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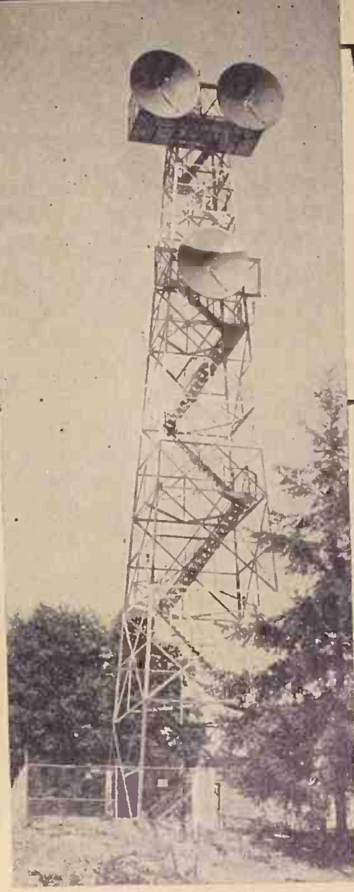
BASIC COMMUNICATION THEORY



One of a series of microwave communication relay stations built by Federal Telephone & Radio Corporation. This system uses pulse code modulation as discussed in the text.

By L. S. SCHWARTZ

Hazeltine Electronics Corporation

Part 1 of a 2-part article presenting basic theory behind the transmission and reception of information.

THE PURPOSE of this discussion is to describe some of the basic concepts of communication theory. This theory is comprehensive and has wide ramifications extending into the biological and other fields. It transcends a mere description of the workings of circuits, tubes, and the other devices of the communications and electronics engineer, and deals with the central fact of communications: the transmission and reception of messages. The tools of the engineer merely provide alternative means for realizing this central fact.

For a long time workers in the field have been aware that there is a relation between the speed of transmitting messages and the bandwidth of electrical circuits. But until as late as 1945 it was generally believed, on the basis of Hartley's theoretical work, that it was impossible for a signal covering a given band of frequencies to be transmitted by a communication channel of lesser bandwidth[1]. In this and in other instances our understanding of communication problems was in many cases incomplete or wrong. Since 1945, thanks to the work of Shannon, Wiener, and others,[2-9] a general theory of communications has been made available with the result that our understanding of the subject has been greatly increased.

Only the basic concepts of this new communication theory will be touched upon herein; all detailed mathematical discussions will be omitted.

Meaning of Information

It has been stated that the central fact of communications is the transmission and reception of messages. What is of interest in the messages is the information that they carry. This brings up the definition of information, which will be discussed first in qualitative and then in quantitative terms. For the sender, information conveyed by a message is measured by the amount of choice at the sender's disposal. For the receiver, information is measured by the uncertainty as to what message may have been sent. The rate at which information can be sent is measured by the number of different or alternative things that might be sent in a second. The greater the choice of messages, the greater the amount of information that can be sent. However, information must not be confused with meaning, for two messages, one of which is heavily loaded with meaning and the other of which is pure nonsense, can be exactly equivalent in regard to information. That is, the semantic aspects of communication are irrelevant to the engineering aspects.

The observation that "for the receiver, information is measured by the uncertainty as to what message may have been sent" brings to mind a story. A merchant left home to go to another town to sell wheat. He completed his deal successfully and was so elated by the bargain he had made that he decided to inform his wife of the good news by telegram. His wording was as follows:

"Sold Wheat Very Well. Coming Home. Love, John."

Upon learning how much it would cost to send this telegram, he decided to eliminate all unnecessary words. (Evidently, this was in the days before the minimum charge.) He thought: "My wife knows that I am selling wheat, not cattle, so why write it?" He crossed out "wheat," and the telegram became:

"Sold Very Well. Coming Home. Love, John."

Then he decided that since his wife knew him to be a shrewd bargainer, she would know that he would not sell his wheat unless he could obtain a good price for it. So he crossed out "very well." He had:

"Sold. Coming Home. Love, John."

Then he analyzed "coming home." Where would he "come" unless it were "home?" He crossed out "home." The telegram read:

"Sold. Coming. Love, John."

My wife is a smart woman, he thought; she knows that I would not return so soon unless I had sold my wheat. He wrote:

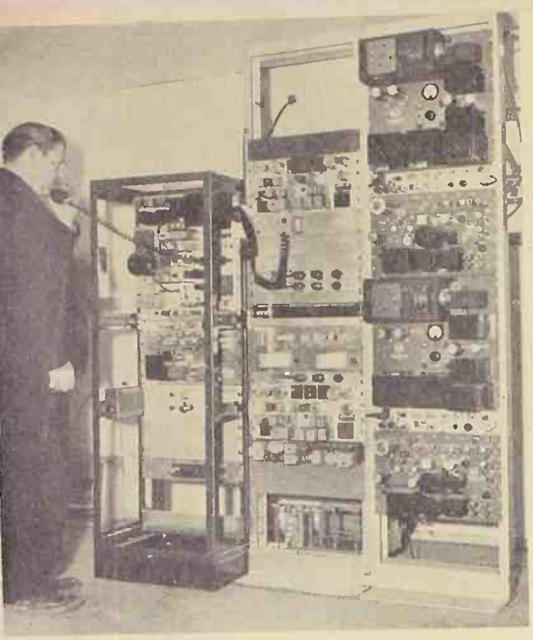
"Coming. Love, John."

Then he decided that although he loved his wife dearly and had told her so many times during the 20 years they had been married, he need not pay for this privilege. He had:

"Coming. John."

But after 20 years of married life his wife should at least have learned his name! He crossed out "John." Only "coming" was left, and he thought it would be silly to send her this one-word cable and frighten her into thinking that something untoward had happened to him. Instead he took the next train home. He was right. The information content of the telegram was zero, so why send it?

The quantity meeting the requirements for a measure of information turns out to be entropy, which in statistical mechanics is a measure of randomness or disorder; the greater the



Testing RCA mobile and microwave gear for use on the New Jersey turnpike.

randomness the greater the entropy, also the greater the choice, and therefore, the greater the information. As entropy is expressed in terms of the logarithm of probabilities, it is logical that information should be similarly expressed.

Thus, information is:

$$H = -\sum_{i=1}^{N} P_i \log P_i \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\sum_{i=1}^{N} P_i = 1, P_i \geqq 0 \quad . \quad . \quad . \quad . \quad . \quad (2)$$

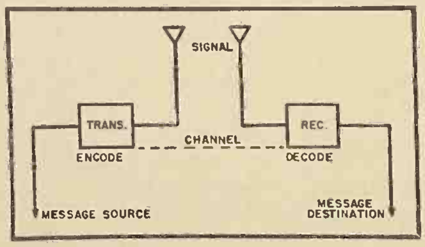
where the P_i are probabilities. If the logarithm is to the base "2," the resulting units of information are called binary digits per symbol or "bits" per symbol.

A "bit" may be thought of as a "yes" or "no," representing the simplest choice that can be made. As an example, consider the number of bits it takes to choose the number 7 from 16 possibilities. This is done by successively halving the range of uncertainty.

Is 7 greater than 8?	No
Is 7 greater than 4?	Yes
Is 7 greater than 6?	Yes
Is 7 greater than 7?	No

Hence, "No," "Yes," "Yes," "No" means 7. Thus, it took four steps to choose among 16 alternatives; that is, sending a message chosen with equal probability from among 16 alternatives means sending 4 bits of information.

Fig. 1. Block diagram showing basic components of a communication system.



Noise-Free Channel

The preceding paragraphs have covered information in a general sense. It will now be related to the basic components of a communication system indicated in Fig. 1.

The channel is the medium used to transmit the signal from transmitter to receiver. It may be a pair of wires, a coaxial cable, or a band of radio frequencies. To obtain maximum transfer of power from a generator to a load, the two must be matched to each other in the impedance sense. Likewise, to obtain maximum transfer of information from the message source to the message destination, the source and the channel must be matched to each other in a statistical sense. The statistical nature of messages is entirely determined by the character of the source. But the statistical character of the signal as actually transmitted by a channel, and hence the entropy in the channel is determined both by what is fed into the channel and by the capabilities of the channel in handling different signal situations.

The best transmitter is that which encodes the message in such a way that the signal has only those optimum statistical characteristics which are best suited to the channel to be used—maximizing the signal entropy to make it equal the capacity C of the channel. Such encoding leads to the fundamental theorem concerning the transmission of information over a noise-free channel.

A noiseless channel, transmitting discrete symbols, has a capacity C in bits per second and accepts information from a source at a rate H in bits per symbol. By devising proper encoding procedures for the transmitter, it is possible to transmit symbols over the channel at an average rate which is nearly C/H, but which, no matter how ingenious the coding, cannot be made to exceed C/H (in symbols per second). Unfortunately, as the encoding becomes more and more nearly ideal, longer and longer delays are made necessary in the process of encoding. This may not be as bad as it sounds because with electronic equipment "long" may mean a very small fraction of a second, and the gain in the transmission rate must be balanced against the loss in encoding time.

Noisy Channel

Information is a measure of freedom of choice; greater freedom of choice means greater uncertainty. Noise increases uncertainty or freedom of choice, and therefore, it increases information. But only the uncertainty which arises from the freedom of choice of the sender is *desirable* uncertainty. Uncertainty which arises from errors or noise is *undesirable* uncertainty. To obtain *useful* information, the undesirable uncertainty must be subtracted from total uncertainty. This is accomplished in theory by establishing a quantity known as the "equivocation," or the amount of ambiguity introduced by noise. Thus, the capacity of a noisy channel is the rate at which *useful* information, *i.e.*, total uncertainty minus noise uncertainty, can be transmitted over the channel.

Given noisy channel of capacity C and entropy of source H, the basic theorem of communication theory is as follows:

1. If $C \geqq H$, then by appropriate encoding, the output of the source can be transmitted over the channel with arbitrarily small frequency of errors.

2. If $C < H$, then it is impossible to encode in such a way as to reduce the error frequency to an arbitrarily small value.

For the significance of equivocation in relation to channel capacity, consider the following example taken from Shannon and Weaver's book.[2] Suppose there are two possible symbols, 0 and 1, and that transmission is occurring at a rate of 1000 symbols per second with probabilities of $p_0 = p_1 = ½$ for each symbol. During transmission the noise introduces errors so that, on the average, 1 in 100 symbols is received incorrectly, *i.e.*, a 0 is received as 1, or vice versa. The question is: what is the rate of transmission of *useful* information? If there were no errors and therefore no equivocation, the rate would be 1000 bits per second, allowing 1 bit per symbol. Since on the average 1% of the symbols are received incorrectly, one might be inclined to say that the useful information rate is 990 bits per second, which is obtained by subtracting the number of errors. This would be incorrect since it does not account for the recipient's lack of knowledge of where the errors occur. Thus, in the extreme case, we might imagine the noise to be so great that the received symbols are entirely independent of the transmitted symbols. The probability of receiving 1 is ½ whatever was transmitted, and similarly for 0. Then, due to chance alone, about half the signals are incorrect, and consistent with the above approach the system would be given credit for transmitting about 500 bits per second, while in fact no useful information is being transmitted at all.

Noise in the channel has introduced undesirable uncertainty which in the foregoing was called the "equivocation." To find the rate at which *useful* information is transmitted, the equivocation must first be found and subtracted from the total uncertainty or entropy.

Noise uncertainty is a measure of information, albeit undesirable information. To find this noise information or equivocation, refer back to Eqts. (1) and (2).

What are the probabilities P_i? If a 0 is received, the probability that a zero was transmitted is 0.99 and that a 1 was transmitted is 0.01. These figures are reversed if a 1 is received. Hence, the probabilities are $P_1 = 0.99$ and $P_2 = 0.01$, and noise information or equivocation is:

$$H = -(0.99 \log_2 0.99 + 0.01 \log_2 0.01)$$
$$= 0.081 \text{ bits/symbol},$$

so that the equivocation is being transmitted at the rate of 81 bits per second. Hence, the rate of transmission of useful information is 1000 − 81 or 919 bits per second. In the extreme case where a 0 is equally likely to be received as a 0 or a 1, and similarly for 1, the probabilities are $P_1 = ½, P_2 = ½$, so equivocation is:

$$H = -(½ \log_2 ½ + ½ \log_2 ½)$$
$$= 1 \text{ bit per symbol},$$

or 1000 bits per second. This means that the rate of transmission of useful information is zero, as it should be.

Relationships

The relationship between channel capacity C, bandwidth W, and signal-to-noise ratio P/N is:

$C = W \log (1 + P/N)$ for all values of P/N, where

P = transmitter power

N = white thermal noise of power N

By sufficiently ingenious encoding systems, binary digits can be transmitted at the rate $W \log_2 (1 + P/N)$ bits per second, with arbitrarily small frequency of errors. Transmission at a higher rate by any encoding system without a definite positive frequency of errors is not possible. It is emphasized that it is possible to transmit at a rate C over a channel only by properly encoding the information. In general the rate C cannot be actually attained but only approached as a limit by using more and more complex encoding and longer and longer delays at both transmitter and receiver.

The extremely important implication of the above relation for capacity is that *if there were no noise whatever, a continuous function could in principle be measured with arbitrarily high precision and could assume an infinite number of amplitude levels.* Thus an unlimited amount of information could be transmitted per second over as narrow a band as desired. This fact represents the great departure of modern information theory from the information theory of Hartley.

Of utmost importance to the communication engineer is the question of how to reduce bandwidth. Communication theory reveals three essentially different ways. These are:

1. The straightforward exchange of signal-to-noise ratio,
2. Utilization of statistical correlation in the source, and
3. Utilization of the properties of the destination.

Consider bandwidth reduction by the *exchange of signal-to-noise ratio.* The relation for channel capacity may be written in the form:

$$C = 2W \log_2 \left(\frac{P+N}{N}\right)^{½} \quad . \quad . \quad (3)$$

where $[(P + N)/N]^{½}$ is the number of amplitude levels which can be distinguished. If the noise voltage amounts to a little less than 1 volt, two amplitudes, "off" and "on", may be distinguished between by sending a signal of either 0 or 1 volt amplitude. Hence,

$$C = 2W_1 \text{ bits per second.}$$

The question now arises: by how much must the transmitted power be increased in order to be able to reduce the bandwidth by a factor of 4 and still have the same channel capacity as before? It is assumed that the noise level in the channel is again a little less than 1 volt.

Then, for $W_2 = W_1/4$

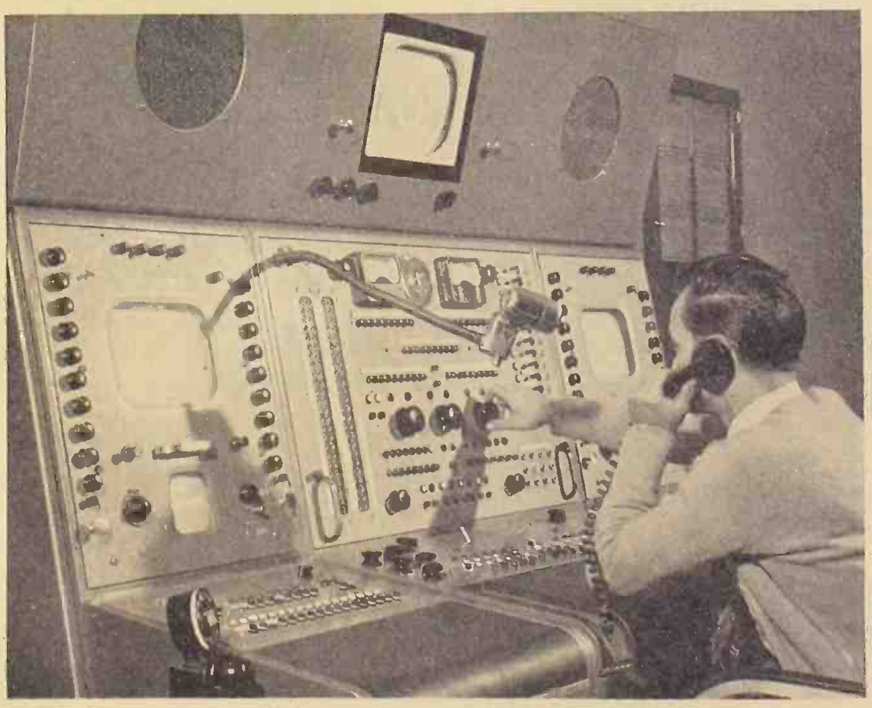
$$C = \frac{2W_1}{4} \log_2 \left(\frac{P+N}{N}\right)^{½} \quad . \quad . \quad (4)$$

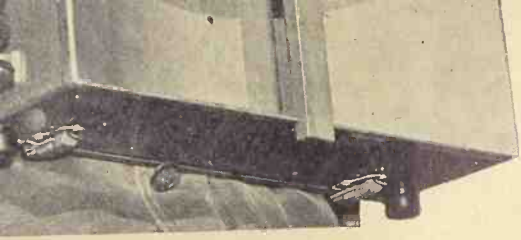
For C to be the same, $\log_2 [(P+N)/N]^{1/2}$ must equal 4. This is equivalent to saying that it must be possible to distinguish among 16 amplitudes. Since zero counts as one amplitude, this means that a signal of up to 15 volts must be sent whereas before it was necessary to send a signal of not more than 1 volt. That is, one may be required to transmit 225 times as much power to reduce the bandwidth by a factor of 4. In most cases the more profitable exchange is in the other direction. Thus, a 10,000-watt FM radio transmitter, which uses a bandwidth of 150,000 cycles per second, is as effective in overriding many kinds of noise as the most nearly comparable AM transmitter, emitting a power of 250,000 watts over a bandwidth of 30,000 cycles. But FM is relatively inefficient in trading bandwidth for power. PCM, for example, does a much better job in this respect.

Consider bandwidth reduction by *utilization of the statistical correlation in the source.* Many present-day communication systems are extremely inefficient in that they fail to make use of the statistical properties of the information source. For example, assume a system for transmitting English speech (no music or other sounds), the requirements on reproduction being only that the transmitted speech is intelligible as to meaning. Personal accents, inflections, and the like can be lost in the process of transmission. In principle, at least, it would be possible to transmit according to the following scheme. At the transmitter English text is printed to correspond with spoken words. The printed text is encoded into binary digits, using on the average not more than two binary digits per letter or nine per word. Taking 100 words

(*Continued on page* 28)

Control panel for TV Station WRGB, Schenectady. Information theory properly applied to TV systems could decrease the required bandwidth.





on board ship to locate the shore
shore station can be established.

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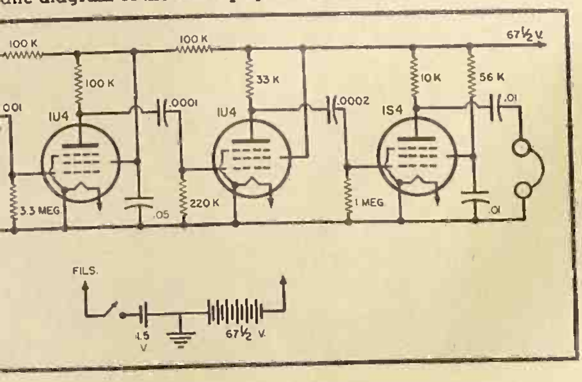
need had to be designed in the low price field and at the same time be simple, rugged and easy for any crew member to operate. Furthermore, it had to be of limited range to permit a reasonable number of units to operate in any one area without interference and channeling problems.

This assignment was handed to the Radar Development Section of the National Research Council at Ottawa. Previously, the only equipment used for the purpose had been the radar responder beacon (a land-based beacon triggered by a radar signal to provide the ship's operator with an azimuth bearing on the PPI tube), and the low

atic diagram of the battery-operated receiver.



7-kw. transmitter operating in the 3-cm. band which could be mounted directly on a jetty or could be located in line with an inlet channel. The receiver—the only equipment needed by the ship operator—was deliberately simplified to keep the price down to $200 or less.

Transmitter

The transmitter is set up on shore. It is a simplified pulse transmitter, consisting of a 3-cm. magnetron modulated by a rotary spark gap at 500 pulses per second, together with its associated power supplies. The photograph (Fig. 6) shows the transmitter with its cover removed. On the top deck at the left is the rotary spark gap in its drum-shaped housing driven by the attached motor which is supplied by the oxide rectifiers at the rear. This provides a simple method of controlling the PRF (pulse recurrence frequency).

The spark gap rotor, revolving at about 3700 rpm, has eight segments which pass a single probe with an adjustable gap. To the right of the spark gap is the keying wheel and its associated motor used to key the output of the twin beam antenna in some suitable form of interlocking code, such as the familiar A-N or B-V combinations in common use on the aeronautical range. (On later models both the spark gap and the keying wheel are driven by a single motor.)

On the middle deck are the power supplies, pulse line and time delay relay for the high voltage. On the lower deck are the magnetron and pulse transformer. The meters indicate—from left to right—the line voltage, running time, power supply voltage and magnetron current, suitable plugs and jacks being used for the latter two. The remote start-stop switch can be seen beside the transmitter. The magnetron drive volt

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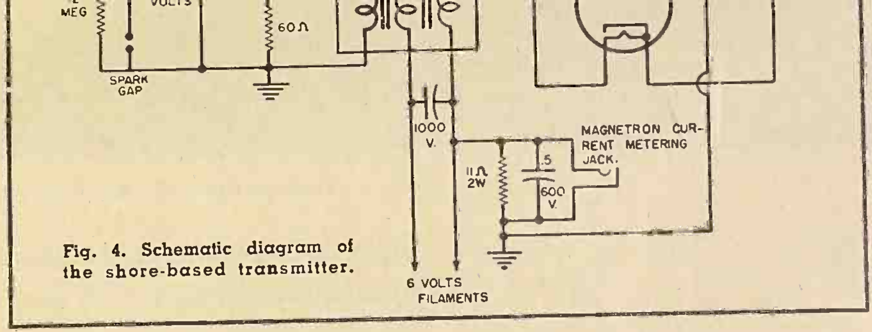

Fig. 4. Schematic diagram of the shore-based transmitter.

within one degree. The whole receiver may either be mounted on a bearing with an azimuth scale or held manually.

