

[54] VOICE PRIVACY SYSTEM

[75] Inventors: **Craig R. Allen; John E. Celto**, both of San Diego, Calif.

[73] Assignee: **The United States of America as represented by the Secretary of the Navy**, Washington, D.C.

[22] Filed: **June 1, 1972**

[21] Appl. No.: **258,560**

[52] U.S. Cl. **179/1.5 FS, 325/33, 179/1.5 R**

[51] Int. Cl. **H04k 1/04**

[58] Field of Search..... **179/1.5 FS, 1.5 R; 325/32, 33**

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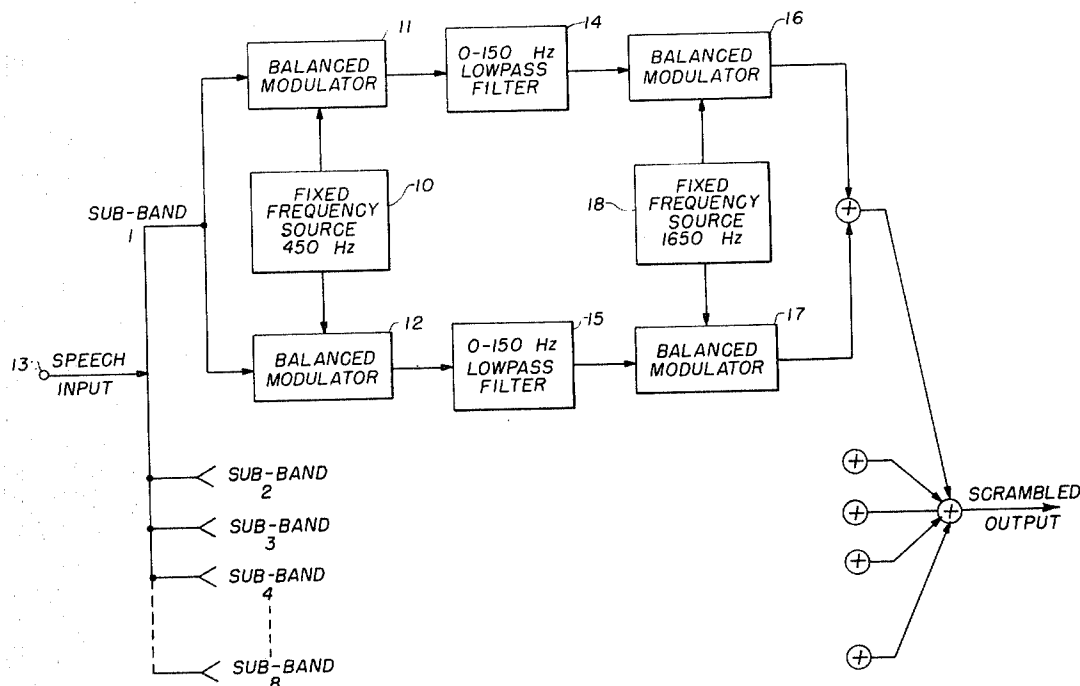
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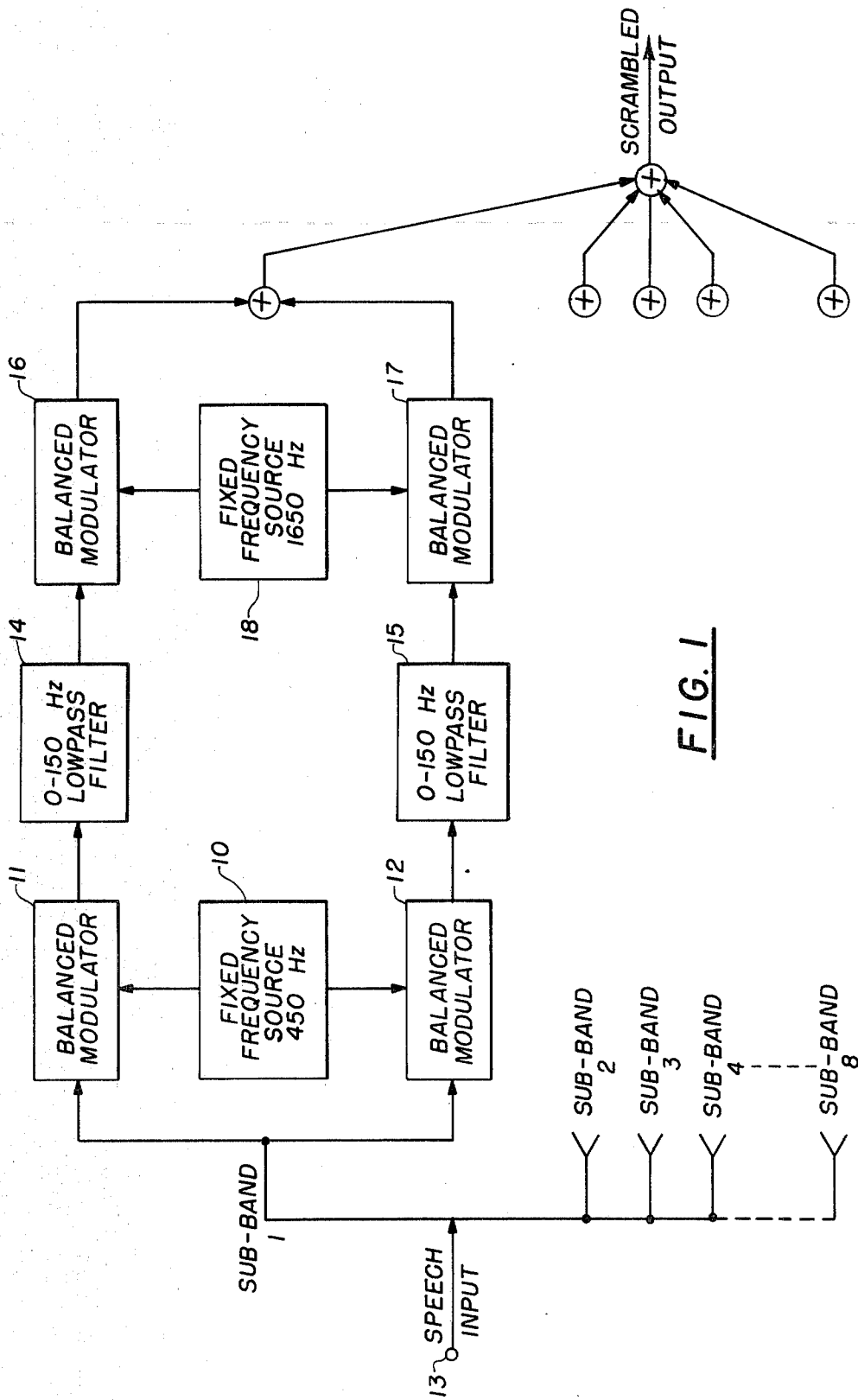
Primary Examiner—Benjamin A. Borchelt
Assistant Examiner—H. A. Birmiel
Attorney—R. S. Sciascia et al.

