Acoustic Properties of the Kuman Voiceless Velar Lateral Fricative

William Steed[1] and Peter Hardie[2]

Phonetics Laboratory, Linguistics Program (Arts)
Australian National University
[1]xiaolong@latinmail.com
[2]phardie@webone.com.au

Abstract

Selected time- and frequency-domain acoustic features of the voiceless allophone of the exotic velar lateral fricative in the Papuan language Kuman are described for one male speaker. This comprises specification of F-pattern and its co-articulation with the preceding vowel, and the articulatory interpretation of spectrographic details, including a (for fricatives) unexpected transient.

1. Introduction

This paper describes the acoustic phonetic features of the voiceless velar lateral fricative [ʟ̥] that occurs in the Kuman (Chimbu) language of Papua New Guinea's Simbu province, focussing on F-pattern and unusual features of articulation. Although velar laterals also appear in neighbouring languages, including Wahgi, Melpa and other members of the Chimbu family (Ladefoged, Cochran and Disner, 1997), they are not a common member of a language's phoneme inventory, and are restricted mainly to languages of Papua New Guinea, Caucasian languages and possibly some East Chadic languages (Ladefoged and Maddieson, 1996: 190). No occurrences are known of velar laterals contrasting in voicing. However, voiceless velar laterals may occur as allophones, as in Kuman. They therefore form an interesting and as yet little studied sound.

The voiceless fricative allophone of the velar lateral phoneme in Kuman occurs in the syllable coda, and exhibits some unusual features, most notably an apparent release spike. There is also considerable variation in its F-pattern as a function of the preceding vowel. There have been no specific studies on Kuman to determine the exact manner of articulation of velar laterals, however Ladefoged and Maddieson (1996: 190) say that Mid-Wahgi speakers articulate their own velar laterals with the dorsum, the tongue being bunched up and retracted behind the lower teeth.

The title of this paper is perhaps slightly inaccurate, because it deals specifically with the word-final occurrences of the velar lateral, using primarily recordings of one male speaker (Speaker 2 in Hardie, 2003). As this is only an initial study of Kuman phonetics, only one speaker is examined, and only in a repetitive pattern rather than in sentence frames. Therefore this paper cannot be taken as a study of this sound across the Kuman language, but only as a study of this speaker's articulation of the sound in a repetitive recording.

Lateral phones are often conventionally represented by a equivalent tube configuration. This consists of a main tube of the pharynx and vocal cavity, with a shunt representing the pocket of air above the tongue (Johnson, 2003: 160, 161). The location of the shunt along the main tube is dependent on the place of articulation of the lateral, at least for coronals. For a velar lateral, made with the dorsum, it is not clear whether there would actually be any shunt, but if there were it would be further back than shunts for other laterals in different places of articulation to represent the larger cavity between the lips and the point of contact between the tongue and the velum. The shunt would also be shorter for a velar lateral than for other laterals in different places of articulation due to the smaller possible area behind the tongue. For coronals, the difference in volume behind the place of articulation will have an effect on the second formant of the lateral.

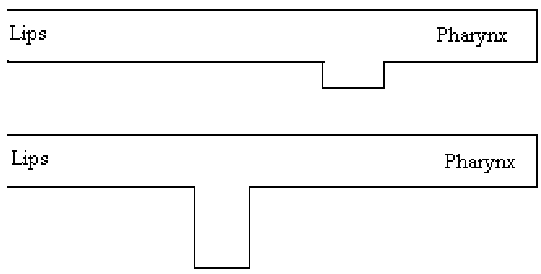

Figure 1. Possible tube configuration for a velar lateral (top) compared with that of an alveolar.

