Progress report for July-September 1953

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RADIO AND ELECTRICAL ENGINEERING DIVISION

PROGRESS REPORT

FOR

JULY - SEPTEMBER 1953

OTTAWA

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NATIONAL RESEARCH COUNCIL OF CANADA

RADIO AND ELECTRICAL ENGINEERING DIVISION

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Comments or inquiries regarding subjects appearing in this report should be addressed to the Radio and Electrical Engineering Document Office, National Research Council, Ottawa, Canada.

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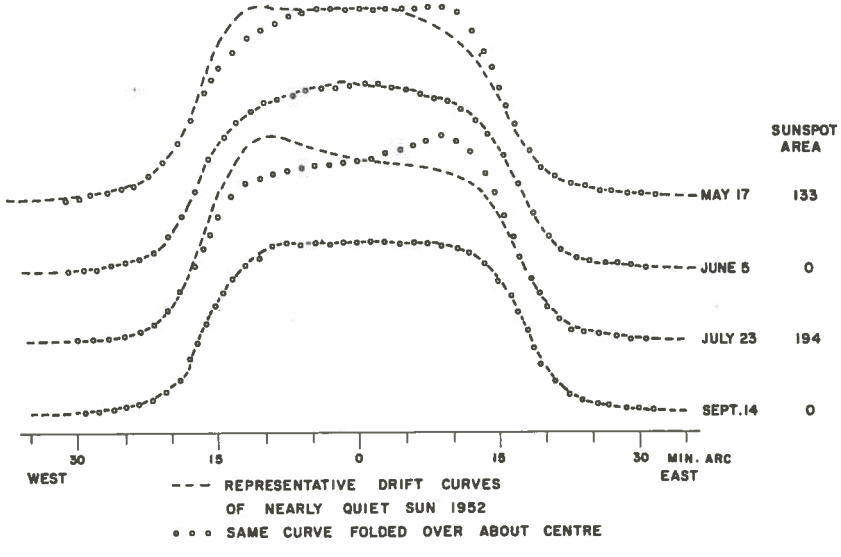
July - September 1953

I

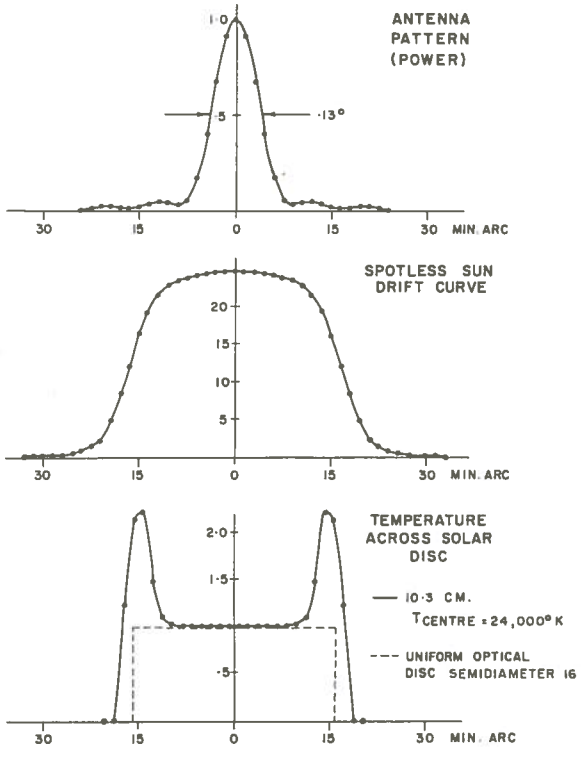
SOLAR NOISE OBSERVATIONS

A slotted waveguide antenna, with an aperture of 450 wavelengths in the long dimension, has been in operation for about two years at a wavelength of 10.3 centimeters. The design of this antenna is discussed on pages 4 and 5. It produces a fan-shaped beam with sufficient resolving power that the emission from the radio sun may be examined in narrow strips. These strips are formed by the rectangular outline of the radiation pattern, which has an angular opening to the half-power points of 1/8° and 20° in the east-west and north-south directions, respectively. The radiotelescope appears as a V-shaped trough or horn, 150 feet long, 18 inches wide, and 12.5 inches deep, with a slotted waveguide in the bottom (see photograph). The horn can be rotated about its long axis, which is held in a level east-west direction so that the radiotelescope is used in the manner of a meridian telescope. Observations are taken by allowing the sun to drift through the narrow part of the beam, and recording the varying intensity of the radio waves as a function of time, on an Esterline-Angus recording meter.



WAVEGUIDE RADIOTELESCOPE FOR THE OBSERVATION
OF 10.3-CENTIMETER SOLAR RADIO WAVE EMISSION

Four typical drift curves are shown above. The "dashed" curve refers to the normal drift curve, while the curve drawn with open circles refers to the same curve reflected about its center. Emissions from the radio sunspots on May 17 and July 23 appear as a separation of the lines. The drift curves on June 5 and September 14 occurred on days when the optical sunspot area was zero and the daily flux was minimum. Comparison of the original and reflected curves for these dates shows that the curves coincide, indicating the absence of a radio sunspot.



The shape and magnitude of the "spotless sun" drift curve (see figure above) is determined by the reception of radio waves from various parts of the solar disc by an antenna whose radiation pattern is of finite width. The antenna characteristics (see upper curve in figure) can be eliminated from the spotless sun drift curve (middle curve) by solving the appropriate integral equation in which the equivalent temperature of the antenna radiation resistance is given by the product of the integral of the antenna gain function and the source distribution. This process gives the original distribution of radio sources on the solar surface, unmodified by the antenna receiving pattern. This distribution is expressed in terms of an equivalent temperature of the radio disc, and appears as the lowest curve in the figure. The curve shows that the radio sun has a bright ring at the

limb (outer edge) of the photospheric disc. The equivalent temperature at the center is 21,800°K, and the radius of the disc is 1.15 times that of the visible sun.

The existence of a bright radio ring around the visible disc in the decimeter region, has been expected from theoretical analysis, and arises from the greater thickness of the bright coronal layer when viewed at the limb. This observed brightening of the radio disc is essentially in agreement with one model of the solar atmosphere derived by Hagen, in which the temperature increases from about 10,000°K in the chromosphere to 1,000,000°K in the corona.

* * * *

During the period under review routine observations with both the 4-foot reflector and the 150-foot array were continued. Analysis of the drift curves for December, 1951, has been completed, and when included with the past work for October and November, sufficient material is provided so that an indication of some of the characteristics of individual radio sunspots may be obtained. The radio sunspot appears on the east limb one or two days before the associated visible spot, and likewise remains on the west limb after the disappearance of the visible sunspot. The spot-excess drift curve data for 1952 and 1953 still remain to be analyzed.

