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[54] **TELEPHONE PRIVACY SYSTEM**

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[52] **U.S. Cl.** .... **179/1.5 R;** 328/14; 328/186; 325/38 B; 340/345 R; 179/1.5 M

[51] **Int. Cl.** **H04l 9/00**

[58] **Field of Search** .... 179/1.5, 6, 1.5 R, 1.5 M; 178/22; 328/14, 142, 143, 151, 117, 186; 332/15; 325/38 A, 38 B, 141; 340/345 Q, 345 R

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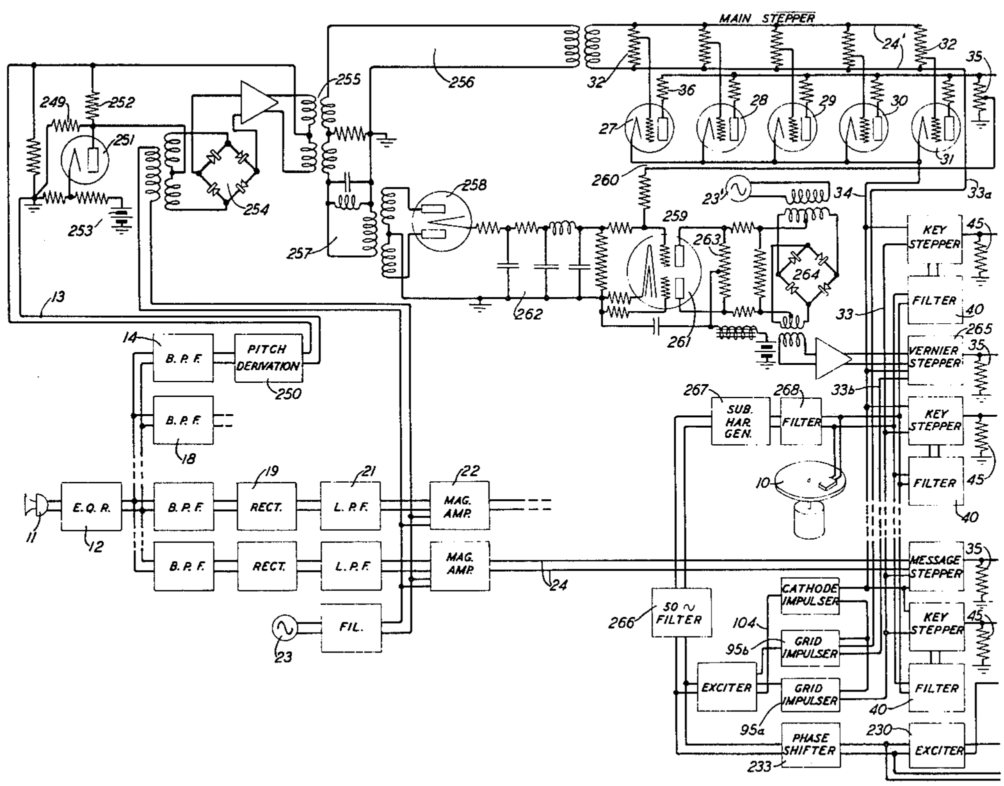
EXEMPLARY CLAIM

1. In a system for transmitting indications of an electrical quantity of varying magnitude, means to transmit indications in the form of stepped values each corresponding approximately to the magnitude of the quantity at the corresponding time, means to compare the respective stepped values against the true values of the quantity to determine the residues of the true values over and above said stepped values in each case, and means to separately transmit indications of said residues.

