ANOTHER LOOK AT THE REGISTER DISTINCTION IN MON

Theraphan L. Thongkum

1. INTRODUCTION

Lee (1983) investigated the acoustical parameters governing the register distinction in Mon and the relative significance of these parameters. Four parameters were looked at : vowel duration, frequencies of the first two formants, fundamental frequency, and distribution of spectral energy. He concluded that for citation forms, only two of these parameters indicated that significant differences exist between the two registers. The second register vowels had longer duration and lower pitch level. No consistent difference could be found between the two registers with respect to vowel quality or phonation type. He ended his paper by saying :

> *Further, our findings suggest that the most significant parameter of the register distinction is that of pitch, in particular the onset Fo and the overall pitch level. Indeed, as Shorto (1962) suggests, Mon is a quasi - tonal language.*
>
> **(Lee 1983 : 95)**

Diffloth (1985) disagreed with Lee's experimental findings. He did not believe that numerical acoustic coefficients could tell us that one phonetic parameter is more important than the other. He commented :

> *An answer to Lee's question does not come from acoustical measurements alone ; it would have required the use of a speech synthesizer able to imitate a wide spectrum of phonation types, as well as pitches, and the computation of recognition and error responses from native speakers of Mon.*
>
> **(Diffloth 1985 : 56)**

He confirmed what he thought he had heard by citing *Shorto (1967), Haswell (1874), Blagden* (1910), Halliday (1922), Huffman (1976), and Sakamoto (1974) : " For Mon, head register is characterized by clear voice and chest register by breathy voice ".

It is possible to end the argument by saying that the problem has been caused by dialect variations which Lee forgot to mention in his article. Diffloth had worked on Burmese Mon for a few years, and he was the one who prepared the wordlist and lined up Mon informants for Ladefoged when the recordings were made in a Buddhist temple in Bangkok. I witnessed the whole procedure. Later, the recordings were used by Lee for his acoustical measurements of " Mon register distinction ". From the above account, we might be able to point out the following weaknesses, if there have been any :

1. The so - called " register distinction " in Mon as has been reported in the literature is only a myth. In fact, Mon is a two - register tone language (as defined by Pike 1948).

2. Influenced by the literature of Mon language studies, Diffloth was inclined to hear what he did not really hear while collecting field data. He happened to work on Mon dialects that do have tone instead of register contrast. As a result, the wordlist prepared by him and which the Mon informants used was not suitable for an acoustical study of a register language, which always involves phonation types.

3. The Mon monks who acted as informants were not familiar with the situation, i.e. three foreigners and a Thai woman directing them to say some words and sentences in order to make good tape -

recordings. Thus, their, speech could have been unnatural. In general, the Mon, at least Thai Mon, are ashamed of " speaking with their mouth, " as described by themselves and the Thai. Perhaps, the informants could control their laryngeal setting so well that phonation differences did not occur when the recordings were being made.

4. Different phonation types do exist, but Lee failed to prove it to us because the technique of measuring used in his study was not adequate. However, the editor of **UCLA Working Papers in Phonetics 60** notes at the end of Diffloth's paper (1985 : 57) that " *although some other technique might reveal a difference in laryngeal setting for the registers in Mon,* careful listening by several persons with ' trained ears ' in the UCLA Phonetics Laboratory does not suggest that breathiness is at all a consistent feature of ' chest register ' in the tape recordings we have, whereas an observable and statistically reliable pitch height difference does occur ".

I must admit that I am not satisfied with the explanation given above. I have worked on tone languages of Southeast Asia that have phonation type as a property of tone, and also on Mon - Khmer register languages. My intuition and experience tell me that something has gone wrong, and that I should help settle the matter. Let us examine carefully what the scholars of Mon - Khmer language have said about the registers in Mon.

Haswell (1901) points out that the Peguan (Mon) alphabet consists of twelve vowels, and that " the vowels are mostly in pairs, the first is light, the second is heavy sound, of what might properly be called the same vowels " (p. 1). It is very interesting that Haswell describes Mon vowels in terms of light vs. heavy. He could have heard some kinds of voice quality. At present, the Mon in Thailand also describe their language as having light words vs. heavy words. We can not tell whether Haswell really heard phonation - type differences or he was influenced by the traditional way of explaining Mon sounds.

Blagden (1910) associates " glottal activity " with the initial consonants in Mon. He notices that the so - called " voiced and voiced aspirated stops " are in fact " voiceless and voiceless aspirated stops " accompanied by glottal activity which also influences the following vowel. He says :

> *........the consonants : g, gh, j, ḍh (only used in Pâli words), d, dh, b, bh called " voiced " are actually pronounced voiceless : k, kh etc. ... but their pronunciation is accompanied by glottal activity which distinguishes them fairly clearly from the consonants of the first series ; this (glottal activity) profoundly modifies the vowel which follows in a way which is difficult to describe, but seems in certain cases to be a rather guttural quality pertaining to the posterior part of the oral cavity. ...*
>
> **(Blagden 1910 : 479)**

Neither Haswell nor Blagden mention pitch differences at all.

Shorto (1962) uses the term " register " as defined by Henderson (1952) to describe the tenseness vs. laxness in Mon speech. He says :

> *The quasi - tonal register distinction, ..., is inherent in all Mon words. Chest register, characterized by breathy voice quality in association with a general laxness of speech organs, and somewhat centralized articulation of vowels, ..., head register, characterized by clear voice quality, ...*
>
> **(Shorto 1962 : x)**

Shorto (1967) gives more phonetic details on the register distinction in Mon. He points out the differences of vowel quality, consonant articulation and voice quality, but not pitch differences. The tense-lax distinction affects not only single consonants or vowels, but the whole complex of the word. He states :

> *The exponents of register are diverse in character, comprising a difference of voice quality ; differences of vowel quality, slight in some cases but in others considerable ; and in some cases differences in consonant articulation. ... . Contrastive voice quality is always present and is probably the feature most readily perceived.*
>
> *Head register is characterized by clear voice throughout the word or equivalent segment, Chest register is characterized by a breathy voice with lowering of the glottis and a relatively centralized articulation of vowels, ...*
>
> *Pitch difference as an exponent of register is lacking. ... .*
>
> *A unitary formulation of the diverse exponents of Mon register — the differences of*

voice quality, of vowel articulation, and of consonant articulation — may be sought in terms of a tense - lax opposition affecting not merely single phonemes but the whole complex of the word or equivalent segment. Thus in chest register laxness results not only in the voicing of prevocalic consonants, but also in less vigorous movements of the tongue towards the periphery, leading to the relative centralization of vowels noted above.

(Shorto 1967 : 246)

Huffman (1976) recognized a similar type of register phenomenon in a Thai Mon dialect spoken in Ban Bang Kradi. Briefly he says :

> *The register distinction in Mon is relatively subtle ; 2nd register vowels are mildly lax and breathy, and are slightly lower in quality (more open) than their 1st register counterparts. The distinction is particularly difficult to hear in the low front /ɛ/ ≠ /ɛ̀/ position.*

(Huffman 1976 : 585)

Diffloth (1984) uses the field data collected by himself at three Thai Mon villages : Ban Nong Du, Ban Bang Khan Mak and Ban Nakhon Chum, and at many Burmese Mon villages, together with the language data gathered from Shorto (1962) and Sakamoto (1974) for reconstructing Proto - Mon and Proto - Monic. Regarding the register distinction in Mon, he says that " Mon has a contrast between vowels pronounced with a clear voice and vowels with a breathy voice, and that there are actually important differences in the phonetic features which accompany these two registers in Mon, notably in pitch patterns " (p. 52).

It is important to note that every scholar of Mon - Khmer languages has talked about voice quality and phonation type in Mon, but only a few of them mention pitch. In his book which appeared in 1962, Shorto used the term " quasi - tonal register distinction ", and later on in 1967, in his article on " The register distinctions in Mon - Khmer languages, " Shorto pointed out " the lack of pitch difference " in Mon. Even though Diffloth disagrees with Lee's conclusion that Mon is " a quasi - tonal language " because the pitch differences in Mon are statistically significant, he himself mentions " pitch patterns " in his book (Diffloth 1984).

2. LANGUAGE DATA

The number of Mon in Thailand is estimated at 200,000. Hundreds of Mon villages are scattered in the central region of Thailand. In 1981, I visited many Mon villages to collect language materials for a dialect survey of Mon. I noticed that the Mon inhabiting different areas spoke differently. My informants often pointed out to me that the Mon living in a nearby village or across the river spoke Mon with a different accent. This was due to the fact that the Mon population in Thailand migrated from different regions of Burma, and that they entered the country at different periods. In November 1986, I stayed about a week in a Mon village located in Nakhon Chum Sub - District, Ban Pong District, Rajaburi Province. About 1,000 words were collected during this field trip. After examining the data obtained carefully, I selected about 116 word pairs for good quality recordings. The pronunciation of these 116 minimal or nearly minimal pairs was carefully checked. Eight Mon speakers from Ban Nakhon Chum volunteered to come to our recording studio in Bangkok. Most speakers of Thai Mon are literate in Thai ; they cannot read Mon script. Writing Mon with Thai script is not an easy task either. The only thing I could do was to elicit the word pairs I wanted by means of interviewing them. During the interviews, the Thai glosses were used as clues. It took quite a long time to obtain the data from eight speakers. The tapes were edited later. However, only 16 word pairs were used for acoustic analysis, the results of which are being submitted in this paper. They are as follows :

1.	a)	/hərip/	**" to blink "**
	b)	/hərḭp/	**" to snatch and run away "**
2.	a)	/ɓi/	**" river "**
	b)	/ɓḭ/	**" you (vulgar) "**
3.	a)	/tep/	**" a kind of bamboo trap "**
	b)	/te̤p/	**" woman who has a lover "**

Due to bad editing of the tapes, the word pair /tep/ and /te̤p/ had to be replaced by /cep/ " to taste " and /ce̤p/ " to seep " for S6 (speaker 6) and S8 (speaker 8).

4. a) /həte/ ~ /te/ " to forge iron "
   b) /həte̤/ ~ /te̤/ " mercury "
5. a) /wɛk/ " slightly torn (of cloth) "
   b) /wɛ̤k/ " to tuck behind the ear (as a flower) "
6. a) /phɛŋ/ " split bamboo "
   b) /phɛ̤ŋ/ " marijuana "
7. a) /cək/ " to gore "
   b) /cə̤k/ " rope, cord "
8. a) /cə/ " to shield "
   b) /cə̤/ " to bump into "
9. a) /pat/ " to smooth and level off "
   b) /pa̤t/ " Mon orchestra "
10. a) /ɗaŋ/ " expensive "
    b) /ɗa̤ŋ/ " king posts (which support the ridge - pole) "
11. a) /put/ " to carve "
    b) /pṳt/ " to rub across (as when making a fire) "
12. a) /cu/ " steep "
    b) /cṳ/ " to stop (in order to rest) "
13. a) /pot/ " to polish "
    b) /po̤t/ " pot "
14. a) /əto/ " ear "
    b) /əto̤/ " jujube "
15. a) /thɔt/ " forcefully "
    b) /thɔ̤t/ " to deepfry "
16. a) /ɓɔŋ/ " to give birth "
    b) /ɓɔ̤ŋ/ " bamboo tube for smoking marijuana "

The above 16 word pairs were chosen for the acoustic analysis of Mon vowels because of the three following reasons : a) they are minimal pairs ; b) they all contain pure vowels : i i̤ e e̤ ɛ ɛ̤ ə ə̤ a a̤ u ṳ o o̤ ɔ and ɔ̤ ; and c) they represent two types of syllable structure, namely dead or checked syllable (CVC̥) and live or ordinary syllable (CV, CVC). During my field trip, I had noticed that syllable structure had some influence on the phonetic characteristics of vowel length, vowel quality and pitch.

3. WIDEBAND SPECTROGRAMS

Wideband spectrograms can provide good displays of the acoustics of different phonation types. During the creaky voice vowels, the vertical striations (i.e. glottal pulses) occur at irregularly spaced intervals. The formants are fairly clear during the modal voice vowels and are less well - defined for breathy voice vowels. (Kirk et al. 1984).

