LESSON 28:
SIGNALLING TONES, TOUCH TONE DIAL GENERATION DESIGN CONSIDERATION, TOUCH TONE DETECTION

Objective

In this lesson we study different signaling tones, Generation and Design of Touch Tone Dial and Detection of Touch Tone.

Introduction

Dual-tone multi-frequency (DTMF) was developed at Bell Labs Bell Telephone Laboratories or Bell Labs was originally the research and development arm of the Bell System, developing everything from telephone switches to specialized coverings for telephone cables, to the transistor.

The Touch-Tone system is based on a concept known as dual-tone multi-frequency (DTMF). The 10 dialing digits (0 through 9) are assigned to specific push buttons, and the buttons are arranged in a grid with four rows and three columns. (The pad also has two more buttons, bearing the star [*] and pound [#] symbols, to accommodate various data services and customer-controlled calling features.) Each of the rows and columns is assigned a tone of a specific frequency, the columns having higher-frequency tones and the rows having tones of lower frequency. When a button is pushed, a dual-tone signal is generated that corresponds to the frequencies assigned to the column and row that intersect at that point. This signal is translated into a digit at the local office.

Signalling Tones

A number of signalling functions are involved in establishing, maintaining and releasing a telephone conversation. These functions are performed by an operator in a manual switching systems or exchange. In automatic switching system or exchange, the verbal signalling of the operator is completely replaced by a series of distinctive tones. There are five subscriber related signalling functions that are performed by the operator:

1. Respond to the calling subscriber to obtain the identification

   of the called party.
2. Inform the calling subscriber that the call is being established.
3. Ring the bell of the called party.
4. Inform the calling subscriber, if the called party is busy.
5. Inform the calling subscriber, if the called party line is unobtainable for some reason.

Distinctive signalling tones are available in all automatic switching systems for functions 1, 3, 4 and 5. A signalling tone for function 2 is usually not available in Strowger switching systems or exchanges. But, most of the modern exchanges provide a call-in-progress or routing tone for function 2. Although attempts have been made to standardise the tones for various signals yet many variations of tones are in vogue in different parts of the world and even in different parts of the same country. These variations in the signalling tones are mainly due to different capabilities and technologies of the telecommunications switching systems used.

Dial Tone: The signalling function 1 given above is fulfilled by sending a dial tone to the calling subscriber. This tone indicates that the exchange is ready to accept dialled digits from the called subscriber. The subscriber should start dialling only after hearing the dial tone. Otherwise, initial dial pulses may be missed by the exchange. Therefore, it may result in the call landing on a wrong number. Most often, the dial tone is sent out by the telephone exchange even before the handset is brought near the ear. Sometimes, it is also possible that dial tone will be heard after few seconds. This happens particularly in common control exchanges which use shared resources for user interfaces. The dial tone is a 33 Hz or 50 Hz or 400 Hz continuous tone as shown in Fig.28.1(a). The 400 Hz signal is usually modulated with 25 Hz or 50 Hz.

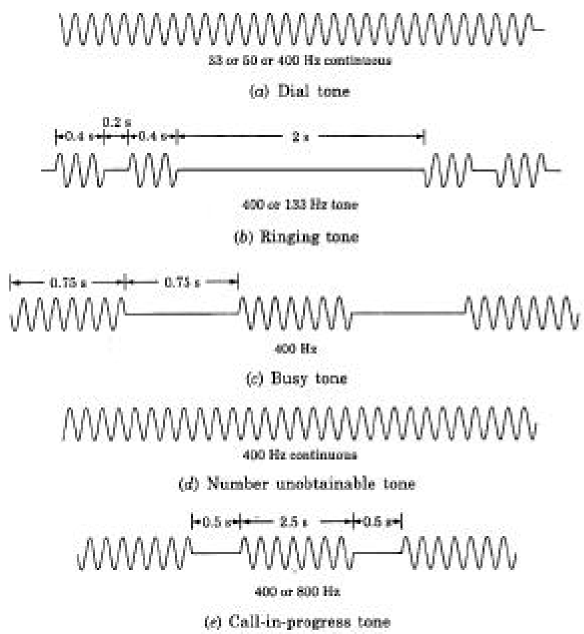


Fig.28.1. Various Signalling tones

Ringing tone: When the called party line is obtained, the exchange control equipment sends out the ringing current to the telephone set of the called party. This ringing current has the double-ring pattern. At the same time, the control equipment sends out a ringing tone to the calling subscriber, which has a similar pattern as ringing current shown in Fig.28.1 (b).

