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A Removable 74 MHZ Dipole

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Summary:

Installation of 74 MHZ dipoles on the VLA exploits the VLA infrastructure to provide 4 m wave length observations with 25 arcsecond resolution and 20 mJ sensitivity, better than anything ever accomplished at that frequency band. However, the 4 m crossed dipoles mounted at the image of prime focus in front of the subreflector cause unacceptable blockage at other frequency bands, and so the dipoles must be removed and re-installed for observations. Blockage is thought to result from shadowing and electromagnetic coupling of the dipoles with the surrounding subreflector support structure.

The success of the initial 74 MHZ observations has led to optimism over providing a rotatable subreflector as part of the VLA upgrade. A rotatable subreflector would provide access to the telescope prime focus for low frequency observations, a configuration preferable to the current deployment at the image of the prime focus. Removal and deployment of the 74 MHZ would not be necessary with a rotatable subreflector. In this paper, we examine various solutions.

The Subreflector Deployable Dipole:

A prototype deployable dipole has been designed, built, and demonstrated off-antenna. It consists of an aluminum tube which is mounted through the central hole in the subreflector. 4 m and 90 cm dipole elements fold up inside the tube, removing them from the optical path when retracted. A screw actuator driven by a motor deploys the dipole elements simultaneously. The elements are aligned when deployed to permit calibration of the 4 m dipole with the 90 cm dipole. Cams at the base of the dipole elements force the elements into position when the screw actuator is fully extended. The elements are pulled up into the tube when the lead screw is retracted. The FRM "trombone" must be modified to accommodate the aluminum tube, but that is not thought to be much of a problem. The deployment cams and threaded screw provide the rigid support for the dipole elements so that no cables are necessary to connect from the quad legs to the dipole.

Connections to the dipole assembly will be via flexible coax to connectors on the receiver. A small receiver could even be mounted to move with the threaded screw to reduce the length of the lead-in cable from the dipole. A 1 dB loss in the 90 cm cable would cause an increase of 90 K, so careful selection of the cable for the 90 cm dipole is important. The dipole arms rotate +/- 90 degrees every deployment and retraction. The arms must be insulated from the metal mechanism, and have reliable, low-impedance connections to the balun/impedance-matching transformers. It may prove difficult to find a suitable conductor.

The RF design for the deployable dipole has not been addressed. We are told it took a year to develop the RF design for the existing P band dipole alone. If modification of the existing P band dipoles is unacceptable because of the potentially long development time for the new configuration to work correctly, then the subreflector deployed dipole may be an unacceptable solution and perhaps should not be pursued further.

The Subreflector Deformable Dipole:

Rick Perley recently tested a "deformable" dipole with moderate success. The scheme calls for pulling the center of the crossed dipoles up to the 90 cm dipoles. Initial tests showed that blockage at L band is reduced from 6% to 4% and the contribution to system temperature is reduced to 1 K with the dipoles deformed. Blockage at other bands is less than the accuracy of measurement, about 1%.

The warped or deformable dipole would require a nonconductive cable and pulley arrangement to pull the dipole center up when not in use. Barry Clark points out that the cable could be fastened to the FRM so that whenever the subreflector is moved back for high frequency measurements, the dipole is pulled up; and when the subreflector is moved forward for 90 cm or 4 m observations, the 4 m dipole would be deployed. It is thought the design would require spring mounting of the dipole elements where they join at the center to prevent metal fatigue. Insulating cables would hold the 4 m dipole in place to the quadrupod legs as they do now, but be permanently installed.

Signal cables now run from the dipole center to the feed ring. The cables would have to be spring loaded or, better yet, run into the FRM cabin. Interference of the cables with the 90 cm dipoles is a problem that must be addressed if the cables are run to the back of the subreflector.

The deformable dipole presents a blockage problem for which no correction is apparent. If any blockage is unacceptable, it may be that the deformable dipole solution should not be pursued further.

The Feed Ring Deployable Dipole:

Durgas Bagri suggests retracting the dipole into a tube mounted at the feed ring instead of into the subreflector housing. An advantage would be to withdraw all conducting elements out of the beam. A disadvantage would be the distance from the feed ring to the deployed location. Deployment would require a guided, telescoping tube or long non-conductive cables extending from high on the quad legs to the tube where the dipole is stored. Such a configuration will require pulleys, springs, and long lengths of cable. The reliability and performance of a feed ring deployable dipole seems questionable.

