International Telecommunication Union

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Radiocommunication Sector of ITU

Report ITU-R RS.2186

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Radio services and radio-frequency environment within the band below 20 kHz

RS Series

Remote sensing systems

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Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R RS.2186

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(2010)

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1 Background

WRC-12 Agenda item 1.16 calls for consideration of the needs of passive systems for lightning detection in the meteorological aids service, including the possibility of an allocation in the frequency range below 20 kHz, and for WRC-12 to take appropriate action. It resolved to invite ITU-R to conduct and complete the required studies leading to technical and procedural recommendations to WRC-12 to decide an appropriate method for providing recognition to the long established systems of the meteorological aids service operating in the frequency range below 20 kHz.

Part of the necessary work for this agenda item involved identification of current spectrum uses and services within the band below 20 kHz, with a view to initiate sharing and compatibility studies to meet the requirements of this agenda item. This Report sets out those services and associated characteristics currently in operation within the frequency band below 20 kHz.

2 Introduction

The Arrival time difference (ATD) system utilizes a network of "detector" outstations to monitor spectral emissions of cloud to ground lightning strikes centred between about 5 and 20 kHz. At these frequencies the sky waves reflected off the ionosphere propagate for very large distances with relatively little attenuation, and at shorter ranges may be preceded by a ground wave. Thus, it is possible to receive the emissions from the cloud to ground strokes at thousands of kilometres from the stroke location.

Naturally occurring emissions from lightning strikes can be easily masked by active radio services. Manmade emissions are distinctly different than those from natural sources; such signals tend to be higher in power than natural emissions and can saturate the ATD receiver.

Additionally, due to propagation effects at these low frequencies, active radio services geographically separated by very large distances can still adversely affect throughput, performance and measurement capability of the ATD network system. This increases the necessity to monitor spectral emissions in a spectrum that is void of other radio transmissions as far as possible.

The optimal frequency for ATD measurements is 9.766 kHz and has been in use since 1939. Recent monitoring since 2004 has shown that it was not practical to use this frequency at all the sensor sites, because of transmissions near 10 kHz in some locations which prevented the operation of the passive sensors. This adversely impacted the performance and accuracy of the system. Due to this, the system now operates at 13.733 kHz. Note that, before this time, the lightning detection systems have coexisted with the existing services below 20 kHz. Technical characteristics of the ATD system are specified within Recommendation ITU-R RS.1881.

This contribution is intended to initiate necessary work on the identification of services and stations within the band below 20 kHz. It also seeks to illustrate the complex RF environment within which the arrival time difference lightning detection system currently operates, and to identify areas of spectrum below 20 kHz where the ATD system can operate without placing any undue constraints on existing services or allocations.

3 Survey of bands below 20 kHz

3.1 Allocations in RR Article 5 before WRC-12

Based on Article 5 of the Radio Regulations, Edition 2008, in the frequency range 9-20.05 kHz a frequency bands are allocated to: radionavigation, fixed, maritime mobile, standard frequency and time services on a worldwide primary basis. Utilization of these bands by the systems of these services is presented below.

3.2 Radionavigation systems

3.2.1 Omega

Omega was originally developed by the United States of America for aviation users. Approved for development in 1968 with only eight transmitters, each station transmitted a continuous wave (CW) which consisted of a pattern of four tones unique to the station that was repeated every ten seconds. The Omega system operated under bilateral agreements with six partner nations (Norway, Liberia, France, Argentina, Australia and Japan). The stations transmitted time-shared signals on four frequencies, in the following order: 10.2 kHz, 11.33 kHz, 13.6 kHz and 11.05 kHz. In addition to these common frequencies, each station transmitted a unique frequency to aid station identification and to enhance receiver performance. Due to the success of the Global Positioning System the use of Omega declined during the 1990s, to a point where the cost of operating Omega could no longer be justified. Omega was permanently terminated on 30 September 1997 and all stations ceased operation.

3.2.2 Alpha system (RSDN-20)

Alpha is a Russian system for long-range radionavigation. Alpha works similarly to the former Omega navigation system but within the frequency band 10-17 kHz.

The Alpha system consists of three transmitters, which stand in the proximity of Novosibirsk, Krasnodar and Komsomolsk. These transmitters radiate 3.6 second long signals consisting of 400 ms long frequency combinations with 200 ms spacing. In June 2010 the following 6 frequency assignments to Alpha system are included in the Master International Frequency Register (MIFR): 11.905 kHz, 12.500 kHz, 12.649 kHz, 13.281 kHz, 14.881 kHz and 15.625 kHz, this system can also use other frequencies of the range 10-17 kHz.

