COM/INT/ICAO/AMCP/WGF/NOV01/DOC04

EUROCONTROL

Date : **01.10.2001**

Subject : **Protection Limits for Navigation Systems**

Origin : **EUROCONTROL**

Prepared by Carol SZABO

EXECUTIVE SUMMARY

This paper provides maximum aggregate interference levels specified for different CATV signals, based on the REG-TP and DFS contributions to CEPT/ERC/SE35.

Protection limits are computed for ILS and VOR equipment.

1 The aeronautical radio services, bands, minimum wanted field strengths in the frequency range 30 to 3000 MHz

Application Abbreviation	Type of Service, short description	Frequency Range/MHz	DOC	Minimum wanted field strengths/ dBµV/m
ILS/MKR	Aeronautical Radio Navigation Service (ARNS).Marker beacon belonging to the ILS system, provides a signal to the pilot or Flight Management System (FMS), when the plane is passing certain fixed points during final approach and landing.	74,8 – 75,2	horizontal: a circle of ....m radius around the position of the beacon. vertical: from 30 m to .....m, depending on the position of the beacon. position of the beacon: 2 or 3 points on the extended centre line of the runway, between ... m and ....m from threshold.	63
ILS/LOC	ARNS. Precision Landing Aid, provides course guidance information to the pilot/FMS.	108 – 111,975	horizontal: angle sector ±10°, 46,3 km from TX, angle sector ±35°, 31,5 km from TX. vertical: from 300 m to 1905 m. within glide path sector increasing from 0 m to 300 m.	32
VOR	ARNS. En-route and terminal (landing) beacon, provides azimuth relating to beacon position to the pilot/FMS.	108 – 117,975	horizontal: a circle of 30 to 180 km radius around the VOR vertical: from 300 m to 15000 m	39
GBAS	ARNS. Ground Based Augmentation System, provides enhanced accuracy of position data to satellite navigation systems on board of aircraft, especially during landing procedures.	108 - 117,975	horizontal: a circle of 60 km radius around the ground station vertical: up to 3000 m	43
ILS/GP	ARNS. Precision Landing Aid, provides glide path information to the pilot/FMS.	328,6 – 335,4	horizontal: angle sector ±8° around the extended runway centre line, 18,5 km (certain States use 28 km) from TX. vertical: angle sector (1,75°x glide slope angle) above, and (0,3°x glide slope angle) below glide slope. Glide slope is from 2° to 3,3°	52
DME	ARNS. En-route and terminal (landing) beacon, provides distance between beacon position and aircraft.	960 - 1215	horizontal: a circle around the beacon position from 30 to 180 km. vertical: from 300 m to 1500 m.	57
GNSS/GPS	Radio Navigation Satellite Service (RNSS)/Global Positioning System. En-route and terminal (landing) means, provides position data for navigation to the pilot/FMS	1164 – 1215 1559 - 1610	horizontal: the whole surface of a State. vertical: from 300 m to 15000 m, for approach and landing from 0 m increasing according to glide slope to 300 m	tbd

Table 1: Some essential characteristics of aeronautical radio applications

Notes to Table 1:

- the mentioned aeronautical radio services are safety of life services, and must claim special protection against harmful interference.

- only the airborne receivers of the respective radio services are considered to be a potential victim of cable TV network interference. It is assumed that the ground facilities (the RX) are normally located in such areas, where cable TV network interference is less probable. But if such an interference occurs, it is a local problem, where the source of the interference may be identified more easily.

- the stipulated minimum field strengths of the respective radio application is taken as the wanted field strengths to be protected. It is recognized that the wanted field strengths exceed the minimum wanted field strengths remarkably in areas close to the ground transmitter, but the calculation of the wanted field strengths cannot take into account the influence of all properties of the surface, e.g. buildings, hills, woods etc. Therefore, as experience shows, gaps of low field strengths may occur even in shorter distances to the transmitter. Hence the worst case scenario has to be used. The excess of the wanted field strengths over the minimum wanted field strengths may be taken into account when assessing safety margins.

2 The cumulative effect of interference from different types of interfering sources:

It is not sufficient to evaluate the interference potential of only one source (e.g. cable TV), but the additional contribution of the regarded interference source (e.g. cable TV) to other already effective interference sources has to be determined, and a decision has to be made whether the overall interference level of the victim radio service is exceeded or not.

Some sources of interference to aeronautical radio services:

- Interference from stations of the same radio application, e.g. ILS versus ILS (intra-system interference).

- This type of interference is handled by the frequency management, using the frequency planning criteria, especially the D/U ratios, of ICAO Annex 10. Due to frequency congestion, the stations are coordinated as close as possible, which results in the highest tolerable intra-system interference.

