# Sky Noise Drift Scans and Sky Noise Dominance

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## 1. Introduction

This report is a summary and conclusions from the sky noise drift scans that I made with the large blade dipoles on Bruny Island during the last nine months. I dismantled and stored the dipole before I went to the USA last April and do not plan to make any more tests during the next three months. Emil Polisensky has recently developed simulated drift curves that represent the data fairly well and it is appropriate to summarize this work at this point.

The main reason for taking drift scan data is that the analysis of these data seems to be the best way of getting at the vexing problem of determining the level of sky noise dominance over receiver noise. Because of the severe impedance mismatch between the dipole output and the preamplifier (active balun) input the straightforward noise calibrations used for matched systems are inappropriate. The drift curve idea is simple; if preamplifier noise dominates sky noise we should find little or no variation in the system output level with sidereal time. If sky noise dominates we will find a strong output variation as the Galactic Plane, especially the Galactic Center region, passes through the response pattern of the dipole. In intermediate cases we would expect to see a rise in output level near Center transit, ~17 to 18 hours LST, but then the curve would be flat during the remainder of the sidereal day. This concept will be quantified below. At the latitude of Bruny Island the sidereal variation is about maximal; the Galactic Center passes nearly overhead and at 2 to 4 hours LST the whole Plane is near the horizon. Thus the drift curve variation is somewhat easier to observe than at northern latitudes.

## 2. Drift Curve Data

I took many drift curve measurements on the large blade dipoles between December, 2005, and March, 2006. Intermodulation effects caused by strong low frequency RFI destroyed many of them and I tried a number of different receiver chain setups to reduce this problem. I did prove to my satisfaction that no modulation was occurring ahead of the first mixer in the HP spectrum analyzer at the heart of the system. I tried various configurations until I was satisfied that the gain ahead of the HP was sufficient that input noise completely dominated the system noise under all conditions while this gain was as low as possible to minimize intermodulation.

All of the intermodulation-free portions of the drift curves were essentially identical to within a few tenths of a dB at identical frequencies so I'm not bothering to display all of them. This could be done if there were any good reason to do so but, for now, I'll just show the results from two of the last runs taken in March. These data are shown in the plots below. Each pair of plots show the data from the two dipoles. Four frequencies are plotted for each dipole. I must admit to possible confusion over the labeling of these figures. When I dismantled the system in April I found that the cables to the E-W and N-S dipoles were labeled in reverse. I'm not certain just when this occurred; I think that these plots are labeled correctly but I have not replotted the previous data to try to sort out this problem. The observation parameters and methods of plotting were modified several times during the program so replotting the data is not straightforward at this point. However, I plotted the simulations for both the E-W and N-S dipoles on each plot. It is not particularly important to know which set of simulations go with which dipole; the simulations fit the data equally well or poorly in either case. I may reassemble the dipole and take another set of drift curve early next year in order to obtain a completely definitive set of data.

3. Simulated Drift Curves

Emil developed the drift curve simulations shown in the figures below. They are the latest in a series simulations of ever increasing sophistication. Such simulations require that the dipole response pattern at each frequency be convolved with a map of the Galactic background visible from the site. He used EZNEC to generate the response patterns with the dipole assumed to be over real ground with dielectric constant of 13 and a conductivity of 0.005 Siemens/m. This dielectric constant is about average for dry sandy or rocky soil . Maps of New Mexico also suggest that ground conductivities will vary from 0.004 S/m to 0.015 S/m. These ground parameters may not be ideal for Bruny Island and this might cause some small errors in the simulations.

