600841

COMMONWEALTH of AUSTRALIA

PATENTS ACT 1952

APPLICATION FOR A STANDARD PATENT

~~I~~ We FUJITSU LIMITED,
OF 1015, Kamikodanaka,
Nakahara-ku,
Kawasaki-shi, Kanagawa 211,
JAPAN

hereby apply for the grant of a Standard Patent for an invention entitled:

"VOICE BAND SPLITTING SCRAMBLER"

which is described in the accompanying ~~provisional~~ complete specification.

Details of basic application(s):—

Number	Convention Country	Date
62-182080	JAPAN	21st July 1987

APPLICATION ACCEPTED AND AMENDMENTS ALLOWED 15-6-90.

The address for service is care of DAVIES & COLLISON, Patent Attorneys, of 1 Little Collins Street, Melbourne, in the State of Victoria, Commonwealth of Australia.

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Dated this 20th day of July 19 88

To: THE COMMISSIONER OF PATENTS

(a member of the firm of DAVIES & COLLISON for and on behalf of the Applicant).

Davies & Collison, Melbourne and Canberra.

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

DECLARATION IN SUPPORT OF CONVENTION OR NON-CONVENTION APPLICATION FOR A PATENT

Insert title of invention.

In support of the Application made for a patent for an invention entitled: VOICE BAND SPLITTING SCRAMBLER

Insert full name(s) and address(es) of declarant(s) being the applicant(s) or person(s) authorized to sign on behalf of an applicant company.

I ~~We~~ Bunichi Oguchi, Executive Vice President and Representative Director of FUJITSU LIMITED of 1015, Kamikodanaka, Nakahara-ku, Kawasaki-shi, Kanagawa 211, Japan

Cross out whichever of paragraphs 1(a) or 1(b) does not apply. 1(a) relates to application made by individual(s). 1(b) relates to application made by company; insert name of applicant company.

do solemnly and sincerely declare as follows :–

1. (a) ~~I am / We are XXXXXXXXXXXXXXXXXXXXXXXX~~

or (b) I am authorized by

FUJITSU LIMITED

the applicant............. for the patent to make this declaration on its ~~XXXX~~ behalf.

Cross out whichever of paragraphs 2(a) or 2(b) does not apply. 2(a) relates to application made by inventor(s). 2(b) relates to application made by company(s) or person(s) who are not inventor(s); insert full name(s) and address(es) of inventors.

2. (a) ~~I am / We are XXXXXXXXXXXXXXXXXXXXXXXXXXXX~~

or (b) 1)Naoya Torii: Suifukan 201, 55-5, Shiratoridai, Midori-ku, Yokohama-shi, Kanagawa 227, Japan

2)Ryota Akiyama: 3-26-15, Nishiogikita, Suginami-ku, Tokyo 167, Japan

3)Mitsuhiro Azuma: Fujitsu Haitsu B-227, 3-12-3, Miyamaedaira, Miyamae-ku, Kawasaki-shi, Kanagawa 213, Japan

~~is~~ are the actual inventor....s..... of the invention and the facts upon which the applicant............ is ~~are~~ entitled to make the application are as follows :–

State manner in which applicant(s) derive title from inventor(s)

The applicant is the assignee of the actual inventors, in respect of the invention.

Cross out paragraphs 3 and 4 for non-convention applications. For convention applications, insert basic country(s) followed by date(s) and basic applicant(s).

3. The basic application........... as defined by Section 141 of the Act was ~~were~~ made

in Japan .... on the 21st day of July, 1987

by FUJITSU LIMITED

in .... on the ....

by ....

in .... on the ....

by ....

4. The basic application.......... referred to in paragraph 3 of this Declaration was ~~were~~ the first application.......... made in a Convention country in respect of the invention the subject of the application.

Insert place and date of signature.

Declared at Kawasaki-shi, Kanagawa, Japan this 11th day of July, 1988

Signature of declarant(s) (no attestation required)

FUJITSU LIMITED

Bunichi Oguchi, Executive Vice President and Representative Director

Note: Initial all alterations.

DAVIES & COLLISON, MELBOURNE and CANBERRA.

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(71) Applicant(s)
FUJITSU LIMITED

(72) Inventor(s)
NAOYA TORII; RYOTA AKIYAMA; MITSUHIRO AZUMA

(74) Attorney or Agent
DAVIES & COLLISON, MELBOURNE

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(57) Claim

1. A voice band splitting scrambler, comprising:

band splitting means for splitting an input voice band into a plurality of different subbands all having the same band width; and

scrambled voice signal generating means, operatively connected to said band splitting means, for obtaining, from said different subbands, a scrambled voice band in which each of said different subbands is relocated and at least a part of said different subbands is inverted in frequency;

said scrambled voice signal generating means including:

first modulating means, operatively connected to said band splitting means, for effecting frequency modulations on said different subbands by the use of a first set of carrier signals to obtain upper side bands and lower side bands with respect to said first set of carrier signals; and

adding means, operatively connected to said modulating means, for adding a part of said lower side bands and a part

.../2

of said upper side bands;

said different subbands, after frequency shifting by said first modulating means, and recombination in said adding means, forming the same bandwidth as said input voice band, the frequencies of said first set of carrier signals being determined in such a way that the added result includes a scrambled voice band in which said different subbands are relocated to form a continuous spectrum and at least a part of said different subbands is inverted in frequency.

COMMONWEALTH OF AUSTRALIA

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COMPLETE SPECIFICATION

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Name of Applicant: FUJITSU LIMITED

Address of Applicant: 1015, Kamikodanaka, Nakahara-ku, Kawasaki-shi, Kanagawa 211, JAPAN

JAPAN

Actual Inventor(s): Naoya TORII, Ryota AKIYAMA, Mitsuhiro AZUMA

Address for Service: DAVIES & COLLISON, Patent Attorneys, 1 Little Collins Street, Melbourne, 3000.

Complete specification for the invention entitled:

"VOICE BAND SPLITTING SCRAMBLER"

The following statement is a full description of this invention, including the best method of performing it known to us :-

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to a voice band splitting scrambler or, in other words, a secret speech apparatus based on a band splitting and band relocating system. Particularly, the present invention relates to a band splitting ~~scramlber~~ scrambler (hereinafter, voice scrambler) having a constitution for collectively carrying out a spectrum inverting process of respective band-split channels to realize a simplification of the hardware.

(2) Description of the Related Arts

As a voice scrambler for realizing scrambled voice communications, an apparatus utilizing a band splitting and band relocation system is in practical use. This apparatus divides a speech frequency band into equal parts and relocates the divided parts. When relocating, the apparatus inverts and shifts predetermined bands.

As a conventional voice scrambler, the HW13 of the MARCONI Co. is known and disclosed in "Explanation of Scrambled Voice Apparatus", Suurikagaku (mathematical science), December, 1975.

This conventional apparatus has a disadvantage of a large amount of hardware or a construction containing too many elements, because the spectrum inverting process and the band relocating process of the split bands are carried out by separate elements, as later described in more detail with reference to the drawings.

SUMMARY OF THE INVENTION

An object of the present invention is to solve the problem of the conventional apparatus by providing a voice band splitting scrambler wherein the number of multipliers is reduced and thus the hardware is simplified.

To attain the above object, there is provided, according to the present invention, a voice band splitting scrambler which comprises a band splitting unit for splitting an input speech signal into a plurality of band channels; and a voice scrambling signal generating unit for carrying out spectrum-inverting or noninverting operations and band-relocating operations on the respective channels to generate a voice scrambled signal.

The voice scrambling signal generating unit includes a modulating unit for band-relocating the respective channels according to noninverting carriers or inverting carriers that are set in different bands respectively; and an adding unit for adding signals of noninverted channels and signals of inverted channels to each other.

More specifically, the invention provides a voice band splitting scrambler, comprising:

band splitting means for splitting an input voice band into a plurality of different subbands all having the same band width; and

scrambled voice signal generating means, operatively connected to said band splitting means, for obtaining, from said different subbands, a scrambled voice band in which each of said different subbands is relocated and at least a part of said different subbands is inverted in frequency;

said scrambled voice signal generating means including:

first modulating means, operatively connected to said band splitting means, for effecting frequency modulations on said different subbands by the use of a first set of carrier signals to obtain upper side bands and lower side bands with respect to said first set of carrier signals; and

adding means, operatively connected to said modulating means, for adding a part of said lower side bands and a part of said upper side bands;

said different subbands, after frequency shifting by said first modulating means, and recombination in said adding means, forming the same bandwidth as said input voice band, the frequencies of said first set of carrier signals being determined in such a way that the added result includes a scrambled voice band in which said different subbands are relocated to form a continuous spectrum and at least a part of said different subbands is inverted in frequency.

BRIEF DESCRIPTION OF THE DRAWINGS

The above object and features of the present invention will be more apparent from the following description of the preferred embodiments with reference to the drawings, wherein:

Fig. 1 is a block diagram showing a principle of an embodiment of the present invention;

Fig. 2 is a block diagram showing a detailed constitution of the first embodiment of the present invention;

Figs. 3A to 3C are views explaining the relationships of carrier frequencies and multiplier outputs;

Figs. 4A to 4E are views showing an example of band splitting process for reducing the order of a bandpass filter (BPF_2);

Figs. 5A to 5D are views explaining signal spectra corresponding to Table 2;

Figs. 6A to 6E are views corresponding to Table 2a for explaining signal spectra at the outputs of the multipliers 231 to 235;

Figs. 7A to 7E are views corresponding to Table 2a for explaining signal spectra after the adders 251 and 253;

Figs. 8A to 8D are views explaining signal spectra corresponding to Table 4;

Figs. 9A to 9D are views explaining a process in which no inverted carriers are prepared;

Fig. 10 is a block diagram showing a constitution of a second embodiment of the present invention;

Figs. 11A to 11G are views explaining signal spectra corresponding to Table 6;

Figs. 12A and 12B are views explaining schematically a band splitting and relocating system;

Fig. 13 is a block diagram showing a constitution of a conventional voice band splitting scrambler;

Fig. 14 is a view showing an example of an output spectrum of a bandpass filter (BPF_{11}) 603;

Figs. 15A to 15E are views showing examples of output spectra of multipliers 611 to 615;

Figs. 16A to 16C are views explaining non-inverting and inverting processes of the prior art;

Figs. 17A to 17E are views explaining the noninverting and the inverting processes of the prior art for each channel in more detail;

Fig. 18 is a view showing an example of a conventional band relocating portion; and,

Figs. 19A to 19G are views explaining the band relocating process and scrambled voice outputs of the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

For a better understanding of the present invention, a conventional voice scrambler apparatus and the problems therein will be first described with reference to Figs. 12 to 19.

Figures 12A and 12B are views explaining an outline of the band splitting and relocating system.

A speech frequency band (0.25 kHz to 3.0 kHz in a radio communication) is split by five into channels ① to ⑤ each having a band width of 550 Hz.

Note that a speech frequency band in a telephone communication ranges from 0.3 kHz to 3.3 kHz. In this case, each of the five split band widths is 600 Hz. In the following description of the conventional device, the speech frequency band from 0.25 kHz to 3.0 kHz is used.

The channels are relocated in the order of $\overline{⑤}$, ③, $\overline{④}$, $\overline{②}$ and ① to provide a scrambled voice signal, and the channels ② (0.8 kHz to 1.35 kHz), ④ (1.9 kHz to 2.45 kHz) and ⑤ (2.45 kHz to 3.0 kHz) are spectrum-inverted.

