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(54) **METHOD AND SYSTEM FOR AUDIO SCRAMBLING AND DESCRAMBLING**

VERFAHREN UND EINRICHTUNG ZUR VER- UND ENTSCHLÜSSELUNG VON AUDIOSIGNALEN
PROCEDE ET SYSTEME DE BROUILLAGE ET DE DESEMBROUILLAGE D'UN SIGNAL
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Description

The present invention relates to a method and system for scrambling and descrambling audio signals.

The prior art uses various frequency shifting techniques for audio scrambling and descrambling. However, prior audio descrambling techniques suffer from hiss in the form of "white noise", and more importantly in band carrier "whistle" caused by inter-modulation of the two carrier frequencies. In the prior art, the use of expensive circuitry, such as band pass filters for mixer circuits, wide band 0 degree and 90 degree all pass networks, and 0 degree and 90 degree circuits, has been proposed for varying the carrier frequencies with constant amplitude and to balance the gain of quadrature mixers for sideband elimination. In addition, since the mixers used in the prior art are generally not stable in time, their drift results in an audible whistle as a result of carrier leak through.

Prior art systems having one or more of the identified problems are described, for example, in US patent No. 4,636,853 of Forbes, and in US patents Nos. 5,058,159 and 5,159,631 of Quan.

For a full understanding of the present invention, a review of the prior art will be helpful.

Figure 1 is a block diagram of the key elements of a descrambler circuit as described in US patent No. 4,636,853 ('853) of Forbes. The Forbes '853 descrambler 10 has a scrambled audio input 34 which is connected to an all pass phase shifter 20 containing a 0 degree output 38 and a 90 degrees output 39. The scrambled audio signal has an offset frequency $36 F_1 - F_2$ as shown in Figure 2A. This shows the scrambled audio offset by an offset frequency determined by the scrambling process. The phase shifted outputs are connected to a first input of linear modulators 21 and 27.

A frequency generator 22 generates a square wave frequency (F_1) which is fed to band pass filter 24 to remove any harmonics, thus producing a pure sine wave. This F_1 sine wave is connected to a 0 degree and 90 degree phase shifter 25. The outputs of phase shifter 25 are in turn connected to second inputs of linear modulators 21 and 27 respectively. The outputs of the first and second linear modulators are added in summer 28 to produce signal 37. This output signal 37 is connected to a first input of a second mixer 30 via high pass filter 29 which passes only F_1 and the upper sideband as shown in Figure 2B.

A second square wave frequency generator 23 generates a signal F_2 as shown Figures 1 and 2B. This square wave is filtered by band pass filter 26 to remove any harmonics to produce a pure sine wave signal. This pure sine wave signal is connected to a second input of third mixer 30. The output of the third mixer 30 is connected to a low pass filter 31 to produce a descrambled output signal 35.

The second spectral diagram in Figure 2B shows the input to the 3rd mixer 30. The frequency F_1 here rep-

resents the residual carrier feed through from mixers 21 and 27. Figure 2C shows the relationship of a carrier F_2 to F_1 in Figure 2B and the scrambled audio signal shown in Figure 2A. Figure 2D shows the relationship of the spectral characteristics of the descrambled signal 35 and the residual difference frequency ($F_1 - F_2$) component to the spectral characteristics of the signals in Figures 2A to 2C.

Figure 3 shows the scrambled audio input of the Quan prior art descrambler 11. This shows the scrambled audio 30 offset by an offset frequency determined by the original scrambling process. The scrambled audio input signal 40 is connected to an all pass shifter 41 which provides 0 degree and 90 degree phase shifted outputs 42 and 43 to first inputs of first and second mixers 44 and 45.

Carrier frequency generator 46 generates a sine wave signal F_c 47 with a frequency of 1 Khz or 2-3 khz. The carrier frequency 47 is filtered by a low pass filter 48 to remove any harmonics to produce a pure sine wave 49. This pure sine wave signal 49 is connected to an all pass phase shifter 50 to produce 0 degree and 90 degree signals 51 and 52 which in turn are connected to second inputs of mixers 44 and 45. The outputs of mixers 44 and 45, signals 53 and 54 are connected to summer 55 to produce descrambled output 56.

Figure 4B shows the relationship of the in band descrambling carrier F_c to the scrambled audio signal. Figure 4C shows the descrambled audio spectrum with the residual carrier F_c that is typically -60 db below the descrambled audio program, but is still audible during silent passages of the audio program.

As seen, US-A-4,636,853 describes a system for descrambling a scrambled frequency translated audio information signal by generating a modulation carrier signal at a frequency lying outside the original frequency spectral range of an original audio signal of about 50 Hz to about 15 Khz, the descrambling system comprising:

- a first signal generator for generating a first modulation carrier signal having a frequency greater than the highest frequency in the original audio signal;
- first modulating means for modulating said scrambled audio signal with said first modulation carrier signal to produce a first modulated signal having said first modulation frequency;
- first filtering means for rejecting a first upper sideband signal from said first modulated signal to produce a first filtered signal;
- a second signal generator for generating a second modulation carrier signal having a frequency less than said first modulation frequency;
- second modulating means for modulating said first filtered signal with said second modulation carrier signal to produce a second modulated signal having said second modulation frequency; and
- second filtering means for passing a second sideband signal from said second modulated signal to

produce a descrambled audio signal.

However, the known descrambling/scrambling system has noise problems in that white thermal or shot noise of circuit components degrades the signal to noise (SNR) of the system. There is also in-band audible carrier whistle.

It is an object of the invention to provide such a descrambler with an improved performance.

According to a first aspect of the present invention a descrambling system of the type defined is characterised in that, to produce a descrambled audio signal containing substantially no audible whistle components said first modulated signal is a first double sideband signal having said first modulation frequency, a first upper sideband signal and a first lower sideband signal; and said first filtering means filters out said first modulation frequency, all its harmonics, and said first upper sideband signal from said first double sideband signal and passes said first lower sideband signal;

and in that said second modulated signal is a second double sideband signal having said second modulation frequency, a second upper sideband signal and a second lower sideband signal; and said second filtering means filters said second double sideband signal and passes only said second lower sideband signal to produce said descrambled audio signal

Preferably, each of said first and second modulation carrier signals is a square wave signal, and each of said first and second modulating means is a square wave modulator arranged to modulate its respective incoming signal with the respective first or second square wave modulation carrier signal

The present invention also extends to a system for scrambling an original audio signal of about 50 Hz to about 15 KHz, the scrambling system comprising:

a first signal generator for generating a first modulation carrier signal have a frequency greater than the highest frequency in the original audio signal; first modulating means for modulating said original audio signal with said first modulation carrier signal to produce a first modulated signal having said first modulation frequency, first filtering means for rejecting a first upper sideband signal from said first modulated signal to produce a first filtered signal; a second signal generator for generating a second modulation carrier signal having a frequency higher than said first modulation frequency; second modulating means for modulating said first filtered signal with said second modulation carrier signal to produce a second modulated signal having said second modulation frequency; and second filtering means for passing a second side-

band signal from said second modulated signal to produce a scrambled audio signal;

the scrambling system being characterised in that, to produce a scrambled audio system with a lower noise level, said first modulated signal is a first quadrature sideband signal having said first modulation frequency, a first upper sideband signal and a first lower sideband signal; and said first filtering means filters out said first modulation frequency and its harmonics, and said upper sideband signal and its harmonics from said first quadrature sideband signal and passes said first lower sideband signal;

and in that said second modulated signal is a second double sideband signal having said second modulation frequency, a second upper sideband signal and a second lower sideband signal; and said second filtering means filters said second double sideband signal and passes only said second lower sideband signal to produce said scrambled audio signal.

Preferably, each of said first and second modulation carrier signals is a square wave signal, and each of said first and second modulating means is a square wave modulator arranged to modulate its respective incoming signal with the respective first or second square wave modulation carrier signal

As scramblers and descramblers of embodiments of the present invention modulate square wave signals, square wave modulators are utilised which are low noise.

Embodiments of scramblers and descramblers of the invention utilising square wave modulators have been found to eliminate in band audible whistle and to eliminate the need to adjust the mixers for minimum in band carrier whistle. As the SNR has been improved, the need for noise reduction circuits has been eliminated.

The square wave modulators may be switching type mixer circuits which are of a lower cost and reduce white noise as compared to linear mixer circuits.

Embodiments of scramblers and descramblers of the present invention also eliminate the use of 0 degree and 90 degree phase shift circuits, eliminate the use of quadrature mixer circuits, and eliminate the need for band pass filters or low pass filters for the modulation carrier.

In an embodiment, said switch type low noise modulators may comprise a differential pair balanced multiplier type modulator.

For example, said switch type low noise modulators may comprise MC1496 modulators, or an analog switch coupled to inverse polarities of an incoming signal.

In an embodiment, said first filtering means comprises an elliptical filter containing at least seven poles.

For example, said first filtering means comprises an active filter having nine poles with general impedance

convertors.

Preferably, said second filtering means comprises a filter with seven or more poles.

The present invention also extends to a method of descrambling scrambled frequency spectrum translated audio information signals by generating a modulation carrier signal at a frequency lying outside the original frequency spectral range of an original audio signal of about 50 Hz to about 15 KHz, the method comprising the steps of:

generating a first modulation carrier signal having a frequency greater than the highest frequency in the original audio signal;

modulating said scrambled audio signal with said first modulation carrier signal to produce a first modulated signal having said first modulation frequency;

filtering said first modulated signal to reject a first upper sideband signal and produce a first filtered signal;

generating a second modulation carrier signal having a frequency less than said first modulation frequency;

modulating said first filtered signal with said second modulation carrier signal to produce a second modulated signal having said second modulation frequency; and

filtering said second modulated signal to pass a second sideband signal to produce a descrambled audio signal;

characterised in that, to produce a descrambled audio signal containing substantially no audible whistle components, said first modulated signal is a first double sideband signal having said first modulation frequency, a first upper sideband signal and a first lower sideband signal, and said first filtering step comprises filtering from said first modulated signal said first modulation frequency, all its harmonics, and said first upper sideband signal and passing said first lower sideband signal;

and said second modulated signal is a second double sideband signal having said second modulation frequency, a second upper sideband signal and a second lower sideband signal, and said second filtering step comprises filtering from said second modulated signal said second modulation frequency, and said second upper sideband signal and passing only said second lower sideband signal to produce said descrambled audio signal.

In an embodiment, the method further comprises the steps of generating each of said first and second modulation carrier signals as a square wave signal; and

modulating each of said scrambled audio signal and said first lower sideband signal with the respective

first or second square wave modulation carrier signal.

Preferably, said first modulation carrier signal has a frequency of at least 19 KHz.

In an embodiment, said second modulation carrier signal has a frequency less than said first modulation frequency by at least 500 Hz. For example, said second modulation carrier signal has a frequency about 2.6 KHz less than said first modulation frequency.

According to a further aspect of the present invention there is provided a method of scrambling an original audio signal of about 50 Hz to about 15 KHz, the method comprising the steps of:

generating a first modulation carrier signal having a frequency greater than the highest frequency in the original audio signal;

modulating said original audio signal with said first modulation carrier signal to produce a first modulated signal having said first modulation frequency;

filtering said first modulated signal to reject a first upper sideband signal and produce a first filtered signal;

generating a second modulation carrier signal having a frequency higher than said first modulation frequency;

modulating said first filtered signal with said second modulation carrier signal to produce a second modulated signal having said second modulation frequency; and

filtering said second modulated signal to pass a second sideband signal to produce a scrambled audio signal;

characterised in that, to produce a scrambled audio signal with a lower noise level, said first modulated signal is a first quadrature sideband signal having said first modulation frequency, a first upper sideband signal and a first lower sideband signal, and said first filtering step comprises filtering from said first modulated signal said first modulation frequency, and its harmonics, and said first upper sideband signal and its harmonics, and passing said first lower sideband signal;

and said second modulated signal is a second double sideband signal having said second modulation frequency, a second upper sideband signal and a second lower sideband signal, and said second filtering step comprises filtering from said second modulated signal said second modulation frequency, and said second upper sideband signal and passing said second lower sideband signal to produce said scrambled audio signal.

