WAG

HAND-HELD RELAYLESS DUAL TRANSMITTER

By WALTER A. GOOD

■ It was probably the jibes from my "friends" that caused me to develop this handheld transmitter for the WAG Dual Proportional TTPW control system. In particular, it was becoming very difficult to sign on a contest mechanic because they all knew about my heavy 32 pound transmitter with its old fashioned Y antenna! Now with a new handheld transmitter weighing only seven pounds, my friends are again more helpful. It was certainly worth the effort to regain their confidence!

The handheld transmitter is not just a repackage of the old dual system, it has several new features. Most important is the elimination of the pulser relays. Besides the problems with dirty relay contracts and bouncing relay contacts, I found it very difficult to make a relay-pulser which did not have "lag" troubles. This "lag" problem showed itself as a shift of the neutral position when you tried to speed the pulser from four cps to ten cps. Or worse yet, with the stick at one end you would get 20/80 and the other end, 100/zero! The relayless pulser cures this problem. And no contacts to clean and adjust! As a result, "rate-buttons" have been included in the transmitter to step the pulsing from four cps to ten cps for additional functions.

Other features are tiny center-reading meters permanently wired to the two pulsers so the pulser operation can be easily monitored. Since there are no clicking relays, monitors like the meters are necessary. No, flying your plane in the fog by watching the pulser meters is not recommended! Incidentally, the meters come from Lafayette Radio as FM tuning meters with a rating of 50-0-50 microamperes at a price tag of $2.95. They are the two small rectangular meters in the photograph.

The transmitter uses surplus nickel-cads and a DC/DC converter for the power supply. The RF section has a low-power switch which permits short range "distance" checks.

The handheld was used for the entire 1961 flying season with good results. It was on 53 mc and steered the *Stink Bug* with proportional ailerons, elevator and three speed engine. Rudder control replaced ailerons in medium engine speed and split drag-flaps were positioned down or up with a long engine pulse. Maynard Hill's copy on 51 mc has also performed well, especially on his 10 ft. dual proportional glider. His "fail safe" worked on a motorized tow-release.

Probably the nicest feature was the self-contained aspect of the handheld. No separate control box to forget, and even the 7-section antenna is permanent. Its 8½" slides almost completely into the box when stored and then extends to 48 inches in use. It's European and available from Polks in NYC.

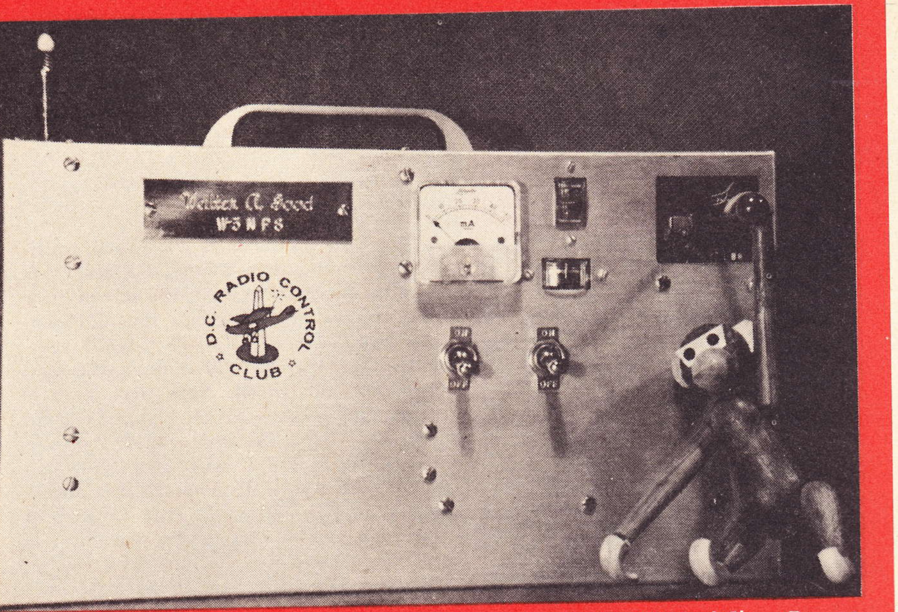
Now let's look at the circuit details of the transmitter. All together there are nine tubes. Two each in the two pulsers, two in the tone oscillator, one for the modulation amplifier, one in the RF crystal oscillator and one in the RF doubler amplifier. The MOPA transmitter is exactly like the old TTPW 50 mc version as described in the March 1957 AM. The circuit diagram of Figure 1 shows the complete pulser-modulator, transmitter and power supply.

