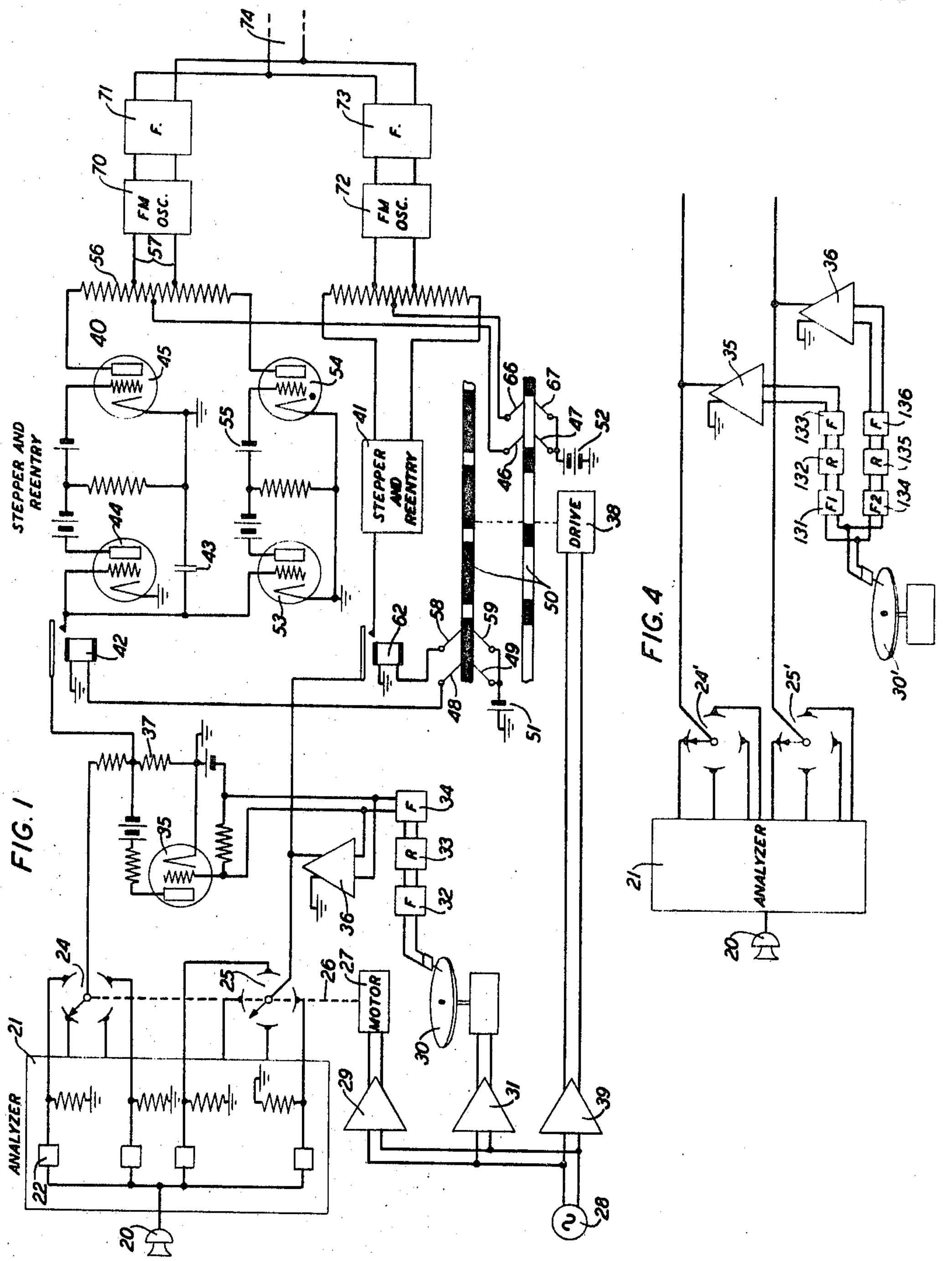
Sept. 30, 1969 H. W. DUDLEY 3,470,323

SIGNALING SYSTEM

Filed June 30, 1944 2 Sheets-Sheet 1



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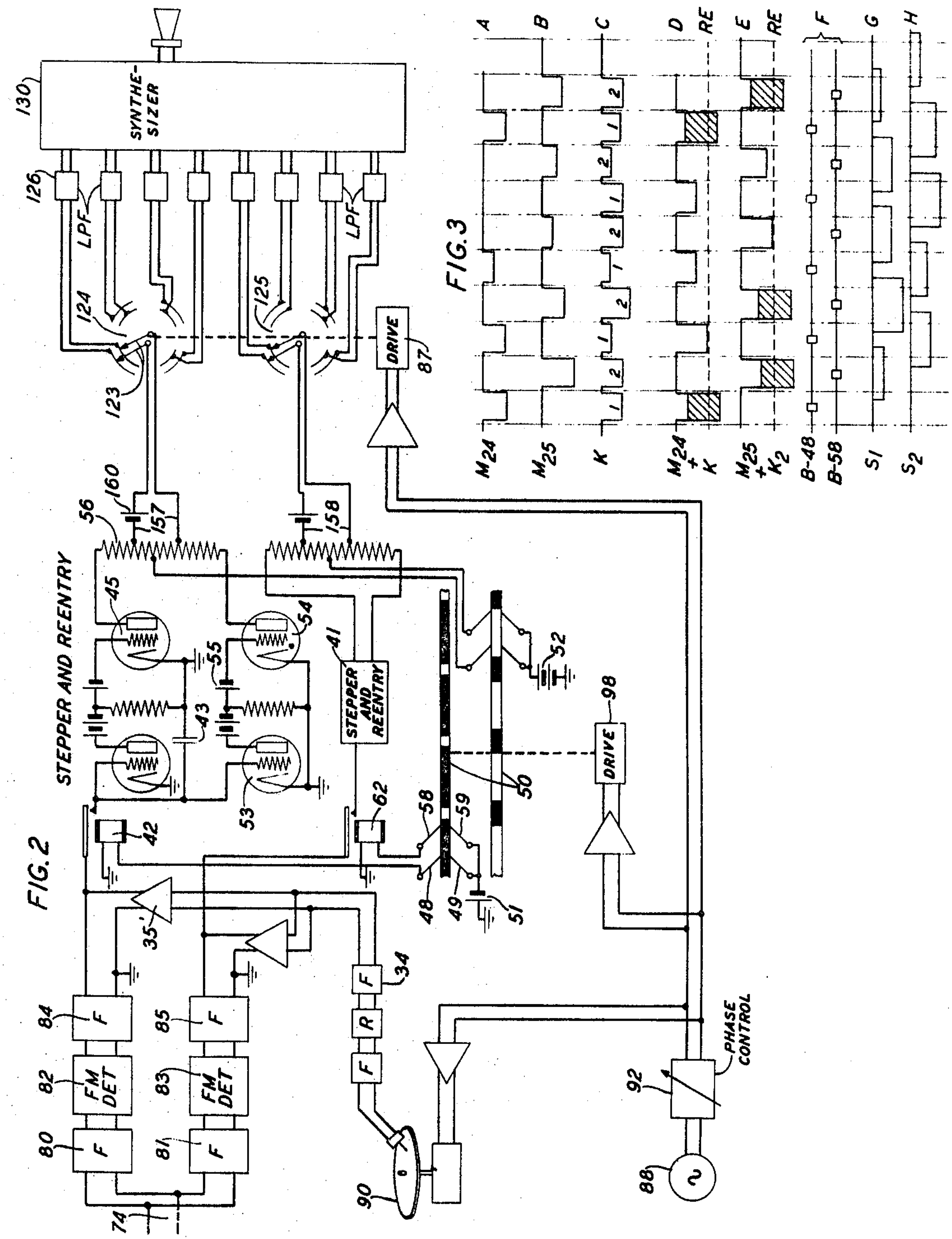

FIG. 2

FIG. 3

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SIGNALING SYSTEM

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U.S. Cl. 179—1.5 3 Claims

The present invention relates to the secret transmission and reception of speech or similar types of signaling waves and more particularly it relates to the type of system in which the speech or other signal is first analyzed to derive a plurality of low frequency index currents in separate circuits which can be separately coded or ciphered and transmitted to a distant receiving point where the speech or signal is reconstructed under control of these transmitted curents after they have been decoded.

Objects of the present invention are to reduce the amount of equipment needed in such a system, to economize on frequency band width required and to relax the requirements as to synchronism between terminals without sacrifice in attainable secrecy.

