Aug. 13, 1963 M. MARKS 3,100,886

COMPRESSIONAL WAVE TRANSMITTER

Filed April 27, 1959 2 Sheets-Sheet 1

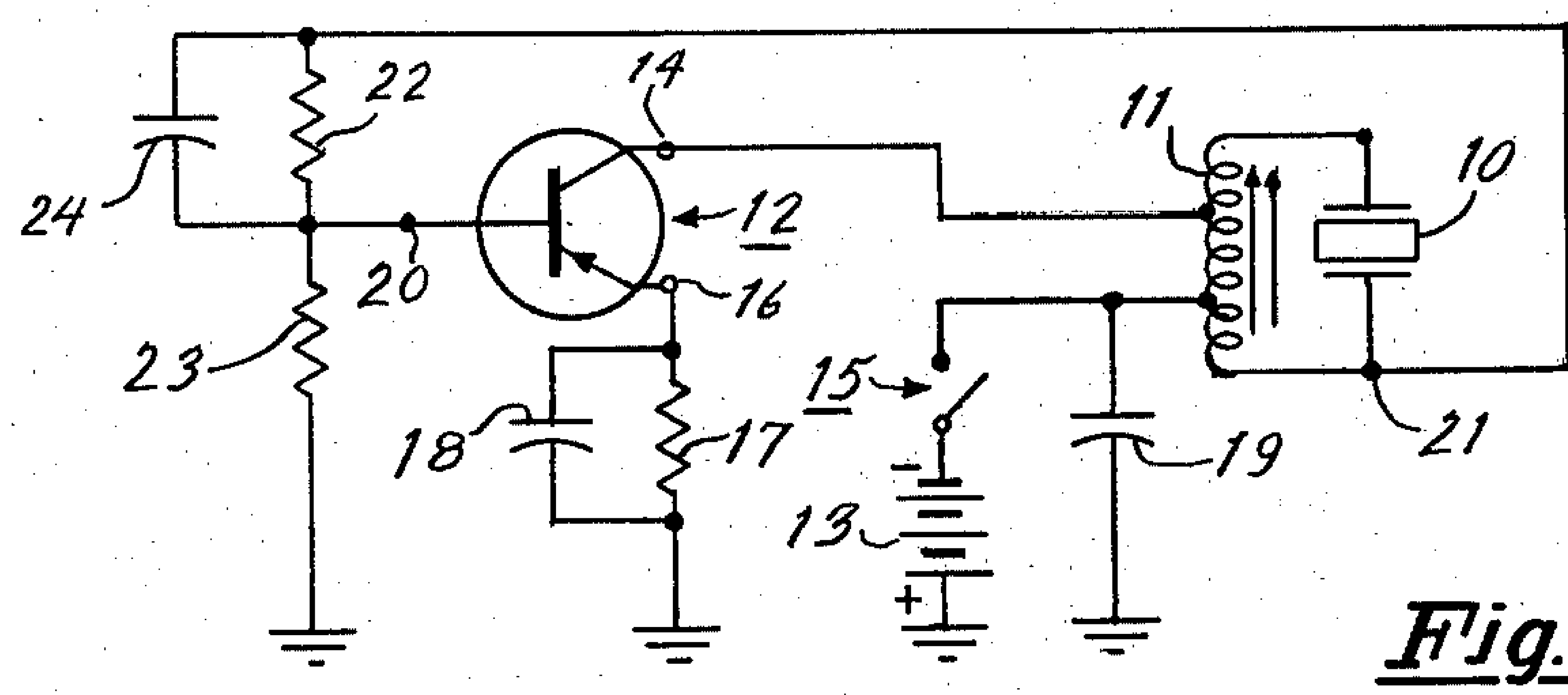

Fig.1.

