HIGH FIDELITY

Extended frequency range is not the answer to the problem of excellent audio reproduction

By McMURDO SILVER

McMurdo Silver, high-fidelity sound pioneer.

WITH numerous panels of the Radio Technical Planning Board today engaged in examination of a multiplicity of subjects, the problems of post-war broadcast services, AM, FM and television, are receiving a considerable degree of attention. It is with the questions of band widths and frequency ranges required in musical reproduction that the writer is herein concerned. He desires to contribute certain views to the general and currently wide-spread thinking upon these subjects in the hope that the most reasonable and serviceable assignments may result for post-war use.

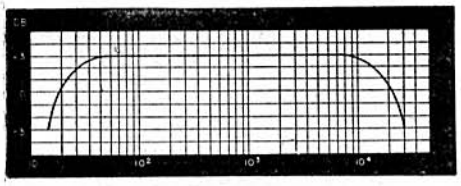


Fig. 1—Response curve of a hi-fi amplifier.

It is one thing to look at the presently usable radio frequency spectrum as a whole and, upon the basis of absolutely zero occupancy, to intelligently apportion segments thereof to the multitudinous services seeking accommodation. It is quite another thing indeed to take the same spectrum currently occupied by difficult-to-dislodge services, and in the face of occupants not easily (often not wisely) to be dislodged from their present frequencies, to patch up a sensible and workable whole in which every service gets an even and fair share of total available frequencies.

The standard broadcast band of 500 to 1600 Kc. is a good example of the difficulty. A shift of the services therein to new frequencies would be difficult indeed. Even a shift of band-widths within the present band is well-nigh impossible in a practicable sense.

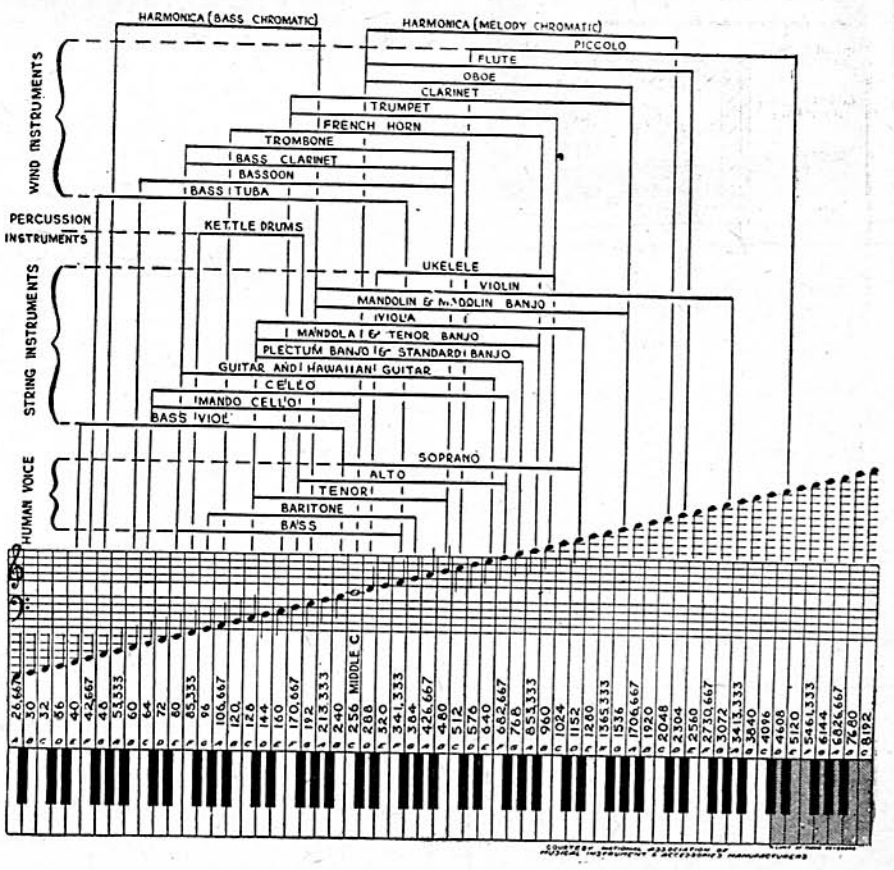
Some might argue, possibly with justification, that all broadcasting should shift over from AM to FM, and consequently to higher, limited-range frequencies which would leave the essentially medium-long-distance frequencies from 500 to 1600 Kc. available to what will unquestionably be the greatly increased needs of commercial circuits bound to exist in a post-war period of increasingly active commerce.

