Advancement in R.F. Stabilizing Systems

A Comparative Analysis of the Most Popular Methods Hitherto Developed

By M. L. MUHLEMAN

RADIO took a novel turn when the regenerative circuit was introduced about fourteen years ago. Before that time very little was known about radio-frequency amplification, and about the best we could do was to rely on the effectiveness of a single vacuum tube employed as a straight detector. The introduction of regeneration provided us with a means of increasing the sensitivity of the vacuum-tube detector beyond our greatest expectations, and without the necessity of adding much in the way of apparatus. A comparatively insensitive vacuum tube became, under the functioning of this newborn circuit, about the most sensitive thing in existence, and even today it stands without equal.

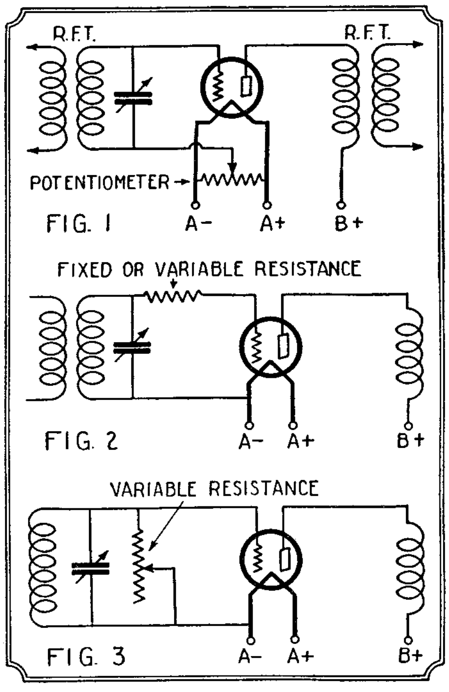

Fig. 1. The potentiometer method of oscillation control. Fig. 2. Stabilizing an R.F. circuit by use of a series grid resistance. Fig. 3. Variable resistance in shunt with the tuned secondary circuit, another damping device.

Radio took a novel turn on the day of regeneration because it is through this basic principle, and through the medium of a regenerative or feed-back circuit, that we are able to make a vacuum tube oscillate. Oscillation has been, at one and the same time, a curse and a blessing. Oscillation opened up a new and larger field than did regeneration and today the vacuum-tube oscillator is the basis of our broadcast transmitters. But oscillation is like a sore thumb for the listeners, and has been ever since regeneration was discovered.

We all know its effects. In a single-circuit regenerative receiver we run into oscillation if we advance regeneration too far. In present day multi-tube radio-frequency sets we run into oscillation if the set is not properly balanced, stabilized or neutralized. Even in superheterodyne receivers, parasitic oscillations are produced in the intermediate-frequency-amplifier stages, if they are not properly controlled. And in any receiver the result of oscillation is the same; the music is either distorted beyond normal limits or the loud speaker is shaken by ungodly noises resembling those made by anything and everything from stuck pigs to disembodied souls.

A RADIO DILEMMA

Unfortunately, there is but one cure and that is to stop the oscillation. Unfortunately, too, if we desire sensitive receivers it is necessary to have the circuits so designed and so coupled that we can work fairly near to the point of oscillation. The reason for this is that the regenerative effect itself is a priceless factor and the more regeneration we can produce in a single- or multi-tube set, the greater will be both the sensitivity and selectivity.

I repeat again that radio took a novel turn on the day of regeneration; for in accepting regeneration we necessarily had to accept regeneration's mischievous brother, oscillation. Since this time we have been doing nothing but a lot of heavy compromising. It has been the desire of every radio engineer to get the most out of regeneration, while defeating oscillation; but, like the proverbial bad penny, oscillation horns in at the most undesirable moment.

The whole business has been more of a scientific warfare than anything else and the scientists have devised special weapons for combatting regeneration's bad-acting brother.

It must be admitted that the task is a most difficult one and most of the radio engineers engaged in it have been in the same dilemma as the surgeon who had been allotted the difficult job of parting the Siamese twins. If we can judge from history, the result is quite often the same; the ultimate death of both.

