Experimental Wireless Telegraphy and Telephony—V*

Describing the More Advanced Types of Receiving Sets, with Particular Reference to Post-Bellum Practice

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THE advent of vacuum tubes, sometimes called electron tubes, has resulted in great advances in radio communication. As such tubes may be used for a variety of purposes, to generate, to amplify, and to modulate radio oscillations, as well as to detect them, they are now used in many types of radio apparatus. New applications have come rapidly, and possibilities of further development are most promising. One fact of importance is that such tubes make possible the use of apparatus that is easily portable—a primary consideration that is often important. The principles underlying the uses of vacuum tubes, and their operation under the widely different conditions met in actual practice, therefore deserve careful study. An entire instalment of this series is devoted to vacuum tubes,

(negative electricity) is established from the filament to the plate.

The three-electrode vacuum tube, which is the type most generally used today, is a great improvement over the two-electrode type. It differs in the addition of a third electrode, inside—and sometimes outside—the tube in the form of a metallic gauze or "grid" of fine wires between the filament and the plate. This makes it possible to increase or decrease the current between the filament and the plate through wide limits, in a manner described in another section.

Suffice it to say here that vacuum tubes are obtainable in various forms and sizes for use as detectors, amplifiers, modulators, and generators. At present it is the vacuum tube for reception and amplifying pur-

expected that he is dissatisfied when he returns to his own car.

The receiving apparatus described in the previous instalments was pre-war material. Today the apparatus used by most amateurs is comparable with that of commercial stations, both in operating efficiency, workmanship, and appearance. Indeed, the same apparatus has been made for the American and other governments.

For one thing, everything operates with a rotary movement in the better types of present receiving apparatus. Sliders are no longer used. The old single- and double-slide tuning coils are replaced by variable inductors known as variometers, which consist of two coils one of which is stationary and the other rotative.

1.—Telephone transformer for use in vacuum-tube circuits. 2.—New type of loading coil which takes the place of the long tubes and sliders of pre-war days. 3.—Modern double crystal detector unit, with switch for connecting either detector in a circuit. 4.—Tuning unit, consisting of a variable condenser and two variometers. 5.—A short-wave regenerative receiving set, comprising a loose-coupler, two variometers, a vacuum-tube holder, and a rheostat for the vacuum-tube filament. Note the rotary adjustments of this set, which typifies the present high-grade amateur apparatus.

Representative instruments now being used by advanced radio amateurs and experimenters

but it is well here to touch briefly upon the subject in connection with advanced receiving apparatus.

VACUUM TUBES AS DETECTORS.

There are two general types of vacuum tubes in common use for detecting radio signals, namely, the two- and the three-valve tubes. The two-valve, sometimes called the Fleming valve, is an earlier form containing an incandescent filament and an electrode or plate. Normally, when the filament is cold, no current can flow between the electrode and the filament, or across the vacuum which separates them. But once the filament is heated it is possible to pass current through the vacuum. The action of this and other forms of vacuum tube depends upon the fact that when a metal is heated in a vacuum, it gives off electrons into the surrounding space. As the electrons have a negative charge, the charge remaining on the metal is positive, therefore few of the electrons go very far, but are attracted back to the metal so that there is a kind of balance established between the outgoing and the returning electrons. When current is caused to flow between the two elements, however, a continuous flow of electrons

poses that interests us most. There are numerous vacuum tubes regularly used in receiving and amplifying signals, among them the DeForest, General Electric, Western Electric, Donle, Marconi, and others. However, so far as amateur use is concerned there is but one tube available, namely, the Marconi, at present.

A WORD ABOUT POST-BELLUM APPARATUS.

The calling of tens of thousands of wireless amateurs into the Army and Navy radio service has naturally had its result on amateur wireless in the United States. Thus, before the United States entered the war, the average wireless amateur was well satisfied with a crude wireless set. The tuning coil might be two feet long, hand-made, and provided with several crude sliders which sometimes made contact and sometimes did not. The condenser might be a set of crude plates sliding between an equally crude set of fixed ones. All in all, appearances counted for little, as might also be said of operating convenience.

But then when these same young men became acquainted with commercial apparatus, they soon forgot the old hand-made apparatus back home. And why not? If a man has been riding about in a cheap automobile and then suddenly is permitted to use a five-thousand dollar car for several months, it is to be

By moving the rotative coil it is possible to increase or decrease the inductance of the two coils, and thus change the inductance in a given circuit so as to tune a receiving set.

There is one disadvantage, however, that must be admitted about variometers when exclusively employed for tuning, namely, that the wave-length ratio of the receiver is only $2\frac{1}{2}$ to 1, and for tuning to a greater range it becomes necessary to use two variometers, one set of low inductance and one set of high, with a wave-length switch to cut in either set. The arrangement of the apparatus is shown in the first of the accompanying sketches.

The sliding secondary type of loose-coupler is not altogether out-of-date. However, the rotary coupling type is fast coming into use. In this instrument there are two coils, a fixed one and a rotative one, after the fashion of the variometer. The adjustment of the rotative coil can be determined at a glance by a calibrated scale on the handle of the instrument.

As for variable condensers, the rotary type remains in use, because its rotary action is in accordance with the ideals of today. However, the condensers are now made so that the capacity is in proportion to the rotation.

The old carbon button and other designs of microphones for amplifying signals have been abandoned

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Wiring scheme for using two variometers, one of low inductance and the other high

Regenerative set in which the tuning is done with loose-coupler, variometer and variable condenser

for the simpler vacuum tubes. The microphone amplifiers do not stop at amplifying signals but go right ahead and amplify external noises, so that little is gained. Today, however, compact audio frequency amplifying vacuum tubes are used with excellent results.

REGENERATIVE RECEIVING.

