May 24, 2016

Intel comments on sharing studies submitted in GN Docket No. 14-177

A sharing study, by definition, is highly dependent on the assumptions and models used. At best, it is an indication of *possible* coexistence conditions. Thus, sharing studies are just one input among many in determining the regulatory conditions surrounding a band and its users.

System parameters and radio interface features of 5G systems are currently under development in 3GPP and ITU-R. Therefore, all parameters affecting coexistence need to be considered as preliminary. However, the major elements impacting the outcome of coexistence studies, their relative importance, and consequences of failing to properly implement them are described below.

1. Methodology

Today's cellular networks are complex systems with many dynamic features. The methodology chosen to model coexistence must properly reflect the dynamic nature of these systems. Deterministic methodologies in most cases are unreliable and unrepresentative of reality. They are often justified as being representative of the "worst case" scenario. However, given there are many elements to each study, the combination of worst cases for all elements might never occur simultaneously or under the same conditions. As such, deterministic calculations could produce several different "worst case" scenarios, making their interpretation ambiguous, and further reducing the usefulness of the deterministic approach.

2. Modeling of the systems involved

Various operational features of modern cellular systems affect the level of peak/average/burst transmissions and receptions. The use of a 1G or 2G system modeling approach will produce erroneous results. For instance, **modeling a 4G or 5G cellular system must include integral elements such as power control, MIMO, downtilt, etc. without which the modeled system wouldn't be representative of an actual 4G or 5G system.** Below are a few examples of incorrect modeling of various aspects of a cellular system in a sharing study.

Handling intra-system interference plays a major role in design and operation of cellular systems. Antenna downtilt is one factor in controlling interference, helping the system to operate properly. Figure 1 is a depiction of the impact on performance of an LTE system when downtilt is modeled correctly vs incorrectly. The figure shows Cumulative Distribution Function (CDF) of an LTE system performance, indicating that up to a 5 dB loss in geometry, with respect to its median, results when downtilt is not considered in the modeling of the network. **This loss translates to about 60% loss in throughput performance to the cell edge user, rendering the system quite unrealistic.**

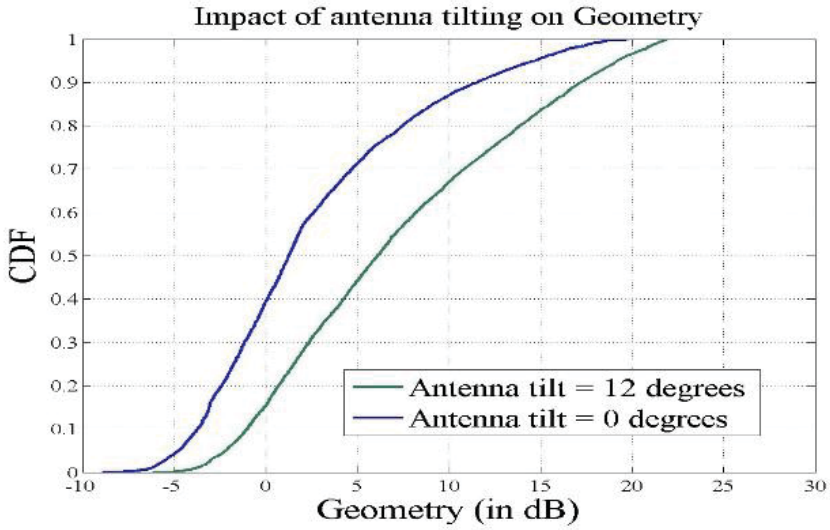

Figure 1 – impact of ignoring antenna downtilt on system performance

Another important element is the role of multiple antenna techniques (MIMO) in cellular networks and correctly modeling it. Figure 2 compares the amount of inter-cell interference generated at the receiver of an LTE user device between the two cases of "with" (blue curve) and "without" (red curve) beamforming implemented at the base stations (2 antennas). **This impact of additional inter-cell interference on the system of this example translates to a throughput loss of about 70% for cell edge users, again unacceptable in a real network.**

