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SINGLE-SIDEBAND SYSTEM


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The invention relates to a single-sideband system comprising a transmitter and a receiver for the transmission of speech signals, in which the transmitter and the receiver are provided with a band compressor and a band expander, respectively. Such single-sideband systems may, for example, be used advantageously in carrier-wave telephone systems, inter alia in order to increase the capacity of speech transmission.

The invention has for its object to provide a comparatively simple single-sideband system of the aforesaid kind, which achieves on the one hand an appreciable economy of the frequency band and on the other hand provides good transmission quality, more particularly with respect to the intelligibility and the identification of the voices.

In accordance with the invention the single-sideband signal is fed on the one hand to an envelope detector in order to obtain a signal envelope and on the other hand, through a band compressor, to an amplitude modulator controlled by the signal envelope obtained from the envelope detector, the output signal of the amplitude modulator being transmitted to the receiver, which, in order to re-obtain the initial single-sideband signal, is provided with a band expander.

In order to further improve the transmission quality the speech signal is converted into single-sideband signals representing different frequency ranges, at least one of the lower frequency ranges being transmitted by means of the measure according to the invention.

The invention and its advantages will now be described more fully with reference to the figures.

Figs. 1 and 2 show one embodiment of a transmitter and a receiver respectively for use in a single-sideband system according to the invention.

Figs. 3 and 4 show a variant of the single-sideband transmitter and receiver shown in Figs. 1 and 2.

Figs. 5 and 6 show one embodiment of a transmitter and a receiver respectively, in which the speech signal is converted into single-sideband signals representing different frequency ranges.

The transmitter and the receiver shown in Figs. 7 and 8 represent improvements of the transmitter and the receiver shown in Figs. 5 and 6.

The transmitter and the receiver shown in Figs. 1 and 2 form part of a carrier-wave telephone system suitable for the transmission of speech signals by means of single-sideband modulation.

In the transmitter shown in Fig. 1 the signals obtained from a microphone 1 are supplied through a filter 2 passing the speech signals of 300 to 3200 C./s., subsequently to-amplification in an amplifier 3, to a single-sideband modulator 4, having an oscillator 5 for example 60 kc./s., connected thereto, and a single-sideband filter 6, which passes for example the upper sideband (60.3 to 63.2 kc./s.). The single-sideband signal thus obtained is fed to a band-compressor 7, which is connected by way of a filter 8 and a group modulator 9 with an oscillator 10 and an output filter 11 to a transmission cable 12.

In accordance with the invention the single-sideband signal in the band compressor 7 is supplied on the one hand, in order to obtain a signal envelope, to an envelope detector 13, and one the other hand by way of a band compressor 15 to an amplitude modulator 16, which is governed by the signal envelope obtained from the envelope detector 13. In practice it has been found to be favourable to provide a limiter 14 before the band compressor.

The band compressor 15 is constructed in the form of a frequency-division circuit, as a counting circuit arrangement comprising a counting tube, provided with an audible output filter to suppress unwanted distortion products. If the division factor is for example 10, a single-sideband signal is obtained from the single-sideband signal of 60.3 to 63.2 kc./s., the said signal lying in the frequency band from 60.3 to 63.2 kc./s., the bandwidth of which (0.29 kc./s.) is reduced in this manner with respect to the bandwidth of the initial single-sideband signal (2.9 kc./s.) by a factor 10.

In the amplitude modulator 16 the single-sideband signal from 60.3 to 63.2 kc./s. of approximately constant amplitude is modulated in amplitude by the output signal of the envelope detector 13, which is constituted by an amplitude detector 17 and a next-following low-pass filter 18 having a cut-off frequency of for example 300 c./s. and supplied through the group modulator 9 to the transmission cable 12.

Compared with the initial single-sideband signal a material economy in bandwidth is thus obtained, whilst the speech signal thus transmitted by band compression can be reproduced at the receiver end with a fairly good quality.

