United States Patent

Burton

[15] **3,656,160**

[45] **Apr. 11, 1972**

[54] **DOWNED-AIRCRAFT RADIO LOCATOR-BEACON EMPLOYING PLURAL LOOP ANTENNAS**

[72] Inventor: **Jay E. Burton,** Fort Collins, Colo.

[73] Assignee: **Burton Instrumentation, Inc.,** Fort Collins, Colo.

[22] Filed: **Feb. 9, 1970**

[21] Appl. No.: **9,880**

[52] **U.S. Cl.** **343/702,** 343/705, 343/742, 343/846

[51] **Int. Cl.** **H01q 1/24**

[58] **Field of Search** 325/111, 113, 114, 115, 119; 343/702, 705, 708, 709, 710, 742, 789, 872, 846

[56] **References Cited**

UNITED STATES PATENTS

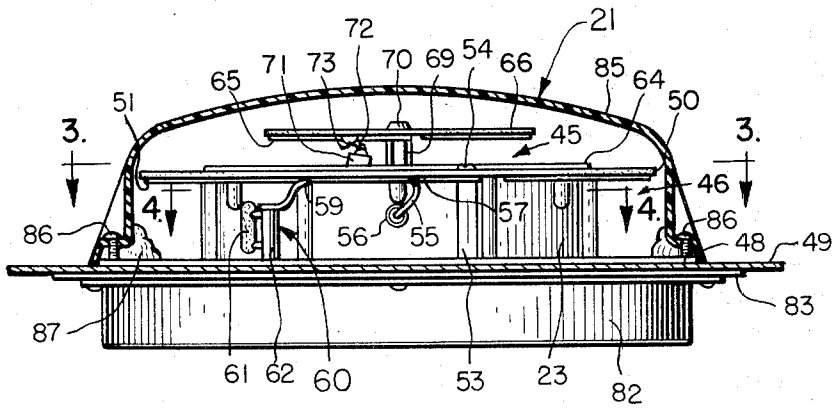
3,216,016	11/1965	Tanner	343/741
3,247,515	4/1966	Boyer	343/742

Primary Examiner—Eli Lieberman
Attorney—Drake, Crandell and Batchelder

[57] **ABSTRACT**

A compact dual-frequency specially-modulated radio transmitter and combined antenna assembly are mounted in an aircraft. Operation is initiated either automatically in the event of a crash or manually by a remote control, with the remote control system incorporated in a manner such that severing or shorting of its connections in a crash will not prevent automatic operation. Overall size and airdrag are minimized by sandwiching the principal transmitter components between a ground plane and a loop-shaped antenna parallel thereto.

14 Claims, 15 Drawing Figures



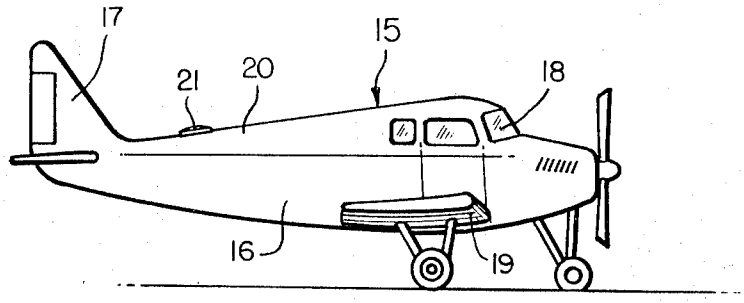


FIG. 1

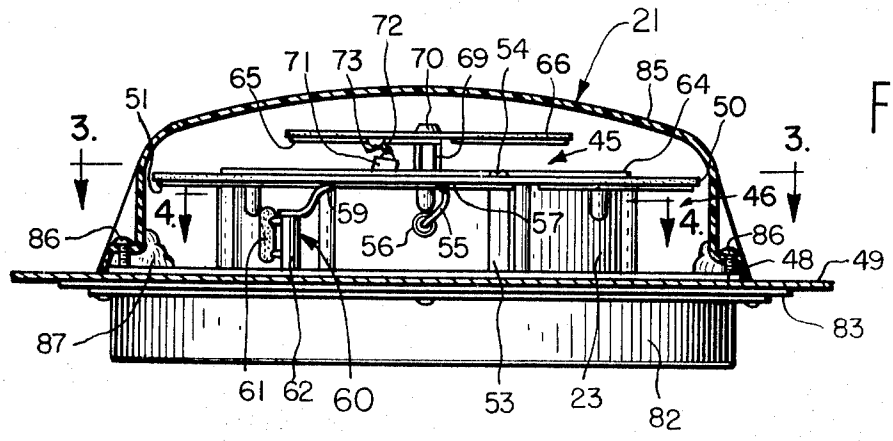


FIG. 2

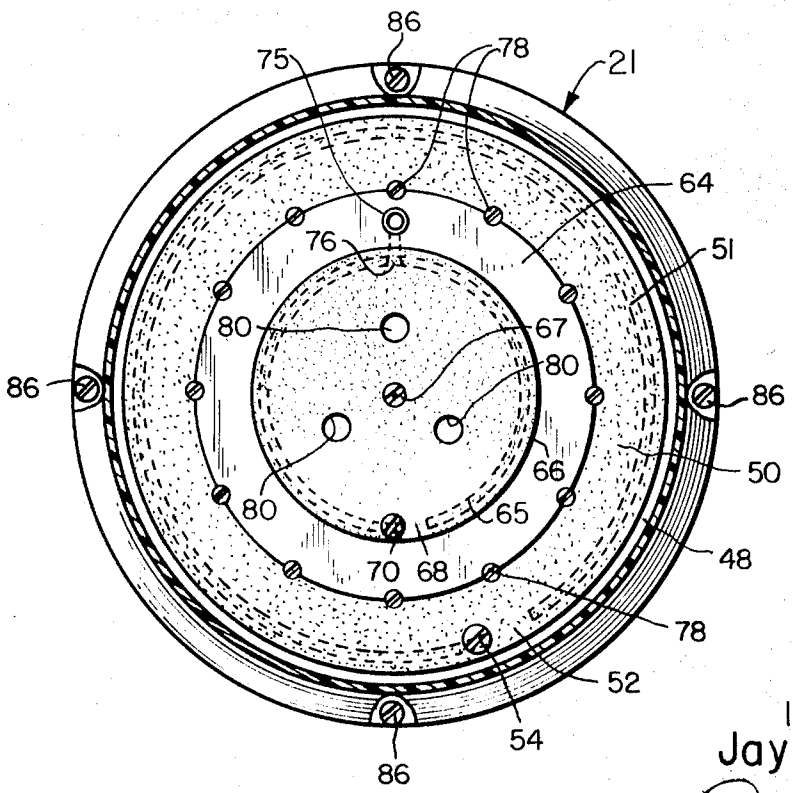
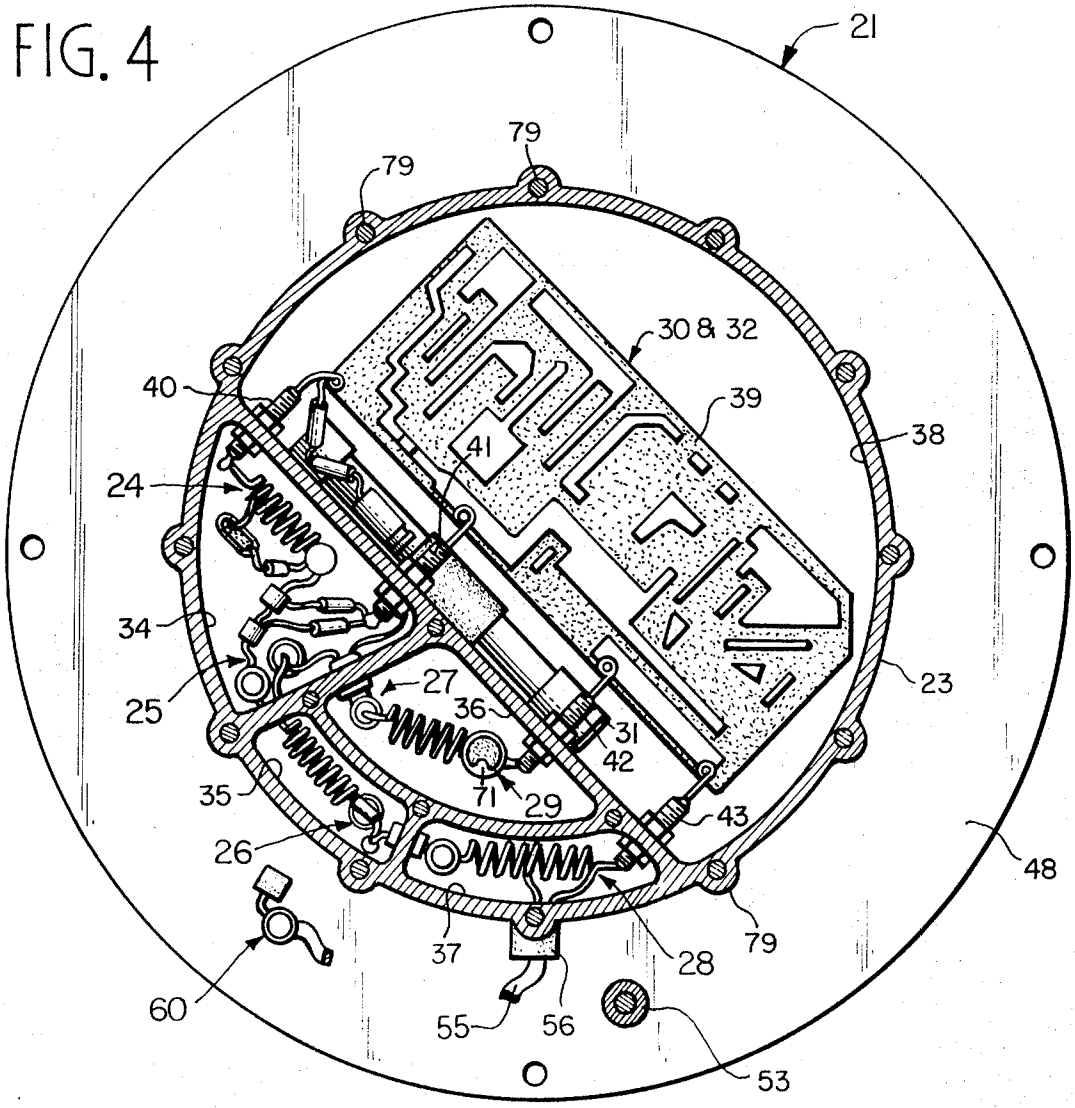


