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Conversion of a Manually Operated Antenna to a Digital Auto-Tracking Antenna System

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A systematic approach has been made to the design of a digital auto-tracking antenna system. When such a system is converted from a manual tracking system, the main design criteria of accuracy, reliability, ease of maintenance, and minimum cost are advanced if the new system is designed around one of the present modes of operation, thus minimizing new equipment and permitting the existing modes still to be used when desirable. In the example of this report azimuth and elevation information for two antennas is stored on Mylar tape in binary form. The tape is read by a controller, which reformats and transmits the digital data at specific time intervals to a digital-to-synchro converter for each antenna. The converter outputs syncro position data through the previously existing manual command unit to the pedestal drive circuitry in a servo control loop, also previously existing.

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PROBLEM STATUS

This is an interim report; work is continuing on the problem.

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CONVERSION OF A MANUALLY OPERATED ANTENNA TO DIGITAL AUTO-TRACKING ANTENNA SYSTEM

INTRODUCTION

Many directional tracking antenna systems presently in operation were designed for manual operation. An operator is required to manually position the antenna through a position syncro or through servo rate control. These systems require constant updating by a skilled operator as data are monitored from a moving source. A skilled operator can successfully track a moving source given the following minimum information. A starting azimuth, elevation, and time and a constantly radiating beacon on the source which the operator can monitor. Once the operator has initially acquired the source, he can follow it by trial-and-error positioning of the antenna. The received signal-to-noise ratio (S/N) of the beacon is the figure of merit. The tracking technique has the disadvantageof potentially large variations in S/N as the operator performs his trial-and-error iterations. A second disadvantage of this technique is that the operator may lose track of the source completely, and the source may be very difficult to locate again.

A better approach to tracking is to supply the operator with detailed tracking information. For example, the operator could be supplied with a table of azimuth and elevation headings versus time. The operator is then required to update the antenna system to a predetermined position at specific time intervals. This of course requires detailed, accurate information about the movement of the source to be monitored.

Typically, many tracking systems require the use of both techniques. The first method is used when detailed information about the source is not available, corresponding to the initial stages of a project or when it is initially determined that a source would be desirable to monitor. The second method is used when detailed information is available about the source.

With the advent of good, reliable, and accurate digital-to-analog converters it has become possible to update manual tracking systems to automatic manual tracking systems at a minimum cost. This allows an operator to control an antenna system manually when this is the optimum mode of operation, as in the first tracking method discussed. It also allows a paper tape reader or computer to control the antennas when such is the optimum mode of operation, as in the second method where detailed information is available on the source to be tracked.

An antenna system typical of the manual tracking systems mentioned has been in use in the Electronic Warfare Division of the Naval Research Laboratory for several years. This is the Scientific-Atlanta, Inc., Model J330 tracking pedestal set (1). Figure 1 is a simplified block diagram of this system. There are three primary modes of operating the antenna system. In all three modes a closed loop is formed to control position. However, the type of closed loop is different for the different modes.

In the manual-rate mode of operation the antenna is rotated at a speed set by front-panel control on the servo control unit. This of course requires an operator's judgment to determine the optimum speed and when and in what position the antenna is to be stopped. Figure 2 shows a simplified block diagram of two forms the closed control loop might take. There would be no closed loop if there were no operator in this mode

