Acoustic Analysis of Standard Arabic Plosives

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***Abstract*—This paper has used the research theory and method of experimental phonetics and Speechlab software (Peking university) and Matlab voice analysis platform to analyze and describe the standard Arabic plosives though the atlases such as wave pattern、broadband sonogram、amplitude curve and logarithm spectrum and some acoustic parameters such as duration and the mean of the amplitude. This paper has further described and analyzed the standard Arabic plosives from the microscopic aspects. And using the method of experimental phonetics to understand the acoustic characteristics of the standard Arabic plosives.**

Keywords- the standard Arabic plosives; energy; logarithm spectrum; duration.

I. INTRODUCTION

Arabic (العربية اللغة) is a very important language, which belongs to Semito-Hamitic family, in the world. It used as common language in Middle East and North Africa area, and it is as the official language of twenty-seven countries and four international organizations. Arabic adapted from the ancient language-Semitic language, most linguists believe that standard Arabic is the most close to the ancestral Semitic language of the Semitic language family. More than two hundred and ten million people speak Arabic as their mother tongue, while it is used as religious language for the Muslim all of the world. Because it is widely distributed, each region formed its dialects. However, the standard Arabic is subject to Koran. Arabic letter, which develops from syllabaries of the west branch of Semito-Hamitic family, belongs to phonemic character. It has twenty-eight consonant letters without vowel letter.

Today, most studies of Arabic phonology mainly concentrate on dialects, such as university of Queensland in Australia, where do an acoustic analysis on pharyngealization in Assiri Arabic, and university of Kansas, where do analyze on acoustic correlates of emphasis in Jordanian Arabic, etc. In our country, there are many linguists do analysis on it, for example, Zhou Wenju、Chen Jie and Chen Zhongyao etc. But there are not many studies of standard Arabic plosives by using the method of experimental phonology.

In this paper, using the method of experimental phonetics to analyze on the seven standard Arabic plosives, which do analysis from microscopic through using available data what can manifest their basic acoustic features. It will mainly use wave pattern、broadband spectrogram、amplitude curve and logarithmic spectrum combined with the method of traditional phonetics to describe the acoustic features of standard Arabic plosives.

II. EXPERIMENTAL DESIGN

It is produced by completely blocking the air stream followed by a sudden release of the compressed air in the oral or throat. There are nine plosives of standard Arabic, this paper choose seven plosives among them to do analyze, such as ب /b/、 د /d/、 ض /□/、 ت /t/、 ط /□/、 ق /q^h/、 ك /k^h/. The plosives in Arabic and Mandarin Chinese are differently characterized, the former being mainly distinguished by the distinctive feature of voice,and the latter asparation. There are د /d/ and ت /t/ is the only group of the opposite phoneme in Arabic.

This paper choose fifty-six samples from the standard Arabic pronunciation table in the first book of New Edited Arabic, every plosives with six CV-syllables and two CVV-syllables as recording transcript. Three Arabic teachers were invited to make recording in natural and moderately paced their speech. The recording has been done in the professional recording room where has good sound insulation and sealing to keep high SNR of recording. There are two students who have been trained to monitor the whole process, and every sound pronounces twice. All the recordings in this paper are using YanShi transcription method.

After recording, using the software called Speechlab which is decelopped by the linguistics laboratory of Beijing University to mark the sound type of all the recording. Then using MATLAB to extract the parameters to analyze on the acoustic features.

III. VOICED STOPS

Voiced stops produced with vibration of the vocal cords. In this paper, though observing and analyzing the wave pattern、broadband spectrogram、amplitude curve and logarithmic spectrum of standard Arabic plosives, it is easy to find out the phonetic features of voiced stops.

A. Voiced Bilabial Plosive /b/ without Aspiration

ب /b/, it manifests a narrow vertical striation and a cloud sprit on sonogram, which means it is a voiced plosive. The compression phrase, during which air is compressed behind the closure, transit to the release phrase, during which the articulators forming the obstruction come rapidly apart and the air is suddenly released. Through the logarithm spectrum, amplitude mainly distribute from -30dB to 10dB in the range of 0~8000Hz. From acoustic graph, it can get some acoustic parameters, such as duration and amplitude. The result of duration is about 150ms. The release phrase of /b/ is very short and energy reaches the peak on about 140ms. The maximum and minimum of the amplitude respectively is 69.18dB and 48.83dB, its energy domain is 20.35dB, and the amplitude average is 59.01dB.

