DTMF Tone Generation and Detection Using Goertzel Algorithm with MATLAB

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2 authors:

S Nagakishore Bhavanam
University College of Engineering & Technology…

Vasujadevi Midasala
K L University

DTMF Tone Generation and Detection Using Goertzel Algorithm with MATLAB

S Nagakishore Bhavanam [1], Vasujadevi Midasala [2]

[1]Research Scholar, JNT University, Ananthapuram, India.
[2] Asst.Prof., Chalapathi Institute of Engineering & Technology, Guntur, India.
e-mail: satyabhavanam@gmail.com,vasujadevi@gmail.com

Abstract - Dual-tone multi-frequency (DTMF) signalling is a standard in telecommunication systems. This is a standard where keystrokes from the telephone keypad are translated into dual tone signals over the audio link. It has been gaining popularity for some years now because of its numerous advantages over the traditional telephone signalling scheme. In this project DTMF tone generation and the detection can be done with the help of MATLAB. The Goertzel algorithm implementation examines the energy of one of the two tones from an incoming signal at 8 DTMF frequencies to determine which DTMF frequency is present. The main advantage of Goertzel algorithm is it reduces the complexity in the coefficient computation. DTMF detection is used to detect DTMF signals in presence of speech and dialling tone pulses. Besides being used to setup regular calls on a telephone line, DTMF detection is used for computer applications such as in voice mail, electronic mail and telephone banking.

Keywords: DTMF, Goertzel Algorithm, DFT, MATLAB.

I. INTRODUCTION

Dual Tone Multi-Frequency, or DTMF is a method for instructing a telephone switching system of the telephone number to be dialled, or to issue commands to switching systems or related telephony equipment. The DTMF dialling system traces its roots to a technique AT&T developed in the 1950s called MF (Multi-Frequency) which was deployed within the AT&T telephone network to direct calls between switching facilities using in-band signalling. In the early 1960s, a derivative technique was offered by AT&T through its Bell System telephone companies as a "modern" way for network customers to place calls. In AT&Ts Compatibility Bulletin No. 105, AT&T described the product as "a method for pushbutton signalling from customer stations using the voice transmission path." The consumer product was marketed by AT&T under the registered trade name Touch-Tone. Other vendors of compatible telephone equipment called this same system "Tone" dialling or "DTMF".

DTMF signalling has many applications such as telephone dialling, data entry, credit checking, and voice mail system control. A DTMF signal Consists of two superimposed sinusoidal waveforms with frequencies chosen from a set of eight standardized frequencies. These frequencies should be generated and detected according to the CCITT Recommendation. The DTMF system uses eight different frequency signals transmitted in pairs to represent sixteen different numbers, symbols and letters. This table shows how the frequencies are organized:

		High-Group Frequencies			
		1209Hz	1336Hz	1477Hz	1633Hz
Low-Group Frequencies	697Hz	1	ABC 2	DEF 3	A
	770Hz	GHI 4	JKL 5	MNO 6	B
	852Hz	PRS 7	TUV 8	WXY 9	C
	941Hz	*	OPER 0	#	D

Fig.1: Keypad having low and high frequencies

The frequencies used were chosen to prevent any harmonics from being incorrectly detected by the receiver as some other DTMF frequency.

II. DTMF GENERATION AND DETECTION

This project is of "DTMF detection by Goertzel algorithm. The first touch tone telephone installation was in 1963. DTMF signalling uses voice-band tones to send address signals and other digital information from pushbutton telephones and other devices such as modems and fax machines. Analog DTMF detection is done using band-pass filter banks with center frequencies at the DTMF signal frequencies. Digital detection of DTMF is done by several algorithms like goertzel, notch filter etc.

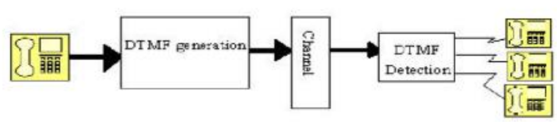

Fig.2 : DTMF communication system

The transmitter of a DTMF signal simultaneously sends one frequency from the high-group and one frequency from the low-group. This pair of signals represents the digit or symbol shown at the intersection of row and column in the table. For example, sending 1209Hz and 770Hz indicates that the "4" digit is being sent.