Measurements of the gain of the horn and of the 4-foot reflector have been completed. The gain of the horn was found to be 434 ± 16 (standard deviation) and may be compared with a value of 428 found from a theoretical calculation. The gain of the 4-foot reflector was re-measured and found to be 701 ± 27. This confirms the original measurements of this quantity, which were made in 1947, when a value of 700 was obtained. Some observations of solar flux were made with the horn antenna in order to secure more data for a comparison with the 4-foot reflector observations.

The percentage power absorbed by the flat load termination of the 150-foot antenna was determined at wavelengths of 10.7, 10.3, and 10.0 centimeters, and found to be 12.5, 5.5, and 14 per cent, respectively.

Design of the mechanical and electrical layout for the radiometer associated with the 10-foot reflector is nearly complete.

* * * *

II

SPECIAL ANTENNA PROBLEMS

A SLOTTED-WAVEGUIDE ANTENNA FOR SOLAR NOISE OBSERVATIONS

Development of a high-gain antenna for solar and cosmic noise observations at a wavelength near 10.3 centimeters was commenced at the National Research Council in 1950. The object was to develop an antenna with sufficient discrimination to scan portions of the sun's surface, and with sufficient gain to detect some of the radio stars which have so far been observed only at much lower frequencies.

It was felt that a half-power beamwidth of one-eighth of a degree, approximately one-quarter of the sun's angular diameter, would be a reasonable compromise between desired discrimination and required antenna size. A paraboloidal reflector which would produce a pencil beam as narrow as that in both the E-plane and the H-plane would have a diameter of about 170 feet. The cost of developing a reflector which would meet the necessary tolerances and which would have a suspension capable of directing the antenna beam to any portion of the sky, was estimated and found to be too high for this laboratory. It was decided therefore, to build a linear, slotted-waveguide array 150 feet long, fitted with a horn designed to produce a beaver-tail beam. The array was to be positioned in an east-west direction, and made rotatable about a longitudinal axis so that the beam could be directed at points close to the meridian, but of arbitrary elevation.

By the use of such an array the angular discrimination in the azimuthal direction can still be made the same as in the case of the paraboloidal reflector, but the beamwidth in the vertical direction would be much larger and the antenna gain would be reduced considerably. Nevertheless, an effective gain of the order of 10,000 could be expected. No radio stars have yet been observed, but the array has become a very useful tool for studying solar radiation.

A design wavelength of 10.3 centimeters was selected and an overall length of 150 feet (450 wavelengths) was decided upon. The electrical length of this array is believed to be greater than that of any other such array so far constructed. An array of this length requires careful design, both electrically and mechanically, especially since it was planned to make doubling or even tripling of the length possible at a later date.

To meet the last requirement, it was necessary to have all slots in the array excited equally. Such a uniform excitation along the array leads to a maximum sidelobe level of 4 percent in terms of power relative to the main beam. This is not too serious in the present application. To avoid mutual coupling between slots and to simplify the design procedure,

longitudinal shunt slots in the broad face of a rectangular waveguide were used as the radiating elements. The phase and amplitude of excitation for such slots can be easily and independently adjusted by proper spacing along the array, and by proper choice of slot offsets from the center line of the guide face. In calculating the slot offsets for so long an array, attenuation in the waveguide must be taken into consideration.

An array of this length cannot be of the resonant-spaced type since the frequency bandwidth would be practially zero and very much smaller than required. Hence a non-resonant slot spacing near 220 electrical degrees was chosen. With the usual staggering of the slots about the center line of the guide, this gave rise to about 40 degrees phase shift between slots, and a squint angle of about 7 degrees between the main beam and the array normal or meridian plane. The squint angle changes with frequency and this causes an effective broadening of the beam, depending on the bandwidth of the intermediate-frequency amplifier used in the receiver.

The array was constructed from fifteen 10-foot sections of standard S-band brass waveguide. It contains about 500 slots. A horn having a total flare angle of 60 degrees and an aperture width of 18 inches was fitted along the entire length of the guide to reduce the beamwidth in the transverse plane and to increase the antenna gain.

The array is mounted in a level east-west position on a long steel shaft. This allows the entire antenna to be rotated along a longitudinal axis. The shaft is held in carefully aligned bearings mounted on a reinforced concrete pier, which in turn is anchored on bedrock.

Direct measurements and solar observations show that the array is operating satisfactorily. The input voltage standing-wave ratio is below 1.1 for wavelengths between 10.1 and 10.9 centimeters. The beamwidth and beam shape deduced from sunspot observations agree well with design objectives. The variation of squint angle with wavelength is close to that predicted.

The power gain at the design wavelength, as estimated from the half-power beamwidths in the E-plane and H-plane (22.5 and 0.13 degrees, respectively) and from theoretical efficiency, is about 10,000. Direct measurement of the gain by comparison with a four-foot paraboloidal reflector and the use of a standard noise source, gave a power gain of 7300. Since the measured amplitude distribution along the array and the power left in the termination agreed reasonably well with the design objectives, it is fair to assume that this discrepancy is due to a small increase in the general level of spurious radiation in directions other than that of the main beam. Inaccuracies in mechanical construction can easily produce an average increase of half a percent in the sidelobe level which is sufficient to account for the discrepancy.

RADIATION PATTERNS OF DIELECTRIC-COATED CYLINDERS

The problem under investigation is to find the azimuthal radiation pattern due to an infinitely long, narrow slot in a circular cylinder — the cylinder being surrounded by a uniform dielectric material. The slot is assumed to be excited by a constant electric field across it.

A rigorous solution of this problem has been obtained, the angular portion of which is given by

$$f(\phi) = \sum_{0}^{\infty} e^{jm(\pi/2)} \frac{\cos m\phi}{\varepsilon_m} \left\{ (\varepsilon_1/\varepsilon_2)^{\frac{1}{2}} U_m H_m^{(2)'}(k_2 b) - V_m H_m^{(2)}(k_2 b) \right\}^{-1} , \tag{1}$$

where $U_m = Y_m(k_1 b)\, J_m'(k_1 a) - Y_m'(k_1 a)\, J_m(k_1 b)$ and

$V_m = Y_m'(k_1 b)\, J_m'(k_1 a) - Y_m'(k_1 a)\, J_m'(k_1 b)$.

ϕ is the azimuthal angle, and a, b are the radii of the cylinder and the dielectric layer, respectively. The index (1) pertains to the dielectric medium, and the index (2) to free space. The series converges rapidly for cylinders of small radii. For large cylinders the convergence becomes very poor, and the series solution is useless for purposes of computation.

