The Robert C. Byrd Green Bank Telescope

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Abstract. The Robert C. Byrd Green Bank Telescope is the world's largest fully steerable radio telescope. Here we describe the current and future capabilities of the GBT.

THE GBT

The Robert C. Byrd Green Bank Telescope is the world's largest fully steerable radio telescope. The Green Bank Telescope (GBT) is located at the National Radio Astronomy Observatory's site in Green Bank, Pocahontas County, West Virginia (79° 50′ 23.40″ W, 38° 25′ 59.23″ N).

The GBT is described as a 100-meter telescope, but the actual dimensions of the surface are 100 by 110 meters. The overall structure of the GBT is a wheel-and-track design that allows the telescope to view the entire sky above 5 degrees elevation. The track, 64 m (210 ft) in diameter, is level to within a few thousandths of an inch in order to provide precise pointing of the structure while bearing 7300 metric tons (16,000,000 pounds) of moving weight.

The GBT is of an unusual design. Unlike conventional telescopes, which have a series of supports in the middle of the surface, the GBT's aperture is unblocked so that incoming radiation meets the surface directly. This increases the useful area of the telescope and eliminates reflection and diffraction that ordinarily complicate a telescope's pattern of response. To accommodate this, an off-axis feed arm cradles the dish, projecting upward at one edge, and the telescope surface is asymmetrical. It is actually a 100-by-110 meter section of a conventional, rotationally symmetric 208-meter figure, beginning four meters outward from the vertex of the hypothetical parent structure.

The GBT's lack of circular symmetry greatly increases the complexity of its design and construction. The GBT is also unusual in that the 2,004 panels that make up its surface are mounted at their corners on actuators, little motor-driven pistons, which make it easier to adjust the surface shape. Such adjustment is crucial to the high-frequency performance of the GBT in which an accurate surface figure must be maintained.

The GBT lies within both the National Radio Quiet zone and the West Virginia Radio Quiet zone. The National Radio Quiet Zone (NRQZ) was established by the Federal Communications Commission and by the Interdepartment Radio Advisory Committee to minimize possible harmful interference to the National Radio Astronomy Observatory

(NRAO) in Green Bank, WV and the radio receiving facilities for the United States Navy in Sugar Grove, WV. The NRQZ encloses a land area of approximately 13,000 square miles near the state border between Virginia and West Virginia.

In the following Figures (1-3) and Tables (1-3) we show the current and planned future capabilities of the GBT. Note that at L-band, only Arecibo is dramatically more sensitive to point sources than the GBT. The GBT has similar sensitivity to the EVLA system. For extended sources, the GBT is more sensitive than any other telescope. This does not take into account the excellent dynamic range and clean beam of the GBT improve its performance beyond what numbers can readily show.

Further information on the GBT can be found at http://www.gb.nrao.edu

THE FUTURE

A larger number of possibilities exist for the long term future of the GBT. Potential projects include beam forming arrays, an increase in the number of (conventional) focal plane array systems, better (on-the-fly?) RFI mitigation, super-cooled wide feed low frequency receiver systems, etc. As the GBT is a public instrument, the path for future development and research on the GBT is driven by the astronomical community. As a result the GBT's development plan will continue to be shaped by the feedback we receive from the community and by the collaborations with University and other research groups which we can develop.

TABLE 1. Current GBT Capabilities

Frequency Coverage:	Almost complete from 200 MHz – 50 GHz Bolometer array from 84 – 92 GHz
Multiple backends:	Continuum (DCR, MUSTANG, CCB) Spectroscopy (Spectrometer, spectral processor) Pulsar (Spigot, BCPM, GASP, CGSR2) Other (Radar, VLBI)
Excellent optics:	High Efficiency Extremely good baselines Increased dynamic range Excellent polarization capability
Excellent pointing precision:	1.5$''$ tracking error Increased efficiency
Low system temperature:	T_{sys}(1.4 GHz) = 17K
Good RFI environment:	Inside the National Radio Quiet zone Inside the West Virginia Radio Quiet Zone

TABLE 2. Future GBT Capabilities (Next Five Years)

Milestones	2009	2010	2011	2012	2013
84 - 92 GHz 64 pixel bolometer array	Shared Risk	Release		256 pixel upgrade[1]	
26-40 GHz analog spectrometer	Shared Risk	Release			
Dynamic Scheduling	Release I	Release II			
3mm Performance			30% Efficiency	Continued Improvements	
New pulsar backend	Release				
18-26 GHz 7 pixel focal plane array		Release			
Next generation spectrometer[1]			Release		
Digital IF[1]				Release	
18-26GHz 61-pixel FPA[1]					Release
80-115GHz 100+pixel FPA[1]					Release

[1]Funding for this project is not yet secured.

