ADAPTING ANTENNA POSITIONING SYSTEMS FOR AUTOMATED TRACKING

David G. Meier N4MW

INTRODUCTION. Many existing moonbounce antenna systems can be adapted for automated tracking. This paper will present ideas for adapting existing and planning new systems. My system, utilizing a 3 meter dish, operates both manually and automatically. Automated tracking is used for all on-the-air operation. Manual control capability provides convenience for testing. Independent display has proven redundant. Designing specifically for automated tracking retains control and display capability.

CONCEPT. Existing moon tracking antenna positioning systems are usually of the elevation over azimuth (AZ-EL) type in which two orthogonal rotating motions combine to steer an antenna beam over the sky. The polar or equatorial mount, used with satellite earth stations and telescopes, has the advantage of only having to rotate one axis for a particular tracking pass. Automation of the AZ-EL positioning system will be discussed in this paper due to its commonality and to practical considerations such as availability of software.

In order to track the moon or other celestial object, its position must either acquired using a sensor or calculated using ephemeris data or algorithm. Sensors provide positive manual tracking but sensor visibility must be obtained and maintained. If the sensor is the human eye or television camera, cloudy skies will preventing acquisition and tracking. The alternative, positioning using calculated moon position, performs well without regard to observing conditions. Such a system must be carefully calibrated to assure accuracy and mechanically stable to assure precision.

In planning to automate a system, mechanical and electrical drive configurations, position feedback devices, control requirements and display techniques must all be considered. The following discussion is based upon the results of my limited experience, with alternatives provided where known.

SYSTEM CONFIGURATION. AZ-EL antenna positioning systems employing calculated positioning are generally constructed as shown in Figure 1. The azimuth and elevation subsystems differ in the range of rotary motion required as well as in practical considerations such as motor and feedback component electrical ratings. Systems can be designed to cover the full 360/90 degrees of azimuth/elevation motion; however, for moon tracking a reduced range of motion is possible. Analysis of projected moon positions will reveal the maximum required range. Obstructions and geographical activity factors may provide further reduction. Range of motion should be carefully considered because it affects some design details. If sufficiently high, a system with 360/90 degree range of motion allows terrestrial use, although reaching the dish feed becomes difficult.

