International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:1, No:9, 2007

Trispectral Analysis of Voiced Sounds Defective Audition and Tracheotomisian Cases

H. Maalem, and F. Marir

***Abstract*—**This paper presents the cepstral and trispectral analysis of a speech signal produced by normal men, men with defective audition (deaf, deep deaf) and others affected by tracheotomy, the trispectral analysis based on parametric methods (Autoregressive AR) using the fourth order cumulant. These analyses are used to detect and compare the pitches and the formants of corresponding voiced sounds (vowel \a\, \i\ and \u\). The first results appear promising, since- it seems after several experiments- there is no deformation of the spectrum as one could have supposed it at the beginning, however these pathologies influenced the two characteristics:
The defective audition influences to the formants contrary to the tracheotomy, which influences the fundamental frequency (pitch).

***Keywords*—**Cepstrum, cumulant, defective audition, tracheotomisy, trispectrum.

I. Introduction

THE performances of vocal signal decrease when corrupted by noise; in this direction, many studies were undertaken. The principal characteristic of the speech signal used is energy, but can be associated for example to the formants and the Fundamental frequency (pitch).

The observation that the vocal signal distribution is non-Gaussian led to various studies to consider the spectral analysis based on higher order statistics or Cumulant (H.O.S) for the speech signal detection. The idea of using H.O.S for speech processing is based on exploiting the Gaussian suppression and phase preservation properties of these statistics. In addition, the H.O.S of speech signals have distinctive features that may be exploited to lead to a better estimation and a more accurate discrimination between various speech types [1].

One purpose here, is to integrate the trispectral analysis based on the fourth order cumulant and cepstral analysis of Arabic speech signal produced by normal men, men with defective audition (deaf, deep deaf) and others affected by tracheotomy; to Extract the parameters which make it possible to describe its Principal characteristics.

H. Maalem is with Department of electronique, University of Skikda, Bp 26, Skikda 21000 Algeria (phone: 213 73 84 16 10; fax: 213 38 70 10 04, e-mail: maalem72@yahoo.fr).
F. Marir is with Department of electronique, University of Mentouri, Constantine, Algeria (e-mail: marirfarid@yahoo.fr).

II. Definitions

A. Fourth Order Statistics

If x(n), n=0, 1, 2, 3 ....is a real stationary discrete time signal and its moments up to order p exist, then its p^{th} order moment function is given by [2]-[3].

$$m_p(\tau_1,\tau_2,\tau_3,......\tau_{p-1})] = E\{x(n)x(n+\tau_1)x(n+\tau_2)x(n+\tau_3).....x(n+\tau_{p-1})\} \quad (1)$$

and depends only on the time differences τ_1 for all i, here E{} denotes statistical expectation, if in addition the signal has zero mean, then its 2^{nd} and 4^{th} order Cumulant function are given by:

2^{nd} order cumulant:

$$C_{2,x}(\tau) = m_{2,x}(\tau) \quad (2)$$

4^{th} order cumulant:

$$C_{4,x}(\tau_1,\tau_2,\tau_3) = E[x(n)x(n+\tau_1)x(n+\tau_2)x(n+\tau_3)] - C_{2,x}(\tau_1)C_{2,x}(\tau_2-\tau_3) - C_{2,x}(\tau_2)C_{2,x}(\tau_3-\tau_1) - C_{2,x}(\tau_3)C_{2,x}(\tau_1-\tau_2) \quad (3)$$

For non zero mean signal, it is enough to replace x(n) by: x(n)-E[x(n)].

We give below some of the relevant properties of the 4^{th} order cumulant, details can be found in [3].

- The 4^{th} order cumulant of a Gaussian process are identically zero.

- If Z(n)=x(n)+y(n), where x(n) is statistically independent of y(n), then the 4^{th} order cumulant of z(n) is the sum of the 4^{th} order cumulant of x(n) and y(n).

$$C_{4,z}(i,j,k) = C_{4,x}(i,j,k) + C_{4,y}(i,j,k) \quad (4)$$

- If Z(n) = x(n)+y(n), with y(n) is Gaussian then:

$$C_{2,z}(i) = C_{2,x}(i) + C_{2,y}(i) \quad (5)$$

$$C_{4,z}(i,j,k) = C_{4,x}(i,j,k) \quad (6)$$

Note that the effects of the Gaussian noise have been suppressed when the fourth order cumulant is used.