Be that as it may, the broadcast band is today apportioned upon the basis of 10 Kc. per channel. This automatically limits modulation frequencies to a basic range of 5,000 cycles—a range quite inadequate for high-quality musical reproduction. Due to geographical and power separation of adjacent stations, it is possible for a powerful station to modulate up to 8,000 to 9,000 cycles with the expectation of rendering better service to nearby listeners for whom its signal will decisively over-ride distant and weaker adjacent channel stations. Thus a distinctly improved service may today be rendered to a limited group of nearby listeners—presuming they are equipped with receivers actually able to translate improved transmission into improved home entertainment.

HIGH FIDELITY—THEORY VS. FACT

Theory says that truly high-quality reproduction should extend from 30 up through 17,000 cycles, approximately. Such a range is a substantial impossibility in the standard broadcast band today. It may be approximated by widening receiver acceptance band-widths to the necessary 34 Kc., but this is almost uniformly unsatisfactory. The reason is that such a band-width automatically accepts three stations each spaced 10 Kcs. away from the next in the frequency spectrum. Even assuming the two undesired stations (one on each side of a desired powerful local station) to be so weak that their modulation as such causes no deleterious interference, the beating of the three 10 Kc.-spaced carriers will produce an annoying beat, or whistle, at 10 Kc. At once the thought occurs—chop out this whistle with a suitable filter. This solution is simpler to envisage than to put into practice. A filter suitable for elimination of the very narrow band of frequencies lying immediately above, at, and below 10,000 cycles would be costly, complicated and cumbersome if in eliminating 10,000 cycles it does not also eliminate frequencies thereabout in a band so wide as to largely destroy the benefits sought through extended total frequency range. For example, a simple filter such as is found in the most expensive receivers will usually attenuate a band of possibly 9,000 through 12,000 to 14,000 cycles if it be effective enough to cut out 10,000-cycle carrier beats—and if it be

(Continued on page 380)



Courtesy Ghirardi's Radio Physics Course

Fig. 2—The second harmonic of most musical instruments falls below the 8,000-cycle limit.

cheap enough to allow of inclusion in even the most costly commercial receivers. What is the gain, one may reasonably ask, of cutting off at around 9,000 cycles, losing everything in between up to possibly 13,000 cycles, and then reproducing the practically insignificant added range of 13,000 through 17,000 cycles?

THE SPECTRUM IS LOGARITHMIC

Some reader may rise to say that 4,000 cycles at the extreme top end of the audio spectrum is as valuable as the same number of cycles at the low-frequency end. The argument is as unsound as it is obvious—possibly even more unsound than obvious. The first aspect of the facts is that this range might be worth as much as the 40 cycles lying between 130 and 170 cycles, or as much as the 400 cycles lying between 1300 and 1700 cycles—to compare only upon the direct basis of the significance given to each range upon the logarithmic scale that frequency-response curves are invariably plotted upon. Such plotting is employed as a means of indicating and evaluating the true importance of different segments of the total audio frequency range one to another. (See Fig. 1.)

The second reason for the insignificance of extreme high frequencies at the top of the audible spectrum is that no human voice or musical instrument generates any fundamental tone in this top range—and what little energy does appear is infrequent in appearance and so low in power in relation to that found on frequencies below about 8,000 cycles as to deserve almost no consideration in any case. The fundamental musical tone range is usually considered as lying between about 30 and 4096 cycles. True it is that harmonics, or overtones, are what give individual instruments playing the same note their individual character—but it does not take the fourth harmonic of the highest conventional musical tone to define individuality—particularly when the energy content thereof is so low as usually to be completely swamped out in the tremendously greater energy of the lower tones. Again, how often are the very high tones heard in music? Infrequently indeed, since most of the energy content lies below 1,000 cycles.

