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EVALUATION OF A COMBINED OMNIRANGE-DISTANCE MEASURING EQUIPMENT AND RACON INSTALLATION

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by

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INTRODUCTION

This report describes certain tests conducted to determine the feasibility of adding a CPN-6 radar transpondor beacon (commonly known as a "Racon") to a standard VHF omnirange and distance measuring equipment (DME) installation. Tests were made to determine whether any interference to the normal operation of omnirange or DME would be introduced as a result of the installation and operation of a closely adjacent CPN-6 racon. The final plan of installation required complete redesign of the DME transpondor antenna, and modification of the omnirange antenna. Tests were conducted with both high and low stability types of DME as well as with both single and double pulse systems. Tests failed to reveal interaction or interference of any type among the three equipments, however, the combined installation proved to be a somewhat cumbersome undertaking with several disadvantages.

The work covered by this report was undertaken as a result of a request made by the Department of the Navy to the Office of Federal Airways.

EQUIPMENT

CPN-6 Racon

The CPN-6 is a heavily constructed 3-centimeter microwave radar beacon designed for ground or ship installation, and is intended primarily to serve as a navigational aid for aircraft equipped with suitable radar. The beacon radiates no signal until interrogated by a 9275 Mc (X-band) radar pulse of $2\frac{1}{2}$ to 5 microseconds in duration. The beacon then replies with a train of one-half microsecond pulses, their number and spacing forming an assigned code for identification purposes. Peak power of the beacon reply is approximately 40 kw on an X-band frequency of 9310 Mc. A horizontally polarized antenna is employed consisting of two linear arrays, one for receiving and one for transmitting. Each array consists of 12 rings of 7 slots each uniformly spaced around a circular wave guide. The two arrays have identical radiation patterns, nondirectional in azimuth and with a vertical beam width of five degrees at the half-power points.

Distance Measuring Equipment

The DME ground equipment is a radar-type transpondor operating on L-band frequencies from 960-1215 Mc. A common antenna is used, fed through 50-ohm RG-17/U cable. Except for a random squitter to operate the automatic frequency control, there is no signal radiated until interrogating pulses are received from an aircraft. Pulse for pulse, the transpondor replies with pulses $1\frac{1}{2}$ microseconds wide at a peak power of 2 to 4 kw. The antenna is a vertically polarized stacked array with a nondirectional horizontal pattern and a vertical beam width of ten degrees. The antenna, which is mounted above and coaxially with the omnirange antenna, has developed into two types. The type manufactured by Hazeltine Electronics Corp. for the experimental system consists of a lightweight aluminum and stainless steel structure four wavelengths high, consisting of eight half-wave diamond-shaped radiators mounted on each side of a central structure. The entire unit is protected by a lightweight fibreglass cover. The type manufactured by Federal Telecommunication Laboratories for the experimental system consists of a stacked array of nine discone elements anchored together with fibreglass rods, and further strengthened by a heavy fibreglass housing.

Omnirange

The VHF omnirange is a navigation facility now in commissioned operation at many locations throughout the country. The omnirange transmitter radiates a cw signal with an output power of 200 watts. For optimum accuracy of azimuth determination, an antenna pattern approaching that realized in free space is desirable. Large objects mounted near the antenna cannot be tolerated, and any object 50 feet or higher within a distance of 1,000 feet radius is highly undesirable.

INSTALLATION AND OPERATION

Original Installation

The CPN-6 first was installed, together with a single pulse type DME transpondor, in a small building located approximately 250 feet from the omnirange station, see Fig. 1. The CPN-6 antenna with connecting waveguides was mounted about 40 feet above the ground on the same pole as the DME antenna as shown in Fig. 2. A specially designed adjustable mounting bracket was designed to allow its position to be made absolutely vertical. Fig. 3 is a view of the complete DME-CPN-6-VOR installation. Operation of both the DME and the CPN-6 at this site for a period of several months proved conclusively that it was feasible and completely satisfactory to operate the two equipments in the same building. Specific tests designed to detect interaction or interference between equipments were negative, both from a video and from a radio frequency point of view.

During this time many flights were made in conducting tests of the DME. On many occasions, while checking the operation of the CPN-6, it was found that an aircraft was interrogating the racon. The Air Materiel Command, Wright-Patterson Air Force Base, reported that a B-17 made three runs over the racon at altitudes of 10,000, 7,500 and 5,000 feet. Continuous indication was received from the racon each time up to a distance of 80 miles from Indianapolis.