At the transmitter, the maximum signal strength of a pair of tones must not exceed +1 dBm, and the minimum strength is -10.5 dBm for the low-group frequencies and -8.5 dBm for the high-group frequencies. When not intentionally sending DTMF tones (including the inter-digit interval), any leakage of these tones must not exceed -55 dBm. The frequencies generated by the transmitter must be nominally within 1.5% of the stated values and the receiver must not accept signals that deviate more than 3.5% from the stated values.

The receiver is responsible for performing several checks on the incoming signal before accepting the incoming signal as a DTMF digit:

1. Energy from a low-group frequency and a high-group frequency must be detected.
2. Energy from all other low-group and all other high-group frequencies must be absent or less than -55dBm.
3. The energy from the single low-group and single high-group frequency must persist for at least 40msec*.
4. There must have been an inter-digit interval of at least 40msec* in which there is no energy detected at any of the DTMF frequencies. The minimum duty cycle (tone interval and inter-digit interval) is 85msec*.
5. The receiver should receive the DTMF digits with a signal strength of at least -25 dBm and no more than 0 dBm.
6. The energy strength of the high-group frequency must be -8 dB to +4 dB relative to the energy strength of the low-group frequency as measured at the receiver. This uneven transmission level is known as the "twist", and some receiving equipment may not correctly receive signals where the "twist" is not implemented correctly. Nearly all modern DTMF decoders receive DTMF digits correctly despite twist errors.
7. The receiver must correctly detect and decode DTMF despite the presence of dial-tone, including the extreme case of dial-tone being sent by the central office at 0 dBm (which may occur in extremely long loops). Above 600Hz, any other signals detected by the receiver must be at least -6 dB below the low-group frequency signal strength for correct digit detection.

The values shown are those stated by AT&T in Compatibility Bulletin 105. For compatibility with ANSI T1.401-1988, the minimum inter-digit interval shall be 45msec, the minimum pulse duration shall be 50msec, and the minimum duty cycle for ANSI-compliance shall be 100msec.

Methods for Generating DTMF tones:

- DTMF generation can be done by different methods for analog and digital systems.
- Use special IC for generating DTMF tones. Modems and telephones use this method.
- Generate DTMF tones using soundcard FM synthesizer chip.
- Load sine wave sample to wavetable soundcard memory. Play that sample using two instrument channels at different frequencies.
- Sample all DTMF tone combinations heeded and playback those samples as needed. 8 kHz at 8 bit resolution is enough for that.
- Generate the sample data which is played back using software.
- Our project is concentrating on the last method, because it is the most generic way to do the DTMF generation. You can use this method with every sound card which can play back samples and it is as well suitable for DSP implementations also.

III. GENERATING DTMF

The another methods for the generation of the DTMF tones will be

- Polynomial approximation
- Look-up table
- Recursive oscillator

Dual tone generation can be done with 2 sine wave sources connected in parallel. Different method can be used for such implementation:
DTMF signal must meet certain duration and spacing requirements:

- 10 Digits are sent per second.
- Sampling is done via a codec at 8Khz.
- Each tone duration must be >40msec and a spacing of 50ms

Minimum between two digits is required. DTMF generator refers to any electronic device capable of generating dual tone multi-frequency (DTMF) signals used for dialing touch-tone telephones. The DTMF dialing system operates by configuring a keypad in a three column by four row grid representing the numbers 0 through 9 and other special characters such as the # and * keys. The touch pad grid is arrayed by assigning a specific high frequency for each column and a designated low frequency for each row.

When a user presses a digit on the keypad, a dual tone is generated that represents the intersection of the two distinct frequencies assigned for each column and row on the grid. For example, when the "2" digit is pressed on the keypad, a unique audio sinusoidal tone is emitted by mixing a pure high frequency of 1,336 Hz with a pure low frequency of 697 Hz. TheDTMF signal tone generated by the keypad is then transmitted to the local office of the phone company where it is translated or decoded into the appropriate corresponding digits which allow the designated phone number to be dialled. Therefore the tones in keypad are generated by taking one of the frequency from the row selector and the other frequency from the column selector.