FIG. 3

Inventor
Jay E. Burton
By Dorsey and Caudell
Attorney

FIG. 4



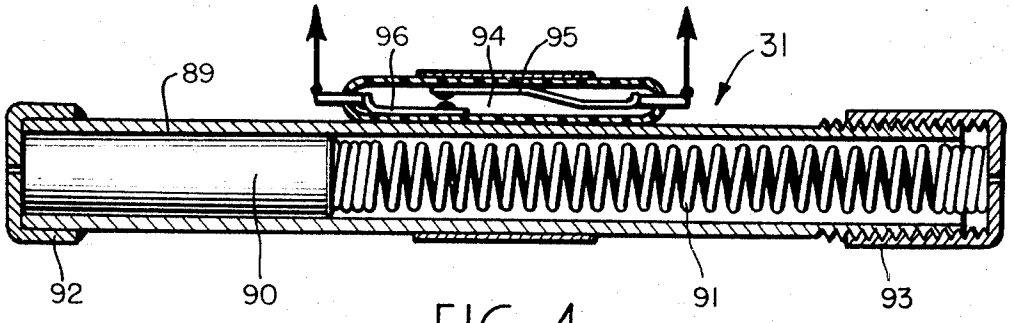


FIG. 4a

Inventor
Jay E. Burton
By Drake and Crandell
Attorney

FIG. 5

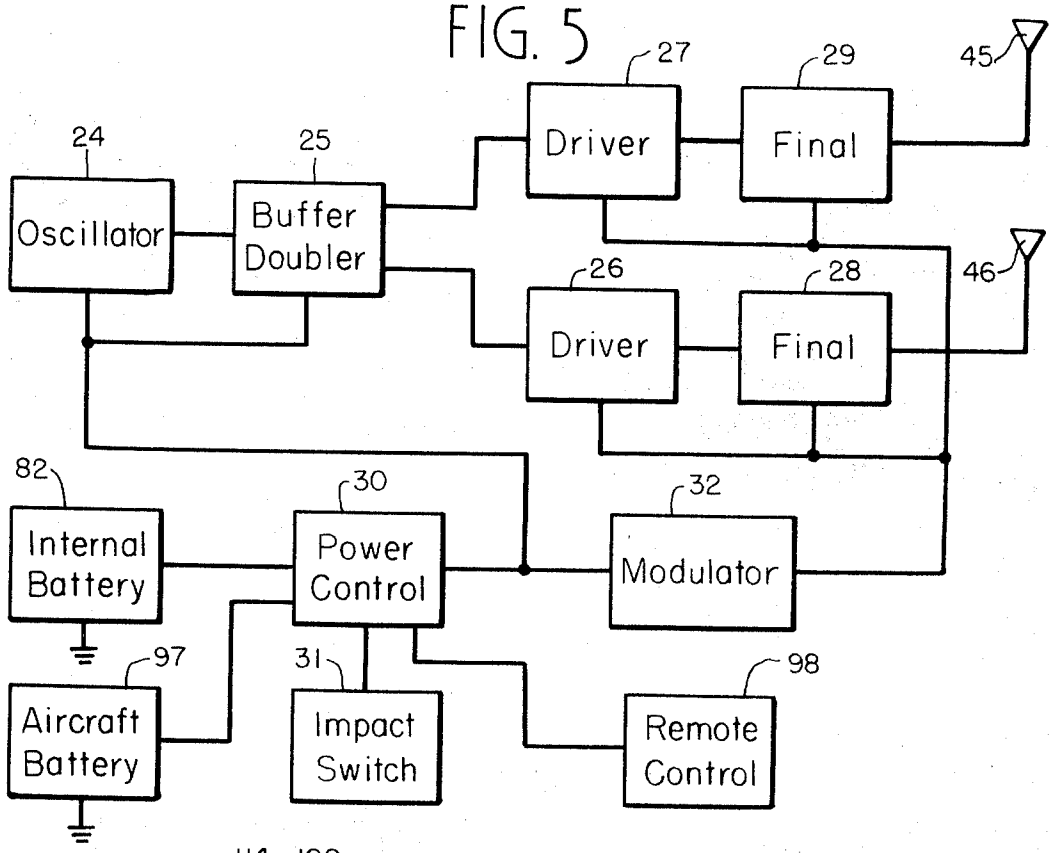


FIG. 10

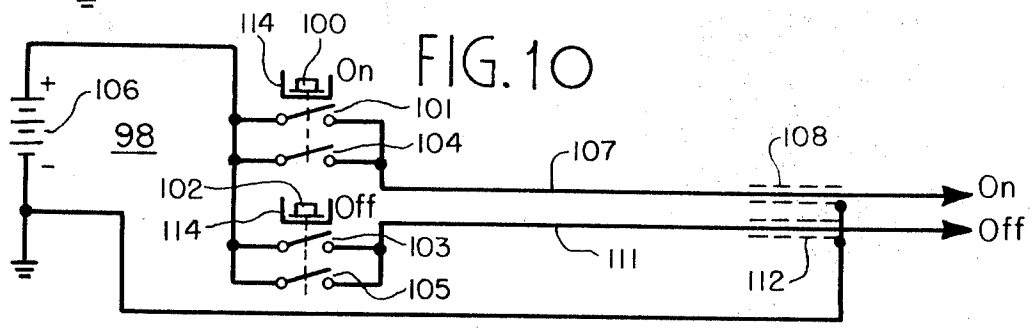


FIG. 11a



FIG. 11b



FIG. 11c

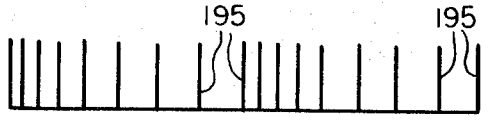
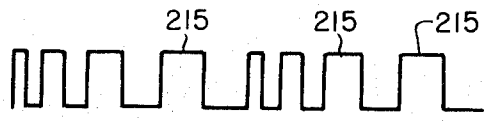


