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Bourcet et al.

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[54] **SYSTEM FOR BROADCAST OF DATA IN AN AUDIO SIGNAL BY SUBSTITUTION OF IMPERCEPTIBLE AUDIO BAND WITH DATA**

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[51] **Int. Cl.**[7] **H04H 9/00**

[52] **U.S. Cl.** **704/500**; 380/253

[58] **Field of Search** 704/501, 229, 704/230, 500; 370/214; 380/253; 455/2

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Assistant Examiner—Harold Zintel
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[57] **ABSTRACT**

A system for broadcasting data (D) that can transmit information in the passband of a broadcast audio-frequency signal (S). The system can determine at least one frequency band ($F'_{13}, \ldots, F'_{24}$) and the amplitude ($A'_{13}, \ldots, A'_{24}$) of the audio-frequency signal (S). The system compares this amplitude with an auditory masking level (Nm(13), . . . , Nm(24)) associated with this frequency band and eliminates the frequency components of the audio-frequency signal in the frequency band if the amplitude of the signal is lower than the auditory masking level of the band. The system can insert the data in this frequency band at a level lower than or equal to the auditory masking level of the frequency band.

8 Claims, 2 Drawing Sheets

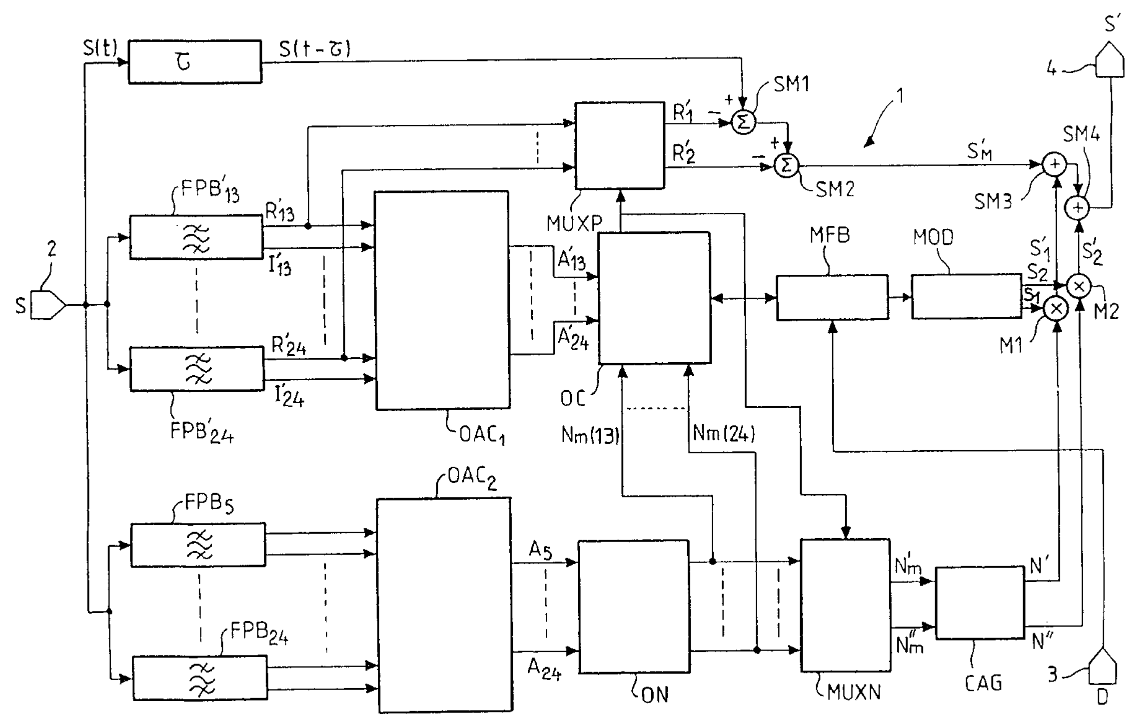


FIG_1

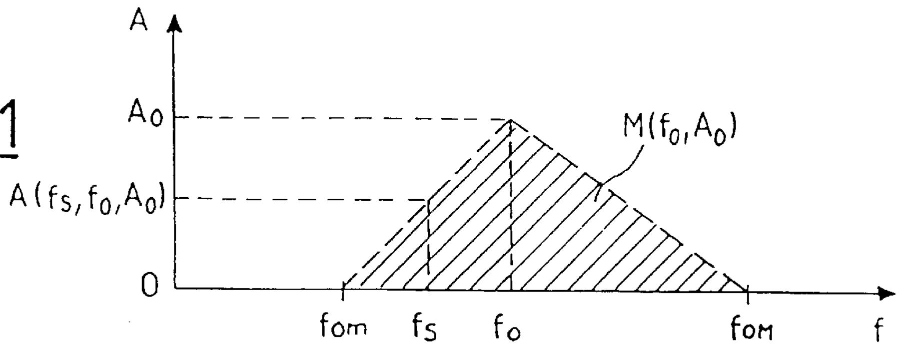


FIG_2

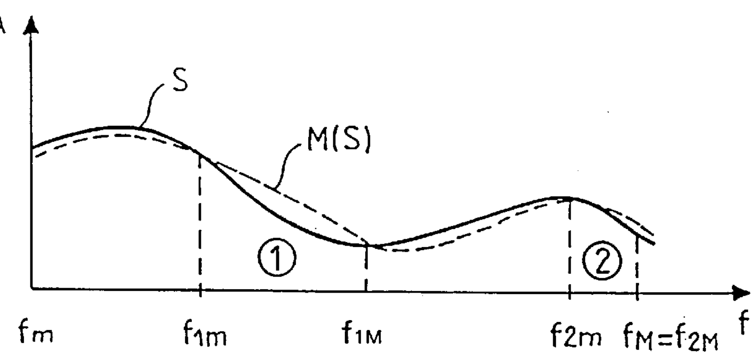
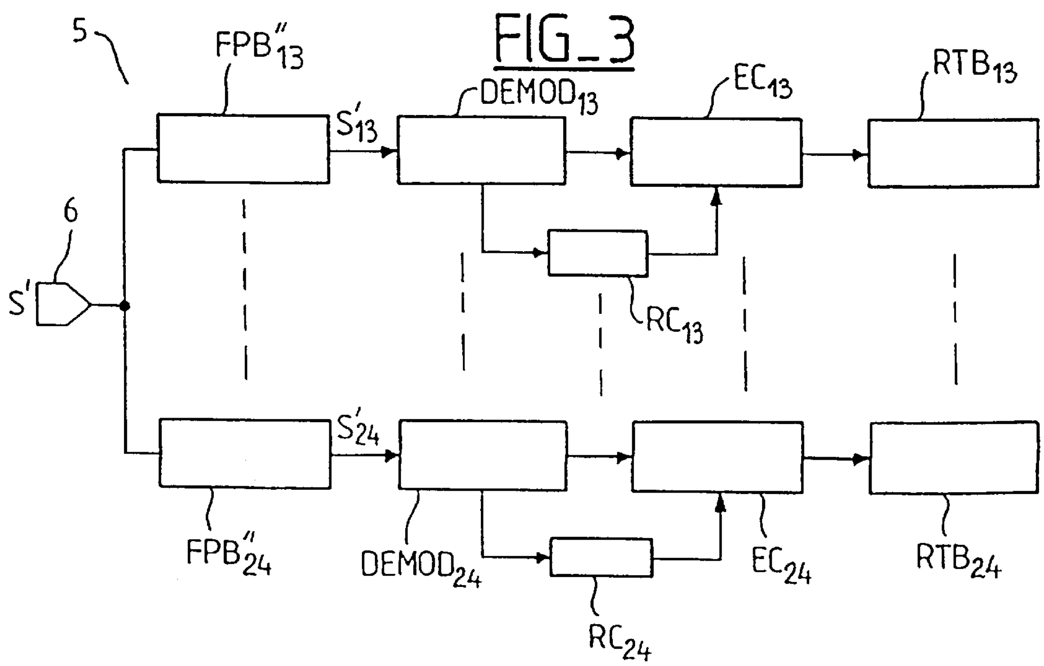
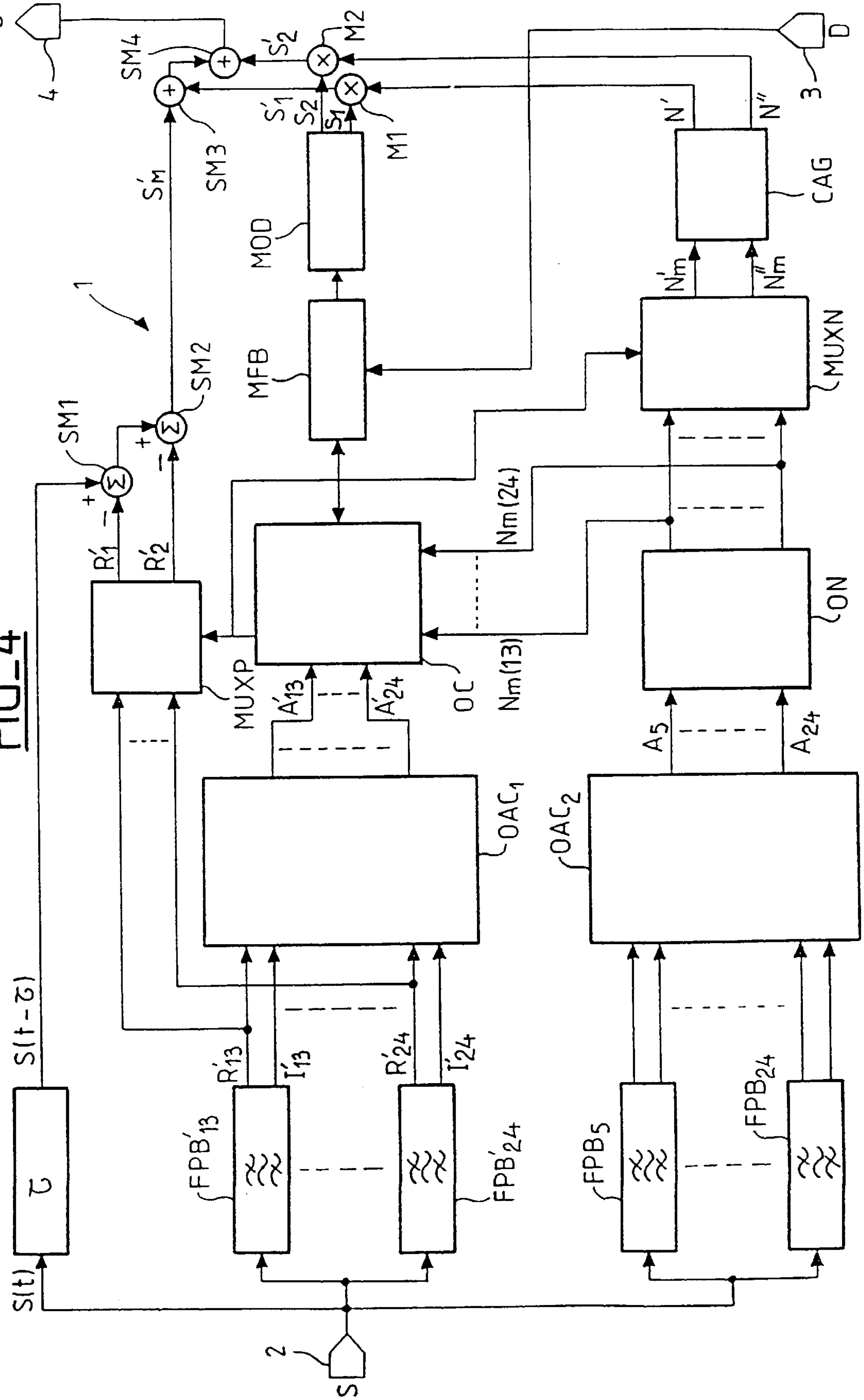


