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A Secure Speech Communication Framework for the Embedded System Powered by the High-Frequency Technique – A Study

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ABSTRACT

Cryptography is the art of information protection so that only those for whom the information is meant can able to read and process. It is the science or technique of transforming a message known as 'Encryption' and then re-transform the message back to its original form called 'Decryption'. Cryptography is of two types, namely symmetric key and asymmetric key cryptography. For the development of this paper, we have used asymmetric key cryptography with eight different sound signals. These signals are recognized using Python script and then is matched with the original signals, it will be encrypted using the ElGamal algorithm, a type of asymmetric key cryptography encryption technique. The encrypted message is digitized and sent through a channel towards the receiver end with the help of the High-Frequency Shift Keying (FSK) modulation. At the receiver end, the signal is demodulated and then decrypted to obtain the original signal. This signal aimed to match with the original voice signal that was encrypted and sent from the transmitter. The equality ratio turns out to be around 70%. Finally, in this work, it has been established that a voice signal can be easily verified and communicated from one end to another using a secure communication framework.

Keywords
Speech Recognition, Cryptography, ElGamal, Frequency Shift Keying, Reflex Klystron

Introduction

Speech communication is an important aspect of our life. Security of speech to maintain its confidentiality, proper access control integrity and availability has been a major issue in speech communication. Therefore, protection of speech passwords or data from misuse is essential. Today in the generation of electronic gadgets, the necessity to prevent data from miscreants is increasing day by day. Cryptography is the process of utilization of codes to prevent anyone from violating speech security. Speech protection can be accomplished by changing the original speech by any means to some other speech codes, so that if someone gets that speech employing hacking then also it must remain in useless bits of speech for that person. This process can be achieved by encrypting that speech by some means of algorithms that are known to the sender and on the other side, similar decryption algorithms must be known to only the desired receiver such that it can convert that encrypted speech back to the user understandable data or signal. To improve the protection mechanism, the ElGamal algorithm [1] (named after its author Taher ElGamal in 1985) is one of the most popular the ElGamal encryption system is an asymmetric key encryption algorithm for public-key cryptography which is based on the Diffie–Hellman key exchange algorithms that are used to ensure speech communication security. It consists of two main cryptographic processes. Firstly, a public key is used to convert an input speech into an unrecognizable encrypted output called cipher speech (encryption process), which makes it practically infeasible to recover the original speech without the encryption key. Secondly, a private key is used which converts the unrecognizable speech back to its original form (decryption process). We can use any other pre cryptography algorithms. Its security depends upon the ability of a hacker to compute discrete logarithms. Encrypted data can be transmitted using FSK digital modulation technique [2]. Here FSK is generated using reflex klystron [3]. Frequency Shift Keying (FSK) is one of the popular digital modulation techniques in which the frequency of the carrier signal changes according to the variation digital message signal. The frequency of the output of an FSK modulated wave is high for binary high input and is low for binary low input. It plays an important role in long-distance communication. Reflex klystron is a microwave generator where velocity modulation technique has been utilized to form a high energy density bunch of electrons which suitably reflect to generate high-frequency RF oscillation in a re-entered cavity. It was used as a local oscillator in some radar receivers and a modulator in microwave transmitters in the 1950s and 1960s. Demodulation and decryption are done at the receiver.

The organization of this paper is as follows:
After an introduction in the first section, the literature Survey has been done next. Afterward, an overview of the proposed method has been introduced, and subsequent Implementation has been done using the experimental setup. Then the theoretical concepts of the Secure Speech Communication framework using FSK modulation with help of a Reflex klystron have been considered. Finally, the experimental setup is described in the next section, followed by experimental results.

