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A Single-Control Receiver

Recent Developments in a Multi-Stage, Neutralized, Tuned Radio Frequency Receiver — Some Experiences and Data on Neutralizing Methods

By C. L. FARRAND

¶ *THIS paper is the second by Mr. Farrand giving the constants and data on his tuned radio frequency receiver known as the super-pliodyne. The first paper was printed in the July* RADIO BROADCAST *and dealt with the experiments and developmental work on the circuit. This paper describes further work on the neutralization methods used in the receiver. It is one of the Radio Club of America papers which appear exclusively in this magazine.*—THE EDITOR

IN A paper read before the Radio Club of America on February 20, 1924, published in RADIO BROADCAST for July, 1925, a method of neutralizing feed-back in vacuum tubes, due to capacity coupling of the electrodes, was described. The purpose of the present paper is to describe a new method of neutralization which leads to greater selectivity and which may be combined with the former method to secure a desired selectivity and sensitivity.

The former method gave what in the present day would be considered minimum selectivity. The greatly increased number of broadcasting stations has, in turn, increased the demand for greater selectivity in sets. It was in attempting to satisfy this demand that the new method was derived. The selectivity of a multi-stage radio-frequency amplifier increases rapidly with the number of stages. The circuit design for each stage may be such that with a single stage, the selectivity may be entirely unsatisfactory; yet, with the chosen number of stages in circuit, the desired selectivity would be obtained. It is therefore necessary, dependant upon the number of stages to be used, to regulate the selectivity of each circuit to the desired value. In this, it is assumed that all the radio frequency circuits of the several stages are similar.

The circuit of each stage of, for example, a two-stage amplifier, must be extremely sharp. This same circuit used in a five-or-six-stage amplifier would have such selectivity that it would be practically impossible to tune the stations in. Amplifiers have been constructed with a single control so selective that stations could only be tuned-in with extreme difficulty. Stations of substantial volume in that case were passed over without being noticed.

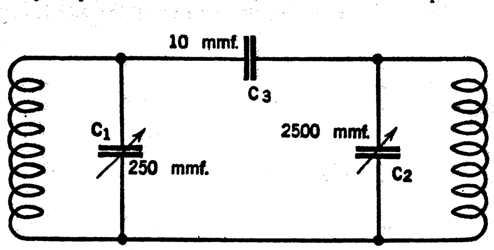


FIG. 1

TUNING THIS SINGLE-CONTROL RECEIVER

IN THE manipulation of a single-control receiver of this type, the rotation of the control dial from 200 meters to 550 meters can be accomplished by a simple half revolution. The incoming signals of different wavelengths, as they are passed through rapidly, give rise only to a dull thud or click, sounding much the same as when the grid of an oscillating receiver is touched, stopping the oscillations. At times, twenty or thirty such station clicks may be heard with one turn of the control dial. If the control is stopped at one of the clicking points, the modulation will come through.

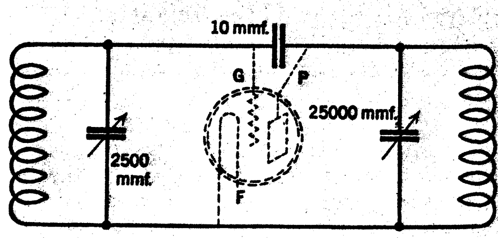


FIG. 2

It is, furthermore, necessary that the amplifier circuits be tuned in unison. It is obvious that the sharper the tuning of each circuit, the greater will be the difficulty experienced in maintaining tuning of each circuit. It is, however, practical in commercial production, to secure selectivity at least equal to that obtained by some super-heterodyne receivers, considering only one tuning position. The super-heterodyne, at the best, tunes at two points and, if not properly designed, at four and more tuning positions. The Super-Pliodyne receiver, using this system, tunes only at one point. The

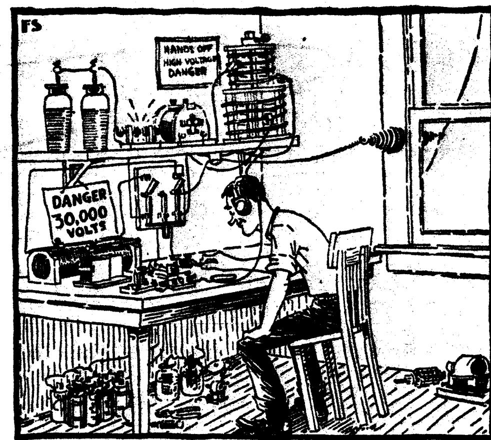
Just to the right above the coil is my d. p. d. t. switch, used to connect the sending and receiving with ground and aerial. My aërial is suspended from two 50-foot poles and is composed of 2 No. 14 B. S. copper wires 50 feet long and 2 feet apart.

