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Electromyographic Studies on the Production of Pitch Contour in Accentless Dialects in Japanese

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Introduction

Most previous studies on the quantitative analysis of pitch contour in Japanese are concerned either with the Tokyo dialect or with the Kinki dialect. In these dialects, pitch contour is generally characterized as the superposition of a component related to word accent and a component related to the prosodic phrase. However, in Japanese, there are many local dialects which do not have distinctive word accent (accentless dialects). These dialects can be expected to serve as an interesting and valuable target for the study of intonation contours because, first of all, in these dialects, pitch contours corresponding to prosodic phrases are directly manifested as actual pitch contours without any interference from word accent. Furthermore, a recent study by one of the present authors (K. Maekawa 5)) has revealed that many accentless dialects show characteristic pitch contours corresponding to prosodic phrases which are quite different from those observed in the Tokyo or Kinki dialects. In the Tokyo dialect, for example, the basic pattern of the pitch contour for the unit of the prosodic phrase can be characterized as a declination pattern (i.e., the initial pitch rise and the gradual pitch fall toward the end of the utterance). The boundaries of the prosodic phrases in the utterance are generally signaled by a pitch rise at the boundaries. However, accentless dialects often have their own characteristic pitch pattern for prosodic phrases and also for marking prosodic boundaries.

Considering these features of accentless dialects, a series of electromyographic studies on the production of the pitch contour in accentless dialects is now being planned by the present authors. Electromyographic studies on these dialects are expected to be particularly useful for the analysis of the role of the laryngeal muscles in pitch control for the following reasons. 1) As stated above, in these dialects, there is no local up-down movement in the pitch contour due to word accent and, thus, the correspondence between muscle activity and the pitch contour will be more straightforward. 2) These dialects often show characteristic pitch patterns which are not usually observed in the Tokyo or Kinki dialects, and thus, can provide a wider framework for investigating the role of specific muscles in the production of the pitch contour.

The present paper is the first report on the data collection being conducted by the present authors. In the following, electromyographic data on the Ibaraki dialect (which is

spoken in Ibaraki Prefecture, near Tokyo) will be presented together with reference data from the Tokyo dialect. The data for these two dialects were collected using the same set of speech samples. More specifically, the electromyographic activity of the cricothyroid muscle and sternohyoid muscle were recorded and the pattern of the activity was analyzed with special reference to the following questions.

1) Is the muscle activity related to the pitch rise and fall in the accentless dialect basically similar to that in the Tokyo or Kinki dialects even though its intonation pattern is quite different from that in the Tokyo or Kinki dialects?

2) Can an examination of an accentless dialect clarify the role of sternohyoid muscle in the control of pitch lowering? Although the activity of sternohyoid is widely observed in connection with pitch lowering, it is not so consistent as that of CT in pitch raising and there still remains uncertainties about the role of sternohyoid muscle 1)-4), 7)-10).

Experimental procedures

The speech material consists of the following pairs of sentences. Incidentally, for the Tokyo dialect and the Ibaraki dialect studied in the present experiment, sentences consisting of the same lexical items can be found for these types of sentences. The differences in these utterances lie only in the acoustic characteristics of some of the constituent phonemes which will be mentioned below.

(1) Simple declarative and yes-no question

Ãni ga iru. (There is an elder brother)
(elder brother) (there is)

Ãni ga iru? (Is there an elder brother?)

Wãni ga mieru. (You can see an alligator)
(Alligator) (can be seen)

Wãni ga mieru? (Can you see an alligator?)

(2) Wh-question and yes-no question

Dãre ga iru? (Who is there?)
(Who) (there is)

Dãre ka iru? (Is there anybody?)

Nãni ga mieru? (What can you see?)
(What) (can be seen)

Nāni ka mīeru? (Can you see anything?)

(3) Presence or absence of focus on noun phrase

Kabe o kiiroku nutta. (We painted the wall yellow)
(wall) (yellow) (painted)

Kabe ò kiiroku nutta. (We painted the wàll yellow)

The pair of sentences in (1) was designed to examine the muscle activity related to the pitch pattern in a yes-no question compared to the pitch pattern in a declarative sentence. The mark "¬" in the above list represents the accent kernel in the Tokyo dialect. As is generally known, word accent in the Tokyo dialect is characterized by the start of the pitch fall at the boundary between the mora bearing the accent kernel and the following mora. In these sentences, the sentence initial nouns "āni" and "wāni" in the Tokyo dialect have the accent kernel on the first mora.

For sentence pair (2), wh-questions were constructed using wh-words like "dāre-ga" and "nāniga", whereas the yes-no questions were constructed using morphologically related words like "dāreka" and "nānika". Thus, for the pairs of sentences in (2), the syntactic and accentual structures are exactly the same. However, it has been pointed out that these sentences are considered to have a difference in their focus placement 7). While the focus in the wh-question is on the wh-word, the focus in the yes-no question is on the predicate. This difference may be reflected in the different prosodic phrasing of these sentences. Especially in the Tokyo dialect, when the verb in the predicate has an accent kernel, the placement of the focus on the predicate in a yes-no question results in a division of the utterance into two prosodic phrases. This effect is generally observable in the pitch contour as a pitch rise at the beginning of the predicate. The present speech material includes these sentences in order to investigate the effect of this prosodic phrasing. (It is generally acknowledged that in the Ibaraki dialect, the case particles in wh-questions and yes-no questions tend to be produced using different segmental phonemes. The case particle in wh-questions tends to be [ŋa], while the case particle in yes-no questions is [ga]. However, for the utterances in the present experiment, there were no significant perceptual differences between the two types of sentences even in the Ibaraki dialect.)

