The Importance of Retaining C-band for Satellite Service in the Asia-Pacific

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1. Why is C-band so important for satellite services in Asia-Pacific region?

C-band is heavily used for satellite communications in Asia-Pacific Region for a multitude of services including: very small aperture terminal (VSAT) networks, internet services, point-to-multipoint links, satellite news gathering, TV broadcasting to satellite master antenna television (SMATV), direct-to-home (DTH) receivers and feeder links for mobile satellite service. The wide coverage of satellites in C-band enables services in developing countries, in sparsely populated and geographically remote areas, and over large distances (e.g. providing program content and data distribution between continents).

Due to its ubiquitous coverage, high availability and instant connectivity, C-band FSS plays a key role on the socio-economic development of many countries to provide vital services and is also crucial for disaster relief operations. This band is also used by governments in conjunction with international commitments; for example, the World Meteorological Organization (WMO) uses this band to distribute meteorological data throughout the world and maritime and aeronautical safety related information is relayed through stations operating in this frequency band. Furthermore, due to its lower frequency, in particular in regions characterized by high rain attenuation, C-band is the only realistic satellite band where FSS services can be provided with high availability.

2. Evidence for incompatibility between Satellite Services and Mobile Services in C-band

2A. History

The issue on the use of this frequency band (3 400 – 3 600 MHz) for various broadband terrestrial applications to individual users has been debated for many years.

In the early 2000s, this band was being considered for Broadband Wireless Access (BWA) / WiMax applications. Office of the Telecommunications Authority (OFTA) of Hong Kong was instrumental in conducting studies and field trials, and in developing Report APT/AWF/REP-5 of the Asia-Pacific Telecommunity (APT) on this topic. This Report was largely the basis of ITU-R Report S.2199. Conclusions drawn were that BWA and Satellite Services could not co-exist within the same geographical area, and that BWA in 3 400 - 3 600 MHz would have a detrimental effect on satellite reception in the entire 3 400 - 4 200 MHz band.

At WRC-07 (year 2007), proposals to use all or portions of the 3 400 – 4 200 MHz band for future mobile phone networks (IMT) were considered. Compatibility studies carried out in preparation for this Conference revealed that even though IMT might be different from BWA and WiMax in respect of usage, access protocols etc., the potential for interference into FSS reception was the same. Application and usage cannot change the underlying law of Physics. Consequently, ITU-R Report M.2109 arrived at the same conclusions as the BWA reports.

WRC-07 decided not to identify any portion of this band for IMT, but allowed some countries to identify the 3 400 – 3 600 MHz band, or portions of it, for IMT within their own territory (7 countries in the Asia-Pacific for the 3 400 – 3 500 MHz band and 9 countries for the 3 500 – 3 600 MHz band, China being one of the countries for both bands). However, recognizing the incompatibility between IMT and FSS reception, an important requirement to allow these countries to identify IMT within their own territory was that defined power flux density limits need to be met all along their borders to protect FSS reception in other countries.

During WRC-15 (year 2015), IMT in, amongst others, C-band was again considered. Studies conducted in the study cycle leading up to WRC-15, as contained in ITU-R Report S.2368 confirm that again, even though the new IMT characteristics may be different in some aspects, the impact of IMT as an interferer to FSS reception remain unchanged and consequently, the previous studies conducted by OFCA, APT and ITU and their results are equally applicable for later generation IMT operating in this band.

For the Asia-Pacific, WRC-15 made no changes in respect of IMT in the 3 400 – 4 200 MHz band, but allowed two more countries (Australia and the Philippines) to identify the band 3 400 – 3 600 MHz for IMT within their own territory, but again on the same express conditions for protecting FSS in other countries.

2B. Summary of the results of various sharing studies on the coexistence between mobile service and satellite service in C-band.

As shown in a number of sharing studies done from early 2000 to year 2015 (see section 2A for detail and see annex 1 for a list of reports), there are three different interference mechanisms which will impact FSS reception:

1. *Co-frequency interference*

Due to the long distance to the satellite and the power limitations of the satellite, the incoming FSS signal's power flux density at the earth station location is very low. IMT equipment which is much closer to the earth station can produce significantly higher power levels at the input to the FSS receiver than the desired satellite signal.

