Some Aspects of High-Quality Reproduction

How It Is Furthered in Radio Receiver Design by Suitable Circuit Values

By PAUL TRAUGOTT

THIS article is in two parts, the first dealing with the R.F. and detector, and (in superheterodynes) the intermediate-frequency and second detector stages. The second part, appearing next month in RADIO NEWS, will be devoted to the A.F. amplifier and loud speaker. It will well repay reading by the constructor who is interested (and who is not?) in obtaining a better quality of output, here defined as fidelity to the original program in both low and high tones, as well as the intermediate. —EDITOR.

IN recent months various products of the art of electrical sound-transmission have been brought to the attention of the general public. The Vitaphone, the new phonographs, public-address systems, good broadcast stations and good broadcast receivers, all make use of what are known as "high-quality" reproducing or transmission systems.

The term "high-quality" is in itself somewhat arbitrary; for the best of high-quality amplifying systems may not always transmit and reproduce a quality of music or speech that is in itself very high. In any event, the estimation of the quality of what emerges from such a system is dependent to a large degree upon individual taste. Properly speaking, the above designation refers to the equipment in the system rather than to what it is required to transmit and reproduce; "high-fidelity" amplifier might be a more definite nomenclature. Nevertheless, in this discussion the more popular term will be used.

A high-quality reproducing system may be defined as one that transmits and reproduces, with the highest degree of perfection and fidelity, sounds or groups of sounds, originating at some point outside of the system itself. The system so arranged is electro-mechanical, electro-physical, or electro-acoustic; either of these terms describes it fairly well. The electrical part, of course, usually comprises the associated vacuum-tube amplifiers and the loud-speaker drive mechanism; the mechanical, physical, or acoustical part being in the final vibrating member of the loud speaker or reproducer. Though much in the way of instruction and advice has recently been written on the subject, it is not quite true that true high-quality reproduction is always favorably received by listeners to radio broadcast entertainment.

SOLVING THE PROBLEMS

High-quality transmission and reproduction probably began, in this country at least, in the laboratories of the telephone engineers. The art was given its first great impetus when two telephone engineers developed the condenser microphone, or condenser pick-up. Since the pick-up is the first step in any electrical sound-transmission system, the advent of this device inaugurated a new era in practical high-quality apparatus. There had been so-called public-address systems prior to the invention of the condenser transmitter; but they were pretty sad affairs, producing great quantities of noise, with almost zero intelligibility in speech and terrible distortion in music. Other perfections rapidly followed the new microphone, for the great majority of which credit is also due to telephone engineers.

It is now common knowledge that electrical sound-transmission and reproduction resolves itself into the problems of producing and amplifying a group of electrical impulses having frequencies related to the sounds which originally produced them, and then of re-converting these electrical currents into sound waves. For the most perfect reproduction, the band of frequencies which must be provided is very wide. In the ideal case it is necessary to transmit equally through the system all frequencies from 16 cycles per second to at least 10,000 cycles per second.

A PRACTICAL PROBLEM

At present, without the complications introduced by radio transmission, it is probably possible to accomplish this ideal in a well-equipped laboratory. But such perfection, though scientifically and aesthetically desirable, is not entirely necessary. For practical purposes, a system that transmits equally from 30 to 7,000 cycles, and delivers these frequencies with wave-forms unchanged, and at the proper intensity level, as sound waves from the loud speaker, is a very high-quality system. The transmission of a band from 50 to 5,000 cycles provides excellent quality and a high degree of naturalness in the sound output. Even if all the frequencies between 100 and 4,000 are passed equally the quality is still very good.

Variations of as much as ten per cent in the equal amplification of these frequencies are probably allowable. The wave-forms of the currents must remain substantially unchanged. The most elementary reasons why the original wave-forms must not be disturbed are: first, the absolute quality of a sound is determined largely by the form of the wave it produces, or which produces it; second, distortion of wave forms causes the production of harmonic currents, which are reproduced finally as tones that were not present in the original music, speech, or whatever it was. In music, the interaction of such locally-generated harmonic currents with the normal currents results in dissonance.