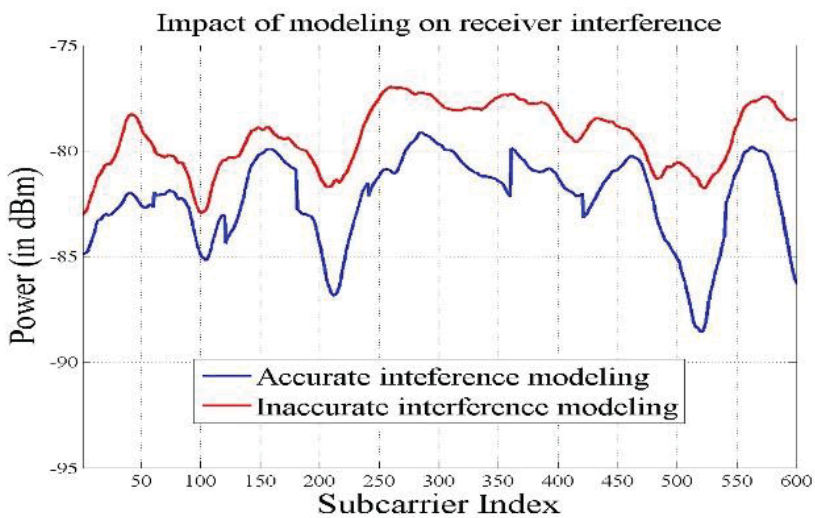

Figure 2 – impact of ignoring MIMO beamforming on system performance

Dynamic power control of user equipment, which is an important aspect of modern cellular systems, also has a significant impact on lowering the overall amount of interference within a network. Consequently, it also impacts the total amount of emissions within a cellular network that could potentially interfere with another system. Figure 3 compares the situation where intra-system interference is modelled correctly (i.e. including the impact of power control) vs

incorrectly. As it can be seen, there is on the average about 10 dB difference in the received interference at any given LTE user device if power control is not considered. Therefore, not including power control in sharing studies in which a cellular system is the interferer largely overestimates the amount of interference generated by the cellular network.

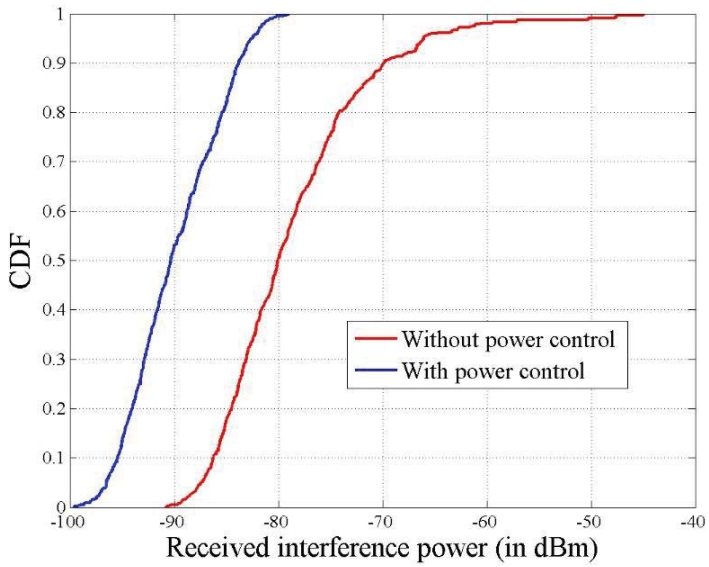

Figure 3 – impact of ignoring dynamic power control on system performance

In summary, as the above examples demonstrate, sharing studies which do not consider (or inaccurately consider) key system features and parameters are not modeling real 4G or 5G cellular systems. Therefore, conclusions of such studies cannot be relied upon.

It should also be noted that in recognition of inaccurate modeling of cellular systems that often occurs in sharing studies, ITU-R WP5D has embarked on developing a Recommendation on how to model IMT systems. This sizeable body of work is currently under development and includes both IMT-Advanced and IMT-2020 aspects.

3. <u>System parameter values</u>

Many system parameter assumptions have direct and often significant impact on the outcome of a sharing study. Some of these important parameters are:

a. Power levels

Power levels need to be commensurate with the deployment scenarios considered. They also need to take into account average transmit power as opposed to a peak regulatory value. In cellular networks, base stations do not transmit all the time and seldom transmit at maximum power, and user devices are power-controlled. Statistics show UEs often transmit at power levels much smaller than the peak values.

