

Nonlinear Spectral Characteristics of Rabha and Bodo Phonemes ---A Comparative Study



Statistics

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ABSTRACT

Linguistically, both Rabha and Bodo language belongs to the Tibeto Burman family-a sub group of Sino Tibetan family of languages. Speech is a nonlinear phenomenon. The information provided by the Pitch analysis is not enough to ascertain the degree of nonlinearity present in the pronunciation of vowels.

In this paper we propose a faster method of classification approach using matrix method of polynomial fitting to identify the degree of nonlinearity of the Rabha and Bodo vowels. In this paper the formant analysis through LPC (Linear Predictive Coding) analysis of Rabha and Bodo Vowels have been presented. The speech signals used here are vowels uttered by male and female speakers of both Rabha and Bodo language.

Introduction:

In spite of extensive research made by different scientists from different part of the world, we are yet get a standard speech recognition technique. To simplify the arduous task we focus on isolated word recognition. The systematic studies on isolated word recognition have been proposed by many workers. But in case of continuous speech recognition the results not up to the work. Speech is a nonlinear time varying phenomenon. Therefore it is very difficult to determine the characteristics of a particular phoneme. The speaker dependency arises immense variation of speech amongst people of different ethnic groups with respect to age, sex, living condition, social structure etc. Even the psychological state of mind such as anger, sorrow, stress and tension make an ideal condition next to impossible.

The smallest units of human speech, which are more refined, are called phonemes. Phonemes essentially represent the various kinds of sounds occurring in the speech. Depending upon the way of articulation phonemes can be classified into different groups. They may be voiced or unvoiced. Voice sounds are produced by the involvement of glottis in the speech production process. They are quasi-periodic and have relatively higher peak-to-peak amplitude and equivalently energy. They have low zero-crossing rate. Vowels are voiced sounds and consonants may be voiced voice less. Unlike the voiced sound, the unvoiced sounds do not involve 'active' participation of the glottis in their production. They are non-periodic, low peak-to-peak amplitude and high zero-crossing rate. They are random noise sound.

The Rabha language is inherited from Bodo language. Some original features of Bodo language are still prevailing in the Rabha language. Further, in pronunciation also they have very resemblance to each other. Traditionally, also the Rabha and Bodo people have many similarities in terms of culture and social customs. So, it is necessary to take a comparative and in-depth study between Rabha and Bodo language. The present Study is mostly concentrated on to explore the various characteristic features of both languages based on non-linear features.

Brief History of Rabha and Bodo Language: Rabha Language:

Rabha is the fifth largest tribe among the 21 ethnic minority communities of Assam, constituting 1.05% of its total population. The distribution of Rabha language speakers in the different districts of Assam are Dhubri, Khokrajhar, Bongaigaon, Goalpara, Nalbari, Kamrup and Darrang and Northern part of Garo Hill district of Meghalaya.

Anthropologically Rabhas fall within the Boro-Naga group of the Mongoloid or Kirita population. Linguistically they belong to the Tibeto- Burman group of languages. There are seven different sub-classes among the Rabha population. They are Randhani, Maitori, Dohari, Pati, Kosa, Bitalia, and Totla. It is noteworthy that among those various subclasses, the Rabha language is spoken only by a handful of the tribes who belong to the Randhani, Maitori and Kosa groups of these sub-classes. There is almost

99% similarity of speech between Randhani and Maitori and 50% between them and Kosa. The remaining sub-classes don't know the Rabha language and use Assamese as lingua franca to communicate. The language spoken by the Rabhas do not have its own script. Any literary material production is done in some other scripts. The Rabha literary society has also unanimously decided to accept the Assamese script while writing books. This is due to the fact that most of the indigenous Rabha speakers use Assamese as the language of communication. Besides, many Assamese words are common to the Rabha language

Originally, the Rabha language was a tonal language like other languages of the Boro-Naga group. But at present Rabha fails in keeping them. Rabha language has six (6) vowel phonemes and twenty two (22) consonant phonemes.

Bodo Language:

The Bodos are considered as one of the most important group in North-Eastern India. They are well scattered throughout the North-Eastern states of India including Assam, Arunachal Pradesh, Meghalaya, Nagaland, Mizoram, Manipur, Tripura, adjoining areas of Bangladesh and in Nepal and Bhutan.