In order to improve the transmission quality with respect to the property of the limiter 14 to pass those speech components of the components supplied thereto which have a larger amplitude better than the other components, it has been found to be favourable to supply the speech signals from the microphone 1 by way of a pre-emphasis network 19 to the single-sideband modulator 4, since the pre-emphasis network 19 provides an amplitude equalization of the transmitted signal so that in the limited single-sideband signal also the higher speech frequency components of the speech frequency band of for example 2000 to 3200 C./s. are fairly well represented.

Instead of using the frequency-division arrangement shown in the embodiment use may be made of other frequency division arrangements. Thus, use may, for example, be made of a counting circuit comprising a plurality of pulse generators exciting one another in succession, each of these pulse generators producing a division by a factor 2 (so-called binary counting circuit). For the frequency division use may furthermore be made advantageously of an oscillator tuned approximately to the desired subharmonic of the carrier-frequency of the single-sideband signal and synchronized by the single-sideband signal (cf. for example Proceedings of the I. R. E. of December 1944, pages 730 to 737).

Fig. 2 shows the receiver cooperating with the transmitter shown in Fig. 1.

The incoming signals from a transmission cable 12 are supplied subsequent to high-frequency amplification in an amplifier 20, by way of a group demodulator 21, comprising an oscillator 22, connected thereto, and an output filter 23, to a band expander 24, comprising an output filter 25 and converting the single-sideband signal transmitted by band compression into the initial frequency band. The single-sideband signal thus obtained is demodulated in a single-sideband demodulator 26, comprising a local oscillator 27 and a filter 28, passing only the speech-frequency band from 0.3 to 3.2 kc./s. and sup-
applied through a de-emphasis network 29 and a low-frequency amplifier 30 to a reproducing device 31.

In order to re-obtain the initial single-sideband signal the incoming single-sideband signal is supplied to the expander 24 on the one hand to an envelope detector 32, which is constituted by an amplitude detector 33 and a low-pass filter 34, having a cut-off frequency of for example 300 C./S., and on the other hand via a limiter 35 and a band expander 36 to an amplitude modulator 37, which is governed by the signal envelope obtained from the envelope detector 32.

The band expander 36 is constituted by a frequency multiplication circuit, comprising a suitable output filter to suppress unwanted distortion products and to this end use may, for example, be made of frequency multiplication circuits of the kind used with frequency-modulation transmission (cf. for example French patent specification No. 972,594). If, in the embodiment shown, for example the frequency band of the single-sideband signal obtained from the limiter 35 is 6.03 to 6.52 kc./s., a single-sideband signal is obtained in the initial frequency band from 60.3 to 63.2 kc./s., subsequent to frequency multiplication by a factor 10 in a frequency multiplier 36 subsequent to amplitude modulation with the signal envelope in the amplitude modulator 36 this signal yields approximately the initial single-sideband signal. The transmitted conversation is, in this case, satisfactory.

In the system shown transit time differences between the envelope channel and the band-compression or the band-expansion channel may produce a reduction of the transmission quality. If these transit time differences are a source of interference, one of these channels may be provided with a network equalizing the transit time differences.

A particularly simple band expansion arrangement is obtained by using a class C amplifying stage, which is controlled by the frequency-compressed single-sideband signal in this case, a suitable output filter permitting the attainment of approximately the initial single-sideband signal.

Figs. 3 and 4 show a variant of the single-sideband system described above.

Fig. 3 shows the transmitter and Fig. 4 shows the receiver. Corresponding elements are designated by the same reference numerals.

The transmitter shown in Fig. 3 differs from the transmitter shown in Fig. 1 in the construction of the band compressor 7. In this system the compression is obtained by supplying the single-sideband signal taken from the limiter 39, and which has been processed by a frequency discriminator 71, and by a frequency multiplier 72, which is connected to an oscillator 73, for example a reactance tube. This band compressor 38, 39, 40 is constructed in a manner such that a frequency variation of the limited single-sideband signal by way of the frequency discriminator and the frequency modulator 40 produces a correspondingly smaller variation of the oscillator frequency. In this case, for example, a frequency variation of the limited single-sideband signal was reduced to a ten times smaller variation of the oscillator frequency i. e. the band compressor factor was 10.

