Radio Control of Model Aircraft

Details of a Simple System Adaptable to Any Unmanned Mobile Unit

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Here is another field in which the ham is destined to play a big part. At first glance the controlling of models by radio is not ham radio as we ordinarily understand it. On second glance, though, it becomes a perfect legitimate ham activity and one to which the amateur falls heir because he alone (aside from scientific institutions with experimental licenses) is privileged to do the transmission. The game is as chock full of problems as it is of thrills and it will be interesting to see just how far we can get in a year or two of activity. The work reported here was done exclusively with a model sailplane. It was simplified by the absence of ignition interference but enormously complicated by the absolute need for precise control from the first moment. The same technique applied to gas airplane models should serve to offset the present steady growth of legislation against their use in free and uncontrolled flight.—**EDITOR**

THE application of ham radio in the operation of controlled model boats, airplanes and autos has received relatively little attention to date. But it must be said that those individuals who have played with radio control of models invariably reveal a tremendous enthusiasm for their game. During the last few years, coinciding with the development of successful gasoline-engine-driven model airplanes, we have seen a steady climb in the interest in the subject and have been called upon quite frequently for details of a practical system.

Most hams are usually far from being one-hobby men and one discovers, almost invariably, an interest in the other sciences and the crafts. A common interest in ham radio, aeronautics, model building and photography, is almost the rule. We happen to be built that way and our interest in aircraft led us, this summer, to take an active interest in this problem of radio control. Fortunately, just as our interests really blossomed, we were able to take a brief trip to the soaring contest at Elmira, New York, and found (amongst the usual array of interesting things) a radio-controlled model sailplane, built by Carl W. Thompson, Jr., of Wilmington, and equipped with radio gear by H. M. Plummer, W3DIA. The ship was arranged to fly ordinarily with right rudder and the armature of an old-time sounder operated from the receiver served to give an alternative left rudder. The ship made several successful hops with the control working but an untimely crackup ended the experiment. We were fortunate enough to be able to acquire the remains and so, on our return to Hartford, were able to go right ahead with an attempt at the control problem. Since that time we have had more than a hundred flights (with some fifteen severe crackups!) and the whole equipment has been rebuilt and rebuilt until substantially nothing is left of the original. But if anyone thinks that the program was tedious work, they're crazy! We have had our full share of thrills in this ham game but the business of controlling a dizzy airplane galloping across the sky has set a new all-time high for sheer fun.

Photo Courtesy Hartford Courant

THE EXPERIMENTAL RADIO-CONTROLLED SAILPLANE IN FULL FLIGHT

Flying an elongated figure-of-eight course above the soaring ridge presents few real difficulties once the ship is in the clear. Tree-dodging is another business! The model is 13 feet span; weighs 10 pounds complete.

THE PROBLEM

A casual glance at the problem would lead anyone to imagine that it is all a perfectly simple business. All one needs is some sort of receiver that produces enough change in the plate current of an output tube to operate a relay of some kind, the relay then being connected to a control device which produces the necessary effect. Closer examination, however, reveals a host of problems which are juicy morsels for any

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experimentally inclined ham. We have solved a few of them, temporarily at any rate, but it must be said emphatically that the scheme to be outlined is the result of a first try. Our only hope is to open the subject wide in the knowledge that a few hundred of us hammering at the same objective will have the problem really licked in short time.

The basic method which has been widely used for model control is that of a selector switch similar to the affair found in automatic telephone installations. It is a gadget which closes one of a series of circuits, depending on the number of pulses transmitted. The circuit so closed is then caused to operate a reversible electric motor or some such device for producing the movement of the control element. This type of equipment has not been used with any appreciable success in model airplane work due, we believe, to its inherent complexity and to the necessity of carrying considerable weight in the batteries for motive power.

A brief study of the subject showed at once that the results were prone to be in inverse proportion to the complexities of the equipment and it became obvious that some extremely simple system was called for. So we ruled out the selector switch and started from the bottom.