The third reason for the lack of real value of frequencies much above 8,000 cycles (so the writer believes) is the inability of most people to hear such high frequencies. They are literally inaudible to all but the very young, and to persons of freak hearing characteristics. Summarizing, the comparative insignificance of frequencies above about 8,000 cycles in conveying intelligence and emotion; the minuteness of the energy involved in them in contrast to that simultaneously present in the predominantly powerful lower frequencies; the inability of a probably sizable majority of listeners to even hear them as isolated tones (practically never found in music); the practical impossibility of their economical reproduction; and the increase in noise and distortion attendant upon any attempt to even partially reproduce them, all have convinced the writer that 8,000 cycles is an adequate upper limit to be established for "high fidelity" musical reproduction.

Before amplifying this thought, it seems well to refer each and every serious reader to the paper prepared by Leopold Stokowski and the equally vital comments thereupon by C. W. Horn, Director of Research and Development of the National Broadcasting Company, both to be found in the January, 1935, issue of the *Atlantic Monthly*. Likewise to be insisted upon as "must" reading is the recent paper by O. B. Hanson, also of N.B.C., entitled "Down to Earth on 'High Fidelity'."* These three papers are of inestimable importance to an understanding of the problem, while the divergence of opinion apparent in the attitudes of the three investigators is refreshing and decidedly productive of individual thought on the part of the reader.

DYNAMIC VOLUME RANGE

Not alone is frequency range important to fine reproduction. It is the important fundamental, but as Mr. Hanson so aptly points out, other items loom up almost equally important. Without repetition of the points he so effectively makes, emphasis may be laid upon one feature inherent in FM, as contrasted to AM, broadcasting which seems to have been woefully neglected. It has struck the writer that the claims anent extended high frequency range made for reproduction of music via FM amount to little of practical value indeed—yet emphasis heretofore has been placed upon them to the almost complete neglect of a vital improvement possible through FM. This much needed improvement is in the matter of dynamic volume range (see papers referred to). Practical requirements of AM broadcasting limit soft-to-loud volume range to about 50 db.—in contrast to the roughly 80 db. dynamic volume range required by much symphonic music to tell its emotional story.

The writer will never forget his first introduction to the possibilities inherent in volume expansion at an I.R.E. Convention held in Detroit in 1935. Several hundred normally quite unenthusiastic and profes-

*Radio, Oct., 1944.

Suggested by: Wilbur Wright, Trenton 9, N. J.

"Making the most of a fishpole antenna."

sionally "hard-boiled" radio engineers listened politely as the lecturer demonstrated a symphonic recording played through a good audio system. The demonstration repeated, but with volume expansion included, and the same audience was upon its feet, upon its chairs, literally stampeding with enthusiasm. Such, on a not particularly sympathetic audience arriving with universal "I'm from Missouri" attitude, was the effect of giving to electrical sound reproduction the full dynamic volume range written into the music by its composer—a range none had seemingly ever heard in radio reproduction before.

Would that the sales departments represented by these same engineers could have been present! Had they seen that spontaneous enthusiasm of those professionally difficult to thrill, broadcast reception might have been immeasurably improved over what it is today. Such performance comes relatively easily to FM—may the proponents thereof shift their emphasis from practically inaudible high frequencies and wake up to "sell" their so far neglected greatest asset—in the humble opinion of this writer.

HIGH VS. LOW FREQUENCIES

It is to be recognized that an 8,000-cycle top limit includes the second, generally considered predominant, harmonic or overtone of substantially the highest musical instrument fundamental tone. It includes the fourth harmonic of every tone above 2,000 cycles—and most of music lies here and below—certainly below 2666 cycles, the highest fundamental of which the third harmonic will fall within the 8,000 cycle range. (See Fig. 2.)