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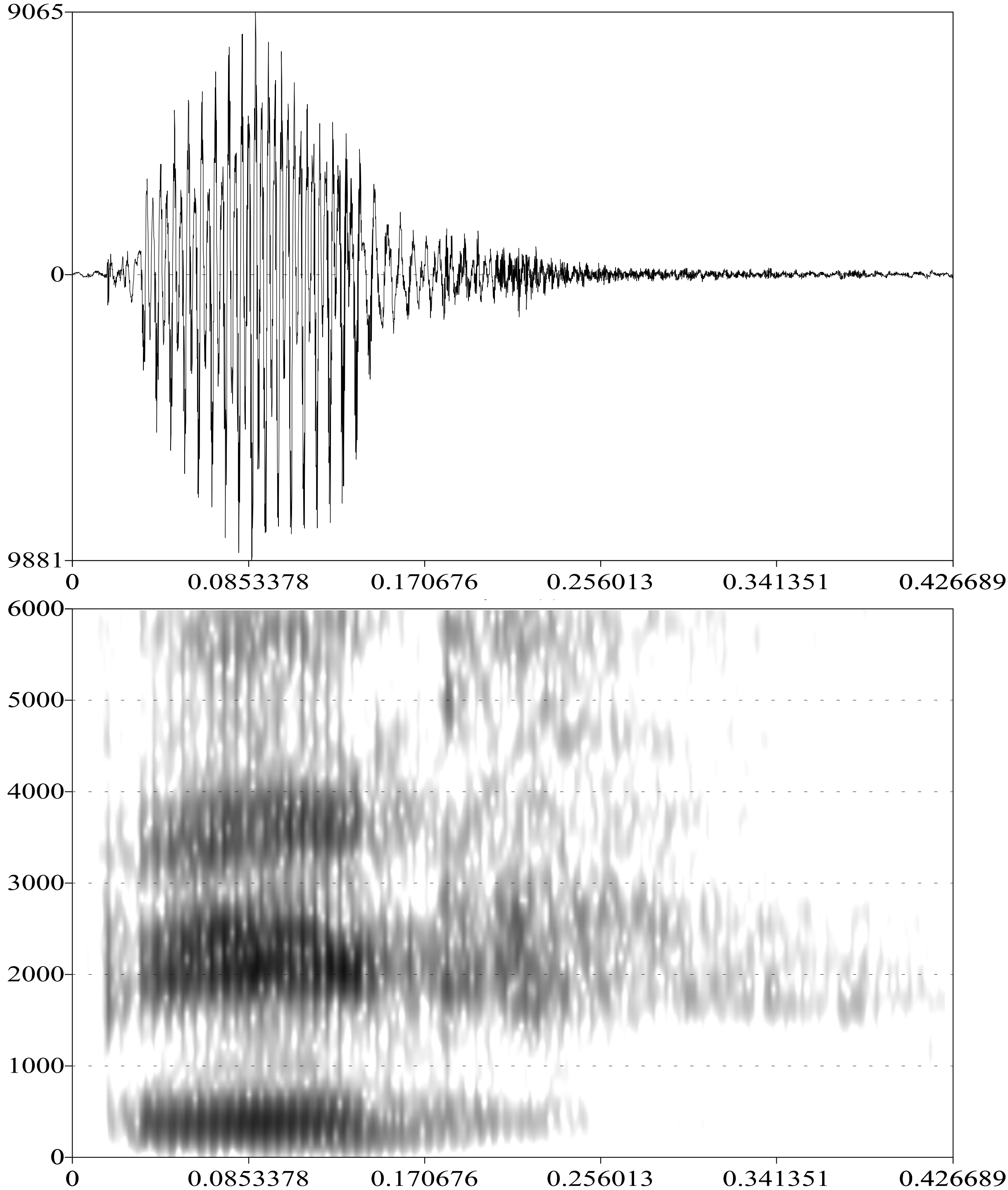

Figure 2. Audio (top) and wideband spectrogram (bottom) of /piL H/ knife. x-axis = time (sec.); spectrogram y-axis = frequency (Hz), audio y-axis = ptp amplitude.