Figure 13 is a block diagram showing an apparatus that realizes the band splitting and relocating system for splitting a speech frequency band into five channels and relocating the channels. The conventional example shown here is that disclosed as a scrambled voice apparatus HW13 of the MARCONI Co., ("Explanation of Scrambled Voice Apparatus", Suurikagaku (mathematical science), December, 1975).

In the figure, a voice signal input to an input terminal 601 is filtered by a bandpass filter (BPF_{11}) 603 to a frequency band from 250 Hz to 3000 Hz and input to multipliers 611 to 615 for channels ① to ⑤. In the multipliers 611 to 615 corresponding to the respective channels, the filtered voice signal (250 Hz to 3000 Hz) is modulated with carriers f_1 (4050 Hz), f_2 (4600 Hz), f_3 (5150 Hz), f_4 (5700 Hz) and f_5 (6250 Hz), respectively. The channels are filtered to 3250 Hz to 3800 Hz with bandpass filters (BPF_{12}) 621 to 625. Signals of the respective bandlimited channels correspond to signals obtainable by splitting the voice signal, which has been band-limited by the bandpass filter 603, by five.

Figure 14 is a view showing an example of the output spectrum of the bandpass filter 603. The voice signal is assumed to have a continuous spectrum in the frequency band of from 250 Hz to 3000 Hz.

Figures 15A to 15E are views showing examples of output spectra of the multipliers 611 to 615 corresponding to the respective channels. In the respective channels, the voice signal (250 Hz to 3000 Hz) is modulated by the carriers f_1 to f_5. For example, in the channel ①, the signal is modulated with the carrier f_1 (4050 Hz) in the multiplier 611 to form a lower sideband from 1050 (4050 - 3000) Hz to 3800 (4050 - 250) Hz and an upper sideband from 4300 (4050 + 250) Hz to 7050 (4050 + 3000) Hz. Other channels are processed in a similar way.

Hatched portions in the lower sidebands indicate output spectra of the bandpass filters 621 to 625.

The outputs of the bandpass filters 621 to 625 are modulated by carriers f1R to f2R of multipliers 631 to 635, and are passed through bandpass filters 641 to 645 whereby the outputs are determined to be noninverted outputs or inverted outputs. Namely, with respect to the channels ⓘ (i = 1 to 5), carriers (frequencies f_{iR}) of direct current components (f_{iR} = 0 Hz) are input to the multipliers 631 to 635 for a noninversion process, and those of sine waves are input for an inversion process.

Figure 16A is a view showing an example of an output spectrum of one of the bandpass filters 621 to 625. With respect to this output spectrum, Fig. 16B is a view showing an output spectrum of one of the multipliers 631 to 635 for the noninverting process (f_{iR} = 0 Hz), and Figure 16C is a view showing an output spectrum of one of the multipliers 631 to 635 for the inversion process (f_{iR} = 7.05 kHz).

Accordingly, to obtain the noninverted channels ① and ③ and the inverted channels ②, ④ and ⑤ as shown in Fig. 12, as an example, it is sufficient to supply the carrier frequencies f_{2R}, f_{4R} and f_{5R} equal to 7.05 kHz, while the carrier frequencies f_{1R} and f_{3R} are set to 0 Hz, as shown in Figs. 17A to 17E.

After the noninverting process or inverting process, the signals are filtered by bandpass filters 641 to 645 to a frequency band from 3.25 kHz to 3.8 kHz, and therefore, an upper sideband (10.3 kHz to 10.85 kHz) at the time of inversion process is blocked.

The signals are then modulated by multipliers 651 to 655 to required bands and relocated. The relocating process is carried out by properly combining the carriers f_1 (4050 Hz), f_2 (4600 Hz), f_3 (5150 Hz), f_4 (5700 Hz) and f_5 (6250 Hz) and assigning them to f_{ip} (i = 1 to 5). Then, the signals of the respective channels are modulated to a base band (250 Hz to 3000 Hz), and synthesized in an adder 661.

Figure 18 is a view showing an example of combination of the carriers f_i of the multipliers 611 to 615 and the carriers f_{ip} of the multipliers 651 to 655.

The combination is determined according to a predetermined logic in a relocating portion 801.

By the example shown in Fig. 18, the relocated channels from the low frequency band to the high frequency band are the original channels ⑤, ③, ④, ②, and ①.

Figures 19A to 19E are views showing output spectra of signals relocated (or modulated) by the multipliers 651 to 655.

Figure 19F is a view showing output spectra of signals added by the adder 661.

Figure 19G is a view showing an output spectrum of signals added in the adder 661 according to the assignment.

The channels ②, ④ and ⑤ are inverted in the multipliers 632, 634 and 635 and the bandpass filters 642, 644 and 645, respectively.

A low-pass filter 671 blocks an upper sideband (5100 Hz to 7850 Hz) of the signals which have been modulated by the multipliers 651 to 655 and added to each other by the adder 661, and outputs a lower sideband (250 Hz to 3000 Hz) of the signals as a scrambled voice signal to an output terminal 673.

As described above, according to the conventional voice scrambler apparatus, the inversion and relocation processes of the spectra of split bands are carried out separately by using the multipliers 631 to 635 and 651 to 655, and thus a problem arises in that the number of components including the bandpass filters 641 to 645 for blocking an upper sideband at the time of inversion process is increased.

Further, because the carrier frequencies for inversion and relocating process are too high, the number of poles of the bandpass filters in the conventional system is so large that it is difficult to obtain sharp cut off characteristics of the bandpass filters.

Embodiments of the present invention will now be described.

Figure 1 is a block diagram showing a principle of an embodiment of the present invention.

In the Figure, a band splitting unit 11 splits an input voice signal into a plurality of band channels.

A modulating unit 15 relocates the bands of respective channels by the use of noninverting carriers or inverting carriers that are set in different bands respectively.

In the following description, the term noninverting carrier refers to a modulating carrier signal used to output the scrambled voice signal in which the band split signals are relocated without inversion; and the term inverting carrier refers to a modulating carrier signal used to output the scrambled voice signal in which the band split signals are inverted and relocated.

An adding unit 17 adds the signals of the noninverted channels and signals of the inverted channels to each other.

The modulating unit 15 and the adding unit 17 form a scrambled voice signal generating unit 13 for performing spectrum-inverting and band-relocating operations with respect to the respective channels to generate a scrambled voice signal.

Preferably, the adding unit 17 includes an adding device for adding the signals of noninverted channels to each other and adding the signals of inverted channels to each other, and a device for modulating at least one of the added signals and adding the signals of both of the channels to form a continuous spectrum.

Alternatively, preferably the noninverting carriers and inverting carriers are set such that the band of an upper sideband of a signal modulated by one of the carriers coincides with the band of a lower sideband of a signal modulated by the other of the carriers.

In operation, the modulating unit 15 relocates the bands of respective channels with the noninverting carriers or the inverting carriers which are set in the different bands respectively. The adding unit 17 adds the signals of the noninverted channels and the signals of the inverted channels to each other, and as a result, the signals of the noninverted channels and the signals of the inverted channels are collectively processed, thus allowing a reduction of the number of multipliers conventionally needed for the spectrum inverting process.

For example, by adding the noninverted channel signals to each other and adding the inverted channel signals to each other, and by modulating at least one of the added signals such that a continuous spectrum is formed when the one added signal is added to the other added signal, a collective process of the noninverted channel signals and the inverted channel signals is realized.

Alternatively, the noninverted carriers and inverted carriers are set such that the band of an upper sideband of a signal modulated by one of the carriers coincides with the band of a lower sideband of a signal modulated by the other of the carriers. By adding signals of the noninverted channels and signals of inverted channels to each other, the band-relocating process and the spectrum-inverting process can be performed simultaneously.

Figure 2 is a block diagram showing a detailed constitution of the first embodiment of the present invention.

A voice signal input to an input terminal 201 is input to multipliers 211 to 215 through a bandpass filter (BPF_1) 203. Carriers f_1 to f_5 having different frequencies respectively are input to the multipliers 211 to 215, and multiplied by the band-limited voice signal. The outputs of the multipliers 211 to 215 are input to multipliers 231 to 235 through bandpass filters (BPF_2) 221 to 225, respectively, and inverting or noninverting carriers F_1 to F_5, which are selected in accordance with a key operated, and having different frequencies respectively are input to the multipliers 231 to 235, for multiplication. The outputs of the multipliers 231 to 235 are input to an adder 251 or an adder 253 through a switching circuit 241, an output of the adder 253 is input into a multiplier 257 through a bandpass filter (BPF_3) 255, an output multiplied by a carrier F_0 of the multiplier 257 is input together with an output of the adder 251 into an adder 261, and an output of the adder 261 is sent to an output terminal 273 through a low-pass filter (LPF) 271.

An oscillator 281 selects predetermined frequencies according to set values of a table 283 to send the carriers to the multipliers 211 to 215, 231 to 235 and 257 as well as sending a switching control signal to the switching circuit 241.

The band splitting unit 11 in the block diagram shown in Fig. 1 showing the principle of the embodiment of the present invention includes the bandpass filter 203, multipliers 211 to 215, and bandpass filters 221 to 225 in Fig. 2. Similarly, the modulating means 15 includes the multipliers 231 to 235, oscillator 281, and table 283, and the adding unit 17 includes the switching circuit 241, adders 251 and 253, bandpass filter 255, multiplier 257, and adder 261.

In this embodiment, an explanation will be made for a case in which a voice signal band-limited in the bandpass filter 203 to a band from 300 Hz to 3300 Hz is split by five (a band of each channel being 600 Hz) (Fig. 3A)

It is, of course, possible to split a band from 250 Hz to 3000 Hz as shown in Fig. 12.

The multipliers 211 to 215 corresponding to the respective channels modulate the voice signal (300 Hz to 3300 Hz) with the carriers f_1 to f_5. The respective channels of the modulated signal are filtered through the bandpass filters 221 to 225 so that the bands of the respective channels are properly arranged.

The number of poles of the bandpass filters 221 to 225 may be reduced by reducing the center frequencies of the filters, if the filters have the same characteristics. Therefore, by setting the carrier frequencies of the multipliers 211 to 215 low enough that the outputs of the bandpass filters are not distorted due to reflected signal components which are called as an "aliasing" noise, the number of the poles of the bandpass filters 221 to 225 may be reduced.

Figures 3B and 3C are views explaining the relationships between a carrier frequency and a multiplier output with respect to the voice signal (an output of the bandpass filter 203 of Fig. 3A).

In the figures, hatched portions represent aliasing noise components. When the multiplier output is filtered with a bandpass filter to a predetermined band, deterioration due to aliasing distortion occurs if a carrier frequency f′ is low, as shown in Fig. 3C, and therefore, an optimum carrier frequency f is determined as shown in Fig. 3B.

According to this embodiment, carrier frequencies of the multipliers 211 to 215 are set as f_1 = 2.3 kHz, f_2 = 2.9 kHz, f_3 = 3.5 kHz, f_4 = 4.1 kHz and f_5 = 4.7 kHz and passbands of the bandpass filters 221 to 225 are set from 1.4 kHz to 2.0 kHz.

In this way, by setting the carriers f_1 to f_5 as low as possible, the center frequencies of the bandpass filters 221 to 225 may be lowered. Therefore, compared to the conventional system, if elliptic characteristics are used, two poles of the bandpass filters 221 to 225 may be omitted, thereby reducing the hardware. In the figure, hatched portions represent bandpass filter outputs corresponding to the respective channels ① to ⑤.

