MULTI CHANNEL RADIO CONTROL FOR MODEL BOATS

PART THREE – By E. J. PEPPER C.Eng. M.I.E.E.

THIS third and concluding article describes the construction of the transmitter and then covers the complete setting up procedure for the whole system.

TRANSMITTER

The transmitter is a simple low power third overtone crystal controlled M.O.P.A. (master oscillator/power amplifier) arrangement operating at 27·255MHz. The circuit diagram appears in Fig. 13.

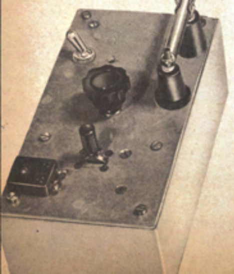
The master oscillator comprises TR5 connected as a conventional feedback oscillator using a subminiature quartz crystal X1 as the collector-base feedback element, ensuring good stability of carrier frequency, for all operating conditions. Stability is further guaranteed by loose coupling of the oscillator output coil L3 to the oscillator tank coil L4.

The collector current of TR5 is controlled by the biasing circuit composed of VR2, C12 in the emitter, and the potential divider R6, R7 on the base. Adjustment of collector current for maximum safe power output is provided by the bias adjustment preset control VR2.

The master oscillator output drives the power amplifier TR4 via its emitter. Bias for this stage is derived from R5, C10, and is self-adjusting and requires no attention.

The power amplifier output coil L2 is in TR4 collector circuit, and is tuned by C7, C8, C9 to the master oscillator frequency (27·255MHz). The common point (at TR4 collector) is "earthy", and the moving vanes of C8 should be connected to this point. This permits adjustment to be made with the minimum of "hand-capacitance" interference. (Non-metallic screw drivers should preferably be used for all adjustments to both transmitter and receiver.)

The aerial couples directly to an effective "tap" on the output coil L2, the "tap" position being determined by the ratio of C7 and the parallel combination of C8, C9. The effective capacitance of the aerial adds to that of C7 and hence final tuning of the output circuit must be done with the aerial connected.



MODULATOR

The collector current of TR4 and hence its resultant radiated output is controlled by TR3, which is connected as an emitter follower with TR4 as its load.

The drive for TR3 is the output of the free-running multivibrator TR1, TR2, which forms the modulator for the transmitter. The multivibrator provides a rectangular voltage waveform varying from zero to the full battery supply voltage.

The multivibrator frequency is set by means of the three position centre-biased P.O. key-switch S1, the throttle control. This selects the relaxation rate capacitors C1–C6, and so provides a frequency of 110Hz, 600Hz, or 400Hz for "increase", "decrease", and "hold" throttle respectively.

The mark/space ratio of the multivibrator is varied by the rudder position control VR1. This potentiometer provides varying degrees of unbalance of the charging resistors, R1, R3, and so determines the on/off time of the multivibrator. In the "rudder amidships" position the multivibrator gives a symmetrical output.

It can be seen that the r.f. carrier is "chopped" or modulated in a manner set by the multivibrator output.

The aerial is a simple centre loaded design 55½in long and is fairly critical in length and wire diameters.

POWER SUPPLY

The most satisfactory power supply for the transmitter is undoubtedly that derived from rechargeable sealed nickel-cadmium cells. A 12V assembly of DEAC 225mAH cells is ideal and will last for 10 hours between charges at an average transmitter load/current of about 20mA.

CONSTRUCTION

The transmitter is of necessity portable and is self-contained in an aluminium box measuring 7½in × 3¾in × 3in.

The electronics circuit is built on a piece of laminated plastics measuring 3in × 4½in which stands off the aluminium front panel on four 4B.A. 2in bolts. The front panel carries the control switches (on/off and throttle), steering potentiometer, and the battery, and also provides support for the aerial.

Details of the circuit board are given in Fig. 14. Holes should be drilled in the material as indicated in Fig. 14b, and tapered pins inserted to provided anchoring points. Perforated "peg board" may of course be used and will eliminate the need to drill holes. The position of the components and the wiring is given in Fig. 14a. Adequate clearance between the output coil L2 and the surrounding case must be provided (say $\frac{1}{2}$in).

The front panel is made from 18 s.w.g. sheet aluminium, as is the transmitter case. See Fig. 16b for dimensions and drilling, and Fig. 16a for arrangement of components and wiring. The "flying leads" are keyed and should be connected up to the similarly coded points on the circuit board (as indicated in Fig. 14a) after the board has been mounted on the four 4B.A. stand-off supports.

INDUCTORS

All inductors used in the transmitter are "home-made". A full specification with winding details for each coil is given in the Components List.

Neosid or Aladdin formers with adjustable dust cores are used for the tuning coils, which are preferably locked against the effects of vibration after adjustment by means of paraffin wax.

The output coil L2 is self-supporting and details are given in Fig. 15.

AERIALS

On the original model the transmitter aerial is of a one-piece rigid design supported by a hardwood mast, but a collapsible unit could be devised, provided that care is taken not to increase the wire diameters too much in an attempt to increase rigidity, otherwise a reduction in antenna efficiency could result. The "free" upper section is best made overlong and then adjusted for optimum results using the receiver as a monitor. See Fig. 18 for details of a suggested design.