The pair of sentences in (3) was designed to examine the effect of focus on the noun phrase. One of the realizations of the focus in a noun phrases is a prominence on the case particle of the noun phrase (the object marker "o" in the present sentences). In the present experiment, pitch prominence was actually given to the particle "o".

The subjects for the present experiments were a male speaker of the Tokyo dialect

(aged 58) and a male speaker of the Ibaraki dialect (aged 35). The electromyographic activities of the cricothyroid (CT) and sternohyoid (SH) muscles were recorded together with the speech signals. The subjects produced 10 to 15 repetitions of each sentence. In this preliminary report, the data for a single representative utterance for each sentence type will be shown. The EMG and speech signals were digitized at 10kHz and read into the computer. Amplitude envelopes of the EMG signals were obtained by rectifying and averaging the sampled values over every 10 millisecond interval. Fundamental frequency contours were obtained basically through the autocorrelation method with time window of 20 milliseconds and a window shift of 10 milliseconds.

Results

Tokyo dialect

The data for the Tokyo dialect utterances are shown in Figures 1, 2 and 3. Each figure shows, from top to bottom, the speech envelope, the fundamental frequency contour and the EMG envelopes for CT and SH.

Figure 1 compares the declarative sentence and yes-no question. The declarative sentence "ā̃ni ga iru" in Figure 1 (a) shows a pitch rise in the initial part of the utterance, as is generally observed for the Tokyo dialect. The noun "ā̃ni" in this sentence has an accent kernel on the first mora, and the pitch contour starts to fall from the second mora in the utterance. After that, the gradual pitch fall continues until the end of the utterance. In accordance with this pitch pattern, the CT is active at the beginning of the utterance. This activity decreases, or is suppressed, with the start of the pitch fall and stays at a low level throughout the utterance. On the other hand, the SH is suppressed at the beginning of the utterance and gets activated with the start of the pitch fall. This activity is maintained until the end of the utterance.

The yes-no question "ā̃ni ga iru?" in Figure 1 (b) has an utterance final pitch rise marking the question. Corresponding to this pitch rise, there is a reactivation of the CT, whose activity is suppressed with the pitch fall from the second mora. At the same time, the activity of the SH accompanying the pitch fall gets suppressed for the utterance final pitch rise. Thus, this pair of sentences confirms the general pattern of antagonistic activities of the CT and SH associated with the pitch control, although it should be noted that in these data there is a considerable timing lag between the onset of the SH activation and the start of the pitch fall. These characteristics in the activity of the SH have also been noted in previous studies 2) 3) and will be discussed in more detail later in this report.

The other declarative sentence, "wā̃ni ga mi̇ē̃ru", in Figure 1 (c) duplicates the basic pattern of the CT and SH activities observed in Figure 1 (a). In the case of the yes-

no question "wāni ga miēru?" in Figure 1 (d), the verb has an accent kernel. As was explained above, this type of utterance is produced as a composition of two prosodic phrases. Thus, there is a pitch rise at the beginning of the predicate "miēru", followed by a pitch fall associated with the accent kernel. Corresponding to this up-down movement of the pitch, the CT and SH also exhibit an antagonistic pattern of activation and suppression. The interesting point to be noted here is that, in the case of the accent kernel in "miēru", the timing of the SH activation nearly coincides with the start of the pitch fall. This pattern is clearly in contrast with the timing lag between the pitch fall and SH activation in "āni ga".

Figure 2 provides a comparison between the wh-questions and yes-no questions constructed using the morphemes "dāre" or "nāni". The pitch contours in the wh-questions "dāre ga iru?" and "nāni ga miēru?" are characterized by an initial pitch rise, a following pitch fall associated with the accent kernel, and an utterance-final pitch rise marking the question. Correspondingly, there are CT activities at the beginning and end of the utterance and SH activities during the period of the pitch fall. This activity pattern is basically in agreement with that in Figure 1. One characteristic pattern of EMG activity which is not observed in Figure 1 is SH activity near the onset of the utterances. These activities are considered to be related to the jaw opening gestures for the syllables "da" and "na", as has been reported in previous studies 2) 7) 8), and not considered related to pitch control. The yes-no question "dāre ka iru?" in Figure 2 (b) resembles the wh-questions both in the pattern of the pitch contour and in the pattern of the muscle activities. However, the yes-no question "nāni ka miēru?" in Figure 2 (d) exhibits two prosodic phrases as does the utterance "wāni ga miēru?" in Figure 1 (d). The SH and CT activities again exhibit an antagonistic pattern corresponding to this up-down movement of the pitch contour.

The data in Figure 3 show the effect of prominence on the case particle "o" in the noun phrase. For the utterance with the focus, there is a local up and down movement of the pitch contour around the segment "o". This pitch pattern also accompanies the CT activity for the pitch rise and the SH activity for the pitch fall.