An attempt has been made to obtain alternative formulae for the radiation patterns when the cylinder radius is large. As a first step, it was decided to investigate the simpler problem obtained by letting the thickness of the dielectric coating tend to zero. The solution of this problem is given by Equation (2), and is subject to similar difficulties of convergence for large cylinder radii,

$$g(\phi) = \sum_{0}^{\infty} e^{jm(\pi/2)} \frac{\cos m\phi}{\varepsilon_m} \left\{ H_m^{(2)'}(k_2 a) \right\}^{-1} . \tag{2}$$

In this case, a different series solution can be obtained:

$$h(\phi) = \sum_{0}^{\infty} \frac{\cos(\pi + \phi)\nu_s \; e^{-j\nu_s(\pi/2)}}{\sin \nu_s \pi \left. \frac{\partial H^{(2)'}}{\partial \nu}(k_2 a) \right|_{\nu = \nu_s}} , \tag{3}$$

where the ν_s are the complex zeros of $H_\nu^{(2)'}(k_2 a) = 0$. This new series converges most rapidly for large cylinder radii. In the shadow region, only a few terms are needed for accurate computation of the patterns. In the forward region, convergence is poor and a different approach must be used. Geometrical optics approximations have been under investigation, but as yet no useful results have been obtained from this approach.

PHASE-MEASURING EQUIPMENT

The ability to measure phase at microwave frequencies is important in the design of microwave antennas. These phase measurements are usually made by determining the relative phase between two signals. Some recognizable condition of the interference pattern produced by the two signals is used as a "zero".

The procedure most commonly used is to divide the power into two branches. One of these branches contains the antenna under test and a pickup probe (or horn). The other branch contains a calibrated phase shifter and suitable attenuators. The two branches are then combined in a balanced detector. This method gives reasonable accuracy only when the two signals have amplitudes of approximately the same value. If the phase shifter is adjusted to the proper value and the amplitudes are equal, the detector output will be zero. However, as the pickup probe is moved across the aperture of the antenna under test the amplitude may vary considerably — as much as ten to one. Subsequent adjustment of the phase shifter will produce only a large and broad band minimum in the detector instead of a null. If the attenuator in the reference branch is used to bring the two amplitudes back to equality, errors are introduced because of the unknown phase shift produced by the attenuator. Many preliminary tests were made using this method, and it was confirmed that the errors are too large when the amplitudes of the signals are unequal. Therefore, this method was abandoned.

Another method examined was the microwave homodyne[1]. The output of a balanced modulator is fed into the antenna under test. This signal consists of the two sidebands since the carrier is balanced out. The output of a pick-up probe is then combined with a reference signal whose phase can be changed. When the reference signal differs in phase by 90° from the suppressed carrier the output of an amplitude-sensitive detector is zero. A null is always obtained, regardless of the amplitude of the sidebands picked up by the probe, providing the reference and suppressed carriers differ in phase by 90°. The success of this system depends on the suppression of the carrier in the balanced modulator. After careful study it was decided that this method would prove too frequency-sensitive to be usable over a broad range, and more emphasis has been placed on a phase modulation scheme which is described below. However, the homodyne method has not been completely dropped. Work is being done to determine the practical bandwidths obtainable.

The method receiving most attention has been that employing phase modulation[2]. As in other methods, the signal is split into two branches. One branch is phase modulated and feeds the antenna under test. As before, the radiated signal is picked up by a probe and sent to a detector. At the same time the second branch consists of a calibrated phase shifter and suitable attenuators, and feeds into the same detector. The output signal of the detector is then of the same frequency as the phase modulation frequency. This signal is amplified and put on one set of plates of an oscilloscope. At the same time a small generator is driven by the same motor used to drive the phase modulator. The generator output is applied to the second set of

oscilloscope plates. The resultant picture on the oscilloscope will be an ellipse whose shape will be determined by the relative phases of the two signals. The familiar in-phase condition — a straight line on the oscilloscope — can be achieved either by adjusting the phase shifter in the reference line or by rotating the field of the generator with respect to the armature.

Several mechanical phase modulators were examined and the one finally chosen was the rotating half-wave plate in circular waveguide. Suitable quarter- and half-wave plate sections have been designed and built and are now under test. The equipment is being designed primarily for manual operation, but it will be possible to include a servo system so that phase may be plotted automatically.

References

1 F.L. Vernon, Jr., "Application of the Microwave Homodyne", Research and Development Laboratories, Hughes Aircraft Company.

2 H.R. Worthington, "Measurement of Phase in Microwave Antenna Fields by Phase Modulation", MIT Radiation Laboratory, M.I.T.

III

ELECTROMEDICAL RESEARCH

ELECTROCARDIOGRAPHY

The Division has cooperated with the Faculty of Medecine of the University of Western Ontario in a limited program to develop a combined heart-sound and electrocardiograph amplifier for simultaneous presentation of heart sound and electrocardiograph tracings on the screen of a multiple-beam cathode-ray tube. It is intended to use the apparatus as an aid both to teaching and to research; for the former purpose a power amplifier is incorporated so that a large class of students may actually hear the heart sounds.

The detection or demonstration of heart murmurs is simplified if the sounds can be filtered in some manner which may accentuate the components of the actual murmur. Sets of adjustable high-pass and low-pass filters have been found quite useful by many workers, as they enable a flexible band-pass system to be set up[1]. The equipment in use at present employs two-section filters of the classical LC type; these are not entirely satisfactory because high inductance coils of reasonably high Q factor are difficult to shield adequately. Since the equipment is operated normally in the presence

of considerable induction fields it is not easy to ensure a really low hum level. The filters are therefore being re-designed, substituting twin-T CR-type elements. It is hoped that, with this modification, a really useful research and teaching aid will be developed.

Electrocardiograph Amplifier

The aim in the design of the electrocardiograph amplifier has been to produce a small simple unit which would be at the same time easy to operate. Most electrocardiograph amplifiers are fairly critical with respect to circuit adjustment and require the constant attention of a capable technician. By deliberate "over design" with respect to such features as common-mode rejection, this instrument has been made to function so that, for example, lead positions may be changed in most cases without re-balancing the input circuit.

The cardiograph potentials are between 10^{-4} and 2×10^{-3} volts, positive or negative, developed in a circuit impedance of about 2000 ohms. Under normal conditions a-c power wiring and equipment may induce interfering signals many times greater than this. A high-resolution difference amplifier may be used as a signal separator because, in general, interfering voltages will be nearly the same at any point on the body, whereas the desired signals will appear as potential differences between two points on the body.