14 Claims, 3 Drawing Figures



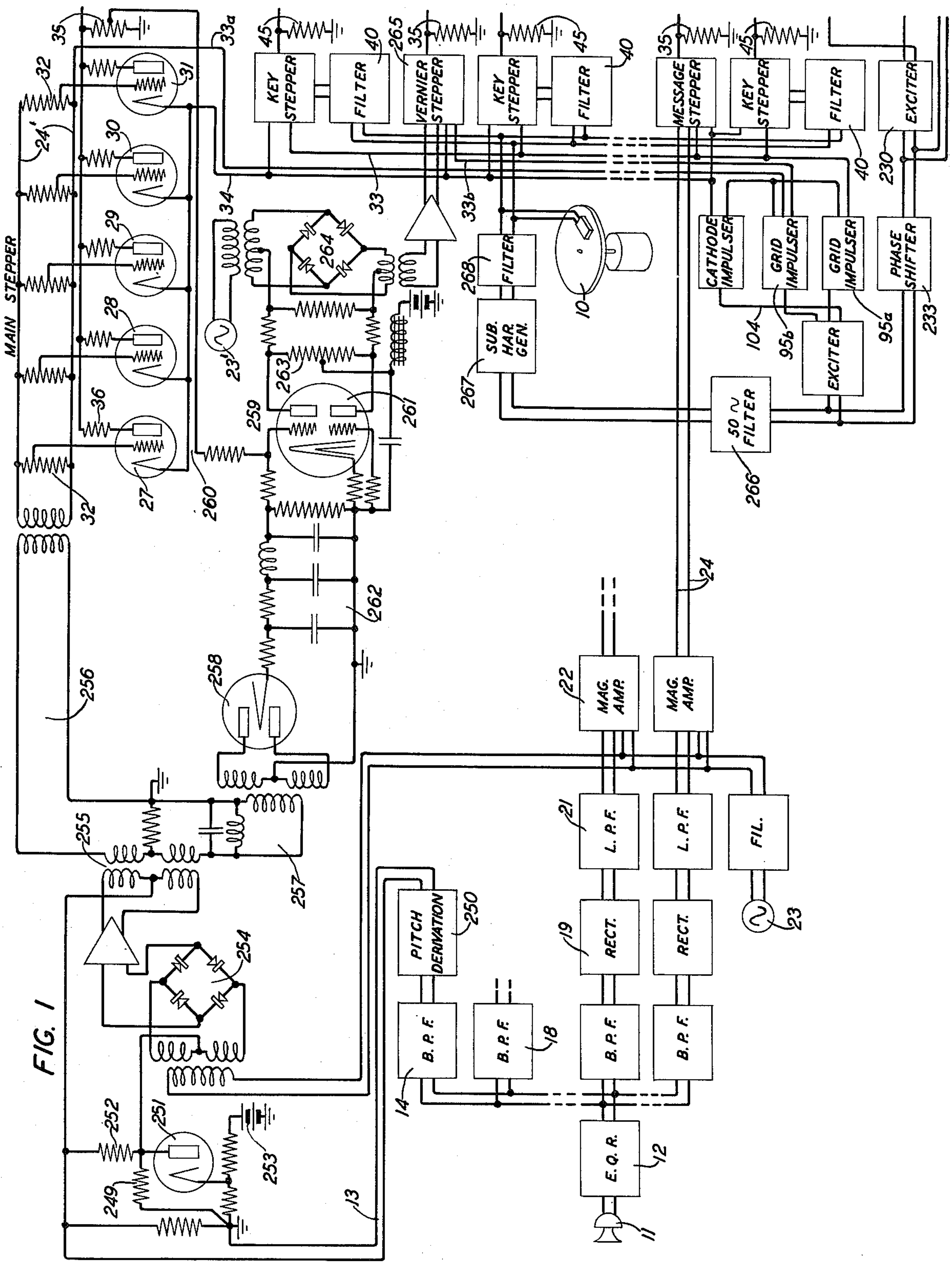


FIG. I

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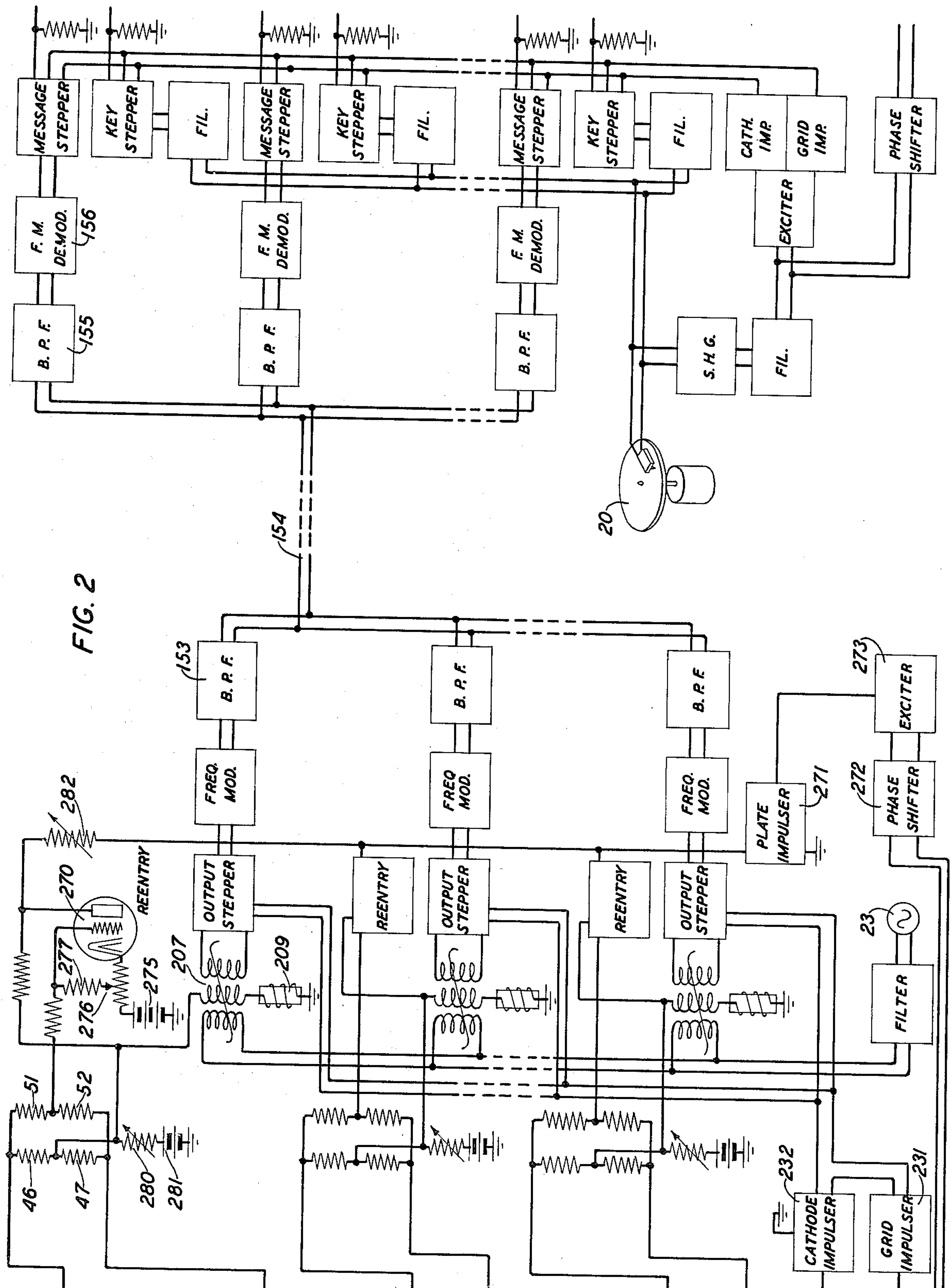