In an embodiment, the method further comprises the steps of generating each of said first and second modulation carrier signals as a square wave signal, and

modulating each of said original audio signal and said first lower sideband signal with the respective first or second square wave modulation carrier signal.

Preferably, said first modulation carrier signal has a frequency of at least 16.4 KHz.

In an embodiment, said modulation carrier signal has a frequency at least 50 Hz greater than said first modulation carrier frequency. For example, said second modulation carrier signal has a frequency of about 19 KHz.

In an embodiment, the frequency of said second modulation carrier signal is pseudo randomly varied.

Embodiments of the present invention will hereinafter be described, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a block diagram of the key elements of the Forbes prior art;

Figure 2 is a spectral diagram of the system in the Forbes prior art;

Figure 3 is a block diagram of the key elements of the Quan prior art;

Figure 4 is a spectral diagram of the Quan prior art;

Figure 5 is a block diagram of a preferred embodiment of a descrambler of the present invention;

Figure 6 is a spectral diagram of the descrambler shown in Figure 5.

Figure 7 is block diagram of a switch type low noise modulator for use in a descrambler of the invention;

Figure 8 is a block diagram of a first implementation of a descrambler of the invention;

Figure 9 is a block diagram of a second implementation of a descrambler of the invention;

Figure 10 is a block diagram of a third implementation of a descrambler of the invention;

Figure 11 is a block diagram of a preferred embodiment of a scrambler of the present invention;

Figure 12 is a spectral diagram of the scrambler shown in Figure 11; and

Figures 13A, 13B and 13C show implementations of first and second low pass filters of scramblers and descramblers of the invention.

Figure 5 shows a block diagram and Figure 6 shows a spectral diagram of a descrambler of a preferred embodiment of the invention. Figure 6A shows the spectral characteristic of the scrambled audio input of the preferred embodiment. This shows the scrambled audio offset by an offset frequency determined by the scrambling process. Figure 6B shows the relationship of the first mixer's carrier and the output of the first mixer. Both the upper and lower sidebands and the residual carrier F_A plus the harmonics of all of these are at the first mixer's output. Figure 6C shows the filter characteristics of the first low pass filter (LPF) following the first mixer's output. This first LPF filters out the residual carrier and its upper sideband harmonics. Figure 6D shows the spectral characteristic of the output of the first LPF fol-

lowing the first mixer's output.

Figure 6E shows the relationship of the second carrier to the output of the first LPF to form the last descrambling step. Figure 6F shows the relationship of the descrambled audio that has passed through a 2nd LPF with a 12 khz cut-off to filter out F_B and its upper sideband above F_B with the absence of whistle frequency component ($F_A - F_B$). The ($F_A - F_B$) whistle frequency component is typically equal or less than -85 db in the descrambled audio.

In this preferred embodiment F_A is about 19 KHz and F_B is about 16.4 KHz. These choices are for economy, since with these frequencies the first LPF can be designed inexpensively. If increased performance at a greater cost is desired, the carrier frequencies can be higher in order to minimize leakage of components from the scrambled audio input so as to not interfere with the lower sideband output of the first mixer. Note that in Figures 6A and 6B there is an overlap between the spectra of the lower sideband frequencies and the scrambled audio frequencies. If the first mixer feeds through enough of the scrambled audio, distortion products will occur at the descrambled output. By setting the carrier frequencies to, for example $F_A = 39$ KHz and $F_B = 36.4$ KHz, scrambled input leak through will not cause distortion products at the descrambled output since it will not overlap with the lower sideband of the first mixer i.e. 36.4 KHz to 24 KHz versus 2.6 KHz to 14.6 KHz of the scrambled input. However raising F_A and F_B two fold causes the steepness of the first LPF to increase to about two fold. This would require higher order filters such as a 10 pole elliptical low pass filter.

Minimal carrier leakage and scrambled audio leakage with lower shot noise is achieved by using a double throw single pole analog switch such as the 74 HCT 4053 or its equivalent i.e. MC1496 switch type mixer with a carrier input equal to or more than 350 mv p-p.

It would found, for instance, with a CD 4053 analog switch that the "on" resistance resulted in a measured noise of 2.5 nv/ /Hz which translates into a noise resistance ($4kTBr = V_N = 2.5$ nv/ /Hz, $B = 1$ Hz, $T = 298^\circ$ Kelvin, $k =$ Boltzman's constant and $R =$ noise resistance of 400 ohms. The "on" resistance of the CD 4053 was measured to be 440 ohms. Thus it was found experimentally that the "on" resistance of the analog switch (i.e. 4053) produces the same amount of noise as a resistor component of the same resistance. Thus an "on" resistance of 440 ohms in a CD4053 has essentially the same noise as a 440 ohm resistor.

Linear modulators such as the AD 534 produces 0.6 mv RMS over a 10 KHz bandwidth or a noise density of 0.6 mv / /10 KHz = 60 nv / /Hz. Therefore the AD 534 linear modulator produces approximately 60/2.5 more noise than the CD 4053 switch. This is equivalent to a 27 db improvement when using a CD4053 over a linear modulator.

Gilbert modulators such as the 1496 or 1495 will produce low noise, i.e. < 5 nv/ /Hz when the carrier input

of these devices switch the differential pairs on and off. This is achieved by either overriding the carrier input with a square wave carrier input with a square wave of $> \pm 200$ mv or a large sine wave of > 1 v pp. When sinusoidal modulators such as the 1495 does not have the carrier inputs over driven to produce linear modulation, the noise is substantially higher versus a switch mode 1496 modulator. This is because the 2 differential pair transistors start amplifying their own noise. The internal base resistance of each transistor is usually about 50-200 ohms. If one assumes a 100 ohm series internal base resistors on the 2 pairs of differential pair transistors in series in a 1495 and 1 kohm load for one output and further assume that each of these transistors has a quiescent bias of 1 ma collector current, the output noise is then equal to $1/2 * 100$ (gm) $V_{nr} = V_o$ noise. $gm = 38$ ma/V for an $I_c = 1$ ma. Therefore $V_{nr} = 1/400$ ohm * $4kT = 2.5$ nv/Hz. V_o noise = $19 * 2.5$ nv // Hz = 47.5 nv // Hz from a 1495 modulator. This is 19 times or 25 db more noise than the CD 4053 with an "on" resistance of 440 ohms. It should be noted that the output noise decreases in the 1495 or 1496 modulator as the carrier input is increased.

The preferred embodiment uses a low pass filter (LPF) after the first mixer which is to reject out a residual carrier from the first mixer and remove all sidebands related to harmonics of the carrier and the harmonics of the carrier. If this is not done, harmonics of the whistle frequency ($3F_A - 3F_B$), ($5F_A - 5F_B$) and etc. will appear at the descrambling output in an audible manner. This first LPF is generally a 7 pole or more elliptical filter with at least one zero tune to notch out the first mixer's carrier frequency, F_A . In practice a 9 pole active filter with general impedance convertors is the best choice for a stable and accurate filter. In the preferred embodiment the 3 db cut off of the first low pass filter is about 17 Khz with at least 40 db attenuation at 19 Khz.

A detailed description of a preferred embodiment is described below with reference to Figure 5. The descrambling apparatus 12 has a scrambled audio signal input 60 and performs the descrambling process. The scrambled audio 60 is inputted into a first input of a first mixer 63. The second input of this first mixer is a first carrier signal F_A generated by frequency generator A_1 61 which is approximately 19 Khz. The output first mixer 63 contains carrier feed through of F_A all its sideband components and the harmonics. The output of mixer 63 is fed to a low pass filter 65 which filters out the first carrier, the upper sideband and all of the harmonics from signal 60. The output of low pass filter 65, signal 66 is fed into a first input of a second mixer 66. The second input of this second mixer is a second carrier signal F_B generated by frequency generator B, 62 which can be 16.4 Khz or 16.4 Khz ± 100 Hz shifted pseudo randomly for security reasons. See U.S. Patent 5,095,279 for a further explanation of this security process. The output of second mixer 70 contains the baseband descrambled audio, residual second carrier and upper sideband com-

ponents above F_B 's frequency. The second low pass filter 71 with a cut-off frequency of approximately 12 Khz removes everything above 12 Khz, but passes the descrambled audio to the output line 23.

In the above preferred embodiment the mixers utilize a switch type low shot or thermal noise modulator as described in Figure 7. The operation of this mixer will be described relative to the first mixer. The second mixer operates on the same principle. Scrambled audio 60 is fed into the + input of unity gain amplifier 73. The output of amplifier 73 is fed on line V_{IN} 74 to one input of a double pole single throw analog switcher 32. The output of 73 is also fed to the input of unity gain inversion amplifier consisting of R2a, R2b, and amplifier 65. The output of amplifier 65 is $-V_{IN}$ 75 which is fed to a second input of the switcher 32. First carrier frequency F_A is fed into the switching control input of the double pole, single throw switcher 32. The double pole, single throw switcher used is one-third of an 74HCT4053 or its equivalent and is fed to amplifier A220. A220 is the mixer output. For minimal carrier leakage of the output of mixer 65, the DC zero signal voltage of the two inputs of switch 32 V_{IN} and $-V_{IN}$ must be exactly the same, i.e. 0v. In addition the inversion amplifier R2a, R2b, 65 must be -1 unity gain to have minimum scrambled audio in V_{IN} feed through. Thus $R2a = R2b$ within 1% or better is required for a wide band op amp 65 (i.e. NE5532).

Figure 13A shows a conventional RLC low pass filter with zeros for the descrambler's first low pass filter. The inductors L_1 through L_3 are rather large, 2 milli-henries to 20 milli-henries, to achieve a low cost. These lower cost inductors suffer from a just adequate Q at audio frequencies. Much more expensive inductors with higher Q's will provide better low pass filtering, but will be beyond the budget of a low cost descrambling system.

Figure 13B shows an active 9 pole elliptic low pass filter that is not as sensitive to parts tolerance as many other active filters. This is important since F_A , the first carrier frequency must be filtered out by at least -40 db attenuation. Figure 13B is a general impedance converter (GIC) active low pass filter that was found to provide very high performance in filtering at low cost. The capacitors can be inexpensive 5% mylar film capacitors. The resistors are inexpensive 1% resistors and the operational amplifiers can be common type such as TL082, NE5532 etc.

Figure 13C shows an example of the second filter as an active 7 pole low pass filter. Amplifiers A1000, A2000 and A3000 can be simple voltage followers of common operational amplifiers or single transistor emitter followers. The second filter in the descrambler can be any low pass filter, passive or active with sufficient stop band attenuation to provide a descrambled audio signal without measurable artifacts such as second carrier tone its upper sidebands and/or audible artifacts.

Figures 8 to 11 show various implementations of the invention.

In addition to a descrambling system as described

above many of the same elements can be used in a scrambler to achieve many of the same advantages achieved in the descrambler described above, i.e. lower shot noise output and less filter requirements than in prior art such as Forbes ('853). Figure 11 is a block diagram and Figure 12 is a series of spectral diagrams of a preferred embodiment of a scrambler.

An audio signal with a spectral response of about 30 Hz to 15 KHz 91 is fed into a low pass filter 20 to eliminate any unwanted signals beyond 15 KHz. The output 93 of low pass filter 20 is connected to 0 degree and 90 degree all pass phase shifters 94 and 95. The outputs of phase shifters 94 and 95 are in turn connected to first inputs of switch type low noise modulators 96 and 97.

Signal generator 98 generates a square wave signal at approximately 16.4 KHz with 0° and 90° outputs which are connected to second inputs of modulators 96 and 97. The outputs of modulators 96 and 97 are summed to produce signal 103, a quadrature modulated signal resulting in a residual 16.4 KHz carrier with a lower sideband. Figure 12 shows the relationship of the quadrature modulated audio components to the original audio signal 91.

