United States Patent

[11] **3,624,560**

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[73] Assignee **General Electric Company**

[54] **MODULATION TECHNIQUE FOR A LIMITED ENERGY SPEECH TRANSMISSION SYSTEM EMPLOYING PHASE REVERSAL OF ALTERNATE PULSES**
6 Claims, 4 Drawing Figs.

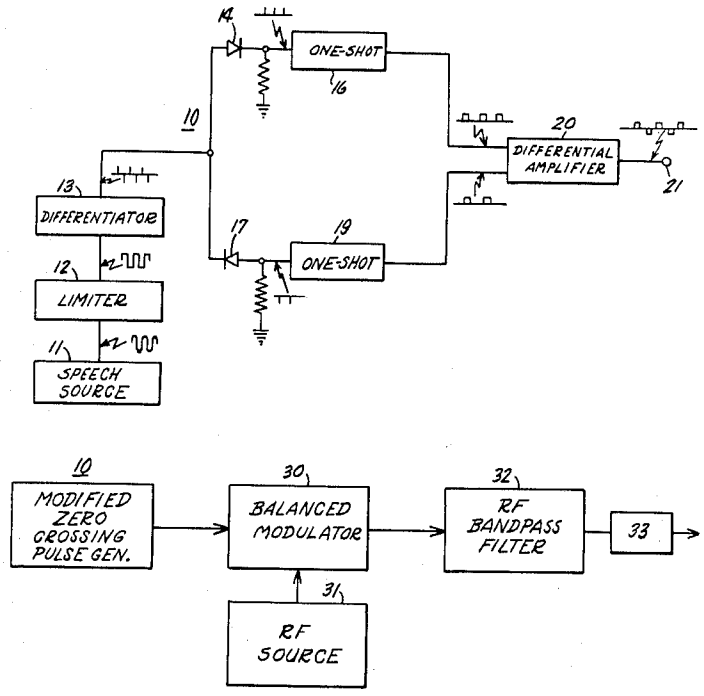
[52] **U.S. Cl.** ..... **332/31 R,** 325/138, 325/148, 238/165, 332/44
[51] **Int. Cl.** **H03c 1/52**
[50] **Field of Search** 332/18, 31, 44, 23, 37; 328/162–165, 166, 140; 325/42, 65, 148, 138

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ABSTRACT: A modulation technique for a limited energy speech transmission system (LEST) is disclosed wherein either alternate speech zero crossing pulses or alternate radio frequency pulses are phase reversed prior to transmission.