Depending on the type of IMT deployment considered, studies have shown that separation distances required to offer adequate protection of FSS receivers in respect of co-frequency interference are in the range of five to tens of kilometres for IMT small-cell indoor deployment to several hundreds of kilometres for IMT macro-cell outdoor deployment. It may also be worth noting that in USA, FCC has used a 150 km protection zone around 86 earth stations operating in the 3 650 – 3 700 MHz range to protect them against terrestrial interference.

2. *Adjacent band interference*

2.1 Unwanted out-of-band emissions of IMT transmitters

Due to the very low power level of the incoming FSS signals, unwanted emissions generated by IMT base stations or user terminals operating in an adjacent frequency bands, can create interference to FSS receivers.

Depending on the type of IMT deployment considered, studies have shown that the separation distances required to offer adequate protection to FSS receivers in respect of out-of-band emissions of IMT transmitters, assuming no guardband between the satellite and IMT signals, are in the range of less than a kilometer for IMT small-cell indoor deployment, some few kilometres for IMT small-cell outdoor deployment and tens of kilometres for IMT macro-cell outdoor deployment. This required separation distance may be possible to reduce by use of a guardband between the two signals.

2.2 FSS receiver LNA/LNB overdrive

Earth station low-noise amplifiers (LNAs) and low-noise block down-converters (LNBs) are optimized for reception of the very low power level of the incoming satellite signal and, hence, have a very high sensitivity. Incoming IMT signals at much higher power levels can severely affect the operating point of the LNA/LNB and drive it out of its dynamic range to where it exhibits a non-linear behaviour. This results in the creation of intermodulation products and gain compression which in turn result in distortion and loss of the FSS signal.

Typically, to achieve a low noise figure to allow reception of the very low incoming satellite signals, LNAs and LNBs are wideband devices with a flat frequency response over the wanted frequency range, having the bandwidth defining filtering only at intermediate frequency (IF) stage, not at the LNA/LNB. As a result, IMT emissions in adjacent bands will have the capability to overdrive the LNA/LNB.

Depending on the type of IMT deployment considered, studies have shown that the separation distances required to offer adequate protection to FSS receivers in respect of LNA/LNB overdrive are about a kilometre in respect of IMT small-cell deployment and can be up to 25 kilometres in respect of IMT outdoor macro-cell deployment.

3. Sharing situation in Hong Kong

Spectrum utilization, including satellite spectrum utilization, is different for every country and in different parts of the world. As a result, a solution that may be working in one place, may not necessarily work in another place. Spectrum for new mobile applications can be found in different frequency bands in different parts of the world. In the Asia-Pacific, with the exception of Japan and Korea, C-band is heavily used and is the dominant frequency band for FSS throughout the region. As mentioned by OFCA, in Hong Kong alone, there are currently an estimated 1,600 C-band SMATV systems and 900,000 outlets. Additionally, there are several C-band teleports and VSAT terminals and hubs operating throughout the SAR, establishing Hong Kong as a satellite communications hub, serving the entire Asia-Pacific region.

It is noted that from the sharing study results, exclusion zones around earth stations are required if satellite services and IMT are to co-exist in C-band. Calculated required separation distances to protect FSS receivers from IMT equipment are more than tens of kilometres for co-frequency operation, 0.5 to 5 kilometres for out-of-band spurious emissions and avoid overdrive of LNA/LNBs of earth stations.

AsiaSat notes the geographically very small territory of Hong Kong where central parts are located within a circle with radius of about 5 km and the entire territory within a circle with radius of about 25 km (see figures 3 and 2). One single IMT base station can potentially wipe out all the co-frequency satellite C-band reception in Hong Kong and well into mainland China (see figure 1). This is even if IMT is limited to only small-cell deployment.

Similarly, one single IMT station operating in the 3 400 – 4 200 MHz range can potentially block all the satellite reception in the adjacent 3 600 – 4 200 MHz band practically in the entire Hong Kong Island and Kowloon area (see figure 3). Even if it would be possible to limit IMT base station and user terminal deployment to only indoor operation, one single IMT transmitter could potentially block all satellite reception in adjacent bands in the entire Central to Causeway Bay area or the Tsim Sha Tsui to Mong Kok area (see figure 4).