FIG. 11d



Inventor
Jay E. Burton

By Drew and Crandell
Attorney

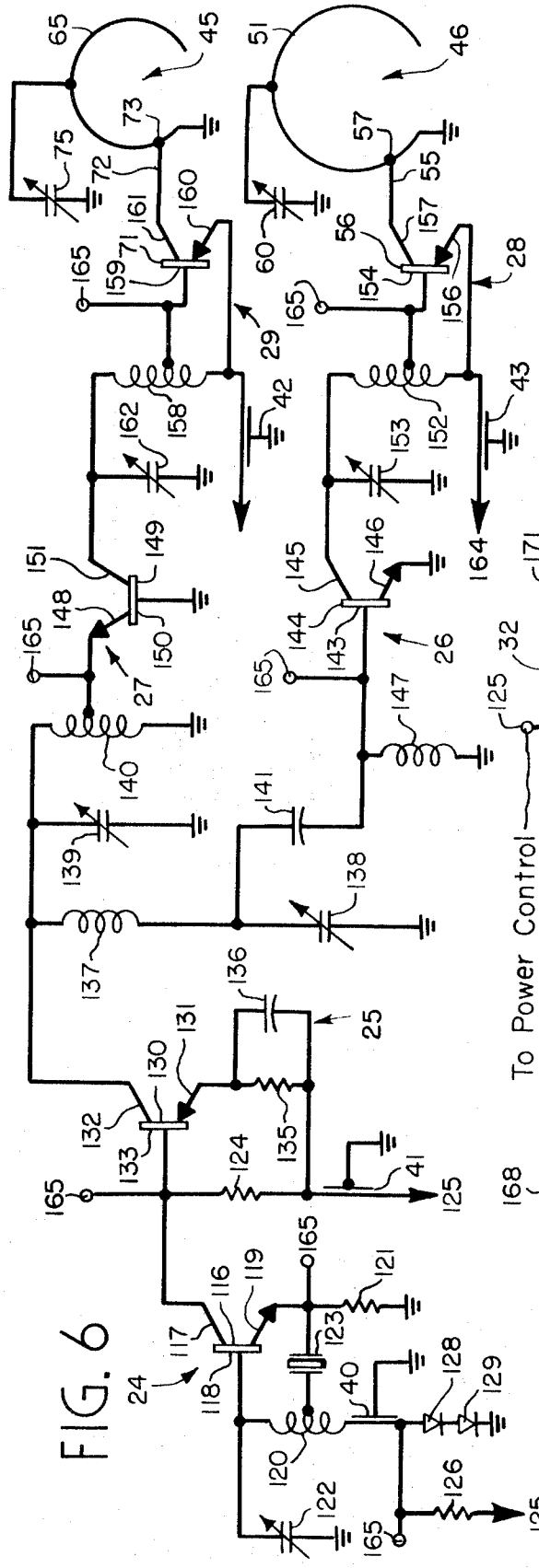


FIG. 6

FIG. 7

Inventor
Jay E. Burton
By Drake and Crandell
Attorney

FIG. 8

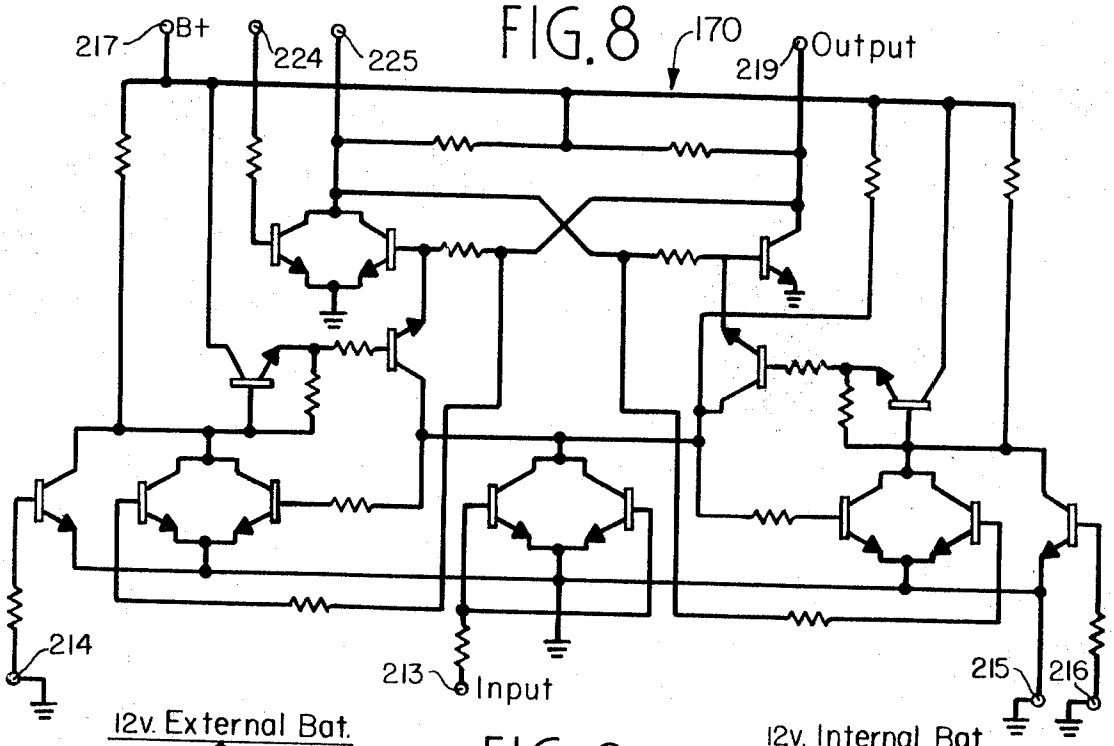
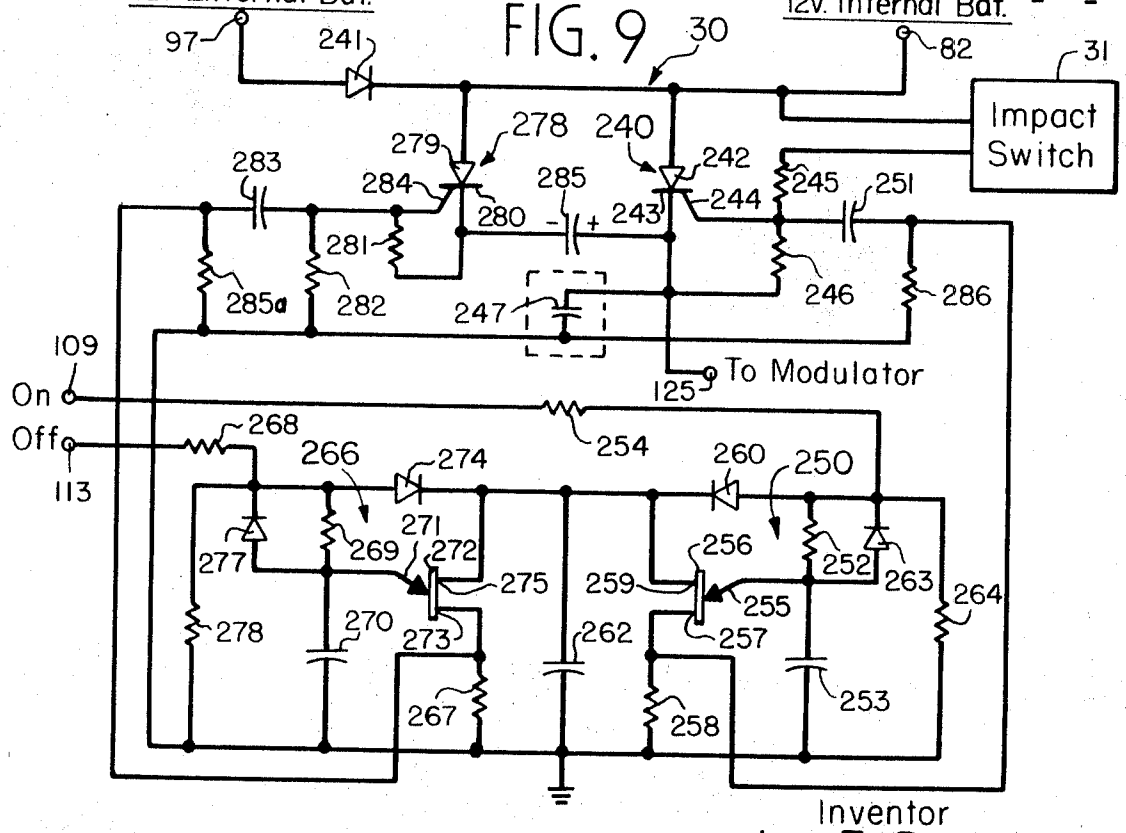


FIG. 9



Inventor
Jay E. Burton
By Drake and Crandell
Attorney

DOWNED-AIRCRAFT RADIO LOCATOR-BEACON EMPLOYING PLURAL LOOP ANTENNAS

Among the numerous more-detailed improvements are the construction of interstage shield pockets formed in part by the antenna assembly, provision for utilizing both an internal battery and, if available, the aircraft battery, a constant-current oscillator which yields high frequency stability, a simplified harmonic-generating and signal-splitting system, direct coupling of the final amplifiers to the respective antennas and a modulator that produces a distress signal swept repeatedly through a range of audio signals at a sub-audible rate of repetition. Other features reside in a power control system that includes delayed actuation for the remote control to guard against false actuation, correlated arming of a firing device and discharge of the delay circuit to insure operation over a wide-range of battery voltage, similarly delayed remote turn-off control and integration into this same system of a shock-actuated or impact switch that initiates automatic operation which, in turn, can be overridden by the remote control in the event, for example, of an unusually severe landing shock that does not impair further operation of the aircraft.

BACKGROUND

The application describes a downed-aircraft radio-locator beacon. It also discloses a number of structural and circuitry features advantageously of use in various related radio apparatus.

With drastically increased numbers of private and commercial aircraft now in use, increasing attention is being given to the problems associated with locating downed aircraft. When an aircraft unintentionally returns to the ground, whether by way of a safe but forced landing, or by a crash, a first concern is for the safety of the persons involved. Besides the frequent necessity of prompt medical attention, most incidents occur in poor weather often involving snow and cold. There are U.S. Coast Guard records indicating that survival prospects deteriorate considerably unless rescue is made within twelve hours after an accident.

Other records indicate that when flight plans are not filed, as often is the case in private flying, the occupants of about only one in every six aircraft are rescued in spite of search efforts. It has been reported that, in 1964, 11 percent of lost aircraft remained missing without a trace of the wreckage. On the other hand, of the lost aircraft that were found, 28 percent had survivors. In 1966, according to reports, there were 171 lost civilian aircraft with a total of 379 persons aboard. Of that number, 111 persons were found alive, 268 perished and 31 of the aircraft were not found.

Such records clearly support the feeling that there is sufficient likelihood of saving lives to warrant the mounting of expensive rescue missions. At the same time, however, these rescue missions too often involve extreme risk on the part of the personnel taking part. In supporting a bill adopted by the California Legislature that requires civil aircraft registered in the State to be equipped with radio-locator beacons, Calif. Sen. Lew Sherman is quoted as saying, "For the first half of this year, there were 42 search missions involving over 2,000 individual flights, 3,000 hours of flying time, and almost 5,000 people." Not only are many of those people endangering their own lives, but it is estimated that search costs can run as high as four-hundred-thousand dollars.

The foregoing demonstrates the desirability of the inclusion in all aircraft of equipment capable of signalling the existence of distress and assisting in locating the distressed aircraft. Emergency radio apparatus is indicated for achieving this purpose, because at least most U.S. military planes and many commercial aircraft carry radio receivers that are automatically activated by distress signals transmitted on an assigned emergency frequency or frequencies. Consequently, it is not surprising that several manufacturers have announced the present or coming availability of emergency radio equipment to be used on such frequencies in the event of an incident.

While downed-aircraft-locator radio equipment thus is highly desirable, its incorporation into the aircraft poses what can be serious problems. For other reasons, aircraft typically have become more and more loaded with different auxiliary or safety apparatus to the point where the weight of and the space occupied by such apparatus has become a distinct limitation. Added weight can also be of difficulty with respect to the affect upon a plane's center of gravity within a given installation. Particularly for the private aircraft owner, the additional costs of such apparatus have become of serious concern. Also of interest with respect to aircraft performance is the additional drag imposed by antennas and the possibility of damage to such antennas while the aircraft is on the ground and also by objects such as birds, while flying.

