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| |  |  | | --- | --- | | **World Radiocommunication Conference (WRC-15) Geneva, 2-27 November 2015** |  | | **INTERNATIONAL TELECOMMUNICATION UNION** |  | |  |  | | **PLENARY MEETING** | **Addendum 2 to Document 4(Add.1)-E** | | **29 October 2015** | | **Original: English** | | **Director, Radiocommunication Bureau** | | | REPORT OF THE DIRECTOR ON THE ACTIVITIES OF THE RADIOCOMMUNICATION SECTOR | | | part 1  activities of the radiocommunication sector in the period between WRC‑12 and WRC‑15 | | | Additional information relevant to Part 1of the Director’s Report | | |

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# Progress report on the development of software tools for determining conformity of non-geostationary-satellite orbit fixed-satellite networks with equivalent power flux-density (epfd) limits contained in Article 22 of the Radio Regulations in accordance with ITU-R Recommendation S. 1503-2

# 1 Introduction

Section 2.2.3.5 of Addendum 1 to Document CMR15/4 (Part 1 on Activities of the Radiocommunication Sector in the period between WRC-12 and WRC-15) contains information on the implementation of Resolution 85 (WRC-03) (Application of Article 22 of the Radio Regulations to the protection of geostationary fixed-satellite service and broadcasting-satellite service networks from non-geostationary fixed-satellite service systems).

This addendum provides further detailed information and status on the development of the epfd validation software tools for the analysis of non-GSO fixed-satellite service (FSS) systems, in accordance with Recommendation ITU R S.1503-2.

# 2 Summary of Progress

Two versions of EPFD engine have been developed by two different companies that implement Recommendation ITU-R S.1503-2 including the additional features in this update such as the improved worst case geometry, and integration into the BR’s software environment, in particular access and treatment of non-GSO FSS network Appendix 4 information directly from the ITU SRS database together with PFD and EIRP masks.

Both software companies are undergoing testing with a set of test scenarios that include both non-GSO reference systems developed and examined during the Rec.S.1503-1 software validation as well as new test cases derived from real satellite systems. Testing is progressing satisfactorily, with adequate matching between software tools for the test cases undertaken so far. The current phase of testing is based upon a set of six defined cases (see Table 1 in §3 below) that cover the range of non-GSO constellation types received by the Bureau and means to define earth station locations.

Although run times for some of the larger non-GSO constellations have been lengthy, the software were able to manage those systems and ran successfully.

The delivery of a test version of the EPFD validation software to the ITU/BR is planned on 1 December 2015 and the production version on 1 may 2016.

# 3 Defined scope of work relating to the development of EPFD validation software

Two versions of the EPFD engine were developed under original contracts in 2010 by Transfinite Ltd and Agenium, based on ITU-R Recommendation S.1503.

The recommendation was subsequently updated in 2013 with the changes identified in the following documents:

• Document WP 4A / 95-E 12th September 2012

• Document WP 4A / 229-E 26th April 2012

• Document WP 4A / 327-E 26th September 2013

The key changes (excluding editorials and restructuring) between Recommendation ITU-R S.1503-1 and S.1503-2 are as follows:

Data Read Updates

• Read additional parameters from the SRS database

• Ensure match process to convert SRS database fields into orbit parameters

• Ensure to read new format of PFD and EIRP masks

• Ensure to read specific earth station (ES) locations from the SRS database

Calculation Engine Updates

• Introduce ability to include different ES EIRP masks by latitude

• Introduce ability to include different satellite EIRP mask by latitude

• Introduce ability to include different PFD / EIRP mask between satellites

• Introduce ability to handle PFD / EIRP mask bandwidth calculations

• Introduce ability to use specific ES

• Update the algorithm for deployment of ES by density

• Update algorithm including selection of non-GSO satellite for EPFD(up)

• Set orbit model for equatorial non-GSO networks

• Define resolution for alpha calculation

• Update time step calculation

• Improve run duration calculation

Worst Case Geometry (WCG)

Worst Case Geometry is the location of the GSO earth station and GSO satellite that analysis suggests would cause the highest single entry epfd values for given inputs.

• New WCGA(down) algorithm

• New WCGA(up) algorithm

• New WCGA(IS) algorithm

The most significant change in terms of complexity has involved the worst case geometry (WCG).