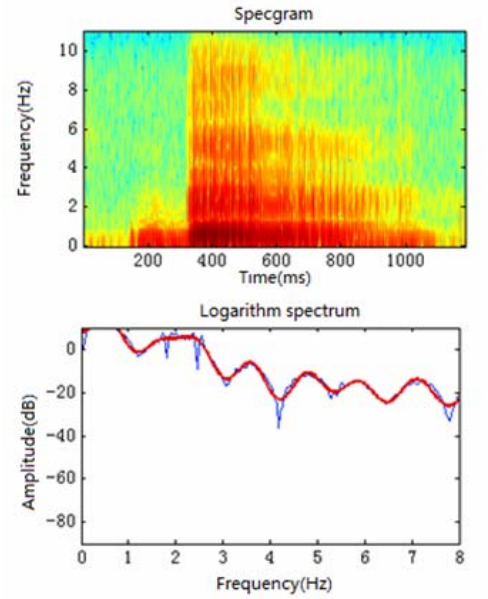

Fig 1.

B. *Voiced Blade-alveolar Plosive /d/ without Aspiration*

د /d/ , made with the tip of the tongue pressed against the ridge of the gum just behind the upper teeth. Air is compressed behind the closure made by the raised soft palate and the shut-off nasal resonator. In this process the vocal folds are wide apart. Then the air escapes with force upon the sudden separation of the alveolar closure with weaker expiration while voiced. It manifests a narrow vertical striation and a cloud sprit on sonogram. The brief elastin means the consonant transit to vowel after the release phrase. Through the logarithm spectrum, amplitude mainly distribute from -40dB to -10dB in the range of 0~8000Hz. From acoustic graph, it can get some acoustic parameters, such as duration and amplitude. The result of duration is about 206ms. The release phrase of /d/ is very short and energy reaches the peak on about 200ms. The maximum and minimum of the amplitude respectively is 71.16dB and 53.41dB, its energy domain is 17.75dB, and the amplitude average is 62.29dB.

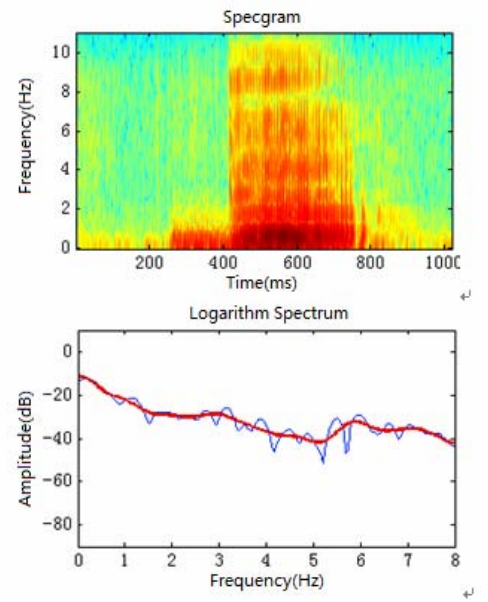

Fig 2.

C. *Voiced Linguo-alveolar Plosive /□/ without Aspiration*

ض/□/ is the specific speech of standard Arabic which made with tongue lip and one side molars. When the breath breaks though the block, the vocal-cord vibrates. It manifests a narrow vertical striation and a cloud sprit on sonogram. Through the logarithm spectrum, amplitude mainly distribute from -60dB to -20dB in the range of 0~8000Hz. From acoustic graph, it can get some acoustic parameters, such as duration and amplitude. The result of duration is about 217ms. The release phrase of /□/ is very short and energy reaches the peak on about 190ms. The maximum and minimum of the amplitude respectively is 71.55dB and 54.38dB, its energy domain is 17.17dB, and the amplitude average is 62.97dB.

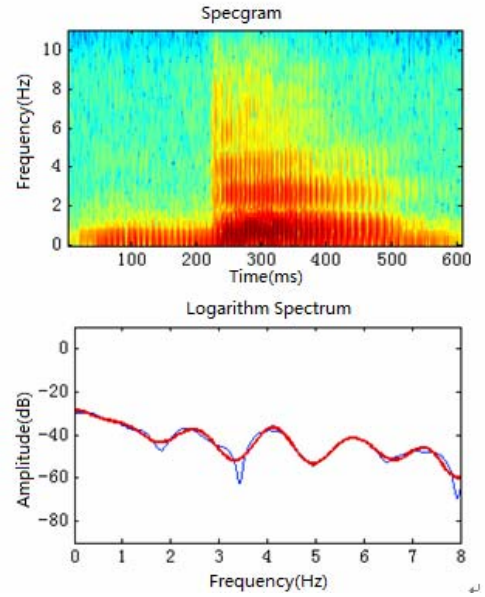

Fig 3.

