UNITED STATES OF AMERICA
PROPOSALS FOR THE WORK OF THE CONFERENCE

Agenda Item 9.0: *to consider and approve the Report of the Director of the Radiocommunication Bureau, in accordance with Article 7 of the Constitution.*

Background Information:
The global demand for broadband communications continues unabated and is not location specific. Such demand includes requirements of connectivity for users on vessels, aircraft and vehicles that operate at both fixed locations and while in motion, often in very remote parts of the globe. The ITU for many years has and continues to address ways of meeting this important need. State of the art 30/20 GHz GSO FSS satellite networks and earth stations that employ advanced technology available today are capable of meeting the connectivity requirements of broadband users on vehicles and vessels, including high-throughput applications.

Advances in satellite manufacturing and directional earth station technology, particularly the development of multi-axis stabilized earth station antennas capable of maintaining a high degree of pointing accuracy while stationary or on rapidly moving platforms, have made earth stations with very stable pointing characteristics both available and practical. These earth stations can operate in the same interference environment, and comply with same regulatory and technical constraints as typical GSO FSS earth stations. Satellite network operators are designing, coordinating, and bringing into use GSO FSS networks that can offer both stationary and moving broadband services using a single stabilized directional antenna within existing GSO FSS technical parameters.

The ITU-R, which has been studying deployment of earth stations in motion operating with GSO FSS networks for many years, has adopted Report S.2223, "Technical and operational requirements for GSO FSS earth stations on mobile platforms in bands from 17.3 to 30.0 GHz". Additional technical work continues in the ITU-R, with the Preliminary Draft New Recommendation, ITU-R S.[GSO FSS E/S in 29.5-30.0 GHz], "Technical and operational requirements for earth stations on moving platforms operating with geostationary FSS satellite networks in the bands 29.5-30.0/19.7-20.2 GHz" ("Recommendation"), expected to be approved prior to WRC-15. The 'upper 500 MHz' of the 30/20 GHz band was studied first because the band is predominately allocated to satellite services. The FSS (Earth-to-space) bands between 27.5-29.5 GHz are shared on a global basis with the fixed and mobile services as well as other users and, therefore, more study on use of these bands by earth stations in motion is required. The Recommendation provides technical and operational guidelines to Administrations that wish to deploy earth stations on moving platforms communicating with geostationary space stations in the fixed-satellite service in the bands 19.7-20.2 GHz and 29.5-30.0 GHz. The Recommendation includes a set of recommended off-axis e.i.r.p. spectral density levels for earth stations in motion as well as an overview of various satellite tracking and pointing techniques that will enable these earth stations to communicate with GSO space stations in the FSS without causing interference at levels in excess of that caused by conventional FSS earth stations.

Currently, in accordance with No. **5.526**, of the Radio Regulations, a satellite network which is both in the FSS and in the MSS can include links between the FSS portion of the network and earth stations in motion using frequency assignments in the bands 19.7-20.2 GHz (space-to-Earth) and 29.5-30.0 GHz (Earth-to-space) in Region 2 and in the bands 20.1-20.2 GHz (space-to-Earth) and 29.9-30.0 GHz (Earth-to-space) in Regions 1 and 3. The Radiocommunication Bureau in implementing this footnote introduced through a Circular Letter a new class of earth station, UC, for use by Administrations when filing an earth station while in motion associated with a space station in the FSS in the bands listed in No. 5.526 (see CR/358). The Circular Letter also noted that in the absence of particular criteria the BR's findings will be based on existing criteria for FSS links in the relevant bands, as appropriate. Thus, the demand for broadband satellite communications to single earth stations that are used at fixed locations and while in motion can be met in 500 megahertz in Region 2 but only 100 megahertz in Regions 1 and 3. Given that the demand from many users of these satellite services, e.g., shipping companies, is global and cannot be met in only 100 megahertz of spectrum, the United States proposes to complement No. **5.526** by adding a new footnote to the FSS allocation in all three regions in the 29.5-30 GHz and 19.7-20.2 GHz bands to make clear in the Radio Regulations that earth stations while stationary or in motion may communicate with GSO FSS networks on the same basis as conventional FSS earth stations. The United States also proposes an associated Resolution that provides technical and operational guidance, based on the studies in the ITU-R, for administrations when deploying earth stations that will operate while in motion.

