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DEVELOPMENT OF COMPONENTS FOR X_a FREQUENCY BAND

by

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CONTENTS

ABSTRACT

R-F Components developed at the Naval Research Laboratory for the X_a frequency band are described. This band covers the frequency range from 5200 to 5500 megacycles which utilizes a hitherto unused portion of the spectrum.

Transmitter power should be increased over that available at X-band (9,000 megacycles) and antenna gain is greater than that at S-band (3,000 megacycles). This provides some advantage for the X_a frequency over either of the two bands now in use.

Components developed for the 1-1/2 in. x 3/4 in. x .064 in. wave guide include choke-flange connector, rotating joint, directional-coupler mixer, standing-wave indicator, wavemeters (two types) and a calibrated attenuator. These components are utilized in receiver and test equipment and have some transmitter applications.

A summary of the entire X_a program is provided.

DEVELOPMENT OF COMPONENTS FOR X_a FREQUENCY BAND

INTRODUCTION

1. In accordance with its policy of spreading radar frequencies in the Fleet to avoid jamming and interference, and to make use of the characteristic properties of the various radar frequency bands, the Bureau of Ships authorized the Naval Research Laboratory to undertake the development of radar components in the X_a frequency band, 5200-5500 megacycles. This authorization was contained in Problem Request S-557 R-C.*

2. The X_a system, termed the XBT, is to be designed primarily for surface search. The phase of the work which has concerned the R-F Research Section is the design of a complete set of r-f components.

3. The X_a frequency band offers the advantage of covering a new portion of the r-f spectrum. The relative advantages of the X_a system to X and S band systems should be much the same as those outlined for the X_b system in an earlier NRL report.† It is impossible to give figures of relative merit due to lack of a transmitting tube for the X_a frequencies.

4. A wave-guide size of 3/4 in. x 1-1/2 in. x 0.064 in. wall was chosen for this band which is the same size employed for the X_b band. This wave-guide size is operated fairly close to its upper useable wavelength boundary. This results in slightly increased attenuation and additional difficulty in designing wave-guide components. However, the use of a larger size seems unjustified, since it was found possible to develop suitable components using this size guide.

5. This report covers the design of suitable wave-guide and other r-f components which have been completed. No consideration is given to transmitter components since no magnetrons, T-R tubes or A-T-R tubes are available.

RECEIVER COMPONENTS

Local Oscillator

6. The local oscillator for the X_a-band was developed by Bell Telephone Laboratories at the request of the Naval Research Laboratory. The tube has the type number 2K27, and is a reflex klystron of the "Shepard tube" type similar in appearance to the 723 A.

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* BuShips ltr. (915) Ser. C-915-7809 of 16 Dec. 1943 to Dir. NRL (SRPPB).

† NRL rpt. No. R-2716 dated 7 Jan. 1946.

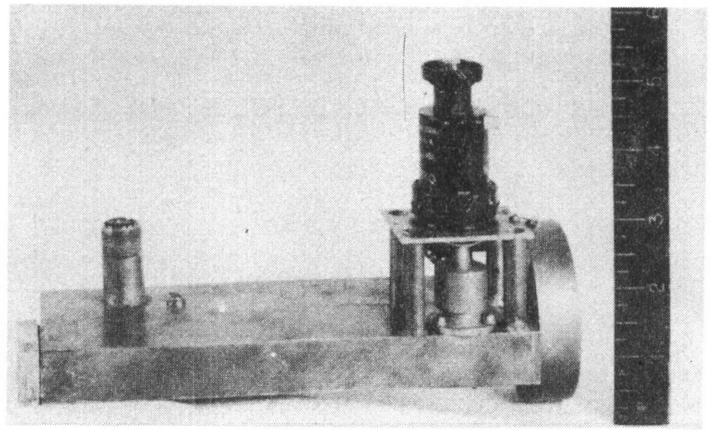

Fig. 1 X_a Converter

In Figure 1 a photograph of this tube is shown as a part of the converter. Operating characteristics of the tube are:

Heater voltage		6.3 volts ac
Heater current		0.44 amp. ac
Anode voltage	approx.	300 volts dc
Reflector voltage	approx.	-130 volts dc
Cathode current	approx.	25 ma
Power output	approx.	40 mw

Crystals

7. The crystals employed in the X_a-band system are of the type 1N23B. These crystals have the following characteristics at X-band:

Conversion loss. . . . . .6.6 db
Noise figure . . . . .2.7 times

The characteristics of this crystal have not been measured at frequencies in the X_a band, but could be expected to be slightly better than the characteristics at X-band frequencies.

