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NATIONAL RESEARCH COUNCIL OF CANADA
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VISIT TO M. I. T.

November 30th - December 3rd, 1942

OTTAWA
December, 1942

NATIONAL RESEARCH COUNCIL OF CANADA
 RADIO BRANCH
November 30th - December 3rd, 1942

I. 3 CM. SYSTEMS

Visit to M. I. T.

1. Magnet November 30th - December 3rd, 1942

systems, C O N T E N T S

2. Magnets - A G.E. 2400 gauss magnet is used in all 3 cm. applications.

I. 3 CM SYSTEMS

3. R.F. Systems

1. Magnetrons

(a) A series of tests of the variation in the cold impedances of production 2. Magnets led to the conclusion that, if excessive losses of received signal are to be avoided, a simple T-R system is not feasible, 3. R.F. Systems R-T system must be used.

II. (b) ECHO BOXES R-T system employed is basically the same as that described in M.I.T. Radiation Laboratory Report #41-2 (N.R.C. #5642) with the following variations:--

1. Theoretical

2. Mechanical Design

III. HIGH POWER 10 CM. SYSTEM

1. Magnetron

2. R. F. System

IV. MAGNETRONS

1. 10 cm.

(c) The matching of the T-R and R-T branches into the main branch is effected 2. 3 cm. placing inductive diaphragms in the proper position in the branches. Their size and position are easily calculated V. MAGNETS

(d) The present H₀₁ → E₀₁ transformer has the following points of interest:

1 - Diaphragm - ooo - from rectangular to round pipe is used.

2 - The "resonant-ring" method of damping out H₁₁ waves has been supplanted by the following construction.

VISIT TO M.I.T.

November 30th - December 3rd, 1942

I. 3 CM. SYSTEMS

1. Magnetrons - The Raytheon type 2J21 magnetron with pre-adjusted waveguide matching system is used in production systems.
2. Magnets - A G.E. 2400 gauss magnet is used in all 3 cm. applications.

3. R.F. Systems the round pipe becomes a resonant cavity for H_{11} waves if the distance between the centre lines of the two waves is $\lambda/2$.

(a) A series of tests of the variation in the cold impedance of production magnetrons has led to the conclusion that, if excessive losses of received signal are to be avoided, a simple T-R system is not feasible, and that a T-R - R-T system must be used.

(b) The T-R - R-T system employed is basically the same as that described in M.I.T. Radiation Laboratory Report #41-2 (N.R.C. #5642) with the following alterations:--

- 1 - This same distance may also be chosen so that the impedance between the T-R and R-T branches has been reduced by $\sqrt{2}$ so that they are practically opposite one another. It has also been found quite satisfactory to make the branches in the H plane if this is made necessary from space considerations.

(c) The T-R box - The original Sperry T-R box, such as in use at N.R.C. has been found to have been supplanted by a single-windowed cylindrical resonant cavity to fit the Bell #724-A filler. The tuning being kept-alive electrode is not used.

(d) The plunger - resonant-slit type of R-T switch has been supplanted by a single-windowed cylindrical resonant cavity to fit the Bell #724-A filler. The tuning being kept-alive electrode is not used.

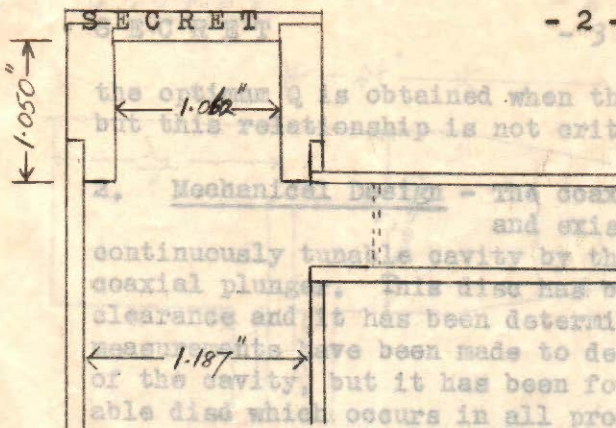
(e) The matching of the T-R and R-T branches into the main branch is effected by placing inductive diaphragms in the proper position in the branches. Their size and position are easily calculated by deciding on a low level loss of 1 db and adjusting window size to give this. The present tube filling is 10 mm. of air.

(f) The present $H_{01} \rightarrow E_{01}$ transformer has the following points of interest: The tuning range of the new switch is 24% whereas the original Sperry had a 10% tuning range.

