Some Aspects of High-Quality Reproduction

Part II---A Discussion of the Elements Affecting It on the A.F. End

By PAUL TRAUGOTT

N Part I of this article, which appeared in the July issue of RADIO NEWS, Mr. Traugott defined high-quality reproduction as that most faithful to the original sounds at the transmitter; and discussed the factors in the R.F. end and detector of the receiver which favorably or unfavorably affect attempts to obtain this result. In the second part, which follows, he analyzes the A.F. and loud-speaker elements of the receiver from this standpoint. The experimenter will almost surely find helpful suggestions here.—EDITOR.

IT is doubtless obvious, from this discussion and those by other writers, that, in conventional R.F. and detector circuits, the higher audio frequencies tend to be depreciated. The lower audio frequencies get through in good shape. In the audio amplifying channel the opposite of this is likely to be the case.

Consider the transformer-coupled amplifier shown in Fig. 4. It works out of the detector tube in the usual manner. In order to transmit a very low tone through to the first audio-amplifying tube, the transformer primary must have an extremely high inductance. Talk about matching impedances at this point is, from the standpoint of high-quality reproduction, mostly hokum. The higher the primary inductance of this transformer, the better—for high-quality reproduction. Similarly, the lower the output impedance of the detector tube, the better.

For effective amplification through this first transformer, the primary impedance must be at least twice the output impedance of the tube at the lowest frequency wanted. Considering fifty cycles as the required low limit, and considering the output impedance of the detector tube to be about 25,000 ohms (as it may easily be), the inductance of this first transformer primary must be equal to approximately 160 henrys. This is rather high, and usually requires special core material, if the effectiveness of the transformer is not to be otherwise reduced. Fortunately, considerably lower primary inductances still give good low-note transmission.

BY-PASS CAPACITIES

Across the primary of this first transformer is usually a by-pass condenser, serving to shunt the R.F. current in the detector-plate circuit to ground and out of the audio system. If the capacity of this condenser be too large, it will also by-pass some of the higher audio frequencies, and may introduce undesirable resonance effects. But there exist in transformer-coupled amplifiers, where the plate load is inductive, certain phase relations which permit this by-pass capacity to be of rather large value without materially reducing the high audio frequencies reaching the grid of the next tube. A capacity of .001-mf. as a detector-plate-circuit by-pass has an entirely negligible effect upon audio frequencies as high as five thousand cycles. Even much larger values can be used without serious frequency distortion resulting. However, in a resistance-capacity coupled amplifier the story is somewhat different. In this case even a comparatively small by-pass condenser results in a loss of high audio frequencies.

HIGHER-FREQUENCY SUPPRESSION

The requirement for low-note transmission through a transformer is then, high primary inductance (principally). In order that the same transformer shall transmit high frequencies equally well, a number of other conditions must exist. Perhaps the most important single factor is the *effective capacity* existing across the secondary windings. Very small values of capacity across the secondary seriously reduce the voltage of the higher frequencies. Condensers shunted across audio transformer secondaries are almost always fatal to high-quality reproduction; though they often cause the production of unnatural musical effects which are quite pleasing to many listeners. Even a resistance shunted across a transformer secondary reduces the high-frequency component on the grid of the tube. Advantage is often taken of this fact, in efforts to reduce the extraneous noises in radio sets. Most of this noise being in the upper register, a resistance across the transformer secondaries will reduce it considerably. The naturalness of reproduction is simultaneously reduced if the shunted resistance is too low.

With modern design, audio transformers can be built to handle equally frequencies from 100 to 6,000 cycles. This range can be extended when special core materials and other special constructions are used.

IMPEDANCE COUPLING

In an impedance-capacity coupled amplifier, the same de ideratum of high inductance holds, if good low-note amplification is wanted. Impedance couplings are sometimes used betwen high-mu tubes. Such tubes have high output impedances and so require coupling impedances having very high inductances. One standard high-mu tube has, under operating conditions, an output impedance close to fifty thousand ohms; to amplify a fifty-cycle note out of this tube requires a coupling impedance having about 300 henrys inductance — that is, if high-voltage amplification is wanted at the fifty-cycle point. Coupling devices can be built so that they have resonance points at very low frequencies, in which case they permit very low note amplification.

In impedance-coupled amplifiers and circuits of similar types, it is essential to have sufficient capacity in the stopping condensers in the grid circuit of each tube. The resistance of the grid leak also must be sufficiently great. These points have been well covered by other writers, and much light has been shed on the subject.

It should be noted that, in these audio amplifiers, whatever frequency-distortion takes place is usually in the form of a reduction in the low frequencies. It would seem that this point in itself would help to compensate for the reverse condition holding in the radio-frequency system. To a certain degree it does; but the difficulty is that the low-frequency reduction is too sudden; it cuts off sharply. If it were a gradual reduction of all frequencies from about 3,000 cycles down, it would compensate very nicely. Fig. 5A shows what the actual frequency-against-amplification curve looks like; Fig. 5B shows how it should look in order to compensate properly.