The purpose of the TTPW (Two-Tone-Pulse-Width) pulser is to generate a 100 cps tone with either 80/20 or 20/80 tone symmetry or a 500 cps tone with 80/20 or 20/80 tone symmetry. Left rudder is 500 cps, right rudder is 100 cps. Up Elevator is 80/20 tone symmetry and down Elevator is 20/80 tone symmetry. Thus the Rudder pulser pulses between 100 and 500 cps tones and the Elevator pulser pulses between the 80/20 and the 20/80 symmetry. The engine escapement is worked by a blip of carrier.

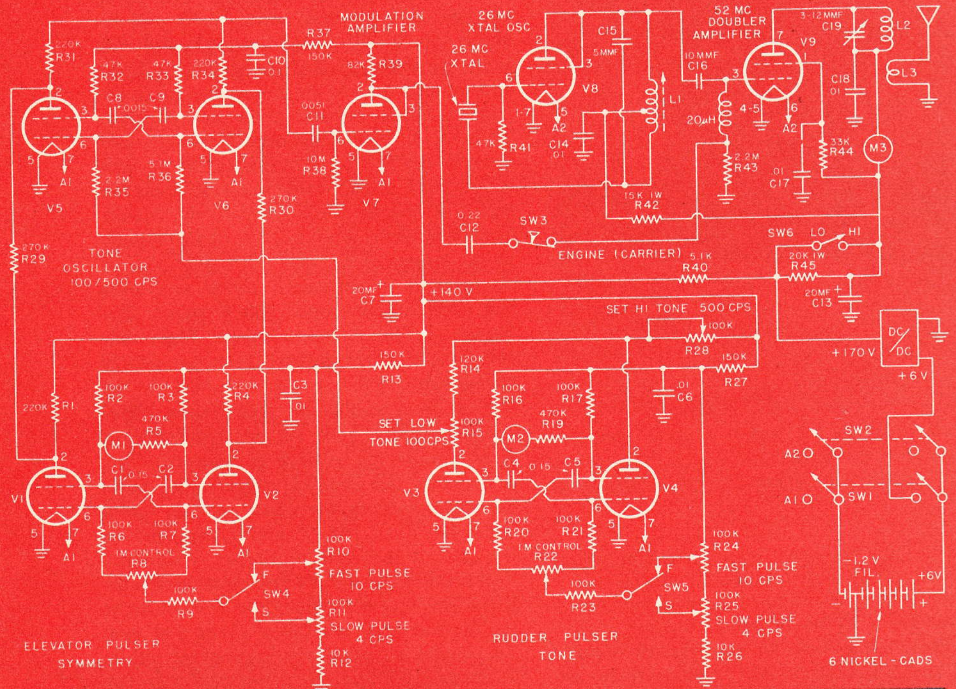
The tone oscillator is a pentode multivibrator using two 3V4's, V-5 and V-6. The feedback is between the screen grids and control grids through the .0015 capacitors C-8 and C-9. The 80/20 symmetry is generated by making the grid resistors unbalanced. Note that R-35 is 2.2M and R-36 is 5.1M, hence V-5 will put out 20/80 symmetry and V-6 will put out an 80-20 symmetry. Now all that is necessary to generate the Elevator signal is to switch the output of the tone oscillator from the plate of V-5 to the plate of V-6. This is done by the Elevator pulser. Note that the only plate voltage for V-5 comes from the plate of V-1 and the voltage for the V-6 plate comes from the plate of V-2. When the Elevator pulser is operating, the plate voltage of V-1 (and hence V-5) will be about 10 V (V-1 conducting) and the plate voltage of V-2 (and hence V-6) will be near 140 V (V-2 non-conducting). The voltages reverse with every pulse. Thus V-5 first has high voltage and then V-6. The two resistors, R-31 and R-34, mix these two outputs together and C-11 sends them to V-7, the modulator amplifier. About 30 V peak-to-peak audio appears at the V-7 grid, so it operates in a saturated mode and puts out a signal with over 100 V swing. See Figure 2 for the waveforms. Only the 500 cps tone is shown here to clarify the graph.