This quadrature modulated signal is fed through low pass filter 104 as signal 105 and is essentially the same filter as the first filter of the descrambler described above. This signal is connected to a first input of a third modulator 106. Modulator 106 is a switch type low thermal or shot noise modulator as described above and as shown in Figure 7. A second carrier frequency is generated by a square wave oscillator 99 generating a frequency of approximately 19 KHz as shown in Figure 12E. The output of modulator 106 contains a 16 KHz carrier and upper and lower sidebands. This signal is filtered by low pass filter 107 to produce a scrambled audio signal with an offset of approximately 2.6 KHz.

Theoretically, to decrease the dynamic artifacts caused by fast step frequency changes of the 16.4 KHz carrier in both the scrambler and descrambler, the low pass filters following the first quadrature mixer the first mixer of both the scrambler and descrambler respectively should be very nearly identical in group delay responses (transient responses). If the transient response characteristics of the low pass filters in the scrambler are different from the transient characteristics of the descrambler, the step changes of the 16.4 KHz carrier has to be slowed down to achieve minimal descrambling artifacts. It is preferred to have faster step changes in the secured carrier (16 KHz +/- 100 Hz) and have the first low pass filter in the descrambler have the same characteristics as filter 104 in the scrambler of Figure 11. In addition, the second low pass filter in the descrambler should have the same characteristics of filter 107 of the scrambler of Figure 11. This permits the step shifting spectrum of the scrambler to be tracked quickly in the descrambler without artifacts caused by time delay skews between scrambler and descrambler tracking the

16 KHz stepped deviations. It should be noted that all carriers for all mixers in this invention for descramblers and scramblers are square wave signals for minimum artifacts.

It will be appreciated that variations in, and modifications to, the embodiments described and illustrated may be made within the scope of the invention as defined by the appended claims.

Claims

1. A system for descrambling a scrambled frequency translated audio information signal by generating a modulation carrier signal at a frequency lying outside the original frequency spectral range of an original audio signal of about 50 Hz to about 15 KHz, the descrambling system comprising:

a first signal generator (61) for generating a first modulation carrier signal (F_A) having a frequency greater than the highest frequency in the original audio signal;

first modulating means (63) for modulating said scrambled audio signal with said first modulation carrier signal to produce a first modulated signal having said first modulation frequency;

first filtering means (65) for rejecting a first upper sideband signal from said first modulated signal to produce a first filtered signal;

a second signal generator (62) for generating a second modulation carrier signal (F_B) having a frequency less than said first modulation frequency;

second modulating means (67) for modulating said first filtered signal with said second modulation carrier signal to produce a second modulated signal having said second modulation frequency; and

second filtering means (71) for passing a second sideband signal from said second modulated signal to produce a descrambled audio signal;

the descrambling system being characterised in that, to produce a descrambled audio signal containing substantially no audible whistle components said first modulated signal is a first double sideband signal having said first modulation frequency, a first upper sideband signal and a first lower sideband signal; and said first filtering means (65) filters out said first modulation frequency, all its harmonics, and said first upper sideband signal from said first double sideband signal and passes said first lower sideband signal;

and in that said second modulated signal is a second double sideband signal having said second modulation frequency, a second upper

sideband signal and a second lower sideband signal; and said second filtering means (71) filters said second double sideband signal and passes only said second lower sideband signal to produce said descrambled audio signal.

2. A system for descrambling as claimed in Claim 1, wherein each of said first and second modulation carrier signals (F_A ; F_B) is a square wave signal, and each of said first and second modulating means (63, 67) is a square wave modulator arranged to modulate its respective incoming signal with the respective first or second square wave modulation carrier signal.

3. A system for scrambling an original audio signal of about 50 Hz to about 15 KHz, the scrambling system comprising:

a first signal generator (98) for generating a first modulation carrier signal (F_F) have a frequency greater than the highest frequency in the original audio signal;

first modulating means (96, 97) for modulating said original audio signal with said first modulation carrier signal to produce a first modulated signal having said first modulation frequency, first filtering means (104) for rejecting a first upper sideband signal from said first modulated signal to produce a first filtered signal;

a second signal generator (99) for generating a second modulation carrier signal (F_A) having a frequency higher than said first modulation frequency;

second modulating means (106) for modulating said first filtered signal with said second modulation carrier signal to produce a second modulated signal having said second modulation frequency; and

second filtering means (107) for passing a second sideband signal from said second modulated signal to produce a scrambled audio signal;

the scrambling system being characterised in that, to produce a scrambled audio system with a lower noise level, said first modulated signal is a first quadrature sideband signal having said first modulation frequency, a first upper sideband signal and a first lower sideband signal; and said first filtering means (104) filters out said first modulation frequency and its harmonics, and said upper sideband signal and its harmonics from said first quadrature sideband signal and passes said first lower sideband signal; and in that said second modulated signal is a second double sideband signal having said second modulation frequency, a second upper sideband signal and a second lower sideband

signal; and said second filtering means (107) filters said second double sideband signal and passes only said second lower sideband signal to produce said scrambled audio signal.

4. A system for scrambling as claimed in Claim 3, wherein each of said first and second modulation carrier signals (F_F ; F_A) is a square wave signal, and each of said first and second modulating means (96, 97; 106) is a square wave modulator arranged to modulate its respective incoming signal with the respective first or second square wave modulation carrier signal.

5. A system as claimed in any preceding claim, wherein said first and/or second modulating means (63, 67; 96, 97, 106) comprise switch type low noise modulators.

6. A system as claimed in Claim 5, wherein said first and said second switch type low noise modulators (63, 67) comprise MC 1496 modulators.

7. A system as claimed in Claim 5, wherein one of said switch type low noise modulators (63, 106) comprises an analog switch coupled to inverse polarities of the incoming signal(s).

8. A system as claimed in Claim 5, wherein said switch type low noise modulators (106) comprise a differential pair balanced multiplier type modulator.

9. A system as claimed in any preceding claim, wherein said first filtering means (65; 104) comprises an elliptical filter containing at least seven poles.

10. A system as claimed in Claim 9, wherein said first filtering means (65; 104) comprises an active filter having nine poles with general impedance converters.

11. A system as claimed in any preceding claim, wherein said second filtering means (71; 107) comprises a filter with seven or more poles.

12. A method of descrambling scrambled frequency spectrum translated audio information signals by generating a modulation carrier signal at a frequency lying outside the original frequency spectral range of an original audio signal of about 50 Hz to about 15 KHz, the method comprising the steps of:

generating a first modulation carrier signal (F_A) having a frequency greater than the highest frequency in the original audio signal; modulating said scrambled audio signal with said first modulation carrier signal to produce a first modulated signal having said first modula-

tion frequency;
 filtering said first modulated signal to reject a first upper sideband signal and produce a first filtered signal;
 generating a second modulation carrier signal (F_B) having a frequency less than said first modulation frequency;
 modulating said first filtered signal with said second modulation carrier signal to produce a second modulated signal having said second modulation frequency; and
 filtering said second modulated signal to pass a second sideband signal to produce a descrambled audio signal;

characterised in that, to produce a descrambled audio signal containing substantially no audible whistle components, said first modulated signal is a first double sideband signal having said first modulation frequency, a first upper sideband signal and a first lower sideband signal, and said first filtering step comprises filtering from said first modulated signal said first modulation frequency, all its harmonics, and said first upper sideband signal and passing said first lower sideband signal;

and said second modulated signal is a second double sideband signal having said second modulation frequency, a second upper sideband signal and a second lower sideband signal, and said second filtering step comprises filtering from said second modulated signal said second modulation frequency, and said second upper sideband signal and passing only said second lower sideband signal to produce said descrambled audio signal.

- 13.** A method as claimed in Claim 12, further comprising the steps of generating each of said first and second modulation carrier signals (F_A ; F_B) as a square wave signal; and

modulating each of said scrambled audio signal and said first lower sideband signal with the respective first or second square wave modulation carrier signal.

- 14.** A method as claimed in Claim 12 or Claim 13, wherein said first modulation carrier signal (F_A) has a frequency of at least 19 KHz.

- 15.** A method as claimed in Claim 10 or Claim 11, wherein said second modulation carrier signal (F_B) has a frequency less than said first modulation frequency by at least 500 Hz.

- 16.** A method as claimed in Claim 15, wherein said second modulation carrier signal has a frequency about

2.6 KHz less than said first modulation frequency.

- 17.** A method of scrambling an original audio signal of about 50 Hz to about 15 KHz, the method comprising the steps of:

generating a first modulation carrier signal (F_F) having a frequency greater than the highest frequency in the original audio signal;
 modulating said original audio signal with said first modulation carrier signal to produce a first modulated signal having said first modulation frequency;
 filtering said first modulated signal to reject a first upper sideband signal and produce a first filtered signal;
 generating a second modulation carrier signal (F_A) having a frequency higher than said first modulation frequency;
 modulating said first filtered signal with said second modulation carrier signal to produce a second modulated signal having said second modulation frequency; and
 filtering said second modulated signal to pass a second sideband signal to produce a scrambled audio signal;

characterised in that, to produce a scrambled audio signal with a lower noise level, said first modulated signal is a first quadrature sideband signal having said first modulation frequency, a first upper sideband signal and a first lower sideband signal, and said first filtering step comprises filtering from said first modulated signal said first modulation frequency, and its harmonics, and said first upper sideband signal and its harmonics, and passing said first lower sideband signal;

and said second modulated signal is a second double sideband signal having said second modulation frequency, a second upper sideband signal and a second lower sideband signal, and said second filtering step comprises filtering from said second modulated signal said second modulation frequency, and said second upper sideband signal and passing said second lower sideband signal to produce said scrambled audio signal.

- 18.** A method as claimed in Claim 17, further comprising the steps of generating each of said first and second modulation carrier signals (F_F , F_A) as a square wave signal, and modulating each of said original audio signal and said first lower sideband signal with the respective first or second square wave modulation carrier signal.

- 19.** A method as claimed in Claim 17 or Claim 18,

wherein said first modulation carrier signal (F_F) has a frequency of at least 16.4 Khz.

20. A method as claimed in any of Claims 17 to 19, wherein said modulation carrier signal (F_A) has a frequency at least 50 Hz greater than said first modulation carrier frequency. 5
21. A method as claimed in Claim 20, wherein said second modulation carrier signal (F_A) has a frequency of about 19 Khz. 10
22. A method as claimed in any of Claims 12 to 21, wherein the frequency of said second modulation carrier signal (F_B , F_A) is pseudo randomly varied. 15

Patentansprüche

1. Vorrichtung zum Entwürfeln eines mit verwürfelte Frequenz umgesetzten Audioinformationssignals durch Erzeugen eines Modulationsträgersignals mit einer Frequenz, die außerhalb des ursprünglichen Frequenzspektralbereiches eines ursprünglichen Audiosignals von etwa 50 Hz bis etwa 15 Khz liegt, wobei die Entwüfelungsvorrichtung aufweist: 20

einen ersten Signalgenerator (61) zum Erzeugen eines ersten Modulationsträgersignals (F_A) mit einer Frequenz, die größer ist als die höchste Frequenz in dem ursprünglichen Audiosignal; 30

eine erste Modulationseinrichtung (63) zum Modulieren des verwürfelten Audiosignals mit dem ersten Modulationsträgersignal, um ein erstes moduliertes Signal zu erzeugen, das die erste Modulationsfrequenz hat; 35

eine erste Filtereinrichtung (65) zum Herausfiltern eines ersten oberen Seitenbandsignals aus dem ersten modulierten Signal, um ein erstes gefiltertes Signal zu erzeugen; 40

einen zweiten Signalgenerator (62) zum Erzeugen eines zweiten Modulationsträgersignals (F_B) mit einer Frequenz, die kleiner ist als die erste Modulationsfrequenz; 45

eine zweite Modulationseinrichtung (67) zum Modulieren des ersten gefilterten Signals mit dem zweiten Modulationsträgersignal, um ein zweites moduliertes Signal zu erzeugen, das die zweite Modulationsfrequenz hat; und 50

eine zweite Filtereinrichtung (71) zum Durchlassen eines zweiten Seitenbandsignals aus dem zweiten modulierten Signal, um ein entwüfeltes Audiosignal zu erzeugen; 55

wobei die Entwüfelungsvorrichtung dadurch gekennzeichnet ist, daß zum Erzeugen eines entwüfelten Audiosignals, das im wesentlichen keine hörbaren Pfeifkomponenten ent-

hält, das erste modulierte Signal ein erstes Zweiseitenbandsignal mit der ersten Modulationsfrequenz, ein erstes oberes Seitenbandsignal und ein erstes unteres Seitenbandsignal ist; und daß die erste Filtereinrichtung (65) die erste Modulationsfrequenz, alle Oberwellen davon und das erste obere Seitenbandsignal aus dem ersten Zweiseitenbandsignal herausfiltert und das erste untere Seitenbandsignal durchläßt;

und daß das zweite modulierte Signal ein zweites Zweiseitenbandsignal mit der zweiten Modulationsfrequenz, ein zweites oberes Seitenbandsignal und ein zweites unteres Seitenbandsignal ist; und daß die zweite Filtereinrichtung (71) das zweite Zweiseitenbandsignal filtert und lediglich das zweite untere Seitenbandsignal durchläßt, um das entwüfelte Audiosignal zu erzeugen.

