Broadcast & Public Address Systems

Describing an elaborate and successful sound installation.

ARTHUR W. SCHNEIDER*

In 1939 at the World's Fair there was dedicated the Court of Peace, and not far from it lay the New York City Building, one of the Fair's permanent structures.

Eight years have passed, and amongst the many changes that have taken place since Hitler's attempt to turn the dedication of the Court of Peace into a mock ceremony has been the conversion of this New York City Building into a temporary home of man's latest concept of the Court of Peace, namely, the United Nations General Assembly.

In 1939 the engineers of Commercial Radio-Sound designed the broadcast facilities and the public address systems for the World's Fair, and these same engineers found themselves very much at home during the installation and design of the systems now in use in the United Nations General Assembly.

There are two systems in use at the General Assembly's headquarters, one for the large General Assembly Auditorium and the other for the Conference Room. Each of these systems is totally independent of the other except for tie-lines between them permitting feeds in either direction. The purpose of both systems is as follows:

a) To make audible to the members of the United Nations, their guests, visitors, press and all others present all words spoken by each speaker; to permit the maximum freedom of movement on the part of the speaker and a minimum amount of concentration on the part of the auditor.

b) To faithfully transmit all sounds picked up to the following services.

1. Broadcast stations and networks
2. Recording for official records
3. Motion picture film recorders
4. Television

c) To accomplish the functions outlined above with the minimum number of controls, ease of operation, and dependability of circuits.

**Gen. Mgr. and Chief Engineer, Commercial Radio-Sound Corp., N. Y. C.*

←

Fig. 1. (top). United Nations conference room.

Fig. 3. (bottom). United Nations general assembly auditorium.

Conference Room

Figure 1 shows a photograph of the actual Conference Room setup which is unique in the application of pickup and reinforcement of the spoken word.

It is necessary to pick up from any one of the delegates sitting around the outside of the large table or from any of the interpreters located within the oval, and permit good hearing with good intelligibility without feedback by all persons in the room. At the same time the intimate character and purpose of the room has to be preserved.

The solution suggested by Commercial Radio-Sound engineers was adapted by the United Nations' engineers for all their Conference Rooms, including those at Lake Success.

As can be seen through the control room window in *Figure 1*, the Conference Room contains a large oval table on which are located thirty-one microphones and loudspeakers for the delegates. Within the table space are two more microphones and speakers for use by the interpreters. The block diagram for the Conference Room is shown in *Figure 2*. To facilitate handling this number of microphones, thirty of those about the table were wired through lever keys into six groups of five each. Each group of five is controlled by one attenuator. The two interpreter microphones within the oval, each through its lever key, are grouped into one attenuator and a single microphone for the chairman of the conference has an attenuator of its own. This grouping of the thirty-three microphones results in only eight controls, the desired microphone being switched in by throwing its lever key. Such an arrangement permits rapid and accurate switching.

These microphone keys are used for a relay interlock operation with the loudspeakers adjacent to the associated microphone, automatically turning off the loudspeaker on each side when the microphone is turned on. Since all the loudspeakers on the table are operated at a low level, the turning off of the two on either side of the line microphone is sufficient to prevent feedback and the remaining loudspeakers permit all the delegates to hear the speaker perfectly.

By throwing these same microphone keys to the opposite side from their "on" position, the associated microphone is connected to a separate cue amplifier and speaker. This arrangement aids the operator in anticipating the next speaker, and permits accurate switching.

The output of the eight-position mixer feeds through two identical circuits of booster and line amplifiers and master gain controls. These provide a continuously protected amplifier chain that meet through a "Regular-Emergency" key. In case of failure of the regular section, throwing this one key to "Emergency" restores operation. Spare amplifiers of all types employed in the system are available on jacks to permit patching if necessary.

A high-pass speech filter is provided with a switch to cut in or out of the circuit at will. This filter cuts off sharply at 200 cps and prevents the "boomy" speech characteristic of some persons. The output of the console is controlled at +8 vu.

Other controls at the console are the monitor, cue, PA gain control, and a utility attenuator. The utility attenuator input and output are available at jacks on the rack and two utility transformers with inputs and outputs are also available. These utility components are useful for setting up special circuits that invariably become necessary from time to time. Another useful control mounted on the rack is the monitor input selector switch. This switch allows spot checking throughout the system in order that any failure may be quickly located.