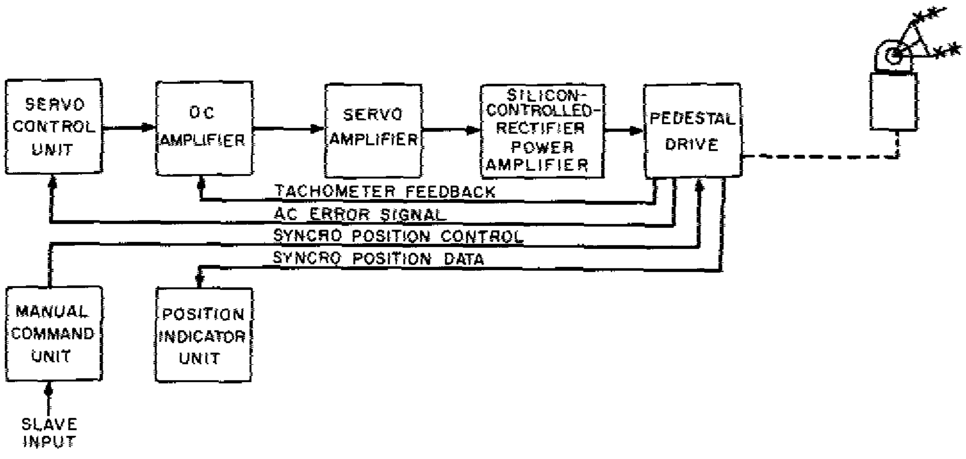

Fig. 1 - Scientific-Atlanta, Inc., Model J330 tracking antenna system. This is a manual system which can be updated to an automatic/manual system as will be shown in later figures.

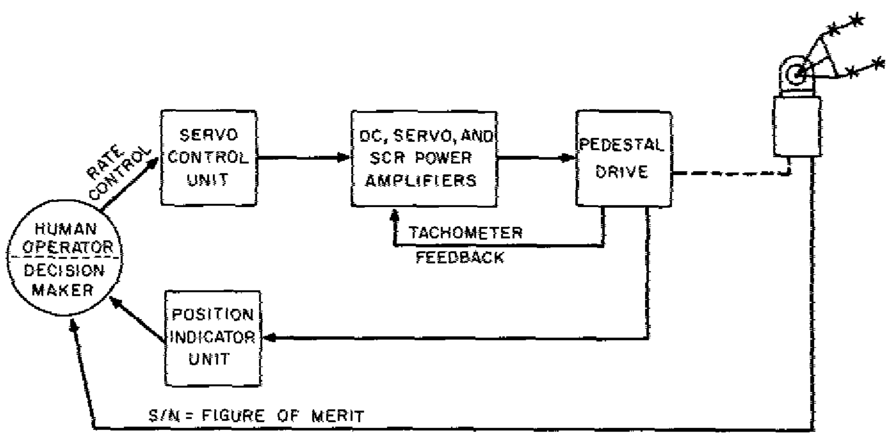

Fig. 2 - Manual-rate mode of operation of the model J330 tracking antenna system

of operation. Therefore constant operator attention is required. For example, when the pedestal drive is not activated, the antenna may drift from the position it was left in. This drifting becomes particularly severe when the wind loading of the antenna is high.

Another mode of operation is the manual-position mode. The operator rotates a syncro transmitter shaft manually by a front-panel handcrank on the manual command unit. (Fig. 3). The syncro position data is sent from the manual command unit to the pedestal drive circuitry. An ac error signal, which is proportional to the angular error between the shaft of the syncro transmitter and the pedestal drive shaft, is sent back to the servo control unit. The ac error signal is converted to a dc error signal in the demodulator circuit of the servo control unit. The dc error signal is then used to drive the pedestal shaft in a direction to reduce the error to zero and make the position of the control shaft coincide with that of the transmitter shaft. When operating in this mode the human operator merely sets the desired position into the manual command unit. He is then out of the control loop until the next position update.

The third mode of operation is the slave mode (Fig. 4). This mode of operation is identical to the manual position mode except that the syncro position data are not generated by the syncro transmitters located in the manual command unit. The syncro position data come from another source, but they must be identical to the output of the syncro transmitters in the manual command unit. This mode of operation allows sets an antennas to be slaved together for ease of operation.

SYSTEM DESIGN

When converting a manual tracking system into a digital auto-tracking system the main design criteria should be accuracy, reliability, ease of maintenance, and minimum