2. Vorrichtung zum Entwürfeln nach Anspruch 1, bei der jedes von dem ersten und zweiten Modulationsträgersignal (F_A ; F_B) ein Rechteckwellensignal ist und bei der jede von der ersten und zweiten Modulationseinrichtung (63, 67) ein Rechteckwellenmodulator ist, der dazu ausgestaltet ist, sein jeweils eingehendes Signal mit dem jeweils ersten oder zweiten Rechteckwellenmodulationsträgersignal zu modulieren.

3. Vorrichtung zum Verwürfeln eines ursprünglichen Audiosignals von etwa 50 Hz bis etwa 15 KHz, wobei die Verwürfelungsvorrichtung aufweist:

einen ersten Signalgenerator (98) zum Erzeugen eines ersten Modulationsträgersignals (F_F) mit einer Frequenz, die größer ist als die höchste Frequenz in dem ursprünglichen Audiosignal;

eine erste Modulationseinrichtung (96, 97) zum Modulieren des ursprünglichen Audiosignals mit dem ersten Modulationsträgersignal, um ein erstes moduliertes Signal zu erzeugen, das die erste Modulationsfrequenz hat;

eine erste Filtereinrichtung (104) zum Herausfiltern eines ersten oberen Seitenbandsignals aus dem ersten modulierten Signal, um ein erstes gefiltertes Signal zu erzeugen;

einen zweiten Signalgenerator (99) zum Erzeugen eines zweiten Modulationsträgersignals (F_A) mit einer Frequenz, die größer als die erste Modulationsfrequenz ist;

eine zweite Modulationseinrichtung (106) zum Modulieren des ersten gefilterten Signals mit dem zweiten Modulationsträgersignal, um ein zweites moduliertes Signal zu erzeugen, das die zweite Modulationsfrequenz hat; und eine zweite Filtereinrichtung (107) zum Durch-

- lassen eines zweiten Seitenbandsignals aus dem zweiten modulierten Signal, um ein verwürfeltes Audiosignal zu erzeugen; wobei die Verwürfelungsvorrichtung dadurch gekennzeichnet ist, daß zum Erzeugen eines verwürfelten Audiosystems, das einen geringeren Geräuschpegel hat, das erste modulierte Signal ein erstes Quadraturseitenbandsignal mit der ersten Modulationsfrequenz, ein erstes oberes Seitenbandsignal und ein erstes unteres Seitenbandsignal ist; und daß die erste Filtereinrichtung (104) die erste Modulationsfrequenz und deren Oberwellen sowie das obere Seitenbandsignal und dessen Oberwellen aus dem ersten Quadraturseitenbandsignal herausfiltert und das erste untere Seitenbandsignal durchläßt; und daß das zweite modulierte Signal ein zweites Zweiseitenbandsignal mit der zweiten Modulationsfrequenz, ein zweites oberes Seitenbandsignal und ein zweites unteres Seitenbandsignal ist; und daß die zweite Filtereinrichtung (107) das zweite Zweiseitenbandsignal filtert und lediglich das zweite untere Seitenbandsignal durchläßt, um das verwürfelte Audiosignal zu erzeugen.
4. Vorrichtung zum Verwürfeln nach Anspruch 3, bei der jedes von dem ersten und zweiten Modulationsträgersignal (F_F ; F_A) ein Rechteckwellensignal ist und bei der jede von der ersten und zweiten Modulationseinrichtung (96, 97; 106) ein Rechteckwellenmodulator ist, der dazu ausgestaltet ist, um sein jeweils eingehendes Signal mit dem jeweils ersten oder zweiten Rechteckwellenmodulationsträgersignal zu modulieren.
5. Vorrichtung nach einem der vorhergehenden Ansprüche, bei der die erste und/oder zweite Modulationseinrichtung (63, 67; 96, 97, 106) rauscharme Schalt-Modulatoren enthalten.
6. Vorrichtung nach Anspruch 5, bei der die ersten und zweiten rauscharmen Schalt-Modulatoren (63, 67) MC 1496-Modulatoren enthalten.
7. Vorrichtung nach Anspruch 5, bei der einer der rauscharmen Schalt-Modulatoren (63, 106) einen analogen Schalter enthält, der mit inversen Polaritäten des eingehenden Signals (Signale) gekoppelt ist.
8. Vorrichtung nach Anspruch 5, bei der die rauscharmen Schalt-Modulatoren (106) einen Differential-Paar-Gegentakt-Multiplizier-Modulator (differential pair ballanced multiplier type modulator) enthält.
9. Vorrichtung nach einem der vorhergehenden An-
- sprüche, bei der die erste Filtereinrichtung (65; 104) ein elliptisches Filter mit zumindest sieben Polen enthält.
10. Vorrichtung nach Anspruch 9, bei der die erste Filtereinrichtung (65; 104) ein aktives Filter mit neun Polen mit Universalimpedanzkonvertern enthält.
11. Vorrichtung nach einem der vorhergehenden Ansprüche, bei der die zweite Filtereinrichtung (71; 107) ein Filter mit sieben oder mehr Polen enthält.
12. Verfahren zum Entwürfeln von Audioinformationssignalen, die mit einem verwürfelten Frequenzspektrum umgesetzt sind, durch Erzeugen eines Modulationsträgersignals mit einer Frequenz, die außerhalb des ursprünglichen Frequenzspektralbereiches eines ursprünglichen Audiosignals von etwa 50 Hz bis etwa 15 Khz liegt, wobei das Verfahren die Schritte umfaßt:
- Erzeugen eines ersten Modulationsträgersignals (F_A) mit einer Frequenz, die größer ist als die höchste Frequenz in dem ursprünglichen Audiosignal;
- Modulieren des verwürfelten Audiosignals mit dem ersten Modulationsträgersignal, um ein erstes modulierte Signal zu erzeugen, das die erste Modulationsfrequenz hat;
- Filtern des ersten modulierten Signals, um ein erstes oberes Seitenbandsignal herauszufiltern und um ein erstes gefiltertes Signal zu erzeugen;
- Erzeugen eines zweiten Modulationsträgersignals (F_B) mit einer Frequenz, die kleiner als die erste Modulationsfrequenz ist;
- Modulieren des ersten gefilterten Signals mit dem zweiten Modulationsträgersignal, um ein zweites modulierte Signal zu erzeugen, das die zweite Modulationsfrequenz hat; und
- Filtern des zweiten modulierten Signals, um ein zweites Seitenbandsignal durchzulassen, um ein entwürfeltes Audiosignal zu erzeugen;
- dadurch gekennzeichnet, daß zum Erzeugen eines entwürfelten Audiosignals, das im wesentlichen keine hörbaren Pfeifkomponenten enthält, das erste modulierte Signal ein erstes Zweiseitenbandsignal mit der ersten Modulationsfrequenz, ein erstes oberes Seitenbandsignal und ein erstes unteres Seitenbandsignal ist, und daß der erste Filterschritt das Herausfiltern der ersten Modulationsfrequenz, aller Oberwellen davon und des ersten oberen Seitenbandsignals aus dem ersten modulierten Signal und das Durchlassen des ersten unteren Seitenbandsignals umfaßt;
- und daß das zweite modulierte Signal ein zwei-

- tes Zweiseitenbandsignal mit der zweiten Modulationsfrequenz, ein zweites oberes Seitenbandsignal und ein zweites unteres Seitenbandsignal ist, und daß der zweite Filterschritt das Herausfiltern der zweiten Modulationsfrequenz und des zweiten unteren Seitenbandsignals aus dem zweiten modulierten Signal und das Durchlassen von lediglich dem zweiten unteren Seitenbandsignal umfaßt, um das entwürfelte Audiosignal zu erzeugen.
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13. Verfahren nach Anspruch 12, das außerdem die Schritte umfaßt: Erzeugen von jedem von dem ersten und zweiten Modulationsträgersignal (F_A ; F_B) als ein Rechteckwellensignal; und
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- Modulieren von jedem von dem verwürfelten Audiosignal und dem ersten unteren Seitenbandsignal mit dem jeweils ersten oder zweiten Rechteckwellenmodulationsträgersignal.
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14. Verfahren nach Anspruch 12 oder Anspruch 13, bei dem das erste Modulationsträgersignal (F_A) eine Frequenz von zumindest 19 Khz hat.
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15. Verfahren nach Anspruch 10 oder Anspruch 11, bei dem das zweite Modulationsträgersignal (F_B) eine Frequenz hat, die kleiner ist als die erste Modulationsfrequenz von zumindest 500 Hz.
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16. Verfahren nach Anspruch 15, bei dem das zweite Modulationsträgersignal eine Frequenz hat, die etwa 2,6 Khz kleiner ist als die erste Modulationsfrequenz.
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17. Verfahren zum Verwürfeln eines ursprünglichen Audiosignals von etwa 50 Hz bis etwa 15 Khz, wobei das Verfahren die Schritte umfaßt:
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- Erzeugen eines ersten Modulationsträgersignals (F_F) mit einer Frequenz, die größer ist als die höchste Frequenz in dem ursprünglichen Audiosignal;
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- Modulieren des ursprünglichen Audiosignals mit dem ersten Modulationsträgersignal, um ein erste moduliertes Signal zu erzeugen, das die erste Modulationsfrequenz hat;
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- Filtern des ersten modulierten Signals, um ein erstes oberes Seitenbandsignal herauszufiltern und um ein erstes gefiltertes Signal zu erzeugen;
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- Erzeugen eines zweiten Modulationsträgersignals (F_A) mit einer Frequenz, die größer als die erste Modulationsfrequenz ist;
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- Modulieren des ersten gefilterten Signals mit dem zweiten Modulationsträgersignal, um ein zweites moduliertes Signal zu erzeugen, das die zweite Modulationsfrequenz hat; und
- Filtern des zweiten modulierten Signals, um ein zweites Seitenbandsignal durchzulassen, um ein verwürfeltes Audiosignal zu erzeugen;
- dadurch gekennzeichnet, daß zum Erzeugen eines verwürfelten Audiosignals, das einen geringeren Geräuschpegel hat, das erste modulierte Signal ein erstes Quadraturseitenbandsignal mit der ersten Modulationsfrequenz, ein erstes oberes Seitenbandsignal und ein erstes unteres Seitenbandsignal ist; und daß der erste Filterschritt das Herausfiltern der ersten Modulationsfrequenz und deren Oberwellen sowie des ersten oberen Seitenbandsignals und dessen Oberwellen aus dem ersten modulierten Signal und das Durchlassen des ersten unteren Seitenbandsignals umfaßt;
- und daß das zweite modulierte Signal ein zweites Zweiseitenbandsignal mit der zweiten Modulationsfrequenz, ein zweites oberes Seitenbandsignal und ein zweites unteres Seitenbandsignal ist; und daß der zweite Filterschritt das Herausfiltern der zweiten Modulationsfrequenz und des zweiten oberen Seitenbandsignals aus dem zweiten modulierten Signal und das Durchlassen des zweiten unteren Seitenbandsignals umfaßt, um das verwürfelte Audiosignal zu erzeugen.
18. Verfahren nach Anspruch 17, das außerdem die Schritte umfaßt: Erzeugen von jedem von dem ersten und zweiten Modulationsträgersignal (F_F , F_A) als ein Rechteckwellensignal und Modulieren von jedem von dem ursprünglichen Audiosignal und dem ersten unteren Seitenbandsignal mit dem jeweils ersten oder zweiten Rechteckwellenmodulationsträgersignal.
19. Verfahren nach Anspruch 17 oder Anspruch 18, bei dem das erste Modulationsträgersignal (F_F) eine Frequenz von zumindest 16,4 Khz hat.
20. Verfahren nach einem der Ansprüche 17 bis 19, bei dem das Modulationsträgersignal (F_A) eine Frequenz hat, die zumindest 50 Hz größer als die erste Modulationsträgerfrequenz ist.
21. Verfahren nach Anspruch 20, bei dem das zweite Modulationsträgersignal (F_A) eine Frequenz von etwa 19 Khz hat.
22. Verfahren nach einem der Ansprüche 12 bis 21, bei dem die Frequenz des zweiten Modulationsträgersignals (F_B , F_A) pseudozufällig verändert wird.