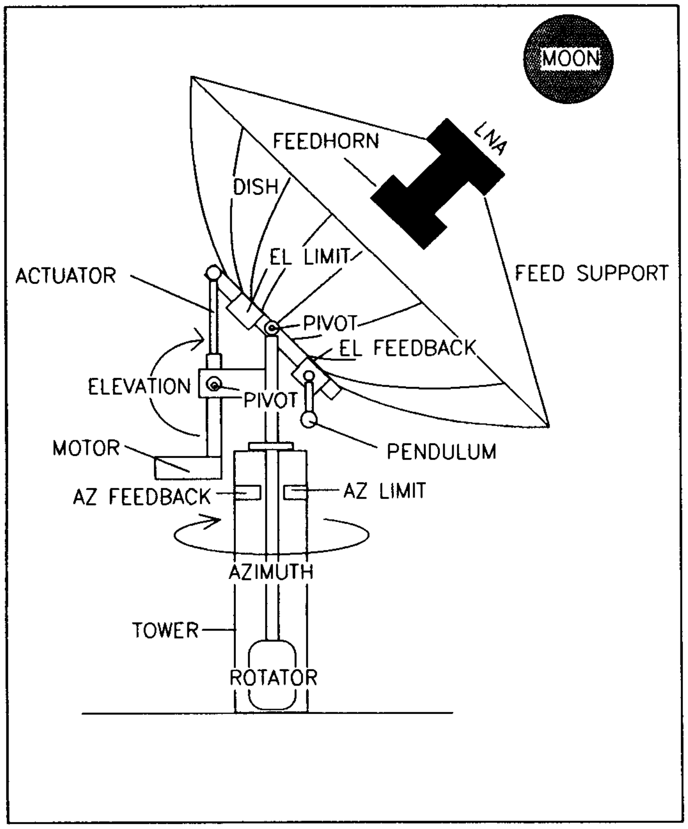

Figure 1. Small Dish AZ-EL Mount Construction

MECHANICAL DRIVES. Torque, slew rate (speed) and coasting time are important considerations. A common amateur style rotator provides sufficient azimuth torque for a small dish but slews at a rapid 360 degrees per minute with minimal coast. A linear actuator will elevate a small dish. In choosing motors, consider that the moon transits the sky at 0.25 degree per minute. Proper tracking might be difficult if the drive system is too fast and coasts excessively. More massive antennas will increase coasting time. Counterbalancing reduces torque requirements and strain on bearings but introduces inertia, perhaps necessitating use of braking mechanisms. My small dish azimuth rotator is a small prop pitch motor operated at half voltage to give a 60 degree per minute slew rate. The elevation motor is a linear actuator using an Acme screw but the recirculating ball screw type (Saginaw) is desirable.

ELECTRICAL DRIVES. *Motor electrical* requirements dictate the type of control circuitry and power supplies employed. DC motor rotation direction is changed by reversing the applied voltage. AC motors use different windings for reversal. Either type can be controlled automatically. Figure provides basic circuits for controlling motors using relays. More complex but desirable solid state approaches have been utilized by others.

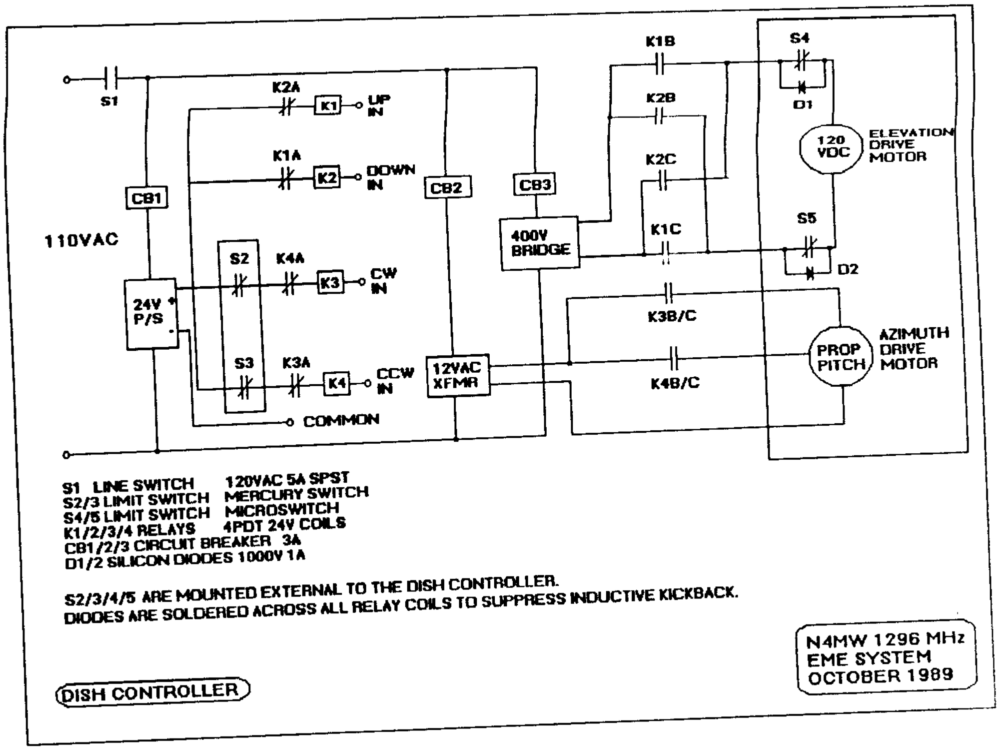

Figure 2. Motor Control Basic Circuitry

POSITION FEEDBACK. In order for calculated positioning to perform adequately, accurate position feedback must be maintained. Exotic synchro-resolver and rotary encoder devices are available and expensive, with the advantage of inherent calibration. The inexpensive alternative is to employ potentiometers to provide analog feedback. Once calibrated, potentiometer feedback is accurate enough for the small dish and has been employed on larger systems too.

