

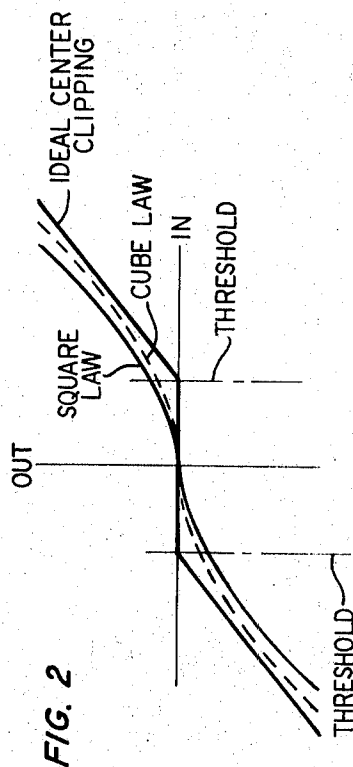
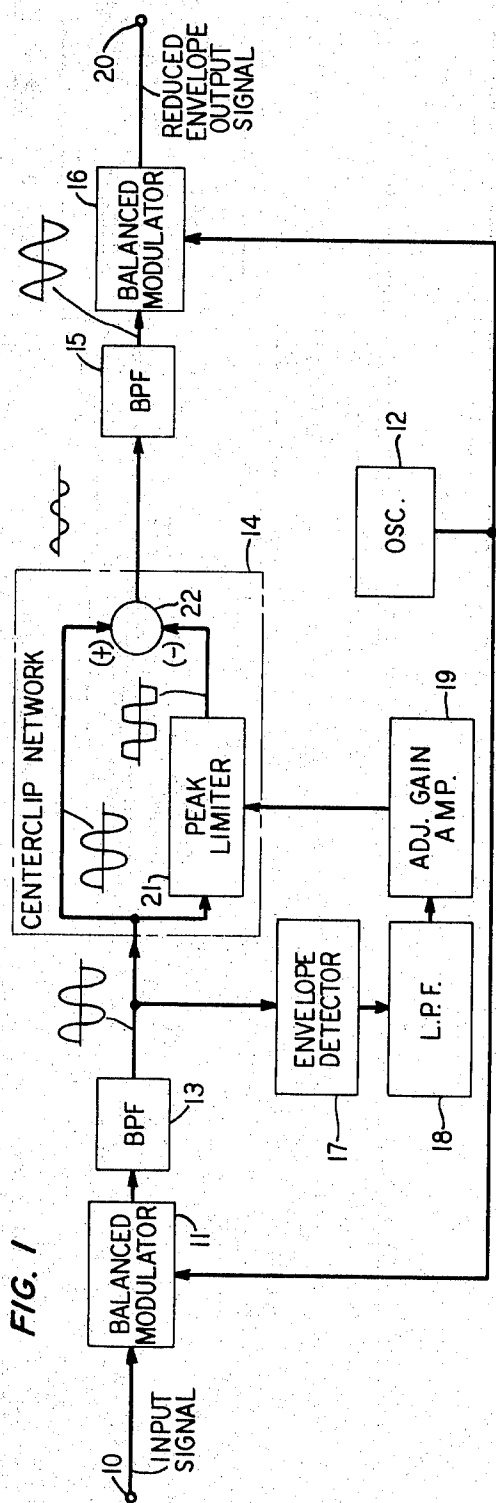
Feb. 23, 1971

M. R. SCHROEDER

3,566,285

PITCH SYNCHRONOUS REDUCTION OF SIGNAL ENVELOPE

Filed July 26, 1968



INVENTOR
M. R. SCHROEDER
BY
G. E. Hirsch
ATTORNEY

1

3,566,285

PITCH SYNCHRONOUS REDUCTION OF SIGNAL ENVELOPE

Manfred R. Schroeder, Mountainside, N.J., assignor to
Bell Telephone Laboratories, Incorporated, Murray
Hill, N.J., a corporation of New York

Filed July 26, 1968, Ser. No. 747,854

Int. Cl. H03k 5/08; H03b 3/02

U.S. Cl. 328—169

10 Claims

ABSTRACT OF THE DISCLOSURE

By reducing the envelope of a signal, such as a speech signal, in a nonlinear fashion a modified signal is produced which, in addition to being highly intelligible, exhibits desirable properties. Pitch synchronous gaps, smoothly established in a reduced envelope signal in place of intervals of low signal levels, are effective in eliminating noise which masks low level signals, reducing reverberation, and in adapting the signal for multiplex transmission. Envelope reduction is efficiently achieved by controllably center clipping a selected modulation sideband of a signal, filtering the resultant, and restoring the signal to baseband.

