WHITEPAPER

# IMT (5G) operation in satellite downlink frequency bands and uplink frequency bands, same-same or ……?

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## 1. Executive Summary

International Mobile Telecommunications (IMT) and Fixed-Satellite Service (FSS) offer very different applications and there is no commercial competition between them. Quite on the contrary, the two are complementary to each other where FSS can support IMT e.g. by providing backhaul services or by offering solutions where IMT for technical and/or economic reasons is unable to offer the services. Therefore, there should be no reason for IMT and FSS to fight each other.

Yet, as demand for mobile broadband is increasing, IMT has been forced to move up in frequency to find the required bandwidths, and as a consequence looking at bands used by FSS where analyses and practical experience have shown technical difficulties for co-existence. The controversy that has emerged between the two sides therefore stems from the fight for access to scarce spectrum resources and not a fight over customers or market shares. Over the years, the debates over IMT moving into satellite frequency bands have become very polarized with little will on either side to recognize the needs of the other side and constructive dialogue has become increasingly difficult to achieve. As a result, decisions have become largely political where one side “wins” and the other side “loses”.

If efficient spectrum usage is to be achieved, it is necessary that both sides work constructively together to identify mutually agreeable solutions that are technically consistent. In doing so, it is important that both sides are prepared to share the burden of co-existence and that both sides do not claim excessive protection based on unrealistic parameters and inflated protection requirements, nor claim unreasonable operational flexibility and power levels. At the same time, it is important to ensure that reasonable and realistic applications can continue to operate with an adequate service quality.

When IMT started moving into FSS frequency bands, it was first in satellite downlink bands. Analyses and practical experience showed that once IMT was deployed in an area, general satellite reception would be impossible at the same or at adjacent frequency bands in that area, i.e. IMT would squeeze out FSS from that area. Now, in a new move, use of satellite uplink frequency bands for IMT systems is also being considered, either through explicit identifications for IMT in the International Telecommunication Union (ITU) Radio Regulations (RR) to help focus industry efforts or through individual administrations licensing such use under RR frequency allocations for mobile use, but without an IMT identification in RR. Such use has already been decided for some cases and more frequency bands are currently under consideration within ITU. Just like when IMT systems have been considered in satellite downlink bands, the response from the satellite industry has been a unison NO, NO!!

**But is the situation the same in satellite up- and downlink bands?**

**Can one up-front conclude that co-existence in satellite uplink bands, as that in downlink bands, is also impossible?**

**Or could there be measures that could improve the potential for co-existence in satellite uplink bands that is worth investigating before drawing conclusions?**

Noting that technically, the interference mechanisms are very different in satellite downlink and uplink bands, this article has discussed the interference mechanisms for the satellite uplink bands and is suggesting some measures for improving compatibility that might be worth investigating. It is important to note that for mutually agreeable co-existence measures to have a chance to be identified, the IMT and satellite industry have to get out of the current polarized positions and cooperate in a manner where both sides accept limitations and where both sides refrain from unduly blocking the other through unreasonable protection requirements, unrealistic technical parameters or inflated power and spectrum demands.

For IMT and FSS to be able to co-exist in satellite uplink bands, this article has identified two requirements and possible ways to achieve these:

**A. Receiving satellites must have a defined maximum interference level stemming from the aggregation of all co-frequency emissions from IMT stations.**

To achieve this:

a. The current limits in sections I and II of Article 21 of RR (RR Art 21) do not lead to a defined or satisfactory protection of receiving satellites from transmitting terrestrial stations, including IMT stations. Noting that there is no frequency coordination procedure between transmitting terrestrial stations and receiving satellites, the best solution would be to revise these sections since this would define protection of receiving satellites from all transmitting terrestrial stations, IMT and non-IMT, with or without an identification.

   Such a revision may however prove to be a long, complex and controversial process with an unknown outcome.

b. As an alternative, as done in other cases when applications of a service are identified, the footnotes for specific frequency bands and sometimes Resolutions associated with these identifications in the Radio Regulations could contain the limits to protect receiving satellites when satellite uplink bands are identified for IMT.

c. Interference limits, whether contained in section I or II of Article 21 of RR or associated with individual IMT identifications, should be defined in terms of emission levels towards the receiving satellites (preferably EIRP density or pfd limits) and not indirect limits as currently contained in sections I and II of RR Art 21 and in RR Resolution 242. As shown, such indirect limits will not provide a defined protection of the receiving satellites while at the same time they may unduly hinder efficient IMT system design. Between EIRP density and pfd limits, the latter is seen to also give the IMT operator the added flexibility to take into account the effect of blocking due to indoor deployment, buildings or local terrain.

d. For practical reasons, limits for IMT must be established for individual stations. The levels for such limits established need to be based on an assessment of the total aggregated interference generated into the receiving satellites.

e. It is important that such limits are hard limits, with no option for individual administration to exceed these. This is because the interference into the receiving satellites will be the aggregation of interference from a large number of transmitting IMT stations, from a large number of countries and from several operators. If interference occurs, it is not possible to complain to one country to have the interference eliminated.

f. IMT power emitted into space for the IMT side is wasted energy since the IMT receivers will be on the ground. In practical design, it therefore should also be in the interest of the IMT side to limit the emissions into space as much as possible. For this reason, the IMT side would have no gain as well from inflated power allowances in the direction of space.

B. **Deployment of future transmitting Earth stations must not be hindered in areas where IMT systems are deployed.**

Transmitting Earth stations have the capability to interfere with receiving IMT stations operating at the same frequency in their vicinity. If appropriate measures are not implemented, this could lead to a situation where, after IMT is deployed, future development and deployment of transmitting Earth stations is hindered due to claims over possible interference into IMT receivers.

In licensing IMT in the 24.25-27.5 and 27.5-28<->29.5 GHz bands, some administrations are seen to specify that IMT and FSS is to co-exist on a “first come, first served” basis without any further provisions to foster co-existence. However, this means that once IMT is deployed in an area, that area in all likelihood is blocked for future development and deployment of transmitting Earth stations due to concerns regarding possible interference into receiving IMT stations.

To avoid this:

a. In comparison with the cell structure of IMT base stations, FSS Earth stations will be few and far between and individual Earth stations will normally transmit at bandwidths much smaller than IMT channels. Also, while transmitting Earth stations are removed and added according to customer demand, the deployment is relatively stable. Moreover, each IMT cell will only use a portion of the entire IMT band at any given time.

   If knowledge about the location and operational frequency band of transmitting Earth stations is available to the IMT system, the system could be arranged such that the frequencies overlapping with the transmitting Earth station is not used in cells in the vicinity of the Earth station. When Earth stations are removed or established, the IMT system could amend its frequency use to adapt to the changed scenario.

   To achieve this, Cognitive Radio Systems supported by Software Defined Radio techniques could be used whereby the IMT system obtains information about the interference environment in an area, e.g. through monitoring or through accessing a database.

b. To further enhance the efficiency of co-existence, to reduce the area around a transmitting Earth station where interference could be encountered by receiving IMT stations, interference mitigation techniques could be implemented. Such techniques include:

   i. Site shielding of transmitting Earth stations
   To reduce the interference potential into receiving IMT stations, Earth stations could be placed at locations providing shielding towards the surroundings, e.g. on ground rather than on rooftops, surrounded by natural hinder and/or buildings etc.

   ii. Shaped IMT beams with nulls or low gains towards transmitting Earth stations
   IMT antennas can use electronically steered array antennas to shape the beam to produce shaped beams with high gains in the direction of the IMT receivers, but also to produce nulls or low antenna gains of the receiving antenna in the direction of an interfering Earth station.

Measures to reduce interference into IMT receivers or make IMT systems more resilient to interference require that this is included in the system design phase since modifying the system design later to include such measures would be far more complicated and costly. ITU does not regulate domestic coordination and since co-existence would be for within the same geographic area, the responsibility for achieving such compatibility lies with the frequency administration responsible for that area. It is therefore important that to facilitate co-existence, administrations have to include this from the very beginning as a part of the licensing conditions as there would be little incentive for IMT or satellite operators to implement them later.

