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Wycoff

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[54] **PLURAL OSCILLATOR SYSTEM FOR GENERATING SIMULTANEOUS PAIRS OF SEQUENTIAL TONES**

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[52] **U.S. Cl.** ..... **331/48,** 325/55, 325/64, 331/55, 331/56, 331/117 R, 343/228

[51] **Int. Cl.** **H03b 3/00**

[58] **Field of Search** 331/46, 55, 56, 48; 325/55, 64; 343/228

[56] **References Cited**

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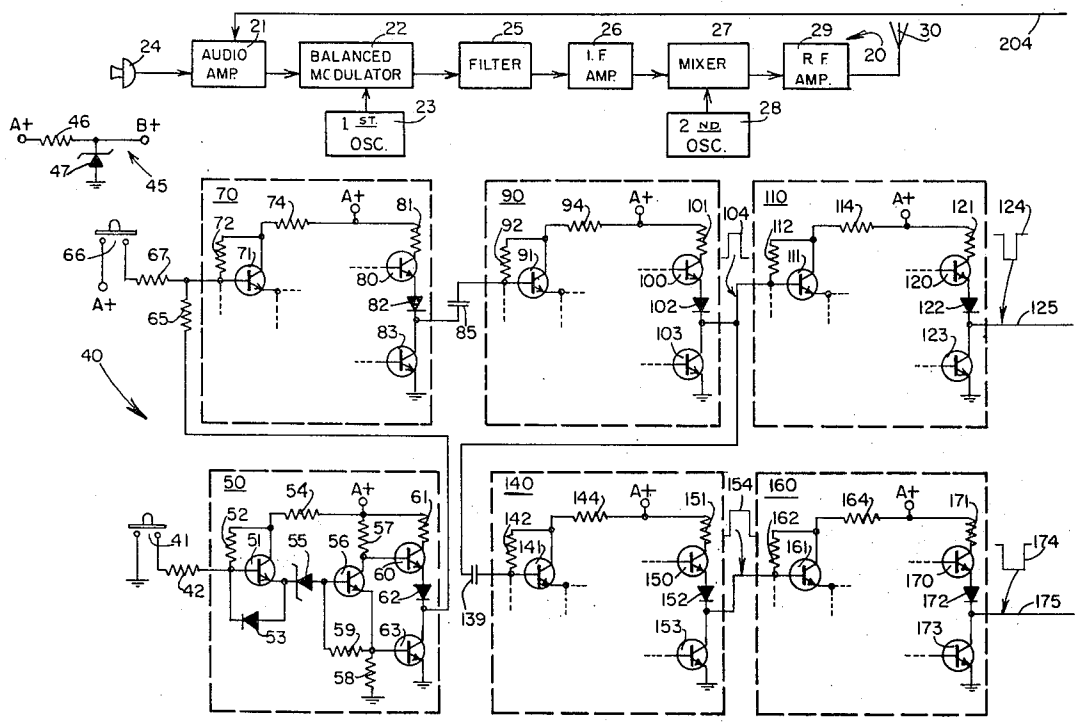
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Assistant Examiner—Siegfried H. Grimm
Attorney, Agent, or Firm—Prangley, Dithmar, Vogel, Sandler & Stotland

[57] **ABSTRACT**

A first oscillator is rendered operative by a pulse to produce a first tone of limited duration. A second oscillator has frequency determining elements which are sequentially coupled in circuit by a sequence of pulses applied to the second oscillator, to produce a sequence of second tones in time coincidence with the first tone.

3 Claims, 5 Drawing Figures



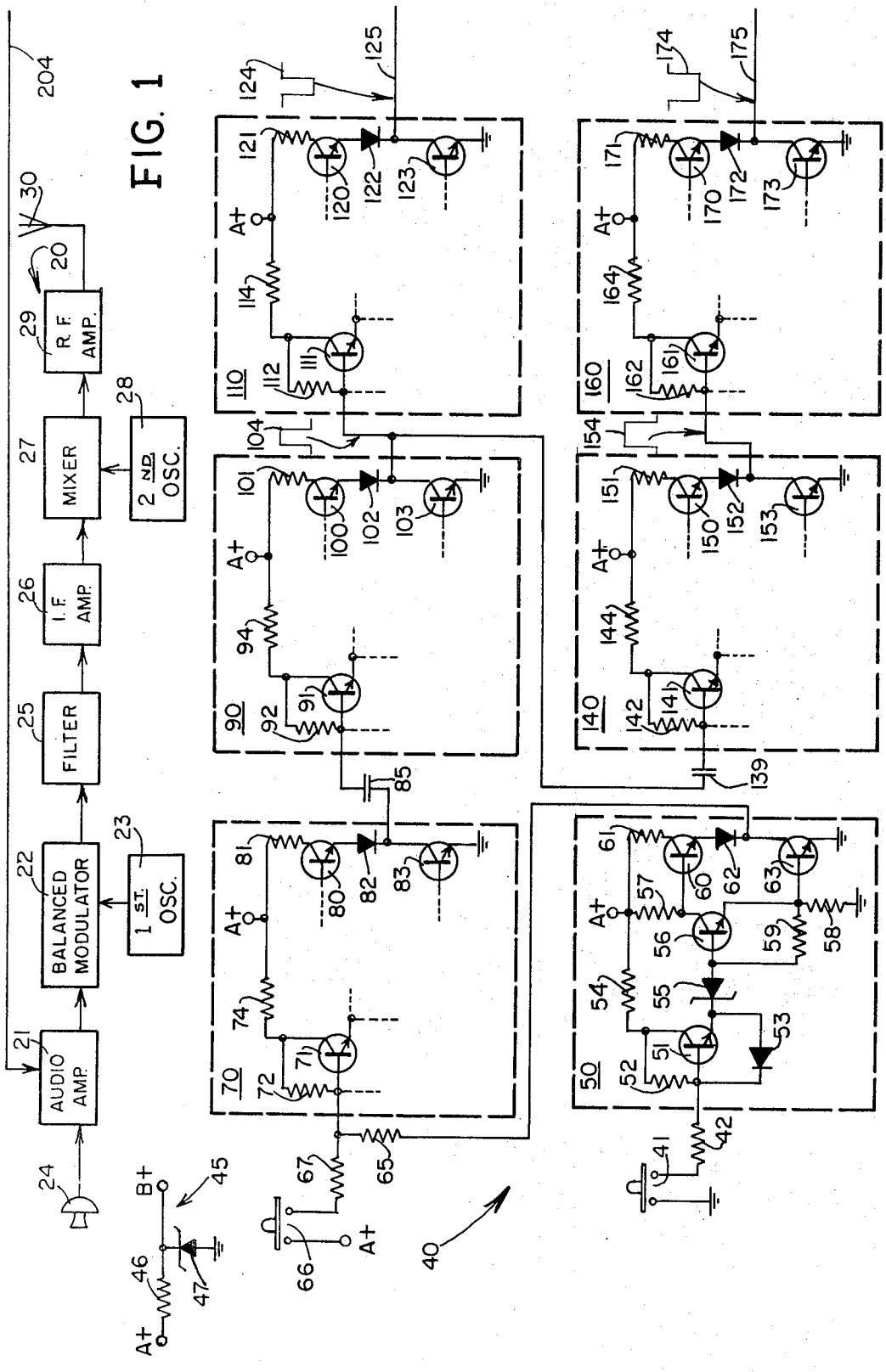

AUDIO AMP.
BALANCED MODULATOR
1 ST. OSC.
FILTER
I.F. AMP.
MIXER
2 ND OSC.
R.F. AMP.
A+
B+
204
21
22
23
24
25
26
27
28
29
30
20
40
41
42
45
46
47
50
51
52
53
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139
140
141
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153
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160
161
162
164
170
171
172
173
174
175