Though at the present the most prevalent use of amplifying and reproducing apparatus is, of course, in radio broadcast reception, nevertheless, the later day phonographs are interesting examples of sound-transmission engineering. Mr. Edison recently expressed the opinion that phonographs gave better reproduction than radio sets. He received, for his temerity, vituperation from whole assemblies of radio experts. Yet Mr. Edison's remarks were not altogether unsound (though it may be *lese majeste* for a radio man to admit so much). But the fact is that the new phonographs, panatropes, orthophonics, and so on transmit well all frequencies from about 100 cycles up to and above 4,500. Even greater ranges are claimed, and probably justly, for some of the machines. Also, the new records are cut with frequencies covering a still wider band of tones, though with probable slight deficiencies at the very high and very low extremities of the scale. As before indicated, such transmission systems give very high quality. Now the *majority* of present-day radio receiving sets (Mr. Edison probably referred to the generality of radio sets) do not, as a matter of sober physical fact, do so well. And, though it is possible to design a radio receiver to do as well and even considerably better, there are special complications which militate against this and, in the case of long-distance reception probably make it impossible. One factor alone—and one which is entirely beyond the control of both the transmitting and receiving engineer—that is sufficient, with the present-day type of radio transmission, to render reliable high-quality reception of distant stations difficult, is the fading of the sidebands in the radiated wave; this causes distortion of quality sometimes to a considerable degree. Static and other extraneous noises are always to be reckoned with. The range over which high-quality radio reception is at all times possible is rather limited; it has been put, by one authority recently, at about thirty miles for a five-kilowatt broadcast transmitter.

The difficulties attendant upon high-quality broadcast transmission have, at the

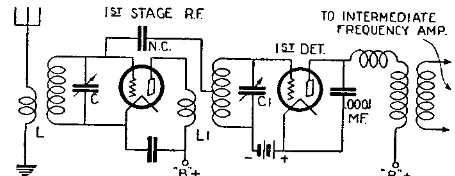

FIG. 1-A

Showing how a tuned R.F. stage is placed before the first detector in a superheterodyne.

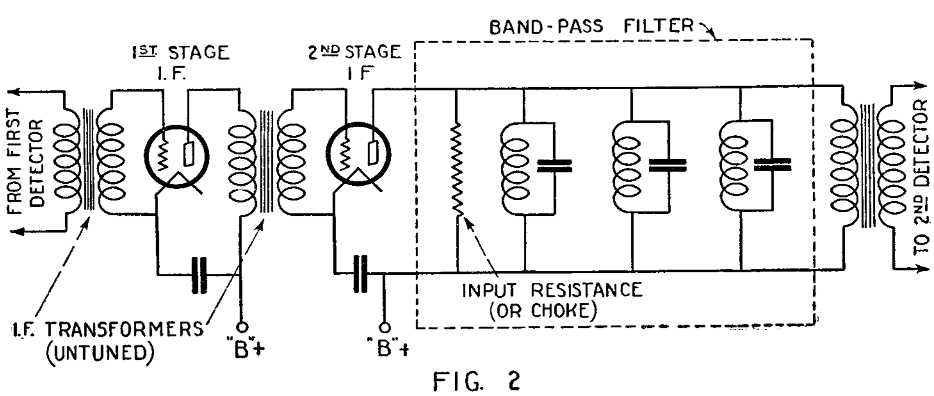

FIG. 2

Here is shown a band-pass filter, located in the output of the I.F. amplifier of a superheterodyne, for the elimination of distortion.

broadcast-station end, been pretty well overcome; the transmission from a first-rate broadcast station is of very high-quality. But at the receiving end new troubles begin. The nature of some of these will be considered.

HIGHER TONES REDUCED

It is probable that the outputs of most existing radio sets, with their associated loud speakers, are quite deficient in the higher frequencies—from 3,000 cycles up. In addition, many of them discriminate strongly against the very low frequencies. In recent receiver design, stress has been placed on low-note reproduction, for the presence of low tones in the output results in a much more pleasant musical effect. Great improvements have thus been made in low-note transmission. But the difficulties especially attendant upon radio reception and reproduction are mostly of such a nature that the high frequencies are reduced. And, to get real high-quality reproduction, this must be corrected.

A radio set of necessity usually has some kind of radio-frequency amplifying system.

