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Design and Implementation of the Cochlear Filter Model Based on a Wavelet Transform as Part of Speech Signals Analysis

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Abstract: In this study, we propose another manner of cochlea filter implementation based on a gammachirp wavelet which is designed to provide a spectrum reflecting the spectral properties of the cochlea. The application of the gammachirp wavelet transformation is then used to analyse some vowels like /a/, /u/ and /i/. We compare then the obtained results with those obtained by two other predefined wavelet families that are Morlet and Mexican Hat. The results show that the gammachirp wavelet family gives results that are comparable to ones obtained by Morlet and Mexican Hat wavelet family.

Key words: Design, implementation, cochlear, wavelet transform, speech signals

INTRODUCTION

In order to understand the human ear system, it is necessary to approach some theoretical notions of our auditory organ, in particular the behavior of the internal ear according to the frequency and according to the resonant level.

The sounds arrive to the pavilion of the ear, where they are directed towards drives in its auditory external. To the extremity of this channel, they exercise a pressure on the membrane of the eardrum, which starts vibrating to the same frequency those them. The ossicles of the middle ear, interdependent of the eardrum by the hammer, also enter in vibration, assuring the transmission of the soundwave thus until the cochlea. The resonant vibration arrives to the cochlea by the oval window, separation membrane between the stirrup, last ossicle of the middle ear and the perilymphe of the vestibular rail. The endolymphe of the cochlear channel vibrates then on its turn and drag the basilar membrane. The stenocils, agitated by the liquidizes movements, transforms the acoustic vibration in potential of action (nervous messages); these last are transmitted to the brain through the intermediary of the cochlear nerve (Liberman, 1974; Miller and Nicely, 1955; Rossi and Peckels, 1975).

These mechanisms of displacement on any point of the basilar membrane, can begins viewing like a signal of exit of a pass-strip filter whose frequency answer has its pick of resonance to a frequency that is characteristic of its position on the basilar membrane. The cochlea can be seen like a bench of pass-strip filters (Calliope, 1989; Greenwood, 1990; Glasberg and Moore, 1990).

To simulate the behavior of these filters, several models have been proposed. Thus, one tries to succeed to an analysis of the speech signals more faithful to the natural process in the progress of a signal since its source until the sound arrived to the brain. By put these models, one mentions the model gammachirp that has been proposed by Irino and Patterson (1997a, b, 2001).

While being based on the impulsional answer of this filter type, it comes the idea to implement as family of wavelet of which the function of the wavelet mother is the one of this one.

THE GAMMACHIRP MODEL OF COCHLEAR FILTER

Several models have been proposed to simulate the working of the cochlear filter. Seen as its temporal-specter properties, the gammachirp filter underwent a good success in the psychoacoustic research. Indeed, globally it answers the requirements and the complexities of the cochlear filter. In addition to its good approximation in the psychoacoustical appareillement, it possesses a temporal-specter optimization of the human auditory filter (Ouni, 2003).

The notion of the wavelet transform possesses a big importance in the signal treatment domain and in the speech analysis. it comes the idea to exploit the theory of the wavelet transform in the implementation of an auditory model of the cochlear filter proposed by Irino and Patterson (1997, 2001) that is the Gammachirp filter.

One is going to be interested to the survey of this filter type and à its implementation as a wavelet under the Matlab flat forms.

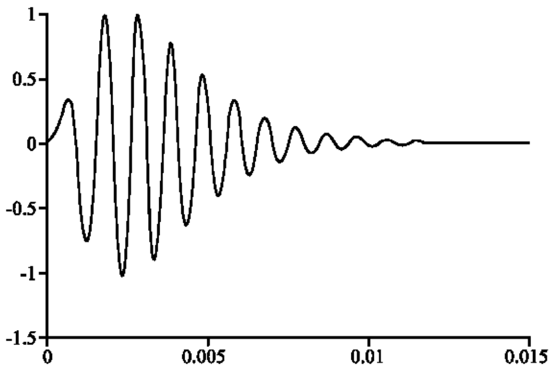

Fig. 1: Temporal answer of a Gammachirp function centered on 1000 Hz, with $\lambda_n = 1$, b = 1, c = 0, n = 2 and $\varphi = 0$

The impulsional answer of the gammachirp filter is given by the following function: (Irino and Patterson, 1997a, b, 2001).

$$g(t)=\lambda_n t^{n-1} e^{-2\pi b ERB(f_0)t} e^{j(2\pi f_0 t + c\ln(t)+\varphi)} \quad t>0$$

n : A whole positive defining the order of the corresponding filter.
f_0 : The modulation frequency of gamma function.
φ : The original phase,
λ_n : An amplitude normalization parameter.
ERB(f0): Equivalent Rectangulaire Bandwith

An example of the temporal answer of the Gammachirp filter is given by Fig. 1.

DESIGN AND INPMLÉMENTATION OF THE COCHLEAR FILTER COHCLÉAIRE PAR ONDELETTES

The gammachirp like a wavelet: The gammachirp function can be considered like wavelet function and constitute a basis of wavelets thus on the what be project all input signal, it is necessary that it verifies some conditions that are necessary to achieve this transformation (Fédéric, 1998).
Indeed it must verify these two conditions:

- The wavelet function must be à finished energy.
- The wavelet function must verifies the condition of admissibility.