It has been proposed to provide transmission channels on a multiplex carrier basis between the communicating stations, with the number of such channels equal to the number of low frequency speech-defining currents into which the speech is analyzed and to provide individual coding or ciphering equipment for the various transmission channels. This results in a large amount of equipment, much of which is not used to full capacity especially where the speech-defining currents are transmitted in stepped pulses with each step value held constant between stepping times.

It has further been proposed to provide a single coding equipment which is shared on a time basis by all of the separate circuits in which the speech-defining currents exist, by being switched rapidly from one circuit to the next in rotation and to provide a single transmission channel between the communicating stations for transmission of the fragmented current in the output of the common coding equipment. While this type of system results in economy of certain types of terminal equipment, it imposes rather severe restrictions upon synchronism between the communicating stations and is more subject to interference arising from atmospheric conditions of the type that affect long distance radio transmission, because of the shortness of the pulses used. The shortness of the pulses also places restrictions upon the minimum band width that can be satisfactorily used.

Assuming a given degree of security against unauthorized reception of the transmitted information, it becomes important to have available different types of systems all having the given degree of security but adapted to different conditions of use, such as systems with different degrees of portability, systems for permanent location, or systems specially suited for long distance radio transmission or for short links or over lines, to cite a few typical examples. Depending upon the conditions and requirements of use, it may become important in one case to conserve weight or reduce the number of moving parts or relax synchronism requirements or conserve band width, etc., while in another case these matters may be secondary in importance to some other considerations.

The system of the present invention represents a great simplification in equipment over the first of the two known types of systems referred to above and offers material advantages over the second-mentioned type in requiring less exact synchronism between the communicating stations, economizing on band width and being less subject to certain types of interference.

In accordance with one feature of this invention, the speech-defining currents in the several channels are sampled by a plurality of different scanning means serving respective groups of channels. The sampling time per channel can, if desired, be made correspondingly longer, and in any case longer pulses can be used in transmission. Multiplex transmission channels are provided for sending the sampled currents from the respective scanning means.

The nature and objects of the invention as well as its various features will be more fully understood from the following detailed description of an illustrative embodiment shown in the attached drawings in which:

FIGS. 1 and 2 when placed together with FIG. 1 at the left of FIG. 2 show in schematic diagram a complete one-way secret telephone system or channel embodying the invention, the transmitting terminal being shown in FIG. 1 and the receiving terminal in FIG. 2;

FIG. 3 shows time relations and pulse shapes illustrative of the operation of the enciphering and transmitting features; and

FIG. 4 shows in schematic diagram an alternative arrangement to that shown in FIG. 1 for supplying the key currents to the two enciphering equipments.

Referring to FIG. 1, the speech input, such as telephone line or microphone **20** is connected to analyzer **21** which may be of the type shown in my Patent 2,151,091 granted Mar. 21, 1939 for deriving from the applied speech waves a pitch-defining current and a number of spectrum-defining currents. For this purpose, subdividing band filters are used each followed by suitable apparatus for deriving a slowly varying direct current indicative of the concomitant variations of the corresponding characteristics of the applied speech. In the case of the pitch channel a rectifier and frequency measuring circuit or counter are used while in the spectrum channels, rectifiers followed by low-pass filters are used. These are all generally shown by the boxes **22** and their construction can follow known practice such as that disclosed in my patent. The number of such channels to be used may vary widely in practice but in the present case is assumed to be eight, comprising one pitch channel and seven spectrum channels. In the case of the latter, the filters may subdivide the total band of 200 to 2,800 cycles into seven equal parts and the low-pass filters in the spectrum channels may have a cut-off frequency of 18 cycles. These magnitudes are not to be considered as limiting but are purely for illustration and are furnished as being consistent with the object of securing simplification of the terminal equipment with only such sacrifice in quality of transmission as is considered to be in accord with the actual economy represented by the rest of the system design. This statement is also true of the other magnitudes that will be included in the disclosure for the guidance of the user, these also being illustrative rather than limiting.