B. Trispectrum

Like the PSD, the Trispectrum can be estimated using two methods: non-parametric methods (direct and indirect), and parametric methods.

- *Non parametric methods*
- Direct method

The measured signal, $x(n)$ $n = 0,1,..N$ is divided into p segments, $x_i(n)$ $i = 0, 1,..p-1$. Each segment can be first multiplied by a window and then its M-point discrete Fourier transform (DFT) $X_i(k)$, $k = 0,1,..., M-1$, is computed.

The trispectrum is, given by:

$$T(k,l,m) = \frac{1}{P}\sum_{i=0}^{P-1} X_i(k)X_i(l)X_i(m)X_i^*(k+l+m) \quad (7)$$

- Indirect method

Estimation of the fourth order cumulants is first computed, and then 3D DFTs of this cumulant is computed after appropriate windowing [2]-[4].

$$T(f_1,f_2,f_3) = \sum_m \sum_n \sum_l c_4(m,n,l)e^{-j2\pi(mf_1+nf_2+lf_3)} \quad (8)$$

- *Parametric method*

If $x(n)$ is a linear process, $x(n) = \sum_i h(i)u(n-i)$ and $u(i)$ is some white noise, then the trispectrum is, given by [3]-[5]:

$$T(f_1,f_2,f_3) = c_{4u}(0,0,0).H(f_1).H(f_2).H(f_3).H^*(f_1+f_2+f_3) \quad (9)$$

Where: $H(.)$ is the Fourier transform of the filter impulse response $h(n)$, C_4 represents the cumulant of order 4.

C . Cepstrum

The cepstrum is defined as the inverse transform of the logarithm of the absolute value of the Fourier transform of the signal.

$$C_R = \int_{-\infty}^{\infty} Ln\ |X(f)| e^{-j2\pi fn}\, df \quad (10)$$

D. Linear Speech Production Model

Many different models have been postulated for quantitatively describing certain factors involved in the speech process, one of the most used models of acoustical speech behaviour is the linear speech production model developed by Fant [6]. The speech production model (AR) is show in Fig. 1.

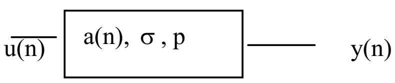

Fig. 1 Linear speech production model

The transfer function H (z) is then:

$$H(z) = \frac{\sigma}{A(z)} = \frac{\sigma}{1+\sum_{i=1}^{p} a(i)z^{-i}} \quad (11)$$

Where σ represents the system gain and a (i) the AR coefficients.

Many ways exist for determining the AR coefficients, one of which is based on the following normal equation [3]:

$$\sum_{k=1}^{p} a(k)r_y(k) = r_y(0) \quad (12)$$

Where, r_y is the autocorrelation function.

It has been shown that the AR coefficient can also be determined using 4^{th} order cumulant, giving the following equation [3]:

$$\sum_{k=1}^{p} a(k)C_{4,y}(\tau-k,k_0,0) = C_{4,y}(\tau,k_0,0) \quad (13)$$

With: $\tau = 1,2,..., p+n$, $n \geq 0$ and $k_0 = -p, -p+1,..., 0$

E. Tracheotomy

The larynx is essential for breathing and vocalizing. When damaged, an emergency tracheotomy may be necessary to ensure survival. Vocal cord paralysis is the second most common congenital irregularity of the larynx, The most common treatment for laryngeal paralysis is a tracheotomy [7].

- *What is a tracheotomy?*

The TRACHEA is the part of the AIRWAY (or breathing passage) commonly known as the "windpipe." A tracheotomy is a surgical procedure that creates a temporary opening in the trachea. The hole itself is called a tracheotomy. The tube that is placed through this hole is called a tracheotomy tube [7].

- *What are the indications for a tracheotomy?*

A tracheotomy is a temporary or permanent treatment for a variety of causes of breathing difficulties in which the creation of a new breathing pathway is required, by-passing the nose, mouth, and throat. A tracheotomy is usually considered when an endotracheal (ET) tube (a tube that goes in the throat through the mouth) either will not be effective (in some emergencies for example), or would be required for a long time. Sometimes, a tracheotomy is performed when an ET tube cannot be placed due to narrowing of the windpipe or blockage of the voice box (larynx).

