… And to Consider Possible Procedures for Free-Space Optical-Links, Taking into Account the Results of ITU-R Studies, in Accordance with Resolution 955 (WRC-07)

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1 Executive Summary

Agenda item 1.6 (Resolution **955** (**WRC-07**)) of the 2012 World Radiocommunication Conference (WRC-12) considered possible procedures for free-space optical links, taking into account the results of ITU-R studies. Technical studies within the ITU-R have resulted in Recommendations and Reports on various applications of free-space optical links. No information has been provided to indicate that interference between free-space optical systems was a concern. As a consequence only one method to satisfy this part of the agenda item was identified in the Conference Preparatory Meeting Report to the 2012 World Radiocommunication Conference (CPM Report to WRC-12). The method was proposing no change to the Radio Regulations for free-space optical systems. WRC-12 reviewed the proposals submitted by administrations which were inspired by the CPM report and agreed for no change to the Radio Regulations and the consequential suppression of Resolution **955** (**WRC-07**).

2 Background

Resolution **955** (**WRC-07**) considers possible procedures for free-space optical links. Because the atmosphere is essentially opaque at frequencies between 3 000 GHz and the near-infrared range, terrestrial free-space optical links operate at frequencies in or above the near-infrared range. Although inter-satellite links do not suffer from absorption, such links also generally use frequencies

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in the near-infrared range, due to the ready availability of transceiver (laser) technology in that range.

No. **78** of the ITU Constitution indicates that the Radiocommunication Sector shall fulfil the purposes of the Union relating to radiocommunications *inter alia*, by carrying out studies without limit of frequency range. No. **1005** of the Annex to the ITU Convention indicates that the term "radiocommunication" is limited to "electromagnetic waves of frequencies arbitrarily lower than 3 000 GHz"[1], except in the context of radiocommunication study groups addressing study questions and WRC Resolutions and recommendations. However, the 2002 Plenipotentiary Conference adopted Resolution **118** (Marrakesh, 2002), which resolves that world radiocommunication conferences can include in agendas for future conferences items relevant to spectrum regulation of frequencies above 3 000 GHz and take any appropriate measures including revision of the relevant parts of the Radio Regulations.

3 Summary of Technical and Operational Studies and Relevant ITU-R Recommendations

No Recommendations or Reports were developed under Question ITU-R 228/1, "Possibility and relevance of including in the Radio Regulations frequency bands above 3 000 GHz" nor was a Report, "regarding the possibility and relevance of including in the Radio Regulations frequency bands above 3 000 GHz" developed under *considering d)* of Resolution **955** (**WRC-07**).

Relevant ITU-R Recommendations referenced under *considering c)* of Resolution **955** (**WRC-07**): ITU-R P.1621, ITU-R P.1622, ITU-R S.1590, ITU-R RA.1630, ITU-R SA.1742, ITU-R SA.1805 and ITU-R RS.1744 contain information pertaining to propagation, astronomical uses, meteorological observations and space-based telecommunication above 3 000 GHz, but no specific information about terrestrial free-space optical links; other relevant ITU-R Recommendations and Reports addressing propagation as well as fixed, remote sensing and astronomical applications: Recommendations ITU-R P.1814, ITU-R P.1817 and ITU-R RS.1804 and Reports ITU-R F.2106 and ITU-R RA.2163.

4 Analysis of the Results of Studies

The following summarizes the relevant findings of concluded studies.

The performance of terrestrial stations operating with satellites at frequencies above 30 THz is strongly influenced by the atmosphere. Propagation considerations include atmospheric absorption, Rayleigh and Mie scattering, refraction, and turbulence. To avoid atmospheric losses as much as possible, optimal locations for a terrestrial station are typically at high altitudes, usually at least 2 km above sea level. In addition, it is difficult to maintain an optical communication

1 In the French text, the frequency limit is "by convention." In the Spanish text it is termed "conventionally," and in the English text it is termed "arbitrarily."

link with a terrestrial station operating with an elevation angle below 40° due to the atmospheric effects at lower angles.

Atmospheric absorption, scattering and turbulence are also significant considerations for terrestrial free-space optical systems. These systems may also operate with some degradation through fog, rain and snow.

Free-space optical communication systems operating in the Earth-to-space, space-to-Earth and space-to-space directions are all exemplified by very narrow beams. The largest fields of regard are used between non-GSO spacecraft during acquisition mode but are still no more than 700 µradian (0.04°). Their field of view typically is reduced to the order of 10 µradian (0.0006°) for regular communication. Unwanted energy received in the side lobes of the receiving antenna pattern may be neglected in the course of interference analyses. Typical transmitting beam widths are also in the order of 10 µradian.