Potentiometers must be of the high linearity type. Very little torque should be required to overcome internal friction. Ball bearing units are desirable but not common. The multi-turn variety is usually adequate. Azimuth feedback potentiometers can be of the 3, 5 or 10 turn variety. Elevation potentiometers for direct mechanically driven or pendant weight use should be one turn low torque units. Some linear actuators intended for satellite earth station use employ a built-in feedback potentiometer (to be discussed further).

Various mechanical arrangements are possible for azimuth feedback. A belt or chain coupling system is viable. Another approach is a single cable wound around the mast tubing, connecting to a torsionally spring loaded potentiometer drum; however, accuracy of this approach depends upon on the concentricity of mast rotation. After several inadequate attempts, a self-aligning friction contact technique as shown in Figure 3 is being used.

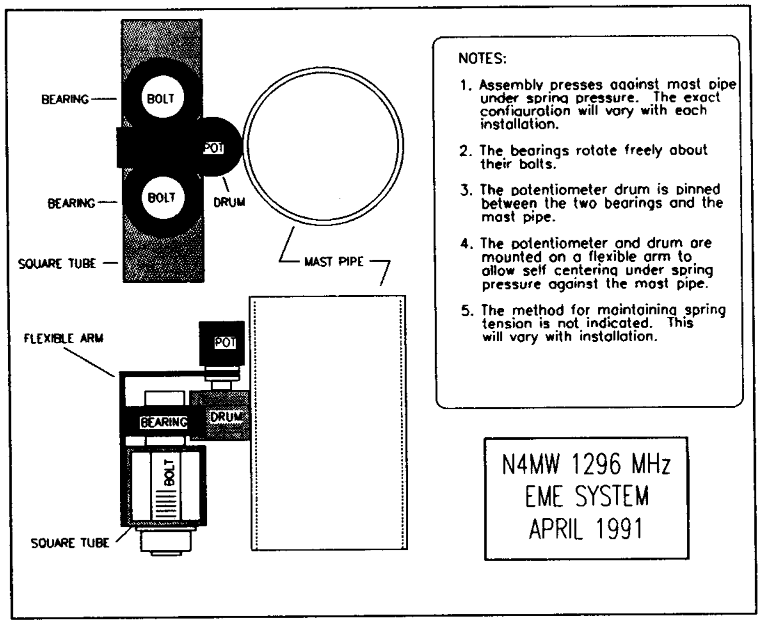

Figure 3. Azimuth Feedback Construction

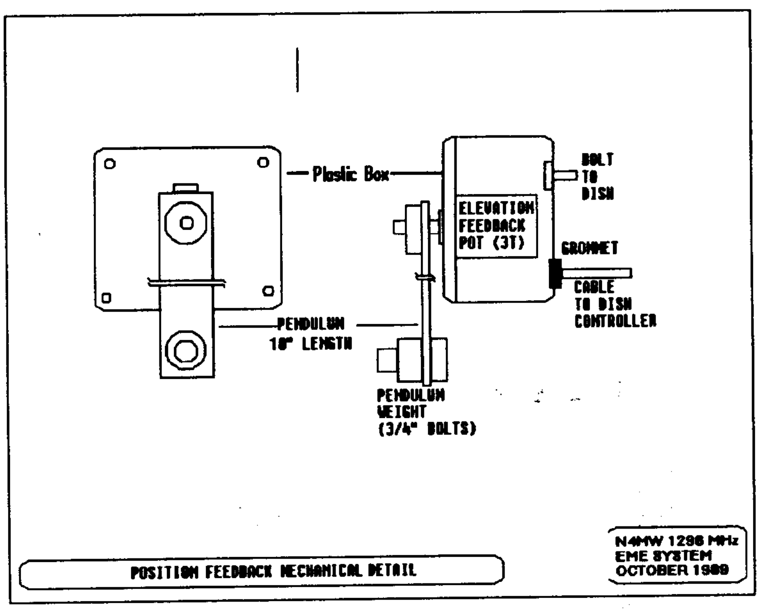

Figure 4. Elevation Feedback Construction

A "gravity coupled" pendant weight elevation feedback potentiometer is shown in Figure 4. The advantage of this approach is simplicity. The drawback is the undesired swinging of the pendulum due to azimuth rotation and wind effects. If critical, a mechanical coupling can be substituted for gravity. The potentiometer should be of the ball bearing one turn variety if one can be found. Otherwise, a three turn pot can be used. The linear actuator internal potentiometer is mechanically desirable; however, actuator potentiometer position is not a linear function of angle produced, and uncompensated readout error is significant (almost 4 degrees) at stroke midpoint.

AUTOMATED CONTROL AND DISPLAY. Computer software provides computation of moon position, display of azimuth and elevation angles and control capability. Hardware is required to run the software and to interface with the feedback devices and axis drives.

W9IP has simplified automation by making his REALTRAK software available for sale very reasonably. REALTRAK contains provisions for automated tracking of the moon, sun and celestial noise sources/cold sky. The program runs on any IBM compatible personal computer (PC).

