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PROCEEDINGS
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Acoustics and Microphone Placing in Broadcast Studios

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PART II

NORMALLY a room of size shown in Table 6 (May issue), containing both lightly and highly absorbing surfaces, would have a period not much under 1.0 second. With the period cut to less than one-third second at 512 cycles, the artist felt as though he could hardly hear his own performance, and the acoustic brilliancy of the performance suffered at the same time, owing to the discrimination against the upper registers. As the acoustic range of receiving sets and loud speakers was increased to include a frequency band from about 100 to above 4000 cycles, or 5–6 octaves, it became essential to attempt to restore the balance in the studios, which in contemporary design are accordingly much less radically damped.

TABLE 7

Studio Dimensions, 30′ by 20′ by 9′
Volume, 5400 cubic feet

	Absorption
Floor (600 sq. ft.) covered with cork tile (coeff. 0.03)	18.
Ceiling (600 sq. ft.) covered with acoustic plaster (coeff. 0.30)	180.
Walls (900 sq. ft.) ⅔ covered with acoustic plaster (coeff. 0.30)	180.
⅓ draped with monk's cloth curtains (coeff. 0.50)	150.
Total Absorption	528.

Period of reverberation at 512 cycles, by Formula (6): 0.50 second.

A modern studio of the same size as that described in Table 6 in the first section of this paper might follow the design given in Table 7.

An alternative design with more concentrated absorption is given in Table 8:

TABLE 8

Studio Dimensions, 30′ by 20′ by 9′
Volume, 5400 cubic feet

	Absorption
Floor (600 sq. ft.) covered with cork tile (coeff. 0.03)	18.
Ceiling (600 sq. ft.) covered with hair felt (coeff. 0.5)	300.
Walls (900 sq. ft.) ½ hard plaster (coeff. 0.03)	13.
½ monk's cloth drapes (coeff. 0.5)	225.
Total Absorption	556.

Period of reverberation at 512 cycles, by Formula (6): 0.48 second.

In practice, the period of such studios is often brought up to 0.6 second by adjustment of the curtains, or limiting the acoustic treatment of the walls or ceiling, or using material with a lower absorption coefficient.

For good-sized orchestral ensembles, the studio design frequently calls for a two-story elevation in an ordinary building, affording a ceiling height in the neighborhood of 20 feet, and thus increasing the period of the room, since the volume goes up as the cube of the mean dimension while the total surface varies as the square (Cf. Formula

6). A modern studio of this design is represented in Table 9:

TABLE 9

Studio Dimensions, 40′ by 25′ by 20′
Volume, 20,000 cubic feet

	ABSORPTION
Floor (1000 sq. ft.) covered with cork tile (coeff. 0.03)	30.
Ceiling (1000 sq. ft.) covered with "Macoustic" (acoustic plaster with coeff. 0.25)	250.
Walls (2600 sq. ft.) ½ "Macoustic (coeff. 0.25)	325.
½ monk's cloth on "Macoustic" (coeff. assumed as 0.50)	650.
TOTAL ABSORPTION	1255.

Period of reverberation at 512 cycles, by Formula (6): 0.80 second.

With 25 men in the above room, allowing 5 units per man, the total absorption is increased by 125 units, giving a total of 1380 units, whereby the reverberation time is reduced to 0.72 second. By adjustment of the spread of the curtains, which are suspended from rollers, the period of such a studio is adjustable between limits of about 0.65 to 105. second.

We may now refer back to Table 5 (in the May issue), which in the lower periods is a practicable design for a broadcast studio of large size. Such a studio will accommodate an orchestra of 30–40 men, a chorus of 10–20, and soloists, with an overall period between 1.00 and 1.25 seconds.

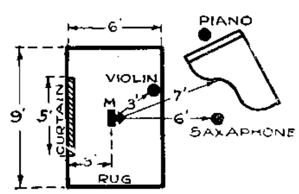

FIG. 2
Set-up for trio—violin, piano and saxophone

The advantage of allowing some flexibility in the studio arrangements, by the use of curtains or similar means, so that the reverberation time may be altered during broadcasting, is not only that it permits the correction of errors in design, but also that it enables the studio staff to adjust the residual acoustic effects for different kinds of performances. For example, a studio may be draped over the total wall area in order to reduce the period to a minimum during a talk, partially draped for chamber music, and the walls may be entirely exposed for symphonic music, when it is desired to simulate the acoustic effect of a large music hall.

It should be pointed out that in designing broadcast studios it is necessary to guard against walls which are so light that a drum action is possible, but as sound insulation

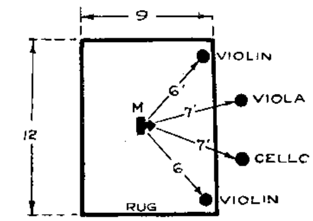

FIG. 3
Set-up for string quartette

is a requisite of such plants, marked diaphragm action in the walls is automatically ruled out when the building construction is correct.