The two rings in the double-ring pattern are separated by a time gap of 0.2 second. The time gap between two double-ring patterns is kept 2 second. The ring burst has duration of 0.4

second. The frequency of the ringing tone is 133 Hz or 400 Hz. Sometimes above frequencies are modulated with 25 Hz or 33 Hz. Here it is noted that the ringing current and the ringing tone are two independent quantities. This explains one of the common fault symptoms where a calling subscriber hears the ringing tone whereas no ring is heard at the called subscriber end.

Busy Tone: Busy tone pattern is illustrated in Fig.28. 1 (c). It is bursty 400 Hz signal with silence period in between. The burst and silence durations have the same value of 0.75 second or 0.375 second. A busy tone is set to the calling subscriber whenever the switching equipment or junction line is not available to put through the call or the called subscriber line is engaged.

It is not possible for a calling subscriber to conclude on the basis of the busy tone that the called party was actually engaged in a conversation. While it is technically feasible to introduce different tones for different conditions, this would only confuse the subscriber, and not serve any useful purpose.

Number Unobtainable Tone: It is shown in Fig.28. 1 (d). It is a continuous signal of frequency 400 Hz. This tone may be sent to the calling subscriber due to a variety of reasons such as the called party line is out of order or disconnected and an error in dialling leading to the selection of a spare line. In some telephone exchanges, the number unobtainable tone is 400 Hz intermittent with 2.5 second on-period and 0.50 second off-period.

Routing call or Call-in-progress Tone: It is shown in Fig.28. 1 (e). It is a 400 Hz or 800 Hz intermittent pattern. In electro-mechanical systems, routing tone is usually 800 Hz with 50% duty ratio and 0.50 on/off-period. In analog electronic exchanges, it is a 400 Hz pattern with 0.50 second on period and 2.5 second off period. In digital exchanges, it has 0.1 second only off periods at 400 Hz. When a calling subscriber call is routed through a number of different types of exchanges, we hear different call-in-progress tones as the call progresses through different exchanges.

Regular users of telephone in a particular area have little difficulty in identifying signalling tones. A subscriber will face a problem in identifying the signalling tone in a new area where frequencies or timings of the tones are different from those in his own area. In order to overcome this problem, recorded voices that announce messages like “Number engaged” or “busy” are used in some modern telephone exchanges. Voice announcement, however, poses problems in multilingual areas.

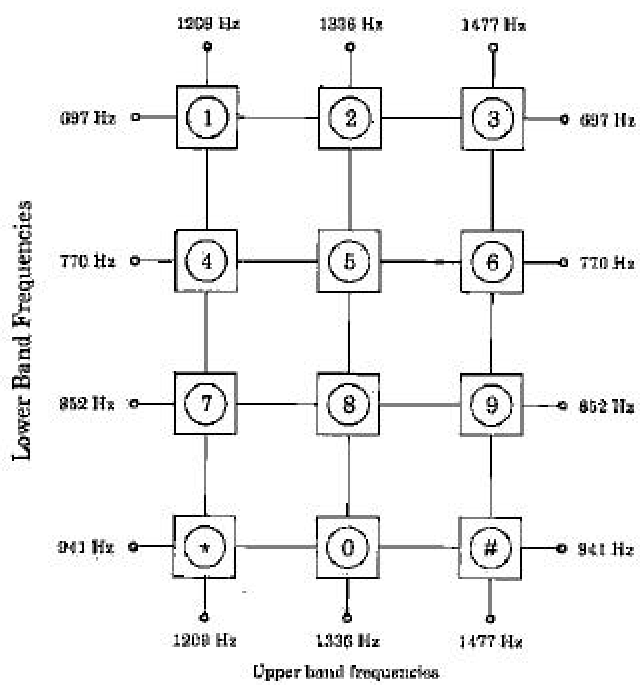
Touch Tone Dial Telephone

We are already familiar with rotary dial telephone. In this (rotary dial telephone) telephone, we require 12 seconds for dialling a 7-digit number. From the subscriber point of view, a faster dialling rate is desirable. The step-by-step switching elements of Strowger systems cannot respond to rates higher than 10-12 pulses per second. With the introduction of common control in crossbar switching systems, a higher dialling rate is feasible. Pulse dialling is limited to signalling between the telephone exchange and the subscriber and no signalling is possible between two subscribers. Signalling between two subscribers is also known as end-to-end signalling. End-to-end signalling is a desirable feature. This type of signalling is possible only if the signalling is in the voice frequency band so that the signalling information can be transmitted to any point in the telephone network to which voice can be transmitted.

