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Application Note

DTMF Analysis with RAPID-TEST

This document describes the testing of devices, that generate or decode DTMF signals, and the specific requirements, that have to be met according to the ITU Q.24 DTMF standard.

1 Introduction

All DTMF (Dual-Tone Multi-Frequency) signals comprise a pair of two individual frequencies, thus identifying a telephone keypad, i.e. number 0 - 9 as well as * and #.
In addition, the DTMF standard comrprises four auxiliary tones *a* - *d* that can be used for special applications.

Fig. 1 shows the 16 possible combinations of the eight DTMF standard frequencies that are grouped in two blocks:

- 697 - 941 Hz to identify the row.
- 1209 - 1633 Hz to identify the column.

Example

In the DTMF matrix, key "5" is represented by the two frequencies 770 Hz + 1336 Hz.
Fig. 2 shows the spectrum of the corresponding DTMF tone.

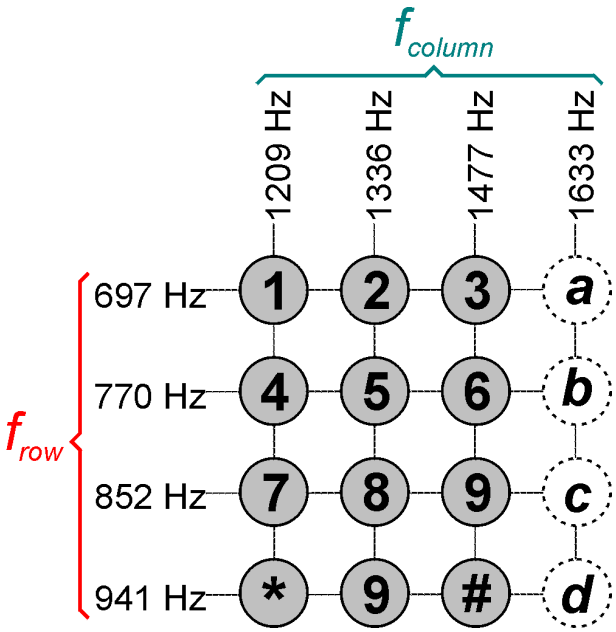

Fig. 1 DTMF frequency matrix

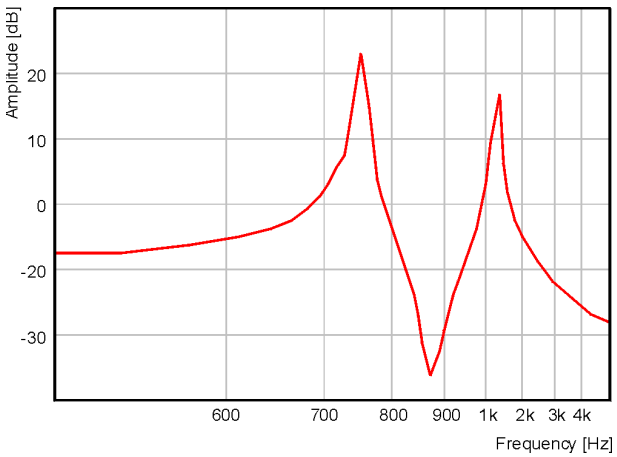

Fig. 2 DTMF spectrum example

2 DTMF Device Testing

The following parameters are typically tested to verify the correct operation of DTMF devices.

a) DTMF signal generators
- Frequency accuracy.
- Amplitude ratio.

b) DTMF decoders
- Correct decoding of DTMF signals with detuned frequencies, asymmetric amplitude ratio, short signal duration etc.
- Ruggedness against similar, but non-complying signals.

2.1 Test Setup

NTI's audio analyzers RT-1M *, RT-2M and RT-2X support independent DTMF testing (i.e. in parallel to the standard measurement functions):

- Generation of DTMF signals.
- Optional de-tuning of the frequency and amplitude ratio.
- Monitoring &decoding of incoming DTMF signals.
- Exact frequency & amplitude analysis of incoming DTMF signals.

