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A PORTABLE SERVO RECORDER FOR ANTENNA PATTERNS

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ABSTRACT

Present microwave-antenna measurements require a portable, single-package pattern recorder. Such a recorder, with an 80-db range of input voltage plotted against angular position of the antenna in rectangular coordinates, has been built for directive antenna patterns. The unit is of the direct-inking type having an effective plotting size of 7 x 10 inches. It is based upon the follow-up servo principle, which makes use of a four-cycle, logarithmic attenuator and a motor-driven, mechanical differential.

The motion of the plotting table is produced by a geared (36-to-1) 5F synchro. The entire assembly, contained in one cabinet mounted on rubber-tired casters, weighs less than 200 pounds. The accuracy of the plotting stylus is about ± 0.25 db. The plotting table motion is accurate to about $\pm 1/4^\circ$ of a precision antenna mount having a normal 1-to-36 synchro angular take-off.

PROBLEM STATUS

This report concludes work on this phase of the problem. Work will continue on the basic problem.

AUTHORIZATION

NRL Problem No. R09-46R

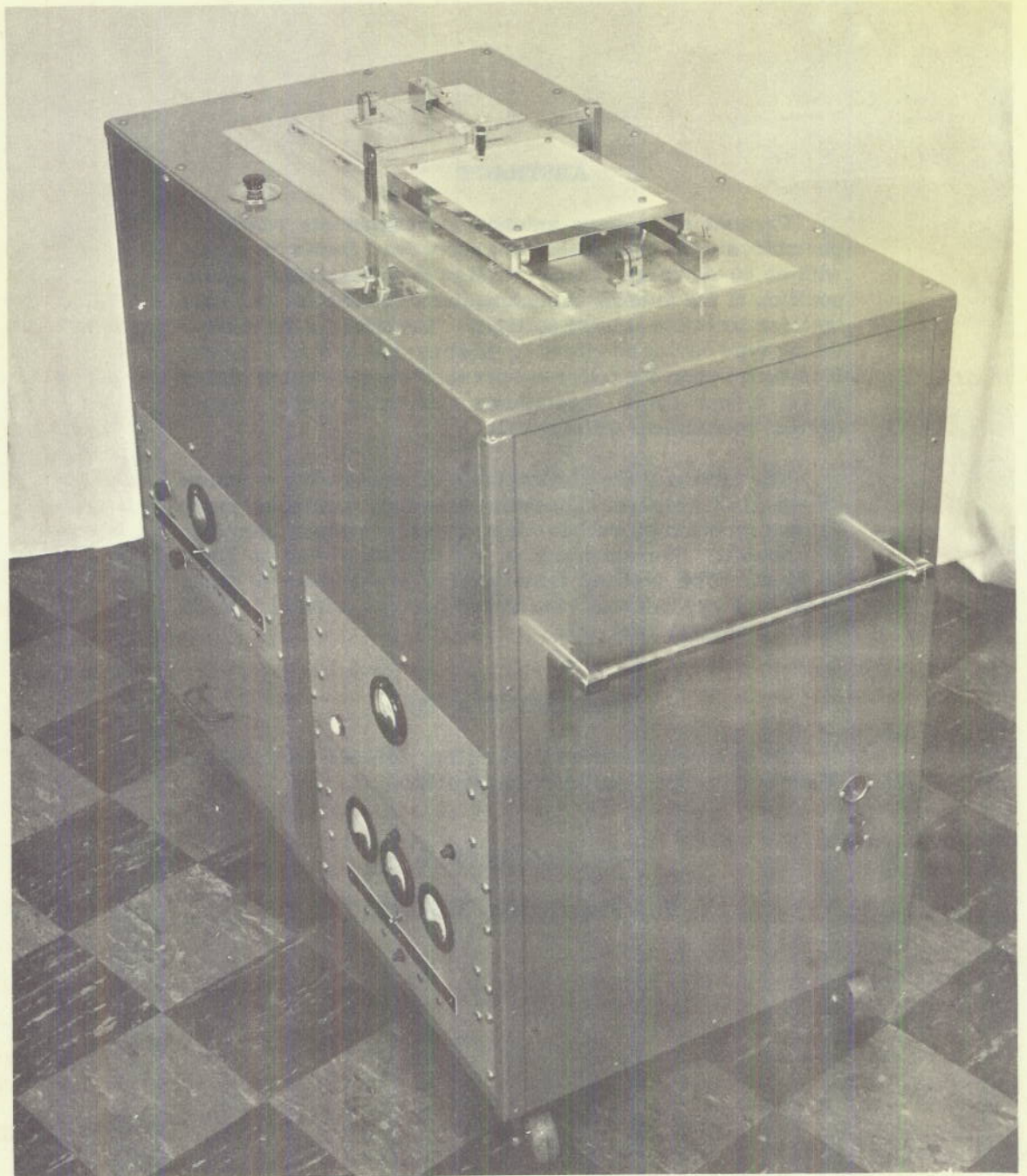


Fig. 1 - The complete recorder

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A PORTABLE SERVO RECORDER FOR ANTENNA PATTERNS

INTRODUCTION

The requirement for antenna-pattern recorders in microwave-antenna work has been well established in practice over the past years of intensive research and development in that field. A number of recorders having special features which adapt them to particular applications in antenna work have been operated and reported by several activities.¹ The recorder herein described is an example of such specialization and is an extension of work done at Radiation Laboratory, M.I.T.² The present version emphasizes portability in a single-package unit which best fits the general requirements of this antenna laboratory.

GENERAL DESCRIPTION