To implement the Gammachirp function g as wavelet mother, one constructs a basis of wavelets then girls ga,b and this as dilating g by a factor has and while relocating it of a b parameter.

Table 1: The values of the three forming firsts

Voyel	Pitch	F1	F2	F3
/a/	100 Hz	730 Hz	1090 Hz	2440 Hz
/i/	100 Hz	270 Hz	2290 Hz	3010 Hz
/u/	100 Hz	300 Hz	870 Hz	2240 Hz

$$g_{a,b}(t)=\frac{1}{\sqrt{a}}g\left(\frac{t-b}{a}\right)$$

Studies have been achieved on the gammachirp function (Ouni, 2003), show that the Gammachirp function that is an amplitude-modulated window by the frequency f_0 and modulated in phase by the c parameter, can be considered like roughly analytic wavelet. it is of finished energy and it verifies the condition of admissibility.

This wavelet possesses the following properties: (Ouni, 2003) it is not symmetrical, it is non orthographic and it doesn't present scale function.

Implementation of the gammachirp like a wavelet: The implementation convenient of the wavelet requires a discrétisation of the dilation parameters and the one of transfer. One takes

$$a = a_0^m \text{ and } b = kb_0 a_0^m \quad (k et m \in Z)$$

he gotten wavelets girls have for expression:

The results gotten based on the works of Ouni (2003) show that the value 1000 Hz are the one most compatible as central frequency of the Gammachirp function. Otherwise our research will be based on the choice of a Gammachirp wavelet centered at the frequency 1000 Hz.

APPLICATION OF THE GAMMACHIRP WAVELET ON A SPEECH SIGNAL

To validate this implementation us applied this wavelet on three synthesized vowels like /a/, /u/ and /i/ of which the valieus of the three forming firsts is regrouped in Table 1.

One applies the Gammachirp wavelt implemented to an input signal that is one of the utilized vowels and that are /a/, /u/ and /i/. One gets the result that represents the first five levels of analysis of the signal by this type of wavelet, as well as the corresponding specters.

This analysis will be followed by a comparison with other types of wavelets as the Morlet wavelet and Mexican Hat wavelet. The gotten results are summarized in figures.

Case of the vowel \a\: The Fig. 5 gives a summary of the results gotten by the different wavelets.

The gammachirp filter detects à practically the first level of analysis the three forming of the signal corresponding to the vowel /a/ and it eliminates at every

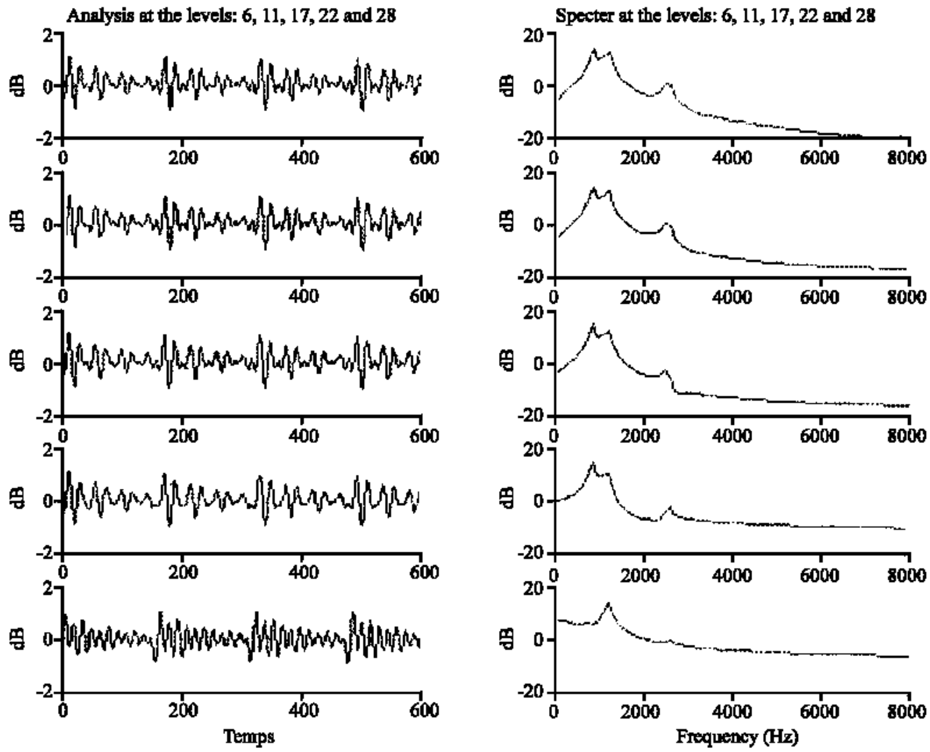

Fig. 2: Analysis by the Gammachirp wavelet and the logarithmic specters correspond for the levels 6, 11, 17, 22 and 28 of the vowel /a /