In Assam, according to 1991 census report of Assam, the estimated Bodo speakers was 11, 84,569. Genetically the Bodos of Assam belong to the Tibeto-Burman sub-family within the Sino-Tibetan family of language. The Boro group include different tribes such as Kachari, or Boro, Lalung (now called Tiwa), Dimas, Garo, Rabha, Tripuri, Koch, Chuttiya (Deuri) and Moran. The Bodo people identify themselves as Bodo after the name of their mother tongue, Bodo. Originally they maintained the Kirata i.e. Mongoloid Culture, but it has been influenced to a great extent by the Indo-Aryan culture. Most of the Bodos are bilingual. They are mostly use Assamese language as a media of communication during conversation with the Assamese people and Bodo within themselves. The Bodo language is a tonal language. It has six (6) vowels and sixteen (16) consonants.

Analysis and Result:

Data for Rabha language has been collected from selected Rabha dominated areas of Goalpara, Nalbari and Kamrup districts of Assam and also from Northern part of Garo Hill district of Meghalaya. Similarly data for Bodo language has been collected from selected Bodo dominated areas of district of Baksa, Nalbari and Udalguri. The voice signals corresponding to the vowel phonemes of both languages have been recorded directly in the computer through microphone. The utterance corresponding to each vowel is recorded for 1 second for each speaker. Sampling frequencies is of 8 KHz and 16 bit resolution.

Formant Analysis of Rabha Vowels:

Vowels and consonants are the phonemes of any language. Vowel phonemes are specific resonant frequency. The formants are the predominant frequency components characterizing each vowel. Out of the three formant frequencies of a sample, the first two frequencies are important because they represent most of the characteristics of the cepstrum and vocal tract. The second

formant gives the manner of production.

A common method of analysis and synthesis of speech based on LPC is formant tracking. We used formant model suggested by Welling at al to determine the formant frequencies based on digitized resonator technique. The model used in this paper is

$$A_k(e^{j\omega}) = 1 - \alpha_k e^{j\omega} - \beta_k e^{-j2\omega} \dots\dots (1)$$

Where α_k and β_k are the real valued prediction coefficients and A_k is frequency of the k^{th} informants. The estimation of formant frequencies for male and female informants is made with the help of the equation

$$F_1 = \arccos \left[\frac{-\alpha_k (1 - \beta_k) / 4 \beta_k}{1} \right] \dots\dots (2)$$

Figure 1 and Figure 2 represent the formant position of six Rabha vowels for both male and female informants.

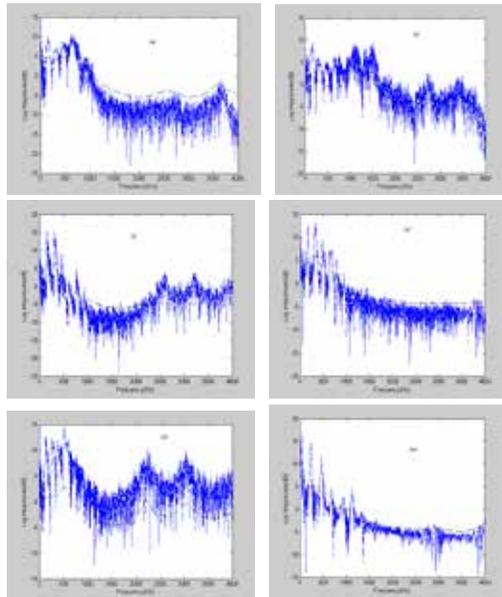


Figure 1: Formants of the utterances of Rabha vowels corresponding to male informants

