

RECOMMENDATION ITU-R RA.1630-0*, **

Technical and operational characteristics of ground-based astronomy systems for use in sharing studies with active services between 10 THz and 1 000 THz***

(2003)

The ITU Radiocommunication Assembly,

considering

- a) that the spectral range between 400 THz and 750 THz has been utilized for astronomical observations for centuries and, just in the last 30 years, technical advances have made it possible to fully explore the entire spectral range between 10 THz and 1 000 THz;
- b) that observations between 10 THz and 1 000 THz provide data critical to answering certain fundamental questions of astronomy that cannot be answered by astronomical observations carried out below 275 GHz alone;
- c) that the spectrum between 10 THz and 1 000 THz is also used for astronomical research as well as many other applications;
- d) that the technology for astronomical observations in the spectrum between 10 THz and 1 000 THz is continuously evolving;
- e) that ground-based astronomical observations in the visible range, between 400 THz and 750 THz, are also conducted routinely by amateur astronomers;
- f) that frequencies between 10 THz and 1 000 THz are now being used for data links, range measuring devices, and other active systems on ground-based and space-borne platforms, and as these systems are rapidly expanding and increasing in number, the likelihood of interference between active and passive systems is likely to increase;
- g) that many applications of active and passive systems operating between 10 THz and 1 000 THz are very similar to those being used at lower frequencies in the electromagnetic spectrum;
- h) that while there are significant differences between the technologies used in this part of the spectrum compared with lower frequencies (e.g. counting photons vs. integrating power over time), there are also many similarities (e.g. both are used for continuum and spectral line observations);
- j) that it is timely to consider the nature of protective measures and sharing considerations to ensure that ground-based astronomical telescopes can continue to operate without interference,

* This Recommendation should be brought to the attention of the International Astronomical Union (IAU) and the International Union of Radio Science (URSI).

** Radiocommunication Study Group 7 made editorial amendments to this Recommendation in the year 2017 in accordance with Resolution ITU-R 1.

*** 1 THz = 1 000 GHz.

recognizing

a) that use and sharing of the spectrum between 10 THz and 1 000 THz has not been studied within the ITU-R,

recommends

1 that astronomers take into account the possibility of interference from transmitters operating between 10 THz and 1 000 THz in their choices of observatory sites and in the design of instrumentation;

2 that astronomers provide the appropriate Radiocommunication Study Groups with information on the latest technological advances to ground-based astronomical observations in the frequencies between 10 THz and 1 000 THz;

3 that studies of interference into astronomy systems operating at frequencies between 10 THz and 1 000 THz take into account the technical and operational parameters discussed in Annexes 1 and 2.

Annex 1

1 Introduction

A large variety of objects in the Universe can be observed by ground-based telescopes at frequencies below 275 GHz as well as in the spectrum between 10 THz and 1 000 THz (30 μm to 0.3 μm). Measurements in different frequency domains usually provide information on the physical properties (like temperature, density and spatial distribution) of various states of the different components (like stars, gas and dust) that constitute the observed objects, as well as on local magnetic fields. In general, the larger the frequency range covered by the observations, the more detailed the information that can be derived about the local physical conditions. On the other hand, certain types of cosmic objects can exclusively, or more readily, be studied at frequencies below 275 GHz or in the spectrum between 10 and 1 000 THz (30 μm to 0.3 μm).

The astronomical community has been observing in the band between frequencies of about 400 THz and 750 THz (0.75 μm and 0.4 μm) with telescopes for about 400 years. In the last 30 years, the advent of detector technologies has widened the bands available for astronomical research to the spectrum from 10 THz to 1 000 THz (30 μm to 0.3 μm). Astronomers generally refer to frequencies between 10 THz and 300 THz (30 μm and 1 μm) as "infrared", while the spectrum between 300 THz and 1 000 THz (1 μm and 0.3 μm) is generally referred to as "optical". The spectral range between 10 THz and 1 000 THz is optimal for studies of cosmic thermal emissions and for a large number of spectral lines from atoms and molecules. During the last 30 years, astronomers have seen technological advances that allow the sensing of certain signals once possible only from orbiting platforms. Amateur astronomers conduct observations in the spectrum between 400 THz and 750 THz (0.75 μm and 0.4 μm).