There are two alterantives for connecting DTMF device to the RAPID-TEST unit.

a) Normally, the DTMF device is connected electrically to the input & output of the test system.

b) Alternatively, a measuring microphone can be applied (e.g. M2010) to establish an acoustical coupling.

Regardless of the coupling, the setup of the whole system has to be adjusted properly. The corresponding steps are described in the subsequent chapters.

2.2 DTMF Signal Decoding

Execute the following steps to let the analyzing RAPID-TEST unit trigger to the incoming signal, record it and return the results to the PC.

1. Adjust the analyzer sensitivity (i.e. input range).
2. Define the trigger condition and arm the DTMF decoder.
3. Start the external DTMF signal generator.
4. Upload the test results from RAPID-TEST to the controller PC.

Use the following commands to let the RAPID-TEST unit trigger to the incoming DTMF signal in the "*Threshold Sync Mode*":

- ***INPut:SYNC THReshold***
- ***INPut:TRIGger:ARMed***
- ***MEASurement[1¦2]:DTMF:STARt***

**: The DTMF option of RT-1M supports only single-channel analysis of externally generated DTMF signals.*

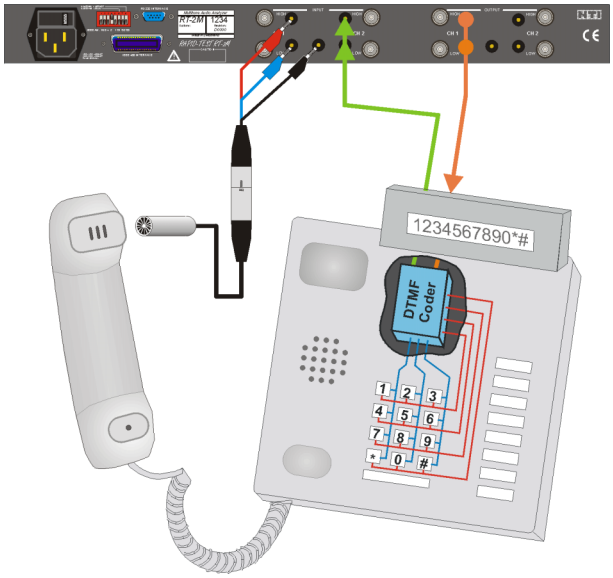

Fig. 3 DTMF test setup

Consequently, the DTMF analyzer module of the RAPID-TEST unit permanently monitors the incoming signals and automatically starts the data acquisition as soon as a certain input level has been exceeded.
If the received signal is a DTMF tone, it decodes it and stores the result in an internal buffer. The decoded data may then be queried by the PC with the command ***MEASurement[1¦2]:DTMF?***. The returned vector has the format:

$$r_1/c_1, r_2/c_2, \ldots, r_n/c_n$$

whereby each pair of numbers r_x/c_x identifies a DTMF signal by its row / column (see ***p. 1***).

2.3 DTMF Frequencies, Amplitudes

RAPID-TEST also supports measuring the exact frequencies (*Fig. 4*) or amplitudes (*Fig. 5*) of an incoming DTMF signal.
The test setup & procedure are identical as described in *chapter 2.2*, whereby the related query commands are:

- ***MEASurement[1¦2]:FREQuency:SELective?*** ***<FreqBand>*** measures the dominant frequency in an user-defined band.
- ***MEASurement[1¦2]:SELectiverss?*** ***<FreqBand>*** measures the dominant level in an user-defined band.

(continued on next page)

Both measurements require proper definition of the <*FreqBand*>, e.g. from 656 - 1031 Hz and from 1125 - 1687 Hz. Thus, the exact signal frequencies and amplitudes of the incoming DTMF signals will be acquired (refer also to chapter ***Application Example***, ***p. 4***).