In summary, the present data for the Tokyo dialect confirm the basic antagonistic pattern of CT and SH activities in pitch control.

Ibaraki dialect

Figures 4, 5 and 6 show data for the Ibaraki dialect. In the case of the declarative sentence in the Ibaraki dialect (Figure 4 (a)), the pitch contour exhibits a slight initial rise, then maintains a flat contour until the end of the utterance. Corresponding to this pitch pattern, the CT keeps a certain level of activity during the utterance, while the SH does not show any significant activity. This pattern is quite different from that in the Tokyo

dialect, which showed a gradual pitch fall and corresponding suppression of CT activity during the utterance.

The yes-no question in the Ibaraki dialect shown in Figure 4(b) has a characteristic pitch pattern marking the question, i.e., a pitch fall at the end of the utterance which starts around the middle of the penultimate mora (in this utterance "i"). The EMG pattern associated with this pitch fall is the suppression of the CT and the activation of the SH. In this case also, the CT and SH exhibit a clear antagonistic pattern. The offset of CT activity and the onset of SH activity nearly coincide in time, and there is no timing lag between the pitch fall and the SH activation.

The pair of sentences in Figures 4 (c) and (d) duplicate the patterns of pitch contour and EMG activity observed in Figures 4 (a) and (b). In this accentless dialect, the difference in the verbs "iru" and "mieru" does not bring about a different phrasing in the two yes-no questions in Figures 4 (b) and (d).

The wh-questions in Figures 5 (a) and (c) exhibit a clear pitch rise at the end of the utterances. Most of the pitch rise takes place during the utterance final mora "ru". Corresponding to this, there is a significant increase in CT activity near the end of the utterance. The yes-no questions in Figures 5 (b) and (d) have an utterance-final pitch fall as do the yes-no questions in Figures 4 (b) and (d). The antagonistic pattern of suppression and activation in the CT and SH is also clear in these utterances.

Prominence on the case particle "o" in the utterance shown in Figure 6 (b) brings about an effect similar to that in the Tokyo dialect. The pitch contour shows a local up and down movement and, in accordance with this pitch pattern, the CT and SH exhibit corresponding activity patterns.

In summary, the utterances in the Ibaraki dialect show an antagonistic pattern of CT and SH activities, an up-down movement for pitch, which is essentially similar to that found in the Tokyo dialect, although there are characteristic large differences in the intonation pattern.

Summary and Discussion

The present experimental results largely confirm the antagonistic pattern for CT and SH activities which has been repeatedly reported in previous studies 1) 4) 9) 10). This antagonistic pattern is confirmed in the Tokyo dialect, as an the utterance- initial pitch rise, a pitch fall related to the accent kernel, an utterance-final pitch rise in questions and an utterance-medial pitch rise for prosodic phrase boundaries. This antagonistic pattern is also confirmed in the Ibaraki dialect for utterance- final pitch rise and fall in wh-questions and yes-no questions, respectively. Thus, the basic pattern of muscle activ-

ities related to the pitch control appears to be essentially the same in the Tokyo and Ibaraki dialects, although actual pitch contours in these two dialects exhibit great differences in their overall shape.

One of the important findings of the present study is that, in the case of the declarative sentence in the Ibaraki dialect, assuming a flat pitch contour during its utterance, a certain level of CT activity is maintained throughout the utterance. This is in contrast to the pattern of CT activity in Tokyo dialect, which exhibits a gradual pitch fall during the utterance and a corresponding suppression of CT activity after the initial pitch rise at the beginning of the utterance. These phenomena can be considered supporting evidence for the assumption that a suppression of CT activity is positively involved in the pitch lowering control and that the gradual pitch fall in the Tokyo dialect is not solely due to a passive mechanical relaxation process in the pitch production system.

The remaining problem to be discussed here is the timing lag between the start of the pitch fall and the SH activation observed for the word "ãni" in the Tokyo dialect. It was noted that no other cases of pitch fall in the present data exhibited such a timing lag. It has generally been known that SH activity is concomitant not only with the pitch lowering process but also with the articulatory gesture for jaw opening 2) 7) 8). This type of SH activation is also discerned in the present data ("dãre" and "nãni" in Figures 2 and 5). The point to be noted here is that this type of SH activity appears to be preceded by a suppression period which is presumably related to the closing movement of the preceding consonant. This pattern of SH suppression can be seen clearly in the additional speech sample shown in Figure 7. The utterance presented in the figure has a gradual pitch fall until its end, and, thus, a continuous SH activity can be expected throughout the utterance. However, contrary to this expectation, the actual pattern of SH activity shows intermittent periods of suppression which are clearly related to the stop or fricative consonants in the utterance. Such a pattern of SH suppression will explain the timing lag in Figure 2.

The above observations suggest that the pattern of SH activity can be interpreted as a sum of the SH activation concomitant to pitch lowering and jaw opening and SH suppression concomitant to selected consonants. If we look at the recorded data considering the contributions of these factors, the pattern of the SH activity appears to be consistent to a large extent. It may be considered that SH activity is basically involved in the process of pitch lowering except when it gets suppressed for the closing movement of a consonant. Then the question to be answered is how the pitch lowering process is maintained even in the presence of SH suppression. One possible explanation is, naturally, that the SH is not the sole muscle responsible for pitch lowering. There are some other muscles which may act cooperatively with the SH. In usual situations, the SH is activated for pitch lowering, but when it gets suppressed for consonantal gestures, some secondary muscles may be activated in its place. At present, the above statements are only speculations and further physiological experiments are necessary to clarify this problem.