Converter

8. The converter to be used in the X_a system was developed at the Naval Research Laboratory. Figure 1 shows the converter assembled. This converter employs the directional coupler principle and is very similar to the converter employed in the X_b system.‡

‡Ibid.

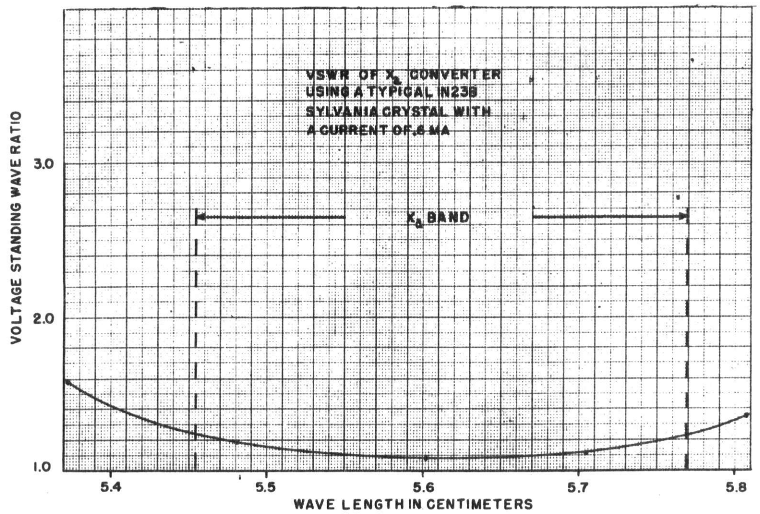

Fig. 2 VSWR of X_a Converter

It employs 1N23B crystals, type 2K27 local oscillator tube, and is tuned to the center frequency of the X_a band. A curve showing the VSWR (Voltage Standing Wave Ratio) over the X_a band of this converter employing a typical 1N23B crystal is shown in Figure 2. The highest VSWR within the band limits is 1.22.

R-F PLUMBING COMPONENTS

Flexible Wave Guide

9. Flexible X_a-band wave guide has been designed and manufactured by the American Brass Company at the request of the Naval Research Laboratory. This is the same flexible wave guide as that employed in the X_b system.§ The attenuation introduced by the flexible wave guide is approximately 0.13 db per meter, and the standing wave introduced by the flexible guide is negligible. Figure 3 is a photograph of a sample piece of the flexible wave guide.

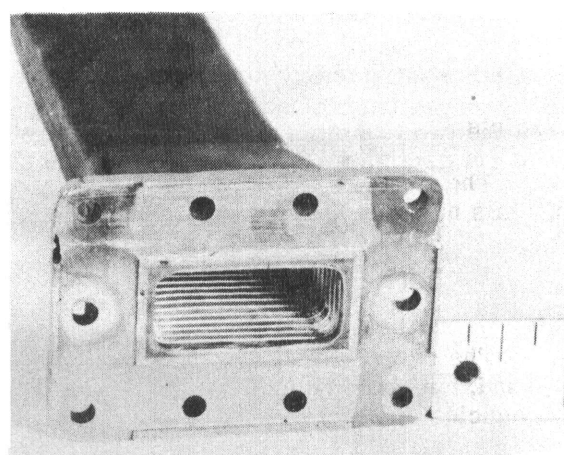

Fig. 3 X_a Flexible Wave Guide and Flange Coupling

Couplings

10. Wave-guide flange couplings of the contact type were developed for the X_b band** and are used for the X_a band. The

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§Ibid.
**Ibid.

designation UG150/U has been assigned to this coupling. The flange coupling attached to a section of flexible wave guide is shown in Figure 3.

11. A circular choke and flange for the X_a band was developed and is shown in Figure 4. The Naval Research Laboratory drawing number for this choke flange is RA 49AA255A.