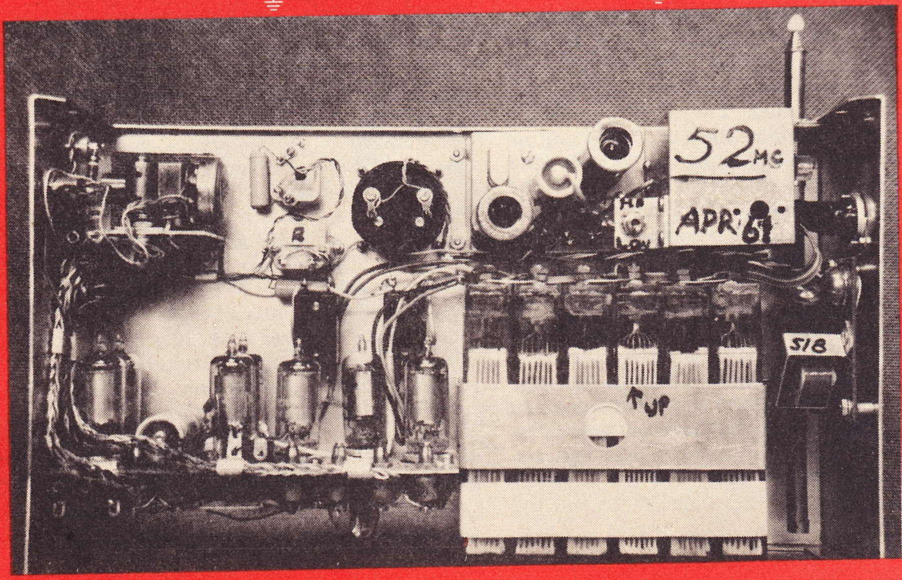
The tone oscillator will change frequency if the grid return (junction of R-35 and R-36) voltage is changed. This is done by the Rudder pulser. The pulsing voltage from the plate of V-3 varies from 10 V to 140 V and is applied to the grid of the tone oscillator. When the V-3 plate is at 10 V, the tone oscillator gives 100 cps and when the V-3 plate is 140 V, the tone oscillator gives 500 cps. To obtain an accurate frequency value, R-15 may be varied to set the 100 cps tone and R-28 to set the 500 cps tone. Figure 3 shows the tone change that would exist at the plate of V-5 and V-6 if they were supplied with a steady B voltage instead of the Elevator pulser voltage. When the symmetry and tone changes of Figures 2 and 3 are combined and sent to the RF section, the transmitted RF signal is shown in Fig. 4. In this example the pulsers have different rates so we see all the combinations of tone symmetry (20/80 and 80/20) and of tone frequency (100 and 500 cps).

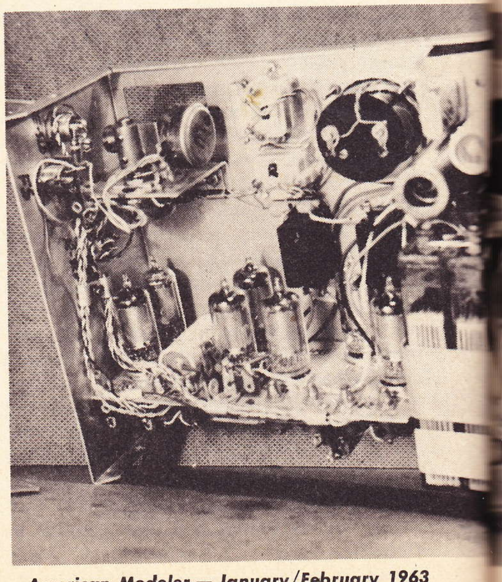
Let's take a closer look at the pulser circuits. Since the two pulsers are almost identical, we will discuss only the Elevator pulser composed of tubes V-1 and V-2. Here again we have a multivibrator with the feedback between the control grids and screen grids through the 0.15 capacitors. The one megohm 60° control pot varies the pulse width from 20/80 to 80/20 and results in the conventional



Good's "handheld" (above). Values for L1, 16T #22E-CTC 3/8"-Red Slug, Tap at 4T; L2, 8T #16 — 1/2" ID — Air; L3, 2T #16 — 3/4" ID — Close to L2.







pulse-proportional response. The meter, M-1 (50-0-50 microamperes), between the screens monitors the pulser action by accurately following the motion of the control stick. At 50/50, it stands at the center and wiggles at the pulse frequency. With the stick at either end, the meter is at the corresponding maximum. The 470 K range resistor, R-5, is selected to permit full meter movement. The pulse frequency is varied from 4 cps to 10 cps by the setting of the pots, R-10 and R-11. A switch, SW4, has been provided to quickly change the pulse rate to operate a pulse rate circuit in the receiver. The resistor, R-9, helps to keep the pulsing frequency constant independent of the one meg control pot setting since most multivibrators of this type tend to speed up with the stick at either end. The pulsing frequency should vary less than one cps for all positions of the control stick.