Data extracted from live network operations of a US operator and submitted to ITU-R WP 5D[1] presents the distribution of actual power levels in an LTE system in all environments (rural, suburban, and urban) and demonstrates the low likelihood of transmission of maximum regulatory, or very high, limits in real networks (1% or less) due to various reasons including power control. The study specifically demonstrates ***"the influence of the dynamic power control (at the macro level) on system base station and terminal transmitting power levels. It demonstrates some of the critical system operating facets must be properly modelled in a sharing study for it to have real world validity."***

b. ***Antenna patterns***

Beamforming will be an integral part of 5G systems including in higher frequencies. As such, peak antenna gain in the main lobe is always directed toward and concentrated around the intended receiver target, e.g. inside the small cell. **The likelihood of main beam coupling between the 5G antenna and an unintended victim, especially an in-orbit satellite, is quite small.** Recommendation ITU-R F.1336 includes reference antenna patterns that could be used to evaluate system operation and interference. However, these reference antenna patterns do not take into account phased array antenna and beamforming capabilities. 3GPP has come up with a reference array antenna pattern that is closer to a real phased array antenna pattern. It should be noted that these preliminary patterns are currently under consideration in the ITU-R.

c. ***Deployment scenarios***

Report ITU-R M.2376 contains various deployment scenarios envisaged for future IMT-2020 systems. There are also many references from industry, academia, standard developing organizations, etc. that include similar visions for 5G. Most of these sources express the cluster deployment as the dominant model for 5G systems using mm-wave and sub-mm-wave frequencies for a variety of reasons including propagation, system capacity, etc. It is clear that ubiquitous coverage of large land areas (as seen in 4G systems in lower frequencies) is not a target for 5G deployments. Rather, 5G systems are expected to rely on 3G and 4G systems in bands below 6 GHz for ubiquitous operation in conjunction with 5G systems in bands above 6 GHz. **As such, uniform distribution of 5G stations over large areas in sharing studies is quite unrealistic and should be avoided.**

d. ***Antenna heights***

Envisioned 5G deployment scenarios, for instance those discussed in report ITU-R M.2376, "Feasibility of IMT systems in bands above 6 GHz," point to situations where base station antennas are typically mounted at lamp-post heights to cover dense urban environments and population centers. While it is theoretically possible to mount antennas at any height, typical heights are expected to be under ten meters given the excessive propagation losses at high

[1] Document 5D/395, "System design information and dynamic data measurements of operating characteristics for a commercial IMT mobile broadband system in consideration of sharing study parameters," AT&T Inc., 3 July 2013

frequencies and the fact that 5G access points are meant to provide consistent user experience throughout the cell area, thus very small cells with radii in the order of 100-200 meters.

e. ***Number of simultaneously transmitting devices***

Another important factor, especially in coming up with aggregate interference, is the number of simultaneously transmitting devices. This is not necessarily equal to the number of active devices since a user device might be in active mode but not transmitting. In real networks, this number is generally small, and depends on the details of the radio interface design and scheduling algorithms. It should be noted that this number is certainly not the same as, and generally much smaller than, total number of users or devices supported by a base station in a network. Also, it should be noted that transmissions from base stations also follow the loading condition of the network set by the network operators, which is typically well below 100%.

f. ***Percentage indoor vs outdoor stations***

Deployment scenarios envisaged for 5G—considering the evolution of 4G usage and integration of licensed and unlicensed systems in hot spot areas—reveal increasing indoor usage of both access points and user devices. While outdoor use will still be an important aspect of 5G systems, it is reasonable to assume significant indoor use at any given time. It is also possible, at least in certain deployment environments, that some percentage of outdoor base stations serve some indoor users depending on the location. Propagation to and from these indoor devices will then need to take into account building and other structural losses which are generally high at mm-wave or sub-mm-wave frequencies. A recent study done by NASA in frequencies between 5 to 32 GHz for three different building types shows the overall increase in building loss with frequency and its dependency on building material. Specifically, in the case of a modern building with low-E glass windows and thermal coating, losses of 38 dB mean with standard deviation of 12 dB have been reported for measurements at 32 GHz[2]. **It is important that sharing studies consider the percentage of indoor use and take building penetration and exit loss into account.**

g. ***Traffic model***

Choice of traffic model is an important element in realistically modeling a cellular system. While a full-buffer model might be simple to implement, actual user behavior and characteristics of user applications, e.g. browsing, file transfer, etc., stress the need for implementing realistic models. **The impact of choosing non-full-buffer traffic on system level performance of a cellular system could be significant.**

[2] The data mentioned here are contained in document US3M-2, "Working Document toward a Preliminary Draft Revision of Report ITU-R P.2346-0," submitted by NASA to US preparatory process as a potential US contribution to ITU-R Working Party 3M.

