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Radio Regulation Development and Radio Spectrum Analysis of Earth Station in Motion Service

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***Abstract*—**Although Earth Station in Motion (ESIM) services are widely used and there is a huge market demand around the world, International Telecommunication Union (ITU) does not have unified conclusion for the use of ESIM yet. ESIM are Mobile Satellite Services (MSS) due to its mobile-based attributes, while multiple administrations want to use ESIM in Fixed Satellite Service (FSS). However, Radio Regulations (RR) have strict distinction between MSS and FSS. In this case, ITU has been very controversial because this kind of application will violate the RR Article and the conflict will bring risks to the global deployment. Thus, this paper illustrates the development of rules, regulations, standards concerning ESIM and the radio spectrum usage of ESIM in different regions around the world. Firstly, the basic rules, standard and definition of ITU's Radiocommunication Sector (ITU-R) is introduced. Secondly, the World Radiocommunication Conference (WRC) agenda item on radio spectrum allocation for ESIM, e.g. in C/Ku/Ka band, is introduced and multi-view on the radio spectrum allocation is elaborated, especially on 19.7-20.2 GHz & 29.5-30.0 GHz. Then, some ITU-R Recommendations and Reports are analyzed on the specific technique to enable these ESIM to communicate with Geostationary Earth Orbit Satellite (GSO) space stations in the FSS without causing interference at levels in excess of that caused by conventional FSS earth stations. Meanwhile, the opposite opinion on not allocating EISM service in FSS frequency band is also elaborated. Finally, based on the ESIM's future application, the ITU-R standards development trend is forecasted. In conclusion, using radio spectrum resource in an equitable, rational and efficient manner is the basic guideline of ITU. Although it is not a good approach to obstruct the revise of RR when there is a large demand for radio spectrum resource in satellite industry, still the propulsion and global demand of the whole industry may face difficulties on the unclear application in modify rules of RR.

***Keywords*—**Earth Station in motion, ITU standards, radio regulations, radio spectrum, satellite communication.

I. Introduction

WITH the development of satellite communication, the demand for use ESIM service is increasing and the frequency allocation for ESIM is a hot topic in ITU. However, ITU does not have unified conclusion that whether the use of ESIM is in FSS or MSS yet. In ITU-R department, all the radio resources are divided by RR. Use of ESIM in both FSS and MSS will cause unacceptable interference to the practical deployment. Thus, this paper illustrates RR Development and analyzes ESIM's Radio Spectrum usage.

Section I is introduction of the whole paper. Section II introduced the basic rules and structure of ITU-R. The history and present situation concerning radio spectrum allocation for ESIM, e.g. In C/Ku/Ka band is introduced in Section III. Then, in Section IV, some limitations are compared and the influence factor is found. Finally, Section V concludes the paper.

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II. Basic Rules and Standard of ITU-R

A. Basic Rules of ITU-R

ITU-R is one department of ITU, which is the global forum on the evolution of radio technologies and uses, where spectrum allocations and provisions necessary to this evolution are decided. [1]

The mission of ITU-R is to "maintain and extend international cooperation among all the Member States of the Union for the improvement and rational use of telecommunications of all kinds" [2].

B. Structure of ITU-R & WRC

Fig. 1 shows the simplified structure of ITU-R. One of the missions of ITU-R is to ensure interference-free operations of radiocommunication systems by implementing the RR and regional agreements. Hence, these instruments are updated through the processes of world and regional radiocommunication conferences. WRC is convened every three or four years, with the mission of reviewing and revising radio regulation.

Another mission of ITU-R is to establish recommendations intended to assure the necessary performance and quality in operating radio communication systems. These recommendations are approved by Radiocommunication Assemblies (RAs), studied and promoted by Study Groups.

Fig. 1 Simplified Structure of ITU-R

The last mission of ITU-R is to seek ways and means to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum and satellite-orbit resources. ITU-R could achieve this mission not only by updating the RR, but also by allocating spectrum, adopting resolutions and modified notification procedures in WRC to meet this demand.

III. Study of ESIM's Frequency Use

Before WRC-15, ESIM is called Earth Stations on Mobile Platforms (ESOMPs). They are earth stations with technical characteristics similar to fixed earth stations, but which operate on moving platforms such a ships and aircraft. ESIM technology ensures that the antenna maintains very accurate pointing towards the satellite, typically with around 0.2 degree pointing accuracy, even on a moving ship or aircraft. Such pointing accuracy is similar or better to that achieved by fixed satellite VSAT terminals. Thus, ESIM could provide mobile service just like fixed service in the frequency region. ESIMs also use directional antennas which achieve efficient use of the orbital resource similar to fixed VSATs (e.g. frequency reuse with 2-3 degree satellite spacing). Hence, with the development of ESIM, the frequency band is more and more narrow for them. The Ka band is the potential choice for the operator of ESOMP to chase. This section illustrates the development of frequency used by ESIM.