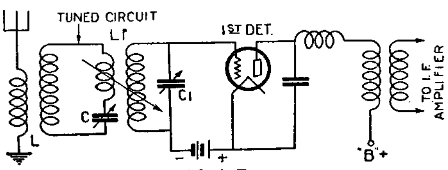

FIG. 1-B

This diagram illustrates how the circuits may be arranged without the addition of an R.F. tube.

Consider first the superheterodyne. This arrangement can be engineered into one of the best of radio receivers; it has at least one special advantage which makes its development worthwhile. A superheterodyne, in order to perform well in crowded radio districts, must have its input circuit made fairly selective. For if more than one radio frequency from outside gets into the first detector, double beats and resultant heterodyne whistles will usually result. Especially is this likely to occur if a desirable intermediate frequency is chosen for further amplification.

REARRANGING THE SUPERHET

The simplest way to eliminate this difficulty is to put a stage of signal-frequency amplification before the first detector; this provides two tuned circuits instead of one and, if properly built, will ordinarily give the requisite input selectivity.

Fig. 1A shows the conventional arrangement. Fig. 1B shows how two tuning circuits may be arranged without the requirement of an additional tube. This latter arrangement is simple and cheap; but of course the first method gives an additional stage of amplification and so greater sensitiveness. (It is not always desirable, however, to have amplification at this point; it is better utilized in the I.F. system).

In this superheterodyne circuit, considered up to the output of the second detector (the audio system will be considered in the second article), frequency distortion, in the form of discrimination against the higher frequencies, occurs as follows: first, in the two tuned circuits forming the input of the detector, it is not likely to be serious if excessive regeneration does not occur, but it is usually not entirely negligible; secondly, in the intermediate-frequency amplifier, with the usual circuit arrangements frequency distortion at this point is likely to be serious. In the efforts to gain selectivity the tuning of the output or filter transformer is usually made quite sharp, and at the frequency or wavelength therein being amplified, the upper components of the audio sidebands are considerably reduced.

The third serious decrease in the upper audio frequencies occurs in the second detector circuits; in this place it is due to the combination of the grid condenser and high-resistance leak. Under certain incorrect conditions of by-passing, further depression of the high frequencies may occur in the output of the second detector. It has been assumed that the first detector is arranged for straight rectification, which method is in general most satisfactory. But this connection increases the output impedance of the first detector, which often results in instability of the I.F. amplifier; for which reason a grid-leak-condenser arrangement might be preferred for the first detector.

CORRECTION OF DISTORTION

By proper design, much of the frequency distortion as noted in the foregoing can be obviated. The not very serious effect of the first two tuned circuits can, if the very highest degree of precision be desired, be corrected by merely increasing the damping of the tuning circuits; high-resistance coils, shunt resistors, etc., will do this easily.

Correction for frequency distortion in the I.F. amplifier is not so readily accomplished. If the tuned filter stage or stages are highly damped, the selectivity of the receiver as a whole will largely vanish. A rather high intermediate frequency may be of some advantage. But the only first-rate method is to include somewhere in the I.F. amplifying system a band-pass filter, to pass equally a band of frequencies at least ten thousand cycles wide or, with certain other methods of operation, at least five thousand cycles wide. With the use of this device the highest selectivity commensurate with high-quality reproduction is obtained.

Band-pass filters are not easy to build, and patents probably preclude the more extensive commercial distribution of them. Hence the usual superheterodyne intermediate frequency amplifier is built for high selectivity and whatever quality can get through it in spite of the selectivity. Fig. 2 shows the band-pass filter in the output of the I.F. amplifier.

IN THE SECOND DETECTOR

The frequency distortion due to the second detector can be avoided by one of two simple expedients; both of which, however, reduce the sensitiveness of the receiver. The first method uses the plain-rectifier principle in the second detector; this scheme is variously known as plate-rectification detection and grid-bias detection. The detector-tube grid is merely biased negatively to such an extent that it functions as a simple rectifier. The audio frequencies get through equally or are produced equally, and the frequency distortion is therefore absent. Unfortunately, with this arrangement, the output impedance of the detector tube is higher than is desirable, a disadvantage that will be mentioned later.

The second arrangement provides merely for the use of a rather low grid-condenser capacity instead of the usual .00025-mf. About .0001-mf. gives some improvement. But the lower value of this capacity also reduces the radio-frequency voltage reaching the detector grid, and so the signal strength falls. Such small grid-condenser capacity also keeps the detector grid pretty well at free potential for all audio frequencies; which, unless the grid leak be lowered in value, is not always desirable. In this second method the output impedance of the tube is very much lower than in the case of the grid-bias detector.

