Subject: WRC-23 Article 21.5

Document 5D/XXX-E
14 February 2023
English only

ITU-APT Foundation of India (IAFI)

STUDIES IN REPLY TO WRC-19 DOCUMENT 550 ON THE VERIFICATION OF RR NO. **21.5** FOR THE NOTIFICATION OF IMT STATIONS WHICH USE AN ARRAY OF ACTIVE ELEMENTS

WRC-23 ARTICLE 21.5

Summary

The Working Document toward a draft Note to the Director of the Radiocommunication Bureau (Annex 4.5 to Document 5D/1555) has been under development in WP5D for quite sometime. The limited time available for this issue at previous WP 5D meetings has not allowed for a thorough merging and assessment of the 50 input contributions on the subject. The editor's note at the beginning of this working document states: *"Furthermore, WP 5D received proposals to develop a draft note to the Director of the BR in the form of a shorter version compared to this compilation working document. However, there was no consensus to initiate such work at the WP 5D meeting in October 2022. Contributions are sought to the next meeting of WP 5D (February 2023) with a view to send out a Note to the Director of the BR from that meeting based on consensus.]"*

This contribution therefore proposes a draft note to the Director of the BR in the form of a shorter version compared to the previous compilation working document

The shorter version document is enclosed at Attachment 1

Attachment 2 contains Summary of the various para in the compilation document (Annex 4.5 of Chairman Report regarding RR-21.5)

Attachment 3 contains a brief of the various terms used, Issues involved and relevant RRs used in the compilation document (Annex 4.5 of Chairman Report regarding RR-21.5)

Attachment 4 contains a list of contributions submitted to the WP-5D regarding RR-21.5

Proposal

It is proposed that WP5D consider and adopt the shorter version contained in Attachment 1 for sending to the Director BR.

Attachment 1

Draft shorter version developed by IAFI based on Annex 4.5 to Document 5D/1555-E (Working Party 5D Chairman's Report)

WORKING DOCUMENT TOWARD A DRAFT NOTE TO THE DIRECTOR OF THE RADIOCOMMUNICATION BUREAU WRC-23 ARTICLE 21.5

1. Introduction:

During the WRC-19 (agenda 1.13), a new frequency band 24.25-27.50 GHz was identified for IMT services. Radio Regulations were updated and relevant provisions for the usage of such band were also included into the Radio Regulations and came into force from 01st January 2021. IMT stations are using antenna consists of an array of active elements (AAS).

After this date i.e. since 01-01-2021, Administrations will have the right to use new frequency bands for IMT and may need to notify IMT stations with AAS, to the BR on regular basis, as a regulatory compliance.

Director, BR invited ITU-R to study, as a matter of urgency, the applicability of the limit specified in No. **21.5** of the Radio Regulations to IMT stations that use an antenna that consists of an array of active elements (AAS), with a view to recommend ways for its possible replacement or revision for such stations, as well as any necessary updates to Table **21-2** related to terrestrial and space services sharing frequency bands.

In accordance with the results of CPM23-1 (Administrative Circular CA/251), Working Party 5D (WP 5D) was appointed as the responsible group in ITU-R to perform the requested studies and was requested to report the results of the studies to the Director of the Radiocommunication Bureau to be considered as the Director deems appropriate.

Issues on which decisions are to be taken.

Issue No.1:

IMT systems uses Array of Active Antenna, so there is no means of measuring the conducted power as such (antenna port are not similar to old microwave antenna).

Issue No.2:

All Administrations has to submit the electronic notices to the BR through the secured web interface, "Submission of Frequency Assignments/Allotments for Terrestrial Services (WISFAT)" as indicated in Circular letter CR/289 dated 24.07.2008. The interface is available at http://www.itu.int/ITUR/go/wisfat/en.

Various administrations are facing difficulty for submission of notification and verification for compliance with RR No. **21.5**, as relevant Item 8AA of RR Appendix **4** Table 1" Power delivered to Antenna" cannot be measured for IMT stations as using AAS.

Few main identifiers used for notification to BR are:

8AA - power delivered to the antenna

7AB - necessary bandwidth

9G - max antenna gain

8B - radiated power

Issue No.3:

Necessary updates to Table 21-2 related to terrestrial and space services sharing frequency bands.

Issue No.4:

RR No. 21.5 does not specify any bandwidth, whereas the interference potential is more related to the power spectrum density than to the (total) power of the transmitter.

2. Summary of views submitted in various studies by administrations/other members in WP-5D meetings from time to time.

2.1 Administrations are facing problem using web portal WISFAT for submitting compliances/notifications to BR for IMT stations, regarding frequency assignments and AAS antenna (8AA).

2.2 Difficulty faced mainly is regarding the power **delivered by a transmitter to the antenna (8AA).** As per the RR -21.5 - The power delivered by a transmitter to the antenna of a station in the fixed or mobile services shall not exceed +13 dBW in frequency bands between 1 GHz and 10 GHz, or +10 dBW in frequency bands above 10 GHz, except as cited in No. **21.5A**. (WRC-2000). RR No. 21.5 is very important to protect satellites systems from aggregated interferences.

2.3 Antenna used for IMT deployment is quite different from old microwave antenna, using AAS antenna consists of several transmitter units, which are not physically separated from the antennas and there is no interface connector between RF transmitters and antennas, So, the power delivered by each transmitter unit to antenna element (8AA) cannot be directly measured, although it can be calculated through other parameters of the IMT systems.

2.3 (a) Explanation regarding 8AA for Antenna used in old microwave systems:

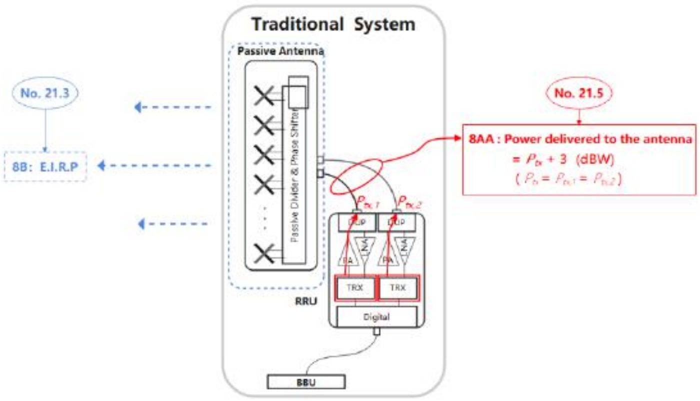
A. **Passive Antenna System**: (as used in old microwave systems)

   8AA = Power delivered to the antenna by one or two transmitters with power Ptx1 and Ptx2 (H and V ports)

   If Ptx1 = Ptx2 , total power delivered to the antenna = Ptx1 + 3 = 8AA (RR-21.5)