FIG. 1

FIG. 2

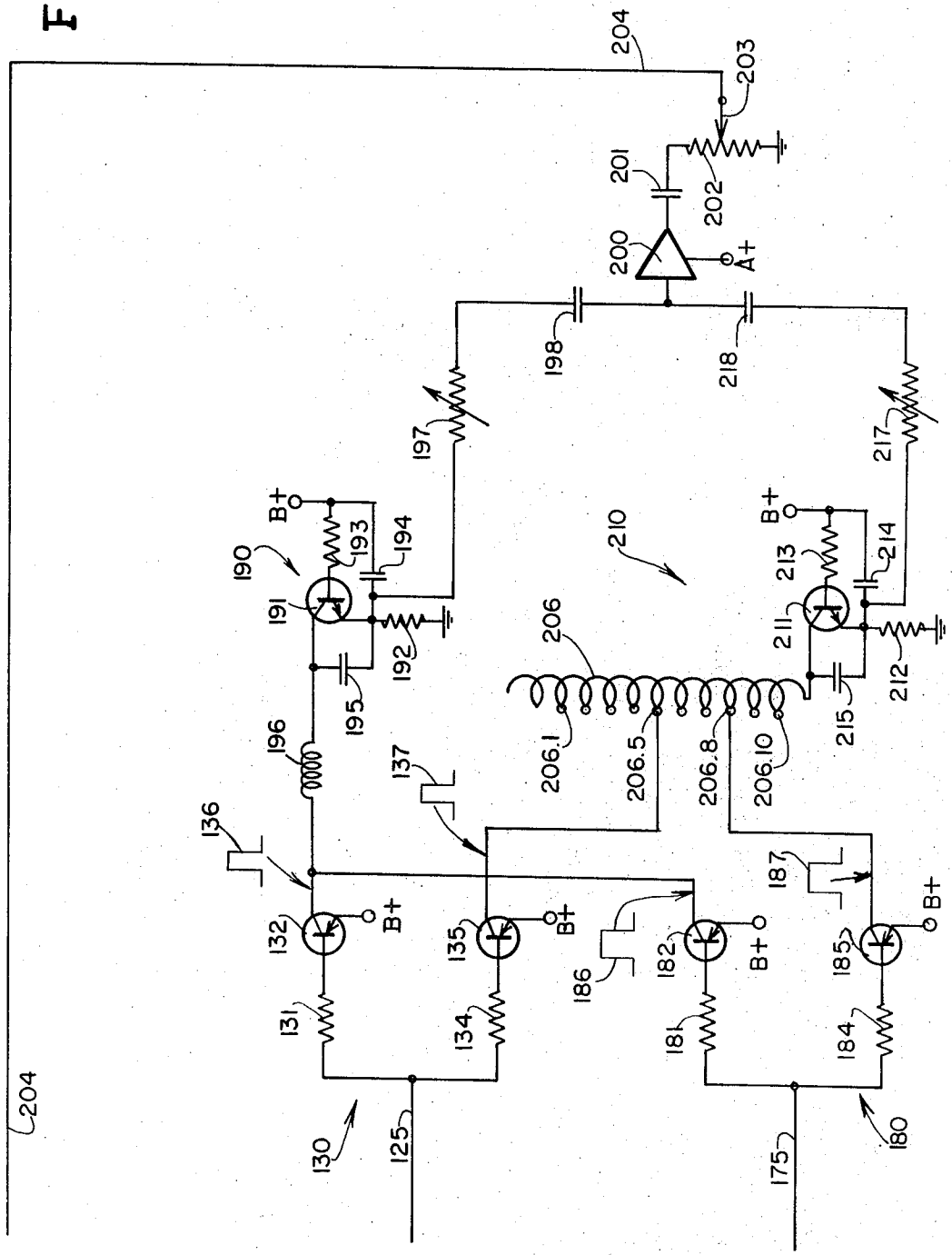

204
203
201
202
200
A+
198
218
197
217
B+
190
191
193
194
192
195
210
213
214
211
212
206
206.1
206.5
206.8
206.10
215
196
137
136
187
132
135
182
185
186
131
134
181
184
130
125
175
180

FIG. 3

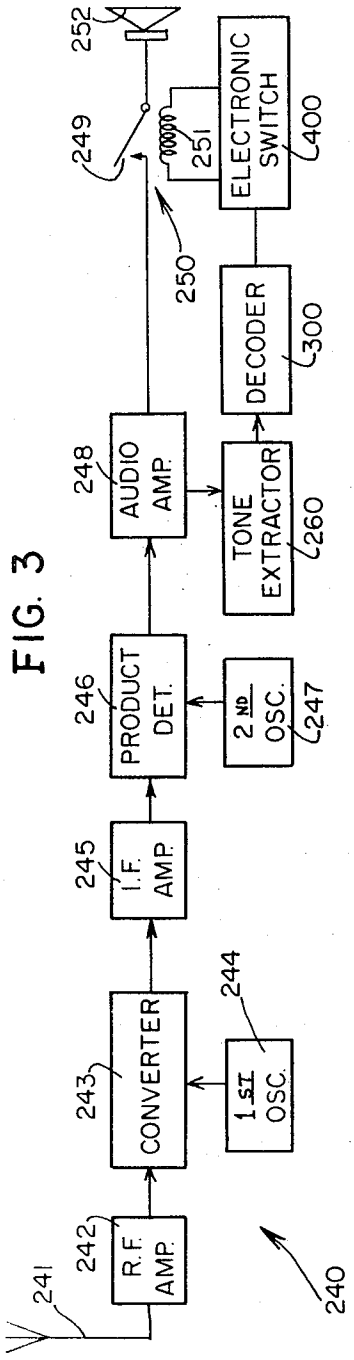
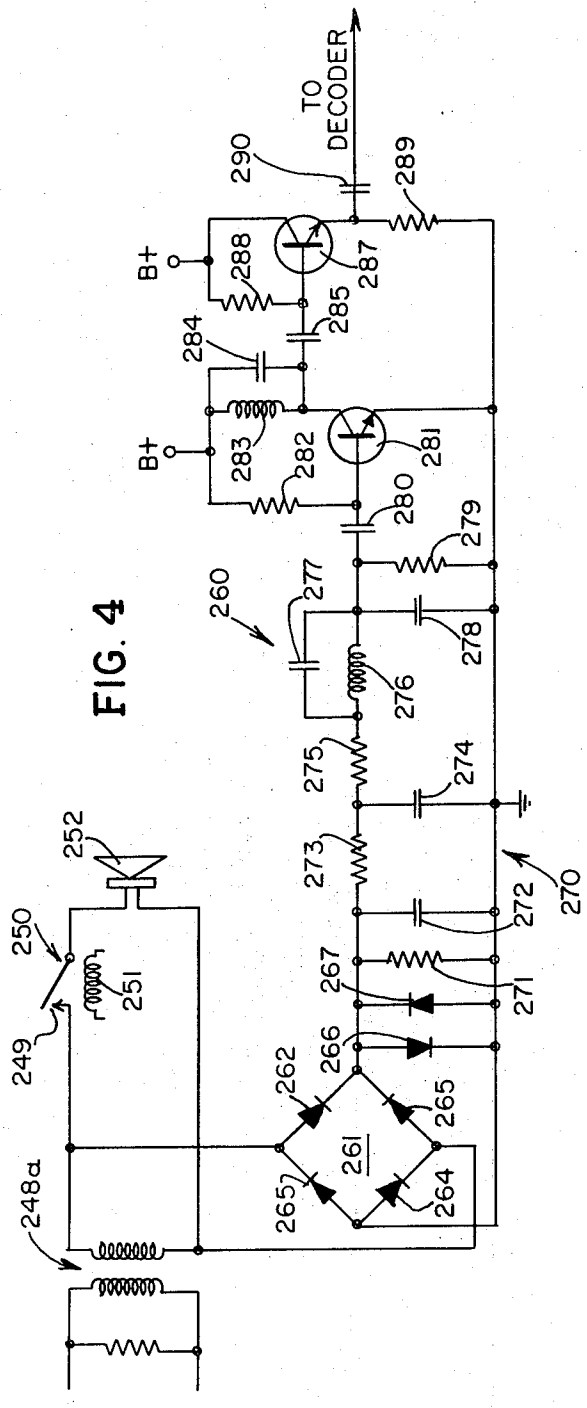