HITTING AT SIMPLICITY

Having had earlier experience with the effectiveness and efficiency of rubber band motors, we decided to use one to supply the power for control. With a motor four or five feet long we knew that we could "charge" the thing with at least 1000 turns and obviously this would serve for several thousand control motions. The only problem then was to provide some means of triggering off this rubber power and connecting it to the control surface. A further preliminary decision was to use a single control surface only and the logical decision was to use rudder. It was obvious that any reasonably stable plane could look after itself longitudinally. The only basic need was to keep the machine flying in any desired horizontal direction. Anyway, after much fiddling, we ended up with the device shown in Fig. 1—a simple escapement driven by the rubber motor and controlled by a electro-magnet operated in turn from the output tube of the receiver. As can be seen from the sketch, the transmission of a series of dots would result in step-by-step rotation of the escapement and swinging of the rudder from left to right. It was simply a matter of transmitting the desired number of pulses in order to acquire the correct rudder setting. The chief disadvantage of this simple scheme seemed to be that the rudder positions were all in a continuous sequence and that once the rudder had been in the left position and had then been centralized it was possible to get back to left rudder again only by passing through right and center rudder. In actual practice this weakness proved to be of little consequence just as soon as we had equipped an appropriate ground control system. It then became possible to whip through the undesired but necessary positions in a fraction of a second without causing more than a slight flicker in the flight path. But there were more problems to come.

THE RECEIVER

We had left the receiver itself for the last feeling that it would certainly be a cinch. Actually it took about a week of evenings to get a two-tube receiver that would perform with any degree of satisfaction. Even then we had to break down and admit that three tubes were really called for if all the desirable features were to be had. We cannot help feeling that this part of the job is just started. Surely there must be some way of building a simple one-tube receiver capable of operating an inexpensive relay! Fortunately, even the three-tube receiver came well within our weight limit. This sailplane was capable of carrying at least five pounds. Without even trying hard we ended up with a complete receiver, power supply and control system that weighed slightly less than three pounds. With some refinements even the present setup could be pulled down to 2½ pounds—a figure within reason even for single-engine models.

Some of the earlier control systems made use of the beat produced by an autodyne receiver to actuate the control tube—the frequency usually being on the 3.5-Mc. band. This procedure we ruled out at once as a result of practical experience in attempting to obtain a sufficiently stable beat. Since it was futile to control the model without being able to see it and since we were aiming at the utmost simplicity we decided to use the 56-Mc. band. There were two alternatives available—to use a continuous carrier with pulses of tone to operate the relay or to permit the characteristic rush noise of a superregenerative detector to keep the relay open, then applying pulses of carrier to close it. It works out that the former scheme will allow a simpler receiver but that the latter method is infinitely preferable because of the negligible interference which its operation causes. Fig. 2 shows the two-tube receiver with which successful operation may be had if pulses of tone are used on a continuous transmitted carrier. The first part of this circuit is a simple superregenerative detector using a 30 tube and fitted with a simple filter for the quench voltage. The output tube is a 1F4—chosen because of its high mutual conductance. The grid condenser and leak in its grid circuit allow the tone voltage to develop a negative grid bias and so produce a plate current change from about 2 to 0.5 ma. This method of obtaining a plate current change has so far proved infinitely preferable to the use of fixed bias with the tube normally operating almost at cutoff. But the 1F4 is the only tube we have met so far that will do the job. The total filament current of the set is 0.18 ampere and the plate current when idling about 3 milliamperes. This should allow a B-battery life of at least a couple of hundred hours even with the very smallest batteries available. The life of a pair of flashlight cells for the filaments will probably not be more than half a day of continuous operation but it will be 20¢ well spent.

The apparatus in such a receiver, as we will later indicate, should be mounted on a small piece of plywood. The gear may be packed on the base in almost any fashion, the only requirement being that everything be attached very sturdily and that tubes be placed where they cannot bump elbows with each other or with the audio transformer. A vernier dial was found unnecessary providing a 6-inch extension rod (a piece of balsa wood) was used for tuning. No particular difficulty should be had in adjusting the superregenerative detector though failure to superregenerate or a desire to howl may have to be cured by a change in the value of the grid leak or in the setting of the tap on L_1. The length of the antenna and the size of the coupling condenser C_5 will also have some effect in these respects.

An antenna not more than two or three feet long should be adequate, while C_5 can have its plates bent until the capacity between them would seem to be zero. The placement of the antenna appears to be of very little consequence. We used a piece of No. 28 wire taped to the outer covering of the fuselage.

