



Recommendation ITU-R M.2101-0
(02/2017)

**Modelling and simulation of IMT networks
and systems for use in sharing and
compatibility studies**

M Series
**Mobile, radiodetermination, amateur
and related satellite services**



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Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

Electronic Publication
Geneva, 2017

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RECOMMENDATION ITU-R M.2101-0

**Modelling and simulation of IMT networks and systems for use
in sharing and compatibility studies**

(2017)

Scope

This Recommendation contains the methodology for modelling and simulation of IMT¹ networks for use in sharing and compatibility studies between IMT and other systems and/or applications. As such, it does not make any assumptions on the system parameters or modelling of these other systems and/or applications and is strictly limited to providing information for the IMT systems.

Keywords

IMT, IMT-Advanced, mobile systems, sharing/compatibility issues

Related Recommendations and Reports

Recommendation ITU-R M.2012 – Detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced)

Report ITU-R M.2292 – Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses

The ITU Radiocommunication Assembly,

considering

- a) that Question ITU-R 229/5 addresses further development of the terrestrial component of IMT and the relevant studies under this Question are in progress within ITU-R;
- b) that Resolution **223 (Rev. WRC-15)** invites ITU-R to conduct a number of compatibility studies between IMT systems and other systems and/or applications;
- c) that Resolution **238 (WRC-15)** resolves to invite ITU-R to conduct appropriate sharing and compatibility studies between IMT systems and other systems and/or applications in a number of frequency bands;
- d) that development of new radio interfaces that support the new capabilities of IMT-2020 is expected along with the enhancement of IMT-2000 and IMT-Advanced systems, consistent with Resolution ITU-R 57-2;
- e) that methodologies for the modelling and simulation of IMT networks are needed to analyse compatibility between IMT systems and systems in other services;
- f) that an accurate description of simulation of the transmissions of IMT networks, including the calculation of the aggregate effect, is required to realistically model IMT systems in sharing and compatibility scenarios,

¹ References to IMT in this Recommendation addresses modelling of IMT-Advanced and IMT-2020 networks.

recognizing

- a) that Report ITU-R M.2292 provides the characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses;
- b) that Recommendation ITU-R M.2012 contains the detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications Advanced (IMT-Advanced);
- c) that Recommendations ITU-R M.2070 and ITU-R M.2071 provide the generic unwanted emission characteristics of base stations and mobile stations respectively, using the terrestrial radio interfaces of IMT-Advanced,

recommends

that the modelling and simulation of IMT networks and systems for use in sharing and compatibility studies should be based on the methodology contained in Annex 1;

List of abbreviations:

ACIR	adjacent channel interference power ratio
ACLR	adjacent channel leakage power ratio
ACS	adjacent channel selectivity
AAS	advanced antenna system
BS	base station
D2D	device-to-device
eMBB	enhanced mobile broadband
FD	full-dimension
FDR	frequency dependent rejection
HO	handover
M2M	machine-to-machine
MTC	machine-type communications
mMTC	massive machine-type communications
MIMO	Multiple Input Multiple Output
MBB	mobile broadband
OOB	Out-of-band
OOBE	out-of-band emission
RB	resource block
RF	radio frequency
UE	user equipment
URLLC	ultra-reliable and low latency communications

Annex 1

Methodology for modelling and simulation of IMT networks for use in sharing and compatibility studies

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1 Introduction

This Annex contains the methodology for modelling and simulation of IMT networks for use in sharing and compatibility studies. It describes the appropriate IMT models to be used for sharing and compatibility studies between IMT and other radio systems in various frequency bands.

Definitions and basic concepts of IMT networks are described in § 2 to facilitate selection of the appropriate IMT model. Section 2 also provides information on technical elements such as output power and antenna pattern, antenna height and environment associated with deployment scenarios, density and distribution of IMT stations and information on propagation models for paths between IMT base stations and mobile stations.

It contains detailed IMT system parameters to be considered in such modelling and their implementation in the simulations as described in §§ 3 through 6. Specifically, § 3 contains simulation steps for modelling total emissions generated by an IMT network (in the case IMT is the interfering system) as well as modelling the impact on the IMT network (in the case IMT is the interfered-with system). Subsequently, considerations in calculating the aggregate effect of potential interference generated by an IMT system is described in § 7.

Furthermore, in order to emphasize the importance of realistically modelling IMT systems in sharing and compatibility scenarios, § 8 describes means to compare the implementation of modelling of IMT system through comparing interim results related to performance and operation of the IMT system.

2 Definitions and basic concepts

2.1 Usage scenarios

IMT-Advanced is the most widely accepted radio air-interface for the provision of mobile broadband (MBB). The IMT-2020 radio interface, in addition to supporting the enhanced mobile broadband (eMBB) use case, will support emerging use cases with a variety of applications such as massive machine-type communications (mMTC) and ultra-reliable and low latency communications (URLLC). The methodology is applicable for all the above scenarios and focuses mostly on MBB and eMBB scenarios, which are the dominant usage scenarios in sharing and compatibility studies.