Before leaving the subject of reverberation time as the principal factor in the design of broadcasting rooms, the writer wishes to call attention to the admitted fact that much data remains to be collected before a really scientific basis of construction and use is reached. More material must be collected on the variation of absorption with frequency, the reverberation time of studios at various frequencies must be calculated and checked by physical measurements, the precise relation between reverberation time and the effective intensity reaching the microphone, at the different frequencies, must be theoretically investigated and the results verified by experiment. The field has been merely touched and much work will have to be done before hit-and-miss methods of studio design and microphone placement can be replaced by exact procedures.

SECTION 3. LOCATION OF MICROPHONES AND PERFORMERS IN BROADCAST STUDIOS

AS THE foregoing statements indicate, the basis of this art is at present largely empirical. Not only is the scientific development incomplete, but differences in performance, construction of rooms, interference patterns, and pick-up conditions, make it impossible to formulate rules which will definitely determine the best microphone and orchestral placements in particular studios. In general, once the studio construction has been completed, setting up a musical ensemble involves problems of three kinds:

1. Organizational, in that technical, program, musical, and sometimes commercial personnel are involved.

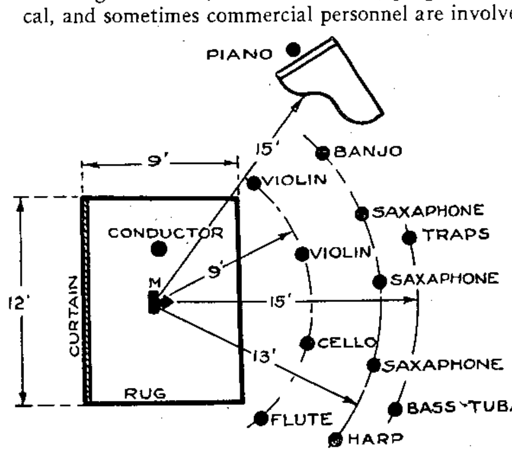

FIG. 4
Set-up for jazz orchestra of 13 men

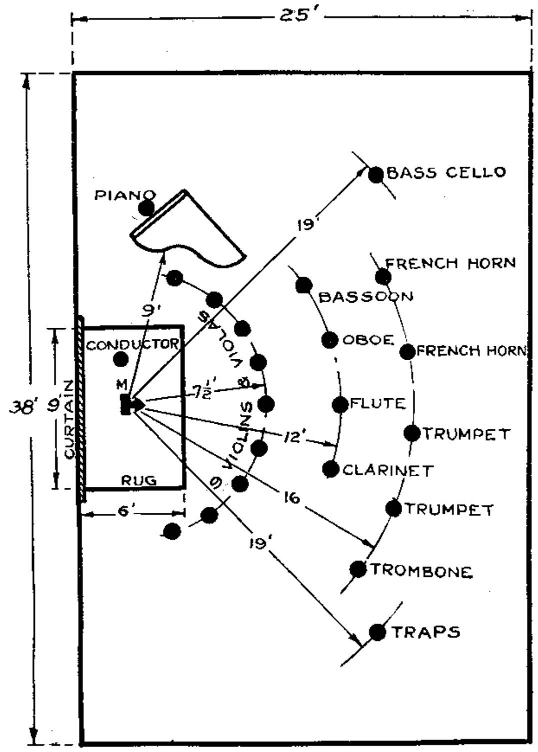

FIG. 5
For a concert orchestra of 23 men. In studio as per Table 9

2. Technical, relating to microphone placing in accordance with acoustic conditions in the studio, control of amplitude, etc.

3. Musical, involving orchestral placing for best rendition and microphone balance.

The factors included under these headings are best reconciled if it is agreed that the microphone position shall be fixed by the technical staff as a physical function of the plant, that the grouping of instruments around the fixed microphone position shall be regarded as a musical function in the hands of the program division, and that control of amplitude shall be a joint responsibility divided according to the rule that a technical man is to handle the gain control with verbal assistance from a skilled musician, who may apprise the operator of impending changes in the music so that any required changes in settings may be carried out smoothly. In this way gain variations during a performance may be reduced to a minimum and such changes as are made will be unobtrusive; at the same time the telephonic level leaving the control room will be above the danger level of noise and below the danger level of overloading.

