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U. S. NAVAL TECHNICAL MISSION TO JAPAN
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SAN FRANCISCO, CALIFORNIA

27 December 1945

RESTRICTED

From: Chief, Naval Technical Mission to Japan.
To : Chief of Naval Operations.

Subject: Target Report - Japanese Centimeter Wave Technique.

Reference: (a)"Intelligence Targets Japan" (DNI) of 4 Sept. 1945.

1. Subject report, covering Target E-04 of Fascicle E-1 of reference (a), is submitted herewith.

2. The investigation of the target and the target report were accomplished by Lt. W.G. Lamb, USNR, with the assistance of Lt. E.E. Schwalm, USNR, and Lt.(jg) S.G. Kadish, USNR, as interpreter and translator.

C. G. GRIMES
Captain, USN

JAPANESE CENTIMETER WAVE TECHNIQUES

"INTELLIGENCE TARGETS JAPAN" (DNI) OF 4 SEPT. 1945

FASCICLE E-1, TARGET E-04

DECEMBER 1945

U.S. NAVAL TECHNICAL MISSION TO JAPAN

SUMMARY

ELECTRONICS TARGETS

JAPANESE CENTIMETER WAVE TECHNIQUE

A general discussion of centimeter wave technique is presented. Most of the equipment inspected and methods investigated were elementary in theory and crude in design. The reasoning of the Japanese physicists was good, but production was almost impossible. About 80% of the productive capacity for microwave equipment had been destroyed by the end of 1944, or was being decentralized to avoid destruction. In addition, skilled workers to produce such components were impossible to obtain. This, together with the lack of co-ordinated scientific effort, places Japanese microwave technique on a level more or less comparable to that of the Allied Nations in early 1941.

TABLE OF CONTENTS

REFERENCES

Location of Target:

Navy Yard, SASEBO
Navy Yard, YOKOSUKA
Second Naval Technical Institute, KANAGAWA
Second Naval Technical Institute, Meguro Branch, TOKYO

Japanese Personnel Interviewed:

(See Enclosure A)

LIST OF ENCLOSURES

(A) Japanese Personnel Interviewed (in connection with this report).

LIST OF ILLUSTRATIONS

INTRODUCTION

This report covers Japanese centimeter wave technique, with special regard to radar.

Information and conclusions are based upon interrogations of Japanese naval and technical personnel and inspection of equipment, installations and experimental facilities.

THE REPORT

Part I - MICROWAVE TECHNIQUES

Lack of technical personnel, poor coordination of research and development and inability of production engineers to translate theory into practice all combined to result in halting, make-shift application of recognized microwave techniques. Even in the later months of the war, when captured or recovered microwave equipment was available to the Navy, they were unable to appreciate and make use of some of its obvious advantages.

In the first place, microwave techniques for aircraft radar began in the summer of 1944 with the initial design problem on the Prototype 19, Air Mark 3, Model 30 radar. This was a 10 centimeter equipment with 6 kw (calculated) peak power, using a 14 microsecond pulse at a repetition rate of 600 cps. A doublet antenna with parabolic reflector and circular scan for presentation to the operator was used. While coaxial feed was used in a few of the laboratory models, it never reached the production stage, and no one knew precisely what sort of transmission line or wave guide it would have had in its final form.

Research physicists, in many cases, knew the theory of wave guide feed and termination, yet did not have the practical, mechanical ability to produce a working model. Production engineers were unable to cope with the mathematics involved in scientific explanations. They were familiar with the principles of automatic frequency control, but it was not applicable to the M-60-A magnetron used as local oscillator in most shipborne radar - 10 cm variety. The airborne set used a 955 as local oscillator, with a harmonic for mixing. Consequently, no research was necessary to provide AFC circuits that would maintain peak performance over a 100° C temperature change and at high altitudes. Many studies were made in university laboratories of velocity-modulated tubes (double cavity and reflex types), but production difficulties were so great that the tubes never reached the services.