That has been the trouble with many of the so-called balancing, stabilizing or neutralizing systems introduced during the past few years. The weapons have been too crude and of a blundering nature and, in their attempt to prevent oscillation, have just about killed regeneration. It is interesting, therefore, to know just what advancement has been made along these lines and to give the reader some idea of the merits of some of the newer types.

CAUSE OF OSCILLATION

First let me say that a radio-frequency amplifier oscillates because too much energy is fed back from the plate to the grid of the radio-frequency tube. This energy gets back to the grid either through the capacity existing between the plate and the grid or through adjacent coupled circuits. Any energy that does get back to the grid is re-amplified, so to speak; it is repeated through the tube and, if the original energy was sufficient, the feed-back action builds up so rapidly and so much electrical momentum is created that the current surges back and forth through the grid and plate circuits. This back-and-forth surging is the oscillation we have been referring to. This will happen in any efficient form of either tuned- or untuned-radio-frequency receiver, unless precautions are taken to prevent it.

The earliest form of preventative was the potentiometer. This permitted biasing the grids of the radio-frequency tubes with various values of either a positive or negative voltage. The manner in which the device is connected in a simple radio-frequency circuit is shown in Fig. 1. If the tube or tubes had a tendency to oscillate, all one had to do was to move the arm of the potentiometer towards the positive side until everything was cleared up. This was fine, except that in doing so one introduced heavy losses in the circuits.

A fixed or variable resistance, somewhere in the order of 200- or 300-ohms, inserted in each grid circuit as shown in Fig. 2, is another stunt that is very effective for stabilizing a set; but this scheme also is a losser and decreases both the sensitivity and selectivity of the set. There have been similar systems, such as those shown in Figs. 3 and 4, which tended to dampen circuits to prevent them from oscillating; but in the end they all amount to the same thing. By using them you may prevent oscillation, but at the same time you defeat the main purpose, which is to get a fair degree of regeneration, so that the set will be selective enough for normal purposes and sensitive enough to warrant the use of the extra tubes. Some of the commercial sets that were placed on the market a few years back were so heavily loaded with damping devices of one type or another that they were practically useless in congested districts, because of the great drop in selectivity. They were unable, also, to pick up distant stations, because of their noticeable lack of sensitivity; *i. e.*, insufficient regeneration. Some of these sets employed as many as six tubes.

Systems of this sort never got us anywhere, as in no case did they allow sufficient regeneration for the satisfactory operation of the receiver. But then, we had no methods that would; as soon as the point of sufficient regeneration was reached the set went into oscillation.

THE NEUTRODYNE

The first real advancement came with the introduction of the first original neutraliza-

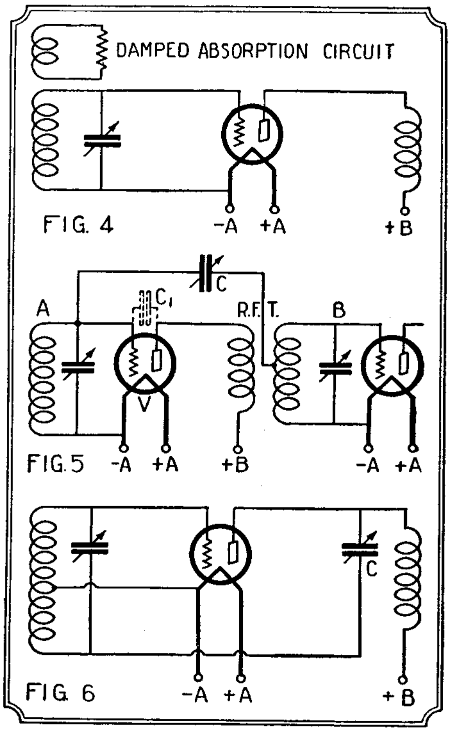

Fig. 4. Damped-absorption method of stabilization; effective, but a losser. Fig. 5. Illustrating the Neutrodyne principle; a portion of a Neutrodyne circuit. Fig. 6. The Rice system of neutralization, similar to the Neutrodyne and theoretically a form of bridge circuit.

tion system, exploited under the name of Neutrodyne. This method demanded no damping of circuits or anything of the sort. The idea might be called a very ingenious one; in essence the scheme as worked out by Professor Hazeltine supplied a means for neutralizing the effect of the internal grid-to-plate capacity of the vacuum tube. This was accomplished by the use of a small, adjustable condenser, C, with a very low capacity value, connected in the circuits as shown in Fig. 5. There is a very long-winded explanation of the functioning of this arrangement which, insofar as the average reader is concerned, runs into foreign territory. Let it be said that the arrangement is one of the many famous bridge circuits and that the explanation of the system in a broad sense is quite comprehensible.