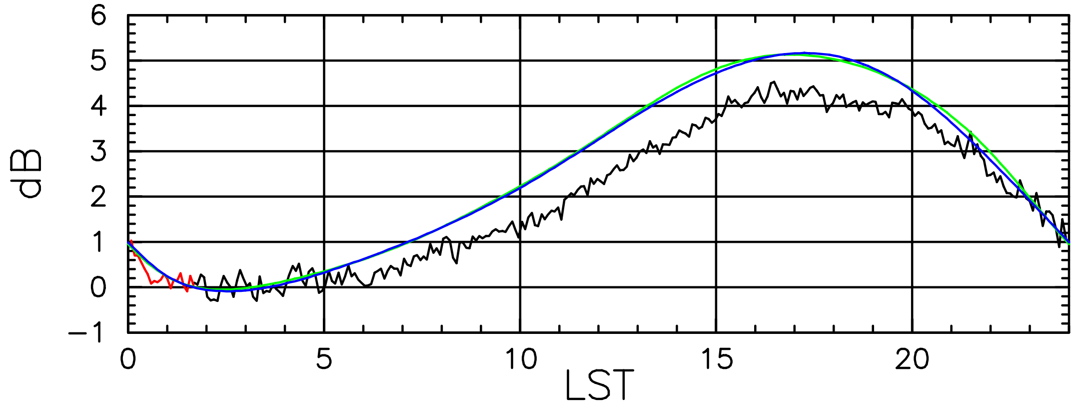
To produce the necessary Galactic background maps, Emil used the 408 MHz map of Haslam et al (1995) scaled to the observed frequency using spectral indices given by Platania et al (2003).

4. Drift Curve Plots

The data plotted below were made from 128 point spectra obtained with my RFI avoidance spectrometer at the rate of one scan per minute. Each frequency point was observed for 20 ms with a bandpass of 30 kHz. Each point in the displayed spectrum consists of an average of data from five scans and five frequency points, i.e. 25 data points, centered on the time and frequency shown.

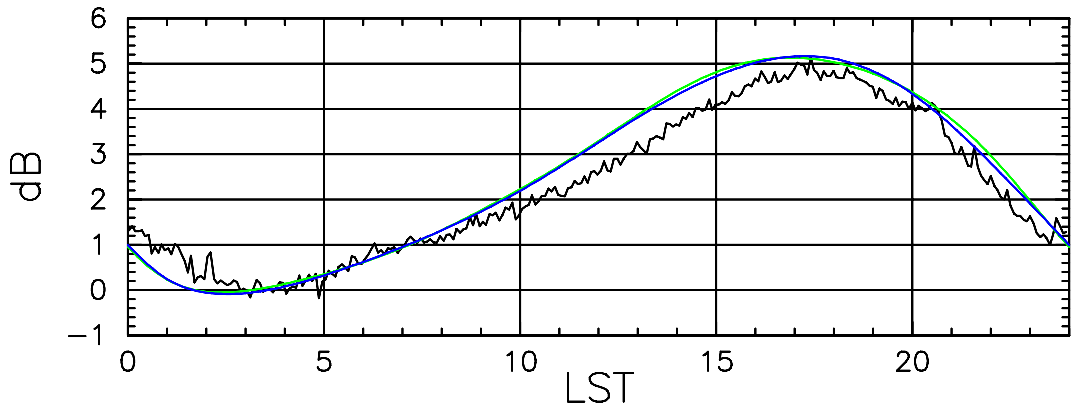
In the plots below, the noisy lines are the data; the smooth green lines are simulations for the E-W dipole and the blue lines are simulations for the N-S dipole.