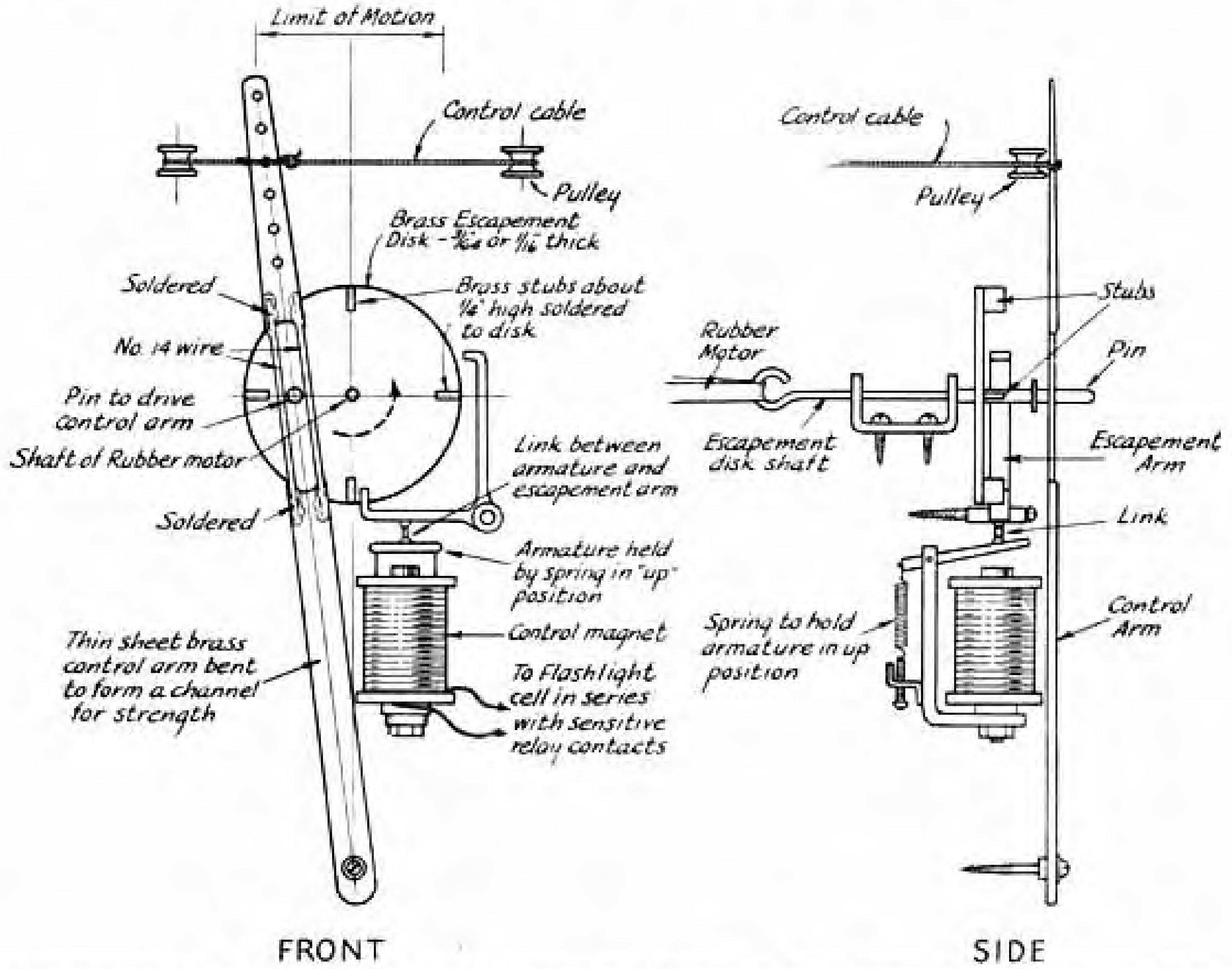

FIG. 1—THE EXPERIMENTAL ESCAPEMENT USED TO CONVERT THE RUBBER-BAND MOTOR TORQUE INTO RUDDER MOTIONS

The escapement disc, turning clockwise in this case, is driven by four strands of one-quarter-inch model airplane rubber. The rotation is limited to steps of a quarter turn by the escapement arm controlled by the electro-magnet connected in series with the sensitive relay in the output of the receiver. The crank pin on the escapement disc carries the control arm from left to center to right, in accordance with its position. No details of the mounting of these components to the bulkhead in the fuselage are given because they will be varied to suit each individual case.

