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INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE (CISPR)
SUB-COMMITTEE I: ELECTROMAGNETIC COMPATIBILITY OF INFORMATION TECHNOLOGY EQUIPMENT, MULTIMEDIA EQUIPMENT AND RECEIVERS

Title: - CISPR 32:2019 Edition 2.1: Justification for radiated electric field emission limits for frequencies above 1 GHz

This INF is the final output following from CIS/I/642/DC and incorporates the accepted National Committee comments contained in CIS/I/645A/INF.

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1 Introduction

Following the successful vote and publication of CISPR 32 Edition 2 Amendment 1 CISPR SC I MT7 were requested to document the justification behind the change to emission limits above 1 GHz.

The requirements for radiated emissions for frequencies above 1 GHz given in CISPR 32 [1] edition 2 were originally developed within CISPR SC I [2] and widely adopted throughout CISPR. This informative document discusses their origins, issues relating to their application and the solution adopted and approved.

- Clause 2 documents some of the considerations that were discussed during the development of the limits.
- Clause 4 documents some of the issues related to results from actual EUT measurements.
- Clause 4 discusses the solution adopted to the issues raised.

In addition, within Clause 5, we have included a model for deriving limits for radiated electric field emission measurements in the frequency range above 1 GHz. This model is based upon methods defined in CISPR 16-4-4 [3]. In doing this work we have started to discuss how to progress the limits above 6 GHz. The inclusion of this model provides an indication of how the previous and current limits compare to a given model. These models use probability factors, statistical analysis and knowledge of radio services to develop the perceived protection requirements and from this a limit can be determined. Often these probability factors have a range and therefore contain variances which leads to the following statement within CISPR 16-4-4 [3], Clause 5.3.6.3:-

> *The derivation of limits from a hypothetical model requires the introduction of various experimental data in such a model. As these data, as pointed out earlier, are based on statistical measurements under different actual circumstances, the usefulness of such data for general application is often debatable.*
>
> *On the other hand, the implementation of suppression measures should be considered on physical, operational, manufacturing and not in the least on economic aspects. Therefore the model should be used as a worthwhile starting point but the final limit value is often the result of an agreement between parties involved after extensive considerations and negotiations.*

NOTE the derivation of the limits using the CISPR 16-4-4 [3] model is not relevant to the change in CISPR 32 [1], as this is based upon changes in the test method / inadequacy of the calibration methods.

2 Original requirements development

2.1 FCC 47 CFR 15 [4]

The original requirements published in CISPR 22:2005, A1:2005 were derived from FCC 47 CFR 15 [4] (USA requirements for ITE) but were limited to an upper frequency of 6 GHz. At the time there was insufficient support to go to frequencies higher than 6 GHz.

Within 47 CFR 15 [4] the amplitude of the limits do not change with respect to frequency, see Figure 1. This assumes that the interference potential is the same at 1 GHz as it is at 40 GHz, this may not be completely valid, see references [5] and [6].

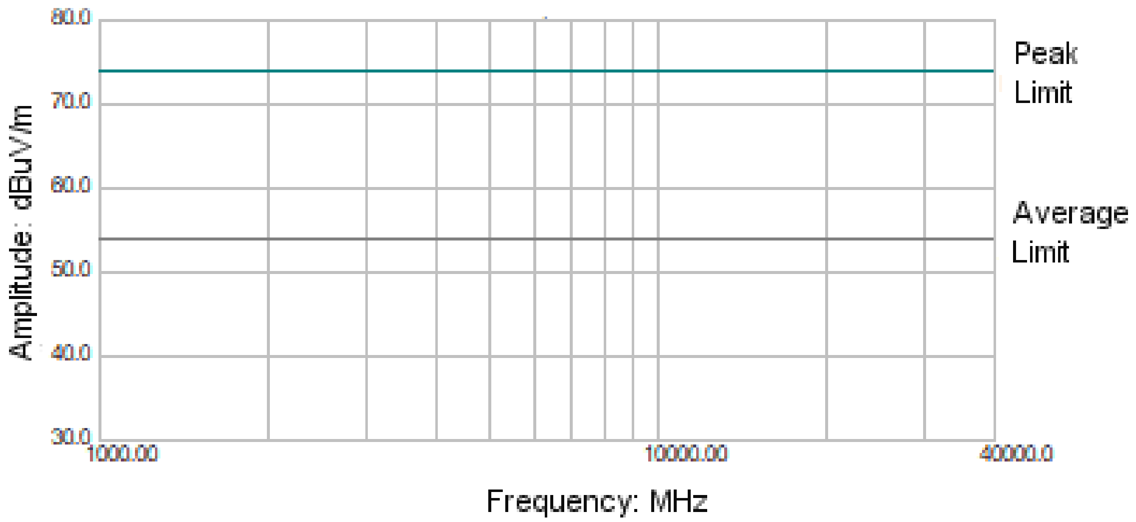


Figure 1 – Radiated Emission Limits for Frequencies above 1 GHz from 47 CFR 15 [4] for Class B Equipment

2.2 Test method

The test method defined within CISPR 16-2-3:2016 [7] utilises a simple free space technique, whereas the one referenced within 47 CFR 15 [4] uses a hybrid free space/OATS measurement technique, and requires the receiving antenna to be height scanned from 1 m to 4 m.

Based upon the upper frequency limitation of 6 GHz, the method defined within CISPR 16 effectively uses a fixed height for typical EUT/antenna combinations. CISPR SC A [8] argued that the beamwidth of the antenna encompassing the equipment is the critical factor and by varying the height of the receiving antenna only a 3 dB variance will occur.

Reference [9] attempts to analyse some of the differences between the two test methods. It is clear that the actual test method and limits are interrelated.

2.3 Original 4 dB limit reduction

When the original limit was set the final agreement approved by CISPR SC I National Committees, the amplitude of the limit values in the frequency range between 1 GHz – 3 GHz were reduced by 4 dB, when compared to those within 47 CFR 15 [4]. During the limit discussions there were requests for a 10 dB reduction [2] whilst others stated that they should remain in alignment with 47 CFR 15 [4]. The final position was a compromise agreement with no technical basis for the 4 dB reduction.

Most of the technical justification for the original reduction in limits compared with the FCC's are contained in reference [5]. These were discussed by CISPR SC I in one form or another during the original debates.

However, one main point behind the agreed compromise was that the test method has an implied 3 dB limit reduction in amplitude measured compared with the worst case limits because there is no height scanning.

Reference [9] attempted to validate the differences between 47 CFR 15 [4] and CISPR 32 [1].

2.4 Class A limits

For frequencies below 1 GHz, the difference in the requirements between Class B (residential) and Class A (non-residential) is 10 dB and this difference has been very successful at protecting radio services in the different environments. For frequencies above 1 GHz, 47 CFR 15 [4] has 6 dB difference. CISPR I decided to follow the 47 CFR 15 [4] model even though there was no technical justification for this reduction. See Figure 2.