Because of the variation of opinion between physicists and design engineers, no definite conclusions concerning wave guide dimensions were ever reached. Consequently, all wave guide, except that which was strictly experimental, was of the large circular variety used on shipborne installations. In one instance, at a radar training school, the wave guide in use was 3 inch "down spout", with no effort at banding the joints for electrical continuity, or preventing discontinuities in the inner surface. Since no need ever existed for flexible wave guide, it was never considered, even as a research problem in the university laboratories.

Crystal detectors of iron pyrites or silicon were used in all recent models of microwave equipment. Earlier, in the 22 Kai 1 and 22 Kai 2, the M60 and M60A magnetrons were used as super-regenerative and autodyne detectors. Results were poor, since the tuning was critical and unstable. Tubes of this type have been collected and shipped, together with their characteristics, to the Naval Research Laboratory, Anacostia, D.C. for further analysis.

Test equipment for the microwave regions was never developed beyond the elemental stages. Spectral analysis was accomplished by plotting the response from a high Q resonant cavity (Q being approximately 30,000) resembling an echo box with a horn-type antenna. Signal generators were available with ranges as low as 3 centimeters, but power output was quite low. A tapered coaxial line with resistance introduced into the inner conductor was used on test equipment as a dummy load. Power output was never measured through use of directional couplers and thermistors or similar techniques. Peak power ratings were calculated from pulse width and average operating conditions. A summary of test equipment used will be found in NavTechJap Report - "Japanese Radio Frequency Measuring Technique" - Index No. E-22.

One interesting aspect of the microwave units was the use of lobe-switching on the receiving antenna. The method of operation is illustrated in figure 1.

LOBE-SWITCHING DEVICE

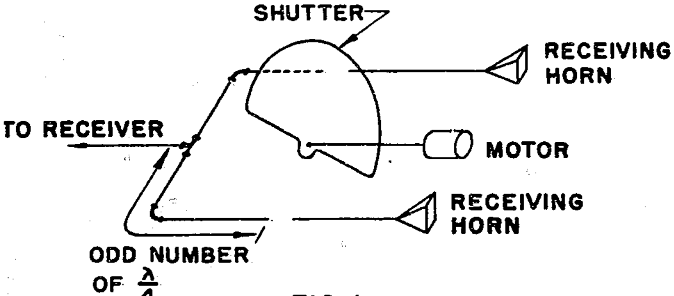


FIG. 1

This consisted of a rotor blade or shutter which alternately opened and closed the two rectangular wave guides from the electromagnetic horns used as the receiving antennas. The length of wave guide involved was critical, but no provision was made for adjusting the device for optimum performance. This was used on the Mark 3, Model 2, an experimental shipborne radar that had never been put in service.

Most operational 10 centimeter radar employed electromagnetic horns, rather intense experimental work was being done, however, on the prototype model 220, a 10 centimeter equipment using a single parabolic reflector, oscillating feed, and duplexers. Beam width of this antenna was 14 degrees between half-power points, and a bearing accuracy of ±40 minutes was claimed. Range and bearing presentation was sinusoidal. Figure 2 illustrates the bearing presentation. Bearing discrimination, incidently, was stated to be ±15 degrees.

BEARING INDICATION-PROTOTYPE 220

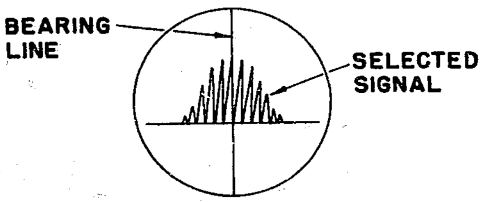
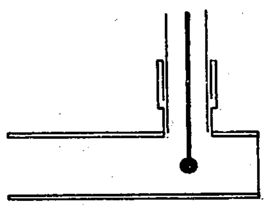


FIG. 2

Part II - EXPERIMENTAL TECHNIQUES

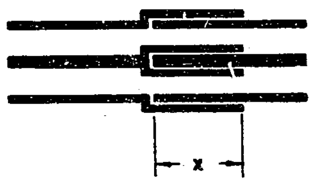
A brief report on the experiments conducted at Osaka Imperial University by Dr. J. ITO is here summarized. In all cases, the wave length employed was 10 centimeters, and the rectangular wave guide had dimensions of 7.0 x 4.5 centimeters. The mode of waves in this guide was H10.