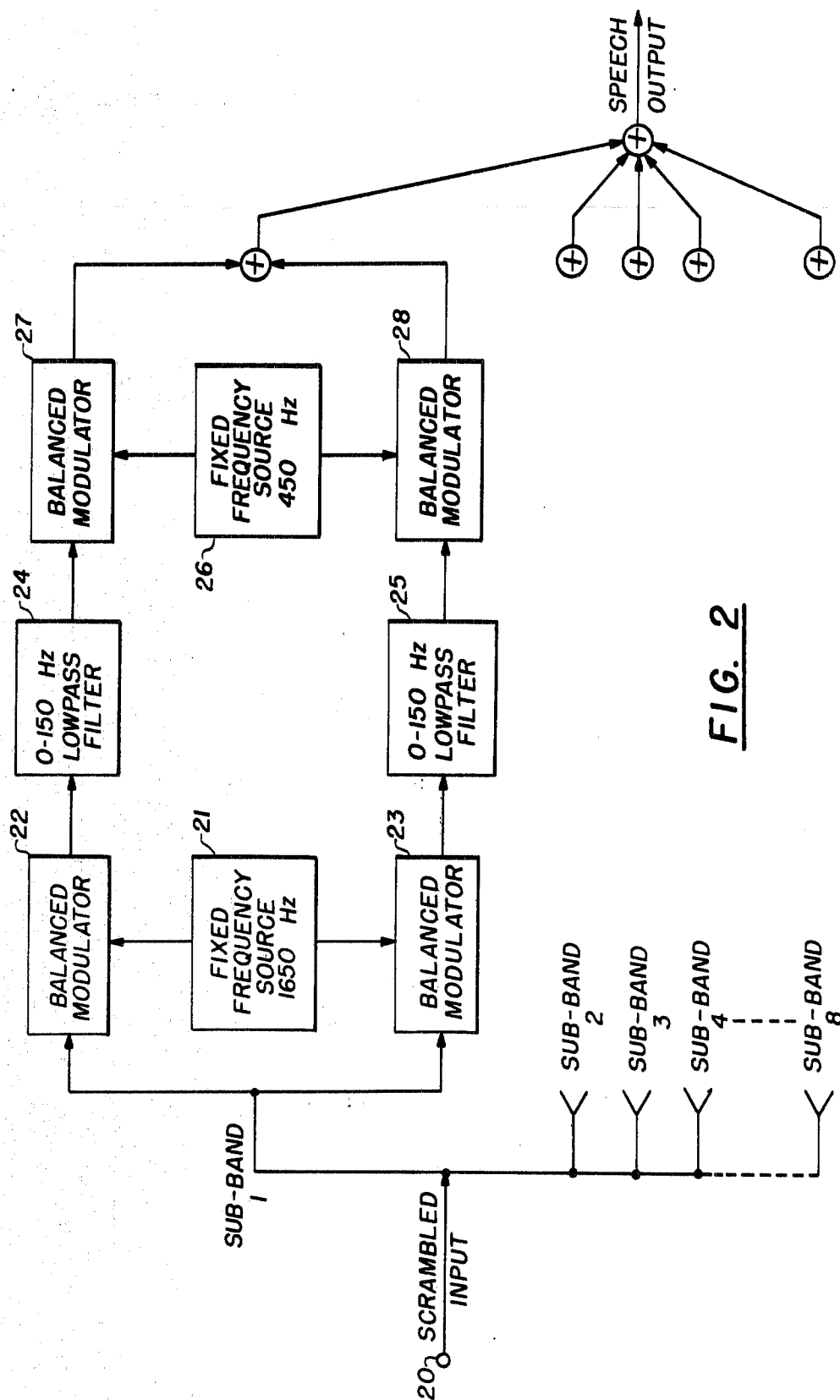
[57] ABSTRACT

A selected bandwidth of speech frequencies is divided into a plurality of sub-bands and each sub-band is processed in a "Weaver modulator" type of circuit for filtering, frequency translation, and inversion. The sub-bands which have undergone frequency translation are then combined to provide a scrambled output which is transmitted to a receiver where the converse processing of the scrambled signals including filtering, frequency translation, and inversion is accomplished to produce the original speech modulated input.