Revendications

1. Système pour désembrouiller un signal d'information audio transposé en fréquence et brouillé en générant un signal de porteuse de modulation à une fréquence se situant à l'extérieur de la gamme spectrale de fréquence originale d'un signal audio original d'environ 50 Hz à environ 15 kHz, le système de désembrouillage comprenant :

un premier générateur de signal (61) pour générer un premier signal de porteuse de modulation (F_A) ayant une fréquence supérieure à la fréquence la plus haute dans le signal audio original ;

des premiers moyens de modulation (63) pour moduler ledit signal audio brouillé avec ledit premier signal de porteuse de modulation afin de produire un premier signal modulé ayant ladite première fréquence de modulation ;

des premiers moyens de filtrage (65) pour rejeter un premier signal à bande latérale haute dudit premier signal modulé afin de produire un premier signal filtré ;

un second générateur de signal (62) pour générer un second signal de porteuse de modulation (F_B) ayant une fréquence inférieure à ladite première fréquence de modulation ;

des seconds moyens de modulation (67) pour moduler ledit premier signal filtré avec ledit second signal de porteuse de modulation afin de produire un second signal modulé ayant ladite seconde fréquence de modulation ; et

des seconds moyens de filtrage (71) destinés à laisser passer un second signal à bande latérale provenant dudit second signal modulé afin de produire un signal audio désembrouillé ;

le système de désembrouillage étant caractérisé en ce que, pour produire un signal audio désembrouillé ne contenant sensiblement aucune composante de sifflement audible, ledit premier signal modulé est un premier signal à bande latérale double ayant ladite première fréquence de modulation, un premier signal à bande latérale haute et un premier signal à bande latérale basse ; et lesdits premiers moyens de filtrage (65) éliminent par filtrage ladite première fréquence de modulation, tous ses harmoniques, et ledit premier signal à bande latérale haute dudit premier signal à bande latérale double et laissent passer ledit premier signal à bande latérale basse ;

et en ce que ledit second signal modulé est un second signal à bande latérale double ayant ladite seconde fréquence de modulation, un second signal à bande latérale haute et un second signal à bande latérale basse ; et en ce que lesdits seconds moyens de filtrage (71) filtrent le-

dit second signal à bande latérale double et ne laissent passer que ledit second signal à bande latérale basse pour produire ledit signal audio désembrouillé.

2. Système de désembrouillage selon la revendication 1, dans lequel chacun desdits premier et second signaux de porteuses de modulation (F_A ; F_B) est un signal en onde carrée, et chacun desdits premier et second moyens de modulation (63, 67) est un modulateur à onde carrée conçu pour moduler son signal d'entrée respectif avec le premier ou le second signal de porteuse de modulation en onde carrée respectif.

3. Système pour brouiller un signal audio original d'environ 50 Hz à environ 15 kHz, le système de brouillage comprenant :

un premier générateur de signal (98) pour générer un premier signal de porteuse de modulation (F_F) ayant une fréquence supérieure à la fréquence la plus haute dans le signal audio original ;

des premiers moyens de modulation (96, 97) pour moduler le premier signal audio original avec ledit premier signal de porteuse de modulation afin de produire un premier signal modulé ayant ladite première fréquence de modulation ;

des premiers moyens de filtrage (104) pour rejeter un premier signal à bande latérale haute dudit premier signal de modulation afin de produire un premier signal filtré ;

un second générateur de signal (99) pour générer un second signal de porteuse de modulation (F_A) ayant une fréquence supérieure à ladite première fréquence de modulation ;

des seconds moyens de modulation (106) pour moduler le premier signal filtré avec ledit second signal de porteuse de modulation afin de produire un second signal modulé ayant ladite seconde fréquence de modulation ; et

des seconds moyens de filtrage (107) pour laisser passer un second signal à bande latérale provenant dudit second signal de modulation afin de produire un signal audio brouillé ;

le système de brouillage étant caractérisé en ce que, pour produire un système audio brouillé ayant un plus faible niveau de bruit, ledit premier signal modulé est un premier signal à bande latérale en quadrature ayant une première fréquence de modulation, un premier signal à bande latérale haute et un premier signal à bande latérale basse, et en ce que lesdits premiers moyens de filtrage (104) filtrent la première fréquence de modulation et ses harmoniques, et ledit signal à bande latérale haute et ses har-

- moniques dudit premier signal à bande latérale en quadrature et laissent passer ledit premier signal à bande latérale basse ;
 et en ce que ledit second signal modulé est un second signal à bande latérale double ayant ladite seconde fréquence de modulation, un second signal à bande latérale haute et un second signal à bande latérale basse ; et lesdits seconds moyens de filtrage (107) filtrent ledit second signal à bande latérale double et ne laissent passer que ledit second signal à bande latérale basse pour produire ledit signal audio brouillé.
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12. Procédé de désembrouillage de signaux d'informations audio brouillés à spectre de fréquence transposé en générant un signal de porteuse de modulation à une fréquence se situant à l'extérieur de la gamme spectrale de fréquence originale d'un signal audio original d'environ 50 Hz à environ 15 kHz, le procédé comprenant les étapes qui consistent :
- à générer un premier signal de porteuse de modulation (F_A) ayant une fréquence supérieure à la fréquence la plus haute dans le signal audio original ;
 à moduler ledit signal audio brouillé avec ledit premier signal de porteuse de modulation afin de produire un premier signal modulé ayant ladite première fréquence de modulation ;
 à filtrer ledit premier signal modulé pour rejeter un premier signal latéral à bande latérale haute et produire un premier signal filtré ;
 à générer un second signal de porteuse de modulation (F_B) ayant une fréquence inférieure à ladite première fréquence de modulation ;
 à moduler ledit premier signal filtré avec ledit second signal de porteuse de modulation afin de produire un second signal modulé ayant ladite seconde fréquence de modulation ; et
 à filtrer ledit second signal modulé pour laisser passer un second signal à bande latérale afin de produire un signal audio désembrouillé ;
- caractérisé en ce que, pour produire un signal audio désembrouillé ne contenant sensiblement aucune composante de sifflement audible, ledit premier signal modulé est un premier signal à bande latérale double ayant ladite première fréquence de modulation, un premier signal à bande latérale haute et un premier signal à bande latérale basse et ladite première étape de filtrage consiste à filtrer dudit premier signal modulé ladite première fréquence de modulation, tous ses harmoniques, et ledit premier signal à bande latérale haute et à laisser passer ledit premier signal à bande latérale basse ;
- et en ce que ledit second signal modulé est un second signal à bande latérale double ayant ladite seconde fréquence de modulation, un second signal à bande latérale haute et un second signal à bande latérale basse, et ladite seconde étape de filtrage consiste à filtrer dudit second signal modulé ladite seconde fréquence de modulation, et ledit second signal à bande latérale haute et à ne laisser passer que ledit second signal à bande latérale basse pour produire ledit signal audio désembrouillé.

13. Procédé selon la revendication 12, comprenant en outre les étapes consistant à générer chacun desdits premier et second signaux de porteuses de modulation (F_A ; F_B) sous la forme d'un signal en onde carrée ; et

à moduler chacun dudit signal audio brouillé et dudit premier signal à bande latérale basse avec le premier ou le second signal de porteuse de modulation en onde carrée respectif.

14. Procédé selon la revendication 12 ou 13, dans lequel ledit premier signal de porteuse de modulation (F_A) a une fréquence d'au moins 19 kHz.

15. Procédé selon la revendication 10 ou 11, dans lequel ledit second signal de porteuse de modulation (F_B) a une fréquence inférieure d'au moins 500 Hz à ladite première fréquence de modulation.

16. Procédé selon la revendication 15, dans lequel ledit second signal de porteuse de modulation a une fréquence inférieure d'environ 2,6 kHz à ladite première fréquence de modulation.

17. Procédé de brouillage d'un signal audio original d'environ 50 Hz à environ 15 kHz, le procédé comprenant les étapes qui consistent :

à générer un premier signal de porteuse de modulation (F_F) ayant une fréquence supérieure à la fréquence la plus haute dans le signal audio original ;

à moduler ledit signal audio original avec ledit premier signal de porteuse de modulation afin de produire un premier signal modulé ayant ladite première fréquence de modulation ;

à filtrer ledit premier signal modulé afin de rejeter un premier signal à bande latérale haute et de produire un premier signal filtré ;

à générer un second signal de porteuse de modulation (F_A) ayant une fréquence plus haute que ladite première fréquence de modulation ;

à moduler ledit premier signal filtré avec ledit second signal de porteuse de modulation afin de produire un second signal modulé ayant ladite seconde fréquence de modulation ; et

à filtrer ledit second signal modulé pour laisser passer un second signal à bande latérale afin de produire un signal audio brouillé ;

caractérisé en ce que, pour produire un signal audio brouillé ayant un niveau de bruit plus faible, ledit premier signal modulé est un premier signal à bande latérale en quadrature ayant ladite première fréquence de modulation, un premier signal à bande latérale haute et un premier signal à bande latérale basse, et en ce que ladite première étape de

filtrage consiste à filtrer à partir dudit premier signal modulé ladite première fréquence de modulation et ses harmoniques, et ledit premier signal à bande latérale haute et ses harmoniques, et à laisser passer ledit premier signal à bande latérale basse ;

et ledit second signal modulé est un second signal à bande latérale double ayant une seconde fréquence de modulation, un second signal à bande latérale haute et un second signal à bande latérale basse, et ladite seconde étape de filtrage consiste à filtrer dudit second signal modulé ladite seconde fréquence de modulation et ledit second signal à bande latérale haute, et à laisser passer ledit second signal à bande latérale basse pour produire ledit signal audio brouillé.

18. Procédé selon la revendication 17, comprenant en outre les étapes consistant à produire chacun desdits premier et second signaux de porteuses de modulation (F_F , F_A) sous la forme d'un signal en onde carrée, et à moduler chacun dudit signal audio original et dudit premier signal à bande latérale basse avec le premier ou le second signal de porteuse de modulation en onde carrée.

19. Procédé selon la revendication 17 ou 18, dans lequel ledit premier signal de porteuse de modulation (F_F) a une fréquence d'au moins 16,4 kHz.

20. Procédé selon l'une quelconque des revendications 17 à 19, dans lequel ledit signal de porteuse de modulation (F_A) a une fréquence supérieure d'au moins 50 Hz à ladite première fréquence de porteuse de modulation.

21. Procédé selon la revendication 20, dans lequel ledit second signal de porteuse de modulation (F_A) a une fréquence d'environ 19 kHz.

22. Procédé selon l'une quelconque des revendications 12 à 21, dans lequel la fréquence dudit second signal de porteuse de modulation (F_B , F_A) est amené à varier de façon pseudo-aléatoire.