In the multipliers 231 to 235, the respective channels are modulated with the predetermined carriers F_1 to F_5 and then band-relocated.

In this embodiment, for the spectrum inversion and non-inversion processes of the respective channels, noninverting carriers and inverting carriers having different frequencies are used in the combinations shown in Table 1.

In Table 1, the noninverting carriers a (2.3 kHz) to e (4.7 kHz) are selected when the lower sidebands produced by the noninverting carriers are used for forming a noninverted scrambled voice signal; and the inverting carriers $\bar{a}$ (5.8 kHz) to $\bar{e}$ (8.2 kHz) are selected when the upper sidebands produced by the inverting carriers are used for forming an inverted scrambled voice. The frequencies of the inverting carriers are determined such that the higher harmonics produced by the noninverting carriers do not overlap the upper sidebands produced by the inverting carriers.

Table 2 shows examples of frequencies of the carriers F_1 to F_5 corresponding to the channels respectively, particularly without band-relocation.

Marks $\bar{c}$ and $\bar{d}$ represent inverting carriers. When the inverting carriers are used, the upper sidebands of the modulated signals are selected for forming scrambled signals.

Table 1

	Non-Inverting kHz	Inverting kHz	
a	2.3	$\bar{a}$	5.8
b	2.9	$\bar{b}$	6.4
c	3.5	$\bar{c}$	7.0
d	4.1	$\bar{d}$	7.6
e	4.7	$\bar{e}$	8.2

Table 2

Carriers for channels	(kHz)
F_1	a (2.3)
F_2	b (2.9)
F_3	$\bar{c}$ (7.0)
F_4	$\bar{d}$ (7.6)
F_5	e (4.7)

The band-relocating and inverting processes can be carried out by setting the carriers F_1 to F_5 to any one of frequencies a ($\bar{a}$) to e ($\bar{e}$).

The switching circuit 241 connects outputs of the multipliers 231, 232, and 235 corresponding to the channels ①, ②, and ⑤ to the adder 251 for the noninverting process while connecting outputs of the multipliers 233 and 234 corresponding to the channels ③ and ④ to the adder 253 for the inversion process.

Figures 5A to 5D are views corresponding to Table 2 and explaining signal spectra after the adders 251 and 253.

Figure 5A shows an output of the adder 251, Fig. 5B an output of the adder 253, Fig. 5C an output of the multiplier 257 (an upper sideband (15.3 kHz to 16.5 kHz) of the channels ③ and ④ omitted), and Fig. 5D an output of the adder 261.

The output (Fig. 5B) of the adder 253 for the inversion process is input to the bandpass filter 255 in which the output is band-limited to 7.2 kHz to 10.2 kHz corresponding to an upper sideband of output signals modulated by the multipliers 231 to 235 (233 and 234 in this example) with inverted carriers $\bar{a}$ (5.8 kHz) to $\bar{e}$ (8.2 kHz) ($\bar{c}$ and $\bar{d}$ in this example), and then modulated to a base band by the multiplier 257 with a carrier F_0 (6.9 kHz) (Fig. 5C).

The adder 261 adds the output of the multiplier 257 (the added output (Fig. 5C) of the inverted channels) to the output of the adder 251 for the noninverting process (the added output (Fig. 5A) of the noninverted channels).

The output of the adder 261 (Fig. 5D) is filtered by the low-pass filter 271 and output as a required scrambled voice signal from the output terminal 273.

In the above description with reference to the Tables 1 and 2 and Figs. 5A to 5D, the inverting carriers of higher frequencies are employed to avoid adverse influences due to the higher harmonics produced by the noninverting carriers of the lower frequencies. The higher frequencies of the inverting carriers are necessary when the multipliers 231 to 235 are formed by simple ring modulators, because the higher harmonics of the modulated signals produced by the noninverting carriers may overlap the upper sidebands, i.e., the inverted bands of the modulated signals produced by the inverting carriers, if the inverting carriers are determined to be nearly equal to the noninverting carriers.

Nevertheless, when the multipliers 231 to 235 are formed by generally known analog multipliers, it is possible to make the frequencies of the inverting carriers the same as the frequencies f the noninverting carriers. In this case, also, the inverted signals are selected from the upper sidebands of the signals modulated by the carriers, and the noninverted signals are selected from the lower sidebands thereof.

When the frequencies of the inverting carriers are the same as those of the noninverting carriers, the carrier table will be as shown in Table 1a.

Table 1a

Non-Inverting kHz		Inverting kHz	
a	2.3	$\bar{a}$	2.3
b	2.9	$\bar{b}$	2.9
c	3.5	$\bar{c}$	3.5
d	4.1	$\bar{d}$	4.1
e	4.7	$\bar{e}$	4.7

Comparing Table 1a with Table 1, it can be seen that the number of carrier frequencies in Table 1a is half that in Table 1.

Instead of inverting the channels ③ and ④, when the channels ②, ④ and ⑤ are to be inverted as in the conventional example shown in Fig. 19, the switching circuit 241 connects the outputs of the multipliers 231 and 233 corresponding to the channels ① and ③ to the adder 251 for the noninverting process while connecting outputs of the multipliers 232, 234 and 235 corresponding to the channels ②, ④ and ⑤ to the adder 253 for the inversion process. In this case, and when carriers are selected from the Table 1a, the Table 2 should be changed so that the frequencies of the carriers F_2, F_4 and F_5 are $\bar{d}$ (4.1), $\bar{c}$ (3.5) and $\bar{a}$ (2.3) kHz. The Table 2 for this case is Table 2a, shown below. In this case also, marks $\bar{d}$, $\bar{c}$ and $\bar{a}$ represent inverting carriers.

Table 2a

Carriers for channels	kHz
F_1	e (4.7)
F_2	$\bar{d}$ (4.1)
F_3	b (2.9)
F_4	$\bar{c}$ (3.5)
F_5	$\bar{a}$ (2.3)

Figures 6A to 6E are views corresponding to Table 2a and explaining signal spectra at the outputs of the ~~multiplexers~~ multipliers 231 to 235. As shown in Fig. 6A, the hatched portion shown in Fig. 4A, which is the frequency band obtained by bandpass filter (BPF_2) 221, is modulated by the multiplier 231 with the carrier frequency F_1 (4.7 kHz) so that a noninverted lower sideband from 2.7 kHz to 3.3 kHz and an inverted upper sideband from 7.1 kHz to 7.7 kHz are obtained. The inverted upper sideband is illustrated by hatching. Similarly, the channels ②, ③, and ⑤ are modulated by the multipliers 231 to 235 with the carrier frequencies F_2 (4.1 kHz), F_3 (2.9 kHz), F_4 (3.5 kHz), and F_5 (2.3 kHz) respectively.

Figures 7A to 7E are views corresponding to Table 2a and explaining signal spectra after the adders 251 and 253.

Figure 7A shows an output of the adder 251; Fig. 7B an output of the adder 253; Fig. 7C an output of the bandpass filter 255; Fig. 7D an output of the multi-~~plexer~~ plier 257; and Fig. 7E an output of the adder 261. As can be seen from Fig. 7C, the bandpass filter (BPF) 257 passes the upper sideband of the output of the adder 253 so that only the inverted sidebands ②, ④, and ⑤ are obtained and the lower sidebands ②, ④, and ⑤ are deleted. The inverted sidebands are then modulated by the multiplier 257 with a carrier F_0 (3.4 kHz) so that the inverted sidebands are relocated from the frequency band ranging from 4.2 kHz to 6.6 kHz to the frequency band ranging from 0.3 kHz to 2.6 kHz, as shown in Fig. 7D.

As described above, it will be apparent that, compared to the conventional constitution in which a spectrum inverting process and a spectrum relocating process for each channel are performed separately, the embodiment of the present invention simplifies the constitution of the multipliers, etc., by separately synthesizing the noninverted channels and the inverted channels and collectively performing an inverting process to synthesize a voice scrambled signal when the band relocating process is effected.

The inverting carrier frequency combination shown in Table 1 is for using an upper sideband of the added output of the inverted channels (Fig. 5B). The non-inverting carrier combination is for using a lower sideband.

Table 3 shows an example of combination of the same frequencies as shown in Table 1 for noninverting carriers and different frequencies for using the lower sideband of the added output of the inverted channel. Namely, the arrangement of the inverting carriers is opposite to the arrangement shown in Table 1.

Table 4 shows examples of frequencies of the carriers F_1 to F_5 corresponding to the channels, particularly without band relocation. Marks $\bar{c}$ and $\bar{d}$ represent inverting carriers respectively.

Table 3

	Non-inverting kHz	Inverting kHz
a	2.3	8.2
b	2.9	7.6
c	3.5	7.0
d	4.1	6.4
e	4.7	5.8

Table 4

Carriers for channels	(kHz)
F_1	a (2.3)
F_2	b (2.9)
F_3	$\bar{c}$ (7.0)
F_4	$\bar{d}$ (6.4)
F_5	e (4.7)

Figure 8A to 8D are views corresponding to Table 4 and explaining signal spectra after the adders 251 and 253.

Figure 8A shows an output of the adder 251, Fig. 8B an output of the adder 253, Fig. 8C an output of the multiplier 257 (an upper sideband (11.5 kHz to 12.7 kHz) of the channels ③ and ④ omitted), and Fig. 8D an output of the adder 261.

The output (Fig. 8B) of the adder 253 for the inverting process is input to the bandpass filter 255 in which the output is band-limited to 3.8 kHz to 6.8 kHz corresponding to a lower sideband of output signals modulated in the multipliers 231 to 235 with inverting carriers $\bar{a}$ (8.2 kHz) to $\bar{e}$ (5.8 kHz), and then modulated to a base band by the multiplier 257 with a carrier F_0 (7.1 kHz) (Fig. 8C).

Similarly, the adder 261 adds the output of the multiplier 257 (the added output (Fig. 8C) of the inverted channels) to the output of the noninverting process adder 251 (the added output (Fig. 8A) of the normal channels). The added output (Fig. 8D) is filtered by the low-pass filter 271 and output as a required voice scrambled signal from the output terminal 273.

In the combinations of carrier frequencies shown in Tables 1 and 3, for example, an inverting carrier band may be set optionally (from 5.8 kHz to 8.2 kHz in tables 1 and 3). By properly adjusting the carrier F_0 of the multiplier 257, the noninverted and inverted channels can be synthesized. Here, to simplify the constitution of the oscillator 281, a part of the inverting carriers is set to a frequency which is double the frequency of a noninverting carrier.

By using the multipliers 211 to 215, 231 to 235 and 257 having proper circuit constitutions, an inversion process at a relatively low frequency will be realized. In this case, inverting carriers are not particularly necessary and the same process may be carried out only with the switching circuit 241, to generate the voice scrambled signal.

Figures 9A to 9D are views explaining a process in which inverting carriers are not used. Figure 9A shows an output of the adder 251, Fig. 9B an output of the adder 253, Fig. 9C an output of the multiplier 257, and Fig. 9D an output of the adder 261.

In this case, the carrier F_0 of the multiplier 257 is 3.4 kHz.

Figure 10 is a block diagram showing an essential constitution of a second embodiment of the present invention.

A constitution for splitting the band of an input speech signal is the same as that for the first embodiment of the present invention, and thus is omitted from the figure.

In the figure, carriers F_{11} to F_{15} having different frequencies respectively are input to multipliers 331 to 335 corresponding to respective channels, respective outputs of the multipliers 331 to 335 are input to an adder 341, an output of the adder 341 is input to a multiplier 361 through a bandpass filter (BPF) 351, and an output multiplied by the carrier F_{10} of the multiplier 361 is sent to an output terminal 373 through a low-pass filter (LPF) 371.

