# Antenna Drive System Performance Evaluation Using PN Codes

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*A maintenance tool for quick and easy evaluation of the performance of an antenna drive system is described and preliminary results are given. The technique uses a PN code as a system input signal and correlates the system output with all possible states of the input PN code. The resulting correlation function has the same shape as the system response to an impulse input and can be considered in the same way. A program description, block diagrams, and some system response curves are given.*

## I. Introduction

Proper maintenance and adjustment of any system requires a suitable technique of performance measurement so that troubleshooting can be performed and the results of component changes evaluated. Existing techniques for measuring the performance of the 26-m antenna drive and positioning system took too long for easy utilization as a routine maintenance and adjustment aid. Initial testing of a method of performance evaluation by using PN codes as an input signal has been done and the results will be briefly described herein.

The 26-m antenna at DSS 13 is an elevation-over-azimuth mount using hydraulic motors for positioning in both axes. The azimuth axis is driven by a conventional "bull" gear arrangement through four drive units. The elevation axis is driven by two recirculating ball screws. These drives give the antenna a capability of slewing at better than 4 deg/s in either axis, in high-speed mode. Either axis can also be driven in low-speed mode at the operator's discretion and this is the mode usually used for tracking.

The servo system is of the "zero velocity error" type and moves the antenna by electrically controlling, with servo valves, the flow of hydraulic fluid to the hydraulic motors in response to signals input into the appropriate points. Figure 1 is a block diagram of the azimuth and elevation system showing the various feedback loops, gear units, hydraulic motors, etc. The system utilizes three feedback loops to achieve maximum stability and smooth tracking.

In normal tracking, signals are input into the position loop, causing the antenna to move in the direction required to drive the input signal to zero. The rate loop, which receives signals from the "dc tachometers" driven by the hydraulic motors, senses rate changes and provides damping for the position loop. The valve drivers that operate the servo valves receive a linearizing signal from the current feedback loop which senses valve current. Properly adjusted, the system is capable of smooth tracking with essentially zero position error.

In order to effect this proper adjustment, the system response must be measured. This is conventionally done by use of a servo network analyzer, although useful data can be obtained by exciting the system with an approximation of an impulse. However, the first method is too time consuming for routine maintenance application, and the second puts undesired stresses on the system if the approximation of an impulse is good.

A properly constructed pseudo-noise (PN) sequence can be used as the system input and obtain the same information as would be obtained if the system were actually excited by an impulse input (Refs. 1, 2). The only requirement is that the PN digit period be short with respect to the servo response time and the code length be long enough to allow complete observation of the system response. If the amplitude of the PN code is kept small, the perturbations of the system will be quite small, and normal operation can be maintained while measurement of the response is under way.

The complexity of the system, as seen from Fig. 1, is such that modeling is extremely difficult; so the values of the various elements of the PN code could not be selected with great confidence in advance. For this reason, plus the availability of an already interfaced SDS-930 digital computer, it was decided to use software to generate the PN code, effect the required correlation, integrate the resulting correlation function, and display the results. This would enable easy modification of any parameter without the expense of building any hardware until the technique had been fully investigated. To further aid in ease of effecting changes, the computer program was written in real-time Fortran with machine language instructions for the high-speed loops.

## II. Technique Description

A 255-state PN code, with bilevel states of $\pm 1$ was chosen, with a basic digit period of 20 ms, variable in multiples of 20 ms. This provides a minimum code period of 5.1 s, with multiples of this period available for use with systems which are slow to stabilize. The PN code is generated and stored only once, when the program is initially loaded. By incrementation of a "pointer" cell and proper addressing, the PN code can be shifted and all delays obtained without actually moving the PN bits in computer memory. The program provides the following control functions and parameter variable inputs: (1) PN code amplitude in degrees, (2) digit period multiplier, (3) position and rate offset inputs, (4) clearing of correlator and accumulator, and (5) data output to magnetic tape, line printer, or plotter. A functional block diagram of the construction is depicted in Fig. 2. Bear in mind that all code generation, correlation, and integration (accumulation) are done by software, and the only additional hardware required is the oscilloscope display. (A Tektronix 585 was used, but almost any oscilloscope could be used.)