Individual countries and international consortia are now investing heavily in building observatories with very large mirrors (antennas) of up to 10 m diameter or even larger, which in conjunction with modern detectors, will achieve unprecedented sensitivities. In the same manner, the advent of

cheap, reliable lasers has led to a revolution in active applications. These include broadband, high-capacity space-to-space, Earth-to-space, space-to-Earth, and terrestrial data and communication links, radar and other range measuring devices.

Astronomical instrumentation operating in the spectrum between 10 THz to 1 000 THz (30 μm to 0.3 μm) is highly vulnerable to interference or even burnout of detectors by strong signals. However, the high directivities of active systems such as telecommunication systems utilizing lasers operating at frequencies between 20 THz and 375 THz (15 μm and 0.8 μm), together with the propagation properties of waves in this frequency range give rise to possibilities for hitherto unknown manifestations of interference, but also a wide range of options for interference avoidance and band sharing. Studies of interference avoidance and band sharing in this frequency range will require knowledge of the technical and operational characteristics of astronomical receivers and telescope systems.

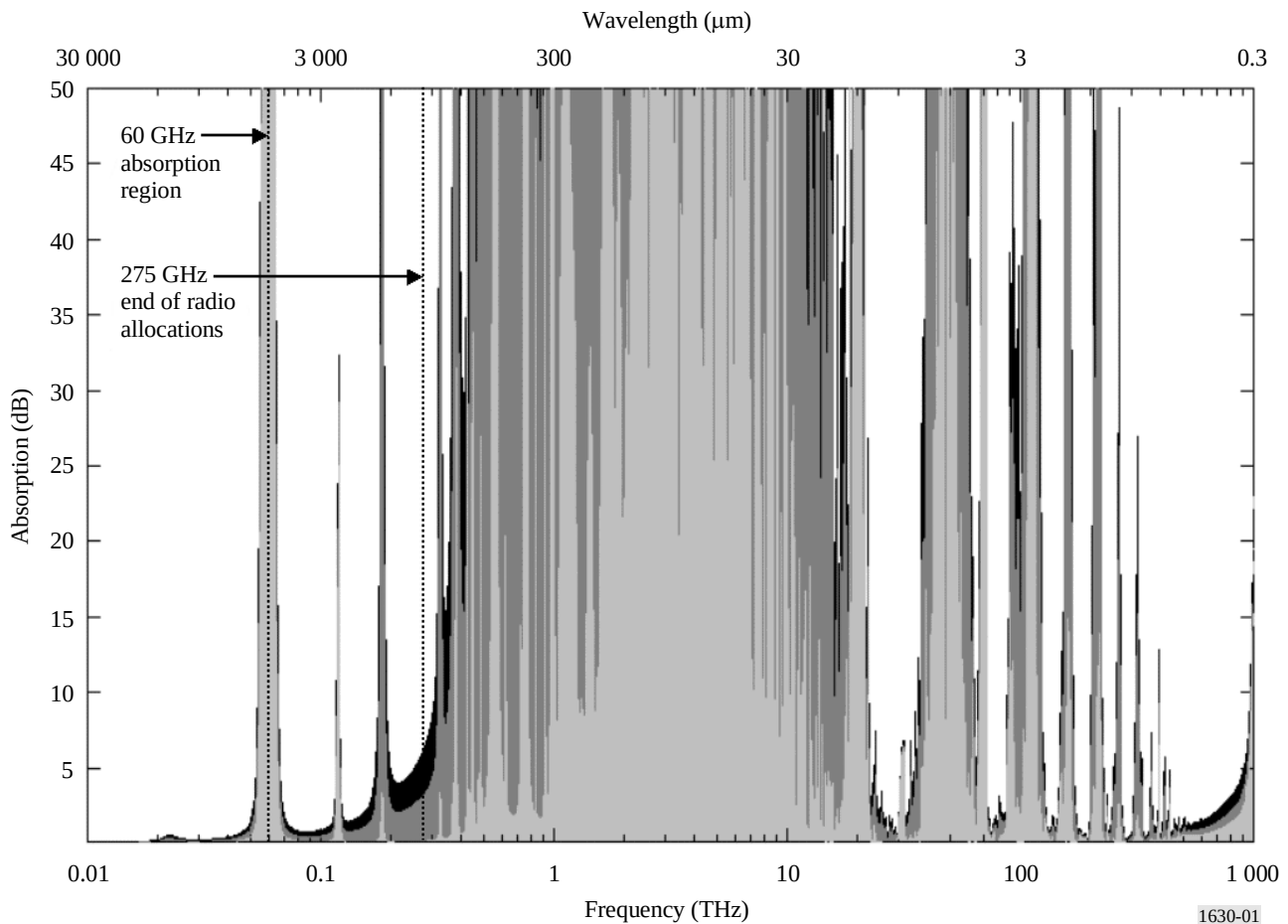
2 Bands of interest

Due to atmospheric constraints, the majority of the ground-based astronomical observations above the current 1 THz upper limit of provision No. 5.565 of the Radio Regulations occurs in approximately the 100 THz to 1 000 THz spectral range. Figure 1 illustrates the frequency dependence of the transmittance of the atmosphere along three zenith paths. The area shaded in light grey represents a high-quality site with dry air located