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Radio Control Circuits

PART II

By the Engineering Department, Aerovox Corporation

IT was shown in last month's article that a separate wavelength is required for each control operation in a carrier-actuated radio control system. Where a number of operations must be performed it becomes necessary to operate the control transmitter throughout a frequency band of inordinate width. A cumbersome array of receivers is also demanded.

A single carrier frequency may be employed, with the advantage of one transmitter and receiver, if the function of control is delegated to superimposed audio frequencies rather than to the carrier wave. It is a relatively simple matter to modulate the control transmitter carrier successively at a number of closely-spaced tones. To each of these modulation frequencies may be assigned a particular control operation. And at the receiving point tone-controlled relays, filter circuits, or comparable devices may utilize the proper audio-frequency components in the demodulator output to translate radio signals into remote mechanical motion.

The number of control operations possible with a modulated signal system is limited only by number of modulating frequencies available and the audio selectivity of the frequency-controlled devices at the receiving point. The actual system selected from the

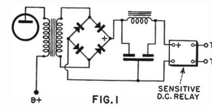


FIG. I

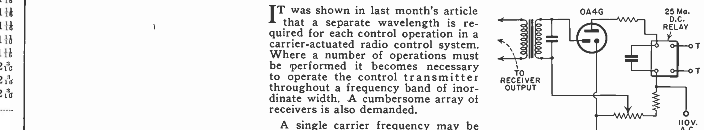


FIG. 2

number of successful ones available will depend largely upon the nature of the application, space and weight requirements for receiving and control equipment, and whether the application is experimental or commercial.

The tone-controlled system is advantageous even in cases where a single modulation frequency is employed. The receiving equipment is responsive to only one tone, which may be changed from time to time according to pre-scheduled arrangement to sidestep pranksters, and is not affected by stray carriers and most forms of electrical interference.

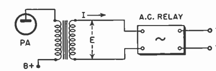
Most tone-controlled radio systems do not lend themselves readily to applications where extreme lightness of weight is a prime essential. This is because the selective audio-frequency equipment is generally composed either of heavy wave filters, tone-controlled relays and auxiliary relays, alternating current relays, or the like. And, in general, such equipment requires a reasonable amount of power for operation, entailing the use of power amplifiers and sizable power supplies. Consequently, serious experimentation with this system is apt to be found where bulky standard receiving equipment can be maintained, not in model control.

The audio-frequency component of signal voltage is utilized at the receiving point in this system. So it is immaterial whether the control transmitter is amplitude modulated or frequency modulated. It is not the purpose of this article to discuss the method of superimposing the tone upon the carrier, but rather to describe as fully as space will permit some of the practical circuits that make use of modulated control signals.

PRACTICAL ARRANGEMENTS

The simplest arrangements for utilizing single-tone control signals are shown in Figures 1 to 5. With a few modifications, as will be explained, these circuits may be elaborated upon for multi-frequency operation.

In Figure 1, the sensitive d. c. milliampere relay described in last month's article has been inserted into the output circuit of a suitable radio receiver. Since the relay, a direct-current device, is to be actuated by the audio-frequency component of the demodulated signal voltage, the rectifier, *R* has been inserted to remove the negative half-



RATINGS OF PA AND TRANSFORMER MUST BE SUFFICIENT TO SUPPLY E and I REQUIRED BY RELAY

FIG. 3

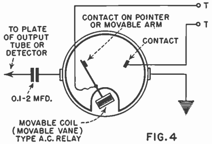


FIG. 4

cycles, and the filter, *F* to smooth out the ripple in the rectifier output. The relay contacts, *T-T* are connected in an auxiliary relay circuit, unless the application is sufficiently light to be handled directly by the contacts, *T-T*.

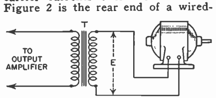
Since the relay has considerable sensitivity, it is likely that the receiver need not be equipped with a power amplifier, the transformer and rectifier being connected directly to the plate of the detector tube. If a power amplifier is employed, it may be operated at a low, economical level.

The arrangement shown in Figure 1 is not immune to interference, having as it does the ability to close the relay on interfering signals of short duration, such as static or carrier interruptions. The arrangement may be restricted, however, to applications which require that the relay contacts be closed for a definite long interval before a control operation is completed.

One manufacturer of sensitive watch-case type milliampere relays has made available a companion plug-in, full-wave oxide rectifier, delivering 15 milliamperes maximum d. c. when operated at 8 volts RMS. He recommends the use of the rectifier in conjunction with an ultra-sensitive relay, as indicated in Figure 1, but without filter.