Here, the modulating means 15 shown in the block diagram (Fig. 1) of the principle of the embodiment of the present invention corresponds to the multipliers 331 to 335 of this embodiment (Fig. 10). Similarly, the adding means 17 corresponds to the adder 341, bandpass filter 351, multiplier 361, and low-pass filter 371.

A feature of this embodiment is that the bands of noninverting and inverting carriers are set such that, for example, the band of an upper sideband of a signal modulated with the noninverting carrier coincides with the band of a lower sideband of a signal modulated with the inverting carrier.

Table 5 shows examples of combinations of carrier frequencies which have been set in the above-mentioned relationship.

Table 5

	Normal kHz	Inverting kHz
a	4.7	8.1
b	4.1	7.5
c	3.5	6.9
d	2.9	6.3
e	2.3	5.7

Table 6

Carriers for channels	(kHz)
F_{11}	a (4.7)
F_{12}	b (4.1)
F_{13}	$\bar{c}$ (6.9)
F_{14}	$\bar{d}$ (6.3)
F_{15}	e (2.3)

Table 6 shows, as indicated with respect to the first embodiment, examples of frequencies of the carriers F_{11} to F_{15} corresponding to the channels, particularly without band relocation.

Figure 11 is a view corresponding to Table 6 and explaining signal spectra after the multipliers 331 to 335. Figures 11A to 11E show respective outputs of the multipliers 331 to 335, Fig. 11F an output of the adder 341, and Fig. 11G an output of the multiplier 361 (an upper sideband (10.7 kHz to 13.7 kHz) is omitted).

As shown in Fig. 11, if the noninverting and inverting carriers have the above-mentioned relationship, it is not necessary to separate a noninverting route and an inverting route corresponding to channels by a switching circuit. By setting a passband of the bandpass filter 351 from 3.7 kHz to 6.7 kHz, and by setting the carrier F_{10} of the multiplier 361 to 7 kHz, a scrambled voice signal modulated to a base band (0.3 kHz to 3.3 kHz) is obtained.

As described above, it is necessary only to finally modulate the signal to the base band with the carrier F_{10} of the multiplier 361, and the frequency band (2.3 kHz to 4.7 kHz) of the normal carrier shown here is not definitive.

For example, a passband of the bandpass filter (BPF_2) is generally assumed to be from $\underline{m}$ to $\underline{n}$ (kHz) (where $\underline{\ell} = \underline{m} + \underline{n}$), and a frequency band of the noninverting carrier is assumed to be from $\underline{p}$ to $\underline{p}+\alpha$ (kHz). Then a frequency band of the inverting carrier will be form $\underline{p} \pm \underline{\ell}$ to $\underline{p} + \alpha \pm \underline{\ell}$ (kHz), and thus will be realized by properly setting the carrier F_{10} of the multiplier 361.

As described with reference to the first and second embodiments, the present invention reduces the amount of hardware (for example, multipliers) for the band relocation and spectrum inversion processes by adjusting carrier frequencies. For example, in the conventional system shown in Fig. 13, 15 multipliers and 12 bandpass filters must be provided, whereas, in the embodiment of the present invention shown in Fig. 2, only 11 multipliers and 8 bandpass filters are necessary.

Although the above embodiments have dealt with five channels, the present invention is applicable even if the number of channels (the number of divided bands) is increased. In this case, the reduction of the hardware required is remarkable.

As described above, according to the present invention, by properly selecting carriers for band relocation and by collectively performing a spectrum inverting process and a band relocating process, the number of multipliers may be reduced, for example, from fifteen to eleven in the case of five channels, thereby reducing the number of poles of bandpass filters shown in the embodiments, to simplify the hardware. If the number of band-divided-channels is increased, a further reduction of the hardware is realized to remarkably improve the practicability of the apparatus.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A voice band splitting scrambler, comprising:

band splitting means for splitting an input voice band into a plurality of different subbands all having the same band width; and

scrambled voice signal generating means, operatively connected to said band splitting means, for obtaining, from said different subbands, a scrambled voice band in which each of said different subbands is relocated and at least a part of said different subbands is inverted in frequency;

said scrambled voice signal generating means including:

first modulating means, operatively connected to said band splitting means, for effecting frequency modulations on said different subbands by the use of a first set of carrier signals to obtain upper side bands and lower side bands with respect to said first set of carrier signals; and

adding means, operatively connected to said modulating means, for adding a part of said lower side bands and a part of said upper side bands;

said different subbands, after frequency shifting by said first modulating means, and recombination in said adding means, forming the same bandwidth as said input voice band, the frequencies of said first set of carrier signals being determined in such a way that the added result includes a scrambled voice band in which said different subbands are relocated to form a continuous spectrum and at least a part of said different subbands is inverted in frequency.

2. A voice band splitting scrambler as claimed in claim 1, wherein said band splitting means comprises:

a plurality of second modulating means for effecting frequency modulation on said input voice band by a second set of carrier signals to produce upper side bands and lower side bands with respect to said second set of carrier signals, the frequencies of said second set of carrier signals being different from each other by an integer multiple of the split subband width; and

a plurality of bandpass filters, operatively and respectively connected to said plurality of second modulating means, for allowing the passage, from the outputs of said plurality of second modulating means, of the signals of said split subband width.

3. A voice band splitting scrambler as claimed in claim 2, wherein said plurality of band pass filters have frequency characteristics which allow the passage of said lower side bands with respect to said second set of carrier signals, whereby the signals of said split band width passing through the bandpass filters are in said lower side bands with respect to said second set of carrier signals.

4. A voice band splitting scrambler as claimed in claim 3, wherein said frequencies of said second set of carrier signals are selected to be as low as possible as long as the outputs of said bandpass filters are not distorted due to alias signal components of said lower side bands.

5. A voice band splitting scrambler as claimed in claim 2, wherein said plurality of bandpass filters allow the passage of the same frequency band.

6. A voice band splitting scrambler as claimed in claim 1, wherein said adding means comprises:

first adding means for adding the signals of noninverting outputs from said first modulating means to output a first set of noninverting subbands;

second adding means for adding the signals of inverting outputs from said first modulating means to output a second set of inverting subbands;

third modulating means for modulating said second set of inverting subbands by the use of a shifting carrier signal to shift said inverting subbands to said input voice band; and

third adding means for adding the output of said third modulating means and the output of said first adding means;

the frequency of said shifting carrier signal being selected in such a way that the added result output from said third adding means forms a continuous spectrum in said input voice band.

7. A voice band splitting scrambler as claimed in claim 1, wherein a part of said first set of carrier signals are noninverting carrier signals, and the remaining part of said first set of carrier signals are inverting carrier signals, said noninverting carrier signals and said inverting carrier signals being determined so that the upper side band of the signal modulated by said noninverting carriers coincides with the lower side band of the signal modulated by said inverting carriers.

8. A voice band splitting scrambler as claimed in claim 2, wherein the number of subbands in said scrambled voice band is n, and the number of said first modulating means, the number of said second modulating means, and the number of said bandpass filters are all n respectively, and further comprising switching means, operatively connected between said second modulating means and said first and second adding means, for separately outputting noninverting signals and inverting signals from said second modulating means to said first adding means and said second adding means respectively.

9. A voice band splitting scrambler as claimed in claim 8, wherein said plurality of band pass filters have frequency characteristics which allow the passage of said lower side bands with respect to said second set of carrier signals, whereby the signals of said split band width passing through the bandpass filters are in said lower side bands with respect to said second set of carrier signals.

10. A voice band splitting scrambler as claimed in claim 9, wherein the frequencies of said second set of carrier signals are different from each other by an integer multiple of 1/n of said input voice band.

11. A voice band splitting scrambler as claimed in claim 10, wherein said frequencies of said second set of carrier signals are selected to be as low as possible as long as the outputs of said bandpass filters are not distorted due to alias signal components of said lower side bands.

12. A voice band splitting scrambler as claimed in claim 10, wherein said bandpass filters have the same frequency characteristic.

13. A voice band splitting scrambler as claimed in claim 8, wherein a part of said first set of carrier signals are noninverting carrier signals, and the remaining part of said first set of carrier signals are inverting carrier signals, said noninverting carrier signals and said inverting carrier signals being determined so that the upper side band of the signal modulated by said noninverting carriers coincides with the lower side band of the signal modulated by said inverting carriers.

14. A voice band splitting scrambler as claimed in claim 8, further comprising table means for storing data of said first set of carrier signals and oscillating means for generating said first set of carrier signals in accordance with said data from said table means, said first set of carrier signals being supplied to said first modulating means.

15. A voice band splitting scrambler as claimed in claim 14, wherein said switching means is controlled so that the output of the inverting signal bands modulated by said first

modulating means are collected to be input to said first adding means.

16. A voice band splitting scrambler as claimed in claim 2, wherein said adding means is an adding circuit having inputs directly connected to the outputs of said second modulating means;

the frequencies of said first set of carrier signals being selected in such a way that the output of said adding circuit includes a continuous spectrum including upper side bands of the noninverting subbands and lower side bands of the inverting subbands.

17. A voice band splitting scrambler as claimed in claim 16, wherein said plurality of bandpass filters have frequency characteristics which allow the passage of said lower side bands with respect to said second set of carrier signals, whereby the signals of said split band width passing through the bandpass filters are in said lower side bands with respect to said second set of carrier signals.

18. A voice band splitting scrambler as claimed in claim 17, wherein the frequencies of said second set of carrier signals are different from each other by an integer multiple of 1/n of said input voice band.

19. A voice band splitting scrambler as claimed in claim 18, wherein said frequencies of said second set of carrier signals are selected to be as low as possible as long as the outputs of said bandpass filters are not distorted due to alias signal components of said lower side bands.

20. A voice band splitting scrambler as claimed in claim 19, wherein said bandpass filters have the same frequency characteristic.

21. A voice band splitting scrambler as claimed in claim 20, wherein a part of said first set of carrier signals are noninverting carrier signals, and the remaining part of said first set of carrier signals are inverting carrier signals, said noninverting carrier signals and said inverting carrier signals being determined so that the upper side band of the signal modulated by said noninverting carriers coincides with the lower side band of the signal modulated by said inverting carriers.

22. A voice band splitting scrambler as claimed in claim 21, further comprising table means for storing data of said first set of carrier signals and oscillating means for generating said first set of carrier signals in accordance with said data from said table means, said first set of carrier signals being supplied to said first modulating means.

23. A voice band splitting scrambler as claimed in claim 6, further comprising a bandpass filter connected between said second adding means and said third modulating means for allowing the passing of the signals of the voice band width from the output of said second adding means.

24. A voice band splitting scrambler as claimed in claim 23, further comprising switching means, connected between said second modulating means and said first and second adding means, for separately outputting noninverting subbands and inverting subbands from the output signals of said first modulating means to said first adding means and to said second adding means.

25. A voice band splitting scrambler as claimed in claim 24, further comprising filter means, operatively connected to said third adding means, for allowing the passing of the signals of said input voice band from the output of said third adding means.

