July 20, 1948. T. W. FORBES 2,445,712

AUDITORY TONE SIGNAL INDICATIONS FOR FLYING

Filed Aug. 21, 1947 3 Sheets-Sheet 1

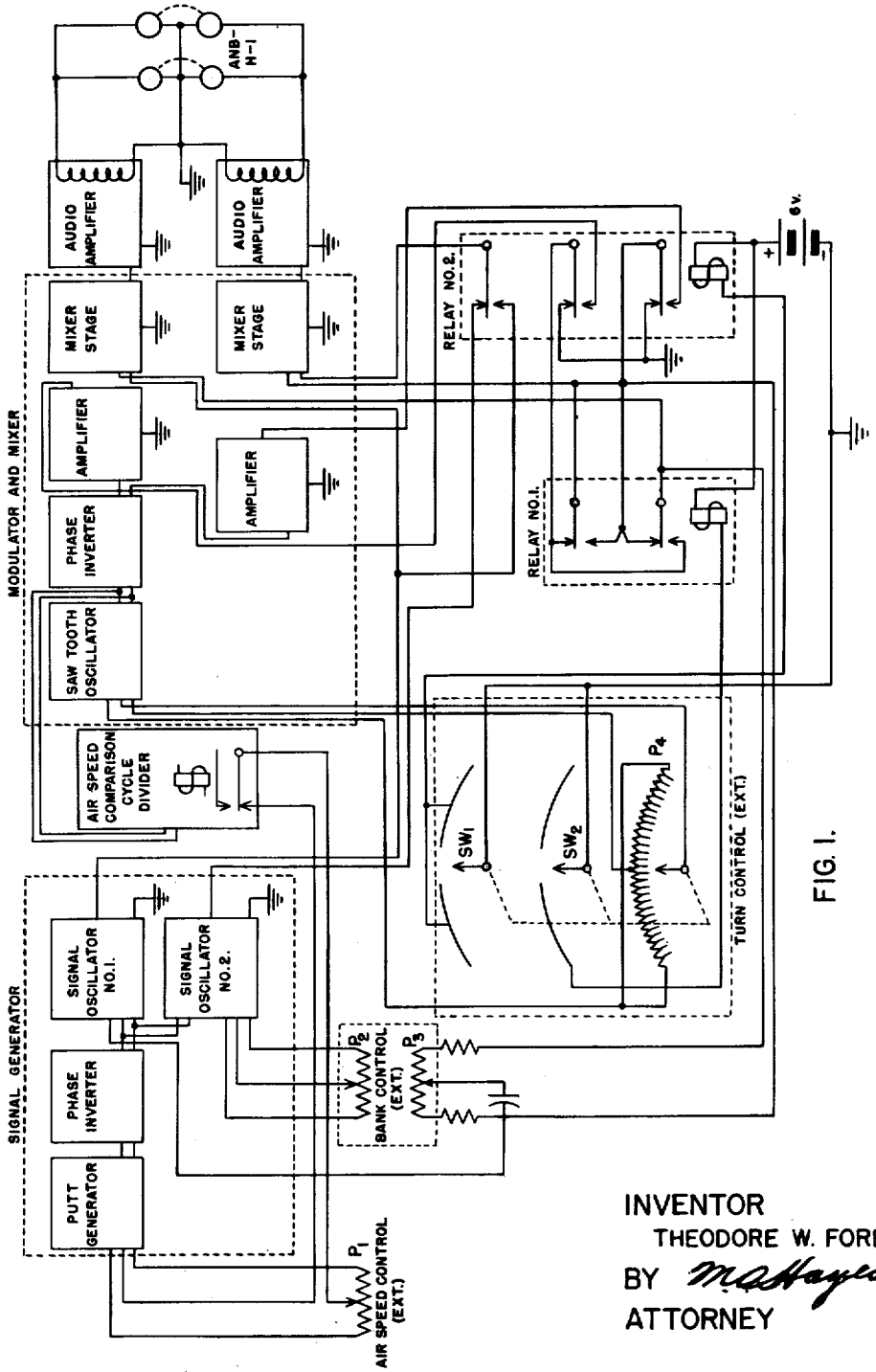


FIG. 1.