FIG_3




S
2
S(t)
τ
S(t-τ)
FPB'13
R'13
I'13
FPB'24
R'24
I'24
FPB5
FPB24
OAC1
OAC2
A'13
A'24
A5
A24
MUXP
OC
ON
Nm(13)
Nm(24)
R'1
R'2
SM1
SM2
SM3
SM4
S'M
MFB
MOD
S1
S2
S'1
S'2
M1
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3
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4
1

FIG_4

SYSTEM FOR BROADCAST OF DATA IN AN AUDIO SIGNAL BY SUBSTITUTION OF IMPERCEPTIBLE AUDIO BAND WITH DATA

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention concerns the signal broadcasting field for signals including an audio-frequency component. More especially, it concerns a data broadcasting system.

2. Description of the Related Art

The broadcasting field (broadcasting of TV or radio programmes, radiotelephony, etc.) is well known.

A current tendency is to transmit, in addition to the programmes (or sound in the telephony field), data useful for the broadcasting companies, for control organisations, or for listeners or viewers. This data can concern for example:

- help in selecting a radio or TV programme (example: automatic tuning aids, search for a radio station by name, search by type of programme, search by menu, etc.),
- information on the programme being broadcast or replayed after recording (for example the name of the company which created a programme, the title of a film broadcast by a TV channel, the record reference of a song broadcast by a radio station, etc.),
- service data in the analogue radiotelephone field.

We also remark the development of so-called interactive broadcasting systems which allow the viewers or listeners to dialogue in a more or less efficient manner with the programme source. These means are used either to act on the content of the broadcast programme, or to play, bet or communicate on the subject of this same programme. Thus, a form of interactivity, via small devices simulating pseudodialogue with a programme designed for this purpose, recently appeared. A remote-sized unit gives the illusion of interactivity as it allows, for instance, to reply to a televised question/reply game as and when the questions are asked. Or again, an electronic device dissimulated in a fluffy toy allows the toy to react to a broadcast programme or a programme played back on a video cassette recorder. In fact, the interactivity is not real as the string of good replies or the reactions of the toy follows preestablished sequences, common to the memory of the interactive device and the broadcast or played back programme. As the audiovisual sequence was prerecorded in accordance with a selected code, its execution is predictable and therefore the only information to be transmitted to the interactive device is the start signal and the exact timing of the questions/replies or the various possible reactions in the case of a toy.

There is also a demand for the automatic identification of a sound sequence, accompanied by an image or not. For the broadcasters, this is used to check that a given programme is correctly broadcast on the frequency allocated to it; this can become fairly complex when a national programme is affected by regional or local disconnectings. This also allows the controlling bodies to count the broadcasting of works protected by copyrights or to check the conformity of the broadcasting of commercials. Finally, for sample survey or audience evaluation organisations, it is used to rapidly identify that which is actually listened to or seen by a listener or a viewer. Today, to assess a radio audience, the only solution available is to conduct a sample survey by interviewing the consumers.

All these applications are easy to incorporate when designing new radio or TV broadcasting systems, especially

digital systems. However, existing systems and equipment populations do not in general easily lend themselves well to this development and experience proves that, from a sales engineering viewpoint, the compatibility and the relative cost of the processes and devices to be implemented are critical factors when introducing a new service.

For the transmission of data concerning a broadcast programme, two techniques are currently used.

The first technique consists in transmitting these data outside of the passband occupied by the signal of the transmitted programme (sound and possibly image). A solution exists, for instance, in sound broadcasting by multiplex frequency modulation, in using the upper part of the multiplex, between 54 and 76 kilohertz. Another example consists in using the lines available during frame retrace for TV broadcasting. These techniques have drawbacks. The saturation of the frequency resources available for broadcasting limits the number of users of these resources. Also, receivers adapted to the passbands used to transmit the emitted information are required.

