MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HAYSTACK OBSERVATORY
WESTFORD, MASSACHUSETTS 01886

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Telephone: 781-981-5407
Fax: 781-981-0590

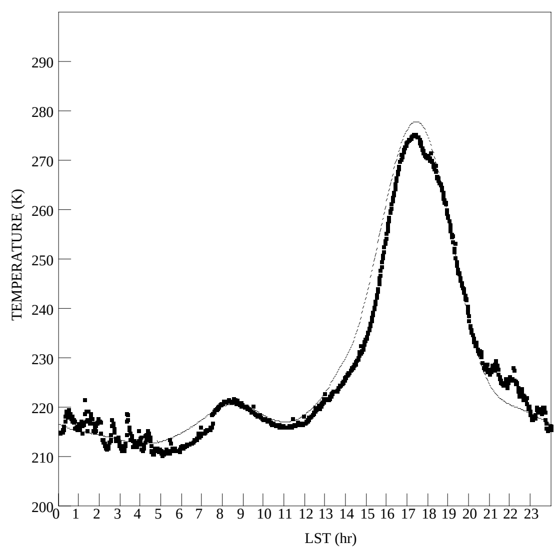
To: RFI Group

From: Alan E.E. Rogers

Subject: Antennas for RFI monitor

1] D1 array monitor

The D1 RFI monitor is extremely sensitive to spectral RFI owing to its high spectral resolution and 80% spectral processing efficiency. In addition the active Yagi antennas have about 13 dBi gain and a noise temperature of about 300 K (i.e. about 180 K plus 40K amplifier noise plus 80K sky noise). The sensitive to continuum is limited by our ability to distinguish continuum noise from changes in gain as there is no “Dicke” switching. In a 24 hours integration the 1 sigma noise in 244 Hz resolution spectra is about 0.1 K so that a 1 K interference temperature is easily detected. The sensitivity to continuum is harder to quantify. Certainly a 10 K change can be seen but a constant 100 K could go undetected. Figure 1 shows a plot over the power from the Yagi pointing South compared with a sky model.



The thin light trace is the predicted temperature obtained from the sky model. The figure shows that despite the lack of load switching the gain is stable enough that continuum RFI is quite apparent at the 5 to 10K level or an equivalent RFI temperature (for an isotropic antenna) of under 1K.

2] Broadband RFI monitor

The FCC definition of interference temperature is vague in that it states that it is the power received by an “antenna” in units of Kelvin. They go on to talk of an interference temperature density as the antenna temperature per unit collecting area. I think it would be better to convert the antenna temperature for a particular antenna to that which would be received by an antenna with 0 dBi gain. In this case the D1 monitor sensitivity would be 0.005 K for spectral line and 5 K for continuum by dividing by the 13 dBi gain.

If we assume that all RFI comes from the horizon, an ideal RFI monitor antenna would have a large gain at the horizon. This could be accomplished, as it is in the D1 monitor, by having a number of directional antennas whose data are simultaneously processed. This has the added advantage of providing added information on the direction to the RFI.

The sensitivity of a monitor to continuum RFI could be enhanced by correlating the signals received at separated antennas or by accurate calibration. For simplicity we have chosen to load switch to remove gain variations in the analyzer and we are looking for an omnidirectional antennal that has more than 0 dBi gain at the horizon along with low VSWR to reduce the effects of reflections of receiver noise.

The maximum magnitude of the errors in antenna temperature measurement is approximately

$$\Delta Ta \sim T_{amb}\left(1-L\right)\left|\Gamma_{amp}\right|\left|\Gamma_{ant}\right| + T_N \rho \left|\Gamma_{ant}\right| + T_{ant}\left(1-\left|\Gamma_{ant}\right|\right)^2$$

where T_{amb} = ambient temperature

T_N = LNA noise temperature

T_{ant} = antenna temperature

Γ_{amp} = LNA reflection coefficient

Γ_{ant} = antenna reflection coefficient

= $(VSWR-1)/(VSWR+1)$

L = cable loss factor (L=0.8 = 1dB)

ρ = correlation between outgoing and input noise in LNA (typically ρ ≈ 0.5)

Unfortunately it is not easy to make or purchase an antenna which covers 30 to 1500 MHz, has more than 0 dBi gain at the horizon and VSWR under 3:1. The following antenna types have been examined:

Antenna type	Model	VSWR 100-1500 MHz	Horizon gain 100-1500 MHz	Comments
Discone	Diamond D-130 J	< 3.5	>-5 dBi	Main beam tends to point down below horizon at higher frequencies
“double” discone	Thunderpole	?	?	Not yet received
Coaxial dipole	R&S HK033	<2.4	>0 dBi	Expensive
UWB monopole	EZNEC simulation	<3	>2 dBi	Large mechanical structure

Comments on the antennas

a) Discone

The discone is an approximation to a double cone. The infinite double cone is a truly broadband antenna whose pattern and match is frequency independent. The bicone requires a balanced excitation. The equivalent single cone suitable for direction connection to a 50 ohm coax is a cone over an infinite ground plane. When the ground plane is reduced it becomes the disc of the discone. The disc is connected to the inner conductor of the coax making an antenna that has a poor match and poor patterns which tend to illuminate the ground rather than the horizon.

b) “double discone”

This is really a bicone given the wrong name. In practice the cones are replaced by spokes which approximate the cones. This is an awkward mechanical arrangement and consequently is not readily available.

c) Monopole

This antenna is like a discone with the cone part driven by the center conductor making this antenna a closer approximation to the bicone. Several recent papers describe development of the monopole and the “volcano smoke” antenna (another approximation to the bicone).. See for example

“An omni-directional and Low-VSWR antenna for Ultra-wideband Wireless Systems” by Taniguchi and Kobayashi, IEEE Radio and Wireless Conference, 2002, p145-8. NEC simulations show that inverting the discone to make it a monopole makes the radiation pattern more like a dipole thereby improving the gain at the horizon.

d) Log periodic

A typical log periodic antenna has a gain of about 7 dBi with E-plane and H-plane beamwidths of about 70 and 110 degrees respectively. Since the antenna is directional we would need 8 antennas or a single rotatable antenna to cover the entire horizon. With a single channel receiver we could spend only about 1/8 of the time in each direction which degrades the sensitivity by a factor of about 3 but this loss is made up by the increased gain over a broadband omni.

However there may be advantages to either switching among a set of log periodic antennas or rotating a single antenna under computer control. One advantage is that we would acquire some directional information and another is that we would have a stronger signal thereby reducing the relative systematic errors.