Literature Review

The conventional MFCC used in [4], [5], [6], and [8] has the disadvantage in removing the specific band noise, has inherently low recognition rates. We have used Noise

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reduction using spectral gating filtering. This algorithm is based on the one outlined by Audacity for the noise reduction effect. The disadvantage of [7] and [9] is that they can recognize voice signals of a very short period containing at the most one word. Our study deals not only with voice clips containing one word but are also able to deal with voice clips containing several words. This is an enormous advantage over the above-mentioned literature. Since most of the voice recognition systems required in the present world need to handle voice clips containing multiple words spanned over a long interval. In [10] the accuracy of voice recognition was not sufficient; we have improved the recognition accuracy by employing a digital filter. In [11] and [12], the degree of effect of voice disguise on the recognition rate varies with different disguising types. So, it is not easy to understand if a voice is disguised. Our system can easily recognize a disguised voice because it compares the input speech signal and therefore the reference speech signal and allows the communication to happen when the equality ratio is over 0.6. Experimental results in the system have shown [15] that a disguised voice could not achieve an equality ratio of a minimum of 0.6 which has used the LabView Programming Model. LabView has several disadvantages like a lot of memory is needed and also time-consuming. This developer edition is very costly and also has a complex operation. We have used Python which is an open-source language and resource-efficient. We used Jupyter Notebooks embedded in Anaconda which is a well-known software for executing Python programs. Several other IDEs are available at which open source.

Proposed Methods

Speech samples are recorded using a mobile recorder in .mp3 format. But .wav format is desirable for working on the speech sample. Therefore, speech samples in .mp3 format are converted to .wav format using one converter application. Plotted the amplitude vs. time graph for each of the speech samples in MATLAB, which are uploaded into a python-based voice identification system. Jupyter notebooks are embedded in Anaconda which is a very well-known software for executing Python programs. Now, when a person speaks his speech is compared with the recorded speech samples. If it is matching with one of the speech samples, then he is an authenticated speaker and his speech is processed for transmission to the receiver. Otherwise, he is an unauthenticated speaker and transmission to the receiver will not take place. After a match is found, the spectrogram of the corresponding speech sample is plotted after eliminating the noise. ElGamal algorithm is applied on noise eliminated signal for encryption of speech signal. or Any other asymmetric cryptography algorithm can use instead of the ElGamal algorithm. Digital signal was then passed through Reflex Klystron to convert this digital signal into the modulated signal using FSK (Frequency Shift Keying) and transmitted to the receiver as shown in Figure:1. Reflex Klystron will assign two frequencies where high frequency (f_1) is assigned for binary high input and low frequency (f_2) is assigned for binary low input. At the receiver, to identify f_1 and f_2, the FSK signal is passed through a coupler which divides the corresponding signal into two parts. These two parts contain both f_1 and f_2 frequencies. The resulting two signals are passed through two different resonating cavities of frequencies of f_1 and f_2 to identify them. The resulting two signals are then summed up using an adder circuit to get the original speech signal. This signal is amplified and applied to DAC (Digital to Analog Converter) to get back the analog signal. ElGamal decryption algorithm is applied on analog signal for decryption and get back original speech signal which is spoken as shown in Figure: 3. We know the Characteristic curves for the reflex klystron (2K25) and reflex klystron play impartment role in our paper. Both repeller voltage vs output power and frequency characteristic curves combine in a single graph to explain this high-frequency FSK system. After observation of combined characteristics selects maximum efficiency mode for obtaining operative power and frequency [3].

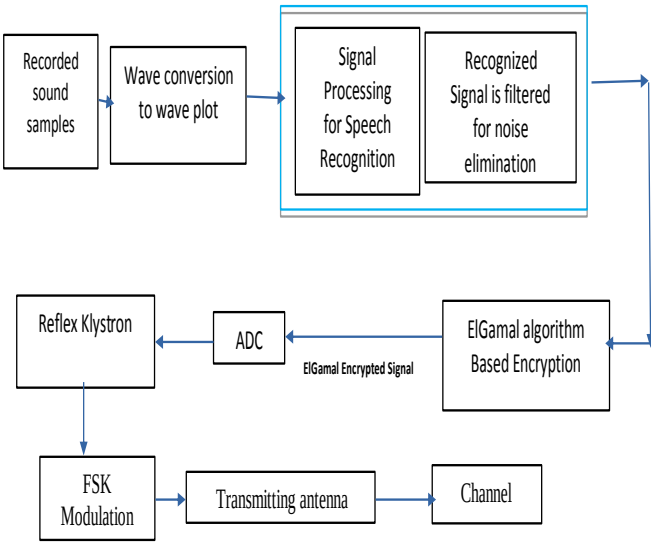

Figure.1. voice authentication, Encryption, and modulation Block

Frequency Shift Keying is a well-known digital modulation technique. Here the frequency of the carrier signal varies according to the digital signal changes.