A short time after installation of the CPN-6, a multiplex DME system employing two pulses was installed. At no time did the operating characteristics or the efficiency of either equipment seem to be affected in any manner by the presence of the other.

Combined Installation

The combined installation presented the problem of mounting both the DME and CPN-6 antennas coaxially above a standard VHF omnirange antenna with provision for two X-band waveguides to pass through both the DME and omnirange arrays. The most difficult portion of the problem was to carry the waveguides around or through the DME antenna without disturbing its impedance or radiation characteristics. To design and produce a DME antenna that would meet these requirements, a contract was let to Federal Telecommunication Laboratories, Inc.

Using their original DME discone antenna, the first solution was a straightforward approach, viz., placing the waveguides around the DME antenna in a gradual spiral, always keeping the small dimensions of the waveguide adjacent to the fibreglass housing. See Fig. 4. The standing-wave ratio versus frequency of the antenna modified in this manner is shown as Fig. 5. Numerous DME flights were made using this modified antenna, and performance was normal at all times. However, a more clean-cut solution to facilitate mounting the CPN-6 antenna was desired. It was evident that the basic design of the discone type antenna would have to be modified considerably to allow the waveguides to pass through its center and retain the same impedance and radiation characteristics. As a solution, Federal developed an 8-element stacked diphorn antenna, so-called because it radiates as a dipole but has the general appearance of a horn. A view of the internal construction of the diphorn showing the X-band waveguide passing through the center is shown in Fig. 6. The standing-wave ratio versus frequency of the diphorn antenna is shown in Fig. 7, and the vertical antenna pattern is plotted in Fig. 8. Fig. 9 shows an experimental arrangement devised to secure the CPN-6 antenna to the top of the DME diphorn and facilitate connection of the waveguides. This unwieldly assembly, weighing approximately 150 lb., was mounted on top of the omnirange antenna by bolting the assembly down on a 4-inch pipe, which extended through and above the omnirange antenna. As a safety measure, the assembly was guyed with nylon cords anchored to the omnirange counterpoise. Waveguide and DME cable were passed through the 4-inch pipe extending through the geometric center of the omnirange antenna, and secured to connections built into the bottom end of the diphorn antenna. The complete installation is shown as Fig. 10.

The DME and CPN-6 were placed in continuous operation for six weeks. After this period the combined array was removed and a conventional DME array was re-installed. This action was necessary because the combined antenna assembly, being connected by means of rigid waveguides and guyed to the counterpoise, made it virtually impossible to rotate the omnirange antenna assembly for any test or calibration purposes.

CONCLUSIONS

Operating the three equipments satisfactorily at a single site is quite possible, but such an installation with the present antennas is far from being a desirable or practical arrangement. The experimental L-band diphorn antenna is considerably larger and heavier than either the conventional Hazeltine or the Federal DME arrays and, when assembled to the CPN-6 antenna, presents a combination so heavy and awkward that a crane is required to effect the installation and removal. The assembly was difficult, if not impossible to service.

At a station where it is desirable to have the CPN-6 equipment associated with the omnirange and DME, two methods of installation are possible. The method to be chosen will depend largely upon the number of such installations and the future planning for the addition of other types of equipments to the basic omnirange and DME facility. If only a few racons are to be installed, the racon antenna may be mounted on a 40-foot pole approximately 250 feet from the omnirange and DME building. A small building at the base of the pole will be required to provide shelter for the racon and to keep the length of the waveguides to a minimum. If, on the other hand, a large number of racons are to be installed, it would prove economical to design a composite antenna incorporating the radiators for the omnirange, DME, and CPN-6, placing all equipments in one building. Basic techniques required in the design of such an antenna system are well known. However, additional work would be required to arrive at a production design.