A further deficiency in certain distress radio apparatus already on the market is the necessity of actuation and control by the pilot or other operator. In a crash situation, of course, the potential operator may be unconscious or otherwise physically unable to manipulate the equipment. Moreover, the distress apparatus must in itself be capable of withstanding the impact of the crash and of initiating operation without dependence upon the aircraft's electrical system which may be rendered ineffective as a result of the incident. Furthermore, the apparatus must be capable of maintaining operation under conditions of extremes in temperature and of wide variations in available power supply potential, while yet retaining its capability of transmitting its signals at the assigned frequencies to which search monitoring receivers are set to respond.

SUMMARY

It is, accordingly, a general object of the present invention to provide a new and improved downed-aircraft radio-locator beacon which overcomes or satisfies the aforenoted deficiencies and difficulties.

It is another object of the present invention to provide various structural assemblies and electronic circuitry which lend themselves beneficially to the attainment of the primary objective.

It is a related object of the present invention to provide such structure and circuitry which also find advantageous utility in similar control and communications environments.

In accordance with the disclosure, a downed-aircraft-locator beacon includes a stable-frequency oscillator which feeds an amplifier for developing an output signal. That signal is pulse modulated with a distress signal swept repeatedly through a range of audio signals at a sub-audible rate of repetition. A remote control permits actuating or deactuating the beacon upon selective manual operation only continuously for a predetermined minimum time interval to guard against false actuation. Also included is an impact switch that automatically actuates the beacon in response to a force thereon representing a crash. The modulated signal is fed directly to a loop-shaped antenna spaced from and parallel to a ground plane, with the signal developing apparatus sandwiched between that loop and the ground plane.

Other features include a compact nested arrangement of two such antennas, an interstage shielding structure completed by a portion of the antenna assembly, arrangement of the remote control system so that there is no interference with automatic impact operation even though the remote control or its connections may become severed or shorted as a result of a crash, and the inclusion of an oscillator for initially generating the resultant signals with a high degree of frequency stability notwithstanding variations in temperature or power source potential. Additional features include simplified signal distribution arrangements within the apparatus, circuitry for developing the special modulation characteristics, circuitry for permitting use of the aircraft's own battery, when available, as well as a self-contained internal battery and a control system coordinating impact switch operation with that of isolated "off" or "on" remote control.

The inventive features which are believed to be novel are set forth with particularity in the appended claims. The invention, together with further objects and advantages thereof, may best be understood, however, by reference to the following description taken in conjunction with the accompanying drawings in the several figures of which like reference numerals identify like elements.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side-elevational view of an aircraft incorporating a downed-aircraft radio-locator beacon located as herein described;

FIG. **2** is a fragmentary cross-sectional view of the beacon depicted in FIG. **1**;

FIG. **3** is a view taken along the line **3—3** in FIG. **2**;

FIG. **4** is a view taken along the line **4—4** in FIG. **2**;

FIG. **4***a* is a longitudinal-cross-sectional view of a component included in the apparatus of FIG. **4**;

FIG. **5** is a block diagram of a downed-aircraft radio-locator beacon of the kind installed on the aircraft shown in FIG. **1**;

FIG. **6** is a schematic diagram of a portion of the circuitry included in the beacon;

FIG. **7** is a schematic diagram of another portion of the circuitry.

FIG. **8** is a schematic diagram of a detailed portion of the circuitry included in the diagram of FIG. **7**;

FIG. **9** is another schematic diagram of a control circuit used in conjunction with the other circuits depicted;

FIG. **10** is a schematic diagram of the remote control portions of the circuitry illustrated in FIG. **5**; and

FIGS. **11***a*, **11***b*, **11***c* and **11***d* illustrate wave forms of signals present in the circuit of FIG. **7**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** illustrates a typical private aircraft **15**. The aircraft includes an elongated fuselage **16** with a tail assembly **17** at the rear end of the fuselage and a pilot station **18** towards the front end. In this case, the wings **19** are disposed below and somewhat to the rear of the pilot's station. Included in the upper portion **20** of the rearward one-third of fuselage **16** is a coded-signal radio transmitter or downed-aircraft-locator beacon **21**. That location is selected because of the discovery, in the course of a study of crash records, that such portion of the aircraft, in the rear one-third but forward of the tail assembly, is most likely to survive a crash intact. Consequently, beacon **21** when in that position is least likely to be directly struck or torn apart in the unfortunate event of a crash.

Referring to FIGS. **2–5**, beacon **21** includes a metallic chassis or enclosure **23** within which are disposed an oscillator **24**, a buffer-doubler **25**, a pair of drivers **26** and **27** and a pair of final amplifiers **28** and **29**. Also within enclosure **23** are a power control system **30**, an impact switch **31** and a modulator **32**. With reference to FIG. **4**, it will be seen that the interior of enclosure **23** is divided by various walls so as to form a plurality of individual pockets that shieldingly surround different stages or portions of the overall circuitry. That is, the principal components of oscillator **24** and buffer-doubler **25** are disposed around a pocket **34**, driver **26** is primarily disposed within a pocket **35**, and an active element in driver **27** is disposed in an aperture between pocket **34** and pocket **36** that houses final amplifier **29**. Final amplifier **28** is principally disposed within a pocket **37**. Situated within a large remaining pocket **38** is a printed-circuit board **39** on the underside of which (as viewed) are affixed most of the components which make up both power control **30** and modulator **32**, those units being interconnected with the other units by means of a series of feed-through capacitors **40**, **41**, **42** and **43**. Impact switch **31** is nestled against the internal wall of pocket **38** adjacent to the printed circuit board. As shown, each of the different stages and other portions of the circuitry have their individual component elements grouped together in their respective different pockets. The intent in FIG. **4** is merely to illustrate the internal element separation of these stages and circuit portions, while the details of their interconnections are depicted more fully in the schematic diagrams of FIGS. **6—9**. Together, the circuitry constitutes radio apparatus in the form of a transmitter capable of broadcasting a pair of output signals on respective different frequencies with both being pulse modulated by a distress signal swept repeatedly through a range of audio signals at a sub-audible rate of repetition.

For radiating the two output signals, beacon **21** includes a pair of antennas **45** and **46** (FIGS. **2** and **3**) each of which is composed of a loop-shaped radiator spaced from and parallel to an associated ground plane. Moreover, the different loops and ground planes together with enclosure **34** are nested together concentrically with enclosure **23** sandwiched between one of the ground planes and its associated loop. In more detail, a conductive sheet **48** is disposed immediately over the skin **49** of aircraft **15**. Enclosure **23** is affixed directly to sheet **48** and carries a substrate **50** of fiberglass or other durable insulating material. Disposed circumferentially around the lower periphery of substrate **50** is a loop **51** of a conductive material such as copper. Loop **51** is continuous except for a comparatively narrow gap **52**. One side of gap **52** is electrically connected to conductive sheet **48** by a metallic post or stud **53** secured to substrate **50** by a screw **54**. A conductive lead **55** directly connects the collector of a transistor **56** in final amplifier **28** to a tap **57** spaced a short distance from post **53** so as to match a comparatively low-impedance point on antenna-loop **51** to the similarly low impedance presented by the output terminals of transistor **56**. From another tap **59** on loop **51** intermediate its ends is a connection to one side of a capacitor **60** the other side of which is conductively affixed to the ground plane defined by sheet **48**. For convenience, capacitor **60** in this case is composed of the parallel combination of a fixed capacitor **61** and an adjustable trimmer capacitor **62**.

In operation, antenna **46** functions generally in accordance with the principles disclosed in U.S. Letters Pat. No. 3,151,328 — BOYER (RE 26,196) and U.S. Pat. No. 3,247,515 — BOYER and as described by J. M. Boyer in an article entitled "Hula-hoop Antennas: A Coming Trend?" which appeared in the Jan. 11,1963 issue of *Electronics* at pages 44–46. Considering the plane defined by loop **51** and its associated sheet **48** to be horizontal, the pattern of radiation from the antenna is omnidirectional in the horizontal plane with an intensity which exhibits a peak amplitude at a comparatively low angle relative to the horizontal plane. Correspondingly, the radiation pattern exhibits minimum intensity of radiation in the vertical direction so that it is said to have a "cone of silence" about a vertical axis with the apex of the cone appearing at the antenna. Thus, a search aircraft attempting to "home in" on the signal radiated by antenna **46** can be aided in its search by flying cross patterns and noting when, as exhibited by fading of the received signals, it passes into and out of the aforementioned cone of silence. As compared with those patents, antenna **46** affords additional flexibility in that, instead of being connected between the ground plane and the side of gap **52** opposite stud **53**, capacitor **60** is tapped to loop **51** at a point intermediate its ends. This permits utilization of a larger value of capacitor **60** so that a greater range of adjustment in that value may conveniently be obtained.

When initially aligning the apparatus, capacitor **60** is adjusted to tune the antenna to resonance at its assigned frequency. In this particular case, antenna **46** is constructed and tuned to resonate at 121.5 Megahertz, the frequency of a standard civilian distress channel. At that frequency, loop **51** has an electrical length corresponding to one-fourth wavelength. It will thus be seen that the antenna exhibits a radiation pattern very much like a conventional quarter-wave vertical antenna. However, that result is achieved with a much more compact structure and that structure is capable of being physically formed with rugged components capable of withstanding the stresses developed under severe impact con-

ditions. Another significant feature of the antenna, in combination with the radio apparatus contained within the antenna structure itself, is the direct single-wire connection 55 from loop 51 to transistor 56; this eliminates any need for the use of matching networks to couple the final amplifier to the antenna.