The reasons for performing a tracheotomy generally fall into three major categories [7]:

To by pass an obstruction in the airway (most common reason)

To help with long term ventilation in patients who cannot do this on their own (patients with respiratory muscle problems or lung problems)

To provide a temporary airway while reconstructive surgery is performed that may cause breathing problems

III. Experimental Results

The signals used in the application consist of 512 samples sections of several voiced sounds for each one (example: the Arabic vowels \a\,\i\ and \u\) pronounced, firstly by a normal man, a man with defective audition (deaf, deep deaf) and another affected by tracheotomy. First, estimation computes the trispectrum of these vowels using the Autoregressive (AR) based on the fourth order cumulant. The spectra obtained by the second horizontal slices of the trispectra are shown in figures: 2, 3, 4, 5, 10, 11, 12, 13, 18, 19, 20 and 21. Contemplating these different figures, one notices that these spectra are the same formantic distribution and the number of the formants from point of view.

The Arabic vowels are voiced sounds then, they are characterized by its fundamental frequency (pitch). The frequential method (cepstrum) is used for pitch detection. See figures (6, 7, 8, 9, 14, 15, 16, 17, 22, 23, 24 and 25).

The values of the first three formants and the pitch value of the vowels produced by the four men are given in tables I, II, III, IV, V and VI respectively.

It appears, after several experiments that:

- In spite of the audition deficiency of the deaf man or deaf deep the fundamental frequency (pitch) of its voice is normal as that of a tending man who locates in the interval of [60Hz at 250 Hz].

- The value of the first formant of the vowel \a\, \i\ and \u\ of a deaf man does not correspond to that obtained by the normal man who is located between [600 and 750 Hz], [250 and 400] and [200 and 450] respectively.

- The value of the second formant of the vowel \a\, \i\ and \u\ of a deep deaf man does not correspond to that obtained by the normal man who is located between [1150 and 1400], [2100 and 2700] and [1000 and 1400] respectively.

- Tracheotomy does not alter the values of the formants.

- The value of the pitch of the man affected by Tracheotomy does not correspond to that of a normal man.

TABLE I
THE VALUES OF THE FIRST THREE FORMANTS (HZ) OF VOWEL \A\ OF A NORMAL MAN, A DEAF MAN, A DEEP DEAF MAN AND A TRACHEOTOMYSAN MAN

	F1	F2	F3
Normal man	689	1270.5	2734
deaf man	366.1	1227.4	2519.4
deep deaf man	689.1	1808	2476.3
Tracheotomysan man	624	1227	2562

TABLE II
THE VALUES OF THE FIRST THREE FORMANTS (HZ) OF VOWEL \I\ OF A NORMAL MAN, A DEAF MAN, A DEEP DEAF MAN AND A TRACHEOTOMYSAN MAN

	F1	F2	F3
Normal man	344	2670	3380
deaf man	559	2261	2691
deep deaf man	279	2885	3337
Tracheotomysan man	344	2477	3100

TABLE III
THE VALUES OF THE FIRST THREE FORMANTS (HZ) OF VOWEL \U\ OF A NORMAL MAN, A DEAF MAN, A DEEP DEAF MAN AND A TRACHEOTOMYSAN MAN

	F1	F2	F3
Normal man	430	1012	22433
deaf man	516	1378	2670
deep deaf man	323	1722	2325
Tracheotomysan man	215	1227	2476

TABLE IV
THE VALUE OF THE PITCH OF VOWEL \A\ OF A NORMAL MAN, A DEAF MAN, A DEEP DEAF MAN AND A TRACHEOTOMYSAN MAN

	Pitch (Hz)
Normal man	200.25
deaf man	200
deep deaf man	239
Tracheotomysan man	482

TABLE V
THE VALUE OF THE PITCH OF VOWEL \I\ OF A NORMAL MAN, A DEAF MAN, A DEEP DEAF MAN AND A TRACHEOTOMYSAN MAN

	Pitch (Hz)
Normal man	189
deaf man	225
deep deaf man	157
Tracheotomysan man	367

TABLE VI
THE VALUE OF THE PITCH OF VOWEL \U\ OF A NORMAL MAN, A DEAF MAN, A DEEP DEAF MAN AND A TRACHEOTOMYSAN MAN

	Pitch (Hz)
Normal man	143
deaf man	225
deep deaf man	167
Tracheotomysan man	380

IV. CONCLUSION

It has been shown that the trispectral analysis can be used for the detection and the recognition of the speech signal.