THE THREE-TUBE MODEL

The business of leaving a carrier running did not appeal to us at all. It was decided to add three or four ounces to the receiver and include the third tube found to be necessary when the pulses were to be carrier only. Fig. 3 shows the complete circuit of this receiver. The detector tube is again a 30 in a superregenerative circuit of slightly different type from that shown in the two-tube receiver. The detector circuits are actually interchangeable in the two receivers. It just so happens that the arrangement shown in Fig. 3 gave us rather better freedom from howling than the previous ones when the extra tube was added. It will be noted that the grid leak runs to positive high voltage in both receivers. This connection seems to iron out some of the howling difficulties and results in smoother operation. The 1B5 was chosen because of its high amplification factor and is considerably better than the 30 as the intermediate amplifier. It will be seen that the diodes are not used though a very slight improvement in the operation of the output tube is found if one of the diodes is connected to the grid of the 1F4. This receiver need occupy very little more space than the two-tube model and, as far as we can see, is the more practical rig of the two. In its operation, the rush from the superregenerative detector

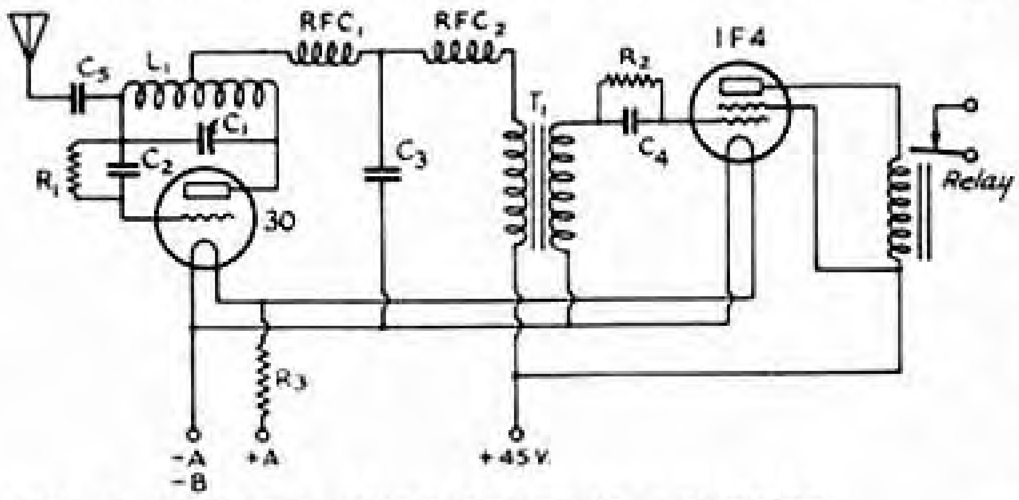

FIG. 2—THE TWO-TUBE CONTROL RECEIVER

C_1—17.5-μμfd. midget variable (Hammarlund HF-15). (Some of the larger types can't take it in a rough landing.)
C_2—100-μμfd. midget fixed condenser.
C_3—0.01-μfd. fixed mica condenser.
C_4—0.002-μfd. fixed mica condenser.
C_5—M-30 National padding condenser adjusted to its minimum setting.
R_1—1 to 5 megohm ½-watt resistor; experiment usually necessary.
R_2—2-megohm ½-watt.
R_3—5-ohm fixed resistor.
RFC_1—Ohmite u.h.f. choke.
RFC_2—Bud 125 millihenry choke.
L_1—8 turns No. 14 wire ½ inch diameter, turns spaced the wire diameter.
T_1—Any very small audio transformer. The one originally used is a push-pull affair with the whole secondary used.
The relay is an Eby Type ER12 with a 5000-ohm winding.

causes the plate current of the 1F4 to drop to about 0.6 ma. A transmitted pulse of carrier shuts off this rush noise, relieves the 1F4 from its negative grid bias and permits the plate current to rise to about 2 milliamperes. This change is ample to close the relay providing the tension spring is adjusted carefully. Naturally, the relay contacts are connected in opposite fashion in this receiver to those in the two-tube receiver. This model is almost as economical in operation as the simpler set. The plate current of the 1B5 is a small fraction of a milliampere, its filament drain 0.06 ampere. Because use is made of the rush noise from the detector it is important not to load the receiver with an antenna more than is absolutely essential. With this rig we are in the habit of operating without an antenna at all and still manage to get ample control signal at distances of a mile or so with a 30-watt transmitter. For our purposes this was sufficient.