Many tests were made to determine the discrimination ratio required to achieve a satisfactory cardiograph design. The best amplifier tested gave a measured discrimination ratio of 250,000:1, and was, of course, purely a laboratory model. By progressively degrading the discriminator, it was found that no noticeable change in the final signal-to-noise ratio occurred until the ratio had fallen below 10,000:1. Even so, the degradation of the trace is very slight with a ratio of about 5,000:1. Below this figure, however, careful balancing and grounding of the patient becomes necessary, so that frequent re-adjustment of the instrument may be required. Accordingly, 10,000:1 was adopted as a target figure for the discrimination ratio. It is worth noting that the "Requirements on Electrocardiograph Performance" set up by the American Medical Association stipulate a minimum acceptable ratio of 100:1.[2] Our experiments indicate that a shielded room would be necessary in many cases to obtain a really good cardiogram with such an instrument.

The input circuit adopted is a variation of the familiar cathode-coupled balanced amplifier, with a pentode tube as the coupling impedance, and with additional negative feedback which is designed to be degenerative principally to common-mode response. This circuit was chosen because, while the desired performance can be obtained with a simpler configuration, provided close-tolerance components are used, the pentode circuit works very well with normal commercial parts.

The second stage is a push-pull cathode follower used as a time constant multiplier. Most authorities agree that the ideal electrocardiograph response would contain a single CR coupling with a period of about two seconds.[3] This would seem to be the best compromise from the point of view of maintaining a satisfactory baseline while removing a large part of the muscular noise voltage.

This stage contains the only a-c coupling; the rest of the unit consists of a typical balanced amplifier as used in most modern d-c oscilloscopes.

All heaters are fed from a stabilized d-c power source. This arrangement has been found to be the simplest method of avoiding hum, drift, and low-frequency noise. Unless tubes with bi-filar heaters are used, a d-c supply is essential for the input stage. Drift and noise will be caused by space-charge changes arising from slow fluctuations in cathode temperature unless the heaters are stabilized. The most convenient arrangement is to feed a series string of low consumption heaters from a regulated d-c power supply.

Measured Performance

Signal Gain	76 db (× 6,800)
Interference Gain (common mode)	0.6 db (× 1.07)
Discrimination Ratio	75.4 db (× 6,300)
Upper Frequency	(3-db point) 1200 cps
Lower Frequency	(3-db point) 0.05 cps*

A full report on the design of the electrocardiograph amplifier is in preparation.

References

1 "A Multi-Channel Cathode-Ray Phonocardiograph" E.M.N. Besterman and J.K. Harrison, British Heart Journal, Vol. XV, No. 2, April, 1953.

2 "Minimum Requirements for Acceptable Electrocardiographs", Council on Physical Medecine, J. Am. Med. Assn., 143, 654, 1950.

3 "The Effect of the Frequency Response of Electrocardiographs on the Form of Electrocardiograms and Vectorcardiograms", A.J. Kerwin, Circulation, Vol. VIII, No. 1, July, 1953.

DIATHERMIC REWARMING

During July a heart operation was performed at Toronto General Hospital in which hypothermic anaesthesia was employed. The patient's temperature was reduced to 84°F by means of refrigerating blankets. At the lowered body temperature the oxygen requirement was reduced, enabling the

* Calculated from the square wave response.

patient to tolerate the interruption in blood circulation during the surgical procedure. NRC-designed radio-frequency rewarming equipment was used to rewarm the patient to normal body temperature, the first such application of diathermy on record. The operation was performed by Dr. W.G. Bigelow of the Department of Surgery, University of Toronto. Divisional staff conducted the diathermic rewarming.

Subsequently, diathermic rewarming was used following other operations in which hypothermia was employed, and further use of this type of heat treatment is planned. Modifications of the blanket coil design will be incorporated in new blankets, and an improved radio-frequency oscillator unit will be built for hospital use.

CARDIAC RESUSCITATION

A simplified model of the stimulator-defibrillator has been used in several instances for successful resuscitation of the heart. Certain controls and adjustments previously incorporated in the apparatus for experimental purposes are deleted from this model to facilitate its use in emergencies.

A visit to Johns Hopkins University during August provided interesting information on closed-chest defibrillation research which is being conducted at that center. Animal experiments at Johns Hopkins Hospital indicate that repetitive sinusoidal defibrillation shocks may tend to induce further fibrillation after cardiac standstill has been achieved.

The increasing number of electrical and electronic equipments now used in hospital operating rooms creates a problem of mutual interference. A cardiac resuscitation "wagon" has been proposed to house the equipment used in the diagnosis and treatment of the heart during or following operation, in an attempt to reduce this interference. Design and availability of suitable equipment is now under investigation.

DETECTION AND RECORDING OF NEURO-MUSCULAR RESPONSES

At the request of the Division of Applied Biology three amplifiers have been built for measuring nerve and muscle potentials in temperature acclimatization tests on rats. For muscle potentials of the order of 100 to 1,000 microvolts, a differential amplifier used with a driver amplifier and pen recorder gives satisfactory performance. However, difficulty has arisen in getting adequate sensitivity with low noise level in the measurement of nerve potentials, which may be as low as 10 microvolts. Further work on preamplifiers will be continued in an effort to improve the sensitivity of the equipment.

IV

ELECTRON-TUBE RESEARCH

OMEGATRON

The development of an "omegatron" for analysis of residual gases in sealed-off systems is almost completed. The tube is designed so that it can be used in either a glass or a metal envelope. It is intended to use the glass-envelope type for measurements on sealed-off systems, and the metal-envelope type for routine measurements. The metal envelope has integral pole pieces, thus reducing the magnet gap and facilitating the alignment of the tube in the magnetic field.

A photograph of the glass-envelope omegatron is included. This particular model employs ground glass joints to facilitate design modifications. The tube may be oriented in the magnetic field by rotation of a ball-and-socket vacuum joint. A field homogeneity of better than one part in a thousand over the working volume has been achieved by using a new permanent magnet.