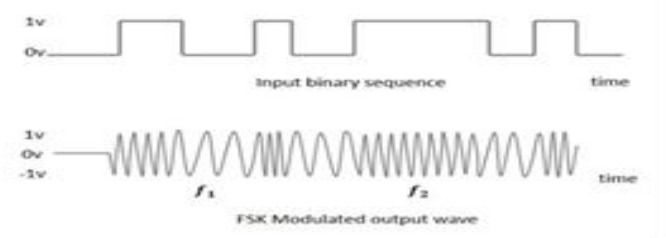

Figure.2. Graphical representation of Frequency Shift keying [2]

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FSK is a type or scheme of frequency modulation. The output of an FSK modulated wave is high in frequency for a '1' i.e., High input and is low in frequency for a '0'i.e. Low input. The binary 1s and 0s are called Mark and Space frequencies. Figure: 2 is the diagrammatic representation of the FSK modulated waveform along with its input. This high-frequency FSK is graphically represented in figure 4.

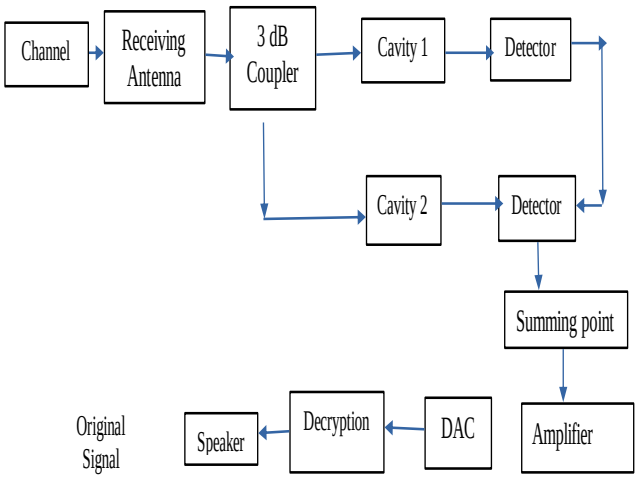


Figure.3. Demodulation and decryption process at the receiver

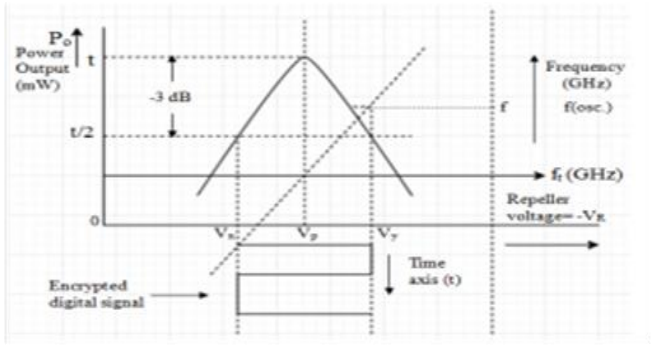


Figure.4. Graph of klystron characteristics using external modulation [3]

Encryption and Decryption Technique

- **Key Generation**
  - Select a large prime as a *q*
  - Select x *to* be a member of the group **G** = < *Zq**, X >, *x* must be "$1 \le x \le q-1$"
  - Select g *to* be a primitive root (generator) in the group **G** = < *Zq**, X >
  - $y = g^{x} \bmod q$
  - Public key ← (*g*, *y*, *q*)
  - *Private key* ← *x*
- **Encryption**
  - Select a random integer *r* in the group **G** = < *Zq**, X >, *r* must be "$1 \le r \le q-1$"
  - $C_1 = g^{r} \bmod q$
  - $C_2 = (p \,.\, y^{r}) \bmod q$ // *p* is the plaintext
- **Decryption**
  - $P = [\, C_2 (C_1{}^{x})^{-1} \,] \bmod q$

Figure:5. ElGamal algorithm [1]