From the output of the console, the circuit feeds the PA and telephone line dividing amplifiers. The output of these amplifiers terminates in a low value of resistance, in this case 15 ohms. Each feed to a PA power amplifier or to a telephone line, as the case may be, bridges the proper 15-ohm resistor with 600-ohm low impedance matching resistor. Since the source bridged is low impedance, the isolation between outgoing 600-ohm lines is of the order of 30 db. This provides an economical means of supplying a number of isolated circuits from one amplifier.

In this case, twenty-four 600-ohm telephone lines with the isolation mentioned are fed with plus 18 dbm each, all from one 10-watt amplifier. All amplifier equipment is located in three racks directly behind the operator.

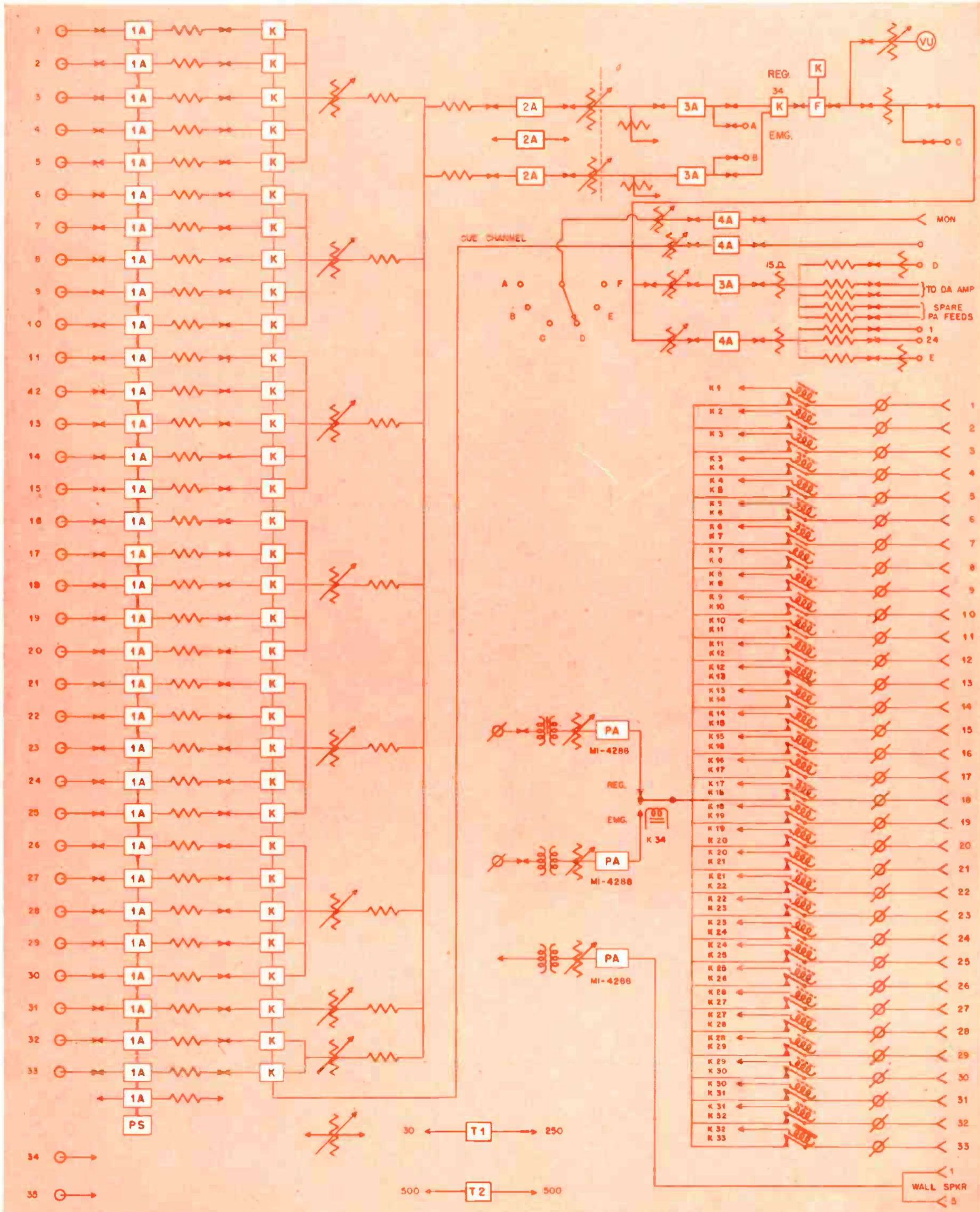

Fig. 2. Block diagram of the conference room layout.

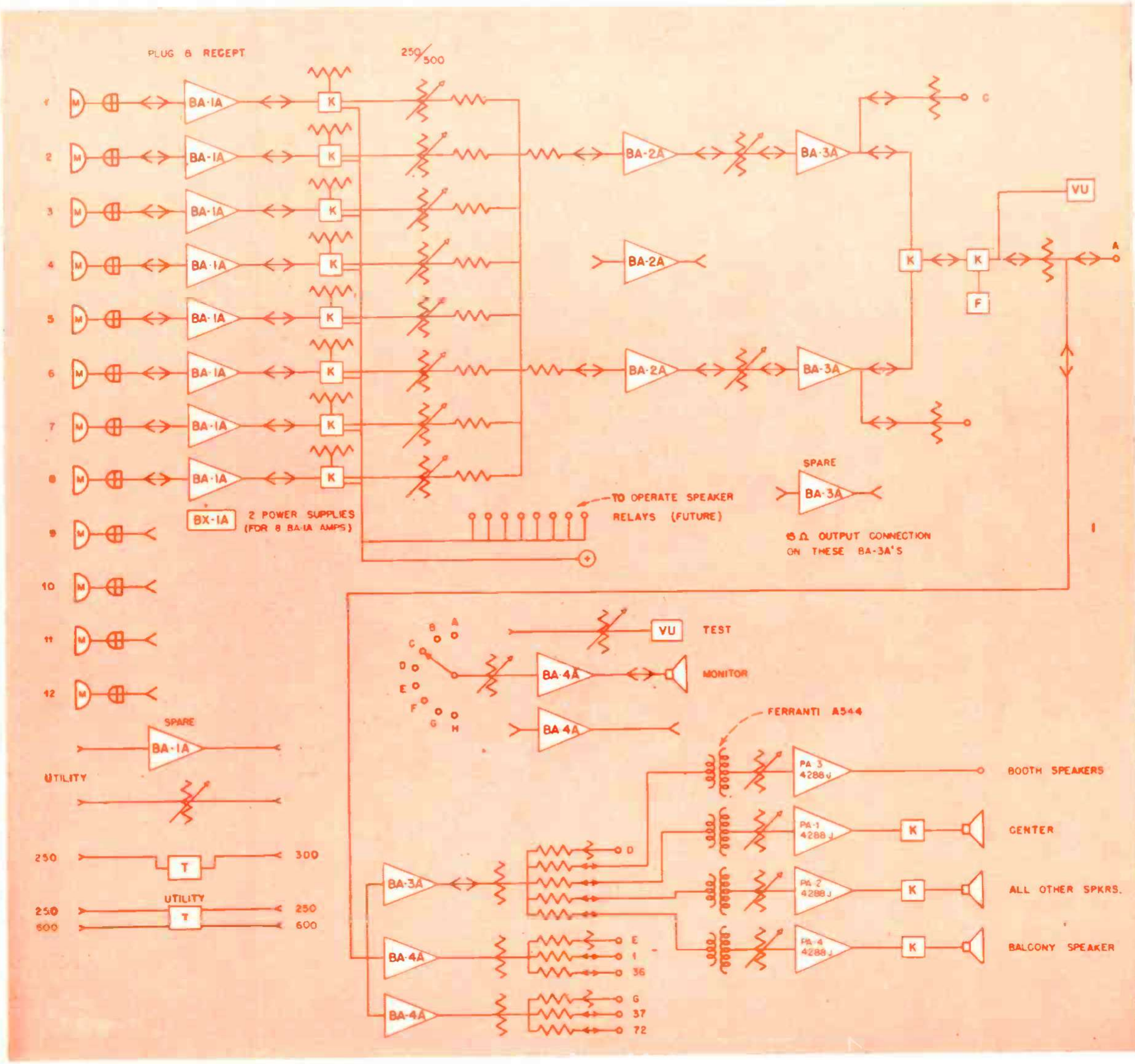

Fig. 4. Block diagram of the general assembly auditorium sound system.