Ladefoged and Maddieson (1996: 196, 197) show that "for laterals without a secondary constriction involving the back of the tongue [such as velar laterals], the frequency of the second formant seems to be inversely related to the volume of the oral-pharyngeal cavity behind the articulatory occlusion." They also consider the possibility of an inverse relationship between F1 and the cross-sectional area of the lateral passage. Although they admit that not all data appears to conform with this hypothesis, its prediction is confirmed for velar laterals by data from Mid-Wahgi (Ladeforged and Maddieson, 1996: 194), and is backed up by Stephens' (1998: 533-534) calculations for laterals in English. According to Ladefoged and Maddieson, velar laterals should

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therefore have a high F1 and a high F2. Very little mention of F3 is made. Stephens (1998: 548) implies that F3 is related to tongue backness in laterals, but it is not clear whether this applies to coronals only. Following this we might expect a higher F3 due to the backness of articulation of velar laterals and the bunching of the tongue. Since this particular sound is a voiceless fricative, we would also expect its formants to be noise-excited.

2. Procedure and Elicitation

The samples were recorded by the second author in Simbu province in Papua New Guinea, as part of a thesis on the tonal status of Kuman (Hardie, 2003). The recording involved six informants being recorded articulating two tokens of a 100 word list, 25 of which contained a velar lateral fricative. The recordings were made on a Sony TCM-5000EV analog cassette recorder, and are of generally high quality. One speaker was selected for analysis (speaker 2) and his tokens digitised at 16 K using CSL.

3. Acoustic Features

3.1 Time-domain features

Figure 2 shows the aligned waveform and wide-band spectrogram of the word /piL H/ *knife*. The spectrogram has been made with a range of 0 - 6 kHz to best show high frequency features. It can be seen from the waveform that the quasiperiodicity of the vowel lasts for about 11 csec., and is followed by a short - ca. 7 csec - portion of a lower ptp amplitude mixed (i.e. quasi-periodic/quasi-random) wave. Roughly in the middle of this portion, in between two glottal pulses, can be seen a transient. The last portion of the utterance is a low amplitude quasi-random wave which lasts for a long time - about 21 csec. This long duration is typical - the average for the data is 17.04csec, with a maximum of 24csec – although it is not clear whether this length is a function of utterance-final position, the recording having no sentence frames. Like other fricatives, it is possible to estimate a pseudo-periodicity for the quasi-random wave of the velar lateral (Painter, 1979: 29). Although the pseudo-periodicity is difficult to gauge accurately, it is considerably higher for Kuman velar lateral fricatives (approximately 1.6kHz) to the figure given for velar fricatives by Painter (1000Hz). This difference may represent a shorter channel in front of the constriction for the lateral, but also will also be a function of the speaker.

The spectrogram in figure 2 clearly shows the acoustic segments described above from the wave-form, in particular the wide-band transient with energy from ca 1 kHz upwards. This transient marks the end of a short (ca 4 csec) segment between the end of the vowel and the onset of more widely distributed noise. During this segment for example, there is little or no energy above 5K, but after it considerable noise is present. It is also clear that the F-pattern from the vowel (F1 through F5) is continuous through the segment. This transient is a common occurrence throughout the recording, especially with the informant in this study. The transient varies between informants, frequently for some, like the informant of this study, less for others. After the transient, the main feature is strong broadband noise between ca 1.5K and 3K, with the upper part (above 2K) dissipating towards the end of the sound. A weak F1 can be seen lasting for 5 - 6 cecs. after the transient. Periodicity can also be seen to last considerably beyond the end of the vowel and well into the lateral.

3.2 Frequency-domain features

In order to examine the spectral features of the /L/ it was necessary to separate the pre- from post-transient portions, since they appeared from the spectrogram to have slightly different structure. Consequently figure 3 shows the ca 4 csec. pre-transient spectrum and figure 4 a ca 8csec. portion of the post-transient spectrum. Both FFT and cepstrally-smoothed spectrum are shown. Cepstral smoothing was used rather than LPC smoothing to avoid the tendency of LPC smoothing to misrepresent spectral valleys which might be expected to occur with fricatives; LPC smoothing does not allow for the presence of zeros in samples (Johnson, 2003: 100).