Fig. 4 shows the corresponding single-sideband receiver, comprising a band expander constituted by a frequency discriminator 41 and a subsequent frequency modulator 42, which is coupled with a local oscillator 43, this band expander 41—43 thus corresponding in construction to the band expander 38—40 used in the transmitter. However, this band expander 41—43 is intended to be such that a frequency variation of the limited single-sideband signal produces a correspondingly larger variation of the oscillator frequency. In the example shown, the band expansion factor is chosen to be 10 in order to re-obtain the initial single-sideband signal.

In the arrangement shown small differences between the band compression factor and the band expansion factor appear to be permissible, which is of particular importance for a simple construction of the band compressor and the band expander.

After the foregoing it will be obvious that the transmitter shown in Fig. 1 may be used in combination with a receiver shown in Fig. 4 or else the transmitter shown in Fig. 3 may be combined with the receiver shown in Fig. 2.

A further improvement in transmission quality may be obtained by converting the speech signal into single-sideband signals representing different formant ranges, at least one of the lower formant ranges being transmitted by means of the single-sideband system described above.

Such a system is shown in the Figs. 5 and 6: Fig. 5 shows the transmitter and Fig. 6 shows the receiver.

In the transmitter shown in Fig. 5 the low-frequency amplifier is connected to a band compressor 44, comprising three parallel-connected channels 45, 46, 47 with input filters 48, 49, 50, passing respectively formant ranges from 300 to 800 C./S., 800 to 2000 C./S. and 2000 to 3200 C./S. Each of these parallel-connected channels comprises the cascade combination of a single-sideband modulator 51, 52, 53, a single-sideband filter 54, 55, 56, a limiter 57, 58, 59, a frequency division stage 60, 61, 62 and an output filter 63. These are connected in parallel with the group modulator 9. The channel 45, associated with the lowest formant range from 300 to 800 C./S., comprises furthermore a modulator stage 66, connected to the frequency division stage 60 controlled by the output voltage of the envelope detector, constituted by an amplitude detector 67 and a subsequent low-pass filter 68, having a cut-off frequency of for example 300 C./S.

To the modulators 51, 52, 53 are connected oscillators 69, 70 respectively, having a frequency of for example 57 kc./s. and 60 kc./s. to obtain the amplitude modulation of the speech frequencies lying in the various formant ranges: the single-sideband filters 54, 55, 56 allow the upper sidebands in frequency bands from 57.3 to 57.8 kc./s., 60.8 to 62 kc./s. and 62 to 63.2 kc./s. respectively to pass. These single-sideband signals are divided, subsequent to limitation, in the frequency division devices 60, 61, 62, for example by a factor 10 and, subsequent to division, they produce single-sideband signals in the frequency bands from 5.73 to 5.78 kc./s., 6.08 to 6.2 kc./s. and 6.2 to 6.32 kc./s. respectively. The frequency space introduced between the single-sideband signal from 5.73 to 5.78 kc./s. and the single-sideband signal from 6.08 to 6.2 kc./s. may be used for the transmission of the amplitude modulation of the single-sideband signal from 5.73 to 5.78 kc./s.. In the example shown the output filter 63 of the channel 45 may, to this end, have a minimum pass-band from 5.73 to 6.08 kc./s.

The output voltages of the channels 45, 46, 47 (only the signal envelope of the channel 45 is transmitted) are transmitted via the group modulator 9 and the output cable 12 to the receiver shown in Fig. 6.

In the receiver shown in Fig. 6, the output voltage of the group demodulator 21, in order to re-obtain the initial single-sideband signal, is supplied to a band-expander 71, comprising three parallel-connected channels 72, 73, 74, which correspond to the band compressor channels 45, 46, 47 respectively in the transmitter.

Each of these channels 72, 73, 74 comprises the cascade connection of the frequency-transformer stages 75, 76, 77, a filter 78, 79, 80, a limiter 81, 82, a frequency multiplier 83, 84 and 85, a filter 87, 88, 89 and the channel 72 associated with the lowest formant ranges comprises moreover an amplitude modulator 90, which is controlled by the output voltage of an envelope detector 91, connected to the filter 78, and the subsequent low-pass filter 92, having a cut-off frequency of for example 300 C./S.

