International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R RS.1881

(02/2011)

Protection criteria for arrival time difference receivers operating in the meteorological aids service in the frequency band 9-11.3 kHz

RS Series

Remote sensing systems

International Telecommunication Union

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Note*: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R RS.1881

Protection criteria for arrival time difference receivers operating in the meteorological aids service in the frequency band 9-11.3 kHz*

(2011)

Scope

This ITU-R Recommendation characterizes the technical properties, operational characteristics and protection criteria of the arrival time difference (ATD) system operating in the meteorological aids service in the frequency range 9-11.3 kHz.

The ITU Radiocommunication Assembly,

considering

a) that long-range lightning detection using observations near 10 kHz has been performed since 1987, using the time differences of signals received to derive strike locations;

b) that maximum spectral emissions from lightning strikes centre between 9 to 20 kHz. At these frequencies the sky waves, reflected off the ionosphere, propagate for very large distances with relatively little attenuation. Thus, it is possible to receive the emissions from a lightning strike at thousands of kilometres from the stroke location;

c) that although national and regional lightning detection systems operating at higher frequency bands currently exist, these require a higher number of receiver stations due to the substantial reduction in coverage area of each receiver. Detection with such systems over large areas of ocean and land mass where local infrastructure does not exist is normally difficult and highly costly to implement. Additionally coverage over large oceanic areas with these systems, such as the middle of the Atlantic, is not possible;

d) that a primary benefit of the arrival time difference (ATD) system is the worldwide coverage provided by a limited number of receivers and these receivers provide a high level of accuracy regards to global detection;

e) that the data provided by the ATD system is used by meteorological organizations worldwide and contributes towards safety of life, both in terms of forecasting for public safety and safety in forecasting aviation operations, especially over the oceans, and large areas of land, where national lightning detection systems do not exist. Additionally it has the potential to give a service in support of disaster risk reduction initiatives;

f) that there is growing interest around the world in lightning detection capability for disaster mitigation, navigation and weather prediction purposes;

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* The Radio Regulations (Edition 2008) allocated bands start at 9 kHz. However the system mentioned in the Recommendation operates between 8.3 and 11.3 kHz.

g) that the ATD lightning detection system relies on naturally occurring emissions from lightning strikes and can be compromised by interference from other sources including man-made emissions;

h) that because of long-range propagation in this frequency band interference can affect many ATD stations simultaneously and this can seriously degrade system performance, including in some cases the total loss of data,

recognizing

a) that there is a small number of ATD receivers located throughout the world;

b) that the ATD network receivers operate on a single frequency basis with a 3 kHz measurement bandwidth,

recommends

1 that Annex 1 should be referred to for the background information for determining the protection criteria for the ATD sensors operating in the meteorological aids service in frequency band 9-11.3 kHz;

2 that the protection criteria given in Annex 1 should be used to assess the compatibility between passive ATD stations of the meteorological aids service and stations in the radionavigation, fixed and mobile services.

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Annex 1

ATD protection criteria

1 Summary

This Annex set out those parameters that should be considered within any compatibility and sharing analysis between ATD receivers and other services in the frequency band 9-11.3 kHz.

2 ATD receiver characteristics

Typical receiver parameters for the ATD sensor are shown in Table 1.

3 Protection levels

Based on the criterion of ATD Sferic[1] event waveform not being able to update when exposed to various levels of interference; two types of simulated interference wave forms at various frequency offsets from the measurement band have been assessed, these being CW and pulsed CW (duty cycle 67%).

[1] * Sferic: A lightning generated electromagnetic signal (abbreviation for radio-atmospheric).

TABLE 1

Typical ATD system parameters

Technical characteristics of the ATD system	
Receiver centre frequency	9.766 kHz
Receiver (sensor unit) amplifier gain	12 dB if switched on by control software (normally the case) otherwise zero[(1)]
Measurement bandwidth	3 kHz
Total "pass band"	6.87 to 20.6 kHz
Antenna type and directivity	2 m Vertical polarization, omnidirectional Whip
Software filter	Broadband highpass filter (3 dB at 2.0 kHz), cascaded with lowpass filter (0.28 dB passband limit at 17.75 kHz)
Software narrow band pass filter	3 dB bandwidth 2.5 kHz 10 dB bandwidth 4.3 kHz 20 dB bandwidth is 5.7 kHz
Typical receiver noise floor	−70.4 dBm in a 5 kHz reference bandwidth

(1) The 12 dB amplifier gain is used for long range detection, in the event of lightning strikes being in close proximity to the receiver, input gain is reduced to zero.