INVENTOR
THEODORE W. FORBES
BY M. Hayes
ATTORNEY

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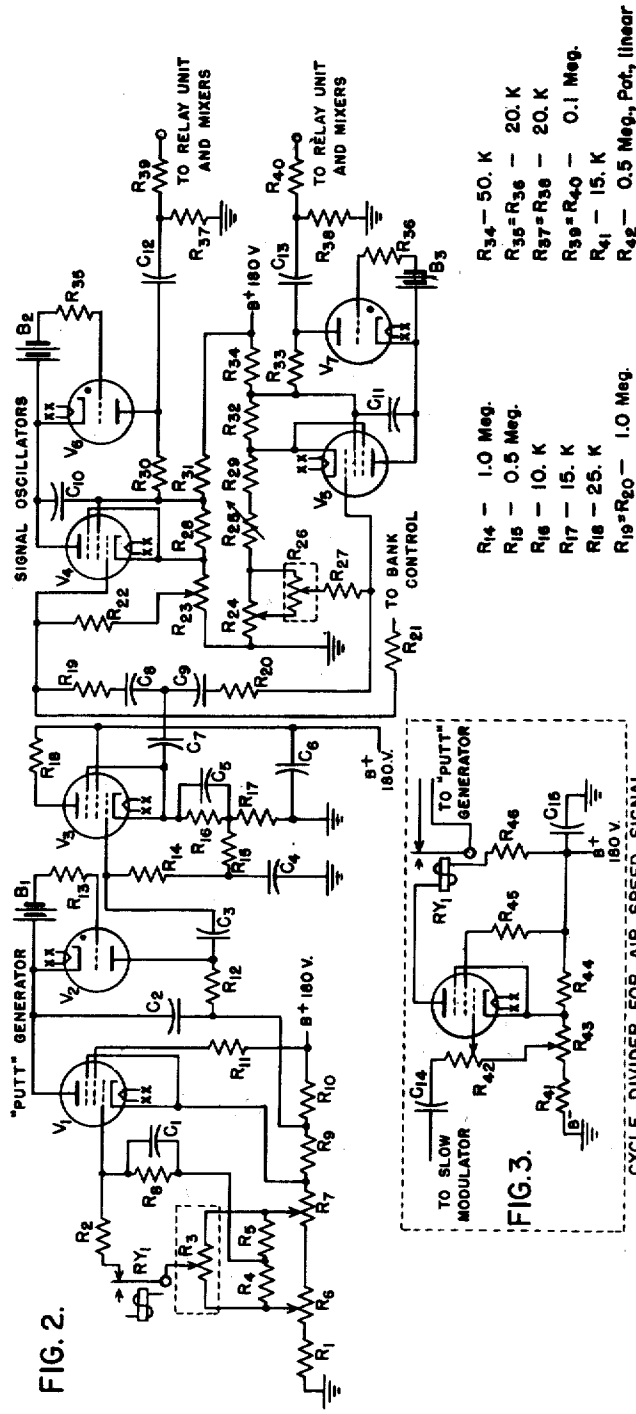


FIG. 2.

FIG. 3.

$B_1=B_2=B_3$ – 6 v. Battery
C_1 – 0.1 μfd.
C_2 – 1.0 μfd.
C_3 – 0.01 μfd.
C_4 – 20. μfd.
C_5 – 10. μfd.
C_6 – 20. μfd.
C_7 – 0.01 μfd.
$C_8=C_9$ – 0.1 μfd.
$C_{10}=C_{11}$ – 0.01 μfd.
$C_{12}=C_{13}$ – 0.01 μfd.
C_{14} – 1.0 μfd.
C_{15} – 25. μfd.