In figure 3 the fundamental is clear at about 155 Hz, but the harmonics are obscured by the interharmonic noise. Energy is present at ca 2kHz with possibly a second peak at ca 2.4kHz. In figure 4 the lower peak is still prominent, although it has shifted down somewhat, but there is now a clear second peak at ca 2.5kHz, and it is these two peaks which contribute to the broadband energy noted above in the spectrogram. The lower of the two peaks is also presumably the source of the ca 1.6 kHz pseudoperiodicity mentioned above. There is also more energy present above 4.5 kHz than in the pre-transient portion.

4. Articulatory interpretation

Aperiodicity is an expected feature of fricatives, and in the case of the velar lateral will reflect the turbulence at the lateral pass through the lateral articulation at the molars. The F2 at ca 1.8 kHz presumably reflects the $\lambda/4$ resonance of the cavity in front of the velar constriction (Stevens, 1998: 406). With C = 35,000 cm/sec (C = speed of light), this gives a plausible cavity length in front of the constriction of about 5 cms. It is not clear what the slightly higher F3 represents: one possibility is that it is a resonance of the side channels.

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The most intriguing feature of this sound is of course the transient, since this is not expected for a [+cont] sound, which this clearly is, given the formant continuity observed. (Also the continued F0 periodicity might also be unexpected if this were a complete hold.) The exact nature of the articulation giving rise to these features is, however, unclear. One possible explanation for the origin of the transient is that there may only be closure on one side of the tongue, which would explain

Sample sequence	N	Vowel F1 (mean, sd)	Lateral F1 (mean, sd)
/ɪʟ/	10	296.2, 36.6	289.7, 59.6
/eʟ/	2	406.0, 6.0	395.0, 5.0
/aʟ/	4	600.8, 73.0	678.8, 109.4
/oʟ/	6	504.2, 19.9	502.7, 18.5
/ʊʟ/	28	346.6, 57.4	326.8, 73.6
Mean F1	5	**430.8, 122.6**	**438.6, 156.8**

Sample sequence	N	Vowel F2 (mean, sd)	Lateral F2 (mean, sd)
/ɪʟ/	10	2063.2, 139.6	1754.3, 83.8
/eʟ/	2	1927, 60.8	1791.5, 9.2
/aʟ/	4	1262.5, 90.7	1456.3, 157.8
/oʟ/	6	863.3, 43.7	970.8, 51.2
/ʊʟ/	28	789.3, 123.1	880.5, 113.7
Mean F2	5	**1381.0, 590.8**	**1349.3, 490.8**

Sample sequence	N	Vowel F3 (mean, sd)	Lateral F3 (mean, sd)
/ɪʟ/	10	2361.5, 85.1	2487.0, 136.9
/eʟ/	2	2332.5, 67.5	2577.5, 67.5
/aʟ/	4	2277.5, 59.5	2547.5, 41.1
/oʟ/	6	2388.3, 134.1	2710.0, 134.2
/ʊʟ/	28	2266.3, 142.7	2364.5, 262.7
Mean F3	5	**2325.2, 52.7**	**2537.3, 126.4**

Table 1. Formant center- frequencies(Hz) for voiceless velar lateral and preceding vowel

the reduced amplitude of the pre-transient portion before the release and the continuity of the formants. The stoppage, if this were the case, would have to be very short and tap-like. Another possibility would be an intermittent closure of the lateral pass caused by the Bernoulli effect. It is worth noting that Ladefoged and Maddieson (1996: 134), in mentioning the 'prestopping' of velar laterals in Mid Waghi give a spectrogram of a word containing two velar laterals, the first of which is clearly prestopped, and the second of which they describe as 'entirely approximant in nature'. This second lateral however also shows a clear transient. Also of interest is that they refer to a transient when describing the palatal lateral of Montana Salish (ibid p.210), and comment 'Exactly how this transient is produced is not clear to us at the moment, but it must involve a very brief obstruction of the lateral escape channel'.