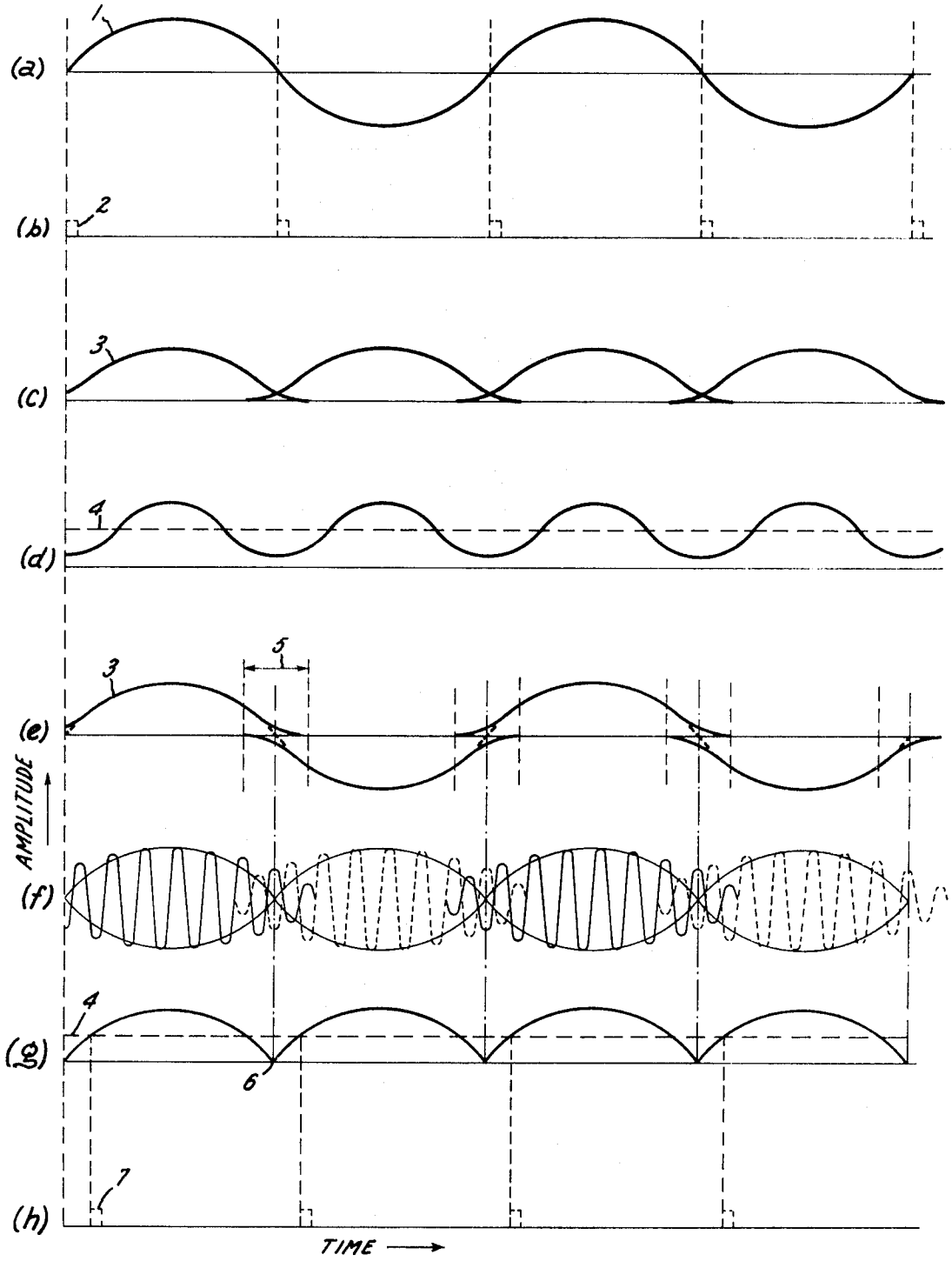


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SHEET 1 OF 2

Fig. 1.



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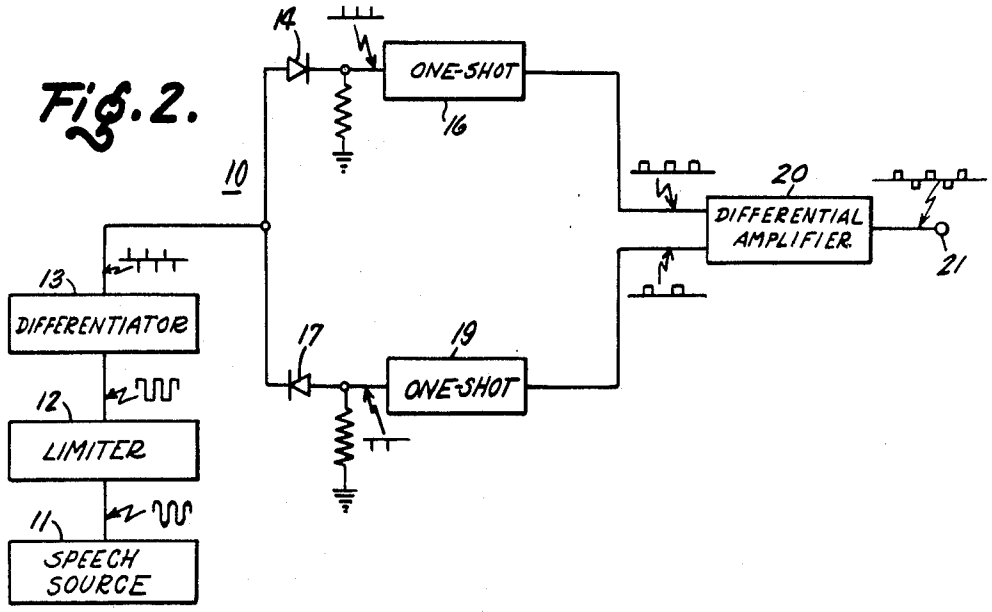


Fig. 2.