Rotary dial signalling is limited to 10 distinct signals, whereas a higher number would enhance signalling capability significantly. Finally, a more convenient method of signalling than rotary dialling is preferable from the point of view of human factors. The development of touch-tone dial telephone leads to enhanced signalling capability. Touch-tone dial telephones were introduced first in 1964 after field treats. Touch-tone dial telephones are continuously replacing rotary dial telephones all over the world.

The touch-tone dialling scheme is shown in Fig.28. 2. The rotary dial is replaced by a push button keyboard. By touching a button, it generates a tone. This tone is a combination of two frequencies, one from the lower band and the other from the upper band. For example, pressing the push button 5 transmits 770 Hz and 1336 Hz. An extended design provides for an additional frequency 1633 Hz in the upper band. Therefore, it can produce 16 distinct signals.

This design is used only in military and other special applications. Another design, known as, decadic push button type, uses a push button dial in place of rotary dial. It gives out decadic pulses when a button is pressed as in the case of rotary dial telephone.



Design Considerations in Touch Tone Dial Telephones

The need for touch tone signalling frequencies to be in the voice (audio) band brings with it the problem of vulnerability to ‘talk-off’ which means that the speech signals may be mistaken for touch tone signals. Therefore, it results in unwanted control actions such as termination of a call. Another aspect of talk-off is that the speech signal may interface with touch-tone signalling if the subscriber happens to talk while signalling is being attempted. We consider following factors for the design of touch-tone signalling. All these factors are considered from the point of view of need of protection against talk-off:

1. Choice of code
2. Band separation
3. Choice of frequencies
4. Choice of power levels
5. Signalling duration.

The choice of code for touch-tone signalling should be such that imitation of code signals by speech and music should be difficult. Simple single frequency structures are prone to easy imitation because they frequently occur in speech or music. Hence, some form of multi-frequency code is required. These codes are easily derived by selecting a set of N frequencies and restricting them in binary fashion to being either present or absent in a code combination. However, some of the 2^N combinations are not useful because they contain only one frequency. Transmission of N frequencies simultaneously involves N-fold sharing of restricted amplitude range. Hence, it is desirable to keep as small as possible the number of frequencies to be transmitted simultaneously. It is also advantageous to keep fixed the number of frequencies to be transmitted for any valid code word. These factors lead to the consideration of M-out-of-N code.

Here a combination of M frequencies out of N frequencies constitutes
a code word. This code generates

$$\frac{\angle N}{\angle M \angle (N-M)}$$

code words.

Here $\angle N, \angle M, \angle (N-M)$ are the factorials of N, M and (N - M), respectively.

Prior to touch-tone signalling, M-out-of-N multifrequency signalling was used between telephone exchanges by the operators M-out-of. N multifrequency signalling is also known as multifrequency key pulsing (MFKP). Here, 2-out-of-6 code was used. This code is known to give a talk-off performance of less than 1 in 5000. However, this degree of talk-off performance is inadequate for subscriber level signalling. In order to improve the talk-off performance, we adopt two measures. These measures are:

1. Firstly, while retaining M as 2, N is chosen to be 7 or 8, depending upon the number of code words desired.
2. Secondly, the chosen frequencies are placed in two seperate bands, and a restriction is applied such that one frequency from each band is chosen to form a code word.

When multiple frequencies are available in speech signal, they are closely spaced. Band seperation of touch-tone frequencies reduces the probability of speech being able to produce touch-tone combinations. The number of valid combinations is now limited to $N_1 \times N_2$, where N_1 and N_2 are the number of frequencies in each band. There will be 12 distinct signals in 7 frequencies. These 7 frequencies will be 4 in one band and 3 in other band. These 12 distinct signals are represented by push buttons in Fig.28. 2.