Main Auditorium System

While this system is the simpler of the two, it is however the more important from the standpoint of the numbers of people served. The main auditorium is designed to seat approximately 1600 delegates, visitors, press, etc. Seats are arranged on the main floor and balcony. The composite photograph of the General Assembly Auditorium is shown on *Figure 3*. The actual control room is located in the second tier in a glass-enclosed booth on the right side of the Auditorium. The photograph shows two of the multicellular speakers used for sound reenforcement.

Figure 4 is the block diagram of this auditorium system. The similarity to the Conference Room is readily apparent. Twelve microphone circuits are wired from receptacles located on the Podium, eight of which are controllable at one time with eight gain controls and "off" and "on" switches. Outputs of the controlled pre-amplifier circuit are coupled into two BA2A booster amplifiers, and from the two master controls on through to the two BA3A program amplifiers to the regular and emergency output buses. Bridging the output bus after the regular emergency key are the amplifiers for the various services. It will be noted that this system feeds a total of 72 telephone lines arranged to provide 36 regular and 36 emergency services. The input for the four 50-watt power amplifiers used to drive the loudspeakers is derived from a separate BA3A amplifier, the input of which is controlled by a separate gain control. This gain control is located on the upper right side of the control console for quick accessibility in case of feedback.

In the auditorium a total of three of the RCA 9486/9497/9448/multi-cellular loudspeakers are used for primary coverage of the auditorium and balcony. Inasmuch as the balcony overhang does not permit sound to be projected from these overhead loudspeakers to the rear and sides of the auditorium, it was necessary to use a large number of the RCA MI-12415 totally enclosed cone-type loudspeakers. These are arranged on the ceiling underneath the balcony and observation booths slanting toward the audience. Inasmuch as some seventy low level loudspeakers are used, spaced approximately every ten feet, we are for-

[*Continued on page* 43]

U. N. P-A Systems

[*from page* 29]

tunate to get uniform coverage without destroying the illusion. Because of the physical construction of the auditorium this is the only method of handling this loudspeaker problem, although the use of multiple loudspeakers is poor practice when physical conditions permit a single source. Tests conducted with a General Radio noise meter using a 400-cps warbled note showed a pattern of coverage throughout the auditorium to be within 2 db. All speakers are painted to harmonize with the background and the overall result is highly satisfactory.

All amplifiers, tubes, microphone

stands and loudspeakers were of RCA manufacture fabricated in Commercial high audio frequency reproduction, it seems that research should be conduct- Chinn and Eisenberg showed that lacquer originals, properly recorded and

In the midst of all the current furore there has been no attempt to get down to fundamentals and decide what it is most important to find. We might characterize the choice enigmatically as the confused reaction versus the considered reaction. So far all tests have been concerned with the confused reaction — a rapid representation of alternating ten or twenty second choices. This possibly correlates with the basis for the choice of a twenty dollar radio. Is it a good correlation with the process of choosing a console set, or with conditions of use? If we give the user a free chance to adapt to both choices for a week or two, what will his reaction be?

Which portion of the public is most important to us; or alternately, how should we weigh the results from the following:

a. The soap opera addict — interested in intelligible speech
b. The serious listener to music—whether the three Bs or boogie woogie
c. The background music devotee — desiring soft, muffled, definitely unobtrusive music.

Fatigue Factors

The question of immediate versus delayed reaction has one aspect which has been completely overlooked in all discussions: the fatigue factor. Why does a listener so often turn a set off after one or two programs? Why do so many listeners use weak, muffled music as a subdued background, but never really listen to a program? We have the artistic side, of course; but the writer believes the fault is often more basic: Listening to the *average* set is *very* fatiguing, and some sets are much worse than others.