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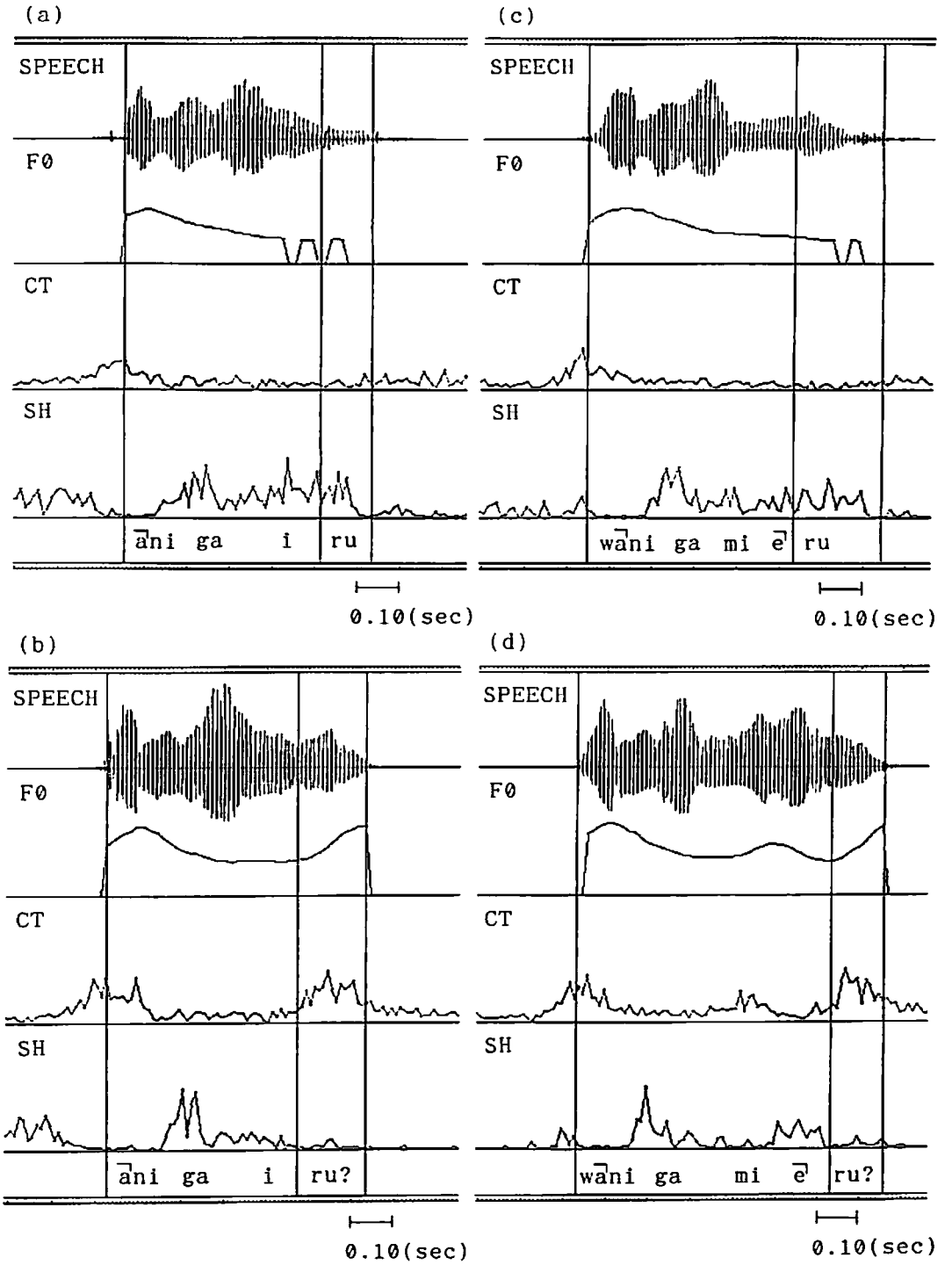

