Submillimeter Arrav Technical Memorandum

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Subject: Optically Assisted Pointing for SMA Antennas
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Background

It is evident from discussions to date that the guiding of the antennas is a critical issue in the performance of the array at the highest frequencies. Absolute pointing by the array antennas will not likely, by itself, be adequate for what we believe to the lirnits of this technology. Furthermore, pressing the limits of technology for absolute pointing is likely to be very expensive and could entail some risk, if other means are not also available. As a fall back approach, it is common to offset the antenna patterns from fixed sources in the same radio wavelengths to eliminate questions of co-alignment. The SMA, however, will be compromised by a limited aperture and the lack of calibration sources that can be acquired at these frequencies .

In order to maintain reasonable cost for the antennas and yet raise the likelihood of very accurate pointing and precise guiding, it is likely that we will need access to an optically assisted scheme that can make use of visible stars to augment whatever can be done by radio. At the very least this optical camera/tracker will be needed to help understand those portions of the mount model that are common to optical and radio. It will also serve as a vital diagnostic tool for understanding the servo performance, transient behavior and mount drift. We should also envision a role for an optical camera in the real time tracking problem.

Real time pointing and tracking assistance can take many modes, from using a full fledged image recognition program, to merely assisting the drive rates by a lock-and-hold technique. Even more combinations of technique are possible using both the radio and optical sources together. We will not to try to chose between the various options, since this discourse will continue over many years, even after the antennas are finished. The purpose of this short note is to calculate whether or not optically assisted pointing is indeed a viable option from the standpoint of available detectors and guide star brightness.

Guider Characteristics

Table 1 lists the characteristics of one commercially available CCD camera. This particular model comes from Photometrics, Inc. in Tucson, Arizona. Its cost is about $10,000 and is one of several detectors currently on the market. For a test calculation it has been married to a 10" aperture, F/10 telescope, such as a Celestron 10, thermal and mechanical stability questions aside. This combination results in a camera with a pixel size of about 1.9 x 1.9 arc seconds, not high enough for imaging, but an excellent scale from which to derive a fairly large field and a proportional guide signal.

Table 1: Characteristics of a Commercial CCD

Manufacturer	Photometric, Tucson
Model	Star I/A System
# pixels large axis	576
# pixels small axis	384
size	13 mm x 8 mm
pixel size	23 x 23 µm
dynamic range	16000/1
sensitivity	60% quant. eff.
thermoelect cooled	yes, to -30°C
dark current (e-/pix/sec)	-50
wavelength range	500-900 nm
Comm port	IEEE 488
chosen resolution per pixel (arc sec)	1.9
required focal length (m)	2.497
diameter of f/10 (cm)	25.
width of field (min)	12.
length of field large (min)	18.
sq min in field	222.
deg sq per sphere	41245.
sq min per sphere	148480576.
number fields in a sphere	669439.
av mag brightest star in field	10
star flux in photons/cm^2/sec/Å	0.14
energy collected photons / sec in 200 nm	135005.
predicted e-/sec	54002.
signal/dark current	-1000
Signal/ noise	-230

It is evident that the resulting guider would have approximately a 10th magnitude star in most fields and have ample signal, at least at night, to guide to small fractions of a pixel. There is sufficient sensitivity to consider much fainter objects in dark regions of the sky. Furthermore, the signal is sufficient to pursue even faster scan rates, although we would not want the antenna to be following the optical image motion. Generally, an observatory would not keep the huge data file necessary to list the locations of all the 10th magnitude stars; but there is no reason that we can not record the location of those stars that are near our calibration sources and study objects. This CCD device is computer controlled with a standard interface and would provide all of the flexibility necessary to pursue optical assistance from a guide telescope. The camera must be mounted in a very rigid portion of the backup support structure that is thought to be representative of the entire structure through modeling studies. One caution which did surface on the manufacturer’s data sheets is that the camera controller must be within 3 meters of the camera head during operations.

Let us presume from the above exercise that there are indeed many options on optically clear nights. Many of our most demanding observations will be made under these conditions. In the daytime the optical situation is much worse. Not only is the antenna likely to need more help, but the guide stars are fewer and farther between. A red 6th magnitude star is probably the faintest object which can be located in daylight conditions, and then only on clear days with the antenna pointing well enough to put the image “close”. The average distance to any sixth magnitude object is over a degree. Except for special cases this large distance will eliminate help during tracking or offset pointing within the guide field. The optical options for daylight would reduce to antenna offsets from brighter stars using the knowledge of the difference between the radio and optical beams. Whether or not this type of optical offsetting will out perform direct offsets from the even more distant radio sources is yet to be determined.

Conclusion

In conclusion, it appears that commercially available CCD's will easily solve the need for mount model development and can be used with modest aperture guide telescopes to provide optical assistance at night. Daylight optical guiding will be very limited and force us to depend more heavily on the raw tracking and pointing capability of the antenna.