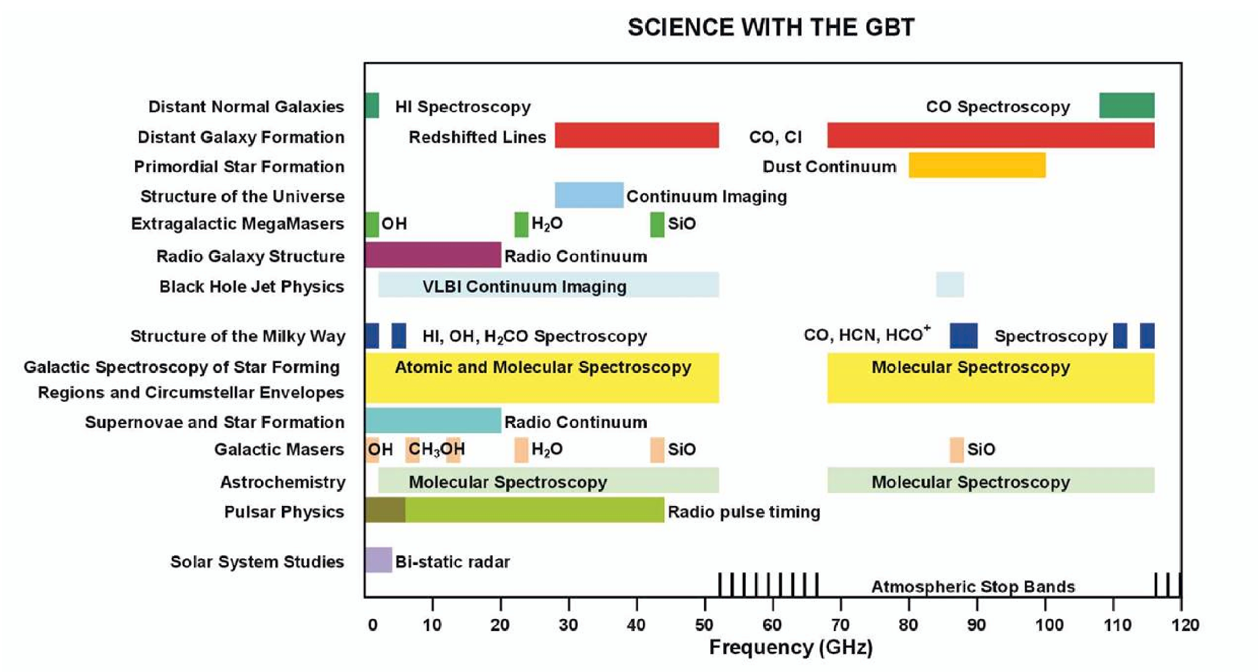

FIGURE 1. Current Capabilities of the GBT

TABLE 3. Telescope sensitivity comparison at L-band (1.4 GHz)

Telescope	Point Source sensitivity σ_s^1 (Jy)	Extended source sensitivity σ_t^2 (K)	Point Source Survey Speed SS_s^3 (sq. deg. s^{-1})	Extended source survey speed SS_t^4 (sq. deg. s^{-1})
GBT	1.00	1.00	1.00	1.00
Arecibo	0.29	1.50	12.4	0.45
Effelsberg	1.53	1.15	2.98	5.29
Parkes	3.51	1.18	2.45	21.8
Nancay	2.50	1.75	0.17	0.34
EVLA-D	0.98	1.30	10.9	0.00
EVLA-E	0.98	1.30	10.9	0.34
WSRT	2.01	1.35	2.60	0.00
GMRT	1.15	3.80	5.11	0.00
GMRT-CS	2.30	3.80	1.28	0.00
ATCA	6.96	1.60	0.26	0.00
ATA-42	15.71	2.20	1.08	0.01
ATA-350	1.89	2.20	74.5	0.01
ASKAP	2.36	1.75	202.	0.00

Note that all numbers in this table are relative to the GBT performance and are not absolute numbers.

See https://wikio.nrao.edu/bin/view/GBT/GBTSensitivityComparison for further details on the calculations and assumptions made.

[1] $\sigma_s \frac{T_{sys}}{G\sqrt{Btn_p}}$ where T_{sys} is the system temperature, G is the gain and is defined as $G = \frac{A\eta_a}{2k}$ where A is the total geometrical area of the telescope, η is the aperature efficiency, and k is the Boltzmann constant, B is the bandwidth or channel width, t is the integration is the number of polarizations. This formula applies when the source is much smaller than beam of the telescope.