R_1 – 2.5 K
R_2 – 0.1 Meg.
R_3 – 50.K, Pot. External air speed control
$R_4=R_5$ – 25. K
R_6 – 5.0 K, Pot.
R_7 – 2.0 K, Pot.
R_8 – 0.2 Meg.
R_9 – 50. K
R_{10} – 50. K
R_{11} – 75. K
R_{12} – 2.0 K
R_{13} – 20. K
R_{14} – 1.0 Meg.
R_{15} – 0.5 Meg.
R_{16} – 10. K
R_{17} – 15. K
R_{18} – 25. K
$R_{19}=R_{20}$ – 1.0 Meg.
R_{21} – 1.0 Meg.
R_{22} – 1.0 Meg.
R_{23} – 5.0 K, Pot.
R_{24} – 2.0 K, Pot.
R_{25} – 2.0 K, Pot.
R_{26} – 50. K, Pot. External alternate bank control
R_{27} – 1.0 Meg.
R_{28} – 50. K
R_{29} – 1.0 K
R_{30} – 10. K
R_{31} – 50. K
R_{32} – 50. K
R_{33} – 10. K
R_{34} – 50. K
$R_{35}=R_{36}$ – 20. K
$R_{37}=R_{38}$ – 20. K
$R_{39}=R_{40}$ – 0.1 Meg.
R_{41} – 15. K
R_{42} – 0.5 Meg., Pot., linear
R_{43} – 5. K, Pot.
R_{44} – 80. K
R_{45} – 75. K
R_{46} – 25. K
RY_1 – 5. K Relay
V_1 – 6J7
V_2 – 884
V_3 – 6J7
$V_4=V_5$ – 6J7
$V_6=V_7$ – 884
V_8 – 6SJ7

INVENTOR
THEODORE W. FORBES
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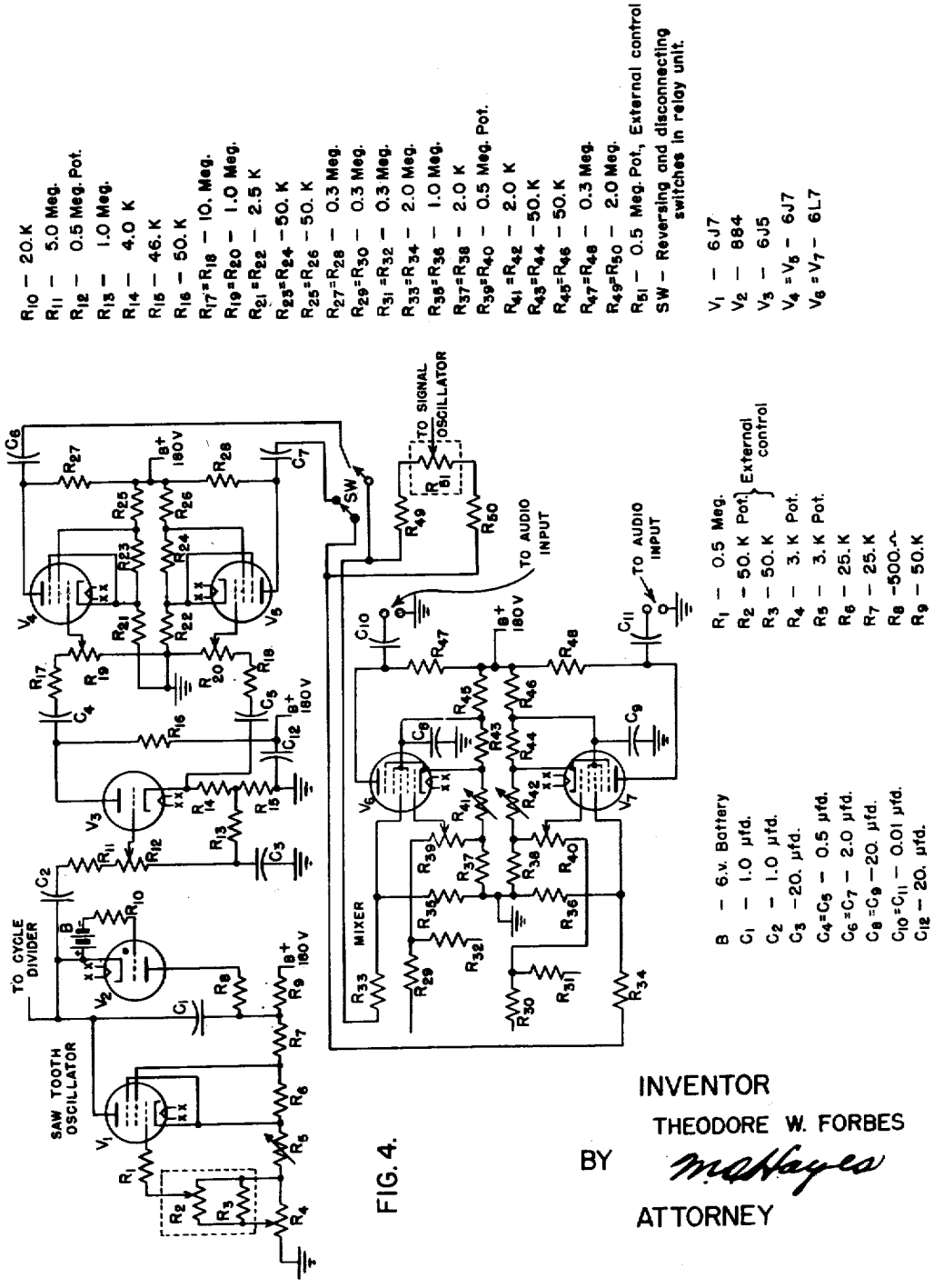