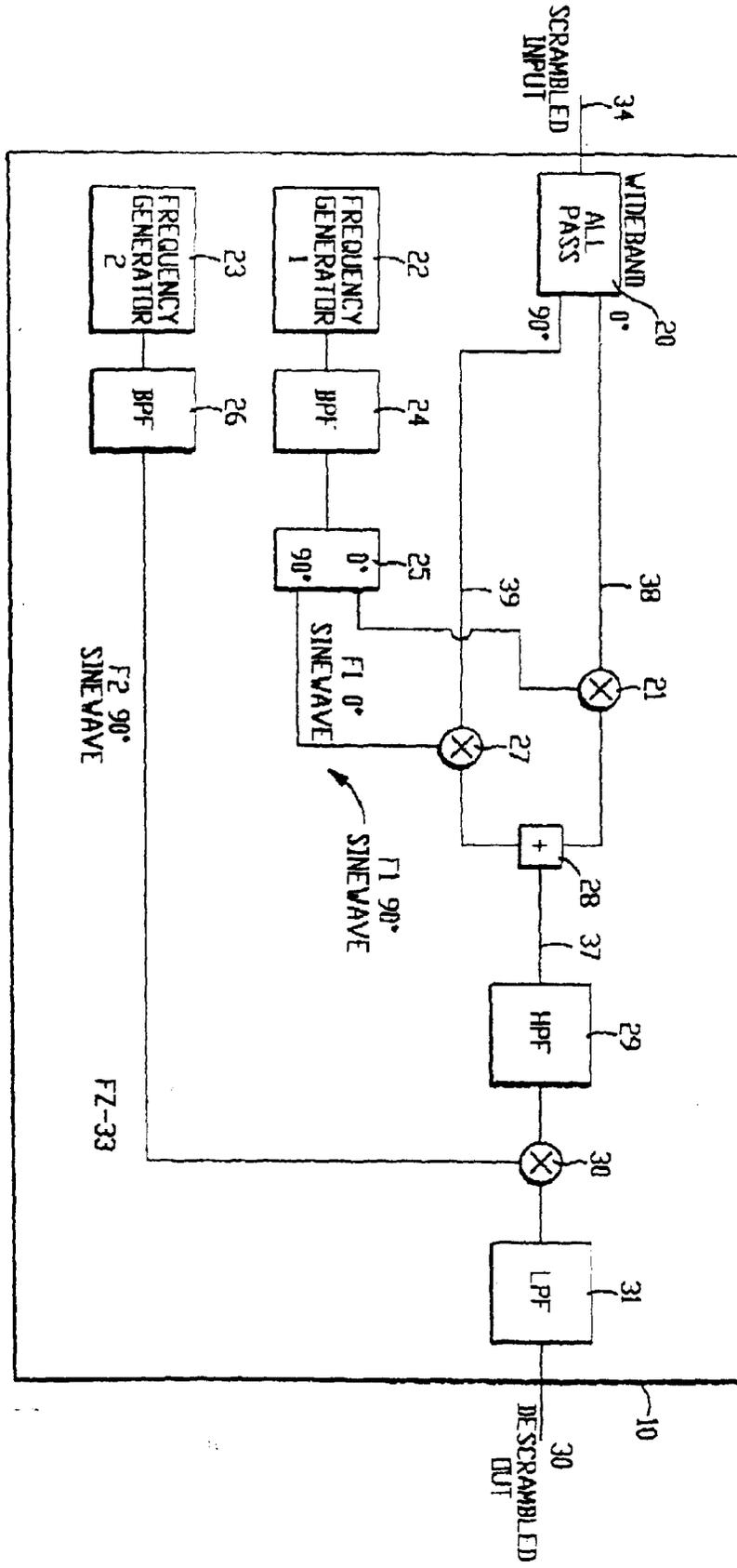


FIG. -1
(PRIOR ART)

FIG. -2A
(PRIOR ART)

FIG. -2B
(PRIOR ART)

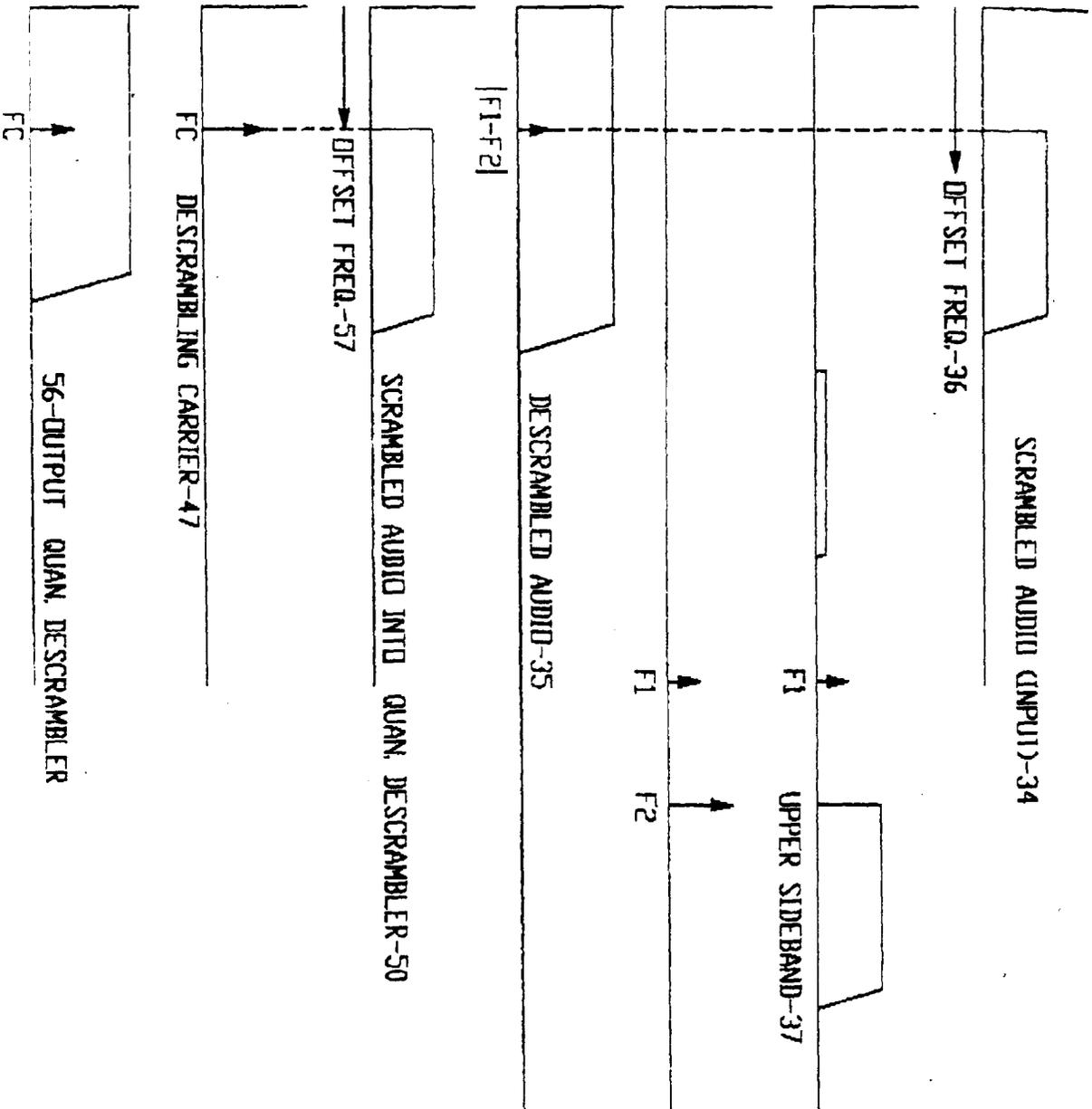
FIG. -2C
(PRIOR ART)

FIG. -2D
(PRIOR ART)

FIG. -4A

FIG. -4B

FIG. -4C



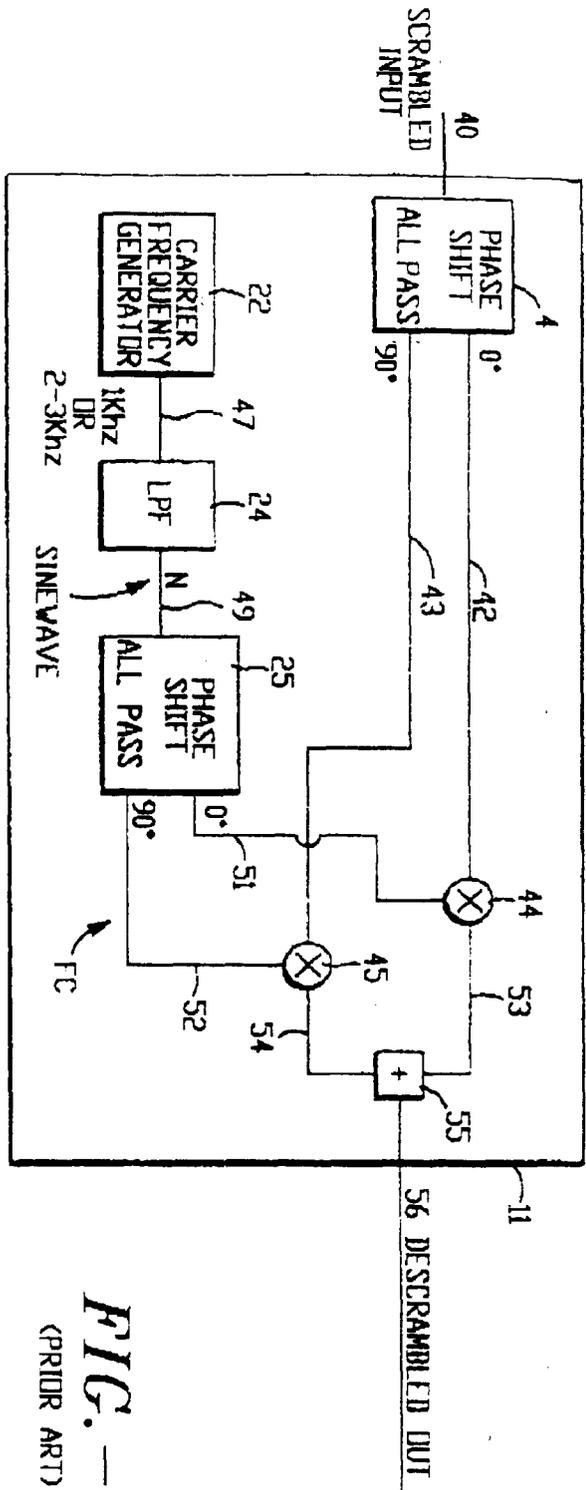


FIG. -3
(PRIOR ART)