Modern Electrics is a fine magazine, especially for wireless experimenters, and is a great help to me.

This was indeed a grand set, and it won the first prize of $3 in the "Wireless Telegraph Contest." The 15-year-old experimenter already had the temerity to feed his spark coil from the 110-volt circuit, curbing it with a water rheostat; yet it was good for 5 miles. He was the possessor of "3 complete outfits," including the 1000-ohm receiver made out of a 75-ohm one—a characteristic touch! Finally, this Sybarite gloried in the possession of such astounding instruments as an electrolytic detector, a tuning coil, a condenser, and a potentiometer made of German silver wire. All I can say is that he would not have been safe in our neighborhood. Unfortunately the picture printed with the description does not lend itself to reproduction.

The runner-up in this "Wireless Telegraph Contest" was Mr. Bowden Washington, who has since become a prominent radio engineer, and a Fellow of the Institute. No doubt in other issues, numerous names appear which were obscure at that time, whose owners later played great rôles on the radio stage.

The contrast between the problems of the radio experimenter of sixteen years ago and those of to-day is rather striking. Broadly speaking, the problems of to-day are those of congestion, while those of 1909 were questions arising from the primitive state of the art and the limitations of both quantity and quality of personnel, equipment, and information. To-day our problem is not to hear stations, but, often, to shut them out, in order that we may listen to one desired signal. At the time of which I am writing, an experimenter often listened for hours without hearing a signal. There were not many stations, and with the rudimentary receiving equipment available only a few near-by transmitters could be heard at best. Picking up a signal was an



you could abuse him in morse

event. "I heard a station last night," the proud operator would inform everyone he met the next morning. To-day there are not wavelengths enough to go around. Stations are crowded 10 kilocycles apart, and most of them have to divide time, or encounter interference, or feel some of the other effects of congestion. In 1909, compared to this, radio was an anarchist's paradise. If you wanted to put up a station and send, you asked no one's leave. You picked any wavelength you pleased, which was probably whatever wavelength your antenna happened to have, in its natural and innocent state. The Government took no notice of you. It did not assign you to 704.2 kilocycles, for no one knew what a kilocycle was. If anyone interfered with you, you could abuse him in Morse, and the police power would not interfere unless you followed it up with a personal assault. This procedure, incidentally, was quite *comme il faut*; many a pair of commercial operators met on West Street, New York, after a voyage, to have it out with their fists over an incident of "jamming" which had marred the serenity of the ether, as late as 1914. Good old days, bad old days, as you please; only one thing is sure:—we shall never see anything like them again.

necessity of matching individual circuits of the receiver has produced a uniformity of circuits from receiver to receiver within very accurate limits and, consequently, the entire receiver becomes practically a precision wavemeter; variation in calibration of the receiver varying about two meters.

COUPLING IN VACUUM TUBE CIRCUITS

IT IS obvious that the coupling of vacuum tubes and their associated circuits caused by the grid-to-plate capacity is dependent upon the proportion of the associated capacities due to the internal capacity of the tube. That is, if the circuit capacity is equal to the electrode, the capacity of tube coupling will be very great. If, however, the circuit capacity is very large in comparison to the electrode capacity, the coupling will be small.

The actual coupling, with a given coupling capacity and given input and output capacities, is independent of wavelength. In other words, the coupling is dependent upon the ratio of electrode capacity to input and output tuning capacity only, and not strictly speaking dependent upon wavelength. The coupling, K, is given by the equation

$$K=\frac{C_3}{\sqrt{(C_1+C_3)\,(C_2+C_3)}}$$

A circuit as shown in Fig. 1 would regenerate and oscillate vigorously when connected as vacuum tube input and output circuit. However, a circuit as shown in Fig. 2, with the input and output tuning capacities increased tenfold, would have a coupling coefficient of one tenth that of Fig. 1 and would be very stable.