FIG. 2

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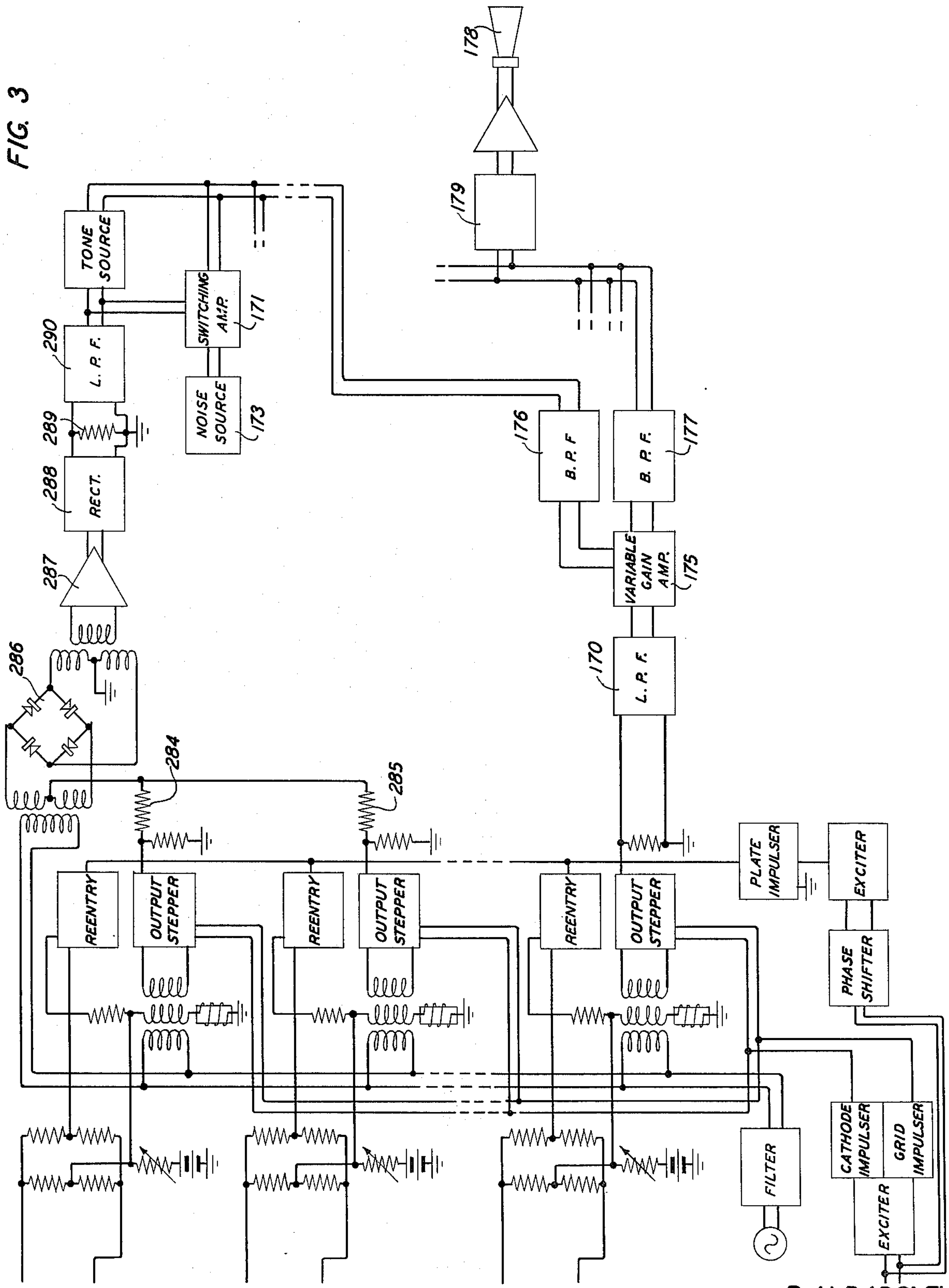
FIG. 3



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TELEPHONE PRIVACY SYSTEM

The present invention relates to the transmission of signal or other current variations and involves sending indications of stepped values to represent both main steps and subdivisions of each main step in order to secure a closer representation of the original signal or other variation than is given by the main steps alone.

The invention is of general application but will be disclosed in connection with a speech privacy system and specifically one in which the speech to be sent is first analyzed to derive elemental components including the fundamental pitch (vocal cord frequency) and in which the invention is employed to transmit information of this frequency and of its variation with time.