After investigating all the wideband spectrograms of the test words that I made in the Phonetics Laboratory of the Linguistics Department at UCLA, I decided to discard the labels " modal voice vowels " vs. " breathy voice vowels ". The choice of the labels " tense vowels " vs. " lax vowels " as suggested by Maddieson and Ladefoged (1985) seems to be more appropriate. Although most speakers pronounced first register vowels with modal (clear or normal) voice and second register vowels with breathy voice (see Figure 1), some speakers do not make this type of phonation distinction. For example, S5 (female) makes a distinction between two different degrees of breathiness, less breathy voice for first register vowels and more breathy voice for second register vowels, as shown in Figure 2. In comparison with the other subjects, S8 (male) has a very low voice. He seems to make three types of phonation distinction : modal voice vs. breathy voice, creaky voice vs. breathy voice, and creaky voice (in the middle or at the end) vs. a combination of breathy and creaky voice (perhaps, whispery - creaky voice), as show in Figures 3 - 5.

From investigating the wideband spectrograms of 128 test words pronounced by eight Mon speakers, we may conclude that different kinds of phonation types do occur, at least, in the Mon dialect of Nakhon Chum.

4. POWER SPECTRA

Phonation type differences are reflected in spectral energy distribution. Narrowband power spectra offer a way of quantifying the spectral tilt. Power spectra produced by the sound spectrograph can be used to quantify the relative amount of energy in different harmonics (Fischer - Jørgensen 1977, Stevens 1981, Lee 1983, Kirk et al. 1984, Maddieson and Ladefoged 1985, Ladefoged et al. 1987, etc.). To detect phonation type differences in Mon, the difference in dB between the amplitude of the fundamental (F_0) and intensity of the second harmonic (Hz) was measured (see Figure 6). The spectra were taken at half or one - third of vowel duration. The difference between the amplitude of the fundamental and that of the second harmonic is displayed in Figures 7 and 8. For the eight speakers, the mean for tense voice (modal voice or slightly breathy voice or slightly creaky voice) is 2.834 dB with a standard deviation of 4.17 (i.e. the fundamental has 2.834 dB less amplitude than the second harmonic). The mean for lax voice (heavily breathy voice or breathy creaky voice) is -3.228 dB with a standard deviation of 5.293 (i.e. the fundamental has -3.228 dB more amplitude than the second harmonic). The difference is highly significant ($p < .0005$ $t = 15.378$, $df = 128$). See Figure 7. For each speaker the relationship of the fundamental and the second harmonic is shown in Figure 8 and Table 1. **My findings indicate that an overall phonation difference in Mon does exist.** This means that my study supports the claim of Mon - Khmer specialists, such as Shorto, Huffman, Diffloth, etc., that the fundamental difference between the register distinction in Mon lies in a phonation difference.

5. FUNDAMENTAL FREQUENCY

Narrowband spectrograms were made and measured at five points starting from the onset to the end of the vowel (see Figure 9). For plotting the results of Fo measurements the 32 test words were divided into four sets based on phonation - type differences and syllable types : CVC̥ (consonant - tense vowel - voiceless stop), CV̤C̥ (consonant - lax vowel - voiceless stop), CV(C) (consonant - tense vowel - ø final or nasal or semivowel), and CV̤(C) (consonant - lax vowels - ø final, nasal or semivowel). The mean values of Fo (in Hz) of the eight speakers and of each individual speaker are displayed in Figures 10, 11 and 12. The results given in Table 2 show that the difference in fundamental frequency at 0% (the beginning), 25% 50% (the mid - point), 75% and 100% (the end point) of the harmonics is statistically significant. My findings here agree with those of Lee (1983).

It should be pointed out that a) vowels in CVC̥ and CV̤C̥ syllable types carry higher pitch and less fall pitch contour than vowels in CV(C) and CV̤ (C) syllable types ; b) tense vowels have higher pitch than lax vowels ; and c) vowels in both registers have fall or rise - fall pitch contour. Most speakers seem to use similar pitch patterns, except S5 (female) and S8 (male). Figure 12 indicates that in both registers, S5 shows a more sharp fall contour, and that S8 does not seem to have pitch difference between the two registers, especially in CV(C) and CV̤(C) syllable types.

6. VOWEL DURATION

Although vowel length in Mon is not linguistically significant, both short and long vowels can be heard. In general, vowels in checked syllables (CVC̥ and CV̤C̥) are shorter than those in other types of syllables.

The mean duration of vowels in CVC̥ and CV̤C̥ syllable types of the eight speakers is 155.14 msec with a standard deviation of 23.22 and 193.08 msec with a standard deviation of 36.61, respectively. The duration difference between tense and lax vowels is statistically significant ($p < .0005$, $df = 64$, $t = 10.824$). In CV (C) and CV̤ (C) syllable types, the mean duration of tense and lax vowels are 328.84 msec and 331.70 msec with a standard deviation of 92.76 and 93.14, respectively. The difference is so minute that it is not statistically significant ($t = 0.841$, $df = 64$). See Figure 13. The duration of vowels of each speaker is shown in Figures 14 - 15 and Tables 3 - 4. Lee (1983 : 82) points out that the second register vowels are longer in duration than the first register counterparts, and that the difference *is statistically highly significant ($p < .001$). His* finding about vowel duration in Mon is somewhat *true.*

7. FORMANT FREQUENCIES

The mean formant frequencies of F_1 and F_2 at the steady state of the vowel duration of the eight speakers are shown in Figures 16 and 17. In every type of syllable, the lax vowels i̤, e̤, ɛ̤, a̤ and o̤ are higher than the tense vowels i, e, ɛ, a and o, but the tense vowels ə, u and ɔ are higher than the lax vowels ə̤, ṳ and ɔ̤. The F_1 difference between the two registers is statistically significant ($p < .05$) only for i/i̤, o/o̤ (in CVÇ̥ and CV̤Ç̥ syllable type), ɛ/ɛ̤ and o/o̤ (in CV(C) and CV̤ (C) syllable type). With respect to the F_2 difference between the two registers, it is significant for ɛ/ɛ̤ (in CVÇ̥ and CV̤Ç̥ syllable type), e/e̤ and u/ṳ (in CV(C) and CV̤(C) syllable type). See Tables 5 and 6. Thus, it is not true that first register vowels are peripheral and second register vowels are centralized, as said by Shorto (1967). My findings agree very closely with those of Lee's (1983).

CONCLUSION

In this study of the register distinction in Mon, four phonetic parameters were examined : distribution of spectral energy, fundamental frequency, vowel duration, and frequencies of F_1 and F_2. The results of the acoustical measurements indicated that the *significant differences between the first register (tense)* vowels and second register (lax) vowels are : 1) power spectra, 2) fundamental frequency, and 3) vowel duration (only in CVÇ̥ and CV̤Ç̥ syllable types). It can be concluded that vowel length in checked syllables and phonation - type differences are as significant as pitch differences. These findings agree very well with the intuition of Mon speakers. My informants sometimes criticized my pronunciation when trying to imitate them as too high vs. too low, too light vs. too heavy, or too short vs. too long. With respect to the register distinction in Mon, these may be regarded as good hints that Mon people listen to different phonetic cues. However, a definite answer can be found only by means of doing perception testing.

Perhaps, we could end the arguments by saying that in the previous studies of Mon registers, none of the investigators were completly right or completely wrong.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Chulalongkorn University for granting me a leave of absence and to Peter Ladefoged who made my visit to UCLA Phonetics Laboratory possible. My thanks also go to Gérard Diffloth who kindly translated Blagden's article into English and provided me references on Mon language and linguistics.

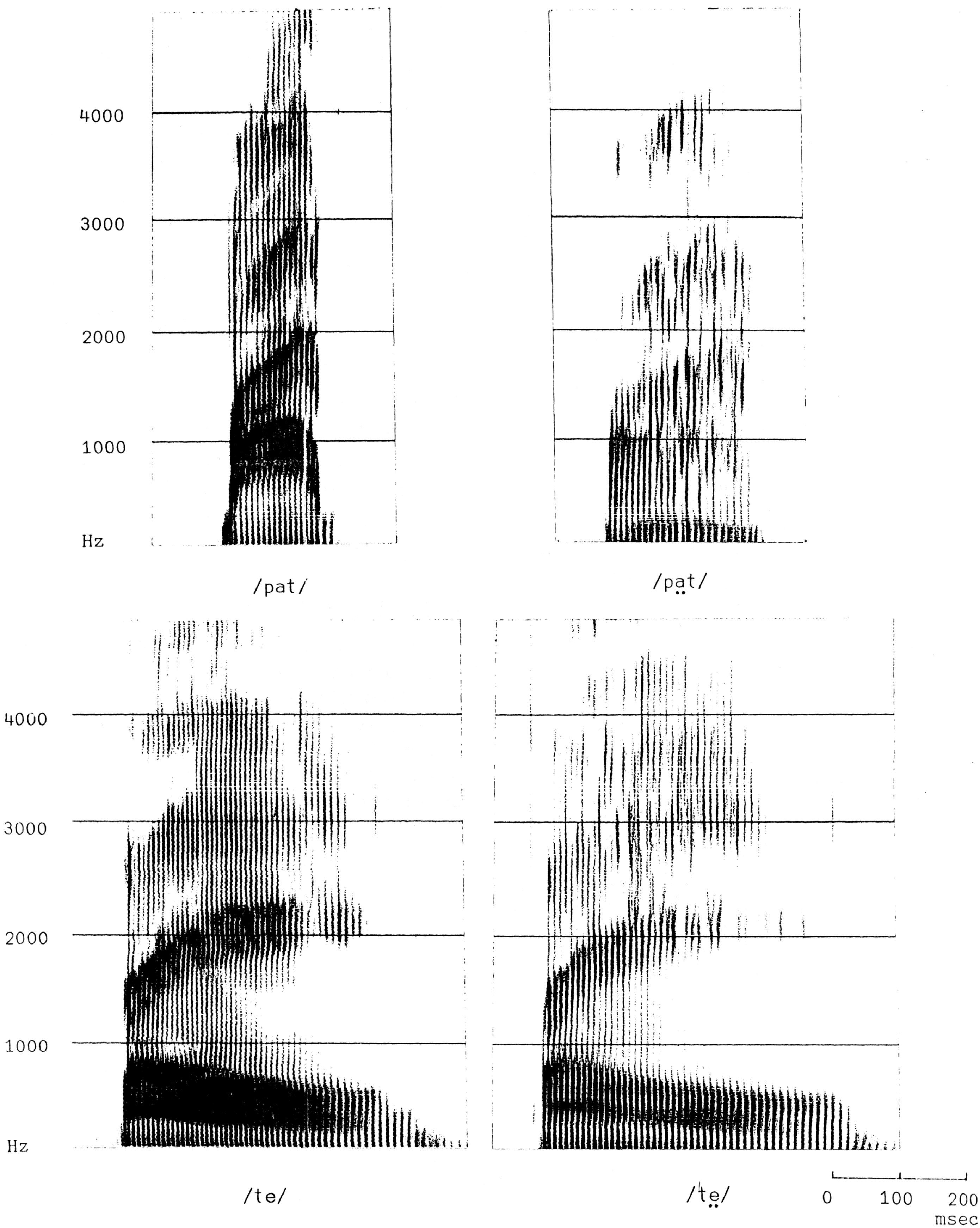

FIGURE 1. : Wideband spectrograms of vowels with modal voice and breathy voice of Speaker 7.