scan16ac     03:49:10 on 03-18-2006



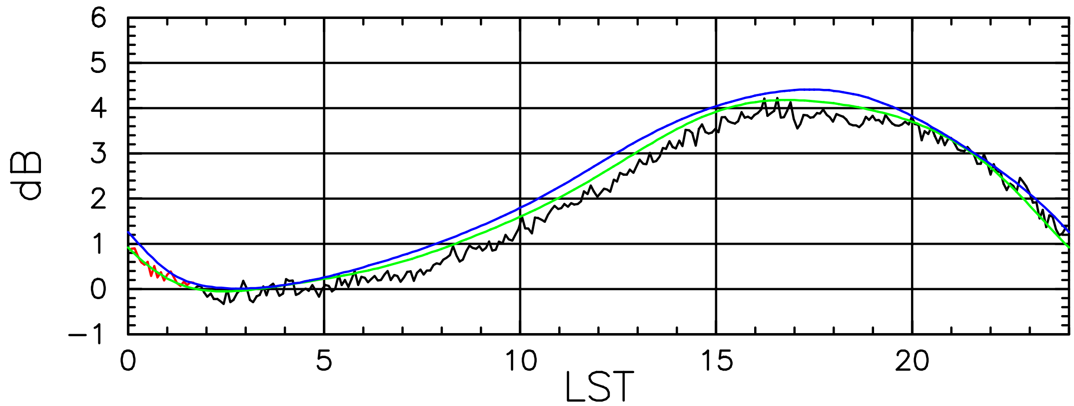

Large Blade Dipole, B Dipole (E-W)  30.31 MHz  Offset −46.3 dB
−45 degree arms, No ground screen
Hicks dual polarization balun+48dB,LR-1

scan17ac     02:12:45 on 03-20-2006



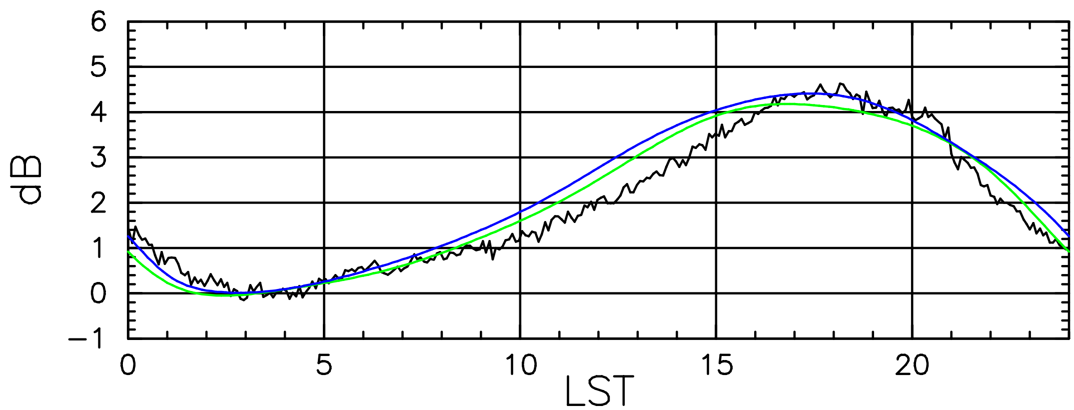

Large Blade Dipole, A Dipole (N-S)  30.31 MHz  Offset −45.6 dB
−45 degree arms, No ground screen
Hicks balun+48dB,LR-15,25MHZ HPF

scan16ad     03:49:10 on 03-18-2006



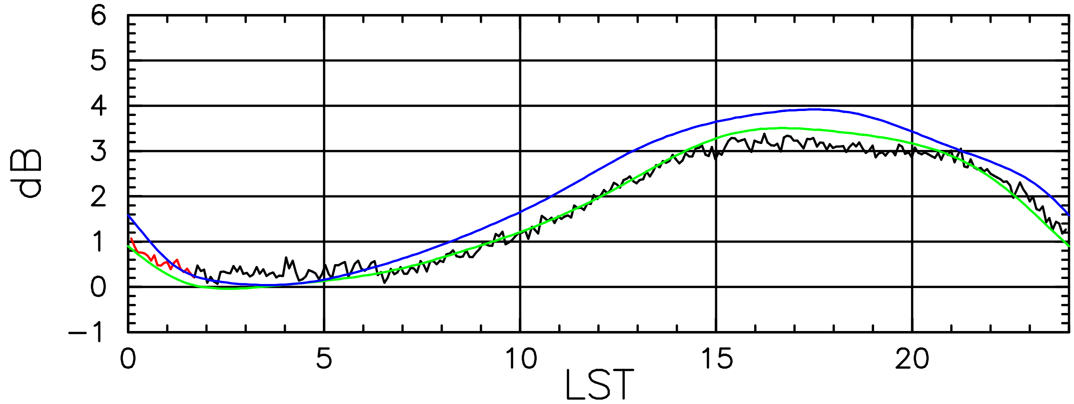

Large Blade Dipole, B Dipole (E-W)  60.00 MHz  Offset -36.4 dB
-45 degree arms, No ground screen
Hicks dual polarization balun+48dB,LR-1