A system of the general type to which the invention is applicable is disclosed in Dudley U.S. Pat. No. 2,151,091 dated Mar. 21, 1939 and that system has come to be known as the vocoder. In that system the input speech waves are analyzed into components representative of the frequency spectrum distribution of sound energy and components representative of the fundamental pitch, and the speech is reconstructed at the reproducing point out of these various components and locally produced energy.

It has been proposed to secure a high degree of secrecy in speech transmission by application of secrecy methods to the transmission of the individual components in such a system. One system for accomplishing secret transmission in this manner is disclosed in Lundstrom-Schimpf application Ser. No. 456,322, filed Aug. 27, 1942. While the present invention in its broader aspects is capable of application to other types of embodiment, it will be disclosed herein as embodied in a system of the type disclosed in the Lundstrom-Schimpf application. In this aspect the invention is in the nature of a modification of and improvement upon the system disclosed in the Lundstrom-Schimpf application.

In the method of transmission disclosed in that application for securing secrecy in transmission of the individual speech components the currents representing these components are converted to stepped wave form. The total range of strengths of current above zero is divided into five steps, by way of example, and no intemediate strengths are transmitted. It is found that when this is done to the current representing the fundamental frequency, the received reconstructed speech has a tremulous or jumpy pitch characteristic which may be unpleasant. It is desirable, therefore, to transmit finer gradations of the pitch than are represented by these five steps. This could be done by dividing the range into a multiple of five parts and using a corresponding multiple number of standard channels each sending five steps of current. This would require a large number of such transmission channels to effect much improvement. For example, if thirty steps were to be sent, six such channels would be needed.

The present invention achieves the desired result of transmitting a large numer of finely spaced steps of the pitch-defining current by using a small number of channels, such as two. One such channel sends large steps covering the total range, while another channel sends steps indicating small subdivisions of the range included between one step and the next in the first channel.

In the specific system to be disclosed, a stepper is included in the main pitch transmission channel to convert the input gradually varying pitch-defining current into a stepped current with five steps above zero. If the input current at any instant exactly corresponds to one of the step values, nothing is sent over the auxiliary pitch transmission channel. If the input current has a value somewhere between one step value and the next, a determination is made of the excess value of such current over the next lowest step and a current is sent over the auxiliary pitch transmission channel which gives a measure of this fractional step value. This fractional step current is amplified by a factor of six and applied to a standard type stepper so that the line current in the axuiliary channel has a similar total range to that in the main channel. At the receiver a six-to-one reduction is made in the current from the auxiliary channel and this is then added as a fractional step to the current received over the main channel. In this way, the use of the two channels permits the pitch-defining current to be divided into a total of thirty-five steps above zero. This may be seen from considering that the main step **0** to **1** is divided into steps **0 - 1′**, **1′ - 2′**, **2′ - 3′**, **3′ - 4′**, **4′ - 5′**, and **5′ - 1** by the auxiliary five-step stepper, current less than **1′** being sent as zero current in both channels and current in excess of **5′** being sent as step **1 - 0.** This same thing is true of each main step except that above step **4 - 5′** which is divided into five parts since there is no step above **5 - 5′**.

The invention will be more fully understood and its various features and objects ascertained from the following detailed description and from the accompnaying drawing in which FIGS. **1, 2** and **3** when placed in line with each other from left to right in that order show in schematic circuit diagram a complete two-way system embodying the present invention, to the extent requisite for an understanding of the construction and mode of operation of the same.

In the various figures of the drawing, various elements of the system are identified by the same reference characters as are used to identify corresponding elements in the Lundstrom-Schimpf disclosure.

The left-hand portion of FIG. **1** shows in block diagram the analyzer part of a vocoder while the right-hand portion of FIG. **3** gives a similar showing of the synthesizer part of a vocoder. The circuits and apparatus intervening between these portions are for coding, transmitting and decoding the vocoder channel currents so as to render the transmission secret. The secrecy is obtained by adding to the vocoder currents before transmission masking or key waves obtained from a suitable record, indicated at **10** in FIG. **1,** and the decoding is accomplished by supplying identical masking waves at the receiver suppplied, for example, from a suitable record indicated at **20** in FIG. **3.** The recorded material is assumed to be known only to the communicating parties.

The single record **10** or **20** has recorded on it as many separate codes or key waves as there are channels to be transmitted, for example, twelve if we assume ten speech spectrum channels and two fundamental pitch channels. A greater or lesser number may actually be used depending on requirements.

Preparatory to adding the code currents or masking waves to the vocoder channel currents, each vocoder channel current passes through a stepper to change the current from a gradually varying current to one changing in abrupt steps. Each code current is similarly converted to a stepped wave, the steps in both the message and code currents being similarly timed so as to coincide with each other. Thus, the summation current is also a stepped wave in which the total step value is equal to the sum of the message and code at the corresponding instant. This summation wave is then put through a reentry circuit to bring its total amplitude range down to the range represented by the signal alone, signal referring, of course, to the vocoder channel current. This is the range actually transmitted. The output is also inverted in order to facilitate removing the key at the receiving end. The channels are multiplexed together on different carrier frequencies for transmission over a common medium.

