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Vibratory Pattern Analysis of vocal folds for layngeal function assessment using electroglottograph system

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ABSTRACT

In this study, we have evaluated the effect of amplitude and frequency perturbation of EGG signal during single vowels associated with laryngeal pathology. The normal EGG signal is properly characterized by an autoregressive model which has the optimal order of ninth using the parametric method. This can be analyzed by determining the transfer function. Perturbations in the fundamental pitch and in the peak amplitude of EGG signal derived with a four - electrode system using the modulation/demodulation techniques were investigated for the purpose of developing a decision criteria for the laryngeal function identification.

1. INTRODUCTION

Electroglottograph(EGG) describes laryngeal behavior as a vocal fold contact. EGG signal is to register the contact between the vocal folds as a time-varying signal[1]. The amplitude variation of these signals are generally thought to be representative of the amount of contact between the vocal folds. An objective of EGG device is to provide a measure of vocal fold activity decoupled from the effect of the supraglottal system[2]. A schematic depiction of the proposed EGG system is shown in Fig.1. Excitation currents[80 KHz, 2 mAp-p] supplied to No.1-and No.4-electrode. The current passed through the skin and larynx was detected by No.2- and No.3-electrode. This frequency current was obtained to be modulated EGG amplitude by the vibrating vocal folds.The proposed EGG system consisted of excitation current source, demodulator, filter bank, and amplifier. Also, autobalancing circuit in system was designed for elimination of instant baseline drift and dc offset.

2. METHOD

The subject of the present study consisted of 30 patients with various laryngeal pathologies(vocal polyp, husky voice, laryngeal cancer) and 30 normal adults for control purpose. The subjects were instructed to sustain the vowels /a/,/e/,/o/,/u/,/i/ for approximately 3 second at their comfortable pitch.

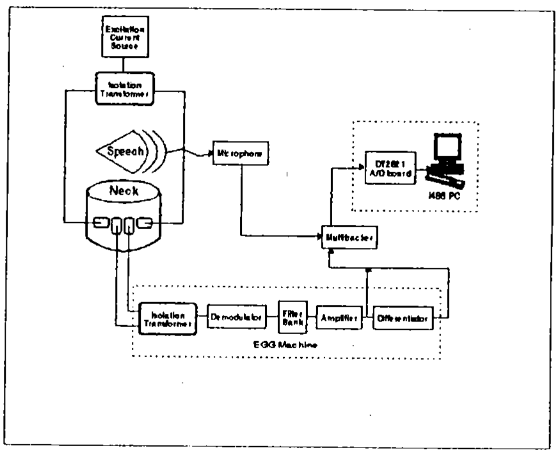

Fig.1 Block diagram of the proposed EGG system

Patient's data was recorded using 4-channel multitracker(FOSTEX Ltd.). The signals were sampled at 10,000 samples/s and digitized with DT-2821 12 bit A/D converter(data translation).

3. RESULTS AND DISCUSSION

In case of normal subject , we assumed that the laryngeal function is a linear system. Also it will be applicable autoregressive moving average model. A part of d-matrix for autoregressive moving average of normal EGG signal is shown in Table 1. Predicted maximum order is 15, and 15x15 matrix is calculated. In order to minimize of error, 64-bit real number calculation was processed. A d-matrix in Table 1 was shown that the difference of absolute value in ninth and tenth was decreased in large scale. In case of normal subject , the order of EGG signal on single vowel 'a' is ninth order in autoregressive moving average model. and zeroth order in moving average model.

Table 1 The calculated d-matrix on Korean vowel of 'a'