Transmitter Antenna

During the course of early equipment trials, it was felt that some means of providing a fixed course, or courses, would be of value. To provide such a course, advantage was taken of a frequently observed phenomenon, namely, the sharply defined shadows cast by objects illuminated by microwave radiation.

The antenna used for this purpose is shown in Fig. 3. It is built around a plane metal surface, one foot by ten feet, at one end of which the two radiators are placed, one on each side of the plane surface. The radiation from the primary antennas is directed along the axis of the surface. Considering one side of the surface, it can be seen that radiation cannot pass through the metal surface and that any radiation which strikes it will be reflected. That portion of the radiated energy which just grazes the farther edge of the plate is slightly refracted. If the radiation patterns of Fig. 5 are examined, it will be seen that the pattern from one side of the baffle is a mirror image

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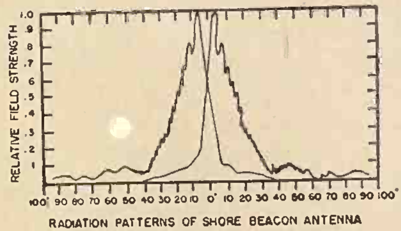
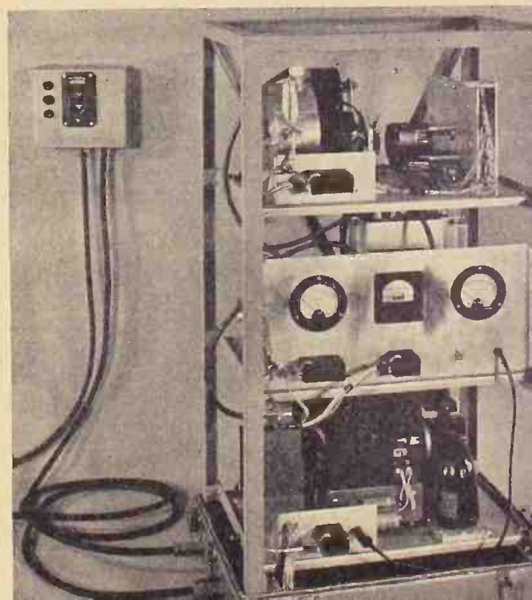
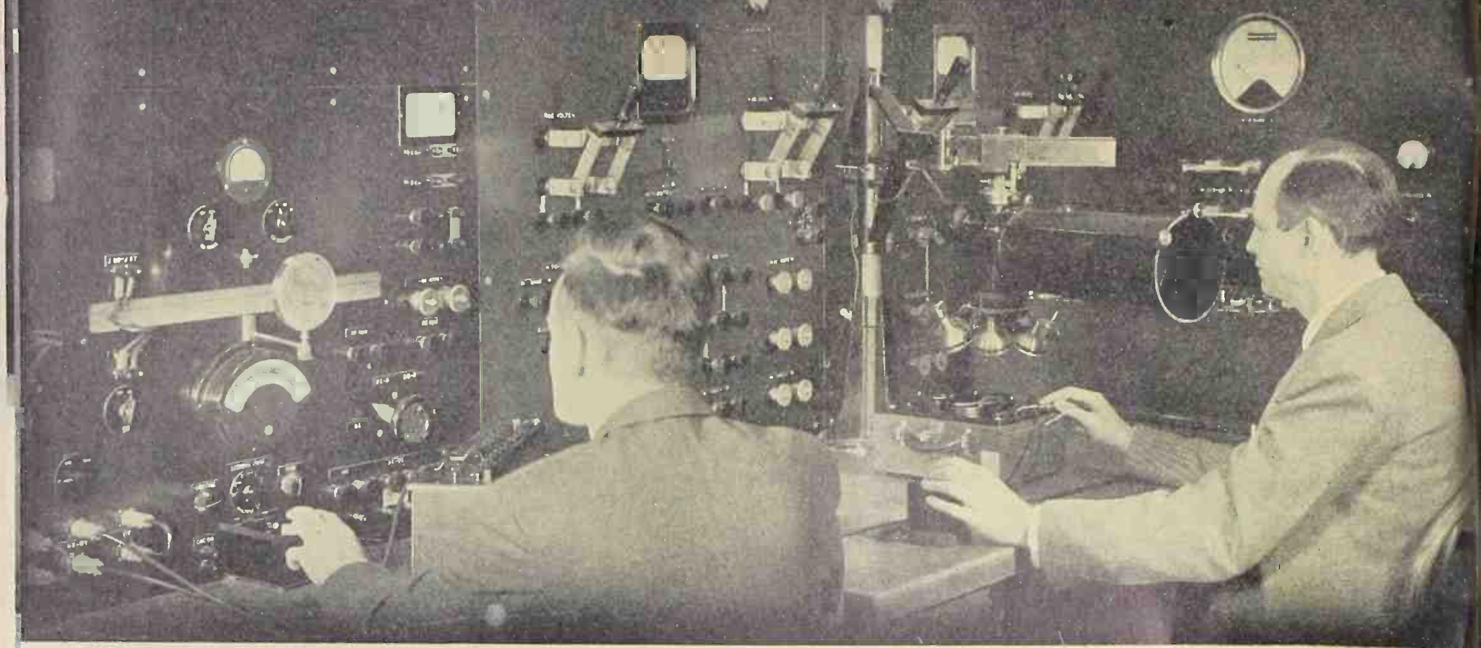


Fig. 5. Radiation patterns of the equi-signal shore beacon antenna.

Fig. 6. Transmitter with cover removed. Rotary spark gap is at top.



AUDIO DEVELOPMENTS at NBS



Standardization of an a.c. voltmeter in the NBS Electrical Instruments Laboratory.

Standardization of a.c. instruments and heater-induced hum measurements in amplifiers at NBS are discussed.

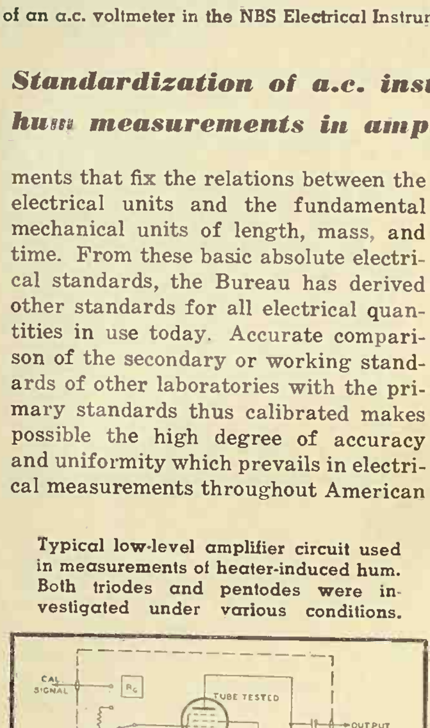
IN SPITE of the tremendous amount of interest in television, microwaves, and the like, there is still a great deal of research and experimentation taking place in the audio field. Here are reports on two National Bureau of Standards projects which deal directly with audio.

Transfer Standards

As a part of a program to increase the range and accuracy of electrical measurements at audio frequencies, NBS has developed highly accurate electrothermic transfer methods for the measurement of voltage and current. Designed primarily for the testing of ammeters and voltmeters, the transfer methods make possible accuracies approaching 0.01 per cent over wide ranges of current and voltage at audio frequencies. They thus enable NBS to meet growing demands for the accurate standardization of electrical instruments at frequencies higher than the commercial power frequencies at which these services have hitherto been available.

As the custodian of the national standards of physical measurement, NBS has the responsibility of insuring that the units of measurement used in science and industry are constant throughout the years and uniform throughout the nation. The Bureau has developed very precise standards of resistance and voltage, the values of which are established by absolute measurements that fix the relations between the electrical units and the fundamental mechanical units of length, mass, and time. From these basic absolute electrical standards, the Bureau has derived other standards for all electrical quantities in use today. Accurate comparison of the secondary or working standards of other laboratories with the primary standards thus calibrated makes possible the high degree of accuracy and uniformity which prevails in electrical measurements throughout American science and industry. As higher audio frequencies are being used increasingly in aircraft, induction furnaces and heating, and in various electronic devices, it has become necessary to develop special equipment and transfer standards for tests of instruments operating in this range. As the fundamental electrical units are maintained by d.c. standards, all a.c. measurements of voltage, current, and power are actually based on transfer instruments, which are standardized on direct current and then used on alternating current.

Typical low-level amplifier circuit used in measurements of heater-induced hum. Both triodes and pentodes were investigated under various conditions.

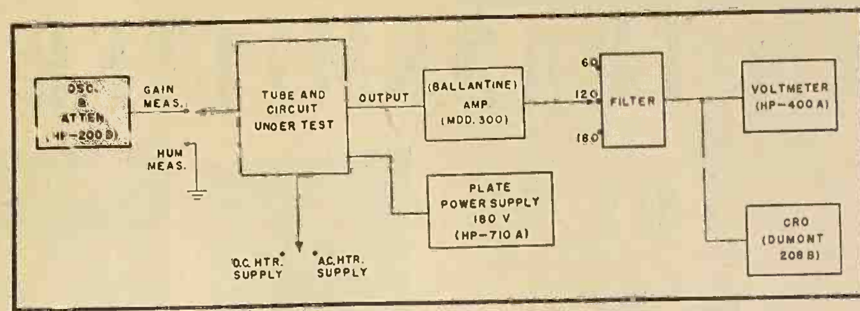


The electrothermic transfer standards used at NBS are thermal converters, often called thermocouples or thermoelements. Each thermal converter consists of a conductor, heated by the alternating current to be measured, and a thermocouple, one junction of which is thermally connected to the heater. The value of the direct voltage produced in the thermocouple thus depends on the value of the alternating current measured. Although such thermal converters have commonly been used for measurements at radio and higher frequencies, it has not been generally realized that they provide the basis for a particularly simple form of electrothermic instrument which responds equally well to direct and alternating current at audio frequencies. NBS investigaons have shown that certain selected ıd tested thermal converters commer- ally available can be used for transfer ork to an accuracy of 0.01 per cent at ırrents from 1 milliampere to 50 am- ›res over the audio-frequency range om 20 to 20,000 cps. Experimental ıd theoretical studies recently carried ıt by Francis L. Hermach of the NBS lectrical Instruments Laboratory have rought out a number of the factors overning the transfer accuracy, par- cularly at these comparatively low equencies. As the requirements im- osed by these factors can readily be ıet, the NBS studies have made pos- ible the specification and purchase of ommercial thermal converters having he required accuracy over wide cur- ent ranges at audio frequencies. Two orms of multirange voltmeter elements vith ranges from 0.2 to 750 volts, con- isting of commercially obtainable re- istors in series with the heater of a elected thermoelement, have been con- tructed at NBS, and their transfer erformance has been carefully studied o make possible accurate alternating- oltage measurements.

In standardizing electrical instru- ıents, these transfer standards are sed for two distinct types of tests: one or instruments which respond to di- ect as well as alternating current, the ther for those which cannot be used vith accuracy on direct current. Instru- ıents of the first type are generally iven a transfer test which directly etermines their a.c.-d.c. differences. he instrument under test and the NBS tandard are connected so as to "see" he same electrical quantity successive- y on alternating and direct current. In ach case the current is adjusted to roduce the same deflection in the test ıstrument, and the response of the tandard is observed. From these ob- ervations the a.c.-d.c. differences of the est instrument are computed by simple ormulas. These differences are rela- ively permanent, and their measure- ıent need not ordinarily be repeated. Thus, when combined with a d.c. test, his procedure gives more information han would an a.c. test alone.

In the a.c. test, the standard and test nstruments are connected together on lternating current, and the current is djusted for the required response of he test instrument. The response of he standard is observed, and the stand- ırd is then switched to direct current, vhich is adjusted to give the same re- ponse. The value of the direct current r voltage required to give this re- ponse is then measured with a poten- iometer and accessory apparatus.

The results obtained show that, when roperly used, certain thermal convert- rs are capable of a transfer accuracy pproaching that of the best electro-



Block diagram of complete arrangement for investigating heater-induced hum.

dynamic and electrostatic instruments and are useful over wide frequency, current, and voltage ranges. For laboratories that may wish to set up similar equipment, the sets of tested thermal converters at NBS make possible direct determination of the transfer performance of other converters to high accuracy. At present, comparison with the Bureau's converters is recommended if accuracies better than about 0.1 per cent are desired. While the equipment used with the standards is not portable, the transfer standards themselves are, and they have been used with a portable potentiometer for measurements of voltage and current at other locations.

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Heater-induced 60-cycle hum in a.c.-operated low level amplifiers can be reduced to less than 1 microvolt by suitable choices of tubes and circuitry. Yet less fortunate tube-and-circuit combinations may give heater hum levels of more than 500 microvolts. These are conclusions of a limited investigation of heater hum recently made at the NBS Electronic Instrumentation Laboratory. Undertaken because of the need for low hum amplifiers for instrumentation work at NBS, the study has yielded useful practical data for designing such amplifiers. Emphasis was on cataloging heater hum characteristics of various tubes and circuit arrangements, rather than on investigating the causes of the hum.

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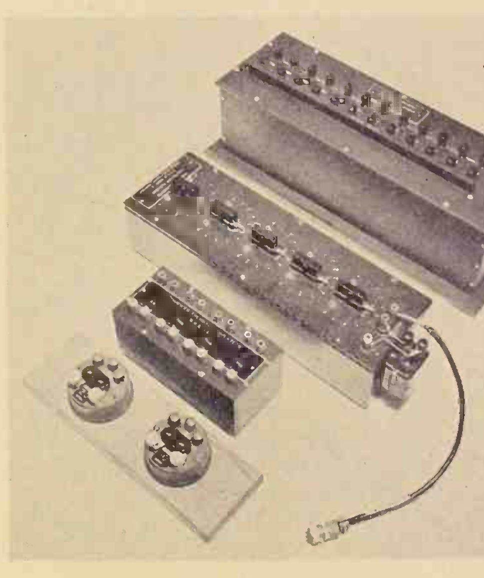
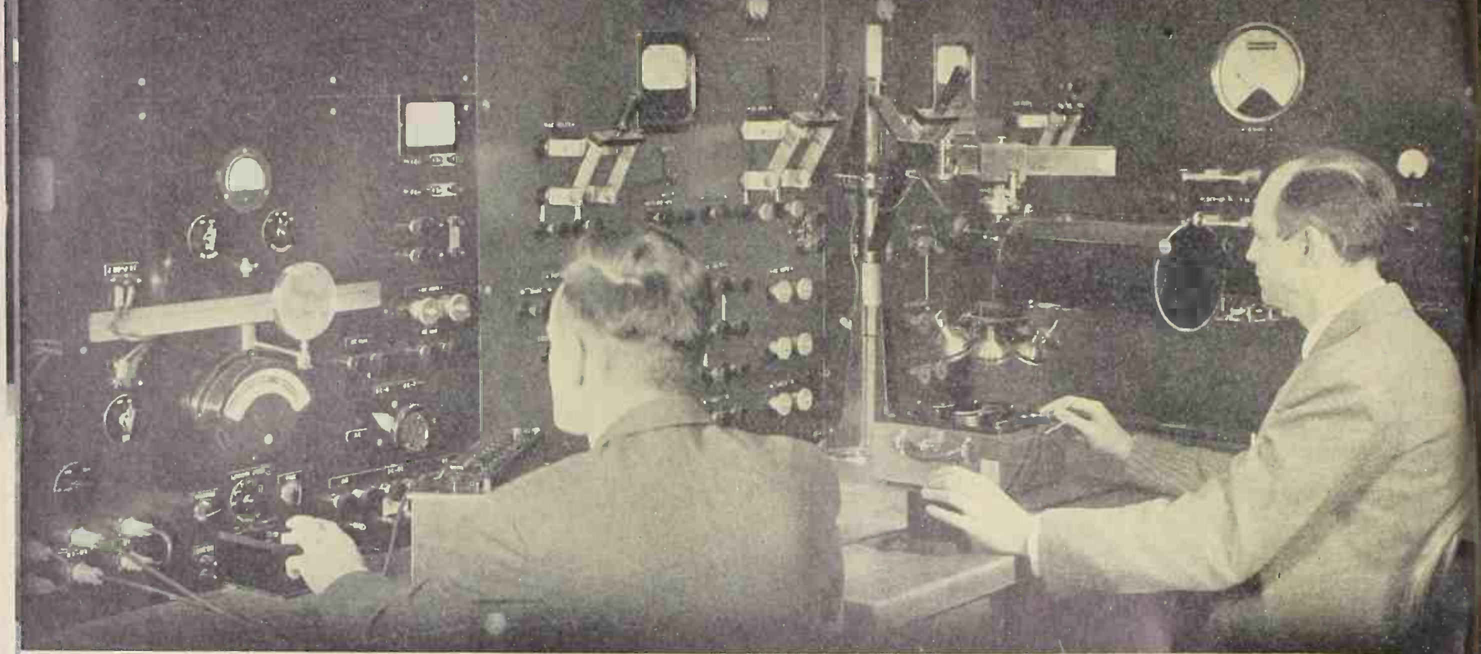
To obtain the desired measurements of heater-induced hum, external a.c. hum was reduced to a negligible value, using recognized shielding precautions;

(*Continued on page* 26)

Thermal converters and voltmeter elements used for testing ammeters and voltmeters at audio frequencies.



AUDIO DEVELOPMENTS at NBS



Standardization of an a.c. voltmeter in the NBS Electrical Instruments Laboratory.

Standardization of a.c. instruments and heater-induced hum measurements in amplifiers at NBS are discussed.

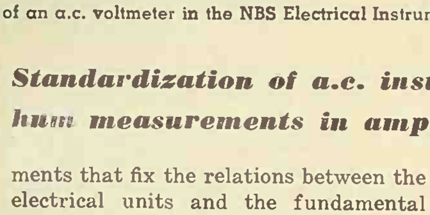
IN SPITE of the tremendous amount of interest in television, microwaves, and the like, there is still a great deal of research and experimentation taking place in the audio field. Here are reports on two National Bureau of Standards projects which deal directly with audio.

Transfer Standards

As a part of a program to increase the range and accuracy of electrical measurements at audio frequencies, NBS has developed highly accurate electrothermic transfer methods for the measurement of voltage and current. Designed primarily for the testing of ammeters and voltmeters, the transfer methods make possible accuracies approaching 0.01 per cent over wide ranges of current and voltage at audio frequencies. They thus enable NBS to meet growing demands for the accurate standardization of electrical instruments at frequencies higher than the commercial power frequencies at which these services have hitherto been available.

As the custodian of the national standards of physical measurement, NBS has the responsibility of insuring that the units of measurement used in science and industry are constant throughout the years and uniform throughout the nation. The Bureau has developed very precise standards of resistance and voltage, the values of which are established by absolute measurements that fix the relations between the electrical units and the fundamental mechanical units of length, mass, and time. From these basic absolute electrical standards, the Bureau has derived other standards for all electrical quantities in use today. Accurate comparison of the secondary or working standards of other laboratories with the primary standards thus calibrated makes possible the high degree of accuracy and uniformity which prevails in electrical measurements throughout American science and industry. As higher audio frequencies are being used increasingly in aircraft, induction furnaces and heating, and in various electronic devices, it has become necessary to develop special equipment and transfer standards for tests of instruments operating in this range. As the fundamental electrical units are maintained by d.c. standards, all a.c. measurements of voltage, current, and power are actually based on transfer instruments, which are standardized on direct current and then used on alternating current.

Typical low-level amplifier circuit used in measurements of heater-induced hum. Both triodes and pentodes were investigated under various conditions.



The electrothermic transfer standards used at NBS are thermal converters, often called thermocouples or thermoelements. Each thermal converter consists of a conductor, heated by the alternating current to be measured, and a thermocouple, one junction of which is thermally connected to the heater. The value of the direct voltage produced in the thermocouple thus depends on the value of the alternating current measured. Although such thermal converters have commonly been used for measurements at radio and higher frequencies, it has not been generally realized that they provide the basis for a particularly simple form of electrothermic instrument which responds equally well to direct and alternating current at audio frequencies. NBS investigaons have shown that certain selected nd tested thermal converters commer- ally available can be used for transfer ork to an accuracy of 0.01 per cent at urrents from 1 milliampere to 50 am- eres over the audio-frequency range om 20 to 20,000 cps. Experimental nd theoretical studies recently carried ut by Francis L. Hermach of the NBS lectrical Instruments Laboratory have rought out a number of the factors overning the transfer accuracy, par- cularly at these comparatively low equencies. As the requirements im- osed by these factors can readily be et, the NBS studies have made pos- ible the specification and purchase of ommercial thermal converters having he required accuracy over wide cur- ent ranges at audio frequencies. Two orms of multirange voltmeter elements ith ranges from 0.2 to 750 volts, con- isting of commercially obtainable re- istors in series with the heater of a elected thermoelement, have been con- tructed at NBS, and their transfer erformance has been carefully studied o make possible accurate alternating- oltage measurements.