It has also been shown, although many more tests have to be made, that the value of the pitch of men affected by Tracheotomy is different from that of normal men. The values of the first three formants, however, are the same.

as well as the values of the first and the second formants of men with defective audition (deaf, deep deaf) respectively is different from that of men with normal audition contrary to the value of the pitch which is the same.

REFERENCES

[1] J. W. A. Fackrell and S. McLaughlin, "H.O.S. of speech signals" *IEE Coll. Tech. In Speech Signal Proc.,* London, June 1994.

[2] H. P. Rathy, S. Prasad and S. D. Joshi , "Conditions for third order stationarity and ergodicity of a harmonic random process" *IEEE Trans. On signal Proc.,* vol. 42, N°1, pp. 222-224, Jan. 1994.

[3] J. Mendel , "Tutorial on higher- order statistics" *Proc. IEEE,* vol 79, N°3, pp. 277-303, March 1991.

[4] V. Chandran and S. L. Elgar, "A general procedure for derivation of principal domains of higher-order spectra", *IEEE Trans. On Signal Proc.,* vol. 42, N°1, pp. 229-233, Jan. 1994.

[5] J. W. A Fackrell *etal*, "Non linearity detection for condition monitoring using h.o.s"Internal rep., Dept of Elect. and Elect. Eng., University of Edimburgh, Scotland, pp. 519-528, July 1996.

[6] J. Markel and A. Gray, *« Linear prediction of speech »,* Springer-Verlag, 1976.

[7] Pediatric Otolaryngology: Learning Center – Tracheotomy http://www.pediatric-ent.com/learning/surgeries/tracheotomy.htm