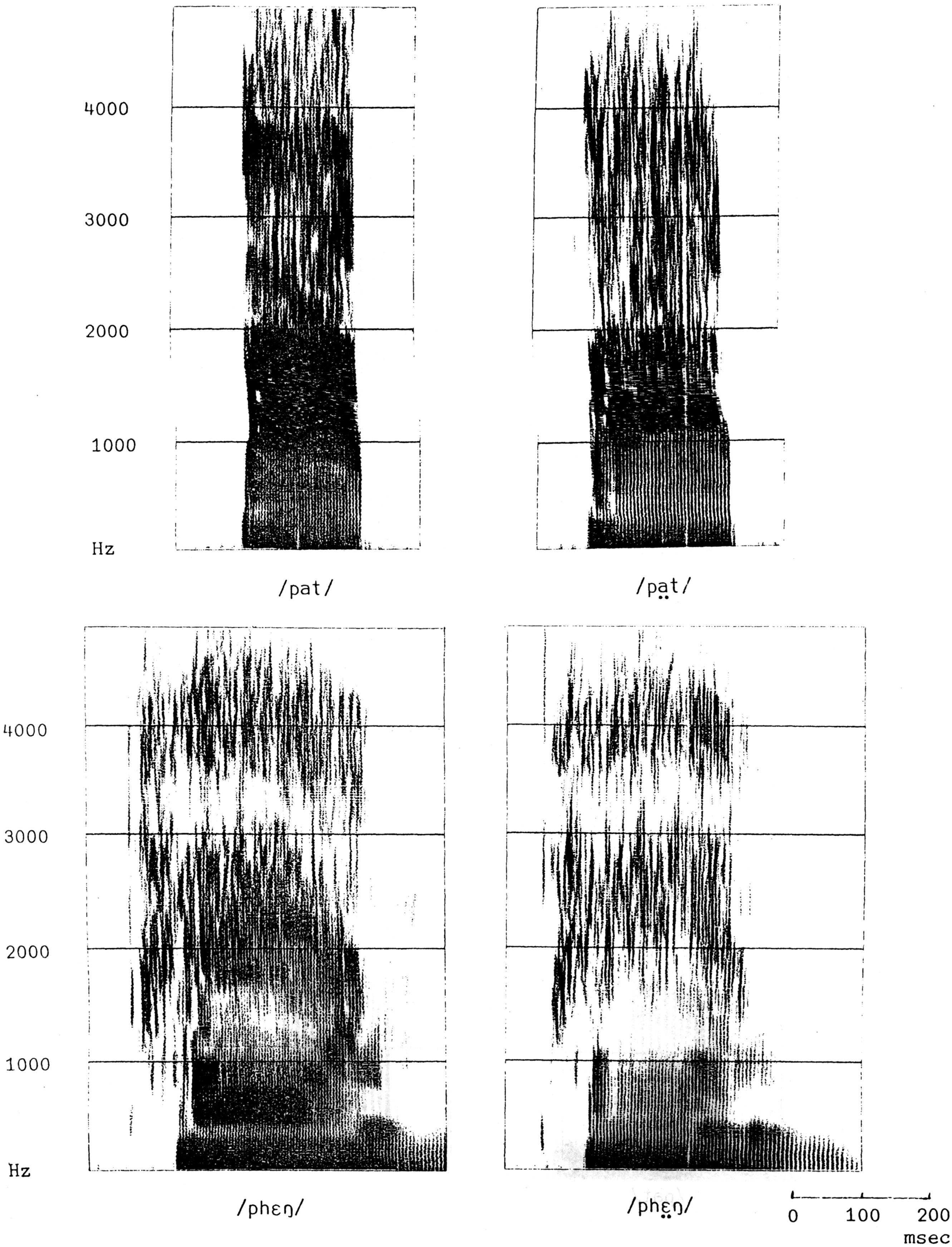

FIGURE 2. : Wideband spectrograms of vowels with less breathy and more breathy voice of Speaker 2.

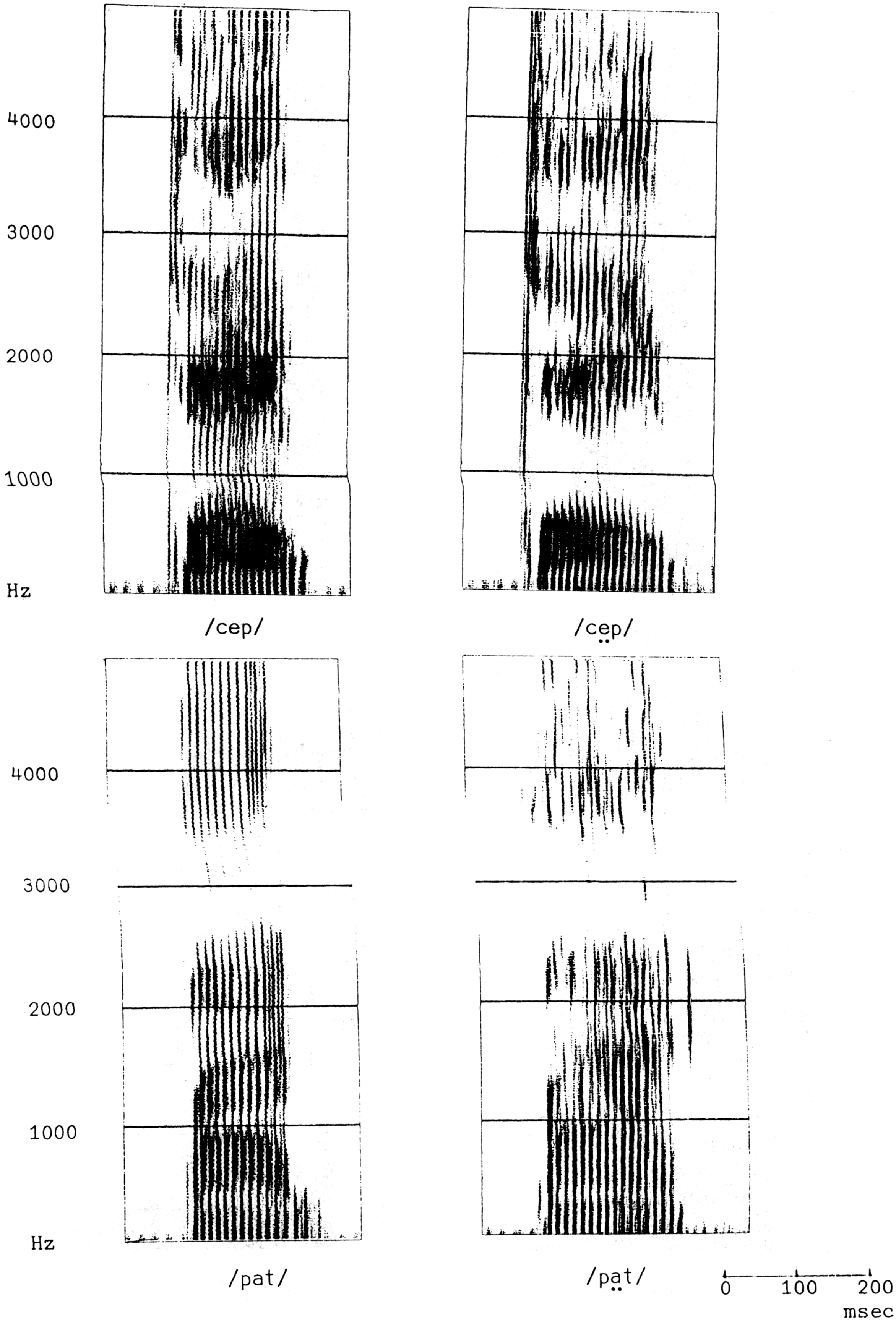

FIGURE 3. : Wideband spectrograms of vowels with modal voice and breathy voice of Speaker 8.

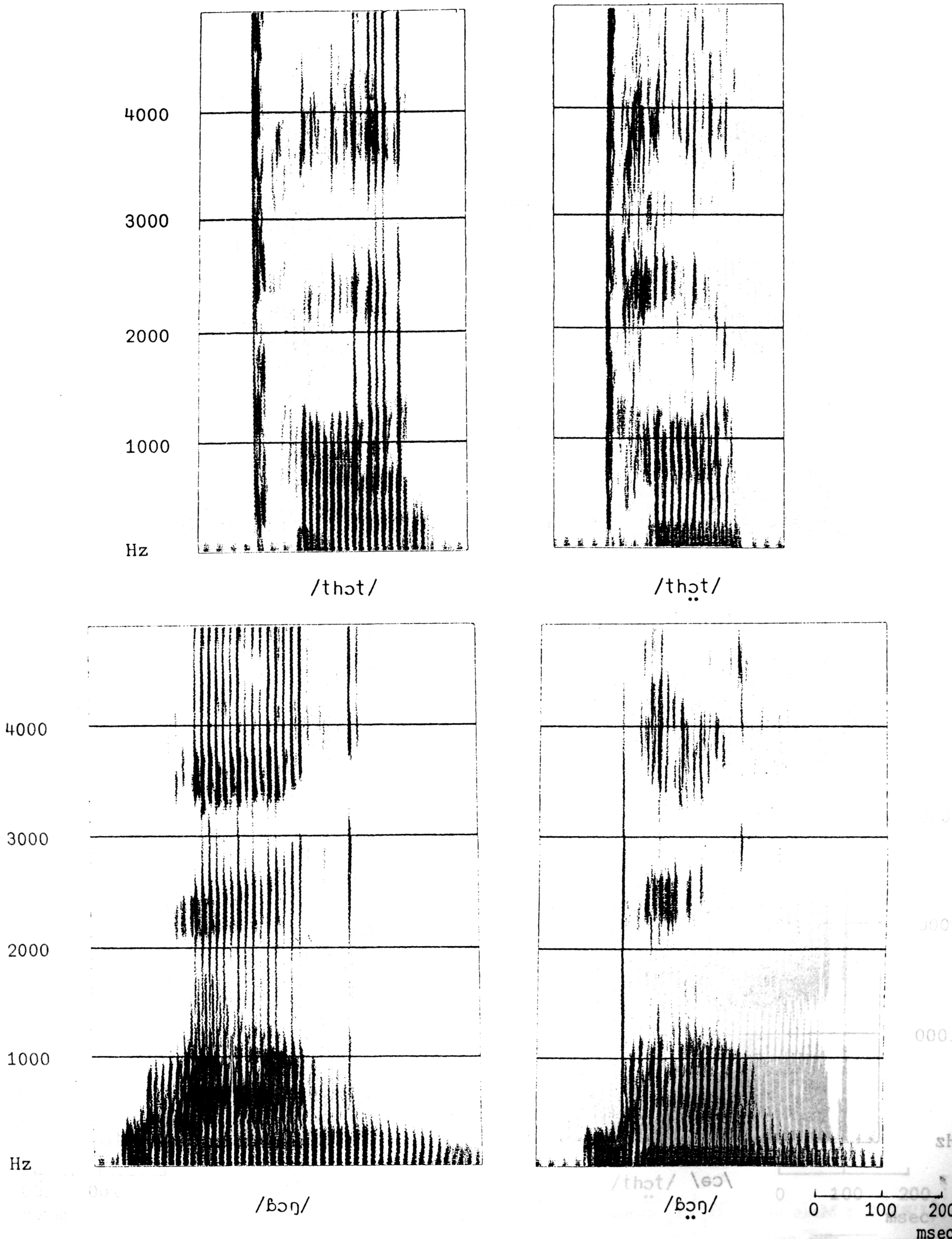

FIGURE 4. : Wideband spectrograms of vowels with creaky voice and breathy voice of Speaker 8.