241
242
R.F. AMP.
243
CONVERTER
244
1 ST OSC.
245
I.F. AMP.
246
PRODUCT DET.
247
2 ND OSC.
248
AUDIO AMP.
249
250
251
252
TONE EXTRACTOR
260
DECODER
300
ELECTRONIC SWITCH
400
240

FIG. 4


TO DECODER
290
289
288
287
285
284
283
282
281
280
279
277
278
276
275
274
273
272
271
270
267
266
265
264
262
261
B+
B+
252
250
251
249
248a
260

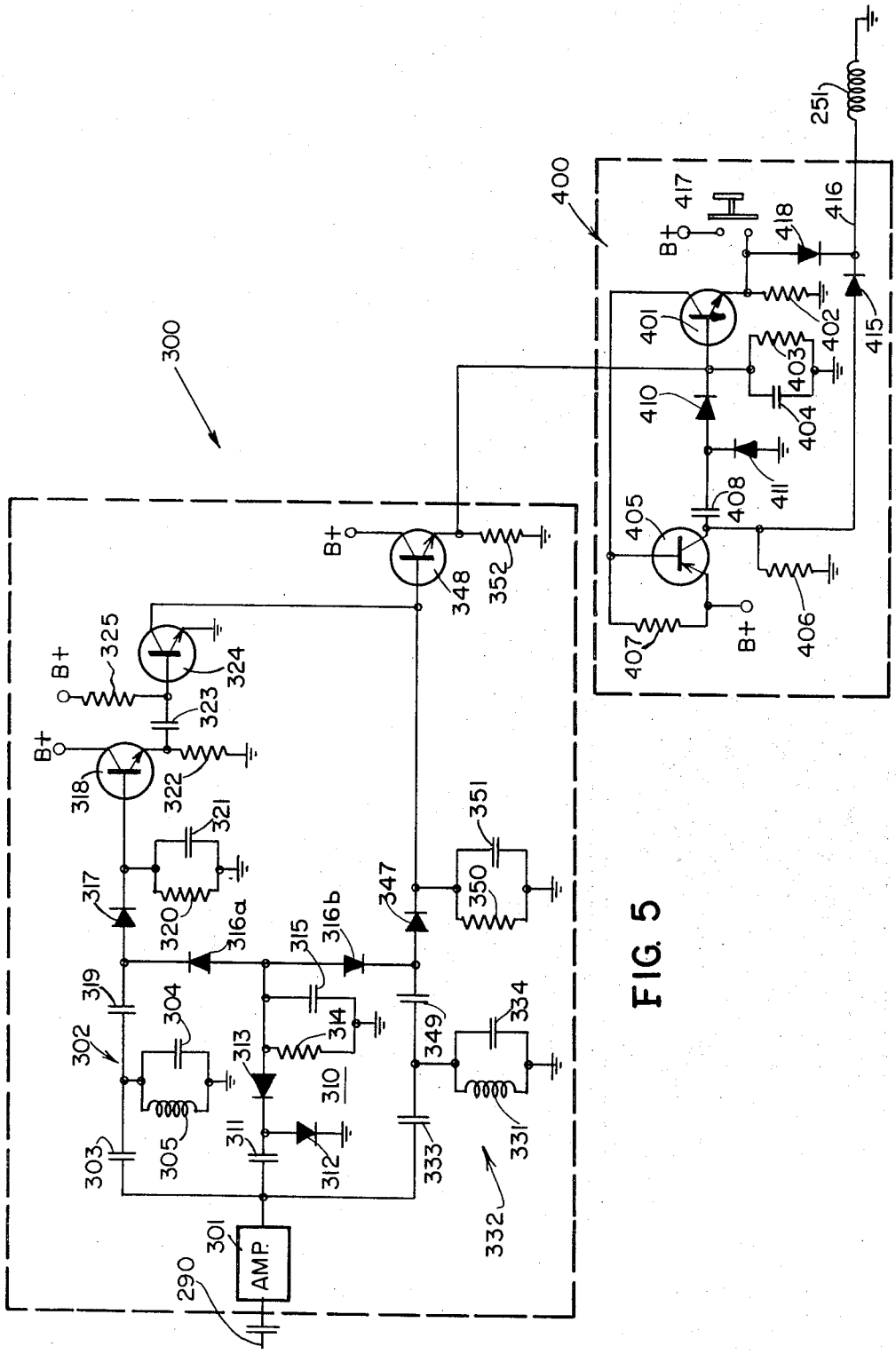

300
400
AMP.
B+
290
301
302
303
304
305
310
311
312
313
314
315
316a
316b
317
318
319
320
321
322
323
324
325
332
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334
347
348
349
350
351
352
401
402
403
404
405
406
407
408
410
411
415
416
417
418
251

FIG. 5

PLURAL OSCILLATOR SYSTEM FOR GENERATING SIMULTANEOUS PAIRS OF SEQUENTIAL TONES

This is a division, application Ser. No. 165,475, filed July 26, 1971, now U.S. Pat. No. 3,771,060.

It is an important object of the present invention to provide an improved oscillator for use in generating simultaneous pairs of sequential tones.

In summary, there is provided a first oscillator for generating a first tone, first means for producing a first pulse of limited duration, the first oscillator being coupled to the first means and responsive to the first pulse to produce the first tone for the duration of the first pulse, a second oscillator having frequency-determining elements and being operative to produce second tones having frequencies respectively in accordance with the frequency-determining elements in circuit said the second oscillator, second means for producing a sequence of a plurality of second pulses respectively of limited durations, the second oscillator being coupled to the second means and responsive to the second pulses to produce a sequence of a plurality of second tones respectively for the durations of the second pulses, means coupled to the outputs of the first and second oscillators for combining the tones therefrom and thereby provide a sequence of a plurality of second tones and a continuous first tone simultaneously with the plurality of second tones.

With the foregoing and other objects in view, which will appear as the description proceeds, the invention consists of certain novel features and a combination of parts hereinafter fully described, illustrated in the accompanying drawings, and particularly pointed out in the appended claims, it being understood that various changes in the details of the circuitry may be made without departing from the spirit or sacrificing any of the advantages of the invention.

For the purpose of facilitating an understanding of the invention, there is illustrated in the accompanying drawings a preferred embodiment thereof, from an inspection of which, when considered in connection with the following description, the invention, its mode of construction, assembly and operation, and many of its advantages should be readily understood and appreciated.

FIGS. 1 and 2 illustrate a transmitter, partially in block and partially in schematic, used in the communication system incorporating the features of the invention;

FIG. 3 is a block diagram of the receiver in the system;

FIG. 4 is a schematic diagram of the tone extractor forming part of the receiver of FIG. 3; and

FIG. 5 is a schematic of the decoder and the electronic switch of the receiver of FIG. 3.

