



Report ITU-R RA.2509-0
(10/2022)

**Technical and operational characteristics
of radio astronomy systems operating
below 350 MHz (85 cm)**

RA Series
Radio astronomy



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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.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from <http://www.itu.int/ITU-R/go/patents/en> where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Reports

(Also available online at <http://www.itu.int/publ/R-REP/en>)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
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F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management

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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operating below 350 MHz (85 cm)**

(Questions ITU-R 129-3/7, ITU-R 145-3/7, ITU-R 237/7)

(2022)

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Scope

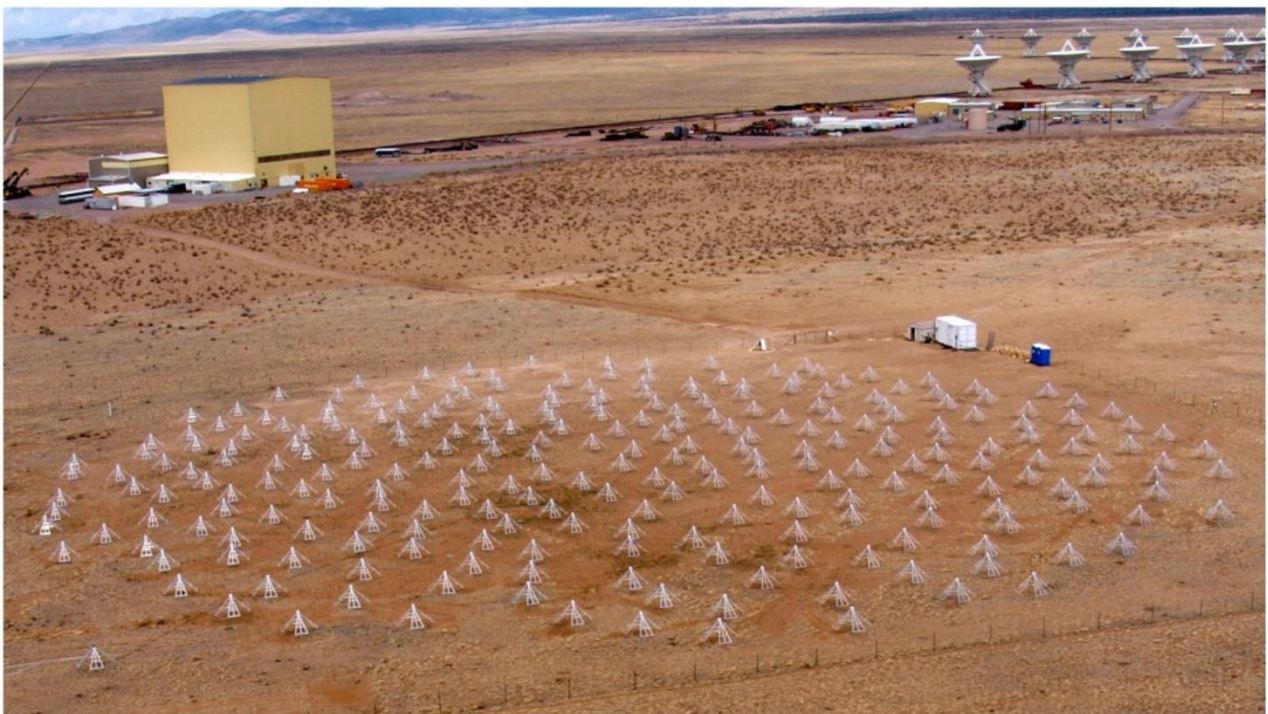
This Report summarizes generic technical and operational characteristics of radio telescopes working at frequencies below 350 MHz. In most cases these are arrays of dipoles; however, in a few cases these are more traditional parabolic dishes designed to work at higher frequencies but instrumented to also work below 350 MHz. To maximize collecting area for very faint cosmic signals, the use of large numbers of elements is needed, which has recently been further facilitated by advancements in digital processing.