10 Claims, 3 Drawing Figures







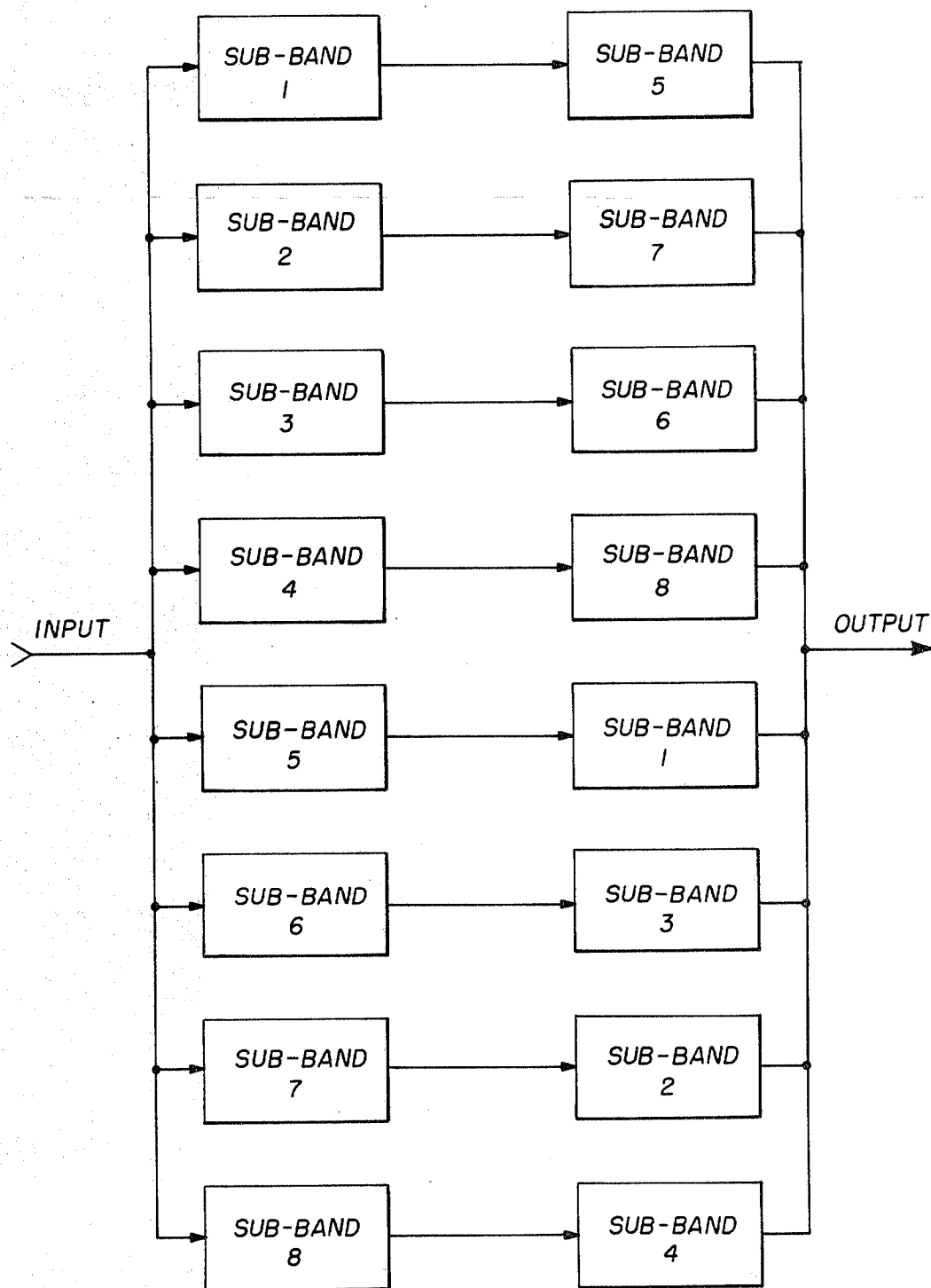


FIG. 3

VOICE PRIVACY SYSTEM

BACKGROUND OF THE INVENTION

Many voice privacy systems or speech scramblers of the prior art have employed band splitting and frequency translation techniques to render voice transmissions unintelligible unless received and desciphered by a specially designed receiver which has the capability of returning the speech frequencies to their original form and correct relative disposition in the normal speech bandwidth.

In such prior art systems it was a practice to employ bandpass filtering in order to separate the chosen speech bandwidth into sub-bands in accordance with well known band splitting techniques. Such bandpass filters, when of the passive type, usually comprised inductive and capacitive elements. The disadvantage of that type of bandpass filter is the fact that the inductive elements are relatively bulky, expensive, and usually occupy considerable space compared to other types of electrical elements.

As an alternative, prior art practices achieved bandpass filtering through the use of active elements such as amplifiers along with resistive and capacitive elements. However, such active bandpass filters have the disadvantage that their transfer functions are sensitive to small variations in the gain of an amplifier or the value of a passive element, such as might result from aging or ambient temperature changes. Moreover, such active bandpass filters are relatively complex and expensive.

Accordingly, it is highly desirable that a voice privacy system or speech scrambler be devised which avoids the requirement for conventional bandpass filtering so as not to incur the disadvantages of prior art devices, some of which have been mentioned hereinbefore.

SUMMARY OF THE INVENTION

The present invention of a novel voice privacy system or speech scrambler employs the technique of band splitting and frequency translation so as to develop a scrambled output signal which has speech frequency sub-bands interchanged to render the intelligence in the original speech signal unintelligible.