12. A curve showing the VSWR over the X_a band for various separations between choke and flange is shown in Figure 5. For normal spacing the maximum VSWR is 1.01. Measurements of the VSWR of a single choke are limited in accuracy due to the low value of VSWR encountered. This difficulty was obviated by employing a series of six chokes spaced approximately one-half guide wavelength apart, so that reflections of the individual chokes are added. Since in this case the reflection coefficient of the individual connectors are additive, a larger VSWR can be measured with corresponding increase in accuracy, and the VSWR of a single choke flange may be computed.

Rotating Joint

13. A rotating joint of the circular wave-guide type was designed for the X_a system. The rotary joint employs circular wave guide operating in the TM_{01} mode. Since this is not the lowest mode in the circular wave guide, mode suppressors of the ring type are necessary. The joint showing ring mode suppressors is shown in Figure 6. The assembled joint is shown in Figure 7.

14. During the development of this rotary joint, investigation of a single transition from rectangular to circular wave guide was conducted. Measurements of VSWR and mode purity (ratio of TE_{11} mode to TM_{01} mode) were made for various sizes of circular wave guide, various short positions in the transition and for mode suppression rings of varying diameter. For the purpose of these measurements a matched load, fabricated of radial pieces of resistive strip, was employed. The VSWR of this load was less than 1.01 over the X_a band.

15. After a satisfactory single transition from rectangular to circular guide was obtained, two such transitions were combined to provide a complete rotary joint. Spacing between the two transitions was varied to provide lowest possible VSWR over the X_a band. A rotating choke was designed for the circular wave guide.

