A Review of Dual Tone Multi Frequency Technique with Analysis of Simulation Model

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Abstract
Freeing the control system from the burden of the manual local system and unleashing the transition to the wireless control system has become an important success factor for multi application in this field. The rapid development of technology has increased the effectiveness of human and reduced the burden on him; one of these technologies is dual tone multi frequency (DTMF). This technology is considered one of the important wireless systems that are used in applications for remote control of a large and unspecified number of applications, remote controlling household electrical appliances, robots, detection, tracking, listening devices, spying camera and others. In this review article, a DTMF simulation model will be created and its basic components explained in detail, also a comprehensive review of the general effected DTMF applications currently in use, types, most important features and the purpose of their use.
Keywords: Home Automation Systems, DTMF, DTMF Decoder, Remote control, Wireless control

I. Introduction

Reliance on modern technologies has led to a great development in many areas, including the areas of automatic remote control. One of these technologies is the DTMF, this technology is used in important fields that require some early work, for example in factories to operate conveyor belts or electric boilers. In home appliances, when a person is outside the house and requires turning ON/OFF devices such as cooling, ventilation, light and heating. In the areas of espionage, for example, controlling a camera or a listening device, where it is required in these sensitive places that there is no human presence and the purpose of the subject is to obtain information. Relying on DTMF technology for automatic control of turning on and off home appliances, after determining the device's status, whether it is on or off via SMS message on the owner's mobile phone [1]. The mobile phone was used as a remote control to operate the cutting machine, which sends a control signal to the SIM card number of the Sudani One modem, as this modem was used in the automatic answer mode. A DTMF tone is generated when a button is pressed on the phone at the case of call it [2]. Remote control of several home appliances using the DTMF technology and two mobile phones, one of them is used in the remote place, through which commands are issued during the call, and the second is located at home, which is used as a recipient [3]. Controlling a robot from unspecified distances, depending on DTMF technology. This process is done by using two mobile phones, one as a transmitter and the second as a receiver with a DTMF decoder and microcontroller to analyze logical tones and issue the necessary decision in the robot's movement based on the pressed key from the remote mobile [4-7]. The use of DTMF controller to operate multiple protective relays as well as generate voltage-regulating signals to improves the efficiency of photovoltaic cells. The system is used for the purpose of remote control in the central control rooms on solar energy units built in far and remote areas [8]. Designing a system for the purpose of cleaning solar cells by controlling a robot designed for this purpose that relies on DTMF technology to operate and control it, This microcontroller system is installed by Arduino in order to issue the relevant commands to control the robot's motors[9]. Building a surveillance vehicle that can be monitored through WLAN based on HTTP protocols and controlled through a mobile phone based on DTMF technology. This vehicle is used in areas where life risks are very high, such as war zones, remote areas, or monitoring suspicious activities that require monitoring without intervention and presence of human. The work based **image acquisition using Raspberry Pi. and Arduino** [10 -12]. For the purpose of overcoming the inefficiency of the manual irrigation system. Designing the required load control system for the irrigation system using dual-tone multi-frequency (DTMF) and using this system in irrigation will result in less time consumption and can be controlled on a large scale and from a distance [13]. A spy robot that performs surveillance functions in the form of a vehicle equipped with a webcam. This robot is controlled by a mobile phone depend on the DTMF technology. The robot, sends the video to a TV or PC. The purpose of the

research is to make a robot for the purpose of working in dangerous conditions instead of using humans to do so [14]. Designing an electronic circuit based on DTMF technology to control agricultural pumps motors. Implement the design with discrete components or microcontrollers. Instead of previously used available decoders, a new DTMF decoder is designed . The MULTSIM simulation software is used to test the total circuit functions. The use of the design achieves the safe remote control of agricultural pumps' motors without the presence of an operator or any person [15]. Generation and detection of DTMF based of Matlab's GUI to simulate of DTMF using and comparison of triple detection algorithms which are Fast Fourier Transform, correlation scheme, and Geortzel algorithm. based on computational efficiency and noise immunity[16]. Wireless control of an electromechanical arm using two phones based on GSM technology as a transmission medium, and DTMF as a means of controlling the arm during the duration of the call, by pressing the cellular phone keypad during the call [17].