The use of the OA4G grid glow tube in conjunction with a 25-milliampere d. c. relay, in a system that employs the audio signal from a receiver, is shown in Figure 2. This circuit has met with the approval of a number of fanciers of wire-control systems who are attracted by the small signal which will trigger off the OA4G and the fact that that tube has no filament.

The tube is operated directly from the 110-volt 60-cycle a. c. line and in most applications is triggered by a simple one-tube receiver which receives carrier currents over the same line. Figure 2 is the rear end of a wired-



1-10-watt sync. motor for signal frequency.
E = voltage required by motor.
T removes d.c. component from amplifier plate current and provides voltage step-up if required.

FIG. 5

wireless system very popular with amateurs who remote-control their transmitters.

Figure 3 shows an alternating-current relay operated directly by the a. c. component of power amplifier plate current. This type of relay is provided with a shading coil which prevents chattering of the armature or contacts. It may be obtained with heavy contacts that will close a sizable work circuit directly.

The a. c. relay is normally supplied for 60-cycle operation. For the arrangement shown in Figure 3, the control transmitter may be modulated at 60 cycles for such a relay, although various experimenters have reported that little difficulty is experienced as the selected frequency swings over a narrow band.

Figure 4 shows a variation of the preceding circuit. Here a meter type of relay is substituted for the coil and armature type. This particular type of relay operates exactly like an a. c. voltmeter which has the travelling contact attached to the movable coil or iron vane. Such relays are frequently constructed directly from a. c. voltmeters by experimenters and from time to time are offered by certain manufacturers. The receiver connections will be recognized as those of the standard output meter.

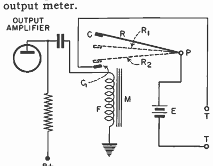


FIG. 6

The use of a tone signal for the propulsion of a small synchronous motor for various purposes is illustrated in Figure 5. Here the motor is connected directly to the secondary winding of the output transformer in the receiver power amplifier stage. The power amplifier must be capable of supplying through the transformer the power required by the motor, and the secondary winding must be capable of supplying the motor voltage.

Such an arrangement has been used to carry continuous correct time electrically into remote localities where alternating current is not available. The motor in this application has been the 1-watt type incorporated in a standard electric clock.

The same arrangement has been used to drive a cam switch for the production of an intermittent impulse or delayed control action, which depends upon rotation of a contact arm over an arc.

Figure 6 shows the simplest tone-controlled relay for radio control work. *F* and *M* are respectively the coil and core of an electromagnet connected in the plate circuit of the receiver power amplifier. The blocking condenser and plate resistor may or may not be employed, depending upon whether *M* is a permanent magnet. Suspended above the core and attached firmly to the point, *P* is a thin reed, *R*, made of steel or some similar magnetic substance, which is provided with a contact, *C*.

When an alternating component of signal voltage is passing through the plate circuit, an alternating magnetic field will be set up about the core, *M* and the reed will be set into vibration. The reed will vibrate at its maximum amplitude, such as to the position, R_2, however, when the signal frequency is such as to correspond to its natural frequency of vibration determined by its length and thickness. At other neighboring frequencies, it will vibrate over a narrower range, such as R_1. This will be recognized at once as the principle made use of in the vibrating-reed frequency meter.

If a second contact, C_1 is placed at such a distance from the contact on the reed tip that the latter reaches it only during vibrations of maximum amplitude, the reed, *R*; contact C_1; battery, *E*; and contacts, *T-T* will establish a relay circuit which will be closed only when the reed is actuated by its natural frequency. The result will be a simple tone-controlled relay.

The obvious drawback of the reed-type relay shown lies in the intermittent nature of its contact. But this disadvantage may in most cases be offset by employing a high signal frequency, with the result that high contact resistance remains as a lone cause for consideration. And this may be compensated for in the use of a higher battery voltage and slower auxiliary relay.

Figure 7 shows a multiple-frequency tone-controlled relay of British origin. Several reeds responsive to different frequencies are secured to the end of the magnet core; contacts, such as *C* in Figure 6, being attached to their free tips. The magnet winding is con-

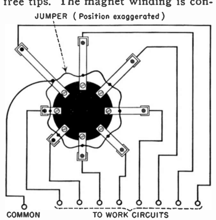


FIG. 7

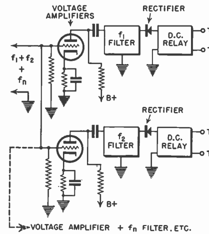


FIG. 8

nected in the power amplifier plate circuit through which passes the various signal tones.