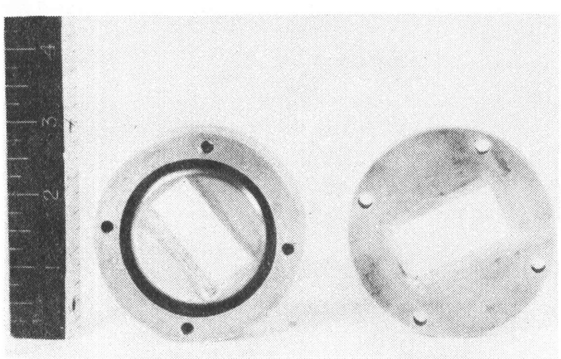

Fig. 4 X_a Circular Choke and Flange

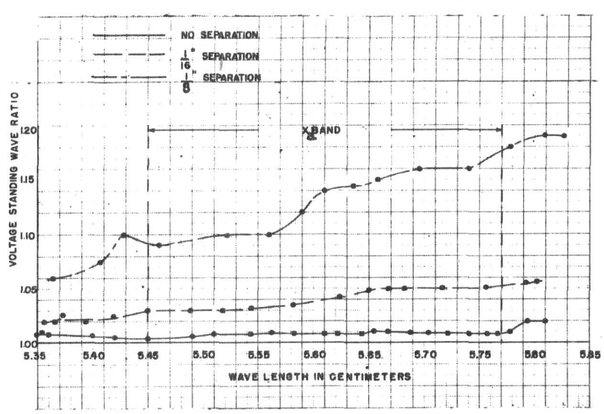

Fig. 5 VSWR of X_a Choke Flange Couplings

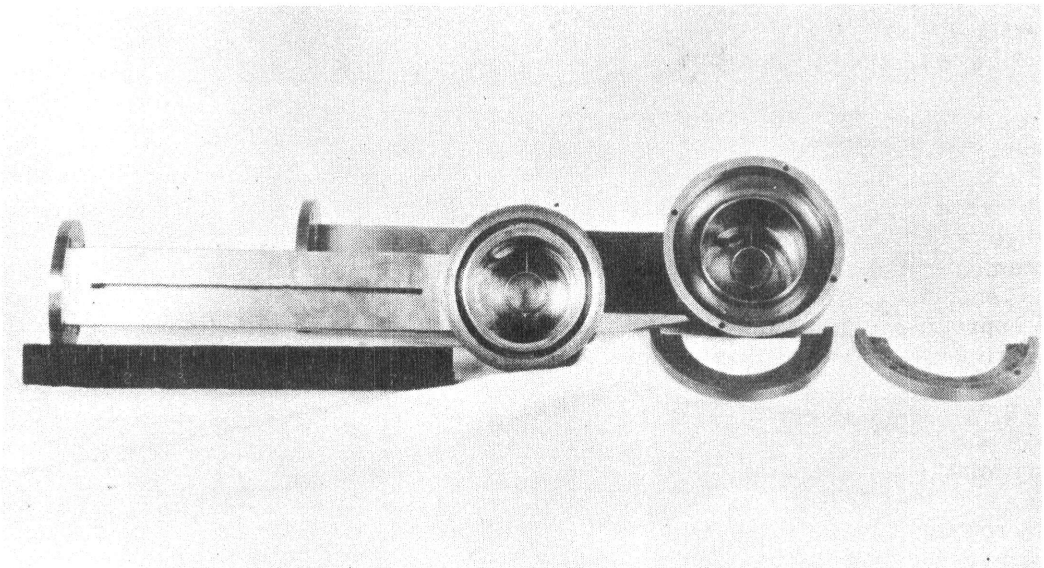

Fig. 6 X_a Rotating Joint (Disassembled)

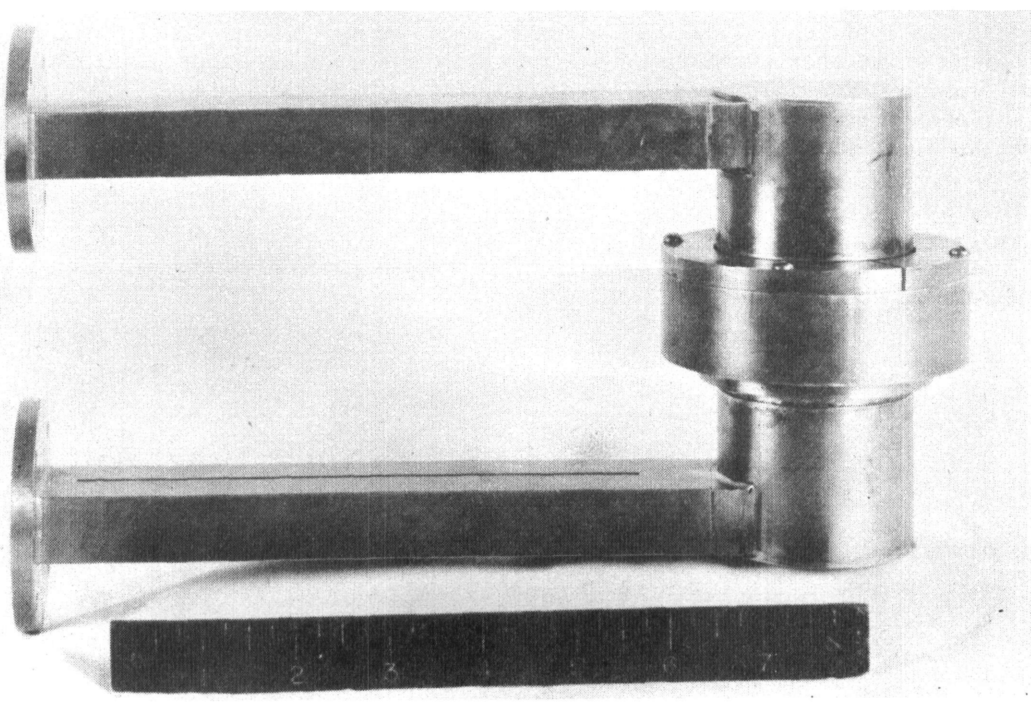

Fig. 7 X_a Rotating Joint (Assembled)

