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| **COMMITTEE 4** | **Addendum 1 to****Document 8 (Add.5)-E** |
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| Regional Commonwealth in the field of Communications Common Proposals |
| PROPOSALS TO BE ADDED TO THE RESULTS OF THE STUDIES ON AGENDA ITEM 1.5 OF WRC-15 |
| Technical and operational characteristics, interference and regulatory environments associated with the use of the frequency bands allocated to the fixed-satellite service not subject to Appendices 30, 30A and 30B for the control and non-payload communication of unmanned aircraft systems in non-segregated airspace |
| WRC-15 agenda item 1.5 |

Introduction

The Annex 7 «Sharing studies on emissions from fixed satellite service earth station transmitters on-board unmanned aircraft into incumbent terrestrial services for link 3» to the draft new Report ITU-R M.[UAS-FSS] (Document 5B/886-E) gives masks of permissible interference power flux-density, produced by UAS transmitters, within the specified frequency band, at the Earth’s surface at the point of location of FS station antenna within the range of possible values of angles of arrival of the interference relative to the horizon. Parameters of these masks are specified only for criteria of permissible short-term interference to FS stations in the frequency bands 14-14.47 GHz and 27.5‑29.5 GHz with interference probabilities of not more than 0.0001-0.001 % of time. Also the values of levels of interference power flux-density produced by UAS transmitters are not given in the paper. Therefore it seems to be impossible to assess the protection level of FS stations from interference produced by UAS stations.

Proposal

The contribution submitted proposes the results of the studies for assessment of levels of FS stations protection from interferences produced by UAS stations using permissible interfering power flux-density masks, produced by UAS transmitters, and specified both for acceptable short-term and long-term interference criteria to FS stations when the interference probability is no more than 20 % of time. In addition, interference to FS stations, produced by single UAS along the line-of-sight from FS station at a distance up to 138 km when the altitude of UAS flight is 3 000 ft, and up to 327 km when the altitude of UAS flight is 19 000 ft, is considered. The results of the studies given in the Annex is proposed to consider under agenda item 1.5 of WRC-15 discussions.

Annex

Proposals to be added to the results of the studies
on agenda item 1.5 of WRC-15

**Technical and operational characteristics, interference and regulatory environments associated with the use of the frequency bands allocated to the fixed-satellite service not subject to Appendices 30, 30A and 30B
for the control and non-payload communication of unmanned
aircraft systems in non-segregated airspace**

**WRC-15 agenda item 1.5**

# 1 Introduction

The proposals to be added in the results of the studies in draft new Report ITU-R M. [UAS-FSS] contain the results of assessment of levels of FS station protection from interferences produced by UAS stations using acceptable power flux-density masks produced by UAS transmitters specified both for criteria of permissible short-term interference to FS stations (in frequency band 14-14.47 GHz according to criterion I/N< +20 dB for p=0.0001% in accordance with Rec. ITU-R F.1494, in frequency band 27.5-29.5 GHz according to criterion I/N< +9 dB for p=0.001% in accordance with Rec. ITU-R SF.1719), and for criteria of permissible long-term interference to FS stations (in the frequency bands 14-14.47 GHz and 27.5-295 GHz according to criterion I/N<-10 dB for p=20 % in accordance with Rec. ITU-R F.758). Interference to FS stations produced by single UAS in line-of-sights from FS station at a distance up to 138 km when the height of UAS flight is 3 000 ft, and up to 327 km when the height of UAS flight is 19 000 ft, are considered.

# 2 Scenarios for assessment of compatibility of UAS transmitting station operating in the Earth-to-space link to FS receivers in the frequency bands 14-14.47 GHz and 27.5-29.5 GHz

Figure 1 shows the scenario of the impact of interference from single UAS for its movement routes towards the azimuth of the main beam of FS station antenna (UAS1) and towards the azimuths of side and back lobes of FS station antenna pattern (UAS2-USA5).