A. C/Ku Band Used by ESIM

Before 2003, there is a demand for global wide-band satellite communication services on vessels and the technology enables ESIM to use fixed-satellite service networks. ESIMs operated in C and Ku band as shown in Figs. 2 and 3 with the compromise that do not cause interference to the incumbent system and do not claim protection from other incumbent systems. However, the negative sides claim that the usage for the ESIM have the potential to cause unacceptable interference to other services in the bands 5925-6425 MHz and 14-14.5 GHz. Due to the coverage attributes of frequency resources, global coverage is only available in the band 5 925-6 425 MHz and only a limited number of geostationary FSS systems can provide such global coverage. To erase the coordination burden of ESIM, it is an urgent demand that ESIM needs regulatory provisions. Thus, during the unremitting effort in WRC-03, in 2003, the resolution is confirmed to allow ESIM using 5925-6425 MHz and 14-14.5 GHz FSS uplink frequency band. This resolution provides regulation evidence for the FSS legal use of shipborne and airborne earth station. The increasing demand for ESIM use is met temporarily.

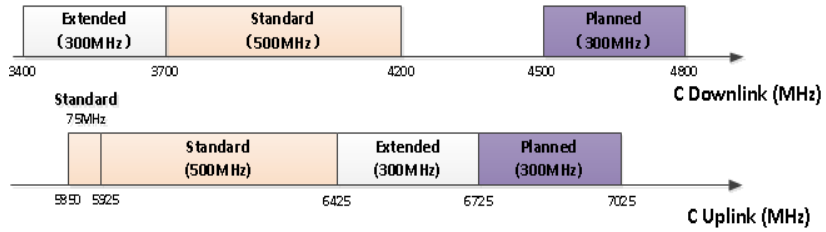

Fig. 2 C band allocation

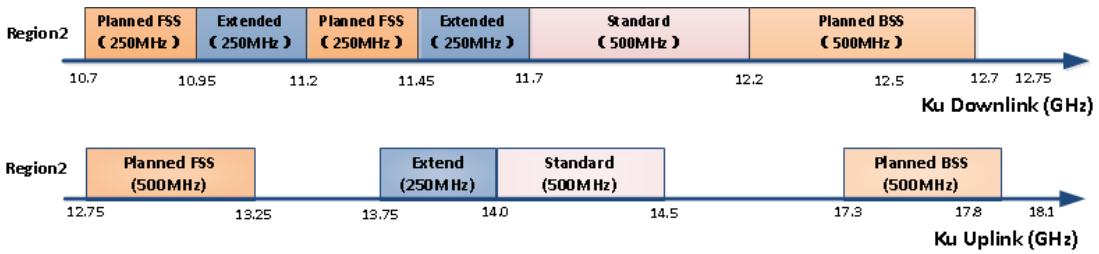

Fig. 3 Ku band allocation

B. Current Usage of Ka Band in Communication

Due to the satellite network filling application procedure of ITU-R, each satellite system must enter into MIFR and complete satellite frequency coordination. Then, the satellite system could use the frequency and orbit resource in a certain time. During this application procedure, there are four status of satellite network fillings, called API (Advanced Publication Information), C filling (Coordination filling), N filling (Notification) and Due Diligence. API fillings just show the general information and the willing to the application of one satellite network. C filling means that the satellite network has the position in the coordination procedure, and the satellite comes into the manufacture process. N filling means that the satellite is launched and this satellite network filling is brought into use. If N fillings could represent the satellite coming into use nowadays, that is to say, the satellite is launched and enter into orbit, then the C fillings could represent the satellite network is in plan or will be launched in the near future. Take the SRS-2814 database of ITU-R as an example, the number of GSO C fillings applied in FSS Ka band is statistic and the total number is 1227. Based on the national attributes, the top 10 countries with most Ka band C fillings are illustrated in Fig. 4, along with the number of GSO N fillings.

Based on the number of satellite network fillings above (until the middle of 2016), it could be seen that the number of C fillings applied by Europe is large while the number of N fillings is small. Although the satellite nowadays used Ka band in ESIM is not that much, yet the future plan for the Ka band in

Europe is prosperous.

