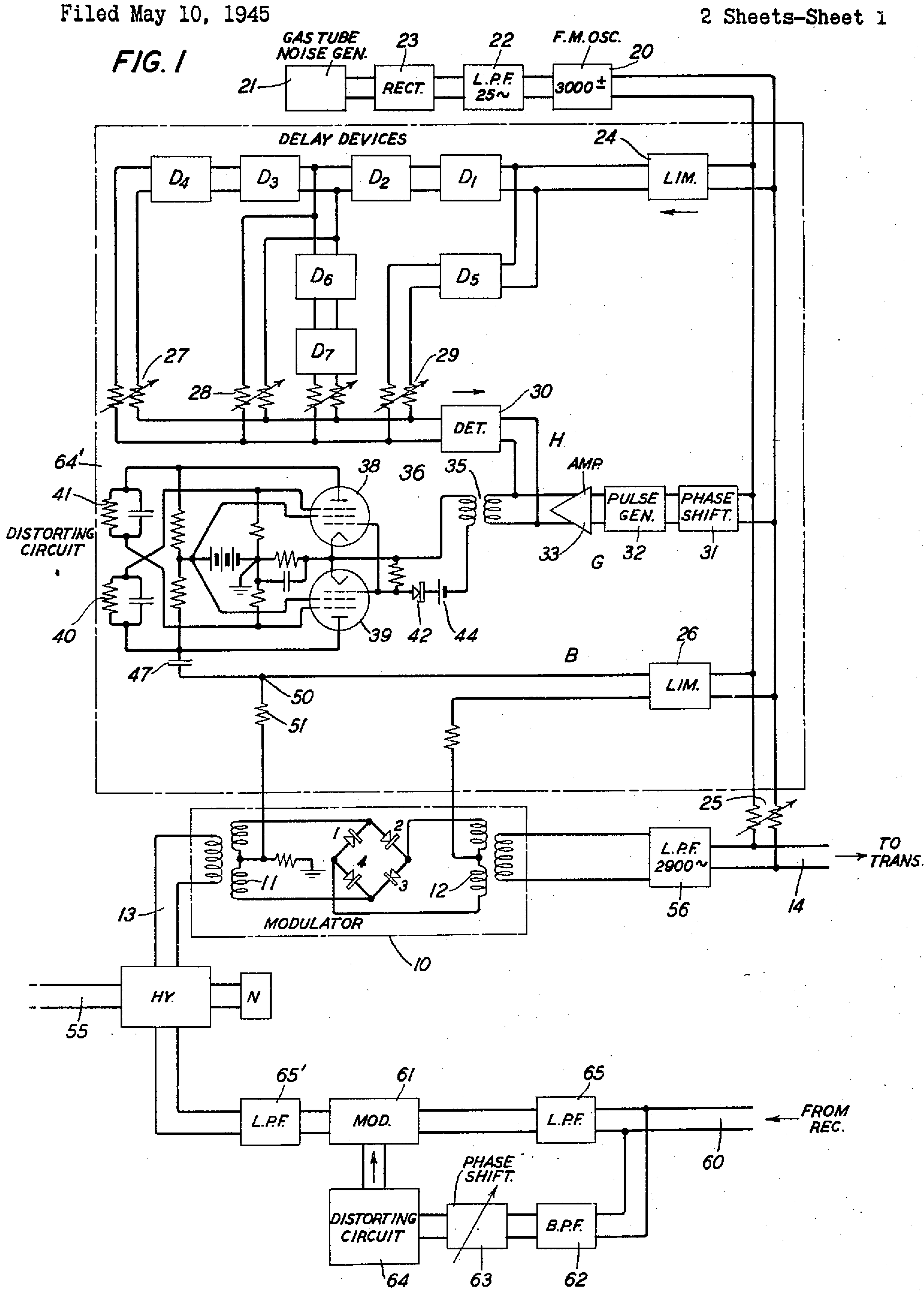
Sept. 20, 1960 W. KOENIG, JR 2,953,643

INVERTED SPEECH PRIVACY USING IRREGULAR INVERTING WAVE FORM

Filed May 10, 1945 2 Sheets-Sheet 1

FIG. 1



INVENTOR
W. KOENIG, JR.
BY
ATTORNEY

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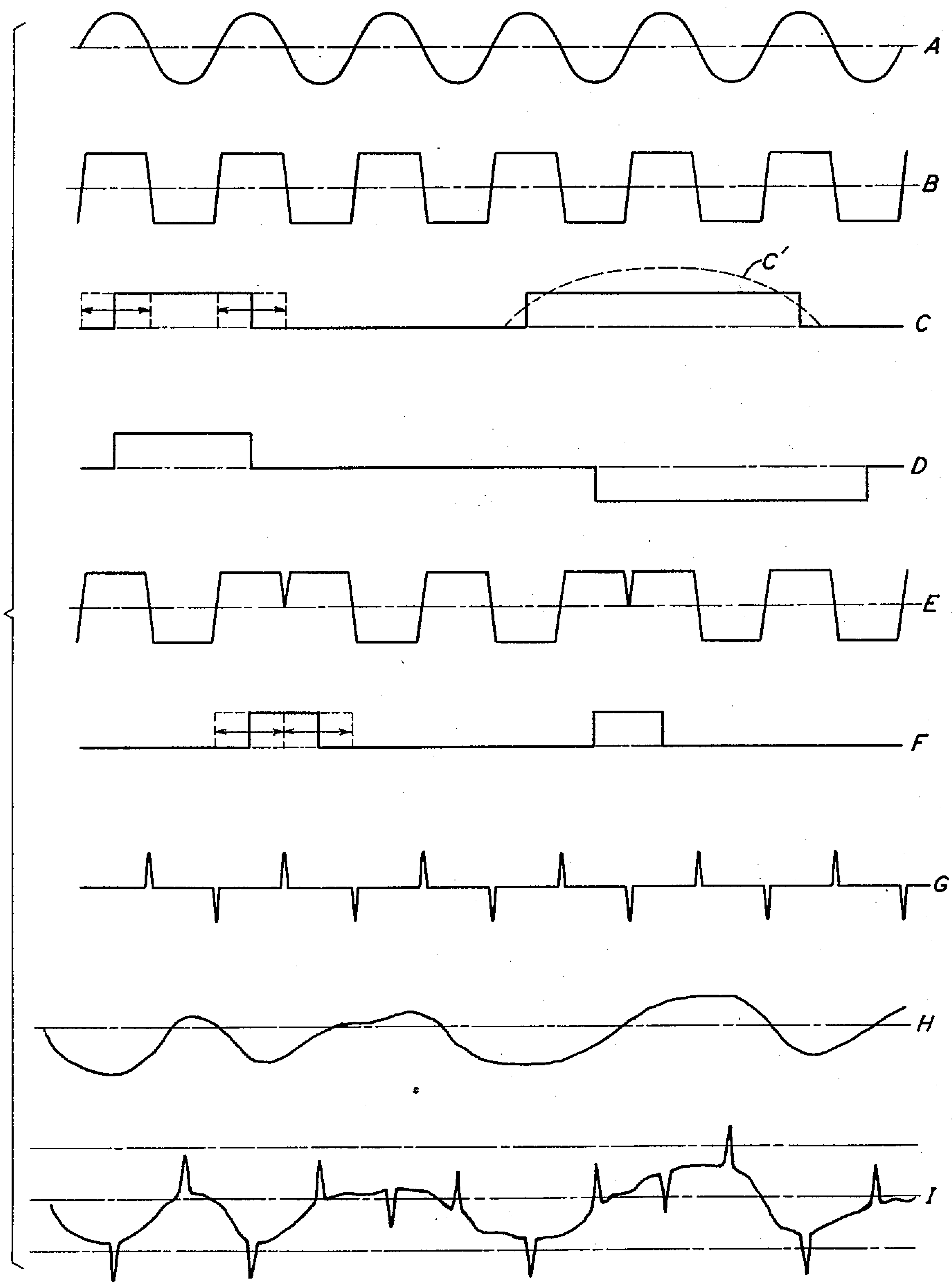

FIG. 2

INVENTOR
W. KOENIG, JR.
BY H. A. Burgess
ATTORNEY

United States Patent Office

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INVERTED SPEECH PRIVACY USING IRREGULAR INVERTING WAVE FORM

Walter Koenig, Jr., Clifton, N.J., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

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13 Claims. (Cl. 179—1.5)

The present invention relates to the transmission of speech or other signaling waves with secrecy.