Graphical illustration of the required separation distance applied to the case of Hong Kong

Below is a graphical illustration of the possible required separation distance in case of Hong Kong. Depending on the actual parameters of the IMT deployment, these separation distances may vary from those illustrated:

- a 150 km exclusion zone (as applied by FCC for co-frequency protection) would block the entire Hong Kong, Macau, Guangzhou and surrounding area (see figure 1)
- a 25 km exclusion zone (to protect against adjacent band operation of outdoor macro-cell deployment) would block the entire territory of Hong Kong (see figure 2)
- a 5 km exclusion zone (to protect against adjacent band small-cell outdoor terminals) would effectively block the entire central parts of Hong Kong (see figure 3)
- a 1 km exclusion zone (to protect adjacent band operation of small-cell indoor terminals) would effectively block the entire Central to Causeway Bay area or the Tsim Sha Tsui to Mong Kok area (see figure 4 and figure 5)

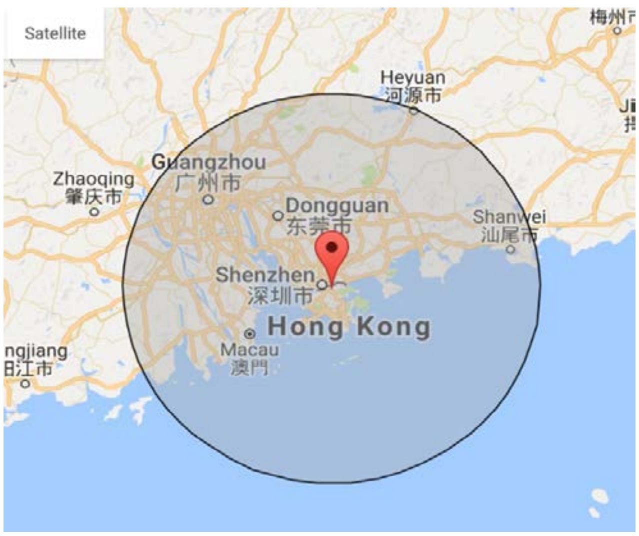

Figure 1. A circle with radius of 150km (as applied by FCC for co-frequency protection)

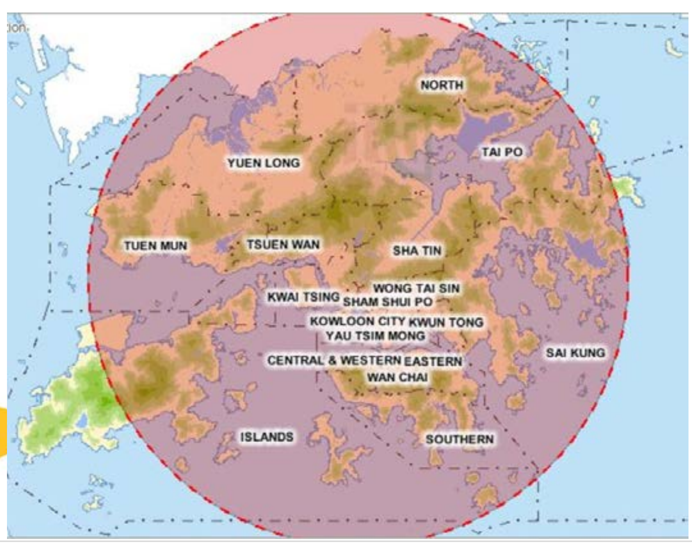

Figure 2. A circle with radius of 25km (to protect against adjacent band operation of outdoor macro-cell deployment)