Mobile broadband and enhanced mobile broadband are the result of applying more spectrally efficient technologies into larger amounts of spectrum, enabling higher data rate services. Massive machine-type communication is about connectivity for large numbers of low-cost and low-energy consumption devices in the context of the Internet of Things (IoT). Ultra-reliable and low latency communications are envisioned to enable real-time control and automation of dynamic processes in various fields, such as industrial process automation and manufacturing, energy distribution, intelligent transport systems – and requires communication with very high reliability and availability, as well as very low end-to-end latency.

Device-to-device (D2D) and machine-to-machine (M2M) communications may be used for mMTC and URLLC applications. In D2D/M2M communications, mobile stations initiate communications with base stations using their control channel. User data traffic is delivered by data channel directly among mobile stations. In this scenario, mobile stations are located within a cell area provided by a base station.

2.2 Deployment scenarios

From a deployment perspective, it is worthwhile categorizing IMT-Advanced and IMT-2020 radio access networks as either outdoor or indoor and as seamless wide area coverage or small area coverage.

Table 1 provides a high level description of IMT deployments. Categories 1 and 2 are the same as the existing configuration of IMT networks with seamless macro coverage. Categories 3 and 4 for coverage of small areas could be operated independently or combined with categories 1 and 2.

TABLE 1
Categories of radio access networks

MS Location	Seamless wide area coverage	Small area coverage
Outdoor MS	Category 1 Conventional Macro Cell (Omni, Sector Antenna, Beam forming Antenna)	Category 3 Outdoor Small Area Coverage (Omni, Sector Antenna, Beam forming antenna)
Indoor MS	Category 2 Coverage by Outdoor Macro Cell (Omni, Sector Antenna, Beam forming Antenna)	Category 4 Indoor Small Area Coverage (Omni, Sector Antenna, Beam forming antenna)

Furthermore, radio access networks may be classified to each deployment scenario by considering the following aspects:

- environments (Rural / Suburban / Urban / Indoor);
- seamless wide area coverage / Small area coverage.

Six deployment scenarios are defined in Table 2 as combinations of the above aspects a) and b). Three deployment scenarios of macro rural, macro suburban and macro urban are the same as the existing configuration of IMT networks with seamless macro coverage. The other three deployment scenarios of micro suburban, micro urban and indoor are deployed to cover small areas.

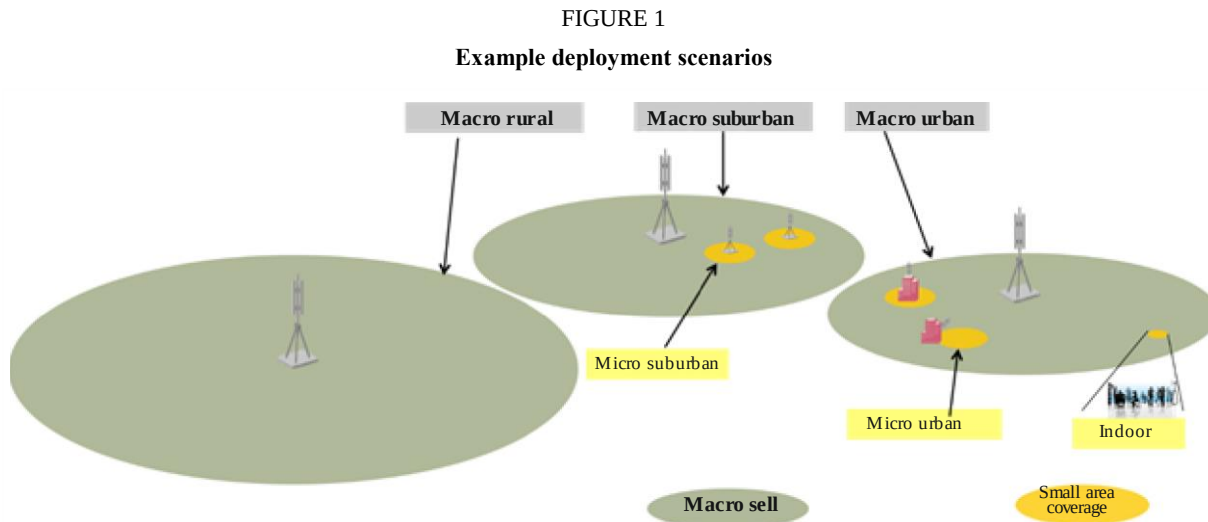
The latter three deployment scenarios could be operated independently in some cases, whereas it could be often the case that they are operated combined with the former three deployment scenarios.