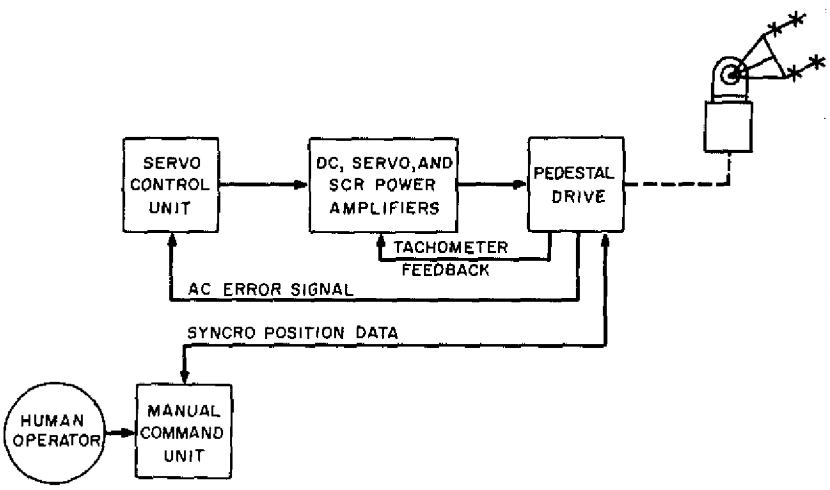

Fig. 3 - Manual-position mode of operation of the model J330 tracking antenna system

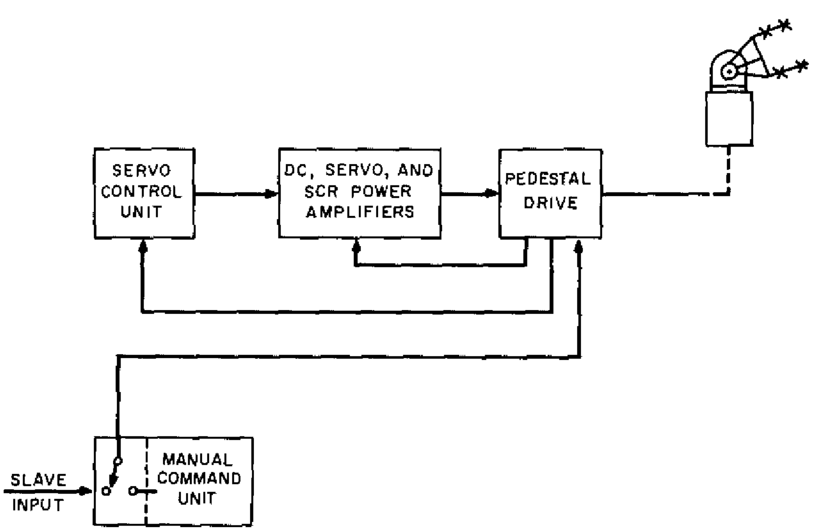

Fig. 4 - Slave mode of operation of the model J330 tracking antenna system

cost. All of these design criteria are advanced when a minimum of new equipment is required to realize the conversion. The obvious way to minimize new equipment is to design the auto-tracking system around one of the present modes of operation. Since a closed control loop is essential and since the operator interface is to be minimized, the manual rate mode of operating may be eliminated from consideration. This leaves the manual position mode and the slave mode. These two modes of operation are nearly identical, since both require syncro position data to be transmitted through the manual command unit. The obvious approach is to use the slave input mode of operation. Once this is decided, the system design is straightforward.

Since the antenna system is to be a digital auto-tracking system, there must be a means of control, the ability to store position information in digital form, and a method to convert the digital information to syncro position data. Figure 5 is a block diagram of such a system. The digital-to-syncro converter accepts the stored position information at specific time intervals and outputs syncro position data through the manual command unit to the pedestal drive circuitry.

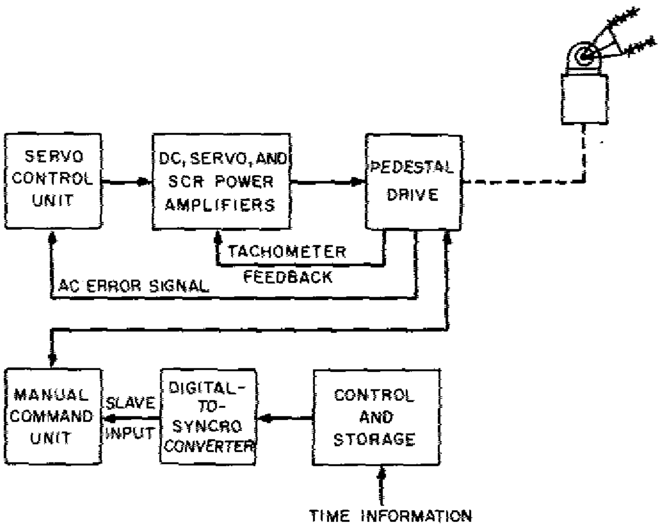

Fig. 5 - An auto-tracking antenna system that incorporates the equipment shown in Fig. 4

