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| **Radiocommunication Study Groups** |  |
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| **4 August 2020** |
| **English only** |
| Annex 3 to Working Party 5C Chairman’s Report |
| [Elements Towards A] Proposed RECOMMENDATION ON principleS **and approachES** OF **constraining unwanted emissionS** FOR IMPROVING **hf electromagnetic environment** |
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*{Editor’s note: This document proposes to develop a Recommendation describing principles and approaches of constraining unwanted emissions in order to improve the HF environment. Among other topics, the contribution describes some issues with some SM-series Recommendations related to unwanted emissions and proposes some approaches to improve the situation.*

*While this proposal is responsive to WP 5C’s* [*Question ITU-R 258/5*](https://www.itu.int/pub/R-QUE-SG05.258-2015)*, it is noted that the subject of unwanted emissions involves radiocommunication services other than just the FS and MS at frequencies of 30 MHz and below, which are not under WP 5C’s remit. Also, the subject of unwanted emissions has historically been treated as a spectrum management issue in SG 1. WP 5C notes that, for example, the discussion on unwanted emissions for specific services in Recommendation ITU-R SM.1541 include an annex on out-of-band domain emission limits for the fixed service.*

*WP 5C has sent a liaison statement to WP 1A (May 2019) asking for their expert advice on where this work should be conducted.*

*This document is being retained in the WP 5C chairman’s report until we receive a response from WP 1A.}*

# 1 Introduction

The background noise of the HF band is increasing annually, the HF electromagnetic environment is continuously deteriorating, and the availability of HF spectrum resources gradually decrease, which seriously threatens the survival and development of HF services. [Question ITU-R 258/5](https://www.itu.int/pub/R-QUE-SG05.258-2015) and its report (Documents [5C/343](https://www.itu.int/md/R15-WP5C-C-0343/en), [5C/394](https://www.itu.int/md/R15-WP5C-C-0394/en)) have pointed out that non-cooperative frequency competition with power competition and unwanted emission increasing are the main causes of the deterioration of HF electromagnetic environment.

# 2 Problems with the unwanted emission constraints of current Radio Regulations

For the sake of discussion, it is necessary to clarify the frequency range of the necessary bandwidth, out-of-band domain, and spurious domain. No. **1.152** of the Radio Regulation defines the necessary bandwidth as the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions. No. **1.146A** of the Radio Regulation defines the out-of-band domain as the frequency range that immediately outside the necessary bandwidth necessary bandwidth but excluding the spurious domain, in which out-of-band emissions generally predominate. No. **1.146B** of the Radio Regulation defines the spurious domain as the frequency range beyond the out-of-band domain in which spurious emissions generally predominate. Recommendation ITU-R SM.1541 defines the emissions in the spurious domain as all emissions that fall at frequencies separated from the center frequency of the emissions by 250% or more of the necessary bandwidth. Then, the necessary bandwidth, out-of-band domain, and spurious domain can be divided as follows:

• Necessary bandwidth: *fc*-0.5*Bn* ≤ *f* ≤ *fc*+0.5*Bn*

• Out-of-band domain: *fc*-2.5*Bn* ≤ *f* < *fc*-0.5*Bn* and *fc*+0.5*Bn* < *f* ≤ *fc*+2.5*Bn*

• Spurious domain: *f* < *fc*-2.5*Bn* and *f* > *fc*+2.5*Bn*

where *fc* is the center frequency, *Bn* is the necessary bandwidth. Unwanted emissions include the emissions in out-of-band and the emissions in spurious domain. The divisions of necessary bandwidth, out-of-band domain, and spurious domain are shown in Fig. 1 [[1]](#footnote-1)。

FIGURE 1

Unwanted emissions in out-of-band domain and spurious domain



Appendix **3** of Radio Regulation, Recommendation ITU-R SM.1541, and Recommendation
 ITU-R SM.329 provide the constraints of unwanted emissions in out-of-band and spurious band, respectively. Specifically, Recommendation ITU-R SM.1541 specifies the relative attenuation values of out-of-band domain emissions for fixed digital services that below 30 MHz, as shown in Table 1.

