BROADCAST NEWS

May 1939

51

RCA MANUFACTURING COMPANY, INC., CAMDEN, N. J.

RCA Manufacturing Company, Inc.

A Service of Radio Corporation of America

Camden, N. J.

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POLICE TRANSMITTERS **POLICE RECEIVERS** **AVIATION RADIO EQUIPMENT**

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TELEVISION EQUIPMENT

BROADCAST NEWS

REG. U. S. PAT. OFF.

PAUL V. LUTZ, Editor

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RCA MANUFACTURING COMPANY, INC.
CAMDEN, NEW JERSEY, U. S. A.

RCA FACSIMILE FOR SCHOOLS

Exhibit at Cleveland Convention of National Educators Association Receives Much Attention

By ELLSWORTH C. DENT

The RCA-NBC exhibit at Cleveland.

THE RCA Victor exhibit at the Cleveland meeting, was as usual, combined with the exhibit of the National Broadcasting Company, to cover the major services of the Radio Corporation of America to schools. An unusually effective background with photo montage treatment gave the proper setting for the various types of equipment and service on display.

Unusual interest was created by the demonstration of facsimile reception of broadcasts from the Radio Division of the Board of Education of the Cleveland Schools. Many interesting samples of teaching materials were broadcast and received three periods each day with receivers in four Cleveland schools, in addition to the one in operation at the exhibit. This first experimental use of facsimile for educational purposes gave a glimpse into the possibilities of the future and may be the basis for many similar experiments in other cities.

Near the facsimile receiver was the new RCA Victor Deluxe School Sound Cabinet, which provides two channel radio and sound distribution for 20 to 120 rooms. This unit was extra complete with an attachment for instantaneous recording and reproduction of transcriptions, and a chimes unit to be used for signals as required. The companion exhibit was a small school sound system designed to accommodate 10 to 40 rooms with radio and sound distribution.

Another part of the exhibit included two entirely new ultra-high frequency receivers designed especially for school use. One was a small Ultra High Frequency Receiver for classroom use, and the other a larger receiver with high fidelity speaker designed to receive and reproduce music with much greater fidelity than standard receiving equipment.

The part of the exhibit which attracted attention second only to the facsimile demonstration included two new instantaneous recording instruments. The larger of the two is a console which is equipped to accommodate any size of record up to 16 inches in size, and to record from the outside in or inside out. This instrument operates at the standard phonograph record speed of 78 r.p.m. and at the transcription speed of 33 1/3 r.p.m. One of the interesting points of this recorder

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The recording booth at the Cleveland convention.

THE UNI-DIRECTIONAL MICROPHONE

Theory and Design of the RCA 77-B

By DR. H. F. OLSON

It is an almost universally established fact that directivity is desirable in any sound collecting system. The particular directional characteristic will depend upon the pickup problem. For example, the uni-directional microphone has been found very useful for overcoming excessive reverberation and undesirable sounds. The uni-directional microphone has been described in various papers.[1, 2, 3] It is the purpose of this paper to describe some of the development work directed towards improving the characteristics and reducing the physical dimensions of the uni-directional microphone.

Fundamental Characteristics

The uni-directional microphone consists of the combination of a bi-directional microphone and a non-directional microphone. The performance of this system is a function of the distance from the source, the spacing of the units, the sensitivity of the units and the phase angle between the units. These fundamental characteristics will be considered in the first part of this paper. The latter part of the paper will be concerned with the characteristics of a specific structure.

The Response of the Uni-Directional Microphone as a Function of the Distance and the Frequency

It is quite well known that the low frequency response of the velocity microphone is accentuated when the distance between the source and the microphone is less than a wave length. The same effect occurs to a smaller extent in the uni-directional microphone. As a matter of fact, for sounds originating in front of the microphone the effect is not pronounced even for very small distances. It is the purpose of this section to consider the response of the uni-directional microphone (Fig. 1) as a function of the frequency and distance from a point source.

The RCA 77-B Uni-directional Microphone.

The voltage output of a non-directional microphone as a function of the distance r is given by

$$e_{ND} = \frac{R_1}{r} \sin \omega t$$

where

R_1 = sensitivity constant of the microphone,
$\omega = 2\pi f$, f = frequency,
t = time.

The voltage output of the bi-directional velocity microphone as a function of the distance and the wave length is

$$e_{BD} = R_2 \left(\frac{1}{r} \sin \omega t - \frac{\lambda}{2\pi r^2} \cos \omega t \right) \cos \theta$$

R_2 = sensitivity constant of the microphone,
r = distance,
θ = angle between the direction of the incident sound and the normal to the ribbon.

If the output of the uni-directional as a function of the angle θ is to be a cardioid of revolution for plane waves, then R_1 must be made equal to R_2. Now we are interested in the output of the uni-directional microphone as a function of the distance and frequency as compared to a pressure microphone. This ratio is given by

$$\text{Response Ratio} = \frac{\sqrt{\left(\frac{1}{r} + \frac{\cos\theta}{r}\right)^2 + \left(\frac{\lambda \cos\theta}{2\pi r^2}\right)^2}}{\left(\frac{2}{r}\right)}$$

This ratio for θ = 0, 30°, 60°, 90°, 120°, 150° and 180° for 1, 2 and 5 feet is shown in Fig. 2. The same ratio for a conventional velocity microphone for 1, 2 and 5 feet is shown in Fig. 2. It will be seen that the accentuation in the uni-directional microphone is smaller than in the case of the velocity microphone.

Efficiency of Energy Response to Random Sounds of the Uni-Directional Microphone as a Function of the Relative Sensitivities of the Bi-Directional and Non-Directional Microphones

The uni-directional microphone consists of the combination of a bi-directional microphone, in

1 Olson, H. F. Jour. Acous. Soc. Amer., Vol. III, Jan. 1932, No. 3, p. 315.
2 Weinberger, Olson and Massa. Jour. Acous. Soc. Amer., Vol V, Oct. 1933, No. 2, p. 139.
3 Olson, H. F. Jour. Soc. Mot. Pic. Eng., Vol. 27, Sept. 1936, No. 3, p. 284.

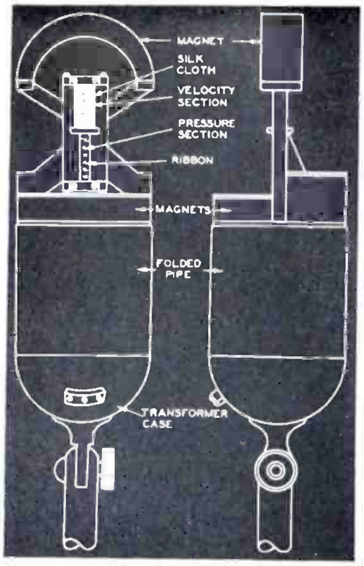

Fig. 1. Uni-directional microphone with the screen removed.

which the output is a function of the cosine of the angle of incidence, and a non-directional microphone. In general, it is customary to make the output of the bi-directional microphone for $\theta = 0$ equal to the non-directional microphone. For this condition the directional characteristic is a cardioid of revolution. In the case of both the bi-directional and the cardioid uni-directional the ratio of energy response to generally reflected sound is 1/3 that of a non-directional microphone. It is interesting to investigate the efficiency of response to random sound of other ratios of sensitivity of the bi-directional to the non-directional unit.

The output of a microphone consisting of a bi-directional and non-directional unit is given by

$$e_{VD} = R_1 + R_2 \cos\theta$$

where

R_1 = voltage output of the non-directional microphone.

R_2 = voltage output of the bi-directional unit for $\theta = 0$.

The efficiency of energy response of the uni-directional microphone as compared to a non-directional microphone for sounds originating in random directions, all directions being equally probable, is

Efficiency =

$$\frac{2\pi \int_0^{\pi} (R_1 - R_2 \cos\theta)^2 \sin\theta \, d\theta}{4\pi\,(R_1 + R_2)^2}$$

$$= \frac{1}{6}\,\frac{(R_1 + R_2)^3 - (R_1 - R_2)^3}{(R_1 + R_2)^2 R_2}$$

For the standard velocity microphone $R_1 = 0$, $R_2 = 1$ and the ratio is 1/3. For the cardioid uni-directional $R_1 = 1$ and $R_2 = 1$ and the ratio is 1/3. However, for other values the ratio is different. For example, between $\frac{R_1}{R_2} = 0$ to $\frac{R_1}{R_2} = 1$ the efficiency is less than 1/3 and becomes .25 for $\frac{R_1}{R_2} = .33$. The efficiency for various values of the ratio $\frac{R_1}{R_2}$ is shown in Fig 2.

The data in Fig. 3 show that it is not so important that the two microphones be of the same sensitivity. It is important, however, that the ratio $\frac{R_1}{R_2}$ be equal to 1 or less than 1.

The same results are shown in Fig. 4 by means of diagrams. This figure shows that the energy response of the bi-directional microphone and the cardioid uni-directional is the same. However, for $0 < \frac{R_1}{R_2} < 1$ the response to random sounds is less than in the case of these two microphones.

Efficiency of Energy Response to Random Sounds of a Uni-Directional Microphone as a Function of the Phase Angle Between the Two Units

In the preceding discussions we have assumed that the phase angle between the outputs of the

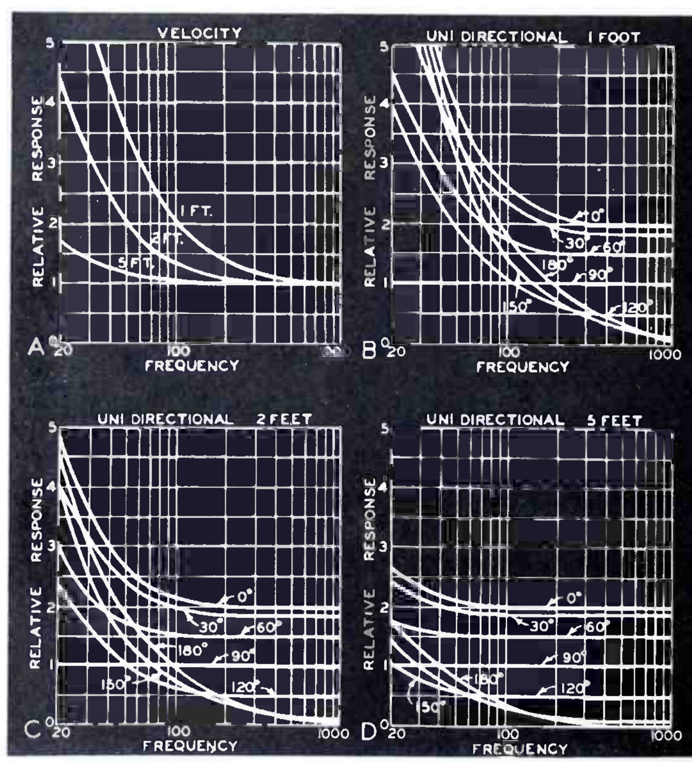

Fig. 2. A. The output of a velocity microphone as compared to a non-directional pressure microphone for distances of 1, 2, and 5 feet. B, C and D. The output of a uni-directional microphone as compared to a non-directional pressure microphone for distances of 1, 2 and 5 feet and for various angles of the incident sound.

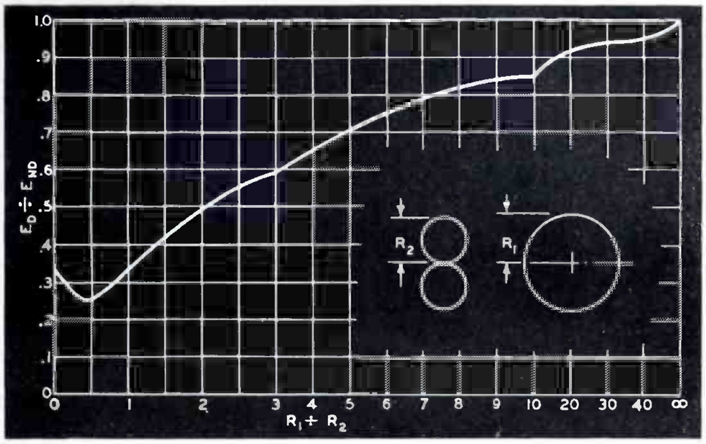

Fig. 3. The ratio of energy response to random sounds of a directional microphone, consisting of a bi-directional and a non-directional unit as a function of the ratio of the outputs of the elements, as compared to a non-directional microphone. END energy response of a non-directional microphone ED energy response of a directional microphone. R_1 voltage output of the non-directional unit. R_2 voltage output of the directional unit.

two units did not change with frequency. In order that the velocity of the pressure ribbon shall be in phase with the particle velocity, the vibrating system must be a pure mass reactance. This is not true at the very high frequencies or at the very low frequencies, due to the resistive part of the air load and the stiffness of the ribbon. In order that the velocity of the pressure ribbon shall be in phase with the pressure in the sound wave, the system must be resistance controlled. If the above conditions are not satisfied there will be a phase difference between the two units. If the units are separated by a definite distance d, then there will be a phase difference between the units which is

$$\phi = \frac{d}{\lambda} 360 \cos \theta$$

where

d = distance between the units,

λ = wavelength,

θ = angle between the directionof the incident sound and the normal to the ribbon.

Note that this separation is in line with the units.

The output of a system having a phase angle 0 due to separation d between the output of the units is given by

$$e = e_0\sqrt{(\cos\theta + \cos\phi)^2 + (\sin\phi)^2}$$

where

e_0 = output of non-directional microphone or the bi-directional microphone for $\theta = 0$.

Substituting $\phi = \frac{d}{\lambda} 360 \cos \theta = K \cos \theta$ we obtain for the output

$$e = e_0\sqrt{[\cos\theta + \cos(K\cos\theta)]^2 + [\sin(K\cos\theta)]^2}$$

The efficiency of energy response of the above system to a non-directional system is given by

$$\text{Efficiency} = \frac{2\pi e_0^2 \int_0^\pi \{[\cos\theta + \cos(K\cos\theta)]^2 + [\sin(K\cos\theta)]^2\} \sin\theta d\theta}{16\pi e_0^2}$$

$$\text{Efficiency} = 1/3.$$

That is, the efficiency is independent of the separation between the units. Of course, for very large distances the separation disturbs the response for $\theta = 0$. However, in the conventional microphone this does not occur. Therefore, the effect of finite size has no effect on the efficiency of energy response.

Now we will consider the case in which there is a phase angle ϕ due to phase shift within the unit.

$$e = e_0\sqrt{(\cos\theta + \cos\phi)^2 + (\sin\phi)^2}$$

The efficiency of energy response of the above system to that of a non-directional microphone is

(Continued on Page 20)

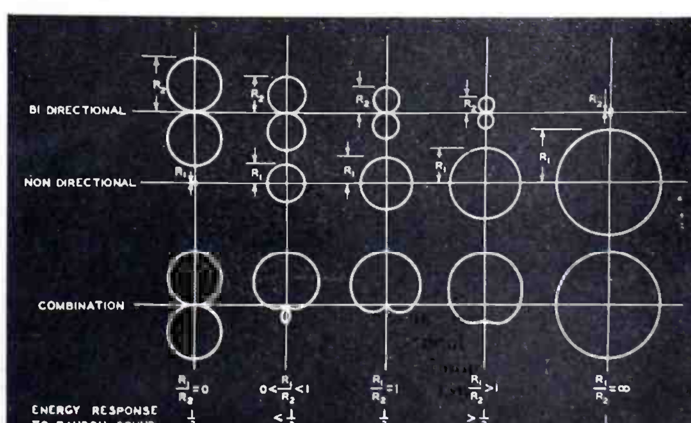

Fig. 4. Directional diagrams of various combinations of bi-directional and non-directional microphones and the energy response to random sounds.

CENTRAL OREGON'S KBND BEND, OREGON

Northwest Station Serves Rich Market

The RCA Equipped Control Room at KBND.

CENTRAL Oregon's newest radio station, KBND, goes all the way with RCA from microphone to the 250-G standard transmitter. With studios located in Bend's well known Pilot-Butte Inn, KBND broadcasts on a frequency of 1310 Kc. serving the vast central Oregon market and the richly irrigated territory of the Deschutes River valley with its only daytime primary radio service.