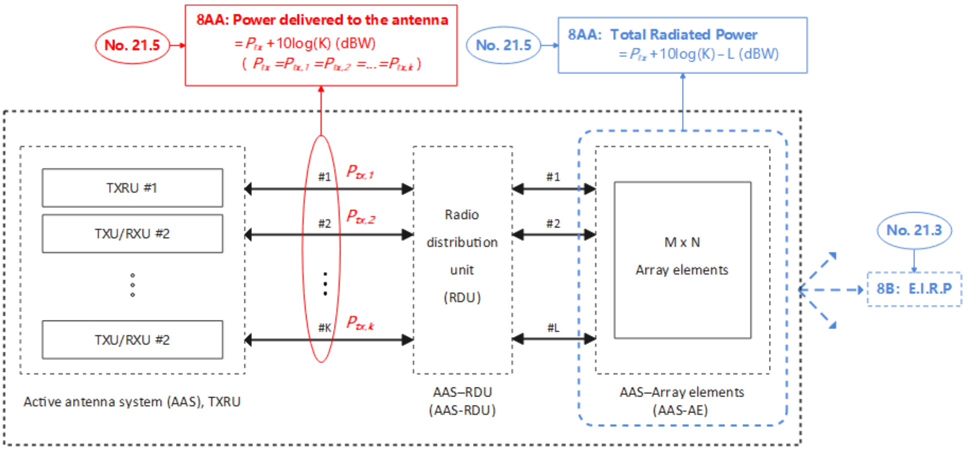
   If antenna gain is 9G and radiated power (e.i.r.p) is 8B (RR-21.3),

   Then 8AA + 9G = 8B



2.3 (b) Explanation of 8AA for AAS antenna used in IMT:

AAS are used in IMT:



Having number of Transmitter (K) with power Ptx1, Ptx2, ….., Ptxk.

Generally, if Ptx1= Ptx2=….=Ptxk, total power to be **delivered to Antenna** = Ptx1 + 10 log (k)

So, 8AA = Ptx1 + 10log (k).

But one difference here that transmitters are connected to antenna (AAS) through a unit RDU (Radio Distribution Unit) incurring some losses, so the **Total Radiated Power (8AA)** -

8AA = Ptx1+ 10 log (k) – L -----------(RR-21.5)

2.4 Many studies suggested that in case of IMT, Total Radiated Power (TRP) can be considered as 8AA (so for IMT systems 8AA = TRP).

2.5 In case of IMT, TRP can only be calculated with the help of other parameters.

2.6 So, many studies suggested that as an **Interim Solution** to WRC-23, **there is no need to change RR-21.5** and notifying administrations should use -

8AA= TRP

9G = maximum gain of the AAS

8B = 8AA + 9G

7AB = necessary bandwidth of the IMT transmission (currently 50, 100, 200 or 400 MHz) for IMT stations.

These parameters like 8AA, 9G and 8B can be easily calculated, as explained by TG-5/1

2.7 TG-5/1 conducted a study regarding coexistence between IMT and satellites. Common parameters of IMT BS were considered as an 8x8 antenna array, with a single element conducted power of 10 dBm, a single element gain of 5 dBi, array ohmic loss of 3 dB, and a 200 MHz reference bandwidth. This leads to:

a. BS total radiated power (TRP) - 25 dBm (i.e. 10dBm + 10*log10(8x8) - 3dB) (8AA)

b. Composite antenna gain - 23dBi (i.e. 5 dBi + 10*log10(8x8)) (9G)

c. Maximum EIRP - 48 dBm (i.e. 25 dBm + 23 dBi) (8B)

2.8 From the above, it is very also clear that there is no need to change RR -21.5, as there is sufficient I/N margin of 12 to 15 dB to protect FSS and ISS from IMT BS (radiated power +25 dBm add I/N margin as 12 to 15 dB = +37 to + 40 dBm <= + 10 dBW (RR-21.5). Before taking any decision, we should keep in mind that RR No. 21.5 is important to protect satellites (Fixed Satellite Service, FSS and International Space Stations, ISS) from aggregated interferences by terrestrial services.

2.9 It may also be noted that RR No. **21.5** has functioned properly for more than 50 years (conceived in EARC-63, revised in WARC-71) to ensure the protection of space stations, where frequency bands are shared with equal rights with the fixed and mobile services. Any modification of RR-**21.5** may cause unexpected consequences such as the limitation of development of terrestrial systems in future and those satellite systems which uses AAS antenna as well.

2.10 It should be noted that the protection of space receivers is ensured by RR No. 21.3, which sets the radiated power limit of the entire terrestrial station, e.i.r.p. of a station in the fixed or mobile service shall not exceed +55 dBW.

2.11 It was also studied by UK that even a TRP level of +19 dBW (in 200 MHz bandwidth), which corresponds to an 128x128 antenna array, will not cause harmful interference to the satellite services at any elevation angle.

2.12 It may also be noted that RR-21.5 applies a radio-frequency channel for both BS and MS regardless bandwidth of the channel.

2.13 With the development IMT technology, bandwidth of a radio-frequency channel is increasing. In IMT-2000, it was 1.6 MHz, for IMT-Advance, it was 15 MHz and now in case of IMT-2020, channel bandwidth has increased to 200 MHz.

2.14 For **Long Term Solution** – One Administration suggested that in order to adequately protect satellite services without being unnecessary constraining for IMT systems, long term solution is 8AA<= X +BAF + ASF, where X = $TRP_{studies}$ + M – K, where $TRP_{studies}$ = TRP assumed, M = I/N margin from study and K = desired margin.

2.15 BAF = Bandwidth Adjustment Factor. IMT systems are using AAS antennas with bandwidths of 50, 100, 200, and 400 MHz (3GPP), while in study by TG-5/1, reference bandwidth 200 MHz is taken. Bandwidth Adjustment Factor (BAF) is defined as

$$\text{BAF} = 10 \cdot \log 10 \left(\frac{\text{BW}_{\text{TX}}}{\text{BW}_{\text{REF}}}\right)$$

$\text{BW}_{\text{TX}} - 50{,}100{,}200{,}400$ MHz. $\text{BW}_{\text{REF}} - 200$ MHz

There are still divergent views among administrations.

2.16 TG 5/1 studies show that increasing the TRP by increasing the array size has a different effect on interferences compared to increasing the TRP by increasing the element transmit power. So, increasing the TRP by increasing the individual element power, there is a x-db to x-dB equivalence in terms of interference. But increasing TRP by 6 dB by increasing array size from 8x8 to 16x16 while keeping all other things equal, the peak EIRP would increase by 12 dB and result from studies show that interferences would typically increase by approximately 3-4 dB. So, considering the change in TRP due to element power and array size, new term ASF is added and defined as

$$ASF = \max\left(5 \cdot \log10\left(\frac{NB}{NB_{REF}}\right), 0\right)$$

where:

NB is the number of antenna elements in the array,

NB_{REF} is the reference array size (8x8 for the 26 GHz band)

2.17 **Suggestion for amending Table -21.2.** - New Frequency Bands and New Parameters.

TG-5/1 covered the following frequency bands allocated to satellite uplinks, as shared bands with fixed or mobile services on a co-primary basis.

