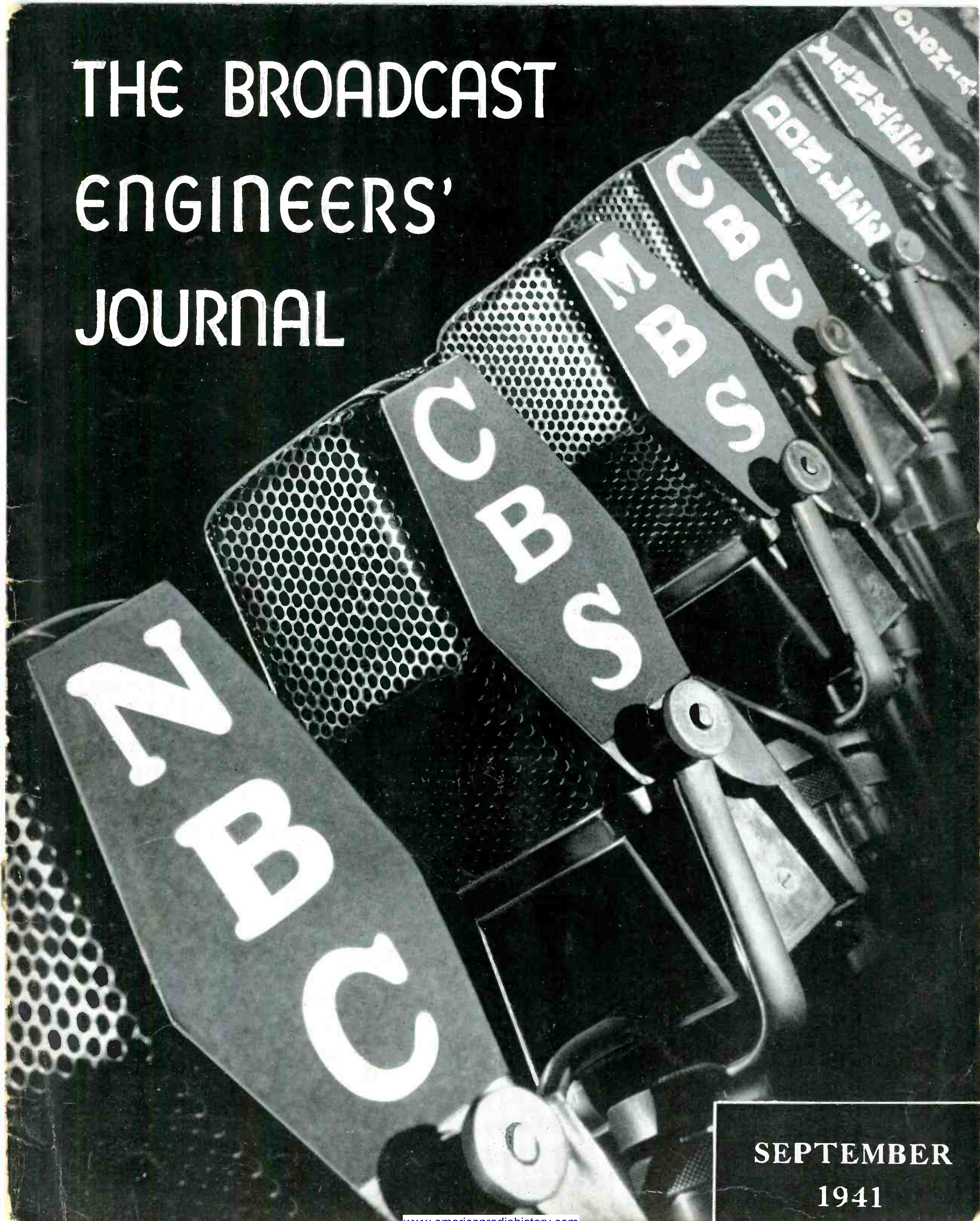
THE BROADCAST ENGINEERS' JOURNAL



SEPTEMBER
1941

formerly A.T.E. JOURNAL
DIRECTED TO BROADCAST ENGINEERS AND EXECUTIVES

Volume 8, No. 9 409 September, 1941

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A.T.E. Publications, Inc.

The Broadcast Engineers' Journal is a privately printed monthly publication, issued by the Ass'n of Technical Employees Publications, Inc., a corporation of the State of New Jersey with office at 30 Rockefeller Plaza, N. Y. City. Address all communications to Editor's office: E. Stolzenberger, 116-03 91st Avenue, Richmond Hill, L. I., N. Y. Telephone VIrginia 9-5553.

The Broadcast Engineers' Journal is the Official Publication of the N.A.B.E.T.

Advertising rates and information supplied on request. Subscription, $1.50 per year; $3.00 for three years. Single copies, except Christmas Yearbook, 25c; Christmas Yearbook, 50c. subject to availability. All remittances in advance. Foreign: Add postage.

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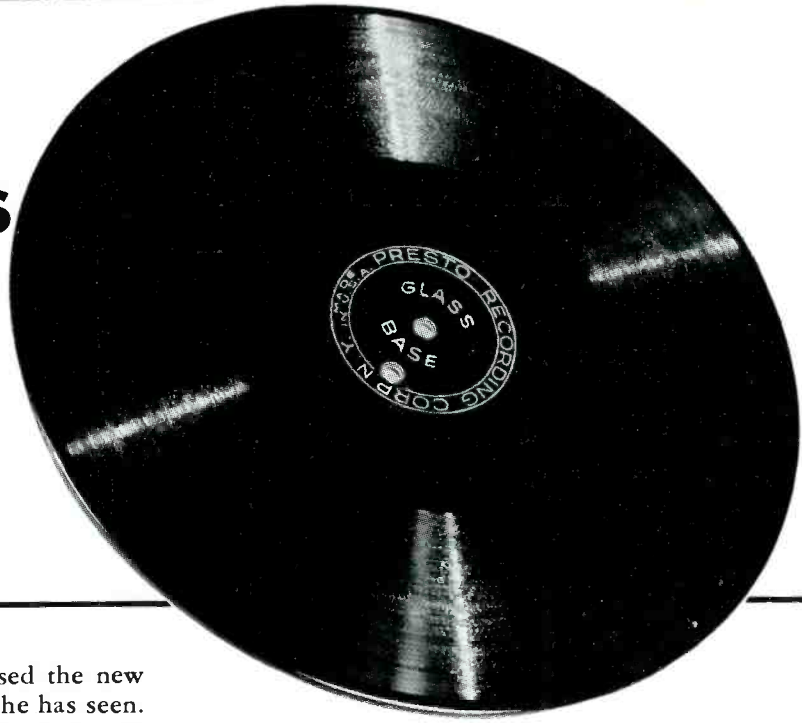

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World's Largest Manufacturers of Instantaneous Sound Recording Equipment and Discs

Lateral Disc Recording

By Beverly F. Fredendall
Audio Facilities Group, NBC Engineering Department

[By popular request, this article has been brought up-to-date and reprinted from our July, 1940, "Recording Issue"— EDITOR]

PART I — THEORY

SOUND recording began about the year 1877 but, only since the introduction of the instantaneous playback lacquer coated disc, has there been a wide-spread demand for knowledge of the recording process. Although there are two general methods of disc recording, i.e., vertical cut and lateral cut, only the latter will be described since it is more widely used, and is the system of recording used by the NBC and RCA. This text outlines briefly the general theory of recording and, more specifically, the steps required to place a system into standard operation or to check the performance of an existing installation.

It is necessary to understand the basic theory of lateral recording before outlining in detail the various steps required to put that theory into practice. Accordingly this text is divided into two parts: Theory and Practice. Under Theory the subject is discussed according to the natural classifications of electrical, mechanical, electro-mechanical, and equalization; under Practice a description of the electrical and optical tests used in determining the required recording characteristic is given. Emphasis is placed upon the need for clear differentiation in considering voltage, current, power, mechanical amplitude, and optical width while performing the necessary steps in lining up a recording system.

GENERAL

There are two general methods of lateral disc recording, namely, embossing and engraving.

In the method of embossing the inclined recording stylus, or needle, presses with continuous uniform force against the surface of the record, depressing and permanently deforming its surface without puncturing it. The resultant groove is an indentation of the record material which the playback needle must follow. In engraving, the recording needle, set almost at right angles to the record surface, cuts a chip or thread from the soft material, just as a machinist's lathe cuts a chip from the work revolving under the cutting tool.

Record materials vary considerably but fall into three broad classifications, namely, wax, lacquer, and film. Wax is the softest of the three, is generally used for making "processed" records but is not suitable for instantaneous playback. Being soft it offers less of a load to the cutting head than lacquer.

The term "lacquer" is used here to designate all those mixtures, applied to a structural base, having about the same degree of density or firmness. Manufacturing formulas are a secret but usually contain cellulose-nitrate as a basic ingredient plus resins, oils, lacquers, glycerine, paint products, and some volitile solvent. The much used term "acetate" is not correct since most of the manufacturers supplying "acetate" records do not use a cellulose-acetate base. The mixture is applied on a supporting base of aluminum, glass or cardboard, aluminum and glass being used for the higher quality recordings.

Film is frequently used for embossed lateral recording in the form of a continuous belt. A sufficient amount of film may be loaded into a long time recorder so that a 24-hour recording may be placed on one loop of film. So far it is mainly used for such recording service as plane to ground communication, where intelligence rather than quality is primary, but it may be used for quality reproduction by increasing the speed of film travel. The film used in the above process should not be confused with a mechanical-optical film method which will only be mentioned here. It employs a long narrow film coated on one side with a layer of opaque material which passes under the cutting needle. When vertical modulation is placed on a "V" shaped needle it cuts through the opaque surface revealing the transparent base material and leaving a variable area optical sound track as well as a vertical mechanical sound track. The optical pattern is used in reproduction by passing the film in front of a photo-electric cell.

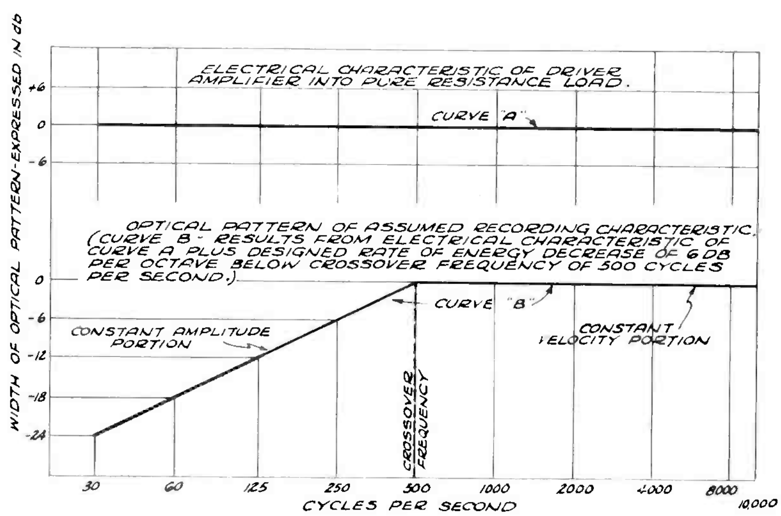


FIG. 1

ELECTRICAL

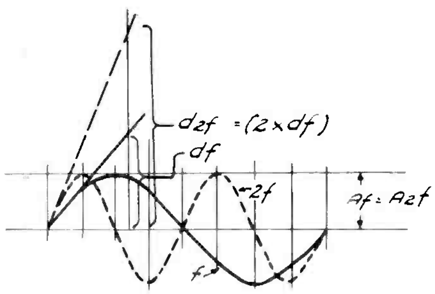
The fidelity of the electrical circuits should be approximately equal to the standards of other broadcast amplifying equipment that is, flat within one db in the frequency band required. In present day recording this may be taken as extending from 30 to 10,000 cycles per second. In taking measurements of the electrical amplifying equipment proper, nominal input and output terminations should be maintained. In the case of the final power amplifier whose output impedance is, for example, 15 ohms, this means that the temporary load for this amplifier should be a 15 ohm pure resistance termination during this part of the electrical test. See Curve A, Fig. 1.

MECHANICAL

The most interesting and fundamental part of recording —its mechanics—is the part where the greatest confusion exists with regard to standards and to the underlying factors involved in the determination of those standards.

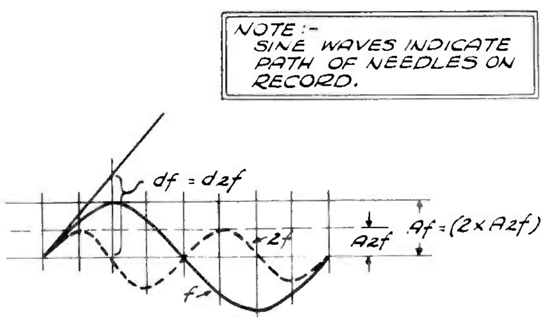
A — Constant Amplitude

An understanding of the terms "constant amplitude" and "constant velocity" as applied to a modulated groove is essential. Fig. 2 shows two frequencies of *constant amplitude* whose frequency difference is one octave, ie., one is twice the frequency of the other. It is important to note that for constant amplitude recording the maximum slope of the wave is proportional to frequency. Thus the distance d2f which is proportional to the slope of the higher frequency, is exactly twice the value of df of the lower frequency. Similarly, for higher frequencies, the slope is proportionately greater. Lateral velocity of stylus travel and slope of resultant groove are related—one is the cause and the other the effect. The maximum lateral velocity of a cutting needle is attained as it crosses the center of the groove, i. e., zero axis, and at this point the slope is obviously greatest. It is useful to note in passing that a constant amplitude characteristic is essentially that of a crystal type cutter.