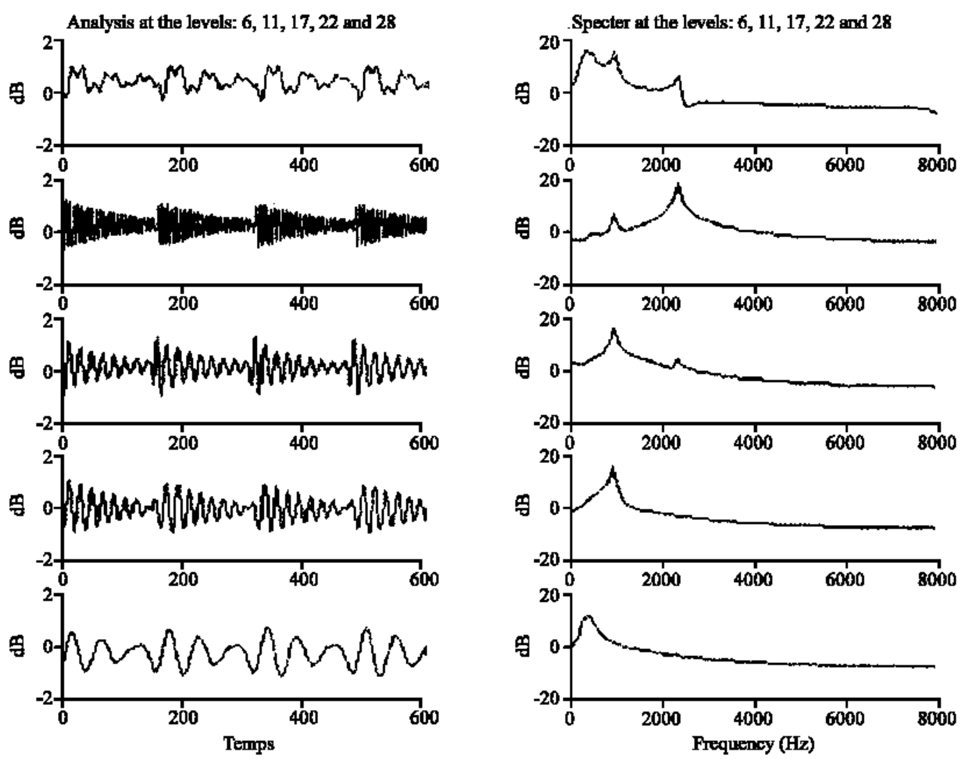

Fig. 3: Application of the Morlet wavelet on the vowel /a/

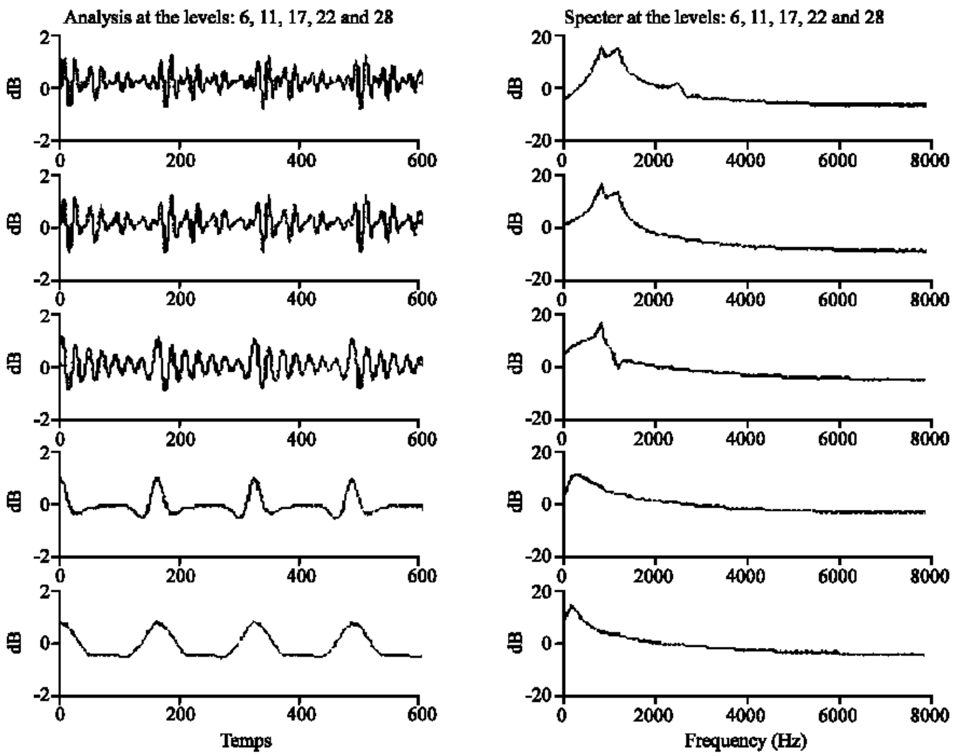

Fig. 4: Application of the Mexicain Hat wavelet on the vowel /a/

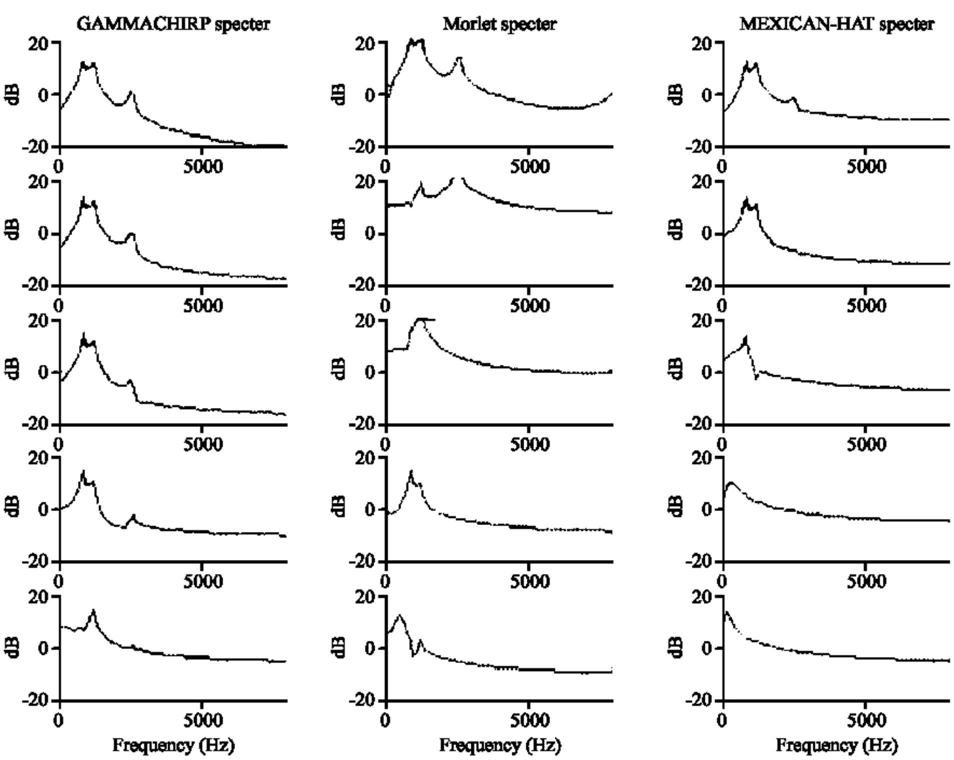