It has heretofore been proposed to invert the frequency order of a speech or signal wave by modulation of a continuous wave of appropriate frequency and selection of the lower side band for transmission. It has also been proposed to use for the wave that is modulated (inverting wave) an irregularly varying wave to render successful reception more difficult.

The present invention seeks to improve upon such prior systems by enabling a high degree of irregularity to be produced in the inverting wave while at the same time making it feasible to duplicate the irregular inverting wave at the receiving station with sufficient accuracy to permit of high grade transmission and reception of the speech.

In accordance with a feature of the invention, variations are introduced into the inverting wave which are non-cyclic in character and which never repeat themselves. One way of insuring this is to derive the variations in the first instance under control of resistance noise currents or other currents of fortuitous type of amplitude-frequency distribution. The primary control currents themselves are transmitted to the distant station and contain no clue to the signal nor to the inverting wave. These primary control currents, however, serve as the basic wave from which the variations to be made in the inverting wave are separately built up at each station by duplicate apparatus. This apparatus is flexible and can be readily reset from day to day so that the character of the inverting wave remains secret even in case of capture of a set or station. The primary control currents serve to synchronize the key producing apparatus at the several stations and, as will be pointed out, the nature of the key used permits of considerable tolerance in synchronism requirements placed on the control current.

The nature and objects of the invention will be more clearly brought out in the detailed description which follows, in connection with the drawings, in which.

Fig. 1 is a schematic circuit diagram partly in block form showing the circuit that would be used at one two-way terminal according to the invention; and

Fig. 2 comprises a series of graphs of wave forms to be discussed in the course of the description.

In Fig. 1 the transmitting modulator **10** has as its modulating elements the four rectifiers **1**, **2**, **3**, **4** connected in the well-known ring circuit, and together with the center-tapped input and output transformer windings **11** and **12**, forms the well-known double-balanced modulator. By this is meant that the balance is such that the speech input at **13** is balanced against direct transmission of input speech currents through to the output circuit **14** and also that the carrier wave applied between the two center taps on windings **11** and **12** is prevented by the symmetry of the circuit from reaching output circuit **14**. The term "carrier" is here used from analogy to high frequency carrier wave transmission practice but in the present disclosure this wave has a frequency of 3,000 cycles per second, for example, and is for the purpose of inverting the speech wave as to frequency order without necessarily shifting the band as a whole in the frequency spectrum. For this reason this wave will also be referred to as the inverting wave.

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In operation this type of modulator, which may employ diodes or copper oxide rectifiers or other rectifier elements, has been likened to a commutator or switch since for one polarity carrier wave, say the positive half wave, the elements **1** and **3** have low resistance while the elements **2** and **4** have very high resistance. This unbalances the circuit and permits a short pulse of speech current to be transmitted through to the output **14**. In the next half cycle of the carrier wave (negative half cycle), the elements **2** and **4** have low resistance and the elements **1** and **3** have high resistance. Assuming the applied speech wave has the same sign or polarity as before, a pulse of speech will be transmitted into output **14** having opposite polarity to the first pulse. In the usual carrier practice the amplitude of the carrier is made large compared with the strongest speech component in order to change the resistance of the switching elements **1**, **3** or **2**, **4** from one extreme resistance value to the other practically instantaneously. If, as usual, a sine wave is used for the carrier, only the portions of the voltage swings near the zero axis are effective in switching the modulator elements, for as the wave changes polarity in crossing the zero axis the resistance changes are effected in the switching elements before the wave has swung more than a small fraction of the distance from the zero axis to the peak amplitude. Thus, referring to Fig. 2, if a sine wave A is used as the carrier, its amplitude is made very much larger than shown so that the switching function of the modulator has some such form as wave B where the horizontal flat portions represent the times in which the resistance of the elements have attained practically their limiting values.

In the present invention, the inverting wave used is a flat-topped wave of the general shape given by B except as modified in ways to be described. The wave has sufficiently amplitude to "open" and "close" the effective switches comprised by the modulator elements and to hold the open or closed condition for the duration of the flat portion of the wave.