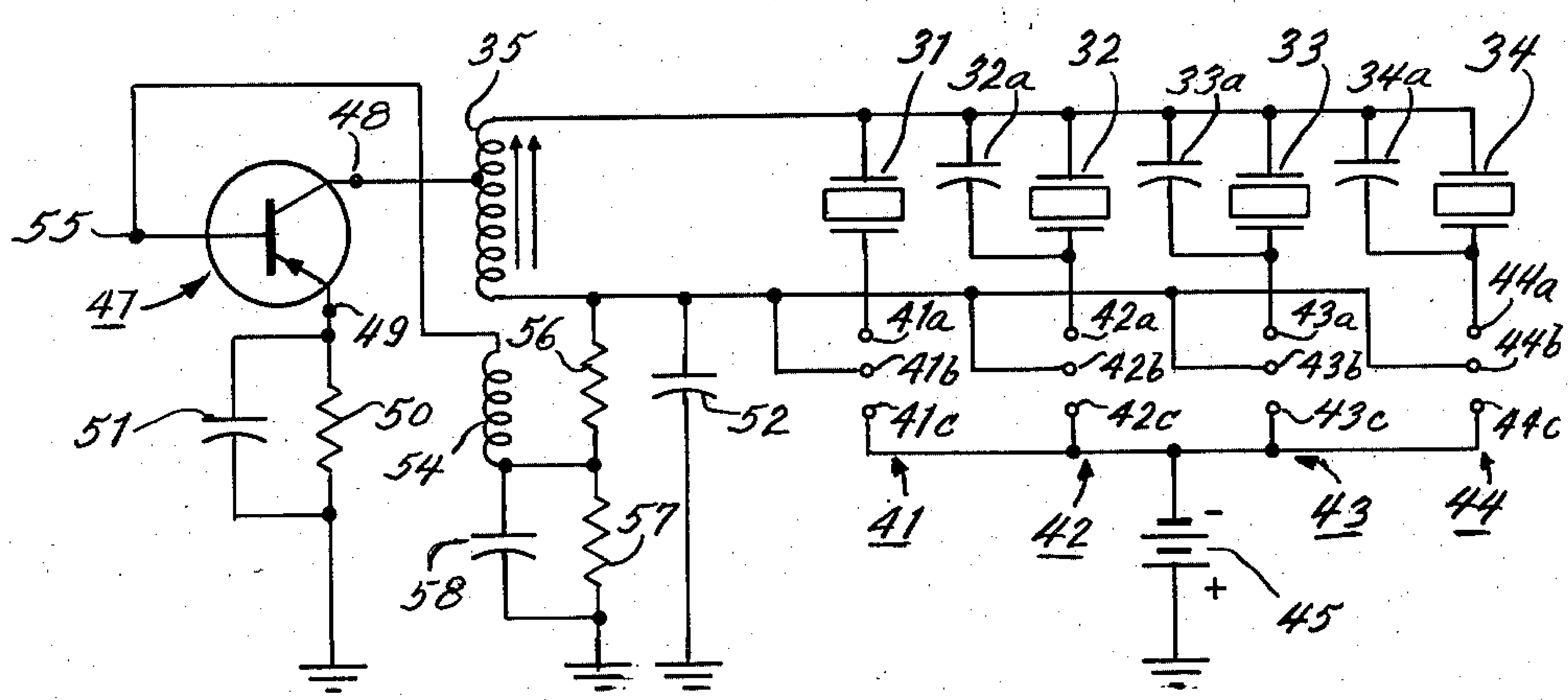

Fig.2.