IV. VOICELESS STOP

Voiceless stop produced without vibration of the vocal cords. Essential differences in sonogram by comparing with voiced stop. All the voiceless stops of standard Arabic in the study in this paper are aspirated.

A. *Voiceless Blade-alveolar Plosive /t/ with Aspiration*

ت/t/, made with the tip of the tongue pressed against the ridge of the gum just behind the upper teeth. Air is compressed behind the closure made by the raised soft palate and the shut-off nasal resonator. In this process the vocal folds are wide apart. Then the air escapes with force upon the sudden separation of the alveolar closure with weaker expiration while voiceless. It manifests a narrow vertical striation and a clear aspiration section on sonogram. Aspiration section means that the vocal cords do not immediately begin to vibrate after blasting, but keep the glottis open in a time and the air flow out rapidly in order to form turbulence by friction in glottis and the narrow channel above the glottis. Through the logarithm spectrum, amplitude mainly distribute from -70dB to -40dB in the range of 0~8000Hz. From acoustic graph, it can get some acoustic parameters, such as duration and amplitude. The result of duration is about 74ms. The release phrase of /t/ is very short and energy reaches the peak on about 70ms. The maximum and minimum of the amplitude respectively is 66.07dB and 42.03dB, its energy domain is 24.04dB, and the amplitude average is 54.05dB.

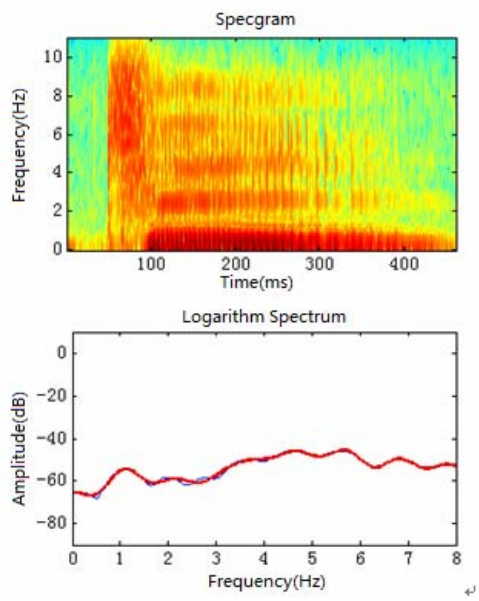

Fig 4.

B. *Voiceless Blade-alveolar Plosive /□/ with Aspiration*

ط /□/, made with the tip of the tongue against between the upper gum and hard palate. Air is compressed behind the closure made by the raised soft palate. Then the air escapes with force upon the sudden separation of the alveolar closure with stronger expiration while voiceless. It manifests a narrow vertical striation and brief elastin on sonogram. The brief elastin means the consonant transit to vowel after the release phrase rapidly. Through the logarithm spectrum, amplitude mainly distribute from -60dB to -20dB in the range of 0~8000Hz. From acoustic graph, it can get some acoustic parameters, such as duration and amplitude. The result of duration is about 66ms. The release phrase of /□/ is very short and energy reaches the peak on about 60ms. The maximum and minimum of the amplitude respectively is 67.94dB and 34.31dB, its energy domain is 33.63dB, and the amplitude average is 51.13dB.

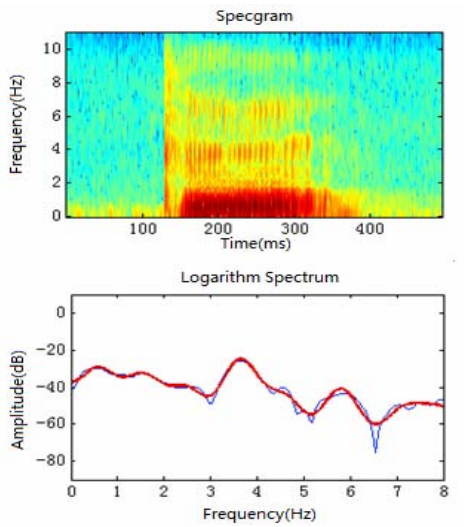

Fig 5.