The easiest solution for administrations would be to license IMT on a non-protected basis in respect of transmitting Earth stations since this would then leave it up to each IMT operator to determine the best solution for them to co-exist with transmitting Earth stations. This would however provide no incentive for satellite operators to employ site shielding or provide information about earth station deployment into a database.

## 2. Background

Over the last 1-2 decades, satellite networks have seen terrestrial networks being licensed by administrations and ubiquitously deployed in frequency bands already being extensively used by satellite downlinks with a multitude of receiving satellite dishes, ranging from the smallest direct-to-home and mobile antennas to the biggest teleports. Most notably is the deployment in the lower part of the C-band downlink, 3 400-3 600/3 800 MHz, first by fixed broadband access networks and later by IMT (International Mobile Telephony, mobile phone networks encompassing 4G and 5G networks). The IMT development got a big boost when ITU in 2007 identified the 3 400-3 600 MHz frequency band for IMT in large areas of the world.

The consequences we know all too well. As predicted, as IMT networks have been deployed in country after country, widespread interference has occurred, rendering general satellite reception impossible in frequency bands used by IMT as well as frequency bands adjacent to IMT in large areas. Exclusion zones, separation distances, guardbands and waveguide filters have become household measures for those satellite users striving to co-exist with IMT.

Now, there is a new trend.

IMT has also laid their eyes on satellite uplink bands.

In 2019, ITU identified 24.25-27.5GHz for IMT. Out of this, 24.65/24.75-25.25 GHz and 27-27.5 GHz are allocated for satellite uplinks in different parts of the world. Furthermore, without any IMT identification, several administrations are seen to license IMT above 27.5 GHz under existing mobile frequency allocations, typically up to around 28.35 GHz, but some are seen to license IMT all the way up to 29.5 GHz which marks the upper boundary for this ITU mobile frequency allocation. The same thing are seen to happen at C-band where ITU at its 2023 World Radio Conference (WRC-23) will consider proposals to identify 6 425-7 125 MHz for IMT. Out of this, the 6 425-7 075 MHz band is a part of the C-band satellite uplink spectrum.

The response by the satellite community, not surprisingly, has been a unison NO, NO, NO!

However, is the impact the same if IMT is deployed in satellite uplink frequency bands as if it is deployed in downlink frequency bands and is such a reaction well founded? Or could it be different?

In this article, we are discussing the technical situation related to co-existence between IMT and FSS in satellite uplink bands and measures that could be worth investigating to enable or enhance the possibility for co-existence.

## 3. Interference

Radiocommunication links, for satellite and terrestrial networks alike normally are from a transmitter at one end, a receiver on the other end. When operating in the same or adjacent frequency bands, interference can occur from transmitters of one service into receivers of the other service, these being IMT or satellite receivers.

In sections 4 and 5, the interference scenarios for frequency sharing in satellite downlink and uplink frequency bands respectively are described. Section 5 furthermore continues by discussing, for co-existence in satellite uplink bands, mechanisms in the Radio Regulations for interference protection between the services and possible measures that could be worth studying to facilitate co-existence.

## 4. IMT in satellite downlink bands

The paths of the wanted and interfering signals in the case of IMT operating in satellite downlink bands are shown in Figure 1.

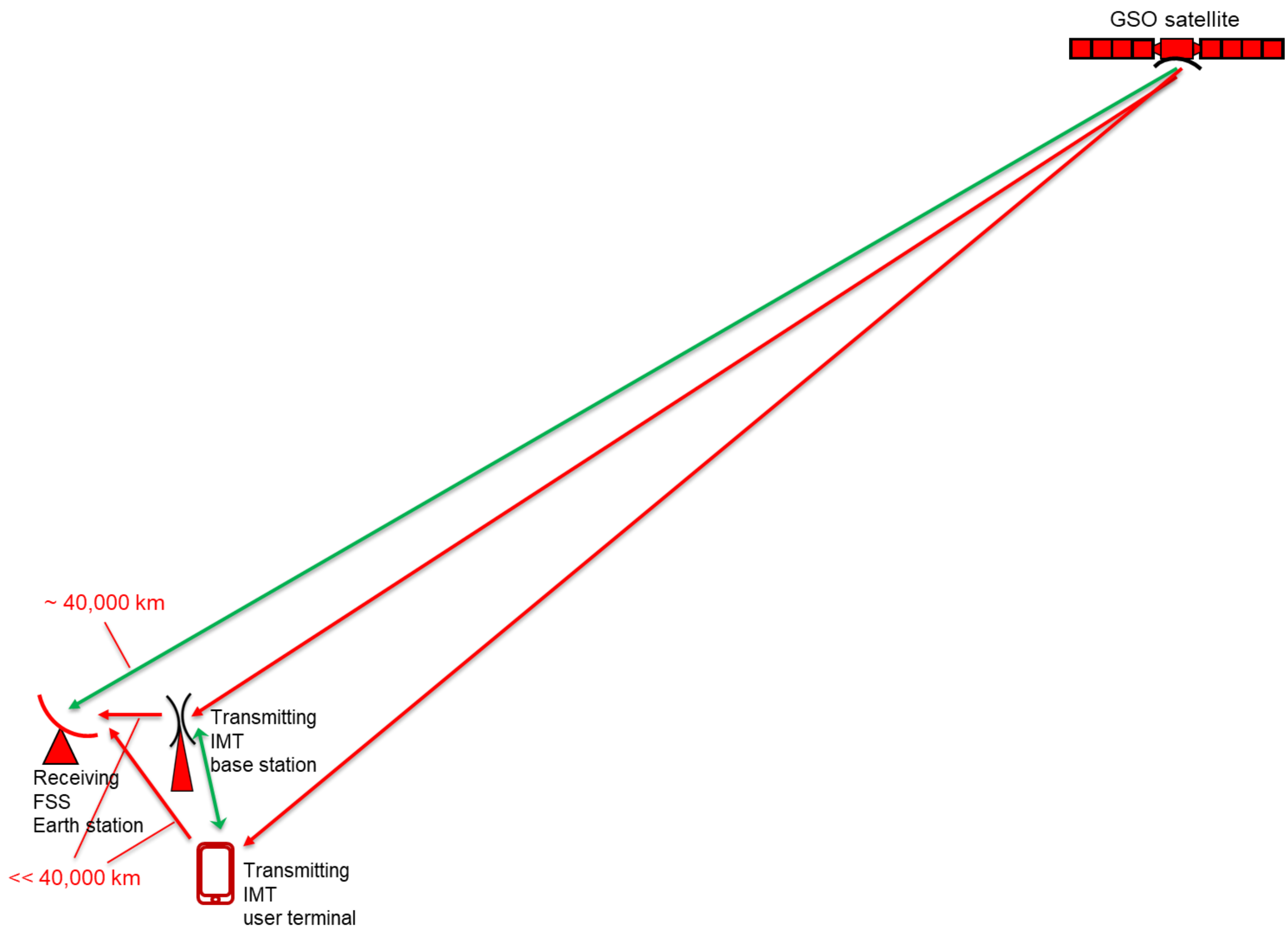


Figure 1: Signal paths when IMT and FSS are sharing FSS downlink bands

In the FSS downlink case;

- the transmitting FSS spacecraft can cause interference into the receiving IMT stations and;
- the transmitting IMT stations can cause interference into the receiving FSS earth station.

In respect of the first case, to protect receiving stations of terrestrial services, including receiving IMT stations, the Radio Regulations (§ 21.16) provide strict hard limits that transmitting satellites are obliged to adhere to. In FSS downlink bands, IMT receivers are therefore automatically protected through these limits.