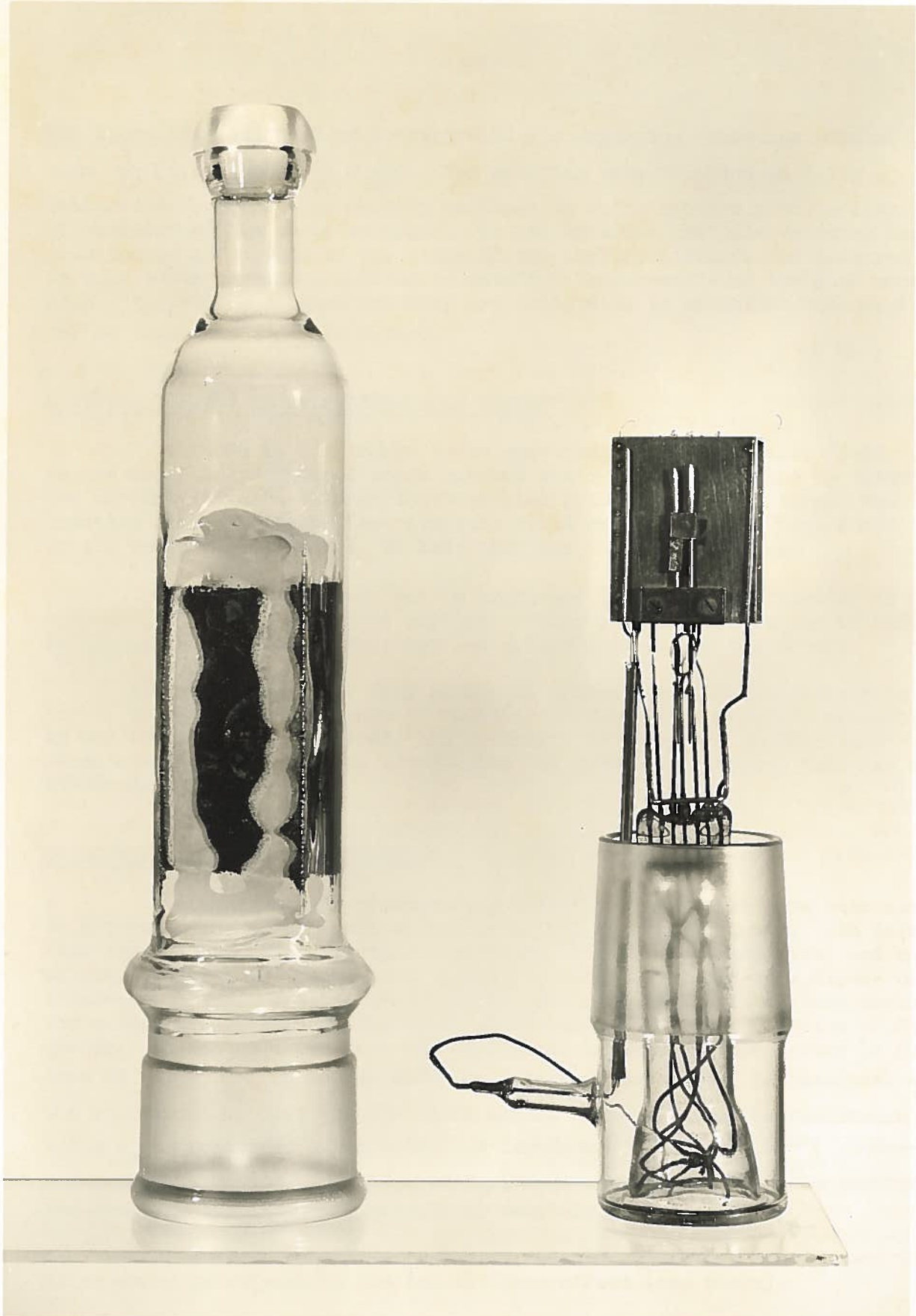
INSELBILDUNG EFFECT

In tubes with a small ratio of grid-cathode spacing to grid wire spacing ($d_g/a < 1$), the electric field at the cathode surface may become negative underneath a grid wire. The negative field prevents the cathode from emitting, and thus non-emitting islands are formed under the grid wires. Owing to this phenomenon, called the "inselbildung effect", the emitting area of the cathode is reduced in high - g_m tubes as the grid is made more negative. This effect can cause large errors in the measurement of cathode impedance of high - g_m tubes.

An analysis of the problem based on Maxwell's expression for the field due to two grids (i.e., the grid and its image in the cathode plane) has been made. The assumptions are that the cathode-anode spacing is large relative to the grid-cathode spacing ($d_a >> d_g$), and that the grid diameter is small compared with the wire spacing ($2r << a$). The emitting area fraction is given by

$$\cos \pi(1 - \theta) = \cosh 2\pi d_1 - \frac{(d_1 - d_2 V_1) \sinh 2\pi d_1}{\frac{1}{4\pi} \log_\varepsilon \left[1 + \frac{\sinh^2 2\pi d_1}{\sin^2 \pi r_1} \right] - d_1 V_1} ,$$

where $d_1 = \frac{d_g}{a}$, $d_2 = \frac{d_a}{a}$, $r_1 = \frac{r}{a}$, and $V_1 = \frac{V_g}{V_a}$.



GLASS-ENVELOPE OMEGATRON DESIGNED
FOR ANALYSIS OF RESIDUAL GASES

The above expression is no longer valid for screening fractions greater than $\frac{1}{10}$ (i.e., where $\frac{2r}{a} > \frac{1}{10}$). The emitting area fraction is being measured on a resistance network analogue to establish the practical range of validity of the above analysis. It can be shown that the emitting area fraction is a function of the value of the amplification factor measured at high anode current and close to cutoff. Measurements of the μ of some high - g_m triodes of good geometry are being made to establish whether θ may be determined by this method.

LIMITING CURRENT IN RETARDING-FIELD DIODES

A diode is considered to be operating in the retarding field region when the product of anode current and dynamic resistance is invariant. The current at which this product deviates from constancy is termed the limiting current (I_c) of the retarding field region. It was been found in all measurements that I_c is less than the theoretical value.

This inconsistency can be explained if a potential barrier is assumed to exist at the anode surface. Other possible causes can be eliminated by the use of pure metal emitters and proper geometry of the diode.

Investigation of this effect is proceeding with two objects in view: first, to establish the range of validity of cathode temperature measurements by the retarding field method; and secondly, to determine whether such measurements can be used to investigate the potential barriers existing at electrode surfaces.

INTERFACE IMPEDANCE MEASUREMENT

Various methods of measuring interface resistance have been assessed to determine the method most suitable for routine measurements. The interface impedance, unlike the tube impedance, is frequency sensitive, and may be measured by a multi-frequency impedance method with the tube diode- or triode-connected. Most of the circuits mentioned in the literature measure the mutual conductance of the tube, triode-connected, as a function of frequency. It can be shown that the equivalent circuit of this system (a resistance of value $\frac{1}{g_m}$ in series with the interface impedance) is identical with the equivalent circuit for the diode method of measurement (a resistance of value r_p in series with the interface impedance). Moreover, $\frac{1}{g_m}$ (triode-connected) is of the same order as r_p (diode-connected) Thus the accuracy and sensitivity of the two methods is very similar.

The diode method is preferred, as the circuit is simpler and there is no error introduced by the inselbildung effect (see above).

OXIDE CATHODES

Measurement of the rate of evaporation of cathode material from oxide-cathodes as a function of crystal size and current are being continued. The method of determining crystal size requires further improvement.

