NEW CBS PROGRAM TRANSMISSION STANDARDS*

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Summary--Over a period of years, broadcast listeners have complained that the musical portions of radio programs are sometimes unpleasantly loud--that is, music is too loud compared with speech. Two surveys conducted by the Columbia Broadcasting System in 1940 and 1944 found this to be true of all broadcast stations, and established the validity of the complaints. This led to more definitive studies.

Two related listener studies in 1945 were undertaken, to (1) discover proper (pleasing-to-listener) relative levels at which music and speech should be transmitted, and (2) determine the range within which the *peak* levels of a program should fall in order to please the largest number of listeners.

A total of 224 persons, representing a cross section of the radio audience, took part in individual listener tests. In both studies the listeners, one at a time, heard a series of passages from radio programs. They were asked to adjust the volume of each passage to the most pleasant listening level. Every variable which could be anticipated was provided for, including such matters as introducing controls to account for differences in room noise levels.

The major findings of the studies were as follows:

(1) Listeners prefer to hear broadcast music and speech at about the same peak levels (as read on a standard volume indicator).

(2) The limit of the range of *peak* volume levels tolerated by the largest number of listeners is approximately 8 db (4 db above or below the average peak-volume level of the passage).

(3) Within this range (8 db) volume-level changes are less annoying when made gradually, in two or more steps.

The 8-db limit mentioned above refers to the range of *peak* or maximum volume levels, *not* to the range of minimum and maximum sound intensities or "dynamic range." It is important that this range of *peak* levels not be confused with "dynamic range."

In addition to the three principal findings, the studies uncovered data on a number of related points which obtained, irrespective of the sex, age, education, or musical taste of the individual listeners. For example:

(1) Listeners like to hear broadcast music and speech at the same *relative* levels, regardless of the *absolute* sound level that is preferred.

(2) Listeners prefer an even level, regardless of whether they are hearing variety, drama, narrative, or music.[1]

(3) The peak sound level that the average listener prefers ranges from 65 to 70 db above the acoustical reference level of 10^{-16} watts/cm^2.

This study has led to the adoption by CBS of a new set of program transmission standards, in order to make broadcasting more pleasing to the listener. The old transmission standards provided for maximum peak levels or "ceilings." The new standards retain "ceilings" (but different from past ones) and, in addition, provide minimum peak levels, or "floors," below which the level of the *main program peaks* should not fall.

I. INTRODUCTION

It is axiomatic that broadcasting programs should be written and produced in a manner that makes for pleasant listening. Aside from the content of a given program, a broadcast may be easy or difficult to listen to, depending upon the method of presentation. Tonal range, sound reproduction level, and the range of peak volume levels are three of several factors that have a bearing on ease of listening. A former study[2] has shown that both tonal range and sound intensity influence listeners' preferences, and that listeners can distinguish more readily between different sound intensities than between different tonal ranges.

Broadcast receivers can be readily designed to provide the listener with means for selecting the tonal range and the sound-reproduction level he finds most pleasant. However, the listener is not in a position to materially alter the *relative* sound levels between different parts of a program.

Radio listeners have complained that, while listening to a program, they have to make volume adjustments because some parts of the program are broadcast too loud, and others not loud enough. The complaint has been registered for many years and to essentially all radio

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We are going to ask you to do something different from what you do at home when you listen to a radio program. At home you are usually seated away from the radio. If the program gets too loud or too soft, sometimes you do not change the volume because it is inconvenient.

But here, the volume-control dial is right before you. It works just like the dial on your radio. We are going to play parts of radio programs, and we would like you to keep your hand on the dial while you are listening. Whenever the program gets too loud or too soft for you, even if it is only for a few seconds, change the dial to the level you like best.

After the participant indicated that the instructions were understood, a practice test was given. For this purpose, a portion of a radio program *not* used in the final test was reproduced. When it was established that the subject understood the instructions--to make an adjustment whenever the sound level became too high or too low for him--the test series was begun.

Each participant heard five samples, varying in length from 2-1/2 to 8-1/2 minutes. The samples were chosen from regular broadcasts and ranged from program excerpts with relatively small volume-level changes to those in which the volume varied considerably. A continuous, synchronized chart was automatically drawn by a moving-tape recorder of the volume control settings made by the participant.

Program Material

All test selections were recorded from broadcast programs, and were chosen to provide a wide variety. Material from five kinds of programs was used, namely, popular music, comedy quiz, comedy variety, narrative drama, and crime drama (see Table II).

Environment

The tests were conducted in a small room furnished as far as feasible like an average living room. The room measured 23 feet long, 14 feet wide, and 10 feet high. The average noise level in the room, without the loudspeaker operating, was slightly less than 29 db above the acoustical reference level.

The loudspeaker was located at one end of the room at a height approximating ear level of the listeners. The person being tested sat in an armchair, directly facing the loudspeaker and ten feet away from it. In front of the participant was a small table, on which there was a small box equipped with a dial for controlling the volume level of the selections heard.

Equipment

Uniformity in the program material presented to each listener was assured by the use of especially recorded "masters" cut on cellulose-nitrate coated disks. The recordings were made by the Columbia Recording Corporation and employed the standard electrical-transcription recording characteristics. Original master recordings were used because of the uniform response characteristic, the low nonlinear distortion, and the very low surface-noise level that this type of recording affords. As soon as any distortion or noise became detectable under the conditions of the tests, a new recording was used.

In order to simulate home listening conditions, a band-pass filter was placed in the reproducing channel. The actual over-all response of the system, including the recording

TABLE II
Program Passages

Passage Number	Type	Content	Duration
1	Popular music	Theme music, announcements (2 male, 1 female); "Just a Prayer Away," by Tobias (male and orchestra); "My Dreams Are Getting Better," by Curtis (female and orchestra)	4 minutes, 59 seconds
2	Comedy quiz	Comedy quiz (3 males, 1 female) Commercial (male announcer) Comedy music (orchestra)	7 minutes, 5 seconds
3	Drama	Opening Announcement (male) Theme music Conversation (2 males)	2 minutes, 17 seconds
4	Comedy-variety	Opening Announcement (male) Theme music Comedy (2 males) Comedy (3 males) Commercial (1 male) Comedy (2 males)	8 minutes, 31 seconds
5	Crime drama	Conversation (3 men in a car) A murder Conversation (2 men) Conversation (several men)	2 minutes, 34 seconds

and reproducing process, but excluding the loudspeaker, is shown in Fig. 1. The loudspeaker was a dual unit, employing a folded horn for the low frequencies and a multicellular horn for the high frequencies. Facilities were not available for a free-space calibration of the loudspeaker, but the manufacturers' measurements, which are believed to be reliable, indicate the system is uniform over a much wider range than was employed for this experiment.

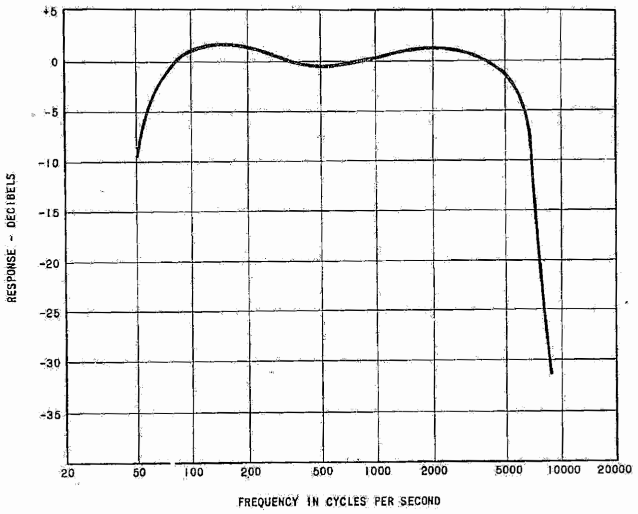

Fig. 1--Average home sound-reproduction conditions were simulated for this study by employing a band-pass filter in the test channel. The frequency-response characteristic of the channel (exclusive of the loudspeaker) is shown in this chart.

TABLE III

Composition of the Group

Number of persons = 92	
	55 per cent
Female	45
	100 per cent
Age	
Under 26 years	47 per cent
26 to 40 years	34
Over 40 years	19
	100 per cent
Education	
Grammar school	12 per cent
High school	61
College	27
	100 per cent

Although probably of secondary importance for the study undertaken, the harmonic distortion of the system was as low as it is possible to obtain with the best present-day equipment.

Subjects

The group of participants were representative of a cross section of the radio audience. They were secured by means of spot announcements over the CBS key station, WCBS, located in New York City. The exact composition of the 92 subjects, all adults, taking part in the individual listener tests, are detailed in Table III.

IV. RESULTS OF MAIN EXPERIMENT

Method of Analysis

The data were analyzed from two points of view: (1) the actual volume changes within the passages as broadcast, and (2) the listeners' reactions to these volume changes.

A unit of analysis was established by dividing each of the five passages into a number of *intervals*. A new interval started whenever any clear change in volume occurred, or when the program content changed. Intervals varied in length from 3 to 20 seconds, although most intervals were of 5 to 10 seconds duration. In all, the five program passages were divided into 390 intervals.

The average peak level of each of the 390 *intervals* was determined, using a standard volume indicator,[5] by averaging the readings of two trained observers who, incidentally, agreed very closely. These readings were expressed as differences (in db) above or below the average level of the *entire passage*. Listeners' reactions were then analyzed in terms of *direction* and *amount* made by the listener with each interval.

Direction of Change

Although listeners could turn the volume up, turn it down, or make no adjustment at all, any changes they made were significant only in relation to the actual volume changes occurring in the passage itself. Therefore, the direction of the change in the passage had to be related to the direction of the listeners' adjustments.

The adjustments made by the listeners were therefore classified as follows:

(1) Counter-adjustments, which offset the change in volume of a passage.
(2) Pro-adjustments, which accentuated the amount of change in the volume of the passage.
(3) No adjustment.

[5] H. A. Chinn, D. K. Gannett, and R. B. Morris, "The new standard volume indicator and reference level," PROC. I.R.E., vol. 28, pp. 1-17; January, 1940. Also, *Bell Sys. Tech. Jour.*, vol. 19, pp. 1-44; January, 1940.

In other words, listeners made counter-adjustments when variations in volume were too great for pleasant listening--that is, they turned the volume up or down to keep it within the range they preferred. They made pro-adjustments when they turned the volume up or down in the same direction as the volume changes occurring in the program material.

Amount of Change

Listener adjustments were also measured by amount of change. It was possible to measure the amount of change in db for each listener and for each interval. These changes were then averaged.

It is worth noting that, since a measurement was taken for each of the 92 test participants for each of the 390 intervals, a total of 35,880 individual reactions were analyzed.

Preferred Range of Peak Levels

Two typical examples of the way listeners reacted to changes in the peak levels during a program passage are shown in Fig. 2. In this figure, the line graphs show the variations in average peak levels, as broadcast, of two of the program passages listed in Table II. In the first example, the maximum variation in peak levels was only 7 db; 3 db above to 4 db below the average for the passage. In the second example, on the other hand, the variation was 17 db; 9 db above to 8 db below the average.

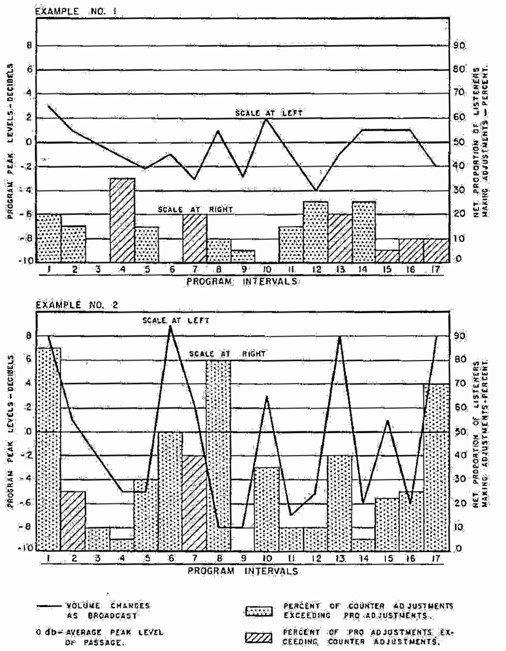

Fig. 2--The variations in peak volume levels, as shown by the line graphs in this chart, are typical of the program excerpts used in this study. In example No. 1 the range of peak levels is not very great whereas in example No. 2 the range is rather large.