- FSS allocations in 24.75-25.25 GHz (Region 1),
- 24.65-25.25 GHz (Region 2),
- 42.5-43.5 GHz, 47.2-50.2 GHz and 50.4-52.4 GHz
- MSS allocations in 43.5-47 GHz and 66-71 GHz
- EESS allocation in 40-40.5 GHz.

3.0 Issues that can be resolved by the WRC - 23:

a. No change in RR-21.3 and 21.5, but Rule of Procedure should be developed.

b. As an interim solution, the limit should remain same i.e. 8AA <= 10 dBW and no bandwidth scaling is proposed**.**

c. It is proposed that the following interpretation is to be made in the various notification fields.

- **8AA** = TRP of AAS.
- **9G** = maximum gain of the AAS
- **8B** = **8AA** + **9G**
- **7AB** = necessary bandwidth of the IMT transmission (currently 50, 100, 200 or 400 MHz)

d. New frequency bands allocated to satellite as shared bands with fixed or mobile services on a co-primary basis, should be added in the Table 21.2.

e. As a long-term measure, in order to adequately protect satellite services without being unnecessary constraining for IMT systems, the interim solution could be improved by adjusting the limit as: **8AA <= X + BAF + ASF**, with BAF and ASF as described above in 2.15 and 2.16.

Attachment 2

Summary of the various para in the compilation document Annexure - 4.5 of the WP-5D Chairman Report :

S. No.	Para	Issue Covered	Remarks
1.	**Para-1**	**Background**	ITU-R is invited to study, as a matter of urgency, the applicability of the limit specified in No. **21.5** of the Radio Regulations to IMT stations that use an antenna that consists of an array of active elements, with a view to recommend ways for its possible replacement or revision for such stations, as well as any necessary updates to Table **21-2** related to terrestrial and space services sharing frequency bands.
2.	1.1	Regulatory Issue	Supply of data/compliances by Administrations to BR When notifying a frequency assignment for a station, an administration provides the relevant characteristics listed in Appendix **4**. (No. **11.15**.). (8AA, 8B, 9G) (8AA-Conducted Power ,8B-Radiated Power and 9G - Antenna Gain)
3.	1.2	Notification Process	Use of web portal WISFAT for compliance- issues involved. Guidelines do not provide a specific guidance on how to provide information on IMT stations which use an antenna that consists of an array of active elements (AAS), noting also that in the notification record of a frequency assignment in an IMT station, the transmitting antenna is usually treated as a sector in IMT station.
4.	**Para-2**	**Various approaches on the application of RR-21.5**	**Based on the TRP / interpretation of RR No 21.5 based on the TRP and results from TG 5/1, with an interim solution requiring no change to the RR and proposals for further long-term improvements**
5.	2.1	**Approach-1 (TRP Based)**	Interim solution requiring no change to the RR and proposals for further long-term improvements
6.	**2.1.1**	**Study – 1**	TRP in line with results from TG 5/1 – Interim solution and a long-term solution. This approach describes an interpretation of RR Article 21.5 based on TRP in line with results from TG 5/1, with an interim solution requiring no change to the text

			of No. 21.5 that could enable early AAS deployments without impacting the protection of satellite services. For notification to BR, set of parameters viz Identifiers **8AA,** , **7AB, 9G** and **8B, as prescribed in T12,** are necessary to examine the applications in the notification process.
7.	2.1.1.1	Historical background and common practices with Non-AAS	Passive Antenna used with old microwave system The passive antenna consists of two polarization antenna ports is usually regarded as one single antenna. The power delivered to the antenna (8AA) is the sum of the power delivered by the two transmitter units over a radio-frequency channel. So **8AA + 9G = 8B**
8.	2.1.1.2	AAS	Active Antenna System of IMT An AAS can consist of several transmitter units, which are not physically separated from the antennas, so there is no interface connector between RF transmitters and antennas, therefore the value of power delivered from each transmitter unit or to each antenna element cannot be directly measured. It can be calculated from other parameters. It may be noted that the antenna gain G of the AAS is a variable and depends on the number of beams (the sub-arrays used in the sector) and on the beam pointing. Maximum antenna gain = G max and maximum EIRP is also known as EIRP max.
9.	2.1.1.3	Purpose of RR No. 21.5 and results from TG 5/1	RR No. 21.5 is critical to protect satellites from aggregated interferences. TG-5/1 study regarding coexistence between IMT and satellites concluded that there was about 12 to 15 dB I/N margin to protect ISS and FSS, with IMT BS, an 8x8 antenna array, with a single element conducted power of 10 dBm, a single element gain of 5 dBi an array ohmic loss of 3 dB, and a 200 MHz reference bandwidth. This leads to: a BS total radiated power (TRP) of 25 dBm (i.e. 10dBm + 10*log10(8x8) - 3dB) a composite antenna gain of 23dBi (i.e. 5 dBi + 10*log10(8x8)) a maximum EIRP of 48 dBm (i.e. 25 dBm + 23 dBi) Therefore, if "The power delivered by a transmitter to the antenna" (8AA) in RR No. 21.5 is to be interpreted as TRP, then IMT deployments in line with the assumptions from TG 5/1 i.e. with an assumed TRP of 25 dBm will inherently be compliant with RR No. 21.5 without any restriction.
10.	2.1.1.4	Proposed Interim solution for WRC-23	No change in RR-21.5

			In order to address the notification of IMT stations that use AAS without impacting the protection of the satellite service, it is proposed that the notifying administration would fill all following fields with the following interpretation: **8AA** = TRP **9G** = maximum gain of the AAS **8B** = **8AA** + **9G** **7AB** = necessary bandwidth of the IMT transmission (currently 50, 100, 200 or 400 MHz)
11.	**2.1.1.5**	Long Term Solution	Proposed changes in the RR-21.5. In order to adequately protect satellite services without being unnecessary constraining for IMT systems, the interim solution could be improved by adjusting the limit as: **8AA <= X + BAF + ASF**. Terms as defined as below.
12.	2.1.1.5.1	Determining the baseline limit **X**	It is proposed to determine the baseline limit as $X = TRP_{studies} + M - K$, where $TRP_{studies}$ is the TRP used as an assumption in the relevant sharing studies M is the I/N margin resulting from the studies K is the desired margin (3 dB)
13.	2.1.1.5.2	Bandwidth Adjustment Factor (BAF)	**BAF** -IMT systems are using AAS antennas have bandwidths of 50, 100, 200, and 400 MHz (3GPP). TG 5/1 have performed study with **reference bandwidth of 200 MHz** and have shown that coexistence could be ensured up to a TRP of 37 dBm/200 MHz (with no margin). Bandwidth Adjustment Factor (BAF) is defined as $BAF = 10 \cdot \log 10\left(\frac{BW_{TX}}{BW_{REF}}\right)$ $BW_{TX} - 50{,}100{,}200{,}400\ MHz.\ BW_{REF} - 200\ MHz$ **There are still divergent views among administrations.**
14.	2.1.15.3	Array Scaling Factor	**ASF** - TG 5/1 studies show that increasing the TRP by increasing the array size has a different effect on interferences compared to increasing the TRP by increasing the element transmit power. So, increasing the TRP by increasing the individual element power, there is a x-db to x-dB equivalence in terms of interference.