The following empirical rules for the placing of microphones and performers may be set down for general guidance:

1. Investigate the standing wave patterns of the room at various frequencies and plot the location of pronounced nodes and anti-nodes which will give false effects if the microphone is placed without regard to them. Observation by ear, using notes generated by organ pipes, whistles, or an audio oscillator and loud speaking telephone will serve in the absence of more elaborate facilities.

2. Place absorbent material under and in back of the telephone transmitter pick-up, as by providing a rug under the microphone stand and setting the stand a few feet from a draped wall, in order to escape from multiple echoes in the immediate vicinity of the pick-up.

3. Find the best all-around position for pick-up and maintain it, grouping the instruments around this fixed point.

4. Avoid microphone blasting, in the case of carbon transmitters, as well as exaggeration of the incidental noises of instrumentation, by not placing instruments too close to the microphone. It is assumed that the transmitters are maintained in first-class condition.

5. Reproduce as nearly as possible the normal arrangement of an orchestra, in order as far as the problem allows to adhere to the conditions which have been found most favorable for the musicians.

6. In case of an imbalance, it is usually preferable to try to rectify it by moving back instruments which predominate, or, in the case of directive wind instruments, to make them blow diagonally with respect to the microphone, rather than by moving dominated instruments closer to the transmitter.

Figs. 2–6 show actual placements of microphones and in-

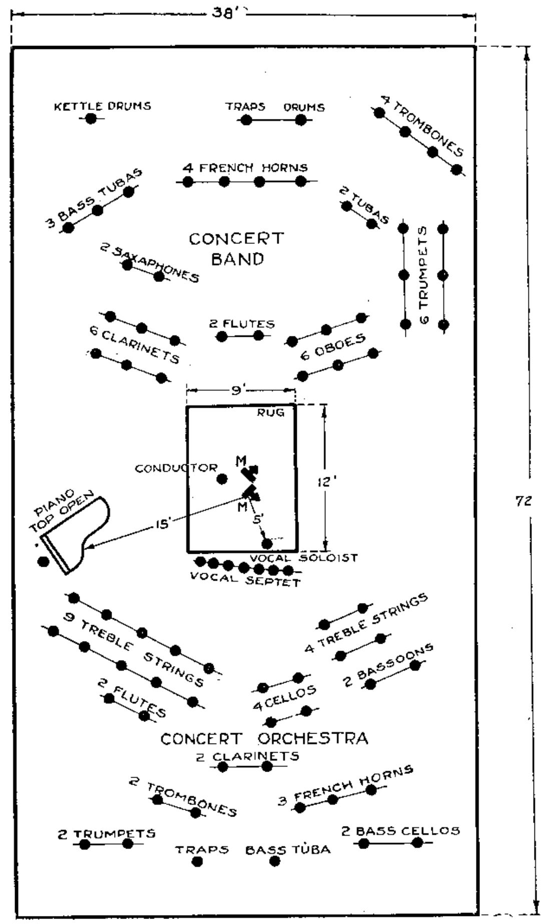

FIG. 6

Placement of concert orchestra, concert band, vocal soloist, and vocal septet.

struments which have been used in broadcasting, although these configurations are not necessarily the most effective, even in the studios in which they were used, and may have to be modified considerably for application in other rooms. In the case of the small ensembles shown in the first three sketches, the studio dimensions are not included; such groups will normally be accommodated in studios of the size given in Table 6, or smaller. The small concert orchestra illustrated in Fig. 5 is placed in a studio of the size described in Table 9. The elaborate set up drawn as Fig. 6 requires some explanation. Here a very large studio was available for broadcasting a concert orchestra of about 40 men, a concert band of about the same size, a soprano soloist, a vocal septet, and an instrumental quartet, all as portions of a single commercial hour. The method used was to set up the transmitters in the middle of the room on a small rectangle of carpet. The concert band played on one side and the concert orchestra on the other, the transmitters being turned according to which of the two was in action. When the soprano sang, accompanied by the septet and orchestra, the placing was as shown; this is also an average set-up for vocal work. The soloist was accompanied by the piano alone for some numbers, and, while the balance was good in the case illustrated, owing to the pianist's tendency to play louder in a large hall, in a small studio the piano would be much closer to the microphone. As a finale the soloist sang with both the band and orchestra accompanying her; the transmitters were then turned to face the right side of the room, looking down on the plan view of Fig. 6, but as there were two microphones mounted at right angles, proper exposure was secured for both orchestral sections. The device of using two microphones with their planes at right angles, mounted a few inches apart, is a common expedient in picking up sound over a wide front. It also possesses other advantages, such as not confining the pick-up to a single point.

The general basis of these placements, it will be observed, is to group the treble strings nearest the microphone, followed by the wood winds in the next row, with the brass to the rear. The bass strings are frequently divided, the 'cellos going with the treble strings, or slightly farther back, and the double-bass being set at a greater range with the percussion instruments. The piano is necessarily placed on one side in most orchestral set-ups, in order not to obstruct the view of the conductor and musicians.