In respect of the second case, to protect receiving earth stations from transmitting terrestrial stations, including IMT stations, there are no similar limits. Instead, protection of receiving FSS Earth stations is provided on a case-by-case basis by establishing contours around individual Earth stations when such Earth stations are filed to ITU. It is also worth to note that under ITU rules, these contours only give international protection, i.e. protection against interference coming from other countries, but no protection against interference coming from the same country since this is regarded as a domestic issue where each country is sovereign to decide their own rules based on their own preferences. With the large number of Earth stations in the regular satellite bands used for a multitude of applications such as private and corporate data networks (VSAT), Satellite News Gathering (SNG), Direct-to-Home TV reception (DTH) and maritime, aeronautical and land mobile Earth stations (ESIMs, ESVs), it is obvious that it is not practically possible for ITU nor national frequency administrations to treat all these Earth stations individually. As a result, these Earth stations are not filed with ITU and operate under blanket licensing with no individual registration. The consequence is that these Earth stations have no protection against interference from terrestrial transmitters, including IMT transmitters.

The consequences we know all too well from the lower part of C-band (3 400-3 600 MHz) when first Broadband Wireless Access (BWA) operators (e.g. WiMax) and later IMT operators (4G/5G) started to deploy services in the band;

- massive interference,
- loss of service in-band and adjacent band,
- customers scrambling to move as far away from frequency bands overlapping with IMT as possible,
- guardbands between IMT and FSS frequency bands,
- retrofitting Earth stations with expensive waveguide filters (where possible),
- frantic negotiations with frequency administrations to establish some kind of protection zone around key teleports etc.

# 5. IMT in satellite uplink bands

Now, the question is whether it will be the same if IMT moves into satellite uplink bands. The geometry for the signal paths in the satellite uplink bands are shown in Figure 2.

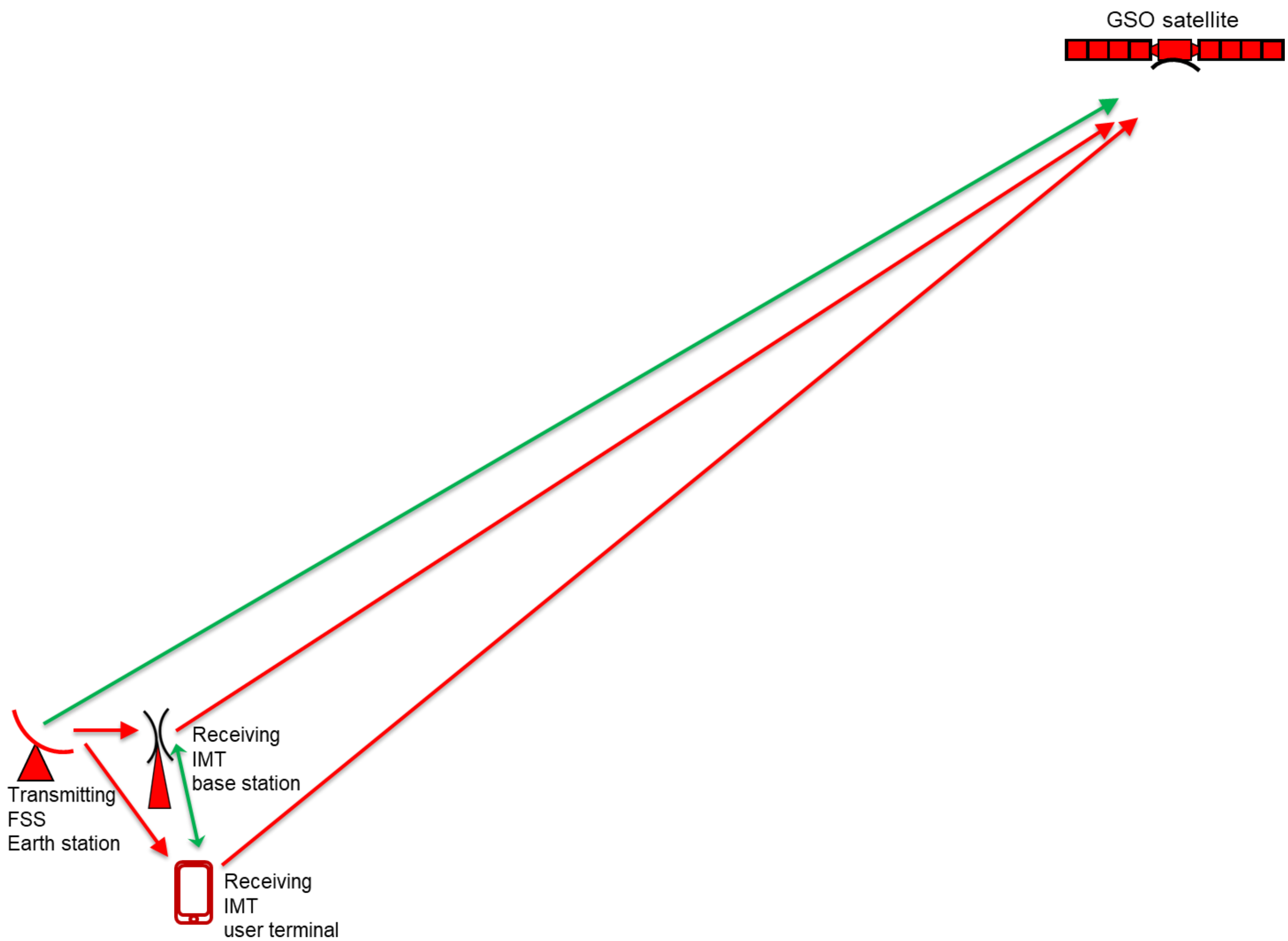


Figure 2: Signal paths when IMT and FSS are sharing FSS uplink bands

Looking at the geometry of the signal paths, it looks similar to that of the downlink situation, but there is one important difference: The direction of transmission is the opposite and thereby also the direction of the interference.

As a result, in the FSS uplink case;

- the transmitting IMT stations can cause interference into the receiving FSS satellite and;
- the transmitting FSS Earth station can cause interference into the receiving IMT stations.

## 5.1 Interference into receiving FSS satellite

Transmitting IMT stations, base stations and user terminals, will all produce interfering signals in the direction of the receiving FSS satellite.

In practical implementation, IMT stations will aim at directing the power in the direction of where they would have receivers, i.e. on the ground and the power from one IMT station in the direction of a satellite therefore may be low compared to that of the uplink signal from the FSS Earth station. However, when several IMT stations are transmitting at the same frequency from several cells of several networks, the aggregation of the interference into the receiving FSS satellite will increase. For example, a C-band beam of the AsiaSat satellites can see roughly 2/3 of the world's population (see Figure 3).