Adoption of this proposal will provide 500 megahertz in both the uplink and downlink to support these important and growing global broadband requirements, on an equal basis in all three Regions and result in rational and efficient use of the radio spectrum resource. Adoption of this proposal will also allow the coordination, notification and recording of these earth stations on an equal basis in all three Regions.

<u>Proposals:</u>

ARTICLE 5

Frequency allocations

Section IV – Table of Frequency Allocations
(See No. **2.1**)

MOD **USA/9/1]**

18.4-22 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
…..		
19.7-20.1 FIXED-SATELLITE (space-to-Earth) 5.484A 5.516B ADD 5.XXX Mobile-satellite (space-to-Earth) 5.524	**19.7-20.1** FIXED-SATELLITE (space-to-Earth) 5.484A 5.516B ADD 5.XXX MOBILE-SATELLITE (space-to-Earth) 5.524 5.525 5.526 5.527 5.528 5.529	**19.7-20.1** FIXED-SATELLITE (space-to-Earth) 5.484A 5.516B ADD 5.XXX Mobile-satellite (space-to-Earth) 5.524
20.1-20.2	FIXED-SATELLITE (space-to-Earth) 5.484A 5.516B ADD 5.XXX MOBILE-SATELLITE (space-to-Earth) 5.524 5.525 5.526 5.527 5.528	
…..		

MOD **USA/9/2**

24.75-29.9 GHz

Allocation to services		
…..		
29.5-29.9 FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.539 ADD 5.XXX Earth exploration-satellite (Earth-to-space) 5.541 Mobile-satellite (Earth-to-space) 5.540 5.542	**29.5-29.9** FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.539 ADD 5.XXX MOBILE-SATELLITE (Earth-to-space) Earth exploration-satellite (Earth-to-space) 5.541 5.525 5.526 5.527 5.529 5.540	**29.5-29.9** FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.539 ADD 5.XXX Earth exploration-satellite (Earth-to-space) 5.541 Mobile-satellite (Earth-to-space) 5.540 5.542

MOD **USA/9/3**

29.9-34.2 GHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
29.9-30	FIXED-SATELLITE (Earth-to-space) 5.484A 5.516B 5.539 ADD 5.XXX MOBILE-SATELLITE (Earth-to-space) Earth exploration-satellite (Earth-to-space) 5.541 5.543 5.525 5.526 5.527 5.538 5.540 5.542	

ADD **USA/9/4**

5.XXX In the bands 19.7-20.2 GHz and 29.5-30 GHz, earth stations that are in motion may communicate with geostationary space stations of the fixed-satellite service. Operation of earth stations while in motion shall be in accordance with Resolution XXX.

Reason: Adoption of this proposal would provide the availability of 500 megahertz in both the uplink and downlink to support important and growing global broadband communication requirements for users on ships, airplanes, and land vehicles, on an equal basis in all three Regions and result in rational and efficient use of the radio spectrum resource. This also allows the coordination, notification and recording of these earth stations on an equal basis in all three Regions.

ADD **USA/9/5**

RESOLUTION XXX (WRC-15)

Use of the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz by earth stations in motion communicating with geostationary space stations of the fixed-satellite service