at 5 km above sea level. The darker grey area shows the additional atmospheric absorption that would occur for a site located 2 km above sea-level (e.g. Kitt Peak). The black regions show the further impact of the atmosphere for a site located at sea-level. All paths utilize the temperature and pressure profiles of Recommendation ITU-R P.835. Absorption below 1 THz is calculated using Recommendation ITU-R P.676. The figure clearly shows that the atmosphere, except at some chosen, high-altitude astronomical sites, is opaque to electromagnetic energy at almost all frequencies between about 1 THz and 10 THz. Above 10 THz, the transparency of the atmosphere becomes favourable to observations of cosmic energy from the surface of the Earth. Above about 1 000 THz the atmosphere again becomes opaque.

The transmittance of the spectral region between 10 THz and 1 000 THz is shown in detail in Fig. 2 for the same three zenith paths. It is characterized by a series of windows of visibility separated by narrow but strong regions of absorption. The individual windows of visibility are limited in their transparency by a fine structure of many weak absorption lines. Individual absorption lines occur due to the presence of gaseous components in the atmosphere including, but not limited to: NH_3 , CO_2 , CO , CH_4 , NO_2 , NO , O_2 , O_3 , SO_2 , H_2O , and various chlorofluorocarbons. Several of these gases, which are significant to astronomical observations between 10 THz and 1 000 THz, are not currently considered in existing ITU-R propagation Recommendations. The strength of the absorption lines is generally dependent on temperature and pressure. As the strength and width of these lines is variable, bands of interest to ground-based optical astronomers include all spectrum between about 10 THz and 1 000 THz.