l \ k	1	2	3	4	5	6	7	8
1	5.9e+03	1.7e+05	-1.5e+06	1.4e+07	-1.2e+08	1.1e+09	-9.9e+09	8.6e+10
2	-1.5e+18	-4.8e+18	4.4e+15	-1.9e+16	-1.9e+15	-9.6e+15	1.7e+16	3.2e+15
3	-1.9e+15	1.0e+16	6.5e+15	5.9e+12	2.2e+13	6.8e+12	1.4e+12	-1.9e+13
4	5.5e+12	-2.4e+13	2.4e+13	-8.7e+11	3.8e+10	1.1e+10	-3.3e+09	-3.7e+10
5	-1.1e+10	3.8e+10	-2.1e+09	1.0e+11	1.3e+10	6.7e+07	2.8e+07	-1.6e+07
6	6.1e+06	-1.0e+07	7.5e+07	1.9e+07	1.5e+08	1.0e+07	6.1e+04	1.7e+04
7	-3.6e+04	-3.0e+04	4.7e+03	2.2e+04	-1.0e+05	-3.8e+04	1.0e+04	9.6e+00
8	9.6e+01	1.1e+02	9.0e+01	-3.1e+02	7.5e+00	-8.3e+00	-1.4e+01	-2.8e+01
9	-2.3e-01	1.0e-01	-3.9e-01	7.7e-02	-3.5e-01	5.0e-03	-8.2e+00	-8.1e+00
10	4.3e-04	6.3e-05	4.0e-05	1.0e-04	6.5e-05	-7.5e-02	2.3e-03	-3.0e-01
11	-5.1e-07	-1.7e-06	-3.9e-07	-5.7e-07	1.3e-04	-4.1e-02	3.9e-03	-1.6e-02
12	-1.3e-09	-2.4e-09	9.3e-09	1.9e-07	2.7e-05	-2.6e-04	1.1e-06	-2.7e-05
13	7.7e-12	1.3e-11	-2.8e-10	8.5e-07	-1.8e-07	-1.7e-06	-2.7e-07	-3.6e-07
14	2.0e-13	-2.0e-12	1.0e-09	-3.6e-09	-1.0e-08	-7.4e-09	-5.1e-09	-4.2e-09
15	-1.2e-13	-1.9e-12	-1.3e-11	-1.6e-11	6.3e-12	7.0e-13	5.0e-13	1.5e-12

The period and amplitude of collected EGG signals were processed by two kinds of techniques. Firstly, a "pitch perturbation" of EGG signal was measured. It is also known that some rapid and abrupt changes exist in the pitch periods, which may be called "pitch perturbation". The perturbation is defined as the difference between the adjacent periods, then the abrupt variations which are assumed to be related to laryngeal disorders. Secondly, 7-point moving average technique was adopted in order to obtain the pitch and amplitude perturbation. Figure 2 is shown the relationship of pitch and amplitude perturbation. Figure 2 was processed by patient data with a vocal polyps.

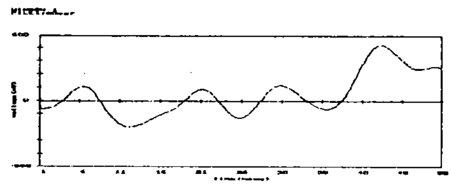

Fig.2 EGG signal perturbation with a vocal polyps

A frequency and amplitude perturbation was defined on the basis of above mentioned considerations[3]:

frequency perturbation, FP= A/B

$$A = 1/n-4 \ \Sigma_{i=4}^{n-3} |F_{i-3} + F_{i-2} + \ldots + F_{i+2} + F_{i+3} \ / \ 7 - F_i |$$

$$B = 1/n \ \Sigma_{i=1}^{n} F_i$$

amplitude perturbation, AP= C/D

$$C = 1/n-4 \ \Sigma_{i=4}^{n-3} |A_{i-3} + A_{i-2} + \ldots + A_{i+2} + A_{i+3} \ / \ 7 - A_i |$$

$$D = 1/n \ \Sigma_{i=1}^{n} A_i$$

Figure 3 shows the correlation between frequency and amplitude perturbation of EGG in normal subjects and patients. Frequency perturbation is better than amplitude perturbation in classing between normal subjects and patients.

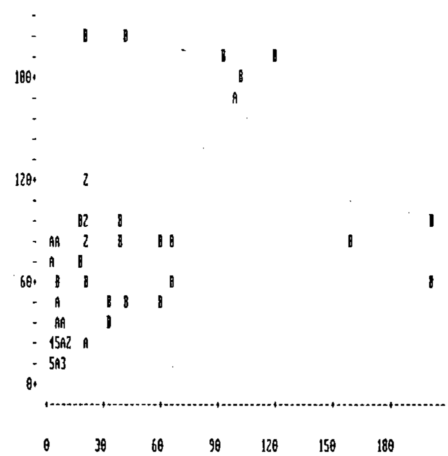

Fig.3 The correlation of frequency and amplitude perturbation of EGG between normal subjects and patients.

In figure 3., 'A' represents normal case and 'B' is abnormal case. m+0.5 *sd is discriminating line on frequency perturbation and m+2*sd is normal amplitude perturbations, respectively.

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