Spaced inside and lying in the plane of loop 51 is a conductive layer 64 that defines a ground plane for antenna 45. In turn, spaced from and parallel to layer 64 is a second and smaller conductive loop 65, loop 65 and layer 64 together forming antenna 45 and operating in the same manner as previously described with respect to antenna 46 except at a much higher frequency because of the reduced diameter and peripheral length of loop 65. As shown, layer 64 is affixed to the upper surface of substrate 50, while loop 65 is carried around the lower periphery of another substrate 66 held in place by a screw 67 threaded into a stud affixed to the center of substrate 50. As in the case of antenna 46, one side of a gap 68 in loop 65 is grounded to layer 64 by a stud 69 into which a screw 70 is threaded. The collector of a transistor 71 is directly connected by a short lead 72 to a tap 73 spaced from stud 69 by a distance to present an impedance matching that presented at the output of transistor 71. Also as before, a trimmer capacitor 75 is connected between a tap 76 on loop 65 and a ground plane defined by layer 64. Capacitor 75 is adjusted to tune antenna 45 to resonance at its assigned frequency which in this case is 243 Megahertz, the frequency of a standard military distress channel. It is on that channel that equipment already carried by many present-day aircraft is designed to be automatically activated by a received signal. Loop 65 has an electrical length corresponding to a quarter-wave length at this frequency. Again, antenna 45 exhibits a radiation pattern which is omnidirectional in the horizontal and includes a cone of silence in the vertical.

Substrate 50 is affixed as a cover to the external sidewalls of enclosure 23 by means of a series of screws 78 threaded into the corresponding fillets 79. Conductive sheet 48 is similarly secured to the bottom of enclosure 23. Screws 78 contact the peripheral portion of layer 64 so that the latter is conductively connected to the metallic walls of enclosure 23 and also to conductive sheet 48. With substrate 50 secured in place, conductive layer 64 serves not only as a ground plane for antenna 45 but also closely overlies the openings in each of pockets 34–38 so as to shieldingly complete the closure of those pockets and thus enhance the isolation between the different stages and other portions of the overall circuitry. Preferably, the shielding effectiveness is further improved by forming another conductive layer on the underside of substrate 50 immediately below layer 64; that layer, therefore, lies in direct physical contact with the upper edge surface of the walls defining and segmenting enclosure 23. In either event, an opening is formed through substrate 50 as well as through conductive layer 64 and the other underlying conductive layer, if included, and transistor 71 that projects upwardly from pocket 36 is disposed in that opening. Thus, the layout of the different pockets formed in enclosure 23 is such as to align transistor 71 with the desired position of tap 73 on loop 65. Similarly, pocket 37 is located so that the opening from that pocket through the wall of enclosure 23, in which transistor 56 is disposed, is in alignment with tap 57 on loop 51. Additional openings, such as illustrated at 80 in substrate 66, may be formed at different places in either of the substrates either for weight-reduction or stress-relief purposes.

Affixed to and beneath conductive sheet 48 is a housing 82 forming a compartment for an internal battery-type power supply. In a typical embodiment, housing 82 is a size sufficient to accept a quantity of eight D-Size alkaline-earth cells which are connected in series to constitute a nominally 12-volt source of power that exhibits a long shelf-life capability.

While the installation of beacon 21 on the aircraft fuselage only requires the formation of a comparatively small hole in skin 49 to accommodate interconnecting electrical leads and a few still-smaller holes to accept threaded fasteners securing compartment 82 through the skin to sheet 48, the beacon assembly further includes a plate 83 of a material stiffer than that of either compartment 82 or sheet 48. In this way, the rigidity of the entire assembly is enhanced.

An insulative and fire-resistant but radio-wave transmissive dome 85 (e.g. fiber glass, polycarbonate or other plastic), fastened to sheet 48 around its periphery by screws 86, forms a housing overlying antennas 45 and 46 as well as enclosure 23. Because of the extremely compact formation of the entire apparatus, housing 85 projects only a very short distance beyond the normal exterior surface of the fuselage so as to present only a minimal air drag during operation of the aircraft. Furthermore, the interior space within dome 85, as well as the spaces within enclosure 23 and compartment 82, are completely filled with a deliquefied foam-type insulating and cushioning material 87. Consequently, the whole unit exhibits a high degree of shock resistance, while at the same time being highly resistant to both moisture and fire. Though constituting two complete antenna systems and transmitters together with a self-contained power source, a prototype unit, including cabling, and an extra or remote control, weighs only 4½ pounds. The transmitter has a diameter of 7½ inches and a height of only 2 inches. Yet, depending somewhat upon terrain and altitude of the search aircraft receiver, the operating range is of the order of 200 miles.

FIG. 4*a* best depicts the details of impact switch 31. Slideable within a sleeve 89 of non-magnetic material is a magnet 90 urged toward one end of the sleeve by a coiled spring 91. One end sleeve 89 is fixedly closed by a cap 92, while another cap 93 is threaded upon the other sleeve end and abuts spring 91; turning cap 93 relative to sleeve 89 permits adjustment of the spring pressure against magnet 90. A reed-type electric switch 94 is mounted upon sleeve 89 in a position such that its movable contact 95 of magnetic material is pulled against a mating contact 96 upon movement of magnet 90 toward switch 94. Beacon 21 is installed in the aircraft so that sleeve 89 is oriented fore and aft with respect to the fuselage and with magnet 90 being toward the rear of the aircraft. Upon a crash of the aircraft, magnet 90 is propelled forwardly against the spring pressure and toward switch 94. The position of cap 93 is adjusted so that the strength of spring 91 together with the mass of magnet 90 results in actuation of switch 94 when a force approximately equivalent to 7 times the force of gravity is applied to the unit. It has been found that the force developed during a crash exceeds that value. Normal, uneven rough, operation of the aircraft does not effect false operation. Of course, the entire impact switch assembly is securely mounted in place within enclosure 23. For this purpose, it has been found satisfactory to utilize an epoxy resin for directly cementing sleeve 89 to the bottom and the adjacent wall of enclosure 23.

Illustrating the overall beacon system is the block diagram of FIG. 5. Oscillator 24 develops a signal of very-high frequency stability at 121.5 Megahertz. That signal is fed to buffer-doubler stage 25 in the output portion of which both the fundamental 121.5 Megahertz and a harmonic 243 Megahertz signals are produced. The fundamental signal is fed through a driver stage 26 to final amplifier 28 which is coupled to antenna 46. Simultaneously, the harmonic signal is supplied through driver stage 27 to final amplifier 29 which is coupled to antenna 45. Power control circuit 30 serves to supply electric power upon either automatic or manual command to oscillator 24, buffer-doubler 25 and modulator 32. The latter, in turn, is coupled both to drivers 26, 27 and to final amplifiers 28 and 29. The modulator develops a specially-coded modulation generally of pulse waveform so that the final amplifiers and driver stages are gated to an on condition in response to the application of each pulse supplied by modulator 32.

Power control 30 is always connected so as to derive electric energy from the internal batteries in compartment 82. The power control circuitry is also arranges so that, when available, power is simultaneously derived from the aircraft's own battery system 97. Without the availability of power from air-

craft battery **97**, internal battery **82** has sufficient capacity to operate beacon **21** for approximately 100 hours at an outside temperature of 70° Fahrenheit and about 60 hours at an outside temperature of 0° Fahrenheit. When aircraft battery **97** is not destroyed or disconnected as a result of a crash, its availability extends the operating time by hundreds of hours.

Finally, the overall system includes a remote control **98** coupled to power control **30**. The remote control is usually installed in the pilot compartment so as to permit manual operation to activate power control **30** either for test purposes or in the case of a forced landing not amounting to a crash. Remote control **98** also permits power control **30** to be deactivated manually whenever desired such as at the conclusion of the test.

As shown in FIG. **10**, the separate remote control circuitry is exceedingly simple. It includes an "on" push button **100** operative upon manual depression to close a switch **101** and an "off" push button **102** manually depressable to close a switch **103**. As a redundancy backing-up switches **101** and **103**, each of them is parallelled by a second switch, **104** and **105** respectively, simultaneously operated by the respective push buttons. The positive terminal of a small long-life battery **106**, in this particular case having a potential of 9 volts, is connected to one side of all four switches **101** and **103–105**. The other terminals of switches **101** and **104** are connected to a lead **107** which is enclosed within a flexible shield **108** that is connected to ground and connects to terminal **109** of power control **30** as shown in FIG. **9** and labeled "on." The other terminals of switches **103** and **105** are similarly connected to a lead **111** enclosed within a grounded shield **112** and connected to a terminal **113** of power control **30** that terminal in FIG. **9** being labeled "off." The negative terminal of battery **106** is returned to ground. Thus, remote control **98** serves as a separate and individual power source the energy from which can be selectively applied either to terminals **109** or **113** of power control **30** as desired. Preferably, push buttons **100** and **102** are mounted on a small panel area within easy reach of the pilot. To help guard against inadvertant depression of either push button accidentally by the pilot or as a result of an object moved toward the push buttons in the case of a crash, each of the buttons preferably is physically disposed within a cup-shaped element **114**. The lips of elements **114** extend beyond the normal or rest position of the respective push buttons so that they may be operated only upon the insertion within the cup of the end of a finger.

Turning next to FIG. **6**, oscillator **24** includes an NPN transistor **116** having a collector **117**, a base **118** and an emitter **119**. An inductor **120** is coupled between base **118** and emitter **119** by way of capacitor **40** and an emitter-bias resistor **121**. An adjustable capacitor **122** is coupled in parallel with inductor **120** and is tuned to resonate therewith at the fundamental frequency of 121.5 Megahertz. A peizoelectric crystal **123** is connected between emitter **119** and a tap on inductor **120**. Crystal **123** serves as a filter having a narrow passband centered at the 121.5 Megahertz frequency. A load resistor **124** is coupled between collector **117** and emitter **119** by way of capacitor **41** and resistor **121**.