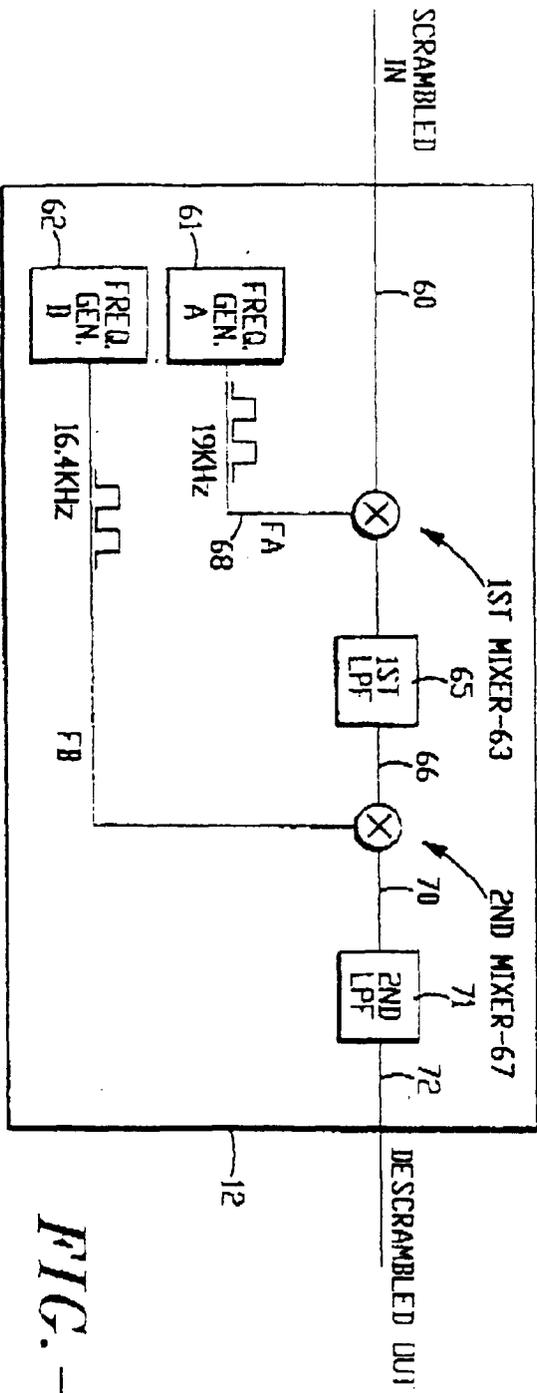


FIG. -5

FIG. -6A

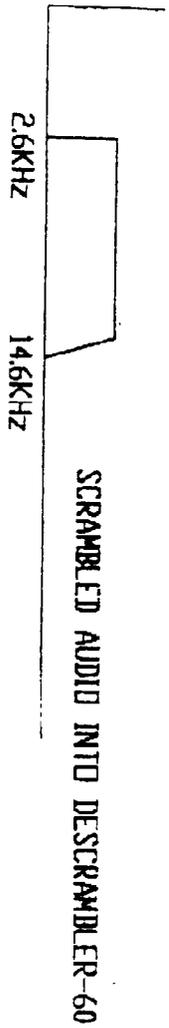


FIG. -6B

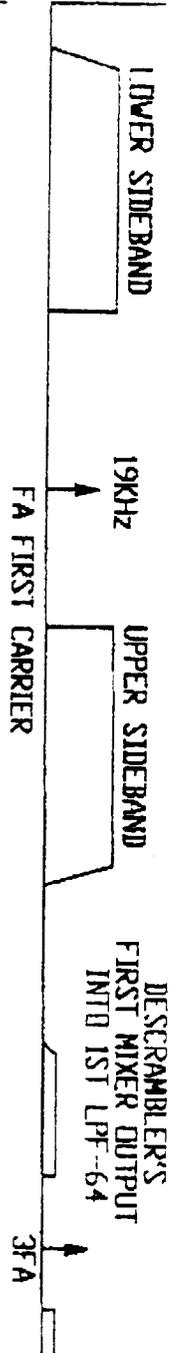


FIG. -6C



FIG. -6D



FIG. -6E

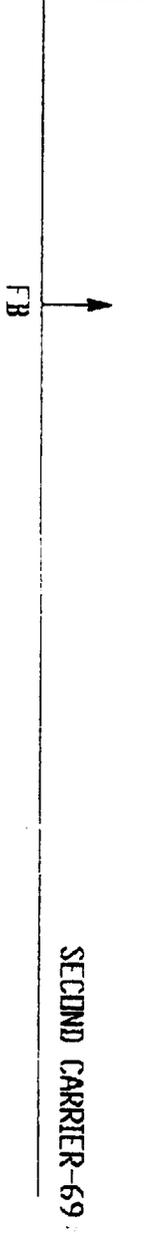


FIG. -6F

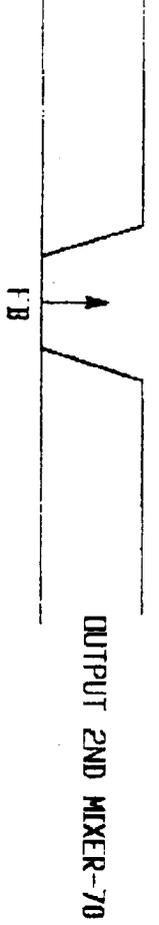


FIG. -6G



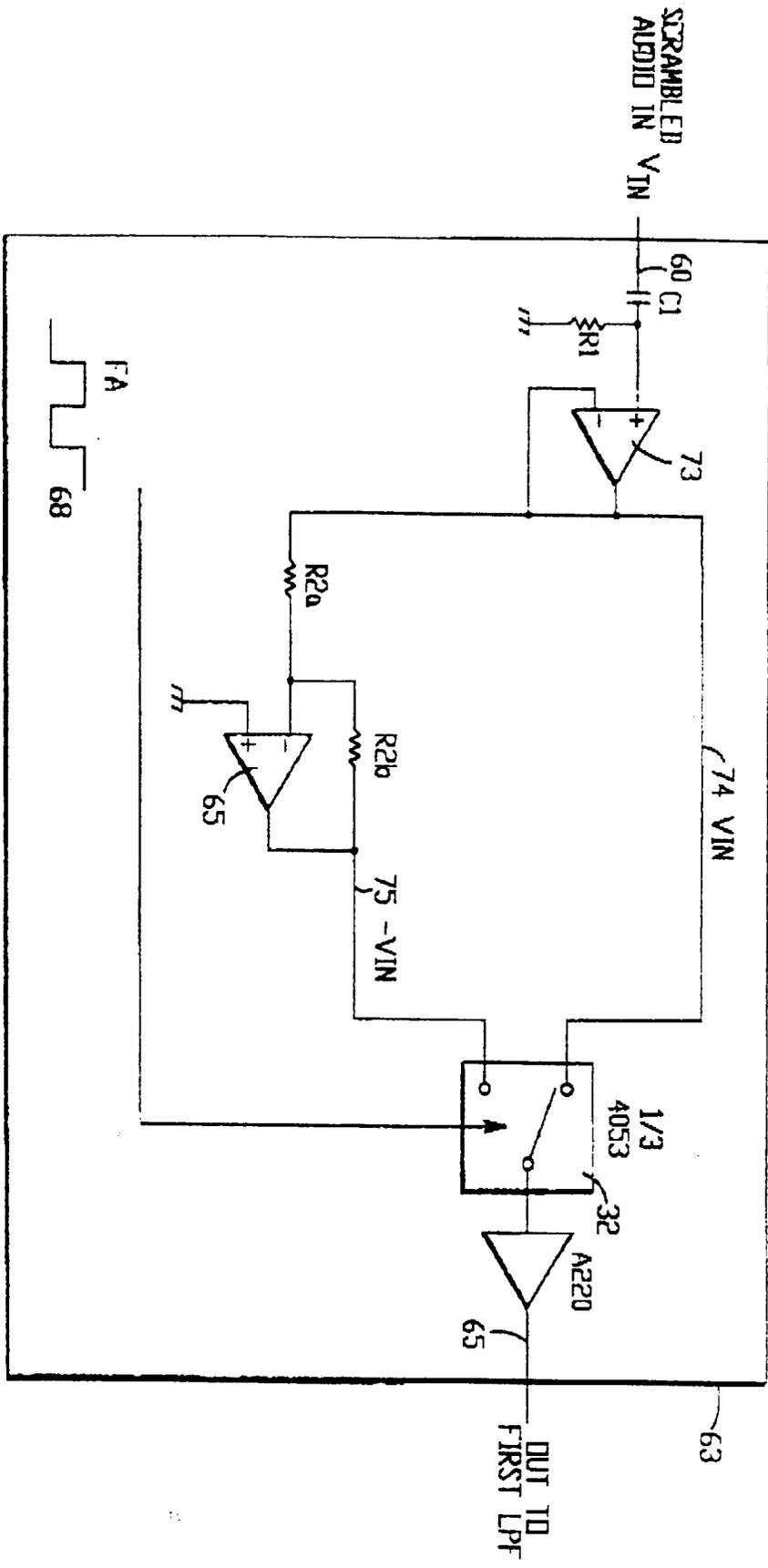


FIG. 7

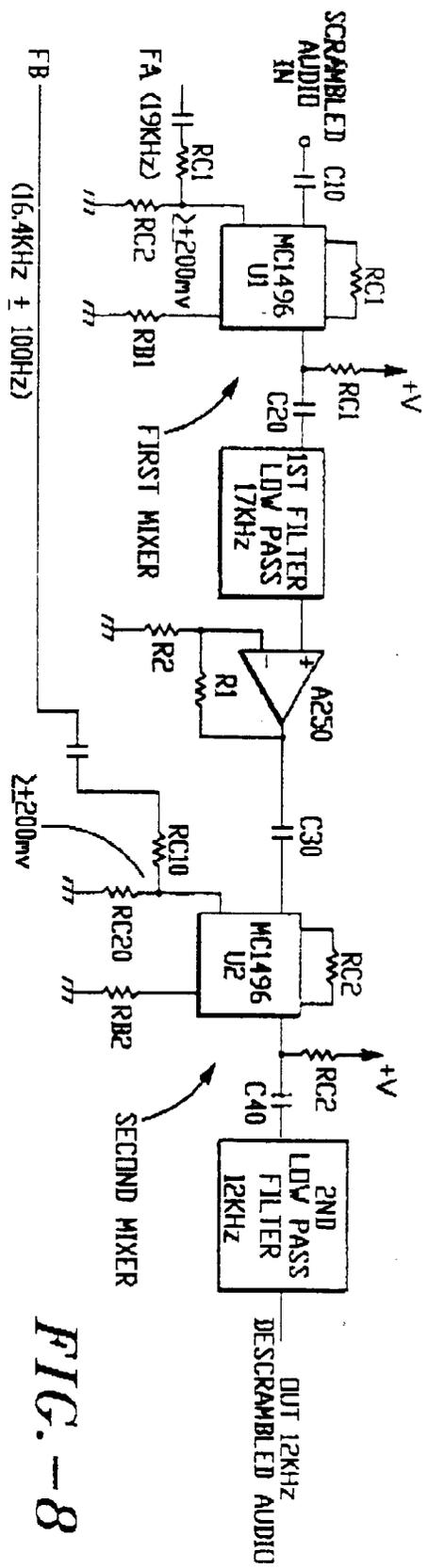


FIG. -8

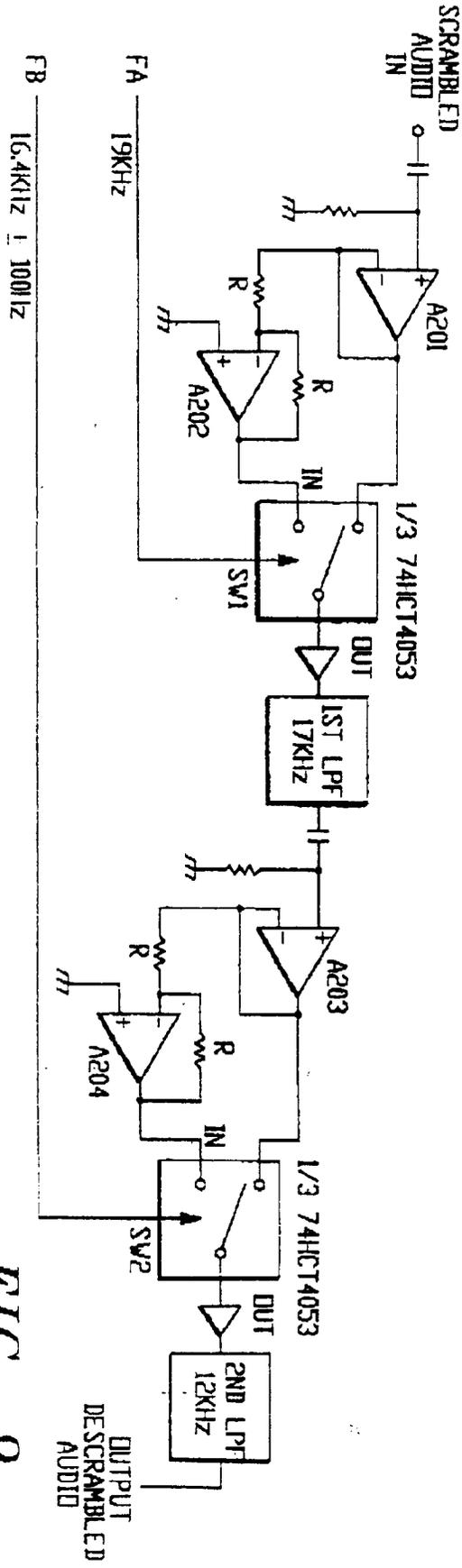


FIG. -9