To address these changes the testing was conducted in two phases, an internal testing that includes running individual tests for each implemented changes and external testing to be undertaken between both EPFD software to guaranty similar results based on the following test-cases:

Table 1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Type | Orbit shape | Equatorial | Repeating | ES locations | Test Case Based Upon |
| A | Circular | No | Yes | Typical (via density) | Skybridge |
| B | Circular | No | No | Typical (via density) | Boeing |
| C | Circular | Yes | n/a | Typical (via density) | O3b |
| D | Elliptical | No | No | n/a | USCSID |
| E | Elliptical | No | Yes | Typical (via density) | (created) |
| F | Polar Limited Coverage | No | Yes | Specific (exact location) | CANPOL |

The Bureau has contracted Transfinite Ltd and Agenium to update EPFD validation software in accordance with Recommendation S. 1503-2.

# 4 Progress report for the implementation of Recommendations S.1503-2

## 4.1 General updates

The following features were implemented in the software:

• Possibility for PFD / EIRP mask to vary between satellites

• Possibility for Satellite / Earth Station (ES) EIRP masks to vary by latitude

• Use of a new algorithm for deployment of ES by density

• Handling of equatorial non-GSO orbits

• Handling of elliptical non-GSO orbits

• Change to the time step / run duration calculations

• New WCG algorithms

• PFD / EIRP mask information extracted from SRS database.

In implementing these changes particular attention was taken to ensure that the code ran as efficiently as possible and utilized modern multi-core PCs. This was critical taking account of the intensive computing in the WCG algorithm and the impact on the software run time.

Some features still need to be further developed and tested:

• Ability to handle PFD / EIRP mask bandwidth calculations

• Ability to use specific ES.

## 4.2 Internal Testing

Orbit Model Changes

The software changes were validated against a reference test case and found to be perfectly matching.

Change to the time step / run duration calculations

The changes introduced in Rec. S.1503-2 have in many cases resulted in significantly increasing the number of timesteps to be performed for each EPFD run, with a major impact on the time required for each run to be completed.

Update to WCG

One of the major changes to the algorithm in Rec. ITU-R S.1503 was the calculation of the worst case geometry (WCG). The new WCG algorithm in version -2 was found to be much more vigorous than that in version -1 and identified alternative geometries to locate the GSO satellite and earth station(s). This resulted in epfd statistics that in some cases had higher percentages of time for a given epfd level, and which suggests that the revised algorithm was operating effectively.

Masks Format

Testing was undertaken to ensure that the software could handle non-GSO FSS constellations that uses multiple PFD masks and masks that vary by latitude.

## 4.3 External Testing

Orbit Model Changes

The software changes were validated using a test harness. The results show excellent agreement in many cases with a delta better than 1e-5.

Change to the time step / run duration calculations

The timestep and number of timesteps were compared and it was shown that there was perfect agreement between both software.

Earth Station Deployment

The locations of the earth stations for the UP scenarios were compared for the relevant test scenarios (note that USCSID doesn’t generate UP runs). There was perfect agreement.

Update to WCG

In order to complete the tests in a reasonable time a fixed latitude step of 1 degree was used when running these tests. The results show good agreement for the various test cases. Work is also progressing to speed up the WCG calculations.

Types E and F( see Table 1 above) still need to be fully tested.

Full Calculation Runs

There was agreement with the 0.1 dB required level for test cases A, B and C. Analysis continues with test cases D, E and F and should be completed by early 2016.

## 4.4 Update of XML-format for submission of PFD/EIRP-mask data

Three masks, as required in Appendix 4, are mandatory to describe a non-geostationary system and examine it under RR Article 22 and Appendix 5: a power flux-density mask for the downlink (A.14.c), an equivalent isotropically radiated power mask for the uplink (A.14.b) and inter-satellite link (A.14.a).

Following an update of ITU-R Recommendation S. 1503-2, the Bureau updated XML-format to be used for the submission of XML-mask data. Detailed definition of these masks, description of their generation and calculation methodology are provided in Rec. ITU-R S.1503-2.

The description of XML-format together with the examples is provided here:

<http://www.itu.int/ITU-R/go/space-mask-XMLfile/en>

The main change is the introduction of latitude element into EIRP-masks.

# 5 Issues under further consideration

## 5.1 Calculation time

For large earth stations with antenna diameter greater than 5 meters, the calculation time may exceed several days. Given that Article 22 examination should be provided for all antenna diameters the overall calculation time could reach one week.