BACKGROUND OF THE INVENTION

This invention relates generally to the processing of signals and in particular to the modification of speech signals such that the envelope of a signal is reduced in a nonlinear fashion.

(1) Field of the invention

Much effort has been expended to develop techniques for the modification of a signal, such as a speech signal, to place it in a form suitable for more economic transmission to a distant station without, however, seriously affecting its intelligibility. One technique that has found favor involves so-called envelope reduction of the signal. By continually reducing the envelope of a signal at a pitch synchronous rate, gaps are created in the signal at irregular intervals. The gaps are effective to eliminate noise components that override weak signal portions, and may be used for time sharing a transmission channel with other signals. In essence, envelope reduction of speech constitutes one technique for increasing communication efficiency.

(2) Description of the prior art

Interrupted speech signals are generally prepared by interrupting a signal, as by chopping, whenever it is determined that the signal is either contaminated by spurious components or that it is conveying insufficient information to warrant retention. For example, it is conventional in receiving signals subject to noise contamination to detect periods of severe noise interference and "chop" the signal to remove these components. The information-bearing signal is, of course, lost in the process. For multiplex transmission it is customary to seek intervals of low signals level, preferably synchronous with the signal content, and to delete signal portions during such intervals to permit other signals to be transmitted in their stead.

If the required gaps in the signals are created simply by interrupting the signal instead of waiting for a period of silence, severe degradation of signal quality and a loss of intelligibility results. The primary reason for speech degradation as a result of signal interruption or chopping is twofold: (1) the interruptions introduce discontinuities in the signals, two for each interruption, and (2) the interruptions, unless they fortuitously occur at pitch-synchronous intervals, create an inharmonic signal. Even

2

if the timing intervals are judiciously selected, for example, by seeking times of low signal amplitude, a reproduction of the inharmonic signal is distorted. Moreover, rather complex signal analyzing equipment is required to seek out appropriate chopping times with only a slight chance of improvement over purely random chopping. Obviously, the extent of the gaps carved out of a speech signal and the manner in which they are created play an important role in determining the naturalness of a reconstituted speech signal.

SUMMARY OF THE INVENTION

It is, therefore, an object of this invention to improve the manner of interrupting a relatively continuous signal.

It is another object of the invention to reduce the envelope of a signal in a nonlinear fashion such that the signal is caused to maintain relatively full amplitude during periods of strength but to fall smoothly to zero during periods of weakness.

The outlined difficulties are overcome in accordance with the present invention by reducing the envelope of a continuous speech signal such that gaps are smoothly created in the signal at a pitch synchronous rate. Envelope reduction is effectively achieved, with a minimum of processing, by modulating an applied signal to shift it to a higher frequency, center clipping a selected side frequency of the modulated signal, e.g., one sideband, selectively filtering the center-clipped signal, and restoring the signal to its original frequency range.

Processing of this sort permits the signal to be reconstituted with selected frequency components only retained; spurious components inharmonically related to the fundamental are removed. The reconstituted signal is thus selectively distorted to exhibit a nonlinear input-output characteristic such that low level signals are effectively removed, while higher amplitude signal levels are preserved. Transitions from intervals of full signal strength to those of zero signal strength are smooth, i.e., there are no severe discontinuities. No actual chopping takes place so that the usual switching noise is avoided. Because of the smooth switching transitions, however, all of the advantages of an interrupted signal are achieved without accompanying degradation of the reconstituted signal. Speech reproduced with such processing is fully intelligible, of high quality, and devoid of contaminating components, such as noise overriding weak signal components. The invention is thus well suited to the processing of a signal to prepare it for multiplex transmission with other signals.

Signal amplifying and processing equipment, such as public address sound systems, hands-free telephone systems, and the like, also benefit from such signal processing. A reduced envelope signal, prepared in accordance with the invention, serves to reduce noise in speech signals and, importantly, the reduction takes place when noise is perceptibly most deleterious, i.e., during silent intervals between connected utterances and, more generally, during instants of low speech envelope. Moreover, reverberation effects are curtailed and system stability is improved.