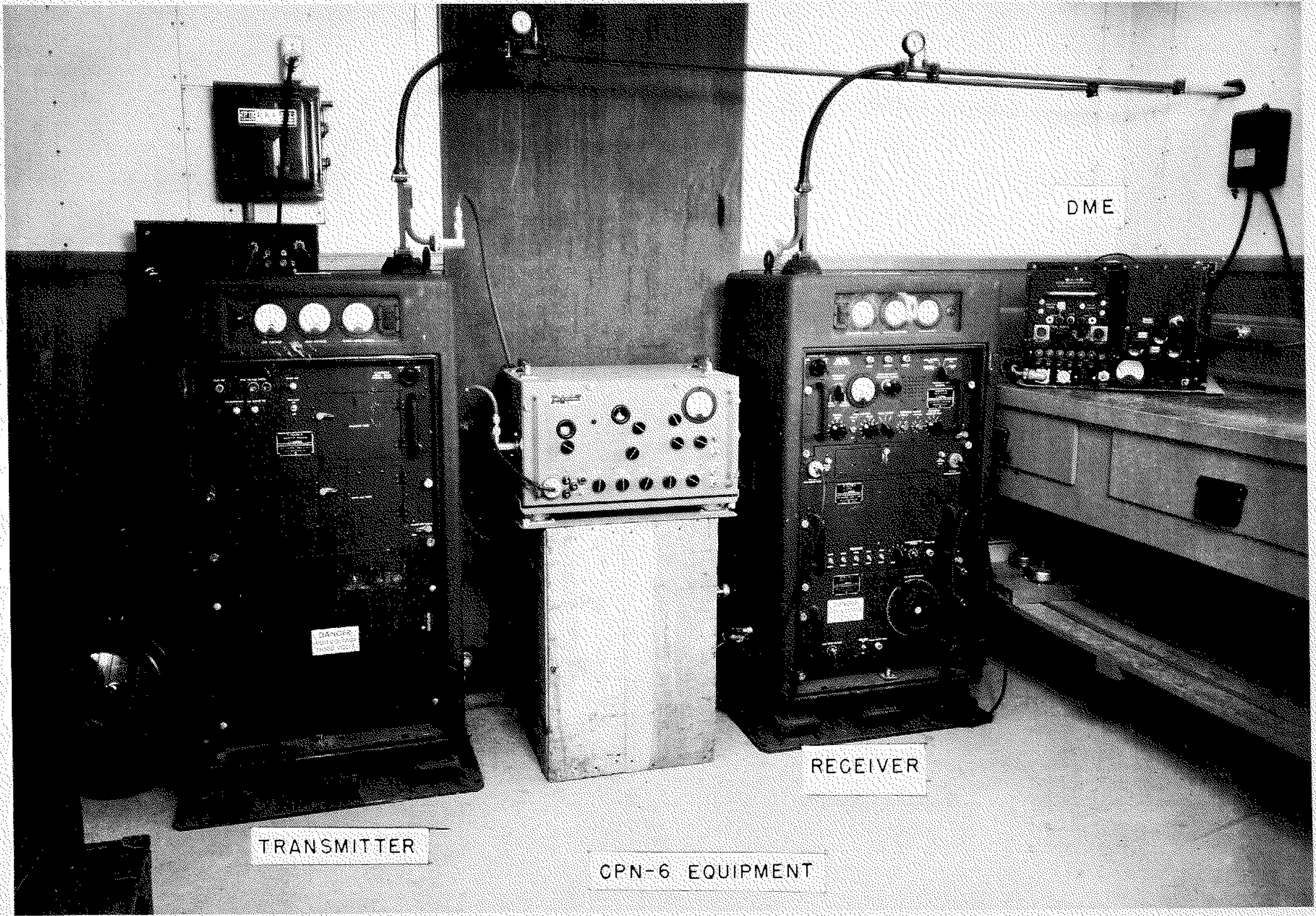

FIG. 1 CPN-6 AND DISTANCE MEASURING EQUIPMENT

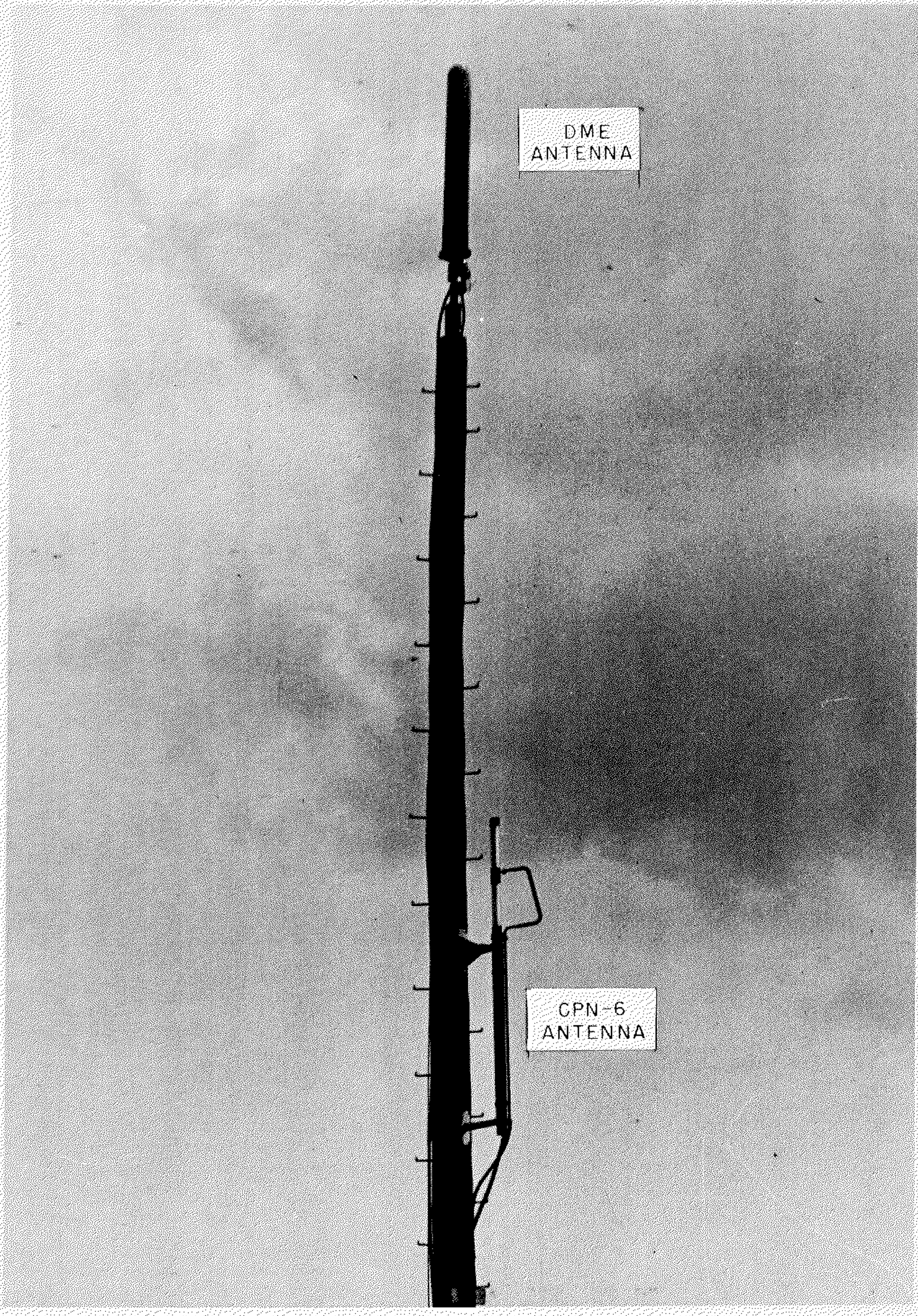