The general layout of the control room equipment at KBND is shown in photograph No. 1 including the standard 250/100 watt transmitter to the right and composite operating console housing two RCA portable OP-4 amplifiers which were revamped for studio mixing and speech input use. The arrangement makes an especially flexible speech input system as well as an economical arrangement for small station requirements where a maximum of 4 to 6 mixing channels is necessary. The installation is so made that one OP-4 amplifier is used for transcription table mixing, one channel for studio microphone and one channel for control room microphone, thus leaving the second OP-4 amplifier available as a program audition unit. All circuits terminate in a patching panel and so permit the second amplifier to be used either as an emergency speech amplifier or used simultaneously with amplifier No. 1 to furnish three additional microphone channels. It also serves the purpose of an emergency portable amplifier and is readily disconnected by several plug-in-connections.

Two RCA type 70-B transcription tables with diamond point pickups have been used with excellent results. Comments from the listening audience have all been highly complimentary on the fidelity of the programs originated. An RCA inductor type 50-A microphone is used for a close-talking announce microphone,

(Continued on Page 33)

The gang at KBND, Bend, Oregon. From left to right.: Frank Loggan, General Manager; Chet Wheeler, Commercial Manager; Frank Hemingway, Sales, Sports Announcer; Mrs. J. Sillery, Bookkeeper; Stanton Bennett, Chief Engineer; Wm. Murphy, Program Director.; August Hiebert, Technician, Announcer.

MORE POWER TO WHBF

New Plant Entirely RCA Equipped

L. C. Johnson, General Manager of WHBF.

RADIO Station WHBF, Rock Island, Ill., for many years an efficient local station, recently was granted an increase in power to 1,000 watts day and night and a frequency change to 1240 kilocycles.

Formerly the station operated on 250 watts day time power and 100 watts night time, on a frequency of 1210 kilocycles.

When the station started operating under the new 1,000 watt license from the Federal Communications Commission in January it opened a new $35,000 transmitter plant located just east of the city limits of Moline, Ill., atop the bluff bounded by the Mississippi and Rock rivers.

Main Studios

The main studios of the station, located on the top floor of the Safety building in Rock Island, and the new transmitter plant are entirely RCA equipped.

A short time before the new license was issued, L. C. Johnson, for the last 10 years advertising manager of the Rock Island Argus, of which the radio station is an affiliate, became vice president and general manager of the radio station.

John W. Potter, co-publisher and editor of The Argus, is president and secretary of WHBF, and his brother, Ben H. Potter, co-publisher and treasurer of The Argus, is treasurer of the radio station.

The opening of the new transmitter also was marked by the station's affiliation with the Mutual Broadcasting System.

Now that the station has been operating its new plant for several weeks, J. E. Gray, chief engineer, said he is entirely satisfied with the results obtained through the use of this equipment.

"I believe," Mr. Gray said, "that the RCA equipment is the best for the men in the field—the men who actually use the equipment."

The new WHBF equipment includes a RCA type 1-G transmitter, an RCA 96-A limiting amplifier, and a new RCA phase monitor to check the phasing of the directional array.

The 1-G transmitter feeds a central radio frequency distribution plant, which in turn feeds two 4-wire transmission lines, one to the main radiator, and one to the second tower of the directional antenna system.

The antenna system consists of two 350-foot Truscon towers spaced 480 feet apart, and the ground system is made up of 120 radials 300 feet long around each tower. In these radials is twelve-and-a-half miles of copper ribbon.

J. E. Gray, Chief Engineer of WHBF.

The radials are buried approximately six inches below the surface of the earth and connect to a ground screen 50 feet square beneath each tower.

Phasing and coupling equipments housed in a small building at the base of each tower.

Tower Lighting

Tower lighting consists of standard equipment required by the Civil Aeronautics Authority and uses at the top of the main radiator a 1,000-watt 300-millimeter flashing beacon, and at the top of the second tower a 100-watt obstruction light, with another 100-watt lamp connected

(Continued on Page 31)

The RCA 1-G Transmitter, Speech Input and Monitoring Racks at WHBF

LACQUER DISC RECORDING AND REPRODUCING

By H. J. HASBROUCK and R. F. BRADY

Above: The RCA 70-B Transcription Turntable equipped with the new high fidelity lateral pick-up and arm.

THE abundance of commercial applications, combined with the practicability of and the fidelity possible with instantaneous lacquer disc recording, has created a rapidly rising demand for both recording and reproducing equipment. The extremely low surface noise, wide range, low distortion, and reasonable wearing qualities of available lacquer discs have been the prime movers in broadening this demand into one for increased frequency range or increased fidelity.

RCA is now supplying equipment with extended frequency range, which, with proper handling, will produce excellent results. It is the purpose of this article to acquaint the broadcasters with new features and improvements, along with a few helpful hints in handling this type of recording. The adjacent photographs illustrate the 70-B transcription turntable equipped with the new high fidelity lateral pickup and arm, the tone arm lifting mechanism, and the 72-B recording mechanism.

Below: The RCA 70-B with pick-up on the side and the 72 B recording mechanism in position.

The lateral pickup and arm, supplied also in kit form with compensator, offers an extended frequency range of from 30 to 10,000 cycles with relatively high sensitivity. The pickup utilizes a permanent diamond point with a life of several thousands of playings.

In the design of this pickup, particular care was taken to produce a mechanism having extremely low distortion. The r.m.s. total harmonic content is less than three percent of the fundamental output voltage, measured with sine wave motion of the stylus and at amplitudes corresponding to the maximum encountered in the reproduction of properly cut records. Fig. No. 1 illustrates the distortion characteristics of the mechanism.

This pickup utilizes a balanced, clamped reed type of armature. The construction is schematically shown in Fig. No. 2. The armature impedance is substantially reduced by employing a lever system. Effectively, the record sees but little impedance beyond that of the diamond point and the extremely light mounting post. Vertical flexibility is provided permitting the stylus to rise and fall

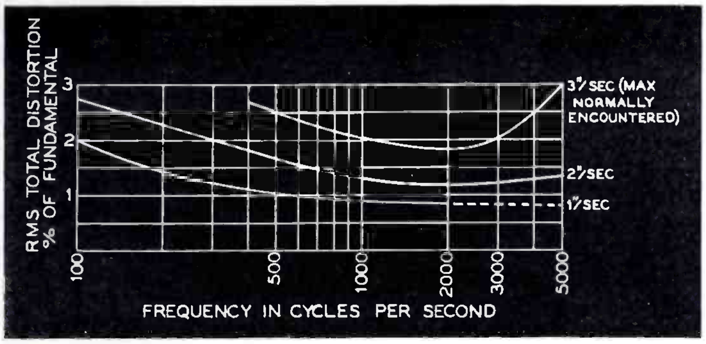

Fig. 1.

at twice the signal frequency during the normal pinching while reproducing lateral cut records. This motion, of course, generates no voltage and has no harmful effects.

In the direction of useful motion, the armature is driven by a light channel link connected to the short end of the stylus lever. High frequency cut-off is determined by the stiffness of this linkage, the effective mass of the moving system and compliance of the stock from which the record is pressed. For Victrolac this cut-off occurs at 10,000 c.p.s. Selective damping is employed to prevent a peak in the high frequency response preceding cut-off. A small block of metallic loaded rubber of predetermined mass and stiffness is attached to the end of the armature. This block is tuned approximately to 9,000 c.p.s. and acts as parallel resonance effectively controlling the peak and keeping the response smooth.

Flexibility has been carried to a practical limit in this pickup insuring best possible tracking at low frequencies. This has permitted a reduction of thirty-three percent in stylus pressure, the weight on the record being two ounces.

Laminated pole pieces and armature of nicaloi are used increasing the efficiency and reducing distortion due to hysteresis. The permanent magnet is of thirty-six percent cobalt alloy steel.

To obtain a nearly constant tracking angle, the head has been slightly off set with respect to the arm. It will be noted upon setting the pickup down in various positions on the record nearly perfect tangency with the groove results.

A light flexible pickup of this type requires a nearly frictionless tone arm pivot. For this reason the MI-4856 pickup arm swings on ball bearings with frictionless cone point bearings for vertical pivoting. Therefore, the record is required to do very little work in moving the pickup across. This feature should be especially appreciated when playing discs of the lacquer coated type in which the grooves are apt to be more shallow than in standard pressings.

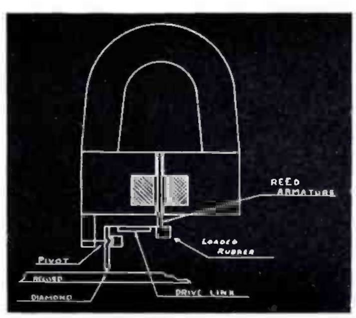

Fig. 2.

For convenience of operation, lifting fingers of extended length are now available which can be eaily attached. A tone arm lifting mechanism is also provided which is cam operated and permits lowering the pickup in any predetermined position.

The MI-4856 pickup is sharply contrasted to the heavy "brute force" type of unit associated for many years with lateral records. Many have erroneously come to believe that a pickup for lateral records is of necessity a massive device incapable of being damaged. They realize that a vertical pickup is fragile and delicate but lateral reproducers have been so ponderous in the past that recently in a number of instances where old pick-ups were replaced with MI-4856 units, breakage has resulted. This was confined mostly to the diamond point and a new, shorter, stronger, "stub" point has been adopted, which offers greatly increased strength yet retains the same 0.0023 point radius.

While the MI-4856 reproducer is relatively rugged and will withstand ordinary use even on a 24 hour schedule, it can be damaged. It is almost impossible to build a high quality wide range pickup that will take carless and rough handling. The reproducer cannot be used for marking records, nor can it be repeatedly dropped, struck against the edges of records, or allowed to run off the edge of the record.

In Fig. No. 3 is shown the response-frequency characteristic of the MI-4856 pickup driven by a test pressing at 33.3 r.m.p. A four position bass compensating switch is provided inside the turntable cabinet for changing the response below 1,000 cycles. Position 1 provides essentially the curve shown in Fig. No. 3, whereas position 4 shifts the curve up approximately 5 db at 100 cycles. Positons 2 and 3 fall between 1 and 4.

A high frequency compensating network is supplied and is controlled by means of a 4 position switch in the upper right-hand corner of the cabinet. Position 1

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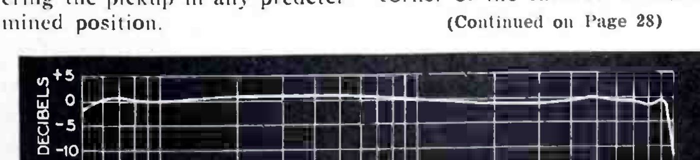
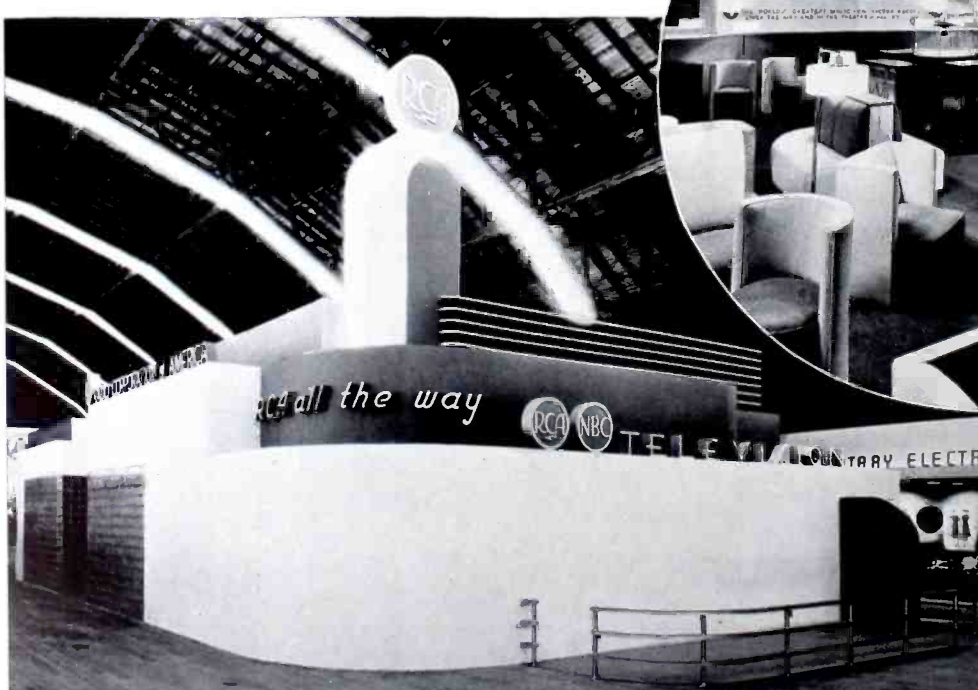


Fig. 3.

RCA GOES TO THE GOLDEN GATE

International Expositi

Above: The Golden Gate International Exposition in San Francisco. Treasurer Island is equipped with RCA sound throughout.



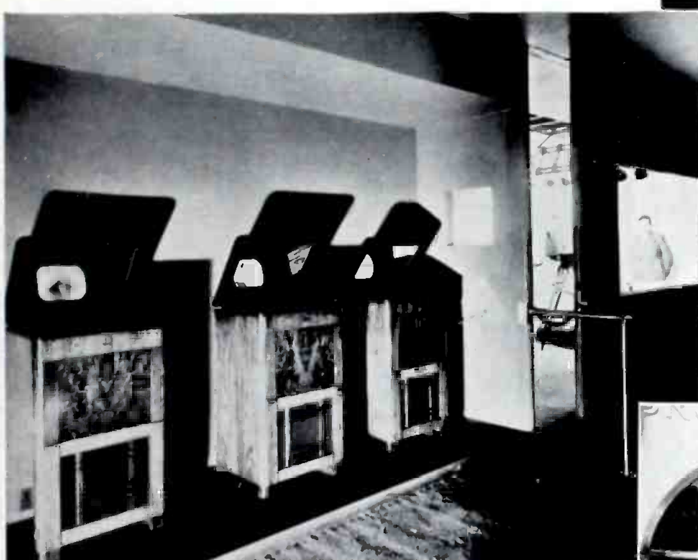
Above: The lounge where visitors may relax and listen to music recorded by RCA Victor.

Left: The RCA exhibit at the fair. A building within a building.

INTERNATIONAL EXPOSITION

Goes RCA All the Way

Right: The television camera on exhibit at the fair. Many visitors have been televised before this instrument.



Above: A line up of RCA Television Receivers—the first RCA presentation of television on the west coast.

Above: A mural of industrial achievements by RCA. Note the control desk of a school sound system in the lower right hand corner.

Above: RCA presents the facsimile transmitter and receivers. Another interesting display of RCA products.

Right: Everyone seems to be interested in the newspaper of the air—well almost everyone.

TOMORROW'S TRANSMITTER TODAY

RCA Ultra-Modern 5-DX Broadcast Equipment

By J. E. EISELEIN

THE RCA Type 5-DX Broadcast Equipment offers a design modernized not to the engineering standards of today but the engineering standards of 1940.

This equipment is refined in all details of the transmission circuit, the control circuits and in the mechanical design. Constructed first for duty without interruption, secondly for convenience, and finally for ruggedness and appearance. The ease and simplicity of installation, operation and maintenance are major features of the equipment. Many of the improvements are based on small details of operation observed in the twelve installations of the 5-D transmitter now in the field.

The 5-DX is, therefore, the result of planned engineering to present the transmitter of 1940 today.

A front view photograph of the 5-DX equipment is shown in Figure 1. The first section on the left is an access door to the transmitter enclosure. The second unit is the radio frequency exciter, better known as the 250-F equipment. The third unit is the modulated amplifier, the fourth the high level modulators and on the extreme right, recessed directly behind a full height door, is the power control panel. The vertical chassis construction has been employed in all units except the power control panel which is of standard switchboard design. The vertical chassis offers a degree of accessibility heretofore unobtainable in ordinary, compact, transmitter design. Without exception, any single unit throughout the transmitter may be removed for replacement without disturbing any adjacent component parts.

The tube complement is entirely air cooled. All tubes are accessible from the front of the transmitter with the exception of the three high power tubes.