The World Radiocommunication Conference (Geneva, 2015)

considering

a) that the bands 19.7-20.2 GHz and 29.5-30.0 GHz are globally allocated on a primary basis to the FSS and that there are a large number of FSS satellite networks operating in these frequency bands at the geostationary satellite orbit (GSO);

b) that there is an increasing need for mobile communications, including global broadband satellite services, and that some of this need can be met by allowing earth stations that can operate while stationary or in motion on platforms (such as ships, aircraft and land vehicles) to communicate with space stations of the FSS operating in the frequency bands 19.7-20.2 GHz and 29.5-30.0 GHz;

c) that this Conference has adopted No. **5.XXX** in order to address this need;

d) that GSO FSS networks in the bands 19.7-20.2 GHz and 29.5-30.0 GHz, are required to be coordinated in accordance with the provisions of Article **9** and **11** of the Radio Regulations;

e) that earth stations in motion are currently communicating with GSO FSS networks in the bands 19.7-20.2 GHz and 29.5-30.0 GHz, and there are plans to expand the use of such earth stations with operational and future GSO FSS networks;

f) that the ITU-R has studied the technical and operational use of these earth stations in motion in the referenced bands;

considering further

a) that some administrations have addressed this matter nationally or regionally by adopting technical and operational criteria for the operation of earth stations in motion communicating with GSO FSS networks;

b) that a consistent approach to deployment of these earth stations in motion will support this important and growing global broadband communication requirement;

c) that these earth stations in motion will operate consistent with the coordination agreements between administrations applicable to the GSO FSS networks with which they communicate;

resolves

1 that administrations authorizing earth stations in motion communicating with GSO FSS networks in the band 19.7-20.2 GHz and 29.5-30.0 GHz require that GSO FSS operators employing earth stations in motion:

a. comply with the off-axis e.i.r.p. density levels given in Annex 1 or other levels mutually coordinated with other affected satellite network operators and their administrations;

b. employ techniques such as those described in Annex 2 that allow the tracking of the wanted GSO FSS satellite and that are resistant to capturing and tracking adjacent GSO satellites;

c. immediately reduce or cease transmission when the earth station antenna mispointing would result in exceeding the levels referred to in *resolves 1a)*;

d. be subject to permanent monitoring and control by a Network Control and Monitoring Center (NCMC) or equivalent facility and that these earth stations be capable to receive and act upon at least “enable transmission” and “disable transmission” commands from the NCMC. In addition, it should be possible for the NCMC to monitor the operation of an earth station in motion to determine if it is malfunctioning;

e. maintain points of contact for the purpose of tracing any suspected cases of interference from Earth stations in motion; and

f. not claim greater protection for such earth stations in the 19.7-20.2 GHz band than the level afforded to stationary FSS earth stations.

ANNEX 1

Off axis e.i.r.p. density levels for earth stations in motion communicating with geostationary space stations of the fixed-satellite service in the band 29.5-30.0 GHz

This Annex provides a set of recommended off-axis e.i.r.p. levels for earth stations in motion operating in the band 29.5-30.0 GHz. However, as stated in resolves 1a, other levels may be coordinated between satellite operators and administrations.

Earth stations in motion operating in GSO FSS networks transmitting in the band 29.5-30.0 GHz should be designed in such a manner that at any angle, θ, which is 2° or more from the vector from the earth station antenna to the wanted GSO FSS satellite (see Figure 1 below for the reference geometry of an earth station in motion compared to an earth station at a fixed location), the e.i.r.p. density in any direction within 3° of the GSO, should not exceed the following values:

Angle θ	**Maximum e.i.r.p. per 40 kHz**
$2° \leq \theta \leq 7°$	(19 – 25 log θ) dB(W/40 kHz)
$7° < \theta \leq 9.2°$	–2 dB(W/40 kHz)
$9.2° < \theta \leq 48°$	(22 – 25 log θ) dB(W/40 kHz)
$48° < \theta \leq 180°$	–10 dB(W/40 kHz)

NOTE 1– The values above should be maximal values under clear-sky conditions. In case of networks employing uplink power control, these levels should include any additional margins above the minimum clear-sky level necessary for the implementation of uplink power control. When uplink power control (UPC) is used and rain fade makes UPC necessary, the levels stated above may be exceeded for the duration of that rain fade period. When uplink power control is not used and the e.i.r.p. density levels given above are not met, different values could be used in compliance with the values agreed to through bilateral coordination of GSO FSS satellite networks.

NOTE 2 – The e.i.r.p. density levels for angles of θ less than 2° may be determined from GSO FSS coordination agreements taking into account the specific parameters of the two GSO FSS satellite networks.

