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Spectrum inefficiencies resulting from the claimed use of steerable beams, multiple beams or large coverage area beams for the Notification of 14/13/12/11GHz-band FSS satellite networks

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1 Introduction

This document provides data and associated analysis to demonstrate the gross inefficiencies in the use of scarce 14/13/12/11GHz-band (referred to hereafter as “Ku-band”) spectrum that results when FSS satellite networks are Notified (under Article 11) as having beams whose coverage area far exceeds the actual service area capability of the satellite. When such networks are entered into the ITU’s Master International Frequency Register in this way they become a permanent obstacle to other satellite networks, at nearby orbital positions, that may wish to provide service to an area that is geographically far removed from the actual service area of the previously Notified satellite. This can result in vast areas of the Earth being deprived of satellite coverage from nearby orbital locations when in fact there would be no unacceptable interference in practice.

2 Actual satellite coverage is limited by technology and economics

In reality the actual service area from a typical Ku-band FSS satellite is limited by technical and economic factors. Although, in principle, a satellite could be built with the capability to provide service simultaneously over the entire visible Earth, this is rarely done in practice. A large antenna beam coverage in and of itself is not a problem, but the power needed to transmit into such a large coverage antenna would be excessively high if normal Ku-band e.i.r.p. levels are to be provided. So a satellite designer normally optimizes the beam coverage such that the satellite transmits its available power only over the geographic area that it intends to serve. Typically, this results in the actual satellite beam coverage being a small fraction of the actual visible Earth.

a. Typical e.i.r.p. service levels for Ku-band FSS satellites

Over the years the typical e.i.r.p. performance levels required from Ku-band FSS satellites has increased in keeping with the trend of reducing earth station sizes. Early Ku-band satellites achieved edge-of-coverage e.i.r.p. levels in the mid 30’s to low 40’s depending on the size of the beam coverage, and used travelling wave tube amplifiers (“TWTAs”) in the range of 20 Watts. These days TWTAs in the 100 to 150 Watt range are the norm and this gives an increase of 7 to 9 dB compared to the use of 20 Watts, resulting in a corresponding increase in e.i.r.p. levels, assuming the same beam coverage area, with edge-of-coverage e.i.r.p. levels in the high 40’s to low 50’s. These e.i.r.p. levels are high enough to provide good service to relatively small earth station antennas (upwards of 50cm), and are

regularly used for one-way DTH (Direct-To-Home) services as well as two-way VSAT type services. Most Ku-band FSS satellite operators today provide edge-of-coverage e.i.r.p. levels of at least 50 dBW as demonstrated further below.

b. Trends in TWTA power levels

There has been a significant trend over the past 20 years of increasing TWTA power levels for communications satellites. This was partly spurred on by the need to implement effective Ku-band direct broadcast satellites, which required ideally several hundred Watts per TWTA to provide the necessary e.i.r.p. levels. In the 1980's it appeared that Ku-band TWTA's in the 240 Watt, or even 450 Watt range would be feasible, but the developments of even the 240 Watt TWTA's ran into problems in terms of TWTA reliability. For this reason the current maximum TWTA power level regularly used in Ku-band satellites is on the order 150 Watts. When higher transponder e.i.r.p. levels are required, as is the case for direct broadcast satellites, two or three such TWTA's are phase combined to produce up to 450 Watts per transponder. This technique is expensive and additional losses are introduced by the power combining elements. For this reason most FSS Ku-band satellites do not implement such combining and are therefore limited to around 150 Watts, or in some cases less, per transponder.

c. Typical beam coverage for Ku-band FSS satellites

In order to achieve the edge-of-coverage e.i.r.p. levels mentioned in the sections above (typically low 50's), while limited to the available TWTA power level of 150 Watts, the antenna must provide a certain minimum gain. A typical e.i.r.p. budget is given in Table 1 below. This shows that the minimum edge-of-coverage antenna gain needs to be greater than 30 dBi to achieve the required e.i.r.p. performance.