A highly desirable and unique feature of the present invention is that it employs lowpass filtering which does not require the use of inductive elements nor of active bandpass filters, both of which inherently incur disadvantages in prior art systems designed to accomplish comparable results. The concept of the present invention is such that lowpass filters of the active-RC type can be employed which are compact, relatively inexpensive, and adequately effective to perform their required function.

In accordance with the concept of the present invention, a selected speech frequency band within the audio range is divided into sub-bands. This is accomplished by the use of circuitry which is similar in configuration to the so-called "Weaver modulator" as disclosed and described in an article titled "A Third Method of Generation and Detection of Single-Sideband Signals," published in the December, 1956 issue of Proceedings of the IRE. However, whereas the combination of apparatus disclosed by Weaver generated a single sideband signal for transmission in a communications system, the concept of the present invention requires that the use of the Weaver modulator type circuitry be employed to develop and operate upon signals entirely

within the audio frequency range and, more particularly, within that portion of that audio frequency range which is selected for division into speech frequency sub-bands.

In accordance with the present invention, the speech frequency input signals are divided into predetermined sub-bands of equal bandwidth by being connected into circuitry which is designed to respond to a particular sub-band, develop lower frequencies corresponding to the speech frequency sub-band, filter such lower frequency signals, and then develop signals of another speech frequency sub-band which correspond to the low frequency signals. All sub-bands are then combined for transmission to a receiving point or a receiving station.

Accordingly, the speech signals within each sub-band are translated to lower frequency, filtered, and then translated to the frequency of a different sub-band. This provides the band splitting frequency translation which renders the speech normally unintelligible. At the receiving point the converse procedure is accomplished; that is to say, the signals within each sub-band are translated to lower frequency, filtered, and then translated to the frequency of their original sub-band, so that the aggregate of the sub-bands is arranged substantially as it was originally and is therefore returned to intelligibility.