Referring now to the drawings, and more particularly to FIG. 1 thereof, there is shown a single side-band transmitter **20** for transmitting single side-band signals with a suppressed carrier. The transmitter **20** includes an audio amplifier **21** for applying an audio signal to a balanced modulator **22**, the modulator **22** having a second input to which is applied an oscillatory signal derived from a first oscillator **23**. The balanced modulator **22** mixes the audio signal (the modulation frequencies) and the oscillatory signal (the carrier wave), and passes the sum and difference frequencies. The modulation frequencies are attenuated substantially because of the band-pass characteristics of the modulator **22**, and the carrier wave is balanced out electronically. The modulation components may either be in the form of a voice message applied to the audio amplifier **21** by way of the microphone **24** or from a tone generator **40** to be described in detail hereinafter.

The upper and lower side bands produced in the balanced modulator are applied to a filter **25** which passes only a selected one of the side bands, the selected side band being amplified in an IF amplifier **26**. The amplified IF signal is applied to a mixer **27** which also receives a higher frequency, second oscillatory signal from the second oscillator **28**, thereby to provide a modulated signal at radio frequencies. The RF signal is amplified in an RF amplifier **29** and is radiated by an antenna **30**. The elements just described are elements well-known in the art, so that further description thereof is unnecessary. Also, it is to be understood that any suitable alternative transmitter capable of single side-band transmission is contemplated.

Turning now to the tone generator **40**, there is provided a power supply **45** having a Zener diode **47** and a resistor **46** coupled in series therewith to an A+ source of supply voltage, which may be a battery, for example. Accordingly, a reduced B+ supply voltage is available across the Zener diode **47**. In one form of the invention, the A+ supply voltage was **12** volts and the Zener diode was of 9–volt variety, so that the B+ supply voltage was **9** volts. Also, the tone generator **40** has a switch **41**, which, in the form shown, is depressible and has a normally-open condition, the switch **41** being coupled between ground reference potential and resistor **42**, to a first switch circuit **50**. The first switch circuit **50** includes a first NPN transistor **51**, with a resistor **52** coupled between the collector and base thereof. A diode **53** is coupled between the emitter and the base of the transistor **51**, the collector thereof being coupled through a resistor **54** to the A+ supply voltage. The emitter of the transistor **51** is coupled by way of a Zener diode **55** to the base of a second NPN transistor **56**, the collector of which is coupled through a resistor **57** to the A+ supply voltage, and the emitter of which is coupled by way of a resistor **58** to ground reference potential. A resistor **59** is coupled between the base and emitter of the transistor **56**. A third NPN transistor **60** has its base coupled to the collector of the transistor **56**, its collector coupled to the A+ operating voltage by means of a resistor **61**, and its emitter coupled through a diode **62** to the collector of a fourth NPN transistor **63**. The base of the transistor **63** is coupled to the junction of the resistors **58** and **59**, and the emitter is coupled to ground reference potential.

When the power supply **45** is energized to provide the A+ supply voltage for the first switch circuit **50**, the transistors **51**, **56**, and **63** are all rendered conductive, thereby effectively to ground (except for the saturation resistance between the collector and emitter) the collector of the transistor **63**. The transistor **56** shunts current away from the transistor **60**, whereby the latter is rendered non-conductive. When the switch **41** is actuated, the base of the transistor **51** is effectively grounded through the resistor **42**, thereby shunting less current away from the transistor **51** and rendering it non-conductive, which, in turn, renders nonconductive the transistors **56** and **63**. Since the transistor **56** is no longer conductive, current will flow through the resistor **57** into the transistor **60**, thereby rendering the

same conductive and causing the A+ voltage, minus the small drop across the resistor 61, the transistor 60, and the diode, to appear on the collector of the transistor 63. Summarizing, if no voltage is applied to the input, that is, to the base of the transistor 51, the output voltage of the switch circuit 50 will be zero, that is, the collector of the transistor 63 will be on ground. For convenience, in future reference, the grounded condition of the output of a switch circuit will be referred to as yielding a zero voltage despite the fact that the voltage is somewhat higher because of the saturation resistance of a transistor. Similarly, a positive voltage at the input of the switch circuit 50 will cause an increase in conduction of the transistor 51, but the output voltage will still be zero. If the input to the switch circuit 50 is grounded, that is, if a zero voltage is applied thereto, the output of the switch circuit 50 will be a positive voltage slightly less than the A+ voltage. Thus, it may be seen that the switch circuit 50 may be considered an inverter, that is, if the input if zero voltage, the output will be a plus voltage, and, if the input is a plus voltage, the output will be zero voltage.

The output of the first switch circuit 50, that is, the collector of the transistor 63 is coupled by way of a resistor 65 to a second switch circuit 70. Also coupled to the input of the second switch circuit 70 is a resistor 67 coupled in series with a normally-open switch 66 to the A+ supply voltage. The second switch circuit 70 has precisely the same construction as the first switch circuit 50, and the parts are therefore numbered with corresponding numbers, but with 20 added thereto. In the interest of simplifying the drawing, only the input and output of the switch circuit 70 are illustrated.

Prior to actuating the switch 41, the collector of the transistor 63 is effectively grounded, so as to divert current from the transistor 71 in the second switch circuit 70. Thus, the transistors 71 and 83 will be rendered nonconductive, and the output of the second switch circuit 70 will be a plus voltage. Actuation of the switch 41, to ground the input of the first switch circuit 50, causes the output thereof to provide the plus voltage, as previously explained, which causes the transistors 71 and 83 to conduct, thereby grounding the output of the second switch circuit 70, so that it supplies a zero voltage. The same result can be accomplished by actuating the switch 66, which would apply the A+ voltage directly to the transistor 71, thereby rendering it and the transistor 83 conductive, to cause a zero voltage to appear at the output of the second switch circuit 70. Thus, actuation of either of the switches 41 or 66 has the same net effect of providing a zero voltage in the output of the second switch circuit 70.

The output of the second switch circuit 70, that is, the collector of the transistor 83, is coupled by way of a capacitor 85 to a third switch circuit 90. The switch circuit 90 has the same construction as the switch circuit 50 and has corresponding numbers, but with 40 added. Again, in the interest of simplifying the drawing, there are shown only the input and output stages of the switch circuit 90.

Before either of the switches 41 or 66 is actuated, the transistors 91 and 103 are conducting, so that the output of the third switch circuit 90 is a zero voltage. When either of the switches 41 or 66 is actuated, the transistor 83 in the second switch circuit 70 becomes heavily conductive, to cause current flow through the resistors 92 and 94 to be diverted from the transistor 91 and through the capacitor 85 and the collector and emitter of the transistor 83. Accordingly, the transistor 91 is rendered nonconductive as is the transistor 103, to cause the output of the switch circuit 90 to rise to the plus voltage. When the capacitor 85 has become charged, further current flow through the resistors 92 and 94 is applied to the transistor 91 to render the same conductive and therefore render the transistor 103 conductive.

Thus, a positively-directed pulse 104 appears at the output at the third switch circuit 90, that is, on the collector of the transistor 103. The leading edge of the pulse 104 occurs at the time that the transistor 83 becomes conductive, which occurs essentially simultaneously with actuation of either of the switches 41 or 66. The capacitor 85 and the resistors 92 and 94 define a time constant network, the values of which control the duration of the pulse 104.