If we consider recent submissions of non-GSO FSS satellite systems with a large number of satellites up to several thousands, the calculation time would increase even more significantly.

Software developers are currently looking further to optimize algorithms in order to decrease calculation time.

Processing power is also an important factor that the Bureau is studying including the procurement of more powerful servers or the use of cloud computing.

An approach to significantly decrease the EPFD calculation time could be to consider the protection of large earth stations with antenna diameter greater than 5 meters to be undertaken at the coordination stage of such E/S when their specific location is known.

## 5.2 Input data required for EPFD validation

While reviewing the submissions from administrations for FSS non-GSO satellite systems, the Bureau found that in many cases required Appendix 4 information to complete EPFD examination were not complete.

A list of the elements missing or incorrectly defined is presented in table below:

Table 2

|  |  |  |
| --- | --- | --- |
| Appendix 4 Data Element | Description | **Comment** |
| A.4.b.6.a  A.4.b.6.a.1  A.4.b.6.a.2  A.4.b.6.a.3 | The maximum number of non-geostationary satellites transmitting with overlapping frequencies to a given location:  – the associated start of the latitude range  – the associated end of the latitude range | Information that could be presented in a separate table. All the latitude ranges should be covered (-90 to 90). |
| A.4.b.7.b | Average number of associated earth stations transmitting with overlapping frequencies per km² in a cell | If submitted, often defined as integer number, which normally should not be the case.  See section 5.2.5 of Rec. S. 1503-2 on definition guidance. |
| A.4.b.7.c | Average distance between co-frequency cells in kilometres | See section 5.2.5 of Rec. S. 1503-2 on definition guidance. |
| A.4.b.7.d.1 | Flag indicating the type of zone: if the exclusion zone angle is the angle alpha [Y] or the angle X [N] | Appendix 4 description imply that there could be other method for establishing exclusion zone. However, Rec.S.1503-2 does not contain any methodology to implement other methods. Therefore, it is suggested that alpha/X angle = 0 be used. |
| A.4.b.7.d.2 | Width of the exclusion zone in degrees | See A.4.b.7.d.1 |
| A.14.a | E.I.R.P mask(s) of the non-geostationary space station | Required for transmitting beams. |
| A.14.b | E.I.R.P mask(s) of the earth station(s) | Required for earth stations in the receiving beams. |
| A.14.c | PFD mask produced by the non-geostationary space station | Required for earth stations in the receiving beams. |
| A.14.b.4 | Minimum elevation angle at which any associated earth station can transmit to a non-geostationary satellite | Required for earth stations in the receiving beams. |
| A.14.b.5 | Minimum separation angle between the geostationary satellite orbit arc and the associated earth station main beam-axis at which the associated earth station can transmit towards a non-geostationary satellite | Required for earth stations in the receiving beams. |

All fields should be specified: in particular the minimum elevation angle and exclusion zone size are required for both the WCG and EPFD calculation, with zero a valid value for both. Note that the elevation angle is the minimum angle at which there could be active communication between a satellite and an ES of a non-GSO FSS satellite constellation. It is derived at the ES and if both uplink and downlink are in bands for which there are EPFD limits in Article 22, then the elevation angle should be the same for the EPFD(down) as EPFD(up) directions.

## 5.3 Documentation

During the development of the EPFD validation software, developers identified further changes which might be required to ITU-R Recommendation S.1503-2. These changes are typically clarification or relate to performance improvements and consistency between the algorithm implemented in the software tools and the algorithm described in Rec. S.1503-2.

The suggested changes are attached below for information:



Note that the update to Recommendation ITU-R BO.1443-3 from -2 was editorial in nature and has no impact on the calculation of EPFD.

# 6 Target delivery date for the EPFD Validation Software complying with the Recommendation S. 1503-2

|  |  |
| --- | --- |
| **Description** | **Finish/Delivery date** |
| • Development of a new version of the EPFD software based on Rec. S.1503-2  • Test version delivery to BR | 06.11.2015  01.12.2015 |
| • Software internal testing  • Software external testing | 31.11.2015  01.02.2016 |
| • Final evaluation of the software including documentation of any discrepancies in S.1503-2 and production version delivery to BR | 01.04.2016 |
| • Software release to Administrations | 01.06.2016 |

# 7 Conclusion

The Bureau believes that the additional information presented in the document would help the work of the Conference in relation to Resolution 85 (WRC-03) as well as consideration of the overall issue of GSO/non-GSO frequency sharing.

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