DISCHARGE DETECTOR

In 1951 it was observed in our laboratories that a glow discharge, such as that in an operating neon bulb, can be used as an effective detector of microwave energy. Detection was observed as a change in voltage across the neon bulb when microwave energy was matched into the discharge.

Subsequent search of the literature revealed that other laboratories are currently investigating this effect with a view to producing a practical video detector in the microwave region. It also was noted that the use of the effect was patented in Germany in 1935.

It was found that the effect is square law (i.e., output voltage is proportional to input power) and this suggested immediately that a large gain in sensitivity could be achieved by a reduction in the size of the discharge. Since this hypothesis did not appear to be universally accepted, it was decided to perform some experiments in the hope of producing a video detector of greater sensitivity than the crystal detector. Some special tubes were constructed and experiments at 3,000 megacycles confirmed that the minimum detectable signal power varies directly with discharge volume. However, the impedance of the small discharge is so large that a very difficult matching problem arises. It is now believed that only a very high-Q, and consequently narrow-band, structure has any possibility of exceeding the sensitivity of a crystal detector. A high-Q toroidal cavity has been constructed but not yet tested.

AIDS TO NAVIGATION

RADAR REFLECTORS

During the past few years the Division has done considerable experimental work on devices to enhance the radar visibility of various objects. Most of these have been in the form of configurations, single or multiple, of three-plane right-angle corners. Tests and trials have been carried out in co-operation with the Department of Transport to arrive at suitable reflector designs for lighthouses and buoys. Units finally evolved are now extensively used on the waterways of Canada.

Improvement of the radar visibility of small life rafts, rubber dinghys, and such emergency units is important in the interests of air-sea rescue operations. In these cases there are advantages to the passive-reflector-type emergency gear, in that no power supply is involved and no continued activity on the part of personnel in distress is required. The design criteria might be set down as minimum weight and bulk, long shelf life, and low cost; any initial erection operations to be as nearly automatic as possible; effectiveness of action to be neither permanently nor temporarily reduced by weather conditions.

Tethered balloons have been used to support antennas for various forms of rescue transmitters, receivers, and beacons. They are easily stowed, light in weight, and can be inflated from a reasonably small hydrogen generator. While special treatment can be used to make the envelopes or close-fitting covers conductive, unfortunately spherical objects are inherently poor radar reflectors as they have very low effective reflecting area. Partial spheres give good echoes only at very specific orientations. Balloons are used to carry elements composed of corner reflectors, but these assemblies are more suitable for free flight tracking in radar wind measurements. They may be quite bulky and are sometimes difficult to erect. Even more serious is the possibility of damage whenever the balloon is blown down on the water surface, which occurs with even less than moderate winds.

One solution appears to be the insertion of a self-erecting reflector system into the balloon. A radar reflector consisting of eight triangular corners formed by three planes mutually intersecting at right angles was constructed of silver-impregnated nylon-mesh material. This assembly was placed inside a four-foot-diameter balloon and the six corners of the target were fastened to the inside surface of the balloon by elastic cord. Thus, when the balloon was inflated the target was erected and held taut by the elastic fastening cords.

Early experiments were carried out with a reflector constructed of $\frac{1}{4}$-inch mesh material, but this material proved to be a poor reflector of three-centimeter radiation. Material with 1/20-inch mesh opening was obtained, and additional reflectors were constructed and mounted inside the balloons. Several such experimental assemblies were also supplied by the manufacturer of the mesh material.

Maximum range trials were conducted at a special test site set up on the shore of Lake Deschenes in the Ottawa area, and at various other locations, using the Division's M.V. "Radel II". The effective echoing area was compared with that of sheet-metal reflectors of known characteristics. In every case the balloon-erected target proved to be an inefficient reflector. However, when a corner reflector was formed by stretching the mesh material over a light plywood frame the maximum detection range was the same as that of an all-metal corner of the same dimensions. This proved that the reflecting properties of the mesh material were quite satisfactory. Thus the poor echoing characteristics of a target of the same size erected inside a balloon cannot be attributed to the mesh material. Poor geometry of the target may possibly be the cause of the poor performance. The problem will receive further study.

MICROWAVE POSITION-FIXING SYSTEM

The equipment was installed on a research vessel of the Quebec Department of Game and Fisheries at Grand River (Gaspe) to demonstrate the system to marine biologists of the Department. The results of this demonstration indicated that, for the type of hydrographic survey now being conducted in the Chaleur Bay area, the present prototype of the position-fixing system could be used. To cope with normal weather conditions in that area, slight modifications of the present model were indicated. One of the changes or additions which would greatly facilitate the reading of relative angles and also improve the accuracy of the "fix" would be to incorporate an azimuth stabilization unit into the receiving system.

No definite figures as to the positional accuracy were obtained, since accurate sextant readings could not be taken because of sea conditions and difficulties in identifying landmarks from the test area due to poor visibility. However, the system gave good relative accuracy. This was indicated by its ability to plot small maneuvers of the vessel in areas approximately ten miles from the control stations ashore.

MERCHANT MARINE RADAR

(a) Navigation and Docking Radar - Mark I

The experimental NAD Mk I equipment installed on the M.V. "Radel II" was used for further operational evaluation of certain features proposed for NAD Mk II.

One type of interference encountered on the displays of radar sets working at extremely short ranges is the occurrence of rings just after the ground pulse. These "noise rings" may be multiple rings, re-occurring at very short, regular intervals. The most usual causes are reflections in either transmitting or receiving waveguide owing to serious mismatch, and insufficiently damped tuned circuits in the receiver. Some experimental work has been done on methods of reducing these rings. In some cases the rings occurred only when certain specific mixer crystals were in use. A type of single-sideband operation of the receiver was found to eliminate them under most conditions at the expense of a slight loss of gain.

A broad-band (15-mc) receiver with three triples was built, since it was felt that the present 15-mc receiver, with two triples only, did not provide quite enough gain for short-range high-definition work. Trials on the M.V. "Radel II" with the new amplifier showed that the extra gain provided a marked improvement in maximum detection range when the short pulse length was used. However, the minimum detection range was increased also, even with the gain control set to reduce the output level to that obtained with the two-triple amplifier. Narrow-band amplifiers are connected in cascade with the wide-band sections for the longer ranges. Units with bandwidths of both 2.5 and 1.6 megacycles were constructed and gave satisfactory long-range performance on the M.V. "Radel II".

(b) Navigation and Docking Radar - Mark II

The waveguide components of the proposed R.F. system were constructed and these, and the necessary attenuators, terminations, bends, etc., were assembled to provide a functional prototype of the receiver "deck". In order to test this receiving system it was used in conjunction with supplementary units of an existing experimental radar, including a double cheese antenna. The system was complete, with the exception of an AFC unit. Generally satisfactory results were obtained, though an increase of the coupling between local oscillator and mixer crystals was found necessary.