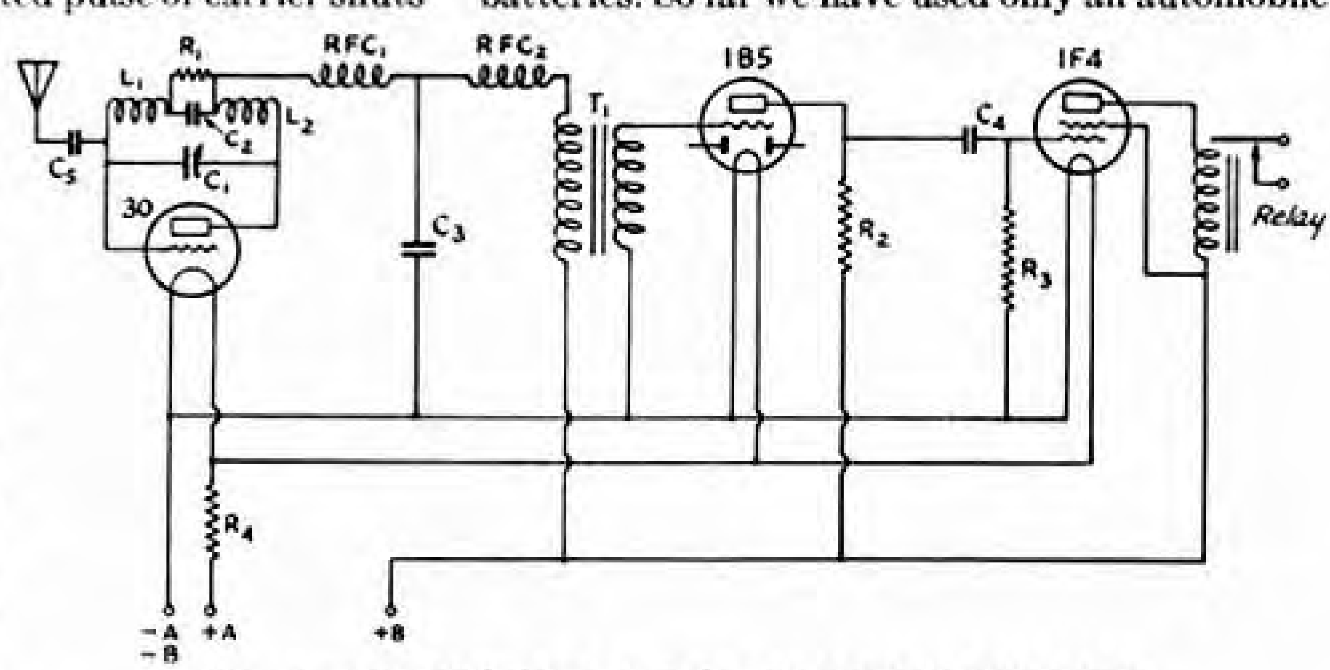

FIG. 3—THE CIRCUIT OF THE PREFERRED RECEIVER

C_1—17.5-μμfd. midget variable (Hammarlund HF-15).
C_2—100-μμfd. fixed condenser.
C_3—0.01-μfd. fixed mica.
C_4—0.01-μfd. fixed paper.
C_5—M-30 National mica padding condenser, with the upper plate bent at right angles to the lower.
R_1—1 or 2-megohm grid leak.
R_2—150,000-ohm, ½-watt fixed resistor.
R_3—2-megohm, ½-watt fixed resistor.
R_4—5-ohm fixed resistor.
RFC_1—Ohmite u.h.f. choke.
RFC_2—Bud 125 millihenry choke.
L_1, L_2—Each 4 turns No. 14 wire, ½-inch diameter.
The audio transformer and relay are the same as those described for Fig. 2.

BATTERIES

It is most fortunate that the battery manufacturers have been weight conscious in recent years, the modern midget "B" battery being really the key to the whole situation. In this work we have used two types—the Burgess W30BPX and the Eveready X203. Both of these weigh approximately 10 ounces and are capable of operating even the three-tube receiver for much more than a hundred hours. For the experimenter who insists on the absolute minimum of weight there is the Burgess W30FL weighing 8½ ounces and still capable of almost a hundred hours of service.

For filament and control magnet batteries we have used ordinary flashlight batteries exclusively. They have the merit of low cost and reasonably light weight and are, of course, available anywhere. The very small sizes could be used in cases where every gram counts.