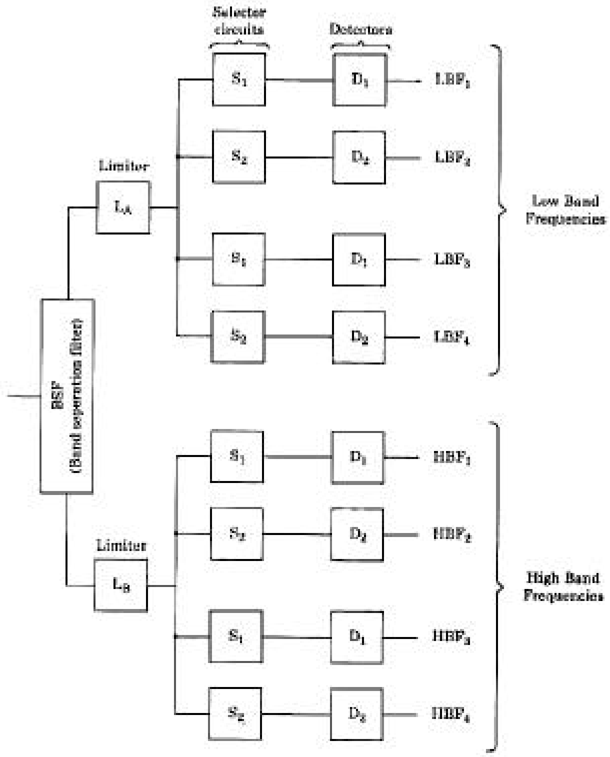
With 8 frequencies (4 in each band), we have 16 possible combinations. Since two frequencies are mixed from a set of 7 or 8 frequencies, CCITT refers to the touch-tone scheme. This touch-tone scheme is named as Dial Tone Multifrequency (DTMF) signalling.

Advantages of band seperation of the two frequencies:

i. Before attempting to determine the two specific frequencies at the receiver end, band filtering can be used to seperate the frequency groups. This renders determination of specific frequencies simpler.
ii. Each frequency component can be amplitude regulated separately.
iii. Extreme instantaneous limiters can be used for each frequency separately to reduce the probability of false response to speech or other unwanted signals. Extreme instantaneous limiters are capable of providing substantial guard action.

A simplified block diagram of Touch Tone receiver is shown in Fig.28. 31.3. The limiters accentuate differences in levels between the components of an incoming multifrequency signal. For example, if two frequencies reach the limiter with one of them being relatively strong, the output of the limiter peaks with the stronger signal and the weaker signal is further attenuated. If both the signals have similar strength, the output of the limiter is much below the full output. Therefore, neither signal dominates at the output. The selective circuitry is designed to recognise a signal as bonafide when it falls within the specified narrow passband and it has amplitude within 2.5 dB of the full output of the limiter. The limiter and selective circuits together reduce the probability of mistaking the speech signal to be a touch-tone signal. Speech signals usually have multifrequency components with similar amplitudes. Hence the limiter does not produce a full output.

As a result, the selective circuitry rejects the signal as invalid. We use band elimination filters in place of band seperation filters at the input of the touch-tone receiver for further improving the talk-off performance. Band elimination filters permit a wider spectrum of speech to be passed to the limiters. Therefore, band elimination filters are less probable for the limiters to produce a full output at the touch-tone signal frequency. The choice of frequencies for touch-tone signalling is dictated by the attenuation and delay distortion characteristics of telephone network circuits for the audio (voice) band frequencies.



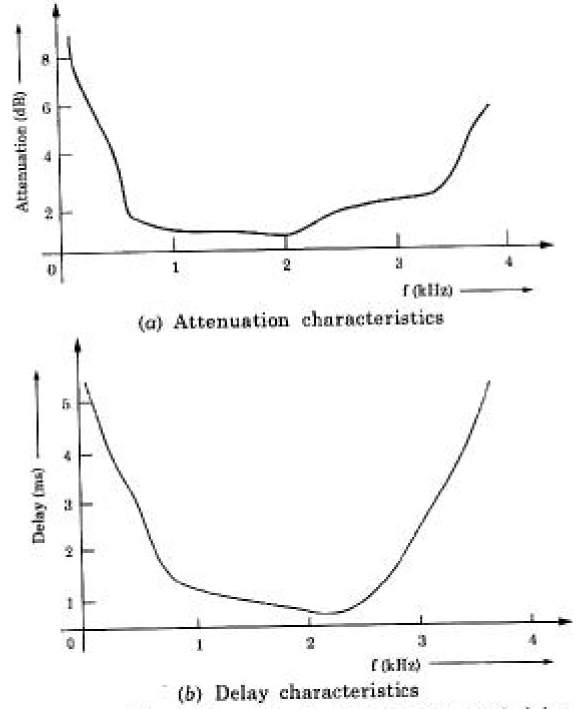


Fig.28. 4 Illustration of typical attenuation and delay characteristics of telephone networks.

Fig.28..4 illustrates the typical amplitude response and delay characteristics. A flat amplitude response with a very low attenuation and a uniform delay response with a low relative delay value are desirable.