FIG. 2 ORIGINAL CPN-6 AND DME ANTENNA INSTALLATION

FIG. 3 EXTERIOR OF VHF OMNIRANGE, CPN-6, AND DME

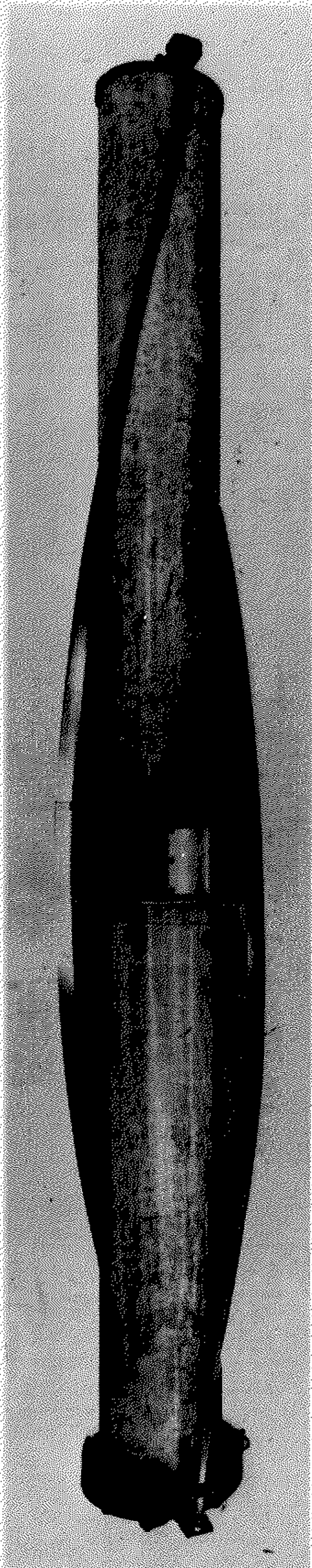

FIG. 4 DISCONE ANTENNA WITH