THE TRANSMITTER PROBLEM

Because model aircraft or even model boats will usually be operated at points unavailable to power lines it is very desirable that the transmitter should be operated either from a 6-volt storage battery in an automobile or from dry batteries. So far we have used only an automobile transmitter. It consists of a pair of 45 tubes—with their filaments connected in series—in a simple fixed-tuned-grid tuned-plate circuit similar to that given on page 260 in the current *A.R.R.L. Amateur's Handbook*. A 6A6 or 6N7 tube would also serve the purpose admirably. We used the 45 tube simply because the rig was already available. We supplied plate voltage from a Mallory Vibropack giving 300 volts at 100 milliamperes but a pack of lower power or a set of B batteries would be quite satisfactory. When operating with carrier pulses alone the transmitter is, of course, a very simple affair. The use of tone pulses will require a modulator, the general nature of which can be decided very rapidly by anyone familiar with 56-Mc. work or anyone willing to glance through the *Handbook*. Personally, we are strong for the elimination of the tone business.

The transmitting antenna may be the usual fishpole affair or a half-wave antenna strung between bamboo poles. It may be fed either with a 72-ohm line to the center of the half-wave antenna or with a tuned line to one end. The problem of rigging this transmitter and adjusting the antenna until it is really doing some radiating will not be a problem at all to any present-day ham.

THE CONTROL STATION

First experiments were conducted with an ordinary key, the pulses being delivered in the necessary amounts in the usual fashion. This was a failure from the start. It was found almost impossible to remember in what position the rudder was supposed to be and several crackups resulting from a misunderstanding between the pilot and the plane caused us to develop some sort of control device. The first model was a 10-inch wooden control wheel with a vertical handle mounted near its rim. Contacts were attached to its under surface so that as the disc was rotated a complete revolution four pulses would be transmitted. A simple ratchet was attached underneath so that the disc could be turned in one direction only. Rotating this disc in a clockwise direction, and starting from a position with the handle at the center rear, produced right, center, left and again center rudder positions. The device still remains a very practical one for this type of control. The Bourne control rig illustrated is, however, our current favorite. It is basically a control stick fitted with a ratchet of such design that it will move to left, right, left, right and not in the reverse direction. Contacts are made as the control arm passes from the center to either side position.

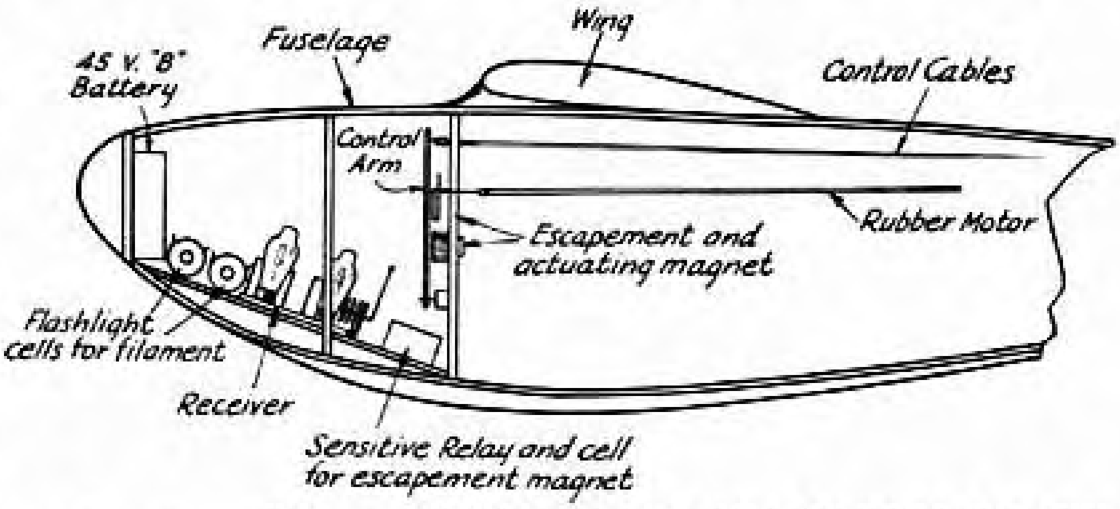

FIG. 4—SHOWING THE PLACEMENT OF THE EQUIPMENT IN THE FUSELAGE OF THE EXPERIMENTAL SAILPLANE

Having no engine to carry the center of gravity of the machine forward, the equipment is all placed ahead of the wing. With the gas-driven model, the gear would be grouped at the center of gravity and the actual arrangement would naturally be varied to suit the particular fuselage in which it is installed.