TABLE 1

Typical relative attenuation values for out-of-band of digital fixed service operating below 30 MHz

|  |
| --- |
| All systems below 30 MHz |
| Frequency offset(CS %) | Attenuation(dBsd) |
| 0 | 0 |
| 55 | 0 |
| 120 | 25 |
| 180 | 40 |
| 250 | 48 |
| CS: Relevant channel separation to the center frequencydBsd: Decibels relative to the average value of psd within the necessary bandwidth. |

Radio Regulations Appendix **3** (Rev.WRC-12) specifies the spurious attenuation to the transmitters operating below 30 MHz as follows:

Amateur service operating below 30 MHz (including those using SSB), the maximum allowable attenuation (dB) in spurious domain is

 *，*or 50 dB, whichever is less stringent(1)

Services operating below 30 MHz, except space, radiodetermination, broadcast, those using SSB from mobile station, and amateur, the maximum allowable attenuation (dB) in spurious domain is

 *，*or 60 dBc, whichever is less stringent (2)

where *X*=*PEP* (SSB) or *P*(other modulation), *PEP* is the peak envelope power in watts supplied to the antenna transmission line, *P* is the mean power in watts supplied to the antenna transmission line, dBc is the decibels relative to the unmodulated carrier power of the emission.

It can be seen from the above items that for the constraint in out-of-band, only the relative attenuation value is specified, which is independent of the total antenna transmission power. For the constraint in spurious domain, although the relative attenuation value to the peak envelope power or mean power is specified, a relative attenuation value of 50 dB (60 dBc) that independent of total antenna transmission power can be adopted, and the less stringent value is available. In practice, although the unwanted emission power of the single station in the HF frequency band may meet above constraints of the relative attenuation values, as the total amount of unwanted emissions increase with the total antenna transmission power, the HF electromagnetic environment will be still polluted.

In addition, current Radio Regulations haven’t specified the distribution of unwanted emissions, especially the distribution of unwanted emissions in spurious domains, while unreasonable distribution of unwanted emissions in spurious domains will also cause the deterioration of HF electromagnetic environment.

It can be seen from above discussions that: (1) under relative power constraints of current Radio Regulations, the total amount of unwanted emissions increases with the total antenna transmission power; (2) without the distribution constraint in out-of-band domain and spurious domain, unreasonable distribution of unwanted emissions will also lead to interferences to other HF systems operating in out-of-band domain and spurious domain.

Considering the problems with the unwanted emission constraints of current Radio Regulations, more reasonable principles and approaches should be adopted to constrain the HF unwanted emissions.

# 3 Proposal

China proposes that WP 5C initiates work to develop a Recommendation providing principles and approaches of constraining unwanted emission for improving HF electromagnetic environment. A proposed outline as well as some preliminary text for this document is included in Attachment 1.

**Attachment 1**: Proposed working document towards a preliminary draft new Recommendation
ITU-R F.[HF-UNWANTED]

Attachment 1

Working document towards a preliminary draft new Recommendation on principles and approaches of constraining unwanted emissions
for improving HF electromagnetic environment ITU-R SM

Scope

This Recommendation gives principles and approaches of constraining unwanted emissions for improving HF electromagnetic environment. It contains the recommendatory principles and approaches of constraining unwanted emissions for improving HF electromagnetic environment. It also contains a list of relevant ITU-R Recommendations.

