NLSRT Memo No. 33

A SUGGESTION for a Cm-λ TELESCOPE

FOR: KEN KELLERMANN
NRAO

DEC. 12/88
(604-991 5836)

Dear Ken,

Here is the suggestion that I mentioned on the phone for possibly making a very big cm-λ telescope. It may not be worth all of the paper to follow, but the chance for a new telescope is so rare that I suppose it is a good idea to look at all the possibilities.

Whatever type of instrument you decide to build, all of us at HIA, Ottawa, wish you and your colleagues evey success.

Yours sincerely,
Tom Legg

BASIC IDEA

The telesope reflector would consist of contiguous, flat, light panels, all nearly horizontal and close to the ground. The panels would be supported by linear actuators capable of being positioned to, say, 0.5 mm within a total travel of 2 m. The whole reflector would be concave upwards and have a very long focal length. (several km).

A radio source at (zenith angle and azimuth) coordinates $Z(t)$, $\theta(t)$ would be imaged by the ~~refl~~ reflector at a point several km from the reflector, approximately in the direction $Z(t), \theta(t)+\pi$. The exact position of the focussed image would be controlled by the actuators to fall anywhere within a volume sketched in Fig. 1. The actuators would also be used to remove off-axis aberration (mostly astigmatism due to forshortening).

The proposed receiver and feed would be airborne. For a source at $Z(t), \theta(t)$,