The writer made a considerable number of experiments with fatigue in radio and record listening, and isolated some fatigue factors. In many cases the effect can be predicted quantitatively, but the remainder can be evaluated only on a relative basis, viz., A is little (or much) better than B as measured in a one (or five) hour test period. He made a curious discovery: One of our most successful low priced radio lines was distinguished by its low fatigue factor *as compared with its competitors' products*. How important was this in its success? We can only guess. Perhaps it gave skilful salesmanship just the extra lift needed to create a dominating position in the low priced field.

The fatigue factors just mentioned refer but lightly to the classical case (fatigue of the hearing organ itself[20]); they mainly govern fatigue of the central nervous system due to the nature of the impulses fed it by the hearing organs. In short, it is brain fatigue[22] rather than fatigue of the organ of Corti which concerns us here. A broad consideration of fatigue factors is beyond the scope of this article, but they include the following primary defects:

1. Harmonic and intermodulation distortion
2. Certain frequency-amplitude relation anomalies
3. Transient distortion
4. Noise
5. Acoustical nature of the space used

Some of these have been discussed by the writer[21] in relation to fatigue of hearing aid listeners, perhaps the only application in the last several years where reduced fatigue has gained considerable commercial recognition. Harmonic and intermodulation distortion heads the list only because it is often so bad as to mask other faults. The moment it is minimized, the other factors assume importance. It should also be remembered that "distortion" is not a dimensionless entity, that certain orders of harmonic distortion are much more offensive to the ear than others, even when the distortion meter readings are equal.

Hearing Aid Improvement

That these principles were of general application was shown in this field not too long ago. The writer was called on to overhaul a hearing aid line, and the problem was found to be not appearance, pride, or economy, but wearer fatigue. Wearers could grade out units of identical frequency response but different fatigue characteristics with an accuracy and consistency which was surprising. Production units were changed accordingly, with no change in visible appearance, in frequency response, in sales procedure, or sales personnel. Within six months sales had doubled, and both customers and dealers were much happier; all of this at a time when other manufacturers were having an acute loss of sales, were cutting prices, and were using extensive advertising campaigns.

Remember that about 50% of hard-of-hearing customers have hearing which is normal in every respect save acuity — that is, their hearing is like that of broadcast listeners except for a loss *which is substantially constant with respect to frequency*. These data are therefore 50% directly applicable to normal listeners.

The improved instrument had several interesting properties:

1. The average time of use increased from nine or ten hours per day to twelve to sixteen hours.

2. Wearers were able to use more low and high frequency response with comfort (this could be adjusted by the dealer on request but could not readily be tampered with by the customer).

3. Without being told of the change, users spontaneously commented on improved "presence" and "easier listening".

4. Ordinary articulation testing methods would not show any improvement in intelligibility, probably because the articulation test period was too short. Perhaps twelve-hour test periods should have been used.

Remember that all these observations were made using the relatively narrow band of 150 to 4500 cycles, wherein the average engineer thinks the annoyance power of distortion to be less than in a broad band system. Remember also that there is a powerful urge to disregard fatigue and continue using a hearing aid — so if excess fatigue would cut use-time of an essential instrument by one-third, what does it do to the use of the ordinary radio which can be taken or left alone?

The writer recalls seeing the effect of replacing a number of home radios by commercial units of what were later found to be *relatively* lower fatigue designs. The daily hours of use approximately tripled, and the increase persisted long after the novelty effect had worn off.

Fatigue effects have also been observed in connection with 16 mm sound on film reproduction.

What Percentage Is Significant?

Remembering that we are unlikely to get a 100% vote for any probable single bandwidth, what should be done? Undesired excess bandwidth can be removed by the radio set's tone control. Missing kilocycles cannot be so restored. On this basis, what bandwidth would be necessary to satisfy what per cent of the listeners? To irritate our readers into creative thought we have utilized the Chinn and Eisenberg data for 5 and 8 kc., and split the remainder in a grossly implausible manner:

Upper Cutoff Frequency	% of Satisfied Listeners
5 kc.	40
8 "	80
10 "	90
12 "	99
15 "	99.99
20 "	100

Seriously, it is evident that to satisfy 80% of the listeners to speech and all types of music, an 8 kc. range would have to be *available* (which they could decrease as desired). If it becomes available throughout the country, the present vicious circle may be broken, and it may foster the increased production of better quality home radios.