CONSTANT AMPLITUDE
(VARIABLE VELOCITY & SLOPE)

FIG. 2



CONSTANT VELOCITY
(VARIABLE AMPLITUDE)

FIG. 3

B — Constant Velocity

Fig. 3 shows two frequencies of *constant velocity* or slope whose frequency difference is one octave. In constant velocity recording the slope of the wave at the zero axis is constant for constant power output, i. e., for a "flat" condition, and the amplitude of the wave is inversely proportional to frequency. Thus, the height A2f of the higher frequency is just half the height Af of the lower frequency, but it should be especially noted that the slope at the zero axis is the same. Similarly for higher frequencies, the amplitude is proportionately less for the same power output. It is also useful to note that the constant velocity characteristic is essentially that of the electromagnetic cutter.

In order to understand some further mechanical considerations, consider a perfectly efficient, magnetic type, electro-mechanical transducer, otherwise known as a cutter-head, which would engrave all frequencies without loss. Such a "constant velocity" head would oscillate with large amplitude at low frequencies and small amplitude at high frequencies. A 5,000 cps wave would have twice the amplitude of a 10,000 cps wave. In a band from 30 to 10,000 cycles per second there are 8¼ octaves and thus, for a given amplitude at 10,000 cycles, the amplitude at 30 cycles would be $2^{8\frac{1}{4}}$, or 320 times greater. Current practice allows approximately 0.0016 inch amplitude modulation at 500 cycles per second. If the perfectly efficient magnetic cutter were used there would be 0.00008 inch amplitude at 10,000 cps, 0.0016 inch at 500 cps, and 0.025 inch at 30 cycles. Allowing 0.005 inch groove width, as in current practice, and modulation space on either side of the groove equal to expected peak amplitude at 30 cps, there would be 0.005 inch groove plus 2 x 0.025 inch modulation or a total equal to 0.055 inch for center to center spacing of grooves. Note that the modulation space would have to be ten times wider than the groove. A 16 inch diameter disc allows about 4¼ inch usable space before being limited by slow cutting speeds, or 4.25/0.055 = 77 grooves. At 33 1/3 rpm this is only 77/33.3 = 2.3 minutes playing time. This would be a severe limitation of playing time and obviously some modification of said efficient electromagnetic cutter would be necessary.

Unfortunately, the necessary modifications of the above described efficient "constant velocity" cutting system have not been standardized. There are several schools of thought with regard to standards. One school calls for a constant mechanical amplitude on the record for any frequency from the top down to the lowest frequency. Another school of thought calls for a constant velocity system above a given frequency and a constant amplitude below that same frequency. Thus, progressing down the frequency scale, from the highest frequency down to a given frequency the amplitude would linearly increase and below the given frequency the amplitude would be held constant. The point in the frequency scale where the two meet has been called the "cross-over point". See curve B, Fig. 1.

In selecting the cross-over point there are two limitations to consider. If too low a frequency is chosen the amplitude of the low frequencies becomes too great to allow closely spaced grooves for a fifteen minute recording on one disc. If a high frequency cross-over is chosen, the resulting modulated groove at high frequencies contains a wave front so steep that the physical slope of the cutting needle, which has a fixed clearance angle, would have trouble in cutting it. Of secondary importance, the power of the amplifier driving the magnetic cutter would of necessity have to be greater due to the choice of the higher cross-over frequency. This latter reason is more of an economic than a mechanical one but is a consideration in any practical system.

The term "constant amplitude", considering the record itself, should not be confused with the value of the electrical voltage, current or power in the electrical circuits of the recording channel. These may or may not follow—depending upon the type and design of the cutterhead and amplifier driving system.

With the present method of constant rpm disc recording there is an important variable which cannot be overlooked—that of variable cutting speed or groove speed due to variable radius. When recording from outside to inside, for example, any single frequency would have a continuously diminishing wave-length, resulting in a steeper or greater wave slope, and for this frequency there would be a critical cutting radius where the slope of the wave would reach the maximum limit value, i. e., both cutting and reproducing would be practically impossible at a higher level. Progressing to a very small groove radius (resulting in a slower cutting speed) the given frequency, forced and held to its maximum cutting slope, would result in a gradually lower value of amplitude as the cutting speed decreases, even though the power to the channel is held constant. The limiting process begins at the highest frequency and passes on to each succeeding lower frequency as the cutting speed is reduced.

As a result of the two basic considerations, first, that of limiting the maximum amplitude of modulation (at low frequencies) in order to secure closely spaced grooves thus providing a greater length of recording time, and second, limiting the maximum slope of the wave at high frequencies,

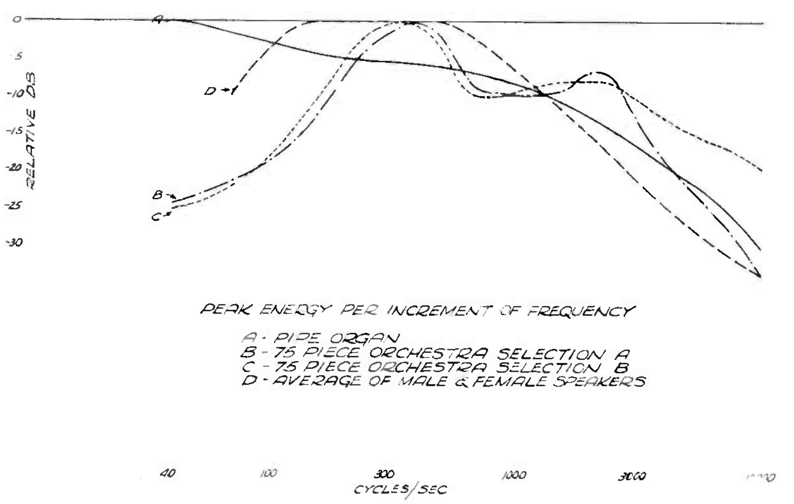


FIG. 4

present day practice calls for spiral grooves of from 96 to 140 lines per inch at both 33 1/3 and 78 rpm usually in an outside-in direction.

ELECTRO-MECHANICAL

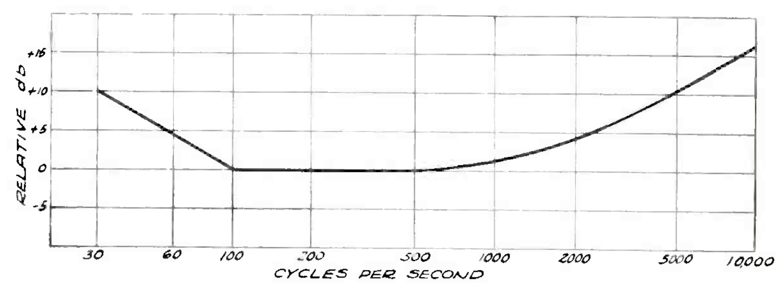
When the mechanical limitations are realized and the standard recording characteristic has been decided, it is possible to correlate the electrical amplifiers and the design of the cutterhead to produce the desired modulation pattern.

The most commonly used cutters are of the electro-magnetic type although crystal cutters have been used recently to some extent. A *crystal cutter* following a "flat" amplifier, results in a *constant amplitude* recording due to the fact that the crystal displacement or distance of motion is proportional to voltage and not to frequency, excluding resonance conditions. In this case, if an assumed recording characteristic is desired, as follows: constant amplitude below a cross-over frequency of 500 cycles and a constant velocity above this frequency, the crystal cutter requires a filter to decrease gradually the amplitude of all frequencies *above* 500 cycles per second. Similarly if an "efficient" electro-magnetic cutter were used following a "flat" amplifier, a *constant velocity* recording will result as described previously. To produce a standard characteristic the perfectly efficient electro-magnetic cutter would require a filter to decrease gradually the amplitude *below* 500 cycles.

The term "perfectly efficient" electro-magnetic cutter has been used to simplify the explanation of how electro-magnetic cutters work. Such a cutter cannot actually be realized. In practice it is easier to obtain the constant amplitude characteristic at the low end by taking advantage of the natural change in impedance of an electro-magnetic cutter toward the low end. It is therefore possible to design a cutterhead having the required characteristic on the low end with the proper cross-over point.

The proper taper on the low end is obtained partly by electrical mismatch. For example, the nominal 15 ohm cutterhead is designed to operate from a 15 ohm output amplifier. At all frequencies where the source and load are equal, a maximum power transfer is thus obtained, (not necessarily maximum undistorted power) but at wide impedance variations the transferred power to the load is greatly decreased. In practice the impedance of the electro-magnetic cutterhead is 15 ohms at one frequency only, rising above the nominal value at high frequencies, and dropping to as low as 1 ohm at low frequencies.

A simple explanation of how this produces a decrease in armature amplitude at the low frequency end follows: If we assume a 15 ohm amplifier output impedance and a frequency at which the cutterhead is 15 ohms, the total EMF in a constant impedance output electrical circuit is divided, for example, into $(15 + 15)$ 30 parts, 15 of which appear across the cutterhead, or $15/30 = 0.5$ of the EMF. At a low frequency where the cutterhead is only one ohm we may assume the same EMF as being divided into $(15 + 1) = 16$ parts, 1 of which appears across the cutterhead terminals, or $1/16 = 0.0625$ of the EMF. The ratio between these two load voltages at the two frequencies is $0.0625/0.5 = 0.125$ or 18 db less voltage is delivered at the lower frequency. A 10 ohm resistor is used in series with the cutterhead to increase this loss by about 2 db and to keep a more nearly constant optimum load impedance on the amplifier at all frequencies.



IDEAL ELECTRICAL CHARACTERISTIC OF ORTHACOUSTIC AS APPLIED IN RECORDING

FIG. 5

SPECIAL EQUALIZATION

In addition to the two basic considerations of maximum amplitude and maximum slope of the recorded groove, there are other factors which enter into the choice of a standard recording characteristic. One of these factors is the signal to noise ratio of the recording. The distribution of noise is mainly at the extreme high frequency end of the spectrum known as scratch or surface noise, and at the extreme low frequency end, known as rumble or mechanical noise, caused by the recording machine gears and driving system. Special equalization may be used to increase the signal to noise ratio and thus obtain better overall performance of the recording system.

Accordingly, a system of pre-emphasis and de-compensation called "ORTHACOUSTIC" has been evolved, which increases the recorded level of a portion of the low frequency spectrum, and of all the frequencies above the cross-over point. This Orthacoustic system is based upon a frequency-energy analysis of speech and music which indicates that the low and high frequency parts of the audio spectrum normally contain a lower energy level than the broad middle portion lying between 150 to 500 cycles per second. See Fig. (4).

The importance of this discovery is the evidence that both the low end and the high end of the frequency spectrum can be increased in amplitude on a recording without danger, at the low frequency end, of over-cutting and without danger of too steep a wave front for cutting and playback tracking at the high end. This possibility derives from the aforementioned fact that the energy content of sounds in nature at both the high and low ends was normally substantially less than in the significant middle portion. In other words, it is not, as heretofore was considered necessary, to provide for a flat system at the high and low ends since it would rarely ever be required under normal conditions—organ music being the most important single exception. To preclude possibility of over-cutting at low frequencies due to organ music, or as a general precaution, the maximum level allowed to pass through the recording system is limited by a special type of automatic audio gain control device, such as is done to prevent over-modulation at broadcast stations. For the electrical characteristic of Orthacoustic as applied to the recording channel see Fig. (5).

PART II — PRACTICE

To set up and adjust a recording system according to a pre-conceived standard characteristic, it is important to know of and distinguish between two methods of measurement, both of which are used in obtaining the final recording characteristic. The first method is the electrical response, or amplitude vs. frequency characteristic of the amplifier system which is used ahead of the cutterhead. The second method is that of optical measurement of the record itself by means of the light pattern reflected from its grooves. This latter measurement is important in checking the performance of the entire recording system and serves to indicate that it has been adjusted correctly and that the proper characteristic is actually being cut on the record.

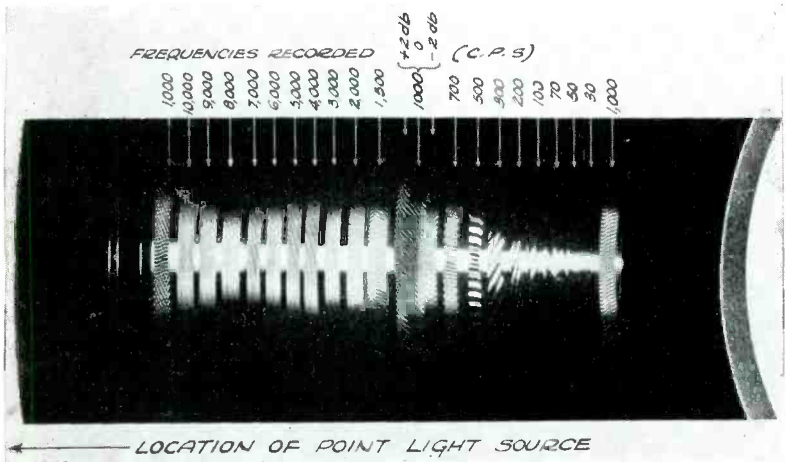


FIG. 6. Optical pattern of typical tone record. Note broad dip at 8,000 cycles, approximately 2 db peak at 4,000 cycles and 1,000 cycles, and the normal taper from 400 to 30 cycles

ELECTRICAL TESTS

By substituting a pure resistance termination for the cutterhead the frequency characteristic of the cutter driver amplifier at normal operating levels can be measured. This test should indicate a flat ± 1 db response from 30 to 10,000 cps for an assumed standard of constant velocity above 500 cps and constant amplitude below 500 cps.