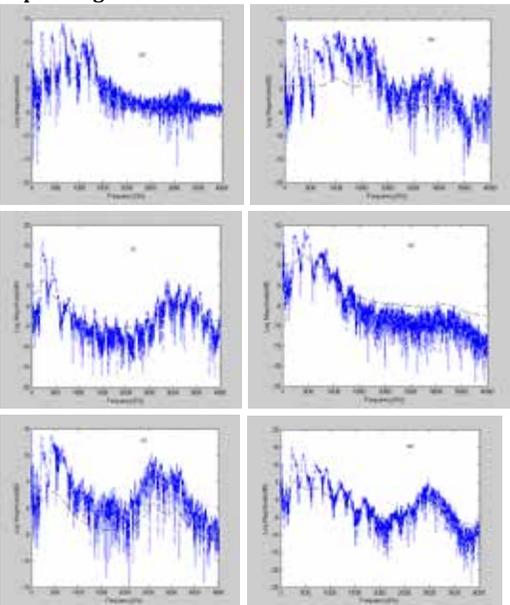


Figure 2: Formants of the utterances of Rabha vowels corresponding to female informants

Table 1 shows the variation of formant frequencies of six Rabha

vowels corresponding to male and female speakers.

Table 1: Range of variation of formant frequencies

Vowels	F1 (KHz)		F2 (KHz)		F3 (KHz)	
	Male	Female	Male	Female	Male	Female
/a/	0.28-0.64 (0.36)	0.56-0.72 (0.16)	0.90-2.90 (2.00)	1.00-1.20 (0.20)	0.23-0.33 (0.10)	0.28-0.31 (0.03)
/e/	0.63-1.00 (0.37)	0.30-1.10 (0.80)	0.52-2.40 (1.88)	1.10-1.70 (0.60)	2.50-3.40 (0.90)	2.50-3.00 (0.50)
/i/	0.28-0.40 (0.12)	0.24-0.30 (0.06)	1.30-2.90 (1.20)	2.80-2.90 (0.10)	2.50-3.20 (0.70)	3.00-3.50 (0.50)
/o/	0.28-0.40 (0.12)	0.32-0.48 (0.16)	1.20-2.40 (1.20)	0.80-1.50 (0.70)	2.20-3.50 (1.30)	2.90-3.50 (0.60)
/u/	0.40-0.50 (0.10)	0.46-0.70 (0.24)	1.10-2.40 (1.30)	2.40-2.60 (0.20)	2.60-3.10 (0.50)	3.00-3.20 (0.20)
/w/	0.34-0.40 (0.06)	0.32-0.92 (0.60)	1.00-2.40 (1.40)	0.70-2.50 (0.80)	2.70-3.40 (0.70)	2.90-3.50 (0.60)

Non-linear Characteristics of Rabha Vowels:

In this paper an attempt has been made to use the data of Rabha vowels as an array to form a matrix for polynomial fitting by matrix method to study the degree of non linearity of vowel utterance. The formant frequencies are used to fit a polynomial of degree p, as described by the following equation:

$$Y = b_0 + b_1 x + b_2 x^2 + \dots + b_p x^p \dots\dots(3)$$

Where $b_0, b_1, b_2, \dots, b_p$ are coefficients to be determined with the help of the following matrix method.

The equation (3) is represented in the matrix form as given by (4):

$$\begin{bmatrix} b_0 \\ b_1 \\ b_2 \\ \vdots \\ b_p \end{bmatrix} \begin{bmatrix} n & \sum x & \sum x^2 & \sum x^3 & \dots & \sum x^p \\ \sum x & \sum x^2 & \sum x^3 & \sum x^4 & \dots & \sum x^{p+1} \\ \sum x^2 & \sum x^3 & \sum x^4 & \sum x^5 & \dots & \sum x^{p+2} \\ \vdots & \vdots & \vdots & \vdots & \dots & \vdots \\ \sum x^p & \sum x^{p+1} & \sum x^{p+2} & \sum x^{p+3} & \dots & \sum x^{2p} \end{bmatrix}^{-1} \begin{bmatrix} \sum x \\ \sum xy \\ \sum x^2 y \\ \vdots \\ \sum x^p y \end{bmatrix} \dots\dots(4)$$

Following this matrix method, the values of b_0, b_1, b_2, b_3 and b_4 etc. are estimated. The range of variation of coefficient b_0, b_1, b_2, b_3 and b_4 for both male and female informants is given in the Table 2 and Table 3.