In the future, like fibre-optic broadband wireless connections, free-space optical links will be a promising system to provide point-to-point line-of-sight networks. For terrestrial applications, the beam divergence of the transmitting signal and the field of view of the receiver are typically a few milliradians or less. However, in the case of initial acquisition of the target terminal, a combination of a higher power beacon with a larger beam divergence and a sensitive acquisition sensor with a wide field of view, such as a CCD (Charge Coupled Device) image sensor, is frequently used. Terrestrial free-space optical links may be deployed at any time and in any place. This is based on today's assumption that no coordination is required to avoid interference between such links operated by different operators. Theoretically, interference between free-space optical links may occur. However, the interference will never have harmful effects unless two links operate under a quite limited geographical environment.

There are many telescopes in the world with the capability to make astronomical observations in the THz bands, and the number is increasing. Although the "antenna beams" are individually narrow, so that the probability for beam-to-beam coupling is low, most of these telescopes are imagers, with an array of many pixels at the focus, "seeing" collectively a patch of sky that could be a substantial fraction of a degree across. Since telescopes observing at frequencies above 100 THz are based at isolated, high-altitude sites, there are few suitable places in the world, and in general these are far from population concentrations (Mauna Kea, USA is a possible exception). It is, therefore, feasible to avoid transmitting towards such sites. Providing spatial separation is large enough, the low-attenuation windows in the atmosphere may be used both by active and passive services.

Active and passive sensing devices utilizing spectrum above 3 000 GHz offer the most diverse technical and operational characteristics of any technology studied with sensitivities and fields of view varying by orders of magnitude. Active sensors take the form of light detection and ranging (LIDAR) devices used by the EESS (active) and terrestrial MetAids type applications. Beam widths and receiver fields of view of terrestrial applications are wider than those of space-based active sensors but are typically no more than a few mradian. Terrestrial meteorological aid systems also make active measurements by transmitting pulsed signals from a fixed source. Atmospheric conditions are determined by analysing signal characteristics received at the other end of the path. To minimize effects of energy from other sources, EMI (electromagnetic interference) filters are placed on the receivers of these types of systems.

EESS passive systems collect information relating to the characteristics of the Earth and its natural phenomena, including data relating to the state of the environment. Instruments operating above 3 000 GHz may be present on about half of all EESS spacecraft. About one to three new EESS systems utilizing the spectrum above 3 000 GHz are anticipated to be launched each year for the foreseeable future, with additional instruments being temporarily deployed on the International Space Station, like previously also on Space Shuttles. The majority of EESS systems utilize non-geostationary orbits, with a significant portion of these systems in sun-synchronous orbits. Each EESS system has unique technical characteristics and mission requirements that directly influence instrument sensitivity. Sensitivity requirements will also vary with solar illumination, measurement subject, and even instrument age. As for passive meteorological aid devices, they conduct measurements such as sunshine detection and sky luminance. Both utilize sensors which may be exposed to direct sunlight.

In summary, because emitters used in near-infrared free-space links have extremely narrow beam widths, and terrestrial emitters can only cause interference over very short distances, cases of terrestrial interference will be very rare and easily resolved on a local basis. Moreover, interference between intersatellite links would also be rare due to directed and narrow beam widths, and the vast geometry of space.

No evidence up until now has been provided that interference between free-space optical systems is a concern. Existing ITU-R Recommendations and Reports sufficiently address free-space optical links. Furthermore, no possible procedures have been identified for free-space optical links.

5 Method to Satisfy the Part of the Agenda Item Related to Resolution 955 (WRC-07)

CPM therefore proposed no change to the RR and consequential suppression of Resolution **955** (**WRC-07**).

6 WRC-12 Decision

WRC-12 reviewed proposals submitted by Administrations inspired by the CPM proposal and agreed for no change to the existing Radio Regulations and the consequential suppression of Resolution **955** (**WRC-07**).WRC-12 recognised that such decision would mean no recognition in the Radio Regulations of free-space optical links or radio services above 3 000 GHz at this time. However, WRC-12 also noted that Resolution **118** (**Marrakesh, 2002**) remains in force thereby providing a procedure for regulatory issues to be addressed if such need ever arises and that ITU-R Study Groups may continue to conduct studies without limit of frequency range as new technologies or sharing scenarios emerge.