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Radio Control Systems

PART I

By the Engineering Department, Aerovox Corporation

WHILE the use of radiant energy to propel, control, or phase distantly-located mechanisms is still regarded in certain quarters as a somewhat nebulous art, earnest investigators are daily applying radio signals to the operation of remote typewriters, full-sized and model vehicles, switchgear, alarms, and the like. They are ardently devising methods for reducing mischief from interfering signals and atmospheric electricity. During the past twenty years, these pioneers have demonstrated the full control of vehicles ranging from miniature airplanes and boats to a full-sized vessel sailing without crew.

It is probably because the field is not yet sufficiently crystallized to warrant exclusive frequency allocations for radio control purposes that many experimenters have abandoned the ether almost entirely, ingeniously adapting their systems to "wired wireless" use. Some of the wire-carrier schemes have demonstrated their practicability in certain industries, notably the power transmission field. Telemetering and remote switch operation have been accomplished with a modicum of success. Power companies are employing carrier currents to switch on home heating plants during off-peak periods, and in the control of street lighting. We may well regard present industrial applications of wire-carrier control as definite offshoots of the primordial impulse to effect control through the air.

This country's patent literature on radio control is already voluminous and enlightening to examine. Dating back to the early days of wireless, it is found to be punctuated with celebrated names. To review the entire progress of the art would require several volumes. We take due cognizance of our space limitations in presenting a resumé of systems and circuits for radio control, and have accordingly selected for presentation here certain schemes which tend to depict the advancement of the art. This digest should provide a cursory view of the field, while at the same time stimulating the ingenuity and imagination of new devotees.

CARRIER-OPERATED SYSTEMS

Of first interest are the systems employed at receiving points to convert radio signals into the mechanical movements that will be used for propelling, controlling, or synchronizing purposes. The transmission of the signals is a subject more generally understood. Of receiving systems there are two main classes, those that are actuated by continuous-wave signals and those that are actuated by modulated signals. They will be discussed in the order just mentioned.

Figure 1 shows the simplest radio control receptor that has actually been applied to recorded experiments. A rudimentary detector, D, of the fixed crystal variety, rectifies c.w. signals picked up from the air by the antenna-ground circuit and selected by the conventional tuned circuit. Corresponding d.c. pulses are delivered to the sensitive relay, R, by the detector.

A sustained carrier from a transmitting station located within the

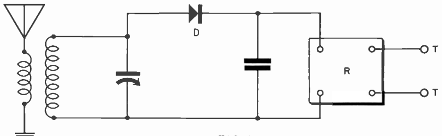

FIG. 1

limited range of such a receiver will produce a steady flow of direct current from the detector and maintain the relay closed. C.W. signals, produced by keying the carrier at the transmitting station, will make and break the relay at the keying rate. Thus, the relay becomes a local switch which may be opened and closed from a distant transmitting station.

The relay work contacts, T-T, may be connected to an external circuit (which may contain another auxiliary relay) in which may be accomplished the starting and stopping of motors; switching of radio equipment, lamps, beacons, bell or horn signals; steering operations and speed control in model vehicles; etc. If the transmitted carrier is keyed at the rate of one impulse per second by a master clock, a slave clock may be operated by the relay.

The relay, R, must be capable of operating at the tiny d.c. output of the crystal detector. Suitable relays designed to close at 15 microamperes or less are commercially available with the work contacts arranged to close either at zero or maximum deflection. Various amounts of power may be controlled by these devices, depending upon the weight of the work contacts, nature of the load, and whether alternating or direct current is employed in the work circuit.

The receptor shown in Figures 1 and 2, while designed for pure carrier wave operation, will not be adversely affected by modulation on the carrier if the current delivered by the detector is slightly in excess of the minimum value required to actuate the relay. The frequency of the carrier wave is immaterial, it being only necessary to design the receiver tuned circuit to resonate at the frequency employed.

Figure 2 shows a variation of the first circuit. In this instance, a fixed capacitor, C has been interposed in the d.c. circuit between the detector

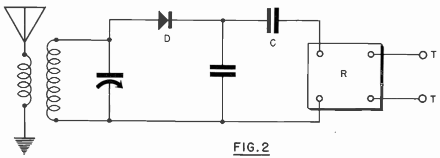

FIG. 2

and relay. The relay is able, as a result, to close momentarily only during the short interval when charging current flows into the capacitor. It is released immediately thereafter. A sustained carrier will not maintain the relay closed. The circuit of Figure 2 was employed in early experiments with slave clocks to obtain the positive action of the pawl-and-ratchet movements afforded by the quick d.c. pulse.

The usefulness of the simple circuits of Figures 1 and 2 is limited by the notorious instability and insensitivity of the crystal detector. Because attenuation of the carrier wave is very rapid as the distance between transmitter and receiver is increased, it becomes difficult to maintain the minimum relay current except comparatively nearby. These circuits are readily affected by atmospheric electricity, the direct current delivered to the relay by heavy static often tremendously exceeding its minimum operating current. Crystal detectors are exceedingly fragile, particularly when adjusted for maximum response to weak signals, and are unable to withstand mechanical shock, heavy static, and excessively strong signals.