5. Formants

Given the relatively clear formant structure for /L/ illustrated in the spectrogram and spectra above, it was obviously important to characterize it in terms of F-pattern center-frequencies. Some degree of coarticulation with the preceding vowel is to be expected, given that both lateral and vowel are [+dorsal]. In the data, velar lateral fricatives occur after all five Kuman vowel phonemes: /a, e, i, o, u/ ([a, ɛ, ɪ, ɔ, ʊ]), which means that possible co-articulatory variation in F-pattern could be examined. For each token the first three formant center-frequencies were extracted for both the preceding vowel and the velar lateral using Praat. Mean values are given in table 1, where it can be seen that there is indeed considerable variation in F-pattern as a function of the preceding vowel. Figure 4 is a plot of the position of the laterals and their preceding vowel in the F1-F2 space (and is simultaneously the first F1/F2 acoustic vowel plot for Kuman).

As far as F1 is concerned it can be seen that, for non-low vowels at least, there is a strong correlation between lateral and vowel (simple regression of all lateral F1 on all vowel F1 gives $r^2 = 0.89$). The lower F1 for the lateral after /a/ might be the result of the mouth opening slightly and the coronal and apical regions of the tongue lowering and bunching themselves to be able to articulate with the dorsum at the velum, but does not appear to be a significant difference, given the magnitudes of the standard deviations involved. A larger sample in this environment would be needed for further analysis.

F2 in the laterals is also highly correlated with the preceding vowel F2 ($r^2 = 0.94$), but it is of a more complex kind than F1. Figure 4 shows that for high- and mid-vowels, the change in formants between vowel and lateral is one of centralisation; that is, the formants are moving toward a centre point. This change is the acoustic reflection of the change in articulation, where the tongue retracts from its place of articulation for [-back vowels] (i.e. laterals following front vowels are slightly fronted), and moves forwards slightly for [+back vowels]. Laterals after [-back vowels] are also less correlated than after [+back] vowels. The maintenance of lip-rounding during the articulation of the velar lateral must also contribute to the lower F2 of velar laterals following the rounded vowels /ɔ/ and /ʊ/.

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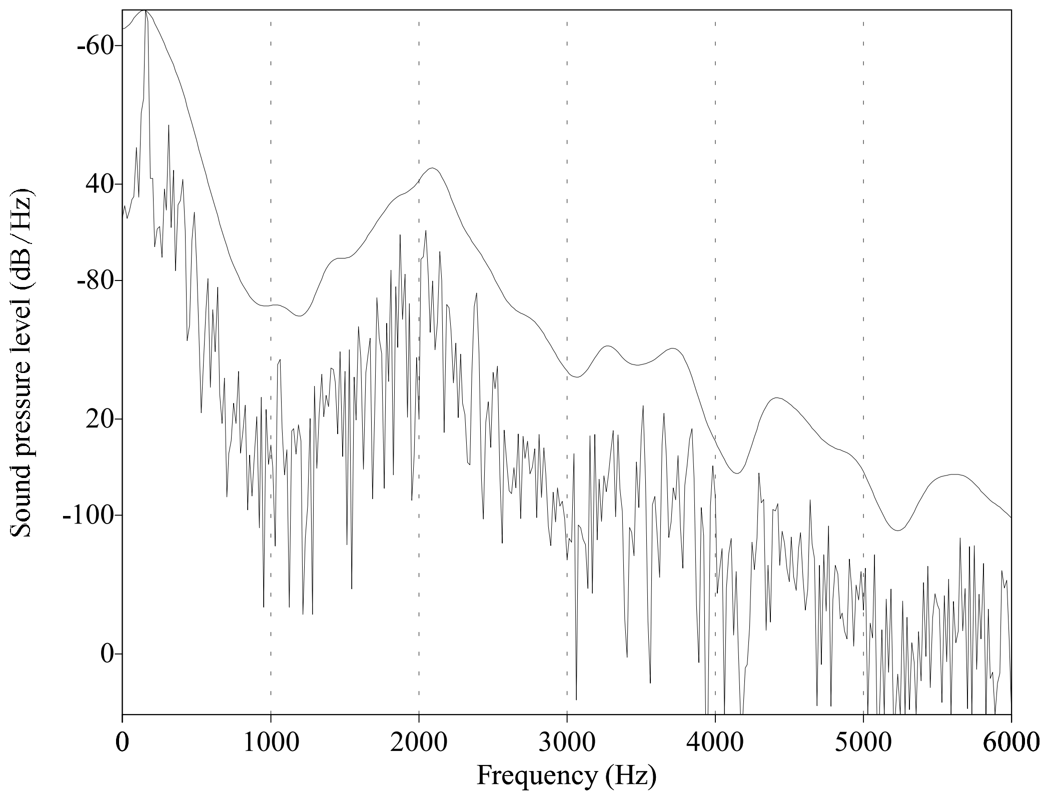