scan17ad     02:12:45 on 03-20-2006



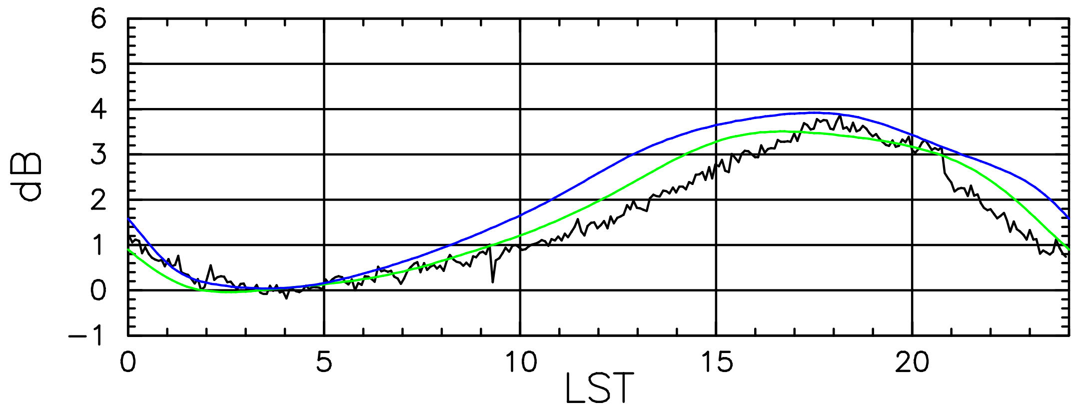

Large Blade Dipole, A Dipole (N-S)  60.00 MHz  Offset -36.4 dB
-45 degree arms, No ground screen
Hicks balun+48dB,LR-15,25MHZ HPF