ISSN: 2517-9438
Vol:1, No:9, 2007

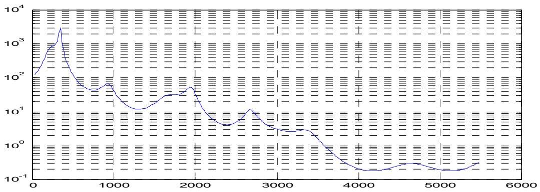

Fig. 2 Spectrum of vowel \a\ of a normal man

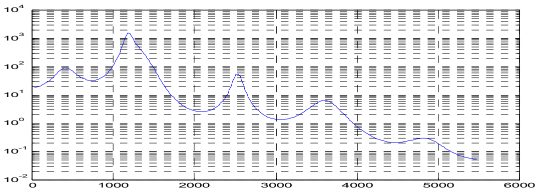

Fig. 3 Spectrum of vowel \a\ of a deaf man

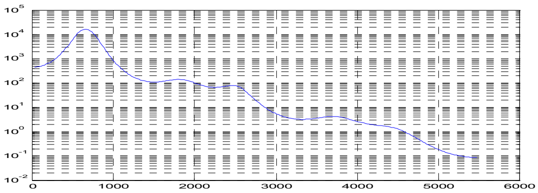

Fig. 4 Spectrum of vowel \a\ of a deep deaf man

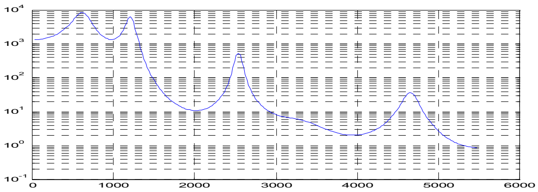

Fig. 5 Spectrum of vowel \a\ of a Tracheotomysan man

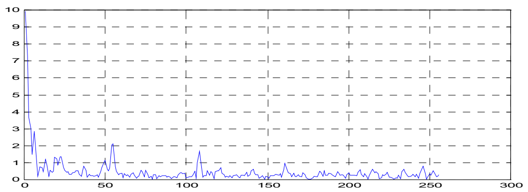

Fig. 6 Cepstrum of vowel \a\ of a normal man

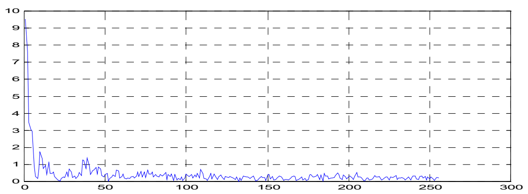

Fig. 7 Cepstrum of vowel \a\ of a deaf man

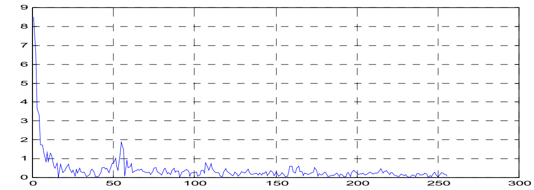

Fig. 8 Cepstrum of vowel \a\ of a deep deaf man

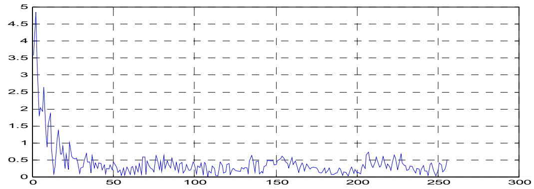

Fig . 9 Cepstrum of vowel \a\ of a Tracheotomysan man

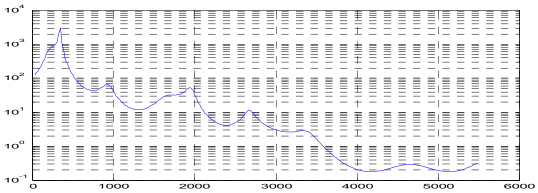

Fig. 10 Spectrum of vowel \i\ of a normal man

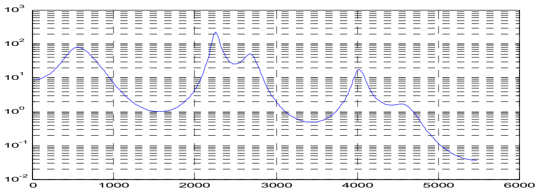

Fig. 11 Spectrum of vowel \i\ of a deaf man

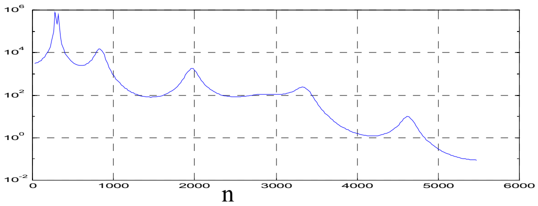

Fig.12 Spectrum of vowel \i\ of a deep deaf man

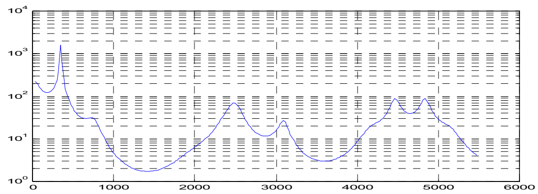

Fig. 13 Spectrum of vowel \i\ of a Tracheotomysan man

