Speech Compression Using FireFly-LBG Algorithm

N.Himaja
Student of ECE,
RVR&JC CE,
Guntur, A.P India,
hnanneboyina@gmail.co

V.Durga Prasad
Student of ECE,
RVR&JC CE,
Guntur, A.PIndia,
durgaprasadvalleboina@g

O.Venkata Sai KiramStudent of ECE, RVR&JC CE
Guntur, A.P India,
venkatasaikiranorsu@gmai

V,Nithin Raju
Student of ECE,
RVR&JC CE,
Guntur, A.P India,
vnithin2605@gmail.com

Abstract — Firefly algorithm is used for codebook generation , the codebook generation is usedin vector quantization for compression of speech signal.The codebook is generated using LindeBuzo Gray for VQ of speech signals is optimized. Using firefly optimization algorithm the optimization is done on the codebook mainly to reduce spectral distortion that is obtained in theoutput of speech signal after compression.The performance measure of optimization algorithm is done by means of time complexity,spectral distortion,computational complexity and memoryrequirements.The performance of VQ is compared with and without optimization.

Keywords—*Vector quantization, Speech compression, Linde-Buzo-Gray, Firefly.*

I.INTRODUCTION

Speech processing isthe study ofspeech signals and the processingmethods ofsignals. Speechsignal transmission requires a large amount of bandwidth which is really expensive.So In orderto overcome this problem we use quantization to compress the speech signal before transmission which results in the usage of less bandwidth. The major important technique for signal compression isVector Quantization (VQ), which is to be optimized. The Vector Quantization (VQ) is one of the block coding technique that quantizes blocks of data instead ofsingle sample. VQ exploitsrelationexisting between neighboring signalsamples by quantizing them together, the goal of VQ code- book generation is to find an optimal code book that yields the lowest possible distortion when compared with allother code books of the same size. VQ performance is directly proportional tothe code-book size and the vector size**.**

Firefly algorithm is used for codebook generation the codebook generation is used in vector quantization for compression of speech signal there are different methods for codebook generation like LBG(Linde- Bu zo-Gray), BAT algorithm Honey Bee Mating algorithm ,Hybrid Cuckoo search, PSO. Linde—Bu zo—Gray (LBG), a traditional method of vector quantization (VQ) generates a local optimal codebook which results in lower PSNR value.

In this paper,the codebook is generated using Linde Buzo Gray for VQ of speech signals is optimized. Using firefly optimization algorithm the optimization is done on the codebook mainlyto reduce spectral distortion that is obtained in the output of speech signal after compression.The performance measure of optimization algorithm is done by means of time complexity,spectral distortion,computational complexity and memory requirements.The performance of VQ is compared with and without optimization.

II VECTOR QUANTIZATION

Vector quantization is an example of lossy compression method used in signal processing to reduce the number of bits needed for representing a signal by means of dividing it into small non- overlapping vectors and encoding each vector using a codebook. This codebook is made up ofsome code vectorswhere invention is to identify the most suitable code vector in the codebook that can represent every vector from the signal. The objective of this process is to minimize distortion between original and reconstructed signals obtained from decoding a book of codes. Linde-Buzo-Gray (LBG) algorithm usually generates such a book, since it partitions training data into clusters effectively. In general, vector quantization remains one of the best ways for reducing data rates at acceptable quality levelsconcerning signals.