Fig. 1 Comparison of declaratives and yes-no questions in Tokyo dialect

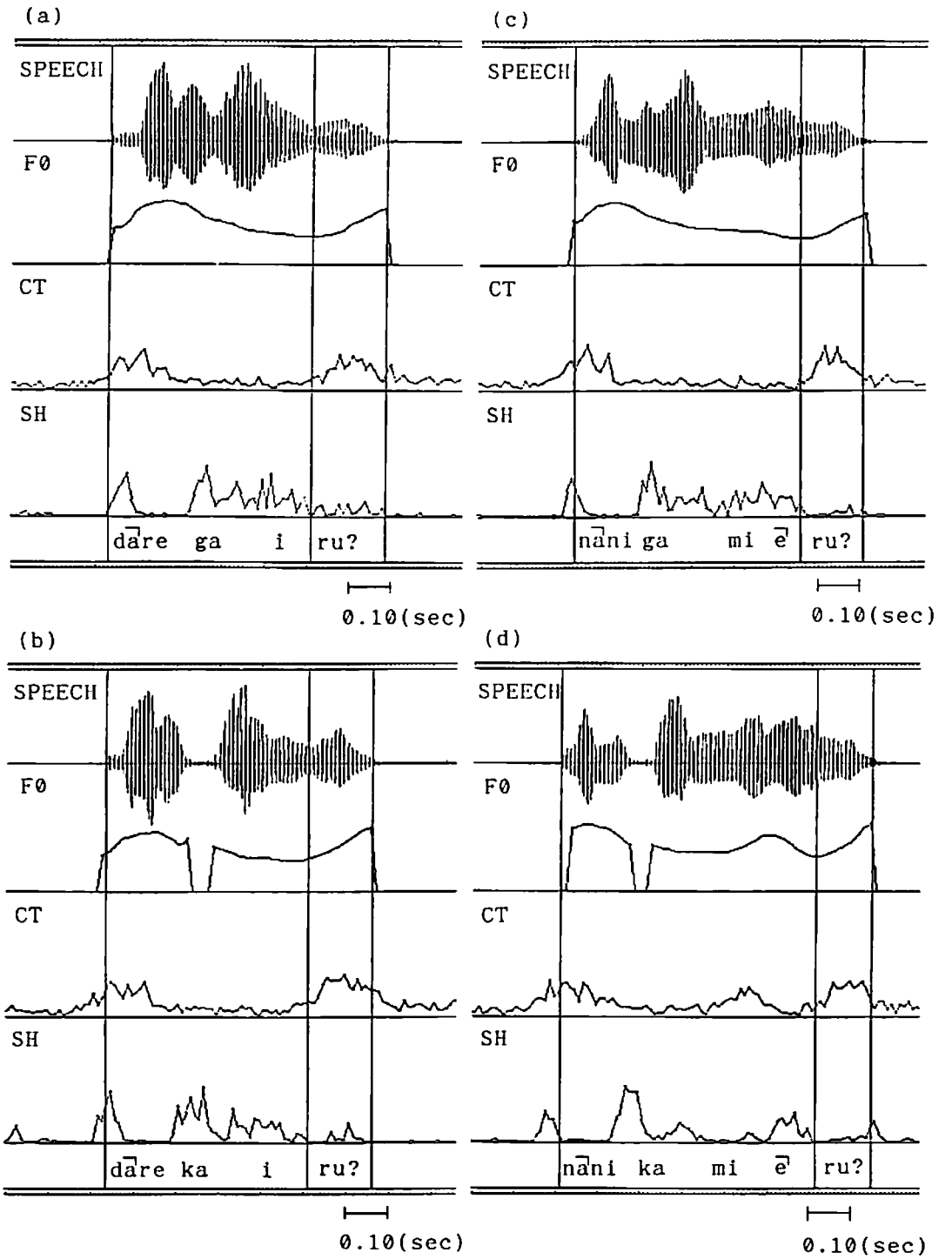

Fig. 2 Comparison of wh-questions and yes-no questions in Tokyo dialect