International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:1, No:9, 2007

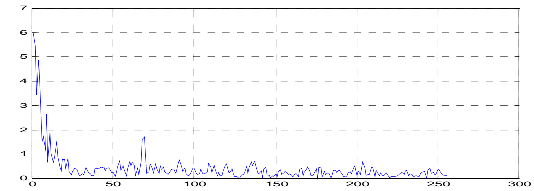

Fig. 14 Cepstrum of vowel \i\ of a normal man

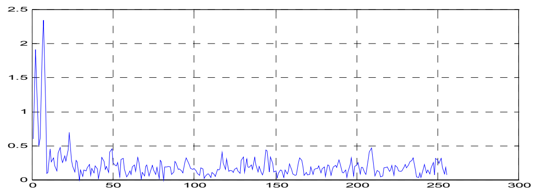

Fig. 15 Cepstrum of vowel \i\ of a deaf man

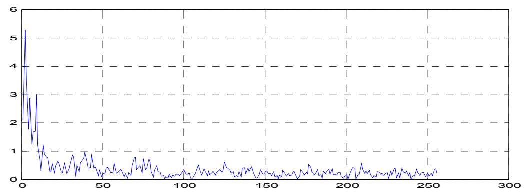

Fig. 16 Cepstrum of vowel \i\ of a deep deaf man

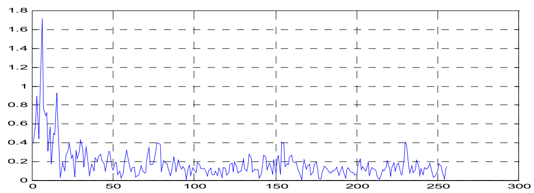

Fig. 17 Cepstrum of vowel \i\ of a Tracheotomysan man

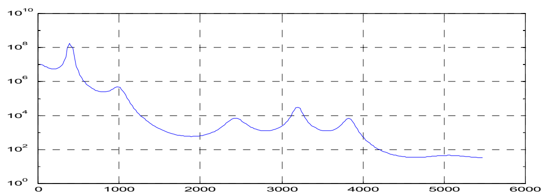

Fig. 18 Spectrum of vowel \u\ of a normal man

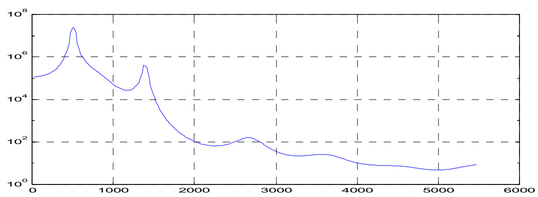

Fig. 19 Spectrum of vowel \u\ of a deaf man

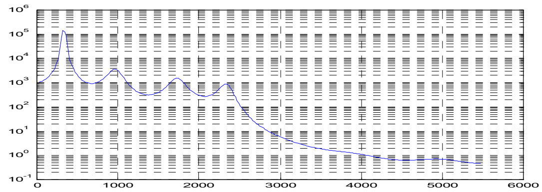

Fig. 20 Spectrum of vowel \u\ of a deep deaf man

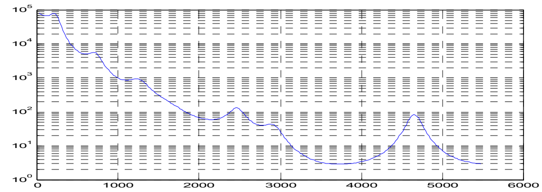

Fig. 21 Spectrum of vowel \u\ of a Tracheotomysan man

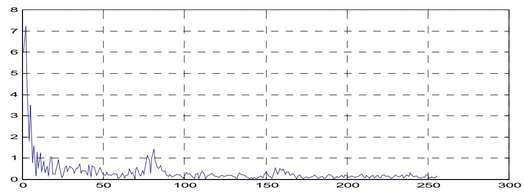

Fig. 22 Cepstrum of vowel \u\ of a normal man

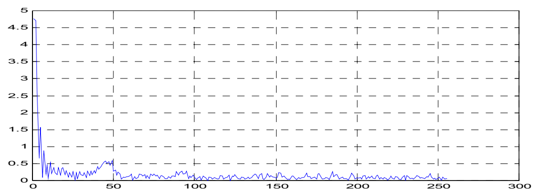

Fig. 23 Cepstrum of vowel \u\ of a deaf man

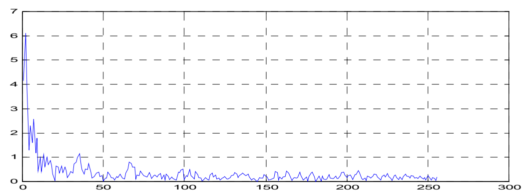

Fig. 24 Cepstrum of vowel \u\ of a deep deaf man

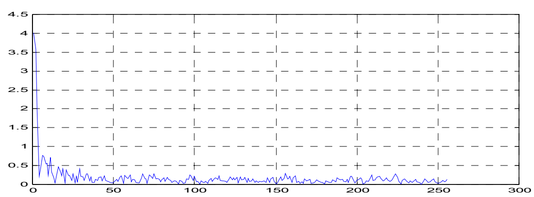

Fig. 25 Cepstrum of vowel \u\ of a Tracheotomysan man