The exciter unit employs an RCA-802 oscillator, RCA-802 buffer, RCA 805 intermediate power amplifier, and two RCA-805 power amplifiers. These latter in turn drive a single RCA-891R modulated amplifier. A modulator-rectifier unit comprises two RCA-892R's to modulate the Class C stage. The six RCA-872A's in the main rectifier are mounted on, and accessible from, the front of this unit.

Audio Equipment

The low level audio equipment, consisting of two RCA-1603's followed by two RCA-807's and four RCA-845 drivers is mounted in a sub-assembly which forms a unit of the power amplifier section. The modulation transformer and reactor form an assembly mounted in the rear of the main units. In addition, the filter rack of the main power supply and the plate transformer are also mounted in the rear of the transmitter. High voltage connections are made by means of overhead copper bus.

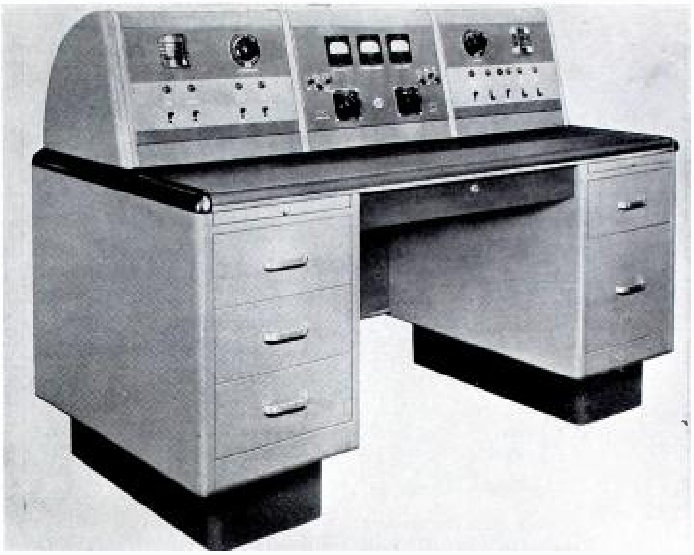
Contrary to a common belief, the air-cooled tubes are not an untried design. The RCA-891R and RCA 892R are made by soldering an 891 or 892 standard water-cooled tube into a radiating copper fin assembly. The 891 and 892 tubes are of a standard design and have been well proven in service. Mounted below each porcelain ring which forms the socket for the 891R and 892R is a Sirocco low speed blower which delivers approximately 500 cubic feet of air per minute to the radiating fins of each tube. These blowers, shock mounted and operating at only 850 r.p.m., are silent under operating conditions. A vane mounted in the air column to each tube interlocks both filament and plate power against a reduction in airflow of more than 30%. Any obstruction in the air path or a reduction in speed of the blower immediately removes both filament and plate power from the tubes.

Cooling System

The operating temperature of the air-cooled fins is surprisingly conservative in comparison with temperatures encountered within the water-cooled type of jacket. The 891R and the 892R are rated for continuous operation at an anode temperature of 160°C. In

The modern 5-DX Broadcast Equipment.

this equipment the Class B modulators will not exceed 80° C during continuous program operation. The Class C stage under the same conditions reaches the maximum of 110°. These temperatures are measured in a well drilled in the radiator fins. The above measurements are based on an ambient of 100°F. Because of the low static plate current at which the modulators are operated, 10 ma per tube, very little power is dissipated into the air-cooling stream. With average program modulation the anode heat dissipated in the air stream would be less than 200 watts per modulator tube. In the case of the Class C, modulated amplifier stage, the high plate efficiency at which this tube operates reduces the anode heat to 1300 watts dissipated by a rapidly moving column of air. This represents a very few degrees increment in the temperature between the input and exhaust air. Giving consideration to the direct heat of radiation from the envelope, jacket and insulating coils of a water-cooled system, together with the increased efficiency of operation, there is little difference in the amount of heat dissipated into the transmitter room using either water or air as the cooling medium.



The RCA 5-DX Control Console.

The blowers require practically no maintenance; being of a standard type and unusually low speed their life is indefinite. Lubrication of the motors is required only at infrequent intervals and the oil cups are readily accessible from the rear of the transmitter. In the unusual event of a blower motor burn-out, the motor may be replaced by an inexperienced person and the transmitter returned to the air in six minutes.

The Class C stage, modulated amplifier is surprisingly simple and straightforward. The grid tank is symmetrical and balanced to ground in such a way as to provide the drive voltage and a voltage 180 degrees out of phase for neutralization. Neutralization in this type of circuit is not critical and it is, therefore, practical to use a fixed value of neutralizing capacitance. Any variation in the circuit constants and distributed capacities may be easily compensated by small variations in the grounding or balance point of the grid tank circuit. Such a shift of the center point permits an accurate control of the phase and amplitude of the neutralizing voltage. In all cases it has been found that mechanical symmetry of the taps provides a proper neutralizing voltage. The tuning, therefore, is very simple. As is usual in Class C circuit design grid leak bias is employed. In order that the regulation in the grid circuit may be controlled a 10mfd. capacitor is available for bypassing any portion of the grid leak. This is desirable in that it permits a fine control of the carrier shift and a balance between low and high frequency distortion. In effect, it is possible to make any desired percentage of the grid bias voltage fixed by means of the bypass capacitor. That portion of the grid leak not included in the by pass circuit will have the normal regulation characteristics of grid leak bias.

Circuits

The output circuit is coupled to the load by means of fixed capacitors. The values of these capacitors are predetermined for fixed frequency bands and require no adjustment at installation, still further simplifying the tuning process. The use of capacity coupling, in addition to its simplicity, offers an excellent means of harmonic attenuation. The variable inductor in series with the transmission line permits panel control of the power output of the transmitter. Variation of this inductive reactance controls the effective reactance of the coupling capacitors. In effect, then, the voltage at the terminals of the transmitter may be controlled and with it the amount of power in the load.

The tank circuit is tuned in the inductive leg. It is to be noted that in any tank circuit which is tuned to resonance by means of an inductance variation, the condition for unity power factor and minimum plate current are no longer identical as is the case with capacity tuning. As the tank inductance is decreased beyond the point which produces minimum plate current the output of the circuit will continue to increase. At the same time the efficiency continues to increase until a condition of unity power factor obtains. Beyond this point the power output will continue to increase but the efficiency will again decrease. A solution of the mathematics of this type of tank circuit shows that for tuning in the region of unity power factor small variations of the tank inductance will produce large changes of the load into which the tube looks, consequently it is possible to obtain a considerable variation in power output without appreciably effecting the efficiency, tuning or modulation characteristics. This tank control, therefore, provides an excellent means of compensating for reasonably wide deviations in output circuit voltage and plate supply voltage.

Audio Frequency System

The audio frequency system as well as the radio frequency circuits have been designed for maximum efficiency and simplicity. The 891R modulators are capable of delivering 4 KW of audio power each without drawing appreciable grid current. The bias supply, therefore is of a simple and economic design as it is not necessary to bleed a large amount of current to obtain sufficiently good regulation of the bias voltage. It might be expected that the driver stage required would be of relatively low power inasmuch as the grids of the 891R tubes do not draw appreciable current. It is not, however, possible to take full advantage of this economy if the extended frequency range required for feedback is to be obtained. In order, therefore, that ideal conditions should exist the design incorporates four type 845 tubes operated parallel push-pull. The d-c voltage available for their operation is sufficient to permit the use of self-bias and at the same time secure the maximum rating as Class A audio amplifiers. Under these conditions the tubes will deliver 1000 volts peak into a high impedance load. This meets the requirements for driving the 891R grids for full audio output. In order to secure a reasonable safety factor in grid driving voltage a small percentage step-up is employed in the coupling transformer between the 845 tubes and the 891R grids. In general, the use of transformer coupling in a feed-back amplifier is a distinct handicap because of the undesirable phase shift that usually occurs in the transmission characteristic at high frequencies. The defect is eliminated in this application by the use of external resistors-capacitor networks that allow the transformer to function normally over the entire range of audio frequencies necessary for modulation of the transmitter, but function as an impedance coupling device at the high frequencies where the phase shift of a transformer would become objectionable.

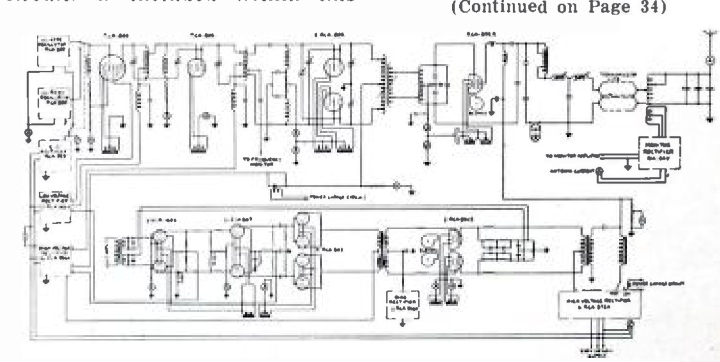
The 845's in turn are driven by 807's which are similar to the 6L6 in operating voltage and characteristics. The high mutual conductance, together with low input capacity makes these tubes ideal for the purpose. The voltage gain in this stage is approximately 22 into a 5000 ohm resistance load. In order to secure sufficient gain to utilize the full feed-back capabilities of the system it is necessary to use still another stage of amplification so that the transmitter required input would be below zero level. The tubes selected for this position are 1603's. They are similar to the 6C6 and are especially designed for low hum. These tubes are operated as pentodes with a 10,000 ohm load. The gain of this stage is approximately 10. The low capacities involved and the low plate load give this stage an extremely good frequency characteristic.

Each stage of the audio system is designed for a particular transmission characteristic in order that the overall results will permit automatic stabilization of the feed-back loop. This loop includes all circuit elements between the secondary of the audio input transformer and the plate circuit of the modulators. The transmission characteristics within this loop is nearly perfect from zero to over three megacycles. No portion of the radio frequency circuits is included within this loop, eliminating any need for a feed-back rectifier.

To summarize, the features of this modulator that make it so desirable for use in broadcast transmitter applications are its high efficiency, low distortion and high signal to noise ratio. The higher efficiency results from operation of the final Class B stage biased to cut off. The normal plate current for these tubes (891R) when operated without feed-back must be of the order of 300 ma. per tube if the distortion contributed by the Class B stage is to be reasonably low. With a plate voltage of 8500 volts the power input would be 5 KW. Without feed-back, therefore, the no signal tube input to a complete 5 KW transmitter would be approximately 21 KW instead of 16 KW as required for the 5-DX. The feed-back results in a signal-to-hum ratio of 70 db. with single phase, 60 cycle heating of the 891-R filaments. The single phase filament heating results in a definite simplification of the circuits that control the filament step-starting and the operating potential.

Every effort has been made to segregate the relay controls from the transmitter units and to provide centralized mounting in a single power control panel. The latest type high speed overload relays of the General Electric PAC type have been used. The main line and rectifier power lines are protected by Deion breakers. The Deion type breaker has also been used for all branch circuit protection and isolation. No fuses are used throughout the transmitter. In addition to this equipment the power control panel carries facilities for individual con-

(Continued on Page 34)



Simplified Schematic Diagram of the 5-DX Transmitter.

WMBI DEDICATES NEW STUDIOS

RCA Equipment Featured in Chicago Station

H. Coleman Crowell, Director of WMBI.

WITH five studios in the tower of the beautiful new twelve-story Administration Building, WMBI, the Radio Voice of the Moody Bible Institute of Chicago, now ranks as one of the best equipped non-commercial stations in the United States.

The $100,000 studios and offices which occupy the tenth, eleventh and twelfth floors of the Bible School's main building, were dedicated with the new $270,000 structure at an impressive ceremony February 4, 1939 in the Institute's new Torrey-Gray Auditorium. About 5000 visited the studios during Dedication Week.

Trustees, officials, faculty, students and an over-flow crowd of nearly 3000 heard Dr. Will H. Houghton, Institute President, broadcast the dedicatory address. Dr. Houghton is well known to many radio listeners through the Sunday afternoon "Let's Go Back to the Bible" program, which is released by network at eleven stations in the East and Middle West, the program featuring a men's octet and originating in WMBI studios.

Four of the new studios are grouped about the master control room, from which all are visible. Using the latest type of RCA equipment in duplicate, dual channel operation has been provided of high fidelity design, the studios have had unique acoustical treatment in which several types of materials were employed. Floating floor and wall construction insures sound isolation. The practical results have proved that earlier theoretical calculations were correct.

The equipment has been designed to permit recording of any program produced in the various studios. Other features include control of the lighting system from the control room, a special private automatic telephone system, and microphone and monitor outlets on all twelve floors of the new building. Control engineers may dip the lights when they desire to signal occupants and performers in any studio.

WMBI Transmitter Station at Addison, Ill.

Studio A, 23 by 39 feet and two stories high, is used for orchestras, choirs, and general purposes. It has an observation gallery seating 75 people. Studio B, 21 by 39 feet, is equipped with a Kimball organ built especally for radio work. Studio C, a smaller room, is used by speakers, announcers, and round-table groups. Studio D is designed for instrumental and solo work, while Studio E, not visible to the public or from the master control room, is planned for speakers and auditioning.

A. P. Frye, chief engineer, designed the studios and supervised the construction. Under his direction, the WMBI engineering staff installed the new studio

(Continued on Page 33)

Looking out of the RCA Equipped Control Room into Studio A. An Institute student program is in progress.

DIRECTIONAL ANTENNAS

A Development of Analytical Method Applicable to General Problems in Array Design

DR. G. H. BROWN

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VII. A Transmitting Antenna With a Number of Parasitic Elements

The foregoing procedure is readily applicable to the analysis of a system containing more than one parasitic element. The treatment is carried through simply as a number of coupled circuits with complex mutual impedances. Let us attack a specific example. Nagy[12] gives the horizontal polar diagram of an antenna and three

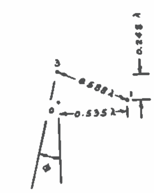


Fig. 43

parasitic reflectors arranged as shown in Fig. 43. The circuit equations are

$$\left.\begin{aligned} \bar{E}_0 &= \bar{I}_0\bar{Z}_{00} + \bar{I}_1\bar{Z}_{10} + \bar{I}_2\bar{Z}_{20} + \bar{I}_3\bar{Z}_{30} \\ 0 &= \bar{I}_0\bar{Z}_{01} + \bar{I}_1\bar{Z}_{11} + \bar{I}_2\bar{Z}_{21} + \bar{I}_3\bar{Z}_{31} \\ 0 &= \bar{I}_0\bar{Z}_{02} + \bar{I}_1\bar{Z}_{12} + \bar{I}_2\bar{Z}_{22} + \bar{I}_3\bar{Z}_{32} \\ 0 &= \bar{I}_0\bar{Z}_{03} + \bar{I}_1\bar{Z}_{13} + \bar{I}_2\bar{Z}_{23} + \bar{I}_3\bar{Z}_{33} \end{aligned}\right\} . \quad (128)$$

From symmetry,

$$\left.\begin{aligned} \bar{I}_1 &= \bar{I}_2 \\ \bar{Z}_{01} &= \bar{Z}_{02} \\ \bar{Z}_{13} &= \bar{Z}_{23} \end{aligned}\right\} \quad (129)$$

so that (128) becomes

$$\left.\begin{aligned} \bar{E}_0 &= \bar{I}_0\bar{Z}_{00} + 2\bar{I}_1\bar{Z}_{01} + \bar{I}_3\bar{Z}_{03} \\ 0 &= \bar{I}_0\bar{Z}_{01} + \bar{I}_1[\bar{Z}_1 + \bar{Z}_{12}] + \bar{I}_3\bar{Z}_{13} \\ 0 &= \bar{I}_0\bar{Z}_{03} + 2\bar{I}_1\bar{Z}_{13} + \bar{I}_3\bar{Z}_{33} \end{aligned}\right\} . \quad (130)$$

In this case.

$$\bar{Z}_{00} = 36.6$$
$$\bar{Z}_{01} = 15.3 \angle -129°$$
$$\bar{Z}_{03} = 25.7 \angle -33°$$
$$\bar{Z}_{13} = 14.3 \angle -147°$$
$$\bar{Z}_{12} = 10.4 \angle +51°.$$

Placing these numerical values in (130) and solving,

$$\bar{I}_1/\bar{I}_0 = \bar{I}_2/\bar{I}_0 = +0.307 \angle +95°$$
$$\bar{I}_3/\bar{I}_0 = +0.929 \angle +142.5°.$$

When these values are placed in the first equation of (130), we find the impedance measured at the terminals of antenna 0 to be

$$\frac{\bar{E}_0}{\bar{I}_0} = [Z_{00} + 0.614 \times 15.3 \angle -34° + 0.929 \times 25.7 \angle +109.5°].$$

The resistance is then

$$R_0 = 36.6 + 7.8 - 7.95 = 36.45 \text{ ohms}$$

and the reactance is +17.15 ohms.