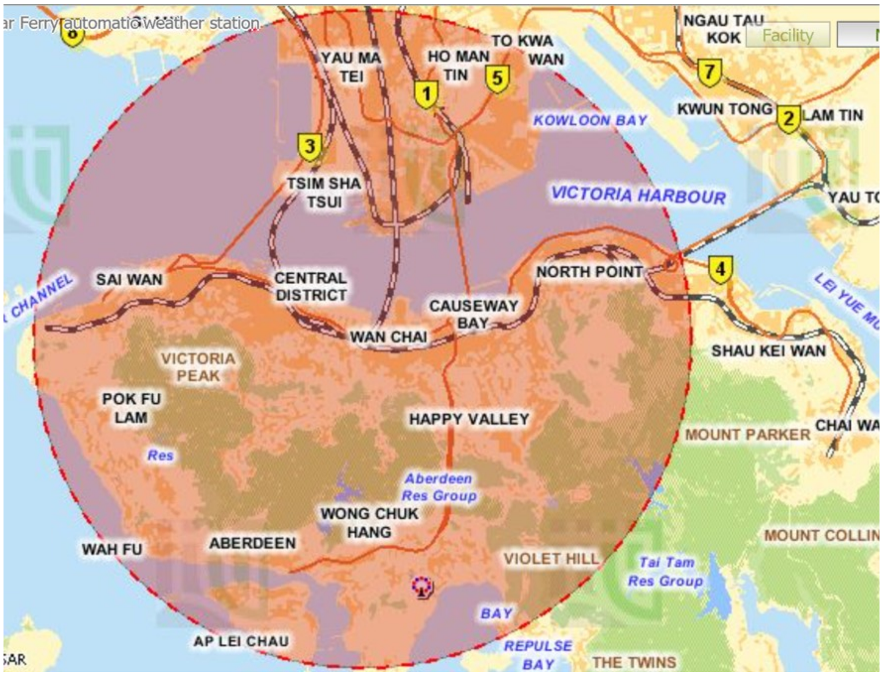

Figure 3. A circle with radius of 5km (to protect against adjacent band small-cell outdoor terminals)

Figure 4. A circle with radius of 1km (to protect adjacent band operation of small-cell indoor terminals)

Figure 5. A circle with radius of 1km (to protect adjacent band operation of small-cell indoor terminals)

However, AsiaSat observes the consistent conclusions drawn in all the various studies by ITU, APT and other international organizations:

"When FSS earth stations are deployed in a typical ubiquitous manner or with no individual licensing, sharing between IMT-Advanced and FSS is not feasible in the same geographical area since no minimum separation distance can be guaranteed." (ITU-R Report S.2368)

Furthermore, exclusion zones are unfeasible with respect to individual mobile user terminals, as their movements cannot be controlled or policed. Consequently, to avoid interference from user terminals too close to an earth station, user terminals would be restricted from emitting any signals when not in contact with a base station. Exclusion zones around earth stations may block large areas for IMT and will block future deployment of earth stations and further development of satellite services.

4. Techniques to improve the potential for sharing

To facilitate sharing between the IMT and FSS, mitigation techniques are under consideration to reduce the required separation distance between the IMT base stations/user terminals and the FSS earth stations. For the geographically very small territory of Hong Kong, the mitigation techniques would need to give rise to drastic reductions of the separation distances to be effective. See Draft new Recommendation ITU-R M. [IMT.MITIGATION] with the documentation of ITU-R Working Party 5D.

4A. On IMT Side

1. Sector disabling

The aim of this technique is to reduce the transmitted output power of base stations in the direction of the interfered-with FSS earth station. Generally, IMT base stations utilize -sectoral antennas (e.g., 3- and 6-sector configuration). Accordingly, one way could be to disable the antenna sector that points towards the FSS earth station, noting that such an area would be served through the use of frequency bands other than 3 400 - 3 600 MHz identified for IMT through proper frequency planning. However, the implementation of this technique would result, as expected, in a degradation of service to IMT terminal users; moreover, it would require that there would be FSS receiving earth stations only at known locations and only in one direction.

2. Adaptive beam-forming

Downlink antenna beam-forming is a technique in which the gain pattern of an adaptive array is steered in a desired direction through either beam steering or null steering signal processing algorithms. When these algorithms are implemented using a digital signal processor, we refer to them as digital beam-forming. This allows the antenna system to focus the maxima of the antenna pattern towards the desired user while minimizing the impact of noise, interference and other effects from undesired transmitters that can degrade signal quality. For this technique to be effective, it would require that there would only be a limited number of FSS earth stations at known locations to null out and that IMT terminals would be served at different frequencies or from different base stations whenever the direction from the IMT base station to the IMT terminal would coincide with the direction towards one of the FSS receiving earth stations.