These eight direct currents varying at syllabic rate are commutated in groups, specifically in two groups of four, by the commutators **24** and **25** assumed to run at 42 revolutions per second with each contact lasting less than 6 milliseconds. If each segment represented a full quarter of a circle, the contact would last almost .006-second but it will be noted that each segment is shown as only about one-eighth of the circumference so that the contact, in the illustrated case, endures about .003-second. Also, the segments of the rings of **24** and **25** are staggered so that a channel of the upper group is sampled, then a channel of the lower group, then a channel of the upper group, and so on. This feature is desirable in the interest of economizing on keying equipment as will be described.

The brush arms of communtators **24** and **25** are driven by a common shaft **26** from motor **27** which may be a synchronous motor driven from a standard frequency oscillator **28** generating a current of **42** cycles per second, with high constancy of frequency output. An amplifier is shown at **29.**

A secret key is recorded on phonograph record **30** dirven at synchronous speed from source **28** by way of amplifier **31.** This key is in the form of a suitable carrier frequency wave modulated by pulses varying over a limited amplitude range in a manner random with time but with equal likelihood of occurrence of any value in the range. The reproduced currents are filtered at **32,** rectified at **33** and put through a low-pass filter **34.** The resulting direct current pulses varying in amplitude from pulse to pulse are supplied through buffer amplifiers **35** and **36** to the two output circuits of commutators **24** and **25** in properly timed relation so that each sample of the channel currents has a key pulse added to it. The character of the message pulses is illustrated in FIG. 3 where line A shows a series of sampled pulses from the message currents in the four channels scanned by communtator **24** and line B similarly shows pulses in the output of commutator **25.** These pulses are assumed to have negative polarity with respect to ground. Line C shows key pulses, also of negative polarity, occurring in the random manner. The odd-numbered pulses are added to the M24 pulses to provide summation pulses shown in line D, and the even-numbered pulses are added to the M25 pulses to give summation pulses shown in line E. In this way a single key of the type shown in line C serves for coding all eight message currents and the key pulses for the different channels are separated on a time basis. The key pulses from the record are applied to the grid of amplifier **35** (or **36**) with positive polarity so that they appear across resistor **37** with negative polarity and thus add numercially to the negative message pulses as indicated in FIG. 3.

The combined message and key currents are supplied in the case of each circuit to a stepper reentry circuit **40** or **41.** Referring to the stepper reentry **40,** there is a relay **42** which is momentarily energized at the middle of each pulse (as indicated in line F of FIG. 3 by the blocks) so as to place a charge on condenser **43** proportional to the peak value of the pulse at its center portion. Relay **42** is operated from commutator **50,** upper ring (shown in developed form in the drawing), over brushes **48** and **49** and battery **51** whenever a conducting segment bridges over these two brushes. Commutator **50** is driven by synchronous motor **38** from source **28** through amplifier **39.** The condenser **43** retains its charge without appreciable change until it receives a new charge at the next energization of relay **42.** The voltage on condenser **43** is amplified by tube **44** and applied to the grid of tube **45** which has no plate voltage applied to it except at certain timed periods from brushes **46** and **47** on commutator **50,** and from battery **52.** As shown by the relative positioning of the conducting segments on the upper and lower rings of commutator **50,** plate voltage is applied to tube **45** an instant after relay **42** releases and continues to be applied until an instant before the next energization of relay **42.**

The reentry part of the circuit **40** comprises a parallel path comprising amplifier tube **53** and gas-filled tube **54,** the latter having its grid negatively biased by battery **55** to prevent it from firing upon application to its grid of all voltages below that corresponding to the reentry value. (It will be understood that negative pulses applied to the grid of tube **53** produce positive pulses on the grid of tube **54.**) Whenever an applied pulse from condenser **43** overcomes this bias, tube **54** fires upon application of the plate voltage from brush **46.** A definite value of current then flows through the lower portion of output resistance **56.** The differential connection of output circuit **57** to tubes **45** and **54** causes the voltage appearing across leads **57** to be the difference between the

pulse value transmitted through tube **45** and the fixed value in the output of tube **54.** Reentry lines are shown in FIG. 3, graphs D and E, and the part of the pulse that is substracted from the total of summation value of message plus key is cross-hatched. The pulse actually transmitted is represented by the difference value, unshaded in each case.

Stepper reentry **41** operates in similar manner, the timing being later than that for circuit **40** as provided by the second set of brushes **58** and **59** for relay **62** and the second set of brushes **66** and **67** for application of plate voltage.