These two frequencies combine and give the dual tone at output. The block diagram of DTMF tone generator will be

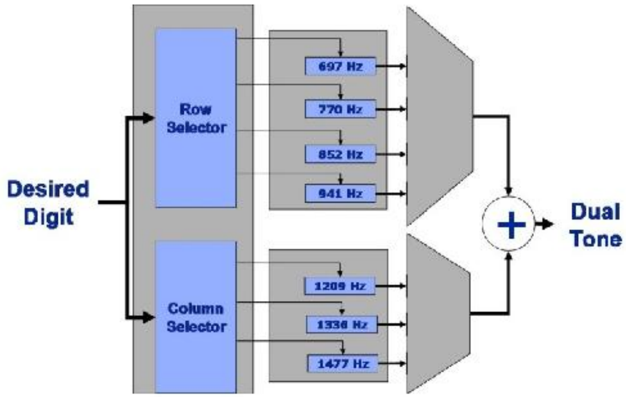

Fig.3 : DTMF tone generator

The first commercial application of a DTMF generator was the introduction of the touch-tone pad dialling system, first offered by AT&T to its customers in 1963. The touch-tone dialling system was demonstrably faster and more convenient than the mechanically based rotary dial pulse system, which it supplanted. After its introduction, touch-tone became the standard dialing system for telephones in the United States and was eventually adopted worldwide.

Touch-tone dialling permits activation and communication with DTMF-compliant equipment. This type of dialing allows users to control answering machines remotely and to activate and interface with many call routing, voice mail systems, or other auxiliary telephonic devices that can decode signals produced by a DTMF generator. Telephones equipped with DTMF-based touch-tone dialling allow consumers to access their account balances at banks, as well as retrieve other information from organizations that provide a telephonic interface based on the DTMF system.

A computer equipped with a sound card and digital audio software is capable of acting as a DTMF generator by producing the dual tone multi-frequencies used on touch-tone telephone keypads. The software program interprets the phone digits and then generates the appropriate audio files that conform to the standardized DTMF paired frequency tones. The dialing process can be activated either by a mouse click or through keyboard commands. This allows for rapid automated computer dialing of outgoing telephone numbers and is used by many businesses.

IV. GOERTZEL ALGORITHM

The Goertzel algorithm is a digital signal processing (DSP) technique for identifying frequency components of a signal, published by Dr. Gerald Goertzel in 1958. While the general Fast Fourier transform (FFT) algorithm computes evenly across the bandwidth of the incoming signal, the Goertzel algorithm looks at specific, predetermined frequencies. Some applications require only a few DFT frequencies. One example is frequency-shift keying (FSK) demodulation, in which typically two frequencies are used to transmit binary data; another example is DTMF, or touch-tone telephone dialing, in which a detection circuit must constantly monitor the line for two simultaneous frequencies indicating that a telephone button is depressed.

Goertzel algorithm reduces the number of real-valued multiplications by almost a factor of two relative to direct computation via the DFT equation.

For a length of N, the Goertzel's series is

$$H_k(z) = \frac{1 - W_N^k z^{-1}}{1 - 2\cos(\frac{2\pi k}{N}) z^{-1} + z^{-2}}$$

Where,

$$k = 0, 1, \ldots, N - 1$$

V. MATLAB SIMULATION RESULTS

A. Generated Waveforms:

The result for generation of number 5 in the telephone keypad specifies of the frequencies of 770Hz of low frequency and 1336Hz of high frequency. The result will be as shown.