FIG. 4.

INVENTOR
THEODORE W. FORBES
BY
ATTORNEY

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2,445,712

AUDITORY TONE SIGNAL INDICATIONS FOR FLYING

Theodore W. Forbes, Cambridge, Mass., assignor to United States of America as represented by the Executive Secretary of the Office of Scientific Research and Development

Application August 21, 1947, Serial No. 769,957

3 Claims. (Cl. 177—311)

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This invention relates to indicators and more particularly to auditory tone signal indications for assisting a pilot in flying an airplane. An object of the invention is to provide auditory signal indications especially suited to "blind flying" of an airplane with a view to freeing the eyes of the pilot for other necessary duties, particularly at critical times.

An important feature of the invention is a system of auditory tone signals which makes use of as many as three basic indications. The three indications are given by various characteristics of a single signal, and the signal combination, therefore, differs from auditory signals heretofore employed in which a number of separate tones are added together. The three-in-one signal of the invention has the advantage that it offers less interference than does a signal composed of many different tones added together with radio and other communications which are necessary to the pilot. The signal of the invention also has the advantage that all three of the indications are always heard together and there is less chance of one signal blanking out the other signals or attracting the pilot's attention to the exclusion of the other signals.

Another important characteristic of the signal of the invention is that the indications are designed to be as simple and as self-explanatory as possible. This is achieved by making the characteristics of the auditory signal "sound like the behavior of the airplane." Other combinations of signal characteristics may also be used although the one described herein has been tried out and found to be satisfactory and therefore constitutes a preferred embodiment of the invention.

Another important feature of the invention is an arrangement of signals which are used to give "turn," "bank" and "air speed" indications. The arrangement of signals may also be employed to give other indications such as indication of deviation from course, bank and horizontal attitudes of the airplane, or other similar information which may be desired. Other features will appear from the following description of the invention.

In the accompanying drawings:

Figure 1 is a block diagram indicating functionally the apparatus of the invention;

Figure 2 is a schematic diagram of the apparatus;

Figure 3 is a schematic diagram of a cycle divider; and

Figure 4 is still another schematic diagram of a part of the apparatus.

