



Report ITU-R RA.2508-0
(10/2022)

Widely-distributed radio astronomy array systems operating above 200 GHz

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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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(Questions ITU-R 226-2/7 and ITU-R 257/7)

(2022)

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1 Introduction

Radio telescopes are designed to detect faint, naturally occurring, cosmic emissions. Radio telescope designs range from pure dipole antennas at low frequencies to shaped, often parabolic, reflectors. Because the angular resolution in radians provided by a single telescope of diameter D is approximately $1.22 \lambda/D$, where λ is the observing wavelength, radio telescopes require extremely large diameters to approach the spatial resolution of optical telescopes. While building a single telescope to achieve such spatial resolution is a challenge, it is possible to operate radio telescopes as an interferometer, where each telescope operates independently, and the recorded data are combined after the fact. Such distributed array telescopes can be designed specifically for such operations, such

as the Very Large Array (VLA), the Australia Telescope Compact Array (ATCA) the Very Long Baseline Array (VLBA), and the Square Kilometre Array (SKA) at centimetre and millimetre wavelengths. It is also possible to combine telescopes, even telescopes designed as arrays themselves, that normally operate independently. Recently, a collaboration was formed to conduct interferometric observations of the nearest and brightest black holes using radio telescopes located around the world observing at frequencies higher than 200 GHz, resulting in unprecedented high spatial resolution images of the black hole at the centre of M87 that captured the imagination of astronomers and the general public alike in 2019. This Report describes the technical and operational characteristics of this distributed array system that is denoted as the Event Horizon Telescope (EHT) and consists of individual radio telescopes, some of which operate as arrays themselves, located in Europe, North and South America, and the South Pole.

2 Radio telescopes as interferometers

As noted above, the angular resolution in radians provided by a single telescope of diameter D is approximately λ/D , where λ is the observing wavelength. Smaller values correspond to finer angular resolution. An interferometer works analogously in that each pair of telescopes, known as a baseline, provides a portion of an effective aperture of a much larger telescope. The fringe spacing of a baseline is λ/B , where B is the length of the baseline (i.e. distance between the two telescopes) projected onto the plane perpendicular to the line of sight to the observed source (see Fig. 1). The part of the aperture covered by the baseline is often referred to as its (u,v) coverage, where u and v refer to the east and north components of the projected baseline length in units of wavelengths, respectively. The instantaneous (u,v) coverage of a single baseline is a point (and a conjugate point that provides no additional information), but the coverage of a baseline tracking a source over finite time is an arc in the (u,v) plane because the rotation of the Earth changes the projection of the baseline onto the plane perpendicular to the line of sight to the observed source (see Fig. 2).

An interferometric baseline acts as a spatial filter. Although it provides an angular resolution approximately equal to its fringe spacing, a baseline is insensitive to source structures that are larger than this angular size. Thus, a single baseline provides only a small portion of the possible aperture, which is insufficient to image arbitrary source structures. As a result, interferometric arrays consist of a larger number of telescopes such that the baselines span a wide range of lengths and orientations. An interferometer with N telescopes simultaneously observing a source provides $N(N-1)/2$ independent baselines. The locations of the telescopes are generally chosen to provide suitably even coverage in the (u,v) plane, given constraints on topography and expected atmospheric conditions.