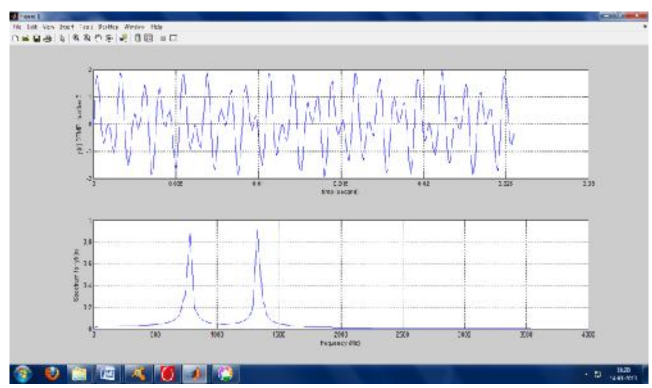

Fig.5.1:Generating waveform for the key “5”.

In the same way the tones can be generated for all the numbers used in this keypad.Therefore the result for the number 7 in the keypad specifies the frequencies of 852Hz of low frequency and 1209Hz of high frequency and the result will be as shown in fig.

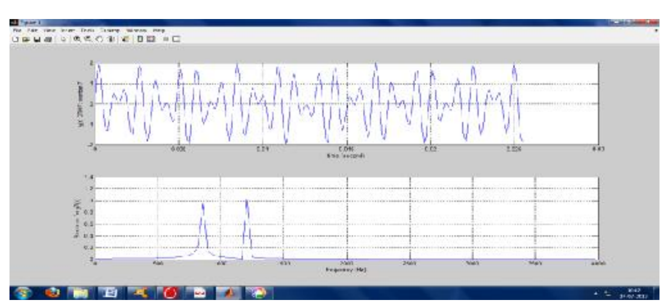

Fig.5.2:Generating waveform for the key “7”.

In the same way the tones can be generated for all the numbers used in this keypad.for example the number 1 in the keypad specifies 697Hz of low frequency and 1209Hz of high frequency the result will be as shown in fig.

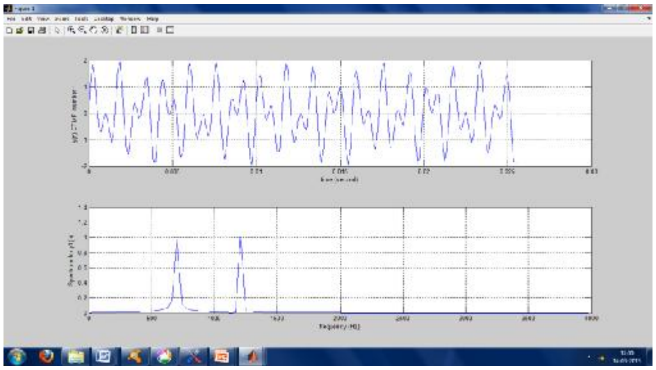

Fig.5.3:Generating waveform for the key “1”.

In the same way the tones can be generated for all the numbers used in this keypad.Therefore the result for the number 2 in the keypad specifies the frequencies of 697Hz of low frequency and 1336Hz of high frequency and the result will be as shown in fig.

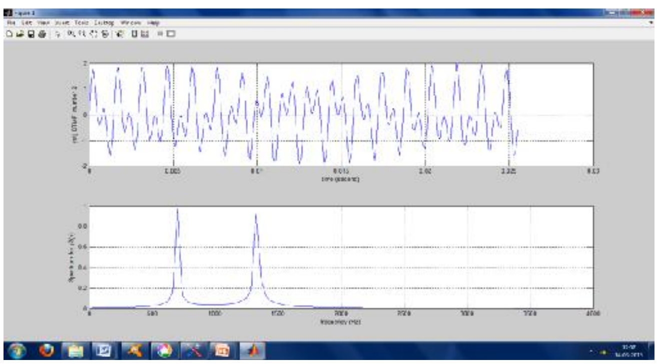

Fig.5.4:Generating waveform for the key “2”.

Therefore the result for the number 3 in the keypad specifies the frequencies of 697Hz of low frequency and 1477Hz of high frequency and the result will be as shown in fig.