In standardizing electrical instru- ents, these transfer standards are sed for two distinct types of tests: one or instruments which respond to di- ect as well as alternating current, the ther for those which cannot be used ith accuracy on direct current. Instru- ents of the first type are generally iven a transfer test which directly etermines their a.c.-d.c. differences. The instrument under test and the NBS tandard are connected so as to "see" he same electrical quantity successive- y on alternating and direct current. In ach case the current is adjusted to roduce the same deflection in the test nstrument, and the response of the tandard is observed. From these ob- ervations the a.c.-d.c. differences of the est instrument are computed by simple ormulas. These differences are rela- ively permanent, and their measure- nent need not ordinarily be repeated. Thus, when combined with a d.c. test, his procedure gives more information han would an a.c. test alone.

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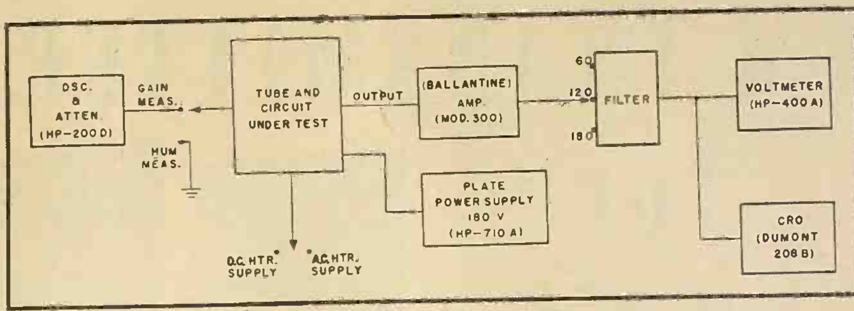

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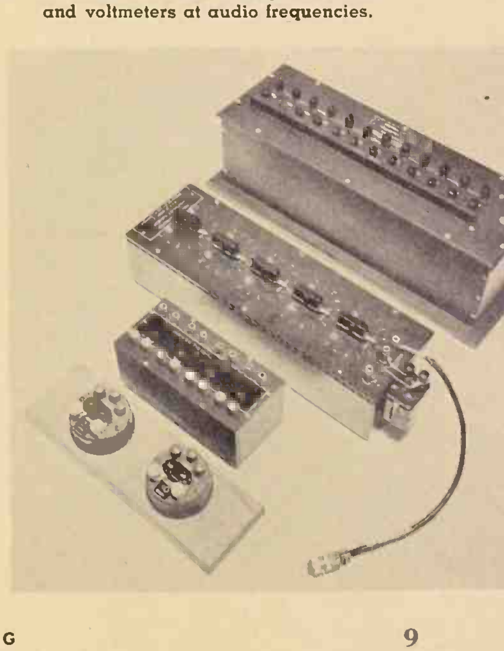
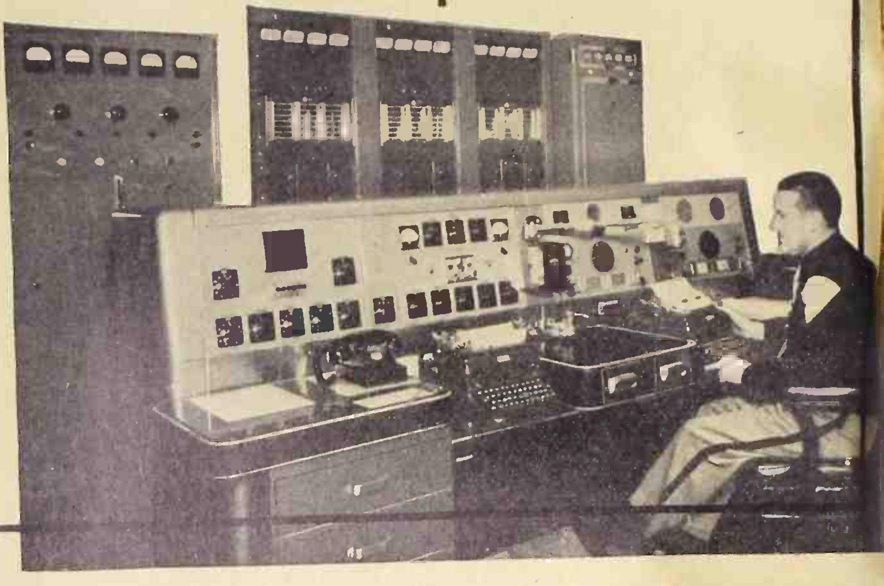


FM TRANSMITTER for 42 MC.

Indiana State Police Post No. 8 at Jasper, Ind. An FM amplifier similar to the one described in the text is at the extreme rear left.



By
HARDIN G. STRATMAN

Design and performance details of a 3-kw. FM amplifier for police communications.

IN RECENT YEARS, the ever expanding field of radio communication has grown so rapidly that increasing interference, both man-made and natural, has made necessary a new medium of transmitting intelligence for the efficient and accurate disposal of messages for the State Police System—frequency modulation.

FM is effectively solving all problems of station interference, cross modulation and other types of direct interference from other stations. In addition, FM equipment as a rule occupies less space and is easier to service than amplitude modulated equipment of equal power. In short, FM radio offers an excellent carrier medium for quick action on messages and is just the type of communication service needed for state police work.

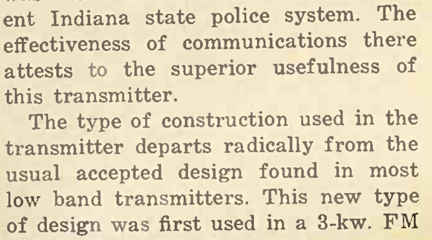
Within the last few years, conversion from AM to FM has gradually taken place in the field of communications as the superior qualities of frequency modulation have become apparent. But until recently, transmitting power on the order of 250 watts was the usual order of the day. Now, due to the fact that station-to-station operation covers several hundreds of miles and the distance from control station to mobile unit may be as much as a hundred miles, many state police installations have increased their power to 3 kw. However, field experience has shown that this is somewhat more power than is necessary for the usual run-of-the-mill everyday communication and, in some instances, power output has been dropped to 2 kw. without losing any advantages.

The 3-kw. FM transmitter described here has proven to be an excellent model for use in the 42-mc. band where most of the state police communication takes place. It was designed and manufactured by *Gates Radio Company* and was first used in the modern and efficient Indiana state police system. The effectiveness of communications there attests to the superior usefulness of this transmitter.

The type of construction used in the transmitter departs radically from the usual accepted design found in most low band transmitters. This new type of design was first used in a 3-kw. FM transmitter in the 88 to 108 mc. commercial FM band and, except for redesign of the plate tank and grid tank circuits and method of input coupling, it is still basically the same.

Vertical construction is used throughout to make the equipment as accessible as possible. All components can be easily reached through doors or removable panels. Forced air cooling is provided for the power amplifier tubes V_1 and V_2 at all times that the unit is in operation, by means of a blower and a fan. The air circulation is continued for approximately two minutes after all voltages are shut off to make sure that the residual tube heat is removed. This feature effectively lengthens tube life. Additional protection is provided for the transmitter by an air switch which automatically keeps high voltage from being applied to the transmitter if the air should fail. A dust filter in the rear door provides dust protection while still allowing forced air circulation.

Fig. 1. Basic diagram of the reflectometer for indicating antenna match.



All wires in the transmitter are numbered for ease of tracing from part to part should trouble develop, and motor tuning of all circuits is used to obtain ease of adjustments and to allow for optimum placement of tank circuit components. Push buttons and their associated indicator lamps are located on the front panel for control of various voltages and other functions.

When the rear door is opened, the door interlock switch S_{10} operates and opens the holding contacts of E_7, the plate contactor, thereupon shutting off the high voltage. Also provided is a high voltage shorting switch S_6 which effectively shorts the power supply and filter condensers directly to ground whenever the rear door is opened. This gives utmost protection to operating personnel.

Circuit breakers and overload relays are provided in the primary side of the plate and screen circuits for the protection of the equipment.

Input a.c. line voltage to the transmitter is 220 volts, single phase, and is connected to a terminal board in the base of the transmitter. From there it is routed to a main breaker S_1 which controls all power to the other circuits. When S_1 is "on" and the "on" button S_3 is depressed, the holding contacts on contactor E_6 close and low voltage is applied to the transmitter, closing all of the other proper relays. The ventilation fan A_{15} and blower A_5 will circulate air through the transmitter, closing air interlock S_9. The lumiline lamp A_{14} over the front panel will light and filament voltage will be applied to all rectifier tubes and power amplifier tubes. Voltage will also be applied to the tuning direction switch S_5, and the time delay E_1 will close after about 30 seconds. Then, if the door interlock S_{10} is closed and excitation is applied to close under-voltage excitation relay E_4, high voltage may then be applied to the power amplifier circuit. This is accomplished by momentarily closing the high-voltage push-button switch S_8 which will cause the holding contacts on plate contactor E_7 to close, which in turn will cause screen and plate voltage to be applied to the power amplifier circuit. Should a short or overload occur somewhere in the amplifier circuit, the unit will be protected by screen overload relay E_3 and plate overload relay E_2 which can be set for a specific value of current. Even if a short should occur somewhere due to ineffectiveness of the overload relays, the unit is protected by the main breaker S_1 which contains a magnetic device to trip it out if more than 35 amperes are being drawn from the line. If excitation should fail, under-voltage excitation relay E_4 will trip off the high voltage. When the unit is to be turned off, high-voltage "off" button S_7 is pressed and then filament "off" button S_2 is also pressed. The blower time delay E_5 will remain closed for approximately two minutes to keep the air circulating and remove all residual heat from the transmitter.

Filament, blower, screen and plate voltages are indicated by pilot lights A_1, A_7, A_9 and A_3 respectively. Filament voltage of the power amplifier tubes can be set correctly by R_1 located on the front panel. The grid, plate and output circuits are tuned by tuning motors Tm_1, Tm_2 and Tm_3 in that order. Switch S_4 determines which one shall be rotated and switch S_5 applies the power to them in a manner calculated to cause them to rotate in the desired direction.

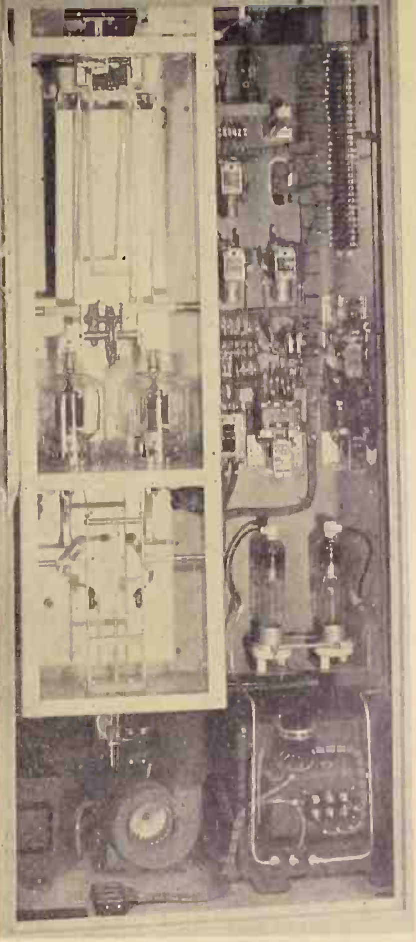
Two terminal boards TB_8 and TB_9 should be noted on the schematic. TB_8 is to be connected to a 90-volt d.c. source and TB_9 to an external 110-volt a.c. source. These two terminal boards and their associated circuits are provided for two specific purposes. First, and most important, they allow remote control of the transmitter. Secondly, they allow personnel to work on the main amplifier with line voltage removed without closing down all communications, because the output of the driving transmitter can be connected directly to the antenna by means of the relays without changing any wiring. Occasionally just the driving transmitter will be used for communication service if not too great a distance is to be covered. Reference to Fig. 3 will clarify the way in which these circuits work. The remote "on-off" control of the transmitter is accomplished by two telephone type relays E_8 and E_9 designed to operate from the 90 volts d.c. Polarization of the d.c. must be observed to prevent damage to C_{24}. E_8 closes momentarily when the 90 volts d.c. is applied from the control desk. The momentary operation is accomplished by utilizing the charging current of C_{24}. Note that the contacts on this relay are in shunt with the "on" push button located on the transmitter front panel. Note that relay E_9 is excited and the contacts remain closed during the total transmission period. This relay has two sets of contacts having two distinct functions. The first set closes and applies excitation voltage to the coaxial relays E_{10} and E_{11}, placing them in the correct position for a 3-kw. transmission. The second set of contacts is in series with the "off" push button on the amplifier front panel and when the 90-volt d.c. control voltage is turned off, the transmitter is cut off the air. In the unexcited position of the coaxial relays, the driver transmitter is connected directly to the output of the 3-kw. transmitter. When it is desired to operate the amplifier from the normal front panel push-button control for servicing, the armature of E_9 should be taped down to close both sets of contacts.

Amplifier Circuit

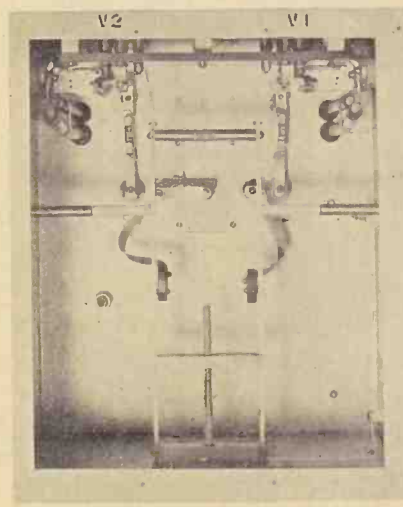
The grid and plate tank of the transmitter consist of quarter-wave linear elements. Input and output impedances are 72 ohms. Note the unique "banjo type" input half-wave delay type balun which changes the single-ended, unbalanced input from the driver to balanced type. This change takes place through connecting the input to the grid of one tube and connecting a length of coaxial cable electrically one-half wavelength long from the grid of the first tube to the grid of the other tube. This causes an electrical phase shift of 180°. The length of coaxial cable is approximately 92".

The amplifier is neutralized by placing variable condensers from the screen connecting pins of the tubes to ground. These condensers, along with the distributed inductance of the tube connections, form a series resonant circuit to ground at the operating frequency and effectively isolate the input circuit from the output circuit.

The tuning of an FM transmitter in the frequency range of 42 mc. offers greater difficulties with regard to tuning the various circuits than are normally encountered on the lower AM frequencies. This is attributable to



Rear view of the complete amplifier.



Close-up view of the grid tank circuit showing method of input coupling.

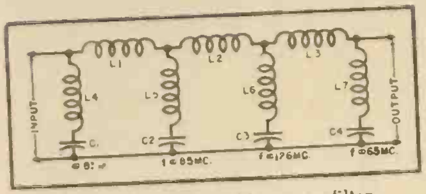


Fig. 2. Schematic of low pass filter.

greater reaction between various circuits, caused by small inductive and capacitive reactances that can normally be ignored on the low frequencies but which become increasingly important at these higher frequencies. Consequently, when tuning a high frequency transmitter, it is well to recheck the previous adjustments constantly as the tuning progresses.

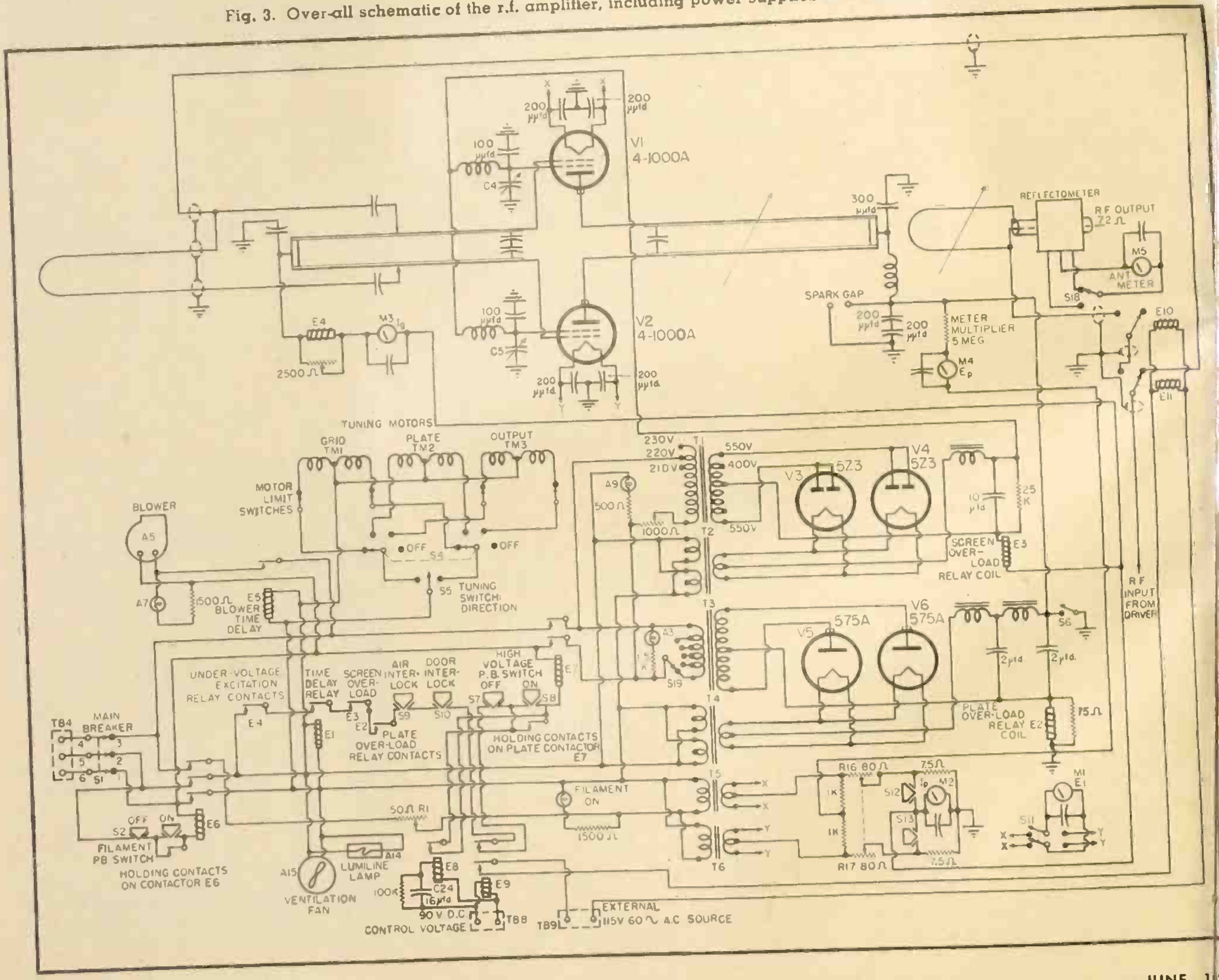
The normal driving source of this amplifier is the *Gates* 250-watt FM transmitter but any good driving transmitter that can produce a minimum output power of 60 watts will suffice as the amplifier drives very easily. It is possible to obtain up to 3.4 kw. continuous power from the 3-kw. amplifier when it has been properly tuned.

Tuning of the grid circuit is accomplished very simply. A fixed capacity has been placed across the ends of the grid tank which causes it to resonate near the desired frequency. With drive applied, the motor-tuned shorting bar is then adjusted to give a maximum reading of the grid current meter. This shorting bar effectively changes the electrical length of the tank elements.

When sufficient drive has been obtained (approximately 150 ma.), tuning of the plate circuit can be undertaken. If the load is properly matched, the transmitter neutralized, and the output coupling is proper, this tuning is easily executed. But, of course, the ideal situation is seldom encountered when tuning is first attempted. As a starting point, with a transmitter that has just come off the production line or is known to be completely out of adjustment, the neutralizing condensers (C_4 and C_5) are set at about half-mesh, coupling is adjusted about half-way toward maximum, and the output connection is made to a non-radiating dummy load of the correct resistance; then low plate and screen voltages are applied. Tuning of the quarter-wave elements which comprise the plate tank circuit is accomplished by a padding condenser consisting of two large, round aluminum plates and a variable vane which varies the surge impedance of the circuit. When the vane is closest to the tank circuit, the surge impedance is lowest and the effective electrical length will be shortened. When the vane is at the farthest point away from the tank circuit, the surge impedance is highest and the effective electrical length will be extended. If unable to hit the desired frequency when the vane is all the way in, less capacity is necessary to reach the desired frequency.

Output power may be varied effectively by three methods. First—and most important—is the use of the output loop, which varies output power approximately 30% with a standing wave ratio of unity in the transmission line. This output loop is set at the optimum point of coupling, the point at which the output power as indicated by the output meter has just stopped increasing appreciably. Overcoupling to a point where undesirable effects such as broad tuning and reactive effects may be introduced back into the plate tank circuit, which might cause oscillation

Fig. 3. Over-all schematic of the r.f. amplifier, including power supplies and control circuits.



or even resonance to a harmonic, should be avoided. The output loop is motor-tuned but if the normal travel is insufficient, the position of the pickup loop may be coupled "closer or more loosely" by means of a setscrew on the drive block. The screen grid control also varies output power about 30% (method 2). This control is customarily set for a definite power output after optimum coupling to the output circuit has been obtained or for increased efficiency between input power to the plate tank circuit and actual r.f. output power. A limiting factor here is the possibility of the screen drawing too much current or parasitics taking place. The third method is by means of a switching arrangement which is also provided on the plate transformer T_3 to alter considerably the r.f. output by varying plate voltage.

