The Wonderful Neutrodyne Explained by Its Originator

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THE neutrodyne receiver has now been before the public for four and a half years and has achieved a popularity and reputation never approached by any other type. It is often considered simply as the embodiment of a single feature, the neutralisation of capacity coupling. But this is far from the truth, for several other important and novel elements entered into its make-up and contributed essentially to its success. As discussed in some detail below, these elements included, in particular, the elimination of all coupling between tuned circuits, the use of high step-up ratio in the interstage radio-frequency transformers, an antenna circuit closely coupled to the first tuned circuit through a step-up transformer and tuned together with this circuit, the electrically similar arrangement of all of the tuned circuits so that the dial settings are practically alike and the mounting of all of the radio-frequency transformers in the same manner but at a particular angle, which results in no magnetic coupling. Some of these additional features have since been copied and applied to other receivers.

Nearly all commercial neutrodyne receivers now comprise two stages of tuned radio-frequency amplification, a valve detector and two stages of audio-frequency amplification. Some audio-frequency amplification is necessary in any receiver for operation of a loud-speaker, because a detector valve alone cannot give sufficient output without distortion. On the other hand, more than two stages of transformer audio-frequency amplification is likely to result in excessive disturbing noises, due to induction and to irregularities in valve and battery operation; so the further amplification usually desired must be at radio frequency. Radio-frequency amplification can be made much higher for the same number of valves, when each stage is tuned, and such tuning has a marked additional advantage in increasing selectivity.

EFFECT OF TUNED TRANSFORMERS.

The tuning of the interstage transformers has an effect similar to the tuning of the plate circuit of a valve—that is, it makes the capacity coupling between the plate and the grid effective in producing regeneration and frequency oscillation. As everyone knows an oscillation in a receiver is the cause of objectionable "squeals," due to the beat note produced with the carrier waves of broadcasting stations which are not quite in tune. These squeals are not only annoying to the user of the set which is causing them, but they are also likely to be annoying to his neighbours, for the oscillating set and its aerial constitute a miniature radio transmitting station. In some neighbourhoods the squeals of oscillating receivers produce such a chorus as often to prevent the reception of enjoyable programmes.

Even when a regenerative receiver is not oscillating, it may be distorting the broadcast programme in a way that is not always recognised. This distortion is due to the fact that when the regeneration is adjusted quite close to the oscillating point it makes the receiver so highly selective as not to respond to the high-pitch components of the music so well as to the low-pitch components. The result is that, although the music may come in loud, the low pitches are accentuated, and its character is lost.

REGENERATION UNDESIRABLE.

With the valves now in general use, and with well-designed coils and condensers, it is possible to make receivers for the broadcast wave-lengths which are naturally as selective as is permissible without the distortion just referred to. For this reason regeneration, even below the oscillating point, is not desirable.

Since the introduction of the neutrodyne receiver, there have been developed certain other receivers which do not eliminate regeneration, but which prevent or control oscillation in some other way, usually by the introduction of some source of loss in the radio-frequency circuit. Theory as well as practice indicates that a cure is better than a palliative, and that the neutrodyne receiver which eliminates regeneration will give the greatest amplification, coupled with freedom from distortion.

STATIONS EASILY LOGGED.

There is another reason for preferring a receiver which has no regenerative control, and this is the convenience in being able to "log" stations once heard, with the confidence that the dials may be set at the same points and the station again picked up at any future date when it may be broadcasting. This is not possible with a regenerative receiver: for the regenerative adjustment is dependent on the condition of the batteries, and the tuning adjustments will be dependent on the regenerative adjustment. In the neutrodyne receiver, on the other hand, all adjustments are independent of one another and the tuning is not affected by the condition of the batteries.

Regeneration is avoided in the neutrodyne receiver by eliminating all coupling between the tuned circuits. There are three ways in which coupling can enter: First, by magnetic coupling, or mutual induction between the coils; second, by capacity coupling, due to capacity between the grid and plate of a vacuum tube and to various other capacities between coils, condensers, and lead wires, and, third, the inclusion of some apparatus or simply connecting wires in the paths of the radio-frequency currents of the different stages.

REDUCING COUPLING.