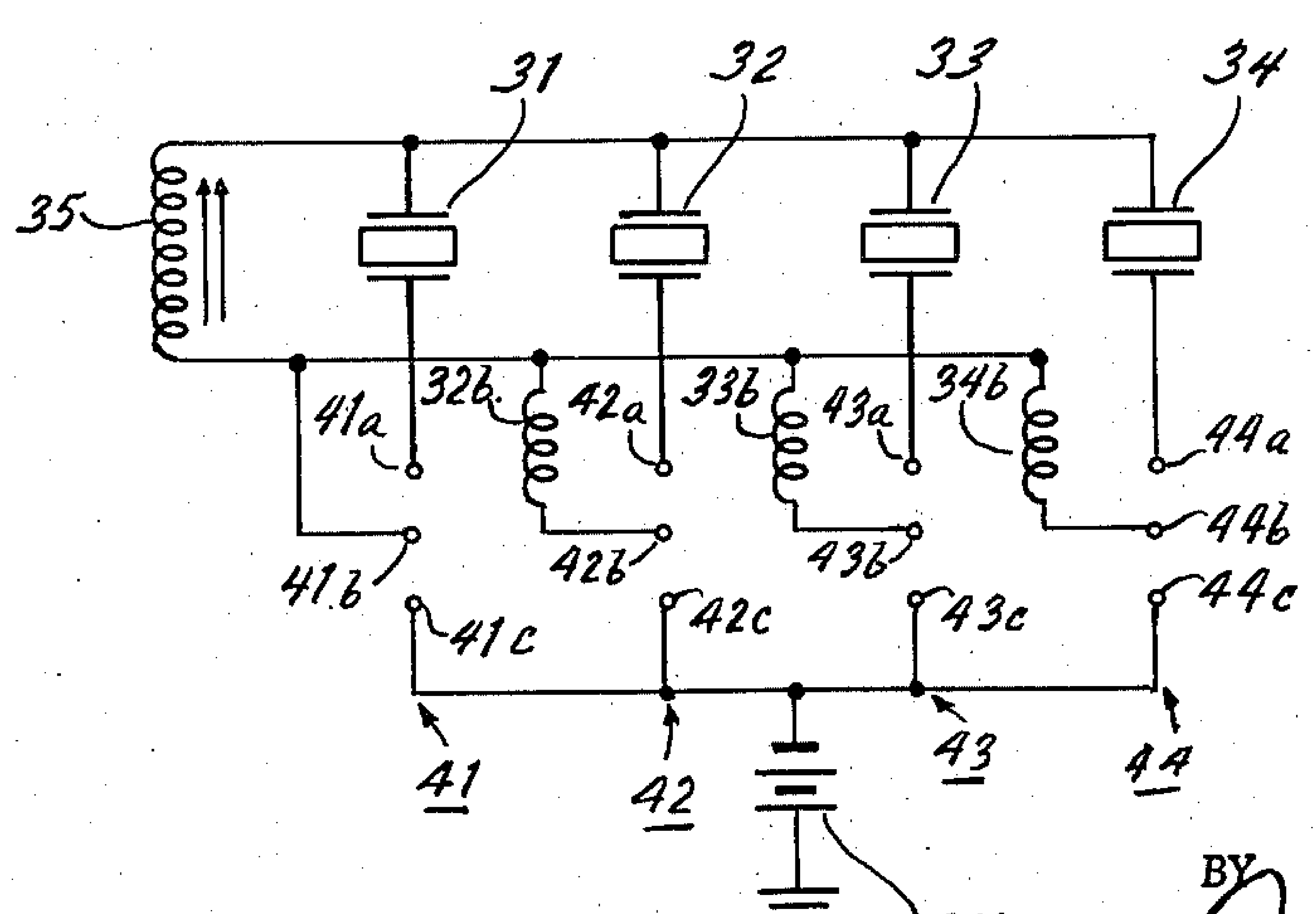

Fig.2a.

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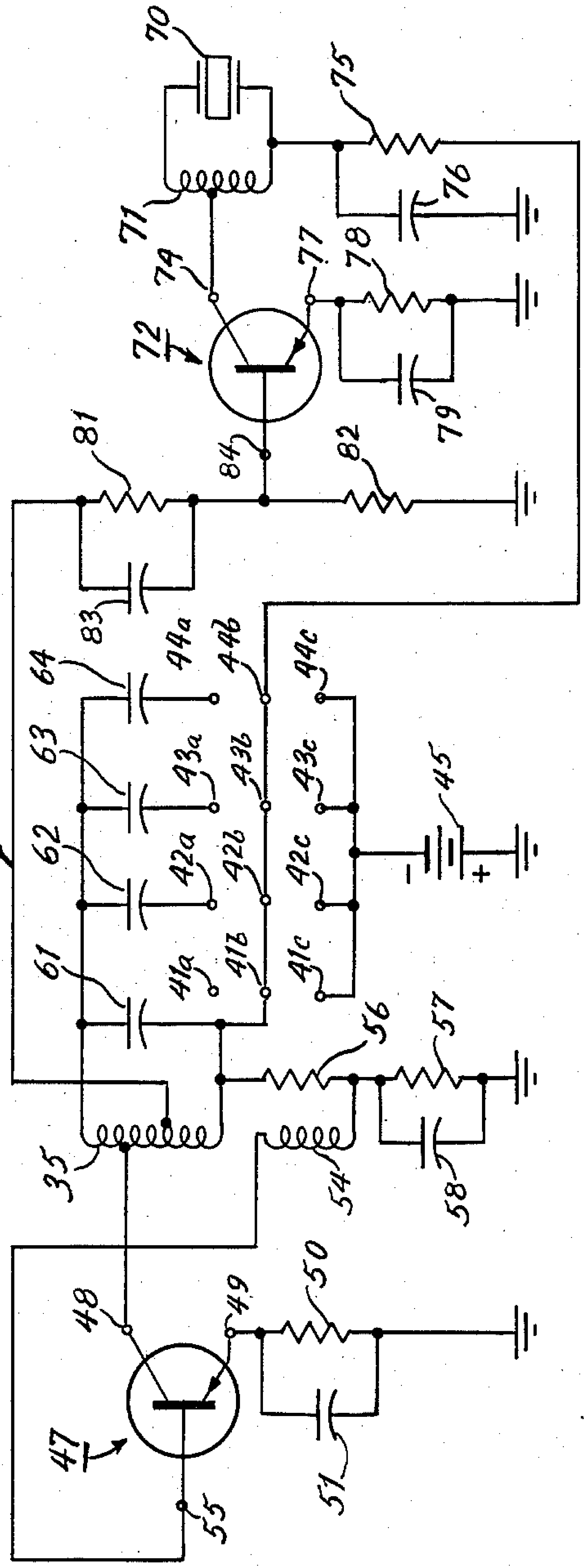

Fig. 3

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COMPRESSIONAL WAVE TRANSMITTER

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3 Claims. (Cl. 340—15)

This invention relates to signal apparatus for producing sound waves of predetermined frequency or frequencies, and it is an object of the invention to provide improved apparatus of that character.