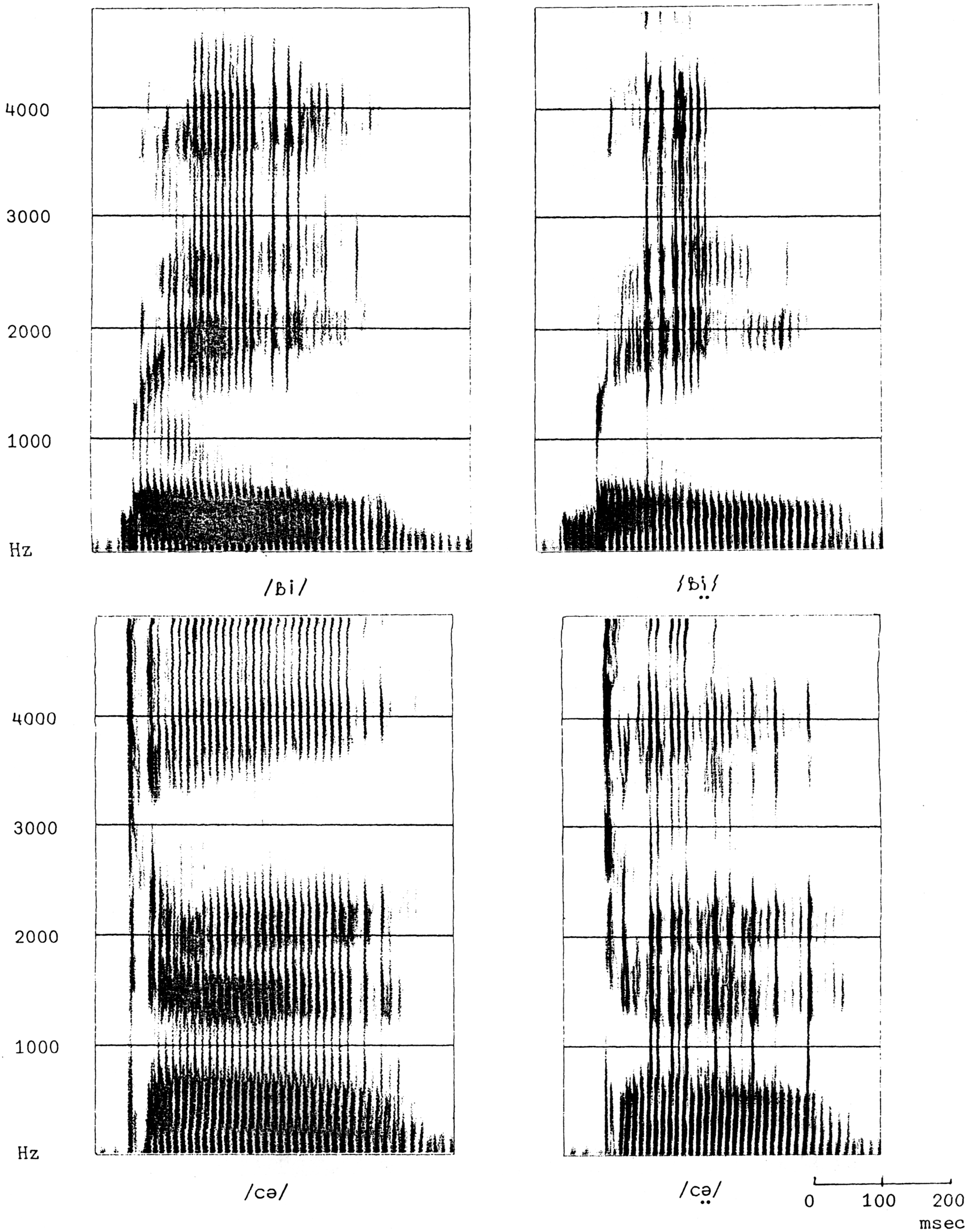

FIGURE 5. : Wideband spectrograms of vowels with creaky voice and a combination of breathy and creaky voice of Speaker 8.

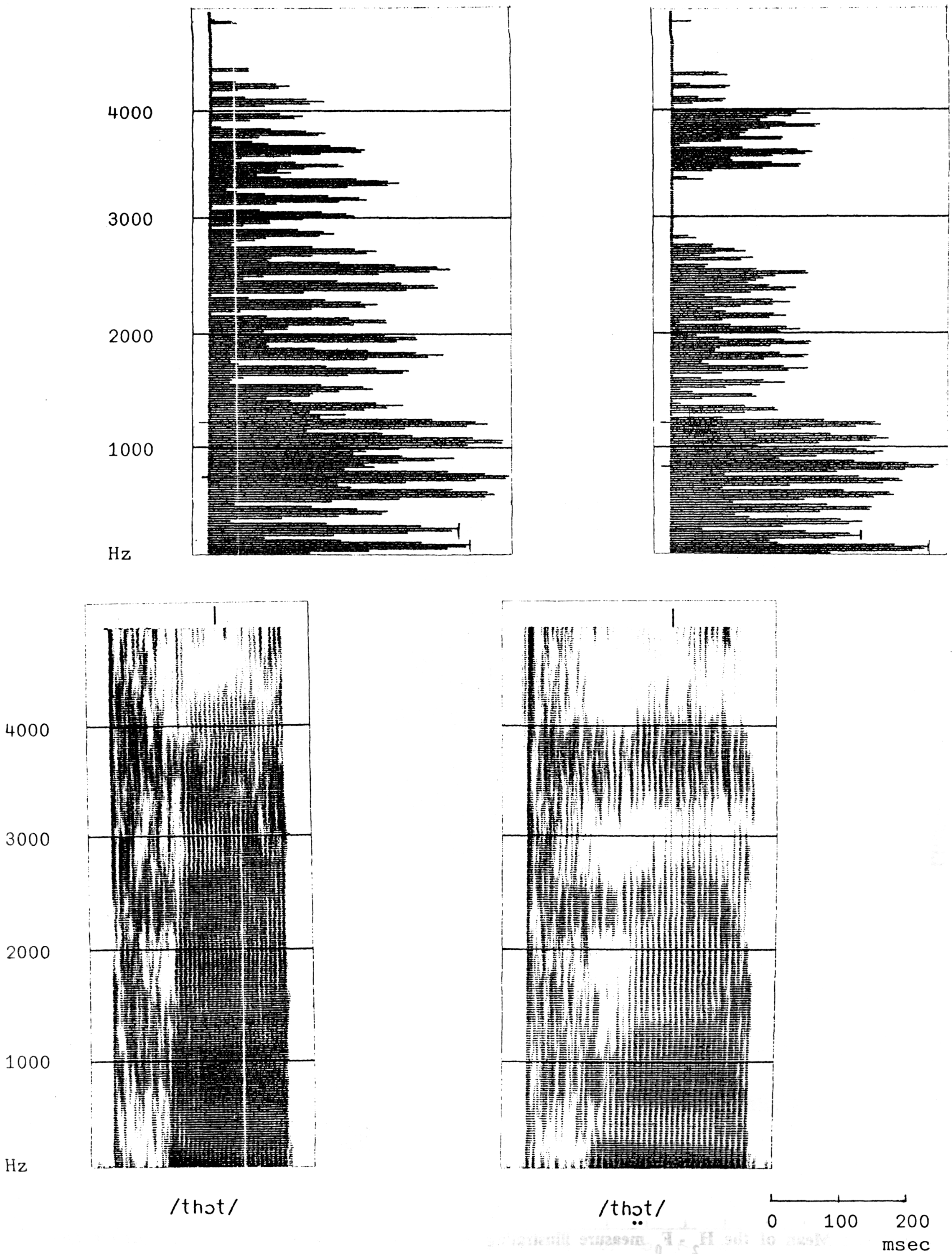

FIGURE 6. : Power spectra and wideband spectrograms of the tense and lax vowels in /thɔt/ and /thɔ̤t/ of Speaker 2.

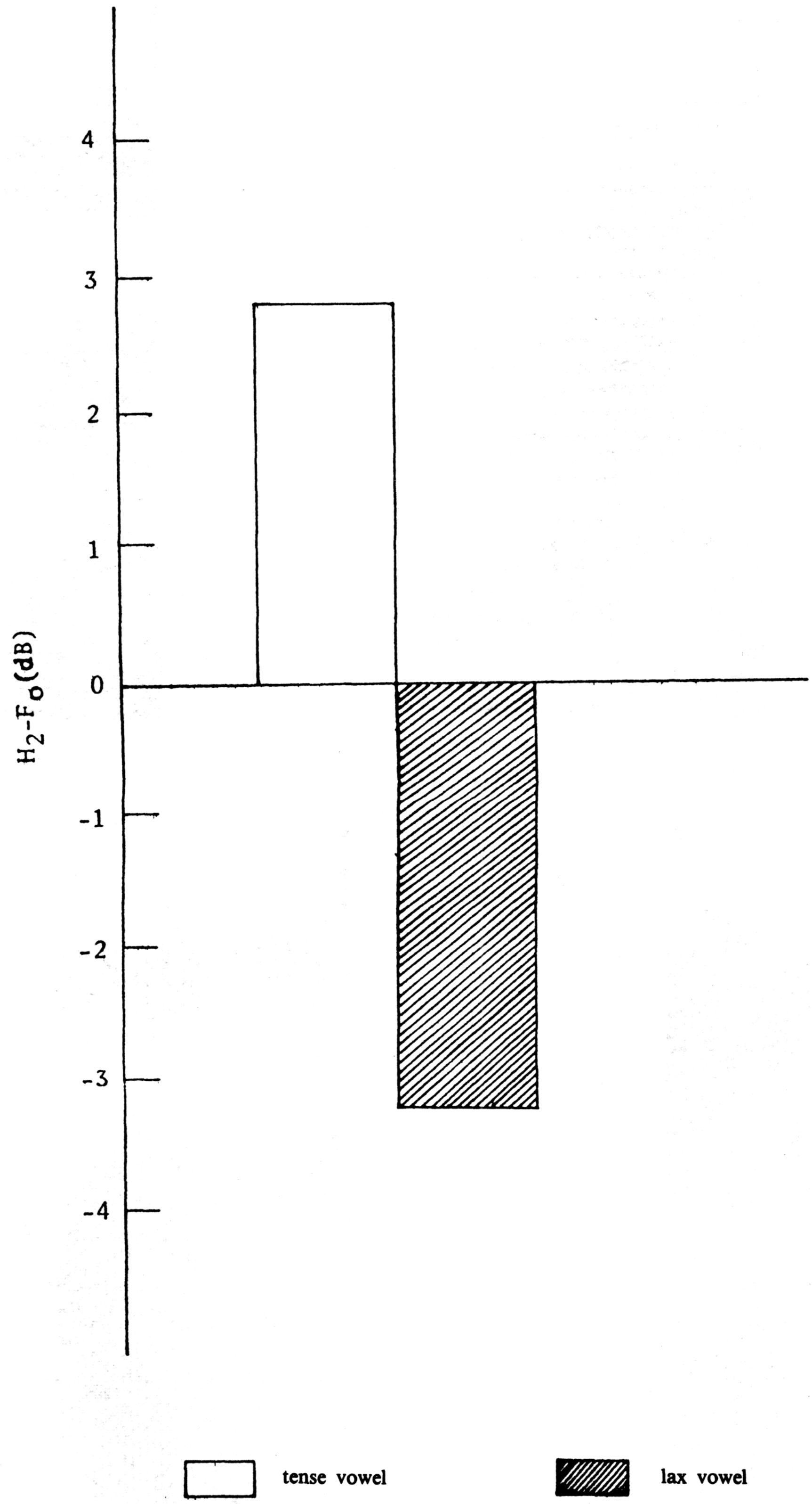

FIGURE 7. : Mean of the H_2 - F_0 measure illustrating the relationship between the amplitude of the fundamental and that of the second harmonic of 8 speakers.