The vertical bars show the extent of the reaction of the listeners to these volume changes. The bars show the difference between the proportion of listeners who made counter-adjustments and those who made pro-adjustments.

The vertical bars in Fig. 2 show the reaction of the listeners to these volume changes. The bars show the difference between the proportion of listeners who made counter-adjustments and those who made pro-adjustments.

In the first example the volume variations were slight, and few of the listeners found it necessary to make volume adjustments. On the other hand, the second example, containing marked volume changes, caused large numbers of listeners (in some instances more than 50 per cent) to make adjustments that offset these changes.

TABLE IV

Distribution of Program Intervals

Deviation of interval from the average level of the passage	Number of intervals
9 + db	15
8	20
7	17
6	31
5	26
4	43
3	51
2	74
1	79
0	34
Total	390

Fig. 2 presents the data for only a few typical intervals. In all the test passages, the intervals totaled 390. The distribution of these intervals, broken down according to the differences (in db) from the average levels of the passages in which they occurred, is shown in Table IV.

The proportion of listeners who made counter-adjustments and the proportion who made pro-adjustments for each of these groups of intervals is shown in Fig. 3. It is seen that when the intervals were transmitted at the average volume level of the passages (0 db), more than half of the listeners made no adjustment at all. Those who made adjustments did so to offset or to accentuate the change in roughly equal proportion (23 per cent made counter-adjustments; 18 per cent made pro-adjustments). In other words, these changes tended to cancel out.

Fig. 3 shows that the farther the average peak level of an *interval* lies from the average

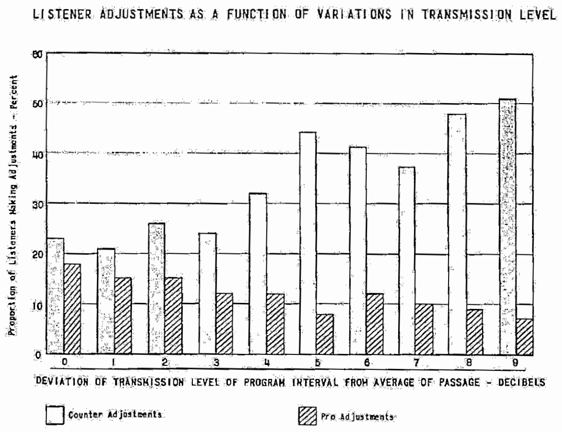

Fig. 3--This chart shows the proportion of listeners making volume adjustments as a function of the deviation of the transmission level of the program interval from the average of the complete passage. The limit beyond which listeners appear to object to large volume variations seems to occur at 4 db above or below the average of the passage.

of its *passage*, the greater is the listeners tendency to offset it--that is, to narrow the volume range down to the limit of pleasant listening. The limit beyond which listeners appear to object to large volume variations seems to occur at 4 db above or below the average of a passage. (At this point, more than 30 per cent of the listeners made counter-adjustments.)

Since listeners evidently will tolerate a variation up to 4 db above or below the average of a passage, *the range of listener tolerance for peak levels appears to be no more than 8 db.*

The foregoing analysis was made by *direction* of adjustment. It remains to analyze the *degree* of adjustment made by the listeners. These data are presented in Fig. 4 which shows by how many db the average listener who made adjustments moved the volume-control dial.

It is seen that where the deviation of the peak level of an interval is 4 db or less from the average for the passage, the amount of adjustment made by the listeners was less than 1 db. Beyond the 4-db point, however, there is an abrupt break, and for greater deviations the listeners tend to counter-adjust by 2 or more db. It is also evident that the farther a peak level lies from the average peak levels of a passage, the greater the adjustment.

Tolerable Rate of Change in Peak Levels

Thus far, the analysis has been limited to listener preferences in terms of peak sound intensity, in relation to the average peak level of passages. This does not however, take into account the complexity of volume changes as they occur in radio programs. At least two other factors are significant in influencing listener reactions: (a) the *amount* of volume change from interval to interval, and (b) the *direction* of the volume change from interval to interval.

An illustration of the effect of these factors can be seen in Fig. 2(b). Interval 10, while it is only 3 db above the average of the passage, is 11 db above the peak level of the preceding passage. A relatively large proportion of listeners reacted to this change (the difference between the percentage of listeners making counter-adjustments and the percentage making pro-adjustments was 35 per cent). This illustrates the importance of the amount of volume change from interval to interval.

Furthermore, the direction of the volume change is of some consequence. In the same example, interval 8, which is 8 db below the average, has moved 17 db, in two steps, from a preceding interval. From a peak at interval 6, the volume dropped in the *same* direction to interval 8.

On the other hand, intervals 13 through 17 illustrate the situation when volume changes zigzag back and forth; listeners' adjustments are in contrary direction. In order to unravel these complexities, it was necessary to analyze listener adjustments of intervals in terms of the two factors mentioned above.

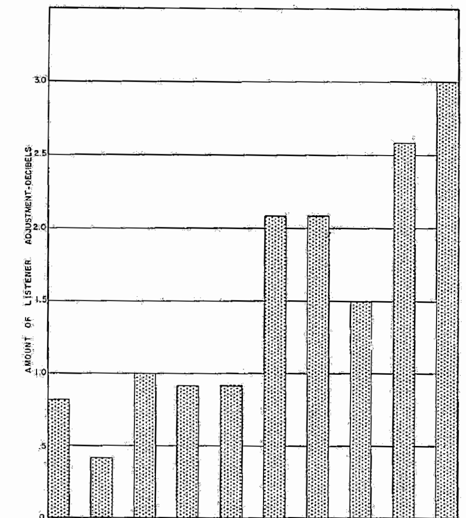

Fig. 4--The extent of the volume-level adjustments made by those listeners who made a change is shown in this chart as a function of the deviation of the transmission level of the program interval from the average of the complete passage. Again it is seen that beyond the 4-db point there is an abrupt break, and for greater deviations listeners tend to counter-adjust by larger and larger amounts.

The amount of volume change from interval to interval was divided into three categories: (1) large = more than 6 db; (2) moderate = 3 through 6 db; and (3) small = 2 or fewer db.

For *direction* of volume change, intervals were divided into those which continued in the same direction as the preceding interval and those which changed direction.

However, the analysis would not be complete unless the *distance* of peak levels from the average were also taken into account. That is, some intervals were either very high or low in volume, as compared with the average for the passage, while others were close to the average of the passage. Therefore, intervals were further subdivided into those which were a large distance from the average of a passage (4 or more db) and those which were a small distance (3 or few db).

The great mass of data resulting from the analysis of all participants' reactions to the 390 intervals involved can best be presented in chart form. Fig. 5 presents the data in terms of the proportion of listeners making adjustments. This figure shows the proportion of listeners making counter-adjustments and those making pro-adjustments where the volume change between intervals is large (more than 6 db), moderate (3 to 6 db), and small (less than 3 db). The left-hand column of bars is for those intervals where the volume level of the interval changed in the same direction as in the preceding interval. The right side of the chart is for those intervals where the volume level changed in a contrary direction to that of the preceding interval.

PROPORTION OF LISTENERS MAKING VOLUME ADJUSTMENTS AS FUNCTION OF VARIATIONS IN TRANSMISSION LEVEL AND DIRECTION

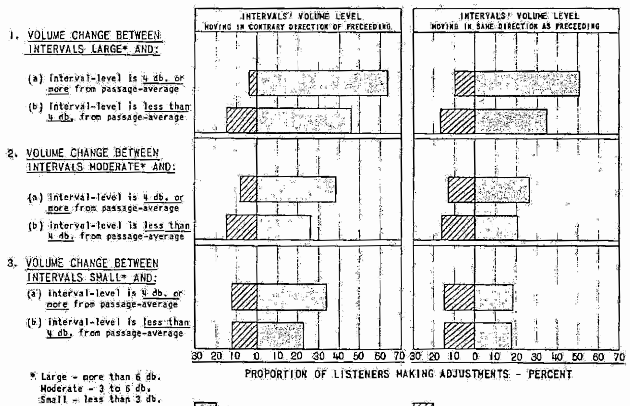

Fig. 5--Listeners' reactions to changes in volume level are complex. As this chart shows, they are influenced by (a) the direction of the volume change, (b) the degree of the volume change, and (c) the relative volume level with respect to the average of the passage.

Figure 6

AMOUNT OF ADJUSTMENTS MADE BY LISTENERS CHANGING VOLUME AS FUNCTION OF VARIATIONS IN TRANSMISSION LEVEL AND DIRECTION

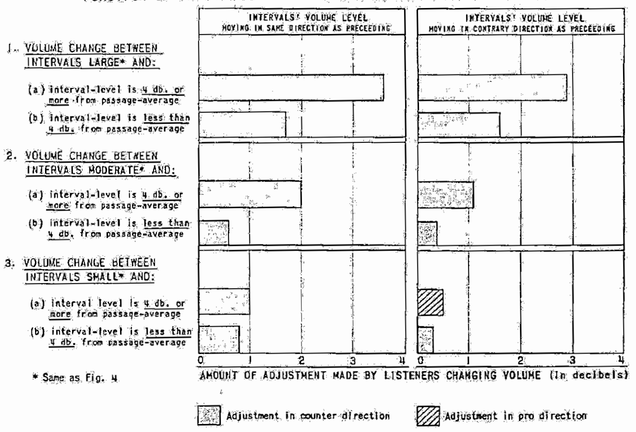

Fig. 6--From the *amount* of the volume adjustment made by listeners, it is seen that not only is a fairly narrow range of *peak* levels preferred, but, in addition, within that range large changes are not liked. Changes in the peak volume level must be made gradually for easy listening.

From these data it is seen that:

(1) The direction of volume change influences listener adjustments. A greater proportion of listeners make counter-adjustments and few make pro-adjustments when volume changes occur in the same direction as the preceding interval.

(2) The degree of volume change from interval to interval also influences listener adjustment. The larger the change, the more counter-adjustments.

(3) Distance from the average peak level of a passage influences adjustments. The greater the distance, the more counter-adjustments.

The intervals in which most listeners make counter-adjustments are those which move in the same direction as the preceding interval and which, at the same time, represent a large volume change from the preceding interval. These intervals are also farthest removed from the average level of a passage. The fewest changes are made in intervals with reverse characteristics.

The data, in terms of average db change, for those listeners who make adjustments, are given in Fig. 6. It is seen that direction of volume change, *amount* of volume change, and *distance from average level* also influence the amount of this compensation made by the listener. These data show that the listener not only prefers a fairly narrow range of peak levels (not more than 8 db) but, in addition, within that range does not like large changes. In other words, the whole range of 8 db cannot be jumped in one step. *Volume changes must be made gradually.*

Influence of Program Content

Thus far, listener preferences have been covered only in terms of relative volume levels without regard to the program content. In general, radio programs can be broken down into three types of content, (1) speech, (2) music, and (3) laughter, applause, and sound effects (grouped together as a "special" type of content.) The test passages were therefore segregated into these three categories and the peak levels analyzed, both as originally broadcast and as adjusted by listeners during this study.

The average difference from the average peak-levels of the passages as originally broadcast was as shown in Table V.

TABLE V

Type of Program	Average Difference from Average Level of Passage
Speech	-0.6 db
Music	+0.7 db
Laughter, applause, and sound effects	+3.9 db

A survey[6] made on a wider basis scrutinized the practices of a variety of programs as broadcast by various networks, and verified that the program samples used in these experiments were typical.

The average peak level of all music invals in these experiments was 1.3 db higher than the average of all speech intervals. This difference corresponds closely with the former standard practice, wherein music was peaked at 100 on the volume indicator and speech at 80. This corresponds to a difference of 1.8 db.

In order to relate the volume differences (as broadcast) to the adjustments which the listeners made, their reactions to each type of program content were analyzed in terms of the distance of each interval from the average of the passage. This analysis shows listeners' adjustments to music and speech intervals of the same loudness.

Fig. 7 shows the proportion of listeners making counter- and pro-adjustments for intervals of various differences from the average of all passages.

Listeners turn the volume up for below-average musical intervals in about the same

[6]Unpublished report, CBS General Engineering Department, April, 1945.