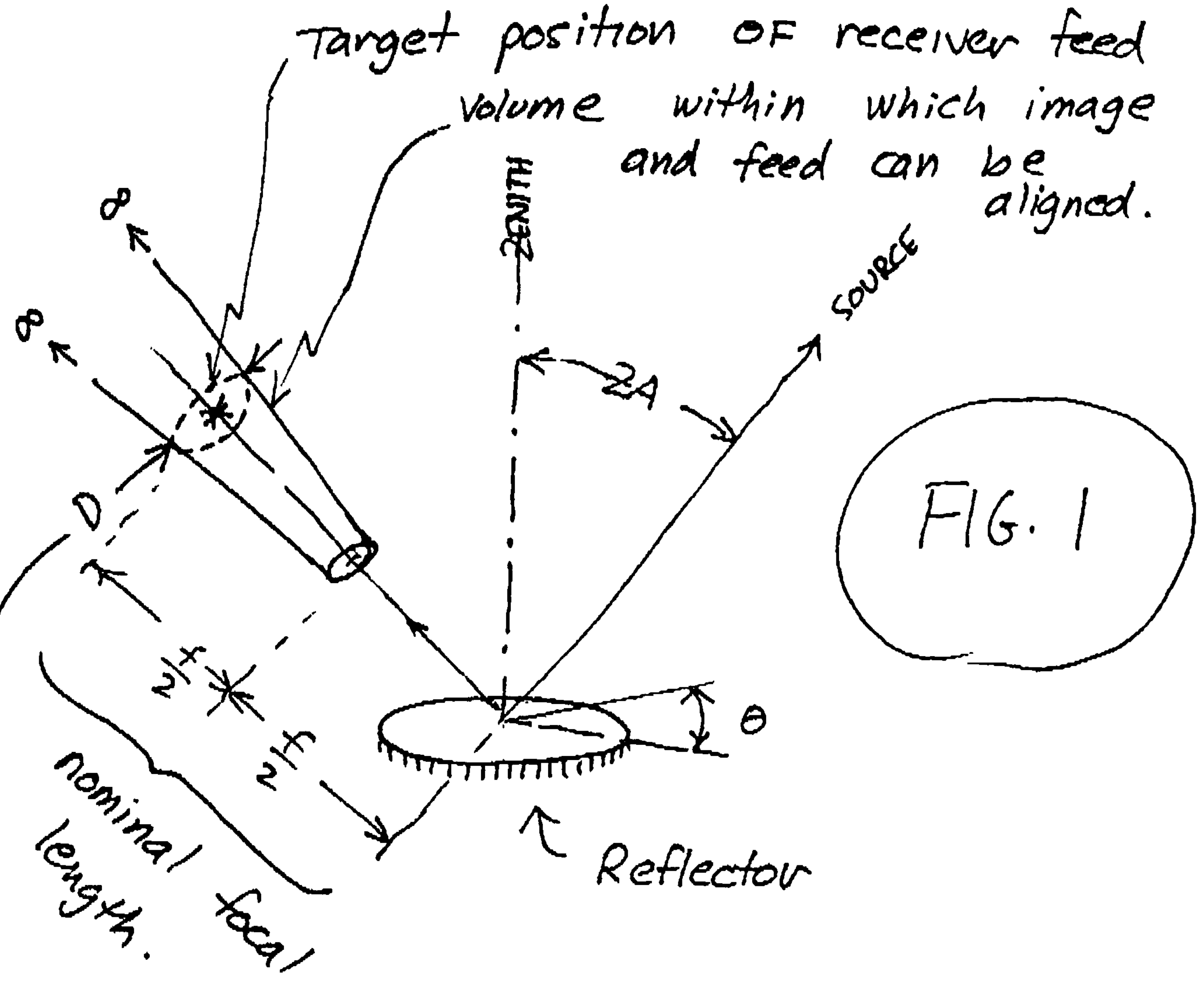

FIG. 1

(For a source near the zenith, and the reflector specified on page 6, the diameter of this circle is 100m. at the nominal focus) the vehicle carrying the receiver would have a target position of f (the focal length) $z(t), \pi + \theta(t)$. However, the image of a point source, i.e. the diffraction pattern formed by the reflector illuminated by a distant source, will be small. An airborne vehicle could almost certainly not be positioned with enough accuracy to bring the feed into coincidence with the source diffraction pattern. It is proposed therefore that the actual position of the receiver feed be accurately and continuously measured, and the reflector surface adjusted by the actuators to bring the diffraction pattern into coincidence with the feed. The feed position could be determined with a 3-element radio-interferometer composed of very small steerable antennas sited around the edge of the main reflector. These would measure path-lengths to a transponder on the receiver vehicle.

SOME DETAILS

To discuss the proposal in more detail consider the design of a telescope aimed at having the following characteristics:

SPECIFICATIONS for an example:

Wavelength range:	1 to 21 cm
Reflector diameter:	400 m
Focal length:	5000 m
Sky coverage:	360° in azimuth Useable* to 75° zenith angle
Feed reflector:	2.6 m - (maximum diameter used at 21 cm)
Panel size:	~8 m on a side
Number of Panels:	~1960
Number of actuators:	~1960 {2 m travel, 0.5 mm accuracy}
Pointing of Feed reflector:	± 0°.25
COLLECTING AREA:	~10 times VLA near zenith.

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* At 21 cm limited size of feed will cause collecting area to fall to about area of Bonn 100 m telescope at ZA = 75°. Area effective is larger at shorter λ.

SPECIFICATIONS, continued.

Airborne vehicle:
- Able to 'keep station' within 100m diameter cylinder (see figure)
- Several vehicles and receivers may be needed because of limited endurance.
- CL 227 a possibility

DISCUSSION of DETAILS.

Airborne vehicle: This is the area where there is presently the least information and potentially the greatest risk. The risk is (in my opinion) not so much in feasibility as in possibly escalating cost if a machine needs to be developed, or substantially modified.

Possible airborne vehicles are: the Canadair 227 'remotely-piloted vehicle (RPV); the larger Boeing Vertol Pointer RPV; a solar powered high altitude airplane (battery powered at night) being developed by Lockheed. There are other RPV's that exist but which I do not have information on. (Information is on the way from the main NRC library).