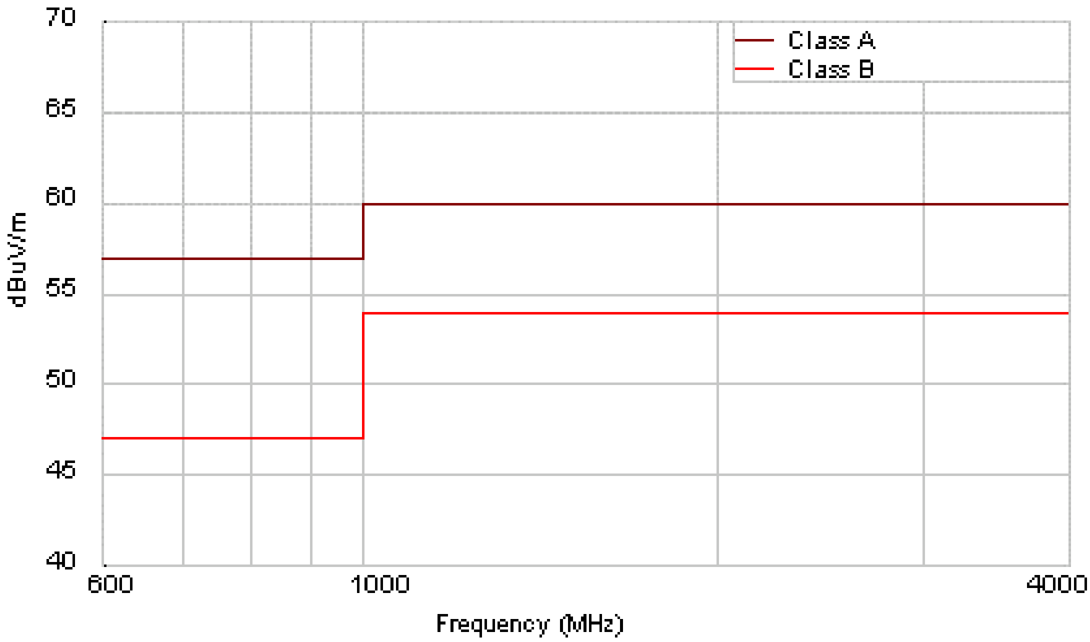


Figure 2 - Difference in Quasi-Peak limits below and Average limits above 1 GHz (CISPR 32:2015+A1:2019)

3 Issues found from the measurement of actual equipment

It has become apparent over the years, that performing measurements using a fixed height antenna does not maximise the response of the EUT and issues have been identified with regard to measurement repeatability for equipment mounted within floor standing racks [10]. These issues have been well documented in working group contributions to CISPR SC I, CISPR SC H and CISPR SC A.

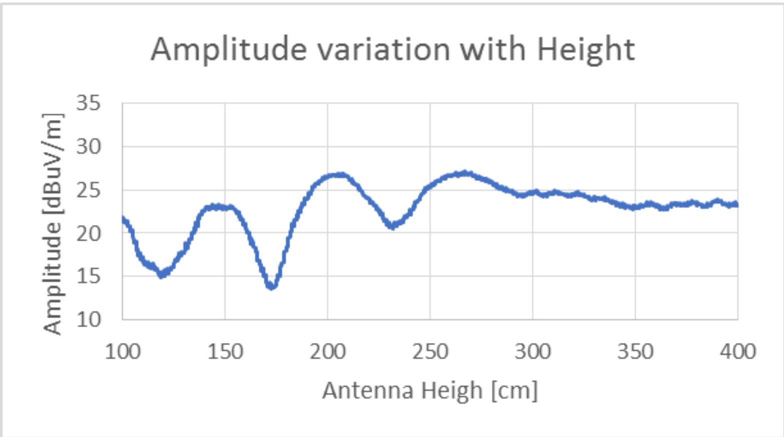
Several examples are shown below of the variance that can be observed when performing a planar linear height scan from 1 m to 4 m on emissions above 1 GHz. These clearly show that performing the measurements at a height of 1 m but with the antenna beamwidth encompassing the EUT can severely underestimate the maximum emission level. In addition, should an EUT be mounted in a rack and could be positioned anywhere from 1 m to 2 m in height then the additional complication of the definition of antenna height at the middle of EUT (The entire rack) becomes a key factor and could easily coincide with a minimum level.

The CISPR A view that measurements will only change by 3 dB is questionable and not an adequate basis for the measurement method.

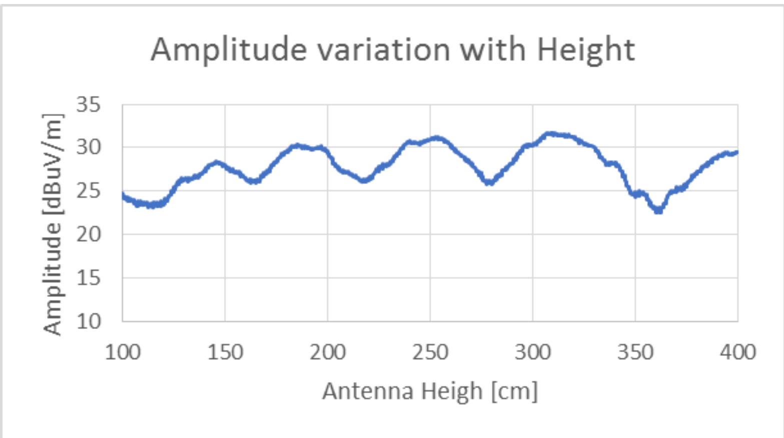
The variances observed are both EUT and frequency dependent. For some EUTs and frequencies the worst case height is 1 m, with limited change in amplitude with respect to height. For others the maximum emission was found at greater heights and was observed to be up to 13 dB greater than the 1m height (without antenna tilting).

The following figures show the amplitude variation with height for several EUTs at particular emission frequencies above 1 GHz. The measurements were performed in an FSOATS as required by CISPR 32 and the process followed to obtain these results was based upon CISPR 16-2-3 [7] however, the antenna height was scanned from 1 m to 4 m. The antenna was parallel to the ground plane during the height scan, no tilting (or bore-sighting) was employed. The antenna height was scanned slowly as the amplitude was recorded, resulting in 4 or 5 measurements per cm in height.

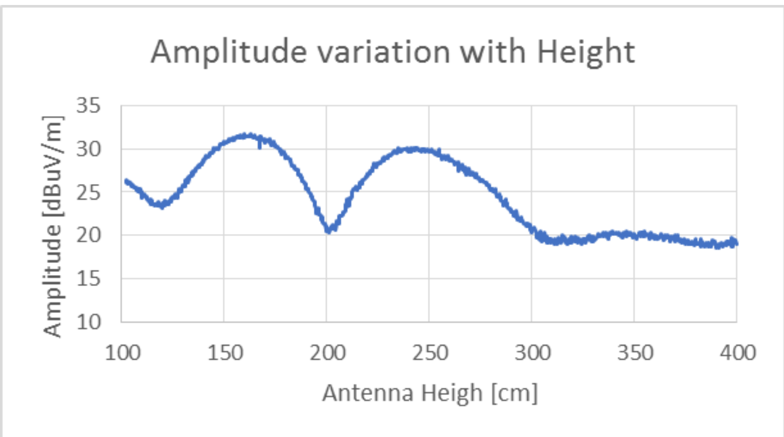
NOTE: The linear antenna height scan is defined CISPR 16-2-3 [7] however the maximum height is limited based upon height of the EUT.