FIGURE 1

Absorption (shaded area) of a standard atmosphere along a vertical path



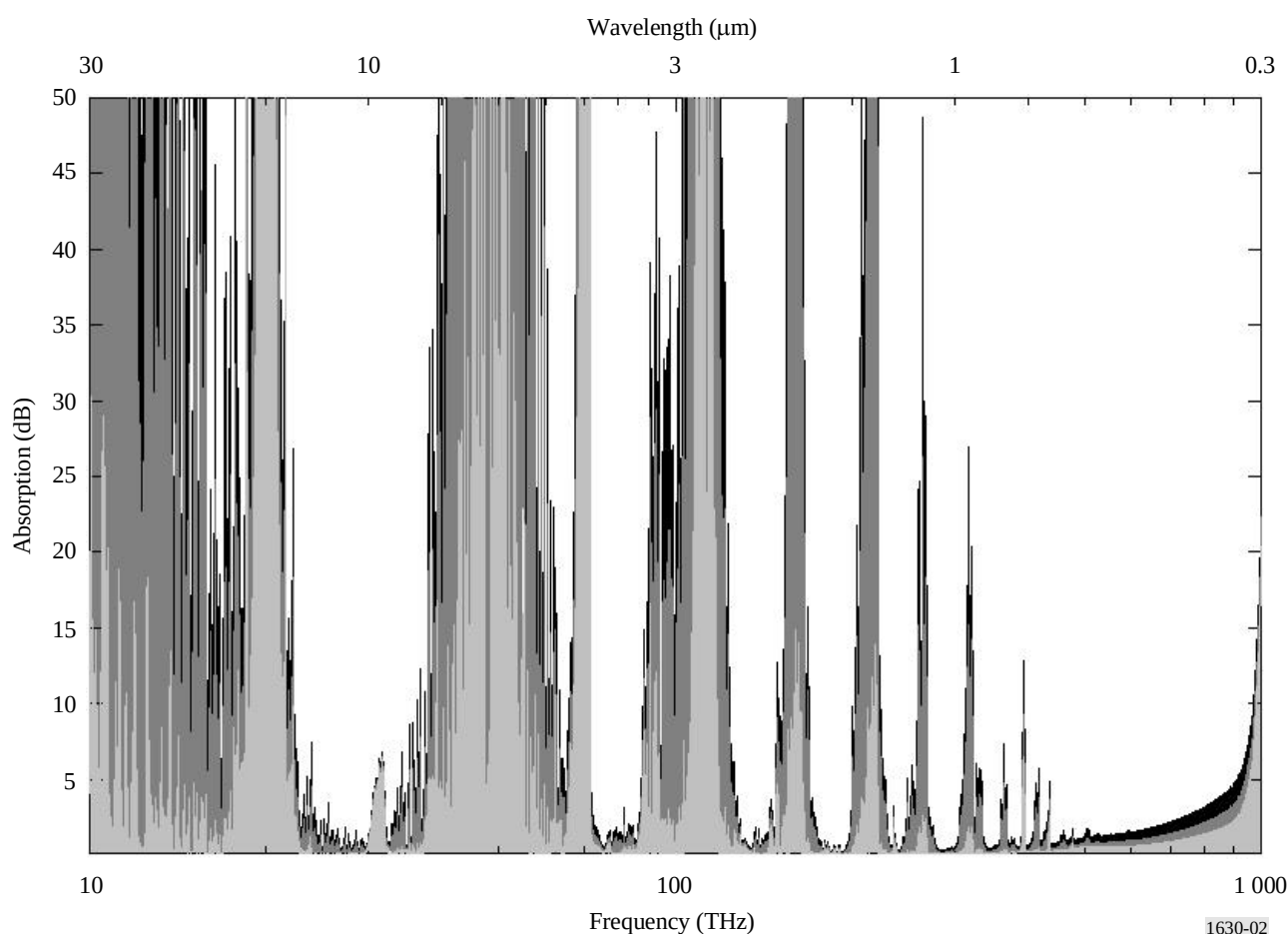
Access to more spectrum is available through the use of airborne observatories, such as balloons and aircraft, dedicated to astronomical observations. In order to have broader access to this astronomically important range, space-borne observatories such as the Hubble Space Telescope are used.

3 Types of observations

Some of the observations made in the spectral range between 10 THz and 1 000 THz frequency range are similar to those made in bands currently allocated to the radio astronomy service, namely measurements of continuum spectral power flux-density (spfd), spectral line properties (line spfd, Doppler shift and shape). One of the notable differences between astronomical observations made at frequencies below 275 GHz and in the frequency range between 10 THz and 1 000 THz is the much greater ease with which direct imaging may be carried out in the latter range, both in continuum and spectral line modes. The availability and sensitivity of detector arrays with several million pixels each, and photographic cameras, make this a widely used technique. Also, generally much wider bandwidths are used.

FIGURE 2

Absorption (shaded area) above 10 THz of a standard atmosphere along a vertical path



Astronomy data in the frequency range between 10 THz and 1 000 THz is collected using several measurement techniques. Each technique provides unique information about the object(s) being measured. Typical values used of parameters such as bandwidth, receiver sensitivity, observed field size and angular resolution are, in practice, dependent on the type of measurement performed.

Integration times commonly used vary widely, ranging from as short as 0.001 s to many hours, depending upon the stability of the atmosphere, the type of detector used and the characteristics and intensity of the emission being observed. Multiple individual measurements made using short integration times are often recorded digitally, and then integrated later to produce the sensitivity benefits of a long integration time.

3.1 Photometry

Photometry is the high-frequency analogue of continuum observations made in the radio astronomy bands below 275 GHz of the spfd of cosmic sources.

Measurements of the spfd in the frequency range between 10 THz and 1 000 THz generally consider all types of galaxies, stars, objects in the solar system and dust between, or around stars in a large variety of objects found throughout the Universe.