The monitor section of the program provides for entering various parameters, and scales the integrator data for the oscilloscope display. It also provides for selection of either azimuth or elevation axis for evaluation, and read-in of previously recorded data. (As a precautionary measure, all input parameters are tested for proper range before acceptance, since the antenna is under slave control.) The functional part of the program, under interrupt control, increments the position rate, increments the PN code clock, demodulates, limits, correlates with all possible PN delays, integrates the correlation function, and outputs the data to an oscilloscope display for observation by the operator.

## III. Initial Results

Thus far, we have only been testing the suitability of our "tool" and have not made any changes in the servo system with the exception of those front panel adjustments commonly made by the operator. Figures 3, 4, and 5 are typical of the response patterns obtained with input conditions as summarized in Table 1. For a given set of conditions, the patterns are quite repeatable and suggest that the antenna drive system is not optimum in either adjustment or design. Remember that the system under evaluation includes the servo electronics, hydraulics, antenna structure, angle encoders, servo repeater, and computer (all items shown in Fig. 1). In future work we plan to investigate these various sections in more detail.

## IV. Conclusions

Using perturbing amplitudes as small as 0.010 deg, we have established that a properly designed PN code, utilized as a system input and then correlated with the system output for all possible states of the input PN code, will produce a correlation function whose shape is identical to the shape of the system response to an impulse utilized as an input.

Initial observation of our results indicates that the 26-m antenna drive system is not optimum, but additional measurements are necessary before the effects of system changes can be evaluated. The technique offers definite promise as a maintenance tool, since all of the DSN stations have computers which are used as antenna drive signal sources. Future work will be directed toward achievement of a simple maintenance tool with simple procedures for servo-system adjustment toward optimum response for the tracking performance desired.

## References


1. Towill, D. R., and Lamb, J. D., "Pseudo-Random Signals Test Nonlinear Controls," *Cont. Eng.*, Nov. 1970, pp. 59–63.
2. Dack, D., "System Identification by On-Line Correlation," *Cont. Eng.*, March 1970, pp. 64–70.

**Table 1. Input parameters**

| Figure | Axis | Rate, deg/s | PN amplitude, deg | Digit period, ms | Code length, s | Servo speed |
|---|---|---|---|---|---|---|
| 3 | Elev | −0.02 | 0.01 | 40 | 10.2 | Low |
| 4 | Elev | −0.1 | 0.01 | 20 | 5.1 | High |
| 5 | Azimuth | 0.05 | 0.05 | 20 | 5.1 | High |