The recorder shown in Figure 1 is a direct-inking type having a continuous 80-db range of input voltage plotted against angular position of the antenna in rectangular coordinates. Effective plotting size is 7 x 10 inches. The inking stylus is controlled by a servo of the follow-up type using a four-cycle logarithmic attenuator and motor-driven mechanical differential.³ The motion of the plotting table is produced by a geared (36-to-1) 5F synchro. The entire apparatus, including amplifier power supplies, servo control unit, and switching gear, are contained in the one cabinet. The unit is 38 inches high, 43 inches long and 24 inches wide, weighs less than 200 pounds, and is mounted on rubber-tired casters. These features provide all the needed portability for general use in the antenna laboratory.

¹ Symonds, R. J., "Microwave antenna pattern recorder," Bell Telephone Laboratories Report MM-44-170-55, November 1944; LeCaine, H., and Katchky, M., "Automatic antenna pattern recorder," National Research Council of Canada, October 1946; Kuder, M. L., "Preliminary instruction book for airborne antenna pattern recorder," NRL ltr. report 1320-159/46, June 1946. In addition, AIL, Mineola, L.I., and the Antenna Research Laboratories, Columbus, Ohio, have developed polar recorders for use with low-directivity antennas.

² Tyson, O. A., "Antenna measuring equipment: automatic antenna pattern recorder," MIT Radiation Laboratory Report 601-4, January 16, 1945.

³ James, H. M., Nichols, N. B., and Phillips, R. S., "Theory of servomechanisms," MIT Radiation Laboratory Series, Vol. 25, New York, McGraw-Hill, 1947; Lauer, H., Lesnick, R., and Matson, L. E., "Servomechanism fundamentals," New York, McGraw-Hill, 1947.

The major components of the recorder, shown schematically in Figure 2, include the signal amplifier, the follow-up attenuator, the attenuator amplifier, the differential control stage, and the mechanical differential and drive motors.

The Signal Amplifier

The signal amplifier is a fixed-tuned (1000 cps) audio amplifier having an input impedance of 200 ohms and an output impedance of 10,000 ohms at the output transformer secondary. The voltage gain is 10^4 , and the maximum output noise into the follow-up attenuator is 3×10^{-3} volt. The unit is linear from less than 10^{-2} volt to more than 10^2 volts output, and hence is more than adequate for coverage of the required 80-db range of the system.