One significant advantage of the present invention is that, if the frequency translation of sub-bands is accomplished by "pairing" of the sub-bands, the scrambling or transmitting unit may also be used without change as an unscrambler or receiver unit which renders the equipment operative for a half-duplex function; that is, the alternate use of the same unit in both transmit and receive modes.

For example, if a selected portion of the speech frequency band is sub-divided into six sub-bands numbered 1 through 6 and one of the units performs a frequency translation from sub-band 1 to sub-band 5, then another unit may be said to be paired in the sense that it causes frequency translation in the converse sense, i.e., frequency translation from sub-band 5 to sub-band 1. Similarly, if in the same system a unit performs the function of frequency translation from sub-band 2 to sub-band 6, then another unit should be paired to perform the frequency translation from sub-band 6 to sub-band 2, and likewise to all remaining sub-band units.

It will be evident to those skilled in the art that with such an arrangement of pairing, the units can be employed to operate in both transmit and receive modes, performing both the scrambling function and the unscrambling function, without the need for a complex switching circuit to change between transmit and receive modes.

Moreover, it will be apparent to those skilled in the pertinent arts that there are certain advantages inherent in the present invention in that elements of certain embodiments of the present invention may be employed for dual functions, such as oscillators which may be connected to supply signals to both the input and output sides of units where the same sub-band is involved. That is to say that, where the input side of a unit, operative in accordance with the concept and teaching of the present invention, operates upon input sub-band 1, for example, another unit will be operative to translate a different sub-band to an output at the frequency of sub-band 1. Therefore, local oscillators can

be employed to operate with the same sub-band whether that sub-band is operative on the input or output side of the unit. This latter advantage will be more apparent from a description of a preferred embodiment of the present invention and an understanding of its operation.

Accordingly, it is a primary object of the present invention to provide a voice privacy system or speech scrambler which overcomes disadvantages of comparable prior art arrangements.

Another most important object of the present invention is to provide such a voice privacy system which is more compact, less expensive, and requires less power than similar prior art systems.

Another most important object of the present invention is to provide such a voice privacy system which is particularly adaptable to simplification by reason of dual functions performed by its elements and components.

An inherent object of the present invention is to provide a voice privacy system which uses active-RC low-pass filtering thereby eliminating the requirement of inductive elements or active bandpass filters for filtering purposes.

A further most important object of the present invention is to provide such a voice privacy system which is adapted to reduction in size and weight through the use of advanced micro-electronic packaging technology.

A further object of the present invention is to provide such a voice privacy system which is capable of frequency inversion as well as frequency translation of speech frequency sub-bands.

These and other features, objects, and advantages of the present invention will be better appreciated from an understanding of the operative principles of a preferred embodiment as described hereinafter and as illustrated in the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a schematic block diagram of an embodiment of the present invention;

FIG. 2 is a schematic block diagram illustrating the receiver portion of a voice privacy system of the present invention; and

FIG. 3 is a schematic block diagram of an alternative embodiment of the present invention.

The concept of the present invention contemplates band splitting a selected portion of the audio frequency spectrum into predetermined sub-bands. For purposes of explanation, the selected portion of the audio frequency spectrum may in a typical instance be determined to be from 300 to 2,700 Hz. This range of 2,400 Hz may be split into eight sub-bands of 300 Hz each bandwidth as designated in Table I

TABLE I

Sub-band 1	300 Hz	600 Hz
Sub-band 2	600 Hz	900 Hz
Sub-band 3	900 Hz	1200 Hz
Sub-band 4	1200 Hz	1500 Hz
Sub-band 5	1500 Hz	1800 Hz
Sub-band 6	1800 Hz	2100 Hz
Sub-band 7	2100 Hz	2400 Hz
Sub-band 8	2400 Hz	2700 Hz

Both the selected audio frequency band and the sub-bands are arbitrarily chosen and predetermined in accordance with the best design judgment in view of the

ultimate requirements of each particular voice privacy system. As those skilled in the art will readily understand, there may be more or fewer sub-bands and the audio frequency band may be chosen to be broader or narrower as desired or required for particular embodiments of the present invention.

As indicated in FIG. 1, the circuitry associated with each sub-band is identical in nature and function, but operative at different frequencies. For example, the schematic diagram of the circuitry for sub-band 1 which, for purposes of explanation may be assumed to be translated to sub-band 5, comprises a first fixed frequency signal source 10 which is operative at 450 Hz, i.e., the center frequency of sub-band 1 which covers a band of 300 Hz to 600 Hz.

