Performance Analysis of Goertzel's Algorithm based Dual-Tone Multifrequency (DTMF) Detection Schemes

M.K.Ravishankar and K.V.S.Hari

shankar@ece.iisc.ernet.in: hari@ece.ernet.in

Abstract*:* A New efficient Dual –tone Multyfrequency detection scheme based on Goertzel's algorithm is presented. Evaluating it with two existing detection schemes for DTMF signal corrupted by random noise and variation in frequency proves the merits of the proposed scheme.

Introduction*:* The DTMF signal is generated by the addition of two sinusoidal tones, one using frequency from a set of 697 Hz, 770 Hz, 852 Hz, 941 Hz called Low band and the other from a set of 1209 Hz, 1336 Hz, 1477 Hz, 1633 Hz called High band to transmit ten decimal digits, four alphabets A, B, C, D and two special characters marked '*' and '#' used in telephones. Mock [1], Gay et al [2], Bagchi et al [3] have used Goertzel's algorithm for the detection of digital DTMF signals. A discussion by G.Arlson et al [4] indicate that Goertzel's algorithm is the best approach for computation of DFT of smaller sequence lengths as in DTMF signal while providing the best computational load and memory usage efficiency. This paper presents a new DTMF detection scheme based on Goertzel's algorithm .A performance evaluation to prove its merits is carried

out with two existing detection schemes under the influence of random noise and frequency

variation (±1.5%, 2 Hz as per ETSI ES 201 235-4 standard).

The proposed detection algorithm DTMFDET-3 is based on the DFT index value

corresponding to peak value of DFT and the fact that product of any two DFT index values are

different from product of any other two DFT index values as shown in Table-1 for converting the

DFT index values to digits which are the best options in the detection of DTMF signal corrupted

by noise and frequency variation. The Goertzel's algorithm uses DFT index values pertaining to

Low band and High band separately and detects two DFT index values corresponding to peak

DFT value of low band and high band. The product of these two DFT index values is matched to

the predetermined products of all the DFT index values as shown in Table-1 to select the digits.

The details of the other two existing schemes of [5] and [6] are given in Appendix.

Table-1. Predetermined values of the Product of DFT index 'k' values.

	Product of 'k' values				Low Band 'k' values
	558	612	684	756	18
	620	680	760	840	20
	682	748	836	924	22
	744	816	912	1008	24
High Band 'k' values	31	34	38	42	

Numerical simulation: The Matlab based algorithms of the proposed detection scheme, denoted as DTMFDET-3 and existing detection schemes of [5] and [6] denoted as DTMFDET-1, DTMFDET-2 were numerically evaluated as follows

The digital DTMF signal corrupted by noise is generated by the addition of variable random noise component to two sinusoidal tones corresponding to the digit using the MatLab expression

X= sin (2*pi* N* f1/8000) + sin (2*pi* N* f2/8000) + R * (randn (size (N)))--------(1)

where *'f1'* corresponds to frequency of the Low band and *'f2'* High band, *'R'* the variable noise coefficient,*'randn', the* random noise,*'N'* number of samples which is equal to *'205'*

The DFT of DTMF signal is computed by the expression

F (X)= gfft (X, N, k) --(2)

where *'gfft (X, N, k)' is* the Matlab version of Goertzel's algorithm, *'k'* is the DFT index

The signal to noise ratio was computed for random noise coefficient*'R'* varying from zero to three times the amplitude of the DTMF signal in steps of 0.1. For each value of random noise all the three detection schemes were evaluated '1000' times on a single platform to compute error in detection of digital DTMF signal for all the digits and characters mentioned earlier. The evaluation was repeated at extreme values of frequencies to satisfy the ETSI ES 201 235-4 standard. The DFT index *'k'* values 18,20,22,24 corresponding to Low band and 31,34,38,42 corresponding to High band are used to detect DFT index values from the magnitude spectrum and were converted to digits as explained for the respective schemes. The error count was incremented by 'one' whenever the value of detected digit differed from the value of transmitted