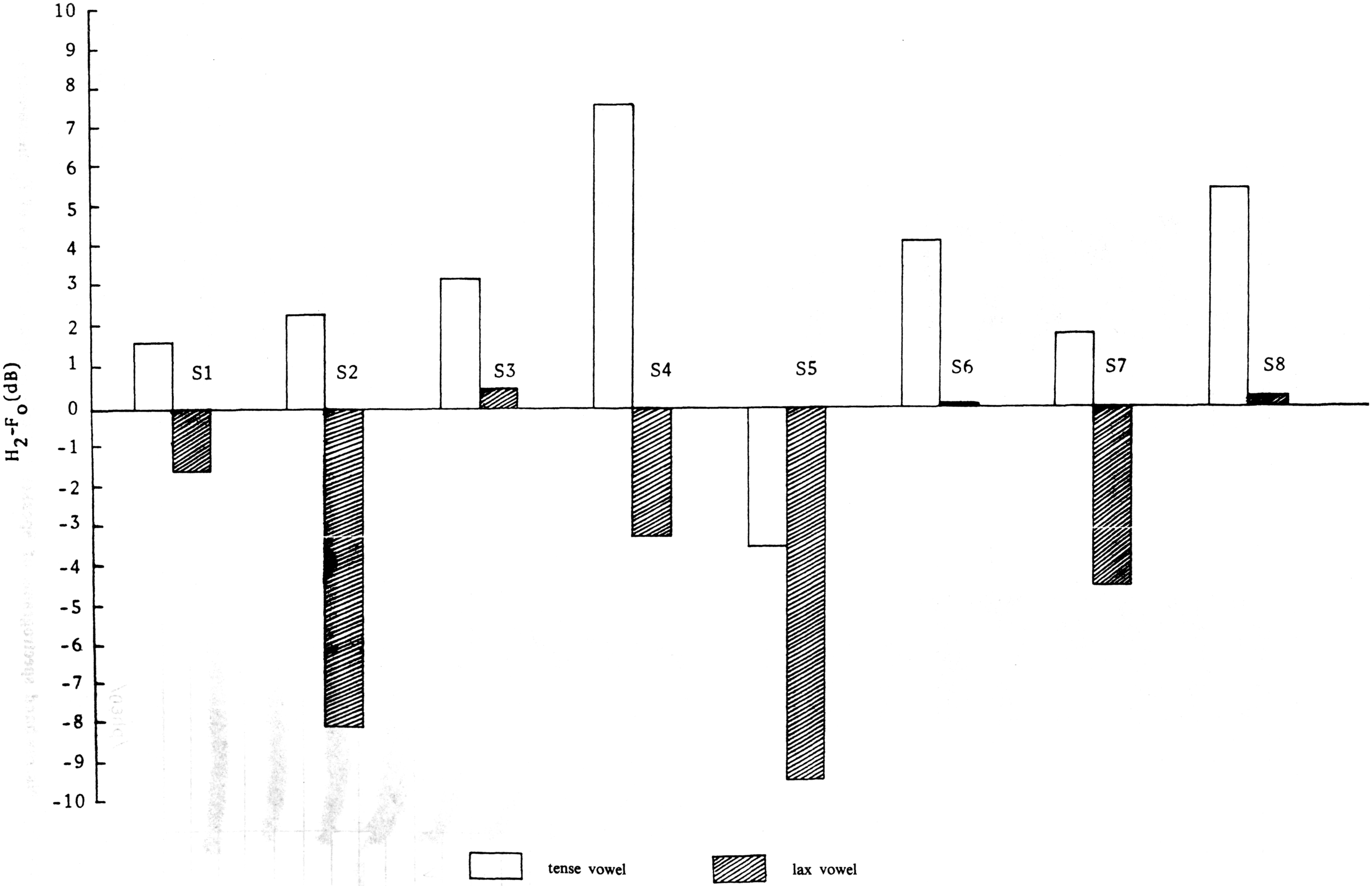

FIGURE 8. : H_2 - F_0 measure of each speaker.

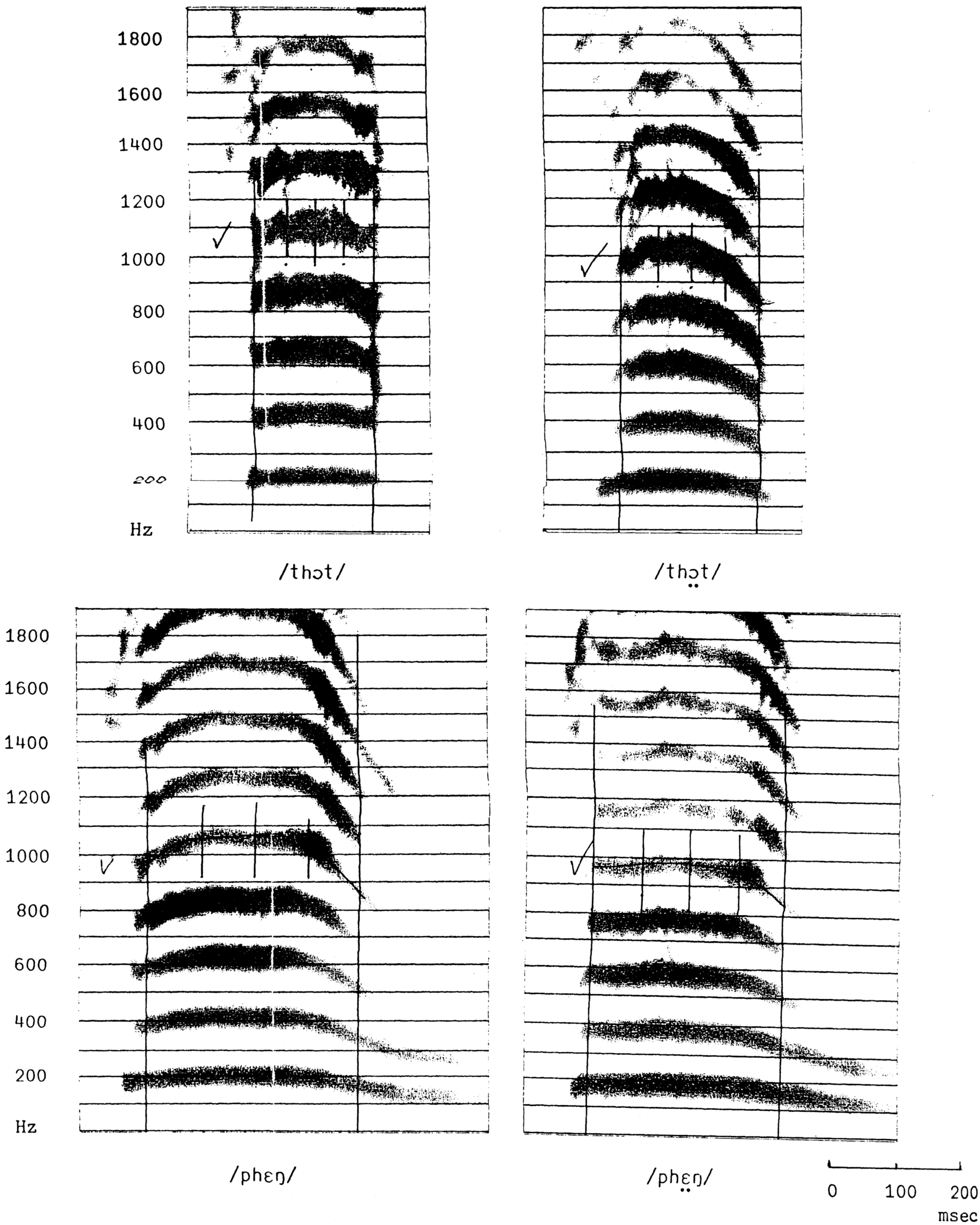

FIGURE 9. : Narrowband spectrograms of Speaker 6 displaying the five points of F_0 measurement.

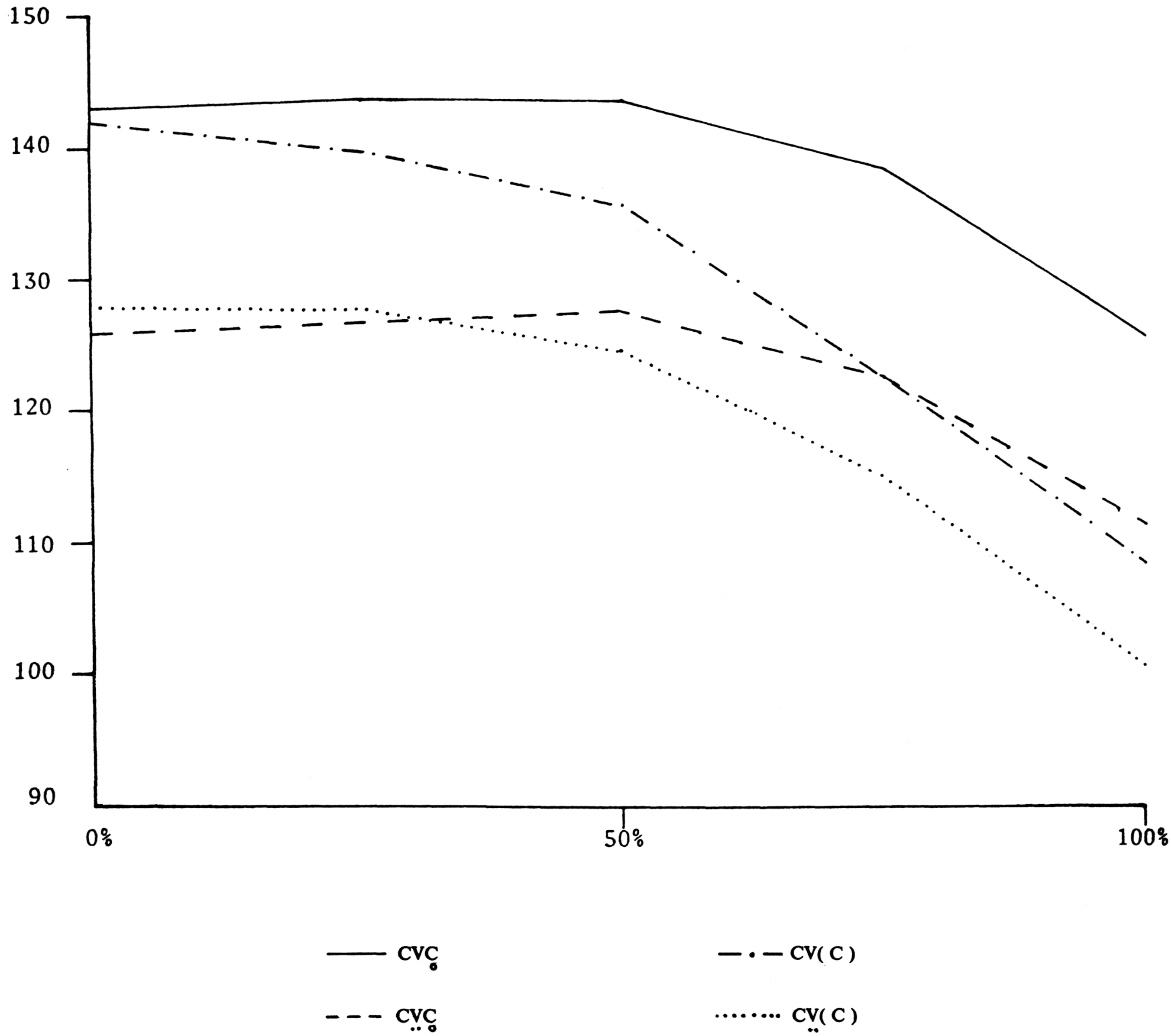

FIGURE 10. : Mean F_0 values of tense and lax vowels in 4 types of syllable structure of 8 speakers.

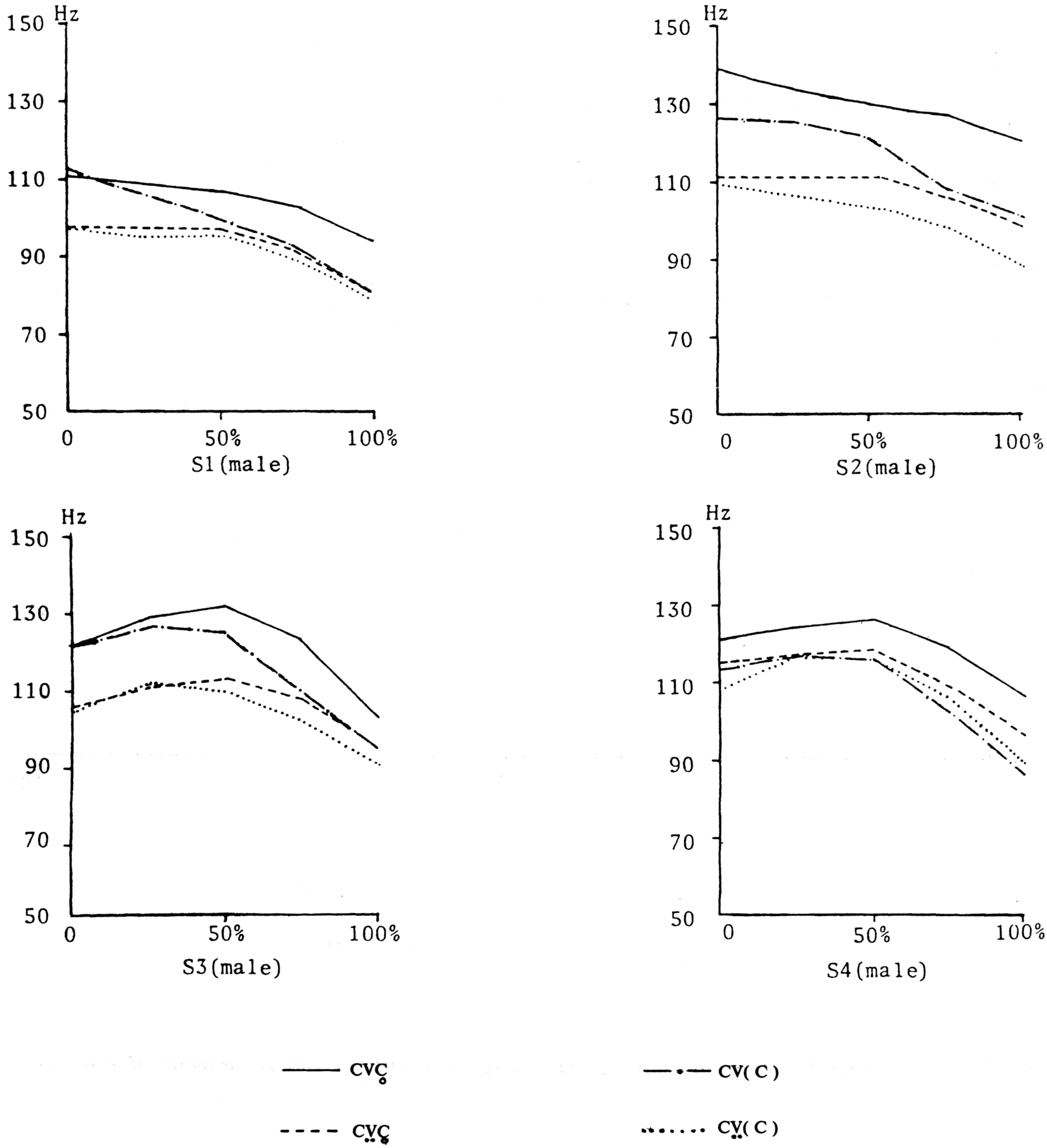

FIGURE 11. : F_0 contours of tense and lax vowels in 4 syllable types of S1, S2, S3 and S4.