Referring to Fig. 5, let us assume that the circuit is operating without the neutralizing condenser C and that the grid or secondary circuits A and B are not tuned to any particular station and are out of resonance with each other. In this state there is very little regeneration taking place. However, as soon as we tune circuits A and B to the wave of some broadcast station, they reach the point of resonance and there is sufficient feed-back of radio-frequency current through the internal capacity C1 of tube V to cause oscillation, in the manner heretofore explained. Though there is no variable condenser connected across the primary coil of R.F.T., connected in the plate circuit of tube V, the coil nevertheless takes on a resonance effect, due to the tuning of the associated secondary coil in circuit B. Now, if we connect in the condenser C, something else happens. This condenser introduces in the grid circuit A of tube V a radio-frequency current equal to but *opposite in phase* to the current fed back through the internal capacity C1. In other words, there are two feed-backs: the natural feed-back through the capacity of the tube, and an auxiliary feed-back through the condenser C. Since these two distinct reactive currents are opposite in phase, they neutralize each other, and consequently no oscillation can take place.

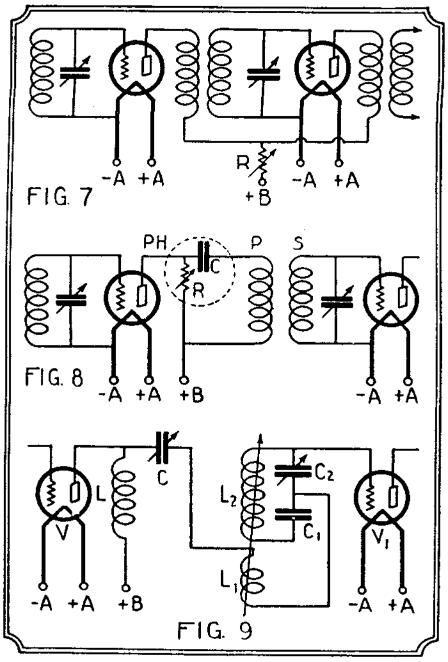

Fig. 7. A resistance-stabilized circuit of improved form, and not a losser. Fig. 8. A circuit employing the Phasatrol, a new and efficient form of stabilizer. Fig. 9. The basic Loftin-White constant-coupling system.

The Rice system of neutralizing, shown in Fig. 6, is similar to the Neutrodyne arrangement, but in this case the condenser C is connected from the plate of the tube to the filament end of the grid. The action and effect is the same; *i.e.*, a current, equal to the natural feed-back current but opposite to it in phase, is fed back into the grid circuit.

There have been a number of other systems devised similar to the two just outlined and they are all about equal in effectiveness. But they have one common fault and that is they do not act the same on all wavelengths. Adjust a set using one of these forms of neutralization for stability on the short wavelengths and there is a noticeable lack of sensitivity on the longer wavelengths. If the set is adjusted for maximum sensitivity on the long waves, it most certainly will oscillate on the short waves. Naturally, the best that can be done is to adjust the neutralizing system so that the set is perfectly stable in operation on the short waves and then to be philosophical about the results obtained on the longer wavelengths.

RESISTANCE STABILIZATION

Whether or not this effect was unforeseen I shall not venture to say; but, at any rate, radio engineers soon learned that there was still much to be done in the way of developing stabilizing or neutralizing systems. The main problem on hand was to devise a means to compensate for the change in electrical coupling between primary and secondary circuits at different wavelengths. The problem was not an easy one, for both capacities (condensers) and inductances (coils) change their reactance or impedance values with a change in wavelength or frequency. The only factor that does not change is a resistance unit and this provided the first form of stabilizer following the bridge circuits. This arrangement is shown

(*Continued on page* 1384)

Advancements in R.F. Stabilizing Systems

(*Continued from page* 1357)

in Fig. 7 and though it is fairly effective in some respects it has a number of disadvantages. At any rate, it cannot truthfully be called a damping device in the same sense that former arrangements were.