Secrecy is accomplished in accordance with this invention by using as the switching function or inverting wave, a wave in which the reversals of polarity occur at a highly irregular rate. This renders the speech entirely unintelligible in an ordinary frequency-inverting receiver but when the inverting wave used for receiving is an exact replica of that used at the transmitter the speech is received with practically unimpaired clarity. The particular method disclosed in this application for producing the irregular shaped inverting wave is first to produce a regular or substantially regular wave as at B, Fig. 2, and to combine with it irregular pulses such as those indicated at C or D by way of examples. The wave B can be produced with great exactitude at both stations since it can be obtained from a directly transmitted wave. The current pulses such as C or D are generated independently at each station under control of transmitted waves and it will be noted that the method of this invention allows of considerable tolerance in the production of these waves. Suppose for example that the first pulse shown at C is to wipe out the negative half cycle of the B wave that is immediately above the pulse in the figure. It is seen that either or both edges of the C pulse could vary in time by the amount shown by the arrows without affecting the result, since it is only necessary that the C pulse completely overlap in time the one negative lobe of the B wave without overlapping any part of the next adjacent negative lobe on either side. Also the C pulses need not be square in form but can have a considerable roundness as shown by the dotted line at C'. The D current pulses illustrate use of different polarities. Without going into further detail it is evident from what has been said that any desired degree of irregularity can be produced in the inverting wave B by adding or subtracting current pulses in irregular manner.

Another variation in method is to reverse the phase of the B wave from time to time, the effect of this being illustrated at E. The short interruptions occurring at the instant of reversal can be eliminated by adding current pulses as indicated at F.

In the further description by way of illustrating in detail how the invention in one form can be carried out in practice, circuits will be shown and described for producing the B wave and combining with it currents of the general forms shown at C to provide an inverting wave of highly irregular form. As will be described this is accomplished with the aid of short pulses G and an irregular current wave H the latter operating as a pedestal current to cause certain only of the G pulses to operate a trigger circuit determining the beginnings and endings and polarities of the C current pulses. Phase shifter **31** enables the G pulses to be shifted in phase relative to the B and H waves.

Referring to Fig. 1, a frequency modulated oscillator **20** generates a mean frequency of 3,000 cycles which is frequency modulated to a depth of, for example, ±30 cycles under control of a resistance noise source **21**. This may comprise a high resistance in the grid circuit of an amplifier or it may be a gas-filled tube noise source, of known type followed by rectifier **23**. Low-pass filter **22** selects a band of, for example, 0 to 25 cycles from the output of rectifier **23** and these currents are caused to modulate the frequency of oscillator **20** in any suitable manner as by means of the well-known reactance control tube modulating circuit not shown but assumed to be present in the box **20**. In this way the frequency of the oscillator **20** is caused to vary to a slight extent in a fortuitous manner. These waves are applied through regulating control pad **25** directly to the output channel **14** for transmission to the distant station. If these waves were used as the inverting wave in modulator **10** the slight variations in frequency would not provide substantial secrecy, the purpose of these frequency variations being to control simultaneous wave-producing processes at both stations.

This wave from oscillator **20** is put through limiter **26** which removes both positive and negative peaks and gives in its output the B wave. This limiter may be of known type using biased valves or rectifiers oppositely poled to pass both half waves but only up to a certain amplitude.

Some of the wave from oscillator **20** is put through a distorting circuit comprising limiter **24**, delay networks D_1 to D_7, attenuators **27**, **28** and **29** and detector **30** to produce the H wave. Each delay network may comprise a standing wave line or equivalent with variable taps along the line to enable any desired phase to be taken off. The devices may be associated in circuit with one another in various ways by switching them in and out of circuit in different combinations and the arrangement can be changed from time to time at both stations following a program. This is true also of the variable attenuators **27**, **28** and **29**. Other variations such as frequency selective circuits and amplifiers may be used, the circuit shown being merely indicative of one form that may be used. By this or similar means the fortuitous variations in the frequency of the wave from oscillator **20**, although themselves small, can be used to build up an entirely unpredictable and very irregular wave of the general character illustrated at H in Fig. 2. Any other suitable type of phase shifters or delay devices may be used at D_1 to D_7 than those specifically mentioned.