26. A voice band splitting scrambler as claimed in claim 6, wherein said first set of carrier signals comprise noninverting carrier signals and inverting carrier signals;

said noninverting carrier signals being used for modulating said noninverting subbands; and

said inverting carrier signals being used for modulating said inverting subbands;

the frequencies of said noninverting carrier signals being selected in such a way that the lower side bands obtained by the modulation by said noninverting carrier signals are within said input voice band; and

the frequencies of said inverting carrier signals and said shifting carrier signal being selected in such a way that the upper side band signals or the lower side band signals obtained by modulating said inverting subbands by the use of said inverting carrier signals are again modulated by said base band shifting carrier signal, and the lower side band signals obtained by the modulation by the shifting carrier signal are within said input voice band.

27. A voice band splitting scrambler as claimed in claim 16, further comprising:

a bandpass filter, operatively connected to said adding circuit, for allowing the passing of said continuous spectrum;

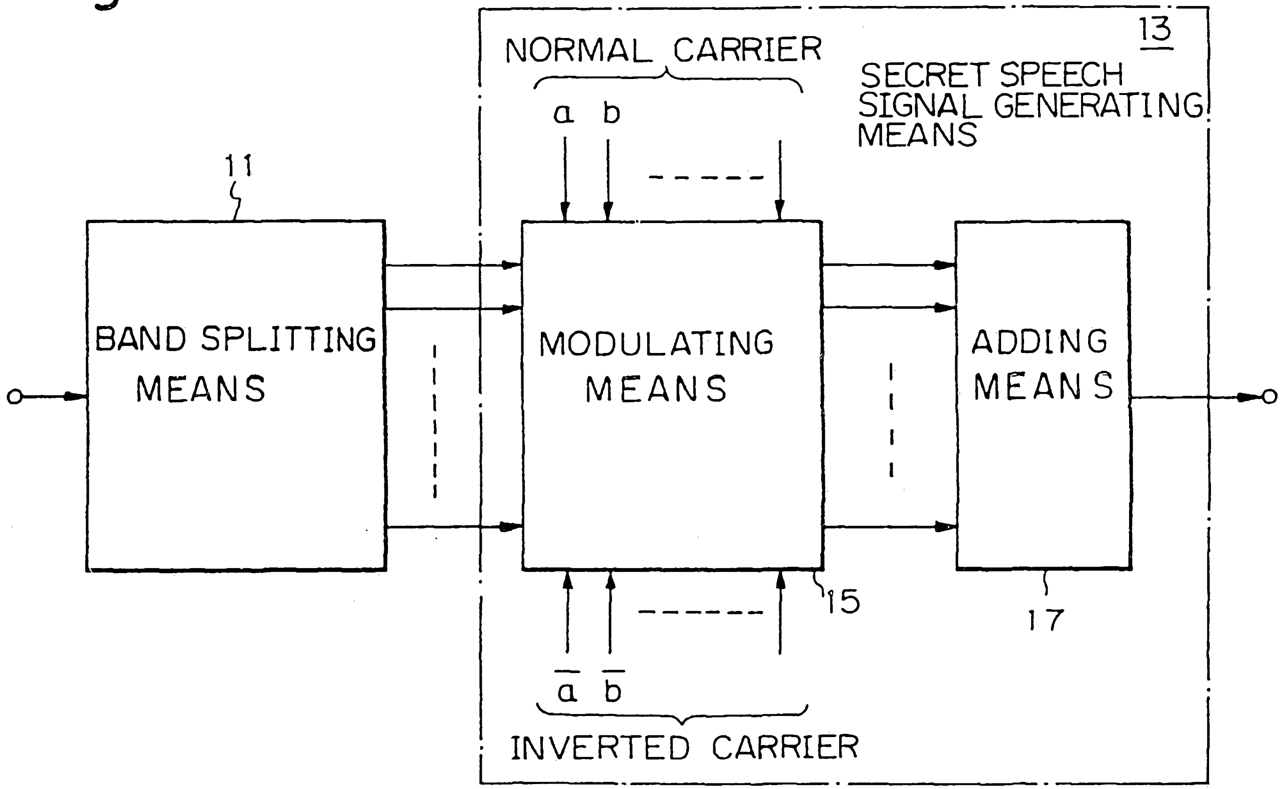
third modulating means, connected to said bandpass filter, for modulating said continuous spectrum output through said bandpass filter by the use of a base band shifting carrier signal, the frequency of said base band shifting carrier signal being selected in such way that the lower side band obtained by said third modulating means includes said continuous spectrum within said input voice band; and

a low pass filter, operatively connected to said third modulating means, for allowing the passing of said continuous spectrum in said input voice band.

28. A voice band splitting scrambler, substantially as hereinbefore described with reference to Figures 1 to 12 of the drawings.

DATED this 7th day of June, 1990
FUJITSU LIMITED
By its Patent Attorneys
DAVIES & COLLISON

Fig. 1



BLOCK DIAGRAM OF PRINCIPLE OF EMBODIMENT OF PRESENT INVENTION

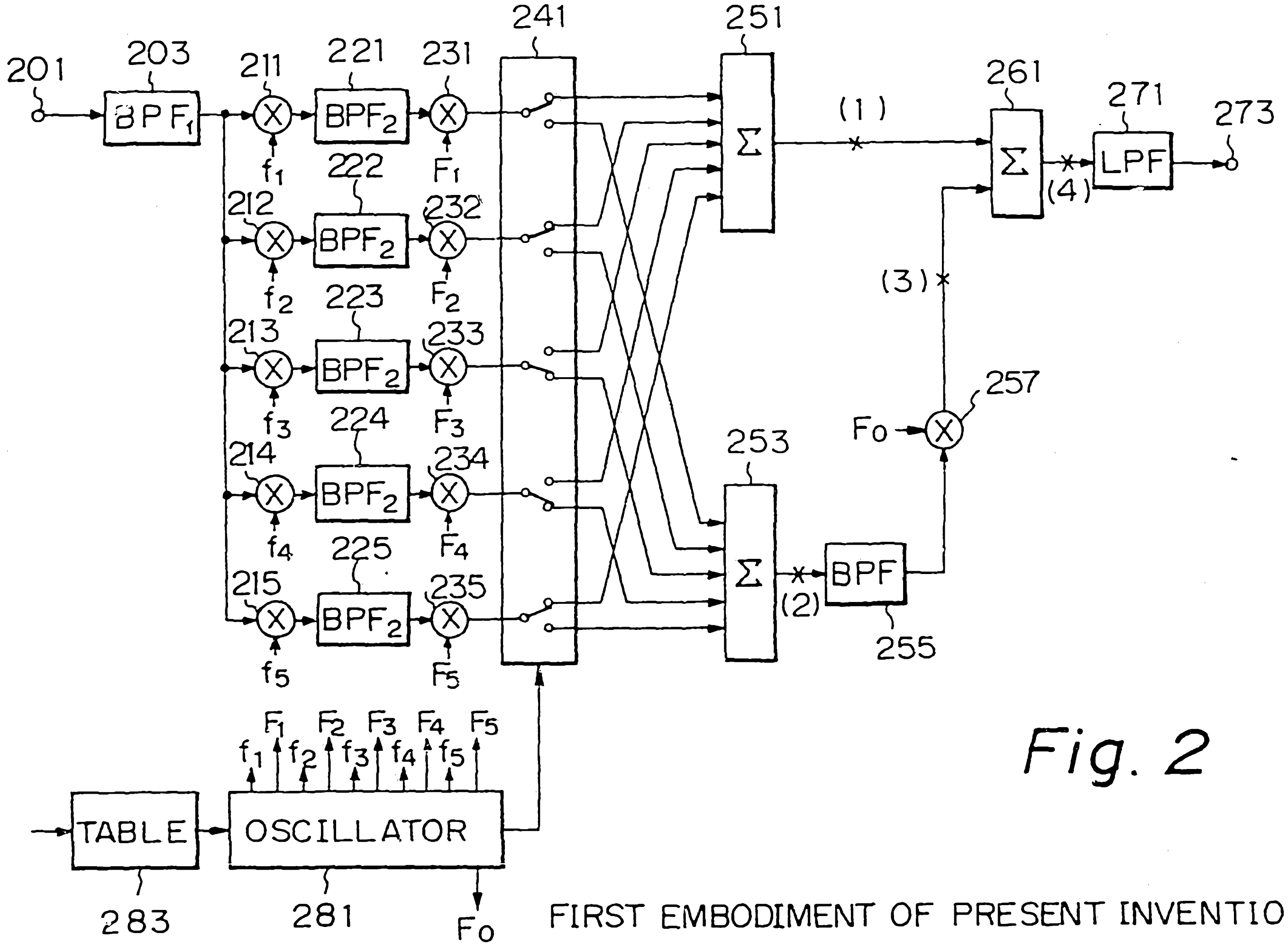


Fig. 2

FIRST EMBODIMENT OF PRESENT INVENTION

19224/88

Fig. 3A

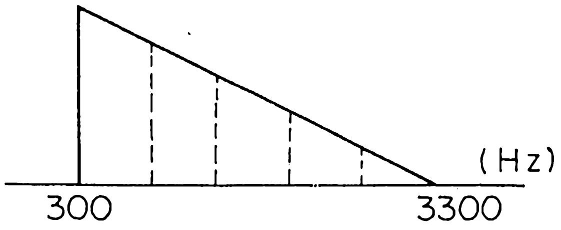


Fig. 3B

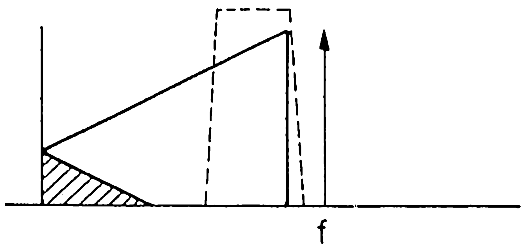
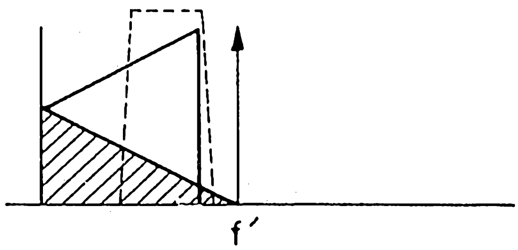
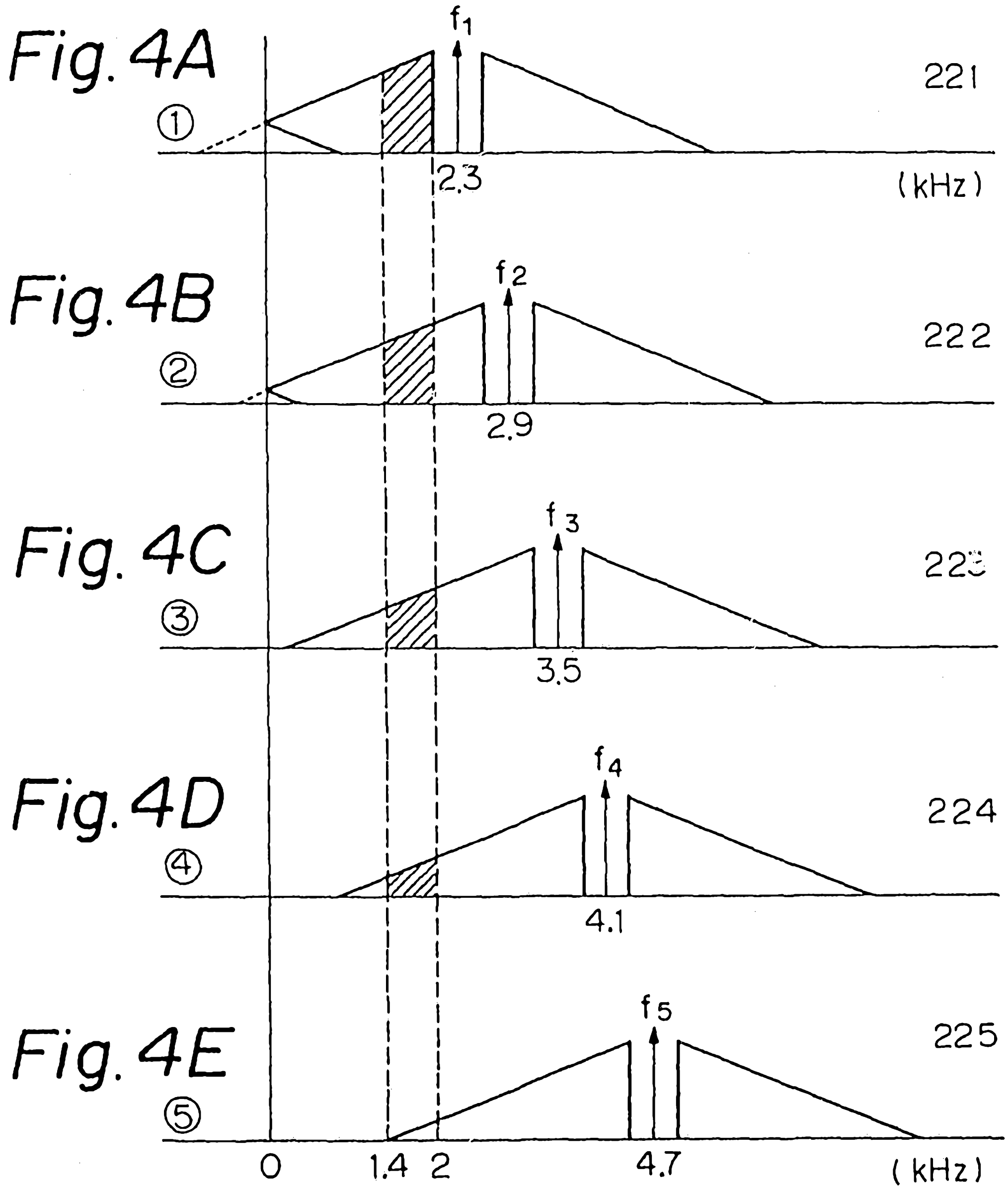