To the frequency transformer stages 75, 76, 77 are
connected oscillators 93 and 94 respectively, producing frequencies such that the single-sideband signal of the lowest formant range with respect to the single-sideband signals representing the upper formant range is shifted into its initial position. In the example shown the single-sideband signal from 6.03 to 6.08 kc./s., which amplitude-modulated by the signal envelope, is produced at the output of the filter 78, having a pass-band of for example 6.03 to 6.38 kc./s., whilst the filters 79 and 80 pass the single-sideband signals of constant amplitude lying in the adjacent frequency bands from 6.08 to 6.2 kc./s. and 6.2 to 6.52 kc./s. These single-sideband signals yield, subsequent to frequency multiplication in the frequency multipliers 84, 85, 86, by a pass-band 10, the single-sideband signals in the initial formant ranges from 60.3 to 60.8 kc./s., 60.8 to 62 kc./s. and 62 to 63.2 kc./s.

The single-sideband signal from 60.3 to 60.8 kc./s., subsequent to amplitude modulation with the signal envelope in the amplitude modulator 90 is supplied, together with the single-sideband signals from 60.8 to 62 kc./s. and 62 to 63.2 kc./s. to the single-sideband demodulator 26, from the output circuit of which the transmitted speech signal is obtained.

In order to avoid interference signals during the speech intervals in the transmission channels for the higher formant ranges, it may be advantageous to provide a threshold device in these channels.

In this arrangement the speech signal is characterized by the three components in the various formant ranges, which determine the quality of the speech signal with a satisfactory accuracy. By using the system described above an improvement in the transmission quality is obtained.

The dynamic power of the speech components, transmitted with constant amplitude, in the formant ranges from 800 to 2000 C./S., and 2000 to 3200 C./S. may be introduced at the receiver end in a simple manner by including an amplitude modulator 95 and 96 in each of the channels between the frequency multipliers 85 and 86 respectively and the output filter 88 and 89 respectively, this modulator being controlled by the output voltage of the envelope detector 91 and 92 respectively of the channel 72. The dynamic power of the speech components in the formant ranges from 800 to 2000 C./S. and 2000 to 3200 C./S. appears to follow that of the lowest formant range.

If desired, instead of using the envelope of the speech component of the formant range from 300 to 800 C./S., use may be made of that of the formant range from 800 to 2000 C./S.

A further improvement in the transmission quality may be obtained by using the system shown in Figs. 7 and 8. This improvement consists in that the speech components of the various formant ranges are united in the correct intensity ratios.

In the transmitter shown in Fig. 7 the output voltages of the frequency multipliers 61, 62 in the band compression channels 46, 47 associated with the higher formant ranges are supplied to amplitude modulators 97, 98 which are controlled by the output voltage of an amplitude detector 99 and 100 respectively, connected to the output circuit of the single-sideband filter 55 and 56 respectively and of a subsequent low-pass filter 101 and 102 respectively, having a low cut-off frequency of for example 40 C./S. The level of the output signals of the channels 46, 47 is then determined by the level of the speech components supplied to the channels 46, 47.

In order to reproduce the speech components of the various formant ranges in the correct intensity ratio at the receiver end (cf. Fig. 8), each of the input filters 79, 80 of the channels 73 and 74 respectively is connected to an envelope detector, being constituted by an amplitude detector 103 and 104 respectively and a low-pass filter 105 and 160 respectively, having a cut-off frequency of for example 40 C./S., the output voltage of which controls a governing tube 107 and 108 respectively, connected after the amplitude modulator 95 and 96 respectively in order to control the level.

In order to avoid a reaction of the level of the channel 72 on the signal levels of the channels 72 and 74, the signals from the envelope detectors 91 and 92 in the channel 72 are supplied to the amplitude modulators 95 and 96 respectively via a automatic volume-control amplifier 109, the automatic volume control-voltage being obtained, for example by rectification of the signals supplied to the channel 72.

For level control the governing tubes 107 or 108 may, for example, be connected between the amplifiers 109 and the amplitude modulator 95 or 96 respectively. The dynamic power control and the level control in the channels 73 and 74 do not substantially influence one another, since they are operative in different frequency ranges.