Neutralization of this transmitter is not accomplished in the conventional manner. There are three general methods of checking as to whether or not the transmitter is properly neutralized:

1. If the grid current (M_3) does not rise to maximum simultaneously with the dip in plate current (M_2) while the power amplifier plate tank is being tuned through resonance, neutralization is not adequate.
2. If excitation is removed from the power amplifier and the excitation relay E_4 does not open (removing plate voltage), it indicates oscillation in the power amplifier itself, a result of improper neutralization. The self-oscillation in the power amplifier produces grid current which holds relay E_4 closed, thus keeping plate voltage applied and allowing the amplifier to continue self-oscillation.
3. If the balance control R_{17} does not permit plate current balance within 10%, further adjustment of the neutralizing condensers is required.

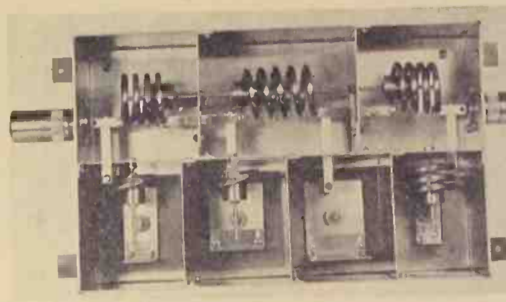
Experience has shown that method 2 is probably the best bet for checking neutralization. Method 1 may not always hold true as it is somewhat dependent on the driver internal impedance as well as on the complex impedance which may be reflected into the amplifier from the antenna-transmission line system.

A favorable method of neutralizing to start with is to block out grid current relay E_4 so that the transmitter will stay on the air without drive; reduce the plate voltage to about one-half and turn the transmitter on; then adjust the neutralizing condensers to a point where no output power is indicated on the output meter. This operation must be carried out swiftly to prevent damage to the final amplifier tubes. Then, with full plate voltage and drive applied to the final tank circuit, the neutralizing condensers can be trimmed slightly to compensate for any difference in the amount of plate current drawn by the individual tubes and to make the grid current peak coincide with the plate current dip as the plate circuit is tuned through resonance. This method of neutralizing applies in general to all types of the higher frequency transmitters. As can be noticed from the schematic, the method of neutralizing used in the transmitter is to provide a low reactance path from the screen grid of each power amplifier tube to ground at the output frequency. This is accomplished by the series resonant circuit in the screen grid circuit and effectively isolates the grid from the plate circuit.

A particularly critical operating factor is getting a good match from the driver transmitter to the grid circuit of the final amplifier. Failing to do so will result in reduced output power and appearances of instability seeming to come from improper tuning of the plate or neutralizing circuits. A good match between the driving transmitter and the 3-kw. power amplifier can often be obtained merely by changing the output coupling of the driver unit or the matching point on the grid circuit of the amplifier. At times it boils down to something as simple as changing the length of the coaxial coupling cable from the driving transmitter to the power amplifier.

Two push-button switches, S_{12} and S_{13}, are provided on the front panel for the purpose of checking the individual plate currents drawn by V_1 and V_2 of the amplifier. The balance control (R_{16} and R_{17}), which is available as a screw driver adjustment from the front, enables the operator to maintain the plate currents of V_1 and V_2 in balance. When the push buttons S_{12} and S_{13} are in their normally closed position, the meter M_2 reads the total plate currents of both V_1 and V_2 combined. This current multiplied by plate volts as indicated on M_4 will give the correct power input to the final amplifier. The sum of the plate currents, as indicated on M_2 when either S_{12} or S_{13} is pressed, is not equal to the total plate current as indicated on M_2 when S_{12} and S_{13} are in the normally closed position. This is due to the fact that normally the screen current and grid current of V_1 and V_2 flow back to the filament through the closed contacts of S_{12} and S_{13}. When either push button is depressed, the screen and grid currents of the respective tube must flow through M_2 before returning to the filament. In doing so this screen and grid current will effectively cancel the same amount of plate current.

A spark gap is provided in the plate voltage supply circuit just across the plate tank bypassing condenser. It has a gap varying from 1/16 to 1/8 inch and protects the transmitter components from line surges. This gap will occasionally arc over with a loud report similar to that of a shotgun and will arc if the plate voltage "on" button is pressed just as the primary line voltage cycle is passing through zero, because at that point the current is changing most rapidly and inducing maximum voltage in the secondary of the plate transformer.



A view of the low pass filter with the top cover removed.

Output Indicating Device

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Essentially, it consists of two directionally sensitive circuits which meas-

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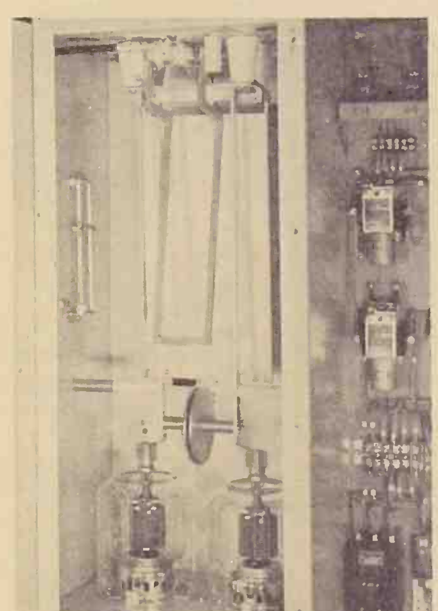
Close-up of plate tank circuit, output coupling loop, tuning vane, monitor loop, and the Type 4-1000A amplifier tubes.



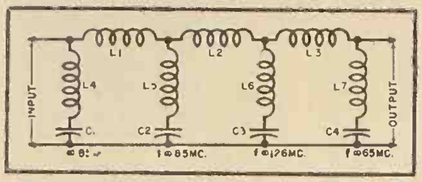


Fig. 2. Schematic of low pass filter.

greater reaction between various circuits, caused by small inductive and capacitive reactances that can normally be ignored on the low frequencies but which become increasingly important at these higher frequencies. Consequently, when tuning a high frequency transmitter, it is well to recheck the previous adjustments constantly as the tuning progresses.

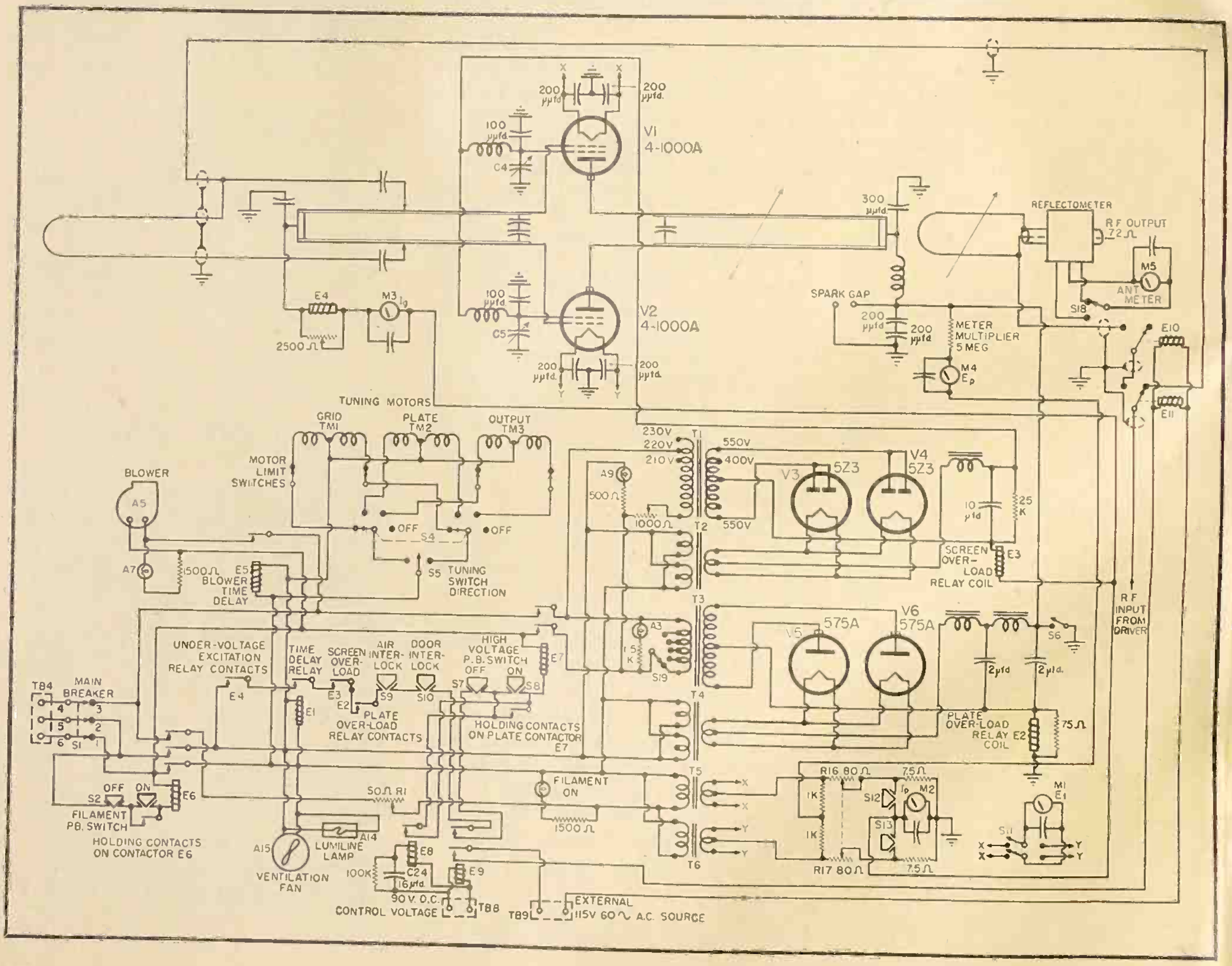
The normal driving source of this amplifier is the *Gates* 250-watt FM transmitter but any good driving transmitter that can produce a minimum output power of 60 watts will suffice as the amplifier drives very easily. It is possible to obtain up to 3.4 kw. continuous power from the 3-kw. amplifier when it has been properly tuned.

Tuning of the grid circuit is accomplished very simply. A fixed capacity has been placed across the ends of the grid tank which causes it to resonate near the desired frequency. With drive applied, the motor-tuned shorting bar is then adjusted to give a maximum reading of the grid current meter. This shorting bar effectively changes the electrical length of the tank elements.

When sufficient drive has been obtained (approximately 150 ma.), tuning of the plate circuit can be undertaken. If the load is properly matched, the transmitter neutralized, and the output coupling is proper, this tuning is easily executed. But, of course, the ideal situation is seldom encountered when tuning is first attempted. As a starting point, with a transmitter that has just come off the production line or is known to be completely out of adjustment, the neutralizing condensers (C_4 and C_5) are set at about half-mesh, coupling is adjusted about half-way toward maximum, and the output connection is made to a non-radiating dummy load of the correct resistance; then low plate and screen voltages are applied. Tuning of the quarter-wave elements which comprise the plate tank circuit is accomplished by a padding condenser consisting of two large, round aluminum plates and a variable vane which varies the surge impedance of the circuit. When the vane is closest to the tank circuit, the surge impedance is lowest and the effective electrical length will be shortened. When the vane is at the farthest point away from the tank circuit, the surge impedance is highest and the effective electrical length will be extended. If unable to hit the desired frequency when the vane is all the way in, less capacity is necessary to reach the desired frequency.

Output power may be varied effectively by three methods. First—and most important—is the use of the output loop, which varies output power approximately 30% with a standing wave ratio of unity in the transmission line. This output loop is set at the optimum point of coupling, the point at which the output power as indicated by the output meter has just stopped increasing appreciably. Overcoupling to a point where undesirable effects such as broad tuning and reactive effects may be introduced back into the plate tank circuit, which might cause oscillation

Fig. 3. Over-all schematic of the r.f. amplifier, including power supplies and control circuits.



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Experience has shown that method 2 is probably the best bet for checking neutralization. Method 1 may not always hold true as it is somewhat dependent on the driver internal impedance as well as on the complex impedance which may be reflected into the amplifier from the antenna-transmission line system.

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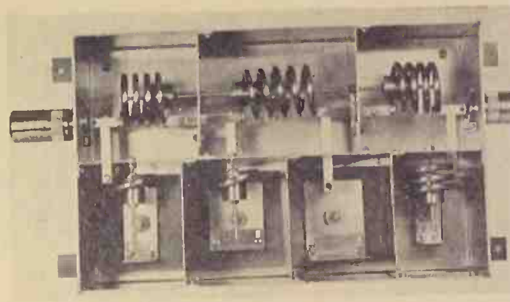

A view of the low pass filter with the top cover removed.

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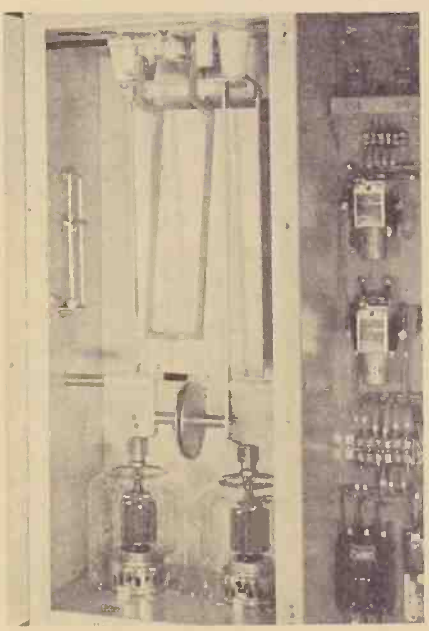
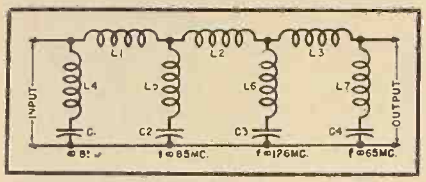
Close-up of plate tank circuit, output coupling loop, tuning vane, monitor loop, and the Type 4-1000A amplifier tubes.





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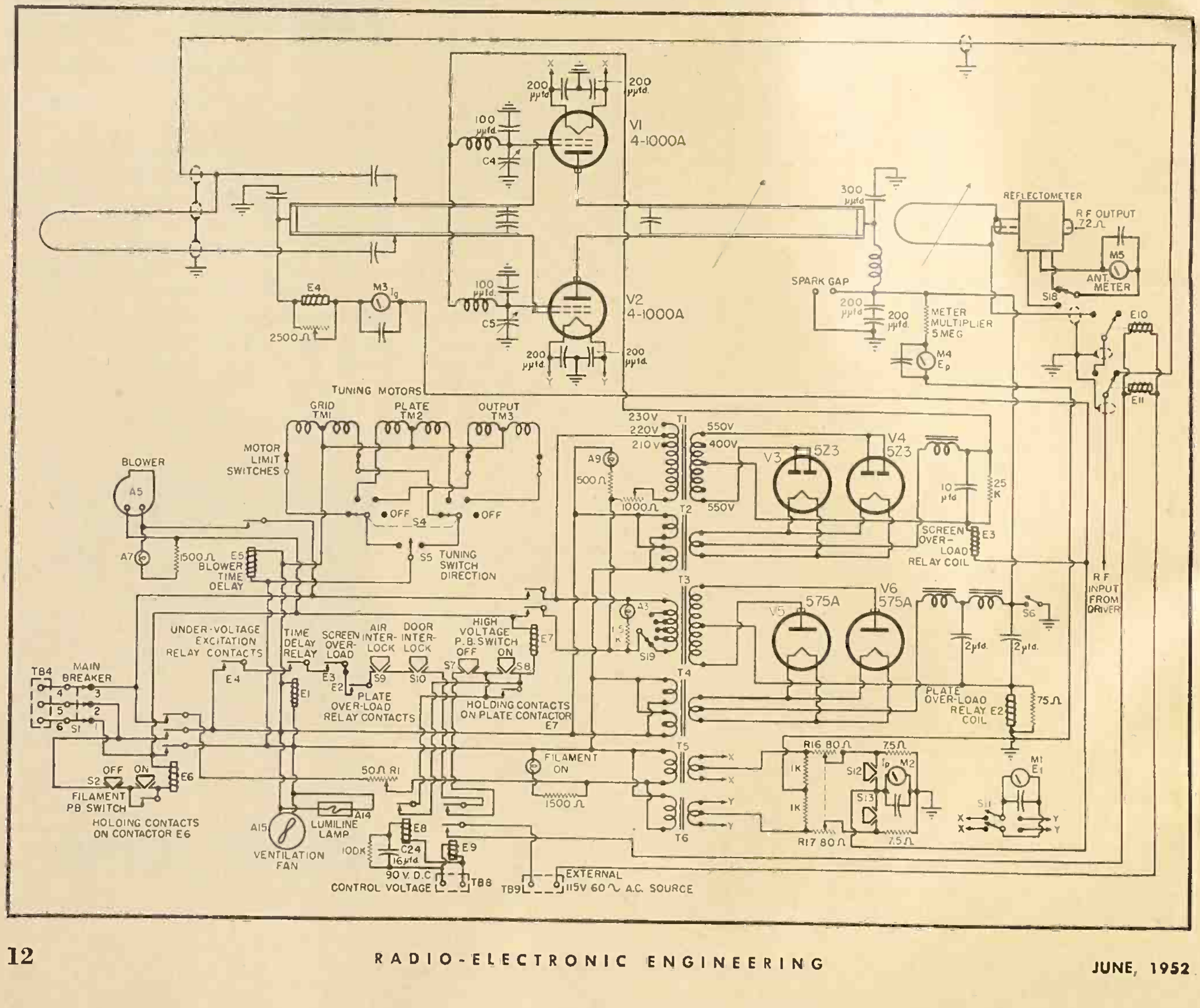

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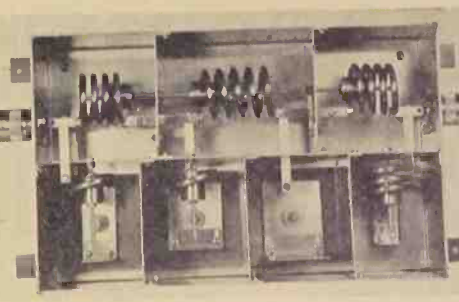

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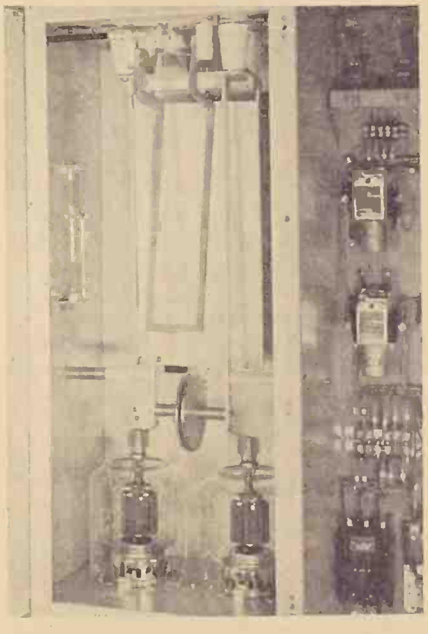
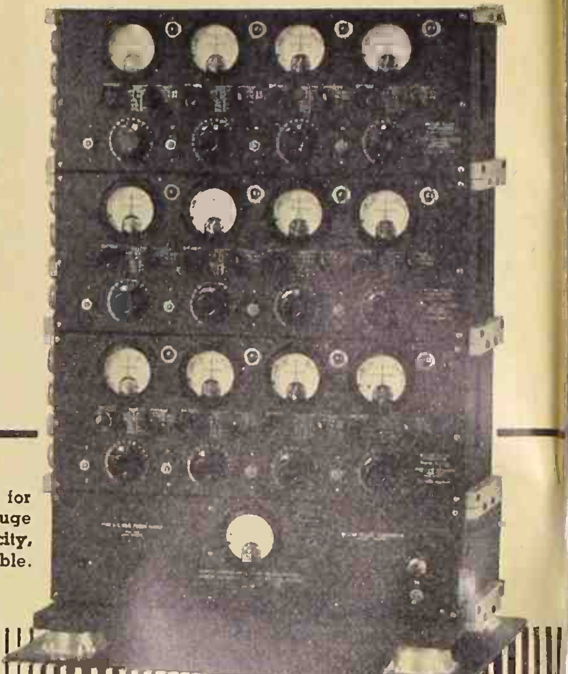


Close-up of plate tank circuit, output coupling loop, tuning vane, monitor loop, and the Type 4-1000A amplifier tubes.

ACCELEROMETER INTEGRATION

By ALVIN B. KAUFMAN

Research Engineer, Northrop Aircraft Co.



Miller oscillograph amplifier CD-2 for use with carrier excited strain gauge accelerometers. Acceleration, velocity, or displacement functions are obtainable.

Criteria involved in the operation of integrator circuitry to indicate velocity and displacement.

THE USE of single- or double-integration circuitry with accelerometers to allow simple switch selection of acceleration, velocity or displacement functions is well known. Similarly, velocity pickups may be single-integrated to indicate displacement. However, there are many criteria in the operation of such equipment and the design of circuitry to accomplish the desired end result which are often overlooked.