These stepper reentry circuits regenerate the pulses and provide longer pulses for transmission than the input pulses as indicated in lines G and H of FIG. 3. Only enough interruption need occur between successive pulses to allow proper operation of relay **42** or **62.** These relays can be made extremely rapid in operation since their contacts carry only minute currents. Mechanical tuning can be used to promote rapid operation since their operation is periodic. Electromagnetic relays have been shown in the interest of simplicity and a mechanical type of commutator **50** has been shown for a similar reason. The invention is not dependent upon these types of devices, however, since electronic circuit controlling devices are known in the art which could be used for momentarily placing condenser **43** under control of the output circuit of commutator **24** to receive a charge therefrom and electronic timing or pulse generating circuits are known which could be used for applying plate voltage in timed intervals to the output tubes **45** and **54.**

The output from stepper reentry circuits **40** and **41** are impressed upon separate carrier channels for transmission over the line or radio channel **74,** these channels comprising respectively a frequency modulator **70** or **72** followed by a band-pass filter **71** or **73.** A wide choice exists as to type of channel apparatus and frequencies used. As one example, one frequency modulated oscillator may have a normal frequency of 1,000 cycles and be modulated to plus and minus 400 cycles giving a transmission band of 600 to 1,400 cycles per second. The other channel may transmit the band 1,600 to 2,400 based on 2,000 cycles mean frequency. The oscillators may comprise, by way of example, multivibrators whose frequency is a function of applied direct current bias, or sine wave oscillators having a tuning inductance on a core whose degree of saturation is controlled by application of the direct current pulse G and H.

Referring to FIG. 2, the incoming circuit from the line or channel **74** is connected to separating band-pass filters **80** and **81** for deriving the two channels. Frequency modulation detectors **82** and **83** of usual or known type recover the direct current pulses which are sent through low-pass filters **84** and **85.** These pulses have the general form of G and H (FIG. 3) except that they have positive polarity and have been rounded off in transmission. However, by the use of amplifiers in usual or known manner, the center portions of the pulses can be made to have very nearly the same amplitudes which the pulses G and H had at the transmitting end. The positive polarity may be obtained in the detector **82** or elsewhere. Key pulses which are duplicates of those added at the sending end are supplied from duplicate key record **90** driven in synchronism with record **30** by means of the standard frequency source **88** which supplies a highly constant frequency of 42 cycles. This oscillator is shown provided with a variable phase control **92** in its output to compensate for transmission delay in the line or channel **74** and terminals.

Since the received signal has positive polarity and the key pulses have negative polarity, their combination in the output of amplifier **35** or **36** results in a numerical subtraction of the key from the received enciphered current. If the message currents are represented by M, the key by K, the reentry pulse by R, and the enciphered current by −S, the enciphering which occurred at the transmitter is represented by

$$-S=-M-K=-(M+K)$$

when there is no reentry, and by

$$-S=-M-K+R=-(M+K-R)$$

when reentry occurs.

Since the enciphered current S is reversed at the receiver,

$$+S=M+K$$

without reentry and

$$+S=M+K-R$$

with reentry. In the former case the message is recovered by simply combining the negative key pulses with the received signal so that

$$S-K=M+K-K=M$$

In the latter case, after the key is subtracted, we have

$$S-K=M-R$$

which is always negative in polarity since $R>M$. Whenever $S-K$ becomes negative in sign and places a negative charge on condenser **43**, the output of tube **45** must be increased by the reentry pulse value R since the quantity $M-R$ must be changed to M. This is done by means of the same type of stepper-reentry circuit that is used in FIG. 1, the value of bias battery being charged, however, on tube **54**. Whenever the charge on condenser **43** is negative, the grid of tube **54** is driven sufficiently positive to cause tube **54** to fire and the resulting flow of a fixed value of current in the output circuit of tube **54** and through the lower half of resistance **56** causes an increase in voltage applied to output circuit **157** sufficient to increase the output current by the reentry value, R. Battery **160** compensates for the output voltage from tube **45** due to normal space current when zero voltage is on condenser **43**, so that for zero message zero current is impressed on the synthesizer channel.

The timing of the relays **42** and **62** at the receiver is controlled by commutator **50** thereat which is driven from source **88** by synchronous motor **98**. The phasing is such as to combine the key pulses from record **90** with the middle portion of the detected line pulses and to operate the relays **42** and **62** momentarily at the middle of the key pulses similarly to the case of FIG. 1.