By using this single-sideband system a very satisfactory speech quality is obtained.

In order to improve the economy in bandwidth, in the single-sideband system the band compression factor may be raised and/or the frequency band of the envelope signal may be reduced: for example band compression factors from 40 to 50 may be used and an economy of the band of the envelope to 100 or even 40 C./S. is possible.

What is claimed is:

1. A single-sideband transmission system comprising a transmitter having a source of a modulated single-sideband signal, an envelope detector circuit connected to receive said signal and produce therefrom an envelope thereof, a band compressor circuit connected to receive said signal and produce therefrom a frequency-compressed signal, and an amplitude modulator connected to modulate said frequency-compressed signal with said envelope thereby producing an output signal, and a receiver for receiving said output signal, said receiver comprising an envelope detector circuit connected to receive said output signal and produce therefrom an envelope thereof, a band expander circuit connected to receive said output signal and produce therefrom a frequency-expanded signal, and an amplitude modulator connected to modulate said frequency-expanded signal with the last-named envelope.

2. A transmission system as claimed in claim 1, in which said source of a modulated single-sideband signal comprises a speech signal source, a single-sideband modulator, and a pre-emphasis network connected between said speech signal source and said single-sideband modulator, and in which said receiver comprises a single-sideband demodulator connected to the output of the last-named amplitude modulator thereby producing a demodulated signal, and a de-emphasis network connected to receive said demodulated signal.

3. A transmission system as claimed in claim 1, in which said source of a modulated single-sideband signal comprises an audio signal source, means for converting said audio signal into a plurality of signals having different frequency formant ranges, and a single-sideband modulator connected to produce said modulated single-sideband signal from at least one of said plurality of signals.

4. A transmission system as claimed in claim 3, including means for transmitting the remaining ones of said plurality of signals, and in which said receiver includes additional channels for receiving said remaining signals, each of said additional channels including a band expander circuit and an amplitude modulator connected to the output of the respective band expander circuit, and means connecting the output of said receiver envelope detector circuit as a modulating voltage to each of said receiver amplitude modulators.

5. A transmission system as claimed in claim 4, including a plurality of automatic volume-control amplifiers.
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5. A single-sideband transmitter, comprising a source of a modulated single-sideband signal, an envelope detector circuit connected to receive said signal and produce therefrom an envelope thereof, a band compressor circuit connected to receive said signal and produce therefrom a frequency-compressed signal, and an amplitude modulator connected to modulate said frequency-compressed signal with said envelope.

7. A transmitter as claimed in claim 6, including an amplitude limiter connected to limit the amplitude of said signal as received by said band compressor circuit.

8. A transmitter as claimed in claim 6, in which said band compressor circuit comprises a frequency division circuit.

9. A transmitter as claimed in claim 6, in which said band compressor circuit comprises an oscillator tuned approximately to a subharmonic of the carrier wave of said single-sideband signal, and means connected to synchronize said oscillator by said single-sideband signal.

10. A transmitter as claimed in claim 6, in which said band compressor comprises a local oscillator, a frequency modulator connected to frequency-modulate said local oscillator, and a frequency discriminator connected to control said frequency modulator.

11. A single-sideband receiver for receiving a frequency-compressed single-sideband signal, comprising an envelope detector circuit connected to receive said signal and produce therefrom an envelope thereof, a band expander circuit connected to receive said signal and produce therefrom a frequency-expanded signal, and an amplitude modulator connected to modulate said frequency-expanded signal with said envelope.

12. A receiver as claimed in claim 11, including an amplitude limiter connected to limit the amplitude of said signal as received by said band expander circuit.

13. A receiver as claimed in claim 11, in which said band expander circuit comprises a class C amplifier.

14. A receiver as claimed in claim 11, in which said band expander circuit comprises a frequency multiplication circuit.

15. A receiver as claimed in claim 11, in which said band expander circuit comprises a local oscillator, a frequency modulator connected to frequency-modulate said local oscillator, and a frequency discriminator connected to control said frequency modulator.

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