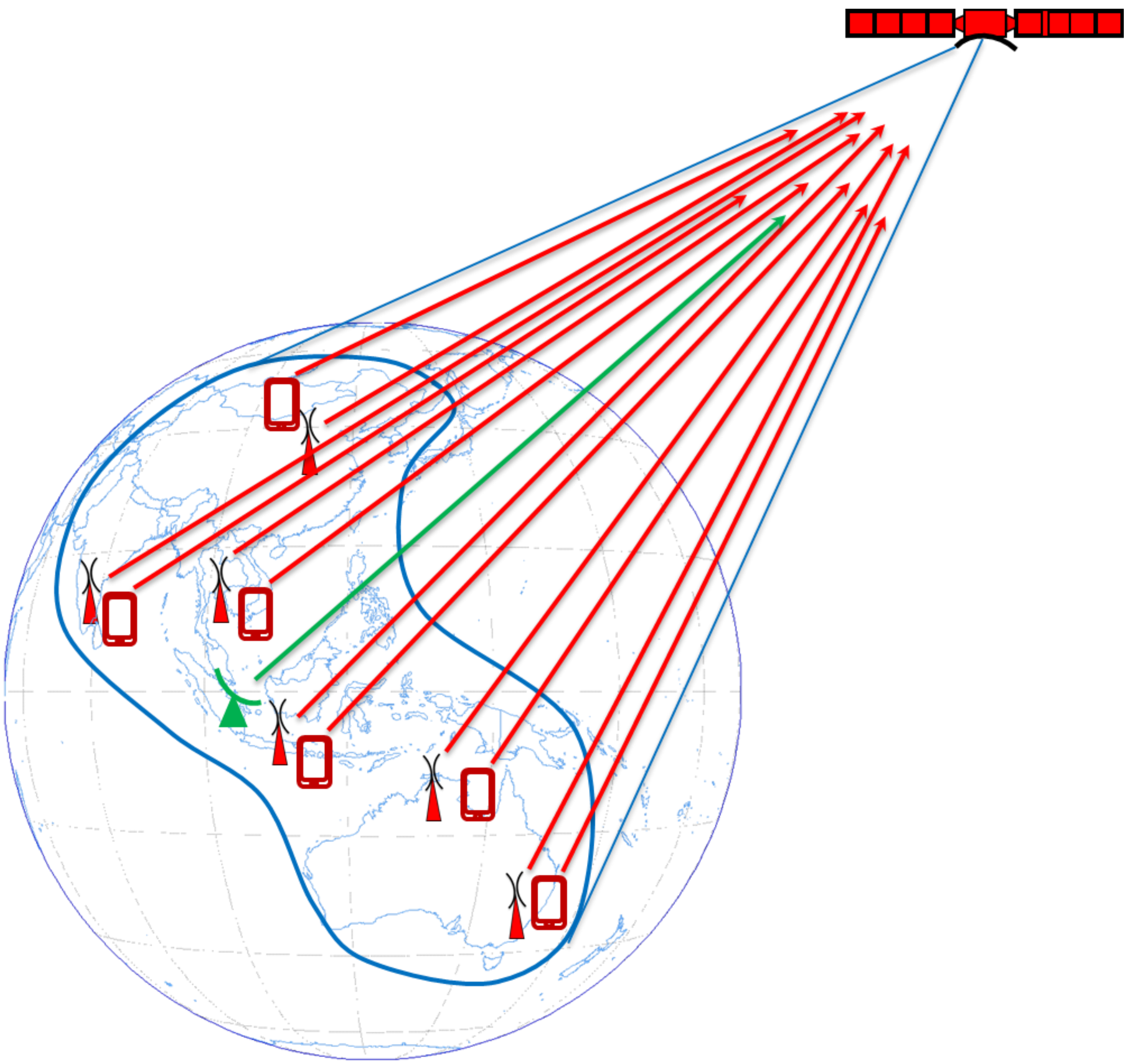

Figure 3: Aggregation of interference from IMT stations into receiving FSS satellite

In such a case, if deployed extensively throughout the coverage of a satellite beam, the aggregation of emissions from all these IMT transmitters could constitute a significant interference.

Another thing to note is that this aggregated interference is a result from emissions from a large number of operators and countries and while the interference from each individual country may be within acceptable limits, the aggregation of the interference from all countries could lead to unacceptable interference. Since no individual country is responsible for the total interference, there would be no country to complain to in the case of excessive interference. The aggregated interference therefore has to be addressed internationally through hard limits in the ITU Radio Regulations that all countries need to comply with, with no opening for individual countries to exceed the limits.

As of today, there are no efficient limits or procedures in the ITU Radio Regulations to protect the receiving FSS satellite from such interference since those limits (sections I and II of RR Art 21) are understood to date back from the 1960'ties and 70'ties and lack vital elements to describe and limit the interference density levels that are actually transmitted in direction of the receiving satellites and which is the important element in determining and controlling the interference received.

In considering protection of receiving satellites from transmitting IMT stations, there are two different types of studies;

- studies in respect of general criteria for protection of receiving satellites from interference by terrestrial transmitters (sections I and II of RR Art 21),

- studies associated with specific frequency bands being considered for explicit identification for IMT in the ITU Radio Regulations (limitations associated with such identifications often provided in footnotes to the table of frequency allocations or in Resolutions of the Radio Regulations).

### 5.1.1 Sections I and II of RR Art 21

Noting the use of active array antennas by new IMT installations, WRC-19 was alerted to the general criteria to protect receiving satellites in sections I and II of RR Article 21 and how in particular it would seem unclear as to how to understand RR 21.5 in that case.

WRC-19 consequently requested that studies should be undertaken on this issue. RR 21.5 which provides one of the limitations that are supposed to protect receiving satellites, specifies a power limit delivered by a transmitter to the antenna (no bandwidth indicated). However, for an active array antenna, the transmitters are an integral part of the antenna and how to apply RR 21.5 is not clear.

In the studies in ITU on this issue, three options seem to emerge:

- RR 21.5 would apply for the Total Radiated Power (TRP) transmitted by the entire array;
- RR 21.5 would apply for the power radiated by each individual active element of the array;
- RR 21.5 would apply for the TRP transmitted per assignment (connection) through the entire array.

Additionally, the studies seem to acknowledge the importance of specifying a reference bandwidth for the power limit, but may seem to focus more on typical bandwidths for IMT emissions than typical bandwidths for FSS carriers.

The studies also would seem to indicate a recognition for a more thorough overhaul of the provisions for protection of receiving satellites from transmitting terrestrial stations as contained in sections I and II of RR Art 21. If so, this could be foreseen to commence after WRC-23, e.g. as an agenda item for WRC-27.

What is worth to note is that all these options are in different ways defining the total power radiated by the antenna, as a whole or for individual elements or assignments. However, none of them define the interfering levels that are actually transmitted towards or received by the satellites. It is also worth to note that using a TRP limit could have the undesired effect of unnecessarily limiting IMT stations. If more elements are added to the array, the directivity of the antenna will increase, enabling the energy to be better directed in the wanted direction. As a result, even if the TRP is increased, the interference towards space could actually remain unchanged or even be reduced (see Figure 4). This drawback of the TRP approach is also recognized in the ITU studies being conducted.

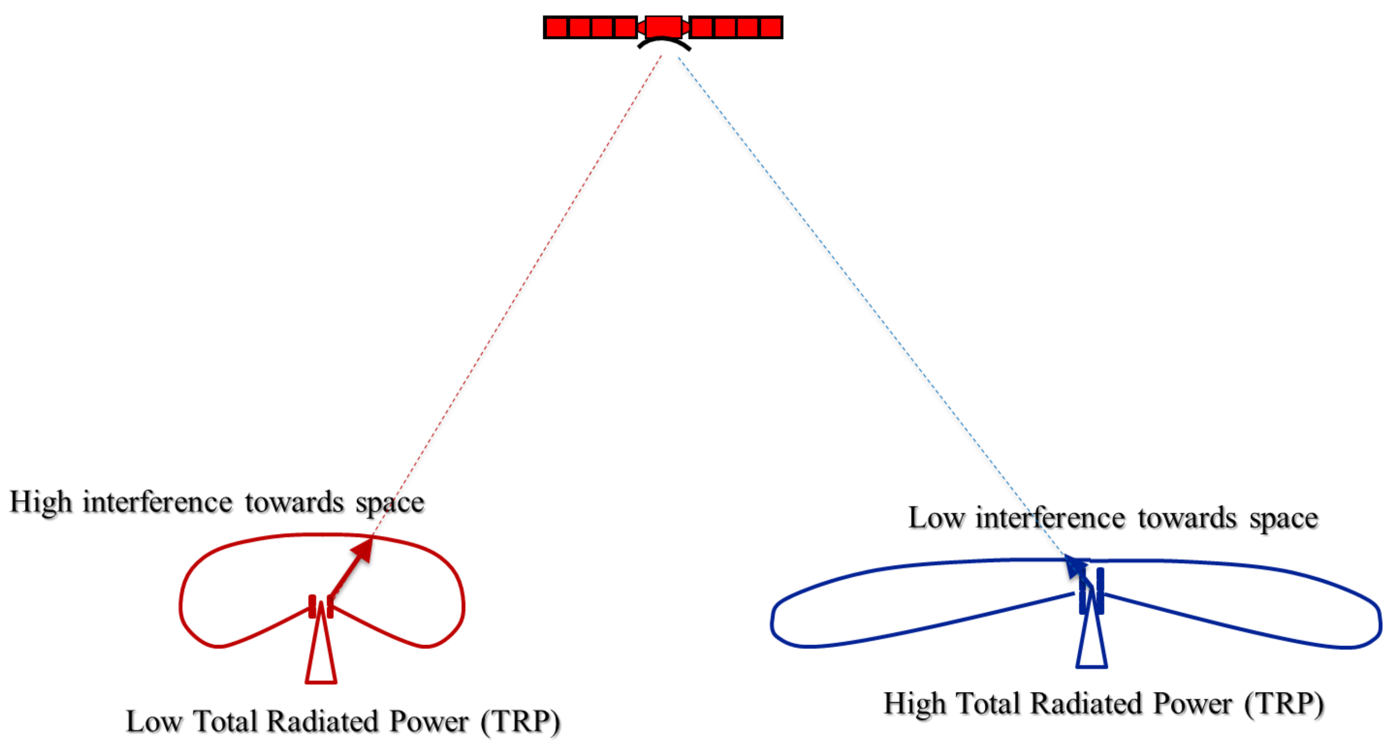


Figure 4: Example where low TRP leads to higher interference into satellite than high TRP