			But increasing TRP by 6 dB by increasing array size from 8x8 to 16x16 while keeping all other things equal, the peak EIRP would increase by 12 dB and result from studies show that interferences would typically increase by approximately 3-4 dB. So, considering the change in TRP due to element power and array size, new term ASF is added and defined as $ASF = \max\left(5 \cdot \log10\left(\frac{NB}{NB_{REF}}\right), 0\right)$ where: NB is the number of antenna elements in the array, NB_{REF} is the *reference array size* (8x8 for the 26 GHz band)
15.	2.1.1.5.4	Bands to be included in the Table 21.2 and associated parameter value	New Frequency Bands and new parameters suggested for the Table -21.2. TG-5/1 covered the following frequency bands allocated to satellite uplinks, as shared bands with fixed or mobile services on a co-primary basis. – FSS allocations in 24.75-25.25 GHz (Region 1), 24.65-25.25 GHz (Region 2), 42.5-43.5 GHz, 47.2-50.2 GHz and 50.4-52.4 GHz – MSS allocations in 43.5-47 GHz and 66-71 GHz – EESS allocation in 40-40.5 GHz. Table including above bands with proposed value of parameters for TRP, M, X, BWREF and NBREF is proposed.
16.	2.1.1.5.5	Discussion on possible RR modifications to be considered for long term solution	**Amendments suggested for WRC**: Following amendments to Article **21** and Appendix **4** Table 1 could be considered at WRC to resolve the issue in the long term: – Add a new provision for IMT stations in the mobile service using antennas with an array of active elements, as an alternative to RR No. 21.5 for ensuring the satellite protection, – Modify RR No. 21.6 to refer to the above new provision, – Modify RR Table 21-2 to refer to the above new provision in conjunction with the necessary updates of list of frequency bands, and – Modify Appendix 4 Table 1 considering the above addition and modifications.
17.	**2.1.1.6**	**Summary and conclusion of this approach**	BR is invited to: 1. Develop a Rule of Procedure to implement the interim solution described in §2.1.1.4, for all cases

			of applications for notification of IMT stations using AAS. 2. Assess, for a long-term solution – adding new frequency bands, BAF and ASF
18.	**2.1.2**	**Study– 2**	TRP with a reference bandwidth of 1 MHz RR No. **21.5** was introduced by EARC-63 (below 10 GHz) and WARC-71 (above 10 GHz). At that time systems uses narrow bandwidths, parabolic antennas and operated below 11 GHz. Radio Regulations commonly uses power prescribed in a 4 kHz bandwidth below 15 GHz and a 1 MHz bandwidth above 15 GHz. Therefore, a 1 MHz Reference bandwidth is appropriate for the 24.45-27.5 GHz. So, RR No. **21.5** should be applied as a power spectral density limit of +10 dBW per 1 MHz to an IMT station with an Advanced Antenna System in the 24.45-27.5 GHz. Administrations may provide “the power delivered to the antenna, in dBW” (P_{tx}) in Item Identifier 8AA (P_{tx}) as Total Radiated Power (TRP) and the following should be applied: $$Ptx = TRP$$
19.	**2.1.3**	**Study -3**	Study suggested the followings. 1. limit specified in RR No. **21.5** of the Radio Regulations is applicable. 2. power delivered to the antenna, in dBW” in Item Identifier 8AA of Appendix **4** should be recorded as Total Radiated Power (TRP). 3. the power level recorded for Item Identifier 8AA needs to reflect how the bandwidth in the original limit relates to the one used by these modern wideband IMT stations.
20.	**2.1.4**	**Study – 4**	Gradual consideration to implement Approach 1: TRP over bandwidth - General consideration and assumption. Study suggested the interim and long-term solutions. 1. *For urgency, the applicability of the limit specified in No.* ***21.5*** *of the Radio Regulations, to IMT stations that use AAS antenna.* IMT stations using AAS, Identifier **8AA** will contain the TRP as power over a certain bandwidth, while **7AB** refers to this bandwidth. If the Identifier **7AB** differs from the reference bandwidth of 200 MHz, an appropriate bandwidth adjustment to the TRP has to be applied 2. For long term solution- new clause -21.5B to be added and changes in the 21.6, 7AB, 8AB and 8B are suggested.

21.	**2.2**	**Approach – 2** **Conducted Power**	No change to the text of No. 21.5, no interpretation – In the RR – 21.5 and 21.3, no indications are given of a "reference bandwidth"(7AB), so there is no need to specify a fixed bandwidth for the limit in RR No. **21.5** or RR No. **21.3**. The limits are given in terms of power and not Power Spectral Density (PSD).
22.	**2.2.1**	**Study– A**	**It is suggested t**he followings. Regarding the notification of IMT stations uses an antenna consists of an array of active elements, Administrations should provide the radiated power (8B) in the application of RR No. **21.6** for the band 24.45-27.5 GHz, which is shown as mandatory data item in RR Appendix **4**. For the application of RR No. **21.5**, "the power delivered by a transmitter to the antenna of a station" (conducted power) should be interpreted as the power delivered by a single transceiver to the antenna of an IMT station and should not be mandatory for notification in RR Appendix **4.**
23.	**2.2.2**	**Study – B**	**It is suggested t**he followings. When notifying a station utilizing AAS, the power delivered to the antenna (8AA) should be the power delivered by a single transmitter to the radiating element(s) connected to that transmitter through the antenna transmission line (ref. RR Nos. **1.157** to **1.159**). This data needs to be provided for all transmitters utilized at any station. It is also important that the BR software used for notification and validation process continues to allow notification of multiple transmitters at a station.
24.	**2.2.3**	**Study – C**	**It is suggested t**he followings. No changes are necessary to RR No. **21.5** when considering IMT stations that use an antenna that consists of an array of active elements for the band 24.45-27.5 GHz. There is no need to provide any additional information for the notification of IMT stations that use an antenna that consists of an array of active elements given the data items already provided in RR Appendix **4** (i.e. data item 8B). Language in 8AA is inconsistent with No. **1.156**. The description of item 8AA should be corrected to reflect the exact language of No. **21.5**.
25.	**2.2.4**	**Study – D**	**It is suggested that no need to change in 21.5.**.