We have considered frequencies in the range of 700 - 2200 Hz in curves shown in Fig.28.31.4. The actual range chosen for touch-tone dialling is 700 - 1700 Hz. Both the lower and the upper frequency bands are defined in this range. The frequency spacing depends in part on the accuracies with which the signal frequencies can be produced. We can obtain an accuracy of ± 1.5% at the telephone sets. The selective circuits can be designed to a tolerance of ± 0.5%.

These circuits lead to a total acceptable variation of ± 2% in the nominal frequency value. Hence, a minimum spacing of 4% is indicated between frequencies.

The specific values of the frequencies can be decided on the basis of frequency band and the spacing. These frequencies can be so chosen as to avoid simple harmonic relationships like 1: 2 and 2: 3 between adjacent two frequencies in the same band and between pairs of frequencies in the two different bands, respectively. Such a selection improves the talk off performance. We already studied that sounds composed of an rnultiplicity of frequencies at comparable levels are not likely to produce talk-off because of the limiter and selector design. Such sounds are produced by consonants. However, vowels are single frequency sounds with a series of harmonic components present in them. Susceptibility to talk-off due to vowels can be reduced by choosing the specific frequencies appropriately. The adjacent frequencies in the same band have fixed ratio of 21 : 19.

In other words, only the 21^{st} and 19^{th} harmonic components have the same frequency values. Across the bands, the frequencies that lie along the diagonals in Fig.28. 2 have a ratio of 59 : 34. Thus, the chosen frequency values are such that they almost eliminate talk-off possibility due to harmonics.

Since signalling information does not bear the redundancy of spoken words and sentences. Therefore, it is desirable that the signal power be as large as possible. A nominal value of 1 dB above 1 m W is provided for the telephone set for the combined signal power of the two frequencies. As we can see from Fig.28.5 (a), that attenuation increases with the frequency. In worst case, the increase in attenuation in the subscriber loop between 697 Hz and 1633 Hz could be as much as 4 dB.

To compensate for this, the upper band frequencies (UBFs) are transmitted at a level 3 dB higher than that of the lower band frequencies (LBFs). The nominal output power levels have been chosen as - 3.5 dBm and - 0.5 dBm for the lower and upper band frequencies, respectively.

The probability of talk-off can be reduced by increasing the duration of the test applied to a signal by the receiver before accepting the signal as valid. But, it is clearly unacceptable to expect the user to extend the push button operation for this purpose, beyond an interval that is natural to his dialling habit. Fortunately, this requirement does not arise as even the first dialler pauses for about 200 ms between digits. Efficient circuits can be designed to accurately determine the signalling frequencies by testing for a much smaller duration.

A maximum of 46 ms has been chosen for signal and intersignal intervals. It allows a dialling rate of over 10 signals/ second. In practice, the median tone duration has been found to be 160 ms and the median interdigit gap to be 350 ms.

We consider the human factors and mechanical design factors such as button size and spacing, stroke length, strike force, numbering scheme and button arrangement. User preference and performance studies coupled with design considerations have resulted in the following specifications:

- 3 / 8 – inch square buttons
- Buttons seperation: ¼ inch
- Stroke length: 1/8 inch
- Force at the button of the stroke: 100 gram
- 4 x 3 array with the digits 1, 2, 3 in the top row and the zero in the middle of the last row.
- The sign # in the third row is usually used to redial last dialed number.

A major advantage of touch-tone dialling is the potential for data transmission and remote control

A powerful application of touch-tone dialling is the DATA IN VOICE ANSWER (DIVA) SYSTEM. A customer calling an airline may receive voice -announcements like "Dial 1 for reservation" and "Dial 2 for flight information"

Touch Tone Detection

Touch tone detection is provided by the telephony card or modem being used. When the modem detects a touch tone, the tone is passed along to Windows Telephony API, which then delivers it to Active Call Center.

Virtually all problems dealing with touch tone detection are hardware related. Usually the problem is caused by one of the following:

- The touch tone detection capabilities of the modem or telephony card are not robust enough to detect tones that are imperfect.
- The telephone being used to dial the Active Call Center system generates tones that are too short for the hardware to detect. This can be a problem with some digital phone systems that generate "blips" instead of longer tones when touch tone keys are pressed.
- The telephony being used to dial the Active Call Center system generates touch tones that are imperfect or outside the bounds recognized by the modem or telephony card.

The solutions to these potential problems are:

- Switch to a better telephone when dialing into the Active Call Center system.
- Install a modem that has better touch tone detection capabilities.
- Install a Brooktrout or similar telephony card that has robust tone detection.

Notes