There is a relation between the size of a studio and the number of musicians who can advantageously be placed in it for broadcasting purposes, but in general the number of cubic feet per man allowed in broadcasting is less than in auditoriums where the performance is intended for the audience physically present. Table 5 in Bureau of Standards *Circular No. 300* (see above) allows from 5000 to almost 9000 cubic feet per instrument. In broadcast studios, where reverberation is less and electrical pick-up rather than direct audition is the objective, from 600 to 1200 cubic feet per instrument is the usual allowance. When instruments are crowded into a studio beyond the limits set by the lower figure the results are likely to be poor. There is some tendency among program directors to disregard this limitation. In many cases fewer musicians give better results in the ultimate reproduction.

This paper does not include any treatment of the electrical factors in broadcasting, inasmuch as these have recently been discussed by the writer in a separate article.*

*Dreher, Carl: "Broadcast Control Operation," *Proceedings of the Institute of Radio Engineers*, April, 1928.

Discussion on "Application of the Four-Electrode Receiving Tube (UX-222)"

by Alan C. Rockwood and B. J. Thompson

(March and April Issues of Proceedings)

A MORE general form of the equation appearing on Page 32 of the *Proceedings* may be of interest. The revised form takes account of regeneration in the radio frequency stages while the original form neglected this regeneration and the consequent effect of phase angles. The unmodified expression is sufficiently accurate within the limits of the broadcast band, but the form appearing below is more generally correct for the whole radio frequency spectrum.

The maximum lead impedance which may be used without oscillation is given by the expression:

$$Rp = \frac{1.41\, rp}{rp\,(2\pi f\ Cpg\, Gm)^{\frac{1}{2}} - 1.41}$$

where Cpg is the feed-back capacity in farads and f is the frequency in cycles per second. The curve (Fig 12-A) shows the relation between maximum lead impedance and frequency for the UX-222, as determined by this expression. The circuit is also shown in simplified form. From the curve it will be seen that at 120 kc, a load impedance of 1.5 megohms may be used without oscillation, while at 1000 kc, an impedance of 240,000 ohms may be used with stability. At 20,000 kc., a load of 45,000 ohms is possible before oscillation occurs. These values are about the maximum which it is possible to build up in the customary manner. Thus, as stated in the paper, it may be seen that at any frequency below 20,000 kc., in ordinary circuits, the UX-222 will operate as a stable amplifier, provided all external sources of feed-back have been eliminated.

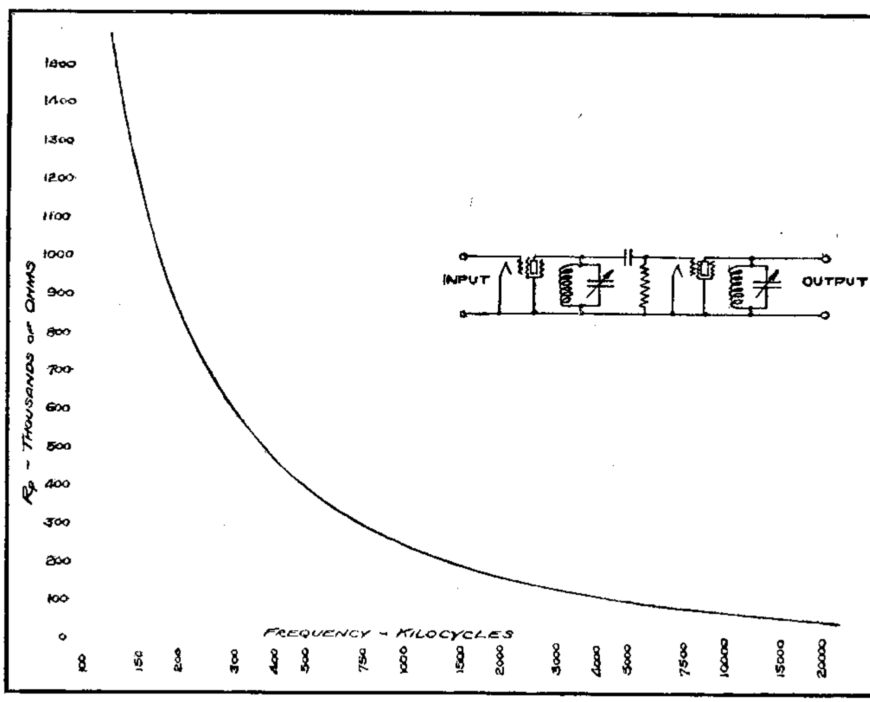

FIG. 12-A