In this review paper, a detailed explanation of the general concepts of the DTMF technology and its components with an explanation of the function of each element without touching on the medium that carries the tone, which is among the existing infrastructures in the country and which is originally used for calling, SMS, as well as the Internet service. Also the review includes the construction and analysis of the DTMF generator and receiver model. Building the basic components of the model includes a bank receiver for a band-pass filter, a spectrogram plot of the generated tones, and a shift register for storing the decoded numbers.

II.   DTMF Technology Concept

Technique generated tones by telephone when the numbers are pressed through call referred to as DTMF. These analogue tones are transmitted with the voice channel [18,19]. Therefore, investing the property of generating tones signals that depend on the uses a combination of hardware components and communication technologies that enable a remote control and management for wide appliances within a home, office, factory control of robotics, alarm, security device, spying, listing, radar and so on. In DTMF signaling, each key on the touch pad is represented by uses two tones. The standard phone keypad has 12 numbered. Also there are **four** special tone denoted by (A, B, C and D). Most mobile phones today use twelve out of sixteen possible tones [20–22] therefore there are 12 distinct tones. The column tone and row tone generated when any key is pressed. As an example, pressing the '2' button generates the row tone 697 Hz and column tone 1336 Hz [23]. Table 1. Shows the process of distributing vertical and horizontal frequencies for phone keypad numbers.

Table no1: Forming frequencies in DTMF

Frequencies Hz	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697	1	2	3	A
770	4	5	6	B
852	7	8	9	C
941	*	0	#	D

The method for calculating the amount frequency of each keypad button is done by adding the row (low) frequency to the column (high) frequency [24].
In other word, the resultant tone is convolution of horizontal and vertical frequencies. The mathematical expressed of the resultant tone can be as follows:

$$f(t) = A_H \sin(2\pi f_H t) + A_L \sin(2\pi f_L t).$$

Where f_H , f_L are the high and low frequency and A_H, A_L is the amplitude of the each frequency [25].
Accordingly, the main characteristics of DTMF frequencies can be summarized as follows:
1. The frequencies were chosen to avoid harmonics.
2. The difference between any two frequencies does not equal any of the frequencies.
3. No frequency is a multiple of another.
4. The sum of any two frequencies does not equal any of the frequencies.

Table 2, shows a full clarification for everything that came in the concept and idea of configuring the frequency of tones associated with each of the standard keypad phone buttons and also referred to in the above equation.

Table no 2: Standard keypad and tone frequencies

Keypad Number	Low Frequency Hz	High Frequency Hz	Tone Frequency Hz
1	697	1209	1906
2	697	1336	2033
3	697	1477	2174
4	770	1209	1979
5	770	1336	2106
6	770	1477	2247
7	852	1209	2061
8	852	1336	2188
9	852	1477	2329
*	941	1209	2150
0	941	1336	2277
#	941	1477	2418

III. General Structure of Remote Control System Based DTMF Technology

The general diagram of remote control system based on DTMF technology explains in figure 1. The system consists of five units which are:

1. transmitter part, which represents the tone generation part consisting of a mobile phone that generates tones during a call and sends them over a GSM network.
2. GSM network represents any mobile network operating in the area and has good and effective coverage.
3. Receiver part, usually consists of a mobile phone, which is may be a simple mobile device and does not have to be a smart phone, because the function of this device only to receive tones from the GSM network and transfer them to DTMF decode. CM8870 integrated circuit (IC), which is the tone decoder, usually the common commercial IC type is used to convert the tones from analogy form to 4-bits digital tone [26-28].
4. The control part can be implemented by using any kind of microcontrollers, Arduino board, and discrete physical logical circuits or by any means to achieve the required control function. Then the output of this part must be supply to load through driver and relay.
5. Load may be any type of electrical device (lamp, TV, camera, water pump, fan, air-condition ....etc), robot, security device, alarm and so on.