OPTICAL TESTS

The optical measurement of actual cutter operation is accomplished by making a test record at 78 rpm. Tone should be supplied to the input of the channel at constant program level for each selected frequency between 10,000 and 30 cps recorded; for example 10 seconds of tone and 5 seconds spacing with no modulation. The 1,000 cycle reference frequency should be recorded at three levels in one continuous band: (a) 2 db below normal input level, (b) normal level, and

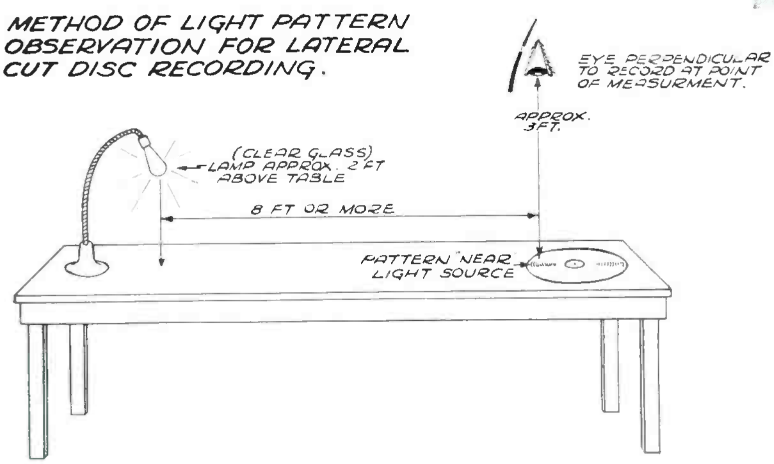


FIG. 7

(c) 2 db above normal level. This will help in identifying the reference frequency and in being able to interpret the variations in amplitude of the optical pattern in terms of db. The high frequency end of the spectrum should be recorded on the outside of the disc. In addition to the regular tones, 1,000 cycles at normal level should be recorded as the first and last frequencies of the tone run. See Fig. (6).

The interpretation of the optical pattern thus produced may be arrived at as follows: Direct illumination per method in Fig. (7) is quite important; diffused light is particularly troublesome. The line of sight should be perpendicular to the record, directly over the observed spot as determined by an image of the eye found by reflection from the uncut portion of the surface. The light source should be somewhat removed from the record, at least 8 ft., and as close to the plane of the record (approx. 2 ft.) as will give a brilliant pattern. With this set-up there will be two patterns, one on each side of the center of the record, one *toward* the light and one *away* from the light source. See Fig. (8). Use the pattern lying toward the light source.

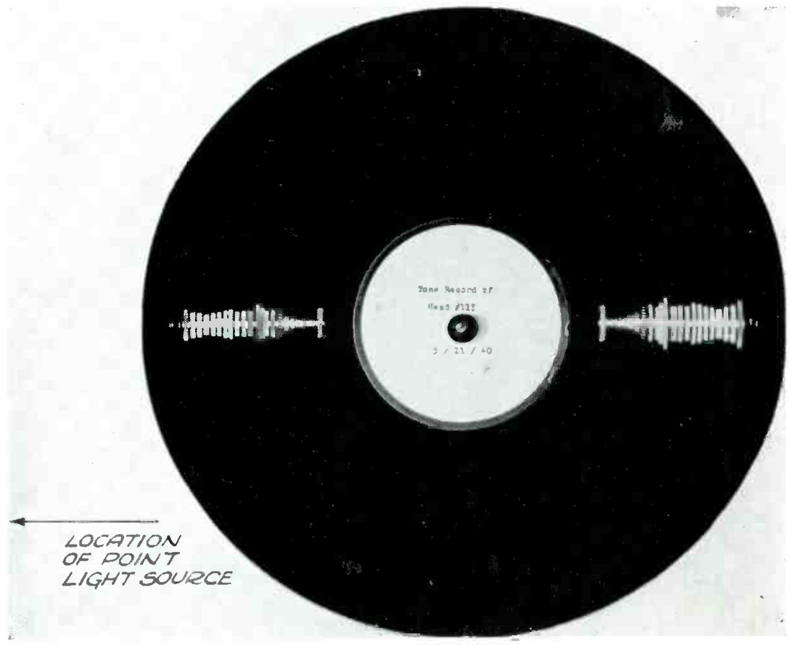


FIG. 8. Variation of optical patterns of typical tone record

There are other ways of illuminating and observing the optical pattern. For example, the pattern lying on the side of the record *away* from the light source could be used but movement of the observer's eye seems to cause a greater pattern change. There seems to be less than 1 db observation error between the near and far patterns and although an average of the two would be more accurate the "near" pattern contains less errors of eye placement and seems to check other measurements closely. A small area light source of high brightness is best, as the small area produces a sharply defined image. In practice the record may be placed on a low table with the light source to the left, slightly above the level of the record. With the eye at as great a distance from the record as practical and perpendicular to the spot of measurement, use a pair of dividers to measure the width of the reflected light pattern for each frequency. The desirable condition is a characteristic based on a cross-over frequency of 500 cycles per second, which is determined when each of the three 1,000 cycle per second bands which are at normal input level have approximately equal widths and all those frequencies from 500 cycles to 10,000 cycles are within 2 db of this measured width. Without resorting to physical measurement, visual observation will show whether this is true by comparing the widths of each frequency band with the 1,000 cycle centrally located bands.

The frequencies below 500 cycles should taper off materially. The 250 cycle band should be half the 500 to 10,000 cycle band widths. Similarly a 125 cycle width should be half the 250 cycle value or one quarter of the 500 cycle value. Since these low frequency band widths are difficult to measure accurately by an optical method, they may be verified by playing them back electrically through a completely flat pickup head and amplifying system. Such a system may be obtained by using the MI-4856 playback head connected to 700 ohms or more load. Make certain all equalizers are disconnected and play back only the low frequency end. The resulting electrical energy of this constant amplitude portion should be reproduced with a taper of 6 db per octave. The higher frequencies cannot be measured successfully with this head due to the mechanical resonance composed of cutterhead plus record material, which, with lacquer coated records, appears to be around 6,000 cycles per second, thus giving a false interpretation of the record. The high frequency end of the spectrum should only be interpreted by physical measurement of the light pattern widths. After each frequency is measured with the dividers to the nearest hundredth of an inch, the characteristic may be translated into an electrical relationship expressed in db by using the relation that the width of each frequency band is proportional to the voltage which that band would produce in a perfect electromagnetic playback head. For example, with two frequencies on the record, one of which was twice as wide as the other, the wider band would be 6 db higher in level than the second band, etc. Use the middle normal level 1,000 cycle tone as a reference value and compare all others to this by expressing each measured width in relation to the 1,000 cycle width as a fraction. The resulting figure then represents the voltage which would be generated at one frequency as compared to the 1,000 cycle voltage. This voltage ratio may be expressed in db by using the *voltage* column of a db table.

The resulting figures should be plotted and compared with the theoretical characteristic showing a downward slope of 6 db per octave below 500 cycles and a flat characteristic above 500 cycles. At present, a tolerance of 2 db from theoretical is permissible. If the cutter power amplifier and head do not fall within these limits under actual operating conditions equalization is necessary. The proper equalizer for each head must then be designed and installed, preferably ahead of or following the cutter driving amplifier. It is possible to locate equalization within this power amplifier, but in such case means should be provided to remove this equalization when electrical tests are made to determine if this amplifier itself has a normally "flat" electrical characteristic.

Personal Notes on Those "Behind the Mike"

By Con Conrad

C. A. SIMMONS—Completed 25 years service with A.T.&T. on August 26. He is in Broadcast Division of Long Lines in Chicago. He is also a member of the Flying Boys at "CQ" soon to try for a Pilot's License.

T. E. La Croix—Formerly of KFAC, Los Angeles, joined the staff of NBC, Hollywood, on September 1, succeeding Don Scheuch, who resigned to return to the University of California.

M. J. Donnelly—WLS Studio Engineer is of the proud Papa variety becoming same early in August with the arrival of Dennis.

R. B. Whitnah—NBC Chicago Recording Engineer now at home in the new house located in Lombard, Illinois.

F. L. Freetly—A.T.&T. Broadcast Division, Long Lines, Chicago, completed 25 years' service on September 1.

Walter Phillips—Night Control Supervisor, WGN, Chicago, received his Masters Degree in Business Administration from the University of Chicago. This happened late in August; Walt is very happy as it is the result of many years of part-time study.

F. C. Shidel—(Capt. Freddy) NBC Chicago Engineer, now in the services, paid short visit to Chicago while on leave from Ft. Monmouth.

Henry T. Bailey—Formerly of Gadsen, Ala., has been added to the staff of WLAC at La Grange, Georgia, in the Engineering Department.

Walt Varnum—WLS Studio Engineer, Chicago, about to leave the ranks of the Sainted Benedicts. Rumors have it that home town gal down in Lawrence, Kansas, is to be the new resident of Chicago.

D. J. Kempkes—NBC Chicago Studio Engineer, had the good fortune to be Engineer on show which guested Dorothy Lamour. Kemps giving the boys around the studios the low down.

Wm. (Stub) Newport—A.T.&T. Long Lines, Chicago, Broadcast Division, former classic league bowler, vacationing in the Ozarks and Southwest. Stub is getting all rested up for another tough winter bowling over the maple.

Bill Taylor—Studio Engineer WLS, Chicago, is just ripe for the draft. Bill claims the air conditioning got him so he supposes the real thing will too. He explains it this way (air conditioning is just a big draft to the folks down on the farm).

Robert Connolly—Acting Chief Engineer at WHAT, Philadelphia, while Chet Geise serves in the Canal Zone as a Lieutenant.

John Bobera—New addition to the staff at WGN Transmitter (FM). John comes up from the Illinois State Police Radio.

Fred Brill and Ted Kalin—Added to the staff of WELI, New Haven. They succeed Joseph Austin and John Reilly. Reilly is the new Chief at WSRR, a newcomer to the Broadcast Field. Mr. Austin joined the staff of WEIM at Fitchburg, Mass.

Charlie Nehlson—WLS Studio Engineer, Chicago, (somtimes we wonder about these boys at WLS). He spent his vacation at the Mayan Dude Ranch in Texas pigeon hunting. Seems Charlie doesn't ride the ponies so well.

Vincent Chandler—Chief Engineer at WMUR, Manchester, N. H., became a Father after much pacing in August. The arrival's a boy and Vince says not a future radio man is he.

J. H. Platz—Control Room Supervisor, NBC, Chicago, now residing at his new home in Elmhurst.

Clyde Diderich—WGN Studio Engineer, vacations for a month on the West Coast.

Leonard Doese—Chief Engineer at WIBU, Poynette, Wis. Add this one to the list of proud Papas with a future president in his home.

W. K. Marks—Formerly of CKPC, Brantford, Ont., and CJKL, Kirkland Lake, Ont., was listed as one of the victims of a plane crash in England. Marks was serving his Country as a Radio Operator with the Trans-Atlantic Ferry Service. Broadcasting loses a good man in Marks. He served his Country well and is a credit to the Industry. "30".

E. A. MacCornack and Wm. Cole—Both of NBC, Chicago, spent their vacations in the North Woods fishing and sampling (' ' ' '). Both returned to work with the most beautiful tan. Bill claims the resorts of the North Woods have all installed sun lamps in the back room.

(Continued on Page Twelve)

WLS to NABET

By Tom Gootee

THE studio engineering staff of WLS in Chicago became members of NABET on July 1, 1941, and the Journal takes pride in presenting these new members to the Association.

Shown grouped around Charles F. Nehlsen in the above photograph are: Walter Varnum, Maurice Donnelly, Burr Whyland, James Daugherty, Herbert Wyers, and William Taylor.

Station WLS first went on the air in 1924, and came under the present ownership of the *Prairie Farmer* in 1928. WLS shares time with WENR—directing most of its programs to agricultural areas in the middle-west. The Saturday Night Barn-Dance program is the oldest continuous weekly show on the networks, now well over 17 years old.

The seven WLS engineers have an average service record of seven years apiece. Oldest from the standpoint of service is Charles F. Nehlsen; after four years of ship operating, he joined the WLS staff in 1925—and has since done transmitter, field, studio and maintenance work. James P. Daugherty came to WLS in 1933, after five years previous work in other Chicago stations. Herbert B. Wyers joined he staff in 1932. Burr Whyland and Maurice J. Donnelly came to the station in 1937; and during the next year William P. Taylor, Jr., and Walter B. Varnum joined the staff of WLS.

Hams Favored as Navy "Op's"

THE U. S. Naval Reserve Training School at Noroton Heights, Connecticut, offers an interesting illustration of the steps the Navy Department has taken to meet its urgent need for trained radio operators. It is perhaps of particular interest to hams and those engaged in various forms of commercial radio work, who fall within the early call classifications of the selective service, because the Naval Reserve offers an opportunity for voluntary enlistment for service of one's own choosing. By enlisting for radio service, the radio man gains the benefit of the training provided by the navy at such schools as this one. In addition he is serving Uncle Sam in the work for which he is probably best qualified.

