The GBT Field of view for Focal Plane Array Receivers

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This note is a slightly revised version of a memo circulated in draft form in September 2009. It gives some expectations about the performance of conventional, feed-based focal plane arrays (FPAs) on the GBT at several frequencies. There are many factors affecting their performance including the precise feed horn design (see Srikanth 2009, GBT memo 262). The aim here is to provide some general numbers that can be used to estimate the size of possible arrays. Data were taken from GBT memos 55, 155, 198, 199, and 262 by Srikanth, Norrod, and Norrod & Srikanth, and from Srikanth's presentation at the KFPA conceptual design review of Feb 2008.

Background: At the Gregorian focus the GBT has a focal length of 190 meters and a focal ratio f=1.9; in that focal plane the scale is ≈11" per centimeter. The Airy disk formed in the focal plane from a point source in the far field has a diameter to first null of $A_D=2.44\lambda f$. About 84% of the incident radiation falls within this area. This, then, is the approximate inside diameter of an FPA feed horn, where λ is the longest wavelength to be covered by the array. The Nyquist sampling interval in the focal plane is λf/2, or a factor 4.9 smaller than A_D. Thus even if the feed horns had infinitesimal thickness, the array filling factor would be $\approx 4.9^{-2} \approx 4\%$ for rectangular packing. The size and the spacing of the actual GBT KFPA feeds is 10-20% larger than A_D.

The array sizes were matched such that the worst performing element -- aways in the outermost ring of feed horns -- had an aperture efficiency, and thus point source gain, reduced to 87% that of the central element. This is accompanied by a beam broadening of typically 5%. The asymmetry of the GBT causes the aperture efficiency to be a function not only of distance from the focal point, but of angle as well. For the 22 GHz FPA listed here, the efficiencies relative to the central element vary between 87% and 96% around the outermost ring of feed horns.

The table below assumes a beam spacing on the sky of 2.7 HPBW (1.12 AD) which is the value measured for the KFPA at 22 GHZ. This gives all arrays a filling factor of 2.5%; it takes 40 pointings to achieve Nyquist sampling of the area covered by an array. The array "Footprint" is the maximum angle on the sky between feeds, and the number of feeds is taken to be the area of the footprint divided by the beam spacing. The amplitude of the coma lobe for the worst-performing array element is also given. The last column gives the approximate physical diameter of the array.

Freq (GHz)	Pixels	Footprint	HPBW	Worst Coma	Diameter
22	91	15.8’	34″	-20 dB	~36 in.
46	500	18.1’	16″	-15 dB	~40 in.
90	800	12.0’	8.3″	-15 dB	~30 in.