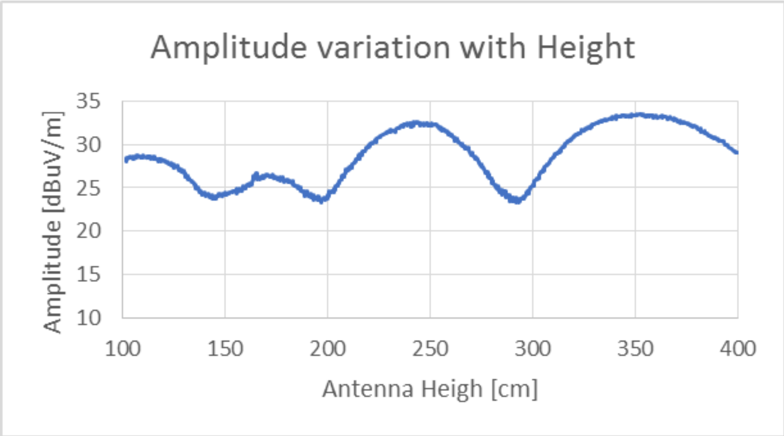
Device	Small Router	
Frequency	1775	MHz
Level @ 1m	21.8	dBµV/m
Min Level	13.6	dBµV/m
Min Height	173	cm
Max Level	27.1	dBµV/m
Max height	267	cm
Level difference 1 m and Max	**5.3**	**dB**
Variance over range 1 to 4 m	13.5	dB



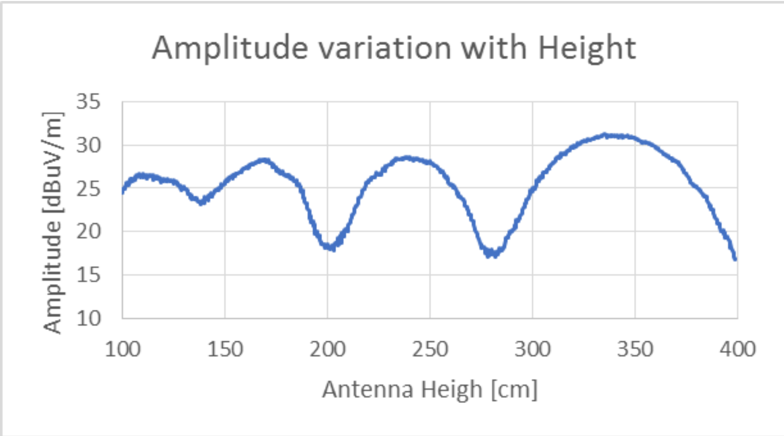
Device	Router	
Frequency	1785.5	MHz
Level @ 1m	24.8	dBµV/m
Min Level	22.5	dBµV/m
Min Height	362	cm
Max Level	31.7	dBµV/m
Max height	308	cm
Level difference 1 m and Max	**7.0**	**dB**
Variance over range 1 to 4 m	9.2	dB



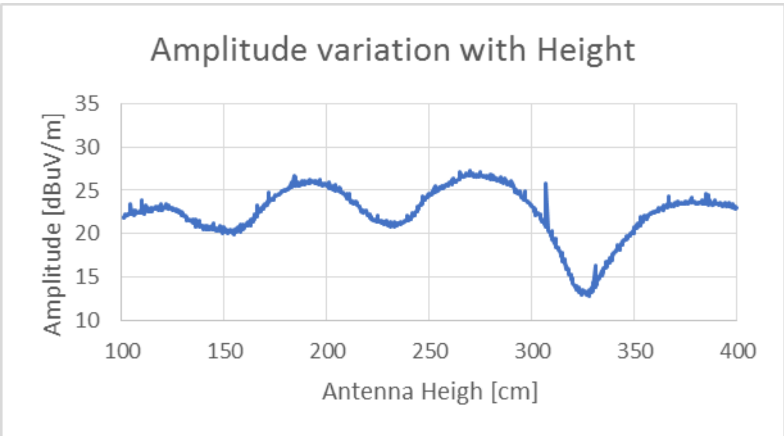
Device	Hub	
Frequency	1125.03	MHz
Level @ 1m	26.4	dBµV/m
Min Level	18.5	dBµV/m
Min Height	391	cm
Max Level	31.7	dBµV/m
Max height	160	cm
Level difference 1 m and Max	**5.3**	**dB**
Variance over range 1 to 4 m	13.2	dB



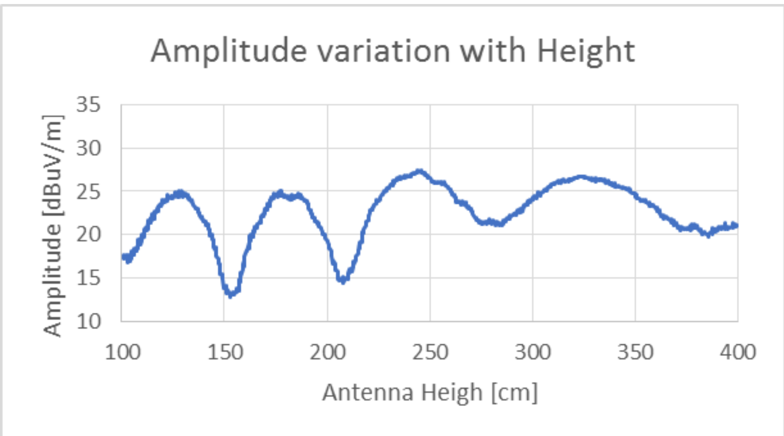
Device	Hub	
Frequency	1125.03	MHz
Level @ 1m	28.4	dBµV/m
Min Level	23.3	dBµV/m
Min Height	197	cm
Max Level	33.5	dBµV/m
Max height	354	cm
Level difference 1 m and Max	**5.0**	**dB**
Variance over range 1 to 4 m	10.2	dB