**R=138 кm**

**S1= 59828.5 km2**

**hTx= 3000 ft (914 m)**

**FS**

**UAS4**

**UAS5**

**UAS3**

**UAS2**

**UAS1**

**hRx= 10 m**

**Rx-Tx**

**Rx-Tx**

**R=327 кm**

**S1= 335927.4 km2**

**hTx= 19000 ft (5791 m)**

**Rx**

**Rx**

Figure 1

The scenario of the impact of the interference from single UAS for its movement routes towards the azimuth of the main beam of FS station antenna Rx and towards the azimuths of side and back lobes of FS station antenna pattern Rx-Tx in the line-of-sights of FS station when altitudes of UAS flight are h1Tx=3 000 ft and h2Tx=19 000 ft

Figure 2 shows the scenario of the impact of the interference from single UAS for its movement routes in the line-of-sight of FS station and with changing in this case the angle of arrival of the interference Rx-Tx relative to the horizon.

**Rx-Tx**

**Rx-Tx**

**UAS**

**FS**

**hTx**

**R2**

**R1**

**Rx-Tx**

**hRx**

**R3**

**1**

**2**

**3**

**d2**

**d1**

**d3**

FIGURE 2

The scenario of the impact of the interference from single UAS during its movement in the line-of-sight of FS station and with changing in this case the angle of arrival of interference Rx-Tx relative to the horizon

# 3 Initial data and assumptions

Parameters of transmitting UAS station operating in Earth-to-space link in the frequency bands 14-14.47 GHz and 27.5-29.5 GHz used in assessment of the interference from UAS station to FS stations receivers are given in Table 1.

TABLE 1

Unmanned aircraft earth station transmit study parameters in the
frequency bands 14.0-14.47 and 27.5-29.5 GHz

| Parameter | Units | Frequency band(s) | Value | Source  |
| --- | --- | --- | --- | --- |
| Antenna Diameters | M | Both | Small = 0.45Medium = 0.80Large = 1.25 | Annex 1 Only small and large antenna studied. |
| Tx Channel bandwidth  | kHz | Both | 250 |  |
| Tx frequency range (evaluation) | GHz | 14.0-14.47 | 14.4 |  |
| Tx frequency range (evaluation) | GHz | 27.5-29.5 | 28.5 |  |
| e.i.r.p. density | dBW/250 kHz | 14.0-14.47 GHz | S,M,L = 43.78, 53.78, 57.68 | Only small and large antenna studied as defined in Annex 1 |
| e.i.r.p. density | dBW/250 kHz | 27.5-29.5 GHz | S,M,L = 42.38, 44.48, 48.08 | Only small and large antenna studied as defined in Annex 1 |
| Antenna patterns |  | Peak-envelope Bessel Function Antenna |  | Applied in Appendix 2, 3, 4 and 5. |
|  | S.580-APL-UM001 | Rec. S.580 for D/Lambda >= 100; BR-IFIC APL APEREC015V01 for D/Lambda < 100; | Applied in Appendix 4 and 5. |
| Altitude | Feet AGL | Both | 3 000’ (914 meters) and 19 000’ (5 791 meters) AGL for long-term; Various altitudes ≥3 000’ at 1 000’ increments as required for short-term. | ICAO Scenarios 2 and 4 |
| Atmospheric gas attenuation  | dB | Both |  | ITU-R P.676-9 |

Table 2 shows the parameters of FS station used in the assessment of interference from UAS station to FS stations receivers.

TABLE 2

Fixed service receive parameters in the frequency bands 14.0-14.47 and 27.5-29.5 GHz

| Fixed service | Units | 14.0-14.47 GHz Parameter | 27.5-29.5 GHz Parameter | Comment |
| --- | --- | --- | --- | --- |
| Frequency  | GHz | 14.4 | 28.5 | FS receive band fixed |
| Bandwidth | MHz | 28 | 56 | Rec. ITU-R F.758-5 |
| Line loss | dB | 6 | 0 | Rec. ITU-R F.758-5 |
| Antenna Gain | dB | 31.9 | 31.5 | Rec. ITU-R F 758-5 |
| Antenna efficiency | % | 60 | 60 |  |
| Antenna azimuth orientation | Degrees | ±180 | ±180 |  |
| Antenna elevation angle | Degrees | −5 to +5 | −5 to +5 | 5B/164-E |
| Locations - latitude  |  | Locations at several latitudes from 10 to 70 degrees are evaluated. | Locations at several latitudes from 10 to 70 degrees are evaluated. |  |
| Antenna pattern for average antenna gain  |  | cid:image001.png@01D0CDF0.068048A0 |  | Rec. ITU-R F.1245 Antenna pattern. fixed for all FS |