If you wish to stop the pulser in "up" or "down" just apply a negative 45 V to one of the grids. This tube becomes non-conducting and its mate becomes conducting. The result is a steady output of the appropriate signal.

The whole set of seven Pulsers-Modulator tubes have a plate current drain of only 7 ma. at 140 V. Stable operation of the circuit was found to exist over a range of plate voltage from 120 V to 180 V. Note that all of the 3V4's are run on "half filaments" so each one has a filament drain of 50 ma., or a 7-tube total of 350 ma. The +140 V supply is obtained by dropping down from 170 V and is filtered by R-40 and C-7 (20 MFD) to prevent noise from the power supply from interrupting the pulsers.

The modulation amplifier presents about 100 volts of audio through C-12 (0.2 MFD) to the grid of the 3B4 doubler. This is more than required to completely cut off the 3B4 and gives close to 100% modulation. The switch, SW3, is opened to remove the audio and permit the RF section of the transmitter to emit only a carrier wave. The RF section draws a peak plate current of 29 ma. during carrier only so the peak

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tice permits the six cells to be charged in series. The seven-pin socket just above the converter is not shown in the circuit diagram but it connects to all six cells. A separate meter plugs into it to monitor each cell voltage after the flying session. The same meter monitors the cell voltage during the charging period.

Notice the carrying handle which was lifted from an old Heathkit and is mounted quite a bit off center. Actually, it is right over the c.g. of the box and hence the carrying level is horizontal.

The experience with the handheld transmitter has been very good. No crashes have been attributed to a malfunction of it! We have other good alibis for our crashes! On one occasion, I tried to fly, unknowingly, on low power RF and didn't realize it until the plane started kicking "up" and "right" about 600 feet away. Quickly flipped to high power and the plane straightened out. Another time, one nickel-cad in the transmitter went dead but the plane kept on working.

There have been occasional kicks of the plane controls indicating the passing through of a signal null. Almost every time this happened one of the following conditions has been present:

1. Receiver was off tune and needed re-tuning.
2. I was standing in line with several tall ground-based antennas which were blocking the signal in one direction.
3. Flying from reinforced concrete runways which seem to give a sharp reflection and a consequent momentary null.

None of these kicks was catastropic but they don't look good in the middle of a procedure turn!

Although in the past I've always worked to keep the Rudder and Elevator pulse frequencies well separated, I was surprised to find the best operation for this transmitter was when they were made the same. Thus, I find that both Rudder and Elevator are being pulsed at 4 cps. This holds well for the all stick positions out to half deflection. From there out the frequencies are slightly different but no serious "beating" or interaction takes place. On the ground the interaction between the controls is noticeable at 10 cps but in the air it is not possible to see the plane react when switching either Rudder or Elevator from 4 cps to 10 cps or back. The next project is to put some rate detectors in the plane to use these rate changes. The Dual system would then give two proportional controls, engine escapement and two on-off controls.

In tuning the pulsers the meters give the best indication. Just center the control stick pot to center the meter. The stick should have enough freedom of motion for the meter to indicate its maximum reading just before the stick hits the edge of its hole. The wiggle of the meter may be damped by placing a 100 MFD, 6 V electrolytic across it. This has been tried and worked for several months, but since the voltage on the meter has both polarities, one of the capacitors went bad and shorted out the meter. These capacitors have now been removed.

The tones may be set by removing tube V-1 to stop the symmetry pulsing and then removing tube V-4 which leaves only the low tone. Now adjust pot R-15 to give 100 cps using an audio oscillator as a reference. To set the 500 cps tone, replace V-4, remove V-3 and adjust R-28. These controls interact slightly so it may be necessary to do this several times to obtain an accurate setting. Once set, the tones should hold very well.