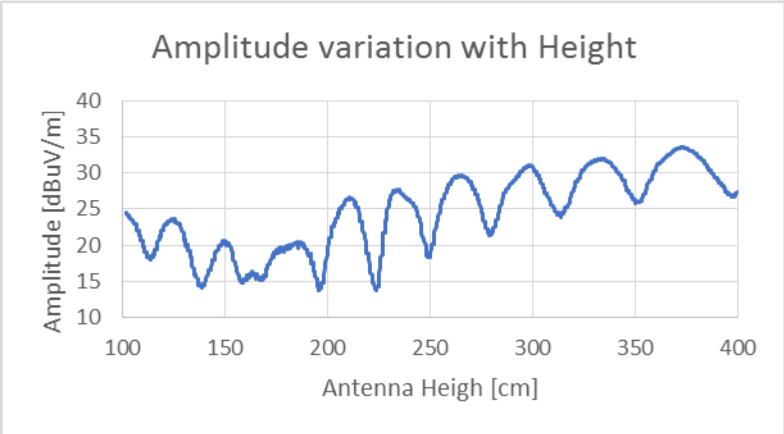
Device	Hub	
Frequency	1500.13	MHz
Level @ 1m	25.0	dBµV/m
Min Level	16.8	dBµV/m
Min Height	399	cm
Max Level	31.2	dBµV/m
Max height	335	cm
Level difference 1 m and Max	**6.2**	**dB**
Variance over range 1 to 4 m	14.5	dB



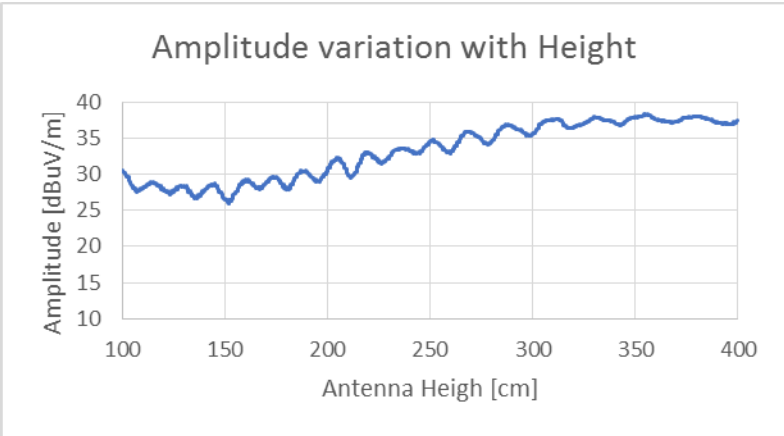
Device	Hub	
Frequency	3124.00	MHz
Level @ 1m	22.0	dBµV/m
Min Level	12.8	dBµV/m
Min Height	328	cm
Max Level	27.2	dBµV/m
Max height	270	cm
Level difference 1 m and Max	**5.3**	**dB**
Variance over range 1 to 4 m	14.5	dB



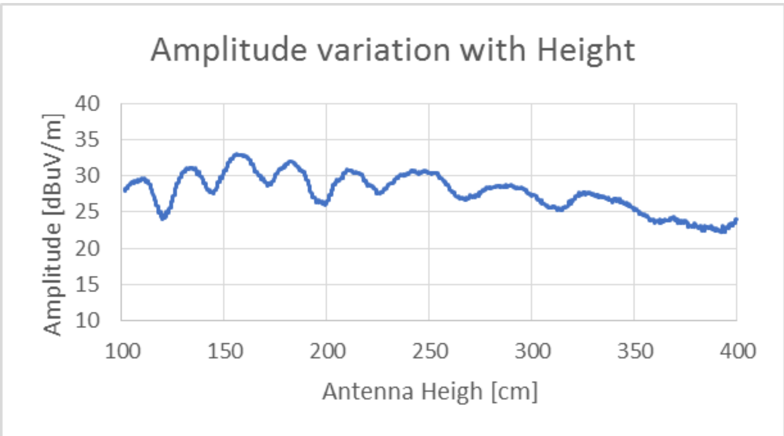
Device	Small Router	
Frequency	1748.0	MHz
Level @ 1m	17.6	dBµV/m
Min Level	12.8	dBµV/m
Min Height	153	cm
Max Level	27.4	dBµV/m
Max height	246	cm
Level difference 1 m and Max	**9.8**	**dB**
Variance over range 1 to 4 m	14.7	dB



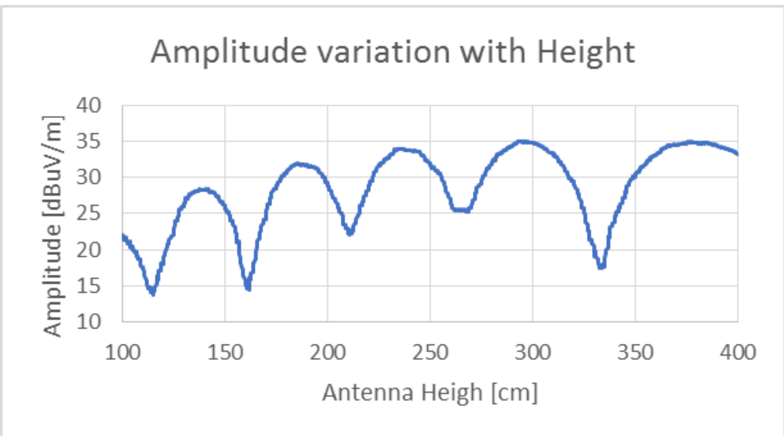
Device	Router	
Frequency	1877.5	MHz
Level @ 1m	24.6	dBµV/m
Min Level	13.8	dBµV/m
Min Height	196	cm
Max Level	33.6	dBµV/m
Max height	372	cm
Level difference 1 m and Max	**9.0**	**dB**
Variance over range 1 to 4 m	19.8	dB



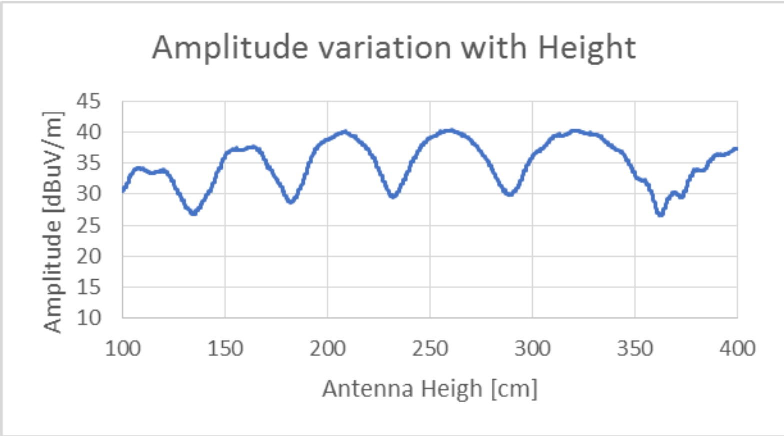
Device	Router	
Frequency	3126.5	MHz
Level @ 1m	30.5	dBµV/m
Min Level	26.0	dBµV/m
Min Height	152	cm
Max Level	38.4	dBµV/m
Max height	354	cm
Level difference 1 m and Max	**7.9**	**dB**
Variance over range 1 to 4 m	12.4	dB