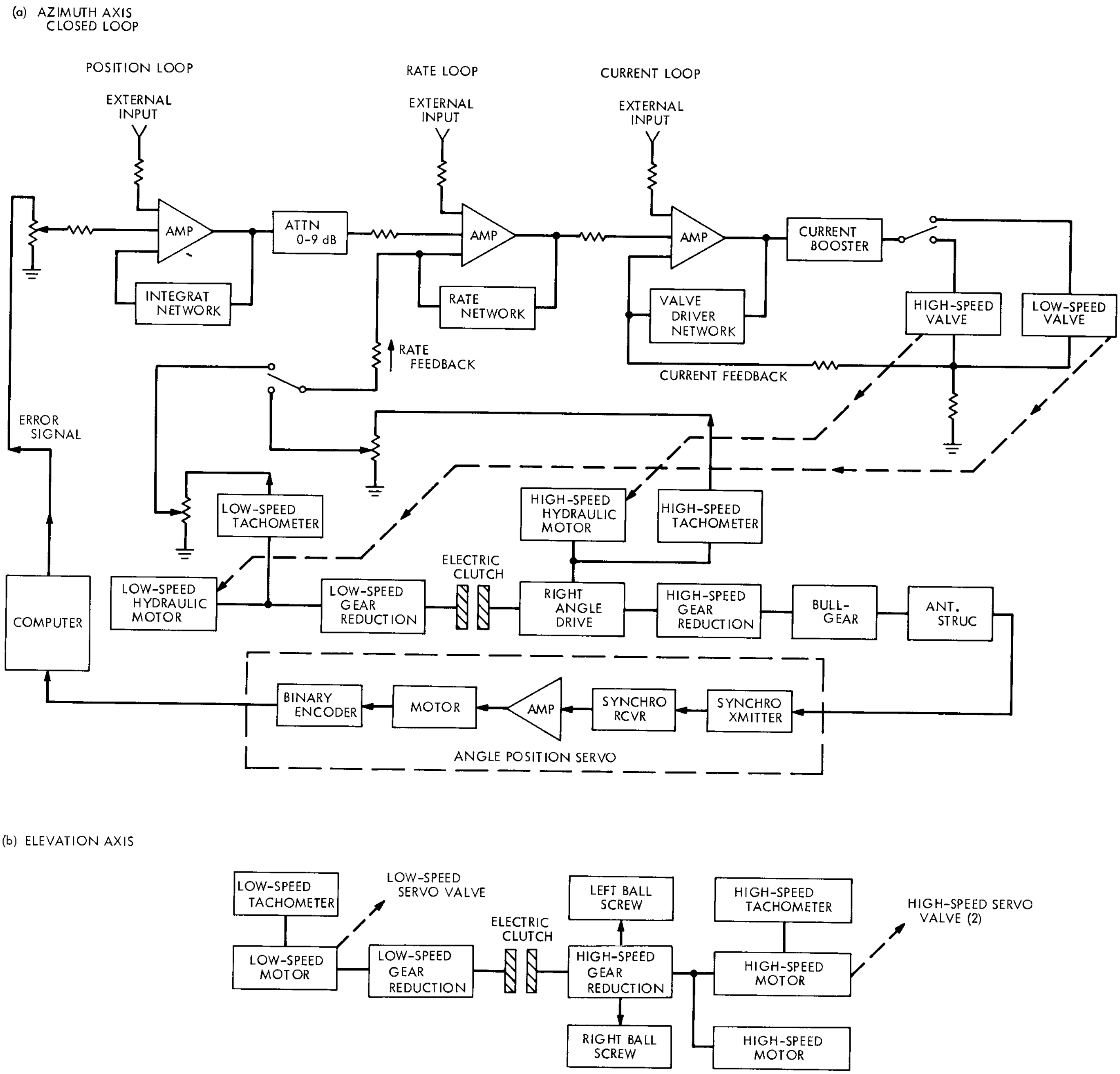


**Fig. 1. Functional block diagram, 26-m antenna servo system: (a) azimuth (closed loop), (b) elevation axis**

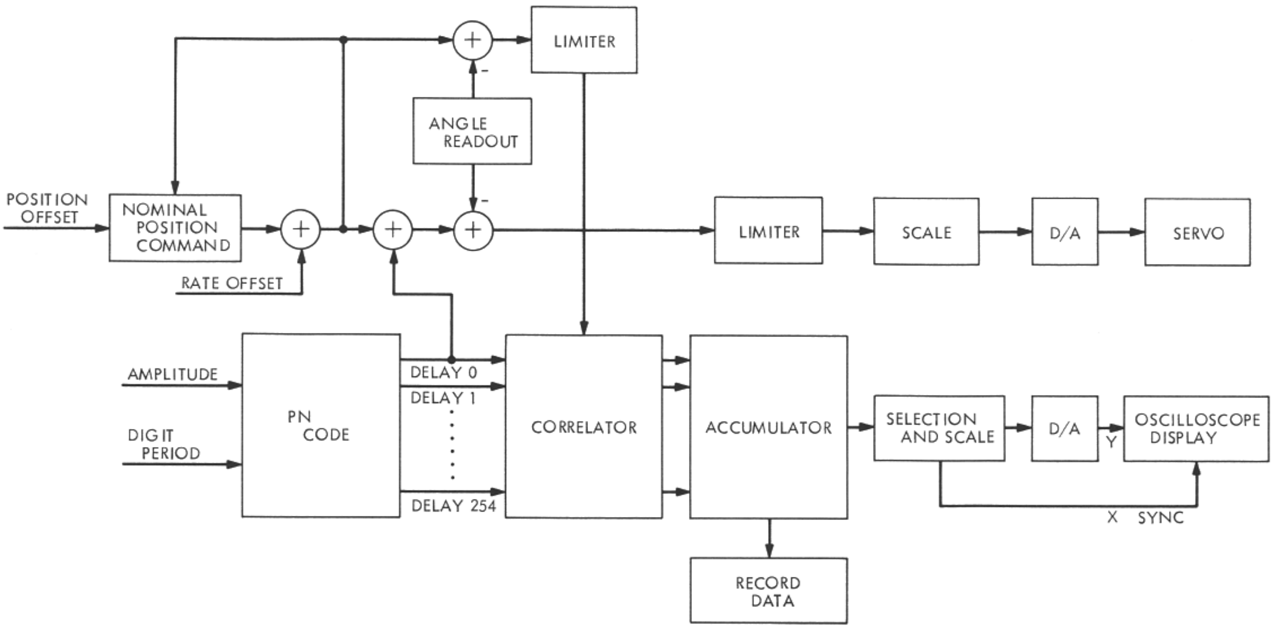


**Fig. 2. Functional diagram, antenna drive system evaluation by PN code**

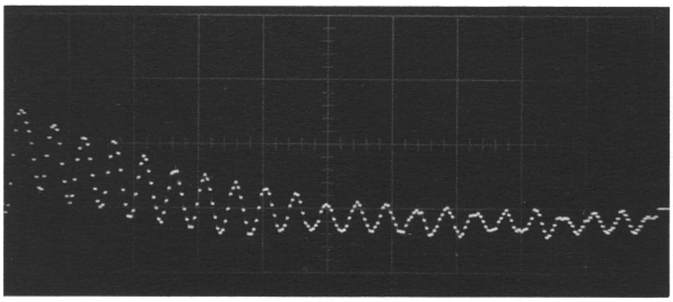