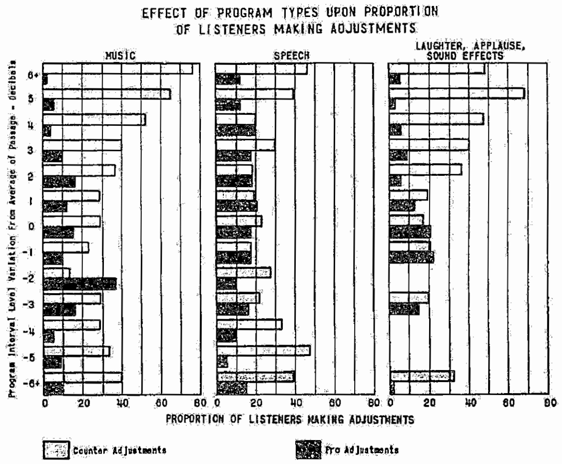

Fig. 7--The reactions of listeners to different types of program material is shown by this chart. Listeners' reactions to musical passages, speech and laughter, applause and sound effects follow the same general pattern.

proportion as they do for speech. The reaction to intervals containing laughter, applause, and sound effects is similar to the reaction to music.

The evidence of this study supports this conclusion: For radio program material (exclusive of symphonic music, which was not studied) listeners prefer a fairly even level for all types of program content.

V. DISCUSSION

The listener's preference for a limited range of peak levels differs sharply with the ideas of some radio program directors, conductors, and performers (and some scientists). They have sometimes felt that a restricted range of peak levels unduly limits the dramatic and musical effects that can be achieved. This feeling on the part of producers, conductors, and performers may be a carry-over from the stage and concert halls, in which, for reasons to be mentioned, a wide range in peak intensities probably does not irritate the listener.

Broadcasting, however, is an entirely different medium. It differs from the stage and the concert hall in at least two important respects: (1) It is intimate. The listener is in a small room and cannot tolerate shouts and loud orchestral crescendos. (The listener, moreover, frequently considers his neighbor's feelings, as well as his own.) (2) Listening to the radio is a monaural process. That is, although the listener actually hears with both ears, the sound comes from a single source and all sense of direction, and almost all sense of perspective, is lost. The listener to "real-life" sound, on the other hand, enjoys binaural listening. He can pay attention to what he *wants* to hear and discriminate against undesirable sounds. The radio listener, however, must listen to all the sounds that come from the loudspeaker.

Although the reason is not yet known, monaural hearing is apparently more pleasant when the range of peak intensities is somewhat restricted. The manner in which sound is used in motion pictures supports this fact. Motion-picture sound, also monaural, is generally reproduced at a narrower range than that which is transmitted by radio.

It is essential that this monaural peculiarity of radio be taken into account. Although it calls for a restricted range of peak intensities, the desired dramatic effect may be gained in another dimension--*timbre*. Varying the distances of speaker or musical instrument from the microphone will effect the apparent loudness, even while maintaining an even level as measured on the volume indicator, because of the change in liveness of the pickup. The opportunity for such effects should be exploited to the fullest degree.

VI. CONCLUSIONS

The conclusions resulting from the two studies reported are:

(1) Listeners prefer to hear music and speech at about the same peak levels (as read on a standard volume indicator).

(2) Listeners like to hear music and speech at the same relative levels, regardless of the absolute sound-intensity level that they prefer.

(3) Listeners prefer an even level regardless of whether they are hearing variety, drama, narrative, or music.[7]

(4) The limit of the range of *peak* volume levels tolerated by the largest number of listeners is approximately 8 db (4 db above or below the *average volume* level of the passage).

(5) Within this range (8 db) it appears that volume-level changes are less annoying when made gradually--in two or more steps.

The 8-db limit mentioned above refers to the range of *peak* or maximum volume levels, *not* to the range of minimum and maximum sound intensities or "dynamic range." It is important that this range of *peak* levels not be confused with "dynamic range."

As a result of this study, CBS has adopted the following program transmission standards:[8]

CBS Program Transmission Standards

(1) *Speech and Music*	*VI Peaks*
Normal passages	Peaks of 100
Low-level passages	Not less than 40
(2) *Theme under station breaks*	Peaks of 40
(3) *Applause and audience reaction*	Maximum peaks of 70

(4) *Transition*

The transition from a low-level passage to a normal-level passage (or vice versa) must be in steps of not more than 4 db, preferably less (i.e., peaks of 40, then 60 and finally 100, or vice versa). Similarly, two succeeding passages (voice, then music, or voice, then a sound effect, etc.) must not differ in level by more than 4 db, preferably less, even when a contrast is intentional.

(5) *Peaking Practice*

Peaking program material according to the prescribed standards means "gaining" in such a manner that the maximum VI peaks reach the specified values as frequently as possible without being inconsistent with the program content. It is understood that occasional peaks beyond the prescribed values are unavoidable, but these must be kept to a minimum.

VII. PRACTICAL TEST

Theoretically, the adoption of new program transmission standards based upon the foregoing conclusions should remove the cause of listener's complaints arising from former practices. To check this, a practical before-and-after test was made. Three pairs of program excerpts were used in these tests. In each pair the excerpt was produced in two ways--the old way, with wide range in *peak* volume levels, and the new way, in accordance with the findings of the study. Thus, listeners were enabled to express their direct preference for one type of transmission or the other. For the test the selections used were as follows:

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[7]These findings do not necessarily apply to symphonic music, which was not analyzed in these studies.

[8]It is hardly necessary to state that the standards contained in this report may not remain static indefinitely, since they are based upon current broadcast-pickup techniques. Future operations and experience may indicate that permanent or temporary departures from them are desirable, and actual practices may, from time to time, vary from these standards. They represent, however, the conclusions which have been reached as a result of the investigation which is reported upon in this paper.

(1) A passage containing a loud, but typical orchestral bridge.

(2) A loud but typical opening followed by conversation in low tones.

(3) A passage containing a loud scream.

The preferences for the old and the new transmission standards are shown in Fig. 8. It can be seen that in two of the three cases there was an overwhelming preference for the new standards.

The third test selection emphasized still another condition which plainly contributes to the sources of complaint mentioned earlier. In this test, production rather than engineering played the major part. The director realized that some of the life-like quality of the scream would be lost if the technician held the transmission level within the prescribed limits by "fading-down" the output of the microphone. To avoid this loss of dramatic effect, the producer accepted an annoyingly loud peak in the original production of the program.

The desirable solution, which would have retained the dramatic effect and eliminated the high peak, would have been to move the performer farther from the microphone. Advantage was not taken of this technique in the third practical test; rather, the levels were simply faded-down. Even so, 60 per cent of the listeners preferred the new transmission practices to the old.

An even more practical test has been the introduction of the new transmission standards to programs originated by the Columbia Broadcasting System. This was done during 1946, and the number of listener complaints on this score has markedly decreased. Furthermore, listeners have not felt that there has been diminution of dramatic value

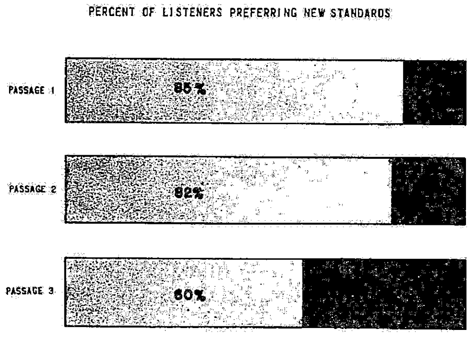

Fig. 8--The proportion of listeners favoring the new standards over the old, in a practical test involving three typical passages, is shown in this chart. In passage 3, changes in production techniques would have been required (as explained in the text) in addition to the new transmission standards in order to make the passage more acceptable.

in program production. Rather, they have experienced a more even transition between segments of program.

(NAB Editor's Note: Immediately following this article will be found CBS Report No. E-611-E prepared by the CBS General Engineering Department and Research Department, outlining the direct application of the Program Transmission Standards.)

VIII. ACKNOWLEDGMENT

Studies of this type require a great deal of detailed preparation and care to insure reliable data. Without the patience, ingenuity, and skill of A. G. Peck and D. C. Battin, it would have been difficult to have successfully completed this study. The authors gratefully acknowledge their contribution.

Report No. E-611-E

December 4, 1945

CBS General Engineering Department and Research Department

CBS PROGRAM TRANSMISSION STANDARDS

The Condition Which Exists

Over a period of years, listeners have complained in writing that the musical portions of broadcasting programs are unpleasantly loud--that is, music is too loud compared with speech. These complaints are supported by comments frequently made by subjects in CBS Research Department Analyzer sessions.

This condition results partially from the practice of operating the monitoring loudspeaker in studio control rooms at abnormally loud levels (as compared to home listening practices), and partially from the program transmission practices that have been standard for some years.

The program transmission standards which are currently in use, result in the broadcasting transmitters being modulated an equal amount, by both speech and music, when the prescribed peak levels are maintained. This practice insures the maximum use of the available power. From a purely technical standpoint, the procedure is sound--however, it does not take into consideration the listener's preferences. Two surveys conducted by the CBS Research and the General Engineering Departments (October, 1940 and October, 1944) established the validity of the complaints and led to further, more definitive study.

The Studies

In order to obtain quantitative data concerning these general complaints, two related listener studies were made (January-April, 1945) designed to:

(1) discover proper (pleasing-to-listener) relative levels at which music and speech should be transmitted.

(2) determine the range within which peak levels of a program should fall in order to please the largest number of listeners.

In both studies the listeners, one at a time, heard a series of test passages from radio programs. They were asked to adjust the volume, by turning a dial, to the most pleasant level. Further information was secured by means of a questionnaire.

A total of 224 subjects, representing a cross-section of the radio audience took part in those individual listener tests.

Every variable which could be anticipated was provided for, including such things as introducing controls to account for differences in room noise levels.

The Major Findings

(1) Listeners prefer to hear music and speech at about the same peak levels (as read on a standard volume indicator).

(2) The limit of the range of peak volume levels which will be tolerated by the largest number of listeners is approximately 8 decibels (4 decibels above or below the *average volume* level of the program).

(3) Within this range (8 decibels) it appears that volume-level changes are less annoying when made gradually.

Some Further Findings

In addition to the three principal findings, the studies uncovered data on a number of related points--which obtained regardless of the sex, age, education or musical taste of the individual listener. Here are three of them:

(1) No matter how loud or how soft the individual operates his radio, he still wants to hear music and speech at the same relative levels.

(2) Listeners prefer an even level regardless of whether they are hearing variety, drama, narrative or straight music.*

(3) The average volume at which listeners set their home radios ranges from 65 to 70 decibels above the acoustical reference level.

Why?

Most professional broadcasters will perceive immediately one of the reasons why present practices are not entirely in accord with listeners' preferences. The explanation lies to a very large extent in the differences between (a) loudspeaker monitoring levels in the home and in the control room and (b) the background noise level in the average home and in the control room.

Surveys indicate that control room monitoring levels from 75 db to 95 db above the acoustical reference level. The average is 85 db and this is 20 db louder than in the home.

Furthermore, the background noise level in the average control room (aside from that created by the occupants) is some 20 db *lower* than in the home. Thus, the control room occupants may have a 40 db advantage over the average listener when it comes to hearing weak sound--not to mention the tremendous advantage of being able to see the source of the sounds and thereby being able to anticipate their nature.

In view of this situation, the home listener must bring the level of his radio up in order to hear weak sounds. But when he does this, loud sounds become excessively loud and irritating. It is for a very practical reason, therefore, that the listener indicates a preference for a range of peak volume levels of no more than 8 decibels.

Abrupt Level Changes

Although the average listener will tolerate an 8 db range in peak levels, he is annoyed if a change in levels as great as this occurs abruptly. Changes of this amount (and more) often occur under present practices in the following situations:

(a) between the end of a speech passage and the following music,

(b) between one speaker and another,

(c) between loud musical opening of a program and subsequent quiet conversation,

(d) between one musical passage and another,

(e) between the end of one program and the beginning of the next,

(f) sudden loud sound effects, screams, etc.,

(g) sudden loud applause or loud audience laughter.

*These findings do not necessarily apply to symphonic music, which was not analyzed in these studies.

Changes in peak volume levels within the 8 db limit should be made gradually--certainly no two succeeding passages should differ by more than 4 db under any circumstances.

The 8 decibel limit used throughout this report refers to the range of *peak* or maximum volume levels, not to the range of minimum and maximum sound intensities or "dynamic range." It is important that this range in *peak* levels should not be confused with "dynamic range."

The Remedy

To remedy this condition, three coordinated steps are necessary:

(a) Control room loudspeakers should be adjusted to levels more commensurate with the home listening habit.