Enlistment in the Naval Reserve is for a term of four years, with active duty extending "for the duration." If the emergency is over within this period those enrolled will be returned to civilian life and serve the balance of their enlistments as reservists. Entering the service as apprentice seamen they are first put through an intensive course of training at one of the several schools similar to this one at Noroton Heights. Here the normal training period extends over a period of sixteen weeks but may be considerably less for those of previous experience in this field. At the end of this period the trainee is immediately assigned to active duty, with the rating of seaman first class, as a qualified operator at a ship or shore station. From that point on his service will depend pretty much on his ability. He may continue at such duties but it is more likely that he will be recalled after a few months of service for further specialized training.

After sixteen weeks the enlisted man is capable of receiving code directly on a typewriter at an average speed of 25 words per minute and of transmitting with a hand key at this same speed. He will have learned touch typing, a good deal about navy radio equipment and will even have taken some of it apart and reassembled it with his own hands. He will have learned some of the fundamentals of visual and under-water signalling, and will have received training in basic naval subjects including regulations, organization, first aid, marching formations, navy communications proceedure, special navy service codes, etc.

The effort throughout this training program is to make it so intensely practical that even a layman will at the end of the period be ready for service at sea or shore stations. It is not considered sufficient, for instance, to teach code reception, navy message handling proceedure, log-keeping, etc., as individual subjects, leaving the student to coordinate these for himself when he goes out on active duty. Instead one room of the school has been equipped with a battery of typical communications receivers. Here, after students have acquired fair speed in the code and typewriting classes, they receive actual "on the air" training, exactly duplicating the reception routine in a regular naval station.

Photo by The Hartford Courant

A battery of "on the air" receiving positions, equipped with Hallicrafters SX-23's, provide practical training in dispatch handling at the Naval Reserve School at Noroton Heights

It is by such methods as this that the navy is striving to meet its requirements for a vastly augmented supply of trained radio men. This one school at Noroton Heights is turning out about 1,500 trained operators per year—and this, while it is the largest, is only one of several such Naval Reserve schools.

Thank You!

The Journal Staff is proud of the fine reception given our new name and cover design, and hereby thanks reader and advertiser alike for the many fine letters we have received. Needless to say, we shall continue to bend every effort to warrant your continued support.

Reminder to combination Ham and Photo Bugs: Next issue contains annual Broadcast Engineers' Journal Photo Contest results. Rules and Prizes were detailed in the August issue.

Wherever possible, inquiries, manuscripts, and advertising copy should be addressed to the Editor's Office: E. Stolzenberger, 116-03 91st Avenue, Richmond Hill, L. I., N. Y. Telephone: VIrginia 9-5553.

Christmas Year-book: We now have plans underway for our annual year-book which will exceed in size and scope our 1940 effort. Advertising inquiries should be made promptly to: E. C. Horstman, Sales & Promotion, The Broadcast Engineers' Journal, Room 624, 201 North Wells Building, Chicago, Illinois. Telephone: State 8116.

Defense Communications Board resolution, dated August 22, 1941:

"WHEREAS on account of the importance to national defense of the plants and facilities of the communications industry it appears desirable to restrict free access thereto;

"BE IT THEREFORE RESOLVED that all persons engaged in the wire or radiocommunications industry, including manufacturing, be requested to take all measures necessary to ensure that access to premises containing communications equipment or facilities (other than the premises necessarily open to the general public) be restricted to employees, federal, state or local government officers acting in their official capacity, and other persons considered necessary by the management in the conduct of its business;

"BE IT FURTHER RESOLVED that all persons engaged in the wire or radiocommunications industry, including manufacturing, be requested to exclude representatives of any foreign government, persons, associations or corporations, from access to the premises containing communications equipment or facilities (other than premises necessarily open to the general public) except only upon express permission granted at the direction of the Defense Communications Board."

Exchange — Swop — Sell

We have received repeated requests to inaugurate an Exchange—Swop—Sell column for the benefit of our readers. In order to prevent this venture from assuming gigantic proportions we are setting a charge of 50c per line (55 typewriter spaces per line) for items received. They will be listed in the order received, and no special type or display will be permitted. In all cases, remittance must accompany order.

BEHIND THE MIKE (Continued from Page 10)

Barrett Schillo—WGN Studio Engineer, Chicago, now on active duty with the Navy. He is stationed at the NAVY'S school in Indianapolis.

H. F. Abfalter — NBC Chicago Studio Engineer, married in August to Miss Frances Morton (Note — the Boss's secretary). The Abfalters spent their honeymoon vacation on board the Goosson, AB's racing yacht. They travelled the East Waters of Lake Michigan. The AB's cut a pretty fancy piece of cake before shoving off into the white caps (see picture).

Denzil Pulley—Formerly with WSIX and WHUB, is the new Chief Engineer of WGAA, Cedartown, Georgia.

Gene Goldrup—KGMB, Honolulu, and KHBC, Hilo, has resigned to return to the States.

Richard Walden—Long Lines, Chicago, and L. V. Adams have both completed their solo time and are now trying for their Pilot's License.

William Six—WGN Xmitter, Chicago, has just completed a new home in Elmhurst and is about to move in. House warming coming up.

W. T. Knight—NBC Studio Engineer, Chicago. Bill is a registered Optometrist and probably outdoes any other in the business. He gives the boys who work nights their examinations after the close of business.

Walter Thompson—Formerly of WCAE, Pittsburgh, joined the staff of WGN. His addition being required due extra duties of FM Xmitter now in operation.

M. W. Rife—Field Supervisor, NBC, Chicago. Last year broke his leg while vacation, did a ditto few weeks later from a swivel. This year during annual trek to the North Woods Rife was well equipped with non-skid boots, which were very much anti-slip. We are happy to report no accidents this year but look out for the swivel.

Ralph Batt—WGN Studio, Chicago. Proud Pappy, Ralph a bit different from the others reported this month in this, that his arrival is a girl.

Ralph Davis—NBC Chicago Recording Supervisor, could be called a proud Pappy. He and the boys about to move into new quarters much enlarged and bedecked with lots of new, shiny, and jeweled equipment. New spot is a fish bowl so boys will have to wear their ties straight.

The Why and How of Frequency Modulation

By Raymond F. Guy
N.B.C. Radio Facilities Engineer

[By popular request, this article has been brought up-to-date and reprinted from our September, 1940, "FM Issue"— EDITOR]

TWENTY years ago all frequencies above 1500 kc were considered to be of such little value that even the amateurs had objections to being confined to them. There is no need to state here what has since occurred on these "useless" frequencies nor to dwell on the fact that the surface has but been scratched. One service after another has wholly or partially transferred the bulk of its activities to them, and a multitude of new and invaluable services have been made possible by their use. So-called "Standard Broadcasting" had a most humble beginning on 830 kc, which was then in the middle of the marine band of 500 kc to 1000 kc. Broadcasting quickly crowded the original occupants out of most of this band. It is not one of the services which have since moved into the high-frequency spectrum. It remains on the former marine frequencies where it started. But some feel that a shift may be approaching.

The use of the ultra high frequencies for sound broadcasting offers technical advantages, not only to the broadcaster but to the public, which is much more important. There are also some disadvantages. The technical advantages consist of escaping the 10 kc channel limitation, getting away from static and eliminating all except spasmodic long distance interference. We've known this for years, have experimentally operated low power UHF stations since "way back," and have enjoyed the experience of receiving "clean stuff" from our little UHF transmitters when QRN washed out our temporarily musclebound 50 kw steamrollers, with devastating wallops. The disadvantages are the lack of UHF long distance night time transmission to the rural areas which are the areas in need of better service. Six years ago the FCC had applications for, or had licensed, over 100 UHF transmitting plants and it seemed that a trend was developing toward UHF broadcasting, but this trend was not sustained. Interest has been revived more recently through the promotion of FM on UHF.

Amplitude-modulated UHF stations can provide greater coverage than standard broadcasting shared-channel stations limited by night-time interference from distant stations operating on the same channel. This interference usually causes such a station's useful service area to shrink to a small fraction of its daytime area and many of these stations are, in addition, required to reduce power at night to minimize similar interference to other stations. Few such stations are free from night-time interference within their 2000 microvolt contour and many are limited to 8000 microvolts. The ultra high frequencies offer an escape from such limitations by virtue of practical freedom from static and shared-channel interference. Frequency modulation can provide a much greater degree of improvement than can amplitude modulation on these ultra high frequencies.

Frequency modulation is a weapon against noise, a sword if you please, with advantages which can be calculated accurately and simply, as we shall see. But unreasonable powers should not be attributed to it. The pen should not be mightier than the sword.

Your scribe bows low and humbly attempts, with these hesitant strokes, to bring to you gentlemen of the Broadcast Engineers' Journal what the "lower classes" vulgarly call the "lowdown."

Let's get to the point. What advantages does FM really give over AM? Using the frequency deviation approved for the industry by the FCC, FM UNDER THE OPTIMUM CONDITIONS gives an advantage of 20 to 1 in background noise suppression, an advantage in rejection of shared-channel interference of 30 or more times, depending on the beat frequency, and some advantage to the broadcaster in capital expenditures and operating costs. There you have it.

One frequently meets laymen who have the mistaken idea that FM is a revolutionary new invention. The justly proud father of your profoundly humble scribe bought him his first lace velvet pants in 1902. Most of you were still unborn during that antediluvian era. It was in that year that a gentleman named Ehret applied for a patent which was issued in 1905 covering the basic method of FM for voice and code transmission and reception. Mr. Ehret proposed to shift the carrier frequency by means of a voice actuated capacitor. He proposed an off tuned circuit in the receiver for converting the frequency modulated waves into waves of varying amplitude. With certain improvements these are the methods now used. For code signalling he proposed to key the transmitter inductance or capacity to change the carrier frequency. Before the No. 1 war this method was very widely used for many years on long wave transmitters. Remember how discombobulated one could become by trying to read the backwave when fatigued?

FM research has been carried on for over 31 years and, except for 1918, 1920 and 1924, patents have been issued on FM methods and devices each year for the last 26 years. They were granted mostly to a number of inventors in the employ of organizations which spend large sums on research, such as GE, Westinghouse, AT&T and RCA, and to a few individuals, particularly Major Edwin H. Armstrong who has promoted use of the feature of "wide swing" in FM.

Other features are important in FM, such as limiting. Gentlemen named Wright and Smith filed a patent application covering it 15 years ago. Fourteen years ago, and subsequently, patent applications were filed and granted to Westinghouse, AT&T and RCA on balanced, or back to back FM demodulators. The most commonly used discriminator today was patented by S. Seeley of RCA. Frequency multiplication of an FM wave to increase the frequency shift is covered in patents issued to Westinghouse, and GE, for which applications were filed in 1926 and subsequent years.

High frequency pre-emphasis and de-emphasis circuits were patented by S. Seeley and others of RCA. However, your humble scribe confesses with enchanting modesty to having participated in the development and installation of a pre-emphasis amplifier to produce rising high frequency response at WJZ in 1924, 17 long years ago. It had a rising frequency response curve almost identical with our "new" 100 microsecond standard. It was used for years, its purpose was to overcome the natural "de-emphasis" produced by lack of high frequency response in receivers, and it is fully described in *Broadcast Transmitting Stations of the RCA*, by Julius Weinberger, Volume 12, 1924 IRE Proceedings.

At the close of 1939 more than 250 patents had been granted on frequency or phase modulation, of which more than 160 covered FM. About 10 years ago RCAC was trying FM on channels between our East and West coasts.

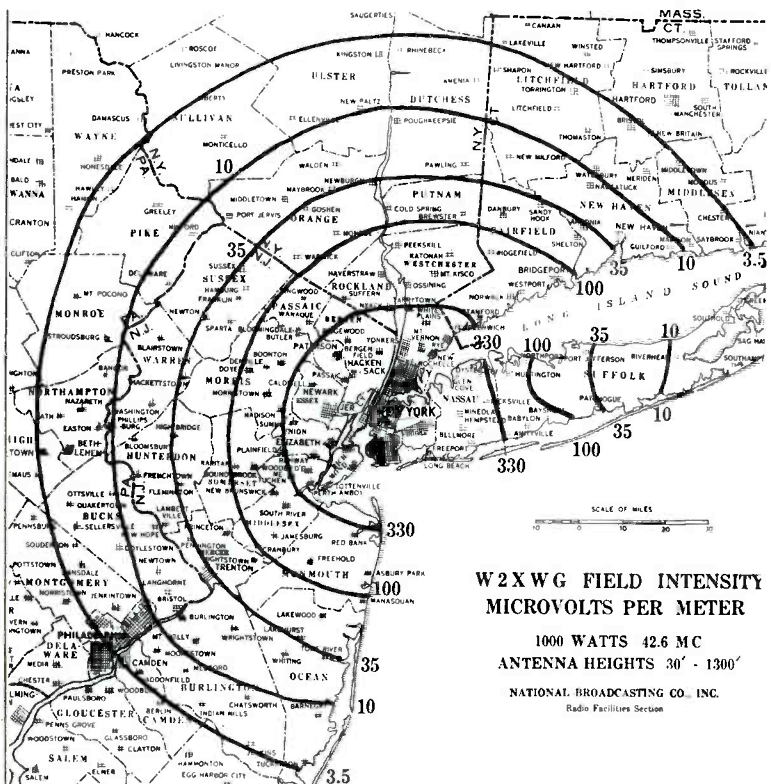


FIG. 1

About 12 years ago your scribe cooperated with Westinghouse in FM tests between New York and Pittsburgh. So you can see FM isn't new.