In practice these control gadgets are connected on the end of a few hundred feet of twisted pair and mounted on a tripod. In this fashion, the pilot is permitted to adjust his location to give the best possible view of the flight.

An alternative control scheme would be to use voice modulation at the transmitter in conjunction with a voice-controlled relay such as that described on page 348 of the current *Handbook* or in the November, 1936, issue of *QST*. With the time delay adjusted properly one could demand by voice "left" and the rudder would move to give that sort of turn. The words "now right"

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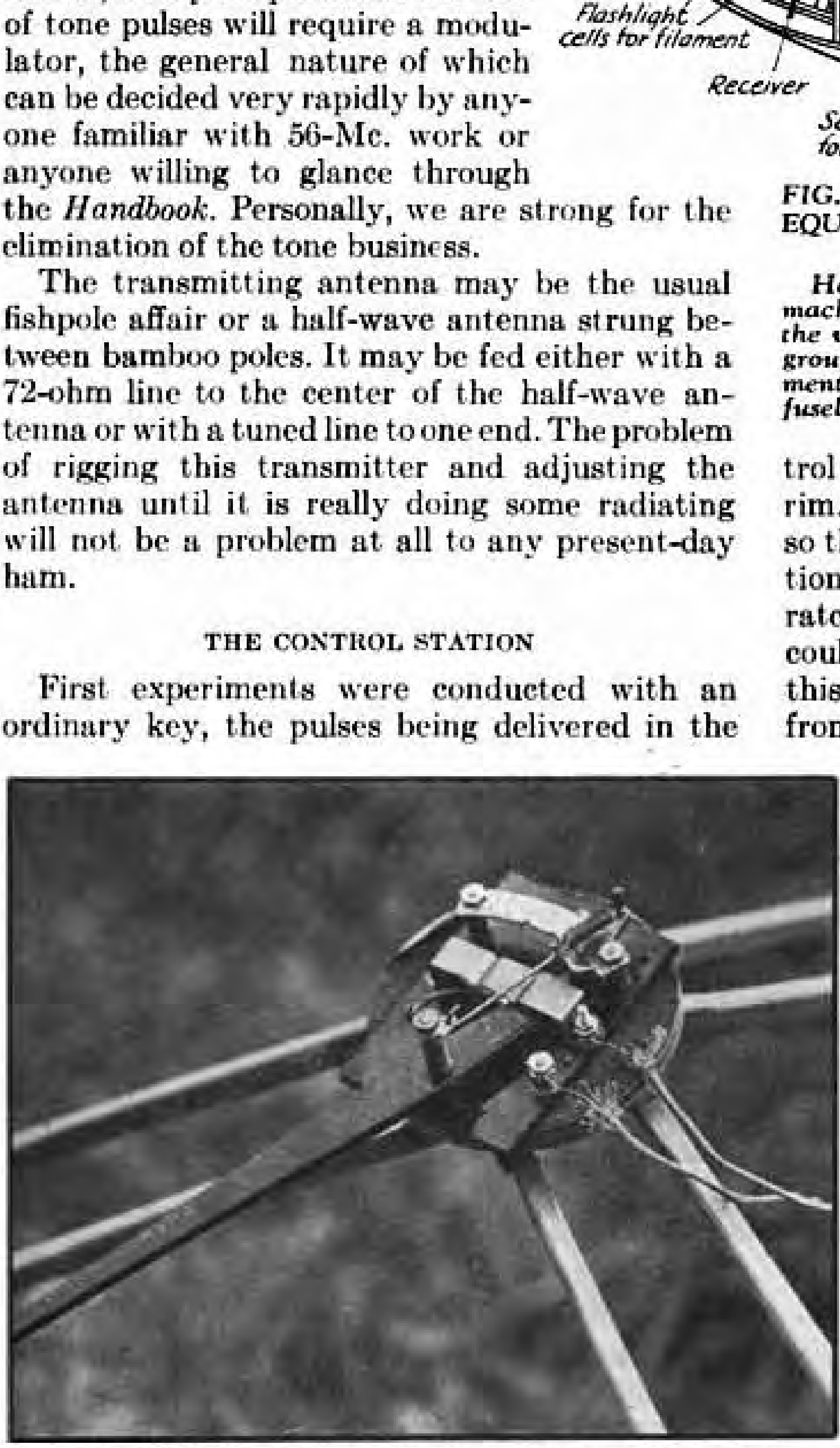