The output of the third switch circuit 90 is coupled to a fourth switch circuit 110 which has a construction identical to the switch circuit 50, with corresponding numerals, but with 60 added thereto. Again, for simplicity purposes, only a portion of the switch circuit 110 is illustrated. When the collector of transistor 103 in the third switch circuit 90 is at the plus voltage for the duration of the pulse 104, the transistor 111 and, thus, the transistor 123 are conductive, effectively grounding the collector of the transistor 123, thus furnishing a negatively-directed pulse 124 on the conductor 125. The conductor 125 is coupled to a splitter circuit 130, which circuit includes an isolating resistor 131 coupled to the base of a PNP transistor 132. The emitter of the transistor 132 is coupled to the B+ supply voltage and the collector is coupled to a first oscillator 190. There is provided another isolating resistor 134 coupled to the conductor 125 and a second PNP transistor 135 having its base coupled to the resistor 134. The collector of the transistor 135 is coupled to a second oscillator 210, which will be described presently. The negatively-directed pulse 124 renders the transistors 132 and 135 conductive so as to furnish upon the respective collectors positively-directed pulses 136 and 137 having durations equal to the duration of the pulse 124.

The output of the third switch circuit 90 is also coupled to a fifth switch circuit 140 by way of a capacitor 139, which switch circuit 140 is substantially identical to the switch circuit 50 and is labeled with corresponding numbers, but with 90 added thereto.

Prior to the appearance of the pulse 104, the transistors 141 and 153 are conducting, so that the output of the fifth switch circuit 140 is a zero voltage. The leading edge of the pulse 104 from the third switch circuit 90 is coupled through the capacitor 139 to the transistor 141 in the switch circuit 140. Since the leading edge is rising, it only increases conduction of the transistor 141, but does not affect the output of the circuit 140. The trailing edge of the pulse 104 occurs when the transistor 103 in the switch circuit 90 becomes conductive to cause current from the A+ supply voltage through the resistors 142 and 144 to be diverted from the transistor 141, through the capacitor 139 and the collector and the emitter of the transistor 103. When the capacitor 139 becomes charged, the current will no longer become diverted through the transistor 103, but, instead, will again be delivered to the transistor 141 to render the same conductive. Thus, the transistor 141

becomes nonconductive, as does the transistor 153. The rate of charge of the capacitor 139 is determined by the values of the resistors 142 and 144 and the capacitor 139. Thus, a positively-directed pulse 154 appears at the output of the fifth switch circuit 140, that is, on the collector of the transistor 153. The leading edge of the pulse 154 occurs essentially simultaneously with the termination of the pulse 104. The capacitor 139 and the resistors 142 and 144 define a time constant network, the values of which control the duration of the pulse 154.

The output of the fifth switch circuit 140 is coupled to a sixth switch circuit 160 which has a construction identical to the switch circuit 50, with corresponding numerals, but with 110 added thereto. Again, for simplicity purposes, only a portion of the switch circuit 160 is illustrated. When the collector of the transistor 153 in the fifth switch circuit 140 is at plus voltage for the duration of the pulse 154, the transistor 161 and, thus, the transistor 173 are rendered conductive, effectively grounding the collector of the transistor 173, thus furnishing a negatively-directed pulse 174 on the conductor 175. In a particular form of the invention, the circuits 50, 70, 90, 110, 140, and 160 constituted a single integrated circuit.

The conductor 175 is coupled to a splitter circuit 180, which circuit includes an isolating resistor 181 coupled to the base of a PNP transistor 182. The emitter of the transistor 182 is coupled to the B+ supply voltage, and the collector is coupled to the first oscillator 190. There is provided another isolating resistor 184 coupled to the conductor 175 and a second PNP transistor 185 having its base coupled to the resistor 184. The collector of the transistor 185 is coupled to the second oscillator 210. The negatively-directed pulse 174 renders the transistors 182 and 185 conductive so as to furnish upon the respective collectors positively-directed pulses 186 and 187 having durations equal to the duration of the pulse 174.

Thus, when either of the switches 41 or 66 is actuated, the simultaneous pulses 136 and 137, each of the same predetermined duration, are produced, followed automatically by a second pair of simultaneous pulses 186 and 187, each of which lasts for another predetermined duration, there being virtually no time lag between the termination of the pulses 136 and 137 and the commencement of the pulses 186 and 187.

The pulses 136 and 186 are coupled to the first oscillator 190 which includes a NPN transistor 191 having its base coupled through a resistor 193 to the B+ supply and its emitter coupled through a resistor 192 to ground reference potential. A pair of capacitors 194 and 195 is coupled in series between the collector of the transistor 191 and the B+ supply voltage. There is provided a connection between the emitter of the transistor 191 and the junction of the capacitors 194 and 195. A coil 196 couples the collector of the transistor 191 to the collectors of the transistors 132 and 182. The junction of the capacitors 194 and 195 is coupled through a variable resistor 197 and a capacitor 198 to an amplifier 200. The output of the amplifier 200 is coupled to the series combination of a capacitor 201 and a potentiometer 202 having a movable arm 203.

In the absence of the pulses 136 and 186, no supply voltage is furnished for the collector of the transistor 191, whereby the oscillator 190 does not produce an oscillatory signal or tone. The appearance of the pulse 136 renders the oscillator 190 operative to produce an oscillatory signal or tone for the duration of the pulse 136, which oscillatory signal is coupled through the resistor 197 and the capacitor 198 to the amplifier 200. Upon the termination of the pulse 136, the pulse 186 commences, as previously explained. Thus, the oscillator 190 is maintained operative for the further duration of the pulse 186 to produce the oscillatory signal or tone. The variable resistor 197 enables adjustment of the amplitude of the tone.

The pulses 137 and 187 are coupled to a second oscillator 210 which includes an NPN transistor 211 having its base coupled through a resistor 213 to the B+ supply and its emitter coupled through a resistor 212 to ground reference potential. A pair of capacitors 214 and 215 is coupled in series between the collector of the transistor 211 and the B+ supply voltage. There is provided a connection between the emitter of the transistor 211 and the junction of the capacitors 214 and 215. A coil 206 having a plurality of taps 206.1 through 206.10 is coupled to the collector of the transistor 211. In the embodiment shown, the tap 206.5 is coupled to the collector of the transistor 135 and the tap 206.8 is coupled to the collector of the transistor 185. The junction of the capacitors 214 and 215 is coupled through a variable resistor 217 and a capacitor 218 to an amplifier 200.

In the absence of the pulses 137 and 187, no supply voltage is furnished for the collector of the transistor 211, whereby the oscillator 210 does not produce an oscillatory signal or tone. The appearance of the pulse 137 renders the oscillator 210 operative to produce an oscillatory signal or tone for the duration of the pulse 137, which oscillatory signal has a frequency determined by the capacitors 214 and 215 and the portion of the coil 206 between the collector of the transistor 211 and the tap 206.5. The oscillatory signal or tone is coupled through the resistor 217 which permits adjustment of the tone amplitude and the capacitor 218 to the amplifier 200. Upon termination of the pulse 137, the pulse 187 commences, whereby the frequency of the oscillatory signal produced by the oscillator 210 is determined by the same capacitors 214 and 215 and a lesser inductance, that is, the portion of the coil 206 between the collector of the transistor 211 and the tap 206.8. The oscillatory signal produced for the duration of the pulse 187 is coupled by the resistor 217 and the capacitor 218 to the amplifier 200.