Fig. 5: Comparison of the three results gotten for the vowel /a/

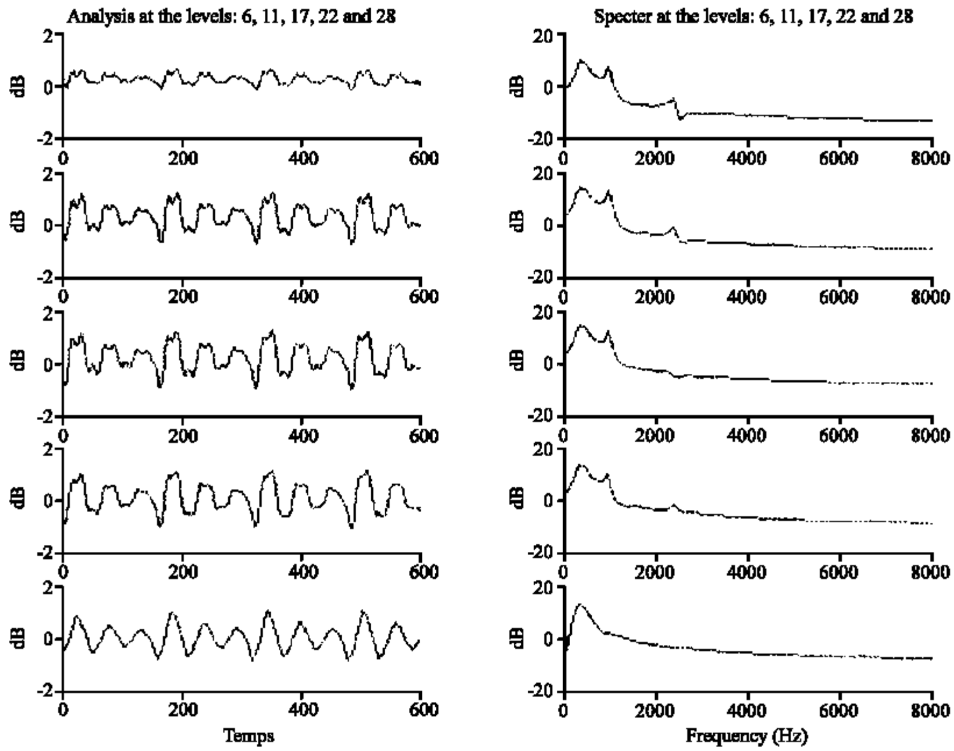

Fig. 6: Application of the Gammachirp wavelet on the vowel /u/

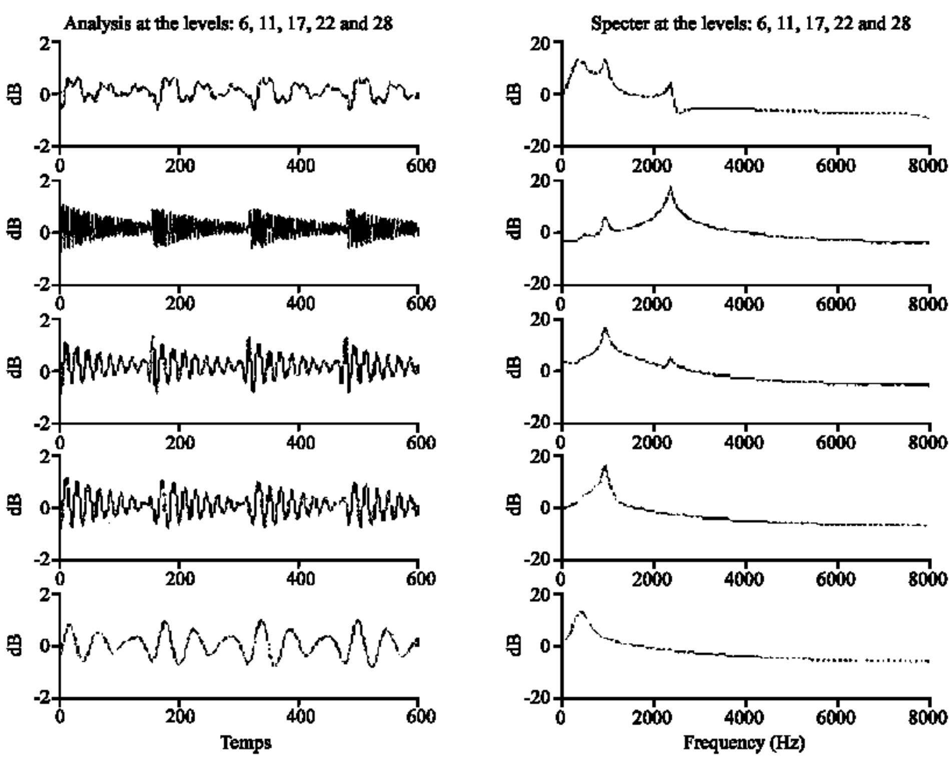

Fig. 7: Application of the Morlet wavelet on the vowel /u/