There is a popular impression that by use of FM and "wide swing" the public may only now enjoy high fidelity. The facts are that with ultra high frequencies the fidelity can be made entirely satisfactory with either frequency or amplitude modulation. Superior UHF fidelity is made possible by getting away from the 10 kc channel allocations of the Standard Broadcasting Band and not by using FM or AM. Furthermore, to get "high fidelity" in AM or FM receivers the listener must pay exactly the same high price for high power, low distortion audio amplifiers, expensive loudspeakers and acoustical systems. However, the time may come when high fidelity will receive the widespread recognition it merits. There is much more interest now in low receiver prices which preclude high fidelity. This is unfortunate but incontestably true regardless of any wishful or idealistic thinking to the contrary.

There is no lack of satisfactory fidelity in present day transmitters because, if for no other reason, the FCC requires it. The loss of fidelity rests in the home receivers. Medium priced receivers satisfy the public demand and high fidelity cannot be obtained in those models. The price paid for so-called high fidelity amplifiers and loudspeakers is in itself more than the cost of many receivers. Possibly one person in ten has a receiver of good fidelity. Many of these listeners normally operate with the tone control adjusted for the lowest degree of fidelity possible with such good fidelity receivers. It appears that the public is not suffering any lack of good fidelity because of the present broadcasting system.

We in NBC, and others, have been providing transmission of excellent fidelity for at least 15 years (network lines excepted) and will continue to do so. We believe in it and endorse it. But we have no illusions about the public reaction toward it.

The problems of high fidelity are problems of cost and of widespread appreciation of improved fidelity and not of any type or method of modulation. In the NBC field test of FM our attention was directed to those advantages which FM inherently has over AM, the reduction of noise and interference.

FM is hailed as static free. It is. But the greatest part of the reduction of static is due to the use of UHF and has no connection with the station itself or the type of modulation. Dr. W. L. Everett estimates in the AIEE Journal that this reduction is 40 to 1. This is presumably based upon the assumption that the static amplitude is inversely proportional to the radio frequency. Your scribe has found this to be true in 26 years of jousting with static, at times in parts of the world where they really have it.

An additional maximum static reduction of 20 to 1 can be obtained from FM. The total reduction, compared with Standard Broadcasting is thus as much as 800 to 1 for *natural static*. However, such *man made* noises as auto ignition systems, which don't bother us in standard broadcasting, rise to plague us instead. Each spectrum has noises peculiar to itself.

This is cold professional realism. An FM station will provide noise-free service to a much greater distance than an AM station of equal power because FM can suppress receiver hiss noise, auto ignition noise and other UHF disturbances about 20 to 1, if the carrier is stronger than the noise and if the receivers have enough gain to make the limiters limit at low field intensities. Many FM receivers begin to slack off at about 100 microvolts. To obtain the full benefit of FM out to the "noise threshold" limit they should hold up down to 10 microvolts. This noise threshold is strictly an FM phenomena of which more will be said later.

We are all confident that television has a most brilliant future. We are not entirely clear on the position that UHF sound broadcasting will have with respect to it. Those of us who have lived with television for many years feel that sound is supplemental to sight but definitely second in importance. When television hits its stride, sound broadcasting may assume the status of silent pictures. Who knows? Nobody does. In any event, sound broadcasting will be with us for many more years and we will give full opportunity to improved methods and devices. FM is one of them. FM is being given its chance to prove itself.

The NBC has for many years viewed realistically the advantages of the ultra high frequencies and has been confident that the industry would, in time, do likewise. Five years ago Mr. Hanson and your profoundly humble scribe wrote a long report on the subject. FM had such promising theoretical advantages that a little later we decided to undertake a full scale field test to determine the extent to which they could be realized in practice.

As a result we recently completed, at a cost of over $30,000, what we consider the most thorough field test of FM ever undertaken, and we have the information we sought. It was obtained, not by laboratory work, which had been done before by others, including RCAC, nor merely by operating an FM station, but by building special transmitters, receivers, measuring instruments, etc., and then painstakingly making thousands of measurements at distant points over many months and under a variety of conditions.

A special 1,000 watt transmitter was ordered from the RCAM Company. It had facilities for both AM and any degree of FM deviation or "swing" desired, with remote control facilities for instantaneously switching to either system. Since the FM deviation varies directly with the audio input level, remote controlled pads could be and were used to select the deviation desired.

W2XWG was installed in the Empire State Building. Special authority was obtained from the FCC to use amplitude modulation as well as FM on 42.6 MC for the term of the project. The television video antenna, having a pass band extending from 30 to 60 megacycles, was used for most of the W2XWG transmissions although a special folded dipole was used at times.

W2XWG was equipped with means for continuous variation of power between 1/10 watt and 1,000 watts, and a vacuum tube voltmeter for accurately measuring the power.

The modulation conditions selected were AM, FM 15 (deviation of 15 kc, or total swing of 30 kc), and FM 75 (deviation of 75 kc or total swing of 150 kc). Tone modulation was used for most measurements. For measuring distortion, or noise levels with modulation present, the tone output of the receivers was cleaned up by passing it through filters and then impressed upon RCA noise and distortion meters.

Four special receivers were built by the RCAM Company for this project. Each was equipped for instantaneous selection of AM, FM 15 or FM 75. Two complete IF systems were built in, one 150 kc wide and one 30 kc wide, each having 5 stages, with both AM and FM detectors. All receivers contained meters, controls, de-emphasis circuits with keys, 8 kc cutoff filters with keys, separate high quality amplifiers and speakers, cathode ray oscillographs, etc. Each receiver had sufficient RF gain to give full output with limiting at input levels much lower than required, theoretically doing so with only 1/10 microvolt input. These receivers were made as good as receivers can be built in order that our conclusions on FM would not be clouded by apparatus shortcomings. Sacrificing good receiver design to price will not permit the full gain of FM, as reported herein, to be realized.

As a part of the project, a field intensity survey was made of the W2XWG transmissions. The map is included herein for 1,000 watts, 1,300 feet antenna height and .7 antenna gain. It is Fig. 1.

Measurements and electrical transcriptions were made under a variety of conditions at the following locations:

Collingswood, N. J.	85	Miles
Hollis, L. I.	12	"
Floral Park, L. I.	15	"
Port Jefferson, L. I.	50	"
Commack, L. I.	36	"
Riverhead, L. I.	70	"
Hampton Bays, L. I.	78	"
Bridgehampton, L. I.	89	"
Eastport, L. I.	65	"
NBC Laboratory	1	"
Bellmore, L. I.	23	"

All above stations are temporary, with the exception of the last two, which are permanent.

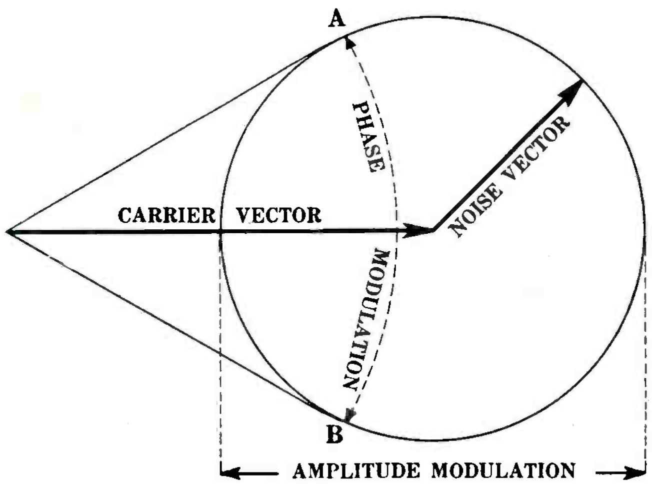


FIG. 2

Most of the measurements were made at the Bellmore station. For the temporary stations, two automobiles were equipped and used, one a Radio Facilities Group measuring car, the other a borrowed RCAC truck full of recording gear. The receiving stations represented a cross section of rural and suburban Americana.

Let's next see what theoretical advantage FM has in noise suppression and how it is obtained. Later we will see what we measured.

In FM the deviation of the carrier frequency can be made as great as desired. If it is 15 kc and the audio band width is 15 kc the deviation ratio is 1, corresponding to the deviation divided by the audio band width. If the deviation is 30 kc the deviation ratio is 2, etc.

The advantages of FM over AM in noise suppression are contributed by three factors:

1. The triangular noise spectrum of FM.
2. Wide swings, or large deviation ratios.
3. The greater effect of de-emphasis in FM compared to AM.

Let us consider them in order.

THE TRIANGULAR NOISE SPECTRUM

An FM system with a deviation ratio of 1 has an advantage in signal to noise ratio of 1.73 to 4.75 db for hiss or other types of fluctuating noise.

Since the figure 1.73 applies to such noises as tube hiss, which is comparatively steady in amplitude, we will consider this type of noise. It differs from impulse noise such as is produced by automobile ignition systems.

Tube hiss consists of a great many closely overlapping impulses or peaks. There are so many of them at all audio frequencies, we are concerned with, that the noise has a steady characteristic. When combined with a steady carrier of fixed frequency, the noise peaks beat with the carrier. The noise peaks also beat with each other. When the carrier is considerably stronger than the noise peaks, beats between the noise peaks become negligible in amplitude and the predominating noise is due to the combination of carrier and noise peaks.

Since a combination of two carriers differing in frequency produces a similar phenomenon, we will treat both cases at the same time. The effect is most easily shown and understood by means of a simple vector diagram.

The strongest carrier vector continuously rotates through 360 degrees and is indicated on Fig. 2. The weaker carrier, or the noise voltage, rotates around the carrier vector at a frequency which is equal to the difference between the desired carrier and undesired frequency. It will be seen that amplitude modulation is produced. If the undesired frequency is 50% as strong as the desired frequency, 50% amplitude modulation results. As the undesired vector rotates around the desired vector, phase modulation also is produced between the limits A and B. The faster the undesired vector rotates, or the faster the rate of phase change becomes, the greater becomes the momentary change in frequency and, therefore, the greater the frequency modulation becomes, because frequency modulation is a function of the first differential of phase modulation. Therefore, the amplitude of the frequency

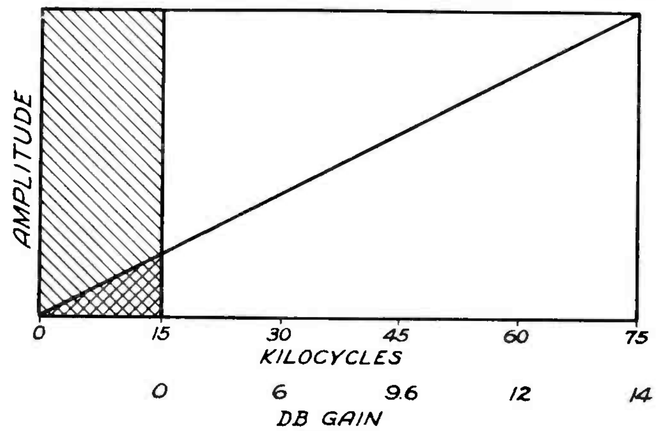


FIG. 3

modulation noise or beat note varies directly with beat frequency. With both frequencies exactly the same there is no amplitude modulation nor is there any frequency modulation.

Such being the case, the noise frequencies close to the carrier produce little frequency modulation noise but as the noise components further from the carrier combine with it they produce more frequency modulation. Therefore, the higher the noise beat frequency the higher its amplitude. This results in a frequency modulation noise spectrum in which the noise amplitude rises directly with its frequency. In other words, it is a triangular spectrum.

In amplitude modulation there is no such effect as this. All noise components combine with the carrier equally. Therefore in amplitude modulation there is a rectangular noise spectrum. The ratio of noise voltages in FM and AM is therefore the ratio between the square root of the squared ordinates of a triangle and a rectangle. This ratio is 1.73 or 4.75 db.

THE DEVIATION RATIO

For an FM System the suppression of fluctuation noise is directly proportional to the deviation ratio. On Fig. 3 the AM noise spectrum corresponds to the total hatched area below 15 kc because the IF system would cut off there. The FM 75 receiver IF system actually accepts noise out to 75 kc and it has the usual FM triangular characteristic. However, the receiver output and the ear responds only to noise frequencies within the range of audibility, around 15 kc, and rejects everything else. Therefore, the FM 75 noise we actually hear corresponds only to the small cross hatched triangle and all the rest is rejected. The maximum height of this FM triangle, corresponding to voltage, is only one-fifth of the height of the AM rectangle. Such being the case the FM 75 advantage is 5 to 1, or 14 db. Simple?

DE-EMPHASIS

When the high frequencies are attenuated in a receiver, the high frequency noise is, of course, attenuated by the same amount. This may make a noisy signal more pleasant to the ear, but it degrades the fidelity. However, if the high frequencies are increased in amplitude in the transmitter, the over-all fidelity will be restored. Nevertheless the noise which comes in at the receiver remains attenuated and therefore a reduction of noise results from this practice. The use of a 100 microsecond filter to accomplish this purpose has been adopted as standard practice in Television and UHF sound broadcasting by the Radio Manufacturers Association and recently by the FCC. It has actually been in use for several years. A 100 microsecond filter is a combination of resistance and capacity which will charge to 63% of maximum, or discharge to 37% of maximum in 100 microseconds.

