Subject: Re: [Cloud Radar]
Date: Mon, 28 Jun 2004 13:42:01 -0400
From: "A. Richard Thompson" <athompso@nrao.edu>
To: Darrel Emerson <demerson@nrao.edu>,
"Backer, Don" <dbacker@astron.berkeley.edu>
CC: Dick Thompson <athompso@nrao.edu>

Dear Darrel and Don,

I have a file of material from 1996-7 on the cloud radar project, and I gave a short talk on the concerns for radio astronomy at the1997 URSI meeting in Montreal. The subject was important at that time since an allocation for the cloud radar was being considered by the ITU. The parameters of the radar satellite have changed somewhat since then.

The situation, as it appeared in 1997 for a single radio telescope antenna, can be briefly summarized as follows. The satellite parameters used were mainly those given in an ITU-R document by Huneycutt and Kiebler, USWP507, dated Feb. 1, 1996. The satellite height was taken to be 450 km, the main-beam footprint diameter to be approx. 1 km, and the footprint velocity at the earth's surface to be 7 km/sec. The peak power received by a 30 m diameter radio telescope was approximately 1 W for a main-beam to main-beam connection. The power level for damage to an SIS front end was taken to be -30dBW. The satellite orbited the earth approximately 15.6 times per day. During one day, the area of the Earth's surface swept out by the footprint was 6.25x10^5 sq km. This is approximately 1/800 of the surface area of the earth. So, on average, any given point on Earth would be swept over by the footprint about once in two years. For a polar-orbit satellite, and a radio telescope near the pole, the situation is much worse. In 1996, the inclination of the orbit was given as 50-60 deg. Now it appears that a polar orbit is being considered. Thus there now needs to be careful consideration of obseratories at the South Polar Plateau.

The duration of the passage of the footprint over any point on the ground was 1/7 sec. Since the satellite antenna is pointed to the nadir, main-beam to main-beam connection requires that the radio telescope be pointing towards the zenith. Thus to avoid damage to a radio-telescope front end it is necessary to ensure that at times of footprint passage the telescope beam was not pointing to the zenith. Since NASA could provide software to predict the footprint position at any time, coordination was deemed to be a relatively simple matter.

Interactions between the main beam of one antenna and the sidelobes of the other would cause interference but would not damage to the front end. Because of the motion of the satellite, such connections would have durations of order 1 second or less, and the loss of data would be negligible. Sidelobe-to-sidelobe interactions would cause interference if the radio telescope receiver passband were tuned close to the radar frequency. This could occur whenever the satellite was above the horizon, which would generally involve about two passes per day, each of duration about 15 min maximum. Overall the situation for radio astronomy was judged to be tolerable.

Looking at the situation today, it is clear that the analysis should be revised to include effects on arrays like ALMA. The message from Dr. Vane indicates that the satellite under consideration would end its mission lifetime in 2006, long before ALMA is completed. However, the frequency allocation for cloud radar at 94 GHz will remain, so it would be wise to consider how it would affect ALMA if the radar project is extended indefinitely. The major change that ALMA introduces is that for the long baseline configuration, the 64 antennas are distributed over an approximately circular area of diameter 3 km, with possible extension to 10 km (these are the current figures in the Project book). Thus, roughly speaking, the occasions when the satellite footpring sweeps across some part of ALMA are likely to be three to ten times more frequent than occurances for a single antenna. We need some realistic predictions of the frequency of footprint encounters by NASA. If the orbit cycle is repeatable, as the latest information suggests, it may be possible to arrange the orbit so that the footprint never travels across ALMA. On the other hand, if the cycle is almost repeatable, but changes very slowly, then there could be periods of frequenct encounters alternating with periods of few encounters. Another aspect of ALMA that needs to be considered is the ten feeds to cover different bands on each antenna. It is not clear how many of the feeds would be susceptible to damage. The higher frequency feeds may be protected if the coupling between the feed and the mixer involves any waveguide for which the radar frequency would be below cutoff. The beams of the feeds are offset from the geometrical axis of the antenna. The anguar size of the zone of avoidance at the zenith during footprint encounters should take account of the beam offsets, the throw of the subreflector wobble, and the accuracy of the nadir pointing of the satellite. The possibility of damage to ALMA could be exceedingly serious. There are a large number of front ends, and to repair a single front end at an antenna one has to change out the big Dewar that contains all ten front ends. Thus it may be wise to consider two layers of protection, which could involve both switch-off of the transmitter over ALMA, and avoidance of the zenith zone during predicted footprint passages. It would also be wise to make the stow position for antennas not in use to be off zenith by the required angle.

As a final point I should mention that John Ponsonby did a rather careful analysis of the cloud radar/radio astronomy situation in 1996. This included a consideration of pulse shaping to minimize the spectral scattering of power resulting from the pulse modulation. This is important to minimize the frequncy range over which interference would ocur during sidelobe to sidelobe coupling. John wrote a report, of which I have a paper copy but not an electronic one. I could send a copy of it to anyone who needs it.

Dick