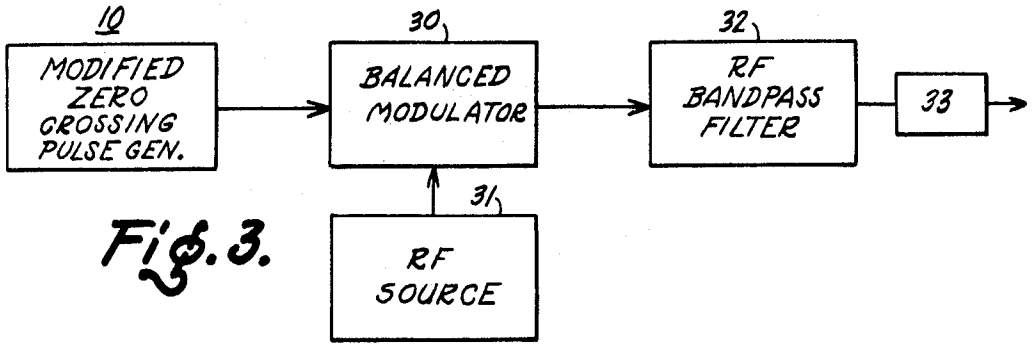


Fig. 3.

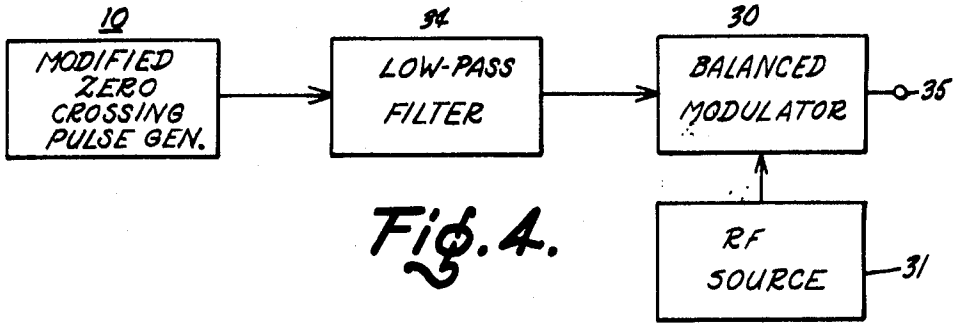


Fig. 4.

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MODULATION TECHNIQUE FOR A LIMITED ENERGY SPEECH TRANSMISSION SYSTEM EMPLOYING PHASE REVERSAL OF ALTERNATE PULSES

This invention relates to a speech transmission system wherein speech signals are clipped and zero crossing detected to produce a series of zero crossing pulses. The zero crossing pulses are then shaped to provide a series of uniform square wave pulses. The square wave pulses may be filtered to limit their bandwidth and used to modulate a carrier or they may be used to modulate a carrier directly and the modulated carrier is filtered to limit its bandwidth. The modulated carrier is then transmitted by any suitable means to a receiving station. By transmitting only the zero crossing pulses, considerable savings are obtained in average power output.

At the receiving station, the received signal is detected to obtain the series of zero crossing pulses. These pulses are then applied to a bistable multivibrator which converts the pulses back into the clipped speech signal. This clipped speech signal, after any desired amplification and filtering, is used to drive a loudspeaker, which conveys the intelligence of the original speech signal.

It has been found, however, that the radio frequency bandwidth for this system must be about four times the speech bandwidth. If the radio frequency bandwidth is less than this, zero crossing pulses of the higher frequency components of the speech tend to overlap. Any overlapping of zero crossing pulses makes difficult the detection of individual pulses at the receiving station.

In view of the above, it is an object of the present invention to provide an improved limited energy speech transmission system wherein the effect of overlapping zero crossing pulses is greatly reduced.