3.1 Typical ATD receiver noise floor

The typical noise floor of the receiver is −70.4 dBm in a 5 kHz bandwidth.

3.2 Receiver sensitivity (at minimum signal to noise ratio of 15 dB)

The receiver sensitivity of an ATD sensor is −69.5 dBm.

3.3 *C*/*N* as function of receiver sensitivity

The *C*/*N* protection ratio was measured in a 5 kHz band width (see Table 2).

TABLE 2

Measured *C*/*N* as a function of minimum carrier level

Minimum carrier (dBm)	**Noise level (dBm)**	***C*/*N* (dB)**
−69.5	−70.4	0.9

3.4 *I*/*N* as a function of frequency offset

The *I*/*N* protection ratio measurements at various frequency offsets from the detection centre frequency using a constant CW and pulsed CW source of interference based on the criterion of the display not being able to update a lightning event.

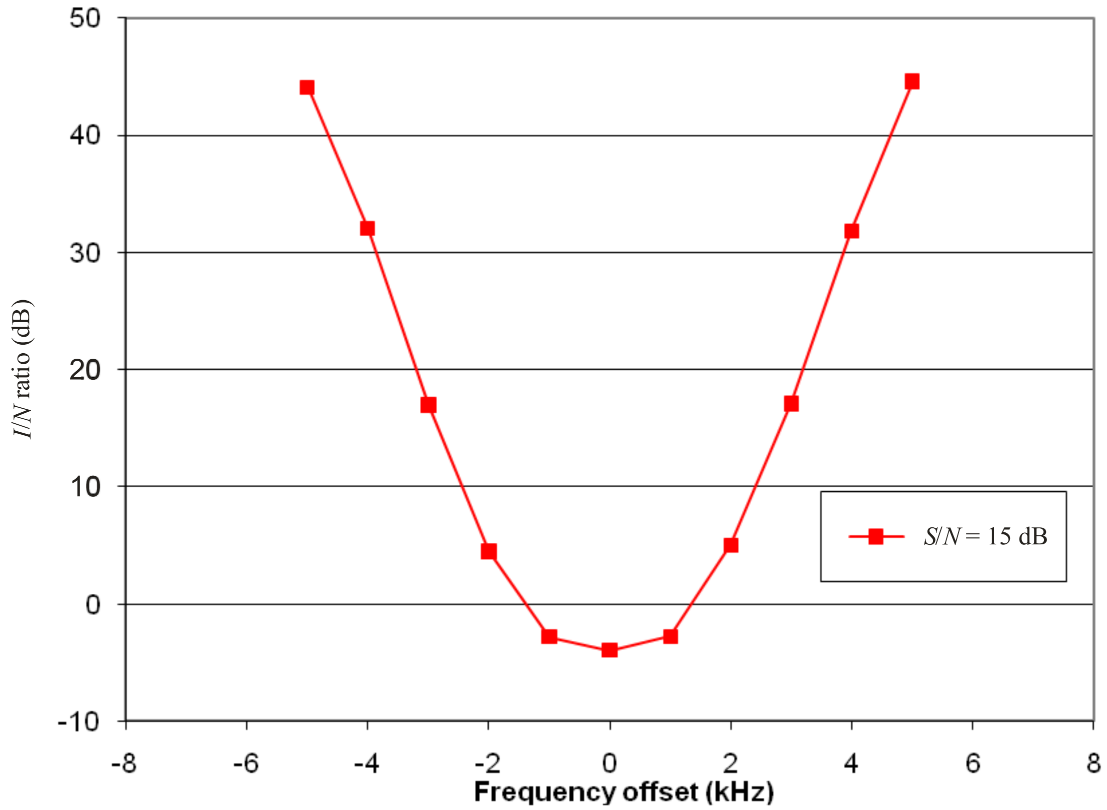
NOTE 1 – *I*/*N* values as shown in the following sections can be reduced in the event that suitable notch filtering is deployed as detailed in § 4.