Each reed will go into vibration at its maximum amplitude and close its contacts when the appropriate signal tone is delivered by the receiver, and only one receiver and amplifier are required for this arrangement.

It is entirely possible in a highly stationary installation to interpose suitable complex wave filters in a receiver circuit, such as shown in Figure 8, in order to select and divert certain control signals of predetermined audio frequency into the proper channels where they will undergo rectification and actuate relays in local work circuits. The filters employed would be of the band pass type.

A means for conveying certain types of intelligence over distances is shown in Figure 9. The usual loudspeaker of the receiving set is supplanted by an indicating audio-frequency meter which is graduated to read in whatever units the intelligence concerns. At the transmitting station, means need only be provided to change the modulating frequency in predetermined steps or at a continuous rate. Thus, a distant thermometer, electrical meter, or steam gauge might cause changes in the tuning condenser of a modulating audio oscillator by some satisfactory method. While the receiver audio-frequency meter scale might be graduated in degrees, pounds pressure, amperes, or similar units.

MULTIPLE CLOSURE SYSTEMS

Increased privacy and certainty in the operation of certain stationary radio control systems may be obtained

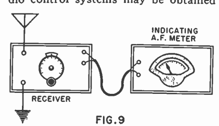


FIG. 9

with schemes which require that a number of intermediate operations be completed before the final control operation is possible. Such schemes are analagous to the operation of a safe combination. The speed with which a multiple closure operation of this type may be completed will depend upon the number of dependent steps and the electromechanical details of the system. Multiple closure signals of both unmodulated and modulated character are frequently transmitted with the aid of a telephone dial arrangement.

Figure 10 shows a simple arrangement which requires the transmission of a predetermined number of signal pulses before the remote switch is closed.

The electromechanical essential of the system is the pawl-and-ratchet movement, *P, R*, which is actuated by the electromagnet, *M*. Modulated signal pulses are delivered by a receiver to the rectifier-filter, *R-F*, and the resulting d. c. impulses are passed from *R-F* to the magnet. At each pulse, the pawl advances the ratchet wheel one notch, moving the rotating switch arm, *S*, over the arc *D-D'*. When a sufficient number of pulses have been received, the arm will have rotated over enough

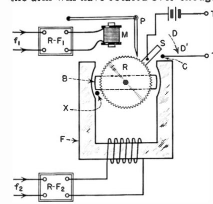


FIG. 10

of an arc to make contact with the stationary terminal, *C*, and close the local battery circuit to the work terminals, *T-T*.

In order to reset the switch arm for a subsequent repetition of the sequence, the iron or steel rotor, *B*, and the field magnet, *F*, have been provided. When the arm has advanced over its full arc, the rotor, *B*, will assume an angular position between the field magnet poles. If then a reset signal on a second tone frequency, f_2, is delivered to a second rectifier-filter, *R-F_2*, the field magnet will become energized, drawing the rotor back to the horizontal position against the stop, *X* and returning the ratchet wheel and switch arm to their initial position.

This simple multiple closure system may be further elaborated upon as shown in Figure 11 by providing an auxiliary signal solely to close the local work circuit after the "lock-closing" sequence has been completed.

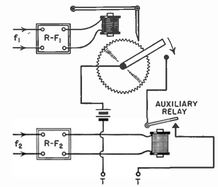


FIG. 11

This auxiliary signal of tone frequency f_3 is delivered to an independent rectifier-filter combination, *R-F_3* to actuate the relay, *R*, in the remote work circuit. Actually, three tone signals would be required for the scheme of Figure 11, since the reset mechanism described in connection with Figure 10 has been omitted from the illustration for purposes of clarity. The extra signal would be the reset impulse.

Figure 12 shows an arrangement in which the rotating switch arm has been replaced by a rotating blade contact of arc shape. The action of the pawl and ratchet causes this blade to make contact progressively with more contacts as its rotation advances, all contacts eventually becoming short-circuited by the blade. The result is effectively to supply grounds to several circuits which may either be separate or interconnected. As in the schemes of Figures 10 and 11, a second tone signal operates a reset mechanism. Figure 12 may be complicated still further by adding the auxiliary relay shown in Figure 11.

Suitable cam or gear mechanisms may replace the simple pawl-and-ratchet movements shown in the last three illustrations. The user's ingenuity will largely determine the actual details of the devices for carrying out the multiple closure scheme. The scheme of Figure 12 may be expanded very simply into that of the dial telephone system with its stepping switch, stepping magnet, and release magnet.

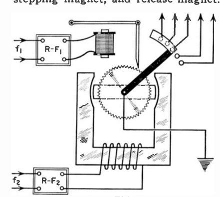


FIG. 12