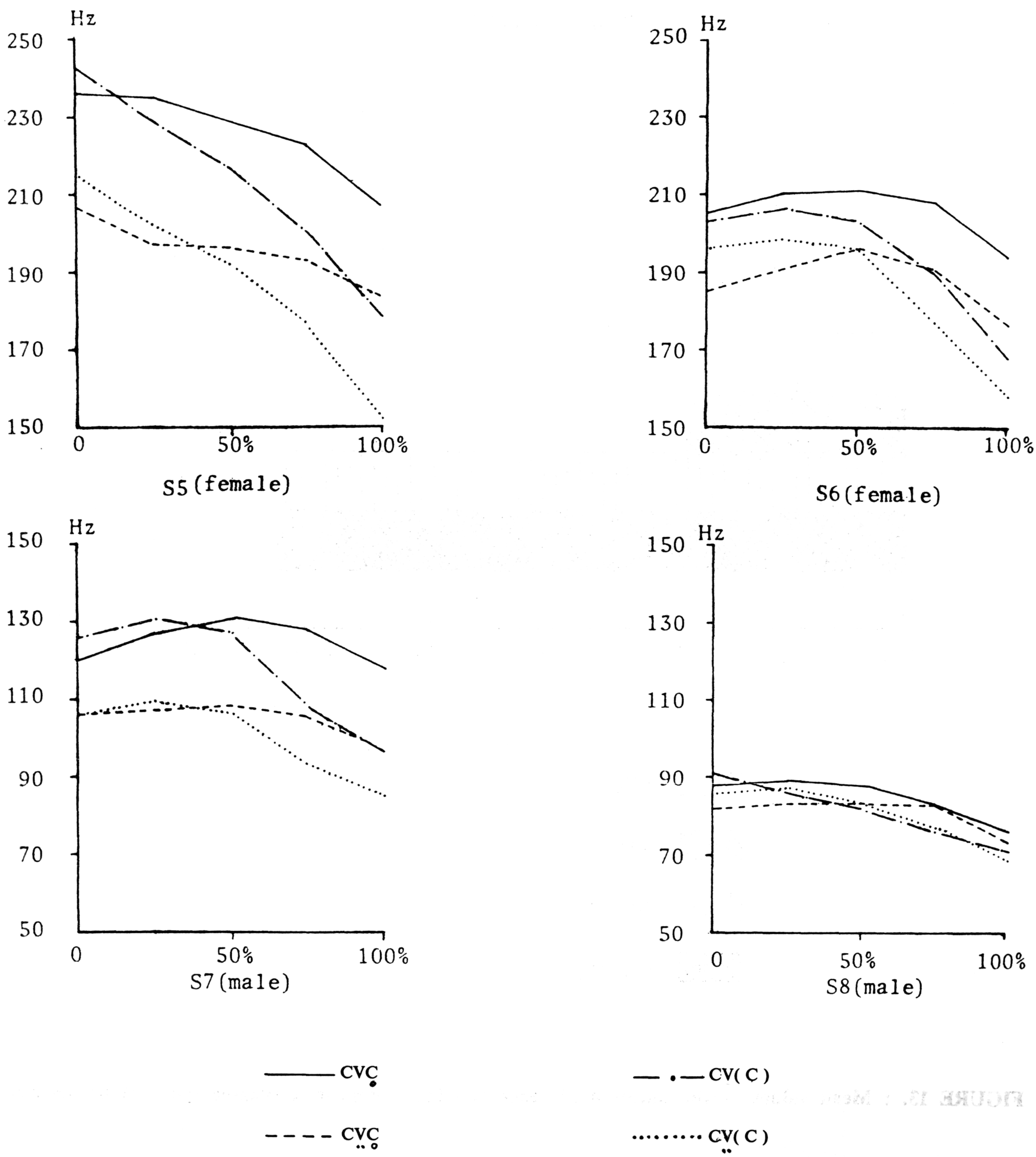

FIGURE 12. : F_0 contours of tense and lax vowels in 4 syllable types of S5, S6, S7 and S8.

VOWEL DURATION

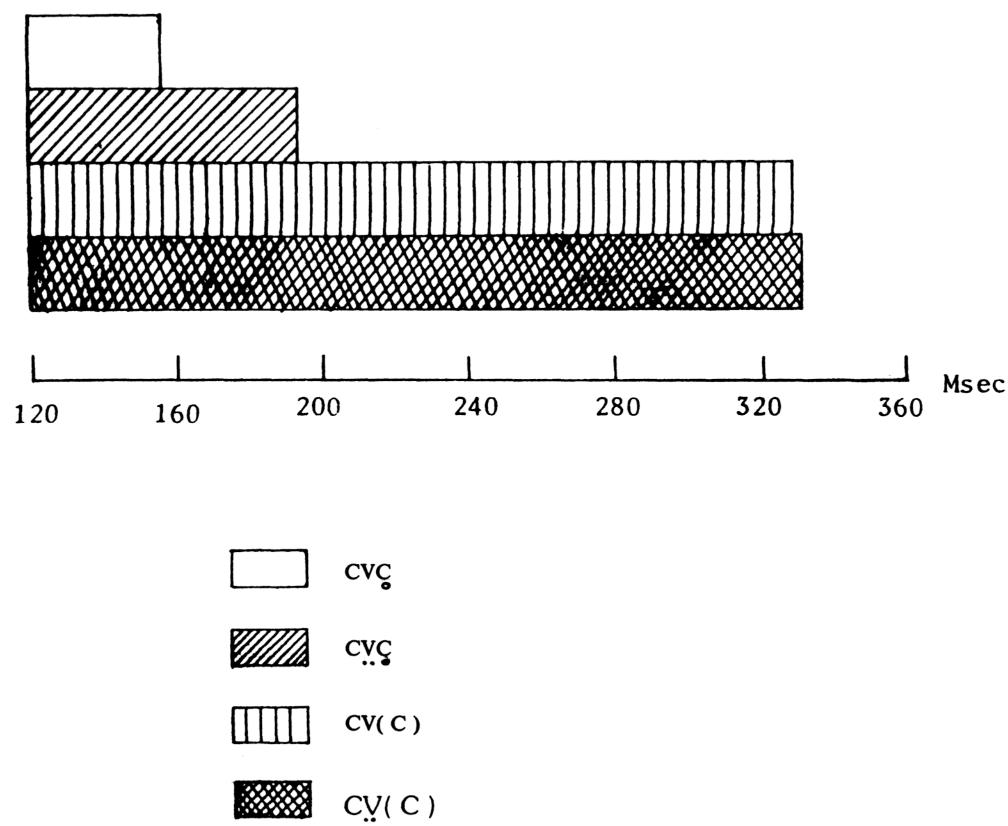

FIGURE 13. : Mean values of the duration of tense and lax vowels in 4 syllable types of 8 speakers.

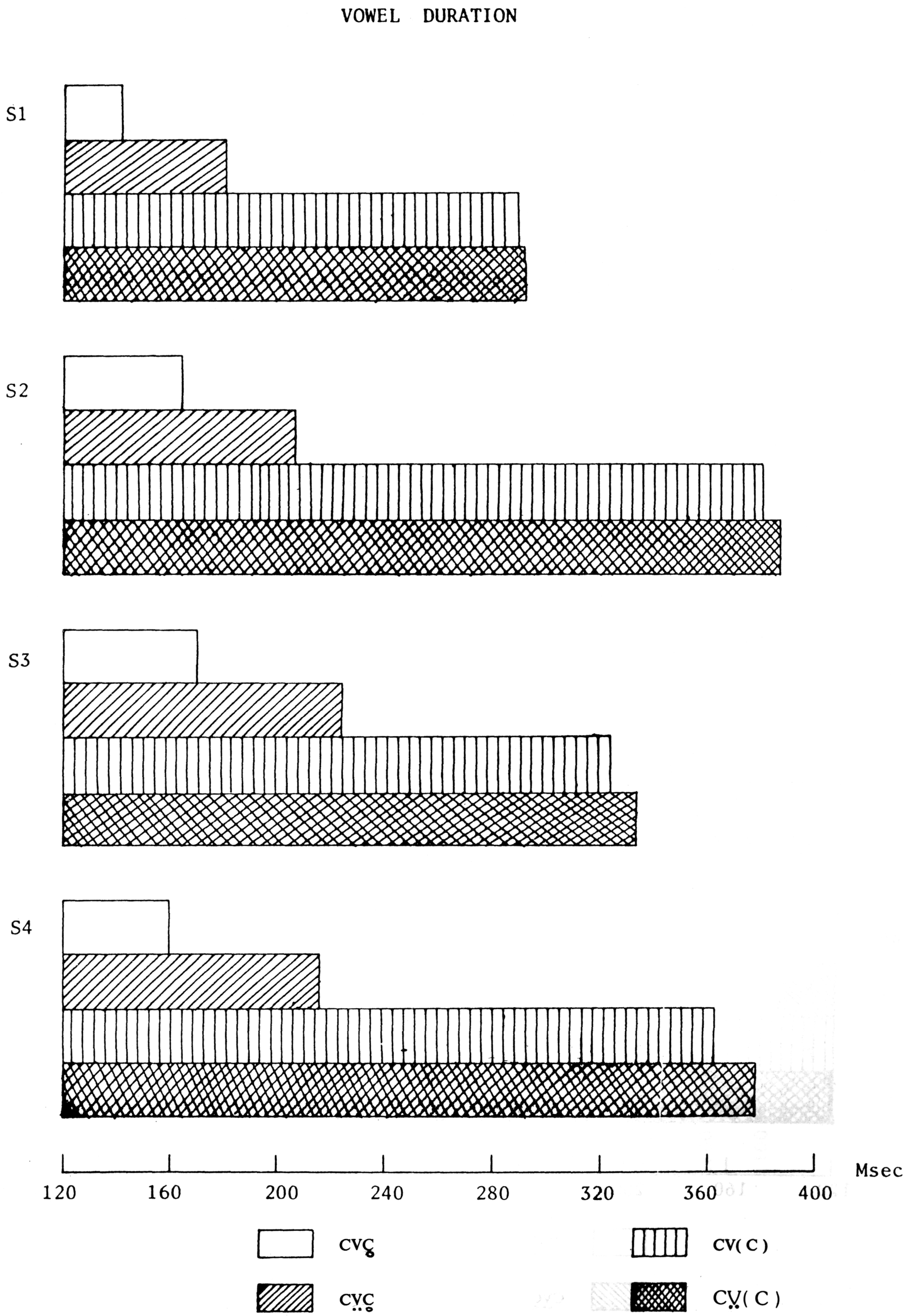

FIGURE 14. : Duration of tense and lax vowels in 4 syllable types of S1, S2, S3 and S4.

