GIANT EQUATORIAL RADIO TELESCOPE*

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Abstract. A giant radio telescope for observing galactic and extragalactic radio sources at metre wavelengths is proposed. By locating a parabolic cylindrical antenna at a site close to the Equator such that its axis lies parallel to earth's axis, it is possible to construct a large collecting area economically. The proposed instrument will be very powerful for studying compact and diffuse features of radio sources, monitoring their variability, recombination and deuterium line work, studies of interplanetary medium and pulsar search.

1. Introduction

High-resolution studies of radio sources at meter and longer wavelengths of the electromagnetic spectrum provide vital information on the energetics of the most powerful radio emitters. Many existing radio telescopes provide high frequency (i.e., cm wavelengths and above) data on these sources. The need for a sensitive and high resolution radio telescope operating at meter wavelengths has long been felt which could throw more light thus covering a wide range in the radio frequency.

The nature of radio galaxies and quasars are still intriguing to understand their energy mechanism. The high resolution studies on radio galaxies indicate very intense emitting regions in them which may play an important role in the evolution of radio sources. To study these intense hot spots we need resolutions of 0.1 to 1 arc sec. These hot spots reside in broader lobes of a few arcsecs in angular size. One of the ways of achieving high resolution in radio astronomy is to use the method of lunar occultation. The Giant Equatorial Radio Telescope efficiently exploits the essence of this method to achieve high resolution.

We here present the salient features of the Giant Equatorial Radio Telescope which is proposed to be constructed as a colloborative effort among developing countries.

2. Design Considerations of the Giant Equatorial Radio Telescope

In a year the Moon covers about 1% of the sky and by restoring the diffraction pattern which is observed when a radio source gets occulted by the Moon's limb, a strip scan across the source is obtained. The resolution obtained depends upon the signal to noise

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ratio of the observations which is a function of the size of the antenna and receiver bandwidth. Within a few years, occultation observations of several hundred extragalactic radio sources with resolution of about 0.1 to 0.5 arc sec at meter wavelengths could be achieved. The radio telescope should have an effective area of about 60 000 m^2 and be steerable $\pm 30°$ in declination and about ± 6 hr in hour angle to track the Moon continuously every day. For a successful occultation observation the antenna beamwidth be made larger in the east–west direction and much smaller in the north–south direction. Apart from these, the antenna should have phase-switched outputs for minimising the changing baseline due to the Moon's brightness temperature.

So the telescope will be a long parabolic cylinder oriented in the north–south direction with the axis of the telescope made parallel to the axis of the Earth. This will accomplish an equatorial mount and a source can be followed for ± 6 hr by a simple mechanical rotation. The cost of such a telescope will be much lower than a parabolic dish of equivalent collecting area.

The antenna part of the proposed GERT consists of a 2 km long and 50 m wide parabolic cylinder. Since the north–south size of GERT is 2 km, it should preferably be located at the equator or very close to it, so that the slope required to facilitate equatorial mounting is reasonably small.

The reflecting surface of the parabolic cylinder will be a mesh of about 3 cm × 3 cm size made out of stainless steel wires of about 0.4 mm in diameter. The mesh will be supported by a grid of parallel stainless steel wires or ropes each 2 km long and placed every 1 or 1.5 m apart along the curved surface of the cylinder. These ropes will be supported by about 86 equidistant parabolic frames about 24 m apart.

Each wire will be given a suitable tension so that the maximum sag of the mesh for zero wind speed is only about 30 mm thus allowing operation up to about 50 cm wavelength. The bolted galvanised structural steel will have a total tonnage of about 2500 tonnes. The 86 parabolic frames would be connected together to a 2-km long drive shaft through suitable gear reduction boxes driven by about 10 electric motors of about 25 HP each for slewing and by one servo motor of about 10 HP for tracking.

The telescope will be operating at two frequencies, 325 MHz and 38 MHz. A rotatable feed with orthogonal dipole arrays with two independent receiver systems will facilitate observations at these frequencies including polarization. At 325 MHz there will be about 4000 dipoles along the focal line and the beam steering in declination will be done electronically by means of a 4 bit-diode phase shifter. The diode phase shifters will provide very rapid steerability in the range of $\pm 45°$ in declination.

The electronics systems for GERT will use the latest technology in VHF, UHF communication engineering. It will fully utilise the facilities provided by the large collecting area of GERT. At 325 MHz, the 4000 dipoles along the focal line will be divided into 84 blocks of 48 dipoles in each block. Each block will be followed by low noise RF amplifier with a bandwidth of about 12 MHz, a mixer and an IF amplifier at 38 MHz. The system temperature will be about 175 K at 325 MHz. But this could be reduced to 140 K if each of the 4000 dipoles is followed by a low noise RF amplifier and a phase shifter.

The IF signals from every 2 adjacent blocks will be combined and brought to a central receiver room, further amplified and equalised in amplitude and phase across the band. A multichannel digital delay line system and a digital correlator (1722 channels) system will provide outputs of all possible interferometer pairs made out of 42 sections of GERT. A computer processing of these data will produce about 80 independent beams at 325 MHz displaced by about 0.45 arc min apart in the north–south direction. Certain interferometer pairs will be suppressed by suitable weighting during computer processing to minimize the effect of the Moon's drift.