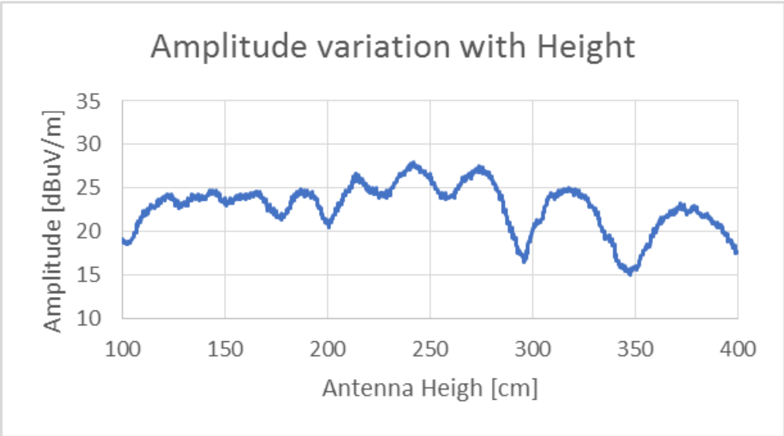
Device	Router	
Frequency	3749.75	MHz
Level @ 1m	28.2	dBµV/m
Min Level	22.3	dBµV/m
Min Height	392	cm
Max Level	33.0	dBµV/m
Max height	156	cm
Level difference 1 m and Max	**4.7**	**dB**
Variance over range 1 to 4 m	10.7	dB



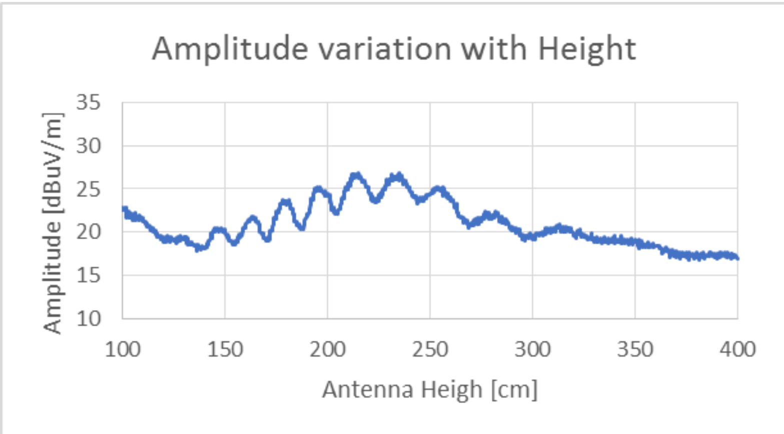
Device	Router	
Frequency	1875.0	MHz
Level @ 1m	22.1	dBµV/m
Min Level	13.7	dBµV/m
Min Height	115	cm
Max Level	35.0	dBµV/m
Max height	294	cm
Level difference 1 m and Max	**13.0**	**dB**
Variance over range 1 to 4 m	21.4	dB



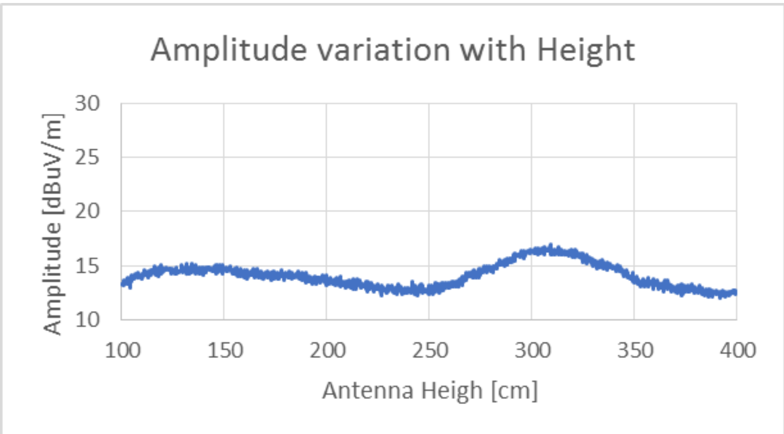
Device	Router	
Frequency	2000.0	MHz
Level @ 1m	30.5	dBµV/m
Min Level	26.5	dBµV/m
Min Height	362	cm
Max Level	40.3	dBµV/m
Max height	261	cm
Level difference 1 m and Max	**9.9**	**dB**
Variance over range 1 to 4 m	13.9	dB



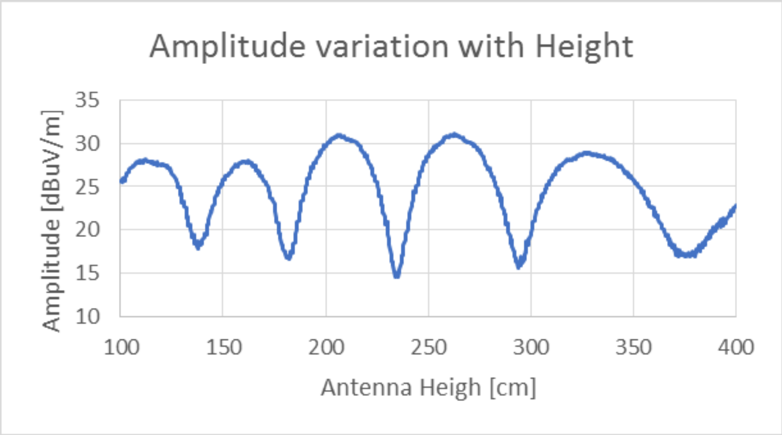
Device	IXIA	
Frequency	2933.0	MHz
Level @ 1m	19.1	dBµV/m
Min Level	14.9	dBµV/m
Min Height	348	cm
Max Level	27.9	dBµV/m
Max height	242	cm
Level difference 1 m and Max	**8.8**	**dB**
Variance over range 1 to 4 m	13.0	dB



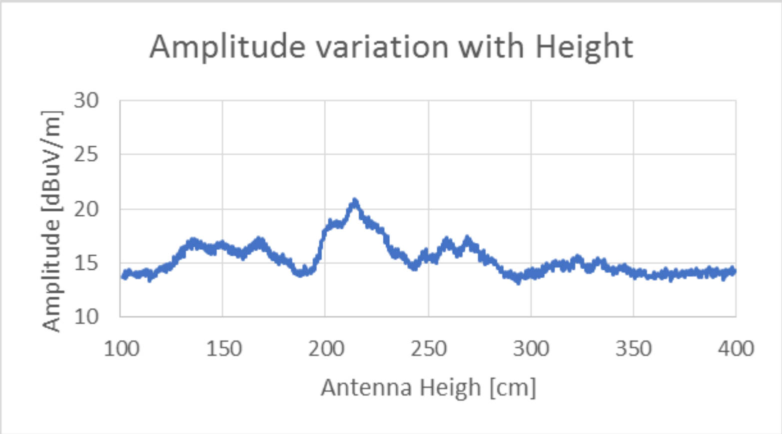
Device	IXIA	
Frequency	4533.0	MHz
Level @ 1m	22.8	dBµV/m
Min Level	16.8	dBµV/m
Min Height	376	cm
Max Level	26.9	dBµV/m
Max height	235	cm
Level difference 1 m and Max	**4.0**	**dB**
Variance over range 1 to 4 m	10.1	dB