At the receiver, a reverse operation takes place, the key supplied from the record **20** being first combined with the received secret message currents (after both message and key currents have been put through steppers) and reentry is made to restore the vocoder signals to their true form. Since an inversion was made before transmission, an inversion is necessary also at the receiver to restore the signals to proper form. With this brief over-all description as introduction, a more detailed description of the various parts of the system will now be given.

A speech input, such as a microphone, is shown at **11** leading through equalizer **12** to a branch point. Branch **13** is the fundamental pitch channel and leads through band-pass filter **14**, to further circuit elements to be described in detail later on. The rest of the analyzer comprises a group of channels, of which there may be ten, by way of example, each consisting of a band filter **18**, rectifier **19** and low-pass filter **21**. Filters **18** have different pass bands for subdividing the speech band into relatively narrow bands.

It is desirable at this point to introduce a rather large amplification of all of the spectrum channel currents and since they comprise frequencies including direct current (zero frequency) and extending to about **25** cycles, magnetic amplifiers can advantageously be used. For this purpose a **2**-kilocycle source of waves, shown at **23**, is used with its output carefully regulated by suitable means to a constant value and thoroughly filtered to remove harmonics. This wave is put through windings on magnetic cores, as illustrated in the Lundstrom-Schimpf disclosure, with other windings leading to the output circuit, the windings being arranged to be balanced when there is no signal input so that none of the 2-kilocycle wave or its harmonics then gets into the output circuit **24**. A signal winding included in the output circuit from filter **21** surrounds both cores and unbalances the circuit in proportion to amplitude of the input signal to let through a corresponding amount of the double frequency (4-kilocycle) which is the principal component. It is not necessary to rectify the waves in circuit **24** since the varying amplitude 4-kilocycle wave is well suited as input to the message stepper. It will be clear that one source of 2-kilocycle wave supplies all of the vocoder channels and that each channel includes a similar amplifier.

The fundamental pitch channel **13** with which the present invention is more particularly concerned includes a pitch derivation circuit **250** comprising suitable rectifying, frequency measuring and purifying circuits and filter, as disclosed more fully in the Lundstrom-Schimpf disclosre or in the Dudley patent, for producing a direct current of slowly varying amplitude, the instantaneous value of which is a direct measure of the instantaneous vocal cord frequency. This current is applied first to a compressing circuit consisting of diode **251** and associated resistances the purpose of which is to develop across resistor **252** a voltage which varies nearly uniformly with changes in fundamental frequency in the more essential range, such as 80 cycles to 220 cycles, but which is only slightly affected by frequencies lower than 80 cycles. These lower frequencies produce only a small current in circuit **13,** insufficient to overcome the bias on tube **251** derived from battery **253.** Under these circumstances the diode impedance is very high and only a small fraction of the voltage from circuit **13** appears across resistor **252** because of the high resistance **249** shunted across diode **251.** For currents in circuit **13** stronger than that corresponding to a fundamental pitch of about 80 cycles the diode bias is overcome, the diode resistance falls to a low value, and a much larger fraction of the voltage in circuit **13** appears across resistor **252.** This gives a relatively steep slope to the input-output characteristic of the compressor circuit over the range corresponding to fundamental frequencies of 80 to 220 cycles.

The voltage developed across resistor **252** is applied to the mid-points of the windings of a double-balanced copperoxide modulator **254** of known type for modulating 2-kilocycle waves from source **23** and producing output waves of this frequency varying in amplitude in accordance with the voltage across resistor **252.** The hybrid coil **255** leads to two conjugate branches **256** and **257.** The former branch leads to the main stepper shown while the latter leads to a rectifier **258** and comparison circuit **259.**

The main stepper comprises, specifically, five gas-filled tubes **27, 28, 29, 30** and **31** having grids connected to graduated points along potentiometer resistances **32** bridged across circuit **24'**. By means of an exciting and bias control circuit to be described at a later point, the grids and plates of these tubes have applied to them rectangular voltages. The common grid lead **33a** has applied to it a voltage which is 21.5 volts negative with respect to the cathodes for 1 millisecond and is then 130 volts negative with respect to the cathodes for 19 milliseconds. The common cathode lead **34** has a voltage of 150 volts negative with respect to ground, applied to it all the time except for 2-millisceond interruptions which are for the purpose of restoring the stepper tubes to normal approximately every 20 milliseconds for a brief instant. The interruption of the cathode supply comes just before the grids are driven in the positive direction. The grids are driven in the positive direction with respect to the cathode so as to allow the stepper tubes to be triggered provided there is a signal present in circuit **256,** and the number of tubes that are triggered depends upon the peak amplitude of the signal in the circuit **256** in the 1-millisecond interval when the grid is driven in the positive direction. Immediately thereafter the grids are driven highly negative relative to the cathodes so that the signal in circuit **256** no longer has any control over the tube discharge. In this way the stepper tubes sample the signal current for an interval and if the signal has sufficient amplitude one or more tubes break down depending on the signal peak amplitude in that interval. The tubes broken down remain so until their plate supply voltage is interrupted after 19 milliseconds. They then restore momentarily and if the signal amplitude has changed in the meantime, a greater or lesser number of tubes break down upon the next 1-millisceond exposure. The currents in the various tubes of the stepper flow through individual plate resistors **36** and return to the plate supply source through common resistor **35** and ground. The current through **35** is, therefore, the sum of the currents through the tubes that are broken down at any one time and the voltage developed across resistor **35** is proportional to the signal amplitude at the sampling times and remains constant between sampling times. Further, the voltage developed across **35** is made proportional to the signal by properly proportioning the resistances **36** in series with plates of the stepper tubes.