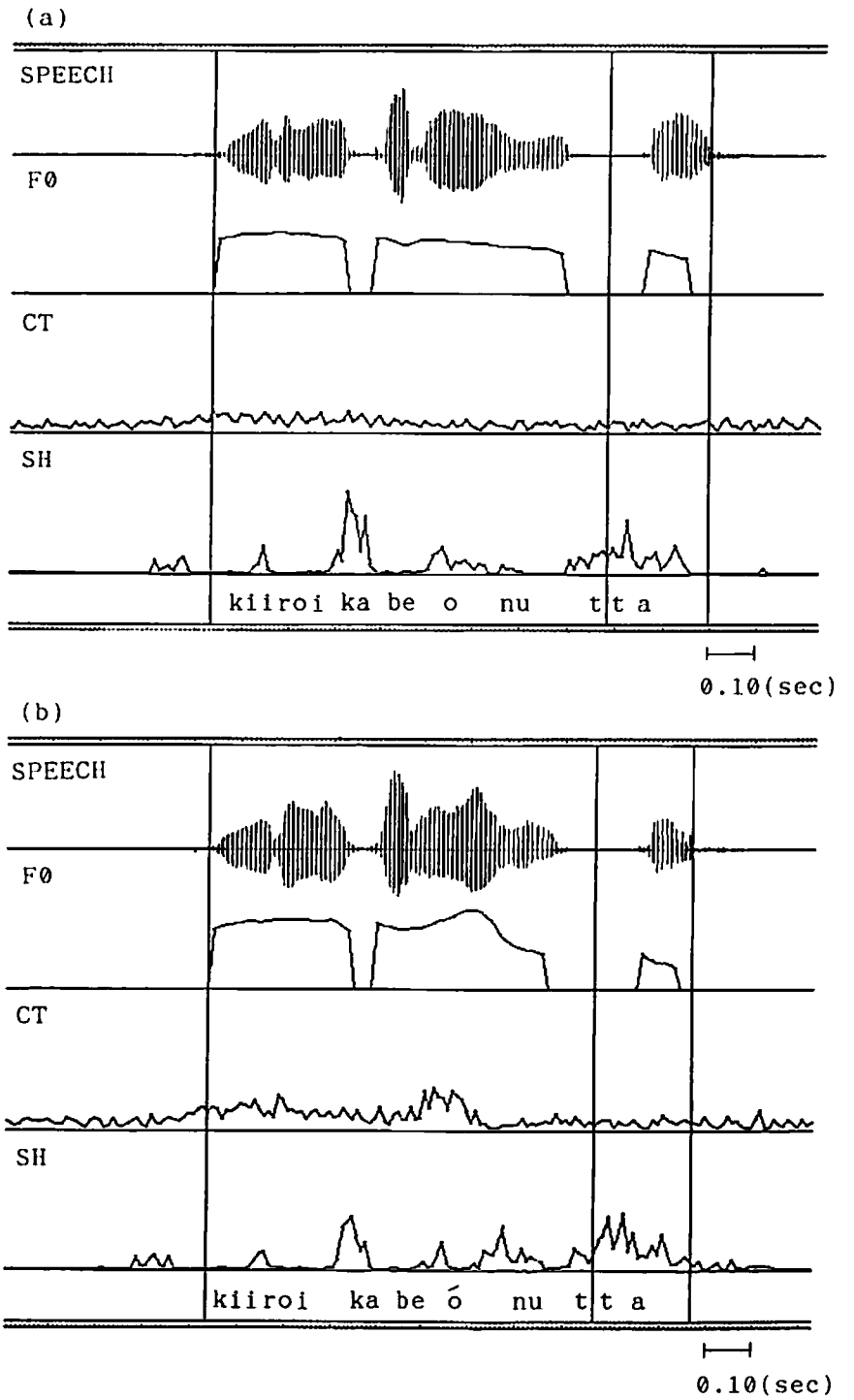

Fig. 3 Comparison of prominence and non-prominence in Tokyo dialect

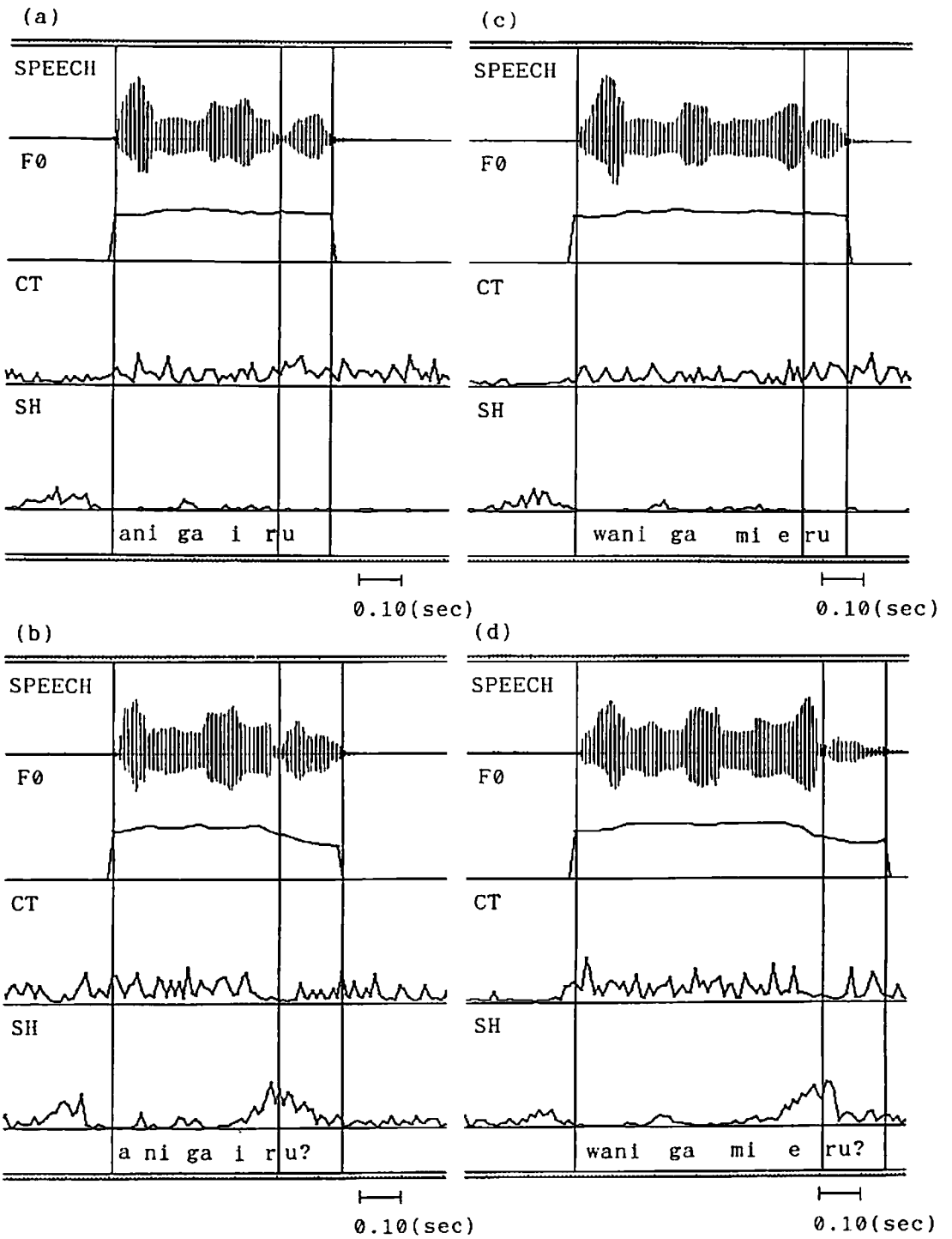