ElGamal encryption system is an asymmetric key encryption algorithm used as public-key cryptography. The basic of this algorithm is the Diffie–Hellman key exchange. It was described by Taher ElGamal in 1985. ElGamal encryption is used in the free GNU Privacy Guard software, recent versions of PGP, and other cryptosystems. The Digital Signature Algorithm (DSA) is one variant of the ElGamal signature scheme, which should not be confused with ElGamal encryption. ElGamal encryption can be defined over any cyclic group G, as a multiplicative group of integers modulo n. Its security depends upon the difficulty of a certain problem related to computing discrete logarithms. Like other cryptographic algorithms, ElGamal Algorithm has three steps, Key generation, Encryption, Decryption as in Figure 5.

Proposed Methodology

1. Start
2. Speech samples are recorded using the mobile recorder.
3. Conversion into.wav format for ease.
4. Plotting the amplitude vs. time graph for each of the speech samples in MATLAB/Python.
5. Uploading it into Python for further analysis.
6. Voice recognition is done by matching with a reference stored speech keyword database.
7. After a match is found, the spectrograph of the corresponding speech sample is plotted in Python after eliminating the noise.
8. Elgamal algorithm or any other algorithm is applied on noise eliminated signal for encryption of speech signal.
9. Digital signal was then applied to Reflex Klystron to convert this digital signal into FSK (Frequency Shift Keying) and transmitted to the receiver. [3]
10. At the receiver, to identify f_1 and f_2, the FSK signal is passed through a coupler which divides the corresponding signal into two parts. These two parts contain both frequencies f_1 and f_2 in the same phase. [16,17]
11. The resulting two signals are passed through two different resonating cavities of frequencies of f_1 and f_2 to identify them and then these output voltage levels are summed up using a circuit to get the original speech signal.
12. ElGamal decryption algorithm or any other decryption algorithm (whichever is applied in Step 8) is applied on analog signal for decryption and get back original speech signal which is authenticated in Step 6.
13. Stop

Data Analysis

The relevant spectrograms obtained from the voice signal preceded by the plotting of wave plots and recognition and implementation of the ElGamal algorithm on this sound

signal are shown respectively in Figure 6 and Figure 7. It shows two such samples used for recognition. The spectrograms after recognition of the correct voice signal and distinguishing its components are shown below in Figure 8.

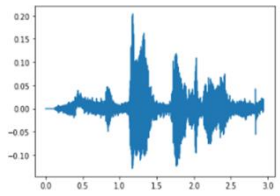
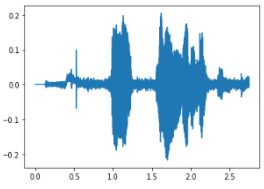


Figure: 6 Sample-



Figures: 7 Sample-2

The sound wave is further processed to plot its harmonic, percussive, and full power spectrogram. This is depicted in Figure 9. The ultimate stage in the encryption stage involves implementing the ElGamal algorithm. The waveforms are shown in Figure 10

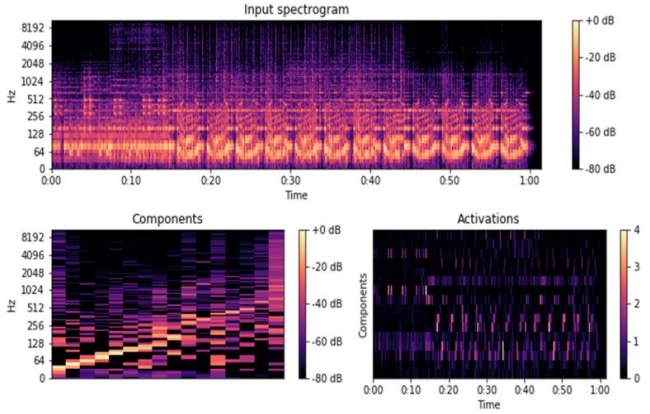


Figure.8 The spectrograms after recognition of the correct voice signal and distinguishing into its components