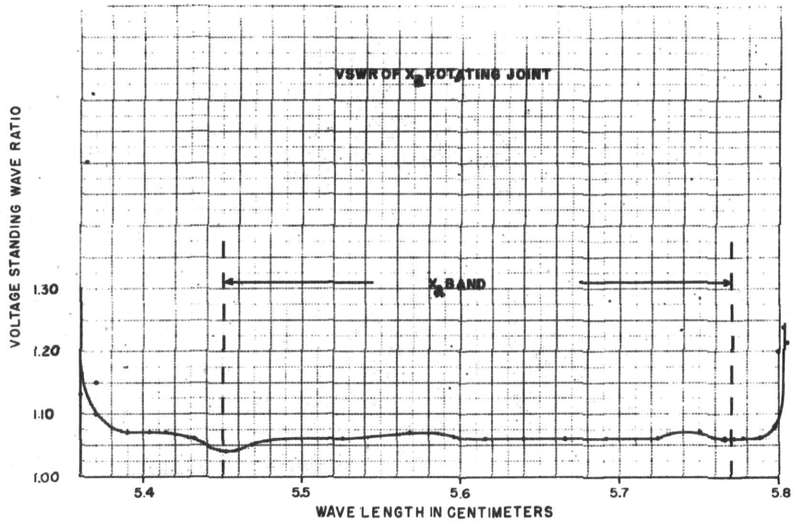

Fig. 8 VSWR of X_a Rotating Joint

16. The joint thus completed has a maximum VSWR of 1.07 over the X_a band. The curve of VSWR versus wavelength is given in Figure 8. No appreciable variation of VSWR with rotation was observed. Power tests were not possible due to lack of a high powered tube.

Tuning Screw (See Figure 9.)

17. A tuning screw for adjusting the VSWR in a wave guide has been developed. It is of the reentrant choke type, is adjustable, and has a lock nut to maintain its setting. This screw gives satisfactory service for low power applications.

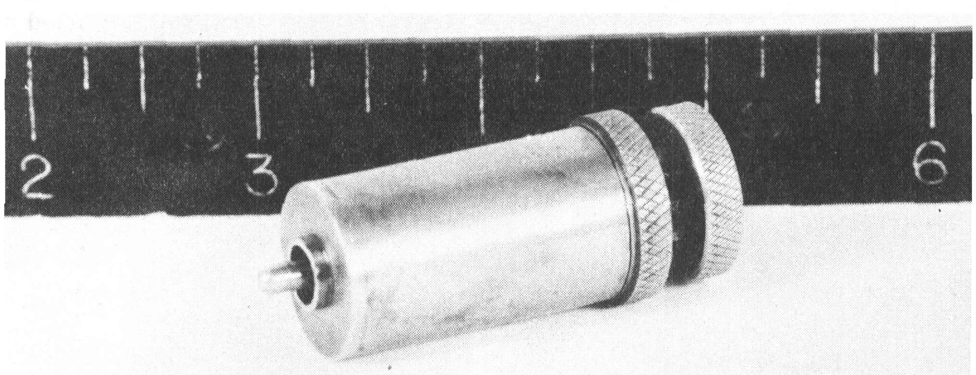

Fig. 9 X_a Tuning Screw

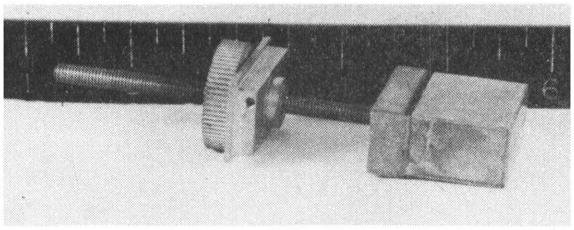

Fig. 10 X_a Shorting Plunger

Plunger (See Figure 10.)

18. A wave-guide shorting plunger for tuning and providing a variable position short circuit has been designed. A choke is incorporated which reflects a short circuit to the face of the shorting plunger and eliminates variable contact with wave-guide walls. This shorting plunger has given satisfactory experimental performance.

TEST EQUIPMENT

Power Measuring Equipment

19. A wave-guide-type thermistor unit has been built for the measurement of power. It is useable for values of average power from about 10 microwatts to about ten milliwatts. The unit is tunable for operation at any frequency within the X_a band.

Wavemeters (See Figure 11.)

20. Laboratory wavemeters of the cavity type were developed. They are similar to the TFX-19GA type wavemeter used at X-band. These wavemeters operate in the TE_{011} mode and cover the entire X_a band. Energy is fed into the wavemeter through a 3/8-inch diameter hole located at a voltage maximum point for the center frequency of the cavity. A short piece of wave guide terminated in a flange carries the energy from the source to the exciting aperture.