Industry's Stake

Many parts of the electronic field have a considerable stake in a correct answer to the questions propounded:

The Broadcast Network—By the time a program has gone a thousand miles from its source over lines of present network characteristics it is no longer of good quality. Would replacing the present 5 kc. lines by 8 kc. service, and reducing intermodulation and phase distortion, increase the ***number*** of listeners (at any given time) enough to pay for increased line costs? How far would such increased quality go in enabling networks to better resist inroads of the 8 to 10 kc. transcription?

The Phonograph Record Maker — Right now he is riding the crest of a boom, and even pressings from worn-out stampers, pressings with intermodulation distortion as great as 20 to 30%, can be sold. But looking more to the future, would it be worth while to improve care in processing to make the finished product sound more like the test pressing?

The Radio Set Manufacturer — A set with reduced fatigue factor costs no more to make than the present designs. A set with somewhat increased bandwidth as well as reduced fatigue factor would cost very little more. It has been profitable for one company to do a better job in the low-priced field. Would it pay others to do the same? A large number of sets have been advertised as "high fidelity"; almost none of them have actually been so. How profitable would it be to substitute a little performance (lower fatigue at least) for a lot of claim? Would it pay the NAB to subsidize set makers to the extent of say $1 per set (payable only for a low fatigue design), to increase the listening time?

The FM Broadcaster—Right now he has 15 kc. speech input equipment and transmitter, but usually 9 or 10 kc. transcription tables. Assuming that better FM sets could be sold, would it be worth his while to change to 15 kc. pickups, and to push the transcription makers for wider-band recordings? Or would it be better to push them for a higher average of pressing quality with the present bandwidth? Many transription pickups have poor quality from 7 to 10 kc. under certain conditions. Would it pay the station to install more modern units?

These have not been rhetorical questions; they face the industry now, and their answers may determine some profit and loss statements two years from now.

The average manufacturing organization can secure an answer for itself, limited to its own conditions, with moderate ease, but it would not be the universal or completely generalized answer. The hearing aid industry (in part) has found such a policy, applicable to itself, for example.

However, the completely generalized problem is too massive, too tied up with self interest. Particularly as regards the broadcasters, a decision which would enjoy broad acceptance is essential, in fact it is most important that the radio industry agree on its broad objectives. The technical facilities are easy to borrow, rent, or construct. What we require most, and which is hardest to find, is an organization with no adverse commercial commitment (ruling out some colleges), and *with a chief skilled in auditory opinion research*. It seems to the writer that this points unmistakably in the sole direction of Professor Harold Burris-Meyer.

Conclusions

For too long have we made reproducing devices which (as Burris-Meyer says) *remind* the listeners of music, but do not reproduce it. Also, for too long have we made sets of which only engineers would approve. Let us concentrate on designs which the public approves of. Let us be conscious of presence—the public is. Let us forswear "high fidelity" designs which reproduce only between 25 and 2500 cycles, or between 500 and 7000 cycles, or from 100 to 1000 and 3000 to 7000 cycles. Let us forswear dealing with loudspeaker manufacturers who offer only an interesting price—but have neither complete test equipment nor adequate quality control. Let us stop blaming "bad public taste" for the lack of success of inadequately engineered sets. Note that the public's dislike of false tones far overpowers its dislike of missing tones.

Let us eschew the easy generalization, the test which proceeds from an incorrect assumption to a foregone conclusion. Let us buckle down to a real study of the finer *dislikes* of the ear. *Let us adopt the principle that the true measure of the quality of an electro-acoustical system is the maximum band-width which the public finds acceptable.*