In the opposite direction, terrestrial receivers receiving interference from transmitting satellites, section V of RR Art 21, protection is prescribed as a power flux density (pfd) mask produced at the surface of the earth, to be met by the satellite emissions. This mask is a function of the angle of arrival (elevation angle as seen from the receiving terrestrial station) and is tighter for lower angles of arrival where terrestrial stations are more likely to have higher antenna gains.

To protect receiving satellites, maybe a similar approach could be taken?

If so, pfd or EIRP density masks or limits could be established for terrestrial stations to be observed in the direction of space, possibly higher for low elevation angles and tighter for higher elevation angles (noting that at high and low latitudes, geostationary satellites can only be seen with low elevation angles and may have beams with high sensitivity also towards those areas). By use of pfd masks, the interference would be defined as the interfering power in space rather than the interfering power going out from the IMT station as would be the case for an EIRP density mask. A pfd mask thus would give IMT operators the added flexibility to take into account blocking due to indoor deployment, adjacent buildings, terrain etc. while the protection of the receiving satellite would remain unchanged.

Unlike terrestrial transmitters that with few exceptions are located on, or close to the surface of the earth, satellites operate at very varying altitudes including low earth orbit satellites (LEO), medium earth orbit satellites (MEO), highly elliptical orbit satellites (HEO) and geostationary satellites (GSO) with altitudes ranging from some few hundred kilometers to 36,000 km for GSO and even higher for some HEOs.

Interference into the receiving satellite is an aggregation of interference from a large number of IMT stations. Due to the lower spreading loss, the interfering powers from individual IMT stations will be higher at lower orbits than those from higher orbits. On the other hand, satellites at lower orbits will also see a smaller portion of the earth and thereby a smaller number of IMT stations. If the same levels would be appropriate to protect satellites at all orbits or if different levels should be considered is something that need to be studied. For a pfd mask solution, the level could be specified at one orbit altitude, knowing that the levels at all other orbit altitudes then would be determined only by the difference in spreading loss.

By establishing suitable limits to protect receiving satellites in sections I and II of RR Art 21, protection would be provided to receiving satellites in all frequency bands and it would not be limited to some specific bands that are identified by ITU for IMT. Moreover, if IMT is introduced under regular mobile frequency allocations in the Radio Regulations, without any specific identification, there would be no protection mechanisms associated with an identification and then, the only quantified protection mechanism would be through these sections of RR Art 21. For these reasons, limits in sections I and II of RR Art 21 would give a more complete protection of receiving satellites than limitations associated with specific IMT identifications.

### 5.1.2 Frequency bands being considered for explicit identification for IMT

Over the last decades one has seen a trend where specific frequency bands have been identified for IMT by ITU in the Radio Regulations. This is done through a footnote to the frequency allocation to the mobile service in a given frequency band for one or more of the three ITU-R Regions or for a list of individual countries. Such footnotes also may specify certain operating conditions, e.g. limitations to protect other services or regulatory relationship with other services. While IMT can be introduced in frequency bands allocated to the mobile service without any identification for IMT, having an identification helps to focus the industry and harmonize IMT deployment internationally.

New IMT identifications are subject to studies in ITU and consideration decision by a WRC. In doing so, the impact on other services sharing the band in question is assessed. When IMT identifications in satellite uplink bands are considered, this means that interference into receiving satellites is studied.

At present, in particular two satellite uplink bands are of interest;

- C-band uplink where WRC-15 considered the 5 925-6 425 MHz band, but ending up not identifying the band for IMT and where WRC-23 will consider the 6 425-7 125 MHz band, most of it overlapping with satellite uplink bands, for a possible IMT identification.

- Ka-band uplink where parts of the 24.25-27.5 GHz band identified by WRC-19 for IMT overlaps with FSS uplinks and where some administrations are also seen to license IMT in frequency bands above 27.5 GHz, often up to around 28.35 GHz, without any IMT identification in the Radio Regulations, but within mobile service frequency allocations;

In preparation for WRC-15, ITU-R Report S.2367 was developed analyzing the requirements for protection of receiving geostationary satellites from transmitting IMT stations in the 5 925-6 425 MHz band. The conclusions of those studies was that to provide the required protection, IMT base stations had to be deployed indoor and with a maximum power of 10-15 dBm/20 MHz.

In preparation for WRC-23, studies have been conducted, analyzing the impact of IMT in the immediate adjacent 6 425-7 075 MHz band. In respect of parameters of satellite applications, for all practical purposes, the parameters in the 6 425-7 025 MHz band are the same as those in 5 925-6 425 MHz. One therefore would have thought that the results of the studies should be the same.

But no!

For WRC-23, there were a total of 20 studies conducted on the impact of IMT outdoor base station deployment, including for large cells. For the same deployment scenarios, these studies arrived at widely diverging conclusions, identifying a margin in respect of the protection requirement ranging from roughly + 25 dB to -25 dB. From these results, it is difficult to get an understanding of the technical impact of IMT operation on receiving satellites. Noting how strongly polarized the discussions between the IMT and satellite camps have become, one might be drawn to suspect that at least some of the studies, submitted by one or the other camp, are tailor made with selected parameters and assumptions to arrive at the desired conclusions.

One interesting thing to note is that in respect of long-term protection, ITU-R Recommendation S.1432 specifies a protection of FSS from other services having co-primary status corresponding to 6% increase of the noise temperature due to the aggregation of interference from all these services (corresponding to an I/N of -12.2 dB). This was used in the studies for Report ITU-R S.2367 in preparation for WRC-15. Furthermore, in respect of short-term protection, ITU-R SF.1006 specifies a protection corresponding to *I*/*N* = –1.3 dB that may be exceeded by up to 0.001667% time.

Yet, in the analyses conducted in preparation for WRC-23, it is noted that I/N of -10.5 dB has been used as the long-term criterion and furthermore, then allocating all the degradation to IMT alone and none to degradation to other primary services sharing the band (e.g. the fixed service). Moreover, for short-term interference, −6 dB *I/N* to be exceeded up to 0.03% and −2.33 dB *I/N* to be exceeded up to 0.001% of time were used. One might wonder what is the background and basis for using these different and reduced protection criteria for satellite networks.

In preparation for WRC-19, studies were conducted in respect of Ka-band uplinks. Again, the results were diverging between the different studies, but at these higher frequency bands, the conclusions were that at least for the baseline parameters used for the studies, the protection requirements for the receiving satellites were met. Some studies indicated that if IMT parameters deviate from the baseline parameters, interference exceeding the protection criteria for the receiving satellites could occur.