digit. The total stored value of the error at each signal to noise ratio resulted in the generation of '
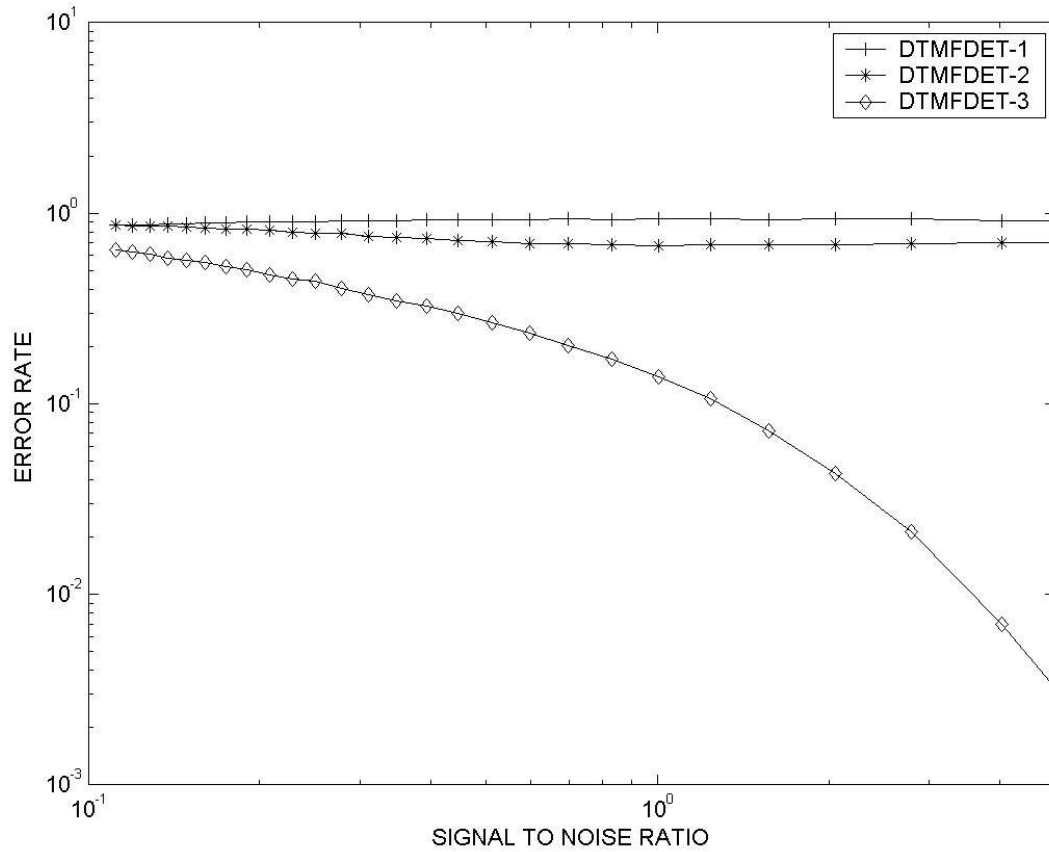Error rate v/s Signal to noise ratio' graph.

Results*:* The results of numerical evaluation are shown in FIG 1 to FIG 3 in a graph of ERROR
RATE v/s SIGNAL TO NOISE RATIO. It is evident that the detection scheme DTMFDET-1 of
[5] and DTMFDET-2 of [6] are less efficient in the detection of DTMF signal under the
influence of noise and variation in frequency. In DTMFDET-1 this is due to comparison of the
product of absolute value of DFT s, which varies with noise components amplitude and
frequency variation with a limit value and in DTMFDET-2 the comparison of ratios of DFT
values to threshold for similar reasons. This results in the detection of DFT index values, which
are not proper or correspond to only Low band or only High band. Further the detected DFT
index values can be more or less than two. The proposed detection scheme DTMFDET-3
exhibits far superior performance even at the lowest value of signal to noise ratio as expected.
This is due to detection of peak value of DFT resulting in only two DFT index values, one
corresponding Low band and one for High band. Further the definite value matching used in
decoding the DFT index values to obtain digits have added its superior performance.