WAVEGUIDES MOUNTED ON EXTERIOR

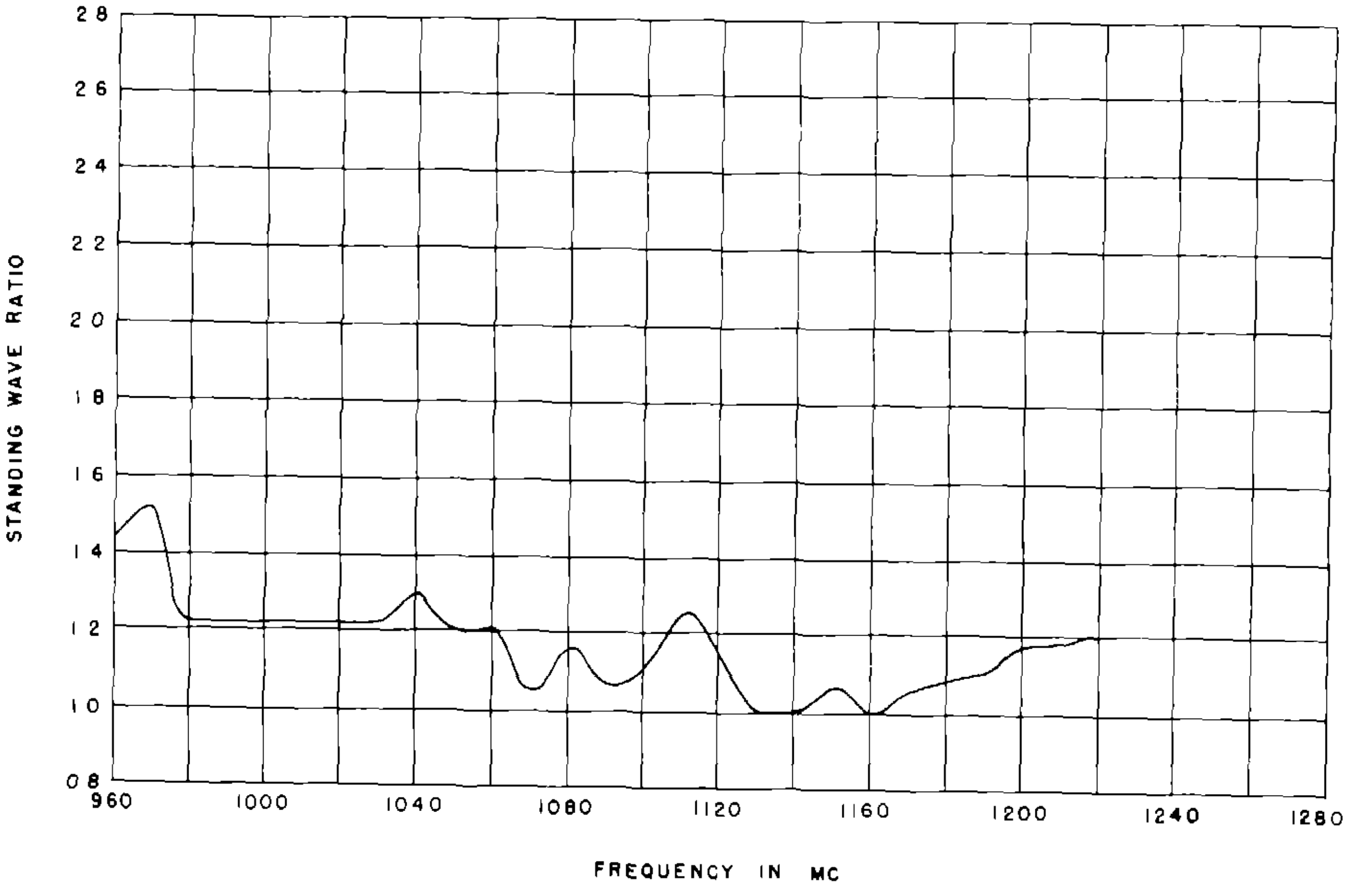

FIG 5 STANDING WAVE RATIO OF DISCONE ANTENNA WITH WAVEGUIDES