- It should be noted here that the D/U ratios of ICAO Annex 10 are only valid for intra-system interference, and in general must not be applied for other types of interference sources.

- Interference from stations of another radio application, but the same aeronautical radio service, e.g. ILS versus VOR (inter system interference).

- This type of interference is also handled by the frequency management, using the appropriate provisions of ICAO Annex 10. Due to frequency congestion, the stations are coordinated as close as possible, which results in the highest tolerable inter system interference.

- Interference from stations of another radio service, using frequency bands adjacent to the aeronautical radio frequency bands, e.g. FM-Broadcast versus ILS/VOR/VHF COM.

- If it deems necessary, relevant ITU Study Groups produce recommendations on how to settle such problems. Regarding FM-Broadcast there is a Recommendation ITU-R IS 1009, which provides guidance on how to coordinate the broadcast stations and the aeronautical stations. In the end the aeronautical radio applications are imposed with tolerable interference levels.

- Interference from high power multifrequency HF or TV Broadcast stations.

- Spurious emissions from these broadcast stations or intermodulation in the aeronautical receivers caused by these broadcast stations may interfere with aeronautical radio applications. The prediction or assessment of this interference is very difficult if not impossible, but has been experienced in practice.

- Interference from Industrial, Scientific and Medical equipment (ISM)

- Radiation limits of ISM equipment were developed by CISPR, and they do not comply with ICAO s position on the need to protect safety services in all cases. The assessment of this kind of interference is difficult, because the tolerable radiation limits are measured on the ground, but no information about the radiation above ground are available.

Evaluation of risk to aeronautical radio applications, caused by the different interfering sources:

Although for most of the known sources of interference Standards for radiation limits or even calculation models exist, the calculation of the compatibility for each single type of interfering source with aeronautical radio applications is rather inaccurate. Much more difficult is the assessment of the cumulated interference potential of all the interfering sources.

Another point is that due to safety reasons a risk assessment has to be performed in the case where a certain interfering source does not stick to the standardized radiation limits. This may happen in cases where the interfering source is such an application of radio frequencies, where unauthorized or an unqualified person has the opportunity to manipulate on the technical configuration, and by doing this enhance (unintentionally) the unwanted radiation. An example for such an interfering source is the in-house distribution network of cable TV. In such cases the maximum possible radiation has to be assessed, and also the time it takes to detect the radiating source and to stop the radiation.

Realizing the difficulties to assess the cumulative interference potential, measurements in laboratories could provide the necessary data. But this is very time consuming and costly, therefore a method to apply safety margins in a more feasible way is needed.

3 Aviation safety factor

Some aeronautical applications (for example, precision approach and landing) are regarded as having high criticality in safety terms, thereby meriting an additional safety factor. In this application, the analysis would consider the probabilities applying in the total operational situation, which would then be narrowed down to the element involving unacceptable interference. From there, an additional protection factor of not less than 6 dB would be applied to increase the operational assurances to the required level.

4 Protection Requirements of the Different Aeronautical Radio Applications against Different Cable TV Modulation Schemes

The required protection of a certain aeronautical radio application against a certain cable TV signal, characterized by its modulation scheme, is determined by the ratio of the desired signal level to the undesired signal level (D/U ratio).

It is stressed that each D/U ratio in general is only valid for a single combination of wanted signal and unwanted signal, and has to be determined by measurements.

RegTP and DFS conducted some measurements of D/U ratios for some aeronautical radio applications and some cable TV signals. Reports of these measurements have been submitted to SE 35 (e.g. Working Papers SE35(01)3a, SE35(01)3b, SE35(01)64), SE35(01)73)

The main results are presented in the following two tables. Table 2 contains measured D/U values, where the wanted signal power is RMS over the whole bandwidth, and where the unwanted signal power is RMS over the whole Bandwidth.

Table 3 contains correction factors, which allow to calculate the RMS power over the whole bandwidth of a digital signal, when the power measurement of the digital signal is made with certain other measurement detectors X, like Quasipeak/120 kHz or Peak/1MHz. The RMS power P_{RMS} of the digital signal is calculated by $P_{RMS} = P_X + C$, where P_X is the power measured by detector X, and C is the correction factor in dB.
For instance, a power of 20 dBpW of a 16QAM signal measured with the detector Quasipeak/120 kHz represents a RMS power of that 16QAM signal over the whole bandwidth of 33 dBpW.