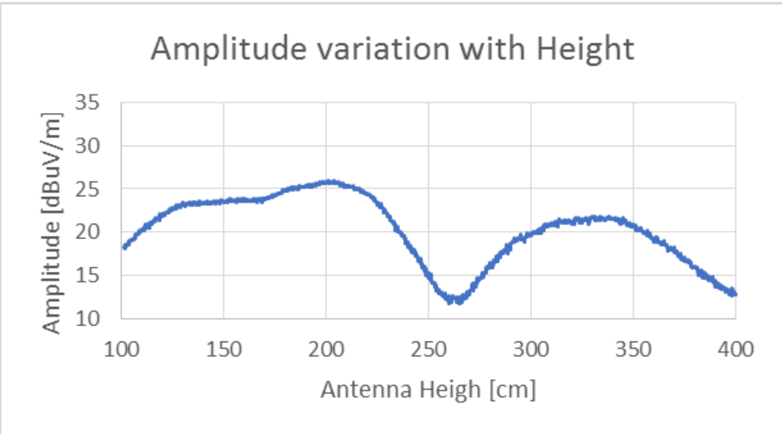
Device	Small router	
Frequency	1000.0	MHz
Level @ 1m	13.3	dBµV/m
Min Level	12.1	dBµV/m
Min Height	392	cm
Max Level	17.0	dBµV/m
Max height	309	cm
Level difference 1 m and Max	**3.7**	**dB**
Variance over range 1 to 4 m	4.9	dB



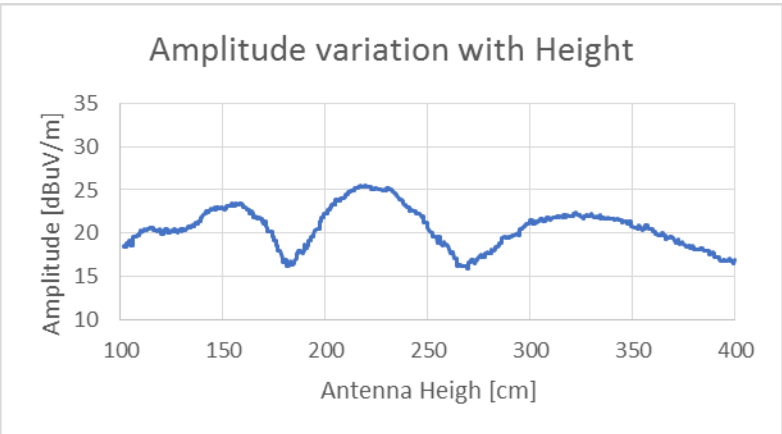
Device	Small Router	
Frequency	1875.0	MHz
Level @ 1m	25.6	dBµV/m
Min Level	14.6	dBµV/m
Min Height	234	cm
Max Level	31.1	dBµV/m
Max height	263	cm
Level difference 1 m and Max	**5.4**	**dB**
Variance over range 1 to 4 m	16.5	dB



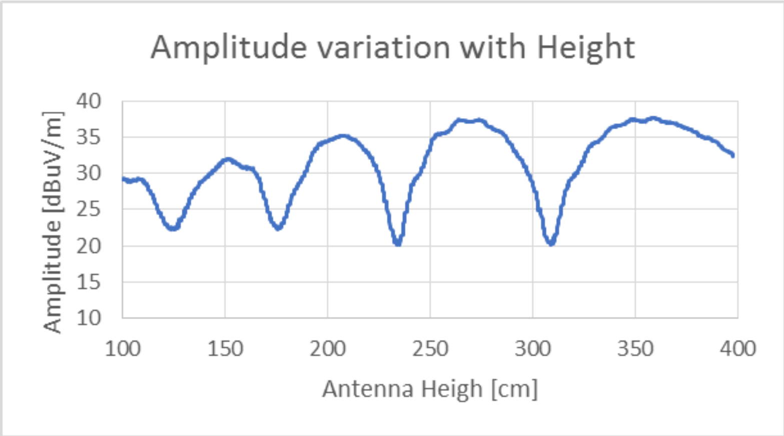
Device	Small Router	
Frequency	1875.0	MHz
Level @ 1m	13.8	dBµV/m
Min Level	13.1	dBµV/m
Min Height	294	cm
Max Level	20.9	dBµV/m
Max height	214	cm
Level difference 1 m and Max	**7.1**	**dB**
Variance over range 1 to 4 m	7.7	dB



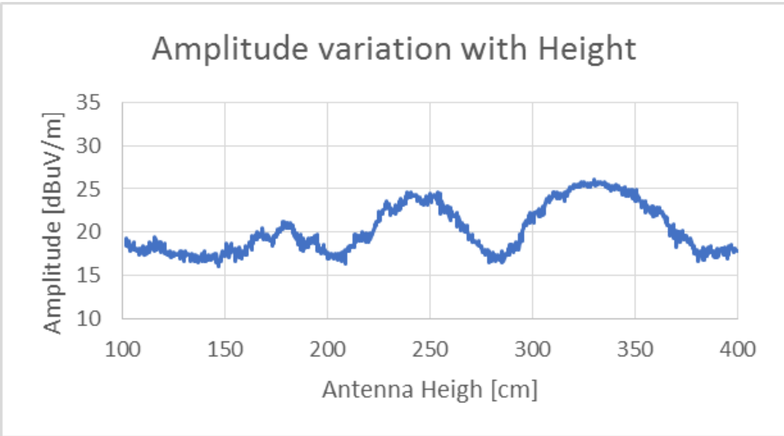
Device	Small Router	
Frequency	1125.0	MHz
Level @ 1m	18.3	dBµV/m
Min Level	11.8	dBµV/m
Min Height	260	cm
Max Level	25.9	dBµV/m
Max height	204	cm
Level difference 1 m and Max	**7.6**	**dB**
Variance over range 1 to 4 m	14.1	dB



Device	Router	
Frequency	1312.0	MHz
Level @ 1m	18.5	dBµV/m
Min Level	15.9	dBµV/m
Min Height	269	cm
Max Level	25.5	dBµV/m
Max height	219	cm
Level difference 1 m and Max	**7.0**	**dB**
Variance over range 1 to 4 m	9.5	dB



Device	Router	
Frequency	1720.0	MHz
Level @ 1m	29.2	dBµV/m
Min Level	20.0	dBµV/m
Min Height	235	cm
Max Level	37.6	dBµV/m
Max height	359	cm
Level difference 1 m and Max	**8.4**	**dB**
Variance over range 1 to 4 m	17.6	dB



Device	Router	
Frequency	1781.0	MHz
Level @ 1m	18.9	dBµV/m
Min Level	16.1	dBµV/m
Min Height	147	cm
Max Level	26.0	dBµV/m
Max height	330	cm
Level difference 1 m and Max	**7.1**	**dB**
Variance over range 1 to 4 m	10.0	dB

Figure 3: Examples of amplitude variation with height

From measurements shown in [11] it identifies one reason why the amplitude varies so much with respect to height. Most chambers when configured as an FSOATS do not have absorber on the turntable but still satisfy the above 1 GHz calibration requirements defined in CISPR 16-1-4 [12]. A typical chamber layout is shown in Figure 4.