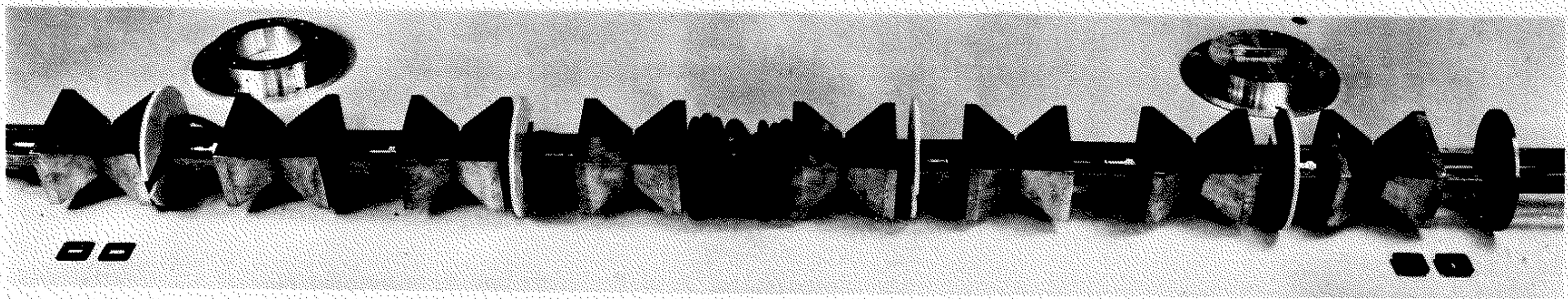

FIG. 6 DIPHORN ANTENNA, INTERNAL CONSTRUCTION, SHOWING
THE 8 STACKED ELEMENTS WITH X BAND WAVEGUIDES

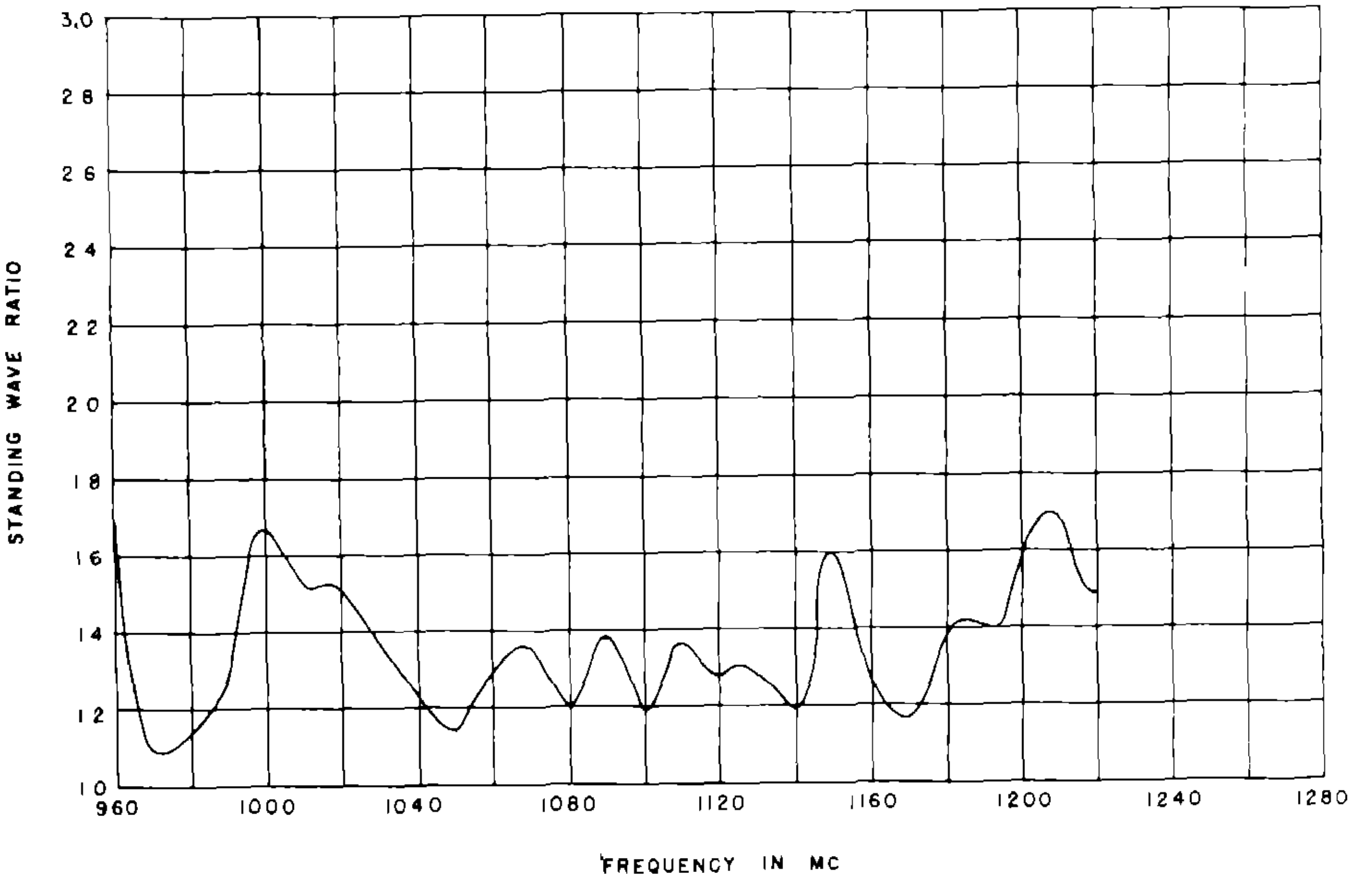