Fig. 4 Comparison of declaratives and yes-no questions in Ibaraki dialect

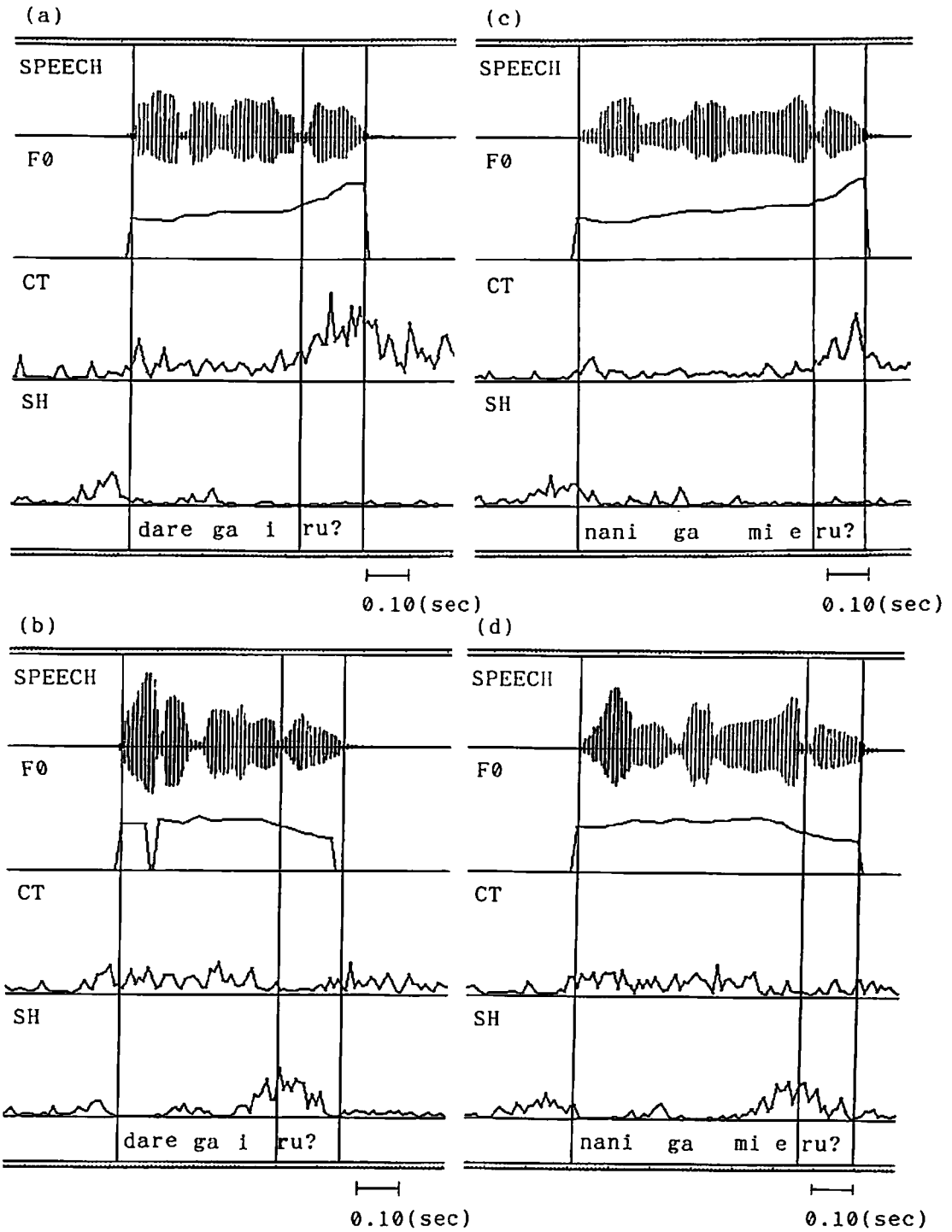

Fig. 5 Comparison of wh-questions and yes-no questions in Ibaraki dialect