1 Introduction

The pioneering days of radio astronomy involved observations below a few hundred MHz. However, the prediction and subsequent detection of the 21 cm line of hydrogen at 1 420 MHz, the quest for higher angular resolution, and technological advances in receiver technology and interferometry, shifted the attention to higher frequencies. Subsequent discoveries in radio astronomy were indeed dominated by these higher frequencies. In the 1980s to early 1990s, renewed interest in low frequencies grew with the realization that many cosmic sources have inverted radio spectra. In the past 20 years, an additional ambitious goal was the detection of neutral hydrogen at cosmological distances, as early as the cosmic dawn, when the first stars and galaxies lit up the Universe and which corresponds to frequencies below 100 MHz. This requires well characterized instruments with huge collecting areas at affordable cost that observe at frequencies below 350 MHz. Further topics of interest include Fast Radio Bursts (FRBs), Meteors, Pulsar and fundamental physics, exoplanets detection, galactic and extragalactic magnetism, and space weather. Many new instruments have been built or are under construction around the world. Figure 1 shows an example of one of such new instruments.

FIGURE 1

Aerial view of the first long wavelength array station (LWA1) with the very large array in the background



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Relevant ITU-R publications are Report ITU-R RA.2195 on the transition to digital television and its impact on radio astronomy [1], Report ITU-R RA.2163 on spectrum sharing at high frequencies [2],

and Report ITU-R RS.2456 on the use of space weather sensor systems that make use of the radio spectrum.

In light of the recent rapid developments in low frequency radio astronomy, it is believed appropriate to describe the characteristics of this new generation of instruments, and the frequencies employed. This Report provides this information.

2 Telescopes using radio spectrum below 350 MHz

The general characteristics for common designs of radio telescopes operating below 350 MHz are highlighted here.

Some smaller single dish telescopes, essentially solar or space weather instruments, observing in that band have not been mentioned in this Report for clarity but the full list can be found in Report ITU-R RS.2456.

2.1 Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO)

The CALLISTO instrument is a sweeping radio spectrometer operating between 45 and 870 MHz. Other frequency ranges can be observed by using either a heterodyne up- or down-converter. The CALLISTO instrument observes 825 MHz of the solar radio spectrum using individual channels which have a bandwidth of 300 kHz and can be tuned in 62.5 kHz increments. The narrow channel width and accurate positioning are essential to avoid known sources of interference. The number of channels per observing program is limited between 4 and 400, and up to 800 measurements can be made per second. For a typical number of 200 channels, the sampling time per channel is 0.25 seconds. CALLISTO instruments are easily transportable and used in many observatories.

As per March 2021, 172 instruments are already deployed worldwide. The current list of CALLISTO instruments can be found under the following link: <http://www.e-callisto.org>

2.2 Region 1

2.2.1 The Low Frequency ARray (LOFAR)

LOFAR (Low Frequency ARray) is a large radio telescope operating at the lowest frequencies that can be observed from Earth. Unlike single-dish telescope, LOFAR is a multipurpose sensor network, with an innovative computer and network infrastructure that can handle extremely large data volumes. The telescope contains 38 stations in the Netherlands, of which 28 are located in a central location. LOFAR is an international telescope with stations in Germany (six stations), Poland (three stations), France, Ireland, Latvia, Sweden and the United Kingdom (one station each); a station in Italy is funded to be built soon. A LOFAR station consists of Low Band Antenna (LBA, 10-80 MHz) and High Band Antenna (HBA, 110-250 MHz).

Core stations consist of 48 HBAs and 96 LBAs and a total of 48 digital Receiver Units (RCUs). The HBAs are arranged in two 24-element fields with a diameter of 30.8 m each, straddling an 87 m diameter LBA field. The two 24-element fields can be used either as individual stations or their signals can be combined to form one station.

Remote stations consist of 48 HBAs arranged in a single 41 m diameter field and 96 LBAs arranged in a single 87 m diameter field and a total of 48 digital Receiver Units (RCUs).

International stations consist of a 70 m wide LBA array with 96 elements, a 56.5 m wide HBA array consisting of 96 antenna tiles and a total of 96 digital Receiver Units (RCUs).