Figure 3 illustrates the rotating and coupling system used in one experiment, going from rectangular guide to concentric line. This was accomplished by simply introducing the inner conductor of the coaxial line into the wave guide by the proper amount. The exact length and the position of the end plate of the guide was determined experimentally. The sphere on the end of the inner conductor was of appropriate size to give broad characteristics for impedance matching. The choke joint, two quarter-wave concentric lines as shown in the figure, provided nearly zero impedance between the outer edge of the coaxial line and the edge of the wave guide. This method afforded a rotating and coupling system with minimum reflections. This system was never put into operational use.



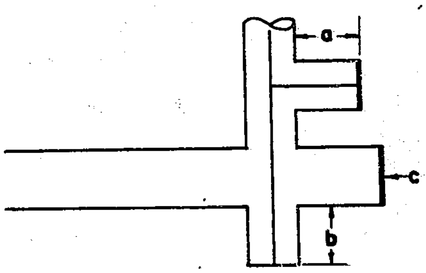
RECTANGULAR TO COAXIAL FEED SYSTEM

FIG. 3



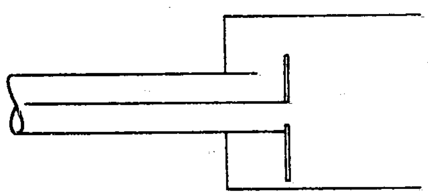
CONCENTRIC ROTATING JOINT

FIG. 4



GUIDE TO CO-AX. "a", "b" and "c" ADJUSTABLE.

FIG. 5



CO-AX TO GUIDE

FIG. 6

Figure 4 shows the normal rotating joint for concentric lines. This line had an inside dimension of 3.4 centimeters, with an inner conductor of 10 centimeter diameter, and gaps were 1 millimeter. In checking theoretical calculations, when length "X" was 2.2 centimeters, no reflections were observed. This joint was proposed for use in one of the Navy radars, which, however, never reached the operational stage.

Other experimental coupling systems - from rectangular wave guide to coaxial conductor - are shown in Figures 5 and 6. The operation is obvious from the sketches.

Two radiating systems were used experimentally, one employing a folded dipole with a circular reflector and placed at the focal point of a parabolic dish 1.5 meters in diameter. The antenna and reflector in the other were enclosed in a polystyrol cylinder as an aid in keeping the line free from moisture. These antennas were symmetrically excited with respect to their center point with coaxial line and phase reversing sleeves.

"It was determined experimentally that slot antennas (slits about one half wave long) in the end of the wave guide radiate as dipoles. This slot, when placed at the focal point of a parabolic mirror, gave a very sharp beam. Properties of the slit, such as its breadth and general shape were under investigation at the end of the war." - (Dr. ITO)

The need for duplexers was recognized when single antennas were used to give all possible protection to the receiver. Two "cut-Off systems" (U.S. designation: T-R and R-T systems) were needed, it was stated, but most investigation was on receiver protection. Experiments were conducted with inserts having gaps sealed in glass in hydrogen gas at about 0.1 atmospheres. Later, argon gas was employed, and finally water-vapor was used. "Keep-alive" systems apparently were not employed since "the ratio of power passed through this system when the discharge was extinguished to that when started was still too small to protect a crystal detector in the receiving system from damage, so we used the same system doubly in series."

Experiments were conducted using an insert in a resonant cavity which was coupled by slits to the wave guide. These were successful in the laboratory, but construction was difficult, and adjustment was not too dependable. Even using this "American and English" type, crystals were frequently damaged by transmitter power.