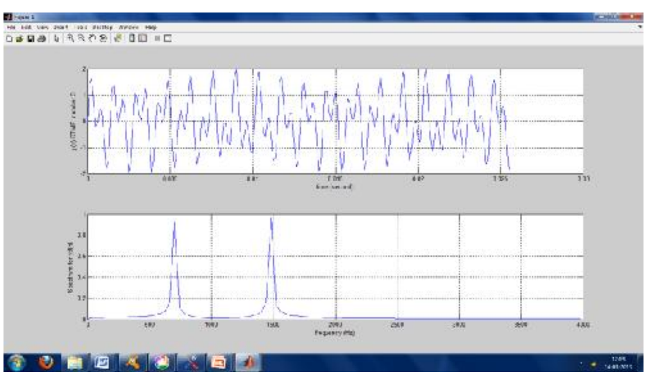

Fig.5.5:Generating waveform for the key “3”.

Therefore the result for the number 4 in the keypad spécifies the frequencies of 770Hz of low frequency and 1209Hz of high frequency and the result will be as shown in fig.

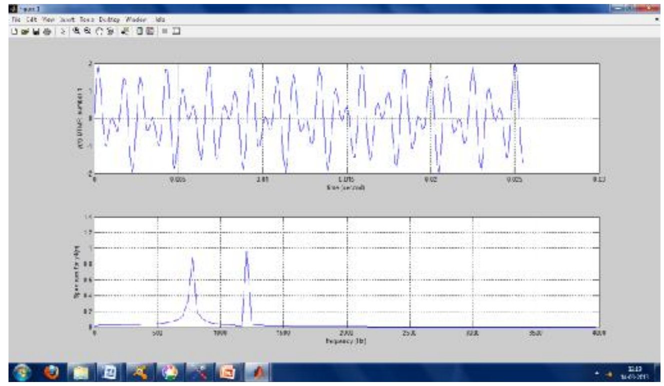

Fig.5.6:Generating waveform for the key “4”.

Therefore the result for the number 6 in the keypad specifies the frequencies of 770Hz of low frequency and 1477Hz of high frequency and the result will be as shown in fig.

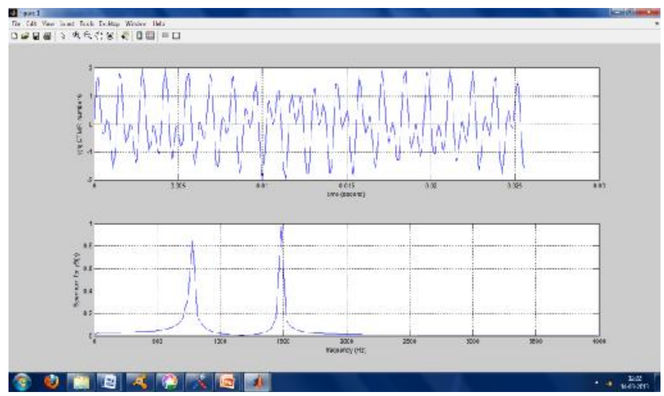

Fig.5.7:Generating waveform for the key “6”.

Therefore the result for the number 8 in the keypad specifies the frequencies of 852Hz of low frequency and 1336Hz of high frequency and the result will be as shown in fig.

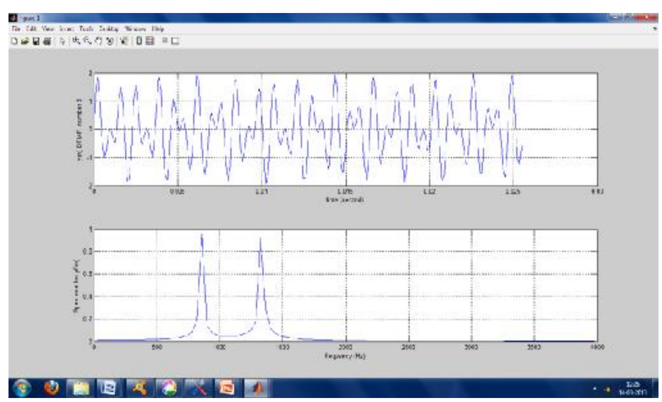

Fig.5.8:Generating waveform for the key “8”.

Therefore the result for the number 9 in the keypad specifies the frequencies of 852Hz of low frequency and 1477Hz of high frequency and the result will be as shown in fig.