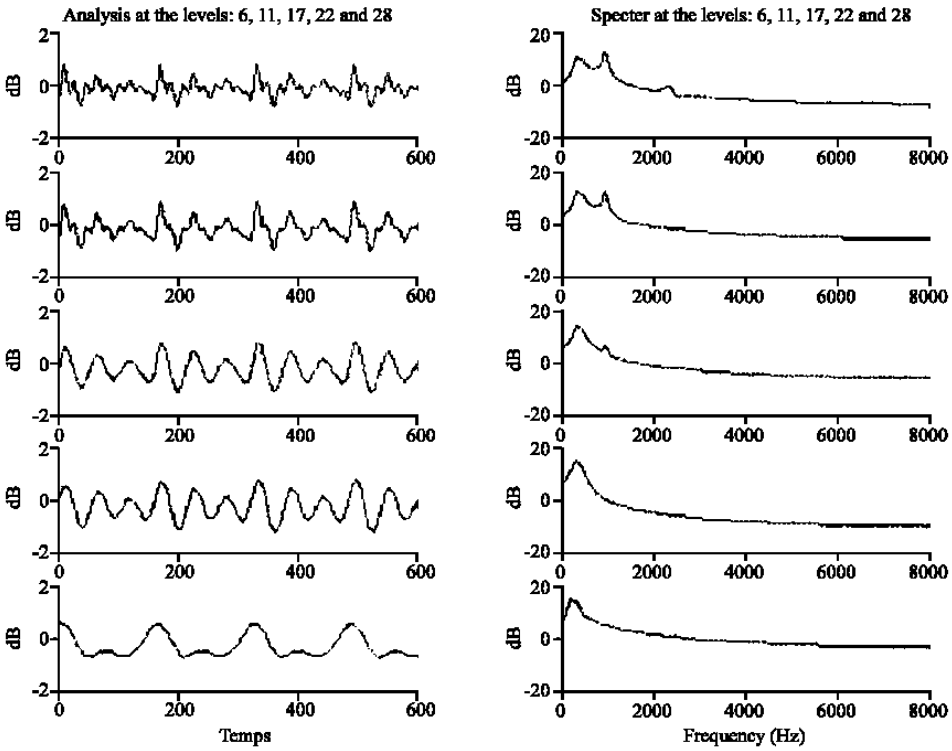

Fig. 8: Application of the Mexicain Hat wavelet on the vowel /u/

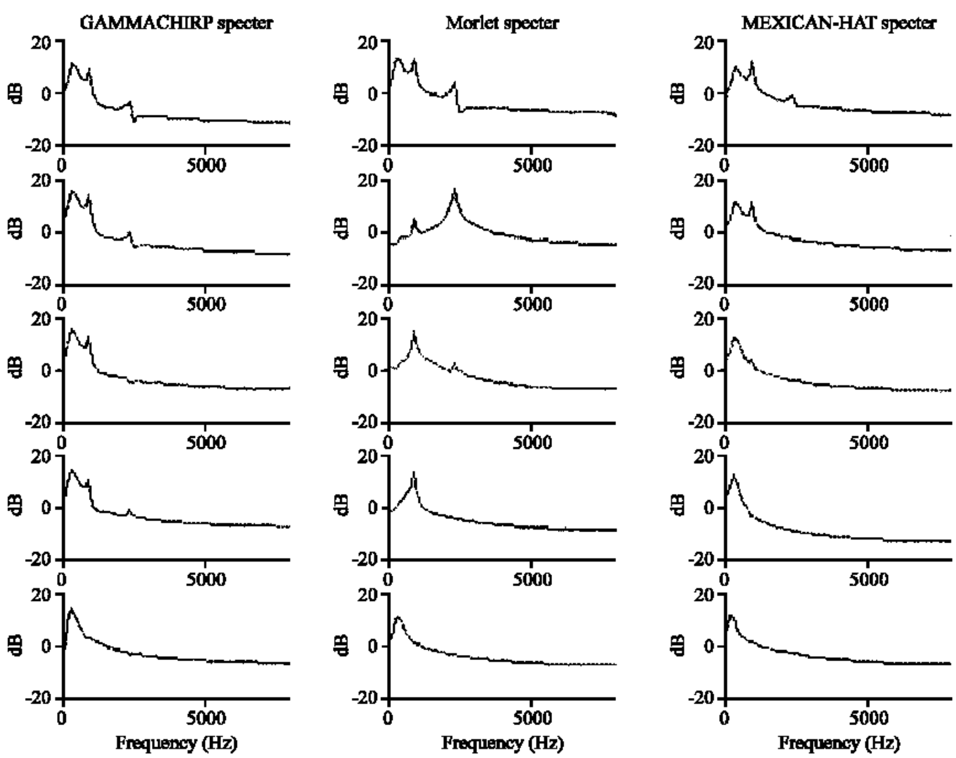

Fig. 9: Comparison of the three results gotten for the vowel /u/

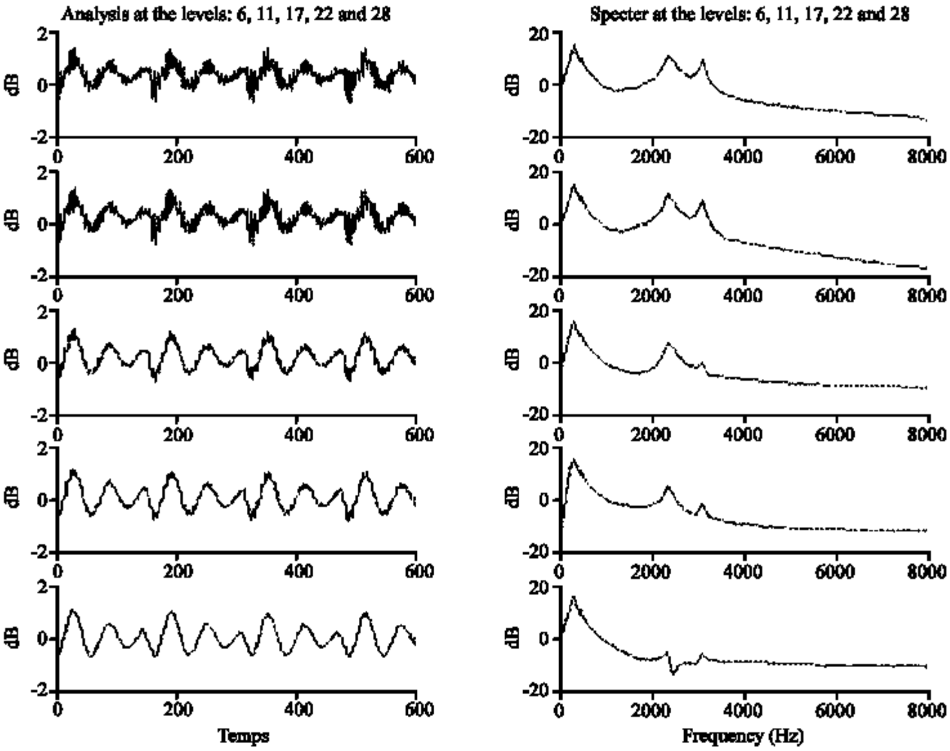