(b) The production of shows must be undertaken with the view towards correcting the shortcomings of our present practices.

(c) New standards for program transmission levels must be adopted.

Control Room Loudspeaker Levels

In addition to the detrimental effects already mentioned (caused by operating the control room loudspeaker at abnormal levels) an even more undesirable phenomenon results from this practice.

This occurs because of the fact that the response of the human ear to sounds of different frequencies varies with the intensity level. Consequently, a program that is "balanced," in accordance with a producer's wishes, at a particular loudness level, is likely to sound completely unbalanced when reproduced at a different level. Furthermore, the effects that seem so dramatic, when reproduced at an abnormal listening level, may fall completely flat at the lower, home-listening, level. Finally, sounds that are quite audible in the relatively quiet control room where the loudspeaker is operating at a high level, are entirely inaudible in the average home with its higher noise level and lower loudspeaker volume.

The remedy in this case is obvious. Every effort should be made to operate the control room loudspeaker at a level which is comparable to that used in the *average* home.

Production

Listeners prefer an "even" volume level--regardless of the particular absolute level at which they listen. This desirable result can only be achieved by the combined efforts of both the program director and the studio technician. The transmission level standards which the studio technician must maintain necessarily require tremendous assistance production-wise if the desired result is to be obtained. Not only must the program director plan his sequences so as to avoid abrupt changes in volume level between one portion of the program and the next, but he must also aid in the control of extreme high level and low level by taking full advantage of studio acoustics and microphone distances.

It is generally conceded that the illusions of distance, intimacy and motion can neither be created nor destroyed by changes in the transmission volume. They are a product of acoustics, placement before the microphone and timbre of sound. With these facts in mind, performers should be properly spaced before the microphone(s) so that the pickup level is much the same for all. Thereafter the distances should vary with the effect desired or volume used in the studio.

When two or more people use the same microphone, they should be placed so that differences in voice levels are eliminated. This is very important on quiz programs when the master of ceremonies may insist on using one microphone for himself and for all the contestants even though the better solution would be to use two microphones.

The new transmission standards are intended to make radio more pleasing to the listener. An acoustical balance in the studio will aid tremendously in doing so.

CBS Program Transmission Standards

The inauguration of new program transmission standards will also contribute materially to the excellence of our broadcasting. The new standards reflect the results of the studies that have been made to determine listeners' preferences.

The old transmission standards provided for maximum peak levels or "ceilings." The new standards retain "ceilings" but, *in addition*, provide minimum peak levels or "floors" below which the peak volume level should not fall.

Peaking program material according to the prescribed standards means "gaining" in such a manner that the maximum VI peaks reach the specified values as frequently as possible without being inconsistent with the program content. It is understood that occasional peaks beyond the prescribed values are unavoidable but these must be kept to a minimum.

VI Standards

Speech and Music	
Normal passages	Peaks of 100
Low level passages	Not less than 40
Theme under station breaks	Peaks of 40
Applause and Audience reaction	Maximum peaks of 70

Rewards

Application of the new standards should result in:

(1) Greater listener satisfaction and, consequently, a steadier audience.

(2) The listener hearing all the sounds and the effects that are being created for his enjoyment.

(3) An end to the protests, often violent, that the more annoyed listeners pen.

Symphonic Music

Since listeners' reactions to symphonic music were not tested, the present standards will be used until such time as study warrants a change. These *tentative* standards are:

Normal passages	Peaks of 100
Pianissimo passages	Must always move VI

Important

The transition from a low-level passage to a normal level passage (or vice versa) must be in steps of not more than 4 db, preferably less (i.e., peaks of 40, then 60 and finally 100, or vice versa). Similarly, two succeeding passages (voice, then music, or voice, then a sound effect, etc.) must not differ in level by more than 4 db, preferably less, even when a contrast is intentional.

MAGNETIC RECORDING IN BROADCASTING

*By S. J. Begun**

(As Presented at 3rd NAB Broadcast Engineering Conference, Chicago, Ill., April 7, 1949)

Mechanical disc recording has been for many years the preferred and practically only method of instantaneous recording employed by broadcast studios. Now there are definite signs that disc recording will soon have to share its place with magnetic recording.

It is one of the objects of this paper to analyze why magnetic recording has been gaining so rapidly in importance for broadcast work. An appraisal of the magnetic recording method discloses the usefulness of its unique features. To mention only a few: (1) There is easy erasability of the recording medium. (2) The practical signal to noise ratio is greater than presently obtained in any other recording method. (3) The recording is relatively permanent and its repeated reproduction without quality deterioration is only limited by the life of the recording medium. (4) An uninterrupted recording period of any desired length can be provided. (5) The making of a good recording requires no particular skill on the part of the operator. (6) A coated tape as recording medium can be easily cut and spliced.

On the other hand, the price of the recording medium for any given length of recording time is high compared to that of mechanical recording. The making of copies, if such are needed, is cumbersome and special equipment is required if it is to be done on a reasonably economic basis. The elasto-mechanical properties of the recording medium make it difficult to play a recording back within exactly the same time period within which it was recorded.

The features enumerated on the credit side of magnetic recording make this method of sound recording particularly desirable when the recording does not need to be preserved for long periods of time. Under these conditions, the erasability of the magnetic recording medium more than outweighs the somewhat lower price of disc blanks. Without any doubt, magnetic recording provides the best economical solution for time delaying of programs. Here, the repeated use of the same recording medium is only limited by the mechanical wear which eventually deteriorates the performance.

There are two other applications in which magnetic recording has already proven its value: For on-the-spot recording and for editing of program material.

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No one instrument will be best suited for all these applications. For time delayed programs a sturdy rack and panel arrangement, preferably remotely controlled, will be most practical, since with such a layout all operations can be initiated by the attendant at the master control board.

For on-the-spot recording, lightweight portable equipment is needed. For this application, some compromises will have to be made. While good performance still is required, one cannot expect to obtain results which are equivalent to that from a studio installation.

Editing requires still another type of instrument. The simplicity of cutting and splicing tapes makes it extremely easy to rearrange the sequence of a program and thus provides a new tool for the program director. The console type of magnetic recorder is presently believed to be most suitable for this application. It is important in this type of instrument that provisions be made to find easily any particular part of the program.

Only a general review of the most essential requirements of these three classes of instruments will be attempted here. A detailed discussion of all the desirable features, which should be associated with each of these devices, is beyond the scope of this paper. One other point needs mentioning here. A recording made on any one of these machines must be reproducible on any other type of instrument. Furthermore, equipment for various applications may be supplied by more than one manufacturer. Interchangeability of recorded program material is a must, if full use is to be made of the potentialities of magnetic recording. This calls for standardization wherever technical developments have advanced sufficiently to make agreement among the interested parties feasible.

A bird's-eye view of the present status of the art at this point might be profitable. There are four main criteria which determine the performance of sound recording equipment:

(1) The signal to noise ratio
(2) The response versus frequency
(3) The nonlinear distortions
(4) Flutter and wow

In regard to the first three points, magnetic recording is at least equal to the best of the optical and mechanical recording methods. Presently available experience indicates that a signal to noise ratio in the order of 60 db might be considered as normal. Of course, this does not necessarily mean that all magnetic recorders will have such a high signal to noise ratio, since only careful design can assure it. Permanent magnetization of the playback head must be avoided since a d-c magnetic field component can increase the background noise of the medium from 10 to 20 db. Permanent magnetization of the recording head will also adversely affect the signal to noise ratio of the system. Furthermore, the erasing and biasing current should be free of harmonics. Only under these conditions will the recording medium be left, in the absence of a signal, in a state of complete magnetic neutralization, which is so essential for noise-free operation.

Proper shielding of the playback head, which should preferably be of hum-bucking construction, is essential. Even small extraneous magnetic fields can do much damage if they are permitted to induce a voltage in the coil of the playback head.

Response versus frequency is associated with the speed of the medium and also depends upon the magnetic properties of the recording medium. In addition, it is a function of the playback head gap length and the choice of the value of the biasing current. Proper adjustment of the recording and playback head are imperative since the response at the high frequency end of the spectrum suffers if the recording head gap is tilted with respect to the playback head gap. Maintenance of intimate contact between the recording medium and the pole pieces of the recording and playback head is another necessary condition.

Experience has shown that with available coated tapes, a flat response can be obtained, with proper equalization, until a frequency is reached which is equivalent to a wavelength of .001". In other words, with a speed of 15" per second, the response versus frequency can be made to be essentially flat up to 15,000 cycles per second. A suitable tape is one which has a coercivity between 200 to 300 oersteds and a remanence between 600 to 900 gausses.

Distortion can be kept to a minimum by proper adjustment of the value of the biasing current. With the biasing current too low, the transfer characteristic is nonlinear; with the biasing current too high, the response at high frequencies deteriorates. The biasing frequency should be at least four to five times higher than the highest audio frequency to be recorded. It is, of course, unnecessary to state that the recording current associated with the maximum signal must not exceed a given value since otherwise overloading occurs.

The amount of distortion is also a function of the magnetic properties of the recording medium and of the dispersion of the magnetic powder in the binder. Each medium must be carefully tested. In general, for a signal to noise ratio of 60 db, not more than 2 to 3% harmonic distortions need be tolerated.

With regard to flutter and wow, no better performance than obtainable with other methods should be expected. Well designed disc, film, and magnetic recording equipment can be made to meet the specified requirements.

But let nobody be fooled into thinking that a high quality magnetic recorder of the studio type can be built less expensively than instruments for other recording methods. If price is an important factor, the purchaser of magnetic recording equipment will have to make concessions in one or in another respect. In many cases where high performance standards are mandatory, it will prove to be worth-while to pay a high price for the proper equipment.

In the course of this paper, reference has been made from time to time to disc recording. It is of particular importance to the broadcast engineer to appreciate where mechanical recording falls short of magnetic recording. The advent of the cellulose nitrate record blank brought about the era where the recordist thought that the crest of performance had been reached. But only most careful attention during the cutting process gives good results. After the disc has been cut, most meticulous protection against dust particles is required to insure the maximum signal to noise ratio of the system. An excessive stylus force coupled with a high mechanical impedance of the moving elements of the pickup cartridge tends to destroy the modulated groove in many cases after the first playing. The eternal problem of translation loss adds an additional difficulty. But worst of all, the tracing distortions are of considerable magnitude, particularly when the recorded wavelength approaches the stylus tip dimension of the reproducing device. Mechanical recording also suffers from the fact that the mechanical vibrations, always present during the recording and reproduction, lead often to an unwanted relative motion between the recording medium and the recording and reproducing stylus causing modulations which are reproduced as rumbling noises.

In contrast, magnetic recording is free of most of these difficulties. While there is a gap length effect in magnetic recording which in some respects might be compared with the tracing problem in disc recording, the gap length effect does not cause nonlinear distortion even if the wavelength approaches the gap length of the reproducing head. Only the frequency response is affected by short wavelengths of the recorded signal.

All this is not meant to imply that magnetic recording is the wonder elixir which solves all problems. In fact, magnetic recording introduces difficulties of its own. The recording medium, particularly when it is a coated tape, is usually extremely elastic and stretches during operation. Its dimensions are also changed by the effect of humidity and temperature. Expansion and contraction of the medium will lengthen or shorten the playback period compared to that of the recording time, if no special provisions are made to decrease or increase the speed of the drive mechanism to compensate for the variations of the length dimension of the tape. The use of sprocket holes has been suggested, but appears to be impractical, since it would require considerable strengthening of the base material resulting in bigger reels for accommodating a given recording period.

The amount of magnetic energy which can be stored on the thin layer of magnetic material is relatively small. Therefore, the impressed signals can only develop weak magnetic fields which must generate the useful voltages in the playback head. To design a highly sensitive amplifier which is responsive to these small signals with the necessary signal to noise ratio, challenges the ingenuity of electronic engineers. The small fields generated by the recording medium are sometimes comparable to the magnitude of external fields. Thus, it is difficult to reduce hum to an appropriate low level. But even though problems are still to be solved, there is good reason to believe that they do not represent unsurmountable barriers in future developments.