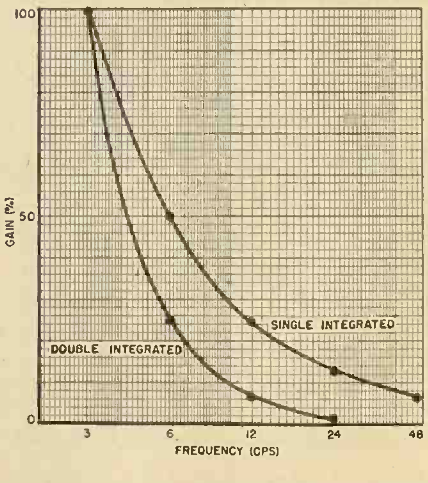
Almost every type of vibration pickup consists of a mass and spring, housed in a suitable case, and damped. When the case is shaken, there is a relative movement between the mass and case, and a transducing device of some sort which is incorporated in the instrument produces an electrical signal proportional to the displacement or velocity of the mass with respect to the case. Such "seismic" instruments—accelerometers, seismometers, vibrometers, velocimeters and the like—are constructed similarly and differ fundamentally only in their natural frequencies and the methods by which relative motion between mass and case produces an electrical signal.

A seismic type vibration pickup responds as an accelerometer in the region well below its natural frequency, as a velocity meter near its natural frequency, and as a vibration or displacement meter in the region well above its natural frequency[1]. However, as indicated above, the accelerometer may be used for all three functions.

The accelerometer has an output proportional to the displacement of the internal mass when the transducer is a strain gauge, or an inductive, capacitive or crystal pickup. The self-generating velocity pickup does not meet this requirement and will be omitted from further discussion except as previously noted in regard to integration. Its output is a function of velocity, i.e., the speed with which the armature or winding cuts a magnetic field. Accelerometers are used by industry where low-frequency to steady-state accelerations are encountered and integrated as required to indicate velocity or displacement.

Single integration for converting "*g*" or acceleration indications into velocity indications requires that the output signal decrease 6 db for every octave increase of frequency. In other words, for every doubling of input frequency the output potential must fall to one-half its previous amplitude. Double integration is identical except that the output decreases 12 db per octave. In practice, double integration is not employed in one stage due to gain problems and inability to secure satisfactory capacitors in the size required.

Fig. 1. Reduction of gain with frequency for single- and double-integrated circuits. Attenuation for the double-integrated circuit is about 12 db per octave.



Generally speaking, the use of integration circuitry implies that the accelerometer used is critically damped and—if over a single stage—puts out essentially a sinusoidal wave. This last requirement is rarely met in instrumentation. It is obvious that steep wavefronts or harmonic acceleration components must be amplified to achieve reliable end results. The problem of obtaining satisfactory integration exists mainly because the integrated amplifier has limited frequency response. This may be seen by Fig. 1, and when it is recalled that 12 db attenuation per octave of amplified frequency means a rapid reduction of gain with frequency.

Integration may be accomplished with the simple *R-C* circuit shown in Fig. 2A as applied to the input of the amplifier. This system is not too practical for the very low frequency ranges, requiring large values of capacity. Integration by this method may also lead to very inaccurate results if more than a short portion of the start of capacity-developed potential is used, due to the non-linear charging current[1]. Figures 2B and 2C are frequency-sensitive feedback circuits for obtaining large equivalent capacitances. This method of obtaining a large, effective capacitance is useful where the physical size or the electrical quality of a very large capacitor is objectionable. The circuit of Fig. 2C is in most frequent use commercially. Integration accuracy depends mainly upon amplifier design. If the amplifier is suitably designed, the output signal will be proportional to the integral of the input signal to within an accuracy of one per cent or better[2, 4]. Five per cent accuracy is generally the tolerance guaranteed by manufacturers of commercial equipment, and this figure for over-all accuracy of the complete system is probably in line with the most favorable configuration.

Before continuing into a discussion of commercially available equipment and design parameters, further discussion of what integration accomplishes and how it does so might be desirable.

For a given amplitude and frequency, assuming a sine wave, the path of the accelerometer (analogic to the electrical output wave) will traverse a given distance. If the frequency were doubled without any change in accelerometer displacement, the amplitude of the accelerometer signal would quadruple. The accelerometer signal increases as the square of the exciting vibration frequency as can be seen from the equation:

$$g = .0511Df^2$$

where D is displacement in inches, f is cycles per second, and g is peak-to-peak acceleration. Thus, doubling the frequency would consequently increase the acceleration and the output amplitude four times.

To reduce the acceleration signal to a velocity signal, single integration is required. The velocity equation[3]:

$$V = \pi f D$$

indicates that a single stage of integration in the amplifier, reducing the wave amplitude by 50% (6 db) at twice the original frequency, would meet the requirements. The output signal would only double for each octave increase of vibration frequency. As the equation indicates, at constant displacement the velocity is directly a function of frequency; therefore, doubling the frequency should double the output signal. Thus it can be seen that with the aid of a switch the amplifier may be connected so as to become a linear amplifier for reading acceleration, or be single-integrated to indicate velocity of the accelerometer.

The output of the velocity pickup or single-integrated accelerometer amplifier supplies a voltage and frequency or velocity signal proportional to displacement and frequency. Thus:

$$D = V/\pi f$$

and an integration of the velocity signal will give a displacement signal. We have previously noted that for a constant amplitude of vibration the doubling of the vibration frequency increased the accelerometer signal output by four times. The first integration reduced this to double-signal amplitude, and this second integration again reduces the signal by 50%, or to unity. With double integration the output signal is independent of frequency, responding linearly only to displacement.

In both cases maximum velocity or displacement indication is limited by the maximum "g" rating of the accelerometer. The previous equations then may be factored to give the maximum allowable values:

$$V = \pi f D \quad (D \text{ calculated below})$$

$$D = g/0.0511f^2$$

The velocity pickup, although widely used because of its high output signal, has a serious limitation. It is suitable for the measurement of velocity or displacement only where oscillatory vibration exists. Prolonged acceleration in one direction allows the pickup to come to rest, at which time the signal indication ceases. On the other hand, an accelerometer such as the *Statham*, with strain gauge pickup, will continue to give a signal as long as the acceleration exists.

It must also be pointed out that for all equations presented the displacement is peak-to-peak (or double amplitude) for vibratory systems, while for centrifuge or steady state acceleration where the "g" loading is in one direction only, the previous equations are not applicable as there is no frequency component. As in the vibratory system, twice the "g" rating is available over the steady state system when alternate acceleration directions are present. Thus an accelerometer tagged $\pm$ 2g could use the figure "4" in the "g" equations. Acceleration forces as produced by a centrifuge may be found from the equation:

$$g = -r \times RPM^2/35.3 \times 10^3$$

where r, the radius, is in inches.

Commercial equipment is manufactured by many companies. On the west coast, *Statham*, *Consolidated Engineering*, and *William Miller* are among the companies well known for their specialization in this field. The *Statham* unbonded strain gauge accelerometer is (*Continued on page* 25)

A typical unbonded strain gauge accelerometer made by Statham Labs.

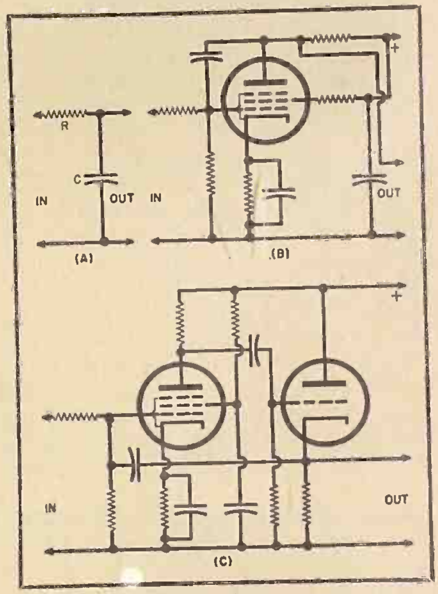
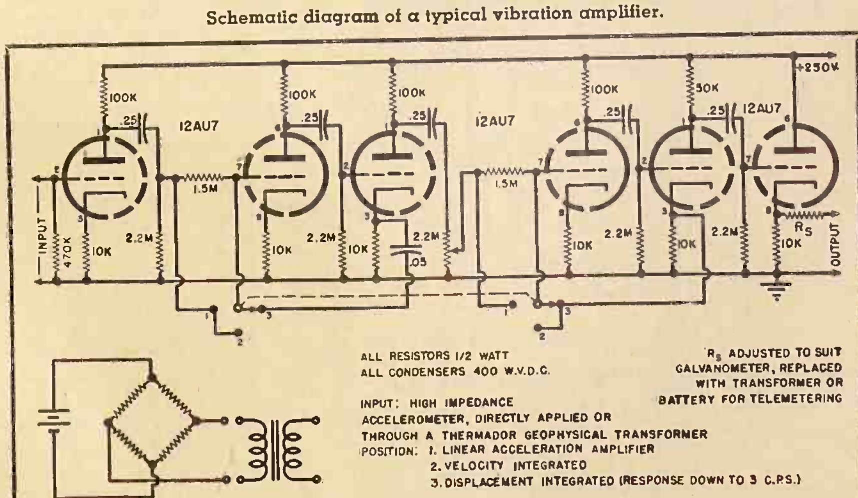


Fig. 2. (A) Simple integration circuit. (B) and (C) Frequency-sensitive feedback circuits for obtaining large values of equivalent capacitance.

Schematic diagram of a typical vibration amplifier.



COUNTING RATE METER

An instrument for indicating events per unit time, whether random or repetitious.

by
EDWIN N. KAUFMAN

AT SOME TIME in the life of every engineer, the problem of designing and putting into use some form of "counting rate meter" invariably arises — an instrument that will indicate the number of events occurring at any given rate, random or repetitious, for any given time. The time is usually based on the number of events per minute but seconds or hours can be used, depending upon the rate.

The alternative to a counting rate meter is an instrument which actually counts the individual events by means of registers or electronic scaling circuits. It has a disadvantage in that the number of events occurring during a given time cannot be determined until after a time interval has past, whereas the counting rate meter indicates almost instantly the predicted number of events for any given length of time. A study of literature on this subject shows conventional circuits (such as in Fig. 2) using, as a rule, large electrolytic condensers. Circuits of this type have numerous disadvantages. For example, a change in electrolytic capacity or a difference in input signal level will cause large errors in calibration. Other disadvantages are inability to handle low counting rates and difficulty in obtaining a linear scale calibration.

However, the purpose of this article is not to discount such circuit instruments but rather to present a logical approach to the problem, and to introduce a successful counting rate meter having a range of 2000 to 50,000 events per minute. The meter can also be designed for lower or higher rates. The meter damping is rated in percentage of probable error (full scale) and does not cause a change in calibration.

Unfortunately, a simple, successful *R-C* type of counting rate meter is impossible to obtain unless the occurring events produce electrical pulses which do not deviate in height and waveform, although the repetition rate may vary. Even so, the problem of obtaining a satisfactory capacitor still remains.

For this reason, the input circuit of this counting rate meter (see Fig. 1) consists of a pulse amplitude discriminator, the bias of which can be adjusted from 0 to 100 volts. Thus, if the discriminator is adjusted to 10 volts, any signal above 10 volts will trigger the circuit and put out a standard pulse. These pulses trigger a univibrator pulse shaping circuit. The univibrator has a quasi-stable state lasting about 15 microseconds. The output pulse (negative) is impressed on a 0.0001 μfd. condenser

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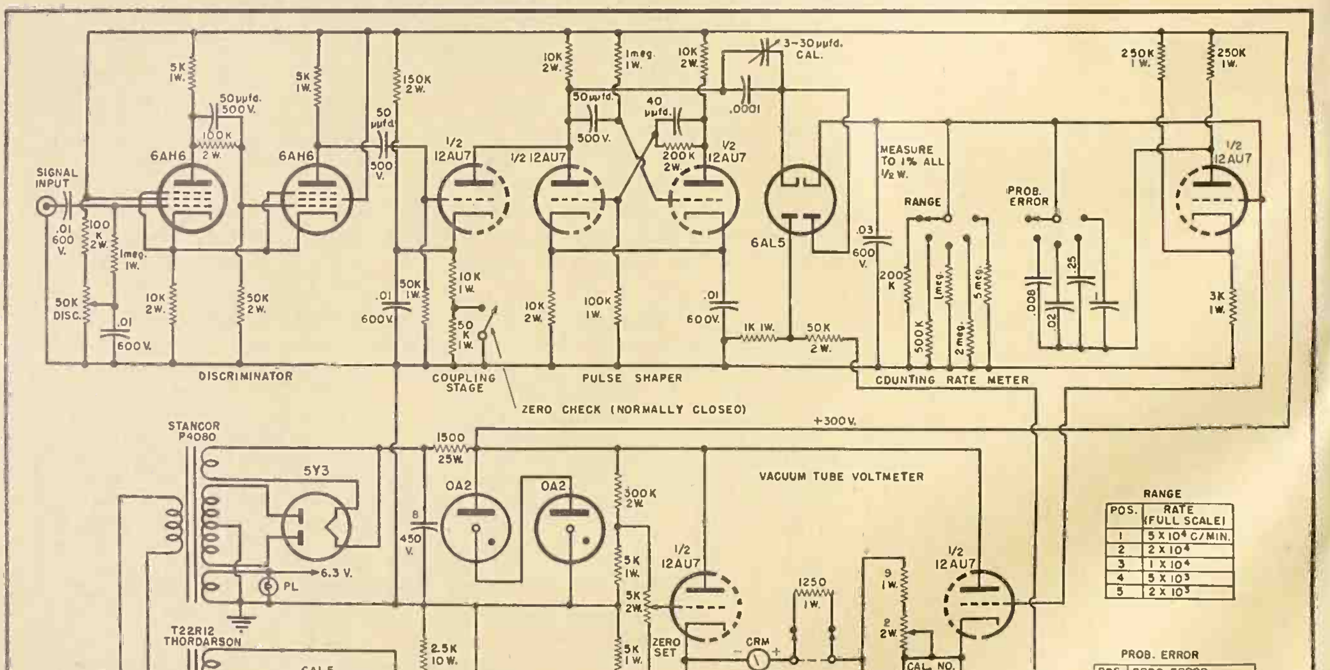
Fig. 1. Complete circuit diagram and parts values of the versatile counting rate meter.



RANGE

POS.	RATE (FULL SCALE)
1	5 X 10⁴ C/MIN.
2	2 X 10⁴
3	1 X 10⁴
4	5 X 10³
5	2 X 10³

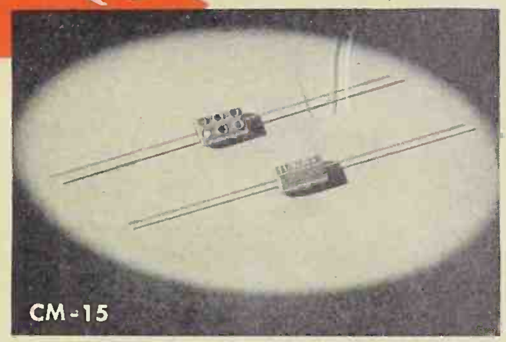
PROB. ERROR

POS.	PROB. ERROR
1	20% (OF FULL SCALE)
2	10%
3	5%
4	2%
5	1%

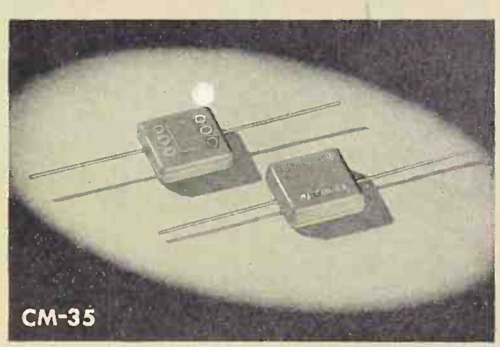
CLOSE! DOESN'T COUNT

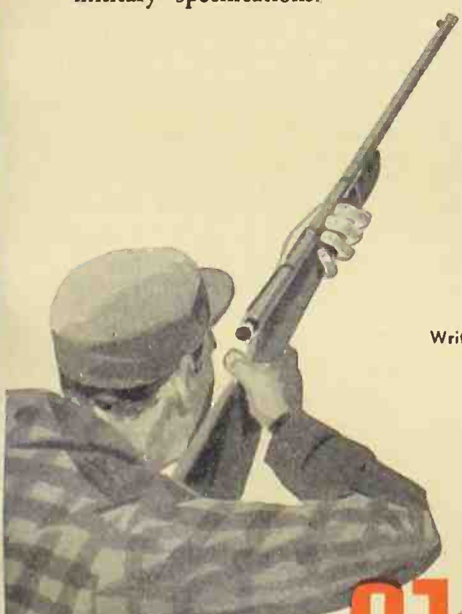
Instruments of war must be unerringly dependable, and every part used in their construction must contribute to this standard. That is why El-Menco Capacitors have won such wide recognition in their particular field . . . Because of their margin of extra wide safety factor they are absolutely reliable.

For higher capacity values, which require extreme temperature and time stabilization, there are no substitutes for El-Menco Silvered Mica Capacitors. El-Menco Capacitors are made in all capacities and voltages in accordance with military specifications.



From the smallest to the largest each is paramount in the performance field.





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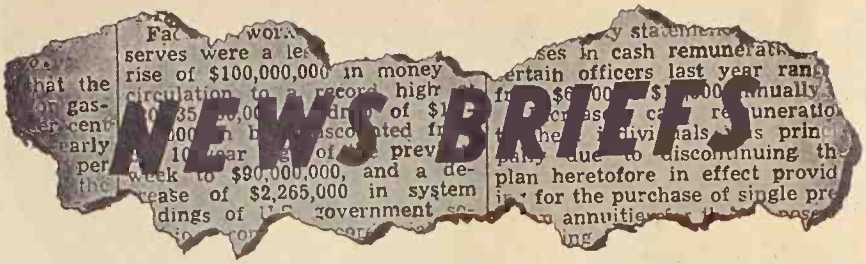
MOLDED MICA **El-Menco** MICA TRIMMER

CAPACITORS

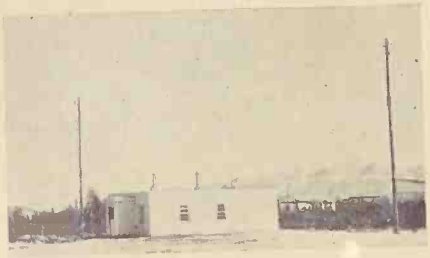
Radio and Television Manufacturers, Domestic and Foreign, Communicate Direct With Factory—

THE ELECTRO MOTIVE MFG. CO., INC. **WILLIMANTIC, CONNECTICUT**



RADIO WARNING SERVICE

The first systematic forecasts of radio propagation conditions in the North Pacific and Alaskan areas were issued recently by the NBS Radio Propagation



Field Station in Anchorage, Alaska. This latest aid to all users of radio communications serves the same function for these areas as does the North Atlantic Radio Warning Service at Washington, D. C.

Disturbances to radio propagation—natural phenomena which result from the intense magnetic fields of the nearby auroral zone—have long hindered communications in the Alaskan area. However, advance warning of their occurrence, together with forecasts of the day-to-day quality of propagation conditions, can lead to more efficient use of the short wave radio spectrum. The North Pacific Radio Warning Service was designed to supply this vital need.

SHOCK-RESISTANT ELECTRON TUBES

Thirty new long-life electron tubes which can be used commercially as well as in military equipment have been produced under a Navy Bureau of Ships project in cooperation with the Army and Air Force, with *Aeronautical Radio, Inc.*, of Washington, D. C., doing most of the development work involved. Use of these tubes in radio, radar, sonar, navigation and fire control instruments will enable operation despite shock of gunfire.

Subjected to tests that would cause immediate failure in most present-day tubes, the newly developed tubes have proved to be from two to ten times more resistant to shock and vibration and have 20 times the life expectancy of former types. While their individual cost will be five to ten times higher than that of present commercial types, total costs will be reduced because of low replacement rate. Over-all savings in critical material also will be accomplished.

COMPUTER LABORATORY

Dr. Warren C. Stoker, professor of electrical engineering at Rensselaer Polytechnic Institute, Troy, N.Y., and member of the department since 1933, has resigned to become director of the Institute's Computer Laboratory. This laboratory has been opened with the installation of the *Reeves* electronic analog computer which is shown in the photograph, Dr. Stoker at left. Other types of electronic computing machines

will be added as Dr. Stoker assembles his staff of four or more computer scientists.

RADIATION LABORATORY

With the opening of Stanford Research Institute's new Radiation Engineering Laboratory in Stanford, Calif., the largest source of radioactivity outside of AEC installations will be made available for research in industrial uses of atomic and nuclear science. Companies wishing to explore uses of radiation for their processes or products may bring samples to the laboratory for irradiation.

SRI's radioactive source will have five times the power of any presently available for industrial and medical research. The laboratory will develop and engineer practical, safe systems for the use of large amounts of radiation in a wide variety of possible applications, including non-destructive testing of metal castings and parts by radiography and the cold sterilization of heat-sensitive foods and drugs using penetrating gamma radiation.

MAGNECORD APPOINTMENTS

George C. Kent and William E. Daly have been appointed to the staff of *Magnecord, Incorporated*, manufacturers of magnetic recording equipment, as senior mechanical engineer and electrical development engineer, respectively.

Mr. Kent was formerly a design engineer with the *Revere Camera Company*, and prior to that, was associated with the *Russell Electric Company* and *Hotpoint.* He received his degree in mechanical engineering in 1943 at Ohio State University.