It will be noted from the diagram that a variable resistance, R, is connected in series with the common "B" battery lead to the plates of the radio-frequency tubes. The fact that the resistance is there means that there will be a certain amount of damping, but this is offset by the functioning of the resistance. In the first place it is associated with the primary circuits only and does not act as a damping factor in the grid circuits, where it certainly would decrease both the selectivity and sensitivity of the set as a whole. What it does do is to slightly damp the action of the primary circuits, alter or adjust the plate-filament impedance of the radio frequency tubes and at the same time, in the same move you might say, adjust the "B" battery voltage. The output or plate-filament impedance of a radio-frequency tube might appear to be a factor of little or no importance, but actually it has a bearing on the regeneration and oscillation tendencies of the tube. The lower the plate impedance or resistance of the tube, the more easily will the tube oscillate. If we increase this internal impedance, which can be done by decreasing the filament brilliancy or the "B" battery voltage, we can effectively control oscillation tendencies and still obtain sufficient regeneration. The system outlined accomplishes this by the use of a single variable high resistance for all the R.F. tubes.

THE PHASATROL

The next real advancement in the art of stabilization of radio-frequency circuits was the Phasatrol, a comparatively recent arrival, which consists of a variable high resistance and a fixed condenser, mounted in a single casing. The internal wiring of the Phasatrol (PH), as well as the manner in which it is connected into a radio-frequency amplifier circuit, is shown in the diagram of Fig. 8. Like a few of the systems already outlined, this one cannot be classed as a damping instrument. Rather, it is a distinctive form of phase-shifting device.

When the Phasatrol is connected in the plate circuit of a radio-frequency amplifier as shown in Fig. 8, the fixed condenser C changes the *time factor* of the feed-back impulses; so that instead of meeting the original signal impulses *in phase* and tending to build them up, they travel through the grid-to-plate capacity of the tube and arrive on the grid just after the signal oscillations have gone. Hence, there is no re-inforcing action and no excessive regeneration to cause undesired oscillation. Theoretically the phase difference is never absolutely complete, some regeneration taking place in each radio frequency circuit. This is highly desirable, for the reasons previously explained. The variable resistance R, being both non-inductive and non-capacitative, has no effect on the phase displacement. It serves primarily to feed the direct current of the "B" battery to the plate of the tube, leaving the primary coil P of the R.F. transformer unrestricted, and, secondarily, as a means for adjusting the plate impedance or resistance of the tube. The advantages of this have already been explained.

CONSTANT-COUPLING SYSTEM

The outstanding system of the year is the new Loftin-White Constant-Coupling system of radio-frequency amplification. Here is a stabilized circuit, with no theoretical losses to speak of, which is based on the hard fact that the reactance of a condenser increases as the frequency decreases (or wavelength increases) and vice versa, and that the impedance of an inductance varies in exactly the opposite ratio. In other words, irrespective of whether the wavelength is being increased or decreased, the resistance of either the inductance or the capacity is increasing while the other is decreasing, as the case may be. The circuit of this system, which is shown in part in Fig. 9, has its inductances and capacities so connected that there is both inductive and capacitative coupling. The values of the inductances and the capacities are so adjusted that, as the resistance of, say, the inductance, starts to drop off, the resistance of the capacity increases and vice versa; so that actually the resistance, *i.e.*, the coupling resistance, remains constant for all wavelengths. The coupling is therefore constant. Consequently, after the associated circuits have once been adjusted to prevent oscillation, there is no change in either the amount of regeneration, the selectivity or the sensitivity at any wavelength.

In the circuit diagram of Fig. 9, it can be seen that inductive coupling is gained through the coils L1 and L2, while capacitative coupling is furnished by the condensers C1 and C2. Coil L is a radio-frequency choke which prevents the leakage of any of the radio-frequency currents into the "B" battery circuit; while C is the phase-shifting condenser which is employed primarily for the purpose of neutralizing in the manner previously explained.