A study was made of the operational controls called for in the preliminary specification. Some reduction in their number appeared reasonable, and a layout was prepared of those retained, together with a ten-inch cathode-ray tube, all on a thirteen-inch-square panel. A three-dimensional mockup was made of the whole display unit. A preliminary chassis layout, designed to fit the space available, was made for the sweep unit and associated circuits. Experimental models of specific units, such as the pulse line system and the sweep transformer, were constructed.

(c) Horizontally Polarized Antenna

The shielded-slot antenna designed for use in merchant marine radar was constructed and the radiation patterns were measured. The design was expected to produce a beam width of 1.5° and side lobes with a maximum amplitude of 3 per cent, except for the first two. The beam width was found to be 1.4° and the maximum side lobe level was 5 per cent. These results were considered to be encouraging. Discrepancies between designed and measured values are believed to be due to mechanical difficulties encountered in constructing the antenna. A second model of the antenna, will be built, and the experience gained in constructing the first one should make a better mechanical construction possible.

REMOTE FOG ALARM CONTROL

A complete fog-alarm control equipment was shipped for installation between Spring Island and Lookout Island on the west coast of Vancouver Island, British Columbia. This is the second installation of this equipment, and differs from the previous installation at Prince Rupert in that the distance between the control point and the fog-alarm station is only about $1\frac{1}{4}$ miles. Since it will be possible to hear the horn blowing at this distance it is not necessary to provide a monitoring radio transmitter at the fog-alarm station. However, a light which can be seen only from the control point will be used to indicate when either engine is running. Thus, if the diaphragm in the horn should become defective, or if, for some other reason, the horn fails to operate, the starting and stopping of the engine can be verified by the light. Since starting and

stopping operations are normally performed before the fog closes in completely and after it has passed, the light should be visible during these periods.

A third equipment has been completed, and is available for a further proposed installation at Sydney Harbour in Nova Scotia.

UNDERWATER TELEVISION

During the month of August demonstrations were held at Halifax for members of the Royal Canadian Navy, including the RCN Reserve, Naval Research Engineers, and Salvage and Frogman groups at Halifax Naval Dockyard. The most successful of these were conducted in quiet, clear water at McNab's Cove wharf. Views of the wharf piling, seaweed, barnacles, and fish were clearly seen. Views taken under the M.V. "Radel II", of her propellors, rudders, shafting, and seacocks were examined with interest by the naval groups.

The equipment was shipped to Madison, Wisconsin, for a demonstration in Lake Mendota at the Convention of the American Society of Limnology and Oceanography. The apparatus performed satisfactorily, but lack of sufficient numbers of fish impeded the demonstration.

The equipment was later moved to the fish hatchery of the State Conservation Department at Madison. In this location, the unit was placed in a fish runway containing about 200 full-grown speckled trout, and a demonstration was given to the Conservation Convention at which about 400 members viewed the trout on the television screen.

VI

PROPAGATION STUDIES

RADAR PROPAGATION OVER LAKE ONTARIO

The analysis of the propagation data derived from the operation of the three-centimeter radar equipment installed on the cableway on the shore of Lake Ontario is being continued (Progress Report, April-June, 1953). This analysis is progressing along two lines.

In one case the analysis attempts to relate the propagation conditions with the meteorological situation — the problem being to determine the atmospheric modification produced by the water surface. This modification depends upon the initial state of the air over land, and hence differs markedly between the afternoon and the early hours of the morning. In the

afternoon the air on land is well mixed, and temperature and dew-point decrease linearly with height. An analysis of two months of afternoon data (August and September, 1952) has been completed using a comparison with the power law theory of diffusion (Booker, J. Roy. Met. Soc., 1948). Results indicate that the theory provides a maximum value of the radio duct width; the duct may be less than that predicted by the theory, but is never greater. In the pre-dawn hours a strong temperature inversion usually exists over land, and this may be maintained over the water. An elevated duct is frequently observed over the lake at this time of day, and although this may be explained qualitatively, no quantitative analysis is possible at present.

A statistical analysis of the propagation data is being carried on simultaneously. Dividing the propagation data into three general classes — standard and substandard conditions, surface trapping, and all other trapping conditions — an average diurnal variation for each month, from April to November, 1952, has been obtained. For the summer months there is a strong maximum of surface trapping conditions in the afternoon (70 to 80 per cent of the time), and a minimum of standard and substandard conditions at the same time. This diurnal variation has a much reduced amplitude at the beginning and end of the shipping season (April and November). A statistical analysis on a height basis has also been completed. The results indicate that the optimum height for maximum range is approximately forty feet. However, the indications are at present that standard and substandard conditions are equally probable at all heights.

TROPOSPHERIC SCATTERING

A start has been made on reconstruction of the transmitter for the scattering link to be established between Ottawa and the Scarboro Field Station. The required component parts have been ordered and the waveguide output has been redesigned.

LINE-OF-SIGHT PROPAGATION

The theoretical aspects of this problem have not been pursued during the period under review. A few of the film records of the Target Project of the Suffield Tropospheric Project have been examined, but the analysis has not proceeded far enough to warrant a report.

ATMOSPHERIC EFFECTS ON VERTICAL ANGLE OF ARRIVAL

The effect of the horizontal stratification of the atmosphere on the measurement of elevation angle and heights in radar and meteorological observations has been examined. A preliminary study of various ray-tracing approximations has been made, and the applicable intervals of distance and height determined. With the suitable ray-tracing approximation, the effect

of the atmosphere on elevation angle measurements is easily estimated. Generally speaking, meteorological instruments (rawin) are negligibly affected. For radar height determination the errors due to the atmosphere may be considerable in certain ranges of height and distance. It is hoped that this work may be completed during the next quarter.

VII

ELECTRICAL ENGINEERING

ELECTRONIC DETECTION OF FLAWS IN PAPER

There are many different types of defects in fine paper, but calendar stamps, dirt, and wrinkles cause the most trouble, and are the most important for an automatic flaw detector to find. The scanner mentioned in the previous issue of this report could detect the first two defects reasonably well, but not wrinkles. A modified unit has been built which can detect wrinkles more effectively, and which appears to be able to pick out calendar stamps and small spots fairly well also. However, more complete tests have been delayed pending the arrival of some further equipment.

1200-KV IMPULSE GENERATOR

The generator was moved to the new laboratory and reassembled. At present it comprises only the original 12 stages. When the components for 6 new stages are constructed, they will be added to the existing structure. This will raise the nominal peak output voltage from 1200 kilovolts to 1800 kilovolts.