21. This wavemeter provides a sharply tuned cavity with a Q of about 8,000 for laboratory measurements. However, it is not recommended for field use, because of the presence of other modes which result in the same reading corresponding to two different frequencies. This presents no difficulty for trained personnel, as the two readings are distinguishable, but may cause considerable confusion if the wavemeter is used by inexperienced personnel.

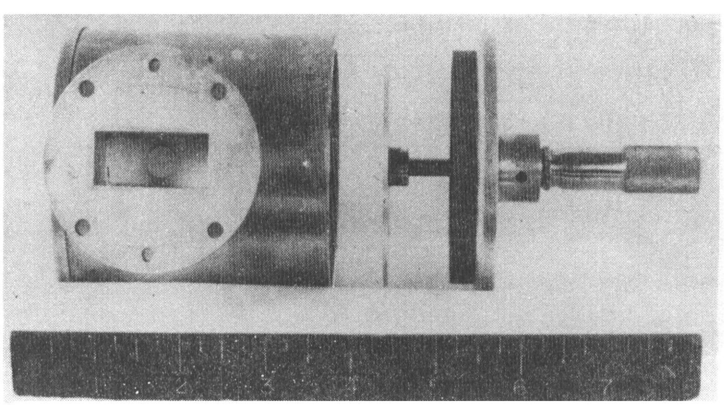

Fig. 11 TE_{011} Wavemeter

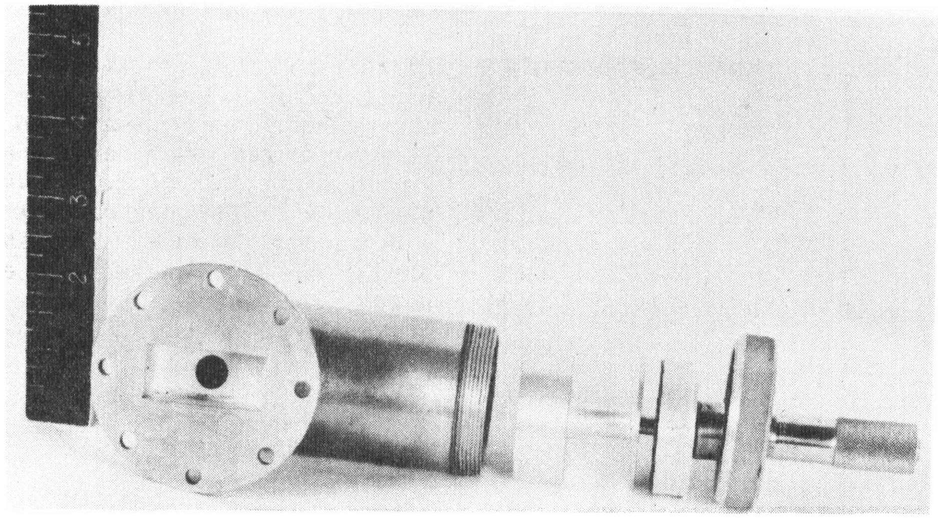

Fig. 12 TE_{111} Wavemeter

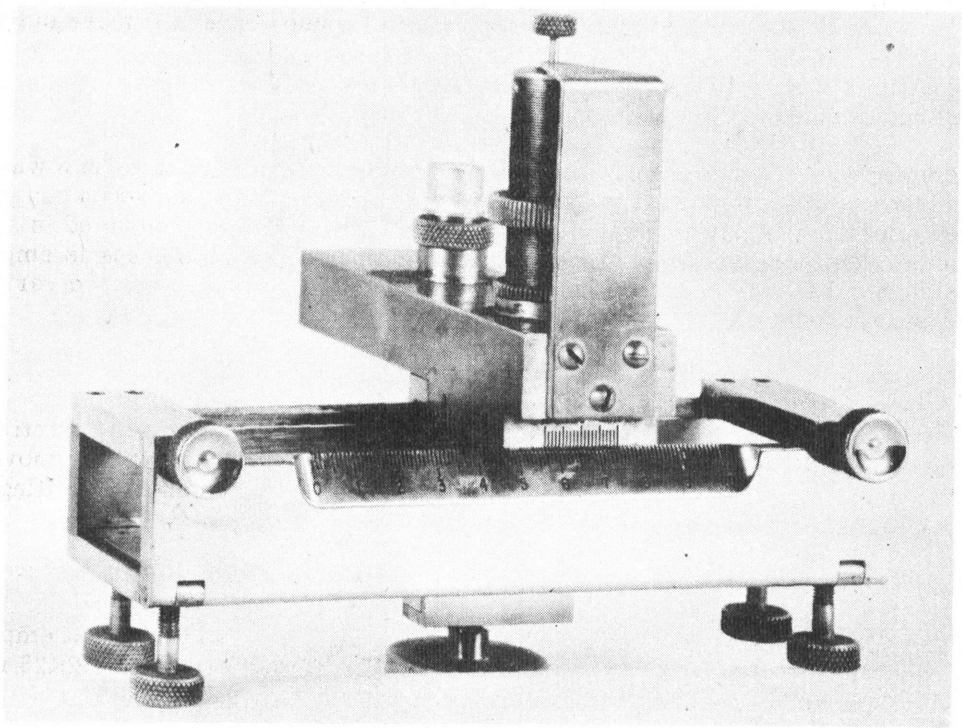

Fig. 13 X_a Standing-Wave Indicator

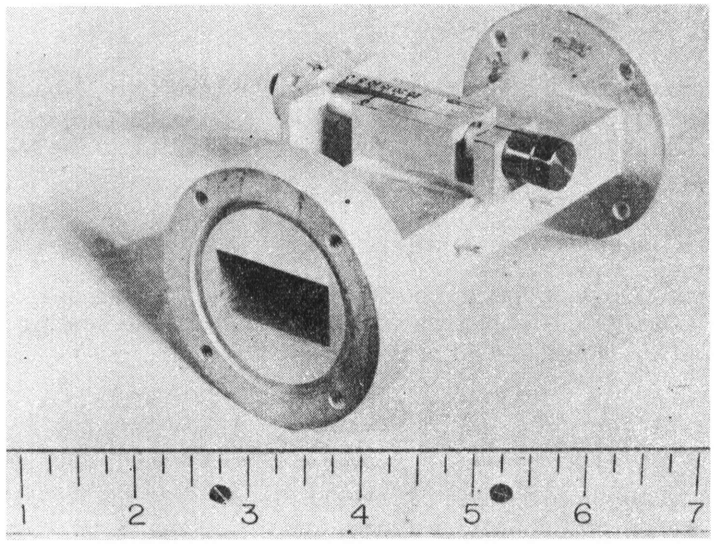

Fig. 14 X_a Attenuator

22. To eliminate this double response characteristic, a lowest mode wavemeter of the TE_{111} type was designed (See Figure 12). The Q of this meter is not as high as that of the TE_{011} meter, being about 3000, but its single response renders it more suitable for field use.

Standing Wave Machine (See Figure 13).

23. A standing wave indicator for the measurement of standing waves in a wave guide has been designed. It is of the removable type which permits assembly on any piece of wave-guide equipment. It employs a crystal detector unit which is mounted in a movable wave-guide section driven by a rack and pinion. A coaxial tunable probe is employed to pick up energy from the main wave guide. The depth of penetration may be varied for different power levels.

Attenuator (See Figure 14.)

24. An attenuator has been designed which employs a tapered strip of resistive material with resistance of 400 ohms per square centimeter. This strip is moved across a section of wave guide by a micrometer drive which permits accurate resetting and calibration of the attenuator.

Spectrum Analyzer

25. The spectrum analyzer employed for the X_a band is the same as that employed for the X_b band.†† A type 2K27 X_a local oscillator tube is substituted for the 2K26 in the X_b analyzer. This spectrum analyzer has provided satisfactory service.

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††Ibid.

Signal Generator

26. A signal generator similar to the Hewlett Packard type X-band signal generator was built by the Hewlett Packard Company for the X_a-band. This generator employs the 2K27 tube as r-f source, and is in other respects similar to the Model 6 signal generator.

Echo Box

27. An echo box was designed but never constructed. It is a scaled version of the X_b echo box type TS 501/UP. This box was designed to facilitate scaling to the X_a band, and as a result the X_a design should prove satisfactory.

ACKNOWLEDGEMENTS

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