The amplifier 200 amplifies the various oscillatory signals or tones applied thereto and couples them via the capacitor 201 to the potentiometer 202. Thus, there appears across the potentiometer 202 a first tone having a frequency determined by the parts 194, 195, and 196 simultaneously with a second tone having a second frequency determined by the parts 214, 215, and the portion of the coil 206 to the tap 206.5. The second tone terminates with the termination of the pulse 137, but the first tone is continuously produced by virtue of the pulses 136 and 186. A third tone, having a frequency determined by the parts 214, 215, and the portion of the coil 206 to the tap 206.8, is produced during the pulse 187. There is provided, therefore, a continuous first tone, a second tone, occurring simultaneously with the first portion of the first tone, and a third tone occurring simultaneously with the last portion of the first tone.

It should be understood that the first oscillator **190** could be replaced with an oscillator similar to the oscillator **210**, so that the tone produced thereby during the first pulse **136** differs from the tone produced thereby during the second pulse **186**. The circuit shown is preferable because of its simplicity. By selecting the taps on the coil **206** to which the transistors **135** and **185** are connected, the frequencies of the tones may be determined. If used in a base station, a switch may be connected between the transistors **135** and **185** and the taps on the coil **206** to enable rapid selection of the tones. In a transmitter actually constructed, the duration of the tone from the oscillator **190** was 325 milliseconds, the duration of the first tone from the oscillator **210** was approximately 200 milliseconds, and the duration of the second tone from the oscillator **210** was 125 milliseconds. All tones produced by the oscillators **190** and **210** are in the voice spectrum, that is, between the range of about 350 Hz to 2,750 Hz. The oscillator **190** produced a tone at 2,450 Hz.

The tones were applied via the conductor **204** to the audio amplifier **121** which couples the tones to the balanced modulator **22**. The tones will actuate a specific receiver, as will be subsequently described. Thus, if the operator wishes to communicate with the specific receiver, the connections to the coil **206** are made by switch, for example, and then the operator actuates the switch **41** or the switch **66**, either of which would constitute a push-to-talk switch. That causes a pair of simultaneous tones immediately followed by a second pair of simultaneous tones to be impressed upon the balanced modulator **22**. The tones, after being modulated on a single side band, are transmitted to actuate the selected receiver. Since the tones are only sent for a very short duration, in this example, 325 milliseconds, the operator may begin speaking into the microphone **24** almost immediately, which voice message is transmitted by modulation components on the single side band.

Turning now to FIG. **3**, there will be described the details of construction of the receiver used in the communication system incorporating the features of the present invention. The receiver **240** includes an antenna **241** which receives the signals emitted by the transmitter **20** and applies them to an RF amplifier **242**. The amplified signals are applied to a convertor **243** having a second input coupled to a first oscillator **244**. The RF signals from the amplifier **242** are mixed with an oscillatory signal from the oscillator **244** to provide an intermediate frequency (IF) signal which is then applied to an IF amplifier **245**. The output of the amplifier **245** is coupled to a product detector **246**, the latter receiving a second input from a second oscillator **247**. The second oscillator **247** reinserts the carrier which was suppressed at the transmitter **20** to detect the modulation components and apply them to an audio amplifier **248**. The input to the audio amplifier **248** will consist of a first pair of simultaneous tones, followed immediately by a second pair of simultaneous tones, followed by the voice message. The output of the amplifier **248** is coupled via the contacts **249** of a relay **250** (which has an energizing winding **251**) to a loud speaker **252**. If the contacts **249** are open, no audio signal will arrive at the speaker **252** and, accordingly, no noise or information not directed to the listener will be emitted therefrom.

The audio amplifier **248** is also coupled to a tone extractor **260**. The tone extractor **260** mixes the tones in a manner to be described, to provide a signal having a frequency equal to the difference of the frequencies of the tones in the first pair, followed by a signal having a frequency equal to the difference in frequencies of the tones in the second pair. The output of the tone extractor **260** is applied to a decoder **300** which will provide an output if the two signals applied thereto are of the frequencies to which the decoder **300** is tuned. The output of the decoder **300** is applied to an electronic switch **400** which, in the presence of a signal of the decoder **300**, will furnish an enabling current through the winding **251** of the relay **250**, so as to close the contacts **249**. Audio signals produced by the amplifier **248** are then coupled to the speaker **252** which converts them into sound waves.

Turning now to FIG. **4**, the details of construction of the tone extractor **260** will be described. As is usual, the audio amplifier **248** has a transformer **248a** to match the impedance of the amplifier stages to the impedance of the loud speaker **252**. The secondary winding of the transformer **248** is coupled in series with the loud speaker **252** and the contacts **249** of the relay **250**. A resistor is coupled across the primary winding of the transformer **248***a* to prevent the amplifier stages in the audio amplifier **248** from oscillating when the contacts **249** are open, so that those amplifier stages are unloaded.

The primary winding is also coupled to a detector or mixer **261** which includes four diodes **262**, **263**, **264**, and **265** arranged as a bridge to mix the tones. A pair of oppositely-poled diodes **266** and **267** is coupled in parallel across the output of the mixer **261**. There is provided a low-pass filter **270**, also coupled to the output of the mixer **261**, which low-pass filter **270** includes a number of stages. A resistor **271** and capacitor **272** are coupled in parallel, providing the first stage. The second stage is achieved in a T network defined by the resistors **273** and **275** and the capacitor **274**; a third stage in the form of an inductor **276** and a capacitor **277**; a fourth stage in the form of a capacitor **278** and a resistor **279** coupled in parallel; and a fifth stage consisting of a series capacitor **280** and a shunt resistor **282**. There is also provided a stage of amplification in the form of an NPN transistor **281** biased by the resistor to B+. There is provided a second NPN transistor **287** connected as an emitter follower, so as to match the impedance of the low-pass filter **270** to the input impedance of the decoder **300**. Further filtering is provided by the tuned circuit consisting of an inductor **283** and a capacitor **284**, a series capacitor **285**, and a shunt resistor **288**. The output from the filter appears across an emitter load resistor **289** and is coupled via a capacitor **290** to the decoder **300**.

In operation, there appears across the secondary winding of the transformer **248***a* a first simultaneous pair of tones which are mixed in the mixer **261** to provide a signal having a frequency of one of the tones in the first pair, another signal having a frequency equal to the frequency of the other of the tones in the first pair, still another signal having a frequency equal to the difference of frequencies of the tone in the first pair, and yet another signal having a frequency equal to the sum of the frequencies in the tones in the first pair. Similarly, there also appears across the second winding of the transformer **248***a* a second simultaneous pair of

tones which are mixed in the mixer **261** to provide a signal having a frequency of one of the tones in the second pair, another signal having a frequency equal to the frequency of the other of the tones in the second pair, still another signal having a frequency equal to the difference of frequencies of the tones in the second pair, and yet another signal having a frequency equal to the sum of the frequencies in the tones in the second pair. The amplitudes of the signals from the mixer **261** are limited by the diodes **266** and **267.**

The elements in the low-pass filter **270** are selected to cause the cutoff frequency thereof to be greater than the frequency equal to the differences in frequency between any pair of tones, but less than the frequency of any individual tone. Thus, the cutoff frequency is less than the frequency equal to the sum of the frequencies of any two simultaneous tones. Accordingly, the low-pass filter **270** passes only a first signal having a frequency equal to the difference in frequencies between the tones in the first pair, followed by a second signal having a frequency equal to the difference in frequency between the tones in the second pair. The two signals that are passed are amplified in the transistor **281** and coupled by way of the emitter follower transistor **287** and through the capacitor **290** to the decoder **300.**