Some question might be raised with regard to modulation noise. Modulation noise is a noise which exists only in the presence of a signal and its magnitude depends upon the strength of the recorded signal. The modulation noise is a phenomenon which is not unique with magnetic recording since it is at least to some extent found in mechanical recording and particularly is present in film recording. Because of the other outstanding performance characteristics of magnetic recording, modulation noise is now looked upon as the one factor which limits the ultimate capabilities of this sound-recording method. It causes fuzziness in reproduction with a corresponding annoyance to the listener. Various statements have been made regarding the order of magnitude of the modulation noise for different types of magnetic recording mediums. Values of 30 to 40 db have been reported but it is doubtful whether great significance can be assigned to these figures. No specific measurement procedure has been agreed upon as yet.

Level variations are another objectionable deficiency in magnetic recording. They occur in the playback process, being particularly pronounced in the reproduction of the higher frequencies of the spectrum. Such level variations are usually brought about by contact variations between the recording medium and the pole pieces of the recording and playback head and are received by the listener as noise and fuzziness. Careful design of the equipment, cleanliness of the heads, smoothness of the recording medium surface and of the pole pieces will all tend to reduce level variations to a minimum.

The need for standardization has already been stressed. Various technical organizations and societies have established committees to review the available information and to see whether an agreement could be reached with regard to certain design features so that interchangeability of such elements could be accomplished which need to be interchangeable for the benefit of the user of magnetic recording equipment. The NAB Magnetic Recording Committee has drawn its membership from industry active in the field of magnetic recording and from broadcasting organizations interested in employing magnetic recording. Thus, there is assurance that the designer's and consumer's viewpoints are properly considered.[1]

A brief review of some of the problems with which the committee was and still is confronted will underline the magnitude of its task. First of all, there must be agreement on the speed and on the physical dimensions of the recording medium. This requirement is so basic that no further explanation is needed here. Secondly, signals must be so recorded that the remanent magnetic induction in the recording medium for any frequency within the specified spectrum should have a definite relationship to the remanent induction of any other frequency. Only under such conditions is it possible to obtain the desired response versus frequency with one setting of post equalization independent of equipment on which the recording has been made. Furthermore, tape reels must be so designed that they can easily be attached to any instrument.

Very definite progress has been made in establishing standards for the physical dimensions and for the speed of the recording medium. After considerable deliberation, 3 tape speeds have been chosen:

(1) *15" per second (primary standard):* Where high fidelity performance is required.

A magnetic recorder operating at 15" per second shall provide a response which should lie between two limits; the upper limit is represented by an equal level line from 50 to 15,000 cycles per second. The lower limit is an equal level line from 100 to 10,000 cycles per second but 2 db down with respect to the upper limit. From 100 to 50 and from 10,000 to 15,000 cycles per second the lower limit is permitted to drop uniforml and progressively an additional 3 db.

[1]Refer to NAB Recording and Reproducing Standards in Section 1 of this Handbook.

(2) *7.5" per second (secondary standard):* Where limited performance, as far as frequency range is concerned, can be tolerated.

Response versus frequency of a magnetic recorder employing a tape speed of 7.5" per second shall have a response in character similar to that of 15" per second equipment, only that in this case, the 2 db allowable level variations are restricted to the band from 100 to 5000 cycles and that beyond 5000 cycles per second to 7500 cycles per second the response can drop an additional 3 db. The requirements from 100 to 50 cycles per second for 15" and 7.5" per second recorders are the same.

(3) *30" per second (supplementary standard):* Wherever special requirements make an increase in speed desirable.

A few explanatory words seem to be in order here. These 3 speeds have been chosen since their ratio is 1 to 2 to 4. Should it at any later time become desirable to provide markings on the tape for speed correction to compensate for elongation or contraction, such ratios which are based on multiples will greatly simplify the problem. Furthermore, speeds of 7 1/2" and 30" per second had already wide use prior to the final proposal made by the NAB Committee.

With regard to the physical dimensions of coated tape, its thickness shall not exceed .002" and its width shall not exceed .250" nor shall it be less than .0244". Only an upper value has been set for the thickness of the tape. There is no objection to the use of a thinner tape, as long as its mechanical strength is high enough to withstand operational stresses and as long as the coating permits sufficient storage of magnetic energy. The maximum permissible thickness of the tape determines the dimensions of the reels for any given recording time and thus controls certain important dimensions of magnetic recording equipment.

The work on standardizing reels has not been completed. This problem is aggravated by the fact that there are instruments in use which require different reel designs for proper operation. After many months of deliberation it seems that the committee can now propose a reel which will be acceptable to all.

Much more work has still to be done in setting standards for remanent induction values versus frequency. There are so many factors which tend to change conditions that only careful consideration can bring about a satisfactory agreement.

BROADCAST STATION AUDIO AND CONTROL CIRCUITS*

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Summary

The author describes the audio frequency control circuits for a typical local station operation utilizing one control room and two studios. The general layout of circuits is shown together with detailed descriptions of various parts of the system. It is not the author's intention to furnish detailed instructions covering the installation of such a system, but rather to provide ideas which experienced engineers might find helpful in designing their own studio circuit arrangements. Those who have not had adequate training and experience in the design and operation of high quality audio circuits are cautioned against assuming that this paper includes complete instructions for making such an installation.

In broadcasting, ease of operation and simplification of equipment maintenance is highly desirable and will pay dividends in the form of improved program production. With a flexible system, the station engineer is able quickly to solve unusual setup problems and system testing. It is much easier to install a flexible design originally than to add a bit at a time after the basic system is on the air. In many stations, lack of time and personnel often prohibit working on equipment once it is placed in service. Hasty modifications usually result in "haywire." Thus it becomes highly desirable to have a certain measure of planning in the original construction.

The Mixer System

There are nine faders in the mixing system, handling normally two microphones from each studio, one microphone from the control room, two transcription turntables, one network line and one remote line. Wiring of key switches and faders is shown on DWG 5 and the values of R shown on DWG 3, FIGS. 2 and 5. Also on DWG 3 is shown a variation of the regular mixing system, three outputs being utilized instead of two. This latter might be used in a small master control position.

As tape recorders are now coming into quite common use it may be necessary to expand the mixer system by one or two more faders. Some of the present day tape recorders deliver at least zero level and may be brought in on the remote key. Since most of these recorders are complete with record and playback amplifiers as well as gain controls all operation and control can take place where the units are mounted.

* Revised 1949

The regular mixing system has two outputs, one for feeding programs to the transmitter and the other for auditioning a second program simultaneously. The mixer is so designed that the throwing of a key switch makes no noticeable change in level either in the program or audition channels.

The use of different colored knobs, or section paneling, is desirable since a row of nine faders may be confusing.

DWG 1 shows all inputs to channels going to the relay arms, and the inputs of the faders to front contacts. In a channel where talk-back or cue circuits do not exist, the relay may be turned around and the fader input connected to the arm. This will make available an extra input to the fader when the channel is in the "OFF" position.

Transcription Cue and Talk-back Circuits

Transcription cueing systems in current use are many and varied and are at times quite inconvenient. The system described here is entirely automatic and is successfully installed in a number of stations.

Many of the smaller stations begin their operations with a stock model console. Most of these consoles have keys for channel control without any room for addition of pushbuttons for relay control. These keys may be wired to turn on a turntable motor relay to start the table from the console position. Placing the key in either "ON AIR" or "AUDITION" will start the table and take the preamp off the cueing circuit and returning it to "OFF" will place the output of the preamp back in the cueing position. A simple switch in the relay control circuit will de-energize the relays and the tables can be operated in the normal manner, that is, one hand on the fader and the other on the table.

By the relay method, provision is made for cueing by automatically setting up a monitoring channel. This means that there is no key switch to throw when cueing a record or listening for checking. A control pushbotton operates relays starting the turntable motor and placing the channel "ON AIR." When the channel relay is released, the output of the pickup preamplifier connects automatically to the cueing amplifier through a back contact of the relay. This is shown in detail on DWG 5. Relays for channels six and seven are wired similarly to channel one. A separate toggle switch on the turntable console may be employed to operate the turntable motor when desiring to listen to a transcription with the system in cueing position.

The talk-back circuit makes the output of a microphone preamplifier available for talk-back purposes when the channel relay is not in the "ON AIR" position. Channel relays are directly ahead of faders in the mixing system, being controlled from the announcing position as well as in the control room. Speaker cutout relays prevent feedback when the studio is "ON AIR", but, when talk-back is used, both the microphone and speaker are on, with the gain of the talk-back amplifier set below the feed-back point.

Talk-back relays are controlled by push-buttons at the three microphone positions. This is a simple circuit using a push-to-make button to apply power to the relay coil. DWG 4 shows the audio wiring in a one-line diagram. It may be desirable to use a separate speaker in the studio so that the regular reproducer will not be subject to interruption at a critical point in the program being monitored.

Remotes

The remote channel, number nine, may be set up to handle two remotes, one following the other. Interlocking prevents putting both on the air at the same time. Details will be found on DWGS 2, 4 and 5.

Several ways of sending cue to a remote operator are indicated. If the microphone talk-back circuit is used, the telephone may be omitted. Usually, the remote operator can make use of a regular microphone and headphones for pre-program communication with the studio. It has been suggested that, by incorporating a switching arrangement in the remote amplifier, crystal headphones can be used for talking and listening.

Relay eleven can be made to operate an indicating device in the control room when the operator arrives at the remote and plugs in his equipment. The center-tap of the remote amplifier output transformer has to be grounded to make R11 operate. This ground, as a rule, effects a reduction in hum level and should be made to a nearby water-pipe. For convenience, the remote line and the ground wire should be connected to a socket. Further, an output plug should be built into the remote amplifier paralleling or replacing the usual terminal strip. A flexible cord connects this plug with the remote line-ground socket, as well as completing the studio call-in circuit. This procedure also facilitates the quick setting up of a remote.

Relay twelve can be used for signalling after the remote has been patched up. This circuit of battery, PB1, R12 and repeat coil is duplicated in the remote setup. The relay at the remote point may be controlled to turn on an unattended amplifier.

Relay Controls

Relay control wiring detail is shown on DWG 2, FIG 1. Relay catalogs will give all information for ordering units with coils of proper resistance for the voltage chosen. Telephone type indicator lights rated at 14 volts will give long service when operating on 12 volts. Should any other voltage be used, the rating of the lamps should be approximately ten percent above the supply voltage for maximum life with satisfactory brilliance.

The D.C. power supply for relays and lamps should be well filtered; an electrolytic condenser of 1000 mfd capacity probably will suffice. A selenium type rectifier supplying 12 volts is a satisfactory source of power. Current requirements should be calculated after relays and lamps have been chosen. Voltage regulation of the power supply should be capable of handling all variations in the load that will occur during operation.

Some trouble may be expected from clicks when relays are operated; a little experimenting will correct this. A resistor or resistor-condenser combination across the "OFF" push-button contacts will minimize interference. Relay and power wiring should be isolated completely from audio circuits, and it is recommended that such control circuits be shielded in conduit or braid. Any contact that breaks a current is a potential source of trouble and should be investigated if clicks persist.

FIG 2 on DWG 2 shows a variation of wiring for the relays in any one channel. This change causes the speaker relay to operate first, thus cutting off the speaker before the microphone is turned on. Also, if used in the transcription channel, it allows the turntable to start before cutting in the channel. In some cases, the bending of relay contacts will produce the desired operation.

Wiring

Audio wiring is carried in shielded pair with two wires for each circuit even though one side is common. Present day practice calls for twisted pair, third wire bare, copper braid shield and cloth braid over-all. The bare wire is used to carry the ground so that the point of grounding a run can be controlled, thus eliminating a "ground loop" and reducing noise in low level circuits. All common wires should be tied together at one point in the mixer console.

An external GROUND is also brought in at this point. Low level circuits can be run in mike cable to permit the grounding of the shield at one point only.

If a noise level of 60 DB below reference is to be obtained extreme care must be taken with all wiring. Keep low and high level circuits well separated.

Wiring from jacks and units in a rack may be brought down to a terminal strip and cross-connected both to one another and to other racks. This will simplify any later changes that may be necessary. Jacks can be numbered in order as they appear in the rack and this number carried to the main block diagram. A sample of this numbering is shown on DWG 5. Jack numbers should also be put on the terminal boards within the cabinets. This makes for rapid tracing of circuits and aids in making special setups.