Automated tracking requires that a special board be added to the PC. At this writing, REALTRAK only implements the IBM Data Acquisition and Control Adapter (DACA) board. Provisions are being made for other boards. The DACA board was originally quite expensive and is no longer manufactured, although it was available surplus at one time. If one shows up in a flea market, grab it. I bought one surplus, found two more at hamfests and have seen others advertised. If a DACA board cannot be obtained, consider purchasing REALTRAK anyway because it is likely to be updated to utilize any new interface boards which become available.

The DACA board contains multiple analog to digital converter (ADC) inputs and digital (logic level) outputs. The ADC inputs accept feedback voltages in the range of 0–10 volts from the azimuth and elevation axes feedback potentiometers. A fixed voltage is applied across the feedback potentiometers and the wiper contacts provide variable, position dependent voltages through shielded cables to the ADC inputs. The applied voltage must not cause the potentiometer power dissipation to be exceeded. As much of the range of the potentiometer is utilized as possible, insuring that the feedback voltage varies over most of the ADC input range without exceeding the limits.

Of the DACA board digital inputs and outputs, only outputs are used for positioning control. A pair of outputs are used for azimuth (clockwise and counter clockwise) and a pair for elevation (up and down). Output voltage increases (logical high) when activated by the program. The outputs can source very little current, only sufficient to interface with devices such as optical isolators. The optical isolator output (an open collector) then activates the drive system.

The axes drive controls must inherently preclude any possible activation in both directions at once. All axes motions must be protected against over travel by physical limit switches. Excellent industrial limit switches are available at high cost from suppliers such as Allen Bradley. Azimuth limit switches can be constructed from two small switches as shown in Figure 5. If sufficiently small, current to the motor direction winding can be directly interrupted by the limit switches. An alternative is to interrupt the supply voltage to the appropriate relay coil.