Turning now to FIG. **5,** the details of the decoder **300** will be described. The decoder **300** includes an amplifier **301** which is coupled to the capacitor **290** and having its output coupled to a tone filter **302.** The tone filter **302** includes capacitors **303** and **304** coupled in series and an inductor **305** coupled in parallel with the capacitor **304.** The decoder **300** further comprises a reference circuit **310** including an input capacitor **311** coupled to the output of the amplifier **301** and a diode **312** coupled to ground. There is also provided a diode **313** connected to the junction of the capacitor **311** and the diode **312.** A filtering network comprises a resistor **314** and a capacitor **315** coupled in parallel to ground. There is also provided a rectifying circuit including a pair of diodes **316**a and **317** coupled in series to the base of a switching transistor **318.** A capacitor **319** is coupled between the junction of the capacitors **303** and **304** and the junction of the diodes **316***a* and **317.** There is also provided a resistor **320** and a capacitor **321** for filtering of the rectified voltage, the resistor **320** also providing a DC return for the base of the transistor **318.** The transistor **318** is connected as an emitter follower, the emitter being coupled to a load resistor **322** connected to ground reference potential. The emitter of the transistor **318** is coupled by way of a capacitor **323** to an NPN transistor **324,** the emitter of which is grounded and the base of which is coupled to the B+ supply voltage by way of a resistor **325.**

There is also provided a second filter circuit **332** which includes capacitors **333** and **334** coupled in series and an inductor **331** coupled in parallel with the capacitor **334.** Also, the reference circuit **310** includes a second diode **316***b* which is coupled in series with a diode **347** to the base of a switching transistor **348.** A capacitor **349** is coupled between the junction of the capacitors **333** and **334** and the junction of the diodes **316***b* and **347.** There is also provided a resistor **350** and a capacitor **351** for filtering of the rectified voltage, the resistor **350** also providing a DC return for the base of the transistor **348.** The transistor **348** is connected as an emitter follower, the emitter being coupled to a load resistor **352** connected to ground reference potential, the collector being coupled to the B+ supply voltage. The base of the transistor **348** is also coupled back to the collector of the transistor **324.**

Prior to reception of any tones, the transistor **324** is conducting by virtue of the forward bias provided by the current flow through the resistor **325.** Thus, the base of the transistor **348** is effectively grounded to prevent amplification of a tone thereby. If tones are received, they are applied to the amplifier **301,** which amplifier has sufficient gain to cause the tones therefrom to be clipped or limited so the signal strength at the antenna **241** does not affect the amplitude of the signals applied to the filters **302** and **332.**

The amplified signal from the amplifier **301** containing the tones and noise will be filtered in the reference circuit **310** and will be rectified thereby to provide a reference voltage on the anode of the diode **316**a. If the signal from the amplifier **301** includes the tone to which the filter **302** is tuned, the filter **302** will develop its maximum voltage which is applied to the cathode of the diode **316***a.* In order that the diode **316***a* may conduct to provide an output, the tone appearing at the cathode thereof must have a peak-to-peak value in excess of the reference voltage on the anode of the diode **316***a.* The rectified voltage, after being filtered by the resistor **320** and the capacitor **321,** is applied to the base of the transistor **318** so as to render it conductive. Current flows from the B+ supply through the collector and the emitter of the transistor **318,** through the capacitor **323** and the base-emitter junction of the transistor **324.** Since the transistor **324** is already conducting, the presence of the tone has little effect. When the first signal terminates because of termination of the first pair of tones, the capacitor **323** discharges through the resistor **322** to render nonconductive the transistor **324,** thereby removing the short on the base of the transistor **348.** The length of time the transistor **324** is nonconductive, and, therefore, the length of time the short is removed from the transistor **348** is determined by the time constant of the resistor **322** and the capacitor **323** and the resistor **325.** However, until the correct second signal is received, the transistor **348** is not rendered conductive.

When the first pair of tones terminates, the second pair of tones commences and if the frequency thereof is the frequency to which the filter **332** is tuned, the filter **332** will develop its maximum voltage which is applied via the capacitor **349** to the cathode of the diode **316***b.* In order to provide an output from the diode **348,** the signal appearing at the cathode of the diode **316***b* must have a peak-to-peak value in excess of the reference voltage on the anode of the diode **316***b.* The signal is rectified by the diodes **316***b* and **347** which, in effect, constitute a doubler circuit and filtered by the resistor **350** and the capacitor **351.** If the short on the base of the transistor **348** furnished by the transistor **324** has been removed, then the rectified voltage renders the transistor **348** conductive to cause the B+ voltage (approximately) to appear on the emitter of the transistor **348.** If desired, a feed-back network may be provided from the transistor **348** to the transistor **324** to maintain the latter nonconductive for the duration of the second tones. Alternatively, the time constant determined by the resistor **322** and the capacitor **323** and resistor **325** may be selected to insure that the transistor **324** is not conductive throughout the duration of the second tones.

There is provided an electronic switch **400**, which, in the embodiment shown, is a monostable multivibrator and includes an NPN transistor **401** having its emitter coupled to ground via a resistor **402** and having its base coupled to ground by way of a resistor **403** and a capacitor **404** coupled in parallel. There is also provided a PNP transistor **405** having its base connected directly to the collector of the transistor **401**, its collector connected through a resistor **406** to ground and its emitter connected to the source of supply voltage, a resistor **407** being connected between the base and the emitter of the transistor **405**. The collector of the transistor **405** is coupled by way of a capacitor **408** and a diode **410** to the base of the transistor **401**. A diode **411** is coupled between ground reference potential and the junction of the capacitor **408** and the diode **410**. The emitter of the transistor **348** in the decoder **300** is coupled to the base of the transistor **401**. A diode **415** couples the collector of the transistor **405** to a conductor **416**. There is provided a switch **417** coupled between the source of B+ operating potential and the emitter of the transistor **401**. The switch **417** is also coupled via a diode **418** to the conductor **416**.

In operation, the appearance of the output signal on the emitter of the transistor **348** causes conduction of the transistor **401** which provides a path for current flow from the source of supply voltage through the base-emitter junction of the transistor **405** and the collector and the emitter of the transistor **401**. This renders the transistor **405** highly conductive so as to provide current flow through its collector and its emitter and the resistor **406** and thereby cause conduction of the diode **415** to place the supply voltage on the conductor **416**. The supply voltage becomes an enabling signal for causing current flow in the winding **251** of the relay **250** to close the contacts **249**. The capacitor **404** must be charged before the transistor **401** will conduct. Thus, the capacitor **404** introduces a slight delay to prevent the electronic switch **400** from producing the enabling signal in the presence of a static charge. The isolating diode **410** prevents the signal from the decoder **300** from being applied to the capacitor **408**. The diode **411** provides a rapid discharge path for the capacitor **408**.

During the conduction period of the transistors **401** and **405**, current flows from B+ through the collector and the emitter of the transistor **405**, through the capacitor **408** and through the base-emitter junction of the transistor **401** to charge the capacitor **408**. Accordingly, when the signal from the decoder **400** is removed by virtue of the tones terminating, the transistor **401** remains conductive because the capacitor **408** has a charge thereon, which charge leaks off through the base-emitter junction of the transistor **401** and the resistors **402** and **403**. Of course, the conduction of the transistor **401** maintains the transistor **405** conductive to maintain the enabling voltage on the conductor **416** for a time interval determined by the RC time constant of the switch circuit **400**, that is, the resistors **402** and **403** and the capacitor **408**. By selecting the value of those parts, the time period that the enabling signal remains on the conductor **416** may be controlled.