Vowels	Coefficients				
	b_0	b_1	b_2	b_3	b_4
/a/	3.0< $b_0 < 4.6$	-10.4< $b_1 < 6.0$	-3.0< $b_2 < 5.4$	10.9< $b_3 < 0.27$	-0.02< $b_4 < 0.05$
/e/	-1.9< $b_0 < 4.62$	-1.75< $b_1 < 6.0$	-1.59< $b_2 < 2.0$	-0.25< $b_3 < 0.45$	-0.27< $b_4 < 0.02$
/i/	4.73< $b_0 < 17.5$	-44.0< $b_1 < 1.25$	-0.48< $b_2 < 15$	-1.46< $b_3 < 0.83$	-3.75< $b_4 < 0.03$
/o/	0.48< $b_0 < 14.0$	-2.40< $b_1 < -2.1$	0.12< $b_2 < 14.5$	0.59< $b_3 < 1.43$	-1.75 $b_4 < 0.08$
/u/	2.89< $b_0 < 7.0$	-5.4< $b_1 < 2.1$	-0.5< $b_2 < 2.1$	-0.41< $b_3 < 0.87$	-0.37< $b_4 < 0.06$
/w/	6.56< $b_0 < 9.78$	-7.0< $b_1 < 11.0$	-30.0< $b_2 < -0.6$	-0.56< $b_3 < 19.0$	

Table 2: Range of variation of b_0, b_1, b_2, b_3, b_4 corresponding to male informants

Vowel	b_0	b_1	b_2	b_3	b_4
/a/	0< b_0 <6.8	-2.9< b_1 <1.4	-56< b_2 <0.0	-0.37< b_3 <1.0	-0.21< b_4 <0.04
/e/	-0.50< b_0 <2.0	-0.50< b_1 <4.0	-0.37< b_2 <0.0	-0.31< b_3 <-0.20	-0.08< b_4 <-0.12
/i/	0.0< b_0 <6.9	-2.4< b_1 <18.3	-3.25< b_2 <1.1	-0.60< b_3 <0.92	-0.54< b_4 <0.09
/o/	7.3< b_0 <11.15	-5.32< b_1 <-1.75	0.80< b_2 <2.0	-1.50< b_3 <3.50	-0.75< b_4 <0.02
/u/	1.0< b_0 <7.09	-8.4< b_1 <2.0	-2.5< b_2 <3.0	-0.75< b_3 <0.03	-1.01< b_4 <0.07
/w/	10.4< b_0 <7.53	-6.43< b_1 <-4.0	-2.3< b_2 <0.50	-0.30< b_3 <1.04	-0.07< b_4 <0.0

Table 3: Range of variation of b_0, b_1, b_2, b_3, b_4 corresponding to female informants:

From these tables, it is seen that the range of variation of the values of the coefficient b_4 lies between -0.02 and 0.08 i.e. $-0.02 < b_4 < 0.08$ (for male) and -0.01 and 0.09 i.e. $-0.01 < b_4 < 0.09$ (for female) and thus the x^4 term of the polynomial could be neglected. Thus the equation for the representation of the formant frequency and amplitude is non-linear with the degree of non-linearity three.

Formant analysis of Bodo vowels:

Applying the same procedure, as already discussed in case of Rabha vowel, the formant frequencies of Bodo vowels are also estimated. Table 4 shows the variation of formant frequencies of six Bodo vowels corresponding to male and female speakers.

Table 4: Range of variation of formant frequencies:

Vowels	F_1 (KHz)		F_2 (KHz)		F_3 (KHz)	
	Male	Female	Male	Female	Male	Female
/a/	0.20— 0.57 (0.37)	0.19— 0.70 (0.51)	0.37— 1.58 (1.21)	0.36— 1.03 (0.67)	1.20— 2.90 (1.70)	0.53— 3.20 (2.67)
/e/	0.41— 0.83 (0.42)	0.48— 0.81 (0.33)	0.63— 1.32 (0.69)	0.72— 1.13 (0.41)	1.20— 2.93 (1.73)	1.47— 1.71 (0.24)
/i/	0.12— 0.52 (0.40)	0.12— 0.19 (0.07)	0.73— 2.37 (1.64)	0.32— 1.38 (1.06)	1.20— 3.21 (2.01)	1.62— 2.39 (0.67)
/o/	0.12— 0.32 (0.20)	0.15— 0.40 (0.25)	0.39— 0.94 (0.55)	0.44— 2.16 (1.72)	1.18— 2.78 (1.60)	1.40— 2.16 (0.76)
/u/	0.20— 0.40 (0.26)	0.20— 0.32 (0.12)	0.54— 2.04 (1.50)	0.69— 1.20 (0.51)	1.22— 2.65 (1.43)	1.53— 2.52 (0.99)
/w/	0.16— 0.46 (0.30)	0.20— 0.51 (0.31)	0.65— 1.54 (0.89)	0.72— 0.95 (0.23)	1.18— 1.54 (0.26)	1.45— 1.74 (0.29)