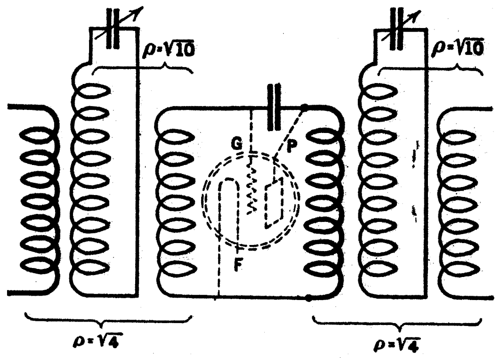
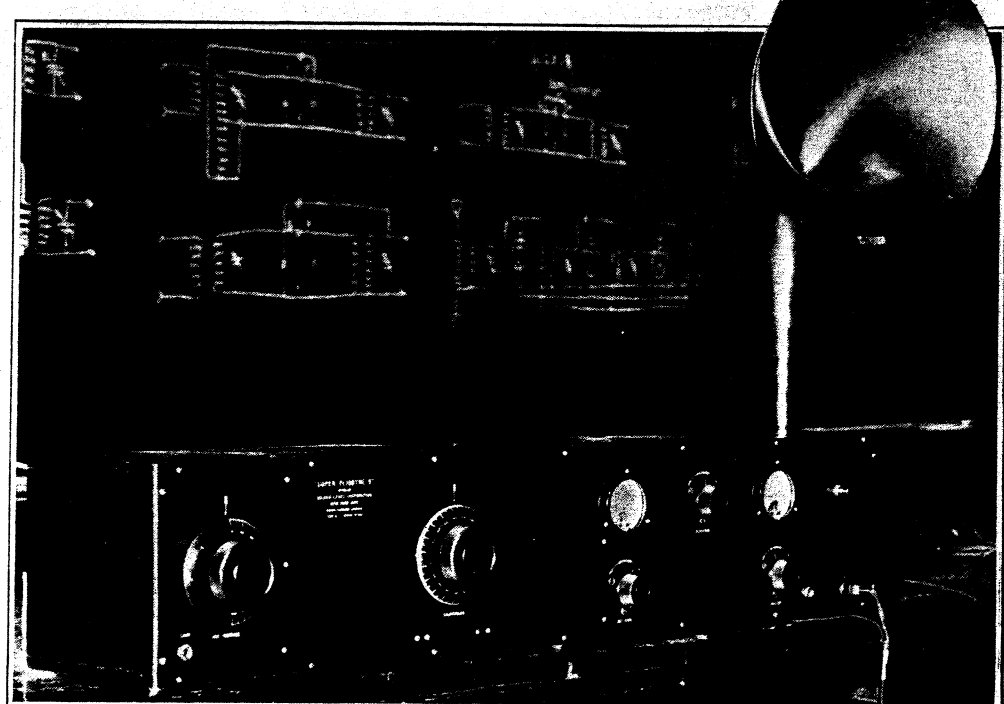


FIG. 3

In other words, a successful radio-frequency amplifier could be built which would have no tendency to regenerate, using a capacity of the order of .0025 mfd. tuning the input circuit, and .025 mfd. tuning the output circuit. It is, however, impracticable to build variable condensers of such capacity, particularly if it is desired to have them agree with each other within close limits.



A COMPLETED RECEIVER

Six stages of radio frequency amplification are used in this model. The set can be used with a very short antenna and in his demonstration before the Radio Club, Mr. Farrand used a 12-foot wire