It was shown that in FM, the noise amplitude decreases as its frequency decreases whereas in AM it doesn't. Therefore, de-emphasis is more effective in FM. Consider Fig. 4. The full rectangle at the left is the AM noise spectrum. The full triangle at the right is the FM spectrum. The application of de-emphasis reduces these areas to those combining the hatched and black sections. Squaring those ordinates gives the black areas, corresponding to power, or energy. Extracting the square root of the ratios of these black areas gives the RMS voltage advantage of FM over AM. It is 4, corresponding to 12 db. Bear in mind that this 12 db includes the gains contributed by both the triangular noise spectrum and de-emphasis. The spectrum advantage was 4.75 db. Hence the de-emphasis advantage is 12 db minus 4.75 db or 7.25 db.

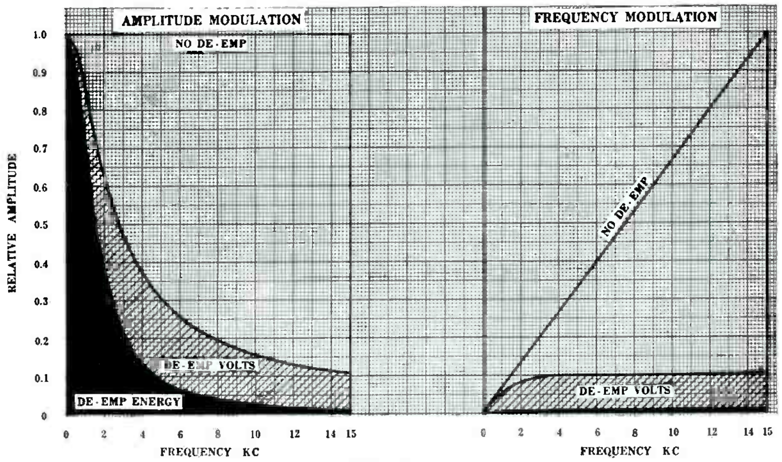


FIG. 4

All commercial FM receivers include de-emphasis and all FM TRANSMITTERS INCLUDE PRE-EMPHASIS. It's an FCC requirement.

Now let's sum up. We saw that the FM noise spectrum advantage was 4.75 db, the de-emphasis advantage was 7.25 db and the deviation ratio of FM 75 was 14 db. Combining these gives us 26 db.

Now let's see what advantage we actually measured as

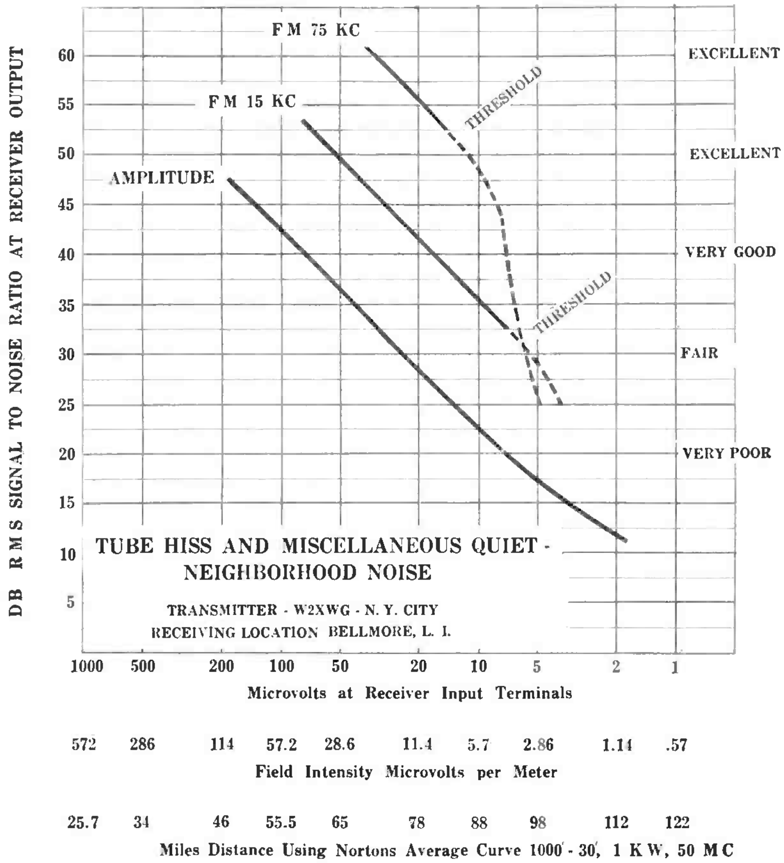


FIG. 5

part of the field test project. Your attention is directed to Fig. 5 which has on it a great deal of information.

It actually condenses to one page much of the data we sought and obtained. Many pages could be devoted to it. The curves may be extended to the upper left in parallel lines as far as desired. The actual field intensity of the noise can be determined from the AM curve. For instance, for 10 microvolts at the receiver terminals the AM signal to noise ratio is about 25 db or 18 to 1. Hence the noise is 1/18 of 10 microvolts, or .6 microvolts RMS.

The ordinates are identified in receiver input microvolts, microvolts per meter and miles distance. Use the one you are most interested in. If you want condensed distance tables refer to the bar chart, Fig. 6, which was made from the data on this sheet.

Compare the measured gains with the calculations we went through. They look to be the same. They are. That means we found that the theoretical gain of FM can be and was obtained in practice.

Note the dotted sections of the FM curves. They are dotted to indicate that operation is not only below the "noise threshold" but is far enough below it that a noticeable increase of noise results as soon as modulation occurs. The dotted sections represent noise in the unmodulated condition. During modulation they break even sharper than indicated. Since there is no such thing as a noise threshold in AM there is no such break. At distances where AM is better than FM 75 it has no entertainment value because it is very noisy. However, the AM signal is useful for intelligent transmission, i. e., telephone communication, code, etc. The result is that wherever useable AM entertainment service is provided, FM 15 is 12 db quieter and FM 75 is 26 db quieter.

THE NOISE THRESHOLD IN FREQUENCY MODULATION

An interesting series of events takes place in a frequency modulated system when the noise peaks equal or exceed the peaks of the carrier. The result is a rapid increase of the noise level or decrease of the signal to noise ratio with modulation. In frequency modulation wherein the maximum swing is 150 kc the point where this begins to occur is reached when the unmodulated signal to noise ratio is about 60 db. When the unmodulated signal to noise ratio is less than about 60 db, or 1,000 to 1, the noise level rises with modulation, and, as the noise peaks exceed the carrier peaks by a considerable amount, this noise level may go up 20 db, or 10 times. When operating above the threshold limit the noise changes very little as the station is modulated. Below the threshold limit the effect is not unlike severe harmonic distortion in an overloaded amplitude transmitter.

In frequency modulation of a lesser swing, such as 30 kc, a similar effect occurs. In this case, however, the threshold limit occurs at about 35 db signal to noise ratio. Fig. 7 shows the results of some of the measurements we made. In order that the noise would not be confused with the small amount of inherent distortion in a practical FM system, the measurements were made in such a manner that the effects of distortion were eliminated. This was done by modulating the transmitter with a 17,000 cycle tone and eliminating at the output of the receiver with a 14,000 cycle low pass filter both the fundamental modulating tone and the distortion products leaving only the noise.

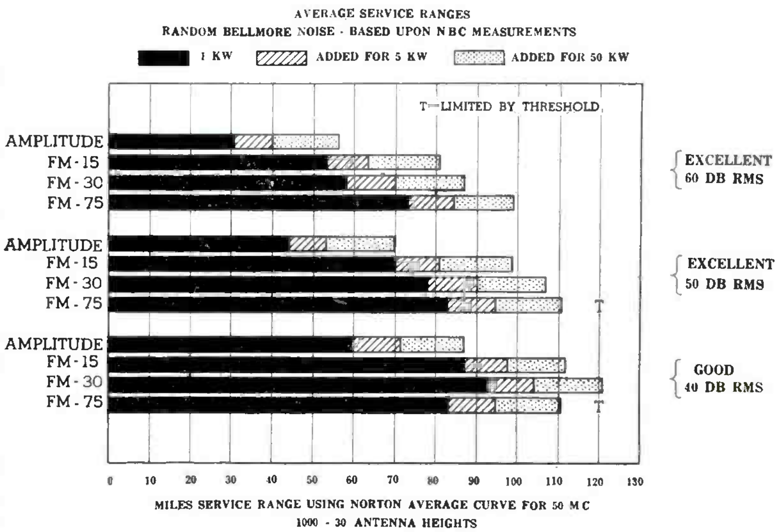


FIG. 6

This effect has no doubt been observed by many without being understood. It is a characteristic of a frequency modulation system. The noise threshold in the case of an FM 40 system having a total band width of 100 kc occurs at about 43 db. Since this provides a very good signal-to-noise ratio and the required band width is only 100 kc, FM 40 is believed by your scribe and many others to have more overall merit than FM 75 when the comparative gains and limited space in the allocation spectrum are considered.

So far as is known, the data on the FM threshold effect presented here, and data published by Murray Crosby of RCAC constitute the only measured data ever published.

FREQUENCY MODULATION FLUCTUATION NOISE THRESHOLD

Transmitter modulated with 17,000 cycle tone. This and any distortion products removed at receiver output with 14,000 low pass filter, leaving only noise.

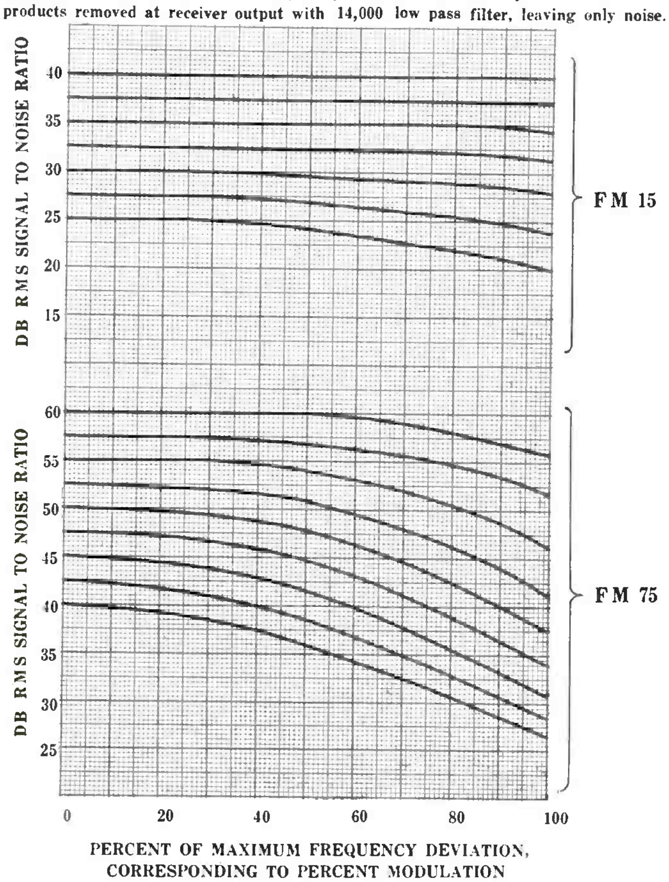


FIG. 7

Fig. 8 shows ignition noise measurements with peak noise input microvolts plotted against peak signal to noise ratio, based upon the signal resulting from maximum 400 cycle modulation. The FM 15 threshold is shown. The FM 75 threshold is not shown because at the time the measurements were made AC hum within the system made the accuracy of S/N measurements in the 60 db region uncertain.