With the discovery of the regenerative action of vacuum tubes by Edwin Howard Armstrong, while experimenting with radio as a so-called amateur, came the big boom in radio communication as practiced by commercial, Governmental, and experimental interests.

The great discovery of Armstrong, who has served as Major in the U. S. Signal Corps in charge of radio research in the A. E. F., permits the use of one vacuum tube as an amplifier, detector, and oscillator at the same time, and thereby increases the sensitivity of the usual receiving station many times. This is done by using a few additional instruments and carefully connecting these in accordance with correct theories.

Major Armstrong discovered that the current flowing in the plate circuit of a three-electrode vacuum tube is oscillating in character and not a straight direct current, as was always taken for granted by scientists and experts in that particular branch of the wireless art. It was found that this oscillating plate current, which oscillated on the positive side only was in exact resonance with the incoming oscillation for which the receiving circuit was tuned. So it occurred to Armstrong that if he increased the amplitude of the oscillations in the plate circuit, he would get a louder response in the telephones. He accomplished this by coupling the plate circuit or output to the grid circuit or input, much after the fashion of placing a telephone receiver against a transmitter to produce a shrill note. This regenerative coupling produces amplified grid oscillations, which, by means of the grid, produce greater variations in the plate current, thus still further reinforcing the oscillations of the system. Simultaneously with this amplification the regular detecting action goes on, and the final signal in the telephones is not in proportion to the original signal strength, but is the final amplitude of the oscillations in the plate circuit.

There are two general methods by which a vacuum tube can be made to regenerate. First, an auxiliary coupling—either electromagnetic or electrostatic—can be used between the plate and the grid circuits, whereby the energy of the plate circuit oscillations may be fed

back to reinforce the grid circuit oscillations. Secondly, placing an inductance coil in the plate circuit of a simple tube receiver and so adjusting it with respect to the capacity of the vacuum tube that the plate circuit becomes resonant. When this condition is approximated the high frequency oscillations in the plate circuit react on the grid circuit through the medium of the coupling of the vacuum tube, thereby greatly increasing the strength of the grid current.

The second method is particularly suitable for the reception of short waves and therefore ideal for experimental radio communication, both because of the amplifying properties and because of the simplicity of adjustments. The accompanying diagrams show a regenerative circuit embodying an electromagnetic coupling for simultaneously amplifying and rectifying received signals, and a regenerative circuit using an electrostatic coupling.

Inasmuch as the vacuum tube is a voltage-operated device, the best results are obtained with a small condenser and large inductance in the grid or secondary circuit; in fact, a condenser can be dispensed with and

Typical variometer, showing exterior and interior construction

the tuning accomplished entirely by means of the distributed capacity of the coils and the capacity of the tube.

In order to eliminate dead ends and obtain the highest efficiency, the grid and plate inductances must be continuously variable. They are best made in the form known as variometers, already referred to, and used in the manner shown in the fourth sketch.

Whether to use separate instruments or complete receiving sets is a question that varies with the requirements of every radio amateur and experimenter. For those who simply wish to receive signals, the complete receivers are no doubt most applicable. But in instances where experimentation is to be carried on, with all manner of circuits for determining how best to receive signals, the amateur and experimenter should turn to the so-called unit instruments, or separate pieces which can be "hooked up" to suit himself.

Among the better types of complete receivers now available are the short-wave and long-wave regenerative sets the description of which is left to the next installment, for lack of space in this issue. Amplifiers will also be described at length in the next installment, particularly those whose wiring is most ingenious and whose operation is of the simplest. A later chapter is devoted to the subject of vacuum tubes and their characteristics.

Proposed Hydraulic Experiment

IN an early paper (1850) Stokes showed "that in the case of a homogeneous incompressible fluid, whenever $u dx + v dy + w dz$ is an exact differential, not only are the ordinary equations of fluid motion satisfied, but the equations obtained when friction is taken into account are satisfied likewise. It is only the equations of condition which belong to the boundaries of the fluid that are violated." In order to satisfy these also, it is only necessary to suppose that every part of the solid boundaries is made to move with the velocity which the fluid in irrotational motion would there assume. There is no difficulty in the supposition itself; but the only case in which it could be readily carried into effect with tolerable completeness is for the two-dimensional motion of fluid between coaxial cylinders, themselves made to rotate in the same direction with circumferential velocities which are inversely as the radii. Experiments upon these lines, but apparently not quite satisfying the above conditions, have been made by Couette and Mallock. It would appear that, except at low velocities, the simple steady motion becomes unstable.

But the point of greatest interest is not touched in the above example. It arises when fluid passing along a uniform or contracting pipe, or channel, arrives at a place where the pipe expands. It is known that if the expansion be sufficiently gradual, the fluid generally speaking follows the walls, or, as it is often expressed, the pipe flows *full*; and the loss of velocity accompanying the increased section is represented by an augmentation of pressure, approximately according to Bernoulli's law. On the other hand, if in order to effect the conversion of velocity into pressure more rapidly, the expansion be made too violently, the fluid refuses to follow the walls, eddies result, and mechanical energy is lost by fluid friction. According to W. Froude's generally accepted view, the explanation is to be sought in the loss of velocity near the walls in consequence of fluid friction, which is such that the fluid in question is unable to penetrate into what should be the regions of higher pressure beyond.

It would be a difficult matter to satisfy the necessary conditions for the walls of an expanding channel, as the travelling bands of which the walls would be constituted should assume different velocities at different parts of their course. But, as a rough approximation, two wheels revolving in opposite directions are suggested in the hope some one will make the test.—RAYLEIGH (*Phil. Mag.*)

Regenerative circuit using electromagnetic coupling

Regenerative circuit using electrostatic coupling