Table 3 shows the criteria of permissible long-term and short-term interference from UAS stations to FS stations.

TABLE 3

Protection criteria for the fixed service in the frequency bands 14.0-14.47 and 27.5-29.5 GHz

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Frequency Range | Value | ITU-R Source Document | Comments |
| I/N (Long Term) | Both14.0-14.47 GHz27.5-29.5 GHz | −10 dB | ITU-R Rec. F.758-6  | Not to exceed for more than 20% of the time |
| I/N (Short Term) | 14.0-14.47 GHz | +20 dB | ITU-R Rec. F.1494-0  | Not to exceed for more than 1x10-4 % of the time. |
| I/N (Short Term) | 27.5-29.5 GHz | +9 dB | ITU-R Rec. SF.1719 | Not to exceed for more than 0.001% of the time. |

When performing calculations, we assume that UAS station antenna is always directed towards FS station within the angle range 90 <  < 180. Then the antenna gain of UAS station towards a FS station is defined as:

 , (1)

Assessment of feasibility of sharing the frequency bands 14-14.47 GHz and 27.5-29.5 GHz between UAS stations and FS stations is performed using the following assumptions: FS station antenna height above ground level is hRx=10 m; elevation of the main beam of antenna radiation pattern of FS station is equal to ***εRx***= 5 degrees. Application scenarios of small, with diameter D=0.45 m, and large, with diameter D=1.25 m, UAS station antennas were taken into account when calculating.

# 4 Evaluation method

The method for evaluation of the feasibility of sharing the frequency bands 14-14.47 GHz and 27.5‑29.5 GHz by UAS stations operating in the Earth-to-space link and FS stations include the comparison of levels of interference power flux-density (pfd) produced by UAS transmitters in a specified frequency band on the Earth’s surface at the location point of FS station antenna within the range of possible values of angles of arrival of the interference relative to the horizon with the permissible levels of interference power flux-density.

Mask parameters of permissible level of interference power flux-density with the angle of arrival of the interference Rx-Txrelative to the horizon, can be defined using the following expression:

 (2)

where:

 *–* permissible level of interference power flux-density in a specified frequency band F, at the point of location of FS station receiver antenna with the angle of arrival of the interference Rx-Tx relative to the horizon, dBW/m2/F MHz;

– thermal noise power density in a typical receiver in the specified frequency band, dBW/F MHz (Recommendation ITU -R F.758-6);

F -

***f*** – frequency assignment to FS station, GHz;

 – permissible ratio of interference level ***I*** to the level of a receiver thermal noise ***N*** (Recommendation ITU-R F.758-6 – for long-term interference, Recommendation ITU-R F.1494-0 – for short-term interference in the frequency band 14-14.47 GHz, Recommendation ITU-R SF.1719-0 – for short-term interference in the frequency band 27.5-29.5 GHz), dB;

 – FS station antenna gain towards the angle of arrival of the interference *χRx*, dB (Recommendation ITU -R F.1245-2);

*χRx* – angle of arrival of the interference (an off-axis angle from the receiver antenna of FS station towards the UAS antenna), degrees.