Similarly, the receiver aerial is not critical, good results being achieved with a single section whip 14in long. The gain achieved by increasing the length is marginal, and the aerial becomes unwieldy.

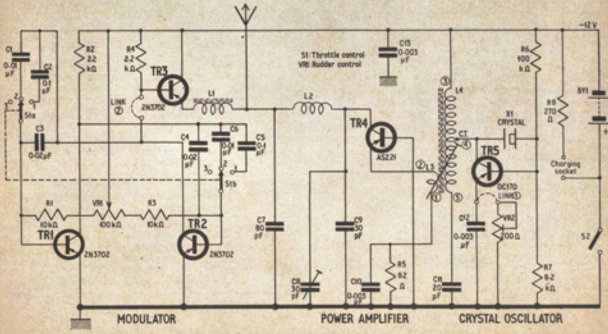


Fig. 13. Circuit diagram of the multi-channel model control transmitter

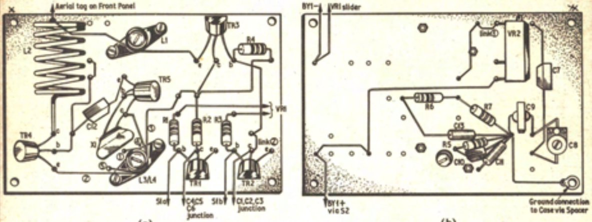


Fig. 14. The transmitter circuit board (a) top view showing arrangement of components; (b) underside view with drilling details, components, and wiring

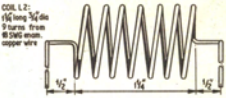


Fig. 15. The transmitter output coil L2

COMPONENTS . . .

Resistors

R1 10kΩ
R2 2·2kΩ
R3 10kΩ
R4 2·2kΩ All 10%, ½ watt carbon
R5 82Ω
R6 100kΩ
R7 8·2kΩ
R8 270Ω

Potentiometers

VR1 100kΩ carbon
VR2 200Ω wirewound preset

Capacitors

C1 0·01μF paper
C2 0·1μF paper
C3 0·02μF paper
C4 0·02μF paper
C5 0·1μF paper
C6 0·01μF paper
C7 80pF ceramic
C8 30pF preset trimmer
C9 30pF ceramic
C10 0·003μF polyester
C11 20pF ceramic
C12 0·003μF polyester
C13 0·003μF polyester

Transistors

TR1 2N3702 or 2N3703
TR2 2N3702 or 2N3703
TR3 2N3702 or 2N3703
TR4 ASZ21 or AF118
TR5 OC170 or OC171

Crystal

X1 27·255MHz type 2MM (Henry's Radio)

Switches

S1 2 pole 3 position Keyswitch, biased to centre position
S2 Single pole on/off toggle

Battery

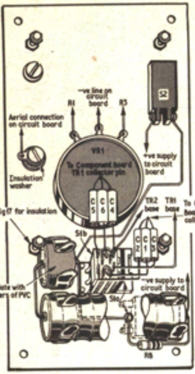
BY1 12V made up from 10 nickel cadmium cells connected in series (Deac 1·25V, 225mAh) (Henry's Radio)

Inductors

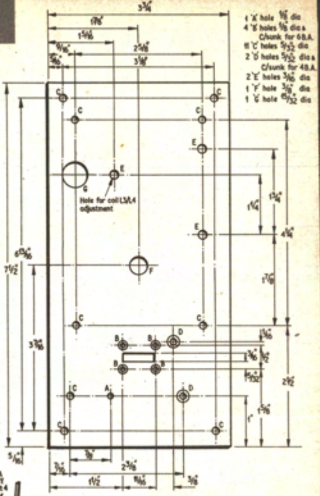
L1 ¼in Neosid former with dust core, single layer of 38 s.w.g. enamelled wire wound to full length
L2 9 turns 18 s.w.g. enamelled wire, spaced by one wire diameter and self supporting, see Fig. 15.
L3, L4 ¼in Neosid former with adjustable dust core. L4 wound first—10 turns 30 s.w.g. enamelled wire close wound, then centre tap and wind 10 more turns. L3 1½ turns 30 s.w.g. enamelled wire wound on top of L4 at bottom (C11) end

Miscellaneous

Aerial, details given in Fig. 18. Plain or perforated s.r.b.p. board. Pins for board. Aluminium for case and front panel. Four 2in 4B.A. bolts and nuts. Two stand off terminals for aerial



(a)



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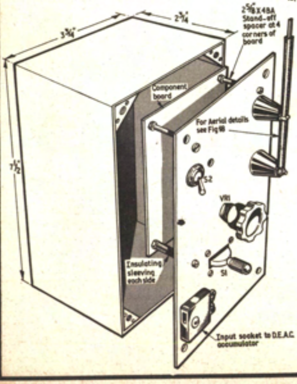

Fig. 16. The transmitter front panel (a) viewed from rear, showing components in position; (b) dimensions and drilling details

Fig. 17. General view of the transmitter with details of the case and aerial fixing

SETTING-UP AND ALIGNMENT

For satisfactory setting-up of the radio control system a multi-range test meter is desirable and, although not essential, a simple oscilloscope can be of enormous assistance.