In the growing art of remote control apparatus for television receiver sets, it is common practice to employ compressional or ultrasonic waves of predetermined frequency as a means of transmitting a signal or a plurality of distinguishable signals from a remote transmitting station to a receiver station within the television receiving set. These ultrasonic waves are of frequencies well above the upper hearing limit of the human ear. This eliminates objectionable audible sound during signal transmission and substantially eliminates the possibility of unintended operation of the receiver set control system by audible noise. Apparatus constructed in accordance with the present invention is particularly well adapted to such use but it will be appreciated by those skilled in the art that the apparatus is of broad applicability.

Prior art apparatus of this general type has suffered from one or more of a number of objectionable characteristics. Among these are objectionable bulkiness of the transmitting unit, short battery life where batteries are employed as a power source, unreliability of operation, delayed operation and high cost. As opposed to this, apparatus constructed in accordance with the present invention may be very compact, requires such a small amount of power that the life of a battery incorporated in the apparatus is substantially the shelf life of the battery, is instantaneously operative and is inherently reliable in operation and economical to manufacture.

Accordingly, it is an other object of the invention to provide improved apparatus for producting ultrasonic waves of one or more predetermined frequencies which is small in size and economical to manufacture.

It is a further object of the invention to provide improved apparatus of the character described above which is inherently reliable in operation.

It is a still further object of the invention to provide improved apparatus of the character described above which employs one or more piezoelectric transducers as an ultrasonic propagating means.

Another object of the invention is to provide improved apparatus of the character described above which employs a transistor as a signal translating device.

Further features of the invention pertain to the particular arrangement of the elements of the ultrasonic producing apparatus, whereby the above outlined and additionl features thereof are attained.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification, taken in connection with the accompanying drawings, in which:

FIGURE 1 is a circuit diagram illustrating an embodiment of the invention for producing ultrasonic waves of a single predetermined frequency;

FIGURE 2 is a circuit diagram of an embodiment of the invention for producing ultrasonic waves of selected predetermined frequencies;

FIGURE 2*a* is a partial circuit diagram illustrating an alternative to the embodiment of the invention shown in FIGURE 2, and

FIGURE 3 is a circuit diagram of another embodiment of the invention for producing ultrasonic waves of selected predetermined frequencies.

As indicated above, the present invention is well adapted to the generation of ultrasonic waves for actuating a remote receiving device which controls a television receiver in response to the generation of such ultrasonic waves. The embodiments of the invention illustrated in the drawings and described below are specifically adapted to such use, but it will be readily apparent to those skilled in the art that the invention is of broad applicability with or without modification or adaptation of the illustrated embodiment thereof.

In the embodiment of the invention illustrated in FIGURE 1, apparatus is provided for producing ultrasonic waves of a single predetermined frequency, but which, with slight modification may produce ultrasonic waves of two or more frequencies. The specific frequency preferred is 40,000 cycles per second, this frequency being well above the audible range whereby it cannot be heard and is not readily duplicated in casual noise. The ultrasonic wave produced by this apparatus may, for example, be employed to actuate control apparatus which advances the channel selecting switch of a television receiver successively from one channel to the next in a manner well known in the art.

Included in the signal generating apparatus of FIGURE 1 is a piezoelectric transducer **10** which may be of conventional form and, therefore, is not described in detail herein. For the purpose of appreciating the present invention it is necessary to understand only that the transducer **10** includes a piezoelectric element with suitable electric terminals and physical mounting such that electrical excitation of the piezoelectric element through the electric terminals causes mechanical vibration thereof which is transmitted to the surrounding air. Where the term "piezoelectric transducer" is employed herein, it is intended that it be interpreted broadly to include microphones, such microphones incorporating not only genuine crystals, either natural or artificial, but materials such as barium titanate, which do not qualify as crystals in the technical sense.

As is also well understood in the art, any given piezoelectric element has a natural or resonant frequency. The piezoelectric element included in the transducer **10** is selected to have a resonant frequency equal to the frequency of the sound wave that is intended to be generated. In the specific embodiment of the invention illustrated in FIGURE 1, the piezoelectric element of the transducer **10** should, therefore, have a resonant frequency of 40,000 c.p.s.