Figure 3. FFT and superimposed cepstrally-smoothed spectrum (Bw = 0.4 KHz) of the ca 4csec. pre-transient portion of the /L/.

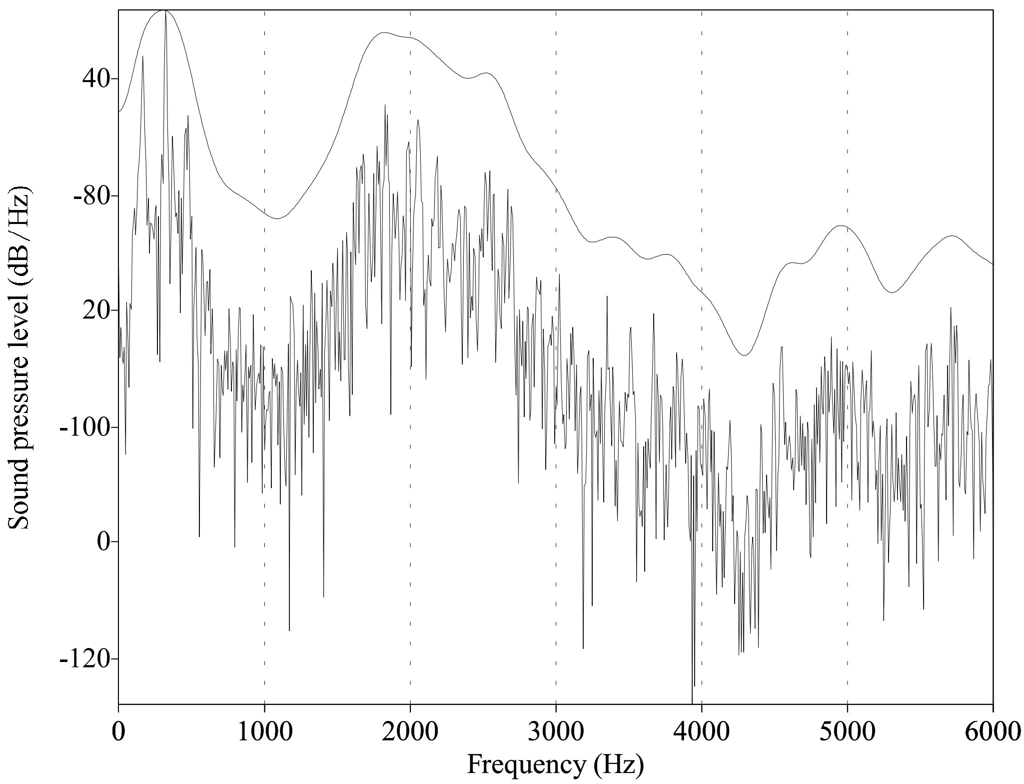

Figure 4. FFT and superimposed cepstrally-smoothed spectrum (Bw = 0.4 KHz) of an 8 csec. post-transient portion of the /L/.