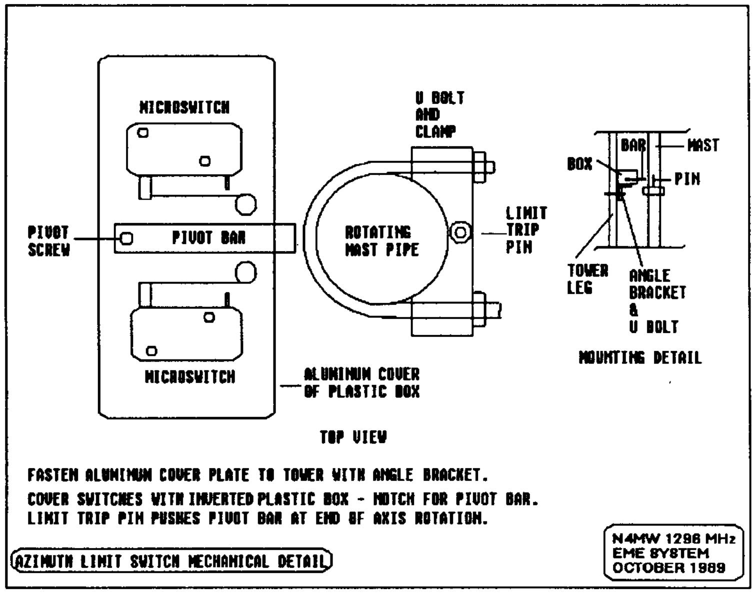

Figure 5. Azimuth Limit Switch Construction

Elevation limit switches can also be mechanical; however, mercury switches and steering diodes can be employed for DC elevation drives as shown in Figure 6. For small DC motors the mercury switches will handle the motor current directly. Both switches are mounted to allow swivelling adjustment so that the appropriate switches open when elevation limits is reached. Steering diodes connected in reverse across the switches allow retreat movement in the direction opposite the limit. Higher current motors can be accommodated using relay control through the switches.

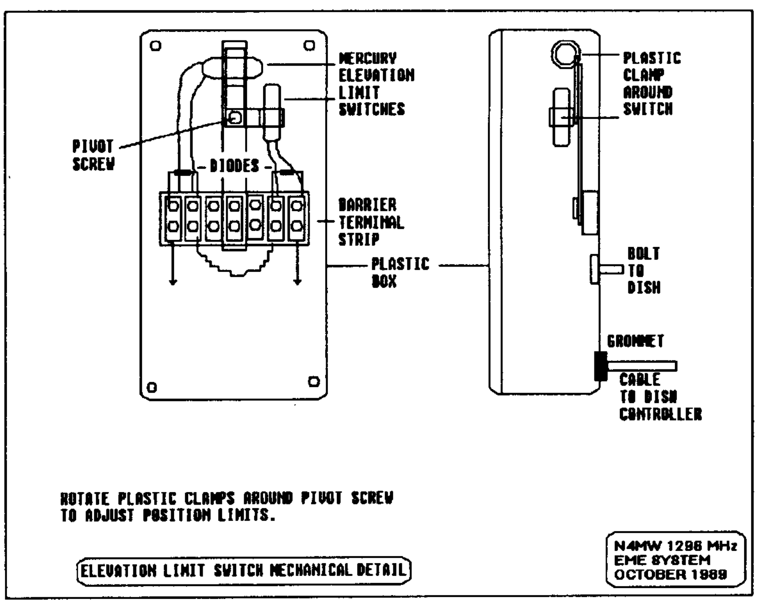

Figure 6. DC Elevation Drive Limit Switch Construction

MANUAL CONTROL AND DISPLAY. Manual control can be added by utilizing normally open switches to simulate the optical isolator open collector outputs. For flexibility, pendant switch boxes can be located both in the shack and at the antenna. Manual display can be provided by scaling and metering the feedback voltage using digital voltmeters as shown in Figure 7. Readout resolution of one degree in azimuth and 0.1 degree in elevation can readily be obtained. Experience has shown manual display to be unnecessary. The computer display is not only adequate, but is more stable because there are no calibration potentiometers to drift. For computer display, the only practical error sources are the regulation of the voltage applied to the feedback potentiometers and mechanical inadequacies which can be minimized through careful design.