Then the current in antenna 0, for the same power, will be practically unchanged whether the parasitic elements are present or not. The horizontal diagram, expressed in terms of the field of a single nondirectional antenna, is

$$F/F_0 = 1 + 0.929 \angle +142.5° - 89.5° \cos\phi + 0.614 \cos (192.8° \sin\phi) \angle +95°.$$

When $\phi = 0$ degrees,

$$F_F/F_0 = 2.02$$

while $\phi = 180$ degrees gives

$$F_B/F_0 = 0.41.$$

Fig. 44 shows $(F/F_0)^2$ plotted as a function of ϕ. The field intensity was squared so that it could be compared directly with

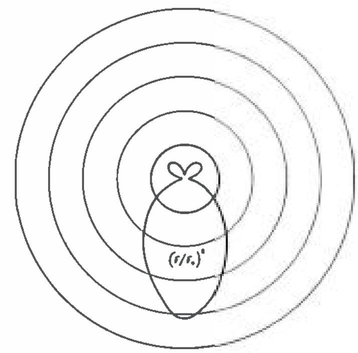


Fig. 44. The horizontal pattern of the array shown in Fig. 43.

the results of Nagy. His measurements were made using a square-law detector. Fig. 45 is a tracing of Nagy's Fig. 8. His curve shows a value of $(F/F_0)^2 = 3$ compared to 4.08 from a theoretical standpoint.

Fig. 45. Nagy's measurements for the array shown in Fig. 43.

VIII. Flat Sheet Reflectors

(a). *The Transmitting Case*

We shall next examine the action of the antenna shown in Fig. 46. The flat sheet is considered to be a perfect conductor, infinite in extent. Then the sheet may be replaced in effect by an image antenna as shown,

[12] A. Wheeler Nagy, "An experimental study of parasitic wire reflectors on 2.5 meters," Proc. I.R.E., vol. 24, p. 240, Fig. 8; February, (1936).

where the current in the image is equal to the main antenna current and in phase opposition. The field at P due to the antenna is

$$\bar{F}' = j\frac{60 I_0}{r_0}\epsilon^{-jkr_0}. \tag{131}$$

The image contributes

$$\bar{F}'' = j\frac{60 I_1}{r_1}\epsilon^{-jkr_1} = -j\frac{60 I_0}{r_1}\epsilon^{-jkr_1}. \tag{132}$$

The total field is then

$$\bar{F}_T = j\frac{60 I_0}{r}\epsilon^{-jkr}\left[\epsilon^{+jkx} - \epsilon^{-jkx}\right] \tag{133}$$

or,

$$|F_T| = \frac{60 I_0}{r}(2 \sin kx). \tag{134}$$

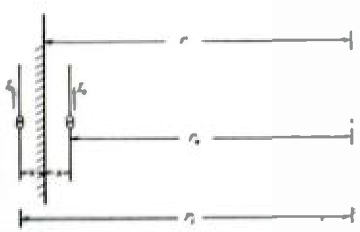


Fig. 46

At the terminals of the antenna

$$\bar{V}_0 = \bar{I}_0\bar{Z}_{00} + \bar{I}_1\bar{Z}_m = \bar{I}_0[\bar{Z}_{00} - \bar{Z}_m]. \tag{135}$$

The resistance of the antenna is then

$$R_0 = R_{00} - R_m \tag{136}$$

while the reactance is

$$X_0 = X_{00} - X_m \tag{137}$$

For a power, P_1 watts,

$$F_T = \frac{60}{r}\sqrt{\frac{P_1}{R_{00} - R_m}}(2 \sin kx). \tag{138}$$

With the sheet absent, and the same power, the antenna produces a field

$$F_0 = \frac{60}{r}\sqrt{\frac{P_1}{R_{00}}} \tag{139}$$

so that the gain ratio is

$$|F_T/F_0| = \frac{2 \sin kx}{\sqrt{1 - R_m/R_{00}}}. \tag{140}$$

On Fig. 47, F_T/F_0 is plotted as a solid curve while the two broken curves show the quantities, 2 sin kx and $1/\sqrt{1 - R_m/R_{00}}$. It is interesting to note that nothing particularly exciting happens when the spacing is one-quarter wave length.

The Value of R_m as obtained from Fig. 7 must be doubled since the present antenna is one-half wave long. Also d/λ on Fig. 7 is $2x/\lambda$ in our present calculations.

The shape of the horizontal polar diagrams are found by inspecting the lower row of figures on Fig. 15. The flat sheet reflector of course yields a unidirectional pattern.

(b). The Receiving Case

Let us now suppose that the antenna in front of the sheet is a reciving antenna. A transmitter is placed at P. The field at the receiving antenna due to the transmitter at P is

$$\frac{A}{r_0}\angle - kr_0 \doteq \frac{A}{r}\angle - kr \angle + kx. \tag{141}$$

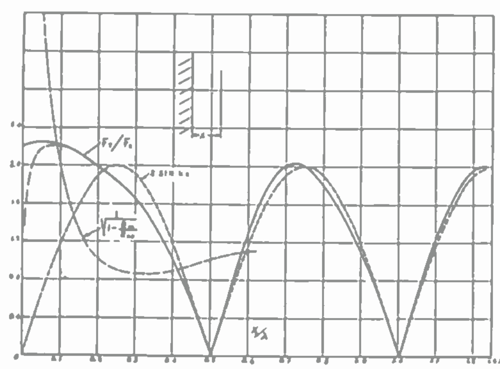


Fig. 47. A transmitting antenna in front of a flat sheet.

The broken curve at the extreme left of Fig. 47 shows the effect of slight losses. We have assumed the antenna to consist of a metallic conductor with an effective loss resistance of 0.5 ohm so that R_{00} is 73.2 + 0.5 = 73.7 ohms.

The field at the receiving antenna due to the transmitter image is

$$-\frac{A}{r_0'}\angle - kr_0' \doteq -\frac{A}{r}\angle - kr \angle - kx. \tag{142}$$

(Continued on Page 30)

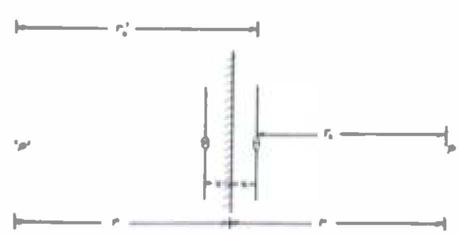
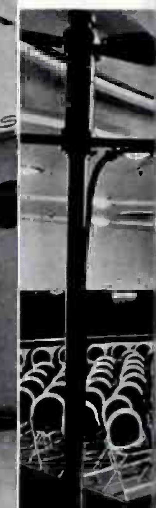


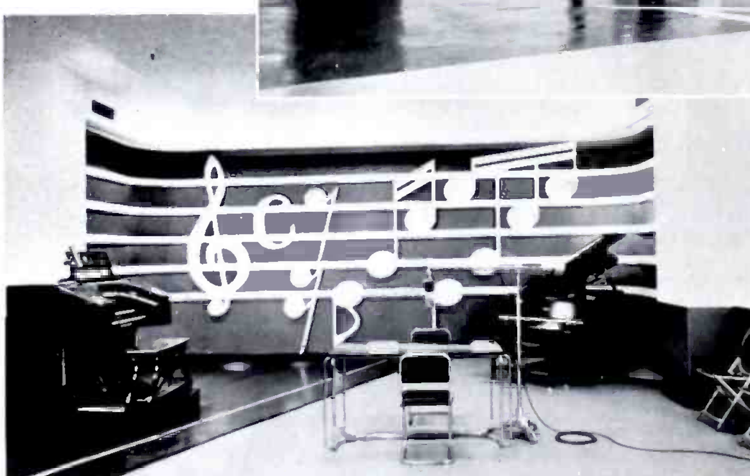
Fig. 48

MODERN IS THE WORD

Right: Reception Lobby at WMCA. The nautical design of this spacious room prevails throughout the studios.

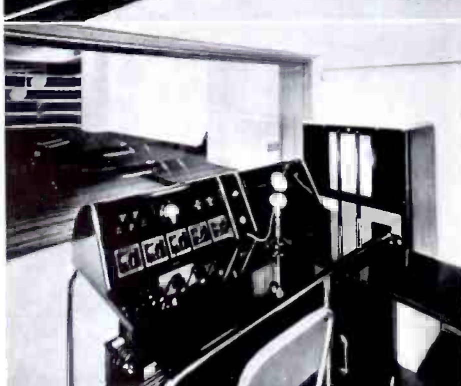
Below: B
Boom Sta
capacity o





Left: The Organ Studio has been acoustically designed to transmit the vibrant tones of the instrument with each tone at its best.

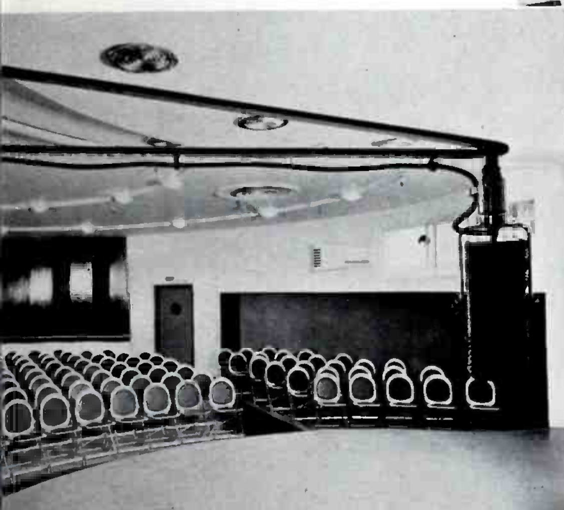
Below: Studio Five, second largest in WMCA, airs many of the larger programs. It easily accommodates a large cast and an audience.



Above: One of the RCA Control Desks which are installed in each Studio Control Room.

OR NEW YORK'S WMCA

tage view of the Theatre-Studio framed by RCA
nd 44BX Microphone. This studio has a seating
persons and will be used for major broadcasts.



Above: The Master Control Room of WMCA is RCA equipped. This control room is one of the most modern and up-to-date rooms in the country.

Left: One of the smaller studios at WMCA.

Below: Special Announce Booth which is equipped with RCA Microphone and 70-B Turntable.

Left: Studio Three was designed primarily for the comfort of the artists utilizing its facilities. Its typical design is carried out in all studios.

UNI-DIRECTIONAL MIKE

(Continued from Page 5)

Efficiency =

$$\frac{2\pi e_0^2 \int_0^\pi [(\cos^2\theta + 2\cos\theta\cos\phi + \cos^2\phi) + \sin^2\phi]\sin\theta\, d\theta}{16\pi e_0^2}$$

$$= \frac{2\pi e_0^2 \int_0^\pi [\cos^2\theta + 2\cos\theta\cos\phi + 1]\sin\theta\, d\theta}{16\pi e_0^2}$$

$$= \frac{1}{3}$$

As in the case of a finite separation, the efficiency is the same as in the case of no phase angle shift.

Fundamental Resonance Frequency of the Ribbon

The ribbon is clamped at the ends and, therefore, the system is a combination of a stretched string and a bar clamped at the two ends. In the case of a very short ribbon it is difficult to obtain a low resonance frequency. The lowest resonance frequency will be obtained when the tension is zero. Then the problem is that of a bar clamped at the two ends. The resonance frequency is given by

$$f = \frac{3.56}{l^2}\sqrt{\frac{QK^2}{\rho}}$$

where

l = length,
ρ = density,
K = radius of gyration and
Q = Young's modulus

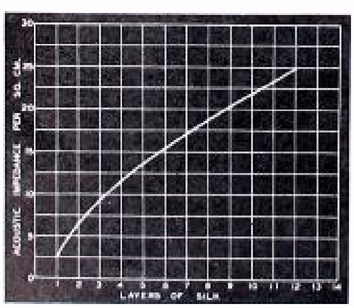


Fig. 5. The acoustic resistance of a sheer silk per square centimeter of layers.

For an aluminum ribbon of thickness .0001 inches the radius of gyration $K = 7.3 \times 10^{-5}$. The modulus of elasticity for aluminum is $Q = 5 \times 10^{11}$ dynes per square centimeter. (Note: the values of Q for aluminum vary considerably.) The density ρ of aluminum is 2.7. However, we have an air load to add which is approximately ½ the mass of the ribbon so $\rho = 4.0$ approximately. The resonance frequency for a conventional ribbon is

$$f = \frac{93}{l^2}$$

where l is in centimeters.

The resonance frequency for various lengths follows:

Length inches	Length centimeters	Resonance Frequency
¼	.63	234
⅜	.95	103
½	1.27	58
¾	1.90	26
1	2.54	14
1.5	3.81	6.4
2.0	5.08	3.6

When the ribbon is corrugated it is possible to reduce the tension so that it is negligible compared to stiffness at the ends. The above values indicate the lowest frequency that it is possible to obtain with a corrugated clamped ribbon. These values check very closely to the experimental results obtained for ribbons from ½ to 1¼ inches in length. For a ½ inch ribbon the resonance frequency is about 60 cycles. This is within the audible spectrum and other means must be employed to eliminate the deleterious effects of resonance.

In the case of a ribbon 2 inches in length, the frequency shown above is 3.6 cycles. For a ribbon of this length some tension must be introduced to keep the ribbon in the air gap when the ribbon is in a horizontal position. In general, the resonance frequency of the standard velocity microphone due to stiffness and tension is 10 to 15 cycles. Therefore, the resonance of the ribbon is not a problem in the large microphones. However, in the case of small microphones the length of the ribbon has been one of the limiting factors. When the resonance frequency falls within the audible spectrum the response to both sound and shock is accentuated. It has been found possible to control this resonance by means of an acoustic impedance consisting of a single layer of silk. Silk as an acoustic impedance will be considered in the next section.

Acoustic Resistance of Silk

Silk was first used as a resistance element in the inductor microphone. Since then it has been used in several different acoustical systems both by the RCA and others. The resonance frequency of the velocity ribbon is 60 cycles. This occurs within the audible spectrum and is, therefore, objectionable. By inserting an impedance consisting of a layer of silk over the velocity ribbon, the resonance is reduced in both amplitude and frequency due to the addition by the silk of resistance and positive reactance. The reactance value can be determined from the difference in resonance frequency. The resistance can be determined from direct current flow of air.

The acoustic resistance is given

$$R = \frac{p}{U}$$

where

p = pressure in dynes per square centimeter,
U = flow of air in cubic centimeters per second.

The acoustic resistance of a very sheer silk determined from direct current measurements is shown in Fig. 5.