- 1 - Diaphragm matching from rectangular to round pipe by Sperry for Ser is used, but is not considered fully satisfactory and it is thought that the box may have to be re-designed to give a low level loss of 1 db.
- 2 - The "resonant-ring" method of damping out H_{11} waves has been supplanted by the following construction.

THEORETICAL

1. Theoretical - It has been shown that the most efficient modes of oscillation for a cylindrical wave box are the TE_{0n} modes since in these modes the electrical field goes to 0 at all boundaries. This eliminates the necessity of having perfect electrical contacts at the joints. It has also been shown that for this mode of oscillation



The diameter of the round pipe in the stub end is adjusted so that the distance "d" is $\lambda/2$ for H_{01} waves, and $3\lambda/4$ for H_{11} waves.

3 - Because the round pipe becomes a resonant cavity for H_{11} waves if the distance between the centre lines of the two rectangular-pipe inputs is an integral number of half waves for the H_{11} mode, the overall length of the transformer must be chosen to avoid this. The allowed variation in magnetron frequencies gives a maximum overall length of 40 cm. for the circular pipe in order to avoid this critical distance; and as short an overall length as possible is recommended.

4 - This same distance may also be chosen so that the impedance mismatch at one conversion point when running off frequency will be compensated for by the mismatch at the other conversion point, and thus the power transferred will remain almost constant.

(e) The T-R box - The original Sperry T-R box, such as in use at N.R.C. has a high unloaded and consequently a high loaded Q , but has been found to have vacuum troubles. The T-R switch at present in use is the Bell No. 724-A which has a cylindrical cavity and conical posts, the tuning being effected as in the Sutton tube. The M.I.T. tapered plug switch is an improved mechanical design of this Bell switch, but electrically similar. The improvement lies in the improved contact between the filler and the cavity. The unloaded Q of this switch is approximately 1600 while the loaded Q is about 150. These figures were arrived at by deciding on a low level loss of 1 db and adjusting the window size to give this. The present tube filling is 10 mm. of H_2 and 10 mm. of H_2O , which replaces the earlier filling of 5 mm. of each which was found to "clean up". The tuning range of the new switch is estimated at 2%, whereas the original Sperry had a 10% tuning range. The ordinary cylindrical type cavity to fit the Bell 724-A filler is being produced by Sperry for Service use but is not considered fully satisfactory and it is thought that the box may have to be re-designed to give a low level loss of approximately 2 db in order to give adequate protection.

II. ECHO BOXES

1. Theoretical - It has been shown that the most efficient modes of oscillation for a cylindrical echo box are the TE_{0nm} modes since in these modes the electrical field goes to 0 at all boundaries. This eliminates the necessity of having perfect electrical contacts at the joints. It has also been shown that for this mode of oscillation

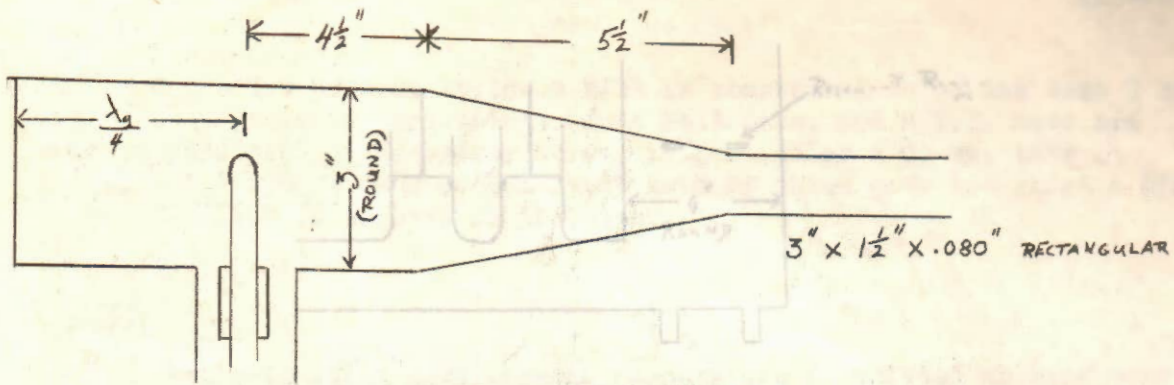
the optimum Q is obtained when the diameter is equal to the height, but this relationship is not critical.