Some of the wave from oscillator **20** after having its phase properly adjusted at **31** is applied to pulse generator **32** which may be of the type shown in Patent 2,117,752, granted to L. R. Wrathall, May 17, 1938, or it may be of other suitable type for generating the G pulses. These are passed through a unilateral device or amplifier **33**, if necessary, and are applied together with the H wave (giving, therefore wave I, with a proper polarity assumed for wave G) to the transformer **35** leading to the trigger circuit **36**. This may be of known type and is shown as comprising two pentode vacuum tubes **38** and **39** with their control grids connected in parallel to the terminals of transformer **35**. It will be assumed that when no one of the C pulses is to be produced, tube **39** is conducting and tube **38** is cut off by the negative bias transferred to its suppressor grid through circuit branch **40** from the plate of tube **39**. When the next negative I pulse having an amplitude in excess of that shown by dot-dash line swings the potential of both control grids negative this has no effect on tube **38** since this tube is already cut off but it causes an immediate diminution of current in tube **39** and due to the well-known cumulative effects of the inter-tube voltage transfers ensuing upon this initial anode current change in tube **39**, the anode current in this tube becomes quickly cut off while the opposite effect is produced in the tube **38**, the anode current in that tube becoming maximum. This type of circuit is stable in both of these extreme conditions (in which one or the other tube is cut off) so that the circuit remains in this last condition until the next negative I pulse of sufficient amplitude is applied to the control grids. When this occurs, anode current in tube **38** decreases and voltage is transferred via branch **41** to the suppressor grid of tube **39** setting up the triggering action that results in cutting off tube **38** and reestablishing full current flow through tube **39**. During this cycle of first cutting off current in tube **39**, leaving it cut off between the high amplitude negative I pulses on the control grids and then reestablishing full current flow in tube **39**, the plate potential variations on tube **39** have executed a C type of pulse which is available in the external circuit connection including condenser **47**, as will be further described.

In order to introduce a marginal effect into the trigger action so that the circuit will not be triggered by the pulses G alone nor until wave H reaches a given pedestal value, giving the high ampltiude I pulses referred to, a properly poled rectifier **42** is shown with bias battery **44**. Negative variations only are conveyed to the trigger circuit grids through rectifier **42** and it is first necessary to overcome the negative bias due to battery **44** in order to apply any negative voltage to the grids. The circuit is therefore triggered on by a pulse of negative polarity and the next negative pulse which gets through to the control grids triggers the circuit off. This gives pulses of C type in condenser **47** whose length is determined by the time between the trigger-on and the trigger-off pulses. The C current pulses are taken off through this condenser **47** and applied along with the B wave to the modulator **10**. These current pulses in flowing to ground through resistance **51** make the potential of point **50** positive and this has the effect of canceling one or more negative lobes of the B wave depending upon the length of the pulse. This trigger circuit comprising tubes **38** and **39** is of the Eccles-Jordan type described, for example, in a book "Time Bases" by O. S. Puckle (London, Chapman-Hall) 1943, p. 54 ff.

The speech waves to be secretly transmited from the station shown in Fig. 1 are received over the two-way telephone line **55** which is terminated in the usual hybrid coil Hy and network N. Speech waves in the branch **13** are applied to the modulator **10** where they modulate the inverting wave of irregular and continually shifting frequency. The condition of balance in the modulator circuit **10** prevents the input speech from being directly transmitted. Low-pass filter **56** in the output allows the lower side band representing inverted speech waves to pass to the outgoing line or channel **14** which may lead to a radio transmitter or other transmission path or medium. Some of the nominally 3,000 cycle wave from the oscillator **20** are also transmitted into circuit **14** through resistance pad **25**.

Secret waves incoming at the receiving channel **60** from the distant station are sent into the modulator **61** which may be similar to modulator **10**. The wave received from the distant oscillator similar to **20** is selected by the filter **62** which separates this wave from the speech-bearing waves. This 3,000 cycle wave with its small degree of frequency modulation is shifted in phase at **63**, if this is found necessary, and this wave is then applied to a distorting circuit **64** which may be a duplicate of that shown in the broken line rectangle **64'** but which has its adjustments made to correspond with those at the distant transmitting station. As a result the inverting wave that is applied to modulator **61** from circuit **64** is of the same form at all times as the inverting wave at the distant station so that the speech is recovered in the output of modulator **61** and sent through low-pass filter **65'** into the line **55**.

What is claimed is:

1. The method of secret telephony comprising inverting the frequency order of a speech wave by modulating a wave of irregular wave form by the speech, selecting for transmission the lower side band of the modulated wave, excluding both the speech wave and said wave of irregular wave form from transmission and causing said wave of irregular wave form to vary discontinuously in the length of individual half-cycles in a non-recurrent manner.