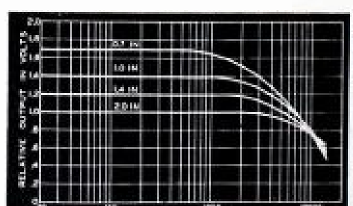
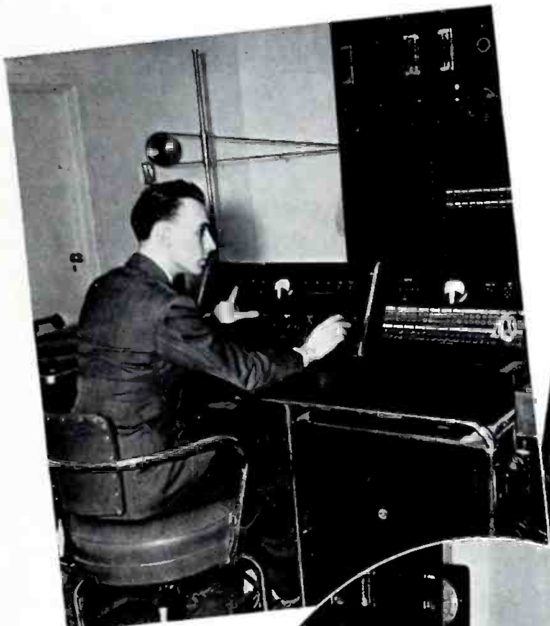


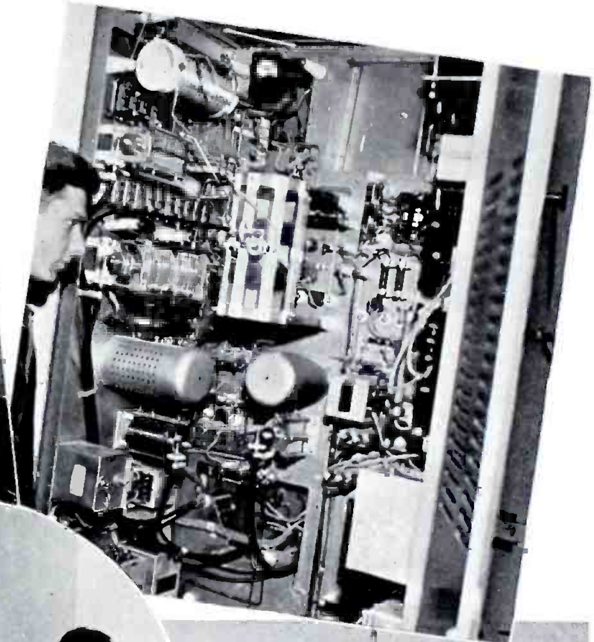
Fig. 6. The relative output in volts of a pressure ribbon microphone system of the type shown in Fig. 1 for ribbon lengths of 0.7, 1.0, 1.4 and 2.0 inches all terminated in the same acoustical impedance and all referred to the same electrical impedance.

(Continued on Page 22)

INSIDE A COMMUNITY STATION WDAN DANVILLE, ILL.



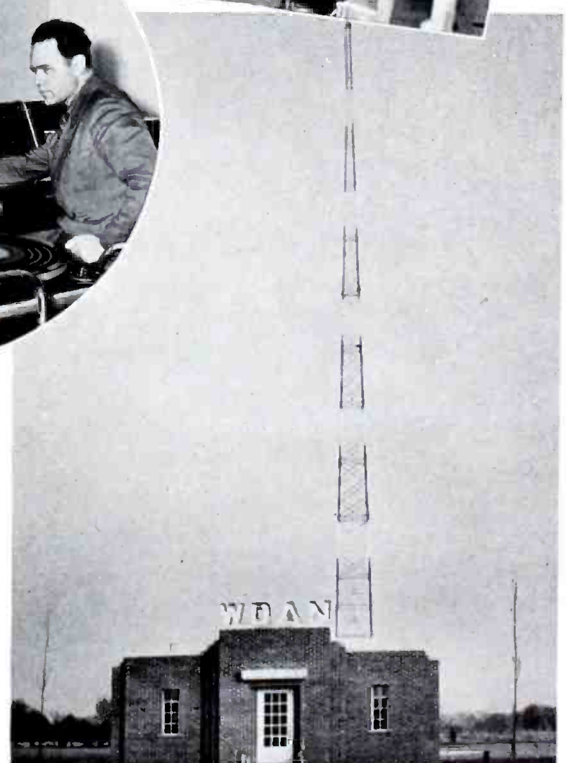
Below: Bill Crist, engineer at WDAN, inspects the vertical construction of the 250D transmitter.



Above: Charles Sebastian of WDAN, Danville, Ill., at the RCA 80-A Control Desk. Studio is RCA equipped throughout.

Right: Perry Esten, chief engineer of WDAN at the RCA transcription turntables.

The RCA 250D transmitter in operation at WDAN.



The Woodlawn transmitter house and 321 foot tower.

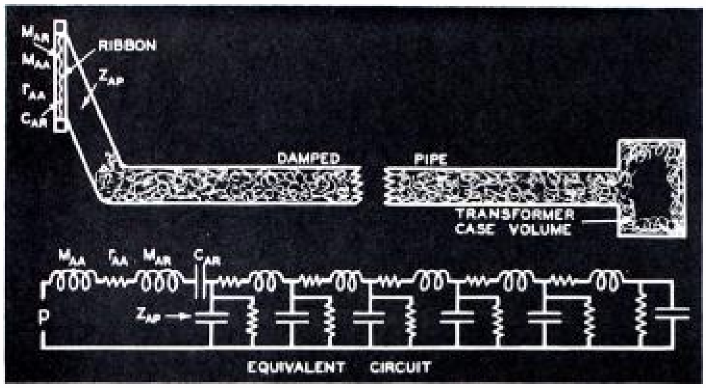


Fig. 7. The elements of the pressure microphone and the equivalent circuit of the acoustical system. M_{AR} inertance of the ribbon. C_{AR} acoustic capacitance of the ribbon. r_{AA} acoustic resistance of the air load on the ribbon. M_{AA} inertance of the air load upon the ribbon. Z_p acoustic impedance of the pipe terminating the ribbon. p driving sound pressure.

UNI-DIRECTIONAL MIKE

(Continued from Page 20)

Sensitivity of a Microphone Consisting of a Ribbon Terminated in an Acoustic Impedance

We will consider the system used in this microphone which consists of a ribbon operating in an air gap of 1/10 of an inch and terminated in a pipe ⅜ inch in diameter. It will be assumed that the acoustic impedance terminating is a pure acoustic resistance of $\frac{42}{A}$ where A is the area of the pipe in square centimeters. This in practice is true except at the very low frequencies, which are not of any concern in the problem at hand. The question is the sensitivity as a function of the length of the ribbon.

The velocity of the ribbon is

$$\dot{X} = \frac{p}{A(r_{AP} + r_{AA} + j\omega M_{AR} + j\omega M_{AA})}$$

where

r_{AP} = acoustic resistance of the pipe.
r_{AA} = acoustic resistance of the air load.
M_{AR} = inertance of the ribbon.
M_{AA} = inertance of the air load.
p = sound pressure, and
A = area of the ribbon.

The open circuit voltage output is

$$e = Bl\dot{X}$$

where

B = flux density, and

l = length of the ribbon in centimeters.

Since the step-up ratio that can be used in a transformer depends upon the resistance of the ribbon, the voltage output must be divided by the square root of the resistance or the length to compare various lengths of ribbon.

The inertance of the ribbon and air load for ribbons of length .7, 1, 1.4, and 2 inches is shown in Fig. 6. The resistance of the pipe is also shown. The resistance due to the air load may be neglected. The relative outputs of these four ribbons for the same flux density are shown in Fig. 6. It will be seen that greater output can be obtained with the shorter ribbon. The output is even larger than shown when cognizance is taken to the fact that the flux density will be greater for the shorter ribbon if the same amount of magnet material is used. In the case of the .7 inch, the loss in high frequencies is too great. However, the loss in the case of the one inch ribbon is approximately the right amount to compensate for the increased pressure on the front of the higher frequencies. Note that these characteristics are for constant sound pressure. Actually the sound pressure is doubled at the high frequencies from 8000 cycles upward.

The Pressure or Non-Directional Microphone

The sensitivity of the pressure microphone for various ribbon dimensions and terminating the ribbon has been considered in a preceding section. These considerations assumed that the ribbon was terminated in a pure resistance. If we use a finite pipe these conditions can be satisfied at the high frequencies. However, at the low frequencies there will be a reactive component due to the finite length of the pipe. A schematic of the vibrating system and the equivalent electrical circuit of the acoustical system of the pressure section of the development microphone (Fig. 1) is shown in Fig. 7. Wihout damping, the pipe and volume resonate at 62 cycles. By suitable damping it is possible to present a constant resistance to a very low frequency. The measured impedance is shown in Fig. 7.

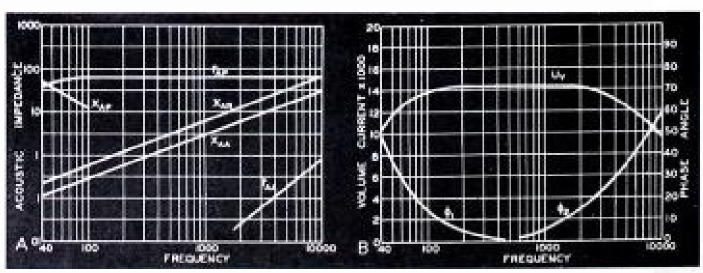


Fig. 8. A. The impedance characteristics of the elements of the pressure microphone. X_{AR} ribbon acoustic reactance. X_{AA} air load acoustic reactance. r_{AA} air load acoustic resistance. X_{AP} pipe acoustic reactance (negative) r_{AP} pipe acoustic resistance.
B. The volume current U_2 of the pressure ribbon for a sound pressure of one dyne per square centimeter. ϕ phase angle between the ribbon velocity and the driving pressure. ϕ_1 lagging ϕ_2 leading.

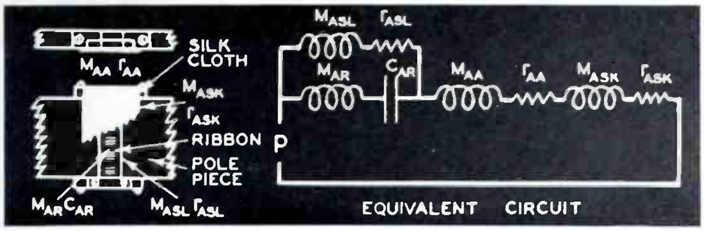


Fig. 9. The elements of the velocity microphone and the equivalent electrical circuit of the acoustical system. M_{AR} inertance of the ribbon. C_{AR} acoustic capacitance of the ribbon. M_{ASL} inertance of the slit between the ribbon and pole pieces. r_{ASL} acoustic resistance of the slit between the ribbon and pole pices. M_{AA} inertance of the air load upon the ribbon. r_{AA} acoustic resistance of the air load upon the ribbon. M_{ASK} inertance of the silk covering the ribbon. r_{ASK} acoustic resistance of the silk covering the ribbon. p driving sound pressure.

This shows almost a pure resistance above 100 cycles. However, below 100 cycles there is a capacitive component.

The velocity of the ribbon is given by

$$\dot{X} = \frac{p}{A}\left[\frac{1}{j\omega M_{AR} + r_{AA} + j\omega M_{AA} + \frac{1}{j\omega C_{AR}} + Z_{AP}}\right]$$

where

$p =$ sound pressure on the ribbon,
$A =$ area of the ribbon,
$M_{AR} =$ inertance of the ribbon,
$r_{AA} =$ acoustic resistance of the air load,
$M_{AA} =$ inertance of the air load,
$C_{AR} =$ capacitance of the ribbon,
$Z_{AP} =$ impedance of the pipe terminating the ribbon. bon, and

The constants of the microphone shown in Fig. 1 are shown in Fig. 8.

The volume current $U_V = \dot{X}_A$ of the ribbon is shown in Fig. 8. The phase angle between the actuating sound pressure and velocity of the ribbon is also shown in Fig. 8.

The Velocity or Bi-Directional Unit

A schematic and equivalent electrical circuit of the acoustical system of the velocity unit of the development microphone of Fig. 1 is shown in Fig. 9. The velocity of the ribbon is given by

$$\dot{X} = \frac{\Delta p}{A}\left[\frac{1}{\frac{(r_{ASL} + j\omega M_{ASL})(1 - \omega^2 M_{AR} r_{AR})}{1 - \omega^2 M_{AR} C_{AR} + j\omega C_{AR}(r_{ASL} + j\omega M_{ASL})} + r_{AA} + j\omega M_{AA} + r_{ASK} + j\omega M_{ASK}}\right]$$

where

$M_{AR} =$ inertance of the ribbon,
$C_{AR} =$ capacitance of the ribbon,
$M_{ASL} =$ inertance of the slit between the ribbon and pole pieces,
$r_{ASL} =$ resistance of the slit,
$M_A =$ inertance of the air load,
$r_{AA} =$ resistance of the air load,
$M_{ASK} =$ inertance of the silk,
$r_{ASK} =$ resistance of the silk, and
$p =$ difference pressure between the two sides.

In order to obtain the maximum efficiency, it is desirable to make the impedance of the slit between the ribbon pole pieces very high compared to the other impedances. This is possible without much difficulty. In this case the velocity is given by

$$\dot{X} = \frac{\Delta p}{A}\left[\frac{1}{j\omega M_{AR} + \frac{1}{j\omega C_{AR}} + r_{AR} + j\omega M_{AA} + r_{ASK} + j\omega M_{ASK}}\right]$$

The values of the impedances for the microphone shown in Fig. 1 are shown in Fig. 10. The velocity of the ribbon computed from the

(Continued on Page 36)

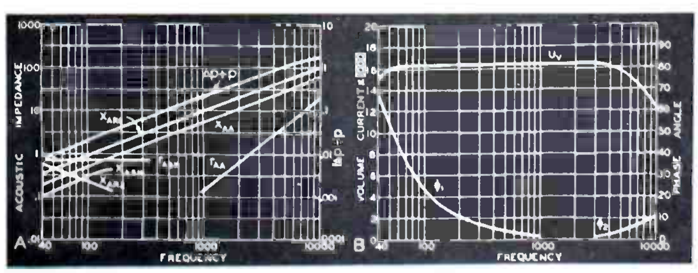


Fig. 10. A. The impedance characteristics of the elements of the velocity microphone. X_{AR1} ribbon acoustic reactance (positive) X_{AR2} ribbon acoustic reactance (negative). X_{AA} air load acoustic reactance. r_{AA} air load acoustic resistance. X_{ASK} silk acoustic reactance. r_{ASK} silk acoustic resistance. $\Delta p / p$ the ratio of the difference in pressure between the two sides of the ribbon and the free space pressure.

B. The volume current U_V of the velocity ribbon for a sound pressure of one dyne per square centimeter. ϕ phase angle between the ribbon velocity and the difference in pressure between the two sides of the ribbon. ϕ_1 and ϕ_2 are both leading.

SIMPLIFIED NETWORK SYNTHESIS

Building Circuits to Specified Performance Requirements

By EDMUND A. LAPORT

Continued from the last issue.

Type II Problem

Problem—We desire to couple a load circuit having an impedance of $Z_0 = 75 - j\,30\omega$ to a circuit which requires a terminating impedance of $Z_{in} = 600 + j\,150\omega$. The transformation, let us say, must be made with a phase difference between the *load current* and the *input current* of plus 60°. What is the network design required?

Procedure—The problem is set up in vector form first, on the basis that power input equals power output so that only reactive elements are required.

Let $I_0 = 1.0$ amp.

Then $E_{0R} = 75\ V$

and $E_{0x} = j30$ v

$E_0 = 81.3\ V$

Power in load = 75 watts

Power input = 75 watts

$$E_{inR} = \sqrt{75 \times 600} = 222\ V$$

$$I_{in} = \sqrt{\frac{75}{600}} = 0.354\ A$$

$$E_{inx} = 0.354 \times j\,150 = 53\ V$$

$$E_{in} = 233\ V$$

To solve for the network required to make the indicated transformation, complete the vector diagram and obtain therefrom the nature and magnitude of the required reactances. There is a choice between a π and T network.

Let us illustrate by assuming a T network. Draw the circuit and label all potentials and currents.

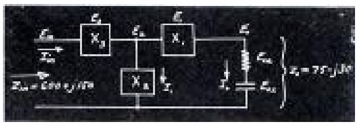


Fig. 17

$$Z_0 = \frac{E_0}{I_0} = \frac{E_{0r} - jE_{0x}}{I_0}$$

$$Z_{in} = \frac{E_{in}}{I_{in}} = \frac{E_{inR} + j\,E_{inx}}{I_{in}}$$

E_1 is drawn in a direction perpendicular to I_0, starting at E_0.

E_3 is drawn in a direction perpendicular to I_{in}, through E_{in}.

The intersection of these perpendiculars locates the lengths of E_1, E_2 and E_3. Draw E_2 from the origin to the intersection. As a check on accuracy, measure the angle between I_1, and E_2, which should be 90°.

As before, I_1 is drawn to connect I_0 and I_{in}.