Another technique consists in transmitting the data in the passband of the signal of the transmitted programme; this technique does not require the use of dedicated frequency bands. It is therefore not necessary to use transmitters and receivers with a frequency adapted to transmit these dedicated frequency bands. Typically, the original signal (corresponding to the programme to be transmitted) is filtered at origin to eliminate the frequency components in a given frequency band and the data is inserted in this band. The original signal is therefore deformed which may be unpleasant for a viewer or a listener not interested in the data. Therefore, the time dedicated to transmitting the information is limited by the broadcasters to the strict minimum which reduces the data flow rate accordingly. Thus, for interactive devices in the television field, the data is loaded globally, in one go, at the start of a given application. It is then impossible to adapt the data subsequent to a modification in the programme which must be run according to scheduled timing and without unexpected interruptions. Filtering means can of course be used at the receivers so as not to systematically pass on the sound or visual data received, this data then being transparent to the listener or the viewer. Nevertheless, we cannot ensure that the signal seen or heard by the viewer or listener will be the same as the original signal that he would have perceived before the insertion of the data.

OBJECTS AND SUMMARY OF THE INVENTION

In view of the above, the purpose of the invention is to propose a system to allow transmission of data in the passband of a signal including an audio-frequency component, without modifying, in relation to the original audio-frequency signal, the signal perceived by the listener. The invention proposes to insert these data in the so-called masked frequency bands of the original audio-frequency signal, if these bands exist, that is at a level lower than the instantaneous auditory threshold due to the auditory masking phenomena induced by the original audio-frequency signal itself. The data transmitted are then inaudible, do not alter the original audio-frequency signal from a subjective viewpoint and do not require the use of frequency components located outside of the spectral band occupied by the original signal. The invention therefore proposes data transmission adapted to the use of existing receivers and transmitters and subjectively not disturbing for the listener.

The invention thus concerns a data broadcasting system, this information being transmitted in the passband of a broadcast audio-frequency signal characterised in that it includes means for determining in at least one frequency band the amplitude of the audio-frequency signal and for comparing this amplitude with an auditory masking level associated with this frequency band, means for eliminating the frequency components from the audio-frequency signal in the said frequency band if the amplitude of the signal is lower than the auditory masking level of the said band, and means for inserting the said information into this frequency band at a level lower than or equal to the auditory masking level of the said frequency band.

BRIEF DESCRIPTION OF THE DRAWINGS

Other features and advantages will appear in reading the description which follows, and which is to be read in conjunction with the appended drawings on which:

FIGS. **1** and **2** represent diagrams showing the auditory masking phenomenon,

FIG. **3** represents a data extraction device,

FIG. **4** represents a data insertion device,

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIGS. **1** and **2** are amplitude versus frequency diagrams illustrating the auditory masking phenomenon which is a phenomenon of a physiological origin.

If we consider the hearing by a human being of an audio-frequency signal with a given frequency and amplitude, the auditory masking phenomenon is reflected by the non-perception, by this same human being, of audio-frequency signals transmitted simultaneously and with amplitudes lower than the given threshold levels.

Thus, in reference to FIG. **1**, if we consider a single-frequency signal at frequency f_0, located in the audio-frequency spectrum (typically between 20 and 15,500 Hertz) and with an amplitude A_0, we can define an amplitude and frequency range $M(f_0, A_0)$ such that any single-frequency signal emitted simultaneously of frequency fs in a limited frequency range [f**0**m, f**0**M] where $f_{0m}<f_0$ and $f_{0M}>f_0$ and amplitude $A<A(f_s, f_0, A_0)<A_0$ is inaudible.

The values f_{0m}, f_{0M} are variable for a given frequency f_0. In practice, the higher the amplitude A_0 the wider the range $[f_{0m}, f_{0M}]$. It can also be noted that the range is not symmetrically in relation to f_0 and extends more widely in the range of frequencies greater than f_0.