C. *Voiceless Velar plosive /q^h/ with Aspiration*

ق/q^h/, made with the back of the tongue aganist the soft palate while tongue base contact with uvula slightly. It manifests a narrow vertical striation and brief elastin on sonogram. Through the logarithm spectrum, amplitude mainly distribute from -50dB to -20dB in the range of 0~8000Hz. From acoustic graph, it can get some acoustic parameters, such as duration and amplitude. The result of duration is about 56ms. The release phrase of /q^h/ is very short and energy reaches the peak on about 50ms. The maximum and minimum of the amplitude respectively is 67.85dB and 43dB, its energy domain is 33.85dB, and the amplitude average is 55.43dB.

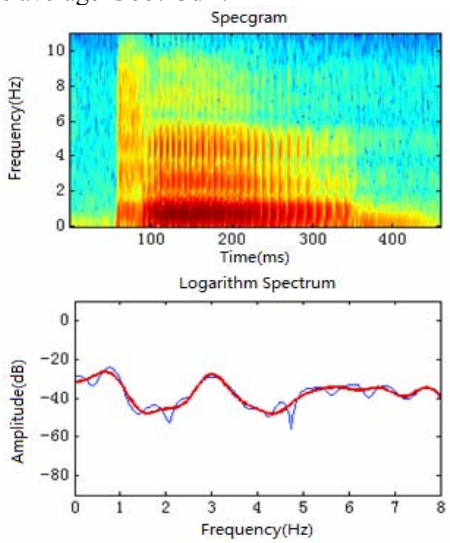

Fig 6.

D. *Voiceless Velar plosive /k^h/ with Aspiration*

ك /k^h/, made with the back of the tongue pressed against soft palate. Then air flow out suddently with voiceless. It manifests a narrow vertical striation and longer elastin on sonogram. Through the logarithm spectrum, amplitude mainly distribute from -70dB to -20dB in the range of 0~8000Hz. From acoustic graph, it can get some acoustic parameters, such as duration and amplitude. The result of duration is about 64ms. The release phrase of /k^h/ is very short and energy reaches the peak on about 60ms. The maximum and minimum of the amplitude respectively is 63.04dB and 38.83dB, its energy domain is 24.21dB, and the amplitude average is50.94dB

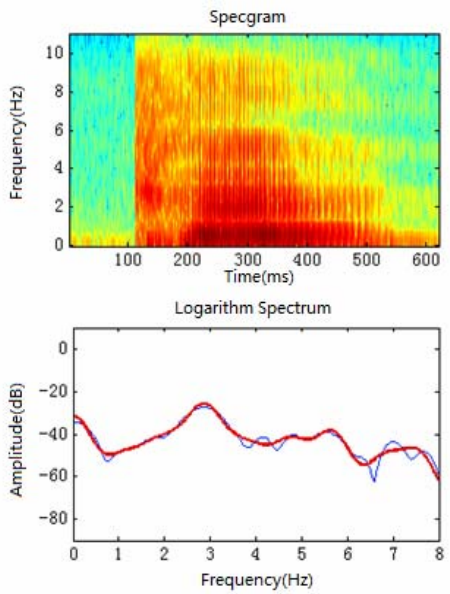

Fig 7.

V. CONCLUSION

This paper combined traditional phonology with experimental phonology, and also combined linguistic theory with the technology of modern experimental linguistics to analyze its duration、 energy and logarithmic spectrum by observing spectrogram of the seven Arabic plosives. Then do a detailed acoustic description and analysis to reach the conclusions as followings:

1) By comparing with the duration data, the durations of voiced plosives with unaspiration are all longer than voiceless plosives with aspiration. The duration order of the seven plosives is: □>d>b>t>t>k^h>q^h.

2) From the amplitude,voiced plosives with unaspiration have more power than voiceless plosives with aspiration in the range of the maximum. But for the energy domain, voiceless plosives with aspiration have more value than voiced plosives with unaspiration, which means the variation range of voiceless plosives with aspiration are big.

3) Through the average of amplitude, voiced plosives with unaspiration have more value than voiceless plosives with aspiration, it manifests that the energy of voiced plosives with unaspiration are bigger than voiceless plosives with aspiration.

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