4. **Propagation/Path loss models**

The choice of a path loss model used to arrive at realistic values between a transmitter and a receiver could significantly impact the outcome of a coexistence study. Assuming free space conditions is the simplest approach but is also unrealistic. Given the envisaged deployment scenarios for 5G, such conditions are unlikely to occur.

However, arriving at scientifically sound models applicable to 5G deployment scenarios has not been an easy task. It should be noted that ITU-R Recommendations on propagation models do not adequately cover all scenarios and frequencies of interest relevant to the 5G NPRM. While ITU-R Study Group 3 Working Parties are working towards augmenting existing models to cover 5G cases, industry has been actively working towards development of channel models that could be used for design and evaluation of 5G systems. The results have been published in various conferences including IEEE Globecom (http://www.5gworkshops.com/5GCM.html) and are being communicated to ITU-R for inclusion in their Recommendations. While this is an ongoing process, **it is clear that propagation conditions surrounding 5G base stations and user devices in envisaged deployment scenarios are far from line-of-sight (LoS)**. In addition, in mm-wave and sub-mm-wave frequencies atmospheric effects play a role especially in situations with long paths such as those involving satellites.

5. **Satellite system parameters**

It is also important to correctly model operation of the satellite systems. Unfortunately, there is no reliable source of standardized satellite parameters to be used in sharing studies. This is specifically true in the case of satellite space station receiver characteristics including filter response and minimum Carrier-to-Interference levels. In the absence of representative values that could be applied to a series of cases, one could question the value of a generalized sharing study assessing the impact to a satellite space station.

6. **Analysis of submitted studies**

Terrestrial 5G systems are under development, and standards bodies and ITU-R are in the process of defining system parameters and details of radio interfaces. Several mobile operators around the world are in the process of setting up trial networks as a first step to commercial deployments. In light of the anticipated 5G deployment models (clusters, etc.) and system parameters, aggregate interference to in-orbit satellites in the 28 GHz band does not appear to exceed satellite protection criteria. Even when the analysis uses assumptions and modeling parameters that are unfavorable toward the 5G systems, interference margin exists. As a result, dense 5G terrestrial networks appear to be feasible, without disruption to FSS operations. Under more realistic operating conditions, the margin increases further. **However, the secondary status of FSS in this band would not entitle FSS systems to protections even if the analysis had shown disruption.**

Annex 1 presents an overview of the sharing studies filed in the 5G mmW NPRM. In summary, a review of these studies reveals the following points:

1. The studies generally present the two systems (5G terrestrial and FSS) on an equal regulatory basis, ignoring the secondary status of FSS in the 28 GHz band. As such, sharing scenarios with FSS as victim should be only considered as informational and no regulatory decision should be derived from them.
2. **None of the studies listed in Annex 1 modeled the 5G terrestrial system accurately.** There is no indication the base stations and user devices considered in the studies are operating under realistic operating conditions. For instance, the assumption of all user devices transmitting at maximum power would never occur in the real world, and there is little value in analyzing it.
3. In most cases, a line-of-sight (LoS) path loss model has been used for the space paths. This choice, on the average, and given all various losses involved (e.g. diffraction, foliage, atmospheric effects), miscalculates the actual path loss by ~20-50 dB. In addition, ignoring building losses altogether, which are reported to be as high as ~50 dB [see footnote 1] for modern buildings, significantly miscalculate interference.
4. There are inconsistencies among the various studies on antenna pattern and gain assumptions. Aside from inconsistencies, none of the studies use a more realistic beam-formed model for the base station or user device antenna. Instead, they use a fixed gain number which is applied to all stations at all times – quite unrealistic.
5. Satellite protection criterion: studies have used I/N as the protection criterion for the satellite space station. It should be noted that I/N is a coordination trigger and not an interference protection criterion. **The level of impact on a receiver from an interfering signal also depends on the carrier level at the antenna port.** As such SINR, or CINR, seem to be more suitable measures for analyzing impact on the receiver. However, acceptable SINR values are not mentioned in any of the studies. Moreover, the value of I/N=-12.2 dB has been used. It should be noted that this value, taken from Recommendation ITU-R S.1432 on apportionment of allowable interference into FSS in bands below 30 GHz, is not clearly defined and justified. The value assumes 20% (or 25%) interference from other co-primary FSS systems using reuse (no reuse), 6% from co-primary Fixed systems, and 1% from other systems for a total of 27% (32%) of total clear-sky system noise. Derivation of the value is not very clear in S.1432, but -12.2 dB seems to correspond to interference not to be exceeded in 100% of the worst month based on extrapolation of other data points, assuming that a 1 dB increase in noise floor leads to ten times increase in BER. Given that S.1432 was written many years ago, it is not clear whether advancement of technology and introduction of new waveforms has had any impact on the BER performance of the satellite systems. In addition, **the apportionment approach and use of -12 dB assumes FSS is co-primary, which is not the case in the US 28 GHz. However, even if one ignores that FSS is secondary, S.1432**