2. In a system in which speech waves modulate a wave having a mean frequency near the upper limit of the essential speech frequency band and in which the lower side band of the resulting modulation products are selected and utilized for transmission, the method comprising imparting non-recurrent irregularities to the wave that is so modulated by adding thereto relatively low frequency pulses to alter the reversal times of said wave.

3. The method defined in claim 2 comprising deriving said pulses from non-periodic waves of substantially random variations.

4. In secret telephony in which speech waves are reversed in phase at an irregular rate in the vicinity of the highest frequency to be transmitted, the method comprising generating a reversing control wave having approximately said frequency, generating an irregular and non-recurrent series of low frequency pulses and adding said pulses to said generated wave to alter the reversal times of said latter wave.

5. In secret telephony in which speech waves are inverted in frequency by modulation with a high frequency wave of irregular form, the method of reproducing at a station said wave of irregular wave form comprising transmitting a continuous wave having a frequency substantially the same as the mean frequency of said wave of irregular wave form, modulating the wave so transmitted by irregular non-recurrent low frequency variations, deriving and then distorting the modulation component of said transmitted wave at a station by variously changing its phase and amplitude relations, generating low frequency pulsations under control of said distorted component, and using said pulsations to modify the form of said transmitted wave to yield said wave of irregular wave form.

6. In a secrecy system, means to invert the signal wave by modulation with an inverting wave of irregular frequency, means to produce said inverting wave including a source of current of random variations, a plurality of adjustable elements for successively modifying the phase and amplitude of components of said random variation current to build up a non-cyclic irregular wave, means to generate a sustained wave and means to modify said sustained wave by said non-cyclic irregular wave to give said inverting wave.

7. In a secrecy system, means to transmit between stations a sustained wave, means to impress on said wave small variations derived from a source of noise waves, means at each station to produce a wave which is a replica of the wave produced at the other station and which has

its reversals of sign occurring at a highly irregular and non-cyclic rate determined by and under control of said variations, and means to use said produced wave at each station as an inverting wave to invert the frequency order of a signal wave for transmission from one station and for reception at the other station.

8. The method of secret telephony comprising inverting the frequency order of a speech wave by modulating a wave of irregular wave form by the speech, selecting for transmission the lower side band of the modulated wave, generating a control wave of fortuitous characteristic, causing, under control of said control wave, said wave of irregular wave form to vary in a non-recurrent manner and transmitting with said lower side band a wave which is an index of said control wave.

9. The method of secret transmission of a speech wave comprising inverting the order of the frequencies thereof by modulating a wave of irregular wave form by the speech wave, suppressing transmission of both the speech wave and the wave of irregular wave form while selecting and transmitting the lower side band of the wave so modulated, generating a control wave of fortuitous characteristic, causing said wave of irregular wave form under control of said control wave to vary in a non-recurrent manner, and transmititng with said lower side band a wave which is an index of said control wave.

10. In a privacy system in which an inverted frequency speech-representing wave is produced for transmission or reception by taking the lower side band of a speech modulated wave in which the inverting wave that is modulated has a frequency near the upper frequency edge of the speech band, means for producing the inverting wave comprising means to generate a wave of nominally the frequency which the inverting wave is to have and means to produce abrupt changes in the reversal times of said generated wave in hap-hazard manner from one cycle to the next to produce a highly irregular wave form in said inverting wave.

11. The invention according to claim 10 in which the means to produce abrupt changes in reversal times of the generated wave comprises a source of waves of substantially random variations, means to derive therefrom pulses of irregular time of occurrence, and means to control the polarity-reversal times of said generated wave by said pulses.

12. In a privacy system in which an inverted frequency speech-representing wave is produced for transmission or reception by taking the lower side band of a speech modulated wave in which the inverting wave that is modulated has a frequency near the upper frequency edge of the speech band, means for producing the inverting wave comprising means to generate a wave of regular wave form, means to generate a wave of irregular wave form, means to make irregular transformations in the shape of the latter wave in accordance with an arbitrary pattern, and means to utilize the wave in which said transformations have been made to modify the shape of said regular wave to produce a resultant inverting wave.

13. The combination of the invention defined in claim 12 with means to transmit to a distant station a portion of said wave of irregular wave form to enable reproduction thereat of an inverting wave identical in form to that produced at the first station.

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