Fig. 10: Application of the Gammachirp wavelet on the vowel /i/

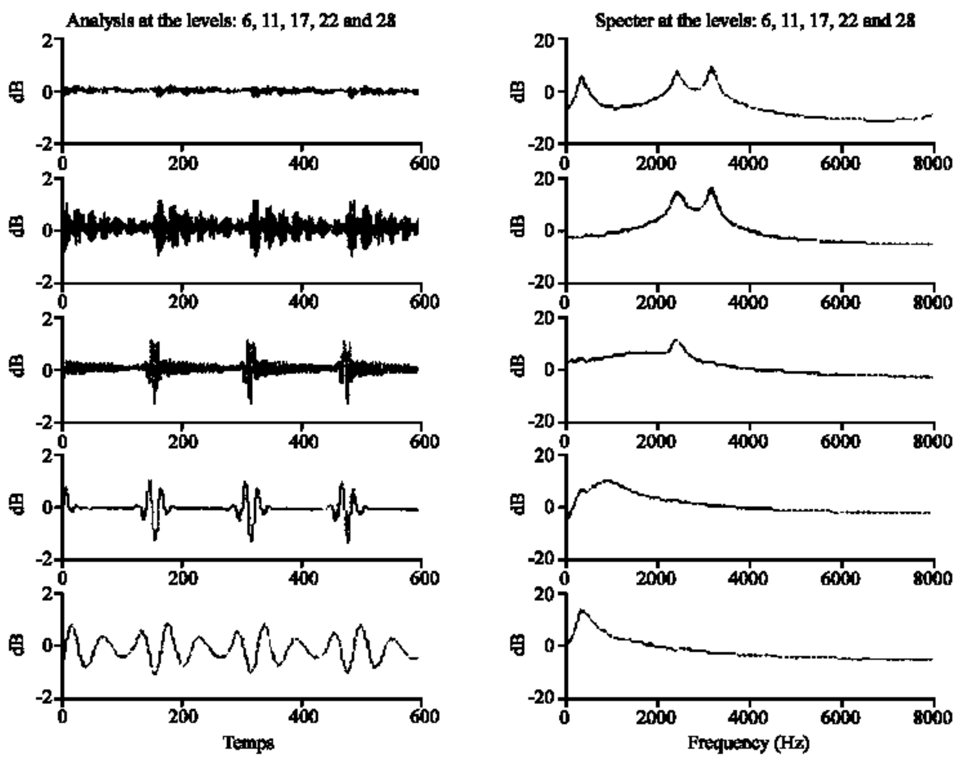

Fig. 11: Application of the Morlet wavelet on the vowel /i/

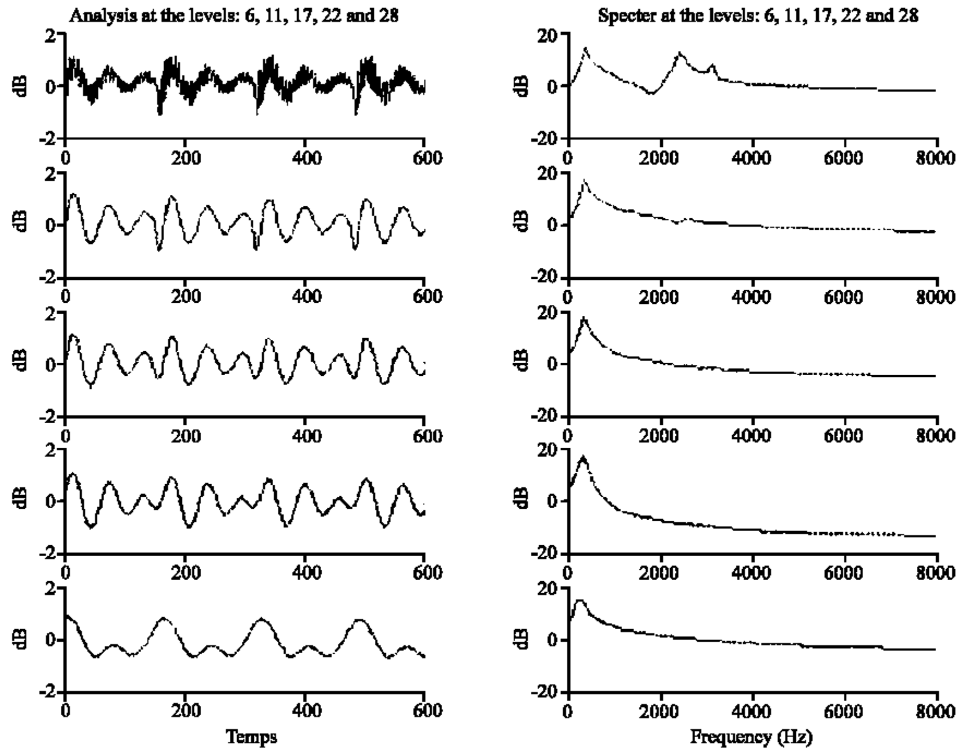

Fig. 12:Application of the Mexicain Hat wavelet on the vowel /i/