Alpha system is used for long-range radionavigation and for short-term earthquake prediction. This prediction is possible due to the fact that before earthquake there are abnormal electromagnetic, geochemical and hydrogeological phenomena which effect electric parameters of the Earth’s crust, atmosphere and ionosphere in the areas of forthcoming earthquake. These changes impact on the propagation conditions of electromagnetic waves in the VLF-range and can be detected by remote sensing stations. It allows to predict earthquake before 10-20 days and to evaluate its magnitude. Currently the Alpha system allows the possibility to predict earthquakes with sources located not lower than 70 km in the Earth’s crust.

The technical characteristics of the Alpha system are given in Table 1.

TABLE 1

Characteristics of radionavigation transmitters registered in the MIFR (June 2010) operating in the 11.905-15.625 kHz band

Parameter	Value
Fixed or mobile	Fixed
Transmission frequency (kHz)	11.905 12.500 12.649 13.281 14.881 15.625
TX power (dBW)	57
Antenna gain (dBi)	N/A[(1)]
Antenna polarization	Unspecified
Modulation – Necessary bandwidth (Hz)	AXX – 100 AXX – 200
Operational range (km)	10.000

(1) N/A: Not applicable.

3.3 Meteorological aids systems

Meteorologists used to utilize radionavigation service signals for a variety of purposes. The use of Omega navigation signals (frequencies between 10 to 13 kHz) became widespread for tracking radiosondes in the MetAids service from about 1985 onwards until its termination of operation. This was because the radiosonde systems could be used with simple base station antenna, processing was automated and the systems were easy to maintain in remote locations.

At the time of the closure of the Omega transmitters in 1997, more than 20% of the radiosonde systems in the WMO network had to be changed. Most of these ground systems were modified or replaced to use radiosondes receiving and processing GPS navigation signals.

3.4 Fixed and maritime mobile systems

Several fixed station transmitters have been identified that operate in the 14-19.55 kHz band. These stations operate in the fixed service and provide information to widely dispersed ship borne receivers operating in the maritime mobile service. A summary of the technical characteristics of these fixed station transmitters is provided in Table 2.

TABLE 2

Characteristics of fixed transmitters operating in the 14-19.55 kHz band

Parameter	Value
Fixed or mobile	Fixed (including transportable)
Tuning range (kHz)	14-19.55
TX power (dBm)	90
Antenna gain (dBi)	N/A
Antenna polarization	Vertical
Modulation – Necessary bandwidth (Hz)	A1A – 100 F1B – 300 F1B – 600 J3B – 600 J7B – 600

3.5 Standard frequency and time signal

No systems under the standard frequency and time signal service operate in this frequency range and no systems are expected to be operating in the foreseeable future.

4 Spectral analysis of ATD receiver locations

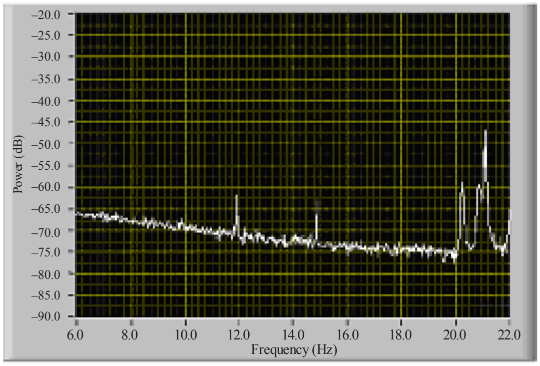
The ATD lightning detection system relies on naturally occurring emissions from lightning strikes and can be badly compromised by interference from other man made sources. Interfering signals are often transient, whilst others have specific repeat cycles. However because of long-range propagation of interfering signals, interference can affect many stations simultaneously and this does seriously degrade system performance.

Interference reduces the number of events seen at one or more outstations and/or cause inaccuracy in measuring the time differences between one or more pairs of stations. This reduces the number of fixes in an area, thus reducing the apparent severity of a storm.

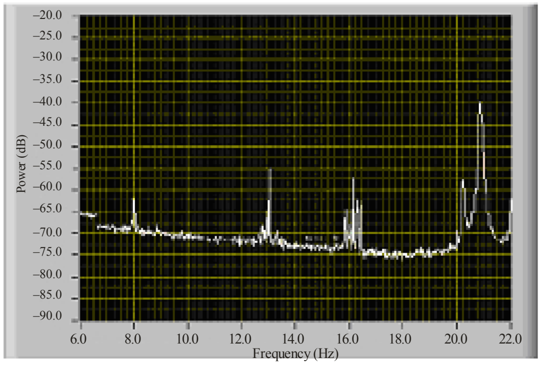
A survey for each of the ATD network receiver locations was executed by the United Kingdom met office to examine the spectral environments and types of interference received at each ATD receiver location within the frequency band 6 to 22 kHz. The results of this analysis are shown in Figs 1 and 2.