These are almost the main components of any system that relies on DTMF technology, with the addition of some other components, depending on the type of application and the place of its use.
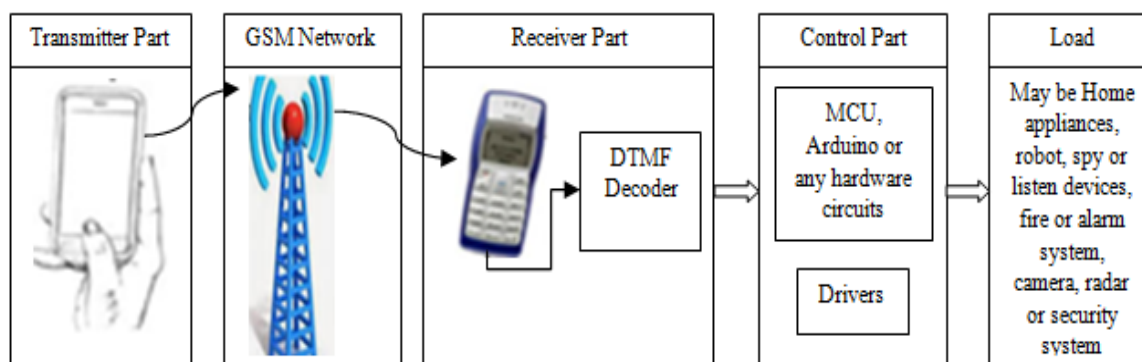
Figure 1: General structure of remote control system based DTMF technology

When used in such types of systems, important things must be taken into consideration. In the mobile, which is used as a transmitter, the keyboard sound must be activated to the maximum value, for the purpose of ensuring the generation of tone signals. While on the other side, which is the receiving side, the volume of the headset must be raised to the maximum possible for the purpose of ensuring the receipt of tones, as well as activating the automatic answering service for the mobile in this part [29].

DTMF tones are generated on the transmitter side phone when a call is made to the other side's phone which is the receiving side and when the transmitter side phone keys are pressed during the call. These tones are transmitted from

the sender side to the receiving side by means of a GSM network where the receiving side phone converts them to a DTMF decoder as analog signals. DTMF decoder will change the single line analogue tone to 4-bits digital

tones matched with number pressed at transmitter phone according the table 3. Which represents all the possibilities of the digital tones generated with their equivalent frequencies.

Table no 3: All tone generated possibilities

Keypad Number	Analog Tones Frequency Hz	Digital Tones Q3 Q2 Q1 Q0
1	1906	0001
2	2033	0010
3	2174	0011
4	1979	0100
5	2106	0101
6	2247	0110
7	2061	0111
8	2188	1000
9	2329	1001
*	2150	1010
0	2277	1011
#	2418	1100

IV. DTMF Simulation Model

DTMF simulation is possible based on several scenarios, one of which is DTMF simulation to operate at eight frequencies tuned using IIR filters, based on Goertzel algorithm in matlab software [30]. Matlab simulation model is used to classify the DTMF tones depend on estimated seven fundamental frequencies by applying Goertzel algorithm and the counter propagation neural network (CPNN) as a classification approach to classify the DTMF tones [31]. Hecht and Nielsen first introduced the Counter propagation Neural Network in 1987 [32-34]. In this review, an electronic simulation system model was built using matlab to simulate the operation of all components of the control system using DTMF technology, figure 2 shows in details the block diagram of the all components of simulation model.
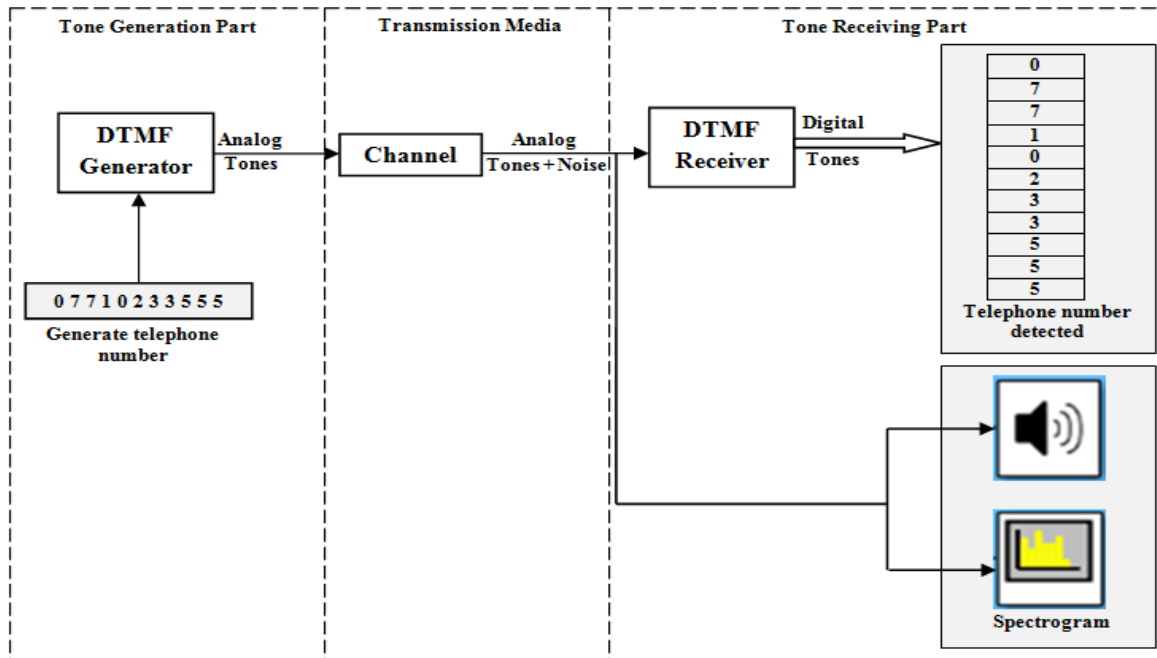
**Figure 2:** Block diagram of DTMF Simulation module