The classification of deployment scenarios in Table 2 is applicable to relevant IMT models and associated propagation environments to apply appropriate IMT modelling for sharing studies.

TABLE 2
Deployment scenarios of radio access networks

Base station location	Seamless wide area coverage	Small area coverage
Rural	Macro rural	Not applicable
Suburban	Macro suburban	Micro suburban
Urban	Macro urban	Micro urban
Indoor	Not applicable	Indoor

An illustration of possible scenarios is provided in Fig. 1 and further described below.



(1) Macro rural

The rural deployment scenario focuses on larger and continuous wide area coverage. Base station antennas are typically deployed at the top of tower.

(2) Macro suburban

The macro suburban scenario focuses on seamless coverage of suburban areas (mainly residential) as well as rural towns with low-rise buildings, but not including the unpopulated areas between them. Base station antennas are typically deployed on tower/rooftop and users can be either outdoors and indoors.

(3) Macro urban

The macro urban scenario focuses on multi-story buildings with base station antennas typically at or above the level of the roofline. Base station power may vary depending on local deployment and coverage needs. Users can either be outdoors or indoors. Repeaters for indoor coverage, if any, are considered equivalent to, and therefore treated as, user equipment (UEs).

(4) Micro suburban

The micro suburban scenario focuses on capacity enhancement in small community areas with low-rise buildings in suburban areas. Base station antennas are typically deployed mounted on poles. Users can either be outdoors or indoors. Repeaters for indoor coverage, if any, are considered equivalent to, and therefore treated as, UEs.

(5) Micro urban

The micro urban scenario focuses on multi-story buildings with base station antennas below the roofline. Base station antennas are typically deployed as single sector antennas or beam forming antennas with low output power. The deployment scenario has an environment that blocking and/or multiple diffractions/scattering are dominant near the antennas, such as street micro cell and small hot spot, from the viewpoint of propagation effects. Users can either be outdoors and indoors.

(6) Indoor

The indoor scenario occurs most often in urban or suburban environments. Base stations and users are indoors.

2.3 Transmit power control

Studies to assess the impact of an entire IMT network should take into account the varying nature of an IMT network, in particular power control.

For uplink, some device types (e.g. low power devices for MTC applications) may operate without any power control while for other types (e.g. enhanced mobile broadband devices) power control will be used. Power control compensates fully or partly for the difference in coupling loss between the different devices connected to the BS and has an initial receive target level per resource block (RB).

For downlink, a number of base station types (Macro, Micro, Pico, Femto, etc.) are used, each having a different EIRP level. Output power of base stations for micro urban and indoor in § 2.2 is generally less than that for other deployment scenarios. No downlink power control scheme is applied at the base station and the transmission power per resource block (RB) is constant. The total downlink power is varied according to the number of RBs used. However, in this Recommendation this effect is modeled in a different way. (See § 3.4).

2.4 Advanced antenna technology and characteristics

Over the past years IMT base station antennas have been developed to optimize the transmission or reception of signals. Also, in IMT terminals the number of receive antennas has increased.

With multiple antenna elements at both the base station and the terminal, new capabilities are possible. Multiple Input Multiple Output (MIMO) allows multiple signal streams to be used for transmit diversity, spatial multiplexing, beam shaping or null steering in one direction or another.

IMT-2020 will, in addition to operation in lower frequency ranges, also operate in higher frequency bands. Antenna size scales with frequency allowing base stations and terminals to exploit smaller antenna footprint with increased number of antenna elements at higher frequencies. Increased number of antenna elements support narrower beam shapes and can reduce the potential interference into other than the intended receiver. Also, higher beam gain can mitigate the higher path loss at higher, e.g. mm-wave, frequencies and support multiple signal streams to multiple users (a.k.a. multi user (MU)-MIMO).

2.5 Antenna height and environment structures

There are few high architectural structures to obstruct line-of-sight propagation around base station antennas in rural environment. Whereas, higher and denser architectural structures appear around base station antennas as the environment varies from suburban to urban. Therefore, the propagation would be affected based on the position of base station antennas and architectural structures around them.

2.6 Density and distribution of stations

It is necessary to consider flexible density and distribution of radio stations in aggregate interference calculations. Demands for high data rate traffic mainly occurs in discrete hot-spot regions. Deployments in higher frequency bands often do not cover all areas in a country/region, as coverage might be complemented using lower frequency bands.

2.7 Propagation models

IMT exists in many deployment configurations, from a single layer homogenous network, e.g. a macro network, to multiple layer heterogeneous networks, e.g. macro/micro network or macro/pico network or micro/pico network etc., and has to handle outdoor to outdoor, outdoor to indoor and indoor propagation environments for several frequency ranges.

In addition, propagation environment between the IMT system and systems of other services subject to any coexistence conditions need to also be taken into account. Several models already exist as P-series ITU-R Recommendations or ITU-R Reports. For calculation of the path loss between the IMT base stations and UEs, see also Report ITU-R M.2135.