References:

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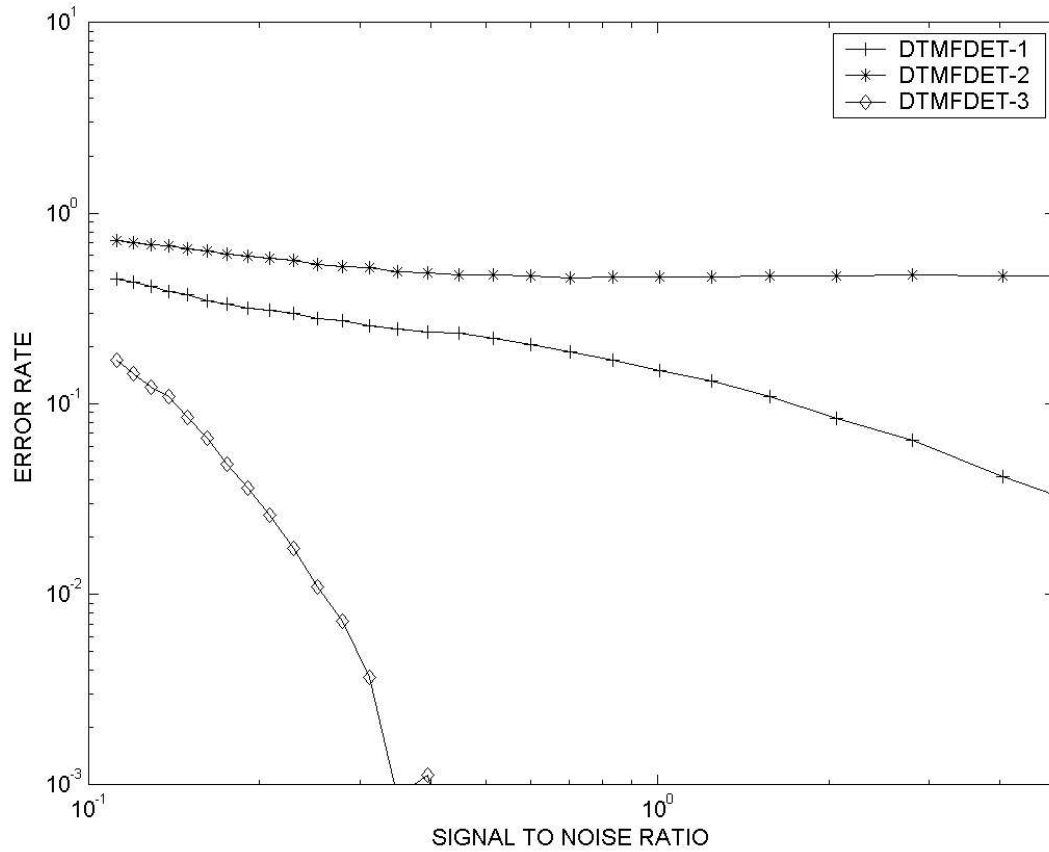
Fig 1.Graph depicting the ErrorRateof each detection scheme v/s to Signal to noise ratio for normal frequency values. DTMFDET-1 detection scheme of [5], DTMFDET-2 detection schemeof [6], DTMFDET-3, new proposed detection scheme.