Several manufacturers produce digital-to-syncro (D/S) converters. They may be designed to accept true binary or binary-coded decimal (BCD) data. All accept the digital input in a parallel fashion. The D/S converters that operate on straight binary information allow the amount of information stored to be minimized. This is a result of binary coding being more efficient than BCD coding. The interface between the control and storage portion of the system and the D/S converter is greatly simplified if the D/S converter does not require the digital input to be always present. This can be implemented by a D/S converter that accepts input data that are strobed in and then stores this information until it is updated by another strobe signal.

The control and storage portion of the digital auto-tracking system may be implemented several ways. A computer can be used to perform this function. The smallest minicomputer is capable of relatively large storage and fast input and output. Using a computer for the control and storage portion of the system may be advantageous if the source to be tracked is moving extremely fast, requiring many updates over a short period of time, if many different types of sources are to be tracked, requiring a great amount of versatility, if the source to be tracked follows a very complex trajectory, or if the computer can do other jobs when it is not controlling the antenna system. Generally, a computer will not be efficiently used unless the particular application is unusual and complex. If a computer is not used, control and storage must be considered as separate entities.

Three main techniques for storing digital information could apply to this application: magnetic tape, IBM cards, or punched paper tape. Magnetic tape allows large amounts of digital information to be stored reliably and compactly. The information on magnetic tape may be accessed at a high rate. However, magnetic tape readers are generally tempermental devices that require special operating environments, and a great deal of maintenance. They also are relatively expensive. An IBM card allows a maximum of 960 bits of storage. For many applications this is not a sufficient amount of data. The greatest disadvantage of using IBM cards is that incremental card readers are unreliable and relatively expensive; hence this type of storage is not recommended. Punched-paper-tape storage gives a good cost-efficiency tradeoff. A maximum of 80 bits/inch of data can be stored on a paper tape, and since the tape can be made any length, the amount of storage is not a problem. Paper tape readers are relatively inexpensive and reliable. Extra reliability can be achieved if Mylar tape is used instead of paper tape. In conclusion, for most applications paper or Mylar tape is the most cost effective means of storage.

There must be a device that will control the auto-tracking process. This controller is relieving the human operator of the tedious job of operating the routine portion of the auto-tracking process. The controller should (a) start the tracking process at a predetermined time, (b) control the information flow from the storage device into the D/S converter, reformatting the data where necessary, and (c) monitor certain critical aspects of the system and sound an alarm if there is a malfunction. Figure 6 shows the D/S converter, the controller, and paper tape storage for a typical auto-tracking system.