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Referring more in detail to the drawings, the basic signal heard when the plane is flying straight and level is a "tone" generated by the two signal oscillators of the signal generator shown in Fig. 1. Each of these oscillators generates a signal which has a "saw toothed" or "spiked" wave form, and the two oscillators are adjusted to the same frequency when the wings of the plane are level. When the plane is not turning, the signal oscillator No. 1 (Fig. 1) sends a signal to the right earphone of the pilot, and signal oscillator No. 2 sends a signal to the left earphone. Under these circumstances, if the left wing drops, the pitch of oscillator No. 2 drops accordingly, and if the left wing rises above the horizontal, the pitch of oscillator No. 2 rises accordingly, while that of oscillator No. 1 remains fixed.

Control of the frequency of oscillator No. 2 is obtained through the external bank control shown in Fig. 1. The term "external" is used to indicate that the control potentiometer is outside of the signal unit and attached to the airplane's indicating instrument. In the case of the bank control, the control instrument may be a pendulum device, indicating in a similar way to the ball indicator of the conventional airplane ball bank instrument. Thus in straight flying, when the left wing of the airplane is above or below the right wing, the pitch of the tone in the left ear is correspondingly heard to be higher or lower than the pitch in the right ear.

When the airplane begins to turn to right or left of a straight course, signal oscillator No. 2 is switched out of circuit and the signal from signal oscillator No. 1 is heard to swing or oscillate from one ear to the other. The relative bank indication of the bank-bank pendulum is now denoted by a "tilt" produced by means of a pitch variation during the apparent motion of the signal from side to side. This pitch variation is produced by potentiometer P_3 of the external bank control as shown in Fig. 1. This potentiometer P_3 was formerly out circuit but is thrown into circuit by the relay No. 2 when the turn indication takes control.

The pitch change is such that if the left wing is too high the pitch of the signal will be higher on the left and lower on the right as the signal swings from one ear to the other. Thus in both straight flight and turning flight, the relative pitch of the signal to the two ears indicates position of the wings of the airplane on the corresponding sides. Furthermore, the pitch variation is such that the pilot does not have to dis-

criminate absolute pitches but always a pitch which is relative to the pitch in the other ear. This is an important feature of the signal since the discrimination of the absolute pitch is difficult for many people and has been shown to be unsatisfactory for auditory signal purposes.

When the airplane starts to turn from a straight course, the signal from oscillator No. 1 is heard to swing or sweep from one ear to the other with a rate of swing which becomes faster as the turn becomes faster. The signal snaps or jumps to one ear and slowly moves to the other in the direction toward which the plane is turning. Let it be supposed that the plane is turning to the right slowly. The intensity of the signal becomes suddenly strong in the left and weak in the right ear. It then becomes gradually stronger in the right and weaker in the left ear until it has become strong in the right and weak in the left. This gives the effect of motion of the signal from the left to the right side. This is accomplished by modulating the intensity of the signal to each ear separately in the two mixer stages of the modulator-and-mixer shown in Fig. 1.

The effect of sudden movement to one side and gradual movement across to the other side is produced by the means of an oscillator giving a saw-toothed wave form of very low frequency. The frequency employed here is in the range of one-fifth to eight cycles per second. The frequency of this oscillator is important since frequencies which are too high are less effective in producing the sensation of motion of the signal when the pilot hears it in the earphones.

Control of the direction of motion and the frequency of the swing or motion of the signal is controlled by the external turn-control of Fig. 1. This control was attached to the rate of turn indicator but may also be attached to the directional gyro. Switches SW_1 and SW_2 in Fig. 1 control the direction of the apparent motion of the signal and potentiometer C_4 controls the rapidity of frequency of its sweep.