states that *"There are currently no Recommendations dealing with interference from co-primary allocated mobile systems into FSS systems."*

Annex 1 - Summary of recent studies submitted in GN Docket No. 14-177

14-177 04-21-2016 ViaSat, Inc. (1 of 2) 60001688144.pdf

This paper analyzes the aggregate interference from 5G stations into FSS space station receivers, and the required separation distance between FSS earth station and 5G stations around 28 GHz.

Key assumptions:

- Interference criteria: I/N <= -12.2 dB (FSS space station receiver); 47 uV/m (5G stations).
- 5G station EIRP: 23 - 43 dBm/100 MHz (mobile station).
- Propagation model: FSL, does not account for attenuation due to the "urban canyon".
- 5G antenna discrimination toward FSS: 6 dB (mobile station).
- FSS earth station EIRP: 65 – 74 dBW

ViaSat Conclusions:

- Interference from 5G stations can significantly exceed protection criteria.
- Separation distance from FSS earth station is on the order of 100 – 200 m.

Intel Comments:

- Propagation loss should take into account obstruction losses and realistic deployment scenarios including some indoor use.
- Realistic 5G system parameters are not used (antenna pattern, downtilt, power control, beamforming, traffic models, number of simultaneously transmitting stations, % indoor use, etc.).
- Realistic 5G deployment scenario is not used.

14-177 05-05-2016 SES Americom, Inc. 60001840621.pdf

This paper analyzes the aggregate interference from 5G stations into FSS space station receivers around 28 GHz.

Key assumptions:

- Interference criteria: I/N <= -12.2 dB.
- 5G station EIRP: 62 dBm/100 MHz (base station); 43 dBm/100 MHz (mobile station).
- Propagation model: FSL, does not account for attenuation due to the "urban canyon".
- 5G antenna discrimination toward FSS: 20 dB (base station); 10 dB (mobile station).

SES Americom Conclusions:

- Deployment of 5G stations severely limited.

Intel Comments:

- Propagation loss should take into account obstruction losses and realistic deployment scenarios including some indoor use.
- Realistic 5G system parameters are not used (antenna pattern, downtilt, power control, beamforming, traffic models, number of simultaneously transmitting stations, etc.).

<u>14-177 05-12-2016 Satellite Operators 60001841543.pdf</u>

This paper analyzes the aggregate interference from 5G stations into FSS space station receivers around 28 GHz.

Key assumptions:

- Interference criteria: I/N <= -12.2 dB.
- Satellite antenna gain: 36 – 61 dBi.
- 5G station EIRP: 62 - 75 dBm/100 MHz (base station); 23 - 43 dBm/100 MHz (mobile station).
- Propagation model: Mix of LOS and NLOS, although the model is not described.
- 5G antenna discrimination toward FSS: 25 dB (base station); 6 dB (mobile station).

Satellite operators' Conclusions:

- Deployment of 5G stations severely limited.

Intel Comments:

- The propagation model needs to be described.
- Propagation loss should take into account obstruction losses and realistic deployment scenarios including some indoor use.
- Realistic 5G system parameters are not used (antenna pattern, downtilt, power control, beamforming, traffic models, number of simultaneously transmitting stations, etc.).