It should not be assumed that peak S/N ratios of 20 or 30 db are unuseable when the noise arises from ignition systems because it isn't true. The relative infrequency of ignition peaks produces an audible result which is very deceiving. Ratios as low as 10 db, while distracting, do not entirely ruin service as is the case with fluctuation noise. It will be noted that the curves of ignition noise threshold flatten off at the bottom. This is to be expected from the character of ignition noise. The impulses are very short in

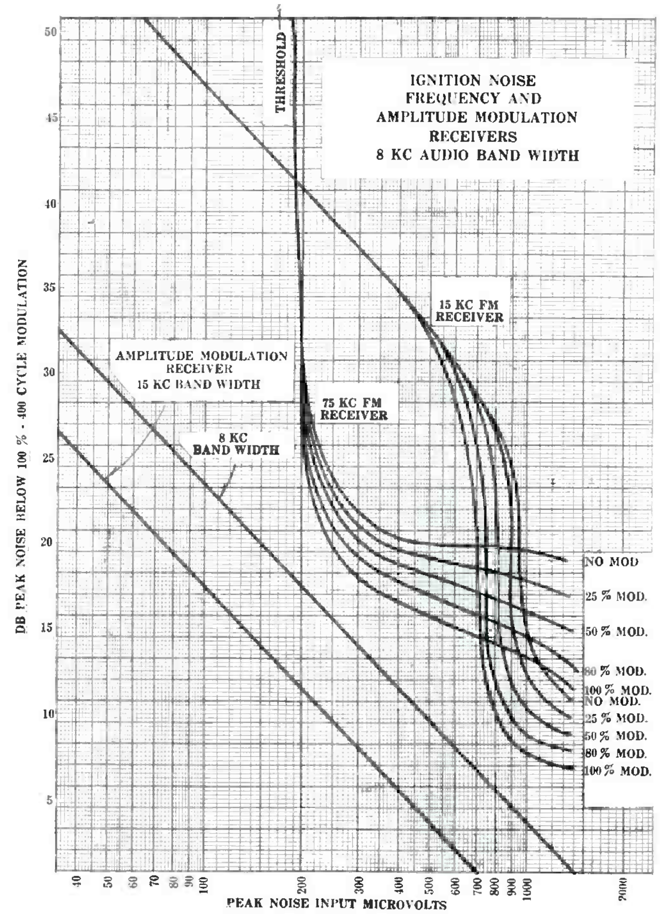
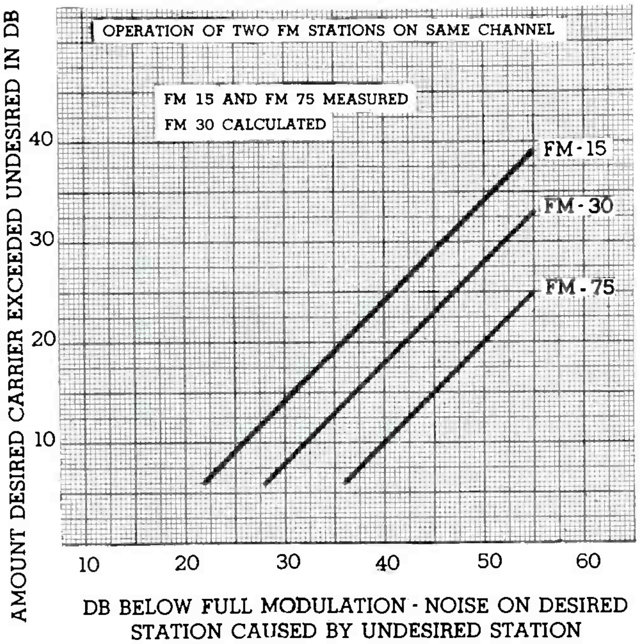


FIG. 8



DB BELOW FULL MODULATION - NOISE ON DESIRED STATION CAUSED BY UNDESIRED STATION WORST CONDITION - BOTH STATIONS UNMODULATED

FIG. 9

duration, very high in amplitude and relatively widely separated. They literally blank out only small portions of the signal waves, without impairing the remainder. The short blanked out intervals of the signal change little over a wide range in noise peak amplitude. Once an ignition peak has risen to the value required to control the receiver and blank out the signal a further rise in the noise level will not occur until the peak increases in breadth, or duration, or until there is a sufficient rise in certain low amplitude components of ignition noise having fluctuation noise characteristics. The peculiar shapes of such curves below the threshold values are due to the wave shapes and crest factors of ignition noise, but they are also influenced by the method of measurements.

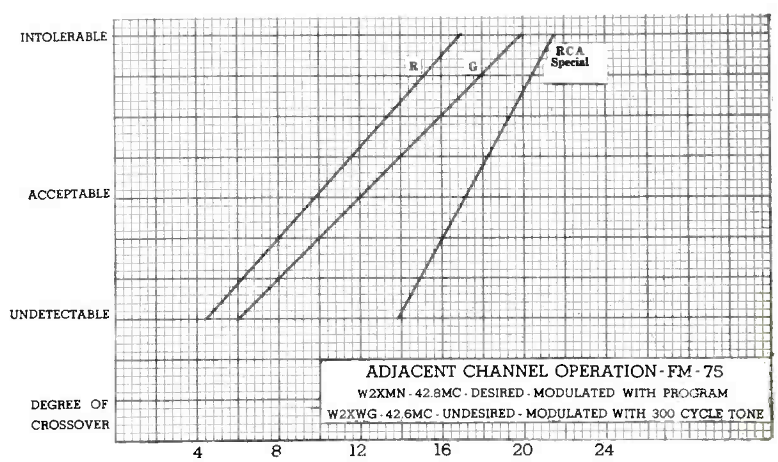
OPERATION OF TWO FM STATIONS ON THE SAME CHANNEL

By referring to the section covering noise interference it can be seen that the worst condition of shared-channel operation occurs when both stations are unmodulated and a fixed beat note, therefore, results. It will also be seen that the higher this beat note the greater will be its amplitude. Fig. 9 was made on the basis of the worst conditions, which occur when the difference in carrier frequency reaches approximately 5,000 cycles. Were it not for the effect of de-emphasis in the receiver the beat note amplitude would rise with frequency. However, de-emphasis of the high frequencies prevents that from happening and the effect may be further understood by referring to the section on pre-emphasis and de-emphasis. It will be noted that the noise on the desired station caused by the undesired station varies inversely with the deviation ratio. FM 75 has a deviation ratio of 5 compared with 1 for FM 15.

When either of the stations producing the beat note becomes modulated, the beat note disappears because one carrier sweeps across the other one. When the desired station is approximately 20 db stronger than the undesired station, interference and cross talk effects become unnoticeable. At 12 db difference they are noticeable but it is the opinion of some engineers that the 12 db ratio would be tolerable. Frequency modulation offers a great advantage over amplitude modulation in the allocation of stations on the same frequency. In AM the carrier amplitude of the desired station must be 100 times, or 40 db greater than the undesired carrier amplitude for a 40 db signal to beat note ratio. For FM 75 it need be only 10 db, or 3 times greater. For FM 30 it need be only 17.5 db or 8 times greater. For FM 15, it need be only 24 db, or 10.5 times greater.

The result is that FM stations can be located much closer geographically, and therefore many more station assignments can be made per channel. Interference due to sky wave transmission from distant stations is ordinarily rejected in FM because the interfering signals do not reach the high amplitude required. This is not so in amplitude modulation.

NATIONAL BROADCASTING CO. INC.
ENGINEERING DEPARTMENT



AMOUNT UNDESIRED CARRIER EXCEEDED DESIRED IN DB

FIG. 10

OPERATION OF FM ON ADJACENT CHANNELS

Can FM stations operate in the same areas on adjacent channels without interfering with each other? Fig. 10 shows some data we accumulated proving that they can't. *(This is* *also verified by the FCC in its Press Release No. 51258 dated June 17, 1941, from which we quote ". . . it is not feasible to use all of the FM channels in the same area, as operation of stations on adjacent channels would result in objectionable interference . . ."—Editor.)* The Commercial receivers had objectionable cross-talk if the undesired station signal intensity was more than about 10 db, or 3 times greater than the desired signal intensity. The special RCA receiver was about 7 db better than the others but it had 5 IF stages compared to 3 for the others. Intolerable cross-talk occurred on all the receivers when the carrier ratio becomes about 20 db, or 10 to 1. It should be noted that the undesired station was modulated with fixed tone of uniformly

TYPICAL NOISE LEVELS 40 - 50 MC.

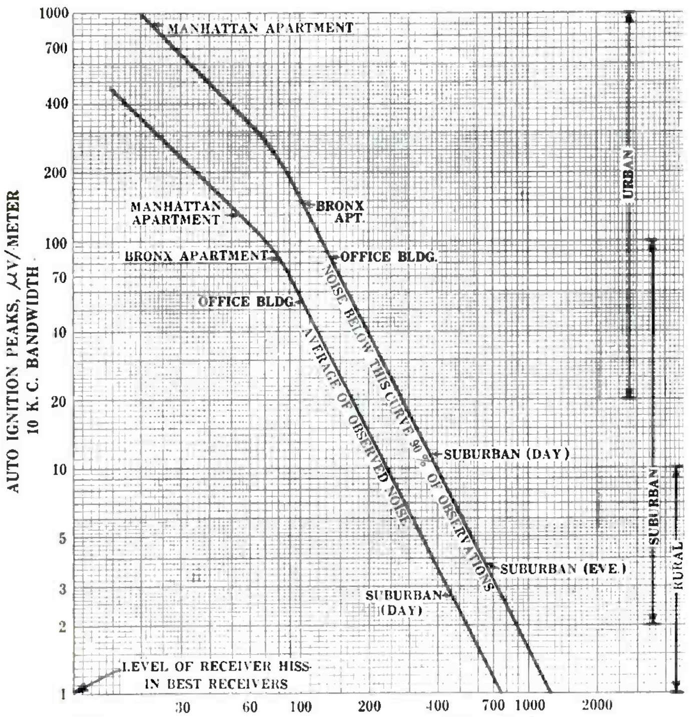


FIG 11.

high modulating level as shown on Fig. 10. As a result the interference was somewhat more severe than would be the case for program transmission of low average level.

In making these measurements the field intensity ratios were changed by controlling the power of W2XWG.

Lack of space makes it seem impractical to try to include more data at this time although much more was obtained. Practically all of it was presented in condensed form by your humble scribe at the FM hearings and presumably it was of some value to the FCC in drafting the new rules and standards for FM stations. That's why it was introduced, at any rate.

How about noise levels? Over a period of many years various groups in the RCA have made noise level measurements in the high frequency spectrums. This information which applies to broadcasting is pooled in Fig. 11. The predominant noise is auto ignition.

Cleveland News

By J. D. Disbrow

THE expression "What goes on here" is quite appropriate around these parts this month. With people going on vacation, people coming back from vacation, first you see them and then you don't. Get them cornered and try to pry some news and they're all tongue tied. Having been away from the grind for a spell myself the news is scarce. Ross Plaisted, NY Television, stopped in to see us for a few hours. Jim Hackett up to his annual stunt of bringing back bushels of sand from the beach at Cedar Point for the kids' sand box. Barney Pruitt bringing in some mighty swell peaches from his farm. Bert Pruitt getting the Bull Durham habit from working nights at the transmitter with Clark. Harold Brandt getting a 33 platter on a table at 78 and giving the listeners a lesson in modified Chinese. That's a good way to get thru a spot announcement quick, equipment failure, no doubt. Caskey was in a swell dither for a few minutes last week when the chimes selector relay on channel two refused to release leaving the network tied in for the next set of chimes no matter where from or for who. Like the kid with his finger in the dike. Harry dammed it up with a patch cord. What is the longest haul to a nemo? We'll start the argument off with Cedar Point, it is 60 miles each way and has to be covered four nights a week. Anybody got a longer one?

RIDING GAIN ON THE AIRIALTO WITH TomGootee

ONE broadcast engineer who turned successfully from operating to radio acting is Ken Griffin—leading actor heard often on the networks. He can trace his twenty-year radio career all the way back to the boom amateur days, following the World War. Living in Enid, Oklahoma, he obtained his first amateur license in 1920—under the call 5PC. A year later he was assigned another call: 5ZAL. But his first commercial operating job was as general factotum around WNAF in Enid—a "one-man" station—which he both owned and operated under his own name. Quite often he was called upon to act as announcer and m. c.—in addition to his engineering duties—and he soon found himself adept at both occupations. This led to announcing jobs with KOMA, KTUL, WBZA and countless other stations.

Finally, in 1928, he wound up working for Westinghouse at KDKA in Pittsburgh—but as an engineer. But a year later he took to the road again, as an announcer. Finally he arrived in Chicago—in 1934—swinging his feet idly over the tail gate of a truck, with just one dollar in his jeans. He had little to show for his years of work—except the experience. In Chicago there were no positions open for announcers—but actors were badly needed. He had done a little dramatic work in school, and always thought he might like to be an actor—so he crashed the field of radio drama and made good.

Ever since that date Ken Griffin has been one of the busiest persons in the radio acting business. He is heard as Larry Noble on *Backstage Wife*, as Dr. Brent on *Road of Life* and countless other daytime and night-time dramas. But despite a heavy acting schedule, he goes in for more hobbies than you'll find advertised in a boys' mechanical magazine. Under one roof on Chicago's near north side, Ken has a modern apartment, and a complete wood and metal working shop. And he indulges in photography, blacksmithing, cabinet-making and general structural activity—part of it on behalf of the racing yacht he sails on Lake Michigan. All of which is a long way from radio operating in Enid, Oklahoma.

Independent radio producers and talent agents look for a good fall and winter radio season, with comedy and comedy-drama shows leading in general popularity. Frank Fay, Bob Burns, and Hal "Gildersleeve" Peary each head their own new programs. Burns and Allen have been recalled for a new series. Ransom Sherman's "Hap Hazard" continues through the fall and winter, as do those two zanies, Abbott and Costello. Eddie East, Budd Hulick, Phil Baker, Ed Wynn and Walter O'Keefe are dickering for sponsors. And finally, all the old favorite comedians will be back: Jack Benny, Bob Hope and Jerry Colonna, Fred Allen, Fanny Brice and Frank Morgan, Col. Stoopnagle, Fibber McGee and Molly, Al Pearce and Eddie Cantor.

The *only* female sound-effects technician in radio broadcasting is believed to be Ora Nichols—currently handling the odd noises and sounds on the CBS *Meet Mr. Meek* program.

Nelson Olmsted—conductor of the *NBC Story-Dramas* program—claims the great 19th century writers unknowingly wrote ideal radio material. At the time Edgar Allen Poe, Charles Dickens, Guy de Maupaussant and others were spinning their tales scores of years ago, radio wasn't even a dream. Yet today their works are particularly well-suited for radio presentation, according to Olmsted, because they wrote their stories to be *read aloud*—and that's where radio counts.

Strangest fan letter of the season was the request from a CBS *Blondie* listener who wanted to buy stock in the program.

A female member of the studio audience at the *Famous Jury Trials* show recently became so incensed at the actor playing the role of a criminal, that she interrupted the "judge" (and the program) by hollering: "He's the one! He's the man who did the murder!"