To study the degree of nonlinearity of Bodo vowels, these formant frequencies are used and the coefficients of the polynomial equation (3) are estimated as used in case of Rabha vowels. The range of variation of coefficients b_0, b_1, b_2, b_3, b_4 for both male and female informants are given in Table 5 and Table 6.

Vowels	b_0	b_1	b_2	b_3	b_4
/a/	-0.49< b_0 <26.16	-32.87< b_1 <1.02	-1.01< b_2 <14.94	-2.73< b_3 <0.095	-0.002< b_4 <0.18
/e/	-0.91< b_0 <4.26	-6.78< b_1 <2.36	-1.25< b_2 <4.09	-0.83< b_3 <0.29	-0.02< b_4 <0.06
/i/	-3.68< b_0 <1.69	-2.13< b_1 <5.60	-1.89< b_2 <1.16	-0.20< b_3 <0.31	-0.02< b_4 <0.00005
/o/	0.77< b_0 <3.93	-7.07< b_1 <-1.32	0.83< b_2 <4.35	-6.87< b_3 <-0.07	-0.0002< b_4 <0.06
/u/	-65.82< b_0 <4.01	-7.28< b_1 <122.31	-71.96< b_2 <4.26	-0.86< b_3 <16.55	-1.27< b_4 <0.058
/w/	-0.66< b_0 <0.79	-1.57< b_1 <1.41	-0.37< b_2 <1.56	-6.25< b_3 <0.08	-0.008< b_4 <0.02

Table 5: Range of variation of b_0, b_1, b_2, b_3, b_4 corresponding to male informants

Vowels	b_0	b_1	b_2	b_3	b_4
/a/	0.33< b_0 <5.84	-0.90< b_1 <0.98	-0.03< b_2 <5.82	-1.19< b_3 <0.06	-0.007< b_4 <0.08
/e/	0.97< b_0 <2.28	-2.61< b_1 <-0.94	0.53< b_2 <1.35	-0.20< b_3 <-0.05	-0.0006< b_4 <0.0089
/i/	-2.23< b_0 <4.67	-8.43< b_1 <3.16	-0.85< b_2 <4.08	-0.95< b_3 <0.09	-0.0016< b_4 <0.063
/o/	0.59< b_0 <2.92	-4.98< b_1 <-0.96	0.59< b_2 <3.03	-0.61< b_3 <-0.06	0.0008< b_4 <0.04
/u/	-1.13< b_0 <2.51	-4.80< b_1 <2.46	-0.35< b_2 <3.07	0.63< b_3 <0.05	-0.0025< b_4 <0.04
/w/	-0.02< b_0 <2.43	-3.60< b_1 <0.16	-0.14< b_2 <2.05	-0.36< b_3 <0.0003	-0.0016< b_4 <0.02

Table 6: Range of variation of b_0, b_1, b_2, b_3, b_4 corresponding to female informants

From the Table 5 and Table 6 it is seen that the range of variation of the coefficient b_4 lies between $-1.27 < b_4 < 0.18$ (for male) and $-0.0025 < b_4 < 0.08$ (for female). Thus the x^4 term of the polynomial can be neglected, as b_4 is very very small. Hence, the equation representing the formant frequency characteristics of Bodo vowels is non-linear in nature with a degree of non-linearity three.

Figure 3 and Figure 4 given below represent the formant position of six Bodo vowels for both male and female informants.