The transducer **10** is connected across the terminals of an inductance coil **11**, as shown, to form an LC circuit also having a resonant frequency of 40,000 c.p.s. One form of transducer which has been employed in the circuit of FIGURE 1 has a capacity of 932 micro-microfarads. An inductance of 17 millihenries for the coil **11** in cooperation with such a transducer produces an LC circuit resonating at 40,000 c.p.s. The coil **11** includes an adjustable slug such that it may be tuned in a well known manner. Preferably, the coil has a relatively high Q factor (e.g. 50) for reasons well known in the art. If desired, additional capacity may be arranged in parallel with the transducer in keeping with various parameters of the circuitry.

The LC circuit formed by the transducer **10** and the coil **11** may be excited by various forms of apparatus. In the preferred embodiment of the invention, the exciting apparatus includes a junction type transistor **12**, which may be a 2N217 transistor, and a power source consisting of a three-volt dry cell **13**. One of the output leads of the transistor **12**, namely, the collector lead **14**, is connected to a tapped point on the coil **11**, and the negative terminal of the battery **13** is connected through a switch **15** to another tapped point on the coil **11**, the positive terminal of the battery **13** being represented as connected to ground. The output circuit of the transistor **12** is completed by connection of the other output lead, namely, the emitter lead **16**, to ground through a bias resistor **17** and a paralleling bypass capacitor **18**. A bypass capacitor **19** is connected between ground and the negative terminal of the battery **13**.

A feedback circuit is connected to the control lead of the transistor **12**, namely, the base lead **20**. This feedback circuit connects a point **21** of the LC circuit to the base lead **20** of the transistor through a resistor **22**, the base lead **20** being connected to ground through another resistor **23**. It will be apparent that the resistors **22** and **23** comprise a voltage divider. A coupling capacitor **24** is arranged across the resistor **22**. It will be seen that the oscillator thus provided is of the Hartley type. As will be apparent, however, to those skilled in the art, various other forms of oscillators may be employed.

It will also be appreciated by those skilled in the art that with the coil **11** adjusted such that the LC circuit, comprising the coil **11** and transducer **10**, resonates at the resonant frequency of the transducer, an ultrasonic wave of substantial magnitude may be emitted by the transducer with a very small power input. The simple three-volt dry cell which is recommended to power the circuit will have long life since the circuit draws very little current and since the dry cell is disconnected from the circuit when the apparatus is not in operation. At the same time, there is no delay in operation of the circuit since the transistor is instantaneously operative. It will also be seen that the apparatus is inexpensive to manufacture since it requires in addition to a small number of conventional resistors and capacitors only a dry cell, a transistor, a slug tuned coil and a piezoelectric transducer.

While the values of the various resistors and capacitors employed in the circuit are not critical, a list of recommended values is given below:

R17—47 ohms	C18—0.1 mfd.
R22—200K	C19—.01 mfd.
R23—5K	C24—150 mmfd.

The apparatus of FIGURE 1 is particularly suited to the production of ultrasonic waves of one predetermined frequency. However, as will readily be recognized by those skilled in the art, the LC circuit comprising the coil **11** and the transducer **10** may very simply be forced to oscillate at frequencies differing by a few hundred cycles from the 40,000 c.p.s. resonant frequency of the LC circuit and of the transducer. Two or more frequencies may thereby be produced to convey different signals to a highly discriminatory receiving station. Since such modification of the frequency output of the apparatus may be accomplished by various well known means, and since such means do not constitute a feature of the present invention, they are not shown, or described in detail herein.

The embodiment of the invention illustrated in FIGURE 2 is much the same as the embodiment of FIGURE 1, with the exception that it includes a plurality of piezoelectric transducers for producing ultrasonic waves of a plurality of predetermined frequencies, and switch means for selecting a transducer and, hence, a frequency of ultrasonic waves. The plurality of different frequencies of these waves may be employed to initiate four different control operations at a receiving station. For example, as applied to remote control of a television receiver, the four different frequency signals may control the on-off switch, the volume control, clockwise rotation of the channel selecting switch, and counterclockwise rotation of the channel selecting switch. Where a single broad-band receiver is provided at the receiving station, followed by apparatus which discriminates between the four different signal frequencies, it is preferred that the four signal frequencies differ by relatively small percentages. In one application of the apparatus illustrated in FIGURE 2, it has been found desirable that the four frequencies be 38,285, 39,285, 40,805 and 41,805 cycles per second.