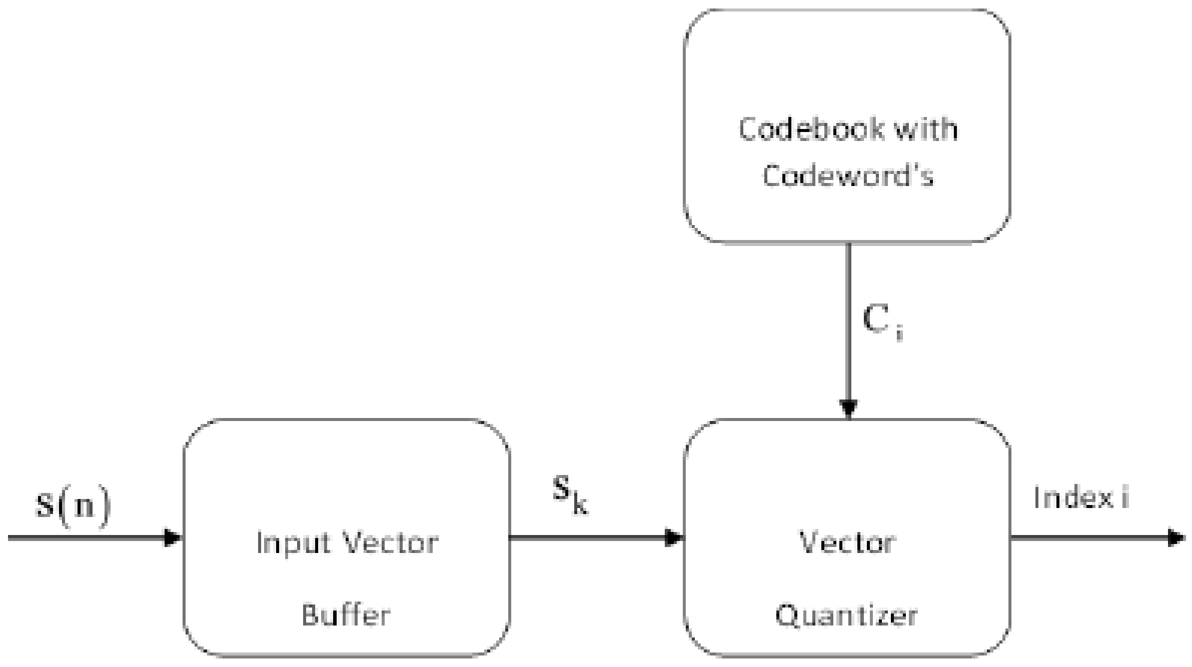


Figure-1. Block diagram of Vector Quantization

III.FIREFLY OPTIMIZATION ALGORITHM

In the firefly algorithm, a metaheuristic optimization method developed by Xin-She Yang, the movement and interaction of the agents within the algorithm are inspired by the bioluminescent communication of fireflies. The foundational principles of this algorithm are articulated through three idealized rules that abstract the natural behavior of fireflies into a computational framework:

(1) Fireflies in the model are considered to be gender-neutral, enabling attraction between any two fireflies irrespective of sex;

(2) The attractiveness of a firefly is directly correlated with its luminosity; therefore, a firefly exhibiting lesser brightness will gravitate towards a more luminous counterpart**.**

If there is no brighter one than a particular firefly, it will move randomly. As firefly attractivenessone should select any monotonically decreasing function of the distance ri,

j = d(xj,xi) to the chosen jth firefly, e.g. the exponential function ri,j=||Xi-Xj||.