Now

$E_0 = 81\ V$; $I_0 = 1.0\ A$

$E_1 = 184\ V$; $I_1 = 0.875\ A$

$E_2 = 230\ V$; $I_{in} = 0.354\ A$

$E_3 = 93\ V$;

$E_{in} = 233\ V$

$$X_1 = \frac{E_1}{I_0} = \frac{184}{1.0} = -j\,184\omega$$

$$X_2 = \frac{E_2}{I_1} = \frac{230V}{0.875} = j\,263\omega$$

$$X_3 = \frac{E_3}{I_{in}} = \frac{93}{0.354} = j\,263\omega$$

The network becomes

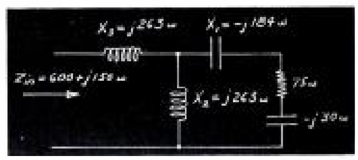


Fig. 19

Solving this same problem on the basis of a π network we get

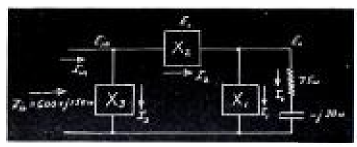


Fig. 20

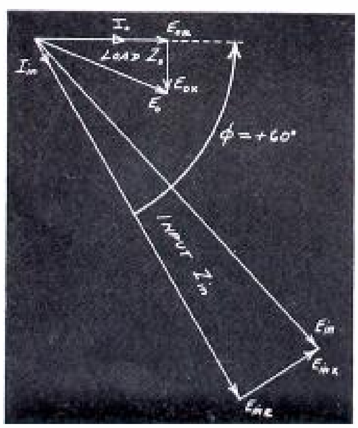


Fig. 16

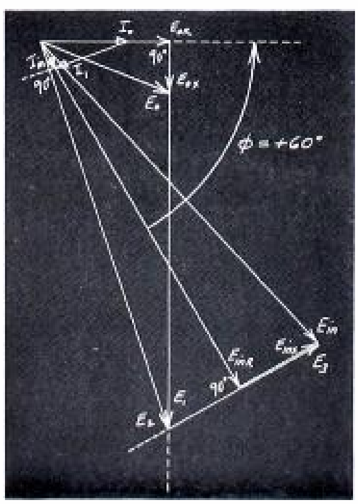


Fig. 18

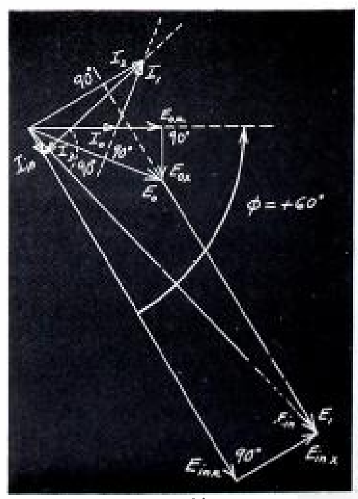


Fig. 21

Tabulating values from vector scales

$E_0 = 81\ V; \quad I_0 = 1.0\ A$
$E_1 = 159; \quad I_1 = 0.72$
$E_{in} = 233; \quad I_2 = 1.47$
$I_3 = 1.50$
$I_{in} = 0.354$

Now

$$X_1 = \frac{E_0}{I_1} = \frac{81}{0.72} \quad -j\,133\omega$$

$$X_2 = \frac{E_1}{I_2} = \frac{159}{1.47} = -j\,108\omega$$

$$X_3 = \frac{E_{in}}{I_3} = \frac{233}{1.5} = j\,155\omega$$

The circuit becomes

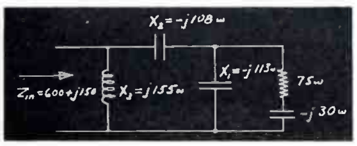


Fig. 22

Extreme Case of a Type II Problem

Problem—Calculate the required elements of a network which will make a transformation from 1500 + j 300 (load) to 300 + j 400, so that the potential across the load is in phase with the input potential.

Vector statement of this problem is, after resolving the input and load potentials into their resistive and reactive components on the basis of equality of power input and output, shown below with the scales chosen (e.g. —1^{in} = 1.0 ampere and 1^{in} = 500 V.)

$$E_{inR} = 1500 \times 300 = 670\ V$$

$$I_{in} = \frac{1500}{300} = 2.24\ A$$

$$E_{inx} = 2.24 \times 400 = 893\ V.$$

$$E_{in} = 670 + j893 = 1118V.$$

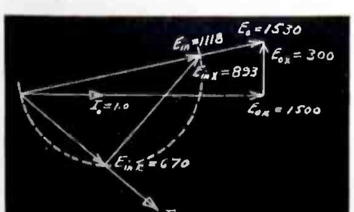


Fig. 23

This shows E_{in} in phase with E_0 as required, and the relative directions of I_0 and I_{in}. It also is marked to show the potentials and currents prevailing in the load and for the input to the network. From this point, the vector diagram must be completed for either a π or T network. We shall demonstrate both and compare them.

π-Network

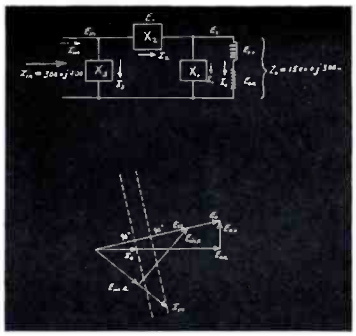


Fig. 24

Because E_0 and E_{in} are in phase I_1 and I_3, being perpendicular to a common line, would be parallel, and never intersect. A solution with a π network is therefore impossible.

NOTE: If the problem had specified that the load and input currents be in phase, then a π solution would have been possible but a T solution impossible.

T-Network

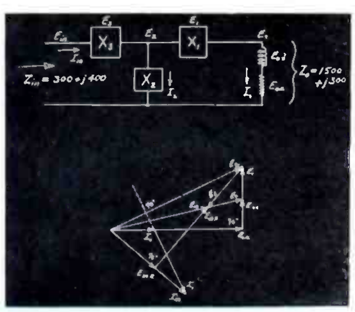


Fig. 25

This type network provides a a solution for the problem.

$E_0 = 1530\ V \quad I_0 = 1.0$

$E_1 = 364 \quad I_1 = 1.62$

$E_2 = 1575 \quad I_{in} = 2.24$

$E_3 = 603$

$E_{in} = 1118$

$$X_1 = \frac{E_1}{I_0} = \frac{364}{1.0} = j\,364\omega$$

$$X_2 = \frac{E_2}{I_1} = \frac{1575}{1.62} = j\,968\omega$$

$$X_3 = \frac{E_3}{I_{in}} = \frac{603}{2.24} = -j\,270\omega$$

The network is

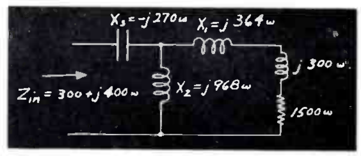


Fig. 26

Type III Problem

Problem: What elements are required for a phase-shifting network which will introduce a phase shift of —120° in a circuit having a characteristic impedance of 100 ohms of resistance?

Procedure: Wire the problem vectorially as follows:

Because input impedance equals the load impedance, the input can

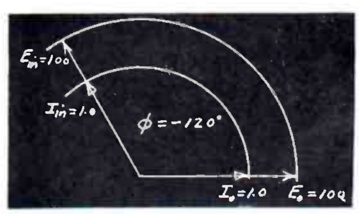


Fig. 27

be represented by the same vectors as those for the load, but with the specified phase difference.

Then, if we chose a T network, we erect perpendiculars through E_0 and E_{in}, and connect I_0 with I_{in}. The general circuit is set up, and the currents and potentials labeled as before, and the vector diagram completed in the same manner as in previous problems.

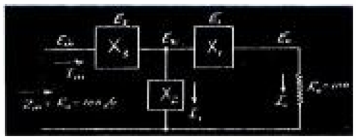


Fig. 28

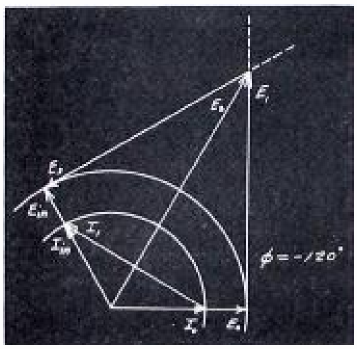


Fig. 29

From this we obtain

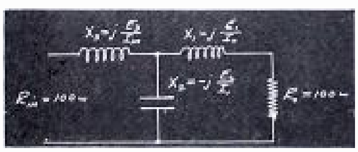


Fig. 30

Had we chosen the Pi solution, the vector diagram would have been

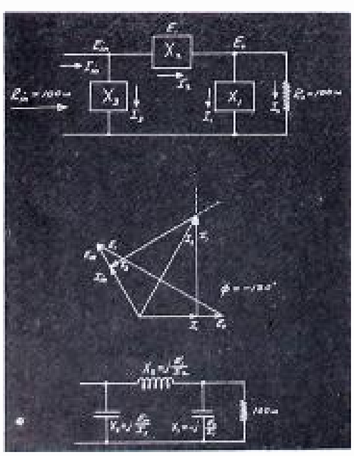


Fig. 31

A reversal of the phase angle in any problem reverses the signs of all the elements. For instance, in this problem, if the phase angle had been $+120°$, all elements would change from L to C and vice versa, maintaining the same numerical values.

A phase shifting network of this type is equivalent to a section of an infinite transmission line having a characteristic impedance R_0 and an electrical-length equal to that of the angle of phase shift, which in such cases must be negative. This provides a handy device to study certain properties of lines, such as the 45° and the 90° sections which have special properties. For example, how does the input impedance of a 45° section of a transmission line change with variation of the terminal resistance from 0 to ∞?

Solve for the equivalent single-stage network having a characteristic impedance R_0 when it is terminated in a resistance R_0 by assuming it to be a $-45°$ phase shifting network. (We illustrate with the T network).

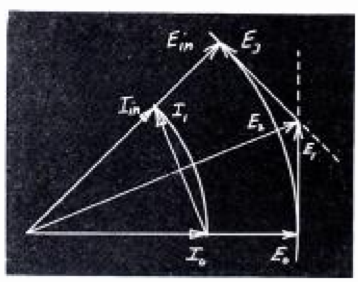


Fig. 32

Thus, assuming R_0 as unity, we obtain the ratio of all other elements to R_0. We can then assume any value of terminal resistance and calculate the resulting input impedance. We obtain

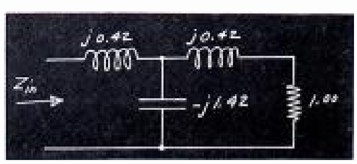


Fig. 33

The limiting conditions are quickly examined by assuming open-circuit and short-circuit terminal conditions. For the former, Z_{in} is the sum of $j0.42$ and $-j1.42$ which is $-j1.00$. For the latter, the solution for Z_{in} yields $+j1.00$. So we easily find that Z_{in} remains constant in magnitude for all conditions of resistance termination, but varies in character from pure capacitive reactance, through pure resistance to pure inductive reactance as the terminal resistance varies from ∞ to 0.

Proceeding in the same manner, the 90° network is analysed. Its special property of impedance inversion is worthy of digression to see why it works as it does. The vector diagram for $-90°$ T network with a characteristic impedance R_0 is

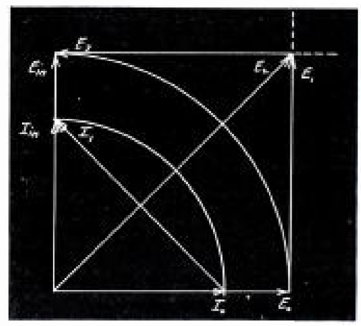


Fig. 34

From this we find the circuit elements, in terms of R_0 to be

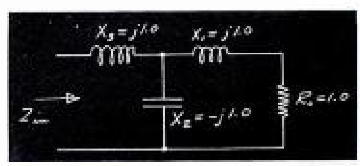


Fig. 35

All the elements of the network have reactances equal in magnitude to R_0. At this point we can test the circuit for open-and short-circuit terminal conditions and see what happens to Z_{in}. When $R_t = R_0$, $Z_{in} = R_0$. When $R_t = 0$, X_1 and X_2 in parallel give a condition of antiresonance and $Z_{in} = \infty$. When $R_t = \infty$, X_2 and X_3 in series tune to series resonance making $Z_{in} = 0$. Thus the boundary conditions of impedance inversion in a 90° network or transmission line section are demonstrated.

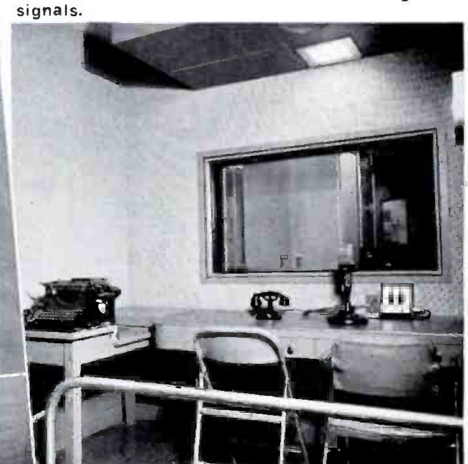
(Continued on Page 35)

LOOKING IN ON WCCO

Minneapolis, Minn.

LEFT: Attractive simplicity is the treatment accorded the office of WCCO's manager, Mr. Earl Gammons.

BELOW: Many of the WCCO local announcements come from the studio which looks out on the Master Control Room for interchange of signals.



LEFT: One of the the larger studios at WCCO. The observation booth can be seen at the left.

BELOW: The RCA 78-C equipment in the Control Room of Studio 1 at Columbia's WCCO.

LEFT: In addition to the CBS network control facilities, WCCO Master Control also contains two complete RCA 78-C studio equipments.

LACQUER DISC RECORDING

(Continued from Page 9)

provides a relatively sharp cut-off starting at 3,500 cycles and down 12 db at 5,000 cycles. Position 2 provides sharp cut-off at 5,000 cycles and down 12 at 7,000 cycles. Position 3 provides a long drooping characteristic starting down 3 db at 3,000 cycles to a point 6-8 db down at 8,000 cycles. Position 4 or out position provides the characteristic shown in Fig. No. 3.

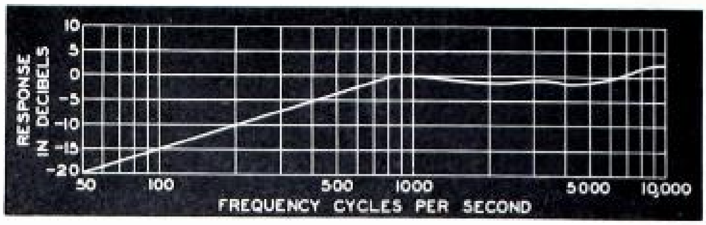


Fig. 5.

Recording Attachment

An improved 72-B recording attachment is available for use with the 70-B turntable. It can be easily adapted to the turntable and consists of a conventional lead screw drive driven from the center of the table. Improved features include greater thread clearance, one hand operation, greater balance spring length for more accurate adjustment, vertical adjustment of the stylus and a flutter eliminating stabilizer, Fig. No. 4.

The cutter head supplied with this equipment is known as MI-4881-A and covers a frequency range up to 6,000 cycles.

RCA will soon have on the market a high fidelity recording head (MI-4887) which has been designed to use in the 72-B mechanism and is interchangeable mechanically with the standard head (MI-4881-A). Slightly more power is required and an amplifier having at least 8 watts output is desirable to provide a safe margin for driving the cutter.

A typical response-frequency characteristic of the MI-4887 head is shown in Figure No. 5, and is based upon optical measurement of the stylus tip motion for constant input. It does not include transfer or needle losses which occur in both recording and reproduction and which are rather severe at high frequencies with low record surface speeds.

The MI-4887 recording head is a bandpass mechanical network terminated in a dry mechanical resistance material. The armature is of the balanced type and is centered by means of a tempered steel spring. The armature is supported on rugged knife edge bearings. Pole pieces are of nicaloi. To obtain the specified operating characteristic, it is necessary to use a sapphire stylus designated as the "short" type. Since the weight of a thumbscrew cannot be tolerated in a wide range head, a small clamping screw is provided which must be tightened with a small jewelers screw driver.

The unit is designed to be used with a fixed series resistance of 10 ohms. With this resistance, the total load impedance remains sufficiently close to 15 ohms throughout the frequency range.