A further object of the present invention is to provide a pulse transmission system where alternate pulses are reversed in phase to reduce bandwidth requirements.

Another object of the present invention is to provide an improved limited energy speech transmission system wherein alternate zero crossing pulses are reversed in phase, either at the baseband level or at the radio frequency level, prior to transmission.

A further object of the invention is to provide a pulse transmission system wherein the overlapping portions of successive pulses are combined to produce a null at some point between the pulses.

Yet another object of the invention is to provide an improved modulation technique for a limited energy speech transmission system in which higher frequency components of the speech can be transmitted.

It is proposed by this invention to improve the basic limited energy speech transmission system by reversing the phase of alternate zero crossing pulses, whereby the overlapping portions of the zero crossing pulses will contain a deeper null.

The various features of the invention may be best understood by considering the following description and the attached drawings in which:

FIG. 1 illustrates a series of waveforms useful in understanding the present invention.

FIG. 2 illustrates a specific form of a modified zero crossing detector used in the present invention.

FIG. 3 illustrates one form of the invention utilizing radio frequency band pass filtering.

FIG. 4 illustrates another embodiment of the invention utilizing baseband filtering.

Referring to FIG. 1 there is shown a series of waveforms (*a*) through (*g*) illustrating the present invention and its advantages over the basic limited energy speech transmission (LEST) system disclosed in the copending application of Roy E. Anderson, Ser. No. 700,310, filed Dec. 22, 1967, now U.S. Pat. No. 3,528,011 and assigned to the same assignee as the present invention. In FIG. 1*a*, the waveform 1 represents the input waveform to the overall system which may, for example, be a speech wave. The zero crossings illustrated in FIG. 1*a* may either be the crossing of a zero point such as ground or a relative zero point such as the overall average level of the input speech waveform. FIG. 1*b* illustrates a series of pulses 2 generated in accordance with the zero crossings of the input waveform. FIG. 1*c* shows a series of overlapping zero crossing pulses resulting from the zero crossing pulses being filtered. The overlap of the pulses 3 is due to the bandwidth restrictions imposed upon the speech transmission system. In FIG. 1*d* there is shown a sum of the overlapping pulses and a threshold level 4 used at the receiving station to distinguish one pulse from the next. As can be seen from FIG. 1*d* the relative amplitude of the zero crossing pulses has been reduced by the overlap. Further, it can be seen that if noise is introduced into the signal transmitted, it will reduce the relative pulse height even further making it more difficult to distinguish one pulse from the other.

In FIG. 1*e* there is shown a series of pulses representing the proposed solution to the above situation wherein alternate zero crossing pulses are reversed in phase or inverted before transmission. Here, the overlapping portions of the successive zero crossing pulses tend to cancel each other out in the overlap region 5 producing thereby a deeper null and a series of pulses having steeper side portions. FIG. 1*f* represents the waveforms occurring when the alternate zero crossing pulse phase reversal takes place at the radio frequency level rather than at the baseband level. As can be seen from FIG. 1*f*, in the overlap region 5, cycles of the carrier frequency from one pulse tend to cancel out cycles of the carrier frequency from the next pulse due to the 180° phase relationship between the carrier cycles of succeeding pulses. Thus, the envelope of the waveform in FIG. 1*f* achieves a deeper null in the same manner as the waveform in FIG. 1*e* at the baseband level. FIG. 1*g* represents the waveform of the detected or full wave rectified transmitted signal. This detected signal has a series of deeper nulls 6 that extend further below the threshold level 4 than that shown in FIG. 1*d*. FIG. 1*h* represents the series of zero crossing pulses generated at the receiving station in accordance with the detected signals as shown in FIG. 1*g*. The relative phase shift between FIGS. 1*b* and 1*g* has no effect on the intelligibility of the reconstructed speech.

Thus, it can be seen from FIG. 1 (*a–d*) the basic LEST system provides a series of zero crossing pulses that may tend to overlap due to bandwidth restrictions. The present invention obviates this by inverting alternate zero crossing pulses prior to transmission so that, at the receiving station, the individual pulses may be more readily detected by virtue of the deeper null occurring between successive zero crossing pulses.