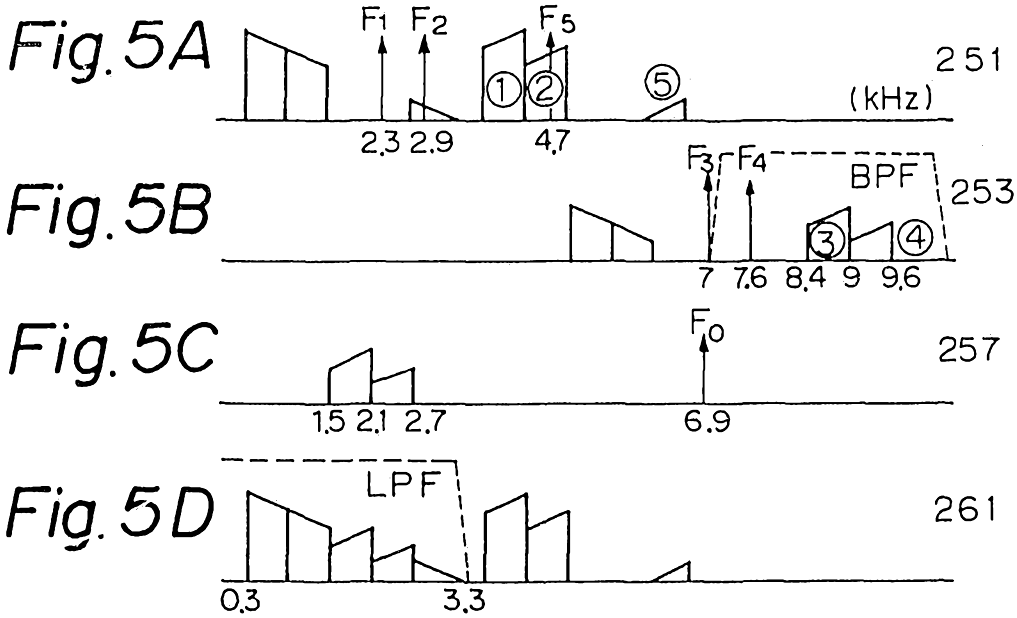
Fig. 3C



RELATIONS BETWEEN CARRIER FREQUENCIES
AND MULTIPLIER OUTPUTS



EXAMPLE OF BAND SPLITTING PROCESS FOR REDUCING ORDER FOR BPF_2



EXPLANATORY VIEW CORRESPONDING TO TABLE 2

Fig.6A

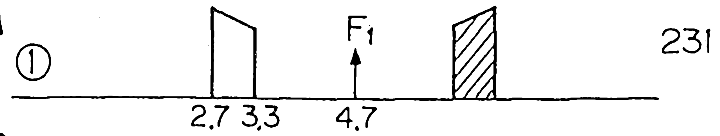


Fig.6B

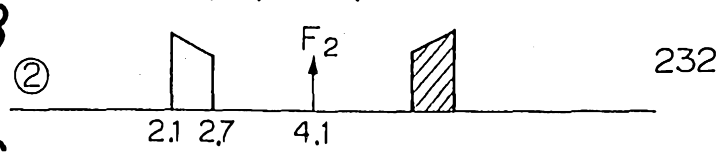


Fig.6C

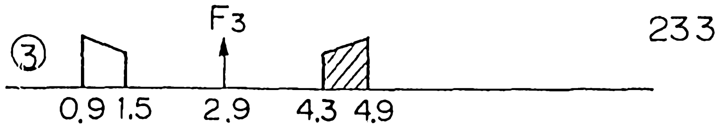


Fig.6D

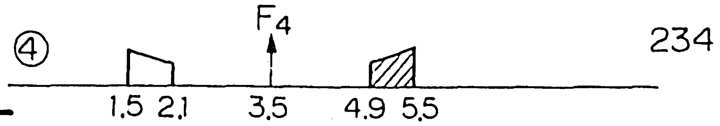


Fig.6E

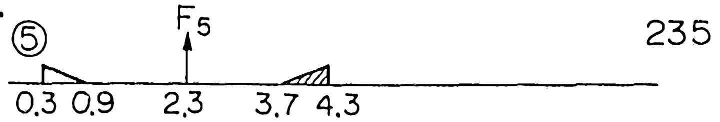


Fig.7A

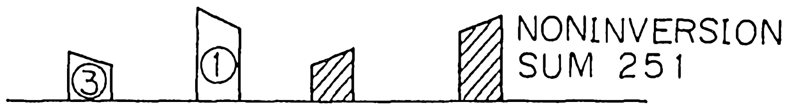


Fig.7B

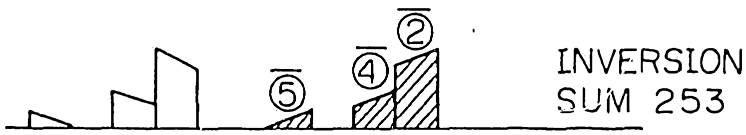


Fig.7C

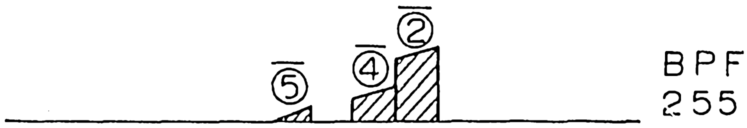


Fig.7D

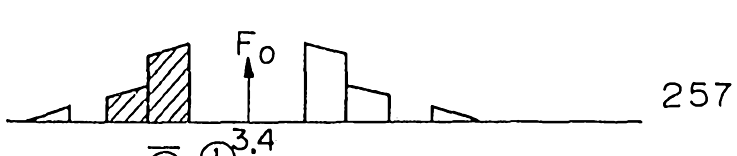


Fig.7E

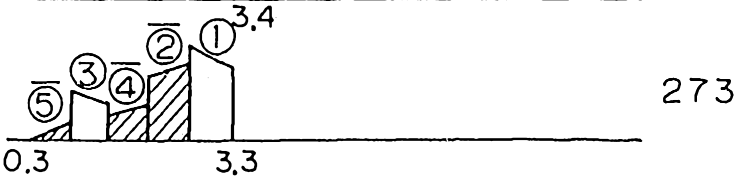


Fig. 8A

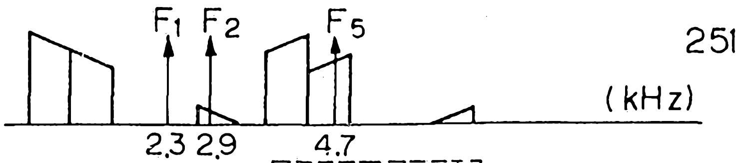


Fig. 8B

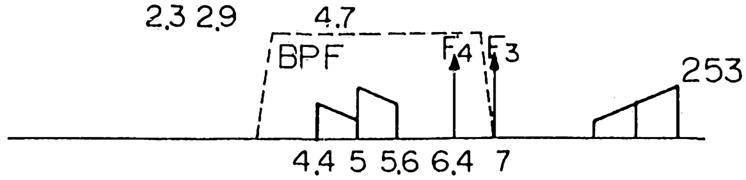


Fig. 8C

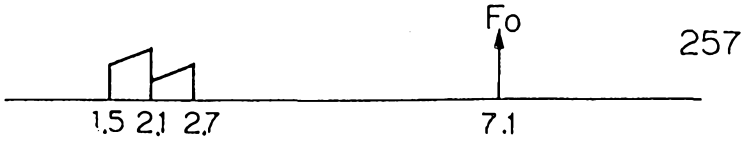
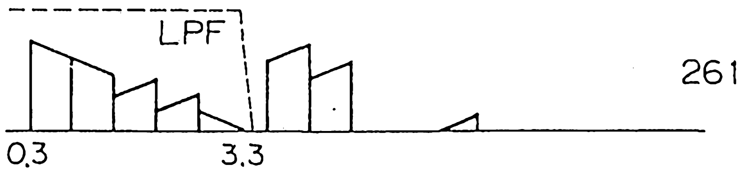