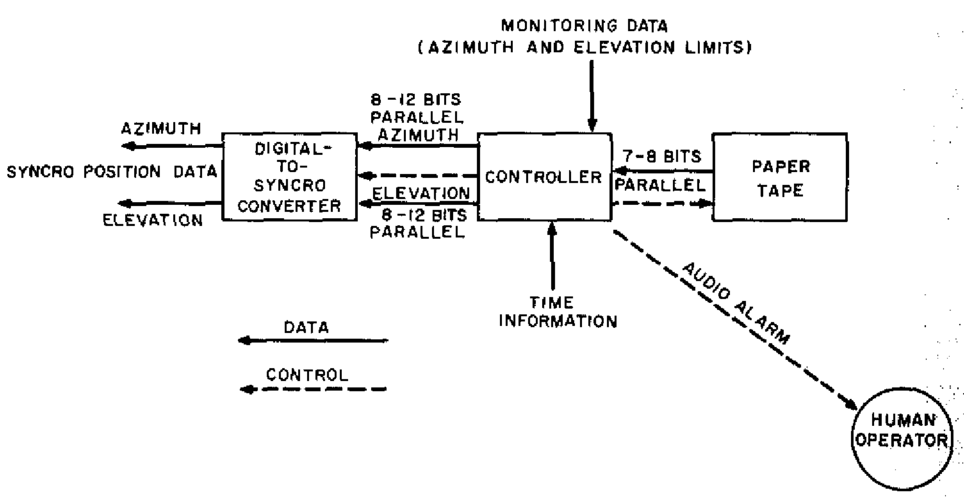

Fig. 6 - Functional system interconnections of the added equipment in Fig. 5

EQUIPMENT DESIGN

Digital-to-Syncro Converter

A block diagram of one channel of the digital-to-syncro converter used in the NRL digital auto-tracking system is shown in Fig. 7. This unit is the Northern Precision Laboratories Model 800735 dual digital-to-syncro converter (2). This D/S converter contains one channel for elevation and an identical channel for azimuth. Ten bits of data are required to activate each channel, the most significant bit being 180 degrees and the least significant being 0.35 degree. The ten bits per channel are input in parallel into the input storage register and buffer. The unit converts the digital input to a three-wire syncro signal having 90 volts line to line at 60 Hz.

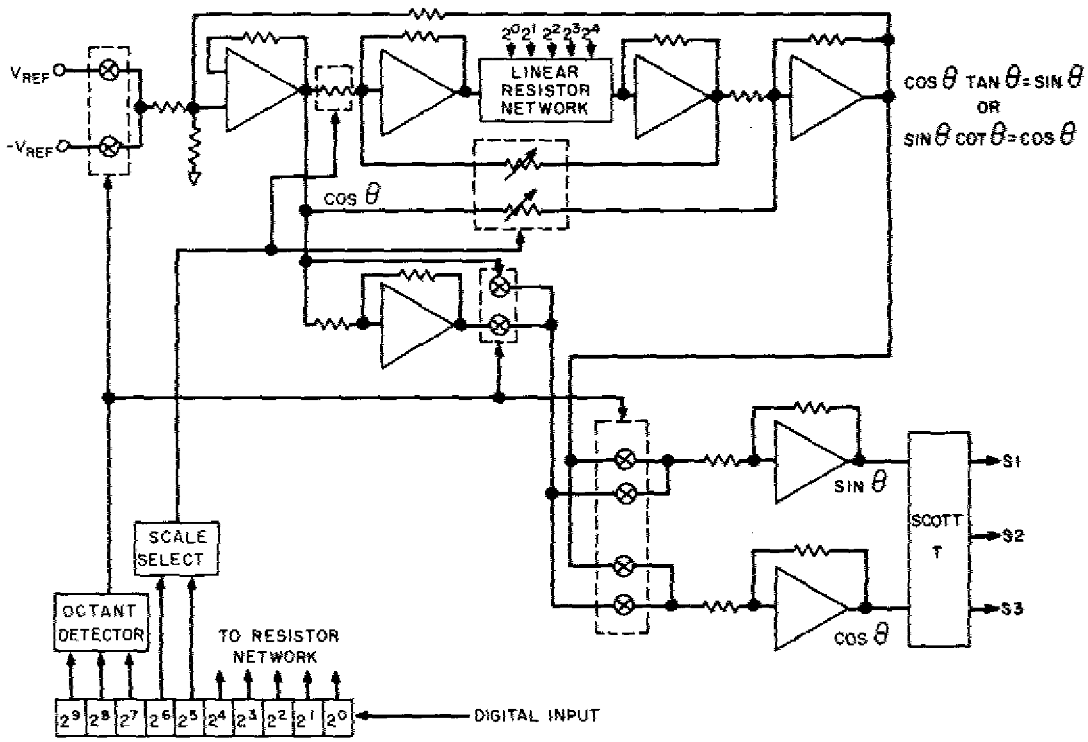

Fig. 7 - One of the two identical channels of the D/S converter shown in Fig. 6. One channel is for azimuth information, and the other is for elevation information.