In FIGURE 2 four piezoelectric transducers **31**, **32**, **33** and **34** are arranged with one terminal of each connected in common to one end of an inductance coil **35**, the latter preferably being slug tuned. The coil **35** is selectively coupled with any one of the transducers **31**—**34** in the manner described below such that the coil **35** and the selected transducer form an LC circuit which resonates at the resonant frequency of the corresponding transducer. In the interest of economy, the four piezoelectric transducers are substantially identical with the exception of their resonant frequencies and, accordingly, their capacitive values are substantially equal. Since the same inductance coil **35** is to be employed in each of the four possible LC circuits, capacitors **32***a*, **33***a* and **34***a* are arranged in parallel with the transducers **32**, **33** and **34**, respectively, to provide the necessary additional capacity to tune the corresponding LC circuit to the resonant frequency of the corresponding transducer.

The transducer and associated capacitors are selectively coupled to the inductive coil **35** to form LC circuits of the desired resonant frequencies by means of switches **41**, **42**, **43** and **44**. More particularly, closing of contacts **41***a* and **41***b* of switch **41** connects the transducer **31** across the coil **35** to form an LC circuit resonating at the resonant frequency of the transducer **31**. Similarly, closing of the contacts **42***a* and **42***b*, or **43***a* and **43***b*, or **44***a* and **44***b* completes an LC circuit incorporating a transducer **32**, **33** or **34**, respectively, along with its associated capacitor and the coil **35**.

Each of the switches **41**—**44** preferably includes three contacts whereby closing of the "*a*" and "*b*" contacts of any of the four switches to form an LC circuit is accompanied by closing of these contacts with a "*c*" contact, whereby the selected LC circuit is connected to the negative terminal of a battery **45**, whose positive terminal is represented as being connected to ground.

Switches such as the switches **41**—**44** are well known in the art and, accordingly, are not described in detail herein. For the purpose of explaining the present invention, it is necessary only to point out that all three contacts of any of the switches are brought into electrical contact with each other upon actuation of the switch, whereby the "*a*" and "*b*" contacts are electrically connected to complete an LC circuit, and these are connected to the "*c*" contact to connect the LC circuit to the power source.

A transistor **47** is provided across the output leads of which the battery **45** and a selected LC circiut are connected by the closing of any of the switches **41**—**44**. More specifically, the collector lead **48** is connetced to a tapped point on the coil **35**, as shown, and the emitter lead **49** is connected to ground through a bias resistor **50** and a bypass capacitor **51**. Another bypass capacitor **52** is connected between the LC circuit and ground, as shown.

In this embodiment of the invention, feedback is provided by a coil **54** which is inductively coupled with the coil **35**. The coil **54** is connected to the base lead **55** of the transistor, as shown, and to the intermediate point of a voltage divider extending between one end of the coil **35** and ground. The voltage divider comprises a pair of resistors **56** and **57**, the latter of which is paralleled by a bypass capacitor **58**.

Operation of the apparatus illustrated in FIG. 2 is believed to be obvious. If the switch **42**, for example, is closed, the contacts **42***a* and **42***b* are closed to complete an LC circuit. The total capacity of the crystal microphone **32** and the capacitor **32***a* coupled with the inductance of the coil **35** provides an LC circuit which resonates at the resonant frequency of the transducer **32**. Connection of the contacts 42*a* and 42*b* to the contact 42*c* completes the output circuit of the transistor 47. Feedback is provided by the coil 54 such that the circuit may oscillate at a frequency determined by the selected LC circuit. The transducer 32, accordingly, emits an ultrasonic wave of substantial magnitude and of a predetermined frequency. Waves of four different predetermined frequencies may be obtained by closing selected ones of the switches 41—44.

A modification of the apparatus of FIG. 2 is illustrated in FIG. 2*a*. This figure is a partial circuit diagram showing only the LC circuits, the selective switches and the power source, since the remainder of the circuit may be identical to that disclosed in FIG. 2. In the embodiment of FIG. 2*a*, the coil 35, the transducers 31—34, the switches 41—44 and the battery 45 may be identical to the corresponding parts employed in the apparatus in FIG. 2. In particular, the transducers 31—34 may be of equal capacity but of different resonant frequencies. The various LC circuits obtainable by selective closing of any of the switches 41—44 are tuned to the resonant frequencies of the corresponding transducer by means of inductive coils 32*b*, 33*b*, and 34*b*, which are connected between one end of the coil 35 and respective ones of the switch contacts 42*b*, 43*b*, and 44*b*. The coils 32*b*—34*b* are of different inductive values whereby addition of the inductance of any one of these coils to the inductance of the coil 35 provides a total inductance which will resonate with the capacity of the corresponding transducer at the resonant frequency of the corresponding transducer. The coils 32*b*—34*b* comprise means, alternative to the condensers 32*a*—34*a* of FIG. 2, for tuning the various LC circuits to the resonant frequency of the corresponding transducer.