Distortion in records made with this head should be extremely low. When distortion is observed, it can usually be attributed to overmodulation which results in failure of the reproducing stylus to follow the groove. The recorder is, of course designed to be capable of placing on the records undistorted amplitides much greater than normally required for full modulation. With improper monitoring or recording level, it is therefore possible to record steep wave slopes which the reproducer stylus will not follow. It should be noted that as the recording level is increased, tracking failure occurs before either the recorder or pickup head introduces distortion. See Fig. No. 6 for distortion curves.

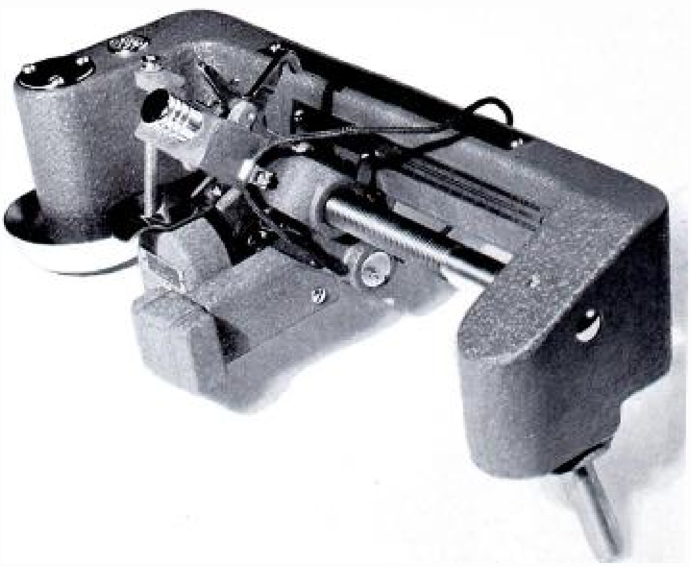


Fig. 4. The RCA 72-B Recording Attachment equipped with MI-4881A cutter head is available for use with the 70-B turntable.

Recording Problems

It is impractical to make a plain statement of the correct recording level for any head. While sensitivity of the heads does not vary more than about 2db, the correct level can be established only by experience and test. There are no fixed boundaries in disc recording representing 100% modulation. At very low frequencies, it is true that the groove spacing limits the amplitudes. At higher frequencies, the wave slope is the limiting factor. This slope varies with

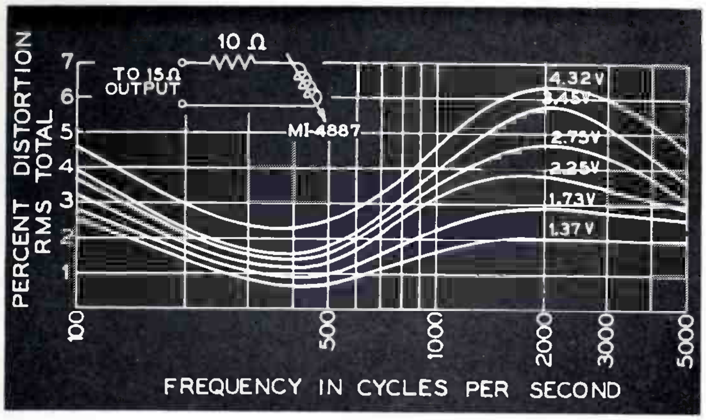


Fig. 6.

applied voltage and with record surface speed.

The correct maximum recording level therefore is governed by the subject matter being rceorded, the energy distribution with respect to frequency, whether pre and post equalization is being employed, whether high frequency needle loss compenation is used, the record surface speed, the type of pickup to be used, and how much distortion the user is willing to tolerate.

It is not difficult to find the correct operating levels for a given installation by making test cuts at the lowest record speed and smallest diameter to be used. These tests should be made at gradually increasing levels and the results noted upon reproducing. The proper volume indicator and attenuator settings can then be determined. In cases where an accidental change in gain of the recording amplifier is possible, a volume indicator or voltmeter should also be used at the output terminals.

As experience is acquired in making recordings, the quality of the reproduced sound will improve. The equipment is reasonably fool-proof and simple to operate. However, some skill is required to obtain the best results which it is capable.

Quality

The 72-B mechanism, when equipped with high fidelity head and when properly used, can consistently produce records equal in quality to the finest commercially produced transcription. This is an everyday occurrence in many installations. When such results are not obtained, the cause can usually be traced to some phase of the operating technique which is not being properly performed.

RCA blanks should be used.

Fig. 7. Damper assembly.

Recent improvements in formulation have produced a lacquer coating which is quieter, cuts more freely, has a longer wearing life and greater age stability. The discs stay fresh longer and while their storage in metal containers is still recommended, the useful life before cutting has been greatly extended. Waxing or lubrication at the time of cutting or afterward is no longer required. The thread clears well and the hazard of fouling the stylus has consequently been reduced.

The use of sapphire stylii is recommended for all recordings except unimportant tests. Initial cost is reasonable and the moderate charge for resharpening brings the cost per minute of recording equal to or below that for steel cutting points. Sapphires, if sharp and not chipped, produce a groove surface quieter by 6 db or more than steel stylii; furthermore, the groove shape is held more accurately.

Noise Tests

It is well to make surface noise tests and high frequency response measurements with all the stylii which are on hand to select those which produce quiet, clean cuts. There should be a reasonable number of spare points available to prevent unnecessary use of worn stylii. Noise tests from time to time will indicate the condition and degree of wear of the stylii. This can be accomplished by cutting unmodulated grooves with each and measuring the relative noise output, using the high fidelity pickup and a volume indicator preceded by a 1,000 c.p.s. high pass filter. This is done to exclude turntable rumble or other low frequency noise and hum, since it will be necessary to open the system gain considerably. High frequency response measurements on stylii can be made at one frequency, for example 8,000 c.p.s., and the relative reproduced output noted. For this test and the noise measurements, all recording should be done as closely as possible to the same diameter on the disc. The results change rapidly with surface speed.

Tests on stylii cannot be omit-

(Continued on Page 31)

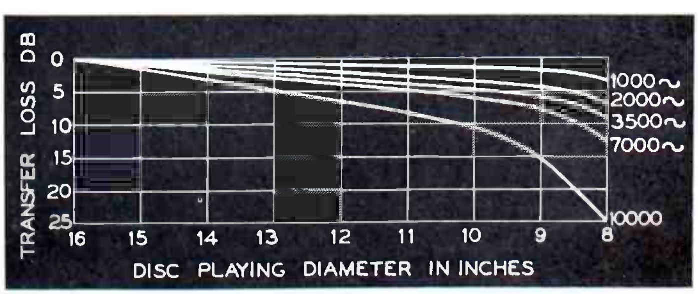


Fig. 8

DIRECTIONAL ANTENNAS

(Continued from Page 17)

Then the total induced voltage due to the impinging wave and its reflection component is

$$\bar{E}_i = 2j\frac{A\lambda}{2\pi}\,\frac{\sin kx}{r}\,\angle -kr. \qquad (143)$$

But,

$$\bar{E}_i = \bar{I}_0\bar{Z}_{00'} + \bar{I}_1\bar{Z}_m$$
$$= \bar{I}_0[R_{00'} - R_m + jX_{00'} - jX_m]. \qquad (144)$$

$X_{00'}$ is made equal to X_m so

$$E_i = \bar{I}_0[R_{00'} - R_m] \qquad (145)$$

or,

$$\bar{I}_0 = \frac{\bar{E}_i}{R_{00'} - R_m}$$
$$= j\frac{A\lambda}{2\pi}\cdot\frac{\angle -kr}{r}\cdot\frac{2\sin kx}{R_{00'} - R_m}. \qquad (146)$$

When the sheet is absent,

$$I_0' = \frac{A\lambda}{2\pi r}\,\frac{\angle -kr}{R_{00'}} \qquad (147)$$

so that,

$$I_0/I_0' = \frac{2\sin kx}{1 - R_m/R_{00'}}. \qquad (148)$$

Fig. 49 shows the ratio, I_0/I_0', as a function of spacing from the sheet. The broken curve is again computed for a loss resistance of 0.5 ohm.

It should be noted that the above treatment applies only to the condition where the detector does not introduce appreciable loss into the system so that practically all of the power taken into the antenna system is reradiated. For the case of a detector of appreciable resistance, where we wish to absorb a maximum amount of power, we may again turn to the transmitting case, just as we did for a parasitic array. Fig. 47 then applies.

IX. Measurement of Mutual Impedance

In the discussion of driven arrays, the consequences of certain current ratios and phase relations were discussed. It was assumed that these relations could be attained. In short-wave work, where the arrays are usually used for the purpose of beaming the energy to furnish point-to-point communication, the correct phases are easily obtained by adjusting the lengths of certain transmission line feeders. In the broadcast range, where the pattern is distorted in numerous odd ways to furnish protection to other stations on the same channel, it is necesssary to divide power and shift phase with lumped constant networks. The remainder of this paper will be devoted to methods of design and adjustment of these associated circuits. It will be assumed that the engineer who is adjusting the array is equipped to measure resistance and reactance.

The first step in the adjustment of an array is the determination of the mutual impedance between each pair of antennas in the array. A knowledge of the mutual impedances is necessary not only to assist in the adjustment but also to enable us to measure the power fed into the antenna when the array is in adjustment.

Let us suppose that we wish to measure the mutual impedance between a pair of antennas, 0 and 1. We first isolate 1 from ground so that no current flows in it. (If it is of such a height that it will resonate when floating, the antenna should be grounded.) Then we proceed to measure the self resistance and reactance of antenna 0, obtaining the values R_{00} and X_{00}. Antenna 0 is then isolated and R_{11} and X_{11} determined at antenna 1. We next connect antenna 1 to ground through a reactance equal to $-X_{11}$, so that thsi antenna is resonant. We then measure the resistance and reactance at the terminals of antenna 0, and obtain new values, R_0 and X_0. This arrangement is nothing more than the case of a single parasitic reflector, tuned to resonance. Then from (80),

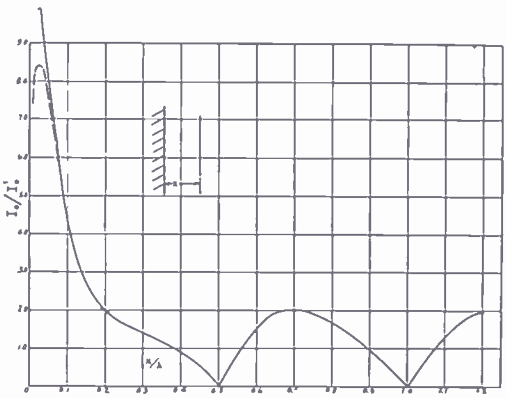


Fig. 49. A receiving antenna in front of a flat sheet.

$$R_0 = R_{00} - \frac{|Z_m|^2}{R_{11}}\cos 2\theta_m \qquad (149)$$

$$X_0 = X_{00} \frac{|Z_m|^2}{R_{11}}\sin 2\theta_m. \qquad (150)$$

Eliminating between these two equations, we find

$$|Z_m| = \sqrt{R_{11}}[(R_0 - R_{00})^2 + (X_0 - X_{00})^2]^{1/4} \qquad (151)$$

and,

$$\theta_m = \tfrac{1}{2}\tan^{-1}\frac{(X_{00} - X_0)}{R_{00} - R_0} \qquad (152)$$

where R_{00} and X_{00} are measured with antenna 1 isolated, while R_0 and X_0 are measured with antenna 1 resonated. The components of mutual impedance are

(Continued on Page 35)

WHBF

(Continued from Page 7)

through a relay to allow it to automatically light in case of failure of the regular light. There are two 100-watt lamps at the one-third and two-third levels on each tower. These lights are all enclosed in regulation glass lenses.

Transmitter House

Returning to the transmitter house, the 1-G transmitter is built into the wall, and the front of the panel is flush with the wall between the main transmitter room and the workshop.

The accompanying sketch shows the advantages of this arrangement, the main advantage being that it places the entrance doors to the transmitter cabinets within easy reach of tools and workbench.

The floor of the workshop is of wood, making it much safer for the engineers while working on the equipment.

Also in the workshop there is a large cabinet for spare parts, spare tubes, test equipment, etc.

Trenches in the floor allow a neat arrangement of wiring between units of the transmitter, and to the speech input and monitoring racks, which are located in the main transmitter room.

These racks are so located that the operator can read any instrument on them from the operating position.

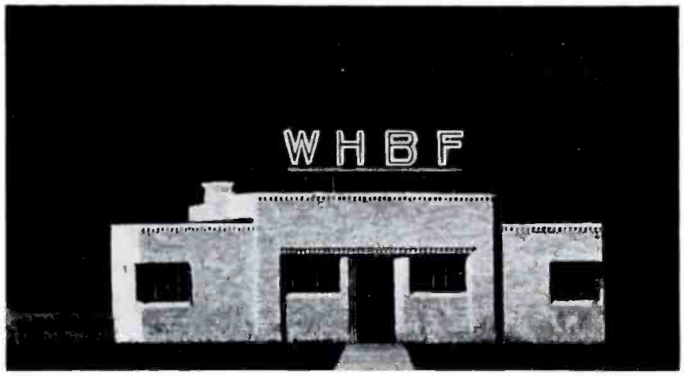
All control wires for operating the directional switches at the tower base, also all the tower lighting cables and concentric lines for sampling current from the towers are placed in trenches, as are the telephone cables and main power service cables from the highway nearby.

In a wing of the building adjoining the main transmitter room is located the heating plant for the building. Here also is the power meter and the telephone line terminal panel. This room is also used for housing the pumping equipment which supplies water to the entire building and grounds. The room is also used for storing various items, such as window screens, etc.

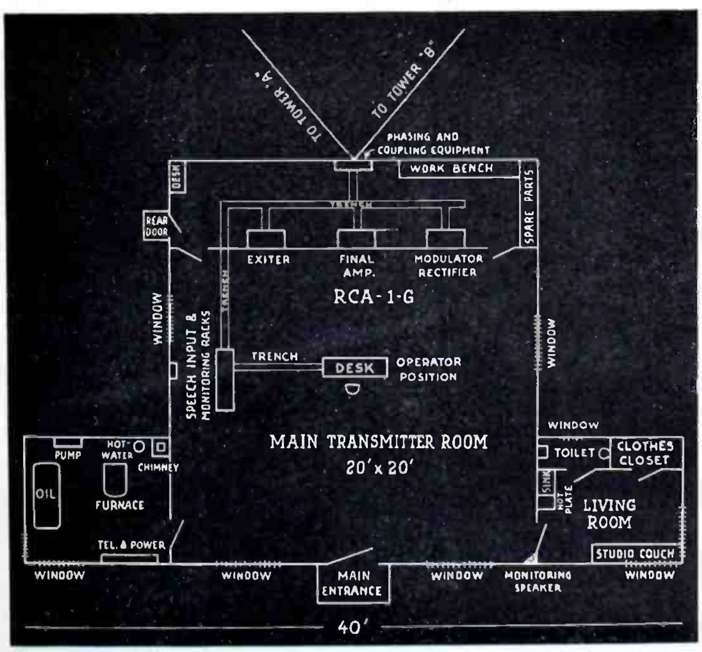
On the east side of the building is located living quarters for one engineer. This small apartment has complete facilities to normally accommodate one person but in emergency two persons could live here indefinitely.

On the roof above the front entrance to the building are the call letters of the station, in green neon lighted letters each three feet high.

With the approach of spring, plans are underway for complete fencing and landscaping of the transmitter grounds.



The new transmitter house at Moline, Ill.



Floor plan of WHBF transmitter station.

LACQUER DISC RECORDING

(Continued from Page 29)

ted if maximum results are desired and as a further advantage, an opportunity is provided to observe the behavior of the thread during cutting. Stylii which throw the thread outward rather than toward the center can be discovered before some program is lost because of a snarl. Such stylii are occasionally found and should be resharpened to correct the shape.

When using sapphires, the recording head should be lowered slowly and with considerable care to avoid cutting through into the metal base. This is especially important when a float stabilizer is employed, because of the added momentum which might carry the point through.