Relay No. 2 in Fig. 1 serves to disconnect signal oscillator No. 2 and to connect signal oscillator No. 1 to both mixer stage inputs. It also connects the turn-control and the bank-control to the output of the slow saw-toothed oscillator when the airplane starts to turn, thus causing the signal to sweep from side to side. Relay No. 1 acts as a reversing switch under the same circumstances, determining the direction of the motion of signal and producing the appropriate pitch change in the bank signal. Both relays No. 1 and No. 2 are controlled by switches SW_1 and SW_2 on the turn control.

The air speed signal is a "putt" or "beep" sound superimposed upon the basic tone signal. The frequency of occurrence of this "putt" increases and decreases with the air speed when the air speed control potentiometer P_1 of Fig. 1 is attached to an air speed meter. Alternatively, if desired, this signal could be used to indicate the horizontal attitude of the airplane. Since the "putt" sounds somewhat like the sound of a motor, a high speed "putt" (high rate of occurrence) is used to indicate high air speed and a slow rate of occurrence low air speed.

In order to allow accurate judgment of the "putt" rate, a standard rate for comparison may be thrown in for one-third of each cycle of the slow saw-toothed oscillator. This is accomplished by the air-speed-comparison cycle-divider which is controlled by the saw-toothed oscillator output wave as shown in Fig. 1.

Phase inverters are used in order to obtain the proper polarity of signals from the "putt" generator and the saw-toothed oscillator. Audio amplifiers are used following the saw-toothed oscillator in order to obtain the proper voltage for modulating the signal intensity in the mixer stages.

The general method of obtaining these three signals consisting of a sweeping motion for turn, a "tilt" effect produced by pitch variation, and a "putt" sound superimposed on the basic tone signal, has now been described. The circuits by which these signals are achieved are shown in Figs. 2, 3 and 4. These circuits have been chosen for simplicity, but other circuits producing similar wave forms and similar modulations may be used.

The "putt" generator circuit consists of tubes V_1 and V_2 of Fig. 2 with their associated networks. The circuit represents a relaxation oscillator of a type well known to the art which produces a wave form of sharply peaked triangular shape, often called "spikes," rising from a flat base line. An increased frequency of oscillation merely results in a closer spacing of these "spikes" but with no essential change of shape of the "spikes" themselves. Frequency control is obtained by varying the bias on the control grid of V_1 as shown in the diagram. The center tap connection between R_4 and R_5 provides a fixed comparison rate or frequency intermediate between the setting of potentiometers R_6 and R_7, while potentiometer R_3 furnishes the variable "putt" rate which is under control of the air speed indicator. Potentiometers R_6 and R_7 furnish adjustments by which the maximum and the minimum "putt" rate can be set to the desired frequency of occurrence. Relay RY_1 is the relay in the cycle-divider which governs the relative time during which the comparison rate is heard.

The output of the "putt" generator oscillator is sent through V_3 and its associated networks which reverses the polarity of the signal.

Signal oscillator No. 1 of Fig. 1 consists of vacuum tubes V_4 and V_6 of Fig. 2 and their associated networks. Similarly signal oscillator No. 2 of Fig. 1 consists of vacuum tubes V_5 and V_7 of Fig. 2 and their networks. These signal oscillators are relaxation oscillators similar to the "putt" generator. Potentiometers R_{23} and R_{24} furnish pitch settings for these two signal oscillators by which the pitch of the basic tone signal from each oscillator can be set. Pitch control is obtained by a bias potential on the control grid of V_4 and V_5.

The variable pitch control for oscillator No. 2 is furnished by R_{25} a potentiometer controlled by the bank pendulum. The variable pitch control for signal oscillator No. 1, which causes the "tilt" effect in the moving signal, is obtained through the potential from the bank control potentiometer P_2 of Fig. 1. This is fed to the grid of V_4 through resistor R_{21}.