A part of the voltage drop across resistor **35** is applied by way of conductor **260** to a point in the grid circuit of symmetrical tube **261** for comparison with the rectified output from tube **258.** This latter output is put through an attenuating and smoothing circuit **262** to bring it to the proper level for comparison with the output of the stepper. The voltage applied from conductor **260** tends to make the upper grid of tube **261** negative while the voltage applied through circuit **262** tends to make the same grid positive. If both voltages are exactly equal, it is known that the input voltage applied to the stepper is exactly equal to one of the main steps of voltage into which the voltage is to be divided and that there is no excess or left-over voltage to be applied to the second transmission channel which transmits only the intermediate values between the main steps. The reason for using a symmetrical tube **261** is to facilitate balancing for zero input and to permit zero difference of potential to appear across the outer terminals of resistor **263** when zero input voltage is applied to the upper grid.

If the voltage applied to the input of the stepper lies between two step values, the upper grid of tube **261** is driven positive a corresponding amount since the voltage received through the path **262** and applied to the grid exceeds by a definite amount the voltage returned from the output of the main stepper over lead **260.** The resulting voltage appearing across resistor **263** has been amplified by a suitable factor and is applied to modulator **264** which may be of the same type as modulator **254,** the 2-kilocycle wave being derived from source **23'** which may be the same as source **23.** The output of modulator **264** is amplified and then impressed on the input of auxiliary stepper **265** which may be of the same type as the main stepper already described. The auxiliary stepper **265** has its grid bias controlled by lead **33***b* and the timing is such that this stepper is exposed to the output of amplifier **264'** 1 millisecond later than the time at which the main stepper is exposed to the voltage existing in circuit **24.** This 1 millisecond gives the main stepper time to stabilize and establish steady output current in resistor **35** against which to compare the current from circuit **262.** There is a slight transmission delay in circuit **262** and this slight difference in exposure times of the main and auxiliary steppers insures that the comparison is made between portions of the original input signal current existing at the same instant of time. The size of the steps of current in the outputs of the main and auxiliary steppers may be the same.

It will be understood that each spectrum channel has a message stepper following the magnetic amplifier **22** of the particular channel as in the Lundstrom-Schimpf disclosure, and that each of the steppers, including the main and auxiliary steppers described above for the pitch channels, is accompanied by a key stepper terminating in an output resistor **45** in each case.

The key currents for all of the various key steppers are derived from record **10** as in the Lundstrom-Schimpf disclosure, the various key currents being separated by respective filters **40** each selective of a different key frequency.

The steppers all derive their cathode impulses from a common cathode impulser **104.** There is a common grid impulser **95***a* for all of the key and message steppers and a second grid impulser **95***b* for the main and auxiliary steppers in the fundamental frequency transmission channels. These are in turn operated from an exciter all of which may be as disclosed in detail in the Lundstrom-Schimpf application. As disclosed in that application, the grids of the key steppers and message steppers are driven in the positive direction relative to their cathodes for a period of 2 milliseconds out of each 20 milliseconds and are driven negative beyond cut-off for the remaining 18 milliseconds. The voltage on leads **33** and **33***a* is shifted in the positive direction at the same instant and this voltage is left on lead **33** for 2 milliseconds but on lead **33***a* for only 1 millisecond. At the time this voltage is removed from lead **33***a* an exposure bias is applied to lead **33***b* for 1 millisecond. These times are readily determined by means of condenser-resistance phase-shifting combinations and pairs of pentode tubes in the exciter in the same manner as is shown in detail in the Lundstrom-Schimpf disclosure, the only changes required being in duplicating elements or varying proportions of parts in obvious manner. In the present case the 50-cycle input wave for the exciter is derived from a trace on the record **10.** It may be recorded as a 50-cycle wave or as a convenient multiple of 50 cycles in which latter case in addition to the 50-cycle filter **266** there would be a subharmonic generator **267** for deriving the 50-cycle wave from the wave of higher frequency selected by filter **268** from the reproducer output current.

The output of each message stepper is added to the output of the companion key stepper by use of the resistance bridges **46,47** and **51,52** in the manner described in connection with FIG. **7** of the Lundstrom-Schimpf application and the addition currents, after reentry, are applied to respective magnetic amplifiers **207** followed by output steppers as there more fully described. In the present case, however, a specifically different type of reentry circuit is disclosed for illustration and a different inversion circuit is shown although the corresponding parts of the Lundstrom-Schimpf application could be used herein also if desired. In fact, the channels beginning with the message and key steppers could be the same as in the Lundstrom-Schimpf disclosure until we come to the output side of the output steppers in the receiving station, there being in the present case an additional channel on account of the use of two pitch channels in place of the one shown in the Lundstrom-Schimpf disclosure.