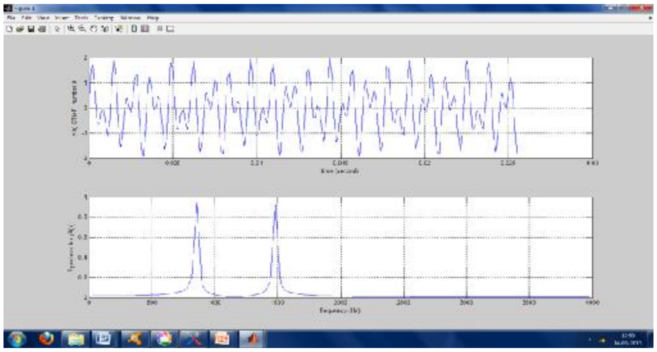

Fig.5.9:Generating waveform for the key “9”.

Therefore the result for the number 0 in the keypad specifies the frequencies of 941Hz of low frequency and 1336Hz of high frequency and the result will be as shown in fig.

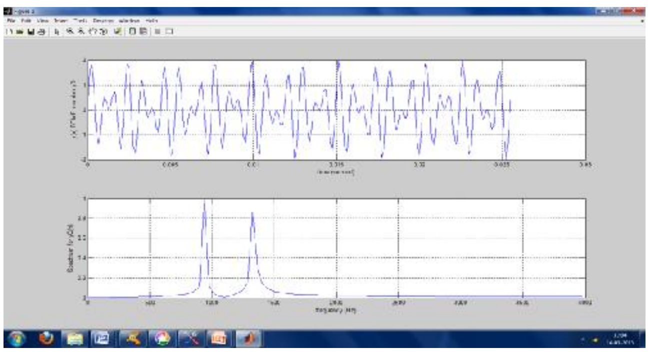

Fig.5.10:Generating waveform for the key “0”.

B. Detected Waveforms:

Result for the key5 in bandpass filter and DFT approach

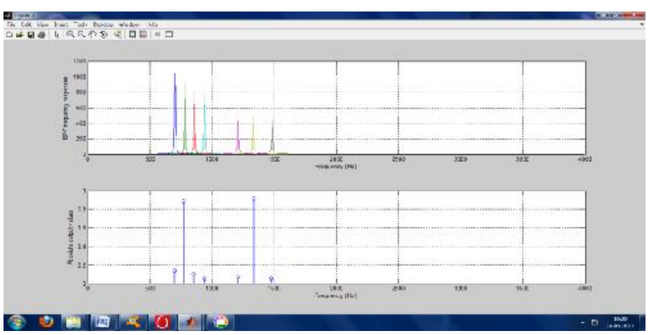

Fig.5.11:detected waveform for the key”5”.

Result for the key7 in bandpass filter and DFT approach

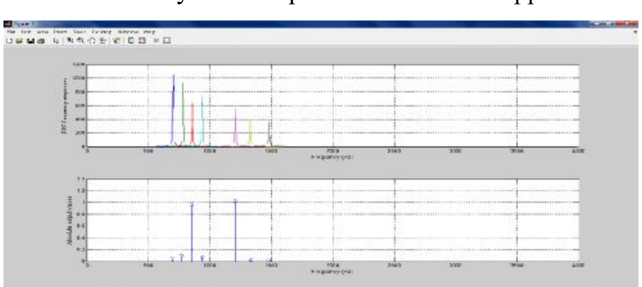

Fig.5.12:detected waveform for the key”7”.

Result for the key1 in bandpass filter and DFT approach

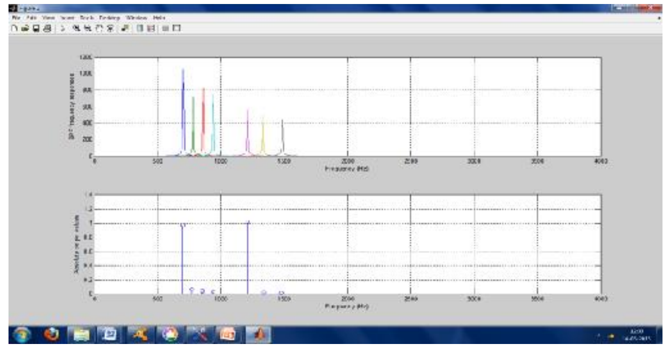

Fig.5.13:detected waveform for the key”1”.