Victim airborne Receivers	D/U values in dB for the following interfering signals			
	16QAM, 64QAM 256 QAM	QPSK	COFDM/DAB	Analog PAL-TV
VOR	-4	-9	+3	10
ILS/LOC	-7	-12	0	20
ILS/GP	-8	-14	-1	10

Table 2: Measured D/U values, wanted signal power and unwanted signal power is RMS over the whole bandwidth

Correction factors applicable for different signal detectors:

R&S ESCS Signal Detector	Correction Factor in dB			
	16QAM, 64 QAM, 256 QAM	QPSK	COFDM/DAB	Analog PAL-TV
Peak 9 kHz	19,3	25,3	15,7	-3,1
Peak 120 kHz	8,1	13,6	2,1	-3,8
Peak 1 MHz	0,2	4,4	-9,3	-3,5
Quasi Peak 120 kHz	12,9	18,8	5,8	-3,1
AV 9 kHz	33,6	37,5	24,8	1,5
AV 120 kHz	20,5	26,3	13,5	1,4
AV 1 MHz	11,4	17,5	5,3	1,4
RMS 9 kHz	30,5	36,4	23,6	1,4
RMS 120 kHz	19,4	25,3	12,4	0,9
RMS 1 MHz	10,2	16,3	3,2	0,8

Table 3: Correction factors for transforming a measured power into RMS power over the whole bandwidth

Notes to Table 3:

- the accuracy of measurement of the signal levels in dB is assumed to be ± 1 dB.
- the correction factors, given with decimals of dB, should be rounded to full dB for further application. They are presented here with decimals in order to alleviate the identification with tables in other papers related to this issue.
- for further application of the correction factors it is assumed that they are valid universally, although they are determined by one device R&S ESCS Signal Detector.
- as far as PAL-TV – signal is involved, the image carrier was always included in the measurements (this is also true for Table 1).
- the measured correction factors for the RMS detector comply satisfactorily with the formula Corr.fact. = $10 \lg (BW_{overall}/BW_{measured})$.

5 Maximum aggregate interference power flux density for VOR and ILS

The Eurocontrol Agency computation for the protection limits is based on the REG-TP and DFS measurements and interference analysis, considering the worst case scenario and the aggregate interference acceptable by the aviation navigation systems. The protection limits are established only for the interference signals analysed by REG-TP/DFS and only for the aviation systems measured in [SE35(01)03] .

Aviation Applications Receiver bandwidth Used band	Minimum Field Strength to be protected (dBµV/m) (ICAO Doc)	RMS D/U Ratio [dB] Measured over the whole BW (correction factors shall be applied for Quasi-peak or Peak detectors and different det. BW)				Maximum aggregate interference power flux density (dBpW/m**2) measured with QPeak det/120kHz (Multiple entry factor (3dB) and safety margin (6dB) are considered			
		PAL	16, 64, 256 QAM	QPSK	COFDM	PAL	16-, 64-, 256-QAM	QPSK	COFDM
VOR 40 kHz 108-117.975 MHz	39	10	-4	-9	3	-2.6	-4,6	-5.5	-4.5
ILS LOC 40 kHz 108.1-111.95 MHz	32	20	-7	-12	0	-19.6	-8,6	-9.5	-8.5
ILS GS 40 kHz 328.6-335.4 MHz	52	10	-8	-14	-1	10.4	12,4	12.5	12.5

Table 4: Maximum aggregate interference power flux density to VOR and ILS

6 List of Relevant Documents

1) "International Standards and Recommended Practices - Aeronautical Telecommunications - Annex 10 to the Convention on International Civil Aviation. Volume 1 (Radio Navigation Aids)"; International Civil Aviation Organisation (ICAO) 5th Edition of Volume 1 - July 1996.

2) "International Standards and Recommended Practices - Aeronautical Telecommunications - Annex 10 to the Convention on International Civil Aviation. Volume 5 (Aeronautical Radio Frequency Spectrum Utilization)" ; International Civil Aviation Organisation (ICAO), 1st Edition of Volume 5 - July 1996.

3) CEPT/ERC/SE35(00)18, Rev.5 on 15.02.2001

4) CEPT/ERC/SE35(00)26 Maisons Alfort July 2000 - ECCA Contribution to the ERC Report

5) CEPT/ERC/SE35(00)48 Mainz Sep.2000 - An aviation view on CATV

6) CEPT/ERC/SE35(01)03 London Jan. 2001 - RegTP and DFS Study

7) CEPT/ERC/SE35(01)64 PARIS May 2001 - DFS Contribution

8) CEPT/ERC/SE35(01)75 Geneva Aug.2001 – Eurocontrol input with aviation protection requirements

9) European Council Directive 89/336/EEC of 3 May 1989.