			RR Nos. **21.3** was established by EARC-63 and RR Nos. **21.5** was by WARC-71. RR-21.5 – means the output power of a single transmitter and RR-21.3 – is total radiated power by antenna (combining the powers of all transmitters). No reference bandwidth is mentioned. Power of a transmitter (21.5) can be measured with the help of TRP, so there is no need to implement potentially drastic changes to RR No. **21.5** for this purpose. Regarding the notification of such stations, Administrations should provide the radiated power (Item identifier 8B of RR Appendix **4**) in the application of RR No. **21.3** for the band 24.45-27.5 GHz, which is shown as mandatory data item in RR Appendix **4**, as well as the conducted power delivered by a single transmitter to the antenna of the station (Item identifier 8AA of RR Appendix **4)**.
26.	**2.2.5**	**Study – E**	**It is suggested for no change in 21.5 and 21.3.** RR No. **21.5** and 8AA shall be applied not only to IMT stations but also to all other stations specified by the relevant provision of RR. Furthermore, RR No. **21.5** has functioned properly for more than 50 years to ensure the reception by space stations where frequency bands are shared with equal rights with the fixed and mobile services. Any modification of RR No. **21.5** may cause unexpected consequences such as the limitation of development of terrestrial systems in future and those satellite systems which uses AAS antenna as well. It should be noted that the protection of space receivers is ensured by RR No. **21.3**, which sets the radiated power limit of the entire terrestrial station, *e.i.r.p. of a station in the fixed or mobile service shall not exceed +55 dBW.*
27.	**2.2.6**	**Study - G**	Impact on existing and future developments of IMT from altering the application of the limit in RR No. 21.5 to be that of the TRP of the station instead of the conducted power of a transmitter
28.	2.2.6.1	General Architecture of an IMT base station using AAS	Two transmitters are transmitting on the same channel. The regulatory limit contained in RR No. 21.5, as well as conducted power limit in various countries regulations do not tie those limits to the architecture of the radio system design.

29.	2.2.6.2	Impact of altering applicability of RR No. 21.5 to that of TRP	If the limit in RR No. 21.5 is altered, or in any way interpreted, to apply to the TRP of the entire station, the new conducted power limit for each transmitter could become much less than the 10 dBW currently specified, depending on the number of transmitters at the station. Modifying No. 21.5 in this way could have significant impact on how much power IMT stations could use to deliver services. This becomes more severe as the number of transmitters at a station are increased. For instance, for a IMT station with 1024 TRXs (e.g. a 32x32 design), assuming 50% efficiency (equivalent to 3 dB losses), the new limit for conducted power decreases from 10 W to less than 20 Mw.
30.	2.2.6.3	Impact on antenna array size, gain, and design	It is explained that under the proposed modification of applicability of RR No. **21.5** to TRP, IMT base stations using AAS would be limited to lower gain options than what technology and regulations currently allow. In addition, assigning the regulatory limit of conducted power (output of the transmitter, before the antenna) to that of the TRP (after the antenna) will hinder system designers to improve antenna efficiency.
31.	2.2.6.4	Impact on deployments – A comparative analysis	A comparative analysis is done using simple link calculations comparing one possible deployment of a 16x16 TRX base station versus a 32x32 TRX base station, assuming same number of antennas, operating at 26 GHz in NLOS conditions. The e.i.r.p. will be 12 dB less for the 16x16 system comparing with 32x32 systems. But, this less e.i.r.p. in 8x8 case, leads to 60% reduction in link budget for the station which leads to significant coverage area reduction (~84%).
32.	2.2.6.5	**Conclusions / Summary of study G**	
33.	2.2.7	**Study - H**	-----
34.	2.2.7.1	**Background**	First generation of cellular systems mostly used omni directional antennas on top of high towers to deliver service to large cells. In the second generation of cellular systems, sectorization was used as a means to reuse available bandwidth and thus increase area capacity. Cellular planning with frequency reuse schemes, e.g. reuse of 7, were used to increase spectrum utilization and enhance capacity. Since then, in IMT deployments of IMT-Advanced and IMT-2020 not only the sectors of an IMT cell cite use the same frequency assignments, but stations in large

			areas of an entire network amassing to thousands of stations transmit on the same carrier frequencies in harmonized IMT bands almost in every country in the world.
35.	2.2.7.2	**Frequency assignments**	The process of **Notification of IMT stations** through ITU-R utilizes a set of parameters listed for reference in Form T-12, including frequency assignment, antenna gain, conducted power, e.i.r.p., etc. The process has never faced any problems with the facts stated above about the operation, function and architecture of an IMT system.
36.	**2.2.7.3**	**Summary**	The process of notification of IMT stations includes declaration of several station parameters including transmitter conducted output power (8AA). Stations operating on the same frequency assignment could be notified separately when one or more other parameters vary. Therefore, RR No. **21.5** simply applies to the entry for the conducted power of each transmitter output power irrespective of the frequency assignment.
37.	**2.2.8**	**Study -I**	Study proposed by Korea during WP-5D #41 meeting. Korea in the study intimated the details regarding the deployment of 5G Base Stations with TRP value (0.5 Watt, 1.6 Watt etc), antenna array including array elements (AE256, AE512, AE1024 etc) and configuration of transmitters (1T1R, 2T2R, 4T4R etc). It is indicated that the number of transmitters is not same value with the number of array elements. These values should satisfy the following equation. $Ptx\ (dBW) = TRP(dBW) - 10\log_{10}(X) + L\ (dB) \leq 10\ (dBW)$ where: Ptx: the power delivered by a transmitter to the antenna of a station; X: the number of transmitters at a station; L: the loss of antenna. Based on the existing notification process such as Radio Regulations, FXM guide(e.g., T12, T13, etc.) and RoP (Rule of Procedure), for the IMT station using AAS, if configuration of transmitters are not single (e.g., 1T1R), it is believed that the multi transmitters notification example (e.g., https://www.itu.int/en/ITU-R/terrestrial/tpr/Pages/FXMNotices.aspx#FXMNotices) could be applied and the 8AA could be filled in T12 form using TRP formula above.

38.	**2.3**	**Approach - 3**	Guidance from WP5D on the calculation of data element 8AA for the notification of IMT base stations utilizing AAS in the frequency range 24.45-27.5 GHz. It is submitted that 8AA information can be obtained from base station specifications or product information from the manufacturer or can be calculated, if TRP / EIRP is known. Regarding reference bandwidth, being a key element, needs further consideration in the context of IMT base stations under RR Article **21**.
39.	**3**	**Additional Technical Analysis**	A study submitted to WP 5D that concluded: i. the interference to satellite is comparable for all the scenarios considered where the Total Radiated Power (TRP) of the 5G AAS Base station is increased (by increasing the antenna array size while keeping other parameters unchanged) (8x8 = - 5 dBW to 128x128 = +19 dBW, reference bandwidth= 200 MHz) and ii. even a TRP level of +19 dBW (in 200 MHz bandwidth), which corresponds to an 128x128 antenna array, will not cause harmful interference to the satellite services at any elevation angle. Therefore, defining 200 MHz as the ‘reference bandwidth’ for the ‘adjustment factor’ to the power limit stated in RR No. 21.5 for AAS in the 26 GHz frequency band does not materially reduce the protection margin towards the satellite. However, it could unnecessarily constrain the deployment of AAS in the future.
40.	**3.1**	**Analysis -1**	Satellite interference from 0 to 80-degree elevation angle was calculated for Antenna Array 8x8, 8x16, 16x8, 16x16, 64x64 and 128x128 was taken and TRP increased by 24 dBi (-5 dBW to +19 dBW) , but increased in interference from -4.4 dB to +3.1 dB is observed. Therefore, the study clearly shows that there is no correlation between the increase interference with the increase in TRP levels as a result in increasing the antenna array size. Since the protection of the satellite is not affected by the increase in TRP level, there is no reason to consider defining a ‘reference bandwidth’ that would unnecessarily limit the deployment of 5G AAS Base Stations in the 26 GHz frequency range.
41.	**3.2**	**Analysis -2**	Radiation of IMT AAS base stations towards satellite space receivers