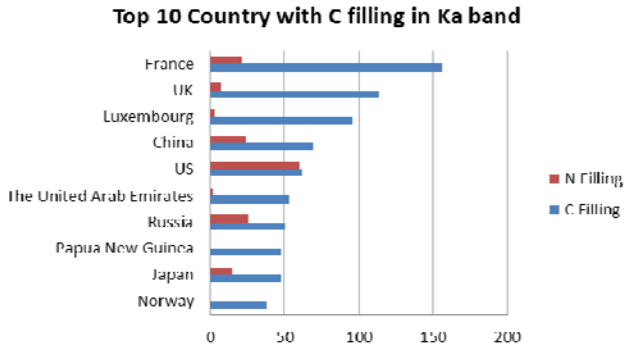

Fig. 4 Top 10 Countries with C filling in Ka band

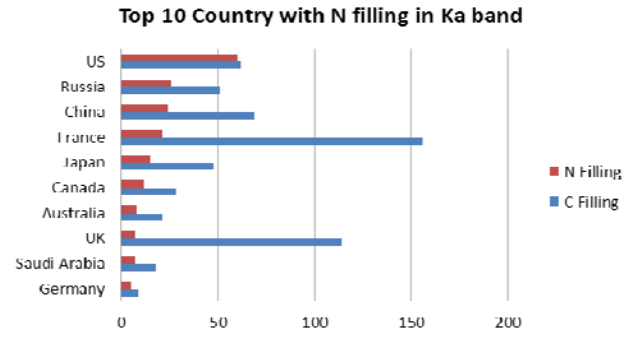

Fig. 5 Top 10 Country with N filling in Ka band

Similarly, the number of GSO N fillings applied in FSS Ka band is statistic and the total number is 217. Based on the national attributes, the top 10 country with most Ka band N fillings is illustrated in Fig. 5, along with the number of GSO C fillings. It is found that US has the most Ka band satellite system and it is identical along with the point that the US proposed in the ITU-R meetings. The traditional powerful aerospace countries occupied the top of Ka band application due to the number of GSO N fillings.

C. The Conclusion to the Different Opinions on the Use of ESIM in Ka Band

With the international known satellite operators' promotion, the discussion for the use of lower part of Ka band (19.7-20.2GHz & 29.5-30GHz) eventually becomes the issues in WRC-15. A new class of station is introduced, code UC, for an ESIM associated with a space station in the FSS in the upper 500M Ka bands in region 2 and upper 100MHz Ka bands [3]-[5]. The main purpose for introducing the UC earth station is that, through the study of the regulation procedure and associate technique boundary, to allow ESIM use part Ka band resource to deploy MSS and legalize the frequency priority of ESIM in Ka band.

The main focus on ESIM study including the positive side and negative side. The representative of positive side is some developed country like US, UK and Canada and the negative side is some developing country like Iran and the United Arab Emirates. The strong promotion side conceive that, the resolution in 2003 provide the foundation of regulation provisions in the usage for ship-borne and air-borne ESIM in C and Ku band. So that the similar frequency resource extension for Ka band. Also, in 2011, and the report for the technical and operation standard for ESIM based on GSO FSS is also accepted by radio-communication assembly. However, the negative side think that the ESIM doesn't comply the definition of FSS in Article 1, RR. ESIM should belong to MSS's earth station but not FSS earth station. Based on the protection and respect for the regulations, the ESIM's application is strongly opposed.

The multiple view from different region and organizations is conclude here to find the regulation development of ESIM.

1) Conclusion from the view of Europe and RCC (Radio Consultative Committee): For ESIM, no matter from the respective of technical or regulation, there is no reason to consider that ESIMs must operate at a network that both FSS and MSS is on. Many proposal indicate that the global market's demand for mobile broadband is grow heavily. The emerging of FSS ESIM in Ka band could meet these demand in some degrees [6]. It is suggested that a new provision need to be set on the restriction, regulation and standard from technical and operation level.
2) Conclusion from the view of Asia-Pacific Telecommunication (APT): There are two sides in APT, the positive side propose that the 19.7-20.2GHz and 29.5-30GHz could be the unified frequency band globally used for ESIMs in Ka band. At the same time, it should be restricted for the demand on ESIM's technique and operation. While the negative side point out that it shouldn't add any frequency allocation for ESIM, neither for modification on the definition of fixed station, mobile station, fixed earth station and mobile earth station.
3) Conclusion from the view of Africa region organization: African countries suggested that 19.7-20.2GHz and 29.5-30GHz could be unified used globally for mobile earth station of FSS on some specific condition.
4) Conclusion from the view of Inter-American Telecommunications Commission (CITEL): It is suggested that ESIM's frequency should be unified globally in Ka band, that is to say, allowing mobile earth station communication with GEO-stationary FSS satellite in 19.7-20.2GHz and 29.5-30GHz on the specific condition.
5) Conclusion from the view of Arab Spectrum Management Group (ASMG): Unifying the FSS allocation globally, need to pay attention that some countries allocating secondary service for the fixed and mobile service in 19.7-21.2GHz and 29.5-31GHz. The ESIM operated in these countries should not cause unacceptable interference to the ground system in those two bands.