With the relay **250** energized, audio signals from the audio amplifier **248** will be applied to the loud speaker **252** for conversions into sound waves. It is thus desirable that the RC time constant in the electronic switch circuit **400** be selected to be long enough to maintain the contacts **249** closed for the duration of audio information. The switch **417** is provided to enable the user to "override" the timing function by rendering nonconductive the transistors **401** and **405**. The B+ supply voltage is then directly applied through the diode **418** to energize the relay winding **251**, whereby the contacts **245** will remain closed as long as the switch **417** is energized.

Summarizing, if the operator of the transmitter **20** wishes to alert the user of the receiver **240**, the operator connects the transistor **135** to a tap on the coil **206** in the oscillator **210** such that the difference in frequency between the tones produced by the oscillator **190** and the oscillator **210** is the frequency to which the filter **302** is tuned. The transistor **185** is connected to a tap on the coil **206** such that the difference in frequency between the tone produced by the oscillator **190** and the tone produced by the oscillator **210** is equal to the frequency to which the tuned circuit **332** is tuned. By actuating his push-to-talk switch, which may be either of the switches **41** or **66**, the operator will cause the tones to be modulated as single side-band components. The tones are received by the receiver **240**, processed by elements **242, 243, 245**, and **246** and applied to the audio amplifier **248**. The mixer **261** first mixes the first pair of tones (the tone produced by the oscillator **190** and the tone first produced by the oscillator **210**) and thereafter mixes the second pair of tones (the tone produced by the oscillator **190** and the tone next produced by the oscillator **210**), to provide sum and difference frequency signals for each. The low-pass filter **270** allows only signals representative of the difference in frequency between each pair of tones to be applied to the decoder **300**. Since the first tuned circuit **302** is tuned to the frequency of the first signal, the transistor **324** will be rendered nonconductive to remove the short on the base of the transistor **348**. Since the second signal has a frequency corresponding to that to which the tuned circuit **332** is tuned, the transistor **348** will be rendered conductive to provide an output signal for application to the electronic switch circuit **400**. The electronic switch circuit **400** in response thereto will produce an enabling signal on the conductor **416** which extends beyond termination of the last pair of tones in the sequence of tones, the duration beyond termination being determined by the RC time constant of the circuit **400**. The enabling signal energizes the relay **250**. Since the relay **250** becomes energized during the presence of the last pair of tones, the user of the receiver **240** will hear the same from the loud speaker **252**. This is advantageous in that it alerts the user of an impending message. All of this takes a very short period of time, for example, 350 milliseconds, so that the operator of the transmitter **20**, immediately upon actuation of the push-to-talk switch, may speak. The voice message is processed in the receiver and is coupled to the loud speaker **252** since the relay **250** is energized.

As previously pointed out, the tones produced by oscillators **190** and **210** in the transmitter **20** have frequencies within the voice spectrum, that is, within the range of about 350 Hz to 2,800 Hz. This is desirable, first to minimize the portion of the frequency spectrum required by any individual communication system. Because the tone frequencies are within the voice spectrum, the extent of the frequency spectrum needed is minimized. Secondly, utilizing tones only within the

voice spectrum narrows the passband to which the receiver **240** must respond. Basically, the narrower the passband of the receiver, the better the signal-to-noise ratio thereof.

The transmission of a pair of simultaneous tones compensates for any drift that may occur either in the frequencies of the tones themselves or in the suppressed carrier. Thus, for example, if the first tone is 2,500 Hz and the second tone is 1,800 Hz, the difference will be 700 Hz. If a downward **100** Hz frequency drift occurs, so that the first tone had a frequency of 2,400 Hz, the second tone would similarly drift to 1,700 Hz, and the difference would still be 700 Hz.

Although the voice spectrum is about 350 Hz to about 2,800 Hz, which would therefore be the required passband for the receiver **240,** the tones should be within a narrower range, for example, 500 Hz to 2,650 Hz, in order to compensate for up to 150 Hz drift. The optimum number of tone frequencies would be obtained if the cutoff frequency of the low-pass filter **270** would be about one half of the uppermost frequency. Therefore, if the uppermost frequency was 2,650 Hz, the theoretical optimum cutoff frequency of the low-pass filter **270** would be 1,325 Hz. If, as is preferable, one tone in each pair of tones always has the same frequency of, say, 2,650 Hz, then the other tones should be selected from within the range of 1,325 Hz (the cutoff frequency of the low-pass filter **270**) and 2,150 Hz (assuming the lower end of the receiver passband is 500 Hz). Of course, because the filter **270** is not perfect, the cutoff frequency may have to be somewhat less than 1,325 Hz. By selecting tones from within the range of 1,350 Hz and 2,150 Hz, all difference frequency signals would fall within the range of 500 Hz to 1,350 Hz.

It should be understood that the instant communication system enables the tones to have frequencies within the voice spectrum and yet not interfere with the voice message because the tones are transmitted before the voice message commences and an electronic switch circuit has timing means to render operative the audio circuit beyond termination of the tones.

In one form of the invention the tone extractor **260** had the following parts: diodes **262, 263, 264, 265, 266,** and **267** were silicon diodes; resistor **271** was **220** kilohms; capacitor **272** was 5.5 microfarads; resistors **273** and **275** were 22 kilohms; capacitor **274** was 0.047 microfarads; inductors **276** and **283** were 3 henries; capacitors **277** and **278** were 8.2 microfarads; resistor **279** was 10 kilohms; capacitors **280** and **285** were 0.01 microfarads; resistor **282** was 5.6 kilohms; capacitor **284** was 0.147 microfarads; resistor **288** was 100 kilohms; resistor **289** was 470 ohms; capacitor **290** was 33 microfarads.

In order to maximize the number of tones available for a selective calling system, it may be desirable to add a multiplier circuit to the output of the tone extractor **260,** which multiplier may be of a standard construction. Preferably, the multiplier would be a frequency doubler, so that, if, for example, the frequency were 1,000 Hz, the multiplier would produce a signal with a frequency of 2,000 Hz. Thus, if the spread of frequencies from the tone extractor **260** were 500 Hz to 1,350 Hz, the doubler would increase the frequency range from 1,000 Hz to 2,700 Hz; that is a 1,700 Hz spread, as opposed to an 850 Hz spread. This would effectively increase the number of tones which can be transmitted and received in the system.

It is believed that the invention, its mode of construction and assembly, and many of its advantages should be readily understood from the foregoing without further description, and it should also be manifest that, while preferred embodiments of the invention have been shown and described for illustrative purposes, the structural details are, nevertheless, capable of wide variation within the purview of the invention, as defined in the appended claims.

What is claimed is:

1. In a communication single side-band transmitter, the combination comprising a first oscillator for generating a first tone, first means for producing a first pulse of limited duration, said first oscillator being coupled to said first means and responsive to said first pulse to produce said first tone for the duration of said first pulse, a second oscillator having frequency-determining elements and being operative to produce second tones having frequencies respectively in accordance with the frequency-determining elements in circuit with said second oscillator, second means for producing a sequence of a plurality of second pulses respectively of limited durations, said second oscillator being coupled to said second means and responsive to said second pulses to produce a sequence of a plurality of second tones respectively for the durations of said second pulses, means coupled to the outputs of said first and second oscillators for combining the tones therefrom and thereby provide a sequence of a plurality of second tones and a continuous first tone simultaneously with said plurality of second tones.

2. In the communication single side-band transmitter of claim **1,** said second means being operable to produce a sequence of two second pulses and said second oscillator being operative in response to said second pulses to produce a sequence of two second tones.

3. In the communication single side-band transmitter of claim **1,** said first tone and the first of said second tones commencing at substantially the same time, and said first tone and the last of said second tones terminating at substantially the same time.

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