In the present disclosure the reentry circuit comprises a gas-filled tube **270** and associated circuits. A pulsing plate supply is derived for this tube from plate impulser **271** controlled in turn from the 50-cycle current obtained from the record, through phase shifter **272** (if found necessary) and exciter **273.** This plate impulser with its exciter is, in general, similar to the grid impulsers and exciters disclosed in detail in the Lundstrom-Schimpf application and the timing is so controlled that the plate lead **274** is driven positive 150 volts a few milliseconds after the message and key steppers fire and just before the output steppers fire, and the positive voltage is kept on the plate lead **274** until just prior to the time the cathode voltage of the main or message and key steppers is reduced to zero. At this time the voltage in the plate lead **274** is reduced to zero.

The grid of tube **270** is biased positive from battery **275** and from an adjustable slider on resistance **276** together with large resistance **277** and the resistance bridges **51, 52** and **46,47** leading to grounds at the outputs of the main and key steppers. The bias is such that the tube **270** fires when there is no input received from the steppers and for all inputs up to and including the fifth step (message plus key). When the message plus key currents amount to six steps, the bias on tube **270** is reduced to too low a value to permit the tube to fire and for input currents corresponding to steps **6** to **10,** inclusive, the tube **270** does not fire.

When the tube **270** is passing current, its plate is at +15 volts and this will send a current of +1 unit (corresponding to one step in terms of the input to the magnetic amplifier and output stepper) into the magnetic amplifier **207.** The resistance **280** is adjusted so that the battery **281** sends current equal to +4 units into the magnetic amplifier. With zero current from the main and key steppers, therefore, there will be an input of +5 units into the magnetic amplifier and output stepper. In this way, inversion takes place, meaning as in the Lundstrom-Schimpf application, that the lowest steps are transmitted at highest level and the largest steps at lowest level. Similarly, if one unit of current is received from the main and key steppers, this subtracts from the +5 units total derived from the plate of tube **270** and battery **281,** giving +4 units to be impressed on the magnetic amplifier.

For input current corresponding to steps **6** to **10,** inclusive, tube **270** does not fire, as already noted, and for this condition resistance **282** is adjusted to send +7 units into the magnetic amplifier. As before, battery **281** sends +4 units into the magnetic amplifier, making a total of +11 units, but actually the current is at no time greater than +5 since the output of the main and key steppers, for steps 6 to 10 as assumed, is always −6 or a still greater negative amount. If the output from the steppers is −6, a current of +5 is applied to the magnetic amplifier and if the stepper output is successively −7, −8, −9 and −10 the current into the amplifier is successively +4, +3, +2 and +1.

Similar reentry and inverting circuits are shown in each of the other channels. Following the output steppers are the frequency modulators and band filters **153** leading to the transmission line or channel **154.**

At the receiving station band filters **155** separate out the different channel waves and apply them to the frequency demodulators **156.** The message and key steppers coming next are the same as those of FIG. **1** already described. The reentry circuits and output steppers are likewise the same as those described in connection with the transmitting station.

At the receiving station it is necessary to recombine the currents sent over two pitch transmission channels so that they will together produce a resultant which is as far as possible a true measure of the pitch. Since the pitch wave was resolved at the transmitter into coarse and fine steps and the fine steps were amplified to have the same levels as the coarse steps for transmission purposes, it is necessary to reduce the amplitudes of the currents representing the fine steps to their proper relative value for recombination with the coarse steps. This is done by the use of resistances **284** and **285** of proper value in the output of the output steppers. Resistance **285** has a value about six times as great as resistance **284** so that when the outputs of the steppers are connected together through these individual resistances the currents add in the ratio of 6 to 1 and the fractional values of the steps transmitted through the second channel are restored.

The added currents are impressed on the modulator **286** where they modulate a 2-kilocycle wave which is then amplified at **287** and rectified at **288.** One reason for this procedure is to invert the negative current in the outputs of the steppers into a current which makes the upper terminal of resistor **289** positive for proper control of the speech synthesizer. Another reason is to amplify these currents to the proper level. The rectified current is sent through low-pass filter **290** and from this point on the apparatus consists of the well-known vocoder synthesizing equipment for generating a tone wave rich in harmonics in source **172** and a continuous spectrum wave in noise source **173** and switching one or the other of these waves into the circuit leading to the variable gain amplifiers **175** of each of the spectrum channels of the synthesizer, one only of which is illustrated. The reconstructed pitch-representing current also controls the pitch of the tone waves generated at **172** from instant to instant and because of the use of the two pitch channels of the present invention this control over the generated tone waves is much more complete than if only a single stepped wave and single transmission channel therefor were used.

The invention is not to be construed as limited to the specific circuits disclosed nor to the magnitudes mentioned, since these are for illustration.

What is claimed is:

1. In a system for transmitting indications of an electrical quantity of varying magnitude, means to transmit indications in the form of stepped values each corresponding approximately to the magnitude of the quantity at the corresponding time, means to compare the respective stepped values against the true values of the quantity to determine the residues of the true values over and above said stepped values in each case, and means to separately transmit indications of said residues.

2. In a system for transmitting indications of the magnitude of a varying electrical quantity, means to transmit one indication for magnitudes between a lower limiting value and an upper limiting value representing one range of magnitudes, and other indications for magnitudes in respective equal ranges between respectively other limiting values, and means to compare the transmitted with the quantity to derive a further indication of the excess of the actual magnitude of the quantity over that represented by said one of said indications and means for transmitting said further indication simultaneously with said one or other indication.