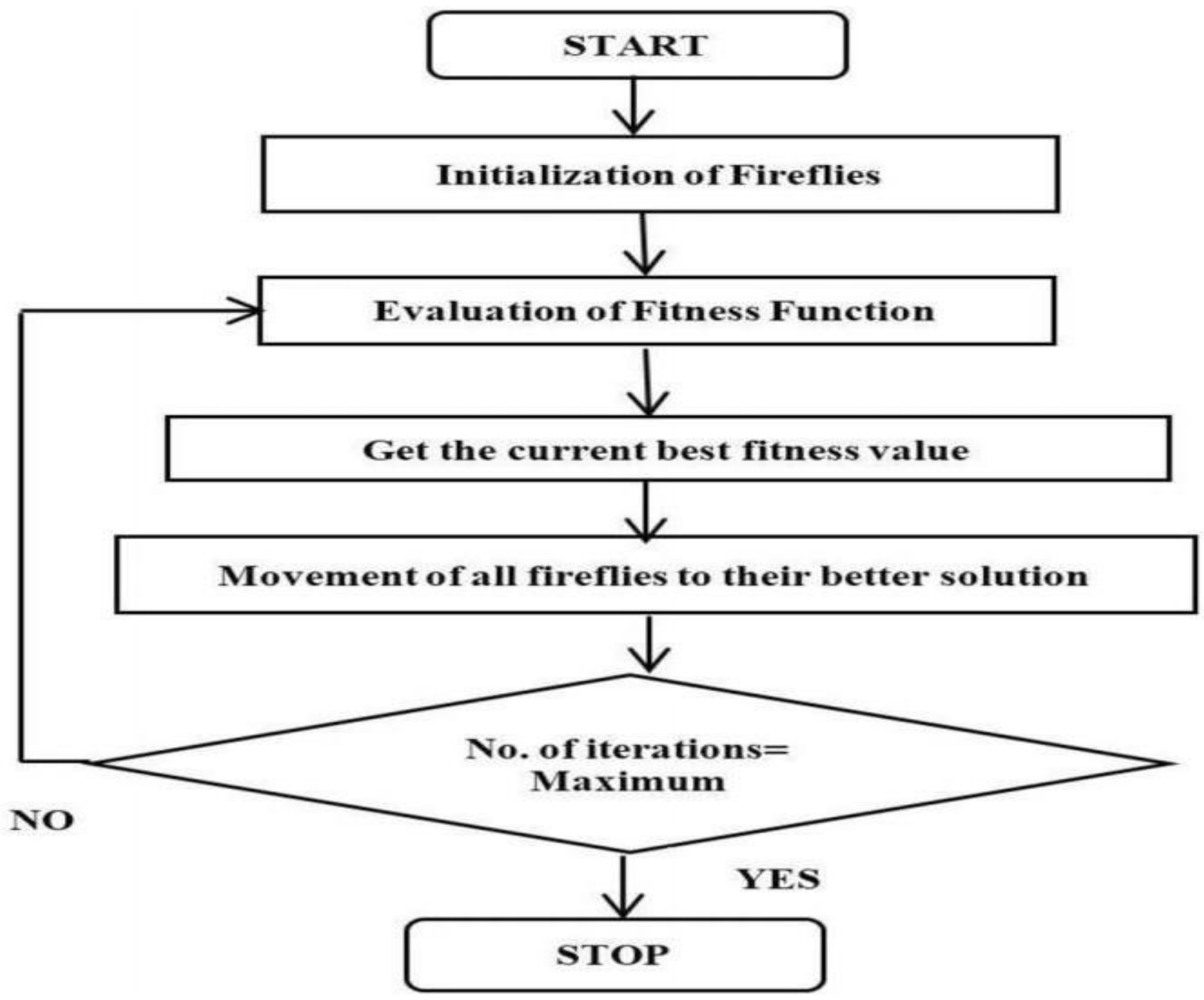
Fitness Function for firefly algorithm:

$$Fitness(C) = \frac{1}{D(C)} = \frac{N_b}{\sum_{j=1}^{N_c}\sum_{i=1}^{N_b} \mu_{ij} \cdot \left\| x_i - c_j \right\|^2}$$

Where Xi is the ith input vector and Cj is the jth codeword of size Nb.

Where Nc is the codebook size.

Where Nb is the codeword size.



IV.STEPS TO IMPLEMENT FIREFLY ALGORITHM

STEP 1:Involves initializing the LBG algorithm by setting the codebook to one of the initial solutions, followed by the random generation of a set of initial trivial solutions, denoted as Xi i=1,2,...,m−1. Each solution represents a codebook with nc codewords. Additionally, this step provides the parameters α,β0 the maximum cycle number L, and .Letl=0 denotesthe initializationstage.

Step 2 :Involves selecting the best solution from all the solutions and defining it as themaximum Xi

, i.e., the solution with the highest fitness. This best solution is then randomly moved to adifferent position.

imax=arg maxi Fitness(Xi)

Ximax=arg maxXiFitness(Xi)

Step 3: In Step 3, each solution Xj calculates its fitness value analogous to the brightness of a firefly. Subsequently, for each solution Xj,this step identifies another solution Xi with greater brightness and moves towards it according to the following equations.

ri,j=||Xi-Xj||=k=1Ncl=1L(Xi,kl-Xj,kl)^2

β=β0e-γi,j

Xj,kl=(1-β)Xi,kl+βXj,kl+vj,kl

Where the vi,kl=V(0,1) is a randomly number

Step 4: The best solution, denoted as maxXi,the **will randomly change its position** following equation.