The value of an off-axis angle of the FS station’s receiver antenna towards the UAS antenna *χRx* is defined by the relation:

 χRx = arccos(cos(εRx) cos(εRx-Tx) cos(αRx-Tx – αRx) + sin(εRx) sin(εRx-Tx)), (3)

where:

***εRx*** - elevation of the main beam of FS receiver antenna;

***εRx-Tx*** - FS receiver antenna elevation towards the UAS antenna;

***αRx*** - azimuth of the main beam of FS receiver antenna;

***αRx-Tx*** - FS receiver antenna azimuth towards the UAS antenna.

The level of power flux-density within the specified frequency band, produced by UAS transmitter on the Earth's surface at the point of location of FS station receiver antenna with the angle of arrival of the interference relative to the horizon can be calculated as follows:

 (4)

where:

 *–*power flux-density level within the specified frequency band F, produced by UAS transmitter on the Earth's surface at the place of location of FS station receiver antenna with angle of arrival of the interference relative to the horizon, dBW/m2/F MHz;

– e.i.r.p. of UAS transmitter within the specified band F, dBW/F MHz;

 – interference attenuation of UAS radiation pattern towards FS station, dB;

 –difference between the direction of the main beam of UAS station radiation pattern and the direction of UAS station towards FS station, degrees;

 –propagation loss in the interference path from UAS station to FS station (Recommendation ITU-R P.525-2 for line-of-sight path), dB;

***f*** –frequency assignment to FS station, GHz;

– specific attenuation due to atmospheric gases (Recommendation ITU-R P. 676-10), dB/km;

 - angle of arrival of the interference relative to the horizon, degrees;

***R*** – separation distance between UAS station and FS station along the great-circle arc, km;

 – UAS transmitter antenna height above ground level, m;

 – FS station antenna height above ground level, m;

 – separation distance between UAS station and FS station, km.

# 5 Results of assessment of the feasibility of sharing the frequency bands 14-14.47 GHz and 27.5-29.5 GHz by UAS stations operating in the Earth-to-space link with FS stations

To perform an assessment of feasibility of sharing the bands 14-14.47 GHz and 27.5-29.5 GHz using the relation (2) according to initial data from Tables 2 and 3, masks of permissible power flux-density for short-range interference produced by UAS transmitters, are specified.

Maximum permissible power flux-density approximation mask of short-range interference produced by UAS transmitters in the frequency band 14-14.47 GHz on the Earth’s surface at the location point of the FS station antenna from angles of arrival of the interference relative to the horizon (according to criterion I/N< +20 dB for p=0.0001% according to Recommendation ITU‑R F.1494):

• For the conditions of the interference arrival towards the main beam azimuth of FS station radiation pattern

 (5)

• For the conditions of the interference arrival towards the side and back lobes of a FS station antenna radiation pattern

 (6)

Maximum permissible power flux-density approximation mask of long-term interference produced by UAS transmitter antennas in the frequency band 14-14.47 GHz on the Earth’s surface at the point of location of FS station antenna from angles of arrival of the interference relative to the horizon (according to criterion I/N< -10 dB for p=20% according to Rec. ITU-R F.758):

• For the conditions of the interference arrival towards the main beam azimuth of FS station radiation pattern

 (7)

• For the conditions of the interference arrival towards the azimuth of the side and back beams of FS station radiation pattern

 (8)

Maximum permissible power flux-density approximation mask of short-term interference produced by UAS transmitter in the frequency band 27.5-29.5 GHz on the Earth’s surface at the point of location of FS station antenna from angles of arrival of the interference relative to the horizon (according to criterion I/N< +9 dB for p=0.001% according to Rec. ITU-R SF.1719):

• For the conditions of the interference arrival towards the azimuth of the main beam of FS station radiation pattern

 (9)

• For the conditions of the interference arrival towards the azimuth of the side and back beams of FS station radiation pattern

 (10)

Maximum permissible power flux-density approximation mask of long-term interference produced by UAS transmitters in the frequency band 27.5-29.5 GHz on the Earth’s surface at the point of location of FS station antenna from angles of arrival of the interference relative to the horizon (according to criterion I/N< -10 dB for p=20% according to Rec. ITU-R F.758):

• For the conditions of the interference arrival towards the main beam azimuth of FS station radiation pattern

 (11)

• For the conditions of the interference arrival towards the azimuth of side and back beams of FS station radiation pattern

(12)

Figures 3 and 4 give the results of assessment of levels of FS stations’ protection from interference produced by UAS stations in the frequency band 14-14.47 GHz according to short-term and long-term interference criteria with UAS flight altitudes are 3 000 ft (914 m) and 19 000 ft (5791 m) for application scenarios with small, with diameter D=0.45 m, and large, with diameter D=1.25 m, UAS station antennas.