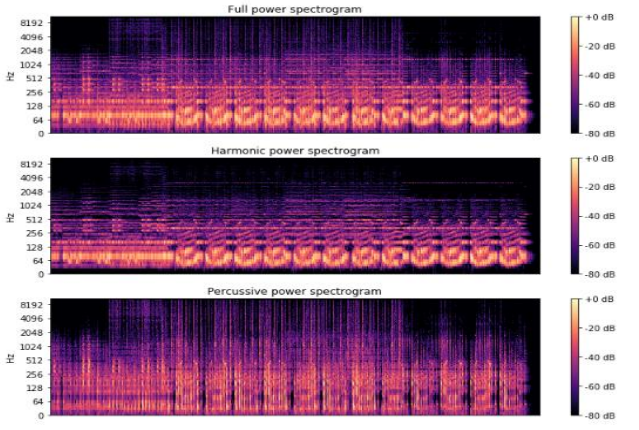


Figure.9 The sound wave is further processed to plot its harmonic, percussive, and full power spectrogram. These breakdowns are suitable when the sound analysis is done at higher levels of processing.

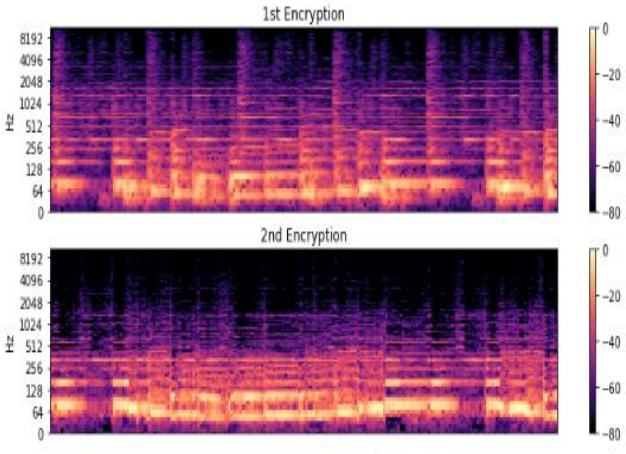


Figure.10 The ultimate stage in the encryption stage involves implementing the ElGamal algorithm. The Encrypted waveforms are shown above.

Results

The recovered waveform after applying the decryption algorithm is shown below in Figure 11.

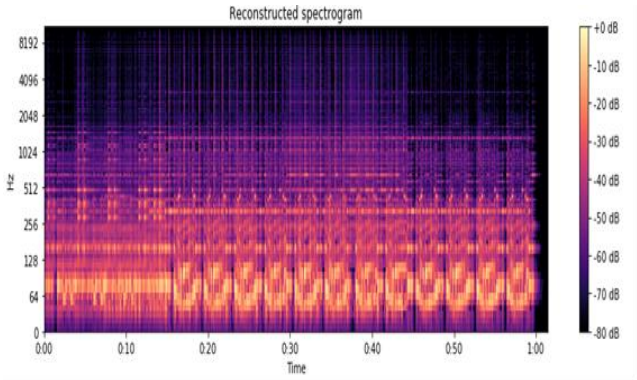


Figure.11. Reconstructed Spectrogram

After that, the same way [17] demodulate the signal at the receiver. Senescing two frequencies (F_1 and F_2) and it is shown that the voltage level at these two points (F_1 and F_2) are the same as the previously selected voltage. In these points, one represents binary '1' (marked here V_x) and another binary '0' (marked as V_y). The results were obtained using python with the help of librosa, matplolib, numpy, PIL, and glob. As the results are based on software simulation hence the original and reconstructed spectrograms show almost match.

Conclusion

In addition to ElGamal Algorithm or other encryption (like RSA Algorithm), techniques used a voice-based authentication process. The Recognition of authentic persons gives additional security to our model. Therefore, only authentic person's data would be taken for encryption and finally for transmission. The methodology can be used in a highly secured environment like in defense applications. High-power microwave devices like reflex klystron are used for the generation of FSK modulated signals. The signals are reconstructed after the FSK

demodulation and decryption process. The similarity index of the reconstructed signal is very high concerning the transmitted signal. Regarding security aspect, the ElGamal algorithm has hardness challenge to solve than the RSA algorithm because ElGamal algorithm has a complex calculation to solve discrete logarithms [18].

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