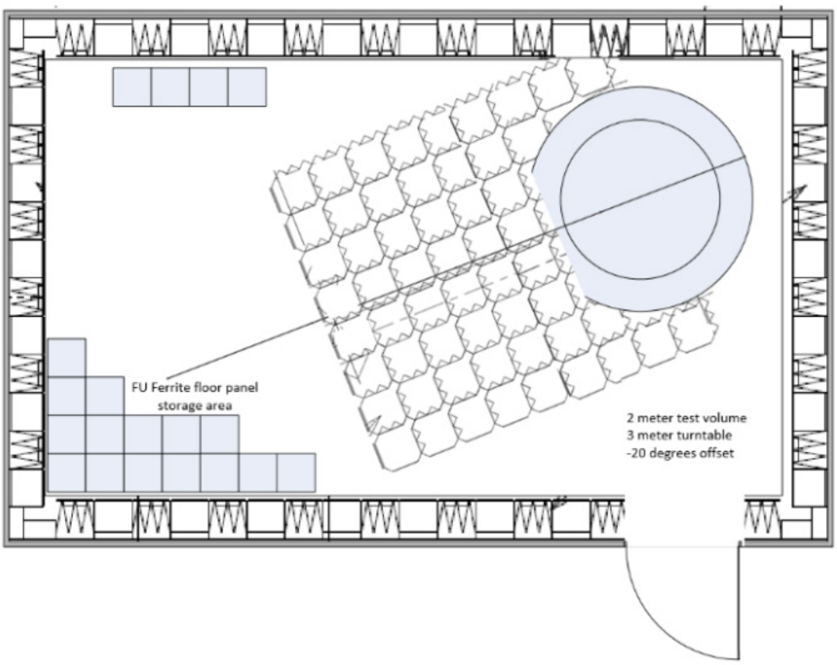


Figure 4 - Typical layout of absorber for a FSOATS

The measurements in [11] show that a significant reflection occurs from the turntable hence the facility is acting more like an OATS than a FAR, and hence there can be constructive interference at the receiving antenna.

4 Solutions to the issues

The original CISPR concept, of fixing the antenna at one height and the political compromise of reducing the limit by 4dB compared with the 47 CFR 15 [4] requirement of height scanning from 1 m to 4 m has been shown to be flawed. By introducing a height scan requirement to ensure the maximum emission level is captured the need to reduce the limit by 4 dB is no longer relevant because the measurand has changed.

It is understood for some EUTs this may be a relaxation of 4 dB over the current requirements but finding emissions that may be more than 10 dB higher is key to limiting interference problems, this also does not take into account the following:

- The flaws in the original proposal, considering that 47 CFR 15 [4] has over the years provided effective protection of the radio spectrum in the USA and Canada.
- That the proposed test method would provide;
  - simplification over the current process,
  - ability to apply one test method;
    - independent of the type of EUT (for example table top, floor mounted or combination),
    - independent of the performance of the measurement antenna.
  - significant increase in test repeatability,
  - for some EUTs measure levels that are more than 10 dB higher than the current method would measure.
- Above 3 GHz the change in method and the increased likelihood of measuring a higher level could be seen as a tightening of requirements giving greater protection for spectrum used for mobile services.

Hence the inclusion in CISPR 32 of height scanning with a realignment of limits with those in 47 CFR 15 was considered as an acceptable way forward and was supported by the majority of National Committees when voting on the CISPR/I/617/FDIS [13].

5 CISPR 16-4-4 Model

In developing the model for radiated electric field emission limits in the frequency range above 1 GHz it is useful to introduce the probability factors that CISPR 16-4-4 defines :-

P Factor	Description
P1	is the probability that the major lobe of the radiation is in the direction of the victim receiver
P2	is the probability of directional receiving aerials having maximum pick-up in the direction of the disturbing source
P3	is the expected mean value that for a mobile receiver the signal to noise ratio can be improved by keeping a certain distance to the disturbance source and that the mobile receiver is used well inside the respective radio service area
P4	is the expected mean margin that the disturbance signal is below the limit;
P5	is the expected mean value that the type of disturbance signal generated will produce a significant effect in the receiving system;
P6	is the expected mean value that the disturbance source is located in a distance to the receiving system within which interference is likely to occur;
P7	is the expected mean value that buildings provide a certain degree of additional attenuation

The proposed values for each of the probability factors used in the model for multimedia equipment are as follows:-

µP Factor	Value [dB]	Description
µP1	10	From the height scan examples we can see at least 10 dB variation so reasonable to assume the same in azimuth.
µP2	various	Data taken from CISPR 16-4-4 [3] Table 5 or CISPR Database
µP3	6 / 0	6 dB for mobile as assumes typically not at edge of coverage / 0 dB for amateur as trying for reception of lowest signal possible
µP4	6	Assumes most products built with a margin to limit to allow for production variability
µP5	variable	Calculated based on an assumed typical emission width of 100 kHz for multimedia equipment compared with receiver BW
µP6	10 / 16 / 20	10 dB for mobile devices based on a 10m protection / 16 dB for amateur assumes external antenna and greater distance / 20 dB for mobile base sites assuming 30m height of base station antenna
µP7	6 / 10	6 dB for mobile devices assuming some loss through internal walls / 10 dB for amateur and base sites assuming external walls

Giving the following model:

Service	Frequency	Sensitivity [µW]	Protection Ratio [Rp]	Calculated Tolerable Noise	Receiver Bandwidth	Tolerable Noise in Target BW E_{noise}	µP1	µP2	µP3	µP4	µP5	µP6	µP7	Sum of µP Factors	Radio Service Protection
-	MHz	dBµV/m	dB	dBµV/m	Hz	dBµV/m	dB	dB	dB	dB	dB	dB	dB	dB	dBµV/m
GSM 1800 Mobile	1805.00	41	9	32	200000	38	10	0	6	6	3.0	10	6	41.01	80
DECT	1880.00	60	10	50	1.00E+06	50	10	0	6	6	10.0	10	6	48.00	98
UMTS FDD Mobile	2110.00	26	-9	35	5.00E+06	28	10	0	6	6	17.0	10	6	54.99	83
UMTS Extension	2500.00	26	-9	35	5.00E+06	28	10	0	6	6	17.0	10	6	54.99	83
WLAN	5150.00	69	16	53	2.00E+07	40	10	0	6	6	23.0	10	6	61.01	101
Amateur Radio	1240.00	-30	10	-40	3.00E+03	-15	10	20	0	6	-15.2	16	10	46.77	32
Amateur Radio	2300.00	-30	10	-40	3.00E+03	-15	10	25	0	6	-15.2	16	10	51.77	37
Amateur Radio	3300.00	-30	10	-40	3.00E+03	-15	10	35	0	6	-15.2	16	10	61.77	47
Amateur Radio	5650.00	-30	10	-40	3.00E+03	-15	10	35	0	6	-15.2	16	10	61.77	47
GSM 1800 base	1710.00	38	9	29	2.00E+05	36	10	18	6	6	3.0	20	10	73.01	109
UMTS FDD base	1920.00	23	-6	29	5.00E+06	22	10	18	6	6	17.0	20	10	86.99	109
UMTS TDD	1900.00	25	-10	35	5.00E+06	28	10	35	6	6	17.0	20	10	103.99	132
DAB	1452.00	46	10	36	2.00E+06	33	10	10	6	6	13.0	10	6	61.01	94