Result for the key2 in bandpass filter and DFT approach

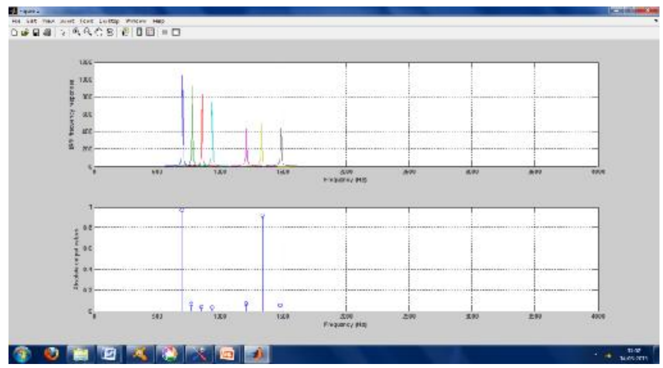

Fig.5.14:detected waveform for the key”2”.

Result for the key3 in bandpass filter and DFT approach

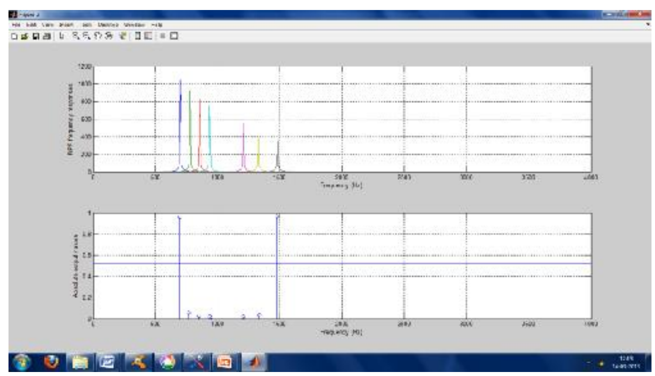

Fig.5.15:detected waveform for the key”3”.

Result for the key4 in bandpass filter and DFT approach

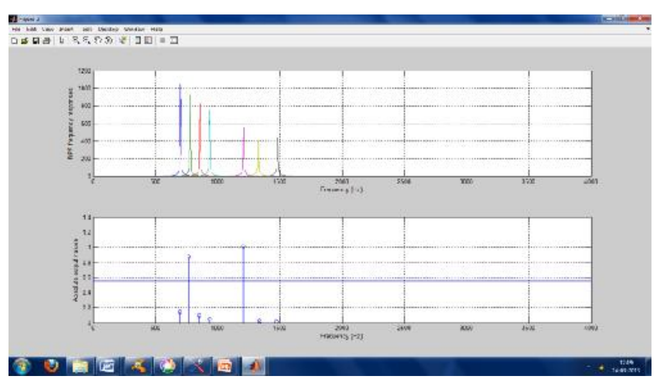

Fig.5.16:detected waveform for the key”4”.

Result for the key6 in bandpass filter and DFT approach

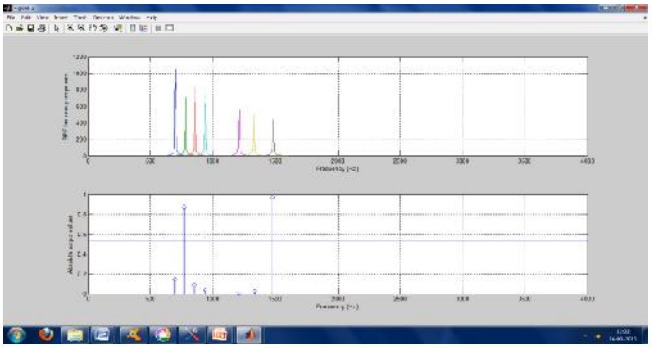

Fig.5.17:detected waveform for the key"6".