2. Mechanical Design - The coaxial method of tuning has been discarded and existing boxes have been converted to a continuously tunable cavity by the addition of a disc to the end of the coaxial plunger. This disc has been constructed with approximately $1/8"$ clearance and it has been determined that this gap causes no loss. No measurements have been made to determine the effect of lack of roundness of the cavity, but it has been found that the slight wobble in the adjustable disc which occurs in all production models causes measurable periodic variation in the Q of the box. The E plane contains an R-T switch consisting of an open air resonant slit followed by an adjustable plunger. The slit is perpendicular to the axis. Coupling is effected by means of loops perpendicular to the axis located midway along the sides, but it has not yet been decided whether or not this is the best method.

The T-R It is planned to damp out unwanted modes by a means of a system of absorbers, but satisfactory results have not yet been achieved by this method. Matching probes which must be adjusted at intervals to compensate for the wearing of the T-R gaps. The waveguide is matched to a coaxial. For a 10 cm. echo box operating in the TE_{011} mode the calculated optimum Q is in the region of 50,000 to 60,000 and experimental boxes which have proved quite satisfactory operationally have Q 's in the region of 35,000. Such a box made of spun steel, copper and silver plated, is now in commercial production. So far no 3 cm. echo boxes have been built although 10 cm. boxes have successfully been used at 3 cm. However, it is felt that the 3 cm. box is theoretically feasible if designed to operate in some higher TE_{0mn} mode. The main difficulty will be to excite the box in the proper mode.

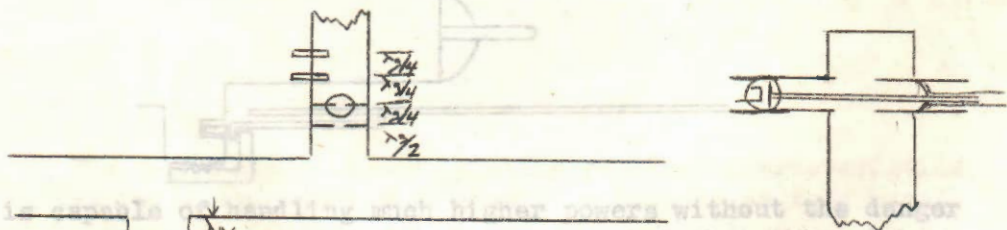
III. HIGH POWER 10 CM. SYSTEM

1. Magnetron - The magnetron used is a Raytheon type 2J or "right angle" tube and is operated at 32 Kv 30 amperes with a 1 micro-second pulse.
2. R.F. System - The magnetron is coupled to a 3-inch circular waveguide by a short length of coaxial line whose centre conductor acts as a probe to excite H_{11} waves in the guide. Matching is effected by means of a quarter wave transformer in the coaxial and a plunger in the waveguide, but these adjustments have been frozen. Circular guide is used at this point to prevent breakdown between the probe and the guide wall which would occur if rectangular guide were used. A smooth transformation is used to convert from the circular guide to a $3" \times 1\frac{1}{2}" \times .080"$ rectangular guide, E-plane with adjustable plungers. The transformer itself is similar in principle to the 3 cm. one in that the stub end is adjusted to be $3\lambda/4$ for H_{11} waves, and $\lambda/2$ for E_{01} waves, but, as shown in the sketch, the design is slightly different. Use is also made of resonant ring to damp out H_{11} waves.



A waveguide branch in the E plane contains an R-T switch consisting of an open air resonant slit followed by an adjustable plunger. The slit is slightly less than $\lambda_g/2$ away from the joint. The gap has tungsten sparking surfaces and is .011" in width. Its life, however, is only about 20 hours.

The T-R system consists of a similar gap followed by a second low pressure gap $\lambda_g/4$ further on. At spacings of $\lambda_g/4$ along the guide are two adjustable matching probes which must be adjusted at intervals to compensate for the wearing of the T-R gaps. The waveguide is matched to a coaxial as shown in the diagram and this leads directly to the diode detector. The diode used is a British CV-58. This tube has proved entirely satisfactory, for though it has a noise factor of 19 db, which is slightly higher than the 15 db noise factor of crystals, the added signal gained by the simplified T-R system makes the two comparable on a performance basis, while the tube has a longer and more stable life. In addition, with a crystal detector the "video splash" from the high powered modulator may, if improperly shielded, be sufficient to burn out the crystal.