Figure 5 provides a graphic presentation of the modelled radio service protection requirements using the probability factors above and compares this with the previous and current CISPR 32 limits.

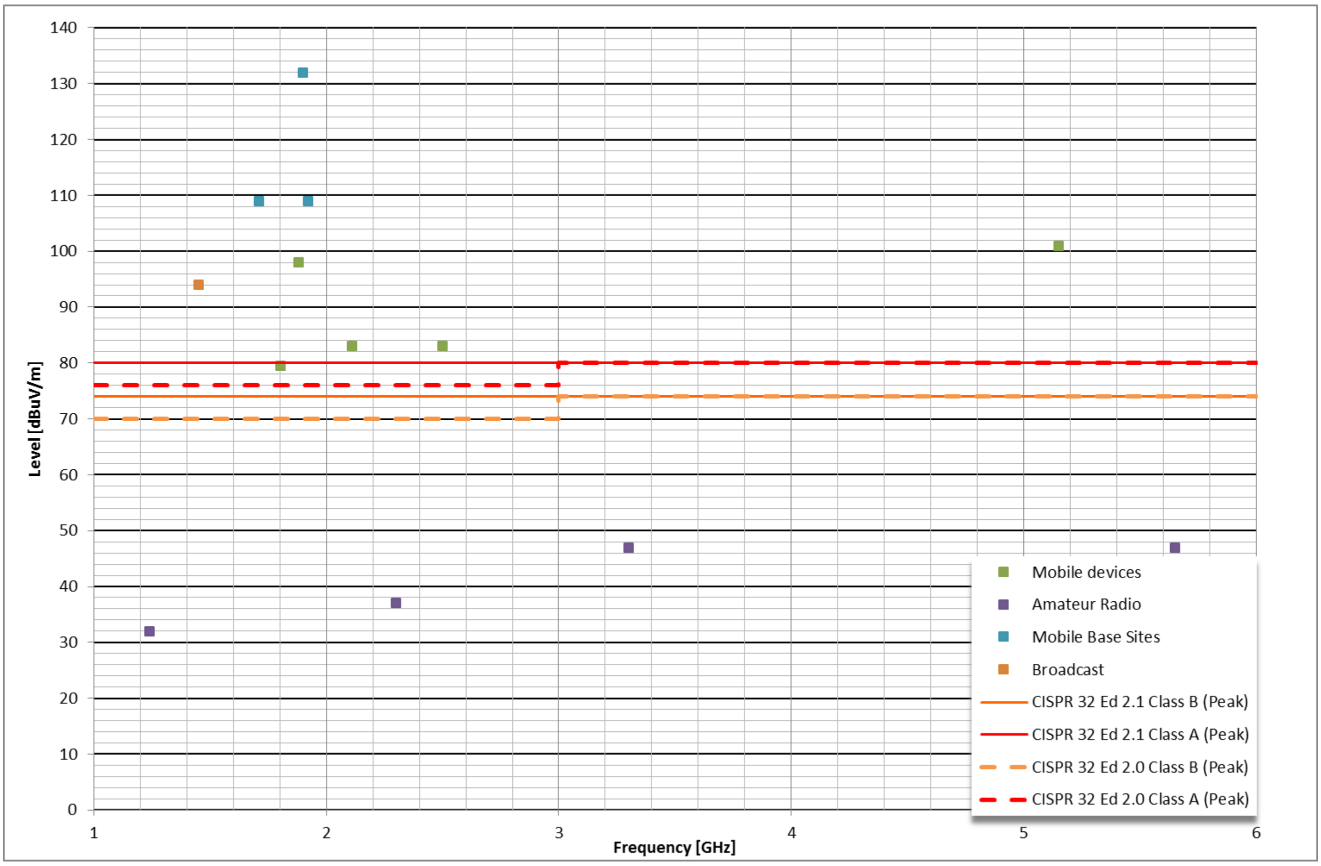


Figure 5 – Modelled radio service protection requirements and CISPR 32 Limits

6 Reference documents

[1] CISPR 32:2015 *Electromagnetic compatibility of multimedia equipment – Emission requirements*

[2] CISPR/I/152/INF *Information on Requirements above 1 GHz.*

[3] CISPR 16-4-4:2020 *Specification for radio disturbance and immunity measuring apparatus and methods – Part 4-4: Uncertainties, statistics and limit modelling – Statistics of complaints and a model for the calculation of limits for the protection of radio services.*

[4] 47 CFR 15:2019 *TITLE 47—Telecommunication Chapter I—Federal Communications Commission, Subchapter A Part 15—Radio Frequency Devices*

[5] CISPR/H/63A/DC *Rationale for Setting Emission Limits in the Frequency Range 1-18 GHz. Used types of detectors, overview of other limits and EMC-environment.*

[6] CISPR/H/62A/INF *Rationale for Setting Emission Limits in the Frequency Range 1-18 GHz. Consideration of the influence factors P1 to P10, their use in the calculation of limits and first estimation of the mean values*

[7] CISPR 16-2-3:2016 *Radio disturbance and immunity measuring apparatus – Antennas and test sites for radiated disturbance measurements*

[8] CISPR/A/1116/DC*, Updated proposal on EUT size specifications for radiated disturbance measurements*

[9] Andy Griffin, *Measurements of a device use methods based upon CISPR 22 and 47 CFR Part 15 in the range 1-6 GHz.* 2009 IEICE EMC'09/Kyoto

[10] CISPR/A/WG2(Griffin)15-01 *Proposed solution for repeatability issues for measurements of radiated emissions in the frequency range 1GHz - 6GHz.*

[11] CISPR/I/MT7/Busan *Above 1GHz absorber data.*

[12] CISPR 16-1-4:2019 *Radio disturbance and immunity measuring apparatus – Antennas and test sites for radiated disturbance measurements*

[13] CISPR/I/617/FDIS *Amendment 1 - CISPR 32: Electromagnetic compatibility of multimedia equipment Emission requirements*

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