FIGURE 1

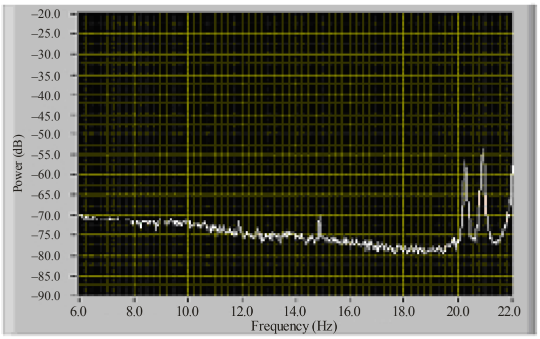
Spectral plots of RFI between 6 and 20 kHz at Helsinki, Payerne, Camborne, Azores, Keflavik and Reunion ATD receiver locations



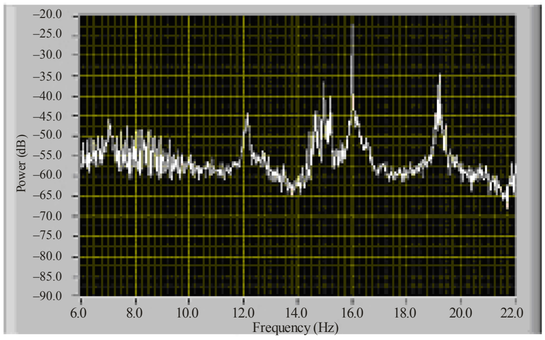
Spectral plot from Helsinki ATD receiver



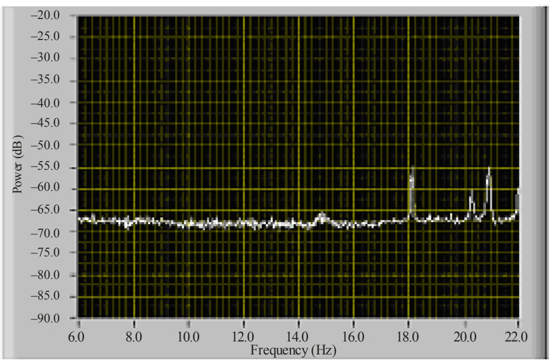
Spectral plot from Payerne ATD receiver



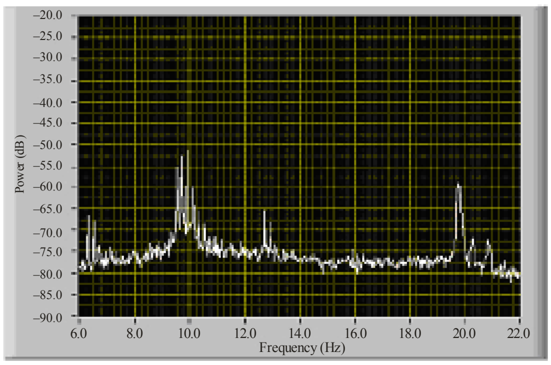
Spectral plot from Camborne ATD receiver