**Fig. 3. Elevation axis, low-speed mode, 26-m antenna, Venus DSS**

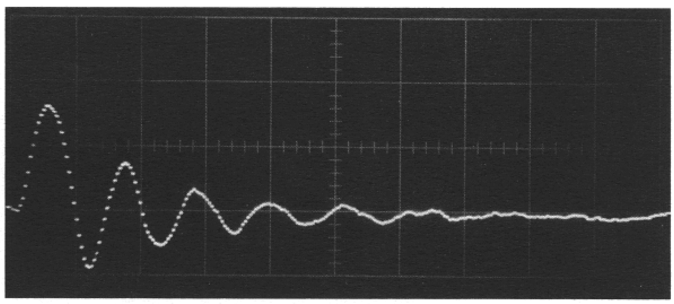

**Fig. 4. Elevation axis, high-speed mode, 26-m antenna, Venus DSS**

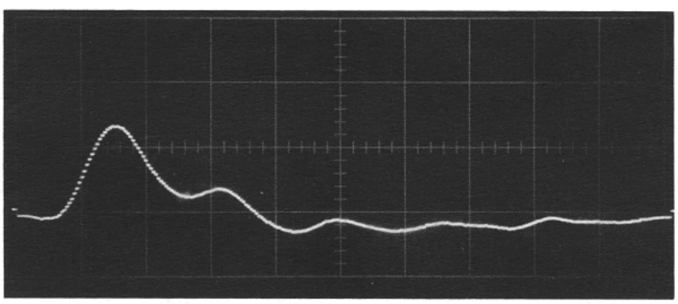

**Fig. 5. Azimuth axis, low-speed mode, 26-m antenna, Venus DSS**