Sing a Song of Wireless,
  Haywire Amateur!
Four-and twenty hook-ups,
  Held with string secure.

When the rig is working,
  And meters hum and smoke,
Isn't it a wondrous thing
  To realize that the transmitter is operating from worn-out, dry storage batteries, without tubes or antenna—and can *still* be heard in Hawaii ! ! ! ! ! !

Though lovely Lee Childs—musical comedy star and singer—is one of the newest members of the *Carnation Contented* program cast, she will join in celebrating the 500th broadcast of the program on September 29th on the NBC-Red network. Dave Kempkes, studio engineer, who will be at the controls during the broadcast, has accomplished this task on the show for 300 broadcasts, —and he gives Miss Childs the accolade as one of the finest singers ever to appear on this popular NBC program.

LEE CHILDS

The NBC *Vox Pop* program goes to the strangest places for its interview programs. Some of the recent spots visited by Parks Johnson and Wally Butterworth were:— Backstage at *Hellzapoppin*; the New York Stock Exchange; a hospital operating room; a newspaper office; a Junior League party in Cincinnati; a Greenwich Village studio party; and lavish movie premiers.

In furthering its international policy of good-will toward our neighbors to the south, NBC is now affiliated with the new Mexican national network of some 21 broadcast stations. In addition to these, 14 other stations in six Central American countries have just joined the newly-formed Pan-American Network. Covering Costa Rica, Guatemala, Panama, El Salvador, Nicaragua and Honduras, this extension assures complete coverage of all Central American countries and Mexico. These new affiliations were arranged by John F. Royal, NBC vice-president in charge of International Relations. Further and even more extensive collaboration is expected momentarily—linking most of South America to this network, and in time making the Pan-American chain the greatest international network ever conceived. Every major country in Central and South America will be represented under the proposed agreement.

Philadelphia's first television station, W3XE, owned and operated by Philco, is now on the air with 15 hours of program a week. Present power of the station is 3 kilowatts, but it is expected that this will be boosted soon to 10 kw., according to chief engineer, David Grimes.

Philco has been engaged in television research since 1926, its work in this field resulting in several outstanding contributions to the development of the art. Probably the most important contribution was the development of alternate-carrier synchronizing. Actual field tests of this method of synchronization have demonstrated a five-fold increase in synchronizing signal from the same transmitter power. In the opinion of Philco engineers, alternate-carrier synchronizing will extend appreciably the effective service area of any television station employing it, make possible trouble-free reception in areas where the picture was formerly destroyed by static from such everyday devices as vacuum cleaners, kitchen mixers, electric razors, doorbells and automobiles.

The only Chinese announcer in U. S. radio is Charlie Chan, heard on WWRL in Woodside, New York. He dates his ancestry back 4,000 years—and is no relation to the film sleuth.

The recent celebration of the 4,000th broadcast of the *National Farm and Home Hour* recalls to mind that only *three* men have conducted the Homesteaders orchestra regularly during the 13 years it has been heard, namely, Jules Herbuveaux, Harry Kogen, and the present maestro, Walter Blaufuss. The m. c. duties over the same 13-year span were first handled by Wallace Butterworth, later by Everett Mitchell.

Ten Years Ago in Broadcasting. The *March of Time* show was going great guns every Friday night, and was probably the most ambitiously cast program of its era. The cast of actors seldom numbered less than thirty or thirty-five persons; and three sound men were used every week for complicated montages and atmosphere effects. All persons in the news (of that day) were impersonated on the program, a procedure which present-day network policies would now blue-pencil.

Twenty Years Ago in Radio. Home receiving sets were judged not by whether they brought in any DX, but by the amount of space occupied by the cabinet and the complexities of the tuning dials and gadgets scattered variously across the heavy bakelite front panel. Large and bulky batteries supplied the only power, the wet "A" battery generally being responsible for those acid holes in the parlor rug directly underneath the receiver cabinet.

San Francisco News

By Lee Kolm

INTERESTING TO NOTE THAT: Dick Parks, KGO, has succeeded in getting his golf score into the low 90's . . . Guy Cassidy, SE, has been the featured actor in Warren Andresen's movies of the SF control room and monitoring booths and a better actor would be hard to find. The "rushes" indicate that Andy will have an excellent film of the old and the new in San Francisco radio; the "old" being our present headquarters at 111 Sutter, the "new" being our future home at Taylor and O'Farrell Streets . . . At this writing George Dewing, SE, is rapidly regaining health after a heart ailment had him on the shelf for nearly two months . . . Dan Williams, FE, has taken over the Doctor I. Q. program for a six-week period while Pierce of Chicago is on vacation . . . Jim Summers, CS, is renewing activities in the home movies line with the purchase of a 70-A projector . . . Mark Dunnigan, SE, is standing up well under the terrific ribbing he is receiving on the purchase of a certain make of camera. Eastman owners greatly outnumber those using B-H equipment . . . Bob Barnes and Mort Brewer of KPO are still trying for a limit of striped bass off Point San Pablo . . . Aubrey Fisher, KGO, sports a new Buick and has been reported fishing on the north bank of the Yuba River . . . the Harold Platts became the parents of a bouncing boy August 30. Congratulations . . . Charlie Kilgore, CS, has nothing to report on rumors that building has started on his fog-less Belvedere Island property . . . James McDonnell, SE, is a match for any of the golfers on the staff with his game falling in the low 80's consistently . . . "Cannonball" Ed Manning, KPO, will spurt to Sharp's Park Beach for a three weeks vacation. It's all of three miles from his home . . . During the first week of his wife's vacation in Maine, Myron Case, KGO, went thru a 12-piece set of dishes. When he ran out of dishes Myron closed the kitchen and mealtimes were spent in the better Oakland greasy-spoons . . . Henry Dunton, KGO, disciple of Isaac Walton and champion flycaster of hereabouts, has been trying his skill on the streams of Lassen National Park . . . Harry Jacobs, SE, is now developing his own titles and doing an excellent job with the positive film . . . "Bev" Palmer, CS, acted as watchman over a neighbor's home during the neighbor's absence in August. One day, upon discovering that the house had been ransacked, Bev turned sleuth and in short order ran down the housebreakers and secured the return of all goods stolen . . . Jimmy Ball, KGO, will vacation at Clear Lake, Lake Tahoe, and Reno during September. The KGO boys are forwarding his mail to the Bankers Club, Reno . . . Ed Poage, KPO, spent his three weeks in southern Colorado. Possibly the fish bite better there . . . J. Alan O'Neil, Ref Reding, is feeling much better after a short illness. After much looking around, he found a saw bones who would OK a little smoking and maybe an occasional glass . . . "Red" Sanders, FE, recent attack on the Bay Bridge trains has been attributed to a "mental condition." He was alert enough that day to keep Dan Williams from learning the secrets of the Western Women's Club set-up and thus maintain his record of being the only man handling shows from that auditorium in the past two years . . . Don Hall, ME; Ernest Jefferson, FE, and Lee Kolm, SE, expect to spend their vacations in the vicinity of Los Angeles, with visits to Hollywood NBC.

FROM hour to hour, on wave-lengths from far and near, Americans owning 50,000,000 radio receiving sets hear the news of war overseas. The broadcasts tell of raiders in foreign skies; they tell of terrific explosions and flames seen more than 100 miles away. Commentators tell of blackouts—15 hours of blackness at a stretch in London . . . In the United States, radio is the voice of national defense.

A light in the darkness that enshrouds the world is the truth of an uncensored radio . . . broadcasts from American aerial towers that stand as sentinels of freedom. The light of truth in American radio is not shaded or hooded . . . it is the glow of hope for free men everywhere. For many months now, the National Broadcasting Company, through modern improvements in equipment and increased power in short-wave transmitters, has helped to make certain that the slit of light on radios in homes throughout the Americas will burn as one great beacon of freedom . . . for these broadcasts spread into the far corners of the darkened world.

By short waves, NBC is flashing the truth, as it is received from its American observers in foreign lands, and from the press associations.

Cordial, two-way relations have been established through exchange of programs between North and South America . . . and NBC is happy that it has the opportunity and facilities to contribute to the cultivation of all-American friendships . . . every one of NBC's programs are sent free of charge to Latin America, that they may be rebroadcast for the pleasure of our southern neighbors.

That there shall be no blackout in the light of American radio . . . that there be no blindfolding of listeners, no hooding or curtaining of the truth, is the aim of NBC . . . Radio's light of truth must never fail.

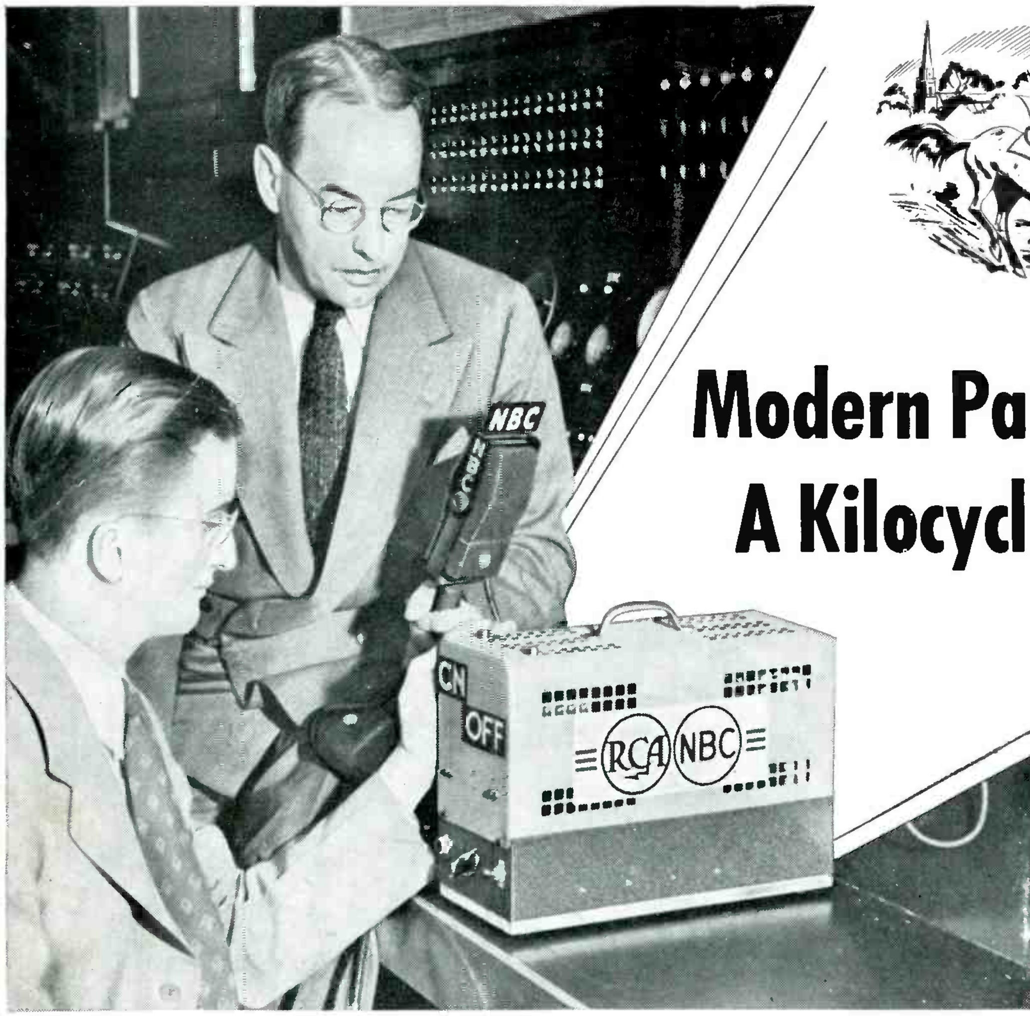
NBC

National Broadcasting Company

A Service of the

RADIO CORPORATION OF AMERICA

Radio City, New York



Modern Paul Revere
A Kilocycle Rider!

Newest development of RCA Laboratories, the RCA Alert Receiver is about the size of a portable radio set and as easy to carry. It operates from an ordinary light socket, either AC or DC, and can be switched to batteries in the event of damage to power lines

NEW RCA LABORATORIES DEVELOPMENT...

RCA Alert Receiver a notable contribution to civilian defense. Turned on and off by broadcasting station!

An emergency warning signal is flashed through space by a radio station. Instantly and automatically, the new RCA Alert Receiver in the home leaps into action, ringing a bell or sounding a siren.

Sleepers are aroused. Listeners are summoned. And then, through its loudspeaker, this modern Paul Revere brings them air-raid instructions or other important messages with the speed of light.

Amazingly simple in design and construction, the RCA Alert Receiver can be produced at a cost approximating that of the average low-priced table model radio. Requiring very little power for operation, it can be used with surprising economy, 24 hours a day over a long period of time.

Even more simple is the transmitting apparatus, which consists of a vacuum tube oscillator generating two sub-audible frequencies. One turns the receiver on, the other turns it off. Installation requires no change in normal broadcast station wiring.

The RCA Alert Receiver is important to National Defense because it makes possible a local, regional or nation-wide instantaneous radio call service. With this new development, the public service of radio is once more expanded—thanks to RCA research.

RCA LABORATORIES

A SERVICE OF THE RADIO CORPORATION OF AMERICA

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R. C. A. Communications, Inc. • National Broadcasting Co., Inc. • RCA Institutes, Inc.