For this simulation model, there are a number of parameters that can be modified namely:
- Channel signal gain and noise power.
- Bias frequency for each tone.
- Receiver bandwidth of the band passes filter frequency.

For the purposes of understanding the simulation model accurately, this model can be dividing it into three main components as shown in the figure 2 which are:
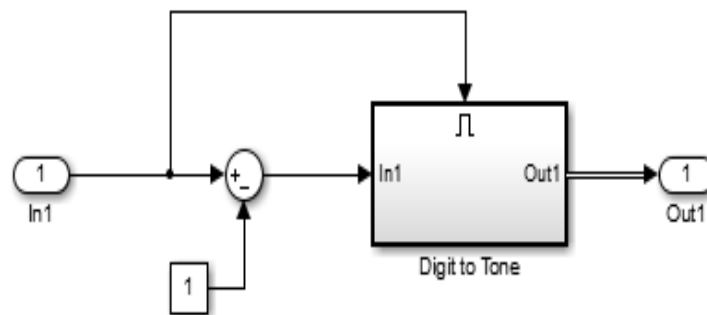
4.1 Tone generation part

The function of this part is to build a simulation for the phone device in the transmitter part, which is divided into two sub parts: a simulation of a number generation mechanism to call it, as well as a simulation of a mechanism for generating analog tones. The simulation of number generation can be done by multiply trigger signal from work space to frame status, the output of this circuit is digital number simulate the phone number generation, this process of simulation clear shown in figure 3.
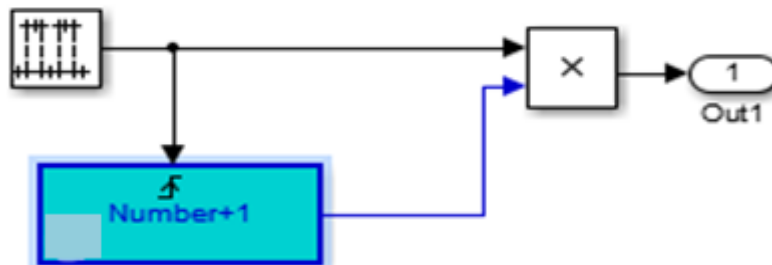
Figure 3: Simulation of number generation

The second sub part is the simulation of a mechanism for generating analog tones, which can be done using the circuit indicated in Figure 4.

Figure 4: Simulation circuit of tone generation part

4.2 Transmission part

This part represents the medium that transmits the tone, and it is one of the working GSM network. Naturally, each carrier medium adds an amount of noise to the incoming signal and simulates it represented by receiving an analogue signal and outputting the same signal with the addition of noise. The signal that we deal with, of course, is DTMF tones.