In reading the foregoing excerpts, it must be remembered that peak power employed was calculated as being approximately 2 K.W. No high peak powers were achieved, which would have exposed even more weaknesses in the methods.

ENCLOSURE (A)

JAPANESE PERSONNEL INTERVIEWED

Rank	Name	School, Degree and Class	Specialities
Vice Adm. (Tech.)	T. NAWA	Tokyo I.U., E.E.S.-1917; S.S.-Chemistry, 1919-1922.	Chief of Radar and Communication Department, 2nd N.T.I.
Capt.	H. TAKAHARA	Naval Academy, 1919; Tohoku I.U. E.E.S.-1932.	Oin-C, Fourth Section (Radar intercept, radio beacons and DF).
Capt.& Dr. (Tech.)	Y. ITO	Tokyo I.U. E.E.S. 1924; Technical High School, Dresden, Germany, 1927.	Oin-C, First Section (Fundamental research).
Capt. (Tech.)	Y. YAJIMA	Tohoku I.U., E.E.S.-1924.	Secretary to T. NAWA and head of production section.
Capt.	I. ARISAKA	Naval Academy, 1923; Tohoku I.U., E.E.S.-1934.	Oin-C, Third Section (radio equipment).
Capt.	K. NAGAI	Naval Academy, 1924.	Member of Administration Department.
Lt. Comdr. (Tech.)	T. HYODO	Tokyo I.U., C.E.S.-1936.	Research work in ultra high frequency materials and components.
Lt. Comdr. (Tech.)	S. MORI	Tokyo I.U., E.E.S.-1937.	Research in shipborne centimeter radar.
Lt. Comdr. (Tech.)	H. TSUJITA	Kyoto I.U., S.S. Physics, 1936.	Research in airborne radar (i.e. FH-3, FH-4, Fk-4, H-6).
Lt. Comdr. (Tech.)	K. KAMIYA	Tohoku I.U., E.E.S.-1936.	Research work in u.h.f. tubes and components.
Lt. Comdr.	O. OKAMURA	Tokyo I.U., E.E.S.-1940.	Research work in u.h.f. tubes.
Lt. Comdr.	S. MATSUI	Naval Academy, 1934; Osaka I.U., S.S. Physics.	Director of research of Yokosuka branch (research on installation of shipborne and land based radio and radar).
Lt. Comdr. (Tech.)	W. SUGIYAMA	Waseda University, E.E.S.-1940.	Research work on transmission lines.
Lieut. (Tech.)	K. OGATA	Tohoku I.U., E.E.S.-1941.	Research work on land based cm radar.
Lieut. (Tech.)	S. KAWAZU	Tokyo I.U., E.E.S.-1941.	Research work on land based low-frequency radar.

ENCLOSURE (A), continued

Lieut. (Tech.)	S. YAMANE	Kyoto I.U., E.E.S.-1942.	Research work on airborne radar and counter measures.
Lieut. (Tech.)	K. MORI	Naval Academy, 1940.	Radar Instructor.
Dr.	K. TAKAYANAGI	Kuramae Tech. College, 1921.	Consultant to T. NAWA, Head of Third Section (Radar).
Eng.	H. SHINKAWA	Waseda University, E.E.S.-1931.	Radar research.
Eng.	M. HAIYAMA	Tokyo I.U., S.S. Physics, 1933.	Research work on u.h.f. circuits.
Eng.	S. SUZUKI	Tokyo Physics School, 1929.	Airborne radar research.
Eng.	K. UEMINAMI	Washington University, 1934.	Research work on airborne radar, intercept receivers, and shipborne DF.
Mr.	R. KIMURA	Waseda University 1930.	Consultant to H. TAKAHARA and research work on r.f. instruments in Electro-Technical Laboratory of Japanese Government.
Mr.	S. NISHIYAMA	Uta University, 1932.	Interpreter with Electro-Technical Laboratory of Japanese Government.

I.U. - Imperial University E.E.S. - Electrical Engineering Section
S.S. - Science Section C.E.S. - Chemical Engineering Section