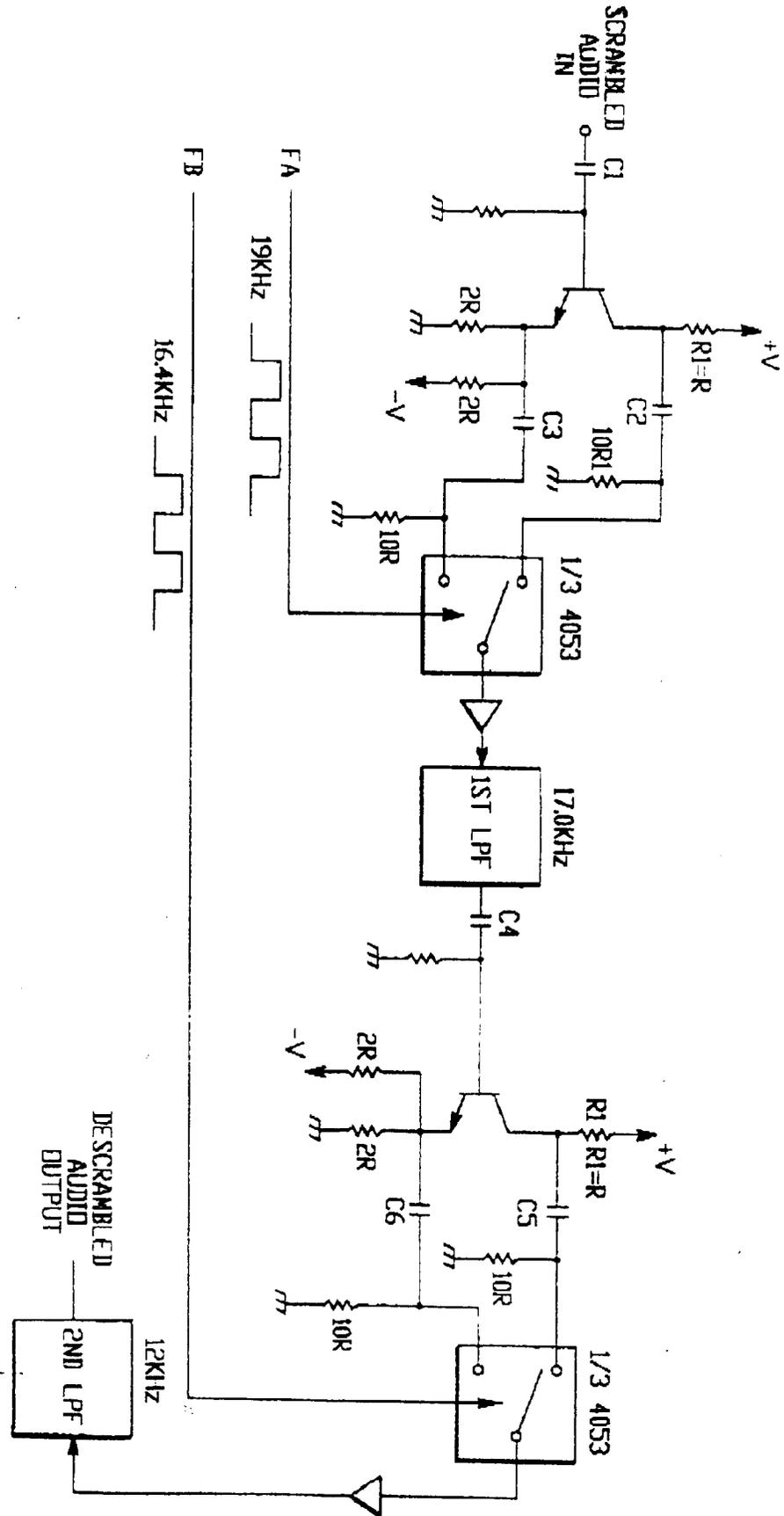


FIG. -10

FIG. - 12A



FIG. - 12B

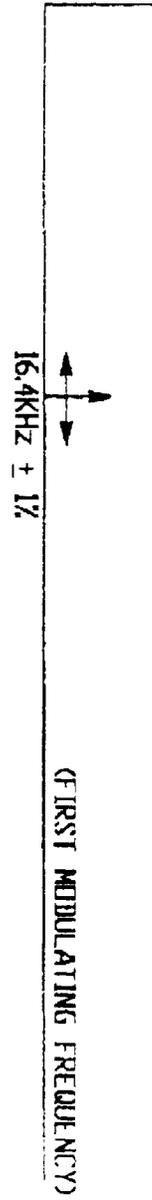


FIG. - 12C

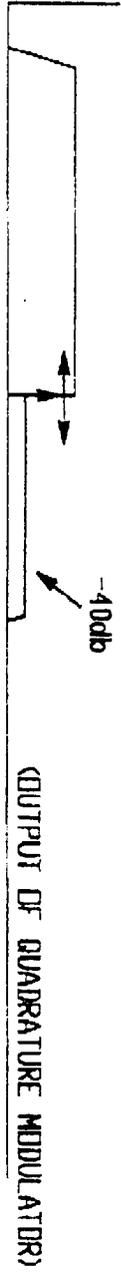


FIG. - 12D



FIG. - 12E

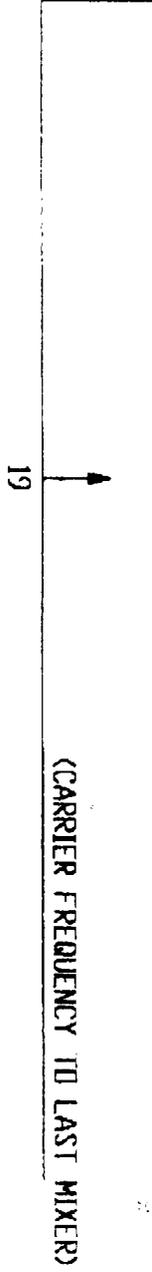
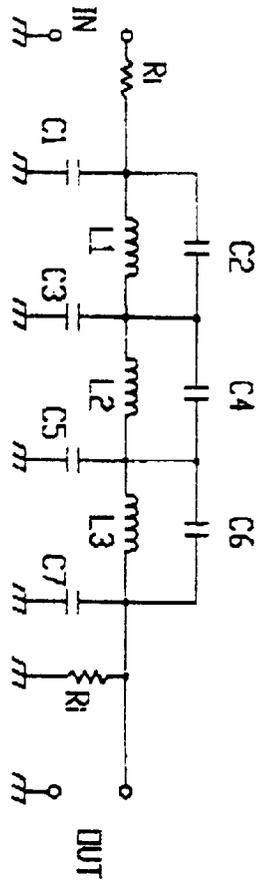


FIG. - 12F



FIG. - 12G





7 POLE ELLIPTIC LOW PASS FILTER ~17KHZ BW

FIG. - 13A

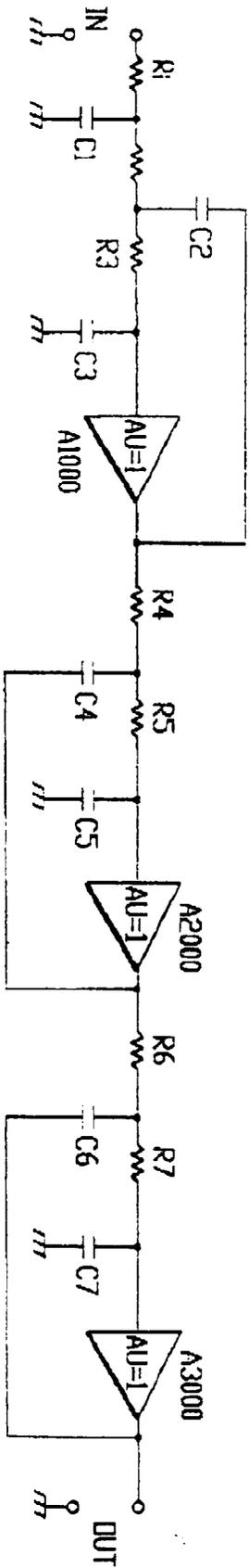


FIG. - 13C

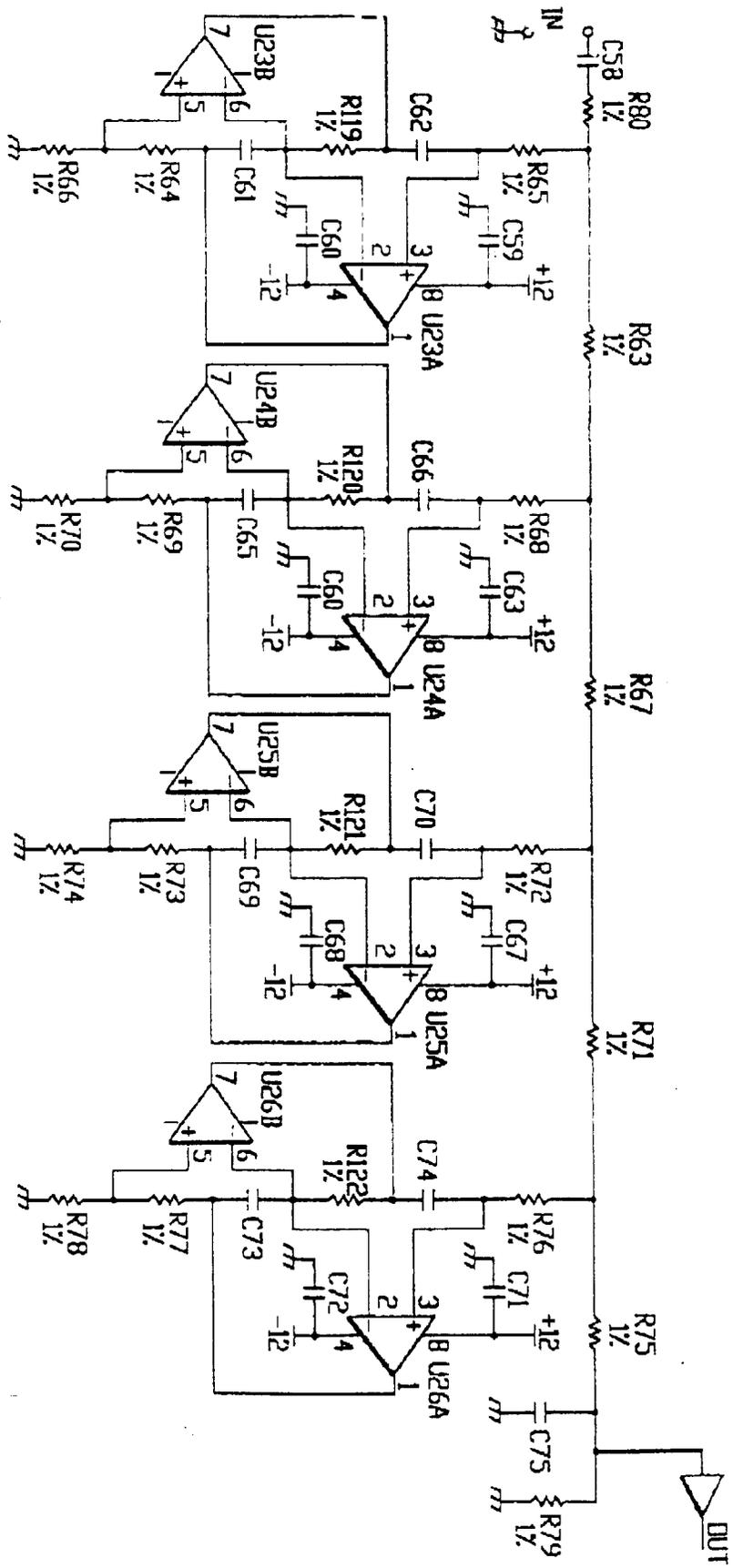


FIG. -13B