3.4.1 *I*/*N* protection criteria for constant CW types of interferer

Figure 1 shows that the minimum *I*/*N* protection ratio for CW types of interferer at various frequency offsets from the detection centre frequency.

FIGURE 1

***I*/*N* as a function of frequency offset using constant CW interference**



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The plot shows that a co-channel *I*/*N* protection ratio of around −3 dB in a 5 kHz bandwidth is required. A higher protection ratio (*I*/*N* = +4 to +5 dB) is observed for frequency separations of ±2 kHz. At frequency separations of ±5 kHz, the level of protection required by the ATD system is around 44 dB. These results are shown in more detail in Table 3.

TABLE 3

***I*/*N* as a function of frequency offset (constant CW interference)**

Offset (kHz)	*I*/*N* protection ratio (dB)
0	−3.9
1	−2.8
2	5
3	17
4	32
5	45

3.4.2 *I/N* protection criteria for pulsed CW types of interferer

Figure 2 shows the minimum *I/N* protection ratio for pulsed CW types of interferer (67% duty cycle) at various frequency offsets from the detection centre frequency. These results are shown in more detail in Table 4.

FIGURE 2

***I/N* as a function of frequency offset (pulsed CW interference)**

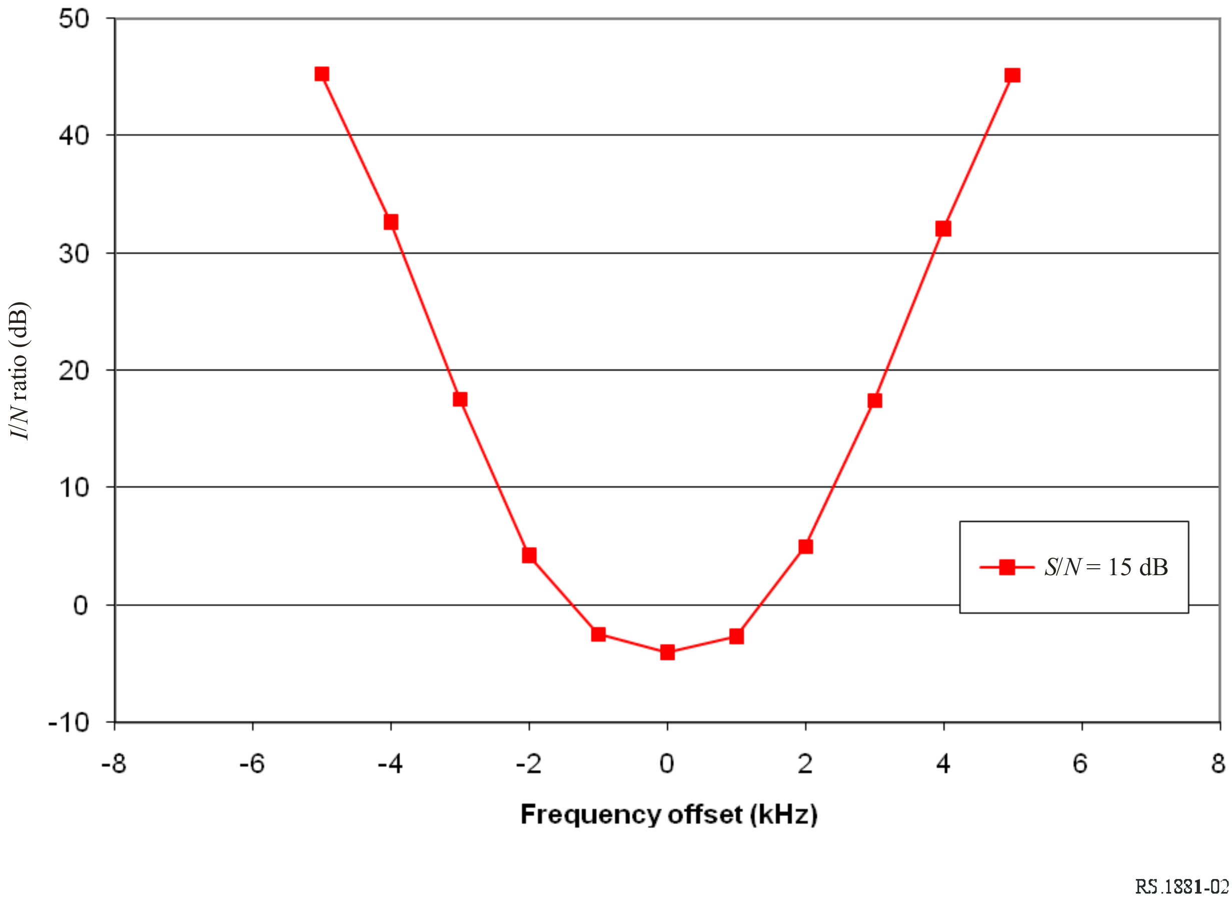


TABLE 4

***I/N* as a function of frequency offset**
(Pulsed CW interference)

Offset (kHz)	**Minimum *I/N* ratio (dB)**
0	−4
1	−2.7
2	5
3	17
4	32
5	45

4 Interference mitigation

Software notch filters can be used on the input to ATD sensors for removing the effects of interfering VLF radio transmissions. In cases where notch filtering can be deployed on ATD sensors, the I/N values as shown in §§ 3.4.1 and 3.4.2 can be modified by the corresponding notch filters resulting attenuation.

As indicated in Fig. 3 the software notch filter function has the form:

$$1 - \exp(-(\Delta f/w)^2)$$

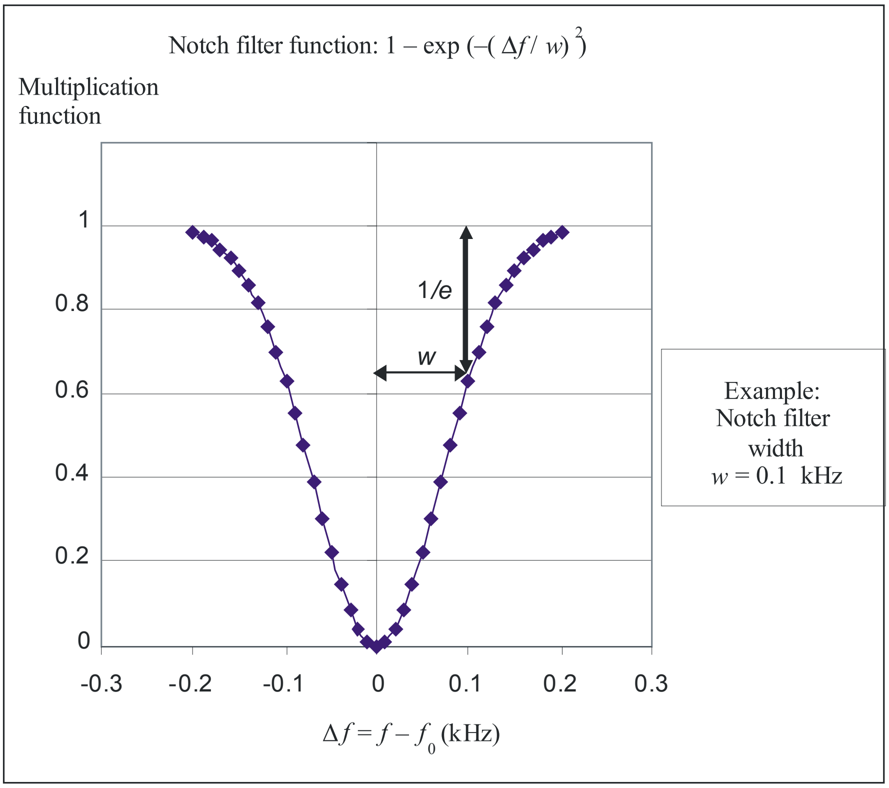
where:

- f_0: nominal frequency of the notch
- Δf: displacement of the frequency f from f_0
- w: its half-bandwidth.

NOTE 1 – Notch filtering can only be deployed at frequency separations more than twice the notch filter bandwidth from ATD measurement centre frequency as in such cases the reduction in wanted signal amplitude is minimal. Additionally notch filtering cannot be deployed for interferer bandwidths greater than 1 kHz.

FIGURE 3

Notch filter function



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