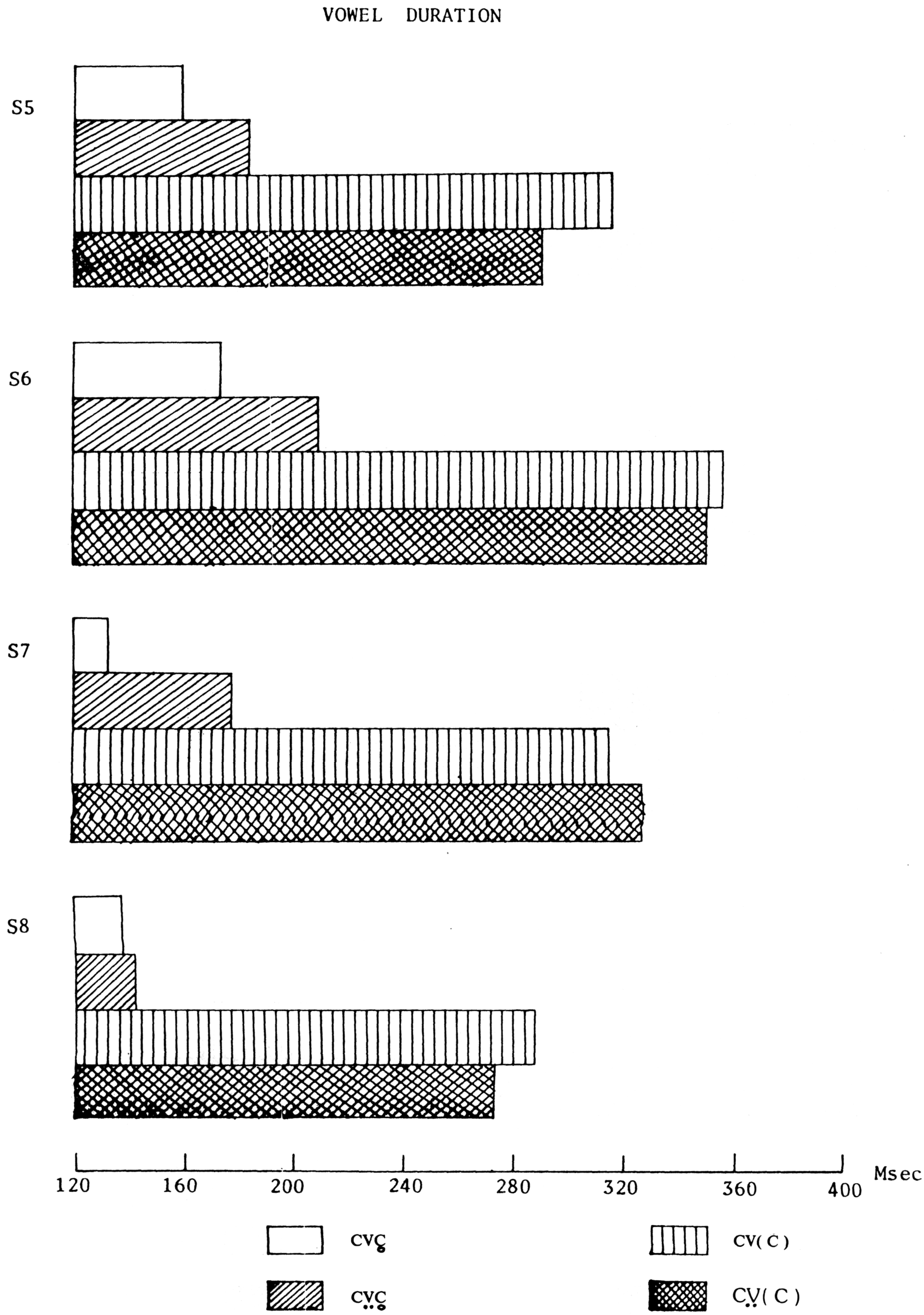

FIGURE 15. : Duration of tense and lax vowels in 4 syllable types of S5, S6, S7 and S8.

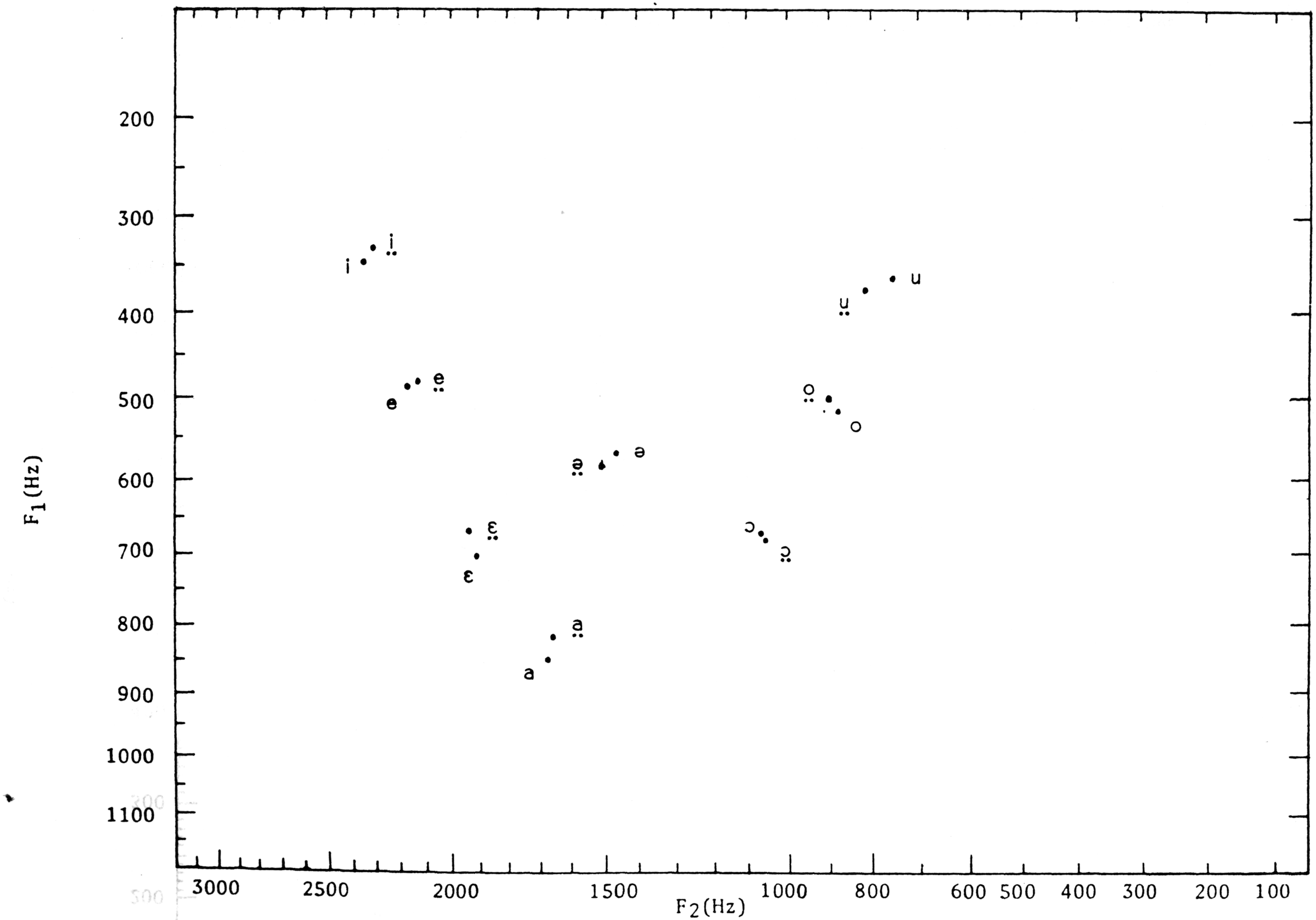

FIGURE 16. : Mean values of the formant frequencies (F_1 and F_2) of tense and lax vowels in CVÇ and CVÇ syllable types of 8 speakers.

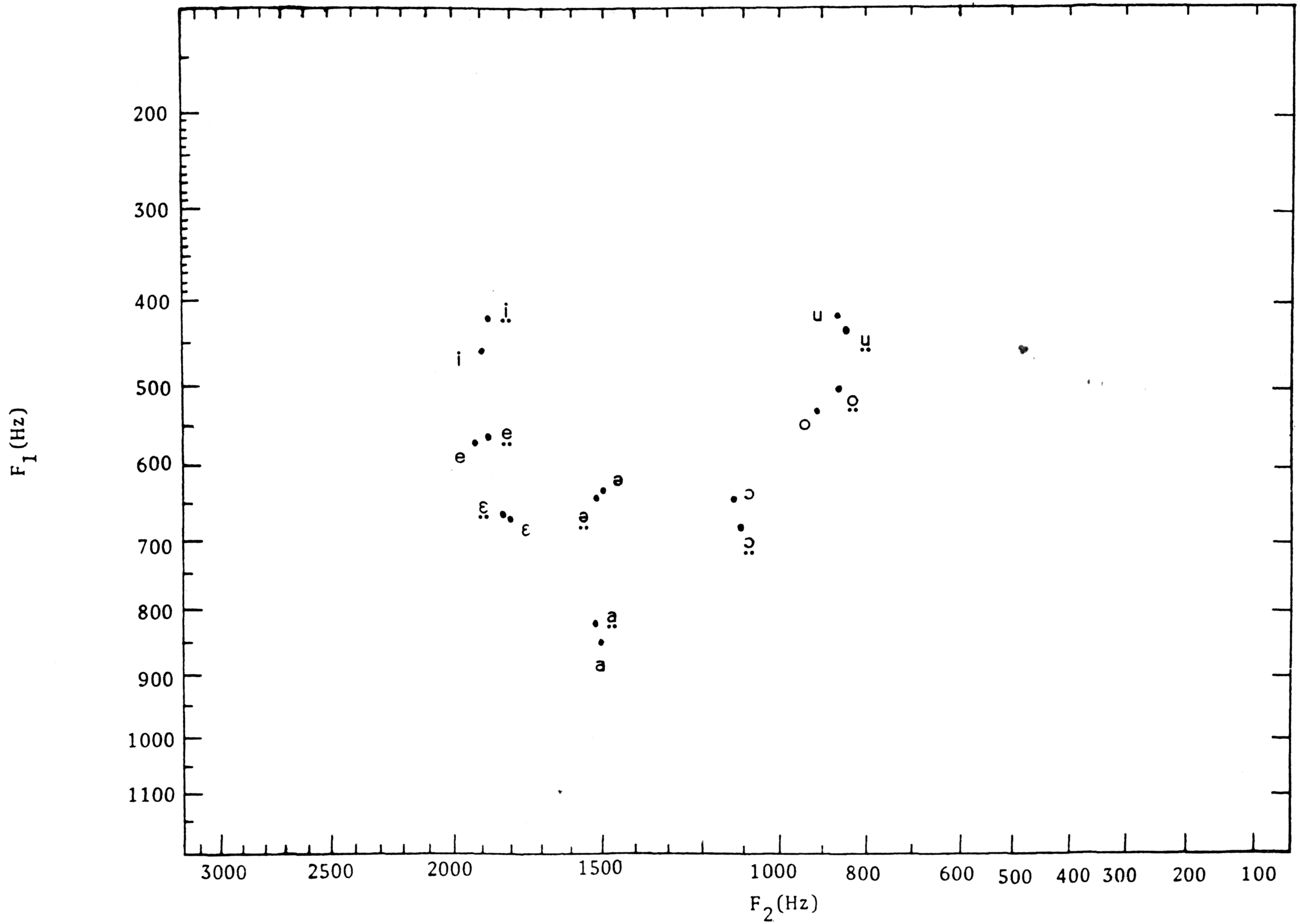

FIGURE 17. : Mean values of the formant frequencies (F_1 and F_2) of tense and lax vowels in CV(C) and CV̤ (C) syllable types of 8 speakers.