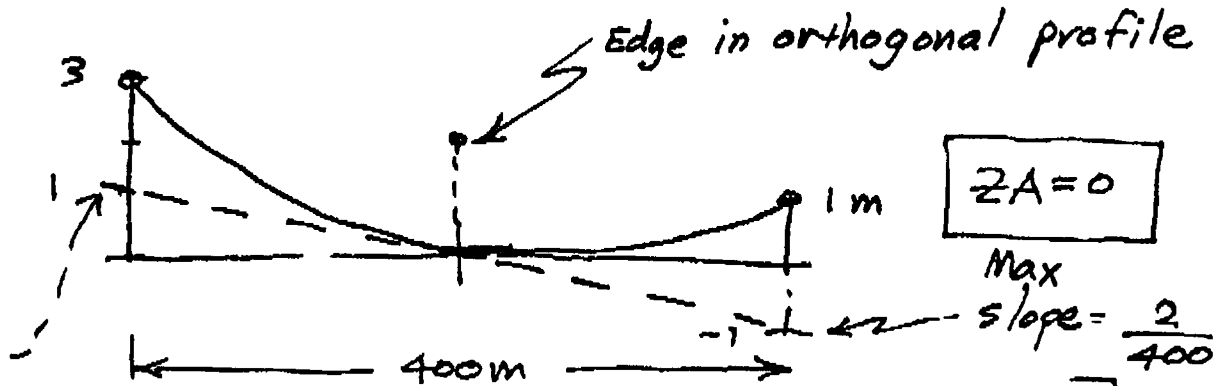
The CL 227 has two contra-rotating rotors powered by a small turbine. Prototypes have flown but the machine is not yet in production. Canadair hopes production will start in 1990-91. The machine has a built-in inertial navigation system that is useful for 'station keeping' as well as for carrying out a pre-programmed flight. A two-way microwave link is used for sending commands and collecting data. The payload of the CL227 depends on the load of fuel, but may be too small for the present application: ~30 kg for a duration of 3 hours. Estimated cost of $200,000 to $300,000 each would allow several to be bought. The larger Boeing Pointer might be a better choice, however, particularly if it also had an inertial navigation system. A Canadair engineer told me that the Pointer has a payload of a few hundred kg.

<u>Actuators</u>: A travel of 2m with settability to 0.5 mm is, according to a specialist in this area, not a problem. Load effects the cost but loads of several tons can be handled fairly economically. (Loads supported in tension though are easier to accommodate than loads supported in compression). Outside enviornments are often coped with - using a rubber boot, for example.

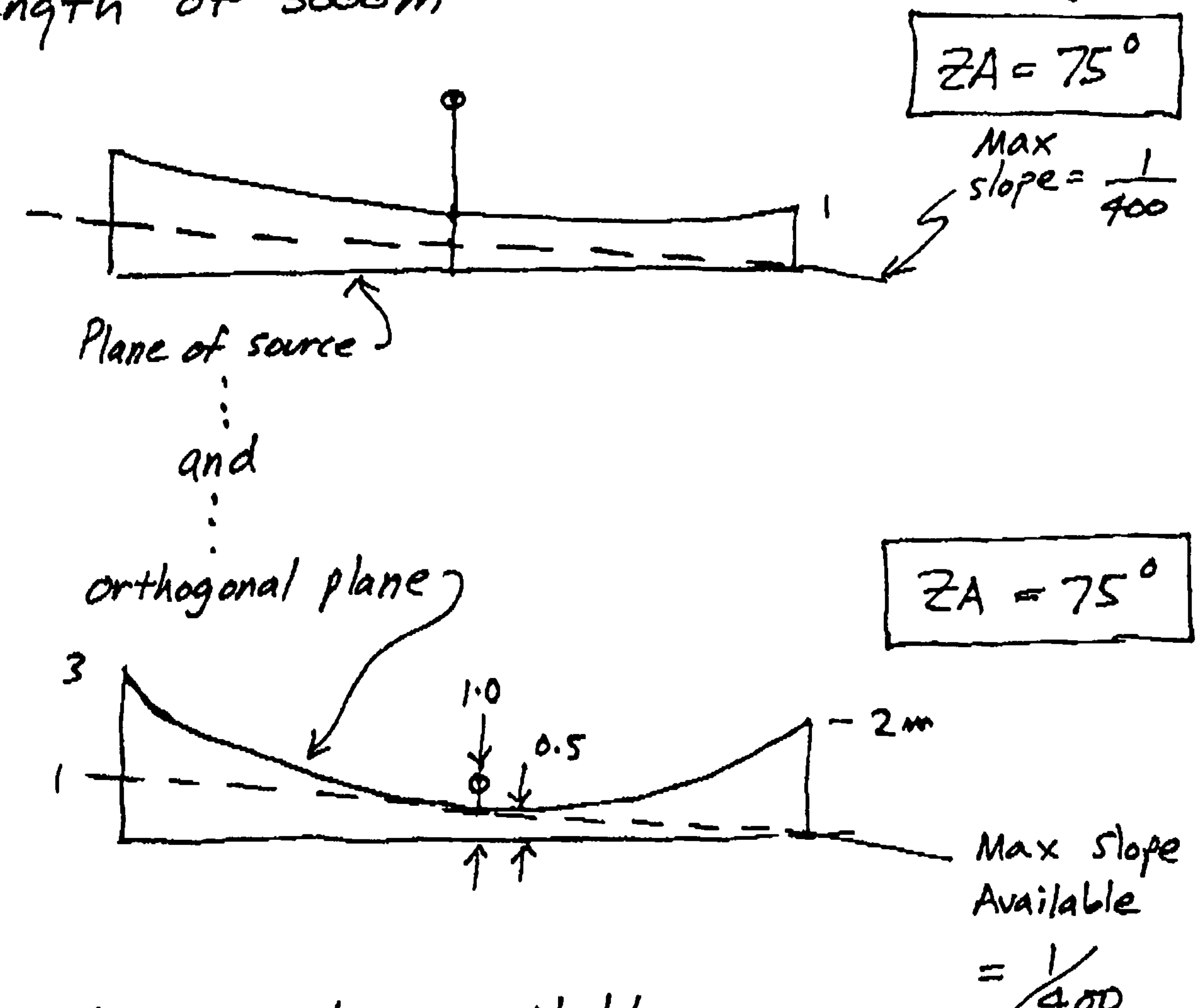
There are hydraulic and pneumatic actuators available with various types of feed back, some using encoded tape. Ball and screw actuators are also available with stepping motors, but may be too slow. The different types are competitively priced. A rough estimate is that a weather-proofed actuator might cost $2000, within a factor of two either way.