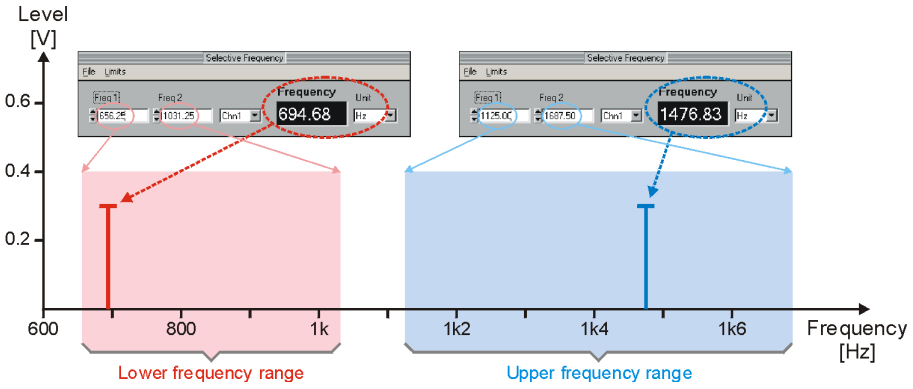

Fig. 4 Individual DTMF signal frequency measurement (key #3)

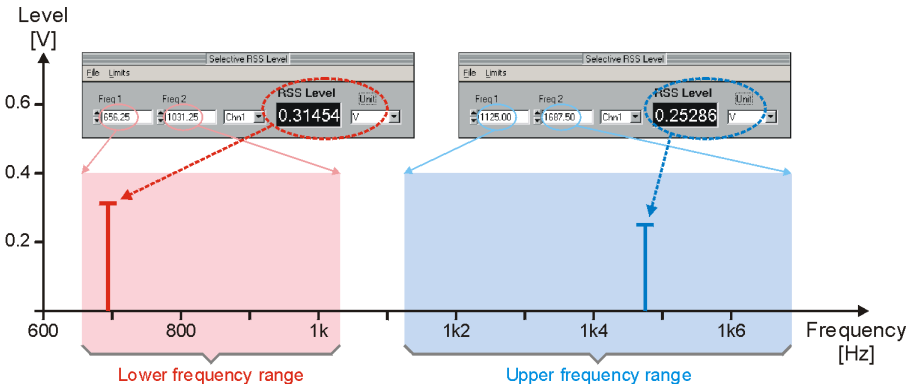

Fig. 5 Individual DTMF signal level measurement (key #3)

2.4 DTMF Decoder Testing

External DTMF decoders can be tested under two aspects.

a) Proper decoding of transmitted DTMF signals.

b) Behavior of the decoder if the DTMF signal parameters are close to or beyond the specified tolerance limits (according to ITU standard).

Use the command ***OUTPut:DTMF <Tone> <Parameter>*** to generate a single DTMF signal or sequence of tones. Thereby, *<Tone>* identifies the basic DTMF tone, whereas *<Parameter>* allows to de-tune the frequencies, amend the amplitude ratio or to define the signal duration.

- Frequency de-tuning up to ± 5.0 %, independently adjustable for the upper / lower frequency group in steps of 0.01 %.
- Amplitude ratio of lower : higher frequency component, selectable from 1:10 to 10:1 in increments of 0.01.
- Signal duration selectable from 1 to 5'000 ms in 1 ms steps.

As soon as the start command is sent from the PC to the RAPID-TEST, the latter immediately generates the user-defined signal. Therefore, the user has to simultaneously start monitoring the DTMF decoder to verify its behaviour.

Please refer to the next two pages for a program example of a complete DTMF coder / decoder test procedure.

3 Application Example

The subsequent program examples describe the procedures to test a DTMF coder / decoder.