Ximax,kl=Ximax,kl+vimax,kl Where

the vi,kl=V(0,1) is a randomly number

Step 5 involves checking the termination criterion of the algorithm. If the current cycle number

V. SPECTRAL DISTORTION MEASURE

For a speech coding system to achieve transparency—where the effects of quantization are imperceptible to the listener—the average spectral distortion must be maintained below 1 dB. This measurement involves a frame-by-frame comparison of the Linear Predictive Coding (LPC) power spectra of the original and quantized speech signals. The overall spectral distortion is subsequently derived by averaging these individual frame distortions. This ensures that the coded speech retains a high fidelity, closely resembling the original signal.

$$SD_i = \sqrt{\frac{1}{(f_2-f_1)} \int_{f_1}^{f_2} [10\log_{10} s_i(f) - 10\log_{10} \hat{s_i}(f)] df (db)}$$

0 to 4000 Hz. The average ormean of the spectral distortion SD is given by equation Where Si(f) and ˆSi(f) the LPC power spectra of the unquantized and quantized ith frame respectively. The frequency "f" is expressed in Hz, while "f1" indicates the frequency range.For narrowband speech coding, the frequency range in use is

SD=1Ni=1NSDi

The conditions for transparent speech coding are:

1. Average spectral distortion (SD) ≤ 1dB.
2. No outlier frames with distortion > 4dB.
3. Percentage of frames with 2-4dB distortion < 2%.

VI. RESULTS

TRANSPARENT SPEECH CODING REQUIRES THAT THE AVERAGE SPECTRAL DISTORTION (SD) REMAINS BELOW 1DB, WITH NO OUTLIER FRAMES SHOWING A DISTORTION EXCEEDING 4DB. ADDITIONALLY, THE PERCENTAGE OF FRAMES WITH DISTORTIONS BETWEEN 2 AND 4DB SHOULD BE LESS THAN 2%.

Bits / frame	SD (dB)	Percentage of outliers

		2-4 dB	>4dB
24(8+8+8)	1.411	0.22	0.03
23(7+8+8)	1.900	0.23	0.03
22(7+7+8)	1.907	0.24	0.03
21(7+7+7)	1.915	0.27	0.10
20(6+7+7)	2.481	0.28	0.10

Table-1. Spectral distortion of LBG Vector quantization

Bits / frame	SD (dB)	Percentage of outliers	
		2-4 dB	>4dB
24(8+8+8)	1.356	0.16	0.0126
23(7+8+8)	1.700	0.206	0.05
22(7+7+8)	1.812	0.24	0.06
21(7+7+7)	1.850	0.21	0.08
20(6+7+7)	2.450	0.265	0.19