The RF section is checked out first on low power with the pulsers off. Tune L-1 until a monitor receiver indicates that the crystal is oscillating; also a downward jump in M-3 will take place. It has been found that the 50 mc transmitter requires a very active crystal. Both ACE and International crystal units have worked well. Then tune C-19 until a nearby field strength meter (FSM) gives a maximum reading. Retune L-1 until it is about ¼ turn from where the oscillations cease. Now try L-3 antenna coil closer to L-2 and re-tune C-19. Try different spacings until you obtain the best FSM reading with the smallest RF amplifier plate current on M-3. All of the foregoing may be done with the back cover removed. Before attaching the cover, switch to high power and place the FSM some distance away; 12 ft. is just right for mine. And check tuning of L-1 and C-19 for the best output but leaving L-1 on the safe side. Put the cover in place and make one final touch up of C-19. Flip on the pulsing and the FSM should drop to about half. Moving the Elevator stick should cause a variation in FS while the Rudder should not. Now she's ready to go to the field!

There are always some improvements that could be made in a new device. I expect the six 9½ oz. (¾" x 2⅝" x 4½") plastic nickel-cads I used could be replaced with a smaller sealed type. The 9½ oz. type were rated at 5AH and give almost four hours of safe flying on a full charge since the current from the 6 V supply is 1.1 amp. Probably a size-D sealed cell of the 4AH sintered type would give well over three hours. They would also take less space and lighten the transmitter considerably. Some of the 6 oz plastic types would also be suitable.

A little more RF power than the present ½ watt would be desirable. One way to get more radiation would be to use a "loaded" antenna with a loading coil in the center. I gave this a quick try using the Graupner antenna, but came up with no improvement on the FS meter. Just why I don't know, but it should help. Another help would be a "straight-through" amplifier of 50% efficiency instead of the doubler with its 25% efficiency. Look at the MAC 50 for ideas on this (ATMA, 1961).

The possibility of a trim control on both the Rudder and Elevator would be handy. Right now this must be done by mechanically shifting the pot relative to the stick, and of course, only between flights. In-flight trim would be more desirable, especially with a new plane.

The handheld has not been tried on 27 mc as yet. There is reason why it won't work just as well there.

Although this has not been a constructional article, it is hoped that some of the ideas and circuits will be useful to the large family of proportional experimenters.

The list of parts required for the transmitter follows:

PARTS LIST

Meters

M-1, M-2—FM tuning meter 50-0-50 microamp. Lafayette TM-13

M-3—0-50 milliamp. Lafayette TM-402

Capacitors

C-1, C-2, C-4, C-5—0.15 MFD, 100 V. Mylar, CD type WMF1P15, tolerance ±10% matched in paris

C-3, C-6, C-17, C-18—0.01 MFD Disc Ceramic, Erie type ED-.01

C-7, C-13—20 MFD, 250 V, Electrolytic Sprague TVA-1508

C-8, C-9—.0015 MFD, Mica, CD type CD19F5D15, tolerance ±5%

C-10—0.1 MFD, 100 V, Mylar, CD type WMF1P1E

C-11—.0051 MFD, Mica, CD type CD30F5D51

C-12—0.22 MFD, 200 V, Mylar, CD type WMF2P22E

C-15—5 MMF, Mica

C-16—10 MMF, Mica

C-19—3-12 MMF, Variable Air

Resistors

R-1, R-4, R-18, R-31, R-34—220 K, ½ watt, 10%

R-2, R-3, R-6, R-7, R-9, R-16, R-17, R-20, R-21, R-23—100 K, ½ watt, 10%

R-5, R-19—470 K, ½ watt, 10%

R-8, R-22—ACE #JU60°, 1 megohm, 2 watt

R-10, R-11, R-15, R-24, R-25, R-28—100 K pot, small size, ½ watt

R-12, R-26—10 K, ½ watt, 10%

R-13, R-27, R-37—150 K, ½ watt, 10%

R-14—120 K, ½ watt, 10%

R-29, R-30—270 K, ½ watt, 10%

R-32, R-33, R-41—47 K, ½ watt, 10%

R-35—2.2M, ½ watt, 5%

R-36—5.1M, ½ watt, 5%

R-38—10M, ½ watt, 10%

R-39—82 K, ½ watt, 10%

R-40—5-1 K, ½ watt 10%

R-42—15 K, 1 watt, 10%

R-43—2.2M, ½ watt, 10%

R-44—33 K, ½ watt, 10%

R-45—20 K, 1 watt, 10½

Switches

SW1, SW2—Toggle DPST

SW3—Push button, SPST, NC

SW4, SW5—Push button, SPDT

SW6—Small Toggle SPST

Tubes

V-1, V-2, V-3, V-4, V-5, V-6, V-8—3V4

V-7—1L4

V-9—3B4

Antenna

Aristo-Craft 6-E (available from Polk's, NYC)