First and second balanced modulators 11 and 12 are connected in first and second signal channels of sub-band 1 to receive the speech input signals from an input terminal 13. The fixed frequency source 10 is operative to produce first and second 450 Hz output signals which are phase displaced in quadrature relative to each other. One of the 450 Hz output signals of the fixed frequency source 10 is connected as a second input to the balanced modulator 11 while the other 450 Hz output of the fixed frequency source 10 is connected as a second input to the balanced modulator 12.

The outputs of balanced modulators 11 and 12 are connected into two lowpass filters 14 and 15, respectively, which pass all frequencies from 0 to 150 Hz. Thus, all speech signal components within sub-band 1, i.e., 450 Hz $\pm$ 150 Hz, are passed by the filters 14 and 15 while components of all other frequencies are rejected. The 0 to 150 Hz components passed by the lowpass filters 14 and 15 are connected to balanced modulators 16 and 17, respectively.

The second input is provided to each of the balanced modulators 16 and 17 from a fixed frequency source 18 which develops two signals at a frequency of 1,650 Hz but phase displaced by $\pm 90^\circ$. Since 1,650 Hz is the center frequency of sub-band 5, it will be readily understood by those skilled in the art that the particular embodiment schematically illustrated in FIG. 1 is operative in the circuitry of the first sub-band to convert or frequency translate the signal components within 300 to 600 Hz to the frequency of sub-band 5 which ranges from 1,500 Hz to 1,800 Hz. Accordingly, the 0 to 150 Hz signals which are connected from low pass filters 14, the first signal channel of sub-band 1, and also to lowpass filter 15 in the second signal channel of sub-band 2, operate to modulate the 1,650 Hz signals developed by the fixed frequency source 18. Thus, the signal components which originated within sub-band 1 have effectively been frequency translated to sub-band 5. The remainder of the sub-band assemblies 2, 3, 4, 5, 6, 7, and 8 similarly translate the signal components detected within each sub-band to another sub-band. These may be arranged as indicated in Table II.

TABLE II

Sub-band 1	→	Sub-band 5
Sub-band 2	→	Sub-band 3
Sub-band 3	→	Sub-band 8
Sub-band 4	→	Sub-band 6
Sub-band 5	→	Sub-band 7
Sub-band 6	→	Sub-band 2
Sub-band 7	→	Sub-band 1
Sub-band 8	→	Sub-band 4

It should be noted that in accordance with the concept of the present invention, eight fixed frequency sources would be necessary, each such source being operative at the center frequency of one audio sub-band, and arranged to drive the balanced modulators at the input of one-sub-band, and also the balanced modulators used at the output of another sub-band.

For example, the fixed frequency source, which is operative at the center frequency of sub-band 5 to drive its balanced modulators on the input side of its circuitry of its two signal channels, can also be employed to drive the balanced modulators 16 and 17 which are employed in the signal channels of sub-band 1 to frequency translate from sub-band 1 to sub-band 5 in the scrambling process. Similarly, each other fixed frequency source can be connected to perform the described dual function.

Moreover, in accordance with the concept of the present invention, reversing the connections from a fixed frequency source to one pair of balanced modulators gives effect to a low-to-high frequency inversion within the sub-band. For example, such frequency inversion, if utilized in sub-band 1, for example, could cause speech components occurring between 300 to 600 Hz to be transformed to corresponding components ranging from 1,800 to 1,500 Hz (the latter being sub-band 5, which is the output of the signal channels of sub-band 1, as illustrated in FIG. 1). This, of course, is a further scrambling of the speech signal and can be unscrambled by carrying out the converse circuit processing in the receiving portion of the system.

FIG. 2 illustrates the receiver portion of the voice privacy system of the present invention and comprises the means for unscrambling the voice signals to provide an intelligible speech output. As may be seen from FIG. 2, the elements and their arrangement are substantially the same as the transmitter input portion of the system illustrated in FIG. 1 connected in a converse order to perform converse functions.

The scrambled speech, after suitable transmission either by appropriate carrier, radiated energy, or direct lines, is received at input terminal 20 and connected, as illustrated in FIG. 2, to each of the sub-band circuits. Assuming that the equipment is divided into 8 sub-bands as previously described, to function with the sending or transmitting station as illustrated and previously described in connection with FIG. 1, the sub-band 1 of FIG. 2 will be designed to perform the function of frequency translation for components about the center frequency of sub-band 5 as it exists in the scrambled input back to corresponding components about the center frequency of sub-band 1 to reconstruct the segment of speech within the sub-band 1 by converse frequency translation, as contrasted to the frequency translation which is accomplished in the transmitting portion of the system as illustrated in FIG. 1.