Magnetic coupling between the coils is avoided by mounting them with the axes in certain relations. If all of the coils are to be mounted in the same manner, their centres should be on the same straight line and their axes should make an angle of about 55 degrees with this line. This method of coil mounting is one of the most conspicuous features of the neutrodyne receiver. There is a form of magnetic coupling that has sometimes given trouble to home constructors; and this is the presence of a closed loop in the wiring or supports which is coupled magnetically to two or more of the coils and so serves to couple these together. For example, sometimes the positive and negative filament leads are run some distance apart. As these leads are connected together through each filament, closed loops are formed. The obvious remedies are to avoid closed loops in the supports and to run the two filament leads close together.

The theory of the neutralisation of capacity coupling has been explained quite often, but will now be briefly reviewed. Referring to the diagram, suppose that a disturbance is started in the second tuned circuit, T1. This will cause a current to flow through the capacity between the plate and the grid of the tube RF1, which current would then tend to flow through the first tuned circuit Ta, building up a potential on the grid and causing regeneration. However, at the same time a current will flow from the tap on the secondary coil SI, through the neutralising capacity Cn1 to the grid. As the plate and the tap are connected to points of opposite polarity, these currents will have opposite directions. The neutralising capacity is so adjusted as to make these currents equal; so the final result is that the current flowing to the grid is equal to the current flowing away and no current flows through the grid circuit Ta. Thus a disturbance originating in the second tuned circuit does not reach the first tuned circuit and there is no regeneration.

Besides the capacity coupling through the individual tubes, there is some slight capacity coupling between the first and third tuned circuits, Ta and T2. This coupling is slight, particularly if the receiver is partially shielded, as by a metal sheet on the back of the panel. Some of the recently developed neutrodyne receivers, however, have introduced the refinement of neutralising this capacity coupling. This method is illustrated by the capacity Cn shown in the sketch, the theory of which is similar to that just given.

SELF-INDUCTANCE IN WIRING.

Coupling due to the inclusion of common apparatus in the different radio-frequency stages is most likely to occur in the leads to the common B battery. Even when these leads are quite short they have sufficient self-inductance to cause objectionable coupling. This difficulty is obviated by the use of the condenser C in the figure, which should preferably have a capacity of the order of 0.1 microfarad or larger. The leads to this condenser should be made very short and should connect exactly as shown, from the junction of the leads from the two primary coils to the junction of the two filament leads. This condenser effectually short-circuits the radio-frequency currents of the plate circuits of the valves RF1 and RF2, and so prevents these currents from flowing through the leads to the B battery. Instead of the single condenser C sometimes a separate condenser is used for each valve and may then connect even more directly from the terminal of the primary coil to the filament.

In case a bias battery, or C battery, is used in the radio-frequency amplifying tubes, it is even more necessary to use a large condenser shunting this battery, connected analogously to C. But even a single condenser so connected may not suffice, in which case a separate condenser is used for each of the amplifying tubes, connecting directly from the terminal of the secondary coil to the filament. It has not been found essential to use C batteries with the radio-frequency amplifying tubes; but a C battery with the audio-frequency tubes, as designated by C in the diagram, is of distinct advantage when a loudspeaker is used in increasing the audio-frequency amplification and improving the quality.

NOT EASY TO BUILD.

The various forms of possible coupling described in the preceding paragraphs are sometimes very elusive in the development of a new model. For this reason home constructors have frequently been disappointed in their neutrodyne receivers because they find themselves unable to eliminate regeneration and oscillation. While the neutrodyne receiver, once properly arranged and neutralised, is simpler to operate than most regenerative sets, it is not so easy to construct with satisfaction; for in a regenerative set one form of regeneration can be combined with another, either assisting or opposing, or can counteract the effects of losses, whereas in the neutrodyne receiver every form of regeneration must be eliminated individually and any losses will result in diminution of amplification.

A valuable feature in the design of the neutrodyne receiver is the use of a high step-up ratio in the interstage transformers T-1 and T-2, as well as a fairly high step-up ratio in the aerial transformer T-A. In both cases this results in a high degree of selectivity, with an amplification that is close to the optimum value. The proper ratio to employ in the interstage transformers depends on the valve for which the set is designed. The better the valve is from an amplifying standpoint the fewer primary turns should be employed. The fairly high-step up ratio employed in the aerial transformer T-A makes the operation of this circuit nearly independent of the aerial constants, particularly its capacity and its resistance. If a very long aerial is employed, which is not recommended on account of the greater interference experienced, a fixed condenser is sometimes connected in series with it.

THE RHEOSTATS.