Before leaving the subject of superheterodynes it might be stated that the double-detection circuit has, for distant reception, the marked advantage that its first detector output varies *linearly* with input voltage. Thus it performs well on weak signals. The ordinary non-regenerative or non-heterodyned detector works on the *input-squared* law, and so gives relatively higher outputs from moderate and strong signals than from weak ones.

TUNED-RADIO-FREQUENCY SETS

Another popular form of R.F. amplifying system is that known as tuned-radio frequency, or T.R.F. The usual form of this consists of two, three, or four stages of R.F. amplification, followed by some form of detector and audio-amplifying system. By properly balancing and stabilizing the system and providing a sufficient number of stages of amplification, the over-all voltage amplification available in such an arrangement can be made to equal, or even to exceed, that of the ordinary superheterodyne; though it has not the advantage of the linear first detector.

In the T.R.F. circuit, frequency distortion is primarily a function of the damping of the individual tuned stages; the lower the damping, the greater the depreciation of the highly modulated frequencies before

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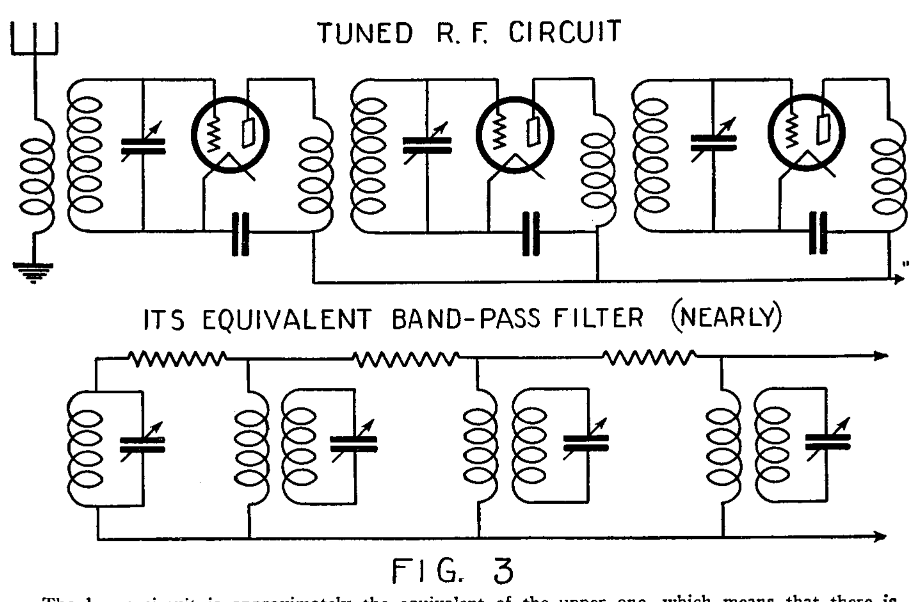

FIG. 3

The lower circuit is approximately the equivalent of the upper one, which means that there is in it practically negligible distortion.

Quality Reproduction

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they reach the detector. To avoid this, the tuning of individual stages must be broadened; which operation of course affects adversely the selectivity of the set. The requisite individual-stage damping, together with sufficient over-all selectivity, can be gained by increasing the number of tuned stages. A T.R.F. system having a number of properly-damped tuned circuits becomes a sort of band-pass filter, with the output impedances of the coupled amplifying tubes acting as the series-coupling impedances (Fig. 3).

Such a system can be designed to produce negligible frequency-distortion of the audio band. Of course the detector that follows the tuned stages will, if it be of the ordinary variety, cause the usual form of distortion; the remedy is the same as that previously mentioned.

The third R.F. system ordinarily preceding the detector is a simple regenerative circuit, or a regenerative circuit following one or more stages of R. F. Such a combination can be made very sensitive to weak signals, when the regeneration principle is skillfully applied. But, when high regeneration is used, the damping of the tuned circuit in which it takes place is considerably decreased, the selectivity goes up, and the attendant drawback of increased selectivity follows; that is the higher audio frequencies are depreciated.

(*The second part of this article will appear in the August number of* RADIO NEWS.)