42.	**3.2.1**	Methodology of the study	Two study cases are performed having the baseline characteristics of the IMT base station, which include 8x8 transmitters with the same number of antenna elements, baseline conducted power per transmitter $P_{Tx\_baseline}$ = 10 dBm (per 200 MHz), leading to a baseline TRP value of $TRP_{baseline}$ = -5 dBW (per 200 MHz): Study Case 1: Increase the number of transmitters of the IMT AAS base station while keeping the baseline conducted power per transmitter. Study Case 2: Increase the conducted power per transmitter of the IMT AAS base station while keeping the baseline number of transmitters. In all studies, the number of transmitters is the same as the number of antenna elements.
43.	**3.2.2**	Simulation results	It is clear that any increase in TRP, there is no increases in emissions towards satellites.
44.	**3.2.3**	**Results**	It is observed that the IMT AAS base station emissions towards satellites are not governed by the TRP of the station, but by the conducted power per individual transmitter of the station. This is in accordance with the letter of RR No. **21.5**, whose limit applies to "*The power delivered by a transmitter to the antenna of a station*".
45.	**3.3**	**Analysis -3**	Application of the bandwidth adjustment factor (BAF) under "Approach 1"
46.	**3.4**	**Analysis -4**	*The BS parameters provided by WP 5D (TG 5/1 document 5-1/36) specified a BS with an 8x8 antenna array, with a single element conducted power of 10 dBm/200 MHz, a single element gain of 5 dBi and an array ohmic loss of 3 dB.This leads to:* *•a BS total radiated power (TRP) of 25 dBm/200MHz (i.e. 10dBm + 10*log10(8x8) - 3dB)* *•a composite antenna gain of 23dBi (i.e. 5dBi + 10*log10(8x8))* *•a peak EIRP of 48 dBm/200MHz (i.e. 25 dBm/200MHz + 23 dBi)* During FSS studies - A sensitivity analysis shows that increasing the antenna array size (8x8 to 16x16 i.e. increase of the TRP by 6 dB while keeping element transmit power unchanged) leads to a decrease of the margin of approximately 3 dB.(Attachment 3 to Annex 3 to Document 5-1/478-E.)

47.	**3.5**	**Analysis -5**	In this analysis, three cases were considered for examining the relation between TRP, Conducting Power and Interference to Satellite. Case-1: Four Transmitters -with conducting power of each is + 7 dBW, so total TRP is + 10 dBW. Case-2: Four Transmitters -with conducting power of each is + 10dBW, so total TRP is + 13dBW. Satellite Interference also increased by 3 dB. Case-3: Eight Transmitters -with conducting power of each is + 10 dBW, so total TRP is + 16dBW. Satellite Interference also increased by 6dB.

Attachment 3

Brief of the various terms used, Issues involved and relevant RRs used in the compilation document (Annex 4.5 of Chairman Report regarding RR-21.5)

During the WRC-19 (agenda 1.13), a new frequency band 24.25-27.50 GHz was identified for IMT services. Radio Regulations were updated and relevant provisions for the usage of the such band were also included into the Radio Regulations and came into force from the 01 January 2021. IMT stations uses an antenna that consists of an array of active elements (AAS).

After this date i.e. since 01-01-2021, Administrations will have the right to use new frequency bands for IMT and may need to notify IMT stations with AAS, to the BR on regular basis, as a regulatory function.

Issues may like to come using frequency band 24.25-27.50 GHz for IMT :

Issue No.1:

IMT systems uses Array of Active Antenna, so there is no means of measuring the conducted power as such (antenna port are not similar to old microwave antenna).

Issue No.2:

All Administrations has to submit the electronic notices to the BR through the secured web interface, "Submission of Frequency Assignments/Allotments for Terrestrial Services (WISFAT)" as indicated in Circular letter CR/289 dated 24.07.2008. The interface is available at http://www.itu.int/ITUR/go/wisfat/en.

Various administrations are facing difficulty for submission of notification and verification for compliance with RR No. **21.5**, as relevant Item 8AA of RR Appendix **4** Table 1" Power delivered to Antenna" cannot be measured for IMT stations as using AAS.

Identifiers used for notification to BR:

8AA - power delivered to the antenna

7AB - necessary bandwidth

9G - max antenna gain

8B - radiated power

Issue No.3:

Necessary updates to Table 21-2 related to terrestrial and space services sharing frequency bands.

Issue No.4:

RR No. 21.5 does not specify any bandwidth, whereas the interference potential is more related to the power spectrum density than to the (total) power of the transmitter.

So, WRC-19 vide Resolution-550 invited ITU-R to study, as a matter of urgency, verification of No. **21.5** regarding the notification of IMT stations that use an antenna that consists of an array of active elements, with a view to recommend ways for its possible replacement or revision for such stations.

What is the Document # 550 of WRC-19 : ITU-R is invited to study, **as a matter of urgency**, the applicability of the limit specified in No. **21.5** of the Radio Regulations to IMT stations, that use an antenna that consists of an array of active elements, with a view to recommend ways for its possible replacement or revision for such stations, as well as any necessary updates to Table 21-2 related to terrestrial and space services sharing frequency bands. Furthermore, the ITU-R is invited to study, as a matter of urgency, verification of No. **21.5** regarding the notification of IMT stations that use an antenna that consists of an array of active elements, as appropriate. (Responsible Group: WP 5D).

What is RR-21.3 :

Interference from any one service to other services is not only the conducted power (delivered by a transmitter to the antenna) but radiated power, which is the product of the conducted power and the antenna gain, often expressed as Equivalent Isotropically Radiated Power (e.i.r.p.).

It should be noted that RR No. **21.3** sets a limit of +55 dBW on the radiated power of a station.

Provision No. 21.4: where compliance with No. 21.2 for frequency bands between 1 GHz and 10 GHz is impracticable, the maximum equivalent isotropically radiated power (e.i.r.p.) of a station in the fixed or mobile service shall not exceed:

• +47 dBW in any direction within 0.5° of the geostationary-satellite orbit; or

• +47 dBW to +55 dBW, on a linear decibel scale (8 dB per degree), in any direction between 0.5° and 1.5° of the geostationary-satellite orbit, taking into account the effect of atmospheric refraction (Recommendation ITU-R SF.765).