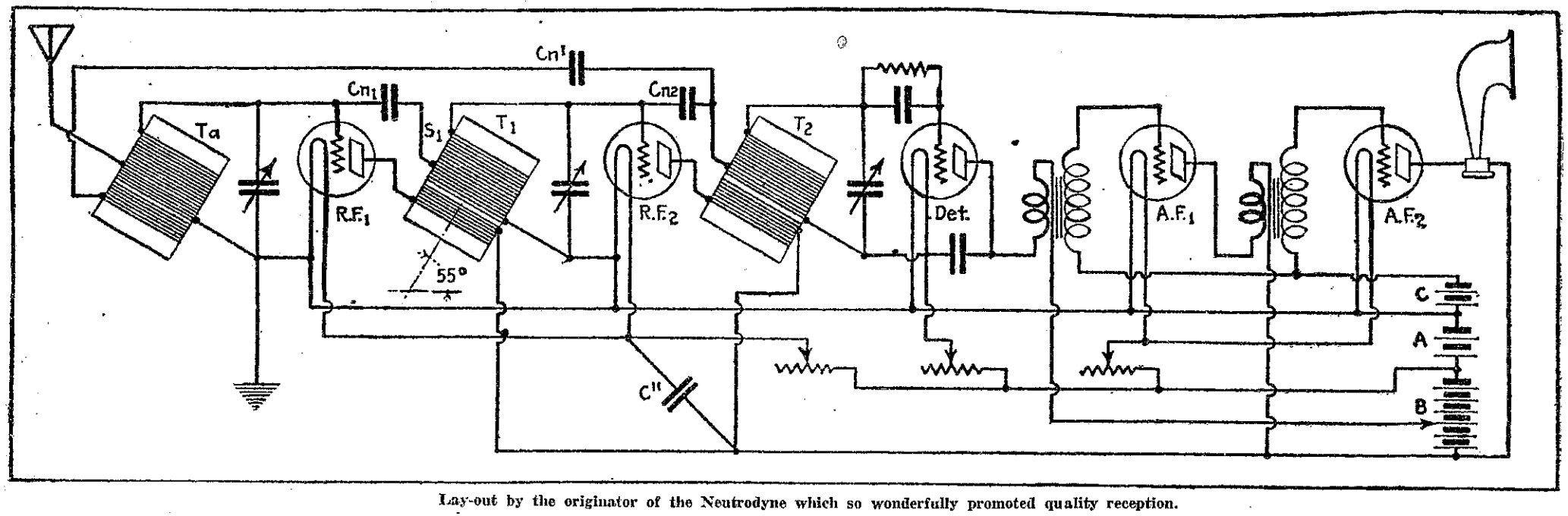
The arrangement of the rheostats is subject to considerable variation. Sometimes a single rheostat is used for all five valves, while at the other extreme a separate rheostat may be used for each valve. If a soft detector valve is used it should have its own rheostat. A rheostat for the two radio-frequency valves together is useful for controlling the volume of the sound. For good loudspeaker operation without overloading of the detector valve two stages of audio-frequency are preferred. If both stages are to be employed at all times a single rheostat for the two audio-frequency valves is appropriate

Probably almost everyone who has operated a neutrodyne receiver has noticed that the three tuning dials read nearly alike for each wave-length setting, and has had the idea that these three adjustments might better be made simultaneously by gearing the dials together, or, better, by mounting the rotors of the three tuning condensers on the same shaft.

This has been successfully accomplished, and tuning much simplified, and it is, therefore, practically impossible to pass through the adjustment of any given station having an audible signal strength without hearing it. The manner in which this simple fixation of tuning has been accomplished has been the improved manufacturing methods enabling condensers and inductances to be so accurately matched in characteristics that the condensers can be simultaneously rotated by a single control, and precision of tuning in each stage maintained. When antennae of various capacities are used, the difficulty of absolute precision is overcome by inserting a compensating control in the interior of the set to match the first tuning arrangement, with its attached aerial. This compensator obtains accuracy at an average wave-length on the scale. Some manufacturers prefer to keep the aerial tuning arrangements separate, and under these circumstances of dual control complete accuracy of tuning is naturally forthcoming, with practically the same simplicity of operation.

The ideal neutrodyne is, therefore, to hand now, because with "gang control" of the condensers as many as four stages of radio-frequency amplification is available, and such sensitiveness of pick-up enable a loop receiver to be used, and, providing the batteries are contained in the cabinet, the whole equipment may be put on legs having castors and rolled freely around the floor to any desired position.

The volume control on modern receivers consists of a single filament rheostat, which drives the filaments of either one or all of the radio-frequency stages.



Lay-out by the originator of the Neutrodyne which so wonderfully promoted quality reception.

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