Propagation effects between the interfering and the interfered-with systems are outside the scope of this document. However, when choosing propagation models the deployment environments of the IMT systems, including the position of the base station antennas, surrounding physical structures and operating frequencies, should be taken into account.

2.8 Repeaters for indoor coverage

In order to overcome large indoor penetration loss, it might be practical to utilize wall-mounted repeaters on the outside of buildings or placed by the window inside buildings to easily obtain near line-of-sight propagation toward a base station.

2.9 Protection criteria for IMT

Protection criteria are given in ITU-R documents such as Report ITU-R M.2292, which provides I/N as the protection criterion. The I/N is the ratio of the allowed inter-system interference level received in the IMT receiver relative to the receiver's noise level (thermal noise + receiver noise figure).

In modelling IMT networks, the degradation of carrier to interference plus noise ($C/(I+N)$) could also be used to evaluate throughput loss or outage of the IMT system caused by inter-system interference.

3 Simulation set up

For modelling and simulation of IMT networks for use in co-existence studies, it is essential to select appropriate deployment conditions. The assumed deployment conditions are critical aspects that will directly impact the results of any sharing study. Examples of such factors are realistic choice of the environment in which the assumed IMT network operates (urban/suburban/rural) and the frequency bands that are to be used in the IMT simulation. In addition, density and distribution of stations and EIRP may be considered depending on factors such as the size of the area over which interference is aggregated. Other factors that need consideration are discussed briefly below.

3.1 Network topology

There are two different types of network structure: Homogeneous networks and Heterogeneous networks. A homogeneous network structure consists of a single base station type. It can be a macro, a micro or an indoor base station. A heterogeneous network structure consists of combination of at least two base station types. For a large area or nationwide studies a combination of network structures may be required.

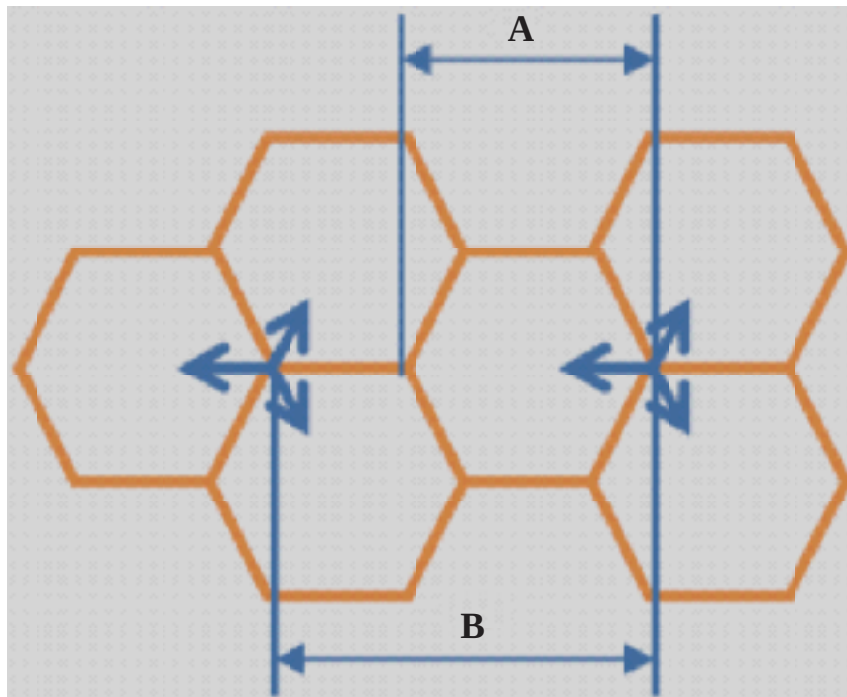
3.1.1 Macro cellular network

Macro base stations are often deployed above roof-top. Figure 2 illustrates the geometry for a 3-sector deployment, and illustrates the parameters cell radius (A) and inter-site distance (B). Each

cell (also referred to as a sector) is shown as a hexagon, and in this Figure there are three cells/sectors per base station site. Cell sizes in IMT networks can vary considerably depending on the environment, carrier frequency and the base station's type.

In large area or nationwide sharing studies using cell radii corresponding to urban and suburban deployment should take into account those that are only deployed in limited, central areas of large cities and suburban areas.

FIGURE 2
Macro cell geometry



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One example of a macro network topology is depicted in Fig. 3. The entire network region relevant for simulations is a cluster of nineteen sites of three sectors each (sites 0 to 18 in the Figure), where other clusters of 19 sites are repeated around this central cluster based on a wrap-around methodology employed to avoid the network deployment edge effects. (See Attachment 2 for information on wrap-around methodology.) In some scenarios, for example in cross-border situations, modelling of the edge effects may be required.