3. Antenna downtilting

A possible technique to improve sharing is antenna downtilting at the IMT base stations. Although antenna tilting is often applied to all base stations of an IMT network it can be additionally used as a mitigation technique, adding protection if its application is tailored to the location of a specific FSS receiving earth station. However, by increasing the downtilt of the base station antenna, there is a potential for an increase of the number of IMT base stations required to provide service in a given area and for a decrease of transmission power per IMT base station. It is also unclear if downtilting alone can sufficiently reduce the separation distances to enable co-existence within a geographically small area as Hong Kong.

4. Additional filtering to address adjacent channel issues

The goal of these mitigation techniques is to decrease the susceptibility of the FSS earth station to the potential interference of the IMT stations, by improving the rejection of the IMT signals by the receiving FSS earth station and/or by reducing the unwanted emissions of the IMT transmitters (base stations or user terminals) falling in the band of the FSS receiving earth station.

5. Unwanted emissions of IMT transmitting stations

To reduce unwanted emissions of IMT stations falling in the receiving band of the earth station, additional filtering requirements could be considered at the output of the IMT base station transmitters. It should however be noted that this technique would not help mitigate the effect of LNB overdrive or emissions of IMT stations operating in overlapping bands with the FSS receiver.

4B. On FSS Side

1. *LNB Overdrive*

To counter the LNB overdrive, adding rejection and/or bandpass filtering to the receiver of fixed FSS earth stations could be attempted. This technique however, would not help to mitigate interference due to unwanted emissions of IMT stations in adjacent bands or emissions of IMT stations operating in overlapping bands. Many earth station antennas, in particular receive only antennas, LNB and antenna feedhorn, are molded together in one unit until it is physically impossible to insert a filter in between. Moreover, insertion of a filter reduces earth station figure of merit (G/T) and may require use of or change to larger antennas. Introducing such filters in receive installations is expensive, so use of LNB bandpass filters can only be considered for some few, large earth stations.

2. *Site shielding of earth stations*

Site shielding techniques would reduce the interference from IMT transmitters, either by shielding the receiving earth station or the transmitting IMT station in a particular direction.

However, this may involve a significant cost and depending on the conditions for specific cases, have limited effect.

In countries where earth stations are ubiquitously deployed and/or without individual licensing or registration, note that mitigation techniques will be less effective.

5. Potential spectrum for 5G mobile services techniques to improve the potential for sharing

Fifth generation (5G) wireless communication systems known also as IMT-2020, aim at providing much higher data rate, ultra-low latency, increased network capacity, reliability and secure services in high-speed broadband communications. One of the main objectives of 5G is to increase the current data rates up to multi gigabits per second (Gbit/s), exceeding 10 Gbit/s. Achieving this involves increasing either the spectrum efficiency or the bandwidth, which requires more spectrum resources and a much larger available bandwidth (more than 500 MHz wide frequency blocks) than ever before.

The Report ITU-R M.2290-0 predicted that the total spectrum requirement for both low and high user density scenarios is 1340 MHz and 1960 MHz (including the spectrum already in use, or planned to be used) respectively for IMT at least by the year 2020. The C-band studied by WRC-07/WRC-15 is not suitable nor sufficient for 5G use. This is why ITU is currently studying the availability to allocate more spectrum to 5G in higher frequency bands.

As a rule of thumb, the maximum signal bandwidth is about 5% of the carrier frequency, and the higher the frequency, the wider the signal bandwidth. The wider the signal bandwidth, the higher data rate could be achieved. Millimeter wave (Mm wave) and Extremely High Frequency (EHF) (mainly above 30 GHz) bands have the most potential to deliver higher data rate and lower latency because of their following features and capability:

- Frequency bandwidth is much larger
- Provides higher throughput, dramatically increased network capacity
- Antenna size is physically small hence large number of antennas (massive MIMO) are packed in small size to increase the antenna gain; narrow beams could reduce the interference between users/devices
- Dynamic beamforming is employed to mitigate higher path loss at mm wave frequencies
- Mm wave enable highly directive antennas and femtocells in very small sizes

With the development of the new technologies, high frequencies are certainly good candidates for deployment of 5G mobile services.