A first fixed frequency source 21 is operative to produce quadrature phase displaced signals at the frequency of 1,650 Hz. These signals provide one of two inputs for each of the balanced modulators 22 and 23. The second inputs to the balanced modulators 22 and 23 is the scrambled speech input as received at the input terminal 20. The balanced modulators 22 and 23 are connected in first and second signal channels of sub-band 1 and deliver their respective outputs to 0 to 150 Hz lowpass filters 24 and 25, respectively.

A second fixed frequency source 26 generates signals in quadrature phase displacement and at the frequency of 450 Hz, which is the center frequency of sub-band 1. These signals are connected as an input to balanced modulators 27 and 28 which also receive the outputs of lowpass filters 24 and 25, respectively. The balanced modulators 27 and 28 produce a reconstructed speech segment about the center frequency of 450 Hz which is substantially the same as the original sub-band 1 segment received in the first and second signal channels of sub-band 1 at the transmitting or sending station of FIG. 1.

All the sub-bands, one through eight, comprise comparable elements with the fixed frequency sources operative at appropriate frequencies in accordance with the selected pairs of sub-bands between which the frequency translation takes place; that is to say, the pairs of sub-bands as illustrated in Table II, for example.

It is further contemplated by the concept of the present invention that sub-bands can be selected by interchangeable pairs. For example, if sub-band 1 (300 to 600 Hz) is translated to the frequency of sub-band 5 (1,500 to 1,800 Hz), then the speech frequency sub-band 5 may be translated to the speech frequency sub-band 1. All the remaining bands may also have the converse order, in the sense that they will be interchangeably paired as illustrated by the interchangeable matched pairs of sub-bands tabulated in TABLE III.

TABLE III

Sub-band 1	→	Sub-band 5
Sub-band 2	→	Sub-band 7
Sub-band 3	→	Sub-band 6
Sub-band 4	→	Sub-band 8
Sub-band 5	→	Sub-band 1
Sub-band 6	→	Sub-band 3
Sub-band 7	→	Sub-band 2
Sub-band 8	→	Sub-band 4

With such an interchangeable matching of pairs incorporated in an embodiment of the present invention, further advantage is realized in that that particular arrangement may be used without change for both transmitting and receiving. Such an embodiment is illustrated in FIG. 3 which schematically represents the configuration of the present invention as shown in TABLE III.

It will be noted that because of the pairing of sub-bands, the configuration illustrated in FIG. 3 accomplishes either a scrambling operation or the corresponding unscrambling operation without need for any switching arrangement to alter the configuration when changing between transmit and receive modes, thereby further enhancing the usefulness and advantages of the present invention.

Those skilled and knowledgeable in the pertinent arts will readily appreciate that the concept of the present invention, using a particular type of modulators in the unique combination of the present invention, permits the use of lowpass filters to perform bandpass filtering. The principal advantages of lowpass filtering are that acceptable filtering can be provided from simple active-RC filter circuits without the use of relatively bulky and expensive inductive elements or of complex active bandpass filters, thereby resulting in smaller size, less cost, and significantly lesser power requirements.

By contrast, many of the prior art systems depended upon conventional bandpass filtering which inherently

required the use of more complex filter techniques, not infrequently employing inductive elements which, in addition to being large in size, were relatively heavy in weight and costly as well.

Moreover, the present invention affords frequency inversion. Consequently, as illustrated in the schematic block diagram of FIG. 3, the operation of an embodiment employing the described matching pairs of speech frequency sub-bands affords the use of such a combination as both a receiver and transmitter further enhancing the usefulness and advantages of the present invention.

One of the more significant advantages of the present invention is that in its preferred embodiment it does not require pre-filtering to separate the selected speech frequency band into sub-bands. This is true in the operation of the present invention wherein the fixed frequency sources are substantially of sinusoidal waveforms and the balanced modulators are of the four-quadrant analog multiplier type.

However, if the fixed frequency sources are square waves, or the balanced modulators are of the switching modulator type, the equivalent fixed frequency inputs to the balanced modulators contain higher harmonics than their fundamental frequency and therefore such higher harmonics can interfere with the preferred operation of embodiments of that type. Accordingly, when square waveform fixed frequency sources or switching type balanced modulators are employed within the concept of the present invention, it is desirable that pre-filtering be accomplished sufficient to filter out those frequencies in predetermined speech bands which are higher than the highest frequency contained within each particular sub-band. Thus, the first and second channels for each sub-band will receive speech frequencies which are equal to or lower than the highest frequency of each particular sub-band. It should be appreciated, however, that this requirement may be eliminated by the use of sine wave fixed frequency sources and balanced modulators of the four-quadrant analog multiplier type. That is, in the frequency translation process, an inversion of the speech signal frequencies can readily be achieved in which the signal components for the input frequency band at its lower end will be reproduced in the frequency translation to the upper end of the output frequency band. Conversely, the upper end of the input frequency band will have its signal components transferred to the lower end of the output frequency band. This further enhances the scrambling effect, rendering the output signals more secure because they are more difficult to unscramble.