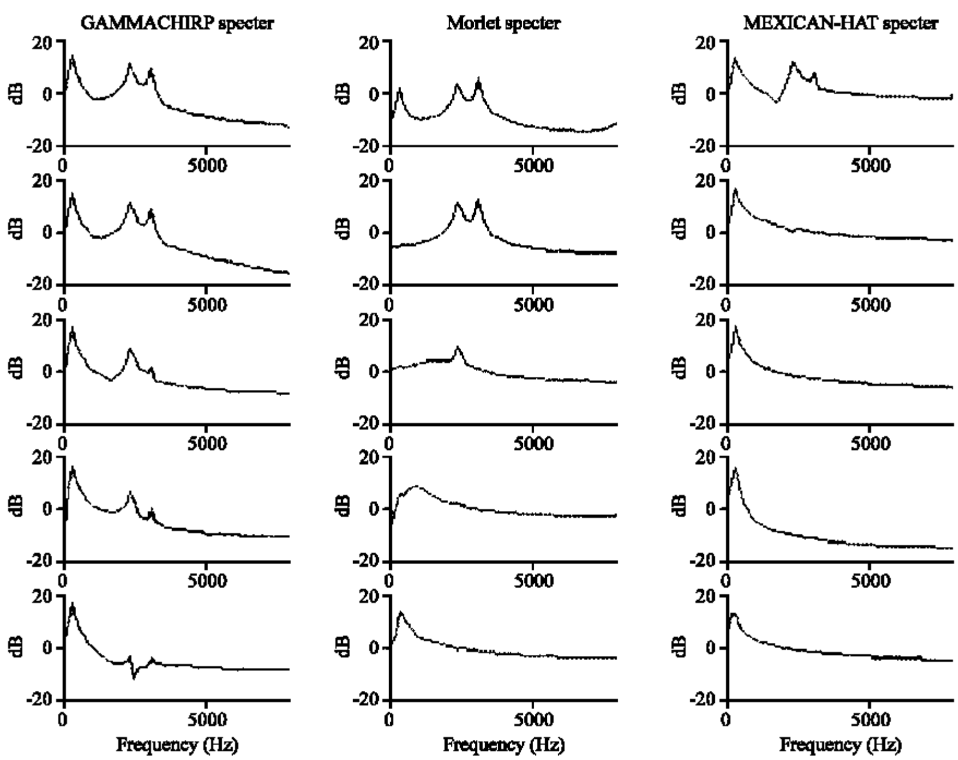

Fig. 13: Comparison of the three results gotten for the vowel /i/

upper level the high frequencies and this as subdividing at every time centers it fréquentiel by s_0^m (with s0 = 1,13 and m represents the level of analysis) (Fig. 2).