DESCRIPTION OF THE DRAWINGS

The invention will be fully apprehended from the following detailed description of an illustrative embodiment thereof read in connection with the appended drawings in which:

FIG. 1 is a block schematic diagram of a signal processing network constructed in accordance with the invention; and

FIG. 2 is a set of curves illustrating signal level discrimination characteristics typical of those achieved by the center clipping apparatus of FIG. 1.

DETAILED DESCRIPTION

A signal processing network for developing envelope reduced signals is illustrated in FIG. 1. Continuous input signals applied to terminal 10 of the system are delivered to balanced modulator 11 in order to elevate the signals to the frequency of carrier signals supplied by oscillator 12. In well-known fashion, sum-and-difference signals are produced by the modulation operation. Bandpass filter 13 serves to eliminate all but a selected one of the resulting modulation products. Consequently a side frequency of the input signal appears at the output of filter 13. This signal is supplied to center clipping network 14 which is momentarily adjusted to clip applied signals severely in order to preserve only the peak wave intervals.

Center clipping a signal produces a new wave rich in higher order harmonics. Consequently, by passing the center clipped wave through a suitable filter with a selected passband, e.g., bandpass filter 15, the added higher order harmonics in the clipped signal are removed. Filter 15 may, in practice, have a passband substantially identical to that of filter 13. The signal developed at the output of filter 15 thus contains in-band components that were present in the signal delivered by filter 13, but none of the out-of-band harmonics, or harmonic products resulting from the center clipping operation. Periodicity of the input wave is, however, preserved.

The resulting wave is then demodulated in network 16, under control of waves from oscillator 12, to produce at output terminal 20 a baseband signal corresponding to the input signal but characterized by a reduced envelope. Obviously, independent signal sources may be used in place of source 12 to energize modulators 11 and 16. If desired, the baseband signal may be additionally filtered to tailor its characteristic to a desired form.

In order to accommodate a wide range of input signals and in order to maintain relatively constant envelope reduction for such signals, it is desirable continuously to adjust the degree of center clipping employed in the envelope reducing system. Any one of a variety of techniques may be employed. One suitable implementation is shown in FIG. 1. The band limited input signal produced by filter 13 is supplied to envelope detector 17, of any desired construction, to produce a control signal whose variations are proportional to signal envelope. The signal is further smoothed by low pass filter 18 and used to control adjustable gain amplifier 19. Amplifier 19, which may be any suitable unit whose gain is responsive to applied control signals, produces a slowly varying control signal whose magnitude is proportional to the magnitude of the envelope of the input signal. As a refinement, envelope detector 17 and filter 18 may be equipped with adjustable holdover circuits so that different time constants may be established to assure appropriate attack and release times for the control signal used to set the center clipper. This has been found to be helpful with certain classes of signals. The control signal developed by amplifier 19 is suitable for continuously controlling the clipping level.

Center clipping systems suitable for use in the practice of the invention may take any one of a number of forms well known in the art. One satisfactory form is shown within the dashed outline of unit 14. It includes a peak limiting network 21 and a combining network 22. Signals from filter 13 are supplied directly to combining network 22 and to peak limiter 21. Peak limited signals thereupon are subtracted from the filtered input signal to produce a signal containing only the peak extremities of the input signal, i.e., a center clipped signal.

Regardless of the form of center clipping employed, the effect on applied signals is much the same; only signals which exceed a fixed threshold level are retained in the output. This characteristic is illustrated in FIG. 2. For an ideal center clipper, a sharp break occurs at a selected threshold; there is no output below this threshold, but there is a reduced output, following a linear input-

output characteristic, above the threshold. An asymmetric power law device approaches this characteristic. A modified square law device may be used, and a cube law system yields good results, as depicted in FIG. 2. As indicated above, the threshold level, (for both positive and negative signal excursions) is, in accordance with the invention, adjusted automatically in response to a measure of the magnitude of the input signal envelope, by means of a control signal from amplifier 19, to maintain an essentially constant relative clipping level.