The "putt" or "beep" signal is led from the "putt" generator and inverter through blocking condensers C_8 and C_9 and resistors R_{19} and R_{20} to the control grid of V_4 and V_5. The spiked shaped potentials from the putt generator cause a rapid frequency modulation of signal oscillators No. 1 and No. 2 simultaneously, thus superimposing the "putt" upon the basic tone signals from these oscillators. Signal oscillators producing sinusoidal or other wave forms may be

used providing they produce a tone which can be frequency modulated by the "putt" signal.

Figure 3 shows the circuit of the vacuum tube controlling the cycle diver relay RY_1 which throws in and out the comparison "putt" rate frequency for the air speech signal. A potential from the saw-toothed oscillator of Fig. 4 is fed to the control grid of this vacuum tube through blocking condenser C_4 and the potentiometer R_{42}. Settings of potentiometers R_{42} and R_{43} determine the proportion of the saw-toothed cycle during which the comparison "putt" frequency is heard. This vacuum tube and relay circuit is of a type well known to the art.

The circuit for the modulator and mixer unit of Fig. 1 is shown in detail in Fig. 4. Tubes V_1 and V_2 comprise the saw-toothed oscillator which is of a type well known to the art. Other circuits producing a saw-toothed wave form and a frequency or occurrence of the same range could be used in place of this circuit. Control of the frequency of occurrence of these saw-toothed potentials is obtained by a bias potential on the control grid of V_1. The basic frequency of oscillation is determined by the magnitude of condenser C_1 and by the setting of the potentiometer R_4. R_2 and R_3 of Fig. 4 represent the center tapped potentiometer P_4 in Fig. 1 which is moved by the turn indicator instrument. The circuit is such that an increasing rate of turn to either side produces an increasing frequency of oscillation of the saw-toothed oscillator.

The potential wave of the saw-toothed oscillator is taken to the cycle divider at the point shown and also the inverter stage V_3. The inverter is connected in "push-pull" to the control grids of vacuum tubes V_4 and V_5 thus producing a saw-toothed potential of opposite polarity at blocking condensers C_6 and C_7.

The saw-toothed potential is transmitted through C_6 and C_7 to SW of Fig. 4 which represents the disconnecting and reversing relay connections in relays No. 1 and No. 2 of Fig. 1. Thus this saw-toothed potential is connected across the resistor network R_{49}, R_{50} and R_{51}. R_{51} is a control potentiometer operated by the bank pendulum. When its wiper is centered, the opposite potentials may be balanced by means of R_{19} and R_{20} so that zero potential is sent to the signal oscillator and no pitch change results in signal oscillator No. 1. If however, the bank pendulum moves the wiper of R_{51} to either side of center, a portion of the saw-toothed potential is imposed on the grid of signal oscillator No. 1. The direction of the resulting pitch change corresponds to the position of the wings of the airplane, and the extent to which the control is moved off center controls the proportion of the saw-toothed signal sent to oscillator No. 1. Thus, as the control is moved farther off center, a greater pitch change in the desired direction is obtained.

The push-pull saw-toothed oscillator signal is also sent from switch SW to the oscillator grids of pentagrid mixer tubes V_6 and V_7. Thus the positive phase of the signal causes an increased sensitivity of one tube and the negative phase causes a decreased sensitivity of the other tube. This sends increased intensity to one earphone and decreased intensity to the other earphone through the audio amplifiers. At the initial peak of the saw-toothed modulating potential, one tube conducts maximally and the other is cut off, midway through the modulating cycle both tubes conduct equally, and at the end of the cycle, the tube which conducted originally is cut off and the other is conducting. Thus, the signal is caused to swing from one ear to the other.

The signals from signal oscillator No. 1 and signal oscillator No. 2 are fed to the pentagrid mixer tubes through relay No. 1 and relay No. 2 as shown in Fig. 1. These signals are sent to the control grid of pentagrid mixer tubes V_6 and V_7 through R_{29} and R_{30} of Fig. 4. Potentiometers R_{39} and R_{40} allow balancing of the signals which reach V_6 and V_7 to offset any unbalance in the foregoing signal circuits. Thus the original signals to each ear will be equally loud. This is of importance in order that the modulation caused by saw-toothed oscillator may produce effective movement of the signal from one ear to the other.