The proper depth of groove can be found by observing the width relative to the remaining wall. The wall should be approximately two-thirds of the groove width or a 40-60 ratio. Some operators prefer to measure the thread thickness with a micrometer having a ratchet for insuring uniform pressure. Because of its shape, the thread will always lie flat in the micrometer. It should measure between 0.0018 and 0.002 inch. When grooves are too shallow, the pickup may slide across the record. Care should be taken that the feed mechanism is adjusted sufficiently level that the depth of cut remains substantially constant over the entire record.

In handling discs they should be protected from dust and fingerprints, two serious problems in record handling. The practice of wearing silk gloves when handling all records including lacquer discs has been suggested but unfortunately, few are willing to take the trouble. Dust and fingerprints cause a rapid rise in surface noise. Records should be kept in their envelopes when not actually being used.

Waxing discs with a solution of carbon tetrachloride, in which a minute quantity of paraffin has been dissolved, increases the initial surface noise somewhat but multiplies the number of playings possible before the record is worn out. If more than 25 playings are required, the waxing process has some merit, provided the noise rise can be tolerated. In general the practice has been abandoned.

Flutter

The term flutter is used to describe a vertical wave which is sometimes cut in the record because of bouncing of the recording head. This condition can often be observed as a series of radial "spokes" or water mark patterns in the form of long spirals which are nearly concentric with the grooves. These markings are usually visible before the record is reproduced, although after playing they may be seen more plainly. The flutter frequency is usually in the neighborhood of 30 c.p.s. and often modulates the surface noise. In severe cases, modulation of the speech wave also occurs. The direction is always vertical. This may be seen with a microscope as an alternating change in width of the cut groove.

The flutter is produced by a resonance condition in which the reactive elements are the mass of the cutting head and stiffness of the record material plus that of the suspension spring. The latter, however, is only slightly effective. Record stiffness can be considered as exerting an upward force against the stylus and depends partly on the surface speed of the material. A steady deflection is represented by a groove of uniform depth while an alternating deflection is associated with flutter. If the stylus is pushed further into the record material by an external force while running, the depth of groove increases, but when the force is suddenly removed, the stylus immediately returns to its normal depth. It is the combination of this springlike condition plus the suspension spring and the recorder head mass which, because of the presence of very little damping, is responsible for the oscillations.

Vertical oscillations may be excited by an irregular record surface, by low frequency building vibration, a mechanical jar or by signal impulses.

Damper Assembly

In developing a suitable damper or stabilizer, Fig. No. 7, which is effective except in the most severe cases, a method was found to determine the degree of stability of the recorder float mechanism. By mechanical means the recording head was dropped from a predetermined height (0.015 inch) on a running record. Inspection of the record indicated the rate of decay of oscillations, also the frequency. A float arm and cutter not equipped with stabilizer was observed to oscillate vertically from 12 to 15 times, leaving the record surface entirely for the first half dozen cycles. This obviously indicated a highly resonant system which could be easily excited into persistent oscillation. With a float stabilizer attached, the number of oscillations for the same excitation was cut to about one and one-half cycles.

In extreme cases when flutter is not eliminated by the stabilizer, the operator should look for exceptionally heavy building vibration, low frequency turntable rumble above normal, or a lacquer disc having an unusually wavy surface.

The stabilizer consists of a projecting lead mass supported by a flexible flat spring which is surrounded by layers of mechanical resistance material. The theory of operation is as follows: When there is rapid motion of the recorder head vertically, there is a deflection in the resistance material in which sufficient energy is dissipated to render the system stable.

High Frequency Losses

Loss of high frequency response at small record diamaters is well-known to those who do recording. All disc systems suffer from it. The losses become more noticeable when an attempt is made to extend the frequency range. Fig. No. 8 shows the approximate losses encountered at various record diameters using standard groove dimensions (0.0023 inch stylus radius). These losses are caused chiefly by the finite size of the reproducing stylus and the wave length of the recorded sound. For frequencies of the order of 10,000 c.p.s. at low record surface speed, complete cancellation nearly results. Therefore, it is obvious that full correction cannot be made by compensation. It becomes necessary to confine the recording to large record diameters, dividing the time on two or more discs, if necessary for maximum quality. Records having extended frequency range cannot be made at a diameter of less than eight to nine inches for 33.3 r.p.m. without extreme loss of high frequency response.

An automatic compensator has been developed for 33.3 r.p.m. recording which assists in reducing these losses. This device may be attached to the rear of the 87-B recording mechanism and contains a moving contact which is at all times synchronized with the position of the recorder head. The amplifier gain is altered at high frequencies by an amount which is considered a practical maximum but which does not completely make up losses described.

Pre and post equalization cannot be used in addition to the automatic needle loss compensation as the total compensation would far exceed a workable limit. For high quality recordings, where playing time is short, pre and post equalization is preferred and the automatic compensator may be omitted. The fixed rise should then begin at about 3000 c.p.s. (3 db up) and increase smoothly to a maximum of 15 db at 10,000 c.p.s. In reproduction, the inverse of this rise should be used. This is obtained at position 3 of the filter switch on 70-B turntables. Pre and post equalization results in a substantial reduction of surface noise. Records having a limited frequency range do not require this technique and cut-off filters may be used in reproduction. (Switch positions 1 or 2).

In conclusion, it may be said that while every effort has been made to provide features in the design insuring trouble free operation, no recording system is infallible. The practice of taking important programs on a single machine indicates unjustifiable optimism. No commercial recording studio does it. Duplicate masters are always made. The loss of a single program could cost as much as an additional machine. One man can easily operate duplicate recorders. It is good insurance.

KBND

(Continued from Page 6)

while the velocity type 74-B's have served very satisfactory for studio and local talent programs.

A standard relay rack just to the right of the speech console holds the RCA Modulation Monitor with Frequency monitor and deviation meter in addition to patch panel, attenuation networks, etc.

A 400 foot concentric transmission line was constructed to carry the 250 watts from transmitter to the 175 foot vertical Lehigh radiator located on the shores of the Deschutes River. One hundred and thirty copper radials approximately one-quarter wave in length were buried in the rocky lava-bed soil in the river, thus offering the best ground system that was practical under existing conditions.

KBND opened with a full schedule of programs and a wide variety of high class entertainment December 19 after an elaborate dedication in which many of the prominent citizens of Oregon participated. The station is owned and operated by the Bend Bulletin under the general management of Frank H. Loggan. Installation and construction was made by Stanton Bennett, Chief Engineer of the station, assisted in final tune-ups by Mr. E. Frost, RCA transmitter Sales Engineer.

The station coverage has been even above expectations, and equipment has given the most reliable service during the first months of operation. Frequency response and efficiency measurements show that transmitter performance is even better than rated specifications.

The many comments and a flood of fan mail carries out the fact that the people of Central Oregon do appreciate the high fidelity signal and reliable program service that KBND is offering.

WMBI

(Continued from Page 15)

equipment. They lost no time when the change-over was made, maintaining a full schedule while making the installation. But WMBI is the primary interest of H. Coleman Crowell, Director of the Station and Assistant to the President of the Institute. He has been actively identified with the station since it first went on the air with a band program July, 1926. Since then its has been on the air continuously—a total of nearly 23,000 hours — and sends out a weekly average of 40 hours of programs, consisting of gospel music, sermons, talks to children, and a variety of other religious programs. Operating on five kw., and on a frequency of 1080 kilocycles, the station widened its range by 43% in July, 1937, when an up-to-date 496 foot vertical radiator was installed.

A flood of mail reporting improved quality in the programs poured into WMBI's offices after the new studios went into operation.

A popular children's program broadcast over WMBI.

TOMORROW'S TRANSMITTER TODAY

(Continued from Page 14)

trol and measurement of filament voltage for each of the three air-cooled tubes. Phase voltages and tube hour life are also metered at this point.

The use of individual filament potential control makes it possible to operate each tube at the lowest possible filament potential, and, since the conservative design of this transmitter permits operation well below the rated potentials, it is possible to greatly extend the life of the tubes. As an example, a new 891R nominally rated at 22 volts on the filament may be operated as low as 17 volts without an increase in distortion. As the tube ages, it is possible to increase the potential to the rated, and if necessary, beyond the 22 volts as the tube reaches the end of its life.

Filament step starting is of the usual type. However, a plate voltage application is by a newly developed method. Instead of a voltage step application, full voltage is applied instantly to the plate transformer; however, by means of series resistors the main filter condensers charge at a comparatively low rate minimizing current surges in the filter circuit. Approximately one second after the initial application the condenser series resistors are shorted out by a contactor. This, again, is an example of built-in circuit simplicity to be found throughout the 5-DX. In this case we not only have simplicity but a definite advantage in that the current surges through the rectifier tubes are reduced to a value considerably below that secured when 50% voltage step-starting is employed. This, of course, means greater life for the rectifier tubes.

For 1 KW operation the main rectifier operates simultaneously as a 3 phase full wave and a 3-phase half wave device permitting half voltage application at the Class C amplifier. A separate filter is used in the half-wave circuit. Power change from 5 KW to 1 KW or the reverse is fully automatic the actual switching is "cold" the rapidity is such that the actual change is barely detectable on the air. The power change control is mounted on the control console panels.

Control Console

The 5-DX control console and desk are pictured in Fig. 2. All operating functions of the transmitter may be controlled from this point. The transmitter may be started or stopped, power changed or the overload circuits re-set from this position. Alternating current power for the speech equipment and the tower lights is controlled at the console. In addition, a complete system of key switching permits the use of the transmitter for emergency program service. The input of the transmitter may be switched from the regular to an emergency line, to a microphone, to a turntable, or to a test oscillator from the control position. A fader is provided for the local audio input circuits and a master gain for the transmitter input. Built into the console are a 13-D vacuum tube type volume indicator and an 82-A monitoring amplifier. Relays operated from the transmitter control circuits automatically maintain the audio input level and the monitoring amplifier output level when a switch is made from 5 KW to 1 KW. Each transmitter control on the console has its associated pilot light indicator to simplify supervision.

To complete the entire system an antenna tuning unit is supplied for transmission line termination and matching to the radiating system. This equipment includes the necessary inductor and capacitors so arranged mechanically as to permit a wide combination of reactance values to terminate any standard line and match any standard radiator. The equipment includes an antenna ammeter with externally controlled shorting switch, meter viewing port and a monitoring rectifier which furnishes audio voltage for the 82-A monitoring amplifier and rectified d-c for a remote indicating antenna ammeter. The d-c flowing to the remote indicator is also used to control a "carrier-off" relay. In the event of failure of power at the radiator the carrier off relay is released and removes all plate potentials from the transmitter.

The 5-DX equipment has been so designed that it may readily be converted to a 10 KW transmitter. The conversion is simple and may be made without changes in the station floor plan and without interruption of normal program service.

Mechanical Specifications

Space Requirements: Overall length, 17' 1⅝". Overall height, 7'. Required depth behind front panel, 8' 0" minimum. Square feet of floor space required totals 150 square feet.

Design: Vertical chassis unit construction with front streamlined single unit appearance.

Finish: Modern two tone. Satin-finish, chrome trim. The station call letter monogram on left access door. Filtered air to all power tubes.

Provision for rapid, economical conversion to 10 KW without change in transmitter front lines or station floor plan.

Electrical Specifications:

Power: Power circuit specification 230 volt, 3-phase, 60 cycle. Crystal heater supply single phase, 115 volt, 60 cycle.

Power: Output nominal 5 KW into grounded transmission line of 70 to 600 ohms or standard antenna.

Power: Input total 16 KW for 5 KW output, 11.0 KW for 1 KW output. (On program modulation.)

Power: Variations in line voltage compensated by high speed regulator.

Modulation: High level Class B.

Efficiency: Plate efficiency of modulated amplifier 80% or better.

Distortion: Less than 3% RMS measured at any frequency from 50 to 7500 cycles at any percentage of modulation up to 100%.

Noise Level: Minimum of 60 db. below 100% modulation, unweighted.

Feed-back: Loop includes audio input grids to modulator plates. Negligible phase shift with inherent stability. Approximately 30 db. feed-back.

Control Circuits:

Full automatic, high speed, with console control. Interlocked for utmost in safety to personnel and equipment. All delay circuits have full inverse time characteristic.

DIRECTIONAL ANTENNAS

(Continued from Page 30)

$$R_m = |Z_m| \cos \theta_m \quad (153)$$

and,

$$X_m = |Z_m| \sin \theta_m. \quad (154)$$

Due regard should be given the signs of the reactances in (152) since it is possible for θ_m to lie in any one of the four quadrants. It will be seen that an ambiguity of 180 degrees may arise in using (152). The correct choice may be made by using Fig. 6 as a guide.

In some instances, it will be found desirable to have a certain amount of reactance in antenna 1. The mutual impedance may be of such a phase angle that either $R_0 - R_{00}$ or $X_0 - X_0$. is close to zero. To increase the magnitude of the small term, the reactance in antenna 1 is adjusted so that the antenna is no longer resonant. Then X_{11} represents the antenna reactance plus the grounding reactor. Then (151) becomes

$$|Z_m| = (R_{11}^2 + X_{11}^2)^{1/2}[(R_0 - R_{00})^2 + (X_0 - X_{00})^2]^{1/4} \quad (151a)$$

and (152) changes to

$$\theta_m = \frac{1}{2}\tan^{-1}\frac{X_{11}}{R_{11}} + \frac{1}{2}\tan^{-1}\frac{(X_{00} - X_0)}{R_{00} - R_0}. \quad (152a)$$

(To Be Continued)

NETWORK SYNTHESIS

(Continued from Page 26)

The synthesis of an equivalent network for a transmission line section provides a ready means for quickly examining the input impedance for a given line with negligible attenuation for any condition of termination. The equivalent circuit for the line is obtained by synthesis and the input impedance for a given termination obtained by analysis.

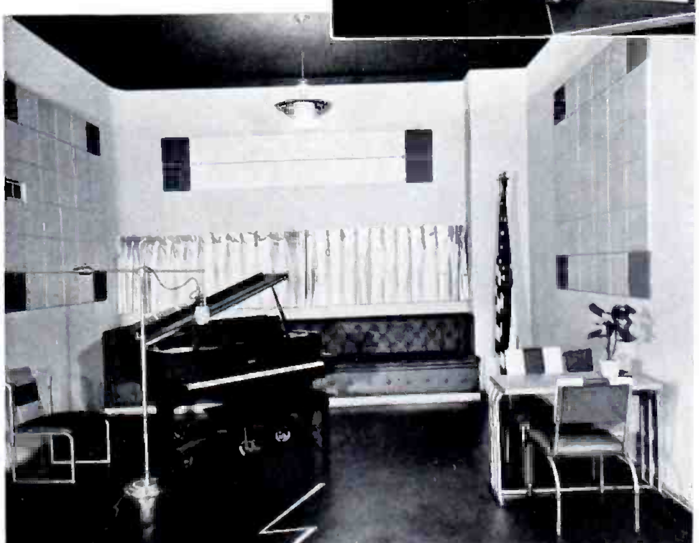
(To Be Continued)

THE BLUE WATER STATION WHLS PORT HURON, MICHIGAN

Above: Leslie Conant with RCA transmitter equipment.

Right: Harmon Stevens of WHLS surrounded by RCA equipment.

Below: The 44-BX provides precision pick-ups in this modern studio at WHLS.



RESPONSIVE COMPACT ADAPTABLE

An Ideal Microphone for Your Remote Pickups

RCA

TYPE 88-A

Another new RCA microphone — this one especially designed for announcing, remote pickups and the like. Pressure-operated, with a styrol diaphragm and a moving-coil element, this microphone is extremely rugged, small in size, and presents an attractive appearance. The response is excelled in smoothness only by the deluxe velocity microphone. As normally used — that is, in the horizontal position — the pickup pattern is semi-directional. If desired, the unit may be tilted on end to obtain a non-directional pickup characteristic. The output has been made somewhat higher than that of the other RCA quality microphones — since this is of advantage for remote work. The output impedances (50 and 250 ohms), the black and chrome finish, and the mounting provisions (½" pipe thread) are similar. A ball-and-socket joint (with a thumb-screw clamp) provides for tilting or turning the unit. The light weight of this microphone (1 lb.) allows its use with any type of stand — or it may be carried in the hand, for interviews and the like, without fatigue.

★

HIGH IN QUALITY
LOW IN COST

★