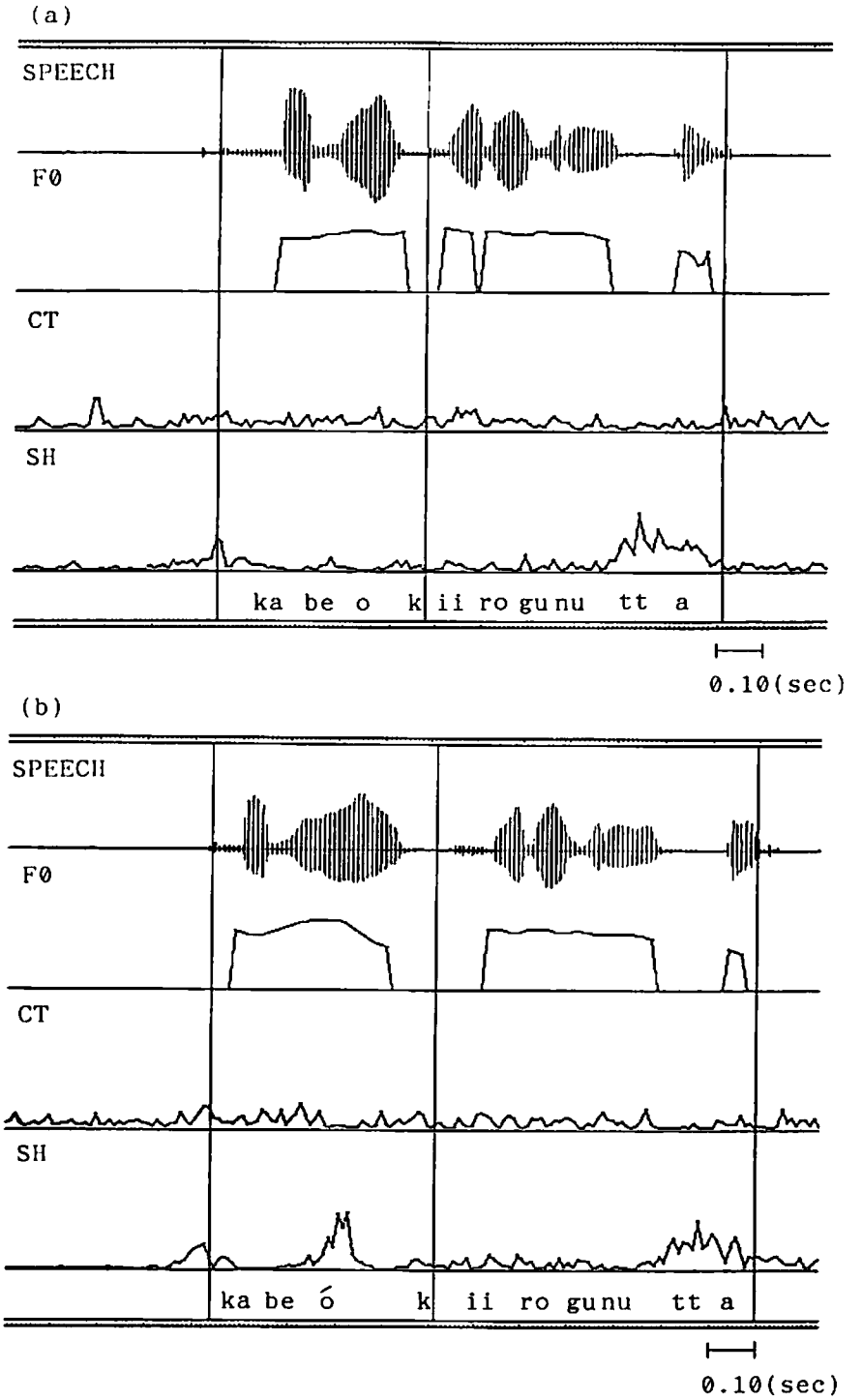

Fig. 6 Comparison of prominence and non-prominence in Ibaraki dialect

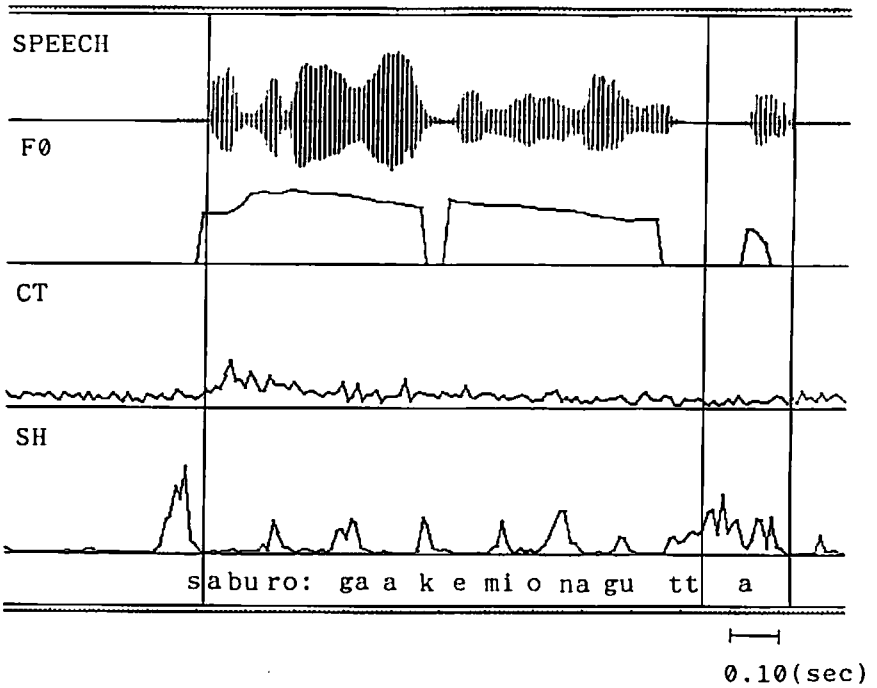

Fig. 7 Pattern of SH suppression (Tokyo dialect)