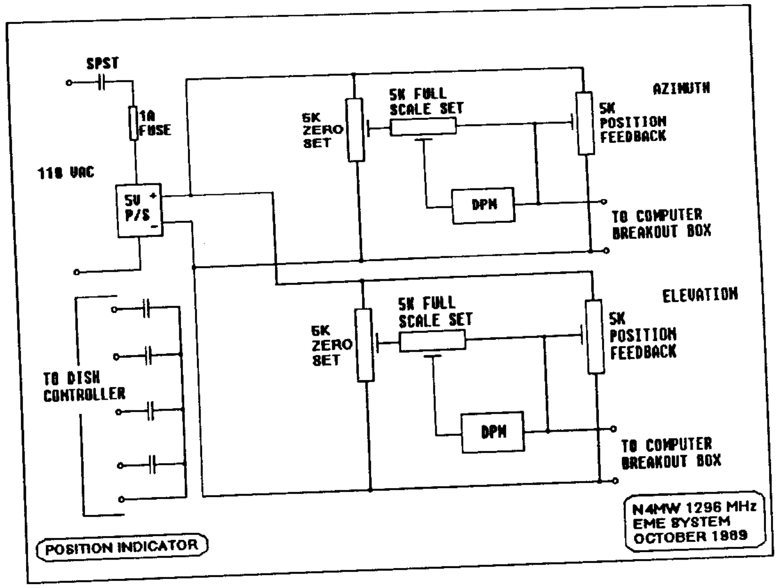

Figure 7. Independent Display Basic Circuitry

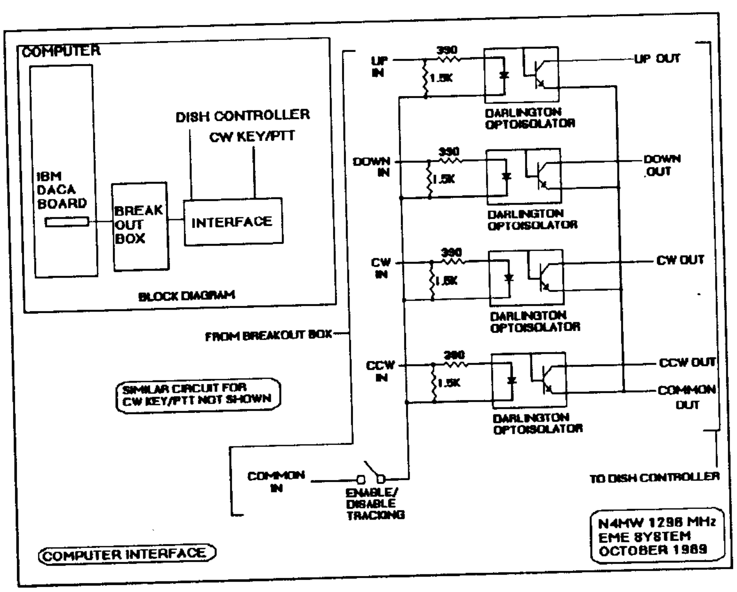

Figure 7. Interface Circuitry

Interfacing the DACA to the drive controller is shown in figure 8. An optional breakout box is sometimes available with the DACA board. Note the enable/disable switch provided to prevent the computer from accidently moving the antenna when tracking is not desired. An emergency stop switch should also be provided to positively shut off power to both axes.

- ✓ Don't plan to use your moonbounce dish for terrestrial work. Height makes service difficult.
- ✓ Do locate your dish where the moon is as unobstructed as possible.
- ✓ Do get a PC. If you are not computer literate, it will take a while to get comfortable.
- ✓ Do purchase Realtrak. It works.
- ✓ Do use shielded cables to the feedback potentiometers.
- ✓ Do use a well regulated power supply for the feedback reference voltage.
- ✓ Do design for automation. Independent display is redundant. Manual control is easily incorporated.
- ✓ Don't use standard panel mount potentiometers. They require a lot of torque.
- ✓ Do make the mechanical assemblies as solid and strong as possible.
- ✓ Don't let the feed assembly sag. Make it sturdy to maintain calibration.
- ✓ Do include bypasses and filters to keep stray RF out of the feedback circuits.
- ✓ Do use properly rated solid state components.
- ✓ Do include positive electrical limit switches for all axes motions.
- ✓ Do keep the axes slew rates low. This will avoid overshooting.
- ✓ Do provide an emergency stop switch.
- ✓ Do include a manual pendant control with a long cord at the antenna to make calibration easier.
- ✓ Do employ circuit breakers. Don't let the search for a fuse make you miss a sked.
- ✓ Do convince the spouse to become licensed. This lets you use radios to save a lot of footwork.
- ✓ Do get a bigger antenna to start with. They never seem to be big enough.

Figure 9. "Dos and Don'ts"

CONCLUSION. Figure 9 contains "Dos and Don'ts" opinions based on my observations and experience. I hope that the above discussion will assist in either adding to existing capabilities or in planning new installations.