With the end of resistor **121** opposite emitter **119** being connected to ground, to which the negative terminals of both batteries **82** and **97** are connected, oscillator **24** is energized by applying a positive battery potential from terminal **125** of power control **30** (FIG. **9**) to the junction of resistors **124** and **135** by way of feed-through **41**. To that end, terminal **125** is connected to collector **117** through resistor **124** and to base **118** through a limiting resistor **126** and inductor **120**. To assist in obtaining optimum frequency stability, oscillator **24** is operated in a constant-current condition. This is assured by returning the point between resistor **126** and inductor **120** to ground through a pair of series-diodes **128** and **129** that exhibit a constant potential drop throughout a wide range of potential variation in the battery power source. While a single diode of the proper characteristics would suffice, for convenience a pair of silicon diodes are employed so as to achieve a constant voltage drop of 1.2 volts.

In operation, oscillator **24** regenerates by virtue of positive feedback at the desired frequency through filter **123**. That feedback potential is applied across the lower portion of inductor **120** which serves as an autotransformer to induce a voltage gain in the feedback signal applied to base **118**. As employed in practice, filter **123** is a quartz crystal active at a submultiple of the desired 121.5 Megahertz and exhibiting active response at either the fifth or seventh overtone of that submultiple. Contributing further to the excellent frequency stability of oscillator **24**, emitter resistor **121** has a low value of resistance, typically 47 ohms, comparable to the impedance presented by emitter **119**. At the same time, load resistor **124** similarly has a value, again typically 47 ohms, that is comparable to the low impedance presented by collector **117**. One result of these impedance relationships is that there is minimal reflection of impedance from buffer-doubler **25** into oscillator **24** by way of collector **117**; the arrangement functions much like the well-known electron-coupled oscillator.

In practice, oscillator **24** had been found to exhibit a deviation from desired center frequency of less than 5 Kilohertz under conditions of temperature variation all the way between minus 60° and 100° Centigrade in the 121.5 Megahertz region. This corresponds to a frequency tolerance of ± 0.005 percent. That same frequency tolerance is exhibited with a simultaneous variation in power supply battery potential from 12 volts to 6 volts. **154** Buffer-doubler stage **25** includes a PNP transistor **130** having an emitter **131**, a collector **132** and a base **133**. Load **124** is coupled between base **133** and emitter **131** by way of an emitter-bias resistor **135** paralleled by a bypass capacitor **136**. Its load circuit includes an inductor **137** series-connected with an adjustable capacitor **138** connected between collector **132** and ground and an adjustable capacitor **139** paralleled by an inductor **140** with both also connected between collector **132** and ground. A capacitor **141** is connected from a point intermediate inductor **137** and capacitor **138** to the base **143** of an NPN transistor **144** in driver stage **26** and which also has a collector **145** and an emitter **146**. Connected from base **143** to ground is a radio-frequency choke **147**. A tap on inductor **140** is connected to the emitter **148** of a transistor **149** that has a grounded base **150** and a collector **151**.

For operation, bias resistor **135** is selected to have a value such that transistor **130** operates as a Class B amplifier and very near to operation in the Class C region. As a result, the signals amplified by transistor **130** include a harmonic frequency of 243 Megahertz. Capacitor **139** is tuned to be in parallel resonance with inductor **140** and the input reactance of transistor **149** at the higher 243 Megahertz frequency. At the same time, capacitor **138** is tuned, together with the fixed reactance of the input network including transistor **144**, to be in series resonance with inductor **137** so that the fundamental-frequency signal at 121.5 Megahertz is fed to driver stage **26**. Thus, the output circuitry of stage **25** serves as a passive network to separate and distribute signals of the two desired output frequencies. Stage **25** also serves as a buffer between oscillator **24** and the driver stages in order to prevent undesired reaction upon the oscillator by subsequent modulation of driver stages **26** and **27**.

In the output circuit of driver transistor **143** is an inductor **152** coupled between collector **145** and ground by way of capacitor **43**. In parallel with inductor **152** is an adjustable capacitor **153** also connected between collector **145** and ground to which emitter **146** is also connected. A tap on inductor **152** is connected to the base **154** of output transistor **56** the emitter **156** of which is returned to ground also through capacitor **43**. Capacitor **153** is tuned, together with the input reactance of transistor **154**, to resonate with inductor **152** at the 121.5 Megahertz fundamental frequency. Consequently, the fundamental-frequency signal is amplified by transistor **143** which in turn drives transistor **56** in final amplifier **28**. As already described in connection with FIGS. **2** and **5**, collector **157** of transistor **56** is directly connected and impedance matched to tap **57** on antenna **46** which radiates the finally amplified fundamental-frequency signal.

Similarly, driver stage **27** includes an inductor **158** coupled between collector **151** and ground by way of capacitor **42**. A tap on inductor **158** is connected to the base **159** of transistor **71** which has its emitter **160** also returned to ground through capacitor **42** and a collector **161** directly connected and impedance matched to tap **73** on harmonic-frequency antenna **45**. An adjustable capacitor **162** connected between collector **151** and ground, together with the input reactance of transistor **159**, is tuned to be in parallel resonance with inductor **158** at the harmonic frequency. Energization for both driver stage **27** and final amplifier **29** is achieved by the application of a positive potential through feed-through **42** from a terminal **164** of modulator **32** in FIG. **7**. Similarly, terminal **164** is connected to driver stage **26** and final amplifier **28** through feed-through **43**. Finally, the diagram of FIG. **6** includes an indication of a plurality of test points **165** for convenience of the technician servicing or adjusting the apparatus.

With reference to FIG. **7**, modulator **32** has a series of stages including a sweep-repetition generator **168**, a sweep-frequency generator **169**, a flip-flop or bistable multivibrator **170** and several additional stages. From terminal **125** of power control **30** (FIG. **9**), a positive potential is applied to a bus **171**, while a negative bus **172** is connected to ground.

Sweep-repetition generator **168** includes a uni-junction transistor **174** having its first base **175** connected to ground and its second base **176** connected to positive bus **171**. A filter capacitor **177** is connected between busses **171** and **172**. A charging network includes a resistor **178** in series with a capacitor **179** between bus **171** and ground. Emitter **180** of transistor **174** is connected to a point intermediate resistor **178** and capacitor **179** from which point a signal also is sent to the base **181** of an NPN transistor **182** which serves as an isolation stage.

In operation, generator **168** develops a series of successive sawtooth pulses **184** as shown in FIG. **11***a* and having a repetition rate of between 2 and 4 times per second. The sawtooth pulses are developed upon capacitor **179** which is charged through resistor **178** until a potential level is reached on emitter **180** to render transistor **174** conductive. At that time, the charge on capacitor **179** is conducted to ground with the cycle then repeating a transistor **174** is thereby rendered nonconductive and capacitor **179** again begins to charge.

Isolation transistor **182** has a collector **183** connected to bus **171** and an an emitter **184** connected to the second base **185** of another uni-junction transistor **186** the other base **187** of which is connected to ground through resistor **188**. Completing sweep-frequency generator **169** is a charging network composed of a resistor **190** in series with a capacitor **191** both connected between bus **171** and ground and with a point intermediate the resistor and capacitor being connected to an emitter **192** of transistor **186**.

While sawtooth pulses **184** developed by sweep-repetition generator **168** have a constant repetition rate and duration, sweep-frequency generator **169** develops sets of successive sawtooth pulsations **194** as shown in FIG. **11***b*. The sets of pulsations **194** repeat at the repetition rate of pulses **184** and also progressively change in duration within each set. Ignoring resistor **188** and assuming for a moment that base **185** is connected directly to bus **171**, the operation of generator **169** would be very much like that of generator **168**. That is, capacitor **191** charges through resistor **190** until the potential on emitter **192** is sufficient to render transistor **186** conductive. At that time, the charge on capacitor **191** would be conducted to ground, transistor **186** would again become nonconductive and the cycle would repeat.

However, the firing potential of emitter **192** is a function of the potential applied to base **185** of transistor **186**, and that base potential is repeatedly changing in proportion to the instantaneous changes in amplitude of pulses **184** from generator **168**. Consequently, the period of time during each charge cycle of capacitor **191**, before emitter **192** fires, is progressively changing throughout the duration of each of pulses **184**. Accordingly, FIG. **11***b* represents the potential on emitter **192**. In practice, pulsations **194** change, during the duration of each pulse **184**, between a repetition rate between about 2,500 and 500 Hertz. It may be observed in passing that pulsations **194** in FIG. **11***b* are idealistically drawn and are shown to reach the like amplitudes. Although it does not affect operation in practice, pulsations **194** do individually increase in amplitude progressively during each set of pulsations because of the increased time permitted for capacitor **191** to charge before again firing emitter **192**.

The value of resistor **188** is small compared to the reactance of charging capacitor **192** so that, when transistor **186** is rendered conductive, the resulting short time constant circuit composed of resistor **188** and capacitor **191** permits rapid discharge of the energy stored in capacitor **191**. Consequently, a series of spike-shaped pulses are developed across resistor **188**, one such pulse appearing each time capacitor **191** is discharged. As shown in FIG. **11***c*, the corresponding series of spike pulses **195** similarly occur in sets repeating at the repetition rate of pulses **184** and progressively changing in interpulse spacing within each set. Spike pulses **195** are then fed successively through a series of three DC-coupled amplifiers from the output of which they appear in amplified form across a resistor **196**.