Alternative inputs are provided through resistors R_{31} and R_{32} in case it is desired to feed voice or radio signals into the mixers in such a way that they will be modulated and caused to swing from one ear to the other.

The outputs from the mixer tubes V_6 and V_7 are fed to two separate audio amplifier channels, each of which supplies one earphone of the pilot's headset.

While I have shown a preferred embodiment of my invention, it should be understood that various changes and modifications may be resorted to, in keeping with the spirit of the invention as defined by the appended claims.

I claim:

1. An auditory indicating device for flying an airplane comprising oscillators for producing a tone signal, means for separately conducting the tone signals to each of a pilot's earphones, means for modulating separately and inversely signals to each earphone to indicate direction of turn of said airplane in a horizontal plane by producing a sound effect in which a single tone signal appears to start from one side of the pilot's head and to move toward the other side, said cycle being continuously repeated and moving in the same direction, means for reversing the direction of cycle of movement to indicate a reverse turn, and means for causing the tone signal to remain stationary thereby to indicate absence of turn of the airplane.

2. An auditory indicating device for flying an airplane comprising oscillators for producing a tone signal, means for separately conducting the tone signals to each of a pilot's earphones, means for modulating separately and inversely signals to each earphone to indicate direction of turn of said airplane in a horizontal plane by producing a sound effect in which a single tone signal appears to start from one side of the pilot's head and to move toward the other side, said cycle being continuously repeated and moving in the same direction, means for reversing the direction of cycle of movement to indicate a reverse turn, means for causing the tone signal to remain stationary thereby to indicate absence of turn of the airplane, and means for continuously varying the pitch of the tone signal during the cycle in which it appears to swing from one side of the pilot's head to the other side, thereby to indicate deviation of the lateral attitude of the airplane from the correct lateral attitude during a turn.

3. An auditory indicating device for flying an airplane comprising oscillators for producing a tone signal, means for separately conducting the tone signals to each of the pilot's earphones, means for modulating separately and inversely signals to each earphone to indicate direction of

turn of said airplane in a horizontal plane by producing a sound effect in which a single tone signal appears to start from one side of the pilot's head and to move toward the other side, said cycle being continuously repeated and moving in the same direction, means for reversing the direction of cycle of movement to indicate a reverse turn, means for causing the tone signal to remain stationary thereby to indicate absence of turn of the airplane, means for continuously varying the pitch of the tone signal during the cycle in which it appears to swing from one side of the pilot's head to the other side, thereby to indicate deviation of the lateral attitude during a turn, means for frequency modulating the said

signal oscillators by means of a potential of spiked wave form, thus causing a rapid frequency change in the tone signal or signals and providing a continuous series of staccato sounds forming a part of the tone signals or signal which appears to move, means responsive to change in longitudinal attitude or air speed of the airplane for changing the rate of occurrence of the staccato sounds, and means for maintaining rate of occurrence of staccato sounds at a predetermined constant value during a portion only of the said cycle of transfer of the signal from one side to the other in order to allow low accurate judgment of the signal.

THEODORE W. FORBES.

Certificate of Correction

Patent No. 2,445,712. July 20, 1948.

THEODORE W. FORBES

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 8, line 13, strike out the word "low";

and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 8th day of November, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.

turn of said airplane in a horizontal plane by producing a sound effect in which a single tone signal appears to start from one side of the pilot's head and to move toward the other side, said cycle being continuously repeated and moving in the same direction, means for reversing the direction of cycle of movement to indicate a reverse turn, means for causing the tone signal to remain stationary thereby to indicate absence of turn of the airplane, means for continuously varying the pitch of the tone signal during the cycle in which it appears to swing from one side of the pilot's head to the other side, thereby to indicate deviation of the lateral attitude during a turn, means for frequency modulating the said

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