Fig 2. Graph depicting the Error Rate of each detection scheme v/s to Signal to noise ratio. for frequency values of –1.5%, 2 Hz.DTMFDET-1 detection scheme of [5], DTMFDET-2 detection scheme of [6], DTMFDET-3, new proposed detection scheme
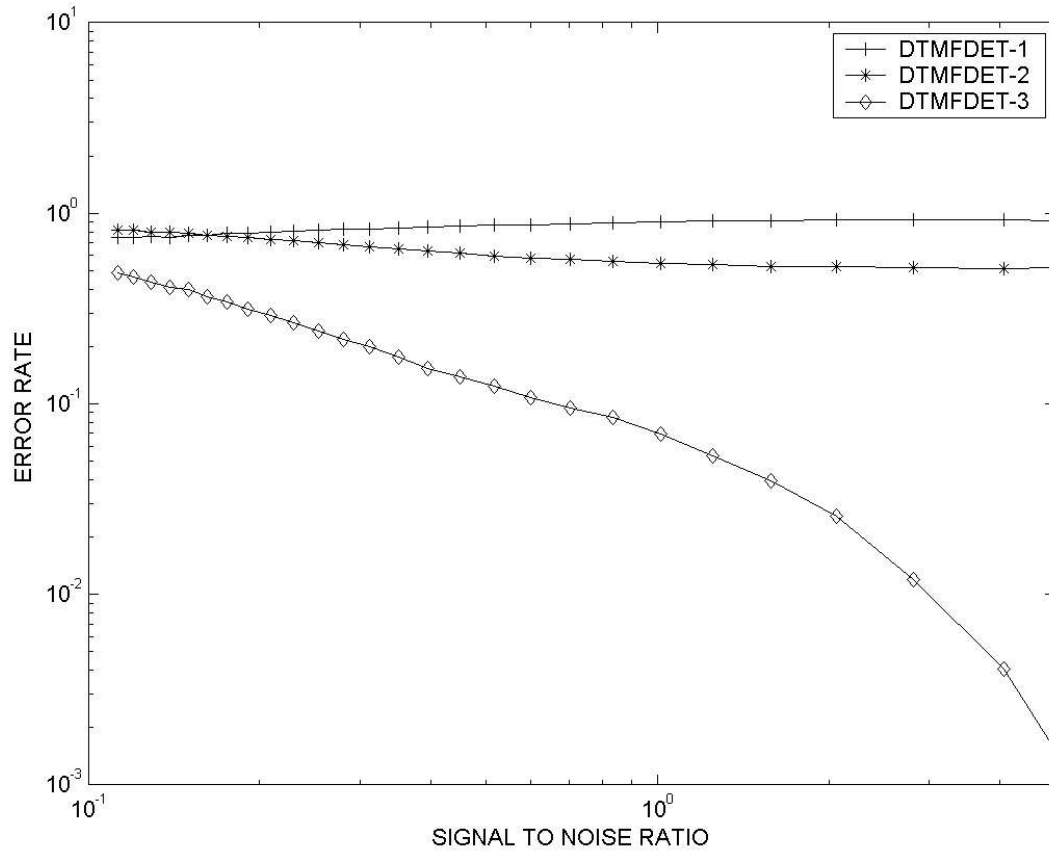
Fig 3. Graph depicting the Error Rate of each detection scheme v/s to Signal to noise ratio

for frequency values of +1.5%, 2 Hz.DTMFDET-1 detection scheme of [5], DTMFDET-2

detection scheme of [6], DTMFDET-3, new proposed detection scheme

Appendix:

Detection algorithm DTMFDET-1	Detection algorithm DTMFDET-2
Goertzel's algorithm 'gfft' uses all DFT index 'k' values corresponding to low band and high band frequencies together. Selects the DFT value for the DTMF signal	Goertzel's algorithm 'gfft' uses DFT index 'k' values corresponding to low band, its second hormonics, high band its second harmonics separately. Selects DFT value for DTMF signal
Computes the product of the absolute values of the two DFTs detected by the above method	Computes the ratio of absolute values of DFT selected for fundamental and its second harmonic for low band and high band separately. Selects the DFT index 'k' values based on a comparison with a threshold value
Based on a comparison of product of the absolute values of the two DFT values with a threshold value equal to '8100', digits are selected.	Based on the two values of DFT index 'k' a row and a column of a table is selected in which the digits are stored