Table-2. Spectral distortion of Fire Fly Vector quantization

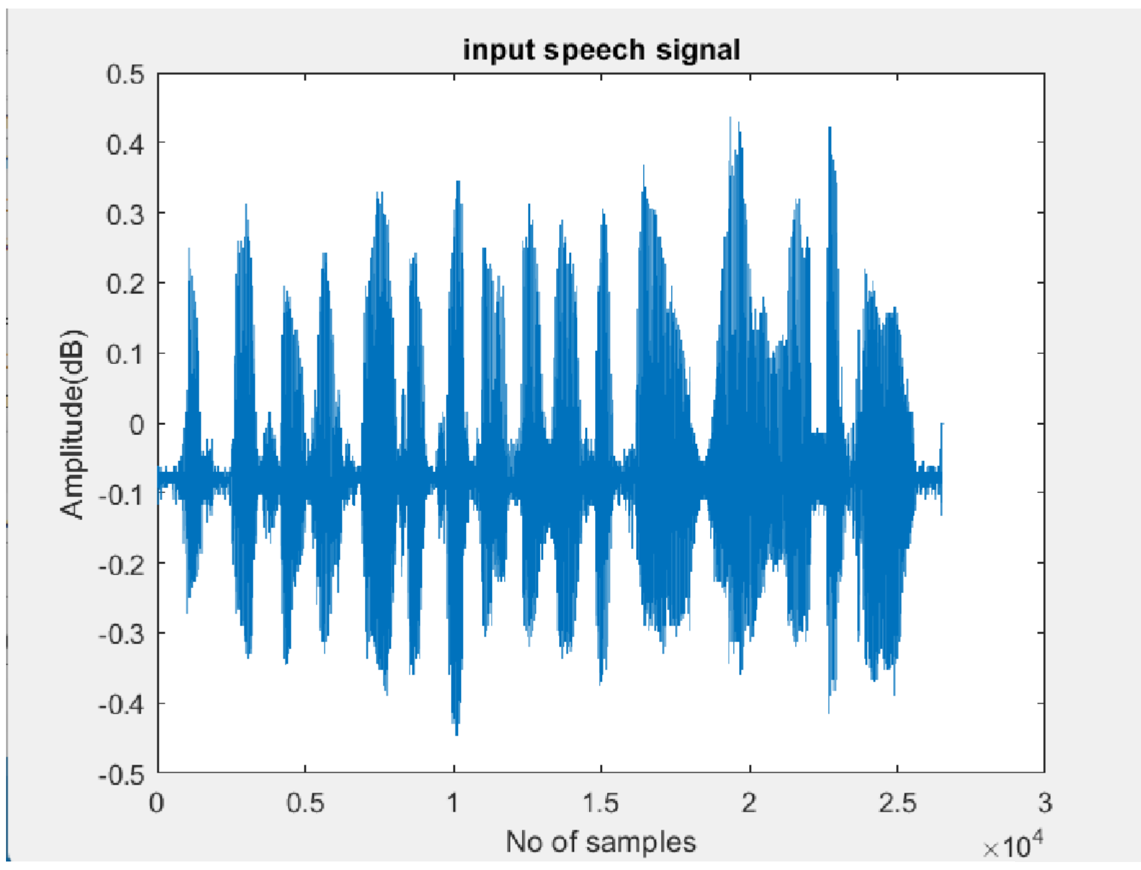


Figure-2(a). Input Speech **Signal**

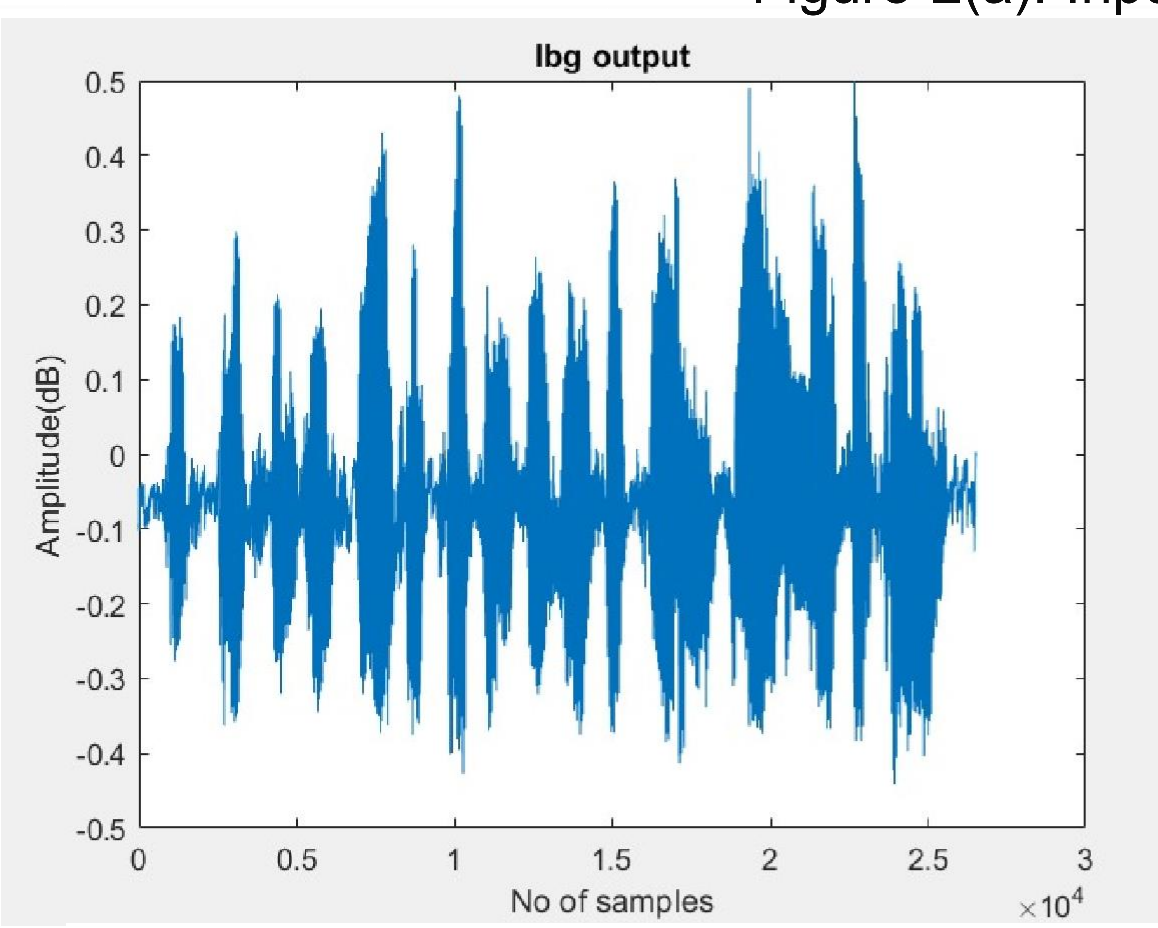


Figure-2(b). LBG Speech Signal (8-**bit)**

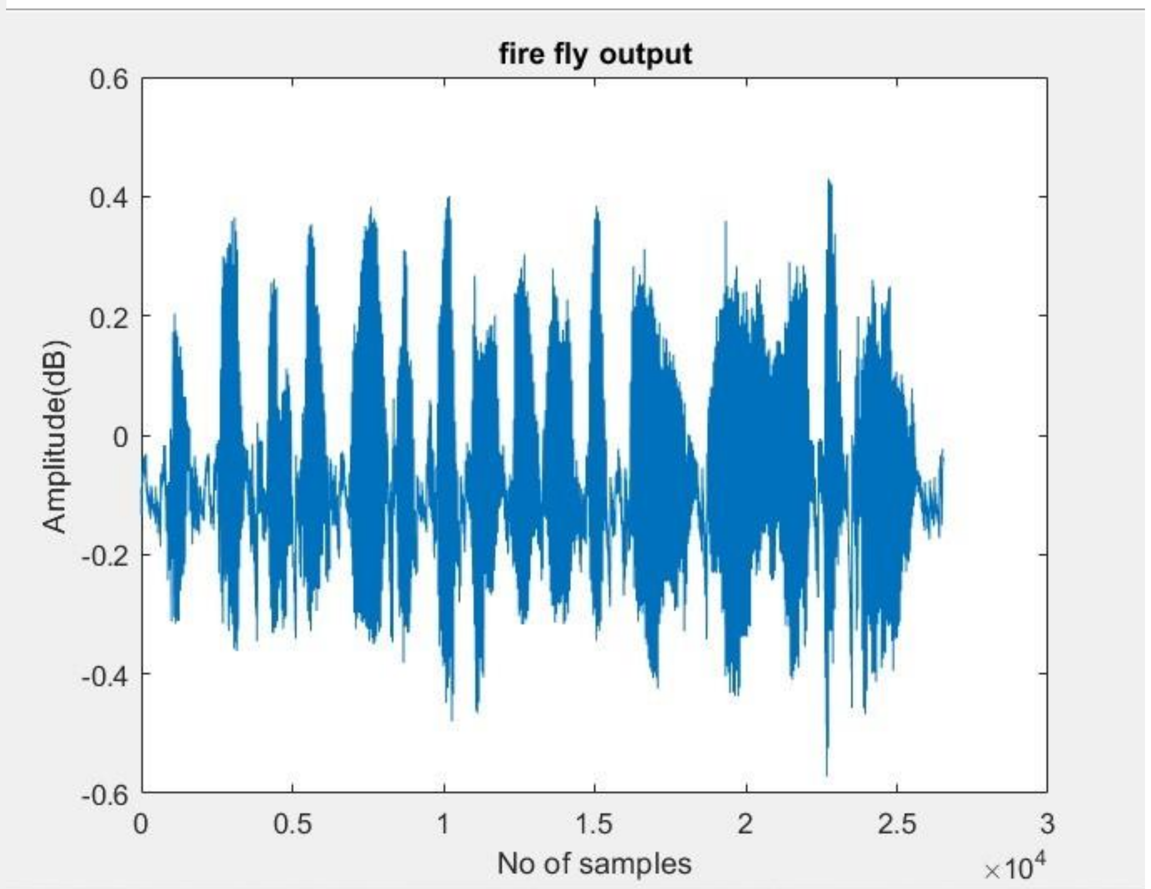


Figure-2(c) Firefly Speech Signal (8-**bit)**

VII . CONCLUSION

In conclusion, the Firefly algorithm presents a promising approach to optimizing codebooks for speech signal compression, leading to a significant reduction in spectral distortion. By harnessing firefly-inspired behavior, this algorithm enhances the efficiency of codebook generation, offering a valuable complement to the established LBG algorithm. The study underscores the potential of the Firefly algorithm in advancing speech processing techniques and optimizing bandwidth utilization within communication systems.

VIII . REFERENCES

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