[2] $\sigma_t = \frac{T_{sys}}{\sqrt{Btn_p}}$ with the same definitions as above. This formula applies when the source is comparable to the beam of the telescope in question.

[3] $SS_s = FBn_p(\frac{G\varepsilon_c\sigma_s}{T_{sys}})^2$ [square degrees per second] where F is the field of view and ε_c is the correlator efficiency. Note that the gain, G, is for the entire telescope. This is the gain per antenna times the number of antennas for an interferometer (for a large number of antennas).

[4] For a single-dish: $SS_t = FBn_p(\frac{\varepsilon_c\sigma_s}{T_{sys}})^2$ [square degrees per second]. For an interferometer: $SS_t = FBn_p(\frac{\varepsilon_c\sigma_s}{T_{sys}})^2 f^2 \varepsilon_s^{-2}$ [square degrees per second] where $f = \frac{A\eta_a N}{\frac{\pi}{4}L^2}$ with L equal to the longest baseline, A is the area of a single antenna, and N is the number of antennas within L; and ε_s is and N is the number of antennas within L; and ε_s is the synthesized aperture efficiency and is equal to 1 for the synthesized aperture efficiency the synthesized aperture efficiency and is equal to 1 for uniform weighting and proportional to $(1/\theta)^2$, so for the VLA with natural weighting it is equal to 0.43. For interferometers, it is assumed that the antennas are in their most compact configuration possible, except when otherwise noted.

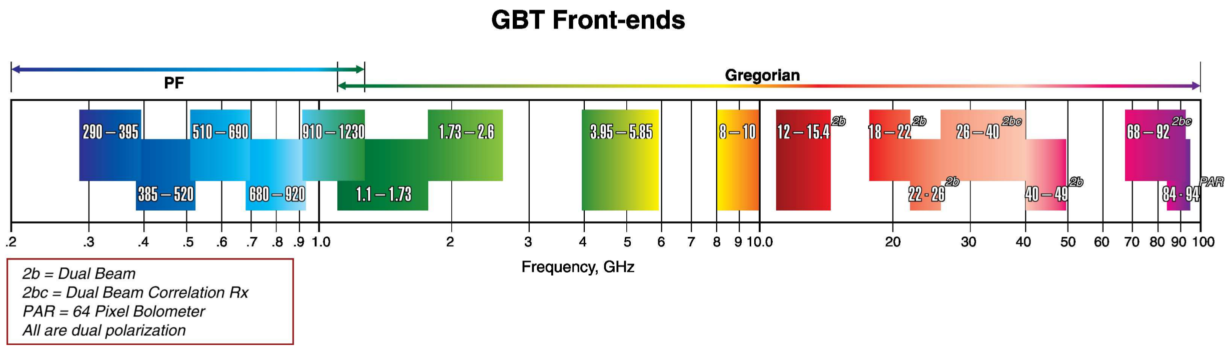

FIGURE 2. Current Frequency Coverage of the GBT

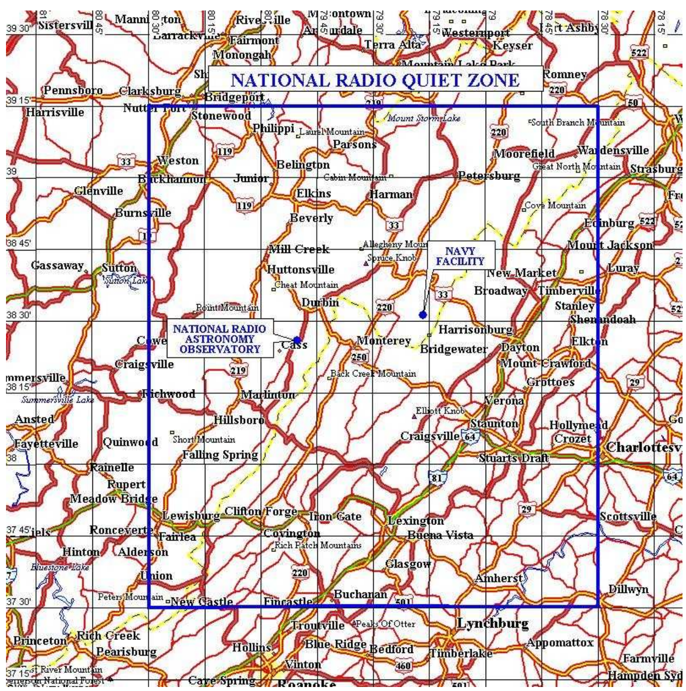

FIGURE 3. Map showing the approximate boundaries of the National Radio Quiet Zone

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