What of the low frequency limit? Mr. Hanson propounds the worthwhile theorem that the product, in a balanced reproducing system, of low- and high-frequency limits should be about 500,000. This would suggest that a balanced system should cover from about 63 to 8,000 cycles. Issue is taken with this thought upon the basis that the well-known public preference for bass emphasis, together with the fact that broadcasting and recordings go down to about 50 cycles, no serious violation of Mr. Hanson's precept would result from a product-figure of 400,000—the result of a range of 50 through 8,000 cycles. Even a little compromise could be effected by extending the 8,000-cycle upper limit up to possibly 9,000 cycles. There it should stop, if adjacent channel carrier whistles are to be avoided by means of the low-cost "whistle-filters" which seem to be all that even the most costly broadcast receivers can provide.

But the writer is not satisfied with even this solution. Recent work has resulted in his being able to produce quite economically, amplifiers flat (to a few db. drop at 1,000 cycles actually desirable for reasons which will appear) from 20 through 25,000 cycles. This extreme upper limit is valueless, as expected, but the ability to go down to 20 cycles has appeared to contribute wonders to reproduced music, even coming from poorly baffled, low-cost commercial 12-inch speakers such as are found in the better receivers.

Because of the variation in sensitivity vs. frequency of the human ear with differing volume levels, good reproduction mandatorily demands the ability to accentuate bass and treble frequencies by substantially 20 db., preferably a bit more, if music reproduced at moderate volume in the home is to sound at all like the same music heard at high volume in a concert hall. Such compensation may be automatic, diminishing middle register tone amplitude as the volume control is manipulated. Though an old

(Continued on following page)

HI-FIDELITY

(Continued from previous page)

method, the writer recalls no commercial example which does this to the necessary degree—the best providing only a partial step in the right direction—a disappointing compromise at best. It is strongly felt that by providing such essential compensation in the form of *separate* bass and treble frequency controls the basic requirement is satisfied, and satisfied exactly as the user may prefer, and as the invariably different and differing acoustics of his particular living room may require.

No impossible project requiring extensive investigation and research is needed to satisfy the desiderata set forth above. At a final selling cost of probably no more than five dollars higher than any good receiver commands today, the need for better than 20 db. of controllable bass and treble frequency accentuation with but one more knob than usual, together with a frequency range flat from 20 cycles up to beyond the top limit of audibility, can be fully satisfied.

DISTORTION ALSO A FACTOR

The question of distortion is also important, and in it lies an opportunity of improvement in actual musical reproduction today believed to be little recognized. Theoretically no harmonic (amplitude) distortion may be tolerated in an ideally perfect reproducing system. In conventional amplifiers phase distortion is usually of insignificant degree and overall effect, so may be neglected. The human ear appears to be not particularly sensitive to even-harmonic distortion, even when present in considerable degree. The ear is noticeably more sensitive to odd-harmonic distortion, and it is this which effort should be expended to minimize. Such is theory. Extended tests upon a reproducing system exhibiting less than 1% total harmonic distortion and involving hundreds of listeners indicated quite positively that reproduction was dull, lifeless and generally unpleasing. The introduction of discreet orders of odd harmonic distortion at once restored the life and brilliance completely lacking in the "distortionless" system. It is felt that this thought is worthy of more serious consideration and quantitative investigation.

If the inescapable conclusions resulting from many tests and investigations conducted by such organizations as the Bell Telephone Laboratories establishing 8,000 cycles to be a top frequency limit adequate to satisfy a predominant majority of all listeners be recognized, then is not a boon—rather than a degradation—conferred upon FM broadcasting by expanding the service it can render through cutting present 200 Kc. channels to 100 Kc.? The writer, basing his decision upon over three decades in radio, with much of this time concentrated upon the design of equipment calculated to provide the then ultimate in tonal reproduction, so believes. He regards 15,000 cycle FM audio range requiring 5:1 deviation ratio—which yields a swing of 150 Kc., and thus necessitate a 200 Kc. total band width to provide a 12½% "guard-band" on each side as possibly unjustified. It is respectfully suggested that two stations where but one grew before, each of quality adequate to fully satisfy probably 99% of all listeners, is more desirable than the questionably idealistic seeking of an ultimate appreciated by but a small minority of the radio audience—at the cost of a possible limitation of useful service.