In FIG. 2 there is shown a modified zero crossing detector 10 which can be used in the present invention to provide alternately phase reversed zero crossing pulses. In the system of FIG. 2 the input speech signal is limited to provide a square wave signal and then differentiated to provide a series of zero crossing pulses. These zero crossing pulses are then used to trigger a pair of monostable multivibrators whose outputs are a series of pulses having the same polarity. These series of output pulses are then applied one to each input of a differential amplifier which serves to substract one set of pulses to the other and provides at its output a series of zero crossing pulses in which alternate pulses are phase reversed or inverted.

Specifically, the modified zero crossing detector 10 comprises a source of speech signal 11 connected to the input of a limiter 12 which provides at its output a square wave signal representing a clipped version of the input speech signal. This clipped version of the input speech signal is passed through a differentiating means 13 which provides a series of pulses at each zero crossing. These pulses are bipolar, that is, there are positive pulses for each positive going zero crossing and negative pulses for each negative going zero crossing. The positive and negative signals are separated into two channels by a rectifying means 14 which passes the positive going zero crossing pulses and rectifying means 17 which passes the negative going zero crossing pulses. The positive going zero crossing pulses are applied to the input of a one-shot or monostable multivibrator 16 which provides at its output a se-

ries of uniform duration pulses in accordance with the positive going zero crossing pulses at its input. In like manner, the one-shot or monostable multivibrator **19** provides a series of uniform output pulses for the negative going zero crossing pulses applied to its input. The output pulses from the one-shots **16** and **19** are of the same polarity, that is, in the example shown in FIG. **2**, they are both positive going pulses. These pulses from **16** and **19** are applied to the inputs of differential amplifier **20** which serves to subtract the two series of pulses from each other, in the well-known manner of operation of differential amplifiers, and provides at its output **21** a series of zero crossing pulses in which alternate zero crossing pulses are phase-reversed or inverted. This is achieved by virtue of the fact that one set of pulses for example, the output pulses from element **16** are connected to the positive input of the differential amplifier **20** and the negative zero crossing pulses provided by the monostable multivibrator **19** are applied to the negative or subtract input of the differential amplifier **20**. Thus, for each pulse from element **16** the differential amplifier provides a positive going output pulse. However, for each pulse from the element **19**, the differential amplifier provides a negative going output pulse since this pulse has been applied to the subtract input of the differential amplifier.

Thus, there has been shown one example of a suitable modified zero crossing detector for use in the present invention. It should be apparent that modification of the detector may be made. For example, if the outputs from the monostable multivibrators **16** and **19** were of unlike polarity, that is, for example, the output pulses of monostable multivibrator **16** were positive going and the output pulses of monostable multivibrator **19** were negative going, the differential amplifier **20** could be replaced with a simple summing circuit. Also, it should be noted, in comparison with the basic LEST system, that if the outputs of the monostable multivibrators **16** and **19** are of like polarity and are applied to a summing circuit instead of the differential amplifier **20**, the net result is the basic LEST system wherein a series of uniform pulses are produced which are all of the same polarity. Conversely, the basic LEST system is also provided if the outputs of the monostable multivibrators **16** and **19** are of unlike polarity and are applied to a differential amplifier **20**. The small waveforms appearing in conjunction with the output lines of the various elements in FIG. **2** show the typical outputs of the preceding elements.

In FIG. **3** there is shown one embodiment of the overall system employing the present invention. In this embodiment, the output pulses from the modified zero crossing detector are used to modulate a radio frequency carrier to provide a radio frequency output signal which is then passed through a band-pass filter to achieve the desired bandwidth requirements, and transmitted. The radio frequency signal prior to transmission may also be translated to a higher frequency. That is, the modulated radio frequency may be multiplied by a factor of N, where N is any whole number, to achieve a higher frequency output or the modulated carrier can be heterodyned with another source of signal to provide the higher frequency output.

