information bit rate per required carrier power-to-noise density ratio for the given channel performance under the given interference conditions for voice plus data mixed traffic.	Q	G1	A1.3.2.4 A1.3.2.4.1 A1.3.2.4.2

FIGURE 6



D1: delay between A1 and A2
D2: delay between A3 and A4
Mux: multiplexer
PC: privacy coder
SC: speech coder

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