The inadequacy of the simple detector has made the use of vacuum tubes obligatory in radio control receivers. This is unfortunate because the power supplies necessary for tube operation are bulky. Batteries, while permitting operation apart from power lines, introduce, along with the tubes themselves, a troublesome replacement factor. Simplicity is generally desired in radio control systems, hence it is usually desirable to employ as few tubes as possible. Some applications, however, will permit the use of elaborate receiving equipment such as a superheterodyne.

Figures 3, 4, and 5 show vacuum-tube arrangements in which the same action may be obtained as was just described for the simple receptor. These schemes possess stability, as well as sensitivity many hundred times greater than that afforded by rudimentary detectors. Operation at considerably greater distances from the transmitter and general reliability are achieved by the electron tube.

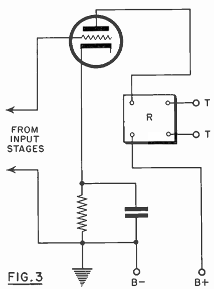

FIG. 3

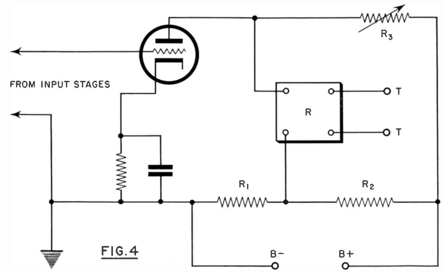

FIG. 4

In Figure 3, the relay is placed directly in the plate circuit of an appropriate receiver stage. This might be the plate or cathode circuit of a superheterodyne second detector or the plate circuit of an r.f. amplifier so biased that a plate current change occurs on application of the signal. If the nature of the amplifier is such that the signal voltage decreases the direct plate current, the relay would be of the zero-action type. If, on the other hand, plate current increases with the signal, the relay contacts would be arranged to close at maximum deflection. Suitable relays may be obtained to operate in either direction or on plate-current increments of a number of varieties.

It is readily seen that a relay employed in the circuits of Figures 3, 4, or 5 need not be so expensive and sensitive as the one employed in the simple receiver, since the tube plate current will be in milliamperes instead of microamperes.

Unless a special relay is used in Figure 3, it will be subject to the normal steady flow of direct plate current and will remain deflected. This is permissible if relay action is to be obtained by a downward deflection of plate current. If, instead, an upward change in current is to actuate the relay, the instrument will have to be rated somewhat higher than the normal plate current of the tube, otherwise the working contacts will be very nearly, if not entirely, closed at all times. This difficulty may be offset by employing the circuit of Figure 4, wherein the relay is connected in a bridge circuit, one leg of which is the tube plate resistance. The bridge is initially balanced to zero by adjustment of one of its legs, R_3, made variable for that purpose. The steady plate current is then removed from the relay which will not be actuated until a signal is applied to the tube grid.

Figure 5 shows a super-regenerative receiver circuit which has been employed very successfully by amateurs in the control of model airplanes. Comprising only one tube, small batteries, and the small components required for ultra-high-frequency operation, the entire device is small and light. In actual practice a separate receiver of this type is used for each flying operation—control of rudder, elevators, etc.

The triode tube is a special dry-cell operated gas-filled type which permits a reasonably large plate-current swing with relatively small signal voltage. The use of super-regeneration results in good sensitivity as well as immunity from the interfering signal pulses normally received from ignition systems, etc.

The plate-current deflection obtained in this circuit is downward and of the order of 1 milliampere. A suitable relay is about the size of a pocket watch and inexpensive.

It is apparent that with any of the systems shown in this article, a separate receiver and separate transmitter frequency would be required for each control operation to be performed. If elaborate control is anticipated, the number of separate circuits and wave channels might soon become prodigious. This would certainly not be a step in the proper direction, since it would not be advisable to have too many of the already scarce radio channels tied up for such a service if such service should ever be considered by the licensing authorities. The number of channels and receivers for the operation of a typewriter, for example, would total very nearly one hundred.

It would be nearer ideal to employ a single transmitter frequency and modulate it at various audio frequencies, arranging a *single* receiver to pick up all the transmissions and automatically utilize them for the accomplishment of the intended purposes.

The fundamental principles underlying operation of such control devices which make use of modulated signals, rather than pure carrier waves, will be discussed in the *June Research Worker*.

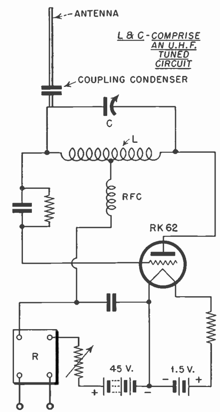

FIG. 5