Upon the analysis of the current frequency use and regulation development, the positive side almost from developed countries or region. Once the regulation is passed, the commercial application could be deployed immediately. However, the developing countries are strongly against the proposal because they may not deploy this kind of application. Once the regulation is passed, the frequency resource would be

used by other countries or organizations which have the ability to deploy these kinds of application. The number of network fillings and regulations development both infer the different sides on ESIM's frequency allocation.

IV. Protection Criterion Development on ESIM

In order to limit the interference into other networks in the FSS, establishing maximum off-axis E.I.R.P. density limits on ESIM emissions has been the tradition in the allocation argument in each step to modify regulations.

In 2003, the restriction on ESIM in C and Ku band include the limitation on the antenna size and E.I.R.P. towards horizon (seen as Table I). Establishing a minimum antenna diameter for ESIM has an impact on the number of ESIM that will ultimately be deployed, hence it will reduce interference into the fixed service.

At the same time, the maximum off-axis E.I.R.P. spectrum density is also the limitation for the ESIM use in C & Ku band (as shown Table II).

TABLE I
ESIM'S LIMITATION ON THE ANTENNA SIZE AND E.I.R.P.

	5925-6425 MHz	**14-14.5 GHz**
Minimum diameter of ESIM antenna	2.4 m	1.2 m
Tracking accuracy of ESIM antenna	±0.2° (peak)	±0.2° (peak)
Maximum ESIM e.i.r.p. spectral density toward the horizon	17 dB(W/MHz)	12.5 dB(W/MHz)
Maximum ESIM e.i.r.p. towards the horizon	20.8 dBW	16.3 dBW

TABLE II
PROTECTION CRITERION FOR C BAND (5925-6425 MHZ)

Angle θ	Maximum off-axis e.i.r.p. per 4 kHz
$2° \le \theta \le 7°$	$(32 - 25 \log \theta)$ dB(W/4kHz)
$7° < \theta \le 9.2°$	11 dB(W/4kHz)
$9.2° < \theta \le 48°$	$(35 - 25 \log \theta)$ dB(W/4 kHz)
$48° < \theta \le 180°$	−7 dB(W/4 kHz)

TABLE III
PROTECTION CRITERION FOR KU (14.0-14.5 GHZ) / KA (29.5-30.0 GHZ)

Angle θ	Maximum off-axis e.i.r.p. per 40 kHz dB(W/40 kHz)
$2° \le \theta \le 7°$	Ku $(33 - 25 \log \theta)$ Ka $(19 - 25 \log \theta)$
$7° < \theta \le 9.2°$	Ku 12 Ka −2
$9.2° < \theta \le 48°$	Ku $(36 - 25 \log \theta)$ Ka $(22 - 25 \log \theta)$
$48° < \theta \le 180°$	Ku −6 Ka −10 dB

In 2015, after twelve years, the upper 500MHz of Ka band is also allocated to ESIM under the limitation of off-axis E.I.R.P. spectral density (as shown Table III) [7]. Compared to the same limitation parameter in Ka band, and converting the E.I.R.P. spectral density into E.I.R.P, the maximum off-axis E.I.R.P. in C band is 3dB higher than that in Ka band. The maximum the maximum off-axis E.I.R.P. in Ku band is about 14dB higher than that in Ka band. The interference suppression is higher in Ka band than C & Ku band. While there is no limitation on the antenna size in Ka band, because the higher the frequency band, the pointing accuracy is higher. It could be seen that Ka band is more suitable than C and Ku band in ESIM.

V. Conclusion

With the prosperous of mobile broadband satellite application, the use of ESIM in FSS band is obvious. Based on the principles of ITU-R, only by use the radio spectrum in an equitable, rational and efficient way and with strict limit, should the ESIM service operate in both MSS and FSS band legally.

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