scan16ae     03:49:10 on 03-18-2006

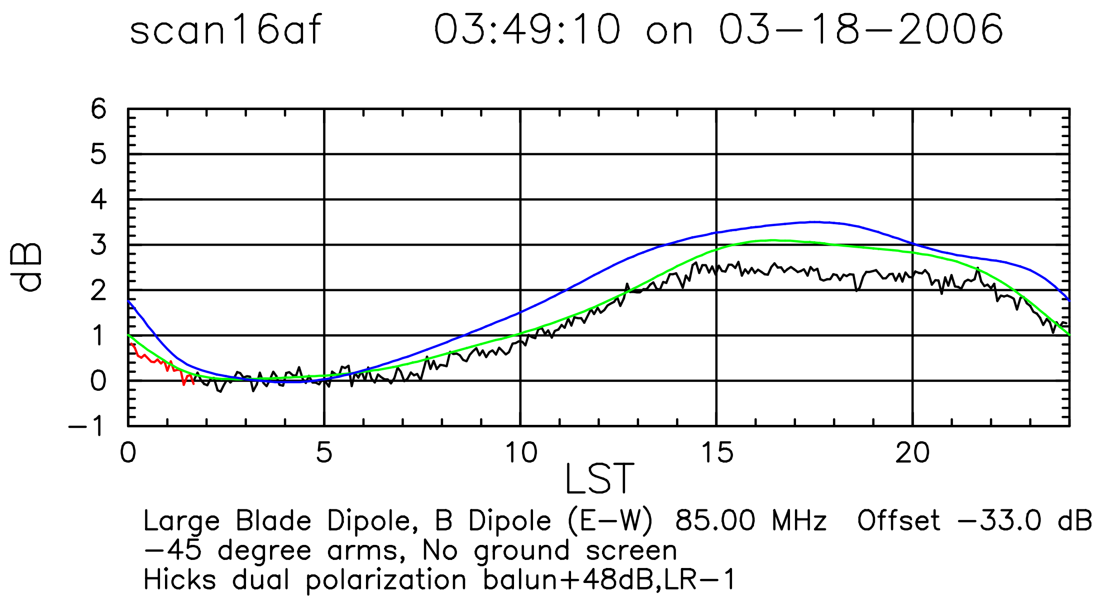


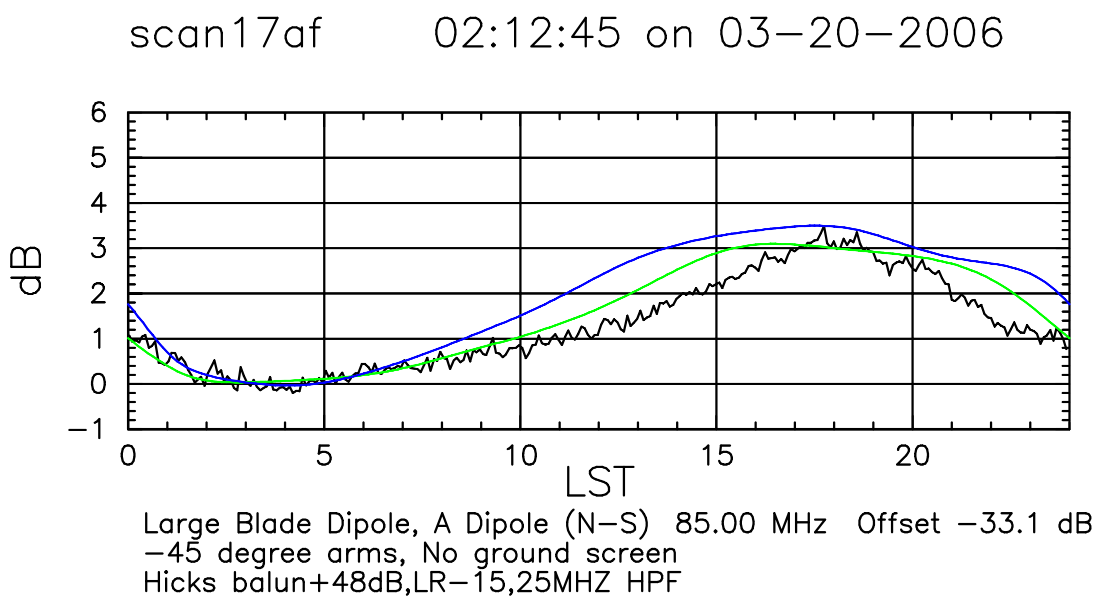

Large Blade Dipole, B Dipole (E−W) 75.23 MHz Offset −33.9 dB
−45 degree arms, No ground screen
Hicks dual polarization balun+48dB,LR−1

scan17ae     02:12:45 on 03-20-2006




Large Blade Dipole, A Dipole (N−S) 75.23 MHz Offset −34.2 dB
−45 degree arms, No ground screen
Hicks balun+48dB,LR−15,25MHZ HPF




5. Discussion and Conclusions

The plots show that the data and the simulations agree quite well. In no case is there an obvious flattening of the observed drift curve near its minimum, as would be expected if the sky noise dominance were low. At 30 MHz the data maxima are significantly below the simulations. At this frequency the sky noise is so intense that there must be high sky noise dominance and, presumably, this difference is caused by the significant HII absorption along the Galactic plane that is not modeled. The 60 MHz data and simulations agree the best, as might be anticipated since HII absorption is low at this frequency and the dipole response pattern is simple. At 75 MHz and 85

MHZ the fits are not very good. At these frequencies the dipole response patterns are becoming somewhat complex and, perhaps, EZNEC does not model them very well. Never-the-less, the peaks of the observed curves and the simulations are within 0.3 dB to 0.6 dB of each other.