The amplitude value $A(f_s, f_0, A_0)$ varies with fs, f_0, and A_0. In practice, the nearer f_s is to f_0, the higher the inaudibility threshold $A(f_s, f_0, A_0)$.

The auditory masking phenomenon has been known for several years. For further details, refer to the work entitled "Psychoacoustique" by E. Zwicker and R. Feldtkeller, Ed. Masson, 1981. The experimental results described in this work gave rise to a standardization (standard ISO/IEC 11172-3).

A masking level curve M(S) can be defined (shown by the dotted line on FIG. **2**) for any signal S covering the audio-frequency spectrum $[f_m, f_M]$, where f_m=20 Hertz and f_M=15,500 Hertz. In the example shown on FIG. **2**, two ranges $[f_{1m}, f_{1M}]$ and $[f_{2m}, f_{2M}]$ can be seen where the masking level curve M(S) has an amplitude higher than that of signal S. In concrete terms, this means that the spectral components in these ranges are inaudible for the human being. Consequently, the subjective auditory rendition of a signal S' identical to signal S outside of these ranges, and without frequency components in these ranges, will be identical to the rendition of signal S shown on FIG. **2**.

The modelling of the auditory masking phenomena has given rise to the dividing of the audio-frequency spectrum into twenty four separate ranges, called critical bands, such that the combination of the twenty four critical bands covers the frequency range between 20 Hertz and 15,500 kiloHertz. Each critical band B_i (i integer index from 1 to 24) is defined by its central frequency fc and its width.

The table below gives, for each critical band, the value of the central frequency and its width.

Critical band	Central frequency fc (Hz)	Bandwidth (Hz)
B1	60	80
B2	150	100
B3	250	100
B4	350	100
B5	455	110
B6	570	120
B7	700	140
B8	845	150
B9	1000	160
B10	1175	190
B11	1375	210
B12	1600	240
B13	1860	280
B14	2160	320
B15	2510	380
B16	2925	450
B17	3425	550
B18	4050	700
B19	4850	900
B20	5850	1100
B21	7050	1300
B22	8600	1800
B23	10750	2500
B24	13750	3500

We can see that the critical bands have variable widths, the narrowest being the first critical band B_1, which covers the lowest frequencies, and the widest being the twenty fourth critical band B_{24} which covers the highest frequencies.

For each critical band, standard ISO/IEC 11172-3 defines a critical band masking level Nm(i) . This is an approximation of the level of the curve of the masking level over the complete critical band (the real level of the masking level curve for a given signal can vary in a given critical band) . The masking level Nm(i) is defined according to the masking levels of the eight lower critical bands (Nm(i−8) to Nm(i−1)) if they exist, and the three upper bands (Nm(i+1) to Nm(i+3)), if they exist.

We have Nm(i)=Σ Nm(j), where

j positive integer index such that j ∈ [i−8, . . . , i−1, i+1, . . . , i+3],

$Nm(j)=10^{[Xnm(j)-Av(j)-Vf(j)]/20}$,

$Xnm(j)=20\log_{10}(Av(j))+5.69$ dB (sound pressure),

Av(j)=6.025+0.275*z(j) for the tonal lines,

Av(j)=2.025+0.175*z(j) for the non-tonal lines, where Av(j) is the masking index of j^{th} critical band and j and z(j) the ratio of the j^{th} critical band,

Vf(j)=(i−j−1)*(17−0.15*Xnm(j))+17, of j from i−8 to i−1, and

Vf(i+1)=0.4*Xnm(i+18)+6,

Vf(i+2)=17*Xnm(i+2)+6,

Vf(i+3)=34*Xnm(i+3)+6.

z(j) is a constant defined for each critical band and z(1)=0.62 dB, z(2)=1.8 dB, $_{z(}$3)=2.4 dB, z(4)=3.6 dB, z(5)=

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