Mr. Daly worked for several years in magnetic recording head development for *Shure Brothers, Incorporated*, and previously was employed by the *Engineering Research Associates* of St. Paul. He received his degree in electrical engineering in 1947 from the University of Minnesota.

FLORIDA U. APPOINTMENT

Dr. Linton E. Grinter, research professor of civil engineering and mechanics at Illinois Institute of Technology since 1946, has been appointed dean of the graduate school and director of research at the University of Florida, Gainesville, Fla.

For the past two years Dr. Grinter has been consultant to the Board of Control for Southern Regional Education and is now a member of the board's commission on graduate studies. He taught civil engineering at Texas A and M College for nine years before going to Armour Institute of Technology in 1937 to organize and head the graduate school. When Armour and Lewis Institute merged in 1940, Dr. Grinter became the first vice president of Illinois Tech.

TRANSFORMERS AND COILS

The *Raytheon Manufacturing Company* of Waltham, Mass., known for its custom-made transformers, announces complete facilities for large volume production, as well as for engineering de-

sign and production of models. Th photograph shows a few of the mor than 30,000 individual designs of *Raytheon* coils and transformers.

One of the few sources equipped for Ayrtzendraht coil windings, *Raytheon* can design and build toroid-L-coils from the problem up, or wind to specified C, *L* and *Q* values . . . precision wound on temperature stabilized, powdered permalloy cores, high permeability solid materials or stamped "O" cores.

MIDGET RADIO TRANSMITTER

Dick Tracy's wrist-watch radio may become a reality in a new "era of ger-

manium," according to *General Electric* engineers, who offer as an example a midget experimental radio transmitter built by Everett Read of *G-E's* Electronics Laboratory at Syracuse, N. Y., which has a broadcasting range of several hundred feet. A tiny germanium transistor (shown at the right) enables the transmitter to operate on a miniature dry cell battery inside the case.

BBC IMPROVES ACOUSTICS

The *British Broadcasting Corporation*, in retreating its largest studio at Maida Vale to improve acoustic qualities, made use of the findings of *BBC* research engineers who determined that rectangular shapes are the most effective for diffusing sound to give good tone and good definition.

Roofing-felt membrane absorbers which serve to reduce reverberation time and also act as scattering elements at all frequencies above about 90 cps. now cover most of the side walls. The highly reflective ceiling surface was broken up by introducing scattering elements consisting of flat rectangular plates supported on pedestals 1 to 3 feet from the ceiling. Composite absorbing units, presenting a serrated wall form, were installed in the rear to prevent sound from being reflected as a strong echo.

PROMOTIONS AT DU MONT

Five top members of the Instrument Division of *Allen B. Du Mont Laboratories, Inc.*, have been promoted to new key posts within the division.

Dr. P. S. Christaldi, formerly engineering manager, has been named assistant division manager; Mr. G. Robert Mezger, formerly technical sales manager, has been appointed engineering manager; Mr. Emil G. Nichols has been promoted from assistant technical sales manager to technical sales manager; and Messrs. Melvine B. Kline and William G. Fockler have been appointed assistant engineering managers. Mr. Kline is the former head of the special projects section of the Instrument Engineering Department, and Mr. Fockler the former head of the development section of the same department.

MICROWAVE DIATHERMY

Microwave diathermy promises to become a useful and efficient new tool in physical medicine, according to the Division of Experimental Medicine at the Mayo Foundation, Rochester, Minnesota, where an investigation has been under way since 1946 on the possibility of using microwaves for medical diathermy.

Studies on the heating effects of microwaves showed that temperatures can be produced which are considered adequate for therapy. Moreover, microwave diathermy has the distinct advantage of being more easily controlled and more conveniently applied than short wave diathermy.

POWDER METAL PRESSES

To meet the exacting operating standards required for carrier equipment, the *Lenkurt Electric Company* of San Carlos, Calif., manufactures many of its own components, including powdered iron cores. Recently, *Lenkurt* installed a *Stokes* tabletting press for use in its component manufacture, and the manager of component sales engineering at

Lenkurt has this to say about it: "Since installing the *Stokes* R-4 press, we have been able to achieve a production rate on some types of products running about 800 per cent of previous rates."

The *Stokes* R-4 eccentric-cam single punch press applies pressure from above and below simultaneously, and uninterrupted production and protection against damage are provided for by an automatic excess pressure release. This press is made by the *F. J. Stokes Machine Company*, 5500 Tabor Road, Philadelphia 30, Pa.

FLEMING AWARD PRESENTED

Dana K. Bailey, of the NBS Central Radio Propagation Laboratory, has received the Arthur S. Fleming Award which is presented annually by the Washington Junior Chamber of Commerce to the Government Service man under 36 years of age who has been of greatest service to the nation.

Mr. Bailey received the award for his contributions to science, particularly in the field of radio wave propagation, and for his extensive service in the field of international relations. Since 1948 he has been a U. S. technical representative at meetings of agencies of the International Telecommunications Union, an organization concerned

with the assignment and most effective use of frequencies for radio communications, short wave and television broadcasts all over the world.

U.H.F. EXPERIMENTAL STATION

Now that Station KM2XAZ is broadcasting experimentally on Channel 22 from its new location in the John Poole Transmission Center on Mount Wilson, Southern California is receiving television signals in the ultra high frequency band for the first time. Owned and operated by John H. Poole for the past two and a half years from atop Signal Hill in Long Beach, the station has been moved to its new location with the authorization of the FCC.

The purpose of this experimental telecasting is the gathering of engineering information on propagation characteristics of these higher frequencies which is expected to be useful to both the FCC and the television industry when the u.h.f. section of the air is "unfrozen".

URSI-IRE Conference

A staff report on thirteen of the papers which were presented at the April URSI-IRE Conference.

The International Scientific Radio Union is one of several world scientific unions formed in 1919 under a general organization now called the International Council of Scientific Unions. It is commonly designated as the URSI (from its French name, Union Radio Scientifique Internationale). Its aims are: (1) to promote the scientific study of radio communications; (2) to aid and organize radio research requiring cooperation on an international scale and to encourage the discussion and publication of the results; (3) to facilitate agreement upon common methods of measurement and the standardization of measuring instruments. The International Union itself is an organization framework to aid in promoting these objectives. The actual technical work is largely done by the National Committees in the various countries.

A joint meeting of the U. S. A. National Committee of URSI and the Professional Group on Antennas and Propagation of the IRE was held in Washington April 21 to 24. Here is a brief report on some of the papers presented at this meeting.

Alan C. MacPherson of the National Bureau of Standards discussed a microcalorimeter for the measurement of absolute microwave power. In this calorimeter, a matched termination is heated with the r.f. power to be measured. The temperature rise of the termination is measured and the calorimeter calibrated with known d.c. power. The unit described operates at X band at power levels from approximately 1 to 15 milliwatts, but the method is applicable to other frequencies. Sensitivity is about 10 microwatts, and estimated accuracy 1%.

Another NBS development, the magnetic attenuator, was described by Frank Reggia. This device consists of a magnetic ferrite as the energy-dissipating material, located inside a coaxial line. An external magnetic field is applied perpendicularly to the axis of the line, resulting in an interaction between this field and the electromagnetic field within the coaxial line. This interaction permits instantaneous changes in attenuation to be obtained. The external field is produced by an electromagnet, permitting convenient control either manually or automatically from a remote or proximate position. This device has been used successfully to amplitude-modulate the r.f. output of a microwave oscillator with sine wave voltages at frequencies from d.c. to above 10,000 cps. It has also been used as a control device in a degenerative feedback circuit to stabilize the output of microwave generators automatically, and as a microwave switch. An interesting sidelight is the fact that the attenuation varies as the magnetic field is rotated around the coaxial cable containing the ferrite, variations of as much as 40 db having been obtained during a complete revolution. This is apparently due to inhomogeneities in the magnetic ferrite. A more complete description of this attenuator appeared in the October, 1951, issue of RADIO-ELECTRONIC ENGINEERING.

Superconductivity is a phenomenon which has been under investigation for some time. C. J. Grebenkemper and J. P. Hagen of the Naval Research Laboratory reported on the measurement of the *Q* of resonant cavities in the 10,000 mc. and 24,000 mc. regions while the cavity was held at temperatures near absolute zero. A logarithmic decrement method was used to measure *Q*, with a recurrent pulse of r.f. energy of about 1 microsecond duration used to excite the resonator. The decay was observed on an oscilloscope. Loaded *Q*'s of over 7 million were measured using a tin or tin-plated cavity. Calculations indicate that unloaded *Q*'s in excess of 14 million are obtainable.

In determining the reflection coefficient in microwave measurements, it is helpful to have a ratio meter working in conjunction with a directional coupler to indicate the ratio between the direct and reflected wave. L. A. Rosenthal, J. L. Potter, and G. M. Badoyannis, of Rutgers University, have developed such an instrument, which consists essentially of two electronic voltmeters working into a conventional ratio meter movement. The meter deflection depends only on the ratio of the average full rectified values of the input signals. Frequency response is limited to below 200 kc., so the instrument is made to respond to the modulation of the r.f. signal. As the ratio meter requires a minimum current of 1 ma. through each coil for reliable operation, this instrument was designed to provide about 15 ma. through each coil with an input of .1 volt. Work on this project was sponsored by the Rome Air Development Center under contract AF 28(099)-33.

In some cases it is necessary to equalize the r.f. powers in two or more circuits to a high degree of accuracy. A microwave power comparator capable of detecting a change of .02 db in power at S band was described by K. C. C. Gunn and K. O. Holmes of the Air Force Cambridge Research Center. This instrument consists of a hybrid junction, rotating eccentric attenuators phased 180° apart in the two input arms, a matched load on one output arm and a crystal detector on the other output arm. The maximum attenuation of the attenuators is equalized by conventional means, and on the other half cycle, the attenuators are removed from the wave guide, effectively shutting off the power in the input arms alternately. The amplitude of the varying voltage at the detector is determined by the input powers, the position of the attenuator wheels and the phase relation between the two input powers. Successive voltage peaks are observed on an oscilloscope.

J. S. Barlow, G. W. Frey and J. B. Newman of Johns Hopkins University discussed atmospheric noise in the very low frequency range resulting from lightning flashes. The power spectrum from such a flash waveform is flat from 180 to 20,000 cps, falling off at lower and higher frequencies. The power spectrum of a daytime tweek is flat in the 100 to 3000 cps range with a +20 db peak at the power weighted mean frequency of the waveform (5850 cps) followed by a sharp drop with increasing frequency. Available information suggests that the maximum of atmospheric noise power usually lies at 6 to 8 kc. Work on this project was done under the auspices of the Office of Naval Research.

An interesting aspect of the correlation between atmospheric noise cycles and sunspot cycles was reported by Edna Schultz of the National Bureau of Standards. Studies show that the radio noise cycles lag behind the sunspot cycles by about 19 months. This knowledge may result in a 10 to 15 db improvement in noise predictions.

The "Ogiver," a radio noise meter

as described by A. W. Sullivan of the niversity of Florida. This meter is esigned to measure the probability disribution of the envelope of atmospheric oise in terms of noise voltages exeeded with any degree of probability etween 0.01 and 0.99. Measurement is ade of the per cent of time that the oise wave exceeds certain arbitrary vels of intensity, and this is equivalent direct probability measurement. The oise wave is injected into a d.c. amlifier with available bias applied to e first stage. This amplifier is used drive a probability computer which easures the probability or per cent of me the noise wave exceeds the bias oltage applied to the first stage. This itput is integrated and fed into an rror corrector, consisting of a differenal amplifier, where the integrated outit of the probability computer is mpared with a standard reference oltage. This difference is amplified and pplied as the bias for the first stage f the d.c. amplifier. Further details on is instrument will appear in an early sue of RADIO-ELECTRONIC ENGINEERING.

A new approach to the problem of librating field strength measuring uipment employing shielded loop annnas was discussed by Harold E. nger and William E. Garner of the aval Research Laboratory. The basic oncept is that of using the shielded op as a transformer. The voltage iduced in the shield due to the presice of a field can be accurately calcuited. This value of voltage can then applied across the shield gap by a gnal generator with the loop turns pen circuited. The meter to be caliated is then connected to the loop d should indicate a field strength ual to that which was used to calcute the induced voltage in the shield. lthough this calibration method is sily performed in practice, it suffers om increasing errors above 5 to 10 c.

Georges Deschamps of *Federal Teleommunication Laboratories* described method of analyzing wave guide juncons using non-Euclidian geometry. He owed how measurements through a inction, lossy or not, can be made by eans of a "hyperbolic protractor" hich gives corrected standing-wave tios as if the junction were not there.

Microwave printed lines have been eveloped as substitutes for wave guides nd coaxial lines. The problem of makg measurements on such lines was e subject of a paper prepared by M. rditi and J. Elefant of *Federal Teleommunication Laboratories*. Applicaon of the principles developed by Mr. eschamps of *FTL*, and discussed in e preceding paragraph, provides a ique method of measuring various arameters in a simple but accurate manner. The advantages to be derived from the use of printed lines can be seen from a comparison between a printed circuit cavity and a conventional cavity for use in the 4400 to 5000 mc. range. The conventional cavity is three times as long, has 200 times the volume, and 250 times the weight of the printed cavity. The Q of the printed cavity is, however, much lower, due primarily to the losses in the fiberglass insulating material which is used.

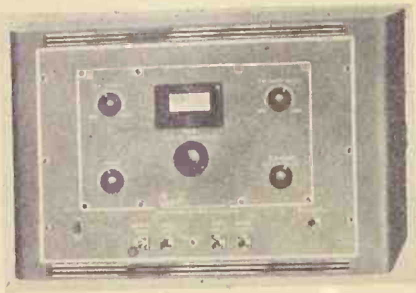
When a series of standard frequencies is desired from a single low frequency standard, it is common practice to use a harmonic generator, with the result that the output is spread over the entire series of harmonics, leaving only a small amount of power for any desired frequency. This problem has been attacked by R. Guenther and A. Hahnel of the Signal Corps Engineering Laboratories and has resulted in a selective spectrum generator which provides a restricted harmonic spectrum with the energy concentrated in the desired harmonics. It consists of a tuned r.f. oscillator, which determines the center of the narrow spectrum, and a pulse generator or shaper with the repetition rate derived from the standard frequency. If the oscillator is pulsed in such a way the oscillation will begin with the same r.f. phase at the start of each pulse, the resultant wave shape is periodical in the period of pulse frequency. Hence, the spectrum contains harmonics of the standard frequency only. The tuned r.f. oscillator need not be particularly stable, since detuning from the desired frequency merely shifts the r.f. spectrum without detracting from the accuracy of generator output.

Continuing research in the field of surface wave transmission was reported by G. Goubau, C. Sharp, and S. W. Attwood, of the Signal Corps Engineering Laboratories, in a paper titled "Investigation of a Surface Wave Line for Long Distance Communication." The authors discussed results of an experimental study on a two-mile, single-conductor, surface wave transmission line, for the frequency range of 100 to 300 mc. The objective of these measurements was to determine whether the theoretically expected low attenuation over a frequency band of more than 100 mc. could be realized and to what extent field distortions, caused by supports and bends, were detrimental. Also the effect of weather conditions was investigated. Further information on surface wave transmission can be obtained from an article titled "Surface Wave Transmission Line" by G. Goubau, which appeared in the May, 1950, issue of RADIO-ELECTRONIC ENGINEERING.

NEW PRODUCTS

FUNDAMENTAL OSCILLATOR

Polytechnic Research and Development Co. announces a fundamental oscillator which is continuously tunable



over a frequency range of 35 to 900 mc. This oscillator—Type 907—contains a novel tank circuit design permitting a 30 to 1 tuning range with an output voltage of not less than 1 volt across 75 ohms at all frequencies. Other features include a video type blanking circuit, which provides a true horizontal zero base line, and provision for the introduction of an external frequency marker.

Further information may be obtained from the *Polytechnic Research and Development Co.*, 55 Johnson Street, Brooklyn, N. Y.

RCA MICROPHONE

Designed to provide broadcasters with a small, low-cost microphone of good frequency response and relative freedom from the effects of wind and moisture, the Type BK-1A microphone introduced by the *RCA* Engineering Products Department, Camden, N. J.,

incorporates the outstanding characteristics of Model *RCA* 88-A, which it replaces, and is styled for pleasing appearance when used in television scenes. Type BK-1A is a semi-directional, pressure microphone for general remote pickup use by AM, FM and TV stations. It has a frequency response of 60 to 10,000 cycles, an effective output level of —53 dbm referred to one milliwatt and a sound pressure of 10 dynes per square centimeter.

PORTABLE SURVEY METER

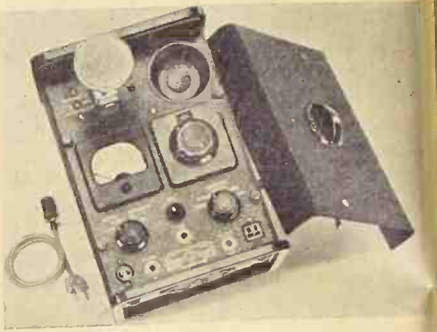
Nuclear Instrument & Chemical Corporation, 229 West Erie Street, Chicago 10, Ill., has announced a new wide-range beta-gamma survey meter based on the principle of the wartime "cutie pie." *Nuclear's* new "cutie pie"

offers many features which eliminate the disadvantages of the previous instrument.

Model 2585 is so designed that it can be set upright for continuous monitoring. It is light-weight, with the circuit and battery housing ahead of and close to the fingers instead of being balanced awkwardly above the handle. The five-position switch is located at the top of the pistol-grip handle to allow simple one-hand operation of the instrument, and zero-adjust and calibrate controls are on top, ahead of the 2½" meter which slopes toward the user for easy reading.

SOUND-LEVEL METER

According to the *General Radio Company*, 275 Massachusetts Avenue, Cambridge 39, Mass., the new Type 1551-A sound-level meter measures product noise quickly and simply both in the design department and in production, and is ideal for studying noise levels in working areas involving worker safety, comfort and efficiency. Other applications include psycho-acoustic studies, measuring the performance of



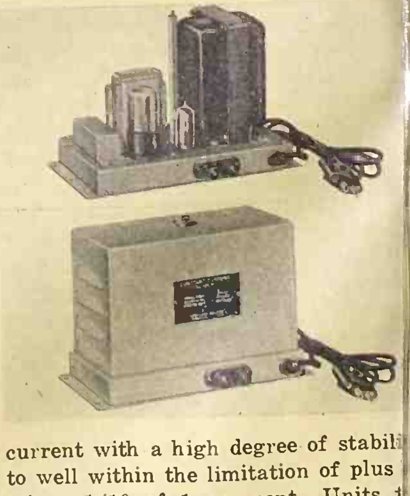
systems transmitting music and speech, and evaluating the characteristics of acoustic materials.

This *GR* sound-level meter has been designed to take advantage of new tubes, components, and miniaturization techniques, resulting in a smaller, lighter and more useful instrument. Weighing only 11 pounds, less than half the weight of its predecessor, Type 759-B, the new meter occupies less than 40% of the volume of the older model.

CONSTANT CURRENT SUPPLY

Providing a steady d.c. source from an a.c. line, the electronic constant current supply just introduced by *Weston Electrical Instrument Corporation* is designed primarily for use with potentiometer indicators, recorders and controllers, where automatic standardization is not feasible or where use of batteries is not desirable. It may also be used with resistance thermometers, strain gauges, or other devices requiring a constant d.c. current.

Model 50220 is intended for a 10-ma output at 1.4 volts d.c., supplying



current with a high degree of stabili[ty] to well within the limitation of plus [or] minus 1/10 of 1 per cent. Units [for] other voltages and currents can [be] furnished on special order. Full [de]tails are available from *Weston Elect*[rical]

cal Instrument Corporation, 617 Frelinghuysen Avenue, Newark 5, N. J.

MAGNETIC TAPE RECORDER

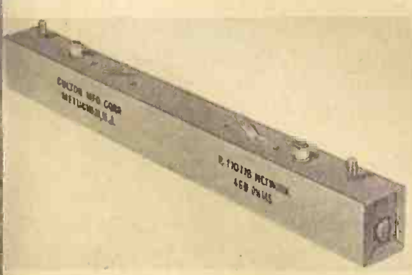
Featured in the magnetic tape recorder just announced by the *Ampex Electric Corporation*, Redwood City, Calif., is a radically new drive system which accomplishes more than a 5 to 1 improvement over the best previous recorders. This system eliminates any effect of tape backing and other usual causes of speed variation.

According to *Ampex*, Model 500 is a precision instrument which reproduces 100 to 100,000 cycles per second with the lowest possible flutter and wow accomplished in the recording field. The

tape is rigidly held to a capstan by vacuum, providing reliable tape motion without introducing any flutter or wow by pressure rollers or slippage. Since both the recorder and playback heads contact the tape at the capstan, tape scrape and vibration are reduced to a minimum.

DELAY LINES

Electrical delay lines for use in computers, radar, television and other electronic applications where delays are required ranging up to 100 microseconds are now being offered by the *Gulton Manufacturing Corporation.* They feature low loss, temperature stability made possible through the use of specially engineered temperature com-

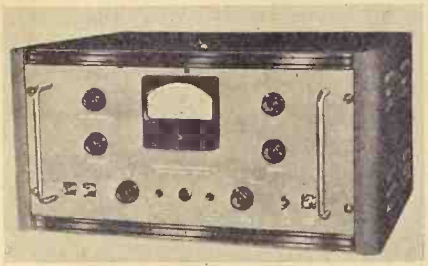


pensating capacitors, and small physical size.