Conclusion

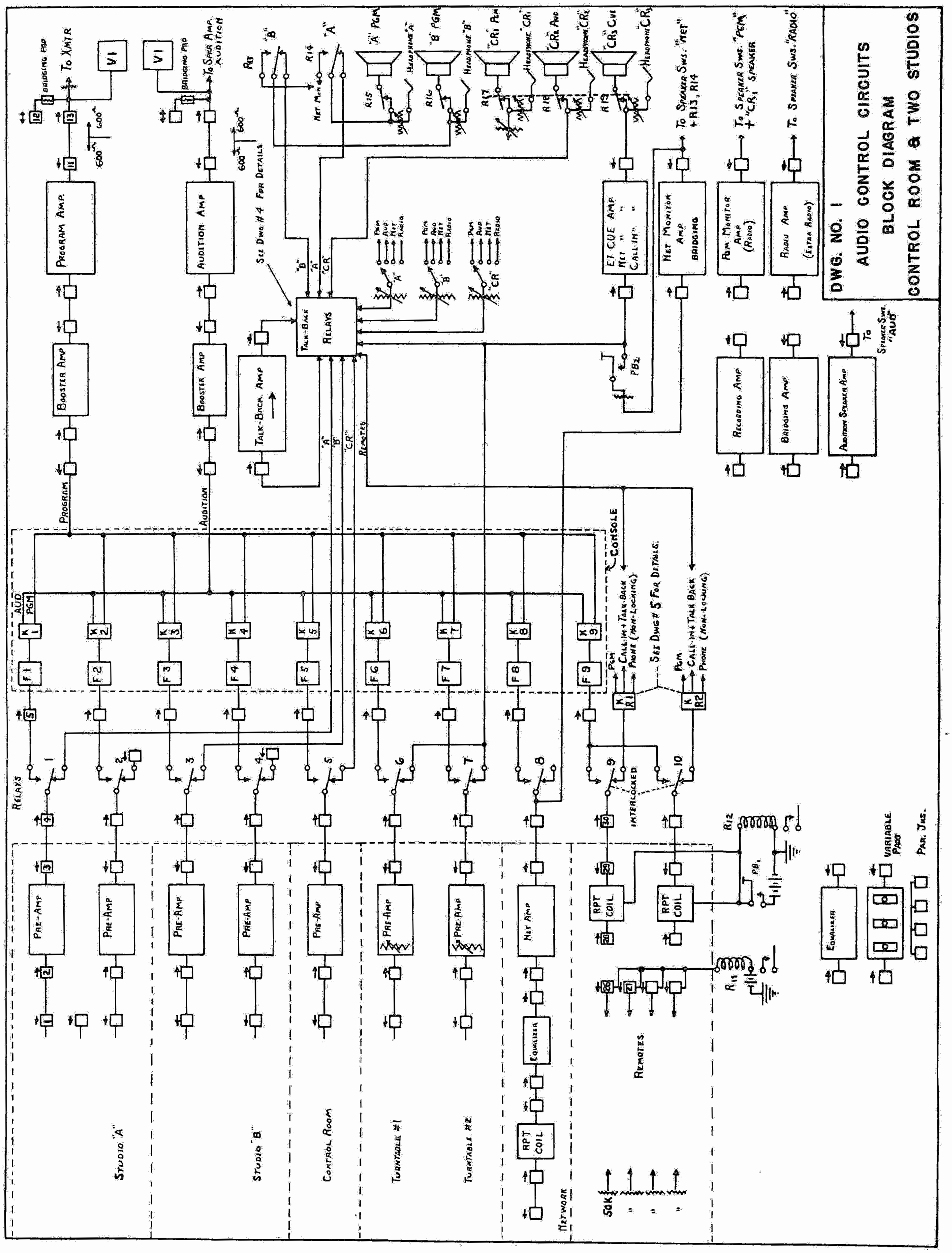
The manufacturer of equipment or components is not specified since each engineer will have his own preference. Satisfactory operation will depend, of course, upon the care with which the selection is made. This choice of high quality relays, pushbuttons and key switches will more than repay the cost in good operation.

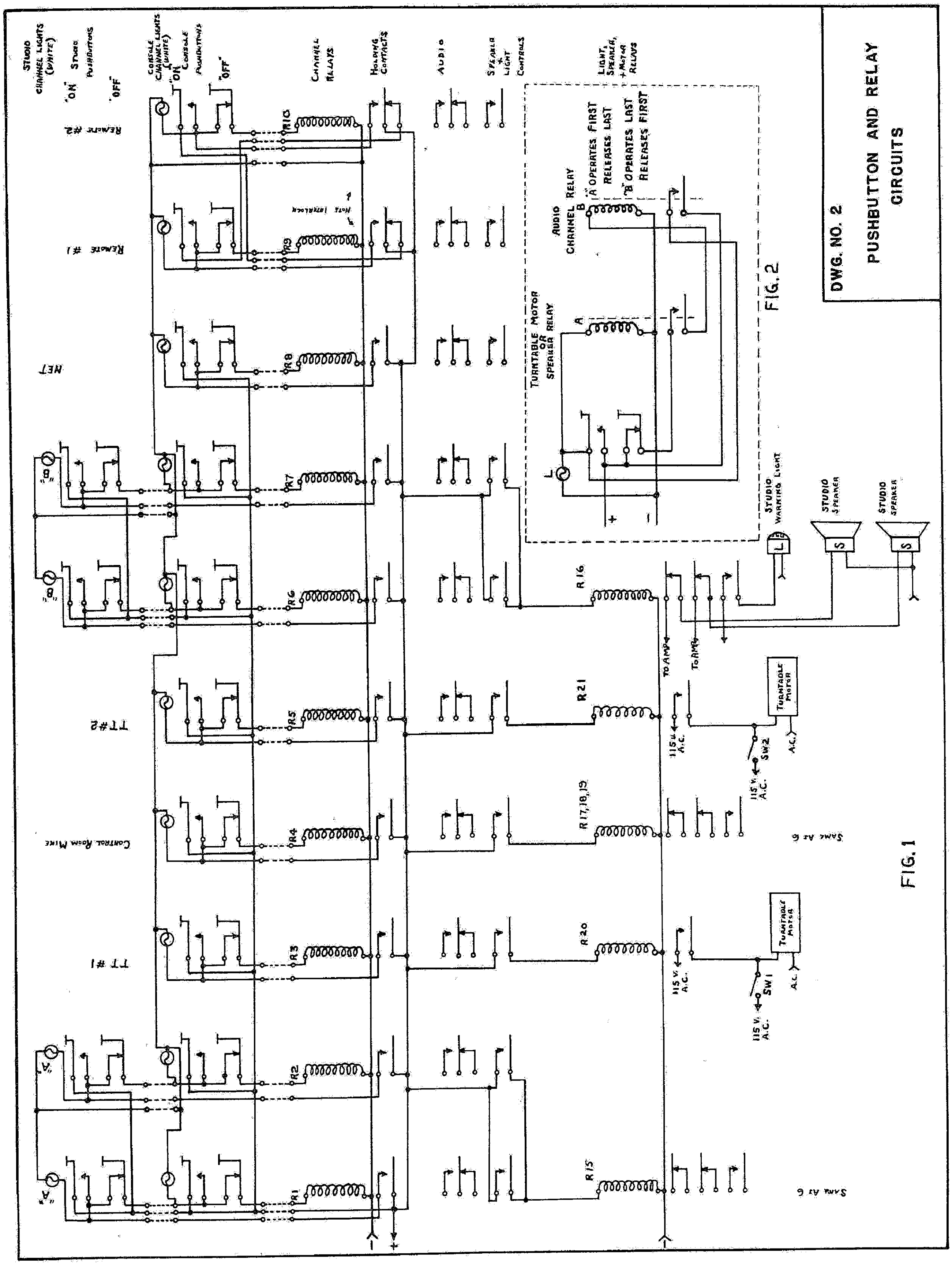
Auxiliary amplifiers are shown for use as indicated, rather than providing one amplifier for many functions. Program and audition channels are identical, with the level set the same to make quick interchange, in the program channel, possible in the case of trouble. Layout and design of the mixing console can take many forms and is left to the individual engineer.

Stations operating full time with records and transcriptions should give serious consideration to the use of a third turntable to accommodate spot announcements, leaving the other two tables for programs. A complete and dependable recording installation, separate from the playback turntables, is a necessity for many stations. It is expected that this system will not fulfill all demands but, once the operating requirements are determined, a minimum number of changes will effect the desired setup.

The present day trend toward tape recording points towards the need for two console mounted machines in the control room and one for portable use. In addition, an editing playback unit should be available for those who have to make short programs out of long ones. This editing can become very tedious and should be done in a room away from everyone else.

The author acknowledges the assistance in the development of these circuits from the following: David W. Jefferies, Radio Station WESB, Bradford, Pennsylvania; Otis L. Atherton, Radio Station WHDL, Olean, New York; John T. Dowdell, Radio Station WIBX, Utica, New York.


DWG. NO. 1
AUDIO CONTROL CIRCUITS
BLOCK DIAGRAM
CONTROL ROOM & TWO STUDIOS
PROGRAM AMP.
AUDITION AMP
BOOSTER AMP
TALK-BACK AMP
TALK-BACK RELAYS
NET MONITOR AMP BRIDGING
PGM MONITOR AMP (RADIO)
RADIO AMP (EXTRA RADIO)
RECORDING AMP
BRIDGING AMP
CONSOLE
PRE-AMP
NET AMP
EQUALIZER
RPT COIL
STUDIO "A"
STUDIO "B"
CONTROL ROOM
TURNTABLE #1
TURNTABLE #2
NETWORK
REMOTES
RELAYS
INTERLOCKED
PROGRAM
AUDITION
TO XMTR
VI
SEE DWG #4 FOR DETAILS
SEE DWG # 5 FOR DETAILS


DWG. NO. 2
PUSHBUTTON AND RELAY CIRCUITS
FIG. 1
FIG. 2
STUDIO CHANNEL LIGHTS (WHITE)
"ON" STUDIO PUSHBUTTONS
"OFF"
CONSOLE CHANNEL LIGHTS (WHITE)
"ON" CONSOLE PUSHBUTTONS
"OFF"
CHANNEL RELAYS
HOLDING CONTACTS
AUDIO
SPEAKER + LIGHT CONTROLS
LIGHT, SPEAKER, + MOTOR RELAYS
Remote #2
Remote #1
NET
TT#2
Control Room Mike
TT#1
TURNTABLE MOTOR OR SPEAKER RELAY
AUDIO CHANNEL RELAY
"A" OPERATES FIRST RELEASES LAST
"B" OPERATES LAST RELEASES FIRST
STUDIO WARNING LIGHT
STUDIO SPEAKER
STUDIO SPEAKER
TO AMP
TO AMP
TURNTABLE MOTOR
TURNTABLE MOTOR
115 V. A.C.
SW 1
SW 2
A.C.
Same As 6
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R15
R16
R17,18,19
R20
R21

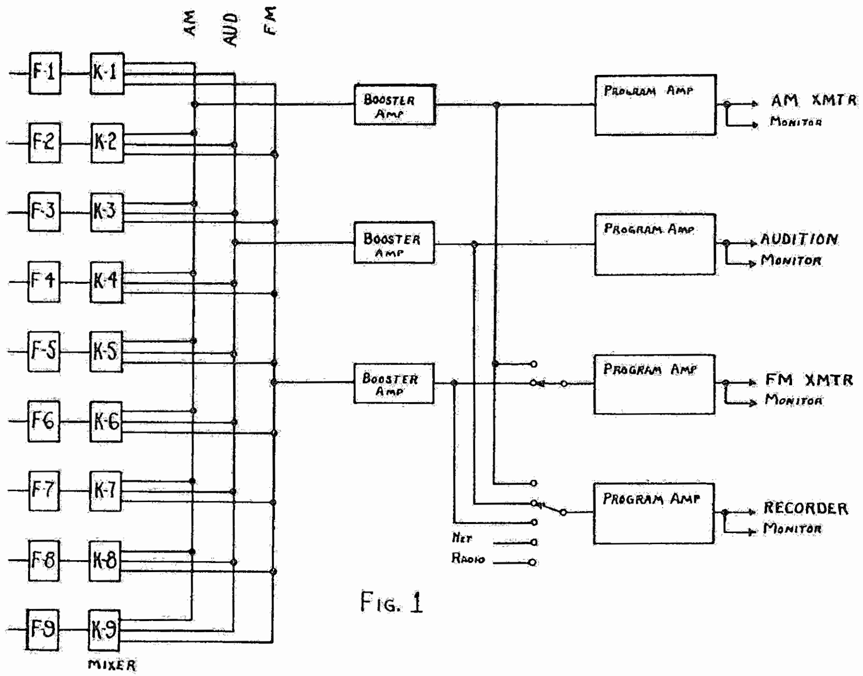
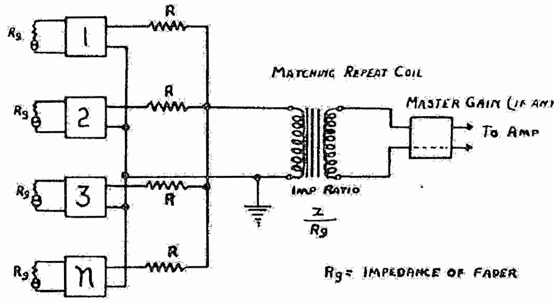
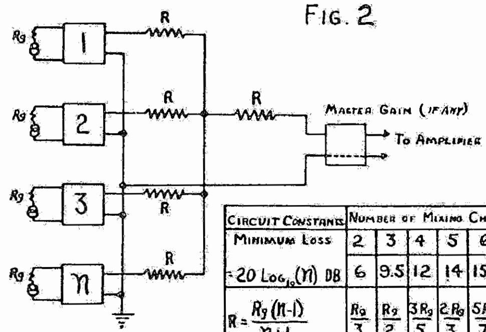