The differential voltage across selected points in resistor **56** is taken off by circuit **157** and applied to the brushes **123** of distributor **124**, and a similar circuit **158** leads from the output of stepper-reentry **41** to the brushes of distributor **125**. As the brushes **124** rotate together across the segments of distributor **124** they cause the different channel message currents to be applied across their respective individual channel filters **126**, and similarly, distributor **125** distributes the currents in the other group of channels to their respective channel filters **126**. These low-pass filters are for suppressing ripples or transients and delivering rounded pulses to the synthesizer **130**.

This latter may be of the same type and construction as the synthesizer shown in my patent referred to above. It contains a source of current (buzz) simulating vocal cord energy and a source (hiss) of resistance noise or gas tube noise, together with a pitch control and energy source selector under control of the pitch channel and, in this case, seven modulators or variable gain amplifiers plus the necessary band filters for enabling each spectrum index current, composed of a succession of the received pulses, to produce output current in receiver **131** of corresponding frequency and varying amplitude to reconstruct the original speech message. Since this synthesizer is fully disclosed in published art, including my prior patent, no further description of it is deemed necessary.

The record **30** or **90** can be prepared by generating resistance noise or gas tube noise currents of a sufficiently wide frequency band to represent random distribution of instantaneous amplitude with time and in sampling these currents at periodic intervals, in this case at slightly under 3-millisecond intervals as represented by the beginnings of the pulses in line C of FIG. 3. The sampling can be done by electronic means or by a fast acting relay, such as **42**, which places a charge on a condenser for the interval between sampling times. A carrier wave is amplitude-modulated in accordance with the voltage existing across such condenser, and the modulated wave is recorded.

While continuous steppers have been disclosed in which any signal magnitude at the instant of sampling is held until the next sampling time, it is, of course, within the invention to use instead a stepper which divides the signal into a discrete number of steps such as five or six and transmits only these stepped values. This latter type of stepper, in and of itself, is known in the art.

Instead of staggering the segments on distributors **24** and **25** and separating the key pulses on a time basis, the keys can be separated on a frequency basis if the record is prepared by separately and simultaneously modulating two carrier waves of different frequency by two sets of voltage pulses separately derived from resistance noise such that the two keys can be recovered by use of separating filters.

Such an arrangement is indicated in FIG. 4 which shows speech input **20**, analyzer **21** as in FIG. 1, but in this case the distributors **24'** and **25'** sample channels in respective groups simultaneously instead of alternately. The length of conductive segments can be longer such as to approach a sampling interval of 6 milliseconds on the basis of 42 revolutions per second, if desired. The keys are recorded in pulses of length corresponding to the length of the sampling contact time as noted above, and the keys are derived in separate channels, one comprising selecting band filter **131**, rectifier **132** and low-pass filter **133**, and the other comprising selecting filter **134**, rectifier **135** and low-pass filter **136**. The receiving terminal circuit would be modified accordingly.

It will be noted that the length of the pulses sent to line is not changed by use of the FIG. 4 circuit since the pulse length is determined in any case by the timing of the stepper and reentry circuits **40**, **41** and not by the sampling contact time.

The invention is not to be construed as limited to the specific circuits or apparatus disclosed herein nor to the quantitative magnitudes given but the scope is defined in the claims, which follow.

What is claimed is:

1. In telephone privacy, means to derive from speech message waves a plurality of relatively low frequency currents in separate circuits representing energy variations in different component frequency bands of the speech, a lesser plurality of enciphering means, common means to supply variable key currents to said enciphering means, means to apportion each enciphering means to a different group of said circuits on a time division basis to cause enciphering of the currents in all of said circuits by said enciphering means, and a transmission channel connected to each enciphering means for transmitting the currents enciphered thereby.

2. The combination recited in claim **1** including a reentry circuit in each enciphering means for changing input currents increasing progressively through a given total range into output currents increasing repeatedly through a smaller range.

3. The combination of claim **1** in which the means to apportion each enciphering means comprises in each case a distributor for effectively connecting said enciphering means to successive circuits of the given group in rotation, said enciphering means including holding circuits for causing the output current from the enciphering means to persist for a longer time than the input current and at constant amplitude.

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