What is RR-21.5:

The power delivered by a transmitter to the antenna of a station in the fixed or mobile services shall not exceed +13 dBW in frequency bands between 1 GHz and 10 GHz, or +10 dBW in frequency bands above 10 GHz, except as cited in No. **21.5A**. (WRC-2000)

The RR No. 21.5, is very old (EARC-63), as can be traced back to the studies in 1960s and 1970s. In 1960s, the power limit to the line-of-sight Radio-relay system sharing the frequency bands below 10 GHz with space services was first introduced in the Recommendation 406 released by CCIR-10 (1963).

It was recommended that t*he power delivered to the antenna input by any such transmitter should not exceed +13 dBW.*

Later, in a Special Joint Meeting of CCIR SGs IV and IX in 1971 (SJM-1971), the limitation on the power of line-of-sight radio-relay system transmitter in shared bands of 10-15 GHz and 15-30 GHz was revised to +10 dBW. Proposal was approved by WARC-71.

Provision No. 21.5A: As an exception to power levels given in No. 21.5, the sharing environment within which the Earth exploration-satellite (passive) and space research (passive) services shall operate in the band 18.6-18.8 GHz is defined by the following limitations on the operation of the fixed service: the power of each RF carrier frequency delivered to the input of each antenna of a station in the fixed service in the band 18.6-18.8 GHz shall not exceed –3 dBW.

What is Active Antenna Arrays (AAS) used in IMT:

Highly efficient mechanical type antennas (old microwave antenna) are costly and often don’t lend themselves to mass production. Therefore, many commercially viable mobile systems, use antenna designs based on PCB technology, e.g. micro strip patch antennas. These antennas are easily mass produced, could be integrated into transceivers, can be implemented in many form factors and are low-cost. Specifically, it is rather straight-forward to create large arrays of these types of antennas, which would become small in size as frequency increases. The benefits are so great that now-a-days many industries (terrestrial systems and satellite, e.g. ESIM) use these types of antennas and even in frequencies as low as 3 or 4 GHz.

Active Antenna Arrays (AAS) are implemented using RFICs (radio-frequency integrated circuits) which integrate transceivers (with a complete RF chain, including converters, amplifiers, filters, etc.) with transmission lines feeding radiating elements. These allow simultaneous operation in different frequency ranges, as well as the use of multiple antennas or antenna configurations. The main advantage of AAS antennas is to confine the energy in narrow beams which is achieved by adding signal from each element with different phases.

These antennas, naturally, are not very efficient, especially if compact and low-profile. This means a considerable portion of the energy fed into the antenna is dissipated in the form of heat, etc., reducing the maximum gain that can be achieved with these antennas. However, advances in antenna design may improve this situation in the future.

As the power delivered by a transmitter to the antenna of a station, i.e., conducted power, cannot be measured in the case of IMT stations using AAS, it is difficult to apply the limit in RR No. **21.5** to such IMT stations.

Appendix 4 data element 8AA

8.3	**8AA**	the power delivered to the antenna, in dBW In the case of a transmitting station, required for an assignment: – in the bands below 28 MHz, in all services except the radionavigation service; or – in the bands above 28 MHz shared with space services; or – in the bands above 28 MHz not shared with space services: • in the aeronautical mobile service, meteorological aids service; or • in all other services, if the radiated power is not supplied In the case of a receiving land station, required if the associated transmitting station's radiated power is not supplied In the case of a typical transmitting station, required if the radiated power is not supplied

8B	the radiated power, in dBW, in one of the forms described in Nos. **1.161** to **1.163**[1] Note – Where adaptive systems in the fixed or mobile service operating in the bands between 300 kHz and 28 MHz (see also Resolution **729 (Rev.WRC-07)**) use automatic power con trol, the radiated power includes the level of power control listed under 8BA. For assignments in all services and frequency bands, except assignments subject to the GE06 Regional Agreement, required if the power delivered to the antenna (8AA), or the maximum antenna gain (9G), is not provided. For an assignment subject to the GE06 Regional Agreement, required if the power delivered to the antenna (8AA) is not provided.
9G	the maximum antenna gain (isotropic, relative to a short vertical antenna or relative to a half-wave dipole, as appropriate) of the transmitting antenna (see No. 1.160) For a directional antenna, the gain is in the direction of maximum radiation In the case of a transmitting station, or a typical transmitting station: – for all frequency bands and services, except assignments subject to the GE06 Regional Agreement, required if the antenna is: – directional, including where the antenna beam is rotating or swept; or

	– non-directional, and the power to the antenna (8AA) or the radiated power (8B) is not provided – for an assignment subject to the GE06 Regional Agreement required if the radiated power (8B) is not provided In the case of a maritime mobile frequency allotment, required if the antenna is directional, including where the antenna beam is rotating or swept

TABLE **21-2**

Frequency band	Service	Limit as specified in Nos.
1 427-1 429 MHz 1 610-1 645.5 MHz (No. **5.359**) 1 646.5-1 660 MHz (No. **5.359**) 1 980-2 010 MHz 2 010-2 025 MHz (Region 2) 2 025-2 110 MHz 2 200-2 290 MHz 2 655-2 670 MHz 5 (Regions 2 and 3) 2 670-2 690 MHz 5 (Regions 2 and 3) 5 670-5 725 MHz (Nos. **5.453** and **5.455**) 5 725-5 755 MHz 5 (Region 1 countries listed in Nos. **5.453** and **5.455**) 5 755-5 850 MHz 5 (Region 1 countries listed in Nos. **5.453** and **5.455**) 5 850-7 075 MHz 7 145-7 235 MHz* 7 900-8 400 MHz	Fixed-satellite Meteorological-satellite Space research Space operation Earth exploration-satellite Mobile-satellite	**21.2**, **21.3**, **21.4** and **21.5**
10.7-11.7 GHz 5 (Region 1) 12.5-12.75 GHz 5 (Nos. **5.494** and **5.496**) 12.7-12.75 GHz 5 (Region 2) 12.75-13.25 GHz 13.75-14 GHz (Nos. **5.499** and **5.500**) 14.0-14.25 GHz (No. **5.505**) 14.25-14.3 GHz (Nos. **5.505** and **5.508**) 14.3-14.4 GHz 5 (Regions 1 and 3) 14.4-14.5 GHz 14.5-14.8 GHz	Fixed-satellite	**21.2, 21.3** and **21.5**
17.7-18.4 GHz 18.6-18.8 GHz 19.3-19.7 GHz 22.55-23.55 GHz 24.45-24.75 GHz (Regions 1 and 3) 24.75-25.25 GHz (Region 3) 25.25-29.5 GHz	Fixed-satellite Earth exploration-satellite Space research Inter-satellite	**21.2, 21.3, 21.5** and **21.5A**

8AB:- the maximum power density (dB(W/Hz)) for each carrier type averaged over the worst 4 kHz band for carriers below 15 GHz, or averaged over the worst 1 MHz band for carriers above 15 GHz, supplied to the antenna transmission line For the fixed service in the bands shared with space services.