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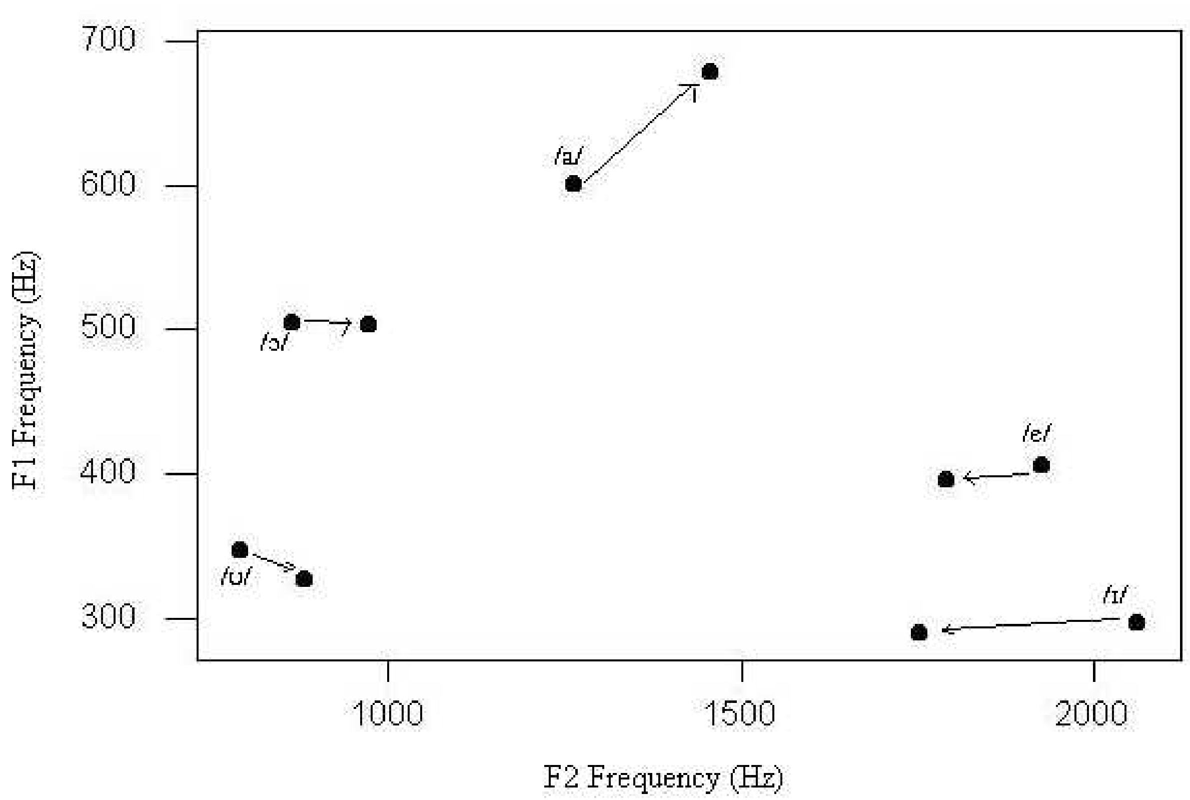

Figure 5. Comparison of F-pattern (F1,F2) in /L/ and preceding vowel. Arrows point to /L/ values.

The amount of variance in the F-pattern center frequencies of /L/ F1 and F2 means that it is probably not sensible to try to quote representative values, but a mean F3 of ca 2.5 kHz is possibly representative.

6. Summary

The velar lateral fricative for this speaker of Kuman receives many of its F-pattern features from its prevocalic environment. The first and second formants are heavily influenced by the nuclear vowel that precedes the lateral, and show a degree of centralisaton, but its F3 seems relatively stable at ca 2.5 kHz. It is characterised by low amplitude wave, and by its length, which is comparatively long compared to the nuclear length. There is an optional extrinsic pre-stopping of an unusual nature, included more often than not, which appears to be a period of low amplitude periodicity followed by a transient reflecting a closure opening up to the lateral fricative segment.

7. Acknowledgments

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