NOTE 3 – For geostationary space stations in the fixed-satellite service with which the earth stations in motion are expected to transmit simultaneously in the same 40 kHz band, e.g., employing code division multiple access (CDMA), the maximum e.i.r.p. density values should be decreased by 10 log(N) dB, where N is the number of earth stations in motion that are in the receive satellite beam of the satellite with which these earth stations are communicating and that are expected to transmit simultaneously on the same frequency. Alternative methods may be used as long as the maximum e.i.r.p. density values are met in the aggregate.

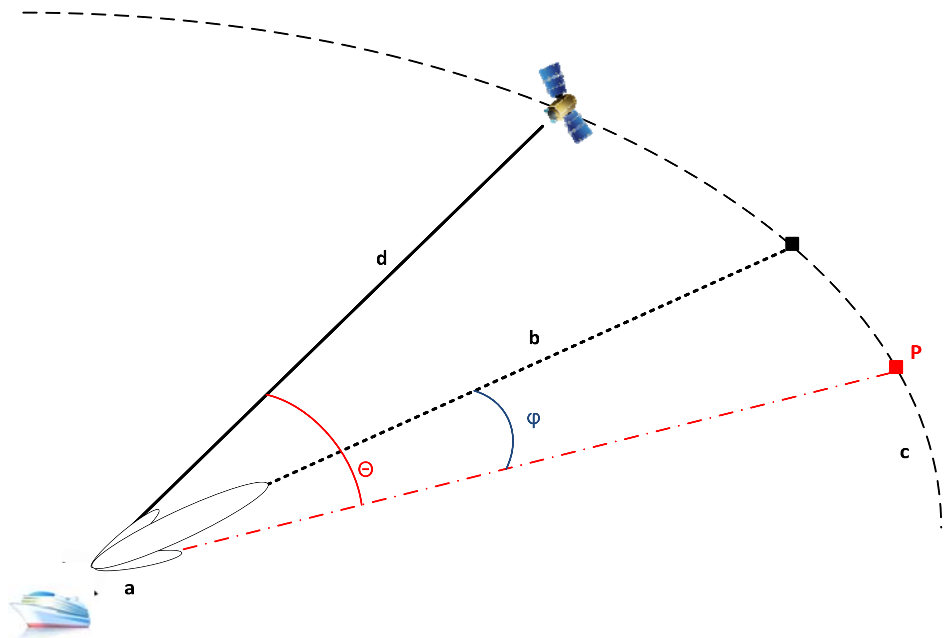
NOTE 4 – potential aggregate interference from earth stations in motion operating with satellites using multi-spot frequency reuse technologies should be taken into account in coordination between the GSO FSS satellite operators and their administrations.

NOTE 5 – Earth stations in motion operating in the band 29.5-30.0 GHz that have lower elevation angles to the GSO will require higher e.i.r.p. levels relative to the same terminals at higher elevation angles to achieve the same power flux-densities (pfds) at the GSO due to the combined effect of increased distance and atmospheric absorption. Earth stations with low elevation angles may exceed the above levels by the following amount:

Elevation angle to GSO (ε)	**Increase in e.i.r.p. spectral density (dB)**
$\varepsilon < 5°$	2.5
$5° < \varepsilon \leq 30°$	$3 - 0.1\varepsilon$

Figure 1 below illustrates the definition of angle θ [1].

[1] In Figure 1 proportions are illustrative and not to scale.



where:

a represents the earth station in motion;

b represents the boresight of the earth station antenna;

c represents the geostationary satellite orbit (GSO);

d represents the vector from the earth station in motion to the wanted GSO FSS satellite;

φ represents the angle between the boresight of the earth station antenna and a point P on the GSO arc;

ϑ represents the angle between the vector d and point P on the GSO arc;

P represents a generic point on the GSO arc to which angles ϑ and φ refer.

.