The analysis of these drift curves can be made semi-quantitative:

Let, N = the (constant) balun noise contribution to the drift curve
S1 = the sky noise contribution at the maximum of the drift curve
S2 = the sky noise contribution at the minimum of the drift curve
S1 + N = the output level at maximum
S2 + N = the output level at minimum

D = S2 / N, is the sky noise dominance at minimum

R = (S1+N) / (S2+N), is the measured ratio between the maximum and minimum of the drift curve

Ro = S1 / S2, is the value of R if N = 0, i.e. infinite sky noise dominance; it is basically an unknown but it may be estimated from the simulations.

Consider R as defined above. Dividing the numerator and denominator by S2,

R = (S1 / S2 + N / S2)/(1 + N / S2) = (Ro + 1/D) / (1 + 1/D)

A bit of algebra leads to,

D = (R - 1) / (Ro - R)

R is measured, and we can estimate Ro from the simulations.

In the ideal case of very high dominance, R ~ Ro and the denominator, (Ro – R), approaches zero so that the exact value of D cannot be determined.

The fit between the data and the simulations at 75 MHz and 85 MHz is not good enough to warrant any detailed quantitative analysis but one can make crude estimates.

Making an eyeball average of the two dipoles at 75 MHz I get R ~ 3.45 dB = 2.21 and Ro ~ 3.70 dB = 2.34. These values lead to

D = 1.21 / 0.131 = 9.3 = 9.7 dB at 75 MHz

At 85 MHz I get R ~ 2.80 dB = 1.905 and Ro ~ 3.2 dB = 2.098, and with these values,

D = 0.905 / 0.184 = 4.9 = 6.9 dB at 85 MHz

The main consequence of a limited value for D is that it increases the integration time required to reach a given signal-to-noise ratio in an output map. We can easily estimate the ratio of the time required to obtain a given sensitivity with the real system, T, to the time required by an ideal, completely sky noise dominated system, To, to be

T / To = (1 +1/D)^2

The above values lead to T / To = 1.22 or a 22% increase at 75 MHz and to T / To = 1.45 or a 45% increase at 85 MHz.

Note that the reductions in sky noise dominance and the integration time increases apply to the periods of the sidereal day near Galactic minimum , i.e. ~ 4 hours LST. At other times of the day the loss of sensitivity will be lower. The minimum sky noise levels are essentially equal in the Northern and Southern Hemispheres, so these estimates should apply to New Mexico sites as well as to Bruny Island.

Note also that the projected discrete component balun would increase D by about a factor of three above that of the GALI-74 balun used for these observations. This would lower T / To from 1.21 to 1.07 at 75 MHz and from 1.45 to 1.14 at 85 MHz. I do not believe that these rather modest increases in sensitivity over a limited frequency range and a limited portion of the sidereal day justify the effort required to develop a new, lower noise balun unless the development work can be justified by substantial cost savings or reliability increases.

There is another way to make the estimates of sky noise dominance more certain. It would be a simple matter to design an LC network that would accurately match the dipole output to the balun input at a single fixed frequency such as 75 MHz. Then conventional thermal calibration methods could be used to determine the sky noise dominance. The dominance should be good in this case. This LC network should have essentially no effect on the dipole response pattern and, if drift curves are found to be the same with and without the LC network, good sky noise dominance would be assured. I would encourage people to try this technique and I may try it myself early in 2007.

REFERENCES:

Haslam, C.G.T., Salter, C.J., Stoffel, H., Wilson, W.E., 1995, NCSA Astronomy Digital Image Library.

Platania, P.; Burigana, C.; Maino, D.; Caserini, E.; Bersanelli, M.; Cappellini, B.; Mennella, A., 2003, A&A 410, 847.