Thus, the point intermediate resistor **188** and base **187** is connected to the base **197** of an NPN transistor **198** that has its emitter **199** grounded and its collector **200** connected to bus **171** through a resistor **102**. The point intermediate collector **200** and resistor **102** is connected to the base **202** of a PNP transistor **203** the emitter **204** of which is connected to bus **171** while its collector **205** is connected to ground through a resistor **206**. Finally, the point intermediate resistor **206** and collector **205** is connected to the base **207** of an NPN transistor **208** having its collector **209** connected to bus **171** and its emitter **210** returned to ground through resistor **196**. Like in the remainder of power control **30** as well as in the circuitry of FIG. **6**, each succeeding transistor, in progressing through a series of direct-connected transistor stages, is of a different polarity-type (NPN or PNP) than the one proceeding or following it. This, of course, enables direct-current energization of the transistors with only a two-terminal source of direct-current power.

Spike pulses **195** are fed from the top of resistor **196** through a limiting resistor **212** to the input terminal **213** of multivibrator **170**. The equivalent circuit of multivibrator **170** utilizing discrete components shown in FIG. **8**, and typical values of all of the components therein together with a detailed description of its operation will be found beginning at page 50 of the Mar., 1966 issue of "Electronics World" as well as in standard reference works and handbooks under the standardized designation "JK Flip-Flop." By itself, the JK Flip-Flop is a fully integrated, monolithic circuit which is the equivalent of 15 discrete transistors combined with 17 discrete resistors. It is capable of counting by two, automatically steering its own input to the proper side on every count and acting as a shift register or memory element. By manufacturer's definition, JK Flip-Flops are available from Fairchild Semiconductor under type numbers UL 923 and 9923. While, as utilized in the present embodiment, several of the capabilities of the JK Flip-Flop are ignored, it is presently preferred because of its low-cost availability as a plug-in unit in a size smaller than an ordinary garden-variety green pea.

Nevertheless, any known device may be substituted which serves as a binary divider. That is, for each one of spike pulses **195**, multivibrator **170** develops an output signal which alternately is first "on" and then "off" as shown by the series of square pulses **215** in FIG. **11***d*. The binary divider function of multivibrator **170** will be noted by observing that it requires two successive ones of spike pulses **195** to define any one of pulses **215**. Consequently, square pulses **215**, being alternately initiated and terminated by successive ones of spike pulses **195**, occur in sets repeating at the repetition rate of sawtooth pulses **184** and progressively changing in duration throughout

each set. By reason of the divider action, the repetition rate or frequency of square pulses **215** changes repeatedly between 1,250 and 250 Hertz. That is, square pulses **215** vary in frequency at an audio-frequency rate, while the sets of audio variations repeat at a sub-audible rate.

Because the JK Flip-Flop is available as a small plug-in unit, the receptacle schematically indicated in FIG. 7 is physically provided as a series of holes in printed board **39** to each of which the different interconnections are conventionally laid down. Completing the necessary connections in FIG. **7**, terminals **214**, **215** and **216** are connected to ground, terminal **217** is connected to B+ bus **171** through a limiting resistor **218** and the output from multivibrator **170** is taken from a terminal **219** and fed to the base **220** of a buffer and inverting transistor **221**. To eliminate possible transient response, a filter capacitor **222** is connected between terminal **217** and ground.

Referring again to FIG. **8**, and utilizing conventional integrated-circuit terminology, it will be observed that spike pulses **195** are applied to toggel input terminal **213**, while square pulses **215** are derived from "zero" output terminal **219**. "Set" input terminal **214** and "reset" input **216** are returned to ground, rendering those two possible functions inoperative. "Preset" input terminal **224** and "one" output **225** remain unconnected.

The isolation stage, including NPN transistor **221**, serves to isolate multivibrator **170** from any switching transients developed during the action of the succeeding modulation PNP transistor **227** which operates as a saturated switch to alternately apply and remove the positive potential on bus **171** to and from driver stages **26**, **27** and final amplifier stages **28**, **29** by way of terminal **164**. Thus, transistor **221** has its emitter **228** returned to ground through a bias resistor **229** and its collector **230** connected through a limiting resistor **231** to the base **232** of modulation transistor **227**. A decoupling resistor **233** is connected between bus **171** and the point intermediate resistor **231** and base **232**. Emitter **234** of transistor **227** is connected to bus **171**, while its collector **235** is connected directly to modulation output terminal **164**.

Transistor **221** is arranged to operate also as an inverter of square pulses **215** so that modulation transistor **227** becomes conductive on the application to its base **232** of each negative-going one of the square pulses. Consequently, the signals radiated from antennas **45** and **46** occur in bursts of energy varying in frequency of repetition rate over an audio-frequency range in sets of bursts that repeat at the sub-audible repetition rate of sawtooth pulses **184**.

Turning finally to power control system **30** in FIG. **9**, the supply of a positive potential from battery **82** to the radio-frequency and modulation apparatus of FIGS. **6** and **7** is under the control of a pulse-operated valve **240** capable of responding to a gating pulse to become and continue being conductive for the purpose of connecting battery **82** to terminal **125**. When conductive, valve **240** is subject to being rendered non-conductive in response to the occurrence of a different electrical pulse in order to disconnect battery **82** from modulator **125** and thereby de-energize the load represented by the radio-frequency and modulation circuitry.

The positive terminal of aircraft battery **97** is connected to the positive terminal of battery **82** through a diode **241** poled to permit current flow to valve **240** only when the potential of external battery **97** is higher than that of internal battery **82**. Thus, the aircraft's own battery power supply may be used, when available and appropriately charged, in order to greatly extend the period of time during which beacon **21** remains operative after being activated. At the same time, isolating diode **241** blocks the occurrence of any drain from battery **82** toward external battery **97** should the latter for any reason become substantially discharged or a short be developed in the lead extending from diode **241**, which is inside the beacon, to that external power source.

To obtain the characteristics mentioned, valve **240** is a silicon-controlled rectifier (SCR) which exhibits a thyratron characteristic and has an anode **242** connected to terminal **82**, a cathode **243** connected to power-supply terminal **125** and a gate electrode **244**. One of contacts **95** and **96** in impact switch **31** is connected to terminal **82** while the other is connected through a limiting resistor **245** to gate **244**. Gate **244** is also returned to its cathode **243** through a resistor **246**, and a filter capacitor **247** is connected between cathode **244** and ground. Accordingly, automatic activation of beacon **21** is achieved simply by the closure of impact switch **31** to fire SCR **240** which, even though the contacts in switch **31** subsequently open, remains conductive.

Thus, both the automatic initiation and continuance of operation of beacon **21** is powered by energy from internal battery source **82** and/or external battery source **97**. Remote and manual initiation of beacon operation, however, requires energy from an additional and separate power source which in this case is battery **106** of remote control **98** (FIG. **10**). It will be recalled that depression of push button **100** causes a positive potential with respect to ground to appear on terminal **109**, while depression of "off" push button **102** similarly causes a potential to appear at terminal **113**. Depression of button **100**, then, results in the supply of energy from battery **106** by way of terminal **109** to a timing or firing stage **250** which, after storage of that supplied energy for a predetermined minimum time interval, feeds an electrical-energy pulse over a blocking capacitor **251** to gate **244** of valve **240** in order to actuate the valve and thereby initiate operation of beacon **21**.

In more detail, firing stage **250** includes a charging resistor **252**, an energy storage device in the form of a charging capacitor **253** in series with resistor **252** between ground and a lead connected through a current-limiting resistor **254** to terminal **100**. The gate electrode **255** of a uni-junction transistor **256** is connected to a point intermediate resistor **252** and capacitor **253**. The first base **257** of transistor **256** is returned to ground through a load resistor **258**, while second base **259** is connected to the supply side of resistor **252** through a diode **260** polarized to pass current from terminal **109** only in a direction toward base **259**. Connected between base **259** and ground is an arming capacitor **262**. A discharge path for capacitor **253** is created from the point intermediate resistor **252** and capacitor **253** through a diode **263** and a resistor **264** to ground. While diode **262** electrically shunts resistor **252**, it is poled to permit current flow only in the direction from capacitor **253** toward resistor **254**.

In operation, the depression of push button **100** enables flow of current through diode **260** into arming capacitor **262** which has a sufficiently large value to exhibit a long-time constant and thereby maintains an arming potential on base **259** relative to base **257**. At the same time, current from terminal **109** through resistor **252** charges capacitor **253**, the rise in potential on capacitor **253** occurring with a sawtooth wave form in the same manner as described with respect to generators **168** and **169** in FIG. **7**. Like in those generators, the potential on capacitor **253** applied to gate **255** continues to increase until, in this case preferably until a time interval of between 4 and 5 seconds has elapsed, transistor **256** becomes conductive. The resultant dumping of energy from capacitor **253** through base **257** and resistor **258** results, like in generator **169**, in the development of a spike pulse across resistor **258**. It is that pulse which is then fed to gate **244** of value **240**, whereupon the latter becomes conductive and the radio apparatus is activated.

By delaying the development of the firing pulse on resistor **258** for several seconds following the depression of push button **100**, inadvertant false actuation of beacon **21** is guarded against, Should the push button be depressed for a lesser time interval and then released, the energy stored on capacitor **253** thereupon discharges through diode **263** and resistor **264** so that the firing circuit is automatically restored to the condition in which it will demand continued depression of push button **100** for the total designed delay interval before actuating valve **240**.