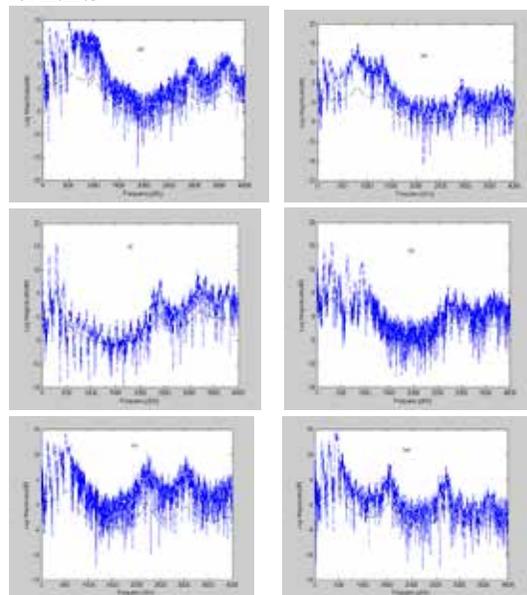
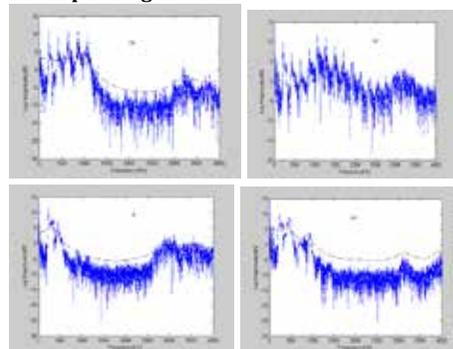


Figure 3: Formant frequency characteristics of Bodo vowels corresponding to male informants



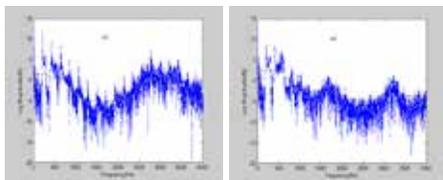


Figure 4: Formant frequency characteristics of Bodo vowels corresponding to female informants.

Conclusion and future scope:

A model polynomial equation to study the degree of non-linearity of variation of the formant frequency could be

$$Y = b_4x^4 + b_3x^3 + b_2x^2 + b_1x + b_0 \quad \text{----- (5)}$$

But in our present study formant frequency(x) and amplitude(y) variation, the equation (5) have reduced to $Y = b_3x^3 + b_2x^2 + b_1x + b_0$ (for both male and female). Thus we have seen that for both male and female informants, the spectral phonetic characteristic of the Rabha vowels is absolutely a non-linear phenomenon. Similar conclusion can be drawn in case of Bodo vowels.

Thus it is found in the present study that the formant features of the Bodo and Rabha phonemes, irrespective of sex, are non-linear, with a degree of non-linearity being 3 (approx.).

There is enough scope of extending the present study. Considering the present study as base, one can further go on integrating the other languages of this region and try to develop integrated transparent role-model of the different ethnic languages of north-eastern languages.

REFERENCE

1. Rabiner,LR and Schafer,RW(1976): Digital Processing of Speech Signal. Englewood Cliff, N J Prentice. | 2. Boro, MR (1999) : The Bodo Structure, 1999. | 3. Basumatary, P : An Introduction to Bodo Language. | 4. Barman, N (2008) : A study on the Non-linear spectral Characteristics | of Rabha Phonemes. A Ph.D. thesis carried out in Guwahati University, 2008. | 5. Goswami, S N : Studies in Sino- Tibetan Languages,1988. | 6. UNESCO : Workshop Report on Community Based Literacy Programme for Minority Languages | in the context of Asia, 2005. | 7. Devi, Basanti (1984) : Vowel Length in Assamese .Acoustic Study in Indian Languages, Ed. By B B Raja Purohit, Central Institute of India, Mysore. | 8. Velayudhan,S and Howle, J M.(1974) : Acoustic Measurement of distinctive Vowel quality in Malayalam. Language and Speech, volume 17,pp-95-101. | 9. Markel, J D.and Gray,A H Jr;(1976) : Linear Prediction of Speech, Springer-Verlag. | 10. Talukdar,P. H.; Goswami, C K and Barman, J(2004): Cepstral Measure of Bodo Vowels through LPC analysis Journal, Computer Society of India. | 11. Hakacham, U.R. : Rabha Bhasa Aru Sahitya, First Edition, Sept. 1997.