CORRECTING FOR R.F. CHARACTERISTICS

However, it is feasible to compensate the audio system to correct for the distortion of the R.F. system preceding it. Fig. 6 shows a circuit for such a compensating arrangement. An extra tube is used. The inductance L1, for standard 201A-type tubes, may be about 1 henry; the series resistor should have a maximum value around 25,000 ohms and be variable. The value of the resistance determines the amount of the equalization. The remainder of the amplifying system must not have any marked peaks in its transmission range; and the loud speaker used must be capable of reproducing high tones. The understandability of speech in the output of a set using this arrangement is usually markedly improved; the female voice is more natural and, of course, music is more brilliant and true.

RESISTANCE-CAPACITY CONSIDERATIONS

To return to audio amplifying channels: the resistance-capacity-coupled amplifier is to be considered. This type of amplifier is probably likely to be freer of frequency distortion than any of the others. Depreciation of the higher frequencies (up to 7,000 cycles, anyway) seldom occurs; and if the capacities of the stopping condensers and the resistances of the grid leaks are properly chosen, very low notes will be amplified well. Blocking of the grids under high input voltages may give trouble, but in actual operating conditions it very seldom does. Whatever high-frequency depression does occur in a resistance-coupled amplifier is usually attributable to a by-pass condenser, of capacity too high, in the detector-plate circuit. Its effect in this type of amplifier is greater than in o'hers, and its value should be reduced to a small figure. If a radio-frequency choke also is used between the detector and the first audio tube, the by-pass condenser can be made very small.

Common impedance in the power-supply circuits of any form of audio channel will

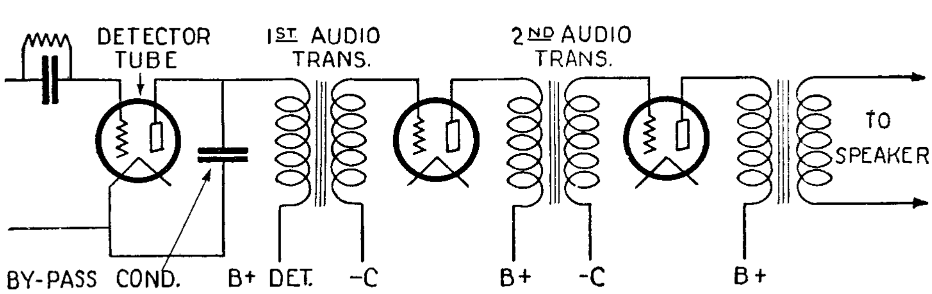
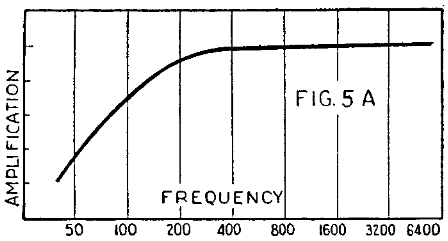


FIG. 4

An typical transformer-coupled audio-frequency amplifier, which, if certain details are observed, is capable of giving excellent reproduction.



An actual frequency-amplification curve, showing the drop in amplification at the lower frequencies.

cause various kinds of frequency distortions. New "B" batteries keep this trouble down; and in "B"-power-supply units ample by-pass capacity must be used. Special arrangements are sometimes necessary to reduce these effects, foı in a high-quality amplifier they may become serious.

USE OF POWER TUBES

There exists in audio channels forms of distortion other than frequency distortion. Wave-form distortion will occur if the operating voltages on the grids of the tubes are not properly adjusted. This subject has been already well covered and explained. The last tube in the audio system is required to handle large voltage-swings, and it must have a high grid bias in order to prevent non-linear operation. The various standard power tubes are designed for high grid-bias operation, and meet the requirements very well.

Tube overloads usually produce wave-form distortion, with its resultant generation of harmonic currents. This condition may easily exist in a high-quality amplifier where low notes are being transmitted. For a given amount of energy, the amplitudes of a low-frequency current are considerably higher than the amplitudes in an equivalent high-frequency current; and on low notes even a large power tube may overload, if too much is required of it.

A contributing factor in low-frequency overloading is the low impedance of the output load at low frequencies, which tends to accentuate the curvature of the tube characteristic. At very low frequencies and moderate output volume, even comparatively large power tubes will generate some harmonic currents; but if they are small with respect to the normal currents no serious distortion results.

The push-pull amplifier arrangement helps to keep down distorting harmonics, but its use is not often warranted in ordinary home radio work. Where power supply limitations necessitate the use of low plate voltages, the push-pull amplifier can be used with excellent results—results not obtainable, with low plate voltages, without its use. The push-pull system has, for power work, the advantage that the output-transformer core is never saturated by direct current flowing to the plate of the tubes. Core saturation in the power end of an audio system can cause serious distortion, but is not often present except in very large amplifiers.