The bandwidth of the 80 independent beams will be restricted to about 7 MHz. In addition, the 42 outputs of GERT, each of 12 MHz bandwidth will be combined in an analogue manner to provide a few phase-switched beams with a multichannel receiver, each channel with a bandwidth of about 50 kHz, and a similar system at 38 MHz too. A de-dispersion receiver along with the above mentioned multiband receivers will be built exclusively for pulsar work. The proposed receiver will be easily adaptable to a line receiver system or a synthesis interferometer. The development effort in modern electronics will provide excellent experience and training for a large number of young engineers and scientists from the participating countries.

3. The Synthesis Radio Telescope around GERT

The second phase of development involves construction of a synthesis radio telescope around GERT which will be spread over an area of 14 × 12 km. Fouteen low-cost antennas of size 50 × 15 m will form the array. Such an array will provide a resolution of about 10 × 10 arc sec for sources of declination beyond 30°. The array configuration will be optimised in such a way we get a good resolution of 10 × 20 arc sec even for zero degree declination sources.

The spatial frequency coverage of a synthesis instrument is an indication of the quality of instrument. As we see from the figures the percentage of UV cells covered over a 12 hr observation is quite high. The rms sensitivity of the synthesis telescope will be about 50μ Jansky (1 Jy = 10^{-26} W m^{-2} sr^{-1}) which means the array is one of the most sensitive one at meter wavelengths and comparable to its counterparts operating at cm wavelengths. However the limitation to the dynamic range of the instrument may be due to the rms phase and amplitude errors caused by the varying ionosphere. But the recent results on closure phase method and self calibration procedures give encouraging indications that ionospheric problems could be alleviated and the attainable dynamic range will be greater than 25 dB. Another way of reducing the ionospheric problems is to have frequent calibration. This will be feasible because of the fast declination suitching that can be accomplished by the diode phase shifters.

4. Scientific Programs with GERT

As mentioned earlier, the lunar occultation observations on several hundred weak radio sources with less than arc sec resolution will provide enormous amount of data with which we can study in detail;

(a) the energetics of radio galaxies,

(b) the evolution of radio galaxies,

(c) the evolutionary trend of hot spots.

Apart from extragalactic radio sources, lunar occultation observations can give fine-structure studies on galactic radio sources and also of nearby galaxies.

The lunar occultation strip scans will be supplemented by the full synthesis maps from the synthesis radio telescope around GERT.

The interferrometer system will be extremely useful to map extended sources with low surface brightness such as halo around spiral galaxies etc.

5. The Fast Survey

The versatality of GERT includes its great ability to survey 40000 radio sources within 24 hr! Such a fast survey when periodically performed will give a wealth of data on variable radio sources and may lead to discoveries of novae and supernovae in distant parts of our Galaxy.

6. Pulsars

The mechanism of pulsars is not yet clearly understood. Their distribution in the Galaxy is not uniquely established. The high sensitivity of GERT will enable to add atleast 400 new pulsars to the existing list of about 300 pulsars. And the time required to do the pulsar search requires approximately 1000 hr of telescope time. It may be possible to make such a search fully ON-LINE by using an array processor along with a powerful minicomputer.

7. Interplanetary Scintillations

The Interplanetary scintillation observations will provide valuable data on the interplanetary medium especially for regions which are close to the Sun or at high ecliptic latitudes and therefore not readily accesible to satellite probes. The high sensitivity and rapid steerability of GERT will allow monitoring of several hundred radio sources around Sun on a daily basis. The information will throw much light about the structure and characteristics of the solar wind. Also detection of travelling disturbances in the interplanetary medium is possible which provides early warning systems for geomagnetic disturbances.

The high sensitivity of GERT is ideally suited to study radio emission from several classes of stars and recombination lines at low frequencies from cold dense clouds. Another important line-work at meter wavelengths is the detection of the hyperfine transition of deuterium at 327.4 MHz. Besides, occultation of weak radio sources by planets could also be studied simultaneously at 327 and 38 MHz which would enable us to study their ionosphere and magnetosphere. Studies on cometary occultations are also viable programs with GERT.

Above all, the very large baseline interferometry at meter wavelengths with GERT and other antennas located in AFRO–ASIAN countries will enable us to study very compact components in radio sources with milli arc second resolution and extreme sensitivity. With the improvement in the closure phase techniques and self calibration procedure a high quality mapping using VLBI network is quite feasible.

8. Conclusions

GERT is proposed as a collaborative effort among developing countries and construction of such a telescope should train many engineers and scientists in the sophisticated art of constructing antenna systems and extremely sensitive electronic hardware. GERT has flexibility in its design in order to obtain optimum performance. The initial feasibility study indicated the project can be completed within five years with the material and technology available in developing countries. Preliminary surveys were conducted for a possible location of GERT in West Sumatra, Indonesia. Two sites were identified closer to equator with the site near Piobang closer to the town Bukittinggi being a promising candidate. The preliminary seismitivity study by Indonesian experts reveal that a suspected seismitivity fault running down this proposed site is not active.

A scientific committee has been formed in Indonesia for project GERT. More discussions and formal approaches are planned by the participating countries in the near future.

The IAU and UNESCO and the Governments of the Republic of Indonesia and India are extremely interested in this astronomical project by developing nations. When completed, GERT will be one of the foremost experimental facilities available to the astronomical community.

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