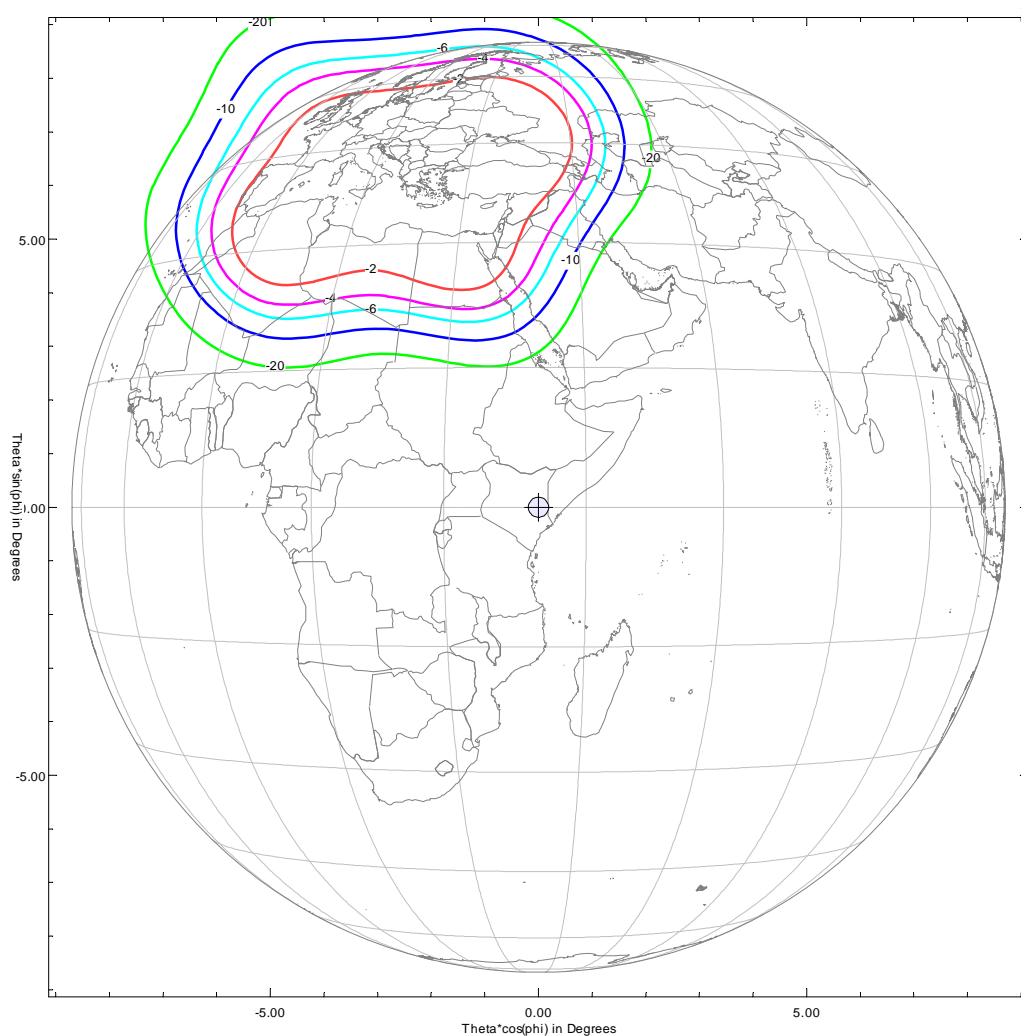
TABLE 1
Typical Ku-band FSS e.i.r.p. budget

Parameter	Value	Units
TWTA saturated output power	150	Watts
TWTA saturated output power	21.8	dBW
Post-TWTA losses	2	dB
Available output power to antenna	19.8	dBW
Antenna peak gain	33.2	dBi
Antenna edge-of-coverage gain	30.2	dBi
e.i.r.p. at beam peak	53	dBW
e.i.r.p. at edge-of-coverage	50	dBW

An antenna beam with this gain performance will inevitably only be able to cover a relatively small portion of the visible Earth. To put this in perspective, from the geostationary orbit, a beam that provides full Earth coverage has a peak gain of less than 19 dBi and an edge-of-coverage gain of typically 17 dBi. This is almost a 15 dB shortfall compared to the required 30+ dBi edge-of-coverage gain necessary. This means that a beam with 30 dB edge-of-coverage gain will only be able to cover approximately one twentieth of the visible Earth's surface.

The effect described above is illustrated in Figure 1 below where a shaped beam over Europe achieves a peak gain of approximately 33 dBi and an edge-of-coverage gain of 30 dBi. Note the vast geographic areas that are unserved by this beam, and which could be served by a nearby, or even collocated, satellite, without creating a mutual interference situation between the two satellite networks. A similar situation exists in the Americas where a CONUS beam has similar edge-of-coverage gain as the European beam shown in Figure 1.

Figure 1
Example Beam Achieving 30 dBi Edge-Of-Coverage Gain



d. Use of Actually Steerable Antenna Beams

It is of course possible to implement satellite antennas that can genuinely steer the beam over the entire visible Earth's surface, or a part of it, but such antennas require relatively complex techniques and result in performance impairments compared to a simple fixed antenna beam.