The ITU-R Radiocommunication Assembly,

considering

*a)* that the background noise of the HF band is increasing annually and the HF electromagnetic environment is continuously deteriorating;

*b)* that the increasing of unwanted emissions pollutes the HF electromagnetic environment, and is an important source of background noise in HF frequency band;

*c)* that Nos. **1.144** and **1.145** of the Radio Regulations define the out-of-band emissions and spurious emissions, respectively. No. **1.146** of the Radio Regulations specifies the unwanted emissions include spurious emissions and out-of-band emissions;

*d)* that Appendix **3** of the Radio Regulations (Rev.WRC-12) specifies the maximum allowable attenuation of unwanted emissions in spurious domain, and Recommendation ITU‑R SM.329 specifies the constraint of unwanted emissions in the spurious domain, which provides relative attenuation values to the peak envelope power or mean power, however, a relative attenuation value of 50 dB (60 dBc) that independent of total antenna transmission power can be adopted, and the less stringent value is available;

*e)* that Recommendation ITU-R SM.1541 specifies the constraint of unwanted emissions in the out-of-band domain, but only provide the relative attenuation values for these HF systems operating below 30 MHz, and independent of the total antenna transmission power;

*f)* that above Radio Regulations items and Recommendations haven’t constrain the distribution of unwanted emissions, while the unreasonable distribution in out-of-band domain and spurious domain will also cause the deterioration of HF electromagnetic environment.

*g)* that the development of radio technology, especially the development of transmission technology and receiving technology, enables the unwanted emissions of HF frequency band could be constrained more reasonably. For example, the maturity and application of new technologies such as digital compensation and digital filtering improve the linearity of analog RF power amplifiers. Digital RF power amplifiers have achieved remarkable progress in recent years, and efficiency are no longer correlate to the linearity, the linearity of analog RF power amplifiers can be further improved. The improvement of receiver sensitivity enables HF stations to reduce the transmission power.

noting

*a)* that Nos. **1.144**, **1.145**, **1.146**, **1.146A**, **1.146B**, and **1.152** of the Radio Regulations define the out-of-band emission, spurious emission, unwanted emission, out-of-band domain, spurious domain, and necessary bandwidth.

*b)* that [Question ITU-R 258/5](https://www.itu.int/pub/R-QUE-SG05.258-2015), adopted at the ITU-R Radiocommunication Assembly in October 2015, requires an in-depth research on reasonably constraining unwanted emissions in HF frequency band;

*c)* that [Question ITU-R 258/5](https://www.itu.int/pub/R-QUE-SG05.258-2015) and its report (Document [5C/343](https://www.itu.int/md/R15-WP5C-C-0343/en), Document [5C/394](https://www.itu.int/md/R15-WP5C-C-0394/en)) indicate the increasing of unwanted emissions is the one of the main factors in the deteriorating of HF electromagnetic environment;

*d)* that the list of relevant Recommendations listed in Annex 2,

recommend

1 that the principles and approaches in Annex 1 should be used to constrain the unwanted emissions of HF frequency band in order to improve HF electromagnetic environment;

2 that the ITU-R and the radiocommunication administrator of each member state should make efforts to support reasonably constraining the HF unwanted emissions considering the development of HF services, in order to establish the foundation for constructing and sharing the harmonious HF electromagnetic environment.

Annex 1

Principles and approaches of constraining unwanted emissions
for improving HF electromagnetic environment

# 1 Introduction

Question ITU-R 258/5 and its report have shown that the increasing of unwanted emissions is one of the main reasons why the background noise of HF frequency band increases annually, the HF electromagnetic environment continuously deteriorating, and the availability of HF spectrum resources continuously decreases. Section II proposes the principles and approaches of constraining unwanted emissions for improving HF electromagnetic environment. Section III provides different approaches in constraining HF unwanted emissions according to various HF services.

# 2 Principles and approaches of constraining unwanted emissions for improving HF electromagnetic environment

## 2.1 Principles of constraining unwanted emissions for improving HF electromagnetic environment

In order to improve HF electromagnetic environment and enhance the availability of HF spectrum resources, following principles should be adopted to constrain HF unwanted emissions more reasonable:

(1) The constraint principle of unwanted emissions related to the total antenna transmission power should be adopted, that is, the higher of total antenna transmission power, the stricter to unwanted emissions;

(2) The constraint principle of unwanted emissions related to distribution should be adopted, that is, the unwanted emissions distribute in spurious domain that far away the necessary bandwidth should be imposed stricter constraint than that distribute in out‑of‑band that near the necessary bandwidth.