During the period under review a small distribution transformer was tested for a Canadian manufacturer.

EXPLOSION HAZARD OF GRAIN DUST

The investigation of ignition of grain dust by electrostatic spark is being continued. Three grain elevators at Port Arthur, Ontario, were visited and a general examination of each was carried out. Measurements were made of the resistance and capacitance between elevator ducts and ground, and between one duct and another. Resistances were never higher than 300,000 ohms. Capacitances were often quite large: 2,000 to 10,000 μμf. The relative humidity at the time the measurements were taken was over 70 per cent at 75°F.

VIII

DIELECTRIC RESEARCH

CURRENTS IN DIELECTRICS

The high-sensitivity d-c amplifier designed for measuring absorption currents has undergone further minor modifications. A large number of measurements of absorption and residual currents have been made on Pyrex and soda-lime glass over a range of temperatures extending from -115° to +50°C. (The residual current is that current which remains constant for periods of the order of minutes at least, after the absorption current has died away.) These results are now being analysed.

An apparatus has been set up for the measurement of volume conduction currents in commercial dielectrics. Measurements will be made over a wide range of temperature, humidity, and voltage with a view to studying the mechanisms involved.

SEMICONDUCTORS

The vacuum-insulated furnace, for growing germanium crystals has been operated at temperatures in excess of 800°C. Some changes have been made in the heating arrangement to minimize tarnishing of the reflecting shields. Vacations, and delays in the move to new quarters, combined to prevent further work on this project.

Some measurements of characteristics of point contact transistors have been made. The tests of crystal diodes submitted by an American manufacturer have been completed.

IX

ASSISTANCE TO OUTSIDE ORGANIZATIONS

The radio-interference factor of plain and silent-glaze pin-type insulators for use on high voltage power lines was measured at a frequency of one megacycle. A report of the tests was submitted to the manufacturer.

X

STANDARD FREQUENCY SERVICES

During the period under review most of the time was devoted to the design and construction of new apparatus that will be required to maintain the standard frequency services in the Sussex Street building after the primary standard is moved to the new headquarters of the Division on the Montreal Road. The frequency multiplying equipment and distribution amplifier were completed and installed in a hut which had been prepared on the roof of the Sussex Street building.

Four high-power amplifiers designed to supply the increased demand for standard 60-cycle frequency at 110 volts throughout the laboratories of the National Research Council were completed and tested. These units have a full-load output of 100 watts and a no-load to full-load regulation of 3 per cent.

The design of a frequency standard system capable of generating 10 kilocycles, 1 kilocycle, 100 cycles, and 60 cycles — all controlled by a 100-kilocycle frequency standard — was continued. The most commonly used circuits utilize a chain of frequency dividers. Some of them employ filters which must have satisfactory selectivity in the frequency range from 20 cycles to 1,000 cycles. Such filters are heavy, expensive, and not readily available. Some time was devoted to a search for circuits in which low-frequency filters would not be required. A system was worked out in which all filters operating below 1,000 cycles could be eliminated. Ferroxcube pot core filters, having excellent selectivity in the kilocycle range, can be used in all the divider stages. The prototype chassis for the frequency divider, having the dimensions and forms of the final chassis, was designed and constructed.

Routine operation of the primary frequency standard was continued. One of the 100-kilocycle quartz oscillators was taken out of service, completely overhauled, and the oscillator circuit modified to improve its performance.

Some trouble had been encountered previously with overheating of the final-amplifier stage of the 150-megacycle standard-frequency transmitter. The tuned circuits of this stage were rebuilt. Improved efficiency was obtained, eliminating overheating of the unit.

XI

PAPERS AND PUBLICATIONS

"The National Research Council's program in Underwater Television and Echo Sounding", presented by H.R. Smyth at a meeting of the International Association of Fish and Game Commissioners held at Milwaukee, Wisconsin, on September 17, 1953.

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"Effect of Radar Sensitivity on Meteor Echo Durations", by D.W.R. McKinley, Can. J. Phys., vol. 31, pp. 758-67, 1953.

> Meteor echo durations were observed simultaneously with two radar systems having a power sensitivity ratio of 33 db. An experimental relation between echo duration and system sensitivity is obtained which shows that the duration of meteor echoes varies slowly, but significantly, with system parameters. Curves are furnished to correct observed durations to zenithal durations, applicable to any system using a horizontal half-wave dipole antenna.

"Radiation Conductance of Axial and Transverse Slots in Cylinders of Elliptical Cross Section", by J.Y. Wong, Proc. Inst. Radio Engrs., vol. 41, no. 9, pp. 1172-77, 1953.

> Expressions for the radiation field of axial and transverse slots in cylinders of elliptical cross-section are derived by a method based on diffraction theory and the principle of reciprocity. Radiation patterns of transverse slots and curves of radiation conductance are presented. It is shown that the radiation conductance is influenced considerably by the degree of curvature of the surface on which the slot is located.

"A Simplified Calculation for Dolph-Tchebycheff Arrays", by G.J. Van der Maas, J. Appl. Phys., vol. 24, no. 9, p. 1250, 1953.

"Absorption of 10.7 cm Solar Radiation during Flare of May 19, 1951", by A.E. Covington and H.W. Dodson*, J. Roy. Astron. Soc. Can., vol. 47, no. 5, pp. 207-11, 1953.

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The following publications were issued by the Radio and Electrical Engineering Division:

"Preliminary Notes on the Accelerated Transmission of Morse Code by means of a Magnetic Tape Record", (ERB-306), by H. Le Caine.

> Preliminary trials indicate that Morse code, transmitted at speeds up to at least twenty-five words per minute, can be recorded on magnetic tape at a tape speed of 0.3 inch per second, or 1/25th of the standard speed of 7.5 inches per second, using commercial low-cost recording heads. When the tape is played back at the same slow speed, the amplitude of the voltage generated in the pickup head and the signal-to-noise ratio are both adequate

* McMath-Hulbert Observatory, University of Michigan.

for easy pickup and transcription. When the tape is played back in a standard machine at 7.5 inches per second, the time of the transmission is reduced to 1/25th of the time taken to record the message. The frequency band involved during transmission at the accelerated speed is such that a telephone circuit or speech channel may be used. A standard 7-inch reel of tape 1/4 - inch wide will hold more than twenty-four hours of continuous Morse code transmission.

"Electric Countershock Treatment of Ventricular Fibrillation" (ERB-267) by J.A. Hopps.

A review of the physiological conditions in ventricular fibrillation is given. The principle of countershock application is outlined, and the procedure for resuscitating a fibrillating heart is described.

The circuit of an electric defibrillator, with a timer to limit the duration of shock, is provided. Data are given on design of electrodes and on the electrical parameters involved.