ANNEX 2

Satellite tracking and pointing techniques of earth stations in motion communicating with geostationary space stations of the fixed-satellite service in the bands 19.7-20.2 GHz and 29.5-30.0 GHz

1 Introduction

Earth stations operating while in motion employ relatively high gain directional antennas with multiple-axis stabilization that allows the signal quality of the link between the earth station antenna and the wanted GSO FSS satellite (and vice versa) to be high. To maintain the signal quality it is also necessary for these earth stations to maintain high pointing accuracy towards the wanted GSO FSS satellite. This Annex describes algorithms that may be employed by earth stations that operate in motion for tracking of the wanted satellite as well as techniques that reduce the possibility of capturing and tracking an adjacent GSO satellite.

There are well-known techniques for antenna tracking of a GSO FSS satellite which can be classified into two categories: those that make use of *open-loop* algorithms and those that make use of *RF closed-loop* algorithms. The following subsections provide a brief description of each of the two types.

1.1 Open-loop pointing technique

An *open-loop* pointing technique employs a process of calculating the azimuth *A* and elevation *E* based upon the position of the earth station antenna on the earth (i.e., its latitude and longitude, acquired, for example, through a GPS signal) and the nominal longitude of the wanted satellite. The following equations show the relationship between the variables mentioned above:

$$A = \arctan\left(\frac{\tan L}{\sin l}\right) \quad (1)$$

$$\varepsilon = \arctan\left(\frac{\cos\Phi - \frac{R_E}{R_E + R_0}}{\sin\Phi}\right) \quad (2)$$

where:

l is the earth station latitude;

L is the earth station relative longitude[2];

$\cos\Phi = \cos l \cos L$;

R_E is the earth radius;

R_0 is the altitude of the satellite.

Due to the movement (relative to the earth station) of the GSO FSS satellite within its *station-keeping box*, depending on the width of the main beam of the earth station antenna, the azimuth and elevation angles of that antenna might need to be adjusted at consecutive instants in order for the link between the earth station and the satellite not to be deteriorated or – eventually – lost.

---

[2] The relative longitude is defined as the absolute value of the difference from the longitude of the earth station to that of the GSO satellite.

By employing an *open-loop* pointing strategy, the angles are calculated in advance for each instant by taking into account the predicted apparent movement of the GSO satellite. Earth stations in motion typically operate as part of a network and under control of a network management system. One method employed by network operators is to broadcast satellite ephemeris data as part of a system bulletin board message that is repeated regularly. Earth stations operating in motion may download this updated ephemeris information and use it as part of the pointing solution to maintain accurate pointing toward the GSO satellite over time. This information is then used by the Antenna Control Unit (ACU), as well as information about the orientation of the antenna platform from an inertial reference unit (IRU) to calculate the earth station antenna pointing angles to the GSO satellite.

1.2 RF closed-loop tracking technique

The second technique – RF closed-loop tracking – employs an algorithm that minimizes the pointing error by analysis of a pre-determined signal received from the wanted GSO satellite. Since earth stations in motion can change their position on the earth continuously and GSO FSS spacecraft move about within their orbital station keeping limits, this technique may be more accurate than the open-loop method. The *RF closed-loop* automatic tracking technique consists in adjusting, at successive steps, the antenna pointing by maximising the strength of a reference signal or a carrier transmitted by the wanted space station. In addition to an accuracy that can be very high (up to $0.05 \cdot \theta_{3dB}$[3]), an advantage of this procedure is its autonomy, since the information used for tracking does not rely on the accuracy of the orbital data of the wanted GSO FSS satellite.

Furthermore, the precision with which the earth station in motion points at the wanted GSO FSS satellite can be increased and maintained by an *inertial platform* in which the earth station antenna is installed. Such platforms are equipped with angular rate gyroscopes that can accurately measure the angular speed in pitch, yaw and roll to allow the servo-loops of the ACU to account for the platform's motion.

Figure 2a and *Figure 2b* provide example block diagrams for earth station antenna systems using *open-loop* pointing and using *RF closed-loop* tracking, respectively. The figures illustrate the relationships between the different elements composing the typical antenna system used by an earth station in motion to perform the pointing and tracking of the wanted satellite network.