FIG 7 STANDING WAVE RATIO OF DIPHORN ANTENNA

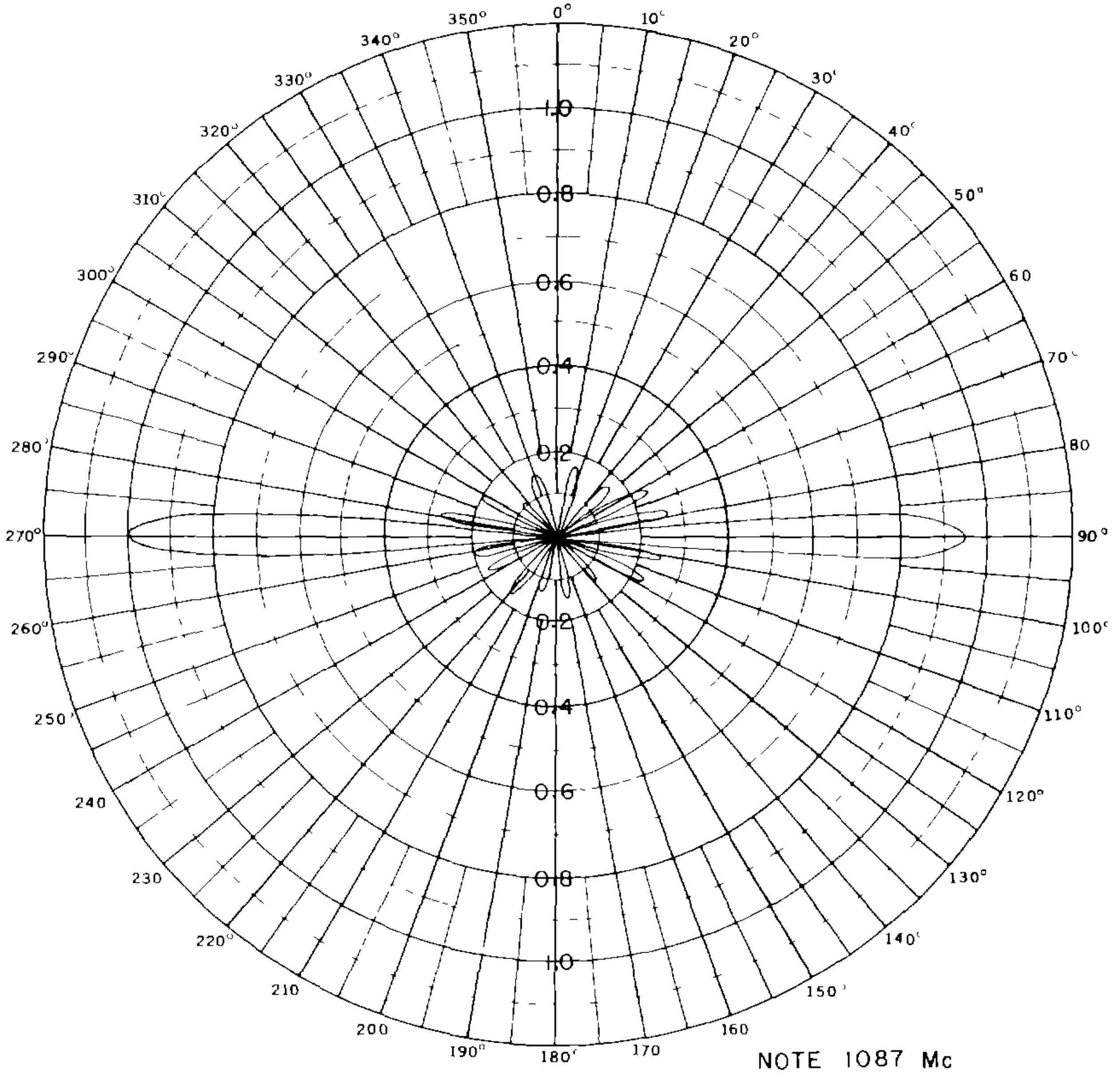

FIG 8 VERTICAL RADIATION PATTERN OF DIPHORN ANTENNA