The first part deals with the *generation* of all standard DTMF key-codes, some of them with de-tuned frequencies or amplitude ratios. By monitoring the behaviour of the device under test (DUT), the operator may check, whether it decodes the generated tones correctly.

```
/* GENERATION OF DTMF SIGNALS
/* Keys 1-3; 100 ms duration; standard frequencies; amplitude ratio 1:1
OUTP:DTMF 1,1,100,0,0,1
OUTP:DTMF 1,2,100,0,0,1
OUTP:DTMF 1,3,100,0,0,1

/* Keys 4-6; 200 ms; LO & HI freq. de-tuned by -/+ 1 %; amp. ratio 1:1
OUTP:DTMF 2,1,100,-1,1,1
OUTP:DTMF 2,2,100,-1,1,1
OUTP:DTMF 2,3,100,-1,1,1

/* Keys 7-9; 200 ms; LO & HI freq. de-tuned by +/- 1 %; amp. ratio 1:1
OUTP:DTMF 3,1,200,1,-1,1
OUTP:DTMF 3,2,200,1,-1,1
OUTP:DTMF 3,3,200,1,-1,1

/* Keys *,0,#; 200 ms; standard frequencies; amp. ratio 2:1
OUTP:DTMF 4,1,200,0,0,2
OUTP:DTMF 4,2,200,0,0,2
OUTP:DTMF 4,3,200,0,0,2
```

The second part covers the *decoding* of an externally generated sequence of DTMF tones, followed by a thorough level & frequency analysis of a single tone.

```
/* Set the system to 48k mode (RT-2X only) and the blocklength to 1024
SYST:MODE 48K
OUTP:MTONE:PARAMETER 1,'1_TONE',1024,1,1,20,20,0,0
OUTP:MTONE:ACTIVE 1

/* Reset & arm the DTMF analyzer of RAPID-TEST
MEAS1:DTMF START
```

Next, the DUT has to be stimulated in a way (e.g. by a robot), that it generates the required sequence of DTMF tones. Afterwards, the recorded & decoded sequence may be queried from RAPID-TEST.

```
/* Read the decoded sequence of DTMF tones
MEAS1:DTMF?
->   1/1,2/1,3/1,1/2,2/2,3/2,1/3,2/3,3/3,2/4
```

In the given example, the returned vector indicates, that the transmitted sequence of DTMF tones are the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, 0.

Additionally, an investigation about the exact characteristics of the external DTMF coder may be executed. The corresponding procedure splits the frequency band in two parts, according to the rows (609 - 1031Hz) and the columns (1078 - 1734 Hz) of the DTMF code scheme.

However, the RAPID-TEST analyzer first has to be *armed*, so that it triggers correctly to the incoming signals. Please notice, that for simplicity reasons, the subsequent procedure has been written for a single-channel analysis only.

```
/* Adjust the input range to the expected level (e.g. of a measuring mic.),
/* and let the analyzer trigger to a threshold level of 25 % with a delay of
20 ms
INP:RANGE 30E-3Vp
INP:SYNC:THRESHOLD
INP:TRIGGER:THRESHOLD:LEVEL 25
INP:TRIGGER:THRESHOLD:DELAY 20

/* Arm the RAPID-TEST analyzer
INP:TRIG:ARMED
```

In this status, stimulate the DTMF coder to generate a single tone. Afterwards, the measurement results may be queried.

```
/* Check, whether the analyzer has triggered to the incoming signal
INP:TRIG:ARMED?
->   STOPPED

/* Set the RSS selective unit to Volts and query the dominant frequency &
level
/* from 609 to 1031 Hz (bin 13 - 22) and from 1078 to 1734 Hz (bin 23 - 37)
MEAS1:FREQUENCY:SELECTIVE? 13 22
->   22/6.96578+02 Hz
MEAS1:FREQUENCY:SELECTIVE? 23 37
->   37/1.33589+02 Hz

MEAS1:SELECTIVERSS:UNIT V
MEAS1:SELECTIVERSS? 13 22
->   22/0.0039 V
MEAS1:SELECTIVERSS? 23 37
->   37/0.0031 V
```

In the given example, the returned vectors correspond to the following characteristics of the received DTMF signal.

- *Exact frequencies* 696.578 Hz / 1335.89 Hz (key #2)
- *Amplitude ratio* 39 : 31 = 1.25