For the f/D of the telescope considered here, the displacement of an actuator at the reflector edge is 1/50 of the deviation of the feed from the target position. If for no other reason than the consumption of power, the feed deviation should be kept small and the focal length of the telescope as long as possible.

Surface profiles for extreme zenith angles and deviation from target position are sketched in Fig. 2. Near the zenith, the focus can be moved laterally ±50 m at the focal distance of 5000 m



[This slope (2/400) implies that the focus can be moved ± 50 m laterally at the focal length of 5000 m]



Maximum slope available for moving focus at ZA = 0° and 75°

FIG. 2.

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<u>Panels</u> Because of the long focal length, the individual reflector panels can be flat. It may therefore be possible to stretch a light screen over edge supports that individually have to be machined straight in one dimension only.

A strong constraint on how light the reflector and support can be made may be the snow fall at Green Bank. Also, Panels presumably should be high enough for a snow plow to pass underneath them. I wonder if a vehicle blowing hot air on a reflector screen from below would be a practical means of snow clearance?

Feeds and Receivers

(i) 21 cm Feed. On writing this Fax message out, I have come to realize that the 21 cm feed is a worse problem than I had thought. With a focal length of 5000 m, a reflector of ~ 3 m is needed to provide a feed aperture. Apart from weighing a lot, a reflector this big would likely interfere with airflow past the rotors of a vehicle like the CL 227.

One way to alleviate the problem would be to operate at 21 cm with a shorter focal length. This is possible because the long wavelength would be tolerant of the flat reflector panels and requires less accuracy in feed alignement than the shorter wavelengths. A focal length of 1/3 of 5000 m would mean that a ~1 m reflector would suffice as a feed at 21 cm – a much more reasonable figure. This would mean, however, a trade-off between more actuator travel or less volume in which the receiver vehicle could be located.

(ii) Other Feeds The feeds would have to be pointed towards the main reflector to an accuracy of ~±0°.25. This would probably present no problem. The feeds might consist of a single (say 1m) reflector with offset horns in a cluster.