Reduced envelope signals delivered, in accordance with the invention, at output terminal 20 (FIG. 1), characteristically preserve high level envelope components but eliminate low level components. Thus, during periods of low input, an output signal is produced which is characterized by a gap, i.e., by zero signal level below a selected input level threshold. Moreover, transitions from intervals of above-threshold level signals and below level signal gaps are smooth and occur at a pitch synchronous rate. Therefore, no switching transients are interposed in the output signal, and signal discontinuity effects are minimized. The regenerated envelope thus exhibits a nonlinear input-output characteristic such that low level signals are effectively removed while higher amplitude signals are preserved.

Use of a network with such a characteristic has been found extremely useful in systems in which noise components are comparable in magnitude to weak signal level portions. By smoothly reducing the envelope of the signal to remove low level signals, which are masked by noise anyway, a signal is preserved which contains only portions whose levels are sufficiently great to withstand the influence of noise.

Similarly, reverberation in speech signals may be advantageously removed by envelope reduction. The action is particularly effective because of the smooth signal level control available. With a fast time constant, loud vowel sounds are noticeably limited; yet following sounds are not clipped.

In acoustic systems, such as public address sound systems, hands-free telephone systems, and the like, it has been found that acoustic feedback, which results in so-called sing-around characterized by a howling sound, is effectively reduced since frequent gaps are created in the signal to break up sustained oscillations. The nonlinear characteristic of the envelope reducing apparatus thus appreciably improves the stability of systems prone to acoustic feedback since the stability of such systems depends on gain averaged over short time intervals rather than on the instantaneous gain of the system.

The invention has been described, by way of example, in terms of a particular form of apparatus. It is to be understood, however, that the described arrangement is merely illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. Signal processing apparatus, which comprises, in combination,
 - means for selecting for processing a modulation sideband of an applied baseband signal,
 - means for controllably center clipping said selected modulation sideband signal, and
 - means for restoring said center clipped signal to baseband.
2. Apparatus for reducing the envelope of a signal which comprises, in combination,
 - means for shifting an applied signal to a higher frequency range,
 - means for center clipping a selected side frequency of said shifted signal, and
 - means for selectively restoring said center clipped signal to its original frequency range.

5

3. Apparatus for reducing the envelope of a signal which comprises, in combination,
 means for modulating an applied signal to shift it to a higher frequency range,
 means for center clipping a selected sideband of said modulated signal,
 means for selectively filtering said center clipped signal, and
 means for demodulating said filtered signal to shift it to the original frequency range of said applied signal.

4. Apparatus as defined in claim 3 in further combination with
 means for controlling the extent of center clipping in response to variations in a selected characteristic of said applied signal.

5. Apparatus as defined in claim 3 wherein, said means for center clipping a selected sideband signal includes, means supplied with a selected sideband signal for selectively limiting the peak excursions thereof, and means for subtracting said peak limited signal from said sideband signal.

6. Apparatus as defined in claim 5 wherein the extent of limiting by said limiting means is controlled by variations in the envelope of said selected sideband signal.

7. Apparatus for reducing the envelope of a signal, which comprises, in combination,

means for developing a relatively high frequency signal with an envelope representative of an applied communication signal,

means for adjustably center clipping said envelope signal,

means for developing an analog signal representative of said envelope substantially devoid of out-of-band harmonic signals,

means for developing a baseband signal representative of said analog signal representation, and

6

means for continuously adjusting the degree of said center clipping in accordance with variations in said applied communication signal.

8. Apparatus for reducing the envelope of a signal which comprises, in combination,

means supplied with a signal for modulating said signal with a selected carrier signal,

means for eliminating all but a selected one of the resulting modulation products,

means for center clipping said selected modulation product to preserve only the peak intervals thereof,

filter means with a selected passband for removing higher order harmonics associated with said center clipped signal, and

means for producing a baseband signal from said filtered signal.

9. Apparatus as defined in claim 8 wherein said means for center clipping said sideband signal exhibits a cube law characteristic.

10. Apparatus as defined in claim 8 wherein said means for center clipping said sideband signal exhibits an asymmetric power law characteristic.

References Cited

UNITED STATES PATENTS

1,550,660	8/1925	Affel	325—65X
3,028,554	4/1962	Hilliard, Jr.	328—117
3,094,667	6/1963	Brown	328—162

DONALD D. FORRER, Primary Examiner

J. ZAZWORSKY, Assistant Examiner

U.S. Cl. X.R.

307—237, 264; 328—162, 165