Noting the data rate requirements for 5G (IMT 2020) and the internationally recognized inability to provide this kind of data rate at C-band, 5G at C-band would only be an interim solution somewhere between 4G and 5G and would need to be transferred to higher frequency bands later to provide the data rates required for 5G. Instead of spending resources on deploying what at best would be of use for a transitional period, it might be better to focus on enhancing the spectrum efficiency in using the existing lower frequency bands already allocated to

2G/3G/4G/5G and develop IMT 2020 in bands suitable to provide the data rates required. For this purpose, mm wave and EHF (mainly above 30 GHz) bands are alternatively good options to provide wide spectrum for 5G deployments.

6. Summary

C-band usage is extensive in satellite communications, TV reception and for satellite networks in Hong Kong, and across the Asia-Pacific. Hong Kong is a major telecommunications hub with several major teleports serving and interconnecting the Asia-Pacific to the world, while C-band is the major frequency band for this activity worldwide.

Due to its ubiquitous coverage, high availability and instant connectivity, C-band FSS plays a key role on the socio-economic development of many countries to provide vital services and is also crucial for disaster relief operations. Due to its lower frequency, in particular in regions characterized by high rain attenuation, C-band is the only realistic satellite band where FSS services can be provided with high availability. It is therefore extremely important to retain C-band for satellite services in the Asia-Pacific region.

All sharing studies and field tests as well as practical experience from other countries demonstrate that sharing between IMT and Satellite Services is not possible within such a small geographic area as Hong Kong. Deploying IMT in C-band in Hong Kong could wipe out existing satellite C-band reception not only in the overlapping band, but in the entire C-band, and cause detrimental impact to satellite services and threaten Hong Kong's ability to retain its role as a regional telecommunications hub.

For 5G to achieve its required data rates, ultra-low latency, increased network capacity, reliability and secure services, more spectrum resources and much larger available bandwidth (more than 500 MHz wide frequency blocks) than ever before is necessary. This is not available at C-band. 5G at C-band would only be an interim solution somewhere between 4G and 5G and would need to be transferred to higher frequency bands later to provide the data rates required for 5G. Instead of spending resources on deploying what at best would be of use for a transitional period, it might be better to focus on enhancing the spectrum efficiency in using the existing lower frequency bands already allocated to 2G/3G/4G/5G and develop IMT 2020 in bands suitable to provide the data rates required. For this purpose, millimeter wave (mm wave) and Extremely High Frequency (EHF) (mainly above 30 GHz) bands are alternatively good options to provide wide spectrum for 5G deployments.

Annex:

Reports on compatibility studies between FSS and BWA/IMT

1. Report No. APT/AWF/REP-5, Mar 2008
   http://www.apt.int/AWG-RECS-REPS (Report No. 5)
   APT Report on "The Coexistance of Broadband Wireless Access Networks in the 3400 - 3800 MHz Band and Fixed Satellite Service Networks in the 3400 - 4200MHz Band"

2. Report ITU-R S.2199, Nov 2010
   http://www.itu.int/pub/R-REP-S.2199-2010
   Studies on compatibility of broadband wireless access (BWA) systems and fixed-satellite service (FSS) networks in the 3 400-4 200 MHz band

3. Report ITU-R M.2109, 2007
   http://www.itu.int/pub/R-REP-M.2109
   Sharing studies between IMT Advanced systems and geostationary satellite networks in the fixed-satellite service in the 3 400-4 200 and 4 500-4 800 MHz frequency bands

4. Report ITU-R S.2368, Jun 2015
   http://www.itu.int/pub/R-REP-S.2368-2015
   Sharing studies between International Mobile Telecommunication-Advanced systems and geostationary satellite networks in the fixed-satellite service in the 3 400-4 200 MHz and 4 500-4 800 MHz frequency bands in the WRC study cycle leading to WRC-15

5. Draft new Recommendation ITU-R M. [IMT.MITIGATION]
   https://www.itu.int/md/R07-SG05-C-0273/en
   Techniques designed to increase the potential for sharing between IMT systems and FSS networks in the 3 400-3 600 MHz band

6. Report ITU-R M.2290-0, Dec 2013
   https://www.itu.int/pub/R-REP-M.2290
   Future spectrum requirements estimate for terrestrial IMT