Monitor points are brought out on the receiver circuit boards to facilitate easy alignment. (Refer to Figs. 2, 4, 5, 6, and 7 June issue.)

The transmitter performance is optimised, using the receiver as a monitor, working at a minimum distance of about 12 feet.

SETTING-UP STEERING MOTION

The steering adjustment is best performed under conditions of artificially reduced signal strength. This can be achieved by disconnecting the receiver aerial, and operating the transmitter at about 10ft distance.

1. Connect supplies to steering panel and monitor square waveform at Monitor Point 2. This should be "clean" and noise-free for all positions of the transmitter steering control, for the three throttle positions.
2. Remove transmitter aerial and increase the distance between the transmitter and receiver until "noise" is apparent and the rectangular waveform at Monitor Point 2 is deteriorating. Adjust VR1 (Set Limiter) for optimum rectangularity at each extreme of the steering control range (this can only be done with the aid of an oscilloscope.)
3. Reconnect transmitter aerial. Set Gain potentiometer VR3 to minimum and switch on rudder motor supply.
4. Unlock Rudder Position potentiometer VR2 from its bracket and rotate body so that the motor MO2 drives to amidships for amidships transmitter setting. Lock potentiometer to bracket.
5. Increase VR3 until motor starts to "hunt" on change of helm setting. Reduce until one overshoot is obtained.
6. Adjust value of R23 if necessary to give correct "lock-to-lock" tracking.

THROTTLE MOTION ADJUSTMENT

1. Switch off rudder motor MO2, and apply supply to throttle panel.
2. Check monostable period at Monitor Point 3 with transmitter "on" in "throttle hold" position. It should be about 1·2ms or so, or approximately 1 : 1 mark/space ratio. Adjust Set Pulse Length potentiometer VR4 as necessary. (Alternatively measure d.c. volts across R40; this should read half the supply volts.)
3. Put transmitter to "throttle close" and helm amidships, and adjust VR4 to give a steady maximum d.c. voltage at TR15 output (across R40). Check at each end of the helm range for a steady output and reduce R40 volts if necessary. (This is the condition of maximum mark/space ratio.)

TRANSMITTER ALIGNMENT

The transmitter can be aligned with the aluminium case cover removed, as the presence of the cover will be found to have little effect on performance. However the final aerial adjustment should be performed with the cover in place. Proceed as follows:

1. Disconnect TR2 collector by removal of link 2. Insert current meter (10mA range) in place of link 1. Set VR2 to maximum.
2. Adjust dust core in L3, L4 for maximum current reading.
3. Adjust C8 for minimum current reading.
4. Adjust VR2 for 5mA on meter; re-check tuning of L3, L4.

The transmitter is now set up and, after removing meter and replacing links 1 and 2, the cover can be fitted.

RECEIVER ALIGNMENT

Alignment should be undertaken with the receiver installed in the boat.

1. Connect an oscilloscope to Monitor Point 1 and earth. With the transmitter "off" several hundred millivolts of noise should be observed at Monitor Point 1 with the receiver supply connected.
2. Switch on transmitter (which will now be modulated) and place it several feet from the receiver. Adjust dust core of L2/L3 for maximum rectangular wave signal at Monitor Point 1. (If no oscilloscope is available the current in the earthy end of R5 should be adjusted for a minimum.) If the optimum appears to be out of range of the core make *small* adjustments to C15 and C5 (this should not really be necessary).
3. Adjust core of L1 for maximum output.
4. The receiver is now aligned, and the transmitter aerial can now be finally adjusted. This is best undertaken when transmitting over a distance of at least 25ft, with the transmitter on the ground and the aerial vertical, away from "earthy" objects. Progressively reduce the length of the aerial upper section an inch at a time until maximum receiver output is obtained.
5. Check the operation of the transmitter modulation controls by monitoring the received signal.

A "kick" on the rudder may be observed when the throttle is actuated. This is in order, and is of such short duration that, in practice, when piloting the boat it will not be perceptible.

CONCLUSION

A reasonably versatile, easy to build, control system has been described, which is not claimed to be able to compete with the most sophisticated commercial equipment, but nevertheless has been shown to give quite creditable results. The actual cost to build complete should only be about £25, two-thirds of which is required for the boat kit, engine and batteries. ★

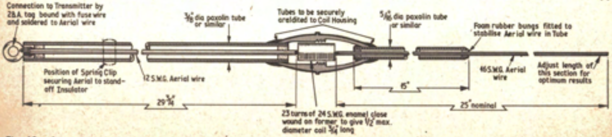

***Fig. 18.** A suggested design for the transmitter aerial. The housing for L2 is the casing of a "torpedo" type mains lead switch. (This is an alternative design to that mentioned in the text)*