## 2.2 Approaches of constraining unwanted emissions for improving HF electromagnetic environment

Total amount and distribution of unwanted emissions can be simultaneously described by cumulative distribution function (CDF). Let  denotes the power spectrum density function (PSD), and represents the distribution of the transmission power in the spectrum, as shown in FIGURE 1(a); CDF of the transmission power  can be obtained by calculating the integral of , which can be obtained by calculating the derivative of  in turn. Thus, the relationship between the PSD  and CDF  can be summarized as

  (1)

Then, the unwanted emissions in out-of-band domain is given by

 (2)

where  is the necessary bandwidth, and the unwanted emissions in spurious domain is given by

 (3)

The total amount of unwanted emissions can be obtained by calculating the integral of  for, as shown is Figure 1(b).

 (4)

FIGURE 1

PSD of transmission power and total amount of unwanted emissions



For the first constraining principle, the corresponding constraining approach is

 (5)

That is, when the total antenna transmission power , the ratio of the total amount of unwanted emission power  to the total antenna transmission power  should be constrained less than , where  is a constant related to the range of total antenna transmission power,  and  are the lower bound and upper bound of , respectively. The constraint to the total amount of HF unwanted emissions can be written as shown in Table 1.

TABLE 1

Constraints to the total amount of HF unwanted emissions

|  |  |
| --- | --- |
| Total antenna transmission power (: dBW) | Limits to total amount of HF unwanted emissions |
|  ≤  <  |  |
|  ≤  <  |  |
|  ≤  <  |  |
| …… | …… |

For the second constraining principle, the corresponding constraining approach is

 (6)

where  is the distribution limit curve of HF unwanted emissions related to HF services, and  is the CDF of unwanted emissions, indicating that the CDF of unwanted emissions  should always be located above the distribution limit curve of HF unwanted emissions , as shown in Figure 2.  is a breakpoint representation of the distribution limit curve of HF unwanted emissions, where  is a constant related to the spectrum range. The constraint to the distribution of HF unwanted emissions can be written as shown in Table 2.

FIGURE 2

 Relationship between  and .



TABLE 2

Constraints to the distribution of HF unwanted emissions

|  |  |
| --- | --- |
| Frequency offset from the carrier center | Limits to distribution of HF unwanted emissions |
|  |  |
| 1.5 |  |
| 2 |  |
| 2.5 |  |
| 5 |  |
| 10 |  |
| …… | …… |

Annex 2

References

# 1 Introduction

This Annex contains a list of references relevant for constraining unwanted emissions studies.

# 2 References of ITU-R Recommendations for constraining unwanted emissions studies

The ITU-R Recommendations related to constraining unwanted emissions are listed as follows.

– Recommendation ITU-R [BT.655](https://www.itu.int/rec/R-REC-BT.655/en) – Radio-frequency protection ratios for AM vestigial sideband terrestrial television systems interfered with by unwanted analogue vision signals and their associated sound signals.

– Recommendation [ITU-R F.1191](https://www.itu.int/rec/R-REC-F.1191/en) – Necessary and occupied bandwidths and unwanted emissions of digital fixed service systems.

– Recommendation [ITU-R F.1819](https://www.itu.int/rec/R-REC-F.1819/en) – Protection of the radio astronomy service in the 48.94-49.04 GHz band from unwanted emissions from HAPS in the 47.2-47.5 GHz and 47.9-48.2 GHz bands.

– Recommendation ITU-R [M.1177](https://www.itu.int/rec/R-REC-M.1177/en) – Techniques for measurement of unwanted emissions of radar systems.

– Recommendation ITU-R [M.1314](https://www.itu.int/rec/R-REC-M.1314/en) – Reduction of unwanted emissions of radar systems operating above 400 MHz.