Fig. 1



Circuit Constants	Number of Mixing Channels, n							
Minimum Loss	2	3	4	5	6	7	8	9
$= 10\log_{10}(2n-1)$ DB	4.8	7	8.4	9.5	10.4	11.1	11.8	12.3
$R = \frac{R_g(n-1)}{n}$	$\frac{R_g}{2}$	$\frac{2R_g}{3}$	$\frac{3R_g}{4}$	$\frac{4R_g}{5}$	$\frac{5R_g}{6}$	$\frac{6R_g}{7}$	$\frac{7R_g}{8}$	$\frac{8R_g}{9}$
Repeat Coil Primary Impedance $= \frac{R_g(2n-1)}{n^2}$	$\frac{3R_g}{4}$	$\frac{5R_g}{9}$	$\frac{7R_g}{16}$	$\frac{9R_g}{25}$	$\frac{11R_g}{36}$	$\frac{13R_g}{49}$	$\frac{15R_g}{64}$	$\frac{17R_g}{81}$

Fig. 2



Circuit Constants	Number of Mixing Channels, n							
Minimum Loss	2	3	4	5	6	7	8	9
$= 20\log_{10}(n)$ DB	6	9.5	12	14	15.6	16.9	18.1	19.1
$R = \frac{R_g(n-1)}{n+1}$	$\frac{R_g}{3}$	$\frac{R_g}{2}$	$\frac{3R_g}{5}$	$\frac{2R_g}{3}$	$\frac{5R_g}{7}$	$\frac{3R_g}{4}$	$\frac{7R_g}{9}$	$\frac{4R_g}{5}$

"Pickups" 9-37

Fig. 5

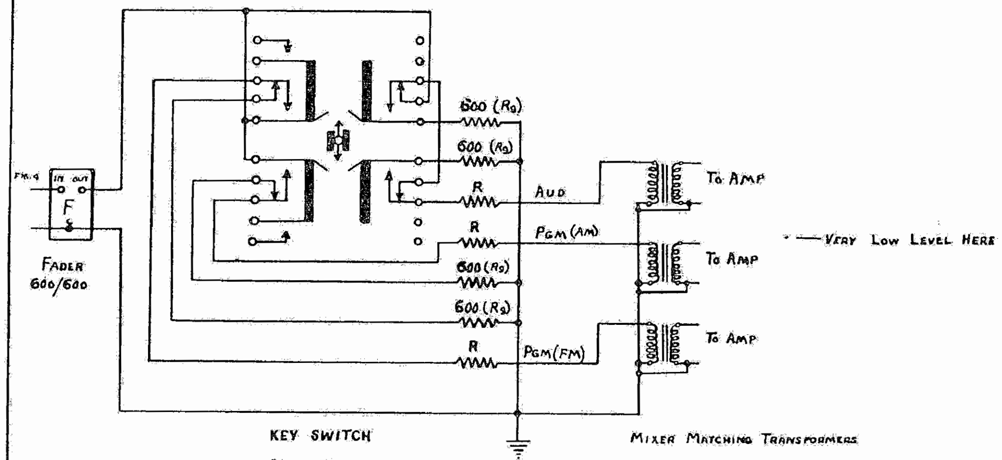
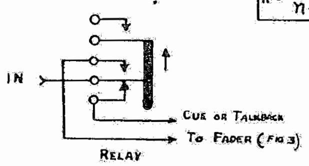


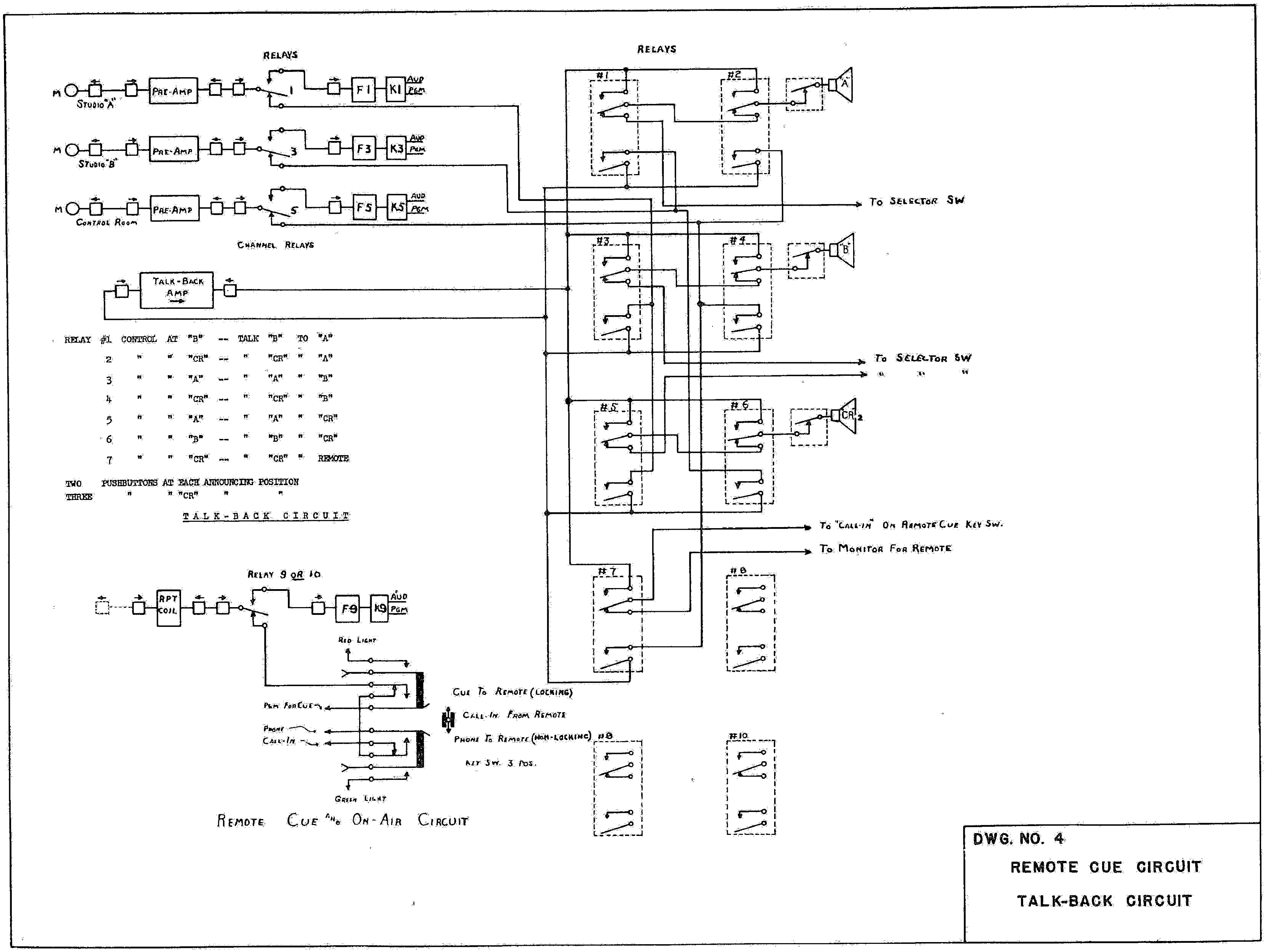
Fig. 3

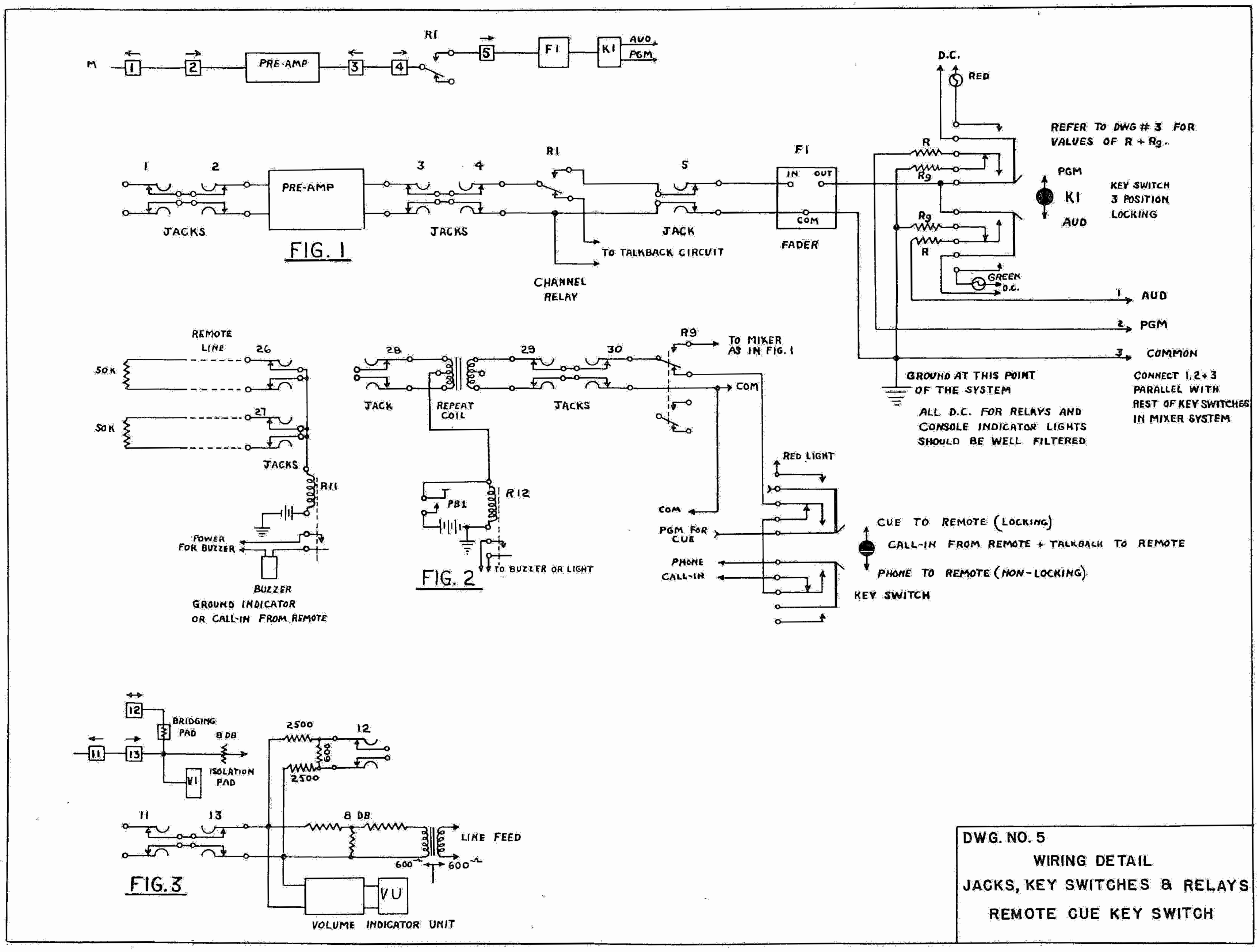


Relay
Fig. 4

DWG. NO. 3

MIXER SYSTEMS


DWG. NO. 4
REMOTE CUE CIRCUIT
TALK-BACK CIRCUIT
RELAYS
M
Studio "A"
Studio "B"
Control Room
Pre-Amp
F1
K1
F3
K3
F5
K5
F9
K9
Aud
Pgm
Channel Relays
Talk-Back Amp
#1
#2
#3
#4
#5
#6
#7
#8
#9
#10
"A"
"B"
CR2
To Selector SW
To Selector SW
To "Call-In" On Remote Cue Key Sw.
To Monitor For Remote
RELAY #1 CONTROL AT "B" -- TALK "B" TO "A"
2 " " "CR" -- " "CR" " "A"
3 " " "A" -- " "A" " "B"
4 " " "CR" -- " "CR" " "B"
5 " " "A" -- " "A" " "CR"
6 " " "B" -- " "B" " "CR"
7 " " "CR" -- " "CR" " REMOTE
TWO PUSHBUTTONS AT EACH ANNOUNCING POSITION
THREE " " "CR" " "
TALK-BACK CIRCUIT
Relay 9 or 10
RPT Coil
Red Light
Pgm For Cue
Phone Call-In
Green Light
Cue To Remote (Locking)
Call-In From Remote
Phone To Remote (Non-Locking)
Key Sw. 3 Pos.
Remote Cue and On-Air Circuit



DWG. NO. 5

WIRING DETAIL

JACKS, KEY SWITCHES & RELAYS

REMOTE CUE KEY SWITCH

SPECIAL ANTI-SIDE TONE CIRCUIT

*REPRINTED FROM THE ENGINEERING NOTICES OF THE NATIONAL BROADCASTING COMPANY**

Purpose

The circuit described herein is designed to provide two-way conversation on the air or three-way conversation with loudspeakers at all points, the loudspeakers and microphones being open at all times. This is made possible without cut-off or switching systems.