Result for the key8 in bandpass filter and DFT approach

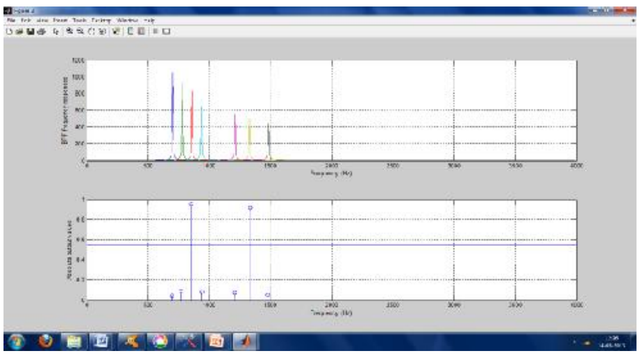

Fig.5.18:detected waveform for the key"8".

Result for the key9 in bandpass filter and DFT approach.

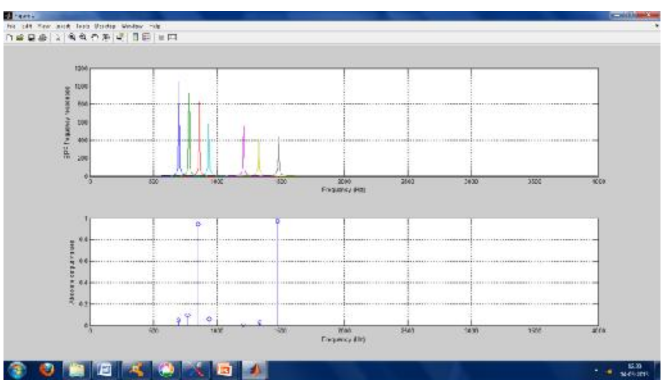

Fig.5.19:detected waveform for the key"9".

Result for the key0 in bandpass filter and DFT approach

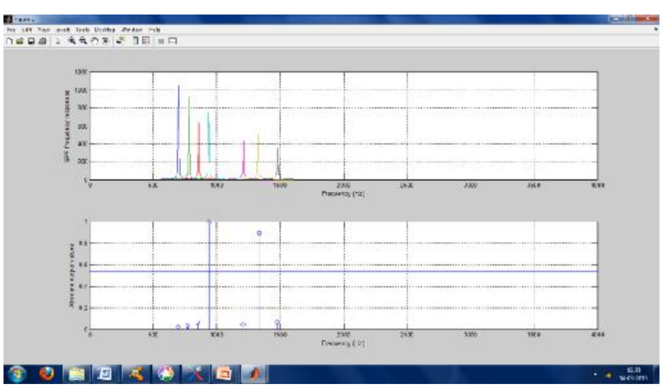

Fig.5.20:detected waveform for the key"0".

VI. CONCLUSIONS

In this paper DTMF tone generation and the detection can be done with the help of MATLAB. The Goertzel algorithm implementation examines the energy of one of the two tones from an incoming signal at 8 DTMF frequencies to determine which DTMF frequency is present. The main advantage of Goertzel algorithm is it reduces the complexity in the coefficient computation. DTMF detection is used to detect DTMF signals in presence of speech and dialling tone pulses. Besides being used to setup regular calls on a telephone line, DTMF detection is used for computer applications such as in voice mail, electronic mail and telephone banking.

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Author Biography

S NagaKishore Bhavanam received his B.Tech degree in Electronics and communication from Acharya Nagarjuna University, Guntur in 2008, M.Tech Degree from JNT University, Hyderabad in 2010. He is currently working as Assistant Professor, Dept. of ECE in University College of Engineering and Technology, Acharya Nagarjuna University, Guntur, India. He is a Research Scholar in the area of Signal Processing & Communications from JNT University, Ananthapur.

Smt. Vasujadevi Midasala received his B.Tech degree in Electronics and communication from Acharya Nagarjuna University, Guntur in 2008, M.Tech Degree from JNT University, Hyderabad in 2011. She is currently working as Assistant Professor, Dept. of ECE in Chalapathi Institute of Engineering and Technology, Guntur, India. Her interesting fields are signal processing, communications and VLSI Design.