– Recommendation ITU-R [M.1580](https://www.itu.int/rec/R-REC-M.1580/en) – Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-2000.

– Recommendation ITU-R [M.1581](https://www.itu.int/rec/R-REC-M.1581/en) – Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-2000.

– Recommendation ITU-R [M.1747](https://www.itu.int/rec/R-REC-M.1747/en) – Protection of the Earth exploration-satellite service (passive) in the band 1 400-1 427 MHz from unwanted emissions of mobile satellite service feeder links that may operate in the bands 1 390-1 392 MHz (Earth-to-space) and 1 430-1 432 MHz (space-to-Earth)

– Recommendation ITU-R [M.1748](https://www.itu.int/rec/R-REC-M.1748/en) – Protection of the radio astronomy service in the band 1 400-1 427 MHz from unwanted emissions of MSS feeder links that may operate in the bands 1 390-1 392 MHz (Earth-to-space) and 1 430-1 432 MHz (space-to-Earth).

– Recommendation ITU-R [M.2070](https://www.itu.int/rec/R-REC-M.2070/en) – Generic unwanted emission characteristics of base stations using the terrestrial radio interfaces of IMT-Advanced.

– Recommendation ITU-R [M.2071](https://www.itu.int/rec/R-REC-M.2071/en) – Generic unwanted emission characteristics of mobile stations using the terrestrial radio interfaces of IMT-Advanced.

– Recommendation ITU-R [M.2090](https://www.itu.int/rec/R-REC-M.2090/en) – Specific unwanted emission limit of IMT mobile stations operating in the frequency band 694-790 MHz to facilitate protection of existing services in Region 1 in the frequency band 470-694 MHz.

– Recommendation ITU-R [RA.1237](https://www.itu.int/rec/R-REC-RA.1237/en) – Protection of the radio astronomy service from unwanted emissions resulting from applications of wideband digital modulation.

– Recommendation ITU-R [RS.2065](https://www.itu.int/rec/R-REC-RS.2065/en) – Protection of space research service (SRS) space-to-Earth links in the 8 400-8 450 MHz and 8 450-8 500 MHz bands from unwanted emissions of synthetic aperture radars operating in the Earth exploration-satellite service (active) around 9 600 MHz.

– Recommendation ITU-R [RS.2066](https://www.itu.int/rec/R-REC-RS.2066/en) – Protection of the radio astronomy service in the frequency band 10.6-10.7 GHz from unwanted emissions of synthetic aperture radars operating in the Earth exploration-satellite service (active) around 9 600 MHz.

– Recommendation ITU-R [S.1586](https://www.itu.int/rec/R-REC-S.1586/en) – Calculation of unwanted emission levels produced by a non-geostationary fixed-satellite service system at radio astronomy sites.

– Recommendation ITU-R [SM.329](https://www.itu.int/rec/R-REC-SM.329/en) – Unwanted emissions in the spurious domain.

– Recommendation ITU-R [SM.1535](https://www.itu.int/rec/R-REC-SM.1535/en) – The protection of safety services from unwanted emissions.

– Recommendation ITU-R [SM.1540](https://www.itu.int/rec/R-REC-SM.1540/en) – Unwanted emissions in the out-of-band domain falling into adjacent allocated bands.

– Recommendation ITU-R [SM.1541](https://www.itu.int/rec/R-REC-SM.1541/en) – Unwanted emissions in the out-of-band domain.

– Recommendation ITU-R [SM.1542](https://www.itu.int/rec/R-REC-SM.1542/en) – The protection of passive services from unwanted emissions.

– Recommendation ITU-R [SM.1752](https://www.itu.int/rec/R-REC-SM.1752/en) – Limits for unwanted emissions under free-space condition.

1. Figure 1 of Appendix **3** of the Radio Regulations (Rev.WRC-12). [↑](#footnote-ref-1)