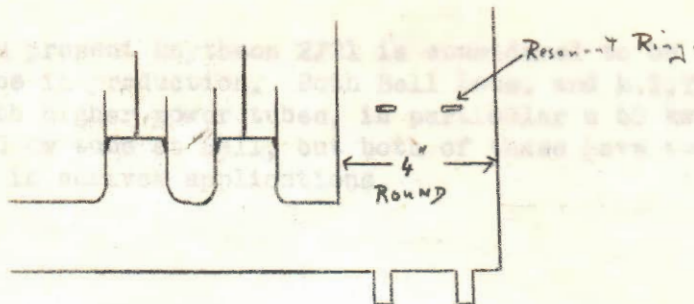


This tube is capable of handling much higher powers without the danger of breakdown across the output seal. It is reported that these tubes can handle output powers of 500 kw. quite easily and that as much as 900 kw. has been obtained. It is understood that Bell Labs. are working on a tube to give 1 megawatt output and the design of 5 megawatt output tube is being considered.

Past the R-T - T-R system in the main guide there is a short branch of below cut-off, circular waveguide from which the signal to operate an A.F.C. circuit is taken.

The square guide is matched into the E_{01} transformer by means of two waveguide branches in the E-plane with adjustable plungers. The transformer itself is similar in principle to the 3 cm. one in that the stub end is adjusted to be $3\lambda_g/4$ for H_{11} waves, and $\lambda_g/2$ for E_{01} waves, but, as shown in the sketch, the design is slightly different. Use is also made of resonant ring to damp out H_{11} waves.

magnetic field about 2000 gauss. This will give about 10 kw. output.

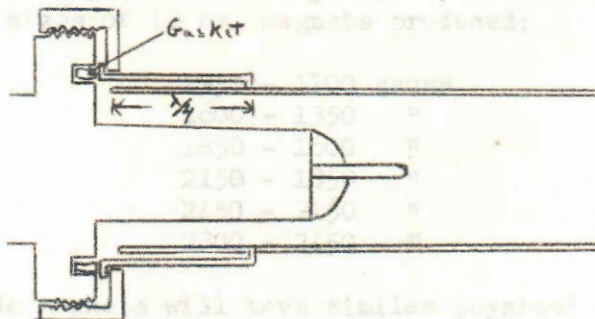


The antenna system consists of a six-foot ($f = 18''$) paraboloid which is rear-fed by an off-set circular waveguide and an eight-inch circular reflecting disc. Matching is achieved by means of a diaphragm just inside the mouth of the waveguide.

IV. MAGNETRONS

1. 10 cm. -

(a) The "straight through" type of Raytheon magnetron which is similar to our R.E.L. models is being replaced by the "right-angle" tube with the capacity-type coupling shown in the sketch.



This tube is capable of handling much higher powers without the danger of breakdown across the output seal. It is reported that these tubes can handle output powers of 500 kw. quite easily and that as much as 900 kw. has been obtained. It is understood that Bell Labs. are working on a tube to give 1 megawatt output and the design of 5 megawatt output tube is being considered at M.I.T.

(b) The design of a low power 10 cm. magnetron is being worked on at M.I.T. This tube is expected to have the following characteristics:

- 1 - For low power an input of 3 kv. 1 amp. and an output of approximately 1 kw. The magnetic field will be about 1500 gauss.
- 2 - For medium power the input will be 5 kv. 5 amps and the magnetic field about 2000 gauss. This will give about 10 kw. output.

2. 3 Cm. - The present Raytheon 2J21 is considered to be the best 3 cm. tube in production. Both Bell Labs. and M.I.T. have had some success with higher power tubes, in particular a 60 kw. tube at M.I.T. and a 250 kw tube at Bell, but both of these have too short a life to be practical in service applications.

V. MAGNETS

A standardization committee on magnets has formulated an extensive plan for the production of magnets for service sets. This plan has not yet gone into effect, but it is expected that it will be adopted shortly. The main points of the plan are as follows:

- 1 - The three main sources of permanent magnets will be:
The Cinaudagraph Company, Stanford, Conn.; General Electric, Schenectady, N.Y.; Indiana Steel Products, Valparaiso, Ind.
- 2 - Magnet strengths will be measured by certain standard sized coils. The coil specifications and measuring data are to be found in a paper entitled "Standard for Magnetic Field Measurements" which is to be found in the Radio vault.
- 3 - 10 cm. Magnets - It is planned to have the following six sizes of 10 cm. magnets produced:

1350 - 1100 gauss
1600 - 1350 "
1850 - 1600 "
2150 - 1850 "
2450 - 2150 "
2800 - 2450 "

These magnets will have similar physical characteristics. In particular they will have four base holes in common.

- 4 - 3 cm. Magnets - The only magnet planned for 3 cm. use is a 2400 gauss one, such as is already in production.
- 5 - It is planned to have all magnets produced with pole faces and aluminum shields.

CHM:HP

C. H. Millar

16th December, 1942