Another firing stage **266** similarly responds to depression of push button **102** to develop a pulse across a resistor **267** that is utilized to render valve **240** nonconductive and, hence, disconnect the supply of power from the radio apparatus. To that end, current from terminal **113** is connected through a limiting resistor **268** and a charging resistor **269** into storage or charging capacitor **270**. After a similar delay interval of 4 to 5 seconds, the potential on capacitor **270** causes a gate **271**, of a uni-junction transistor **272**, to establish a conductive path to ground through a first base **273** of that transistor and load resistor **267**. Also as before, current from terminal **113** initially assures operative arming of transistor **272** by means of rapid current flow through a diode **274** into arming capacitor **262** which is connected between the second base **275** of transistor **272** and ground. Additionally the same as in firing stage **250**, a diode **277** shunts resistor **269** and establishes a discharge path from capacitor **270** through a discharge resistor **278** to ground.

Capacitor **262** thus serves in common to arm both transistors **256** and **272**. Moreover, the value of capacitor **262** is sufficiently high that its discharge rate, through bases **275** and **259** and the back resistances of diodes **260** and **274** together with the resistances of any other leakage paths, is correspondingly sufficiently slower than the discharge rates of either capacitor **253** or capacitor **270**, through their respective resistors **264** and **278**, that transistors **256** and **272** remain in an armed condition over a substantial range of potential variation in battery **106**. Even should the potential of battery **106** become lower than normal, the arming potential maintained on bases **259** and **275** is kept sufficiently high that a lowered potential on gates **255** or **271** is not permitted to cause pre-mature firing of transistors **256** or **272** as otherwise could occur with a reduced potential available for bases **259** and **272**.

Completing the circuitry for extinguishing operation of value **240** is response to depression of push button **102** is a similar valve **278** in the form of a silicon-controlled rectifier having an anode **279** connected to internal battery terminal **82** and a cathode **280** returned to ground through a resistor **281** in series with another resistor **282**. The point between resistor **267** and the base **273** is connected through a blocking capacitor **283** to the gate electrode **284** of SCR **278**. Connected directly between cathodes **243** and **280** is an extinguishing capacitor **285**. Finally, the side of capacitor **283** opposite gate **284** is returned to ground through a resistor **285***a*, a similar resistor **286** returning the corresponding side of capacitor **251** to ground.

When valve **240** is fired, either by impact switch **31** or firing stage **250**, its continued operation thereafter maintains a charge across capacitor **285** polarized to negative in the direction away from cathode **243** by reason of the conductive path through valve **240** to source **82** and the ground return on the other side through resistors **281** and **282**. Upon subsequent depression of push button **102** and the thereafter delayed development of the spike pulse across resistor **267**, the application of that pulse to gate **284** momentarily renders valve **278** conductive. Consequently, cathode **280** is connected to the positive potential of battery **82**, and, by reason of the ground return from cathode **280** through resistors **281** and **282**, the total instantaneous potential on cathode **243** of valve **240** (with respect to ground) becomes twice the battery supply voltage that appears in the other and normal direction between anode **242** and cathode **243**. The result of so imposing a net potential across valve **240**, in a direction which renders its cathode **243** positive relative to its anode **242**, is to deactivate valve **240** so that it once again becomes nonconductive but yet ready again to energize beacon **21** upon the next occurrence of an energy pulse either from impact switch **31** or firing stage **250**. At the same time, resistor **282**, connected between ground and gate **284** as well as to cathode **280** by way of resistor **281**, is assigned a sufficiently high value of resistance that SCR or valve **278** ceases to be conductive immediately upon cessation of the spike pulse, developed across resistor **267**, and the discharge of capacitor **285**.

It will be observed that the arrangement of power control **30** and remote control **28** is such that continued operation of beacon **21** in response to actuation by impact switch **31** is assured regardless of disruptive effects upon remote control **28** or its interconnecting leads. As noted earlier, each of those leads **107** and **111** are individually ensheathed within respective grounded sleeves **108** and **112**. As a result of either or both of leads **107** and **111** may become grounded or entirely disconnected. Similarly, the lead between the push button switches and the battery or the battery itself may become grounded or disconnected. In any of those events, however, there is absolutely no affect upon power control **30**. Consequently, the integrity of automatic crash activation of beacon **21** is retained regardless of damage to the remote control system included to enable manual operation by the pilot or other operator.

Where desired, various refinements and modifications are available. For example, an audio monitor of the distress signal may be provided in the pilot compartment. Instead of being semi-permanently installed, beacon **21** may be mounted upon an eject mechanism operable to propel the beacon away from the aircraft in case of a crash into a body of water. In that case, the beacon may be affixed on its underside to a mass of buoyant material and that mass may be formed about the internal batteries to constitute an enclosure therefor.

It will be evident that the many different advantages present in the disclosed downed-aircraft-locator beacon stem from the incorporation of a number of distinct but related features. In addition to other points of merit already mentioned, a successfully operated beacon constructed as above described develops a power output, at full battery voltage, of about 500 milliwatts peak at each of the two assigned frequencies. This has been found to permit the desired omnidirectional range of transmission of up to 200 miles. Since the small batteries required are available at the present time with a shelf-life of perhaps two years with a retention of 90 percent or original capacity, their low-cost replacement at each annual inspection of the aircraft assures continued reliability. Being of very rugged, compact construction, composed of fire-resistant material, such as fiberglass in the formation of substrates **50** and **66**, dome **85**, compartment **82** and foam **87**, and capable of automatic operation within its self-contained assembly, as well as reason of its location in a portion of the aircraft least likely to be subject to injury, the beacon affords a highly maximized degree of enduring operability. The coordination of the two different antenna assemblies and the physical inclusion therewithin of the radio apparatus not only results in a minimum overall space requirement but contributes to the complete self-containment wherein no reliance is placed upon the integrity of cables and leads disposed through the different parts of the aircraft.

In addition to the overall attributes of the beacon, beneficial enhancement of performance is secured by careful attention to and selection of the nature of the different system components. These include the extremely high stability available from the oscillator, the simplified yet effective frequency-doubling and separating circuitry, the highly efficient mode of coupling between the final amplifiers and their respective antennas, the modulation techniques employed and the safeguarding functions of the power control. At the same time, it is recognized that these individual features find advantageous utility in other but related environments.

While a particular embodiment of the present invention has been shown and described, it is apparent that changes and modifications may be made therein without departing from the invention in its broader aspects. The aim of the appended claims, therefore, is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. In a radio apparatus translating signals on at least a pair of mutually-different frequencies, an antenna assembly comprising:

a conductive sheet defining a first ground plane;

a substrate of insulating material spaced from and parallel to said conductive sheet;

a first conductive loop affixed to said substrate and together with said conductive sheet constituting an antenna responsive at one of said frequencies;

a conductive layer, defining a second ground plane, affixed to said substrate and spaced inside said first loop;

and a second conductive loop spaced from and parallel to said conductive layer and together therewith constituting another antenna responsive at the other of said frequencies.

2. Apparatus as defined in claim 1 in which said second conductive loop is disposed on the side of said substrate opposite said conductive sheet.

3. Apparatus as defined in claim 1 which further includes a second substrate of insulating material to which said second loop is affixed.

4. Apparatus as defined in claim 1 in which at least one of said conductive loops includes a gap with said one loop at one side of said gap being conductively connected to its associated ground plane, a capacitor coupled between said associated ground plane and a point on said one loop intermediate its ends for resonating said one loop at its respective frequency of response, and means tapped on said one loop at a point spaced from said gap for coupling the respective one said signals between said radio apparatus and said one loop.

5. Apparatus as defined in claim 4 in which said radio apparatus is disposed between said conductive sheet and said substrate and said coupling means extends through said substrate and said conductive layer from said second loop to said radio apparatus.

6. Apparatus as defined in claim 1 in which said radio apparatus is disposed between said conductive sheet and said substrate.

7. Apparatus as defined in claim 6 in which said radio apparatus includes a plurality of individual pockets of shielding material respectively housing different stages of said apparatus, said substrate closely over-lies the openings in said pockets and conductive material affixed to said substrate shieldingly closes said pockets.

8. Apparatus as defined in claim 6 in which an insulative dome affixed to said conductive sheet forms a housing overlying said loops and said substrate, and the interior space within said housing and said radio apparatus are filled with a deliquefied foam of insulating and cushioning material.

9. Apparatus as defined in claim 6 which further includes a compartments, in which batteries are disposed for energizing said radio apparatus, affixed to the side of said conductive sheet opposite said substrate.

10. Apparatus as defined in claim 9 which further includes a plate disposed between and of a material stiffer than said compartment and said conductive sheet.

11. Apparatus as defined in claim 6 in which said radio apparatus has a plurality of pockets respectively housing different stages of said apparatus including separate pockets for selective stages individually responsive at respective ones of said frequencies, which includes means for coupling said selective stages individually to corresponding taps on respective ones of said first and second loops, and in which the pockets housing said selective stages are individually disposed in at least approximate alignment with respective ones of said taps.

12. Apparatus as defined in claim 11 in which the one of said selective stages coupled to said first loop is disposed adjacent to an exterior wall housing said radio apparatus.

13. Apparatus as defined in claim 6 in which said radio apparatus is contained within an enclosure and the side walls of said enclosure, said conductive sheet, said substrate and said loops all are nested together with mutual concentricity.

14. In a radio apparatus translating signals on at least a pair of mutually-different frequencies, an antenna assembly comprising:

a conductive sheet defining a first ground plane;

a first conductive loop spaced from and parallel to said sheet and together therewith constituting an antenna responsive at one of said frequencies;

a conductive layer, defining a second ground plane, disposed in the plane of and spaced inside said first loop

and a second conductive loop spaced from and parallel to said conductive layer and together therewith constituting another antenna responsive at the other of said frequencies.

* * * * *