The embodiments of the invention illustrated in FIGS. 2 and 2*a* permit the generation and transmission of ultrasonic waves of four substantially differing frequencies with a minimum of power and with a single signal translating device. The four frequencies suggested above differ in steps of approximately two and one-half percent and four percent. With these selected frequencies, a single broad-band received may accept all four signals and readily distinguish between them. It will be appreciated by those skilled in the art that the transmitting apparatus of FIGS. 2 and 2*a* may, if preferred, generate and transmit ultrasonic waves of much more widely differing frequencies.

Recommended values for the various resistors and capacitors employed in the circuits of FIGS. 2 and 2*a* are tabulated below:

R50—47 ohms	C51—0.1 mfd.
R56—200K	C52—.01 mfd.
R57—5K	C58—.01 mfd.

It will be understood that the values of the capacitors 32*a*—34*a* are selected to produce resonance of the associated LC circuits at the desired frequencies, in a manner well understood in the art.

The embodiment of the invention illustrated in FIG. 3 differs from that illustrated in FIG. 2 primarily in that the plurality of transducers 31—34 of FIG. 2 are replaced in the oscillator stage of FIG. 3 by conventional capacitors, and an amplifier stage incorporating a second signal translating device is provided which is excited by the oscillator stage. A single transducer is employed in an LC circuit across the output leads of the second stage signal translating device. The single transducer, preferably resonant at 40,000 c.p.s., is readily driven at the four frequencies suggested above in connection with the embodiment of FIG. 2.

Since the entire first stage of the embodiment of FIG. 3 is identical to that of the embodiment illustrated in FIG. 2 with the exception of the substitution of conventional capacitors 61, 62, 63 and 64 for the transducers 31—34 of FIG. 2, this stage will not be redescribed. Each element of the oscillator stage of FIG. 3 is identified by the same reference numeral as in FIG. 2.

It will be noted that the capacitor 61 which replaces the transducer 31 is not connected to the contact 41*a* of the switch 41 but is, instead, connected directly across the coil 35. This capacitor is, therefore, included in all four LC circuits. Accordingly, the capacitors 62, 63 and 64 need be only of such value as to add to the capacitance of the capacitor 61 to provide total capacitance which will resonate with the coil 35 at the desired frequencies. With this arrangement, the coil 35 may be tuned by slug adjustment with the capacitor 61 such that this basic LC circuit resonates at the highest of the desired frequencies. Discrepancies in the capacitive values of the capacitors 62—64 because of manufacturing tolerance then have less effect upon the total capacity of the LC circuits obtained by closing any one of the switches 42, 43, or 44 than would be the case if the capacitors 62—64 comprised the total capacitance of these LC circuits.

The second stage of this embodiment of the invention includes a piezoelectric transducer 70 arranged across a coil 71. The capacitance of the transducer 70 and the inductance of the coil 71 form an LC circuit resonating at 40,000 c.p.s., this also being the resonant frequency of the transducer 70. A transistor 72 of the junction type has its collector lead 74 connected to a tapped point on the coil 71. Upon the closing of any of the switches 41—44, one end of the coil 71 is connected through a resistor 75 and the "*b*" and "*c*" contacts of the selected switch to the negative terminal of the battery 45. The same end of the coil 71 is connected to ground through a bypass capacitor 76. The output circuit of the transistor 72 is completed by connection of the emitter lead 77 to ground through a resistor 78. A bypass capacitor 79 parallels the resistor 78.

A signal is fed from the oscillator stage to the output stage of this embodiment of the invention through a lead 80 which connects to a tapped point on the coil 35 in the output circuit of the oscillator stage. This lead connects to one end of a voltage divider comprising a pair of resistors 81 and 82, the other end of the voltage divider being connected to ground. The resistor 81 is bypassed by a capacitor 83, and the base lead 84 of the transistor 72 is connected to the intermediate point of the voltage divider.

Recommended values for the various resistors and capacitors employed in the second stage of the circuit of FIG. 3 are tabulated below:

R75—47 ohms	C76—0.1 mfd.
R78—47 ohms	C79—0.1 mfd.
R81—200K	C83—150 mmfd.
R82—5K	

As will be apparent to those skilled in the art, the oscillator stage is unaffected by the output stage, and, accordingly, oscillates at a frequency determined by the selected LC circuit of the first stage. A signal is fed from the oscillator stage to the output stage through the lead 80 whereby the output stage is made to oscillate at a frequency dictated by the oscillator stage. While the LC circuit, including the coil 71 and the transducer 70 contained in the output circuit of the second stage, tends to oscillate at 40,000 c.p.s., it is readily forced to resonate at a frequency as low as 38,285 c.p.s., or as high as 41,805 c.p.s., as dictated by the oscillator stage. Accordingly, a single transducer 70 may be made to propagate ultrasonic waves of various frequencies which differ sufficiently that they are readily distinguishable by a receiving station.