Mylar Tape

Aluminized Mylar tape is used to enhance system reliability. Data are packed on the tape in the most efficient manner possible. The position data are put on the tape eight bits per line in a true binary form, with the sprocket holes used to distinguish lines of data from blank tape (Fig. 8). In the NRL system the information for two antenna systems is placed on one tape. The first ten bits read are azimuth information for system 1, the second ten bits are elevation information for system 1, the third ten bits are azimuth information for system 2, and the fourth ten bits are elevation information for system 2. Many good paper tape readers are commercially available, and the selection of one is not discussed.

Controller

The system controller must increment the tape reader as necessary, read five lines of data from the tape, reformat the digital position data, transmit the digital position data in parallel to the D/S converters, and repeat the preceding steps until tracking is terminated. It must also monitor the limit signals from the antennas and output an audio alarm if an antenna hits a limit. The system controller should have the capability of manual start, manual stop, automatic start, and automatic stop. It should also monitor the line power so that in the event of a power failure an audio alarm will be sounded. Figure 9 shows a block diagram of the controller used in the NRL digital auto-track system.

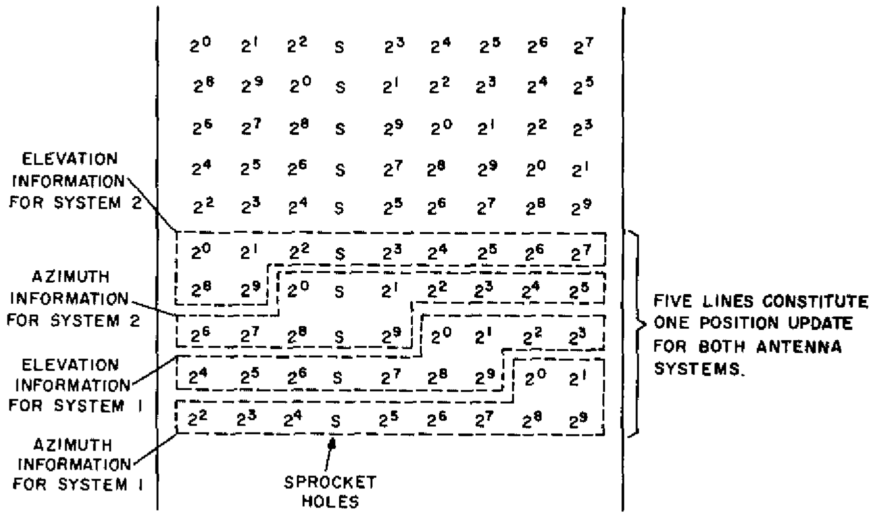

Fig. 8 - Data format on Mylar tape for the NRL system, which is a system updated as shown in the preceding figures except that the tape reader and the controller control two antenna systems