TABLE 1 : Relative amplitude of the Fundamental (Fo) and the second harmonic (Hz) in dB. (H_0 : $\mu_1 = \mu_2$, p < .005, df = 15 (n - 1), t = 2.947)

		First register vowel Tense voice ($H_2 - F_0$)	Second register vowel Lax voice ($H_2 - F_0$)
SPEAKER 1	$\bar{x}$	1.64	-1.54
	SD	4.80	5.26
	t	4.834	
SPEAKER 2	$\bar{x}$	2.35	-7.98
	SD	1.03	2.53
	t	16.688	
SPEAKER 3	$\bar{x}$	3.21	0.49
	SD	2.24	3.01
	t	3.147	
SPEAKER 4	$\bar{x}$	7.54	-3.23
	SD	1.97	6.57
	t	7.602	
SPEAKER 5	$\bar{x}$	-3.46	-9.3
	SD	4.53	2.65
	t	6.706	
SPEAKER 6	$\bar{x}$	4.14	0.063
	SD	2.51	3.08
	t	6.885	
SPEAKER 7	$\bar{x}$	1.79	-4.49
	SD	1.55	3.94
	t	6.399	
SPEAKER 8	$\bar{x}$	5.47	0.16
	SD	2.82	3.76
	t	6.481	

TABLE 2 : Mean F_0 values in Hz of tense and lax vowels of 8 speakers measured at 5 points. ($H_0 : \mu_1 = \mu_2$, $p < .0005$, df = 64, t = 3.460)

SYLLABLE TYPE : CVC̣ vs. CV̤C̣

	0%		25%		50%	
	tense	lax	tense	lax	tense	lax
x̄	142.73	126.09	144.45	126.72	144.06	127.50
SD	49.61	43.43	48.40	40.72	47.73	41.43
t	9.578		11.240		10.684	

	75%		100%	
	tense	lax	tense	lax
x̄	139.22	123.20	127.27	112.42
SD	47.60	41.51	46.15	40.97
t	11.428		9.987	

SYLLABLE TYPE : CV(C) vs. CV̤(C)

	0%		25%		50%	
	tense	lax	tense	lax	tense	lax
x̄	142.27	127.89	140.70	128.44	136.09	125.23
SD	49.76	46.78	47.29	42.86	45.99	41.72
t	9.298		7.662		6.160	

	75%		100%	
	tense	lax	tense	lax
x̄	123.20	114.84	109.30	101.25
SD	44.25	38.72	39.95	34.30
t	4.814		6.201	

TABLE 3 : Duration of tense and lax vowels in CVC̥ and CV̤C̥ syllable types in msec. ($H_0 : \mu_1 = \mu_2$, $p < .005$, df = 7 (n - 1), t = 3.499)

		First register vowel (Tense voice)	**Second register vowel** (Lax voice)
SPEAKER 1	x̄	140.88	180.63
	SD	18.73	31.93
	t	4.352	
SPEAKER 2	x̄	164.25	207.50
	SD	21.63	32.61
	t	6.023	
SPEAKER 3	x̄	170.00	224.00
	SD	26.33	30.91
	t	5.881	
SPEAKER 4	x̄	159.75	217.00
	SD	21.07	42.71
	t	4.217	
SPEAKER 5	x̄	160.00	184.25
	SD	14.42	17.87
	t	4.476	
SPEAKER 6	x̄	174.50	210.25
	SD	25.16	26.74
	t	6.300	
SPEAKER 7	x̄	133.75	178.5
	SD	10.66	17.03
	t	5.741	
SPEAKER 8	x̄	138.00	142.50
	SD	10.69	17.62
	t	0.590	

TABLE 4 : Duration of tense and lax vowels in CV(C) and CV̤ (C) syllable types in msec, ($H_0 : \mu_1 = \mu_2$, p < .005, df = 7 (n - 1), t = 3.499)

		First register vowel (Tense voice)	Second register vowel (Lax voice)
SPEAKER 1	x̄	288.25	291.13
	SD	81.71	75.50
	t	0.406	
SPEAKER 2	x̄	377.75	384.75
	SD	119.92	115.66
	t	0.478	
SPEAKER 3	x̄	323.50	333.50
	SD	64.42	64.32
	t	1.104	
SPEAKER 4	x̄	362.50	378.00
	SD	100.31	104.26
	t	2.026	
SPEAKER 5	x̄	316.50	311.50
	SD	83.36	81.95
	t	0.802	
SPEAKER 6	x̄	357.25	351.75
	SD	96.25	85.91
	t	0.633	
SPEAKER 7	x̄	316.00	328.75
	SD	102.31	115.48
	t	1.233	
SPEAKER 8	x̄	289.00	274.25
	SD	87.57	74.46
	t	1.391	

TABLE 5 : F_1 and F_2 in Hz of tense and lax vowels in CVC̥ and CV̤C̥ syllable types of 8 speakers.
($H_0 : \mu_1 = \mu_2$, $p < .05$, df = 7 (n - 1), t = 1.895, * = significant difference)

	/i/ F1	/i̤/ F1		/i/ F2	/i̤/ F2
$\bar{x}$	453.75	418.75	$\bar{x}$	1891.88	1866.88
SD	87.50	82.71	SD	114.33	172.15
t	*1.900		t	1.019	

	/e/ F1	/e̤/ F1		/e/ F2	/e̤/ F2
$\bar{x}$	573.75	561.88	$\bar{x}$	1903.75	1875.00
SD	87.00	96.58	SD	226.78	248.60
t	0.737		t	1.481	

	/ɛ/ F1	/ɛ̤/ F1		/ɛ/ F2	/ɛ̤/ F2
$\bar{x}$	666.25	657.50	$\bar{x}$	1792.50	1838.75
SD	54.76	66.06	SD	143.70	136.35
t	0.590		t	*2.290	

	/ə/ F1	/ə̤/ F1		/ə/ F2	/ə̤/ F2
$\bar{x}$	631.88	633.75	$\bar{x}$	1483.75	1516.88
SD	51.54	82.80	SD	152.22	165.81
t	0.087		t	1.475	

	/ɑ/ F1	/ɑ̤/ F1		/ɑ/ F2	/ɑ̤/ F2
$\bar{x}$	842.50	817.50	$\bar{x}$	1486.88	1513.13
SD	166.00	197.83	SD	132.99	162.68
t	0.863		t	0.882	

	/u/ F1	/ṳ/ F1		/u/ F2	/ṳ/ F2
$\bar{x}$	414.38	426.88	$\bar{x}$	865.63	840.00
SD	61.96	86.97	SD	111.59	107.30
t	0.352		t	0.518	

	/o/ F1	/o̤/ F1		/o/ F2	/o̤/ F2
$\bar{x}$	523.13	490.63	$\bar{x}$	910.00	863.75
SD	86.06	85.46	SD	102.12	84.46
t	*5.646		t	1.666	

	/ɔ/ F1	/ɔ̤/ F1		/ɔ/ F2	/ɔ̤/ F2
$\bar{x}$	646.88	676.25	$\bar{x}$	1106.25	1095.00
SD	76.16	100.42	SD	114.76	101.42
t	1.337		t	0.878	

TABLE 6 : F_1 and F_2 in Hz of tense and lax vowels in CV(C) and CV̤(C) syllable types of 8 speakers.
(H_0 : $\mu_1 = \mu_2$, $p < .05$, df = 7 (n - 1), t = 1.895, * = significant difference.)

	/i/	/i̤/		/i/	/i̤/
	F_1	F_1		F_2	F_2
$\bar{x}$	348.75	336.88	$\bar{x}$	2303.75	2267.50
SD	56.17	44.96	SD	245.93	247.60
t	1.221		t	1.163	
	/e/	/e̤/		/e/	/e̤/
	F_1	F_1		F_2	F_2
$\bar{x}$	487.50	481.25	$\bar{x}$	2140.00	2090.00
SD	80.13	70.80	SD	247.50	263.76
t	0.413		t	*2.017	
	/ɛ/	/ɛ̤/		/ɛ/	/ɛ̤/
	F_1	F_1		F_2	F_2
$\bar{x}$	703.13	667.50	$\bar{x}$	1898.13	1910.63
SD	77.41	72.90	SD	187.12	205.64
t	*3.037		t	0.560	
	/ə/	/ə̤/		/ə/	/ə̤/
	F_1	F_1		F_2	F_2
$\bar{x}$	564.38	579.38	$\bar{x}$	1461.25	1484.38
SD	81.74	94.36	SD	115.32	110.95
t	1.381		t	0.868	
	/a/	/a̤/		/a/	/a̤/
	F_1	F_1		F_2	F_2
$\bar{x}$	845.00	814.38	$\bar{x}$	1661.88	1653.13
SD	170.29	164.39	SD	63.80	91.45
t	1.060		t	0.228	
	/u/	/ṳ/		/u/	/ṳ/
	F_1	F_1		F_2	F_2
$\bar{x}$	350.63	361.88	$\bar{x}$	766.25	821.25
SD	61.67	46.75	SD	89.75	69.32
t	0.551		t	*3.333	
	/o/	/o̤/		/o/	/o̤/
	F_1	F_1		F_2	F_2
$\bar{x}$	508.75	488.75	$\bar{x}$	883.75	895.00
SD	69.17	58.42	SD	97.09	86.19
t	*1.965		t	0.492	
	/ɔ/	/ɔ̤/		/ɔ/	/ɔ̤/
	F_1	F_1		F_2	F_2
$\bar{x}$	656.25	633.75	$\bar{x}$	1065.00	1059.38
SD	68.44	105.25	SD	116.62	132.57
t	0.655		t	0.262	

REFERENCES

Blagden, C.O. 1910. Quelques notions sur la phonétique du Talian et son évolution historique. *Journal Asiatique,* 477 - 505.

Diffloth, Gérard. 1984. *The Dvāravati - Old - Mon Language and Nyah - Kur.* Monic Studies, Vol. I. Bangkok : Chulalongkorn University press.

_____________. 1985. The registers of Mon vs. the spectrographist's tones. *UCLA Working Papers in Phonetics* 60, 55 - 58.

Fischer-Jørgensen, E. 1977. Phonetic analysis of breathy (murmured) vowels in Gujarati. *Annual Report of the Institute of Phonetics of the University of Copenhagen* 2, 105 - 156. (Reprinted from 1967).

Halliday, R. 1922. *A Mon - English Dictionary.* Bangkok : Siam Society.

Haswell, J.M. 1874. *Grammatical Notes and Vocabulary of the Peguan Language,* 2nd Ed. 1918. Rangoon : American Baptist Press.

Henderson, Eugénie J.A. 1952. The main features of Cambodian pronunciation. *Bulletin of the School of Oriental and African Studies* 14.1, 149 - 174.

Huffman, Franklin E. 1976. The register problem in fifteen Mon - Khmer languages, in *Austroasiatic Studies,* Part I, 25 - 37. Honolulu : University Press of Hawaii.

Kirk, Paul L. et al. 1984. Using a spectrograph for measures of phonation types in a natural language. *UCLA Working Papers in Phonetics* 59, 102 - 113.

Ladefoged, Peter et al. 1987. Investigating phonation types in different languages. To appear in the *Proceedings of the 5th Conference on Vocal Fold Physiology,* Tokyo, January 19 - 23.

Lee, Thomas. 1983. An acoustical study of the register distinction in Mon. *UCLA Working Papers in Phonetics* 57, 79 - 96.

Maddieson, Ian and Ladefoged, Peter. 1985. Tense and lax in four minority languages of China. *Journal of Phonetics* 13 : 433 - 454.

Pike, Kenneth L. 1948. *Tone Languages.* Ann Arbor : University of Michigan Press.

Sakamoto, Y. 1974. Notes on the phonology of Modern Mon (Pakkret dialect). *Journal of Asian and African Studies.* Tokyo. (In Japanese).

Shorto, Harry L. 1962. *A Dictionary of Modern Spoken Mon.* London : Oxford University Press.

Shorto, Harry L. 1966. Mon vowels systems : a problem in phonological statement, in *In Memory of J.R. Firth,* ed. by C.E. Bazell et al. London : Longmans.

_____________. 1967. The register distinction in Mon - Khmer languages. *Wissenschaftliche Zeitschrift der Karl Marx Universität Leipzig* 16, 245 - 248.

Stevens, Kenneth N. 1981. Vibration modes in relation to model parameters, in *Vocal Fold Physiology,* ed. by K. Stevens and M. Hirano. Tokyo : University of Tokyo Press.