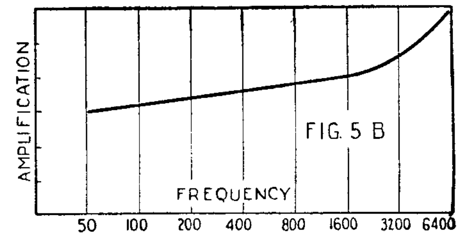
The loud-speaker coupling devices now available prevent a great deal of D.C. saturation distortion in home radio receivers. In large power amplifiers, even the A.C. flux of the audio currents may cause core saturation and distortion.

THE SOUND REPRODUCER

The final link in the high-quality reproducing chain is the loud speaker. It is improving rapidly, and many good speakers are commercially available. Loud speakers are apt to be deficient in high frequencies as well as low; that is, their output, measured in sound pressures is materially less for both low notes and high notes than for notes in the middle of the register.

Horn-type speakers, to be good, must have the right kind of unit, or driving motor, and must as well, for low note reproduction, have very long properly-tapered horns, with a mouth of large area. Twenty feet is not too long for a high-quality horn. High-note transmission from a horn-type speaker is largely dependent upon the unit behind the horn; its diaphragm must have the proper mass, stiffness, and area; and the electromagnetic or electrodynamic machinery which actuates it must be right.

Many cone speakers are relatively efficient on low notes, but discriminate badly against high tones. One of the most successful cones functions somewhat in the fashion of an electromechanical band-pass filter; its action occurs as a series of resonances. But as these resonances cover a very wide range of frequencies, the over-all output from this cone is rather good. Another excellent cone speaker has an electrodynamic drive unit and a small stiff conical diaphragm which acts substantially as a plunger at all the more important sound frequencies. This type of cone speaker requires a baffle board to give good low note radiation; the larger the baffle the better. A baffle, in this case, is merely a vertical surface interposed between the front and back of the vibrating diaphragm or cone.



If the amplification curve would assume this shape, better reproduction would result.

Cone speakers, for the lower frequencies in any event, are roughly non-directional in their sound radiation. For small places and moderate volume-outputs, they will probably always be best. The horn-type speaker is distinctly directional and, because of this property, will project a given quantity of sound into a large place with rather more efficiency than the non-directional speakers. Horn-type speakers will probably always be used in theatres, halls, etc., where sound is desired only on one side of the loud speaker.

DON'T BLAME THE SOPRANOS

In summing up, it becomes apparent that the principal difficulty in high-quality work in radio reception is in getting good high-note transmission. For true high-quality reproduction, equal transmission of the high notes is essential. Real and natural musical brilliance requires high frequencies. For high intelligibility and naturalness in voice (more especially in the female voice) reproduction, the higher frequencies are necessary; and frequencies even up to 7,000 cycles should be present for best results. It is possible that the common objection to women as radio artists is really due to the fact that many radio sets drop the high tones somewhere in the system; and, as the overtones of the female voice are rather well up on the scale, low intelligibility as well as drummy unnaturalness results.

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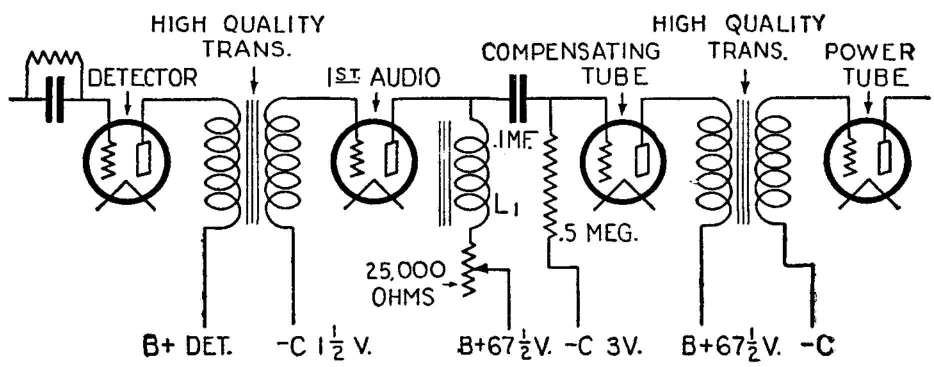

FIG. 6

An A.F. amplifier, which may be compensated for any distortion that occurs in the R.F. circuit.

High-Quality Reproduction

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It is quite possible, also, that a large number of persons do not like brilliant and natural musical reproduction; a preponderance of low tones gives a mellow, soft sound that often pleases. Truly high-quality systems are therefore not always to be recommended. In radio reception another limiting factor exists: the higher the quality of the over-all amplification, the greater will be the noise admitted; and in a high-quality reproducer the noises will sound very much like distinct noises rather than like vague, shadowy sounds mingled with the voice and music.

So that, perhaps, a quality of reproduction not so extremely faithful would, all things considered, be the best for plain, worthy listeners. For those with highly-cultivated musical sensibilities the high-quality system is available. And for public-address systems and similar work, the high-quality machinery is of course, an economic necessity.

At any rate, great credit is due to those scientists and engineers who, laboring in high, still places, twisting about mathematical symbols and wires, have made possible the utilization of some of the great forces of nature in the further interests of humanity.