As will be readily recognized by those skilled in the pertinent arts, the concept of the present invention is not limited to the particular frequency bands as described in specific embodiments, nor to the number of sub-bands into which the predetermined speech bandwidth may be sub-divided.

Additionally, any combination of predetermined frequency translation schemes may be employed within the teaching of the present invention through special advantages are to be realized by employing the matched pair technique as described, disclosed and taught herein.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within

the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A voice privacy system comprising:

a first fixed frequency signal source associated with each speech frequency sub-band of a plurality of speech frequency sub-bands and operative at the center frequency of its associated speech frequency sub-band for producing first and second output signals in quadrature phase displacement; first and second balanced modulators connected in first and second signal channels, respectively, of each separate speech frequency sub-band to receive speech input signals and the first and second output signals, respectively, of each said first fixed frequency source, for producing corresponding lower frequency output signals in each said first and second signal channels;

a lowpass filter of predetermined bandwidth connected in each said signal channel for filtering the output signals of said first and second balanced modulators in each signal channel;

second fixed frequency sources, each operative at the center frequency of one of said speech frequency sub-bands for producing first and second output signals in quadrature phase displacement and being connected to the first and second signal channels of another of said speech frequency sub-bands;

third and fourth balanced modulators connected in said first and second channels, respectively, of each said speech frequency sub-band to receive the filtered output signals of the lowpass filters in said first and second channels and the first and second output signals, respectively, of said second fixed frequency source, for producing output signals correspondingly disposed about a center frequency other than said first fixed frequency as determined by the frequency of each particular second fixed frequency source;

means for summing the output signals of said third and fourth balanced modulators of each speech frequency sub-band; and

means for summing the output signals of all said plurality of speech frequency sub-bands.

2. A voice privacy system as claimed in claim 1 wherein the first fixed frequency source associated with each speech frequency sub-band produces first and second output signals having quadrature phase displacement of the same sense as the quadrature phase displacement of the first and second output signals of the second fixed frequency source of the same speech frequency sub-band.

3. A voice privacy system as claimed in claim 1 wherein the first fixed frequency source associated with each speech frequency sub-band produces first and second signals having quadrature phase displacement of the opposite sense relative to the quadrature phase displacement of the first and second output signals of the second fixed frequency source of the same speech frequency sub-band.

4. A voice privacy system as claimed in claim 1 wherein the first and second fixed frequency sources produce sine wave output signals and all balanced modulators are of the four-quadrant analog multiplier type.

5. A voice privacy system as claimed in claim 1 wherein all balanced modulators are of the switching modulator type and the first and second fixed fre-

quency sources produce either sine wave or square wave output signals, and also including lowpass filter means connected at the input to the first and second signal channels of each sub-band for limiting the speech input signals to frequencies not higher than the highest frequency of that particular sub-band, and also including lowpass filter means connected at the output of the summing circuit which combines the outputs of the first and second signal channels of each sub-band for limiting the frequency-translated signals to frequencies not higher than the highest frequency of that particular output sub-band.

6. A voice privacy system as claimed in claim 1 wherein the first and second fixed frequency sources of each sub-band produce two different frequencies which are the converse of the two different frequencies produced by the first and second fixed frequency sources of another sub-band.

7. A voice privacy system as claimed in claim 6 and further including switch means arranged and connected to permit half-duplex operation by use of the same combination of equipment in transmit and re-

ceive modes to affect the flow of signals appropriately to and from the associated speech transmission equipment.

8. A voice privacy system as claimed in claim 1 producing a speech frequency band-split scrambled output and also including means for transmitting said output to a receiving station.

9. A voice privacy system as claimed in claim 8 wherein the receiving station comprises a combination of equipment identical to that of the transmitting station but connected to perform the corresponding unscrambling operation.

10. A voice privacy system as claimed in claim 1 and further including switch means arranged and connected to connect the fixed frequency sources to appropriate balanced modulators so as to enable the system to selectively scramble speech or to perform the corresponding unscrambling operation for employing the same combination of equipment in transmit and receive modes without the need for pairing corresponding sub-bands.

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