The Follow-up Attenuator

The attenuator consists of two 2-cycle logarithmic potentiometers, which are mechanically ganged and electrically connected in cascade by an isolation amplifier which prevents loading of the first section by the second section. The attenuation range is 80 db. Physically, the attenuator (shown in Figure 3) is a circular unit 1-5/8 inches by 1-5/8 inches having a torque requirement of about 2 ounce-inches. It is manufactured to specification by the Fairchild Camera and Instrument Corporation.

The Attenuator Amplifier

The attenuator amplifier is also a tuned amplifier which delivers approximately 30 volts d.c. from the signal rectifier to the differential control stage when the latter is at balance. The adjusted voltage gain is about 1000.

The Differential Control Stage

A pair of 807's are so arranged that the field currents of the two differential drive motors are separately controlled by the d-c output of the attenuator amplifier. This is accomplished (1) by connecting the motor fields in series with the anodes of the 807's and (2) by the use of common bias so that a departure of d-c control voltage from the balance point will cause an increased current flow in one motor field while at the same time reducing the current flow in the other motor field.

The Mechanical Differential and Drive Motors

The mechanical differential and drive motor assembly (shown in Figure 4) consists of two standard, medium-inertia, shunt-wound motors driving a small miter-gear differential. The mechanical output of the differential propels the writing stylus and the follow-up attenuator in accordance with the difference between the drive motor speeds and in a direction determined by the sign of the difference. A small over-ride clutch limits the differential output torque so that positive mechanical limit stops can be used without appreciable rebound. Woven phosphor-bronze cable is used to link the several moving parts of the stylus servo as well as to link the plotting table to the synchro-reduction gear.

PERFORMANCE

The accuracy of the plotting stylus is, of course, largely dependent upon the accuracy of the follow-up attenuator. In this case it averages about ± 0.25 db. The incremental sensitivity is approximately 0.1 db. Maximum writing speed at critical damping is about 40 db per second.

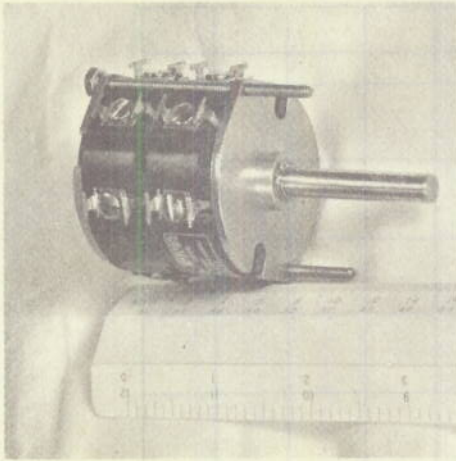


Fig. 3 - The follow-up attenuator

The accuracy of the plotting table motion is better than $\pm 9^\circ$ of a 5G synchro generator connected as shown in the schematic diagram. This means an accuracy of about $\pm 1/4^\circ$ on a suitably geared antenna mount with the normal 1-to-36 synchro angular take-off.

ILLUSTRATIVE APPLICATIONS

Figure 5 is a typical plot, taken by the recorder, of a horn-fed, 24-inch paraboloidal antenna at a wavelength of 1.25 cm (aperture in wavelength 48). The antenna was affixed to a standard mount with a 1-to-36 angular take-off. The square-law bolometer used as a demodulator, as is customary in this type of work, accounts for the 40-db maximum range with the 80-db recorder. It is to be noted that, while the antenna was scanned from -90° to $+90^\circ$, no noise energy appears at any point in the graph.