References

1. H. F. Olson, Frequency Range Preference for Speech and Music; Talk before Acoustical Society of America, May 9, 1947.
2. W. B. Snow, Audible Frequency Ranges of Music, Speech, and Noise; *JASA*, Vol. 3, No. 1, pp. 155-166, July 1931.
3. H. A. Chinn and Philip Eisenberg, Tonal Range and Sound-Intensity Preferences of Broadcast Listeners; *Proc. IRE*, Vol. 33, No. 9, pp. 571-581, Sept. 1945.
4. E. Massell, W. Van B. Roberts, C. C. Eaglesfield, B. Groom, H. A. Chinn and P. Eisenberg, Discussion of Chinn and Eisenberg Paper; *Proc. IRE*. Vol. 34, No. 10, pp. 757-761, Oct. 1946. L. V. Wells, T. Powell, same; *Proc. IRE*. Vol. 35, No. 4, p. 378, April 1947. James Moir, same, *Proc. IRE*, Vol. 35, No. 5, p. 495, May 1947.
5. N. D. Webster and F. C. McPeak, Experiments in Listening; *Electronics*, Vol. 20, No. 4, pp. 90-95, April 1947.
6. B. B. Bauer, Crystal Pickup Compensation Circuits; *Electronics*, Vol. 18, No. 11, p. 132, Nov. 1945.
7. George M. Nixon, Higher Fidelity in Sound Transmission and Reproduction; *JASA*, Vol. 17, No. 2, pp. 132-135, Oct. 1945.
8. Willis C. Beasley, Characteristics of Hearing Loss in Various Types of Deafness; *J. SMPE*, Vol. 35, pp. 59-85, July 1940.
9. J. C. Steinberg, H. C. Montgomery, M. B. Gardner; Results of the World's Fair Hearing Tests, *JASA*, Vol. 12, No. 2, pp. 291-301, Oct. 1940.
10. S. S. Stevens and Hallowell Davis, Hearing; pp. 209-217, Wiley (1938).
11. Harvey Fletcher and W. A. Munson, Loudness, Its Definition, Measurement and Calculation; *JASA*, Vol. 5, No. 2, p. 91, Oct. 1933.
12. D. E. L. Shorter, Loudspeaker Transient Response; *BBC Quarterly*, Vol. 1, No. 3, pp. 121-129, Oct. 1946.
13. J. P. Maxfield and W. J. Albersheim, An Acoustic Constant of Enclosed Spaces Correlatable with Their Apparent Liveness; *JASA*, Vol. 19, No. 1, pp. 71-79, Jan. 1947.
14. Elmo Roper, Survey Pitfalls; *Fortune*, Vol. 35, No. 4, p. 6, Apr. 1947.
15. D. F. Seacord, Room Noise at Subscribers' Telephone Locations; *JASA*, Vol. 12, No. 1, pp. 183-187, July 1940.
16. Daniel F. Hoth, Room Noise Spectra at Subscribers' Telephone Locations; *JASA*, Vol. 12, No. 4, pp. 499-504, Apr. 1941.
17. O. B. Hanson, Comments on High Fidelity; *Electronics*, Vol. 17, No. 8, pp. 386-387, Aug. 1944.
18. Frank Massa, Permissible Amplitude Distortion of Speech; *Proc. IRE*, Vol. 21, No. 5, pp. 682-689, May 1933.
19. Research Council, Academy of Motion Picture Arts and Sciences, Revised Standard Electrical Characteristics for Two-Way Reproducing Systems for Theaters; *J. SMPE*, Vol. 32, No. 2, pp. 213-216, Feb. 1939.
20. S. S. Stevens and Hallowell Davis, Hearing (Wiley, 1938); pp. 217-220.
21. C. J. LeBel, Hearing Aid Technic; *Electronic Industries*, Vol. 4, No. 1, pp. 104-106, 198-205, Jan. 1945.
22. A. C. Matthews, High Fidelity; RADIO, Vol. 29, No. 11, pp. 33-37, Nov. 1945.
23. Report on Dr. Harry F. Olson's Listener Preference Tests, AUDIO ENGINEERING, Vol. 31, No. 5, pp. 27, 43-44, June 1947.
24. N. M. Haynes, Listening Tests; *Electronics*, Vol. 20, No. 6, pp. 268, 270, June 1947.
25. Harvey Fletcher, Hearing, The Determining Factor for High-Fidelity Transmission; *Proc. IRE*, Vol. 30, No. 6, pp. 266-277, June 1942.