While WRC-15 ended up not making any IMT identification in the 5 925-6 425 MHz band, WRC-19 did identify the 24.25-27.5 GHz for IMT. In doing so, they included Resolution 242 (WRC-19) into the Radio Regulations. Resolves 2.1 and 2.2 addresses compatibility with receiving satellites:

"*2.1 take practical measures to ensure the transmitting antennas of outdoor base stations are normally pointing below the horizon, when deploying IMT base stations within the frequency band 24.25-27.5 GHz; the mechanical pointing needs to be at or below the horizon;*

*2.2 as far as practicable, sites for IMT base stations within the frequency band 24.45-27.5 GHz employing values of e.i.r.p. per beam exceeding 30 dB(W/200 MHz) should be selected so that the direction of maximum radiation of any antenna will be separated from the geostationary-satellite orbit, within line-of-sight of the IMT base station, by ±7.5 degrees;*"

It might be said that "…*are normally pointing below the horizon*…" and "*as far as practicable*…." may appear to be more encouragements or requests to administrations deploying IMT rather than limits that provide a guaranteed protection of receiving satellites. Also, the quantification in resolves 2.2 is referring to the on-axis EIRP density, but does not specify the off-axis EIRP density that would be transmitted towards space and receiving GSO or NGSO satellites.

In respect of the studies on 6 425-7 125 MHz for WRC-23, the positions in ITU again are very polarized making constructive discussions virtually impossible. This probably means that the decision taken by WRC-23 on this topic, similar to decisions taken by earlier WRCs on similar topics, will be a political decision rather than a decision based on technical merits. In doing so, establishing practical technical compatibility based on pragmatic solutions and burden sharing is something which unfortunately is often lost.

In respect of interference into receiving satellites, the proponents of an IMT identification have suggested several options;

1. Identification with no limitations on IMT emissions apart from sections I and II of RR Art 21.

2. *Identifications* with limitations contained in a resolution associated with the identification. There are two options for what the protection mechanisms in this resolution could be:
    a. Mechanisms similar to those of Resolution 242 (WRC-19).
    b. A limit on IMT base station expected EIRP as a function of elevation angle, averaged over azimuth angles and relevant beamforming directions. Since the interference received by the satellite is an aggregation of contributions from a large number of IMT base stations pointing in various directions, averaging at an elevation angle around the entire azimuth would seem to give a correct measure of the total received interference level from IMT base stations.

It is recognized that sections I and II of RR Art. 21 in its current form does not provide any reliable protection for receiving space stations. Furthermore option 2a would seem to provide only non-binding encouragements to administrations. Option 2b is defining an EIRP in the direction in space, but by defining it as "expected" EIRP, it is unclear how binding this limit would be.

For these reasons, it would seem that none of the options associated with an IMT identification for the 6 425-7 125 MHz band would offer a guaranteed maximum interference level for receiving satellites.

Noting that the ITU-R studies, although diverging, would seem to indicate that there would be significantly higher potential for interference from IMT emissions into receiving satellites at C-band (6 425-7 075 MHz in respect of the issues to be discussed at WRC-23) compared to at Ka-band (e.g. 24.65-25.25/27-27.5 GHz as studied before WRC-19), if WRC-23 is to consider identifying the 6 425-7 075 MHz band, or portions of it, for IMT, quantified limits in respect of the interference density transmitted towards or present by receiving satellites, e.g. an EIRP density or power flux density (pfd) mask as a function of elevation angle would be required. Taking into account that the interference will be an aggregation of emissions from a large number of countries and operators and that it is not possible to point at one single administration if interference occurs, it is also important that these limits are hard limits and cannot be exceeded by individual administrations.

## 5.2 Interference into IMT receivers

Unlike IMT operating in satellite downlink bands, in satellite uplink bands, the transmitter of the satellite link is located on the ground, at the Earth stations, i.e. much closer to IMT receivers than the transmitting satellite in the case of IMT in the downlink bands. Moreover, transmitting Earth stations can be more powerful than transmitting satellites.

Compatibility between Earth stations and stations of terrestrial services, including IMT stations, is established by submitting a filing to ITU for each specific Earth station whereby a coordination contour is drawn up around the Earth station. The notifying administration of the Earth station then needs to seek the agreement of other countries having terrestrial stations inside the coordination contour and later, other countries filing for terrestrial stations located inside the coordination contour need to seek the agreement of the country having filed the Earth station.

However, with the large number of Earth stations in the regular satellite bands used for a multitude of applications such as private and corporate data networks (VSAT), Satellite News Gathering (SNG), and maritime, aeronautical and land mobile Earth stations (ESIMs, ESVs), it is obvious that it is not practically possible for ITU nor national frequency administrations to treat all these Earth stations individually. As a result, these Earth stations are not filed with ITU and operate under blanket licensing with no individual registration. Similarly, for the same reasons, stations of terrestrial services are rarely filed with ITU. The consequence is that there is no recognition of these Earth and terrestrial stations in the ITU databases and subsequently, there is no mechanism within ITU to ensure compatibility between them.

It is also important to note that the ITU regulations only aim at assessing compatibility between stations of different countries while compatibility between stations within a country is not assessed by ITU and is regarded a domestic matter.

When considering prospective new IMT identifications, just like when considering prospective new frequency allocations, there is a tradition in ITU to study interference from the newcomer into the incumbent, i.e. interference from IMT into satellite in this case, but not interference from the incumbent into the newcomer. As a result, there are less studies for this scenario, including interference from transmitting Earth stations into IMT receivers.

Nevertheless, as shown in Figure 2, transmitting Earth stations have a clear capability to interfere with IMT receivers in their vicinity. Moreover, it is recognized that since most Earth stations as well as IMT stations are not filed to ITU and also since this largely is a domestic matter, there is no mechanism in ITU to regulate co-existence between the two.

A consequence of this is that if IMT is deployed in an area, cries for interference into IMT receivers could hinder Earth stations from operating in the same area and could prevent future deployment of new Earth stations and use of transportable or mobile Earth stations.

Some studies have nevertheless been conducted:

1. In preparations for WRC-15, Report ITU-R S.2367 contains some studies in respect of interference into IMT in the 5 925-6 425 MHz band.

2. In preparations for WRC-19, some studies were conducted in respect of interference into IMT in the 24.65-25.25/27-27.5 GHz band. These are summarized in the Conference Preparatory Meeting (CPM) Report to WRC-19.

In respect of the 5 925-6 425 MHz band, Report S.2367 concludes:

"*For protection from co-frequency, in-band interference due to FSS earth station transmission the study showed that depending on the azimuth bearing of the IMT base station relative to the FSS station, the following minimum separation distance should be maintained:*

*1) 10-78 km to protect outdoor macro cell in a suburban environment,*

*2) 6-33 km to protect an outdoor macro cell in an urban environment*

*3) 4-33 km to protect an outdoor small-cell in a suburban environment*

*4) 2.5-13 km to protect an indoor small cell in a suburban environment, depending on the indoor building penetration loss.*

*With regard to spurious FSS transmissions, the study showed that only outdoor IMT base stations would be impacted. Accordingly, depending on the azimuth bearing of the IMT base station relative to the FSS station, the following minimum separation distance should be maintained between an IMT station and an FSS earth station:*

*1) 4-13 km to protect an outdoor macro cell in a suburban environment,*

*2) less than 1 km to approximately 7 km to protect an outdoor macro cell in an urban environment*

*3) 1-6 km to protect an outdoor small-cell in a suburban environment."*

In respect of the 24.65-25.25/27-27.5 GHz band, the CPM-19 Report concludes:

"*For the case of a FSS earth station interfering into IMT, the results of studies showed separation distances of less than 100 m up to about 10 km between the FSS earth station and IMT stations.*

*In the case of deployment of FSS earth stations at specified locations, when the required separation distance can be maintained between a location of a FSS earth station with known position and a deployment area of IMT stations, sharing between IMT and the FSS is feasible.*

*In case of deployment of small FSS earth stations at unspecified locations and IMT stations in the same geographical area, the separation distance between FSS and IMT stations cannot be ensured.*

*Therefore, sharing may or may not be feasible and could be dealt with on a case-by-case basis."*

From these studies, one can conclude that the required separation distance between a transmitting Earth station and a receiving IMT station operating at the same frequency is significantly higher at lower frequencies.