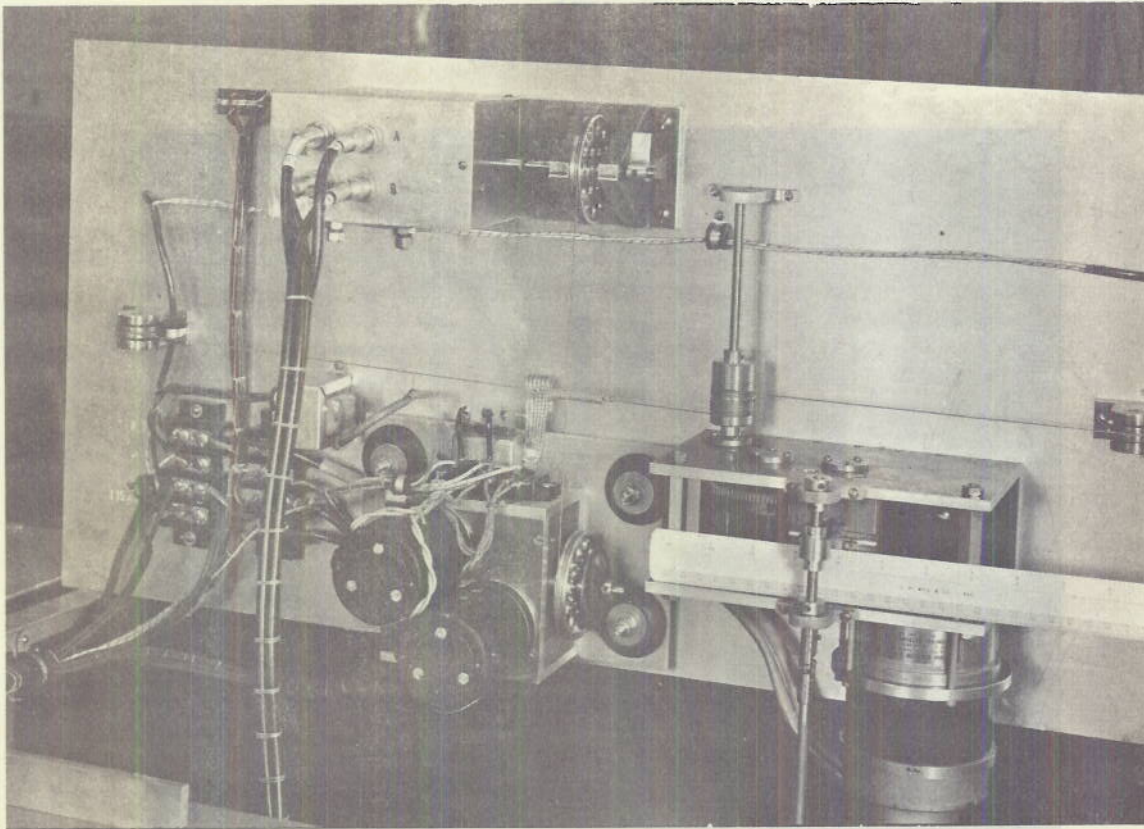


Fig. 4 - The differential and drive motors

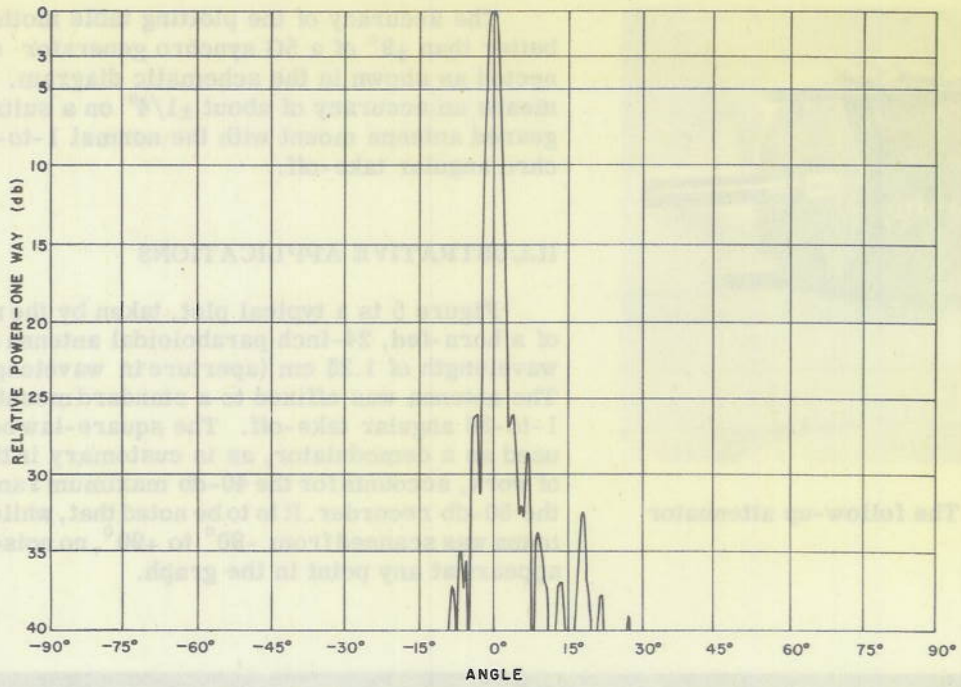


Fig. 5 - A typical plot

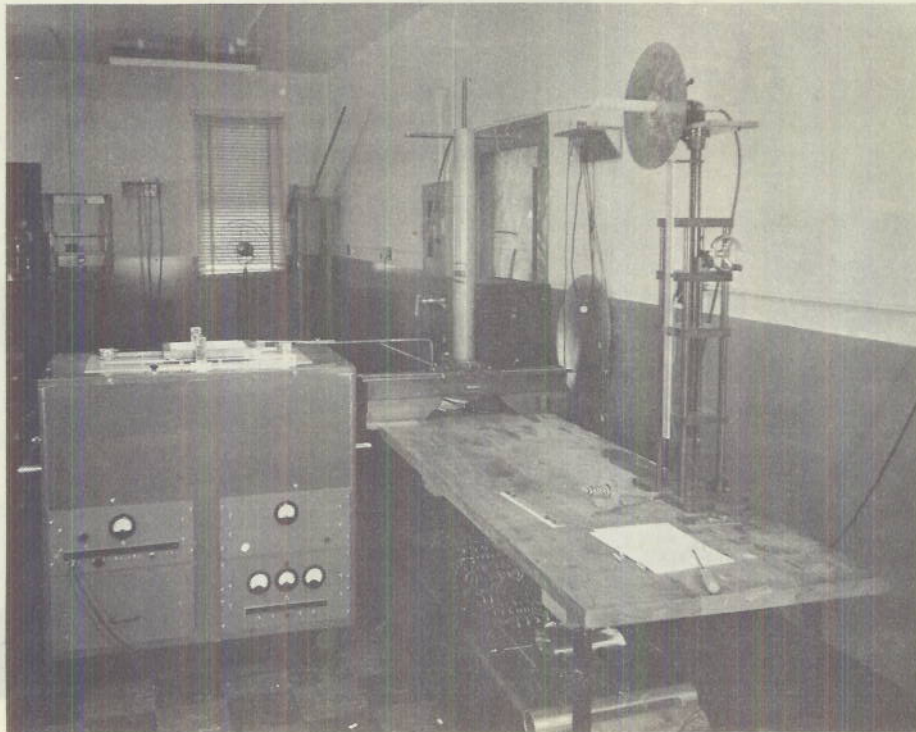


Fig. 6 - A laboratory setup

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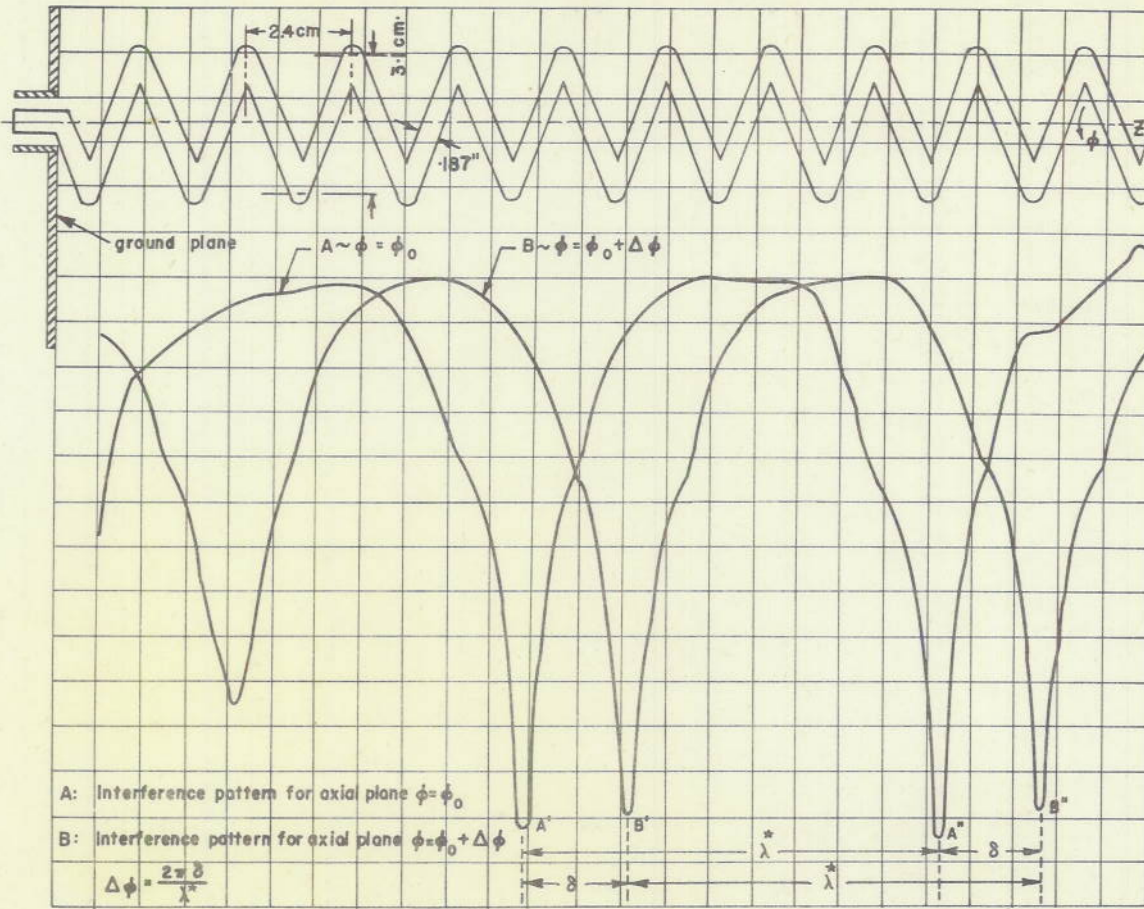


Fig. 7 - Phase vs ϕ and Z

Figure 6 shows the recorder connected to a specialized laboratory set-up for the measurement of relative phase from point to point in the very near field of a helical radiator. The search probe and supporting column are mounted on a small lathe bed, thus affording a means of accurately propelling the probe along the helix in a line parallel to its axis. In this instance the plotting table of the recorder is secured by an extension arm directly to the supporting column. Hence, a one-to-one correspondence is obtained between the probe motion and the table. For this type of measurement the plotting table release clutch is set to neutral.

Figure 7 is the resulting graph of the phase detector output versus position. The two curves shown are those obtained for $\phi = 0$ and $\phi = 2\pi\delta/\lambda \approx 91^\circ$.