All of these delay lines are custom-engineered to the exact mechanical specifications and electrical characteristics required. Further information may be obtained by writing to the *Gulton Manufacturing Corporation*, 212 Durham Avenue, Metuchen, N. J.

STANDING WAVE AMPLIFIER

The Type 275 amplifier designed by *Polytechnic Research and Development*



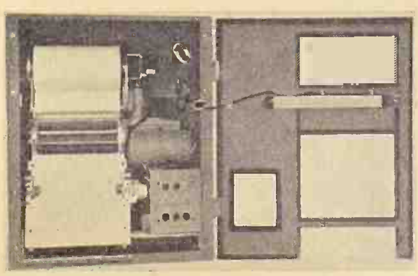
Co. is a high gain linear audio amplifier for accurately indicating voltage standing wave ratios. It may be operated either as a broad-band amplifier over a range of 300 to 3000 cycles per second, or as a narrow-band amplifier at 500, 1000 and 1300 cycles per second.

The input circuit of this unit provides for either crystal or bolometer operation with a variable bolometer bias of 2.5-8 ma. The square law meter, calibrated to read directly in db, and the high voltage gain of 140 db make this unit particularly suitable for microwave attenuation measurements with a bolometer r.f. detector.

Inquiries for additional information should be addressed to: *Polytechnic Research and Development Co.*, 55 Johnson Street, Brooklyn, N. Y.

HIGH SPEED PRINTER

The "Synchroprinter" is a high speed printer developed for recording the output of analog or digital computers in



directly readable form on standard paper. Capable of printing 15 lines of 40 characters each in one second, it may be used in any application where data is available in electrical or mechanical form.

Featuring independent control of printing and paper feed, this high speed printer permits data produced at irregular time intervals to be consolidated into adjacent lines of print. Printing is accomplished by means of continu-

(*Continued on page* 30)

NEW LITERATURE

ENGINEERING SURVEY

It was disclosed in a recent nationwide survey made by the National Society of Professional Engineers that an estimated 60 per cent of the potential managerial talent of engineers is being lost to industry today, due to poor communications between engineers and top management. A 48-page report on the survey has now been released, and copies may be obtained from the headquarters of the Society at 1121 Fifteenth Street, N. W., Washington 5, D. C.

This survey report, entitled "How to Improve Engineering-Management Communications," is the first of a series of research projects initiated by this society to help alleviate the current shortage of engineers by assisting industry to secure the best utilization of its present engineering force. Contained in the report is a detailed suggested formula for improvement in engineering-management communications.

MOBILE RADIO

Outlining the uses of two-way mobile radio equipment for materials handling, plant maintenance and protection, and other industrial applications, the four-page, illustrated leaflet which has just been issued by *RCA* Engineering Products Department is designed to provide management with such information as what two-way radio is, what it does, and how it can be used to help cut costs and improve efficiency.

The leaflet, entitled "Mobile Industrial Radio," and known as Form MC-1752, may be obtained by writing to the Mobile Communications Section, *Radio Corporation of America*, Camden 2, N. J.

NBS CIRCULARS

Two new publications have been announced by the National Bureau of Standards. The first, entitled "An Adhesive Tape-Resistor System," by B. L. Davis, presents a complete description of NBS developmental work on an adhesive tape-resistor permitting close control of resistance values. Containing 83 pages and many illustrations, it is available for 30 cents from the Government Printing Office, Washington 25, D. C.

The second publication is "Nuclear Data, Supplement 2" which brings up to date NBS Circular 499. "Nuclear Data" may be obtained for $4.25 a set from the Government Printing Office. Each set includes Circular 499 (310 pages), two supplements already published, and one supplement scheduled for publication shortly.

IRON-NICKEL ALLOYS

"Iron-Nickel Alloys for Magnetic Purposes (20 to 90% Nickel)," a 20-page bulletin available from *The International Nickel Company, Inc.*, Dept. EZ, 67 Wall Street, New York 5, N. Y., discusses the more important magnetically soft alloys. Tables and graphs correlate chemical composition with magnetic properties, trade names and sources of supply. Typical applications suggest uses for the alloys depending on their predominant characteristics.

LENKURT DEMODULATOR

The *Lenkurt* Demodulator is a new house organ which will be mailed regularly to individuals interested in the field of telephone and telegraph carrier equipment. Each issue will contain articles on such subjects as special problems of carrier operation, unusual applications of carrier equipment, and methods of using carrier equipment to obtain better and more economical communication channels.

Requests for the Demodulator should be addressed to the Publications Department of the *Lenkurt Electric Company*, San Carlos, Calif., and should include name, company, position and address.

PLASTICS FOR ELECTRONICS

Currently being distributed by the *Emerson & Cuming Company*, 126 Massachusetts Avenue, Boston 15, Mass., is a four-page folder describing their plastic materials, products and techniques, as well as their facilities for research and development. As illustrated, some of the products to which the various plastic materials have been applied include: packaged electronic sub-assemblies, missile-borne telemetering systems, gas-pressurized wave guide antennas, thermistor assemblies, and precision capacitors.

VOLTAGE REGULATORS

Functions and applications of Regohm direct-acting, finger-type voltage and current regulators are analyzed in Engineering Bulletin 505.00 just announced by the *Electric Regulator Corporation*, 50 Day Street, South Norwalk, Conn. The two-color, 12-page book tells how Regohm regulators provide close control of voltage, frequency, and current, and how they can be used in servo systems. Typical circuits are included.

OTS PUBLICATIONS

Many valuable developments for the electronics industries in the fields of materials, manufacturing techniques, electronic devices and theoretical advances are reported in the February issue of the Bibliography of Technical Reports, while the March issue features technical developments in the food, textile, electronics and metallurgical industries. These Bibliographies may be obtained for 50 cents a copy from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C., orders to be accompanied by check or money order payable to the Treasurer of the United States.

Also available from the OTS are three reports covering technical advances which make possible better radio transmission systems. PB 105 591, entitled "Determination of Microwave Atmospheric Absorption Using Extraterrestrial Sources," and PB 105 410, "Monitor Tuning Indicators for FSK Reception," each sell for 75 cents a copy. PB 106 131, "Upper Atmosphere Research Report No. XIII Rocket-Borne Instrumentation for Ionosphere Propagation Experiments" sells for $1.25.

REINFORCED PLASTICS

For the first time, a single dependable source for the major raw material of reinforced plastics is available to th plastics industry, according to a four page brochure which has just bee printed by the Plaskon Division o *Libbey-Owens-Ford Glass Compan* Toledo 6, Ohio.

Polyster resins reinforced with Fibe Glass form ultra high strength lam nates that are light in weight and ca be adapted to a wide range of product The dimensional stability of these lan nates permits production of parts wi uniformly close tolerances. Resistan to common solvents, rusting and rotti is an added advantage.

Technical service is also featured this brochure, which will be furnish on request by the Plaskon Division

LEAD CLAD METALS

A 22-page booklet has just been p lished by *Knapp Mills Inc.* entitled " History and Development of Ferro Lead Clad Steel and Cupralum L Clad Copper." Thoroughly cove these two mediums suitable for the h dling and processing of radioactive terials, the booklet also contains a arison of Ferrolum lead clad steel with heet lead and a comparison of Cuprasum lead clad copper with lead pipe.

Copies may be obtained by writing to he Research Department, *Knapp Mills nc.*, 23-15 Borden Avenue, Long Island City, N. Y.

RECISION CASTINGS

The Microcast Division of *Austenal Laboratories* has just published a 16-page booklet in full color entitled "New Opportunities for The Creative Product nd Design Engineer" which outlines he development of the Microcast process of precision investment casting from the first uses of the process in producing intricate dental appliances o today's thousands of applications in irtually every branch of industry.

Copies may be obtained from the Microcast Division, *Austenal Laboratories, Inc.*, 224 East 39th Street, New York 16, N. Y., or 7001 S. Chicago Avenue, Chicago, Ill.

Accelerometer

(Continued from page 15)

ised widely and may be used in conjunction with the *William Miller* Model CD-2 integration amplifier. Velocity pickups of *Consolidated Engineering* or others may be used with *Consolidated's* Model 1-110B vibration meter.

Integration amplifiers for accelerometers may be of two distinctly different types. If the accelerometer is of the strain gauge type, it may be excited with a d.c. supply, in which case the amplifier perforce would have to be of the direct-coupled type or capable of response down to two or three cycles. Otherwise quasi or steady state acceleration, velocity, or displacement could not be indicated. When a.c. is used to excite the strain gauges, capacitive or inductive pickups in an accelerometer, a carrier type amplifier is employed. Typical of these commercial units is the *William Miller* Model CD-2 unit. As an a.c. carrier is amplified, capacitive coupling may be used and steady state conditions may still be recorded. It is essential to use a phase sensitive detector (or to unbalance the bridge) where the sign of the acceleration, velocity, or displacement is required. For actual steady state displacement *not due to acceleration*, strain gauges installed on the structure may be used to indicate the deflection, accelerometers not being suitable for this purpose. The accelerometer will only indicate displacement where acceleration forces are involved.

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MICROWAVE ABSORPTION BY SNOW

By ARTHUR G. ROBERTS

NEW light has been shed on the strength of radar echoes from snow- and ice-covered targets and on the attenuation of microwave energy through snowstorms as the result of a long-term investigation by the Division of Radio and Electrical Engineering at the National Research Council in Ottawa. One of the practical conclusions to be drawn from this essentially fundamental study is that a few inches of moist snow may be enough to mask out many types of radar targets when temperatures are approximately at freezing point. It is important that this limiting factor in the use of radar be recognized in navigation.

Two experimental assemblies were used: one out-of-doors, for studying reflection coefficients of natural snow surfaces at microwave frequencies; the other in a cold chamber, for measuring the dielectric properties of snow under controlled conditions.

The outdoor assembly consisted of two towers, 30 feet high and some 50 feet apart, with a 3-cm. transmitter mounted on one tower and a receiver on the other, both instruments being free to move on vertical tracks. With the transmitter in a fixed position and the receiver moving slowly up or down, the output of the receiver would vary, indicating the extent to which the radiation reflected from the surface between the towers interfered with the direct radiation. From the interference patterns thus measured, the reflecting properties of the surface between the towers could be determined.

The assembly was first calibrated over a surface of bare ground between the towers. A sheet-metal platform was then placed between the towers to provide a uniform surface of known characteristics. Measurements were made whenever snowfalls covered the surface. Data collected during several winters showed that the attenuation of microwave radiation through snow was, in some instances, much greater than expected.

The apparatus in the cold chamber has made it possible to measure, for the first time, permittivity (i.e., the real part of the complex dielectric constant) and loss tangent (i.e., the ratio of the two components of the complex dielectric constant) of both snow and ice at precisely controlled temperatures. The work was done by means of wave guide techniques, some of them specially developed for this purpose.

Permittivity of snow and ice was found to be independent of temperature in the range from 0°C to −18°C. The loss tangent of ice was highest at 0°C while that of snow varied linearly with snow density, indicating that snow is a low-loss dielectric substance. It was also discovered that the loss was greatly increased when free water, even very little of it, was present in snow.

Personals

R. T. CAPODANNO was recently elected vice president in charge of engineering of the *Emerson Radio and Phonograph Corporation*, New York, N. Y., having held the post of director of engineering since 1949. Prior to his *Emerson* connection, Mr. Capodanno spent 22 years in engineering and development of industrial and commercial television and radio receivers, communication equipment and Government electronic projects.

J. H. DuBOIS has been named vice-president in charge of engineering at the *Mycalex Corporation of America*, Clifton, N. J. Formerly with *Plax Corporation, Shaw Insulator Company* and *G-E*, he brings to *Mycalex* a wide experience in both the electrical and mechanical fields. A member of the American Ordnance Association, Mr. DuBois has been associated with numerous armament projects including radar, projectiles, and communications.

DONALD G. FINK, one of the nation's leading electronic authorities, now joins *Philco Corporation*, Philadelphia, Pa., as co-director of research—operations. Editor of Electronics since 1946, Mr. Fink headed the Loran Division of M.I.T. Radiation Laboratory during the last war, was consultant to the Secretary of War from 1943 to 1945, and recently served as U. S. spokesman at the Zurich, London and Geneva television conferences.

GEORGE L. LOOMIS is the new manager of the radio tube plant of *Sylvania Electric Products Inc.* at Burlington, Iowa. Mr. Loomis, who joined *Sylvania* in 1936, has had long experience in radio tube design and has addressed engineering groups on this and allied subjects. He was manager of the radio tube plant at Altoona, Pa., before becoming engineering manager of the division's Product Development Section in 1950.

JOHN H. PAINTER, newly appointed special representative for *General Electric* broadcast equipment, with headquarters at Washington, D. C., will be responsible for liaison between all *G-E* broadcast equipment personnel and broadcast consulting engineers. A graduate of Newark College of Engineering, Mr. Painter has been with *G-E* since 1945. Prior to this appointment, he was engaged in application engineering work on television broadcasting systems.

RUSSELL J. TINKHAM has been appointed manager of the newly established Chicago office of *Ampex Electric Corporation;* he will supervise factory representation, application engineering and service for *Ampex* magnetic recorders in the midwest. Mr. Tinkham was connected with much of the original development work on magnetic recording carried on by Armour Research Foundation, and was one of the founders of *Magnecord, Inc.*

Audio Developments

(*Continued from page* 9)

heater leads were twisted and shielded and kept away from the grid circuit, which was also shielded.

Circuit components were based on median values given in manufacturers' manuals. Preliminary checks indicated that hum is not significantly affected by the usual variations in components—plate, screen, and cathode resistors, and cathode and screen bypass capacitors—required to match different load impedances.

The most hum-free amplifiers investigated so far at NBS used either of several triodes (6F5, 6SF5, 7F7, or 5691) or a pentode (5693) in a circuit including bypassed cathode, heater grounded through an adjustable potentiometer, and low grid impedance. Wide hum differences were found for different tube types as well as for different circuit arrangements. Apparently, however, the 60-cycle equivalent input hum of almost any tube type tested, whether triode or pentode, can be reduced to 10 microvolts by suitable circuitry; and all of the triodes tested could be brought below 2 microvolts.

The NBS figures are for the 60-cycle components alone and are therefore not fully comparable with figures given in the literature, which generally include harmonics. The 60-cycle components were measured because of their importance in low level power-frequency amplifiers, often required in instrumentation applications. Some of the low 60-cycle values measured at NBS were accompanied by harmonics no greater or even substantially less than the 60-cycle figure; in other instances the harmonics were many times greater than the 60-cycle component.

The general effects of the circuit variations were not unexpected. Without the cathode bypass condenser, hum was of course much greater; a sufficiently large bypass condenser is obviously desirable for all low hum applications. Return of the heater circuit through an adjustable potentiometer connected across the heater supply reduced the hum to as little as 1/20th or even 1/50th of the initial value when adjustment was optimum. Returning the heater circuit through 45 volts, either positive or negative but preferably positive, reduced hum somewhat in most cases. Increased grid circuit resistance tended to give greater hum in triodes, while in pentodes hum in general either showed no change or else decreased with increased resistance.

Various theoretical and practical aspects of heater hum have been treated in the literature. The NBS investigation, however, provides more practical data than have been generally available

c tube and circuit selection for mini-
mizing heater hum in low level am-
plifiers.

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Counting Rate Meter

(*Continued from page* 16)

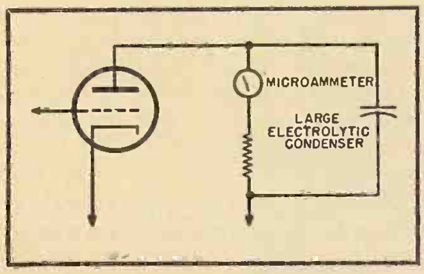
shunted by a trimmer condenser marked "CAL.," whose capacitance can be varied to calibrate the instrument. This condenser (fixed unit) may have to be varied somewhat in capacity to put the instrument within the calibration range of the trimmer condenser. One section of a 12AU7 is used to increase the effective value of the "damping" condensers which determine the fractional probable error. The capacitances are effectively multiplied by the factor, $1 + G$, where G is the gain of the stage between grid and plate. Large values of effective capacity can be obtained by this method, allowing the use of small paper or oil-filled condensers. In the circuit shown, the condenser's effective value is 14 times larger than its rated value.

The counting rate meter can be calibrated by connecting a sine wave oscillator or pulse generator with an output signal of 10 volts or more to the input circuit. Signals less than one microsecond in width are not recommended. Using an audio oscillator at any audio frequency times 60 will give the counts per minute which should be indicated. 167 cycles per second would give 10,020 cycles per minute, which is detected by the counting rate meter as 10,020 counts per minute. Thus, by selection of some audio frequency, any scale can be calibrated.

However, if the range resistors are accurate, calibration on any one range will automatically provide calibration for all scales. Since the repetition rate of an audio oscillator is consistent, the "damping" or probable-error-switch position is immaterial.

This instrument can be employed for many purposes other than indicating events per minute, including use as a tachometer or unknown-frequency indicator.

Fig. 2. A counting rate meter can be constructed as shown, wherein a charge is built up across a condenser by successive counts, and the voltage across the condenser measured. When the charging and discharging rates of the condenser are equalized, the meter will give an indication of the counting rate.



TRANSOCEANIC TELEVISION?

THE URSI meeting in Washington in April, reported in greater detail on page 20, was the scene of some lively discussions concerning the mechanism of tropospheric propagation well beyond the horizon. Taking part were Thomas J. Carroll, Massachusetts Institute of Technology; Joseph Feinstein, National Bureau of Standards; Martin Katzin, Naval Research Laboratory; and L. J. Anderson and J. F. Colwell, Navy Electronics Laboratory. Regardless of the mechanism of such propagation, the fact that it exists forms a basis for some highly interesting speculation.

It has been found during the past seven years that field strengths measured well beyond the horizon from high power transmitters throughout the v.h.f. and microwave range have shown much higher fields than conventional theory had predicted in the absence of ducts. The signal at these distant points, although small, is always present and is independent of antenna height. It appears that after about 30 miles the field strength falls off at the rate of about .7 db per mile for all frequencies from 30 to about 4000 mc., whereas theory predicts a drop of 2.5 db per mile at 3000 mc. Of equal importance is the fact that modulation is apparently unaffected at extreme distances. One report from *Bell Telephone Laboratories* indicates a received signal 700 db above the theoretical level, with modulation substantially unaffected.

Here, then, is a possibility of obtaining reliable microwave signal transmission over long distances without intervening relay stations, merely by using extremely high power, very high-gain antennas, and sensitive receivers. One thought is, of course, the possibility of intercontinental or even transoceanic television, a development which would undoubtedly better world relations.

The reluctance of the Federal Communications Commission to grant unlimited power to TV stations and the fact that the FCC has considered it necessary to enforce rigidly the minimum spacing of TV stations are now understandable. With increased antenna gains being obtained for fringe area reception, and with increased sensitivity of TV receivers, together with the use of boosters, it becomes obvious that TV signals can interfere with each other over distances heretofore considered impossible, even when duct transmission does not exist.

Here is a discovery which will indeed bear watching!

TECHNICAL BOOKS

"ELECTRICAL MEASUREMENTS" by Forest K. Harris, Ph.D., NBS Physicist and Professional Lecturer in Electrical Engineering at George Washington University. Published by *John Wiley & Sons, Inc.*, 440 Fourth Avenue, New York 16, N. Y. 784 pages. $8.00.

Designed for the student of electrical engineering or of physics, and for the laboratory worker, this book is based on more than 25 years of laboratory work and 10 years of teaching. It combines the points of view of the practicing engineer and laboratory worker on the one hand, and the research worker and student on the other.

"Electrical Measurements" emphasizes the nature and magnitude of the errors encountered in practical measurements and the means that may be taken to minimize or correct them, as well as presenting the devices and arrangements by which various types of measurements are made.

All necessary material from basic principles to applications within the field of d.c. and low-frequency applications is covered more thoroughly than in any other book on the subject.

"COPYRIGHT, DESIGN & PATENT GUIDE" by Henry J. E. Metzler, LL.B., Registered Patent Attorney. Published by *Ameliorant Co., Inc.*, P. O. Box 108, Halesite, L. I., N. Y. 125 pages. $2.00.

The purpose of this book is to outline the basic principles of the present copyright and patent laws, and to render assistance and helpful suggestions to those who seek protection for their intellectual property. One of its more specific objects, however, is to aid authors, composers, inventors, business men and general law practitioners in distinguishing among the various types of protection available, namely, whether patent, copyright or design protection is best suited for a specific work, article or the like.

Considerable space has been devoted to copyrights because many schemes attempting to substitute something else for patent protection propose copyrights in cases where patents only can afford protection. It is believed that anyone who has read this book will be able to select the proper type of protection for his invention and thus will save himself unnecessary expenses and disappointments.

The subject has been treated in abridged form in order to reduce reading time to a minimum, and a comprehensive index is designed to help locate any one of the various matters covered herein.

"GENERAL NETWORK ANALYSIS" by Wilbur R. LePage, Professor, and Samuel Seely, Professor and Chairman, Department of Electrical Engineering, Syracuse University. Published by *McGraw-Hill Book Company, Inc.*, 330 West 42nd Street, New York 18, N. Y. 516 pages. $8.00.