## 5.3 Could there be solutions to enable IMT and FSS to co-exist in uplink bands?

While there is by now well established experience regarding the potential, or lack of potential, for co-existence between IMT and satellite in downlink bands, there much less experience regarding possible co-existence in uplink bands. As seen from the above discussion, the technical situation in uplink bands is very different from that in the downlink bands. One therefore cannot, based on the experience from the downlink bands, draw the conclusion that co-existence in satellite uplink bands is not feasible.

To enable co-existence, there would be two requirements;

- Aggregated interference into receiving satellites must be below a defined reasonable and realistic level.
- Interference into receiving IMT stations must not unduly hinder deployment of transmitting Earth stations.

In the following subsections, some thoughts on measures that could make co-existence possible in satellite uplink bands are discussed.

### 5.3.1 Transmitting IMT stations interfering into the receiving FSS satellite

IMT stations are generally located on the ground and links between IMT user terminals and IMT base stations therefore are between two stations on the ground. IMT networks therefore has no interest or motivation to transmit power into space. Quite on the contrary, since this would represent lost energy and lost link performance, IMT networks would have an interest in directing its emissions towards its intended receiver on the ground and minimizing the emissions into space.

At the same time, it is also important for satellite networks to have a defined maximum interference level into their links such that their quality objectives can be met. To facilitate co-existence, it is important that while realistic links are guaranteed an adequate and reasonable protection, unrealistic link parameters and protection criteria are not used to unduly limit practical IMT operation.

A limit for the protection of the receiving satellite needs to be based on the characteristics and protection criteria of the receiving satellite and not on the characteristics of IMT transmitting stations. Since the interference into the receiving satellite will be an aggregation of a large number of contributions, normally from a large number of countries such that no single country is responsible for the total interference, it is important that limits that are established for individual IMT stations take into account the aggregation from many IMT stations and also that these limits are hard limits that individual administrations cannot choose to exceed.

Ideally, such limits should be contained in sections I and II of RR Art 21 such that they would apply to all shared frequency bands whether they have an IMT identification or not. However, it is seen that the current limits in these sections do not provide any guaranteed or satisfactory protection of receiving satellites. Some people have therefore voiced a desire to revise these sections and this may be a good idea. Noting that this would include reviewing conditions for a large number of frequency bands, in principle all frequency bands shared between satellite uplinks and terrestrial services, this might prove a long and complicated process with a most uncertain outcome.

As an alternative, possibly as an intermediate solution, limits could be associated with specific applications of a service identified in a given frequency band. This has become a common practice for many such identifications being made in the Radio Regulations. If making such an identification, it is important that unlike Resolution 242 as mentioned in section 4.1.2 above, the limits are hard limits that individual administrations cannot choose to ignore or exceed.

In respect of the type of limits to protect the receiving satellites, whether they appear in sections I and II of RR Art 21 or in footnotes or Resolutions associated with identifications for specific frequency bands, it would seem preferable, for both satellite and IMT operators to have limits that directly describe the interference at or transmitted towards the receiving satellite rather than a limit which at best only indirectly gives an indication of this, e.g. power fed to the antenna of the transmitting IMT antenna, on-axis EIRP or total radiated power (TRP). These latter criteria may unduly limit IMT operation while at the same time not offering known adequate protection of the receiving satellite. For this reason, an EIRP density mask in the direction of space, e.g. more stringent at higher elevation angles (e.g. above 5-20 degrees) or power flux density (pfd) limits in space could be better option, giving the satellite operators the defined, known protection and at the same time giving IMT operators more flexibility in their base station design. Out of these two options, pfd limits would also give IMT operators the flexibility to take into account blocking due to indoor deployment, buildings, terrain and other factors that reduce the power radiated into space.

### 5.3.2 Transmitting FSS Earth stations interfering into IMT receivers

As discussed above, transmitting Earth stations have the capability to interfere into receiving IMT stations operating at the same frequency in its vicinity. Once IMT is deployed in an area, there therefore is the danger that deployment of Earth stations in that area will not be permitted due to the requirement for protection of the receiving IMT station, thus blocking the possibility for co-existence between IMT and FSS.

In some countries, when identifying frequencies for IMT in the band 24.25 up to around 29.35/29.5 GHz, co-existence with FSS is defined to take place on a “first come, first served” basis.

**But what does that mean?**

IMT is by its very nature deployed for continuous coverage of an area and once it is deployed, protection would be required within this entire area. The “first come, first served” approach then would mean exactly what is feared; that once IMT is deployed in an area, deployment of new transmitting Earth stations in the same area will not be possible, meaning that there will be no co-existence.

**But is this necessary?**

**Could there be ways for the two services to co-exist within the same area?**

As mentioned, IMT will be deployed for continuous coverage over an area. To enable this, base stations will be deployed throughout the area in a cell structure. The bandwidth used by each cell will vary depending on frequency band used and many other factors, but in the frequency bands shared with satellite uplinks, typical bandwidths per cell are understood to be in the range from some few tens to some few hundreds of Megahertz.

Satellite uplink Earth stations on the other hand will not be omnipresent and will not be deployed anywhere near in the same number as IMT base stations. Furthermore, with the exception of some very few teleports and gateway stations, transmitting Earth stations will only transmit a relatively small bandwidth, normally only around some few Megahertz or less. This means that a transmitting Earth station will only have the capability to interfere into one or maximum two IMT channels. This is illustrated in Figure 5.

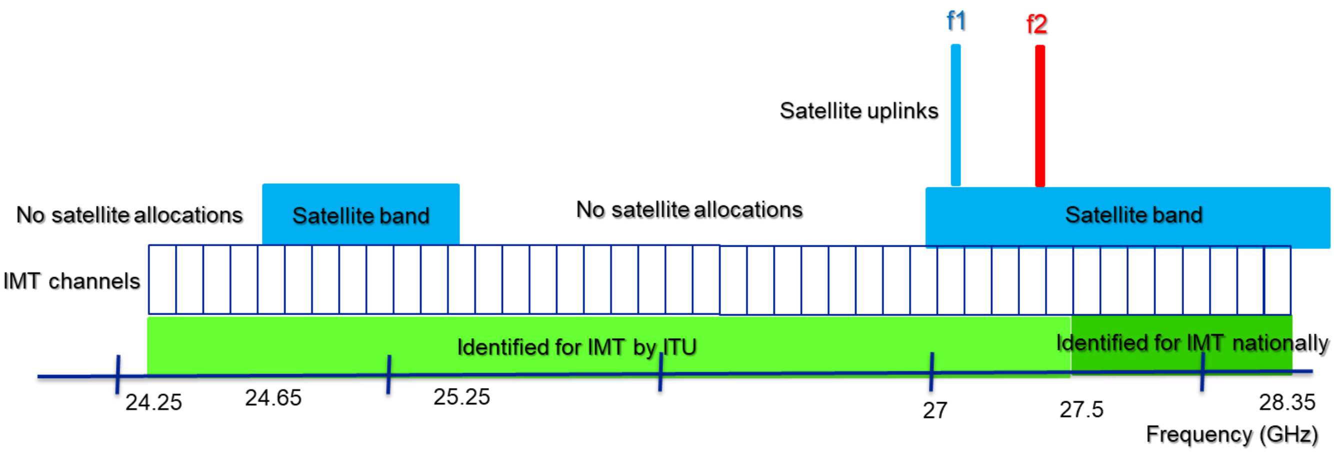


Figure 5: Illustration of frequency bands identified for IMT and satellite uplinks

From this figure, it may be seen that if the cells in the vicinity of the transmitting Earth station use frequencies other than those used by the transmitting Earth station, there would be no difficulties for the two services to co-exist in that area. It can also be seen from the illustration that there will be many IMT channels that would not be affected by the transmitting Earth station. Moreover, as illustrated in Figure 6, within a cellular network, there will only be a limited number of transmitting Earth stations affecting only a limited number of cells and at limited and different frequency bands.