Figure 3

Results of assessment of feasibility of sharing the frequency band 14-14.47 GHz by UAS stations operating
in the Earth-to-space link with FS stations according to short-term interference criterion

Figure 4

Results of assessment of feasibility of sharing the frequency band 14-14.47 GHz by UAS stations operating
in the Earth-to-space link with FS stations according to long-term interference criterion

Analysis of results of assessing levels of FS stations protection from interference produced by UAS stations in the frequency band 14-14.47 GHz according to short-term interference criteria (Figure 3) shows that non meeting the criterion of FS stations protection in this case occurs when angles of arrival of interference relative to the horizon are less than 10 degrees (***εRx-Tx*** < 10 degrees) when the interference arrives in the direction towards the main beam azimuth of FS station antenna (-2.6 degrees< ***αRx-Tx*** **<+**2.6 degrees) in application scenarios when UAS station uses both small and large antennas, with diameter D= 0.45m and D=1.25 m, when the UAS flight altitude is equal only to 3 000 ft. This scenario of the interference impact occurs when UAS is located within the sector of the main beam of FS station antennа within 5 to 138 km area from the point of location of FS station.

In addition, it should be noted that permissible percent of time during which the value of short-term interference criterion could be exceeded is equal to p%<0.0001%. Therefore the result obtained should be taken into consideration when making a decision on allocation of the frequency band 14‑14.47 GHz for sharing by UAS stations with FS stations.

In all others interference impact scenarios criterion of permissible short-term interference from UAS station to FS station is fulfilled.

Analysis of results of assessment of levels of FS stations protection from interference produced by UAS stations in the frequency band 14-14.47 GHz according to criteria of long-term interference (Figure 4) shows that the non-meeting of criterion of FS stations protection in this case occurs with any angles of arrival of the interference relative to the horizon (0 degrees < ***εRx-Tx*** < 90 degrees) and when the interference arrives in the direction towards the main beam azimuth of FS station antenna (-2.6 degrees< ***αRx-Tx*** **<+**2.6 degrees) in application scenarios when UAS station uses both small and large antennas with diameters D = 0.45m and D = 1.25 m, with UAS flight altitudes equal to 3 000 ft and 19 000 ft in the area limited by the radius equal to the line-of-sight value from place of location of FS station to UAS station (138 km).

Non meeting of the criterion of FS stations protection will also occurs when the interference arrives in the direction towards the azimuths of side and back beams of FS station antenna (2.6 degrees< ***αRx-Tx*** **<** 357.4 degrees) within the area from 0 km to 10 km from the place of location of FS station in application scenarios when UAS station uses both small and large antennas, with the diameters D = 0.45m and D =1.25 m, with UAS flight altitudes equal to 3 000 ft and 19 000 ft.

The results obtained allow making the conclusion that even if one UAS will be located within areas mentioned above more than 20% of time then in this case the criterion of permissible long-term interference to FS stations from UAS stations will not be met.

Figures 5 and 6 show the results of evaluation of levels of FS stations protection from interference produced by UAS stations in the frequency band 27.5-29.5 GHz according to criteria of short-term and long-term interference with UAS flight altitudes equal to 3 000 ft (914 m) and 19 000 ft (5791 m) for scenarios of application of small, with diameter D=0.45 m, and large, with diameter D =1.25 m, antennas of UAS stations.