Channel it is the medium that use for transmits the tone signals, and of course, in communication sciences, the use of any communication channel will add addition of noise to the tone signals. Therefore, this process can be simulated using the circuit shown in the figure 5. Simulation of this part of the system consists in entering the number to be transmitted with the addition of an amount of gain, and then combined with an amount of noise, and the simulation output is an analogue signal that represents the transmitted tone with an amount of noise added by the carrier medium.
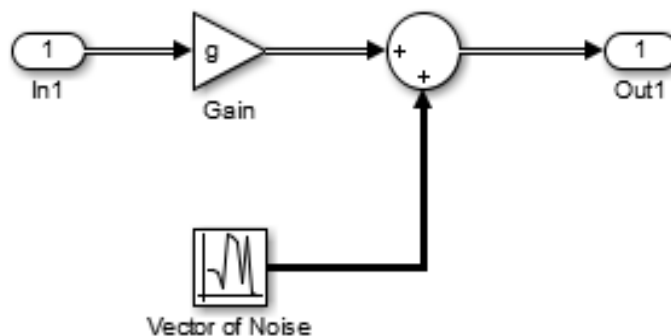
Figure 5: Simulation circuit of communication channel

4.3 Tone receiving part

This part represents the receiving phone device and the tone decoder, simulation of this part, first section is detecting the transmitted phone number and tone decoder to change the analog tones signals to digital tone signal, figure 6 represent the simulation of this part and then simulate the reception of the tone in the form of loudspeaker and spectrogram for the receiving tones.
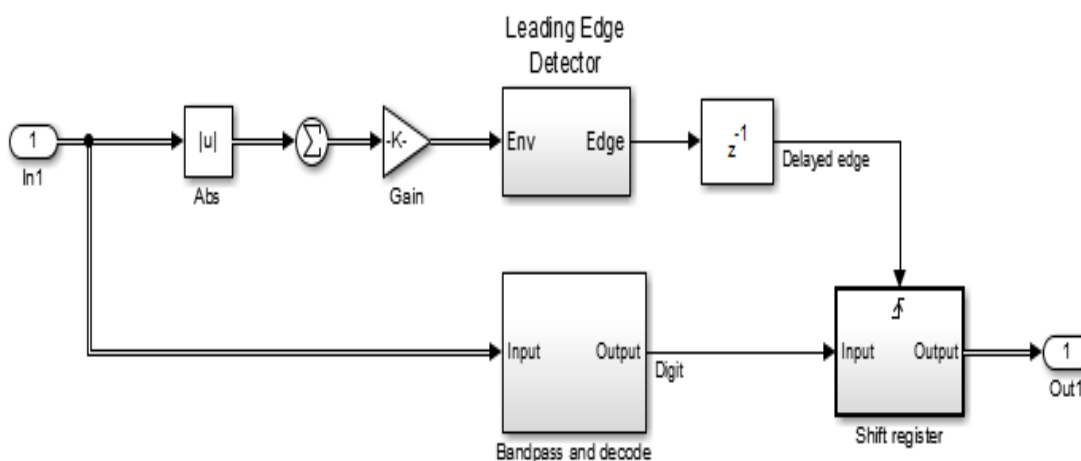

Figure 6: Simulation circuit of the receiving part of DTMF

Finally, the tone receiving part expressed in the simulation model as a display, which is the part that detect and analyzes the tones and identifies the number compressed by the sending phone. A section of this part is represented by a loudspeaker to indicate that the process is performed by receiving audio tones and the second section is the spectrogram, it is the method used to display the spectrum of the received tone. The final output of the system, which is not explained in the model, it is the target electrical device for the purpose of controlling it without human intervention.