A CLOSE-UP OF THE BOURNE CONTROL STICK

The stick itself is pivoted at the post right in the center of the picture. Contacts are made between a brass screw-head on the stick and depressions on the brass strip crossing it. The curved strip in the rear has notches into which a half-moon shaped rocking ratchet runs. This ratchet, seen near the nut toward the right corner will permit, in its present position, moving the stick from left to right. Upon reaching the right position the ratchet rocks over to the opposite side, then preventing the stick from being backed off once it has been moved toward the center position.

(Continued from page 18)

would produce that effect, "straight" being then required to centralize the rudder. The scheme is practical enough but there is the possibility that the pilot would become confused in somewhat the same fashion as he invariably does when using a straight key. It is all simple enough when the machine is flying fairly close and when the rudder movements can be seen. It is a different matter, though, when the ship is a quarter of a mile away and making an up-wind turn. In such a case the response to the rudder movement may be relatively slow and there is always the feeling that the mechanism has failed.

BUG ELIMINATION

After getting what appeared to be perfect operation of this equipment in the workshop, we proceeded with the installation in the plane. The receiver was built in a rectangular aluminium frame and lent itself readily to "shock-proof" mounting —a heavy rubber band being used from each corner of the frame to some members in the fuselage. Then began a series of preliminary experiments, hand-launching the machine for a glide of a few hundred yards. Within an hour we had decided that we should have made the equipment ten times simpler. We began to appreciate the difficulties that some of the fellows must have bumped into with complex selector switch multi-control systems. The first problem was that in landing one or more of the tubes would usually be bumped out of existence. Then, a couple of severe crackups (the plane hitting a tree) told us the story. In both cases the receiver was substantially demolished and in addition the batteries were pushed through the front of the fuselage and the control equipment wrecked. It appeared that our fancy shock-proof mounting permitted the receiver to plunge forward as the plane hit, pushing the battery supply out the front then recoiling to wreck the remaining apparatus. Promptly, the shock mounting was dispensed with and the receiver built on a small piece of plywood screwed to the bottom of the fuselage. From that time on the machine has suffered equally severe crashes without a tube being broken and usually without the receiver even being knocked out of tune. But the problem of microphonic tubes then reared its head. The shock of the escapement releasing proved sufficient, with most 30-Type tubes, to generate an additional pulse of plate current, so messing up the whole works. This difficulty has been cured simply by selecting tubes which have the least microphonic effect. Doubtless, some almost rigid shock mounting for the detector tubes would provide a complete solution. But we are still a little afraid of shock mounting.

An almost infinite number of problems arise in the design of the plane and in its handling but these are beyond the scope of this story. We will admit, though, that the business of learning to fly on the ground, even with nothing other than a rudder, is actually quite difficult. It is relatively simple to fly the machine in a simple curved path in still air and it is reasonably simple to steer the machine clear of objects providing both they and the machine are within a hundred yards or so. Trying to land the plane on a tree-studded field a quarter of a mile distant is, however, something that demands a very special order of skill and, we know, simply cannot be done without a great deal of practice. But it all adds up to a most extraordinary field for experiment and one for which we can see a grand future.

LAUNCHING THE SAILPLANE FOR A GLIDE TO THE VALLEY

Normally the ship is winch-towed to a hundred feet or so before being released. In this particular instance we have a hand-launched kick-off. Hull, in the foreground, has run with the ship as fast as he could lick, then launched it with an almighty shove. At the moment he is busy putting on the brakes.

FUTURE DEVELOPMENT

This crude one-control may seem rather primitive to the fellow who has no difficulty in getting a five-stage transmitter to bend to his will. And it may not fulfill the requirements of the model plane experimenter who insists on a full set of controls. It is, though, an excellent first installation for even the most advanced plane builders. Getting completely reliable and precise operation of nothing more than a rudder is a job full of problems. Acquiring the necessary judgment to use it effectively on even a gas plane (let alone a sailplane) is still tougher.

Before long we will certainly duplicate the rig for elevator control or fix some sort of audio filter to allow the use of a single channel. Possibly, others have already done the job successfully. Naturally, we are eager to swap ideas with other workers in this field. Somehow or other we hams have to lick the thing.