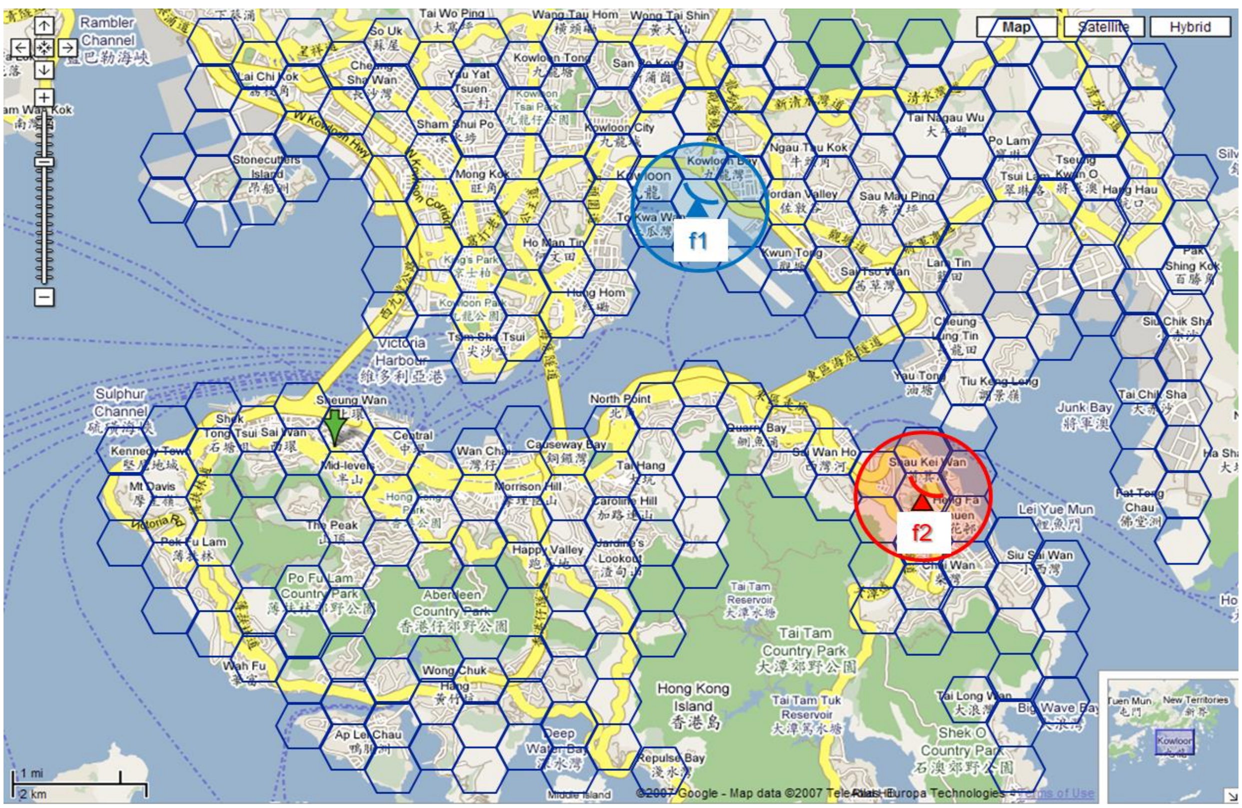


Figure 6: Illustration of IMT cellular network and cells affected by transmitting Earth stations at different frequencies

If the cellular network can be arranged such that the cells within the vicinity of a transmitting Earth station avoid operating at frequencies overlapping with the transmitting Earth station, co-existence would be feasible and one service would not hinder the other. It is known that there will only be a limited number of transmitting Earth stations with each transmitting only within a limited bandwidth. However, this deployment of transmitting Earth stations will change over time depending on customer demand. One challenge is how to enable the IMT network to adapt to these changes.

ITU-R Report M.2242 provides a description of use of "Cognitive Radio Systems" (CRS) and "Software Defined Radio" (SRD) techniques for IMT systems. In the report, these are defined as:

***"Cognitive radio system (CRS):*** *A radio system employing technology that allows the system to obtain knowledge of its operational and geographical environment, established policies and its internal state; to dynamically and autonomously adjust its operational parameters and protocols according to its obtained knowledge in order to achieve predefined objectives; and to learn from the results obtained."*

***"Software-defined radio (SDR):*** *A radio transmitter and/or receiver employing a technology that allows the RF operating parameters including, but not limited to, frequency range, modulation type, or output power to be set or altered by software, excluding changes to operating parameters which occur during the normal pre-installed and predetermined operation of a radio according to a system specification or standard."*

In short, to facilitate co-existence between receiving IMT stations and transmitting Earth stations, CRS could allow the IMT network to obtain information about the interference from transmitting Earth stations and possibly with the help of SDR could adapt the network to use non-overlapping frequencies in cells close to the transmitting Earth station. To obtain the required information, possible solutions could include the IMT base stations monitoring their interference environment or the IMT network accessing a database with information about Earth station deployment.

To further enhance co-existence, traditional interference mitigation techniques could be used to reduce the area within which co-frequency operation of transmitting Earth stations and receiving IMT stations is not feasible. Such mitigation techniques could include site shielding and shaped beam techniques.

Placing transmitting Earth stations at locations offering site shielding towards the environment, e.g. placing the Earth stations at low level, between buildings or behind natural obstructions such as hills, escarpments, or mounds would help reduce the area around the Earth station where it has the potential to create co-frequency interference.

Also, by use of IMT array antennas it is possible not only to produce shaped beams with high gains in the direction of the IMT receivers, but also to produce nulls or low antenna gains of the receiving antenna in the direction of an interfering Earth station. The information of the location of the transmitting Earth station to generate the null could, for example, be obtained through the CRS. This would also help reduce the distance required between the co-frequency Earth station and the IMT station and would facilitate co-existence.

It is recognized that both FSS and IMT characteristics as well as propagation mechanisms are different in different frequency uplink bands that are or are being considered for IMT. For this reason, measures to facilitate co-existence within the same area need to be considered for each frequency band separately to determine what gives the best effect for each case.

The above measures to obtain compatibility between transmitting Earth stations and IMT stations require that the desired techniques are incorporated in the system. Such measures necessarily have a cost and operators may not be overly motivated to implement such measures if they can get away with just blocking the spectrum usage of the other side. Trying to include such measures in already built and deployed systems may be much more costly, if at all possible.

For these reasons, it is important that any undertaking by the IMT operator to cope with transmitting Earth stations, existing and future, is clearly identified by the administration licensing the IMT operation. Similarly, it is important that any requirement for the satellite operator to provide information about transmitting Earth stations to a database or to limit the emission levels towards IMT stations are also clearly specified by the frequency administration.

## 6. Conclusions

Technically, the issues related to co-existence between IMT and satellite are very different in satellite uplink bands compared to those in satellite downlink bands. Experience from IMT in satellite downlink bands may therefore not be used to conclude that co-existence in satellite uplink bands is not feasible.

This article discusses the technical issues related to IMT operation in satellite uplink bands and measures that could help facilitate co-existence between IMT and FSS in satellite uplink bands could be worth exploring. Such measures would involve appropriate changes to the ITU Radio Regulations and recognition of administrations of the need to include measures in the licensing conditions to enable co-existence between the two services.

However, and very importantly; to make this happen, the IMT and FSS sides must come out of their respective trenches and start a constructive dialogue based on reasonable and realistic requirements of both sides with a will to find pragmatic solutions where both sides accept to take their share of burden of co-existence.

### Contributor


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## About AsiaSat

AsiaSat offers reliable satellite connectivity, media and data solutions to customers in the broadcast, telecom and mobility sectors through its fleet of six in-orbit satellites – AsiaSat 4, AsiaSat 5, AsiaSat 6, AsiaSat 7, AsiaSat 8 and AsiaSat 9, and teleport infrastructure. From content distribution to headends, telcos, DTH, DTT platforms; Occasional Use; to One Click Go Live streaming service; IP-based, hybrid OTT service; hosting services; cutting edge VSAT solutions serving aviation, maritime, mobile backhaul, AsiaSat helps bridge the digital divide, aiming to be the foremost satellite solutions provider and an instinctive partner of choice in the Asia-Pacific.

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