General

Referring to figure 1, if we assume that R-1, R-2 and R-3 are all of equal value and R-1¹, R-2¹ and R-3¹ are of equal value then, if a voltage be applied across R-1, a voltage will be observed across all other resistances of the network except R-1¹. This will be apparent with reference to Wheatstone Bridge circuit theory. if, now, the resistance R-1 represents a microphone output and the resistance R-1¹ be a loudspeaker input then when the microphone represented by R-1 is spoken into no feedback will be noted from the adjacent loudspeaker represented by the resistance R-1¹. Similarly, R-2 and R-3 may be microphones and R-2¹ and R-3¹ may be adjacently mounted loudspeakers.

In the case noted above full three-way conversation may be held. If it is desired to communicate between two points and have the resulting conversation transmitted to local or network channels, then we assume that R-1 and R-2 be the two sources of program and R-1¹ and R-2¹ be their adjacently located loudspeakers. R-3 becomes a pure resistance and R-3¹ will be the input to the outgoing line or channel amplifier.

It will be obvious that for proper operation of this circuit all of the resistances shown in figure 1 representing as they do the output of microphone amplifiers or input of loudspeaker amplifiers must be accurately balanced against each other, that is R-1, R-2 and R-3 must have very nearly the same values within close limits and the same will be true of R-1¹, R-2¹ and R-3¹. In order to accomplish this close balance it will be necessary in some cases to isolate these circuits by use of balanced H pads.

It is most convenient, in this connection, to arrange the output of the microphone amplifiers for 125 ohm operation and to terminate the same in a 125 ohm resistor. The variation in balance with this arrangement is reduced to a satisfactory minimum.

*Compiled by Mr. Raymond A. Monfort and Mr. Donald H. Castle.

The loudspeaker amplifier input is usually of high impedance subject to some variation with a change in the volume control. It is, therefore, found best to isolate the inputs to these loudspeakers with suitable H pads. A 6 db 6000 to 6000 ohm pad is generally sufficient isolation.

Typical Circuits

Figure 2 shows a typical 3 way talking circuit with loudspeakers at all talking points. Figure 3 shows a two way talking circuit feeding a program bus for network or local station feed.

Precaution

Although primary feedback into the talking circuit by the loudspeaker located adjacent to the microphone is eliminated by use of this circuit a source of secondary feedback is possible. This occurs when a signal from, let us say, microphone #1 heard on loudspeaker #2, re-enters microphone #2 and is transmitted back to loudspeaker #1. A judicious choice of loudspeaker levels will minimize this difficulty.

Discussion

This circuit has been used to advantage in such broadcasts as those originating on the yacht "Seth Parker" in which a conversation with the studio is carried on during the broadcast.

No appreciable frequency discrimination is noted by use of this bridge circuit.

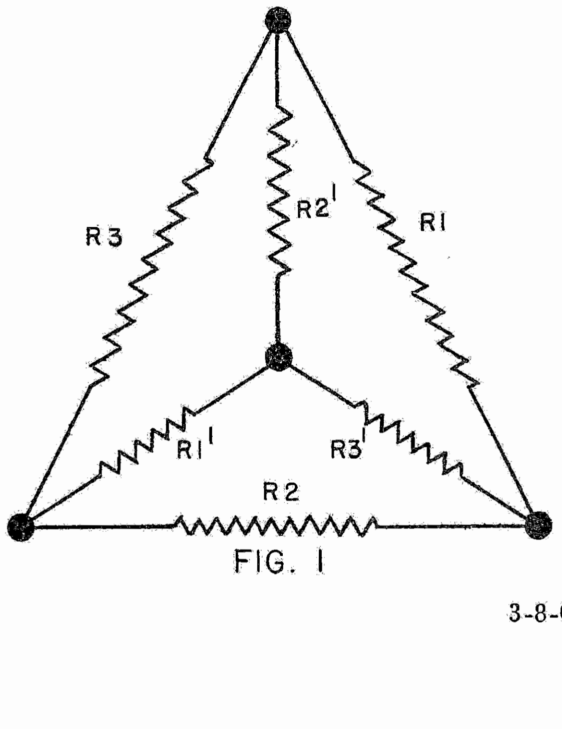


FIG. 1

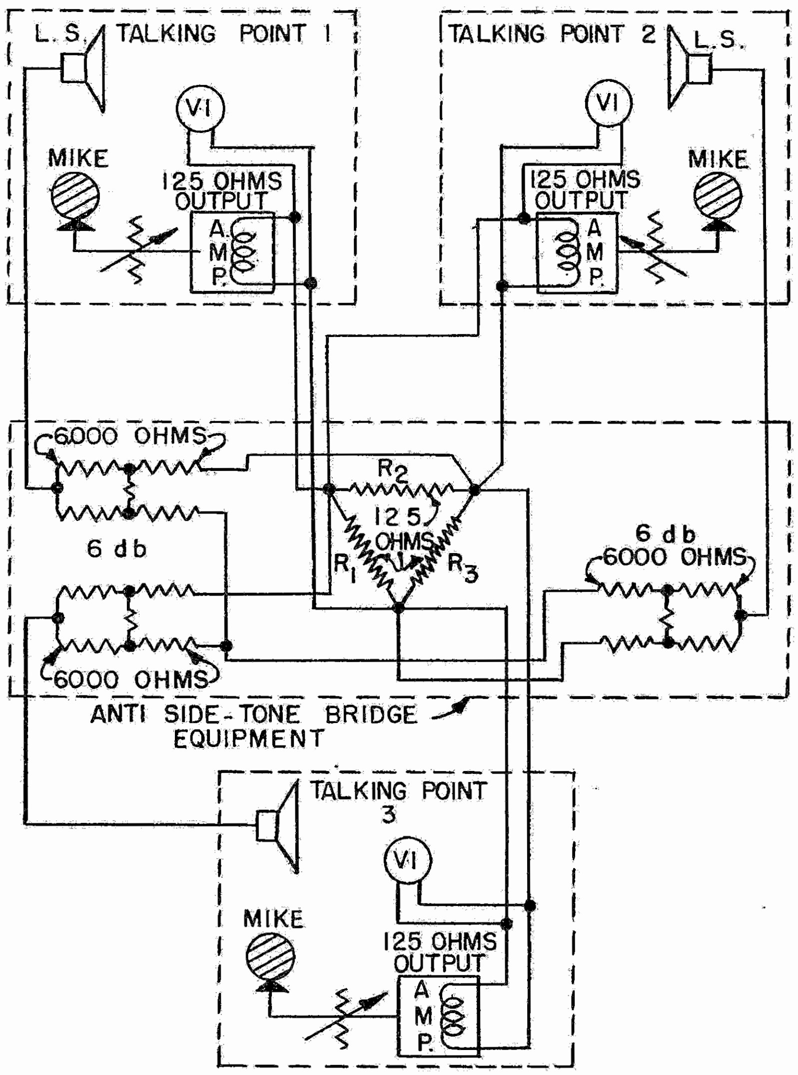

L. S.
TALKING POINT 1
MIKE
VI
125 OHMS OUTPUT
A M P.
TALKING POINT 2
L.S.
VI
125 OHMS OUTPUT
A M P.
MIKE
6000 OHMS
R2
125 OHMS
R1
R3
6 db
6000 OHMS
6 db
6000 OHMS
ANTI SIDE-TONE BRIDGE EQUIPMENT
TALKING POINT 3
VI
MIKE
125 OHMS OUTPUT
A M P.

FIG. 2

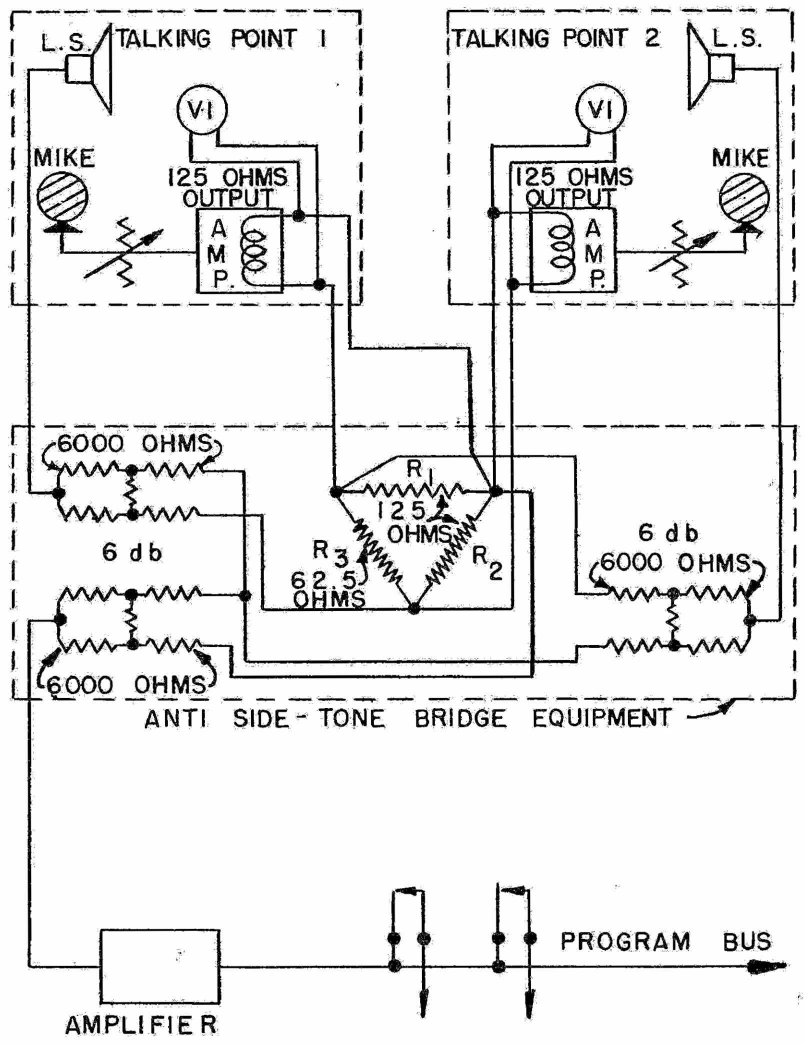

L.S.
TALKING POINT 1
VI
MIKE
125 OHMS OUTPUT
A M P.
TALKING POINT 2
L.S.
VI
125 OHMS OUTPUT
A M P.
MIKE
6000 OHMS
R1
125 OHMS
R3
62.5 OHMS
R2
6 db
6 db
6000 OHMS
6000 OHMS
ANTI SIDE-TONE BRIDGE EQUIPMENT
AMPLIFIER
PROGRAM BUS

FIG. 3