---

[3] θ_{3dB} is the 3 dB angular width of the earth station in motion antenna and can be approximated by the following:

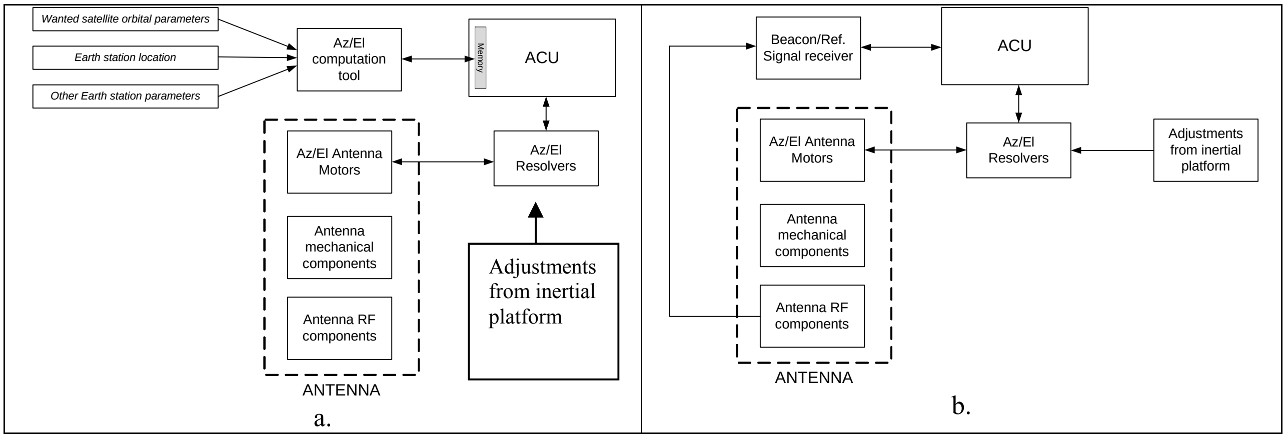
$$\theta_{3dB} = 70\,\frac{\lambda}{D}$$

where:

λ is the transmission wavelength (in m); and

D is the earth station antenna diameter (in m).

FIGURE 2



2 Summary

Meeting the limits specified in Annex 1 of this Resolution helps to minimize potential harmful interference from mis-pointing of earth stations in motion.

Taking into account the pointing accuracy and tracking capabilities of earth stations in motion, it is important to implement measures to ensure that GSO FSS satellite networks located near the wanted GSO FSS satellite do not receive harmful interference from these earth stations. This Annex provides two example measures that can be applied to ensure that earth stations in motion comply with the e.i.r.p. density limits specified above.

In the case of the open-loop pointing technique, the maximum mis-pointing of the earth station is determined by design and operational knowledge of wanted GSO satellite station keeping manoeuvers and the maximum transmitted e.i.r.p of the earth station is set accordingly to ensure that the recommended limits are met.

In the case of the *RF closed-loop* tracking technique, the antenna pointing is continuously adjusted by maximising a pre-determined signal received from the wanted GSO FSS satellite. The choice of the signal is up to the satellite operator – some employ a separate carrier, such as a satellite beacon, while others use the same wide band carrier as that used for the forward link. The technical parameters of the signal employed by the RF closed-loop algorithm are important and should be coordinated between GSO FSS satellite network operators. This is to ensure, the pointing error to the wanted geostationary satellite can be determined instantaneously, so that continuous adjustments to the transmitted e.i.r.p. can be applied, as needed. In the case of both open and closed loop systems, the earth station ceases transmission if it loses its wanted GSO FSS satellite acquisition.

Reason: Adoption of this proposal would provide the availability of 500 megahertz in both the uplink and downlink to support important and growing global broadband communication requirements for users on ships, airplanes, and land vehicles, on an equal basis in all three Regions and result in rational and efficient use of the radio spectrum resource. This also allows the coordination, notification and recording of these earth stations on an equal basis in all three Regions.