The simplest antenna steering technique is a mechanically steered antenna, where either the antenna reflector or the antenna feed/subreflector, or both, are physically rotated using an antenna pointing mechanism ("APM"). The APM increases the cost and the weight (mass) of the satellite and reduces the reliability of the communications payload. Use of an APM with a large (e.g., greater than 1.5 meter) antenna reflector increases even further the cost/mass burden because of the physical requirements on the APM. Such techniques also degrade the antenna performance if only the reflector is rotated because they effectively move the feed away from the geometric focal point of the reflector. For these reasons, the APM approach is often not implemented and instead a fixed pointed antenna is used.

A more advanced antenna steering technique has been used in a limited number of satellites in recent years. This involves using a phased array satellite antenna that can electronically steer the beam over the visible Earth's surface. The drawbacks of phased array antennas are well known and will not be expanded upon here. To date these techniques have not been used in any commercial Ku-band FSS satellites.

The antenna beam of a satellite can also be effectively steered if the spacecraft pointing can be biased away from its nominal Earth pointing direction. However, the attitude control systems on geostationary satellites do not permit any significant adjustment of the beam in the north-south direction (i.e., roll bias usually limited to $\pm 0.5^\circ$) even if they can permit more east-west movement (pitch bias adjustment of $\pm 3^\circ$).

The above reasons explain why many commercial Ku-band FSS satellites are not implemented with any, or very limited, capability to actually steer their antenna beams.

3 Review of actual vs Notified beam coverage for a sample 18 degree wide arc

We have taken a random 18-degree wide segment of the geostationary orbit and assessed the actual beam coverage of the satellites that are currently in use in Ku-band in that orbit arc. This 18-degree arc constitutes one twentieth of the entire global arc.

The results of this assessment are given in Table 1 below, where the inconsistencies between actual and Notified beam coverage are highlighted. Note that out of the total of 12 operational satellites in this orbit arc, seven are claiming steerability in their Notification (in some or the entire used spectrum) when in fact such steerability does not exist. In all of these cases the actual fixed beam coverage capability of the satellite is vastly less than the visible Earth, and the estimated percentage is given in Table 1. The land areas (as well as the sea areas) not covered are therefore being denied service by any other satellite networks at or close to these orbital locations because of the inaccurate claims made in the Notification of the satellites in question. Based on this example assessment alone it is estimated that an average of approximately 50% of the world's land mass is being denied satellite service in the Ku-band, averaged across all orbit locations where frequency re-use should be readily achievable (i.e., co-frequency satellites every 3 degrees in the GSO orbit).

Table 1
Notified vs Actual Beam Coverage Flexibility
for Actual Operational Ku-Band FSS Satellites in a Sample 18° Arc

Satellite #	Notified Beam Coverage	Actual Beam Coverage Capability	Estimated % of Visible Land Area Served by Fixed Beam
1	Fixed & Steerable	Fixed in 75% of used spectrum Steerable in 25% of used spectrum	<5%
2	Fixed & Steerable	Fixed	<5%
3	Fixed & Steerable	Fixed in ??% of used spectrum Steerable in ??% of used spectrum	<10%
4	Fixed & Steerable	Fixed	<5%
5	Fixed & Steerable	Fixed	<5%
6	Fixed	Fixed	
7	Fixed & Steerable	Fixed	<5%
8	Fixed & Steerable	Fixed & Steerable in 100% of used spectrum	
9	Fixed	Fixed	
10	Fixed	Fixed	
11	Fixed & Steerable	Fixed	<10%
12	Fixed & Steerable	Steerable in 100% of used spectrum	

4 Need for regulatory procedures that permit more efficient use of spectrum

Before 1997 the Radio Regulations permitted Notified assignments in the MIFR to be made for all the frequency assignments in all frequency bands of a network based on the fact that only one of those assignments was actually brought into use. This situation was changed by WRC97 by the addition of RR 11.44 which now means that only the actual frequency assignments that are brought into use within the permitted time period can become protected assignments in the MIFR.¹ This important change to the Radio Regulations was made to improve the actual usage of the scarce orbit/spectrum resources.

The situation regarding the Notification of beam coverage areas is directly analogous to the RR 11.44 situation referenced in the preceding paragraph. RR 11.44 relates to spectrum usage whereas the ideas presented here relate to beam coverage. Both directly impact the efficient use of spectrum. Orbit/spectrum efficiency can only be optimized when the resource is not warehoused by the Notification of satellite characteristics that go beyond what the satellite is actually capable of providing.

Therefore, radio regulations and/or rules of procedure need to be developed that require administrations to Notify only the beam coverage that the satellite is physically capable of providing, although not

¹ Other changes were made relating to Resolution 49 that effectively made this new rule apply retrospectively to existing Notified assignments in the MIFR.

necessarily simultaneously, at the time it is brought into use. A provision similar to RR 11.44, but relating to beam coverage, would help to achieve this.