Various embodiments of the invention have now been described which produce compressional or ultrasonic waves of one or more predetermined frequencies. The simple embodiment illustrated in FIG. 1 is intended primarily for the production of one predetermined frequency but can readily be made, with minor and obvious modification, to produce ultrasonic waves of two or more frequencies which differ by relatively small percentages. The embodiment illustrated in FIG. 2 employs a plurality of transducers for producing ultrasonic waves of a plurality of frequencies which may differ from each other to any desired extent. The embodiment illustrated in FIG. 3 employs a single transducer but two signal translating devices. This embodiment may produce ultrasonic waves of a plurality of frequencies which may differ from each other by substantial percentages.

The apparatus included in the various illustrated embodiments of the invention may readily be arranged in a very small housing. As will be readily apparent to those skilled in the art, the apparatus incorporated in the illustrated embodiments of the invention is inherently reliable in operation and will produce ultrasonic waves of frequencies varying only minutely from preselected values as a result of changes in temperature, humidity, and battery strength.

The invention is well adapted to the use of transistors as signal translating devices and accordingly may be instantaneously operable even though the power source is idle except when the apparatus is actually producing sound waves. This, combined with the fact that the apparatus draws very little power even when actually producing ultrasonic waves, assures battery life substantially equal to shelf life of the battery where a battery is used as the power source. It will also be apparent that the illustrated embodiments of the invention incorporate relatively inexpensive components whereby the total cost of the sound producing apparatus is low in spite of the above referred to and other desirable characteristics of the apparatus.

It will be apparent to those skilled in the art that many modifications of the illustrated apparatus may be effected without departing from the spirit of the invention. By way of example electron tubes may be employed where desired in place of the suggested transistors. In general various types of exciting circuits may be employed and various forms of apparatus may be employed for controlling oscillator frequency.

Accordingly, while there has been described what are at present considered to be the preferred embodiments of the invention, it will be understood that various modifications may be made therein, and it is intended to cover in the appended claims all such modifications as fall within the true sprit and scope of the invention.

The invention having thus been described, what is claimed and desired to be secured by Letters Patent is:

1. A portable transmitter for generating and transmitting ultrasonic compressional waves of predetermined frequency comprising; a transistor having a base, an emitter and a collector; a tank circuit coupled in the emitter-collector circuit of said transistor, said tank circuit being resonant at said predetermined frequency and including an inductive element and a capactive piezoelectric transducer element; a battery source for said transistor; a voltage divider; means, including a portion of said inductor for coupling said voltage divider to said battery source so as to supply voltage to said divider and to the collector-emitter circuit of said transistor; said base being connected to a point on said voltage divider, and being supplied both a direct current potential from said battery source and a feedback potential from said tank circuit, whereby said transistor oscillates at the frequency of resonance of said tank circuit and said piezoelectric transducer element transmits said ultrasonic compressional waves.

2. A low powered battery operated portable transmitter for generating and transmitting ultrasonic compressional waves of predetermined frequency comprising: a transistor having an emitter, base, and collector electrode; a resonant tank circuit, including an inductor and a capacitive piezoelectric transducer for transmitting compressional waves responsive to electrical excitation thereof, coupled between said collector and said emitter electrodes; a portion of said resonant tank circuit being coupled between said collector and said base electrodes to provide a feedback connection for feeding back a portion of the voltage across said resonant tank circuit to cause oscillation of said transistor; biasing networks for said base and said emitter electrodes; a battery source of electrical power having a first terminal connected to said collector electrode through said resonant tank circuit, and a second terminal connected to said base and said emitter electrodes through said biasing networks respectively; said transistor oscillating at the resonant frequency of said tank circuit upon connection of said battery source thereto, whereby said capacitive piezoelectric transducer transmits corresponding compressional waves of said predetermined ultrasonic frequency.

3. A low powered battery operated portable transmitter as claimed in claim 2 further including another capacitive piezoelectric transducer for resonating at a different predetermined ultrasonic frequency with said inductor and means for selectively including said transducers in said resonant tank circuit.

References Cited in the file of this patent

UNITED STATES PATENTS

1,968,617	Osnos	July 31, 1934
2,435,548	Rosenthal	Feb. 3, 1948
2,592,703	Jaffe	Apr. 15, 1952
2,741,700	Hall	Apr. 10, 1956
2,842,959	Henry	July 15, 1958

FOREIGN PATENTS

312,962	Great Britain	June 4, 1929
916,072	Germany	Aug. 28, 1954