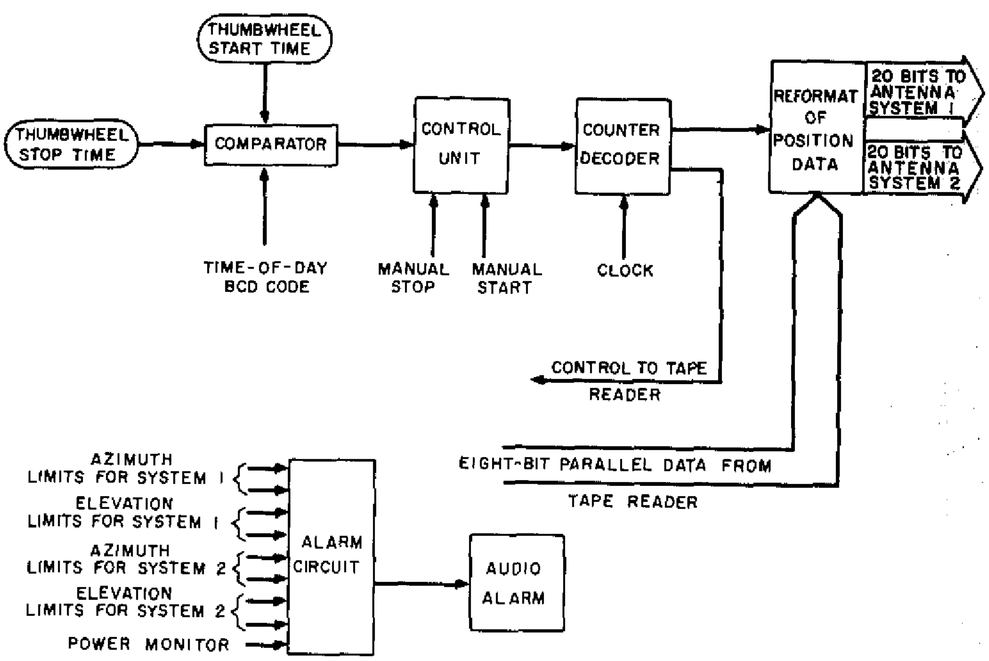

Fig. 9 - Controller in the NRL system

CONCLUSION

Figure 10 shows the block diagram of a digital auto-tracking system that allows two antenna systems to be controlled independently in azimuth and elevation. The additional equipment required to change from the manual system is one controller, one tape reader, and two D/S converters. The approach taken proves to be a very cost effective method of converting a manual antenna control system to an automatic system with a minimum of additional equipment.

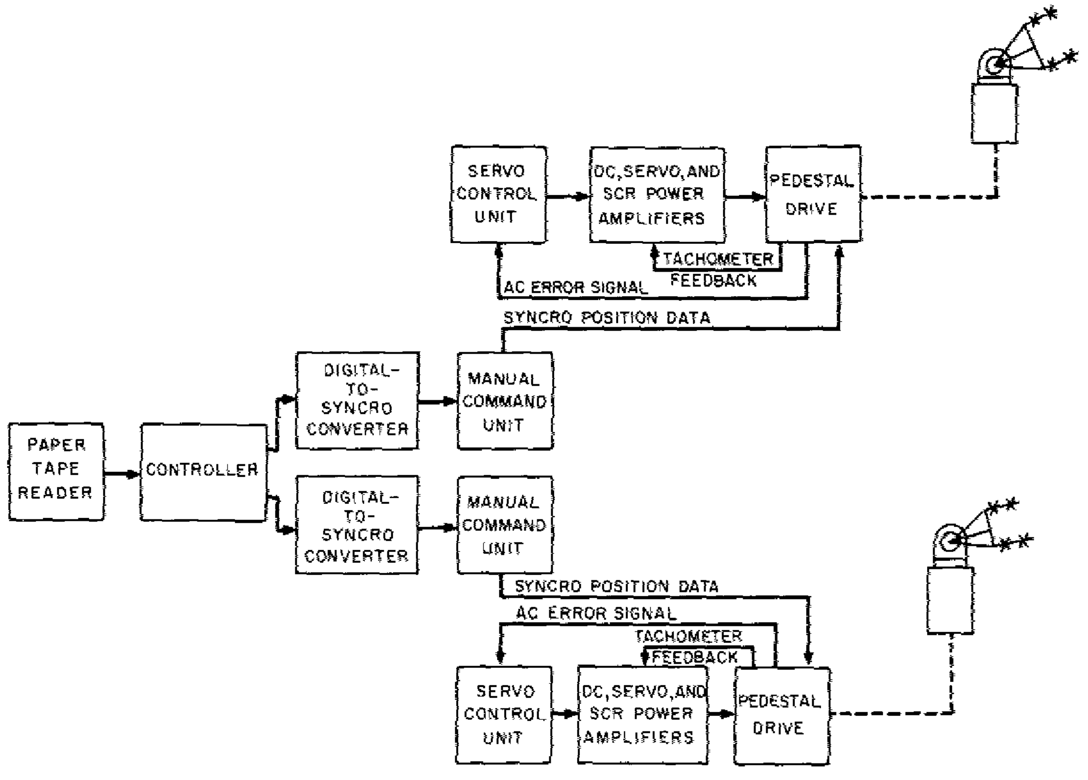

Fig. 10 - Digital auto-tracking antenna system. This is the automatic/manual system updated at NRL from two of the manual systems shown in Fig. 1

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