Spectral plot from Azores ATD receiver



Spectral plot from Keflavik ATD receiver



Spectral plot from Reunion ATD receiver

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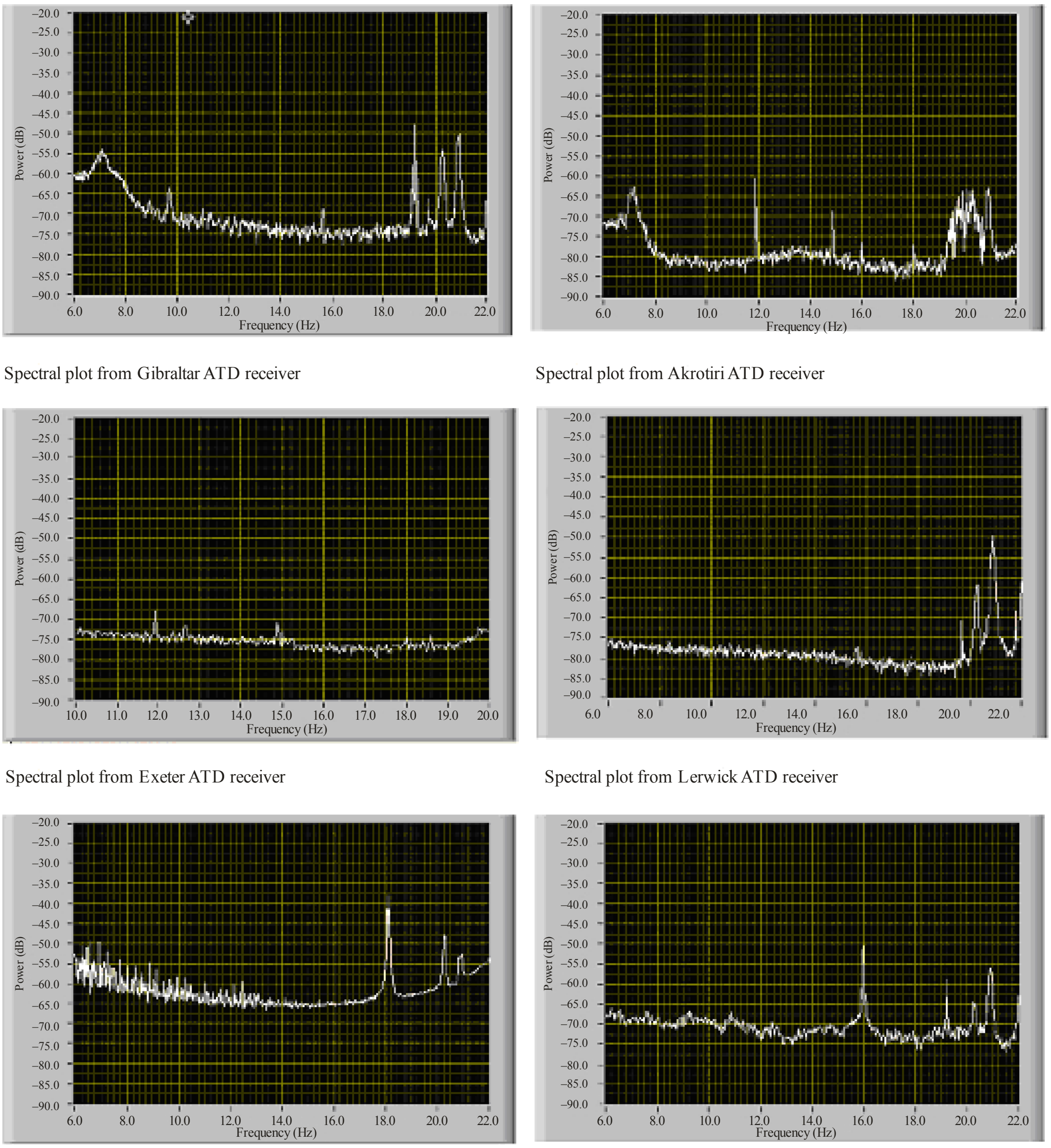
FIGURE 2

Spectral plots of RFI between 6 and 20 kHz at Gibraltar, Akrotiri, Exeter, Lerwick, Nordeney and Valentia ATD receiver locations



Spectral plot from Gibraltar ATD receiver

Spectral plot from Akrotiri ATD receiver

Spectral plot from Exeter ATD receiver

Spectral plot from Lerwick ATD receiver

Spectral plot from Nordeney ATD receiver

Spectral plot from Valentia ATD receiver

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The above examples, which are typical, are useful for understanding that man-made transmitter sources vary in frequency and amplitude from ATD receiver location. In addition, the same sources of interference can affect different geographically separated ATD receiver sites. To demonstrate this, the same RFI can be seen at around 12 kHz and 15 kHz at both Helsinki and Camborne receiver sites.

Additionally, interference sources can be seen to be about 20 dB to 30 dB above the level of the atmospheric noise. These effectively dominate and mask any sferic[1] emissions, preventing measurements within the same frequency of interest.

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

The survey of RFI at each receiver location was taken at the same time so they do not necessarily show some cases of intermittent interference. An example of the intermittent interference is shown in the signal at 18 kHz, which can be seen in the image for Nordeney: this RFI was absent a few days later.

It can also be seen that the majority of all ATD receiver sites are affected by varying transmissions based on frequencies around 11.9 to 20 kHz, with most sites indicating a void of transmissions within the frequency range 9 to 11.9 kHz. Only one site, Reunion, indicates transmissions that are centred around 10 kHz.

It is useful to note that this is the optimal frequency for measurements for sferic lightning detection (optimal frequency for lightning detection is 9.7 kHz).

The one anomaly is the ATD receiver based at the Azores. This is unique in that RFI levels throughout the whole band are in excess of 20 dB above the normal noise floor, which renders this receiver location inoperable and lessens the accuracy of the ATD system, especially in the middle of the north Atlantic, where it is the only source of information on lightning, and where the location accuracy of the lightning strokes drops rapidly in the vicinity of the Azores.

5 Summary

Therefore this text presents the available information appertaining to services in operation within the frequency band below 20 kHz at June 2010.