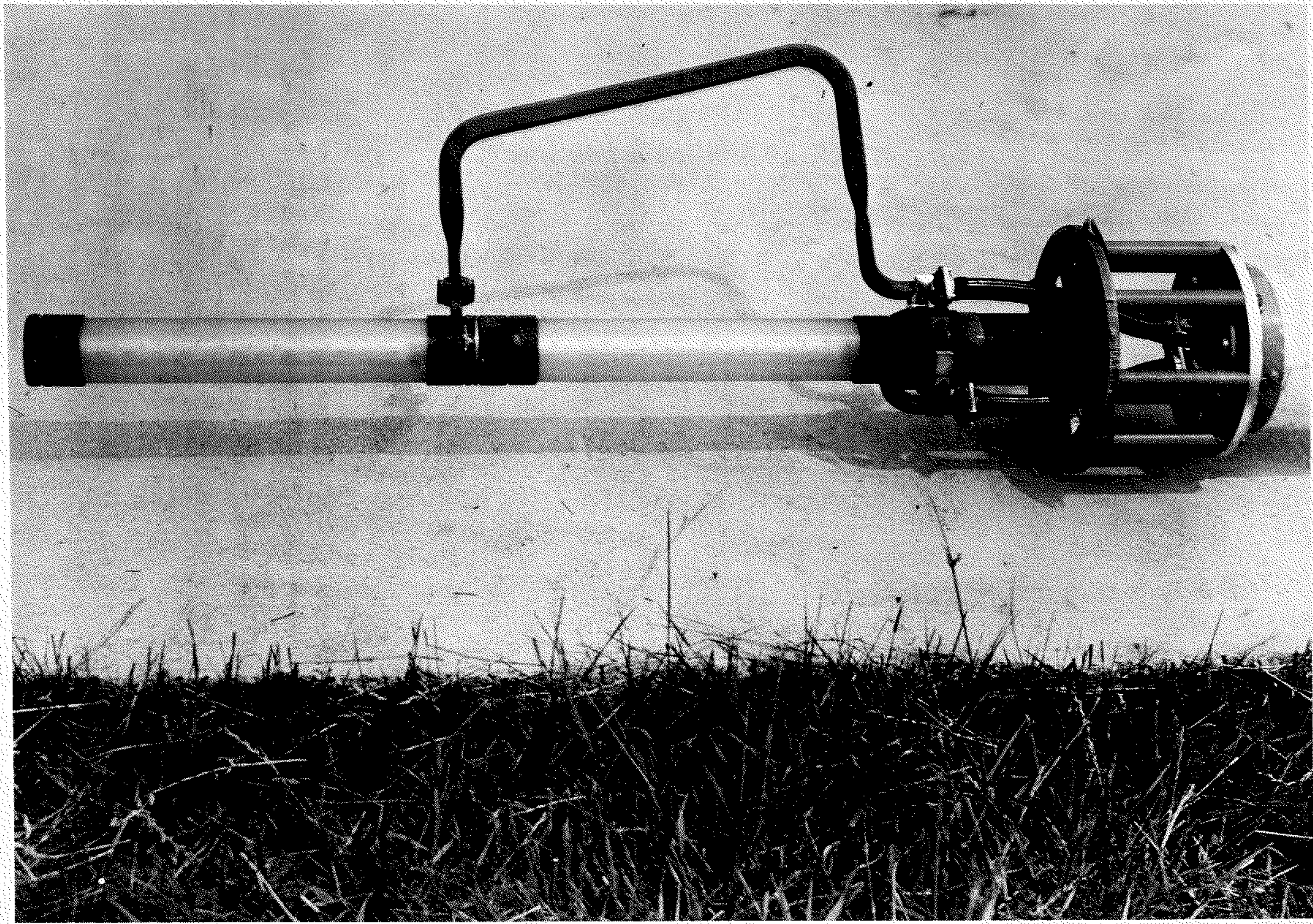

FIG. 9 ATTACHMENT OF CPN-6 ANTENNA TO DIPHORN ANTENNA

FIG. 10 COMBINED ANTENNA MOUNTED ON OMNIRANGE