Indeed, the first forming the vowel /a/ corresponds to the frequency 730 Hz. It is detected in the first five levels of analysis. It is waited, since the fifth level is limited by the frequency 522 Hz.

The second forming corresponds to the frequency 1090 Hz. One notices that it is only detected in the first four levels of analysis. The fourth level corresponds to the limit frequency 1087 Hz, what explains the presence of the second forming.

The third forming corresponds to the frequency 2440 Hz. One notices the attenuation of that forming begins dice the third level whose limit frequency is of 2003 Hz.

The Fig. 3 and 4 show the results given by application of the Morlet and Mexican hat wavelets. One notices that the results found by application of the gammachirp wavelet (Fig. 5) are comparable at those given by the Morlet and Mexican hat wavelets.

Case of the vowel /u/: The application of the wavelet transform as using the Gammachirp wavelet, Morlet and Mexican Hat wavelets on this vowel gives the following results:

The Fig. 9 gives a summary of the results gotten by the different wavelets:

The first forming of the vowel /u/ corresponds to the frequency 300 Hz. He/it is detected in the five levels of analysis. It is waited, since the last level is limited by the frequency 522 Hz.

The second forming corresponds to the frequency 870 Hz. One notices that it is only detected in the first four levels of analysis (Fig. 6) and this while applying the Gammachirp wavelet.

The last level corresponds to the limit frequency 522 Hz. Whereas the frequency of the second forming (870 Hz) passes this limit, what explains the presence of a weak fluctuation at the level of its specter, slightly.

The third forming corresponds to the frequency 2240 Hz. One notices the disappearance of that forming dice the third level and this practically for the three types of wavelet (Fig. 7 and 8).

One notices by comparison with the Morlet wavelet that the Gammachirp wavelet as the Mexican hat wavelet detects better the first forming of the vowel /u/.

Thus, with regard to the detection of the three forming firsts of the vowel /u /, one notices that the results found by application of the gammachirp wavelet are comparable at those given by the Morlet and Mexican hat wavelets (Fig. 9).

The Gammachirp wavelet present sometimes a light improvement opposite the two firsts in the detection of the first and the third forming of the vowel /u /.

Case of the vowel /i/: Figure 13 gives a summary of the results gotten by the different wavelets.

The first forming of the vowel /i / corresponds to the frequency 270 Hz. It is detected in the first five levels of analysis. It is waited, since the last level is limited by the frequency 522 Hz.

The second forming corresponds to the frequency 2290 Hz. One notices that it is only detected in the first four levels of analysis and this while applying the Gammachirp wavelet (Fig. 10). whereas by application of Morlet (Fig. 11), one notes the absence of the second forming dice the third level of analysis (Fig. 12).

One recalls that for the analysis by the Gammachirp wavelet, the third level corresponds to the limit frequency 2003 Hz, whereas the fourth level corresponds to the limit frequency 1087 Hz. Although the frequency of the second forming (2290 Hz) passes these two limits, one notes its presence in these two levels.

The third forming corresponds to the frequency 3010 Hz. One notices the disappearance of that forming dice the third level and this practically in the three types of wavelet.

In the case of the analysis by the gammachirp wavelet, one sometimes notices some fluctuations of the specter. These oscillations correspond to the forming of which their frequencies pass the limit frequencies of the analysis levels. It is due to the fact that the spectral slope of the wavelet is not perfectly vertical. The cut of the axis fréquentiel in strips can have the overlaps, what explains the redundancy of the cover of the axis fréquentiel given by this wavelet type.

Thus, with regard to the detection of the three firsts forming (Fig. 13) one notices that the results found by application of the gammachirp wavelet are comparable at those given by the Mexican hatwavelet. The Morlet wavelet presents a light improvement opposite the two firsts in the distinction between the forming of the vowel /i /.

CONCLUSION

While being based on the results gotten by application of the Gammachirp wavelet on the different above-stated vowels and while comparing them at those gotten by application of other types of wavelet families, one notices that this filter gives acceptable results and that present specificities of remarkable improvement sometimes. Indeed one used the two families of Morlet wavelet and Mexican Hat wavelet for the comparison because they are in the same way standard that the Gammachirp wavelet.

Concerning this study, we presented the implementation in wavelet of the gammachirp model of the cochlear filter.

We validated this implementation by its use in analysis of some vowels.

The results gotten after application of this filter on the vowels /a/, /u / and /i / show that this filter gives acceptable and sometimes better results by comparison at those gotten by other types of predefined wavelet families as Morlet and Mexican hat.

Thus, as perspectives of this research, one can consider:

- To spread validation done on a richer basis of speech signals.
- To pursue the research on the valeurs of the parameters of the Gammachirp wavelet to act on the coefficients of analysis and to get better results thus.
- To improve the Gammachirp model to simulate the human auditory system more closely.

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