The Box Dipole and other:

A box dipole consisting of a pair of dipoles mounted around the circumference of the subreflector was tested. The configuration was outside the beam and so avoided blockage, but the spacing of the dipoles was greater than two wavelengths. Possibly because of the spacing, the antenna pattern was complicated and non symmetrical, compromising polarization measurements. For that reason, the box dipole idea was set aside.

Some nebulous ideas of dipole elements deployed from reels were discussed. So far there has been little enthusiasm for such a design for two reasons: 1) concern over complexity and reliability, and 2) the blockage problem. One test showed that any metal object left in front of the subreflector caused blockage, so a design would have to provide for complete removal of all conductive material from in front of the subreflector.

Costs:

Built in quantity, subreflector-deployable dipoles will cost about $900 in parts and material. Machine shop time will be on the order of 80 man-hours each. Deformable dipoles might cost as little as $250 and 30 man-hours each if they can be powered by the FRMs as mentioned above. Costs of the feed ring deformable dipole will probably compare closer to the costs of the subreflector-deployable dipole than to the deformable dipoles.

Baluns and Impedance Matching; Control :

A dipole is a balanced source with an impedance which depends on the environment. The dipole impedance must be transformed to an unbalanced 50 ohm source. At 327 MHZ the transforming is handled by the configuration of rods and shorting plates in the "dipole" assembly, which will have to be replaced by something small enough to be placed at the dipoles and ride up and down with them. The 74 MHz configuration will be similar.

Spare circuitry in the FRM electronics provides remote control capability from the on-line system. An existing small prototype driver board provides the motor control, interlock with limit switches, and status bits back to the on-line system.

Tests Required:

Blockage. Part of the subreflector deployed dipole elements protrude through the subreflector hole when the dipole is retracted. Tests must be performed to see if these folded metal elements perpendicular to the subreflector cause blockage at other bands. If blockage exists, it would be necessary to perform more involved modifications of the subreflector housing to permit complete retraction.

It is not known if the existing 90 cm crossed dipole causes blockage at other bands. If there is blockage, then retracting the 90 cm dipole, too, could help improve efficiency at other bands. An on-off-on test of the 90 cm dipole should be performed to measure blockage. If blockage from the 90 cm exists, this reason alone could sway the decision in favor of the deployable dipole.

Any other prototype tested must be tested thoroughly for blockage.

RF Test. Both off-telescope and on-telescope tests are proposed. Is the RF performance of the deployable 90 cm as good as the existing? Can the receivers be mounted to the apparatus to reduce cable lengths between dipole and receiver? Is the parasitic ring on the 90 cm dipole necessary to enhance polarization? Will pulleys and cables for the feed ring deployable dipole cause any blockage?

Reliability. To test reliability and performance, we propose installing the prototype on an antenna. The current design could be mounted on a second antenna for an RF performance comparison. This test should run from 1 to 6 months, depending on the observing schedule. A simulation of three years of deployment cycling should be done during this test.

Scheduling:

Here is a straw man schedule for a deployable dipole. This schedule should be fleshed out in the planning meeting. "Students" refers to a NM Tech EE Senior Design Project, the format for designing and building the initial prototype.

Milestone	Goal	Who
0. Planning meeting	Sept '99	ES, Elect., Sci.
1. Mechanical designs complete.	Dec '99	Jim Ruff
2. RF-mechanical (Connections, cable loops etc,)	Dec '99	Elec or Students
3. RF design. (Impedance match, cable loss, etc.)	Dec '99	Elec or Students
4. Prototype test. (Pattern, efficiency, etc.)	Dec '99	ES and Elec or Students.
5. Life test. (3 years-worth of cycles)	Apr '00	ES and Elec or Students.
6. Report and recommendations.	May '00	All

Conclusions:

Using the VLA infrastructure to support 74 MHZ observing has received scientific support. The existing 74 MHZ crossed dipoles were useful to prove the concept but should be replaced because of the effort required to deploy and remove them, and because of wear and tear to the antenna main reflector panels when installing and removing them. Other "passive" designs do not appear practical. Thorough prototype testing is necessary before proceeding with further construction. The solution selected should be inexpensive since the system could be rendered obsolete by a rotatable subreflector proposed as part of the VLA upgrade. In fact, if there is a chance of the rotatable subreflector coming to be, perhaps we should just wait. ES Division will wait for a decision and definitive description of the course of action to be taken before taking further action.