3. In a system for transmitting indications of the magnitude of a varying electrical quantity, means comprising differently biased tubes to subdivide the total range of variation of such quantity into a given number of contiguous ranges, means to transmit over one communication channel an indication that the magnitude of the quantity is within a certain one of said ranges, means comprising differently biased tubes to subdivide each of said ranges into a given number of subranges and means to transmit over another communication channel an indication that the magnitude of the quantity is within a certain one of said subranges.

4. In combination, a circuit carrying a gradually varying current, a plurality of marginally operating devices selectively operated by such current in accordance with the instantaneous strength of the current, means to subject said devices periodically to the control of said current to cause a different number of the devices to be operated at one time depending upon the instantaneous strength of the current, means to determine the excess of the current strength over the smallest strength required to operate the device responding to the greatest strength of current at any instant, a second plurality of marginally operating devices selectively operated by such excess current in accordance with its strength, means to subject said second plurality of devices periodically to the control of said excess current to cause a different number of the second plurality of devices to be operated at one time depending upon the instantaneous value of such excess current and means to transmit indications identifying the operated devices of said pluralities of devices.

5. A combination according to claim **4** including means operating in response to the transmitted indications to produce a first current having a strength determined by the number of the devices of the first-mentioned plurality that are operated at one time, and a second current having a strength determined by the number of the devices of the second plurality that are operated at the same time, and means to add together the first and second currents to reproduce a current substantially corresponding to the current carried by said circuit.

6. In a speech transmission system including an analyzer for resolving input speech waves into their elemental components including as one component a current representative of the fundamental pitch, means to transform said current into stepped form, means to determine the difference between any step value and the true value of the current, means to transform said difference value into a current of stepped form, and means to transmit both of said currents of stepped form to a reproducing point.

7. In a speech transmission system including an analyzer for resolving input speech waves into their elemental components including as one component a current respresentative of the fundamental pitch, a first and second transmission channel, means to transmit over said first channel a current varying in abrupt steps, each step respresentative of the approximate instantaneous value of said current respresentative of the fundamental pitch, and means to transmit over said second transmission channel a current varying in abrupt steps, each step representative of a fractional part of one of the steps of current transmitted over said first channel and together with the current transmitted over said first channel giving a closer approximation to the instantaneous value of said current respresentative of the fundamental pitch.

8. In a system of transmission, means to derive from speech waves a wave representative of the fundamental pitch of the speech, means comprising a plurality of separate transmission channels for transmitting indications of said fundamental pitch to a distance, means to produce from said wave a current of stepped form representing coarse subdivisions of the amplitude of said wave and to transmit said current over one channel, means to compare said current of stepped form with said wave to determine the difference between each step value and the true value of amplitude of said wave, and means to transmit indications of said difference value over another channel.

9. In a system for transmitting indications of the fundamental pitch of speech waves, means to derive from the speech waves a current representative of the fundamental pitch, a stepper for converting such current to stepped form, means to subtract a current derived from the output of said stepper from said pitch-representative current, a stepper for converting the difference current to stepped form and means to transmit said two currents of stepped form over respective transmission channels.

10. In a speech privacy system, a circuit for deriving in the form of a gradually varying current wave a measure of the fundamental pitch of the speech waves varying with time, means to produce a stepped wave approximating in wave form to said gradually varying current wave, means to derive a wave which represents at all instants the difference between said stepped wave and said gradually varying wave, means to produce a stepped wave approximating in wave form to said difference wave, means to combine a separate key wave with each of said stepped waves, and means to transmit the combination waves to a distance.

11. The invention defined in claim **10,** including means to receive the transmitted waves, means to combine with each a separate key wave respectively similar to the first-mentioned key waves to recover the stepped waves, and means to add the second-mentioned stepped waves to the first-mentioned stepped waves to recover a wave which is a close approximation to said gradually varying wave.

12. In a signaling system for transmitting signals of varying amplitude, means to sample the signal at periodic intervals to determine its instantaneous amplitude, said sampling means producing an output current which varies in magnitude in definite steps corresponding approximately to the true value of the signal at the instant of sampling, means to transmit indications of said current magnitudes, means to determine the residue of signal over and above the value represented by said current for each sampling time, means to produce a second output current varying in the same sized steps as said first-mentioned output current and representing to a close approximation the true value of said residue, and means for transmitting indications of the magnitudes of said second output current.

13. The invention as claimed in claim **12** including means to produce separate key currents each having the same total range of magnitudes as said first-mentioned and second-mentioned currents each key current varying in steps in highly irregular manner, means to combine one of said key currents with said first-mentioned currents and means to combine the second key currents with said second-mentioned currents, for transmission.

14. In a signalling system, an incoming channel, a plurality of outgoing channels, means to receive electrical signals over said incoming channel, means to make a coarse subdivision of said signals into relatively large equal fractional steps, means to transmit over one of said outgoing channels an indication of the magnitude of the signal in terms of the number of said large fractional steps contained in the signal, means to make a fine subdivision of fractional portions of one of said large fractional steps into small fractional parts, and means to transmit over a second channel an indication of the number of said small fractional parts contained in portions of said signal over and above the number of large fractional steps so contained.

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