Fig. 8D



EXPLANATORY VIEW CORRESPONDING TO TABLE 4

Fig. 9A

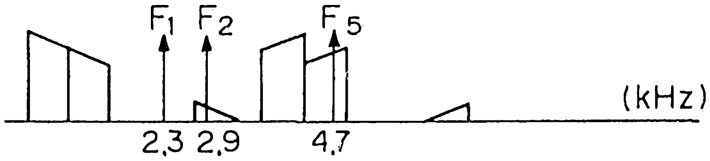


Fig. 9B

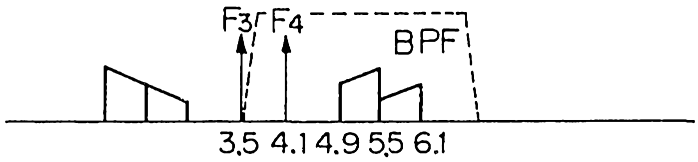


Fig. 9C

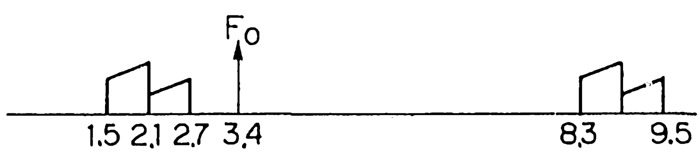
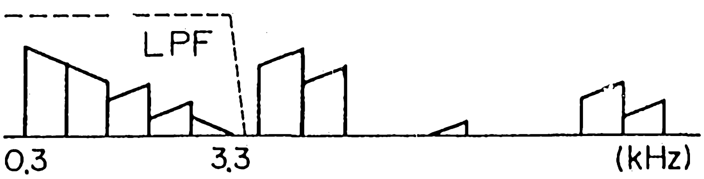
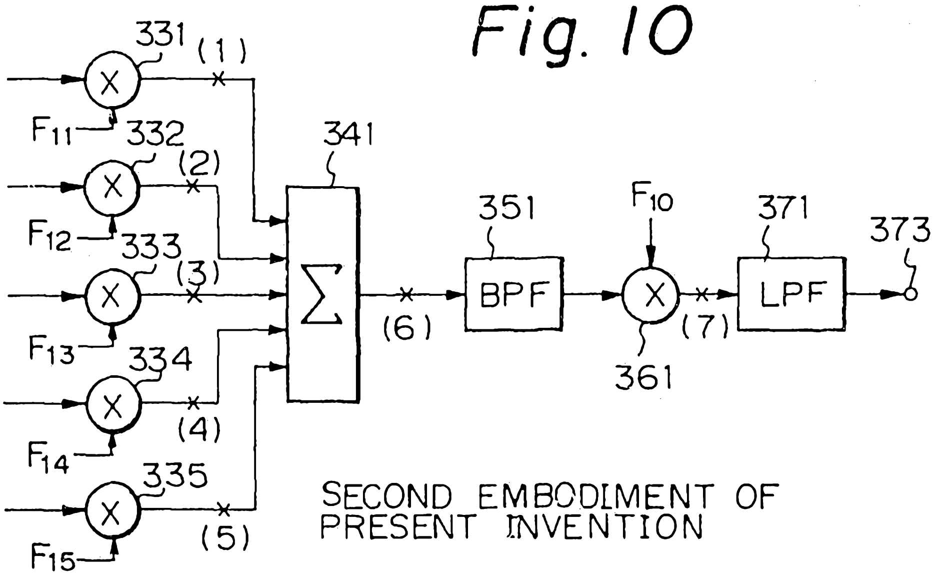


Fig. 9D



EXPLANATORY VIEW OF CASE WITH NO INVERTED CARRIERS PREPARED

Fig. 10



SECOND EMBODIMENT OF PRESENT INVENTION

Fig. 11A

Fig. 11B

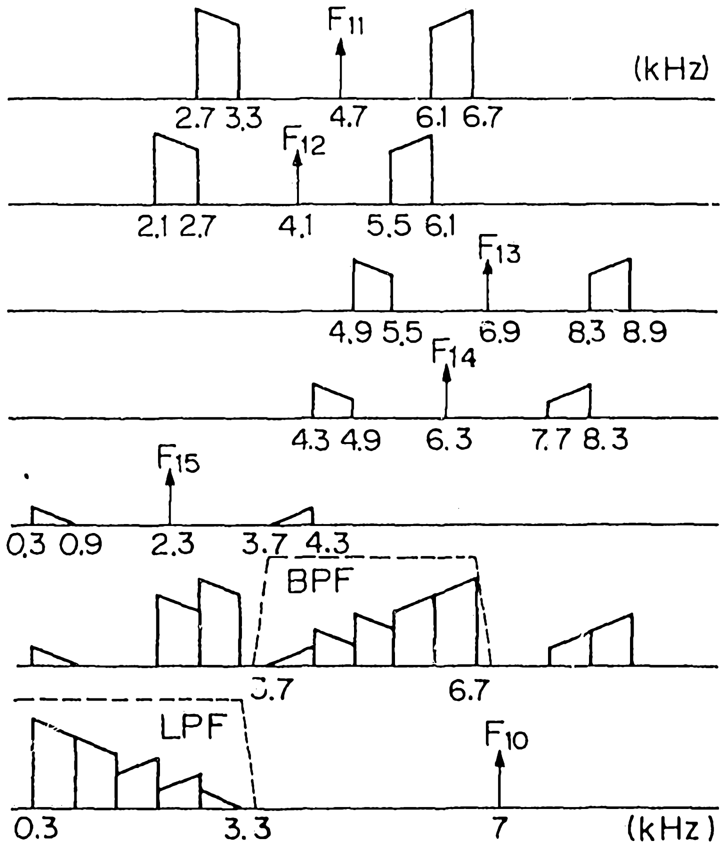
Fig. 11C

Fig. 11D

Fig. 11E

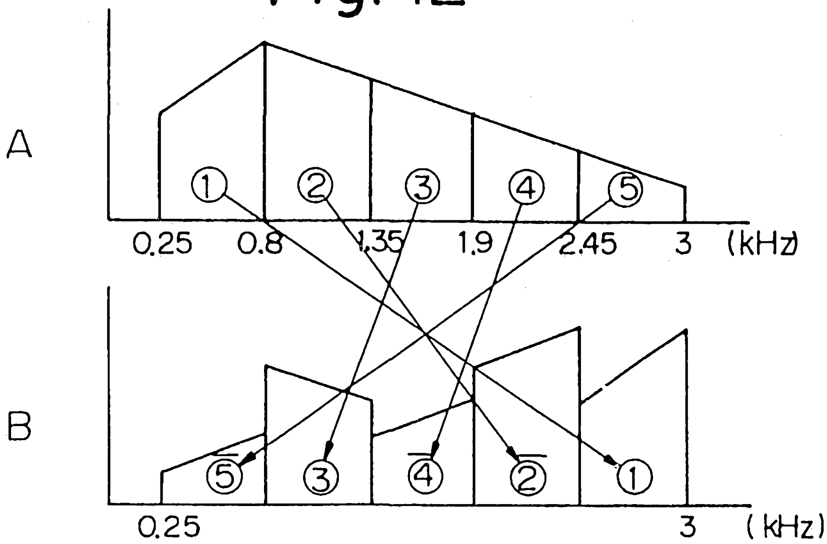
Fig. 11F

Fig. 11G



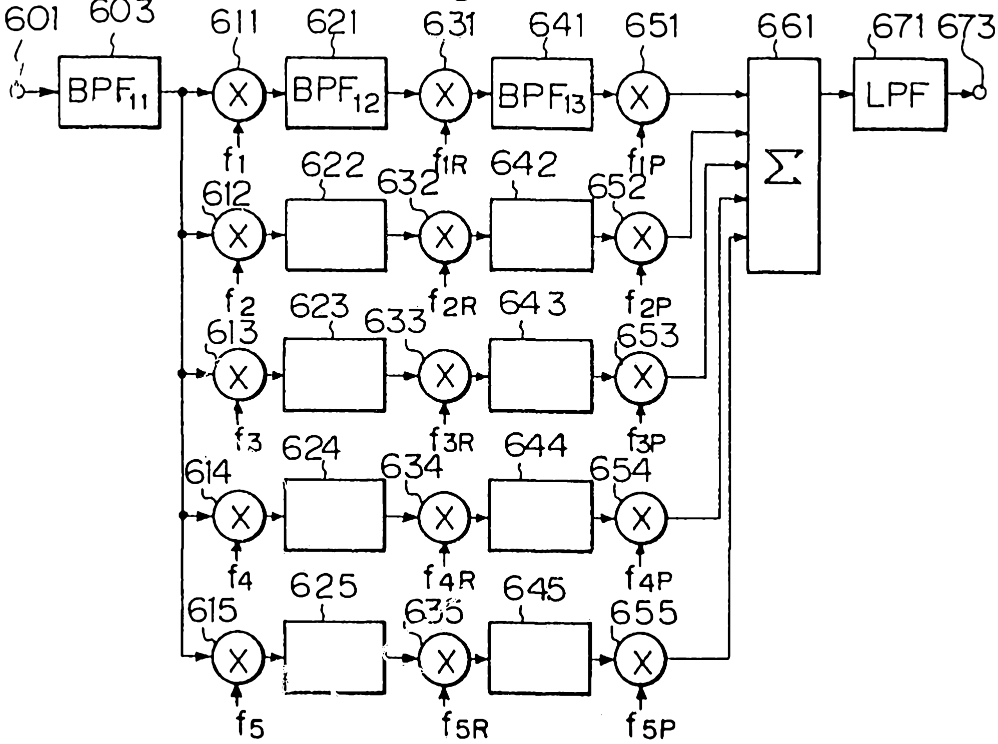
EXPLANATORY VIEW CORRESPONDING TO TABLE 6

Fig. 12



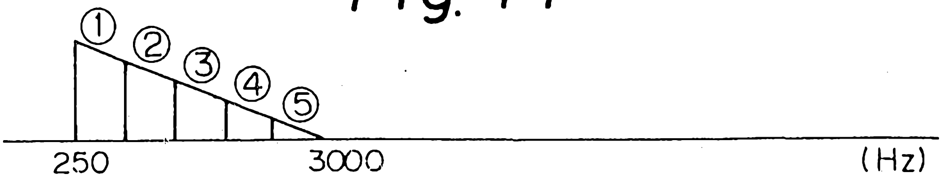
OUTLINE OF BAND SPLITTING AND RELOCATING SYSTEM