Figure 5

3. Pfd mask approximation at the Earth's surface when UAS is moving along the azimuth of the main beam of FS station antenna

The results of evaluation of feasibility of sharing the frequency band 27.5‑29.5 GHz by UAS stations operating
in the Earth-to-space link with FS stations according to the criterion of short-term interference

Figure 6

The results of evaluation of feasibility of sharing the frequency band 27.5-29.5 GHz by UAS stations operating
in the Earth-to-space link with FS stations according to the criterion of long-term interference

Analysis of the results of assessment of levels of FS stations protection from interference produced by UAS stations in the frequency band 27.5-29.5 GHz according to the criteria of short-term interference (Figure 5) shows that the non-meeting of the criterion of FS stations protection in this case occurs with angles of the arrival of the interference relative the horizon less than 10 degrees (***εRx-Tx*** < 10 degrees) when interference arrives in the direction towards the main beam azimuth of FS station antenna (-2.6 degrees< ***αRx-Tx*** **<+**2.6 degrees) in application scenarios when UAS station uses both small and large antennas, with the diameters D= 0.45m and D=1.25 m, with UAS flight altitude only equal to 3 000 ft. This scenario of interference impact occurs when UAS is located in the main bean sector of FS station antenna within the area from 5 km to 327 km from FS station place of location.

In addition, it should be noted that permissible percent of time during which the value of the short-term interference criterion could be exceeded is equal to p%<0.001%. Therefore the result obtained should be taken into consideration when making the decision on allocation of the frequency band 27.5-29.5 GHz for sharing by UAS stations with FS stations.

In all others interference impact scenarios the criterion of permissible short-term interference from UAS station to the FS station is fulfilled.

Analysis of results of assessment of levels of FS station protection from interference produced by UAS stations in the frequency band 27.5-29.5 GHz according to the criteria of long-term interference (Figure 6) shows that non meeting of criterion of FS station protection in this case occurs with any angles of arrival of the interference relative to the horizon (0 degrees< ***εRx-Tx*** < 90 degrees) when interference arrives in the direction towards the main beam azimuth of FS station
(-2.6 degrees< ***αRx-Tx*** **<+**2.6 degrees) in application scenario when UAS station uses small antenna with diameter D= 0.45m only with UAS flight altitude equal to 3 000 ft. This interference impact scenario occurs when UAS is within the main beam sector of FS station antenna within the area from 0 km to 327 km from the place of location of FS station.

For application scenario when UAS station uses large antenna with diameter D=1.25 m and UAS flight altitude is equal to 3 000 ft non meeting of the criterion of FS station protection will occur when interference arrives in the direction towards the main beam azimuth of FS station
(-2.6 degrees< ***αRx-Tx*** **<+**2.6 degrees) and when angles of arrival of the interference relative to the horizon are within the range of 0 – 20 degrees (0 degrees <***εRx-Tx*** < 20 degrees). This interference impact scenario occurs when UAS is located within the main beam sector of FS station antenna within the area from 2 km to 327 km from FS station place of location.

With UAS flight altitude equal to 19 000 ft. non meeting of the criterion of FS station protection will occur when the arrival of interference is directed towards the main beam azimuth of FS station (-2.6 degrees< ***αRx-Tx*** **<+**2.6 degrees) and when angles of arrival of the interference relative to the horizon are within the range of 0 – 10 degrees (0 degrees <***εRx-Tx*** < 10 degrees). This interference impact scenario occurs when UAS is within the main beam sector of FS station antenna within the area from 33 km to 327 km from FS station place of location.

Non meeting of the criterion of FS station protection will also occur when interference arrival is directed towards the azimuth of side and back beams of FS station (2.6 degrees< ***αRx-Tx*** **<** 357.4 degrees) within the area from 0 km to 1.3 km from the place of location of FS station for application scenario when UAS station uses small antenna with diameter D= 0.45m and only if UAS flight altitude is equal to 3 000 ft.

The results obtained allow making the conclusion that even if any UAS is within the area mentioned above more than 20% of time, the criterion of permissible long-term interference from UAS stations to FS stations will not be met.

# 5 Conclusions

Results of evaluating the feasibility of sharing the frequency bands 14-14.47 GHz and 27.5‑29.5 GHz between UAS stations operating in the Earth-to-space link, and FS stations, show that the use of frequency bands allocated to FSS, to which Appendices 30, 30A and 30B are not applied, for control and non-payload communication in non-segregated airspaces in not possible.

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