4.5 Simulation model output

When the simulation model is run, a spectrogram of the received tone will be generated as shown in figure 7 as display of spectrum analyzer. The detected numbers are also displayed in the digital display as shown in figure 8. In addition, the tone received for each number could be heard and therefore represented in the simulation model as a speaker.
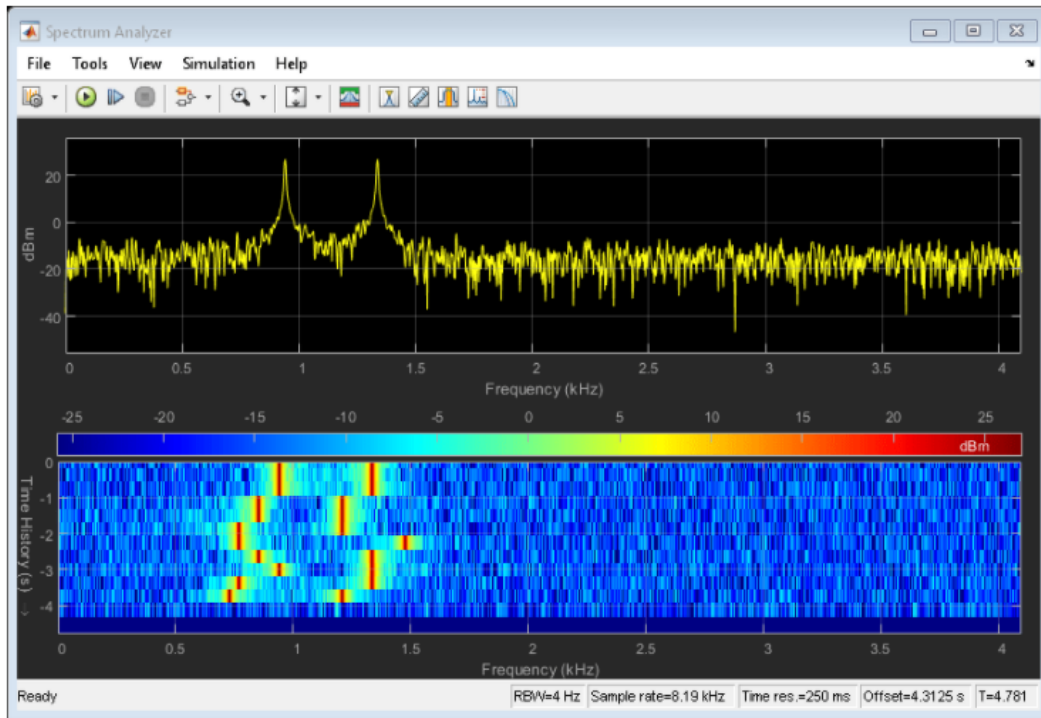
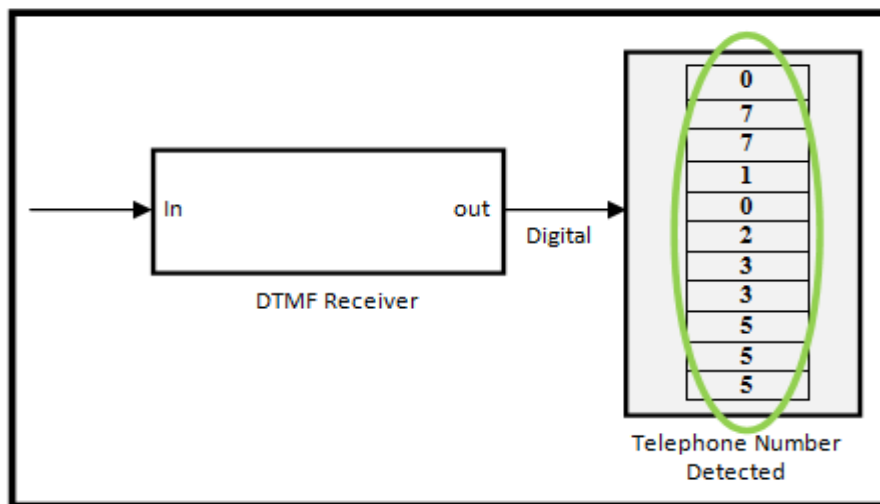**Figure 7:** Spectrogram of received tones

Figure 8: Telephone number detected display

V. Conclusion

DTMF technology is one of the important technologies that are used in remote control. this technology is characterized by important specifications or advantages such as being quick to respond, building the system at a low cost, possessing high efficiency and reliability, controlled from long and unlimited distances, the number of remote devices can be controlled as much as the number of keypad buttons of the mobile phone and an important technology to increase energy efficiency and reduce energy consumption. In this review paper, a comprehensive study was conducted on this technology and a detailed explanation of the concept of this technology, its components and the multiplicity of its applications. Also, a simulation model of the system was created with all its details, divided into groups, and a simulation was performed for each part.

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