In FIG. **3** there is shown the modified zero crossing pulse generator **10** having its output connected as one input to balance modulator **30**. The other input of balance modulator **30** is connected to the output of a radio frequency source **31**. The output of balance modulator **30**, which may be in the form of a double sideband suppressed carrier, is passed through a radio frequency band-pass filter **32** to achieve desired bandwidth requirements which may include conversion to single sideband. Also shown in FIG. **3** is a translating means **33** which can be used as desired to increase the output frequency of the radio frequency signal from the band-pass filter **32**.

Filtering at the carrier frequency as shown in FIG. **3** may impose high Q requirements on the filter when the carrier frequency is very much higher than the assigned bandwidth, since the Q required is proportional to the ratio of the carrier frequency to the bandwidth. The embodiment of FIG. **4** overcomes this by filtering at baseband. In FIG. **4**, the output signals from the modified zero crossing detector are first filtered to achieve the desired bandwidth and then used to modulate a radio frequency source.

There is shown in FIG. **4** the modified zero crossing pulse generator **10** having its output connected to low-pass filter **34** which in turn passes the filtered zero crossing pulses to balance modulator **30**. The second input to the balanced modulator **30** is connected to radio frequency source **31**. At the output **35** of the balanced modulator **30** there appears a modulated signal in which alternate pulses are phase reversed.

In connection with FIG. **1**, the output at **35** of FIG. **4** is shown diagrammatically in FIG. **1** as the waveform in FIG. **1***f*. In FIG. **1***f* any overlap between succeeding pulses from the output of the modulator **30** would tend to cancel each other out. The output of the low-pass filter **34** in FIG. **4** is shown in FIG. **1** as the waveform of FIG. **1***e*. FIG. **1** does not directly show the waveforms involved in the operation of the circuit of FIG. **3**; however, the output of the modified zero crossing pulse generator **10** would correspond to FIG. **1***b* with alternate pulses reversed in phase or inverted. The output of the band-pass filter **32** in FIG. **3** would correspond to FIG. **1***f* wherein alternate radio frequency pulses are phase reversed.

While a specific embodiment of the present invention has been shown and described, many modifications will be apparent to those of skill in the art. For example, the balanced modulation of a carrier is not the only means by which the objects and advantages of the present invention can be achieved. Other forms of modulation may also be used.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An improved limited energy speech transmission system wherein the zero crossings of the speech waveform are transmitted, the improvement comprising:

zero crossing detector means for sensing the zero crossings of an input analog waveform and for generating a pulse train by producing a pulse in response to each zero crossing;

means for reversing the polarity of alternate zero crossing pulses to produce a modified pulse train; and

means for modulating a radio frequency carrier signal with the modified pulse train prior to transmission thereof.

2. The system as in claim **1** wherein said radio frequency modulating means comprises:

a source of the radio frequency signal;

balanced modulator means having coupled as inputs thereto the radio frequency signal and the modified pulse train; and

a radio frequency filter coupled to receive the output of said modulator.

3. A system as in claim **1** wherein said radio frequency modulating means comprises:

a low-pass filter coupled to receive said modified pulse train;

a source of the radio frequency signal, and

balanced modulator means receiving as inputs the output of said low-pass filter and said radio frequency signal.

4. The system as in claim **1** wherein said zero crossing means and said polarity reversing means detector comprises:

limiter means for limiting the amplitude of the input waveform to produce square waves;

differentiating means for differentiating the square waves to produce positive and negative spike pulses;

rectifying means for separating said positive and negative spike pulses;

a pair of pulse generating means, one triggered by said positive spike pulses and the other triggered by said negative spike pulses, for producing output pulses of the same polarity, and

differential amplifier means subtracting the pulses from each pulse generator to produce said modified pulse train.

5. An improved limited energy speech transmission system wherein the zero crossings of the speech waveform are transmitted, the improvement comprising:

means for sensing the zero crossings of an input waveform and for producing a pulse in response to each zero crossing;

means for producing a series of radio frequency pulses in synchronism with said zero crossing pulses; and

means for reversing the phase of alternate ones of said radio frequency pulses.

6. A system as defined in claim 5 further comprising:

means for translating said radio frequency pulses to a higher frequency.

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