Fig. 13



CONSTITUTION OF PRIOR ART

Fig. 14

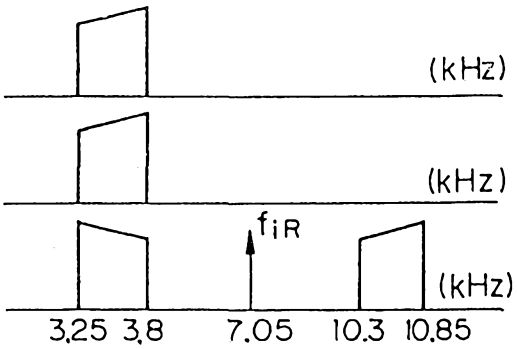


EXAMPLE OF OUTPUT SPECTRUM OF BPF_{11}

Fig.16A

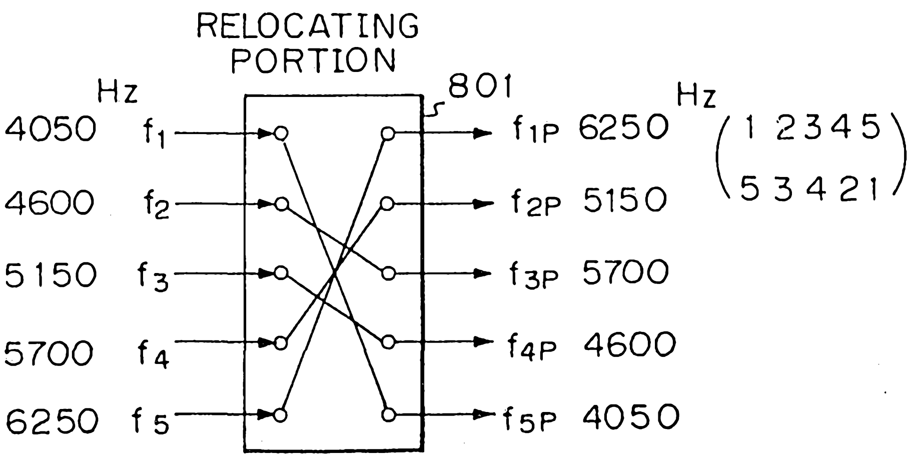
Fig.16B

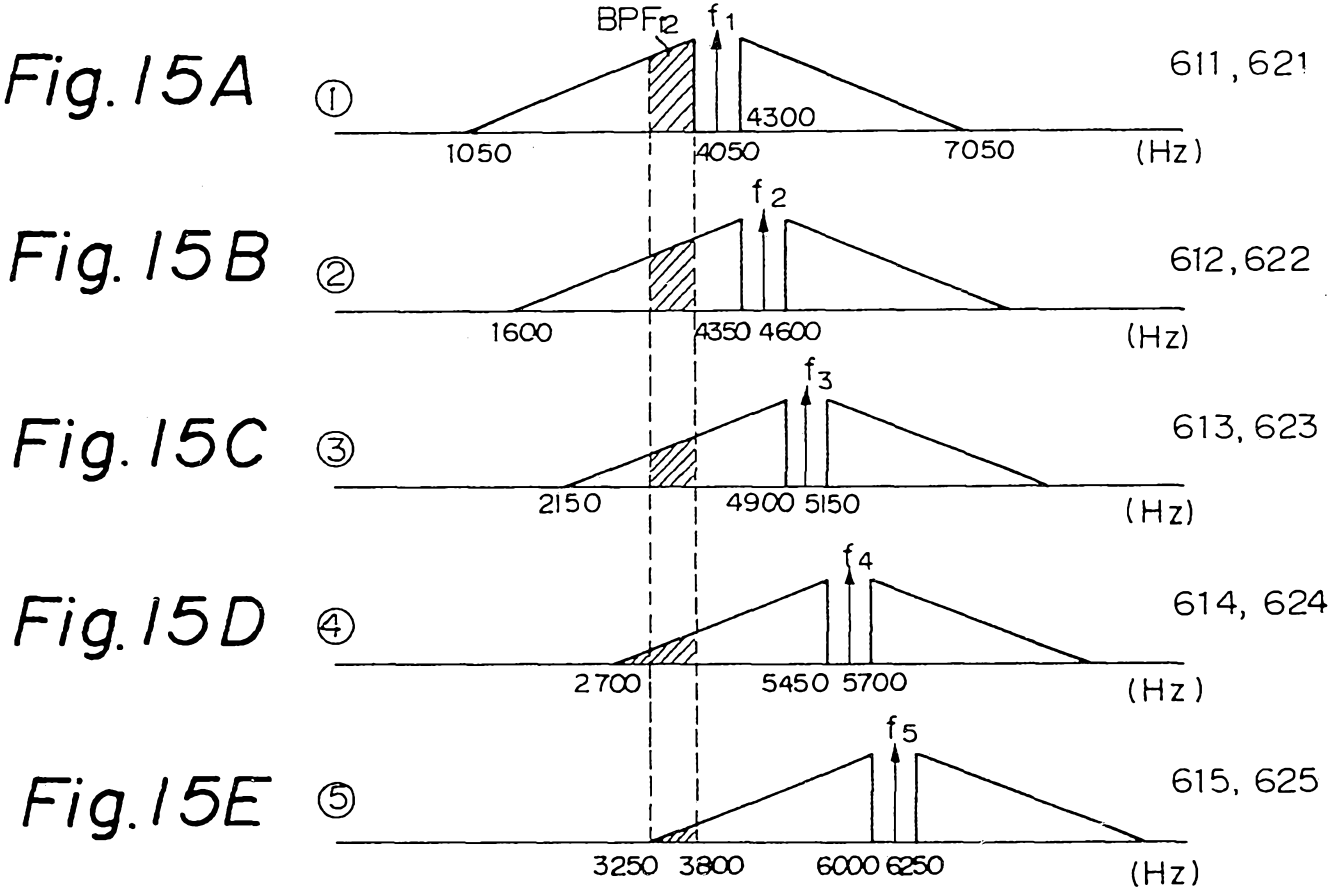
Fig.16C



EXPLANATORY VIEW OF CONVENTIONAL NONINVERTING AND INVERTING PROCESSES

Fig. 18





EXAMPLES OF OUTPUT SPECTRA OF MULTIPLIERS 611 TO 615

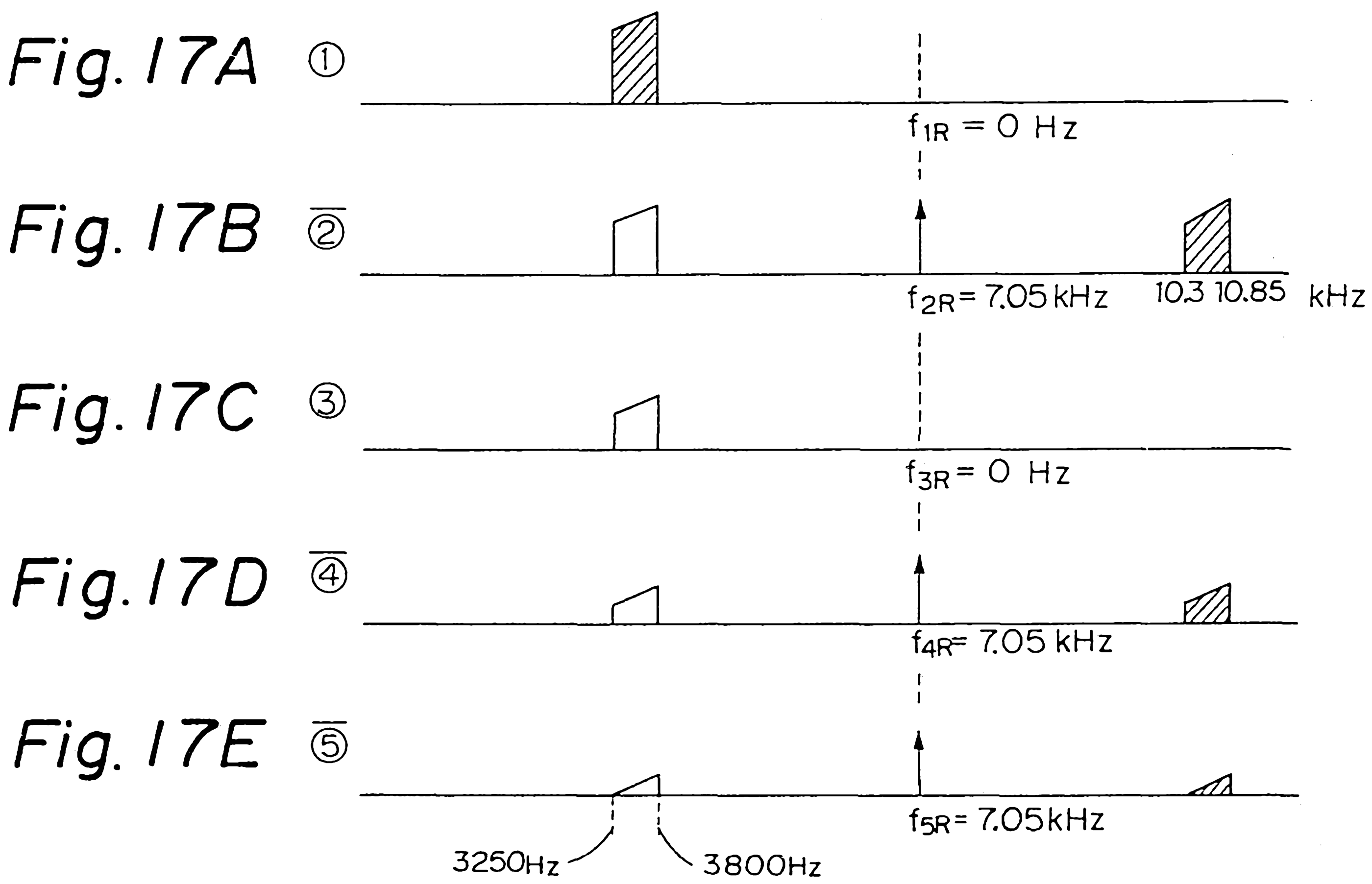


Fig. 17A ①
f1R = 0 Hz
Fig. 17B ②
f2R = 7.05 kHz
10.3 10.85 kHz
Fig. 17C ③
f3R = 0 Hz
Fig. 17D ④
f4R = 7.05 kHz
Fig. 17E ⑤
f5R = 7.05 kHz
3250Hz
3800Hz

Fig. 19A

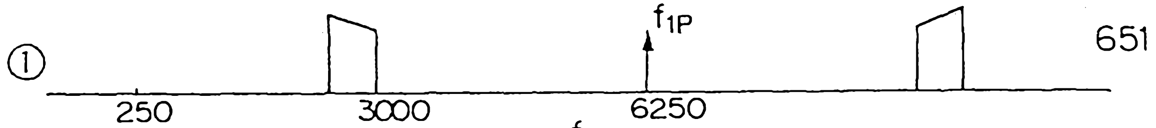


Fig. 19B

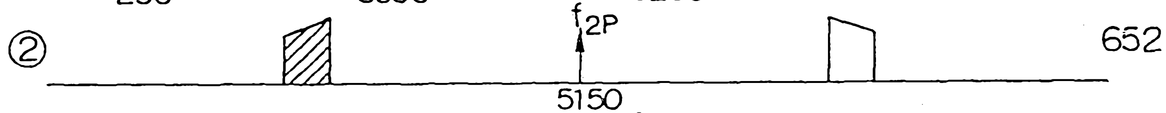


Fig. 19C

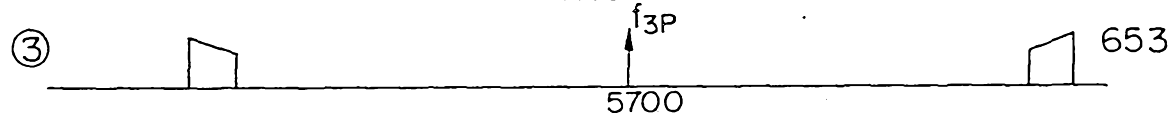


Fig. 19D

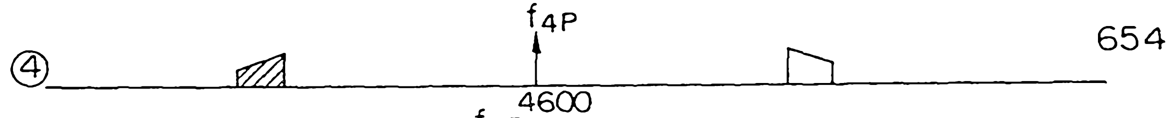


Fig. 19E

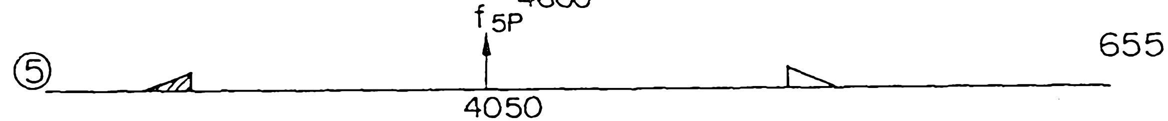


Fig. 19F

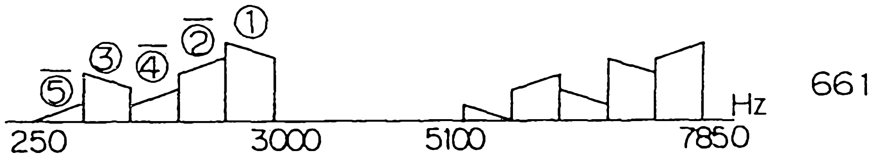


Fig. 19G