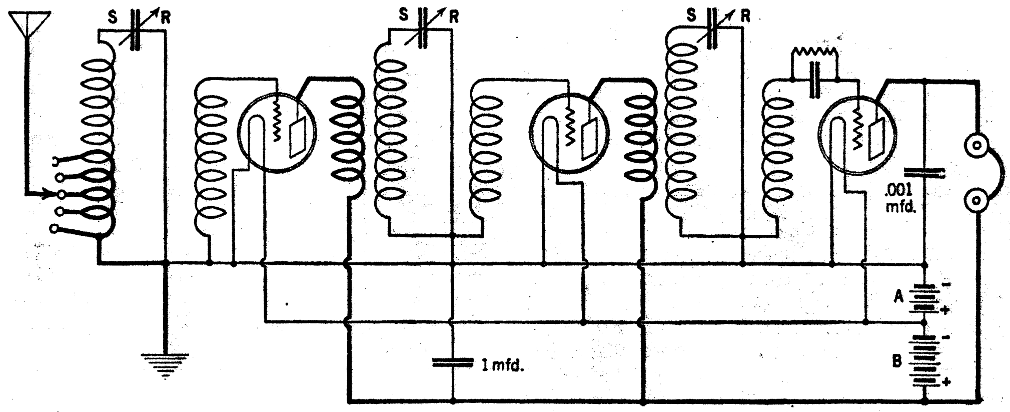


FIG. 4

The same result can be secured by resorting to a transformer. It is well known that a capacity connected to one winding of a transformer will be effective across the terminals of the other winding inversely as the square of the ratio of turns of the transformer, assuming the transformer has unity coupling. In practice it is difficult to approach unity coupling and the relations are slightly different, requiring, in general, an increase in turns of the untuned windings.

TUNING CIRCUITS OF THIS SET

THE present method involves connecting the tuning condenser of a chosen size which, from practical consideration, should be approximately 250 mmfd. across the terminals of a tuning winding. (See Fig. 3) Closely coupled to each other and to this winding are an input winding and an output winding. The input winding and output winding are chosen with a step-up ratio to satisfy the output and input impedances of a tube. This ratio should be between 3 and $4\frac{1}{2}$ to 1, depending upon the tubes used. In the Figure, a ratio of $\sqrt{10}$ or 3.16 is used. The ratio of turns of these two windings to the tuning winding is chosen so as to increase the effective tuning capacity of the grid circuit and, consequently, will increase the effective tuning capacity of the plate circuit. In practice, the ratio to be chosen depends upon the number of stages to be used, as it is necessary to use a more broadly tuned circuit with a greater number of stages.

For a two-stage amplifier, the ratio of tuning winding to grid winding should be about 2. For a five-stage amplifier, this ratio should be about three.

In view of the fact that the effective tuning capacity of the grid circuit has been increased, the resulting load of the input impedances of the tube upon the tuning circuit has been decreased. In this way, tuning is materially sharpened. In case the selectivity is too great, the compromise design may be made with the method described in the previous paper. The transformer may be designed so that only a portion of the interstage coupling is neutralized by increasing of effective capacity, and the remainder of the capacity is neutralized by connection of resistance between the plate and grid electrode. (A condenser may be connected in series with a resistance to prevent a flow of direct current from the common plate battery.) In this way, the over-all selectivity of the amplifier may be regulated within very wide limits.

The effect of the input capacity of the vacuum tube upon the tuning is less. This is because the transformer makes the effective tuning capacity larger in proportion to the input capacity. This is advantageous as it is possible to increase the wavelength range within the scale of a condenser of given size. In practice, a range of 200 to 555 meters can be secured with a capacity of 250 mmfd.

The same effect may be produced by auto transformer construction but is less desirable on account of circuit difficulties.

It is desirable to destroy the natural period of the grid winding of the transformer by winding it with resistance wire. This has no effect upon the operation of the transformer.

It is also desirable to locate the transformer (input and output) winding at the low potential end of the tuning winding. This tends to prevent losses and permit a larger wavelength range.

Fig. 4 shows a two-stage radio-frequency amplifier circuit. The plate winding consists of 15 turns, wound left hand; the grid winding 47 turns of resistance wire wound right hand; the tuning winding 80 turns, wound right hand. The plate and grid windings are tightly coupled together, of equal length and about one third the length of the tuning winding, and are placed at the filament end. The plate winding is placed between the grid and tuning winding; the end of the plate winding opposite the filament ends of grid and tuning winding is connected to plate. The end of the plate winding opposite the grid end of grid winding, toward the stator end of the tuning winding, is connected to positive plate battery.