This book has been developed to provide a unified approach to the subject of network analysis. The treatment is general and is intended to supply the background for advanced work in either power or communications. Although some filter-design theory is included, the text deals primarily with analysis.

The material may be classified into the following broad aspects: steady state in lumped networks, steady state in distributed systems, and transients in lumped networks. A number of specialized techniques of fundamental importance in the development of the material are included, such as matrices, symmetrical components, transmission-line charts, Fourier series, Fourier integral, and the Laplace integral.

Emphasis has been placed on the understanding of underlying phenomena, as well as on techniques for finding solutions to problems.

"PROCEEDINGS OF THE NATIONAL ELECTRONICS CONFERENCE"—1951—Volume 7. Published by the National Electronics Conference, 852 E. 83rd Street, Chicago 19, Ill. 736 pages, including charts, diagrams and tables. Cloth edition. $5.00.

This book contains either complete or in digest form the 79 papers which were presented at the 1951 National Electronics Conference held in Chicago on October 22, 23 and 24. A program of the three-day session is also given.

Topics covered by these papers include: servo theory and distance measurement; electron tube developments; information theory; audio systems; signal detection; high frequency measurements; high frequency electron tubes; analog computers; circuit analysis; industrial inspection and measurement; television; medical and industrial applications; magnetic amplifiers and their application; components, measurement and assembly; microwaves and propagation.

The appendices include a catalog of the various exhibitors at the 1951 Conference, and contents of previous issues of the Proceedings. Copies of Volumes 2, 4, 5 and 6 may also be obtained for $5.00 a copy.

Communication

(Continued from page 5)

per minute as a reasonable rate of speaking, 15 bits per second is obtained as the rate of producing information in English speech when intelligibility is the only requirement. For a channel having a 40 db signal-to-noise ratio, a bandwidth of about 1 cycle would be sufficient for transmitting this information.

In the present state of the telephone art, channel capacity for transmitting speech by the ordinary inefficient means is ample, and it would be economically disadvantageous to effect the bandwidth compression just described. But with television the case is different, because it uses about a thousand times as much channel capacity as does speech. Reduction in the channel capacity needed in transmitting television could save money, and in fact workers in the field are addressing themselves to this problem. They are trying to take advantage of the fact that in many areas of a picture the brightness does not change from one point to another abruptly and erratically, but for the most part rather slowly and smoothly. They would like to take advantage of the fact that successive pictures or "frames" are not much different, only a little new information being added from picture to picture. They have, in one case, already taken advantage of the nature of the average picture and of the nature of human perception in transmitting color television with reduced bandwidth by using "mixed highs."

Consider bandwidth reduction by *utilization of the properties of the destination*. In speech transmission, for example, the ear is relatively insensitive to phase distortion. Consequently, phase information is not as important as amplitude information and need not be sent so accurately. This can be translated into a bandwidth saving. Moreover, the reduction in frequency discrimination of the ear as frequency increases indicates that a further reduction in bandwidth is possible. To a considerable extent the *vocoder*, a *Bell Laboratories* development, utilizes equivalences among speech sounds by largely eliminating phase information and by lumping groups of frequencies together, particularly at the higher frequencies. The transmission of color television by the "mixed highs" principle takes advantage of statistical correlation at the receiving end, that is, the correlation in the human perception mechanism.

In summarizing the relative merits of the three methods for reducing bandwidth, it might be said that bandwidth reduction by the exchange of signal-to-noise ratio would in many cases be the most economical approach.

Bandwidth and PCM

The object of a transmission system is to reproduce at the output any function of time which appears at the input. It can be shown by a Fourier series expansion that any time function of duration T and highest frequency component W cycles per second can be reproduced exactly by 2 WT independent samples of its amplitude taken at a regular rate of 2 W samples per second. Noise and other interference introduce errors in the recovered information concerning the size of the sample. However, this can be minimized by allowing only certain discrete levels of amplitude or position of the transmitted pulse, so that when the signal is sampled, the level nearest the true signal level is sent. If noise and interference are not too great, the original level of the signal is determined, and the signal can be reformed, or a new one created having the level originally sent.

In a PCM system all of the above features are incorporated: the input signal is band-limited to W; the signal is sampled at a rate of 2 W; samples are quantized and encoded; code groups are then transmitted by time or frequency division; the code groups are regenerated at intervals. In the receiver, regenerated code groups are decoded to form impulses proportional to the original samples, and the impulses are sent through a low-pass filter of bandwidth W to recover the original signal wave.

Properties of PCM: (1) The bandwidth for PCM is at least n times as great as that required for direct transmission of the signal, n being the number of pulses per code group. That is, if the coded message is to be transmitted in the same time as the original, the pulses will have to be transmitted at a higher rate than the original samples, since there are more code pulses than samples. This transmission at the higher rate requires more bandwidth. (2) Because of regeneration the transmission requirements for a PCM link are almost independent of the total length of the system. (3) The signal-to-noise ratio in PCM systems is set by the quantizing noise alone. (4) PCM approaches closer to the full utilization of channel capacity than any other system in use but still requires about 8 db in power over the power theoretically required to realize a given channel capacity for a given bandwidth. (5) In PCM the signal-to-noise ratio in db varies linearly with the number of digits per code group, and hence, with the bandwidth; but as the bandwidth is increased the noise power increases, and a proportional increase in signal power is required to stay adequately above threshold. Contrast this with FM in which the signal-to-noise ratio varies with the log of the bandwidth. On the other hand, as the received signal rises considerably above threshold, the signal-to-noise ratio improves with FM but not with PCM. Also, there is smaller complication in FM transmitters and receivers for high signal-to-noise ratios than in the case of PCM. In the end, communication theory cannot determine whether FM or PCM should be used; this depends on such matters as cost and simplicity of equipment.

Some Observations on Coding

General

To economize on time, bandwidth, or power, it is necessary to encode in such manner that the message contains maximum information. If the interval between samples is constant, the spectrum of the maximized information function is that of "white" noise passed through an ideal low-pass filter. Maximum signal-to-noise ratio consistent with bandwidth is obtained by coding in the binary system of units.

Redundancy and Self-Checking Codes

An approximation to ideal coding would have the property that if the signal is altered in a reasonable way by noise, the original signal can be recovered. That is, alteration will not bring the message closer to another reasonable signal than to the original. This behavior is accomplished at the cost of some redundancy in the coding. For example, there is a redundancy of about 50% in the English language, and this remains in the channel symbols of telegraphy. Hence, in a noiseless telegraph about 50% in time could be saved by proper encoding of the messages. This is not done, with the consequent advantage that in spite of a considerable amount of noise in the channel a significant percentage of the letters can be received incorrectly without subtracting appreciably from the information content of the message.

Redundancy is the price that is paid for being able to read a message corrupted by noise. Consider communication by a form of telegraphy in which "on-off" pulses are transmitted. Because of noise or faulty operation there is a certain small chance of receiving a pulse when an "off" was intended. If each message were repeated, an error could be detected but not corrected. Most errors could be corrected if each message were sent three times, but it can be shown that this is an inefficient method of guarding against errors. A much more efficient procedure is to utilize the recently developed error-correcting code techniques of R. W. Hamming of the *Bell Telephone Laboratories*.[5] These error-correcting codes make perfect operation possible in the presence of relatively infrequent errors by the utilization of a self-checking principle which involves minimum redundancy. Error-free operation is particularly important in work with large digital computing machines, since obtaining the correct answer depends on carrying out each of a long sequence of operations correctly with no possibility of error.

The concluding portion of this article,

scheduled for the July issue, will discuss periodic, aperiodic and random time functions as applied to communication theory.

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(*To be continued*)

New Products

(*Continued from page* 23)

ously rotating type wheels and cooperating print hammers.

The "Synchroprinter" is manufactured by the *ANelex Corporation*, Concord, N. H., and is furnished in a dustproof case which may be placed on a table or mounted in a standard relay rack.

PLASTIC TAPE

A new calendered tape, said to have excellent chemical resistance and unusual dielectric strength, has just been announced by the *Irvington Varnish and Insulator Company*, Irvington, N. J. Superior oil resistance makes the tape a natural selection for use with transformers or diesel equipment, while the high tensile strength makes its use on taping machines more effective.

Being calendered, Temflex 105 tape possesses perfect uniformity of thickness far superior to an extruded product, according to the manufacturer, and

virtually eliminates internal stresses caused by uneven tensions in the wound pad. Further information, technical data and samples can be obtained by writing to the Sales Promotion Department, *Irvington Varnish & Insulator Company*, 6 Argyle Terrace, Irvington 11, N. J.

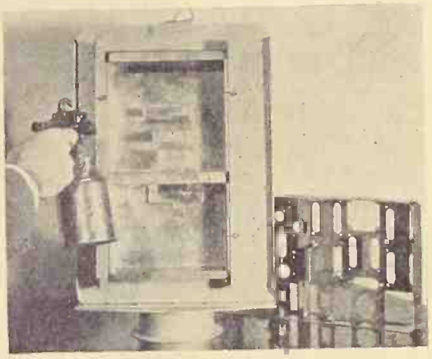
FERRITE CORE KIT

Grayburne Corporation has announced the availability of a special experimenter's ferrite core kit to enable engineers to familiarize themselves with the high-permeability, low-loss ferrite cores used in *Grayburne's* new miniature Ferri-Chokes and high-ratio Vari-Chokes. This core kit, Type FCK, consists of 27 various-sized cores which are well adapted for experimentation in i.f. and r.f. coils; solenoids; linearity, width and other variable controls; and in many electromechanical applications.

For further details, write directly to *Grayburne Corp.*, 103 Lafayette Street. New York 13, N. Y.

ELECTRONIC SPRAY STENCILS

Increased code marking production of any complicated electronic device is



claimed possible with the precision stencils developed by *Jas. H. Matthews & Co.* In a few seconds, a complete electronic chassis can be coded for its component parts by paint spraying.

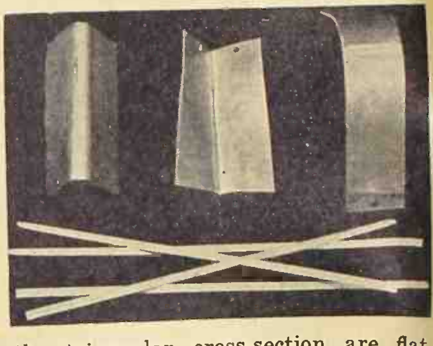
Matthews precision stencils are made by specification to fit over the parts to be marked, regardless of their shapes or sizes. Stencil holders make it possible to spray both sides of a chassis in a single operation, and eliminate the necessity for handling a "wet" stencil.

For more complete information and literature, write to *Jas. H. Matthews & Co.*, 3868 Forbes Street, Pittsburgh 13, Pa.

"BRAZINAL"

With the substantial increase of aluminum application in the various industrial fields, there has been an increasing need for an easily applied, strong and corrosion-resistant joint, obtainable at a reasonably low temperature. *A. E. Ulmann & Associates, Ltd.*, 342 Madison Avenue, New York 17, N. Y., announce a brazing type filler alloy for aluminum and its alloys—"Brazinal"—which does not require a flux and which produces a strong corrosion-resistant joint, with joint cleansing eliminated.

Brazinal is available in triangular rod in several sizes. The advantages of



the triangular cross-section are flat surfaces, sharp edges and a 90° angle, all of which aid in applying the rod. The rod is supplied in lengths of 12, 15 and 18 inches.

SERVO STABILIZER

A simple device for stabilizing a.c. servo systems was recently announced by *Kalbfell Laboratories, Inc.* It contains a variable damping adjustment, is equipped with cathode followers for input and output, and plugs into an octal socket.

The twin-T servo stabilizer has a phase shifting network to compensate for the lag caused by motors or other inertial elements, and overcomes hunting while maintaining the fastest possible response time. The twin-T network is made up of silver mica condensers and deposited carbon resistors to give excellent stability with respect to time and temperature.

For a descriptive pamphlet, write to *Kalbfell Laboratories, Inc.*, P. O. Bo[x] 1578, San Diego 10, Calif.

IGNITRON TUBE

In production at *National Electronics, Inc.*, Geneva, Ill., is an air-cooled type ignitron tube designed especially for the control of small resistance welders and for similar a.c. control applications. This tube, designated as NL-1001, is capable of controlling 60[0]

CALENDAR *of Coming Events*

AUGUST 15-16—Annual Summer Seminar, Emporium Section of IRE, Emporium, Pa.

AUGUST 27-29—Western Electronic Show and Convention (WCEMA and IRE), Municipal Auditorium, Long Beach, Calif.

SEPT. 29-OCT. 1—National Electronics Conference, Sherman Hotel, Chicago, Ill.

mp. r.m.s. demand or 9 amp. d.c. at 50 volts a.c.

The manufacturer states that NL-001 is lower in cost than any other gnitron now available and that it tilizes an exceptionally economical iounting arrangement. Complete data iay be secured from *National Electronics, Inc.*

FM Transmitter

(*Continued from page* 13)

re the voltage of the incident and eflected components of the wave travelng down the transmission line. The ncident voltage is calibrated in kilovatts, and the reflected voltage in 'SWR. The wattmeter scale is accurte as specified for unity standing wave atio. It should be corrected by a caliration factor for large standing wave atios. This correction factor, however, mounts to less than 10% for VSWR ess than 2. (See Fig. 1). Voltage is nduced in the loop consisting of R and ' by current flowing in the center conuctor, and by the voltage drop across ie resistor R from current flowing irough the capacitor C. One of these oltages is directly proportional to the ne current I, and the other is directly roportional to the line voltage E. hese two voltages add or subtract deending on the direction of energy flow own the line, or upon the position of ie transmitter and load. For correct peration of the coupler, these two voltges are made equal when the line is rminated in its characteristic resistnce R_0. The two directional couplers re carefully adjusted for a transmision line impedance of 72 ohms.

se of the Transmitter

In the particular case of the Indiana ate police installation, the output of ie transmitter is being fed into an '-derived low-pass filter to eliminate ossible television interference. The inut and output impedances are calcuted to match the impedance of the output coax and the antenna.

L_4 and C_1 is a series resonant circuit t the second harmonic of 85 mc. The ame applies to circuit L_5 and C_2. Ciruit L_6 and C_3 is tuned to the third haronic or 126 mc. Circuit L_7 and C_4 is ned to a frequency of approximately 5 mc. and is so tuned to help maintain the correct impedance of 72 ohms. L_1, L_2, and L_3 also help to assert the correct impedance and isolate the various circuits from one another. Refer to Fig. 2 for the schematic of the low-pass filter.

The output of the filter is fed into an *Andrews* folded unipole antenna. The 3-kw. amplifiers are providing 75 to 100 mile talkout range from 400-foot towers for the Indiana state police system at the present time.

PHOTO CREDITS

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Lighthouse

(*Continued from page* 7)

of the pattern from the other side. It will also be readily seen that radiation from each side of the baffle has a pattern similar to that caused by diffraction over a knife edge, which accounts for the sharp slope on the diffracted side. The part of the pattern not caused by diffraction is readily controlled by adjusting the primary feed so that the distribution of phase of the directly radiated energy and of the reflected energy causes them to combine to give the desired pattern. A wide variety of patterns is obtainable. The saw-toothed outer edge is, of course, the interference pattern caused by the phase difference of the reflected and directly radiated energy.

Returning to the diffracted radiation, the slope of the pattern on the diffracted side is a function of the length of the surface plate, and of the distance of the primary feed from the plate (in this case—a quarter of an inch). The slope becomes greater with increasing length and less with increasing distance from the plate.

The radiation patterns indicate that as an observer moves in either direction from the crossover there will be a very marked increase in the signal from the side facing the observer, and that at the crossover both signals will be equal. If the signal on each side is modulated in a distinctive manner, such as in the interlocked "A-N" coding, a very simple means of providing a straight and easily recognized course is available. With the equisignal antenna shown and the use of a receiver similar to the one described, it has been found that the angle over which the two modulated signals are of equal intensity is less than 15 minutes of arc. In actual practice, it was found that at a distance of five miles out, in line with the point of crossover and with the vessel beam on, it was possible to pick up the A and the N signals separately and distinctly by carrying the receiver from one end of the 110-foot vessel (Radel II) to the other.

The output from the transmitter is

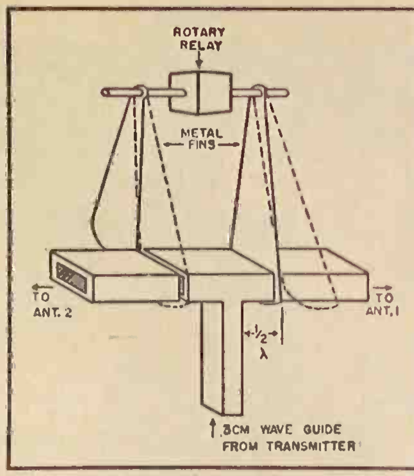


Fig. 7. Schematic diagram of the antenna switching arrangement.

fed through a standard wave guide system terminated at the antenna by a T junction, at which point the energy is alternately switched from one slotted wave guide array to the other. This is done with a pair of semi-rotating vanes mounted on the shaft of a rotary relay. The vanes slide into slots one-half wavelength on each side of the junction, thus alternately shorting the path to one or the other of the antennas (Fig. 7).

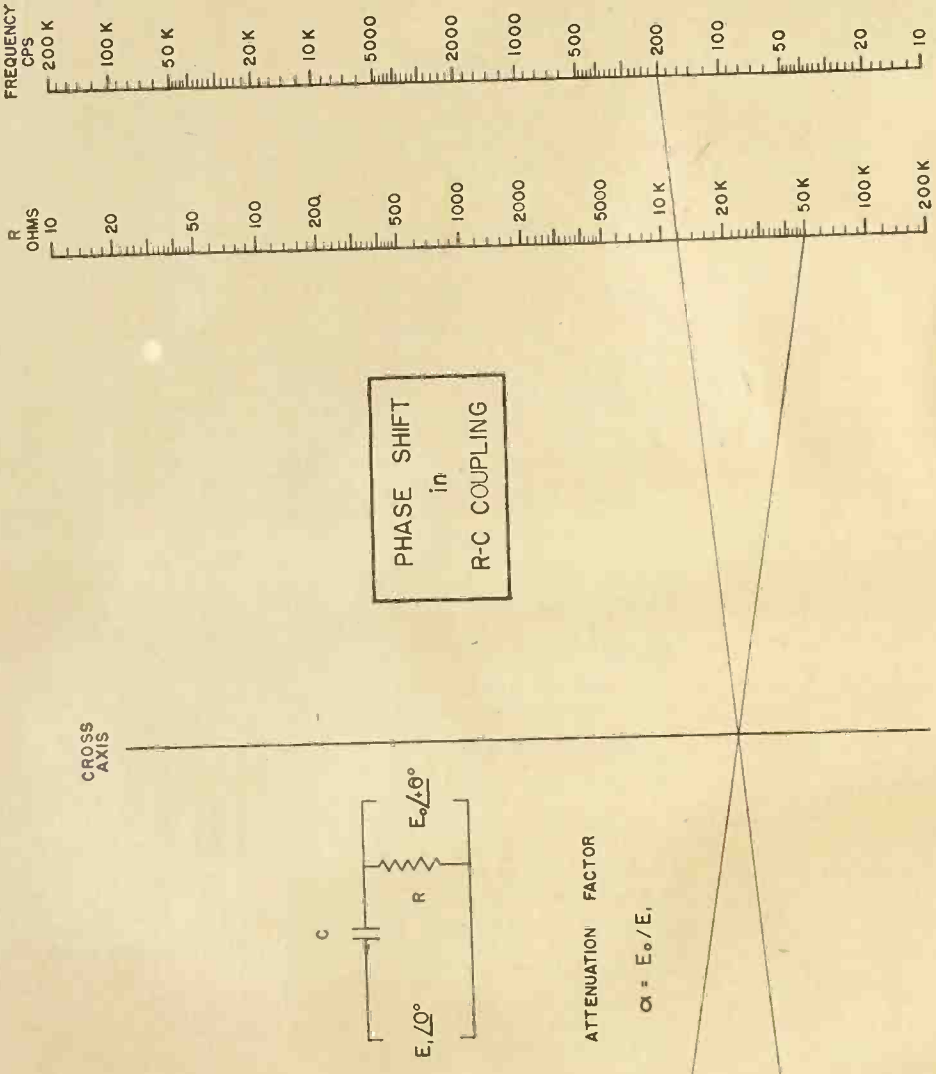
Two of these transmitters have been set up in Halifax Harbor and eight receivers have been loaned to local shipping companies for trial purposes. Comments from the shipping companies trying out this equipment have all been enthusiastic.

R-C COUPLING NETWORKS

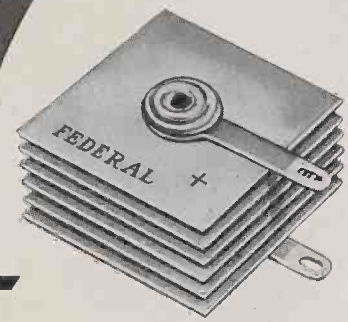
By GILMORE BOWERS

This nomograph provides an easy method of calculating phase shift and attenuation in R-C coupling networks.

DRAW a line between the value of *C* on the capacity scale and the operating frequency on the frequency scale. Draw another line from the point where the first line intersects the "cross axis" to the value of *R* on the resistance scale. Extend this line to the attenuation and phase shift scale, and read the values of attenuation and phase shift.



"It pays to replace with the BEST" Federal –



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