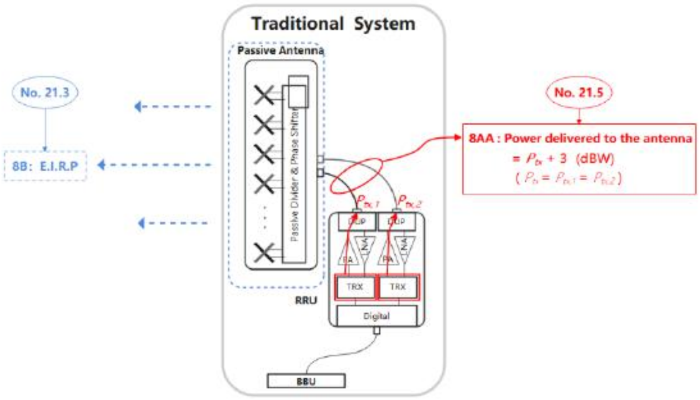
Explanation of 8AA for Terrestrial Antenna (old microwave systems) :

B. **Passive Antenna System**: (as used in old microwave systems)

8AA = Power delivered to the antenna by two transmitters with power Ptx1 and Ptx2

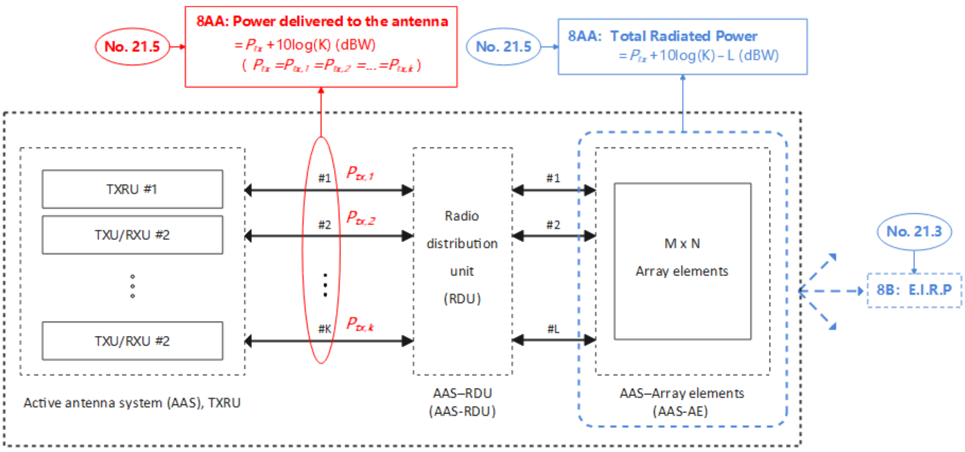
If Ptx1 = Ptx2 , total power to antenna = Ptx1 + 3 = 8AA (21.5)

Total radiated power = e.i.r.p = 8B (21.3)



Explanation of 8AA for AAS used in IMT:

AAS are used in IMT:



Having number of Transmitter (K) with power Ptx1, Ptx2, ….., Ptxk.

If Ptx1= Ptx2=….=Ptxk, total power to be **delivered to Antenna** = Ptx1 + 10 log (k)

So, 8AA = Ptx1 + 10log (k).

But one difference here that transmitters are connected to antenna (AAS) through a unit RDU (Radio Distribution Unit).

There is some loss so total **radiated power** 8AA = Ptx1+ 10 log (k) – L -----------(21.5)

It may also be noted that the antenna gain G of the AAS is a variable which depends on the number of beams (the sub-arrays used in the sector) and on the beam pointing.

Maximum antenna gain is denoted as G max and maximum EIRP is also known as EIRP max.

Definitions of:

1. No. 1.157 - Peak envelope power (of a radio transmitter).
2. No. 1.158 - Mean power (of a radio transmitter).
3. No. 1.159 - Carrier power (of a radio transmitter).
4. No. 1.161 equivalent isotropically radiated power (e.i.r.p.): The product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain).
5. No. 1.162 effective radiated power (e.r.p.) (in a given direction): The product of the power supplied to the antenna and its gain relative to a half-wave dipole in a given direction.
6. No. 1.163 effective monopole radiated power (e.m.r.p.) (in a given direction): The product of the power supplied to the antenna and its gain relative to a short vertical antenna in a given direction.

Attachment 4

List of Contributions submitted to the WP-5D regarding RR-21.5

A total 50 contributions were submitted since WRC-19 on the issue by various administration/other members

S. No.	Contribution No.	Date	Submitted by
1.	1525	03-10-2022	France
2.	1480	03-10-2022	UK, Northern Ireland
3.	1445	10-09-2022	Japan
4.	1389	26-09-2022	Canada
5.	1302	06-06-2022	Japan
6.	1301	06-06-2022	Japan
7.	1222	06-06-2022	Korea
8.	1143	12-04-2022	Intel Corpn
9.	1114	11-04-2022	Germany
10.	1102	09-04-2022	USA
11.	1101	09-04-2022	USA/UAE
12.	1083	22-03-2022	Japan
13.	1059	30-01-2022	China
14.	1041	31-01-2022	France, Luxemburg, Russia, Italy
15.	1006	31-01-2022	Germany
16.	952	31-01-2022	Samoa
17.	951	28-01-2022	Korea, USA
18.	939	27-01-2022	Canada
19.	844	23-09-2021	Telefon, LM Ericson, GSMA, Huwaei, Intel, Nokia
20.	818	27-09-2021	UK
21.	805	27-09-2021	Japan
22.	800	27-09-2021	New Zealand
23.	786	24-09-2021	Korea
24.	776	24-09-2021	Russia
25.	772	23-09-2021	Egypt, Jordan, Korea, South Africa, UAE
26.	696	11-05-2021	Austria, Belgium, Croatia
27.	691	31-05-2021	China

28.	645	31-05-2021	Japan
29.	641	31-05-2021	Germany
30.	623	28-05-2021	UK
31.	571	05-05-2021	Chairman SWG
32.	527	22-02-2021	China
33.	514	22-02-2021	Austria, Belarus, Crotia,
34.	503	22-02-2021	Nokia, Huwaei, Intel
35.	491	22-02-2021	New Zealand
36.	482	22-02-2021	Japan
37.	474	22-02-2021	IAFI
38.	418	12-02-2021	USA
39.	311	28-09-2020	Egypt, UAE
40.	300	28-09-2020	GSMA
41.	287	25-09-2020	France
42.	285	25-09-2020	USA
43.	272	24-09-2020	Russia
44.	250	04-09-2020	Japan
45.	205	16-06-2020	France
46.	194	16-06-2020	China
47.	185	16-06-2020	Japan
48.	181	16-06-2020	USA
49.	172	11-06-2020	Russia
50.	45	07-02-2020	France