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RESOLUTION ANALYSIS OF MODERN METHODS FOR FREQUENCY AND PERIOD MEASUREMENTS

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Abstract: The resolution analysis of modern methods for frequency (period) measurements such as the ratiometric counting method and the method of the dependent count (MDC) is described in the paper. Comparative metrological performances for the methods and modeling results of resolution for the MDC with the help of Maple 6 software are given.

Keywords: frequency, period, resolution, method of the dependent count, ratiometric counting method

1. INTRODUCTION

The resolution is one of main metrological performance of methods for frequency and period measurements together with a quantization error, time of measurement and frequency range. For example, if a frequency counter has a resolution of 10 Hz, it could produce a reading of 3340 Hz or 3350 Hz but not a reading of 3345 Hz. This is because 10 Hz is the smallest significant difference the instrument can measure. Any finer measurement would require more resolution. This paper is a first comparative resolution analysis of modern methods for frequency and period measurements. The resolution for the most advanced method for frequency (period) measurements - the method of the dependent count (MDC), was not analyzed before [1]. It is a reason, why this research is timely and important for the modern metrology.

2. RESOLUTION ANALYSIS FOR ADVANCED METHODS OF FREQUENCY MEASUREMENTS

Advanced methods for frequency measurements supply the constant quantization error in all frequency range. The main advanced methods are the following: the method of coincidence [2], ratiometric counting method [3], reciprocal counting method [4], M/T method [5], CET method [6], single- (SB) and double buffered (DB) methods [7], direct memory access (DMA) method [8], method with non-redundant reference frequency [9] and method of the dependent count [10].

The last one has essential advantage in comparison with the others because of it has the non-redundant conversion time and programmable quantization error.

Let determine the resolution for the reciprocal counting method. Its time diagrams are shown in Figure 1.

The measurand frequency is calculated as

$$f_x = \frac{n}{N} \cdot f_o \qquad (1)$$

If the number of pulse N is increased by one, the frequency f_{x1} should be determined as

$$f_{x1} = \frac{n}{N+1} \cdot f_o \qquad (2)$$

Then the resolution will be calculated by the following way:

$$Q_N = f_x - f_{x1} = \frac{f_0 \cdot n}{N(N+1)} \qquad (3)$$

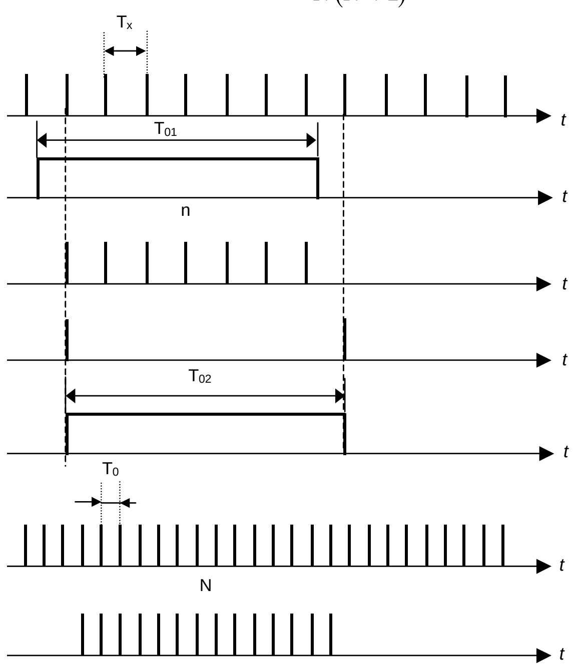

Fig. 1. Time diagrams of reciprocal counting method

Taking into account the following equations: $n=T_0 / T_x$ and $N=T_{02} \cdot f_0=n \cdot T_x \cdot f_0$ we will have:

$$Q_N = \frac{1}{T_x(N+1)} = \frac{f_x}{n \cdot T_x \cdot f_0 + 1} = \frac{f_x}{T_{01} \cdot f_0 + 1} \qquad (4)$$

As it is visible from the equation (4), the resolution for the reciprocal counting method is determined by the reference frequency f_0 and first reference gate time T_{01}.

The time diagrams of the MDC are shown in Fig. 2. The measurand frequency is determined according to the same equation (1) but the algorithm of formation and nature of numbers *n* and *N* are differ.

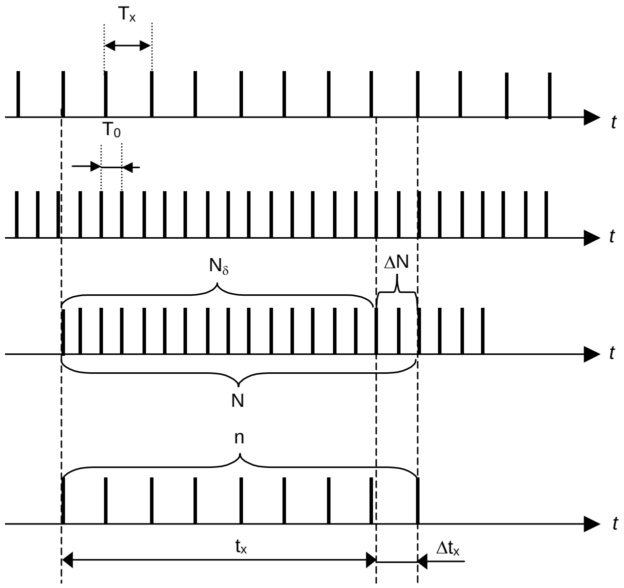

Fig. 2. Time diagrams of MDC

Taking into account the main equations for the MDC [1]: $t_x=n/f_x=(N_\delta+\Delta N)/f_0$, $N=(N_\delta+\Delta N)$, and $N_\delta=1/\delta_q$, where δ_q is the quantization error; $\Delta N \in [0 \div \Delta N_{max}]$ and $\Delta N_{max} = f_0/f_x$. Hence, the resolution for the MDC is determined according to the following equation:

$$Q_N = \frac{f_0 \cdot n}{N(N+1)} = \frac{f_x}{(N+1)} = \frac{f_x}{(N_\delta + \Delta N + 1)} \qquad (5)$$

Taking into account the range of ΔN changing we will have:

$$Q_N = \begin{cases} \dfrac{f_x}{(N_\delta + 1)}, & \Delta N = 0 \\ \dfrac{f_x}{(N_\delta + \Delta N_{max} + 1)} = \dfrac{f_x}{(N_\delta + \dfrac{f_0}{f_x} + 1)}, & \Delta N = \Delta N_{max} \end{cases}$$

The resolution for MDC is determined by the quantization error δ_q and measurand frequency f_x. The resolution is programmable and in comparison with the reciprocal counting method can be achieved at non-redundant time of measurement. It is one of the most advantages of the MDC. There are many applications where this advantage can be used efficiently, for example, adaptive frequency relays.

3. MODELING RESULTS

The resolution modeling was made for the designed and developed by authors universal frequency-to-digital converter (UFDC-1) based on the MDC [11]. Its reference frequency f_0 is 500 kHz, the frequency range was chosen from 0.05 up to 100 Hz for the good layout and $N_\delta \in [100 \div 10\ 000]$. Modeling results for $\Delta N=0$ and $\Delta N=\Delta N_{max}$ are shown in Figure 3 a) and b) accordingly. The dependence of the resolution on f_x is observed at $\Delta N=\Delta N_{max}$.

4. CONCLUSION

Together with such advantages of the MDC as the constant quantization error and non-redundant time of measurement, the method has programmable resolution. Such advantage can be used efficiently at the design of adaptive frequency relays as well as different measuring instruments (frequency counters and tachometers) and frequency-to-digital converters.

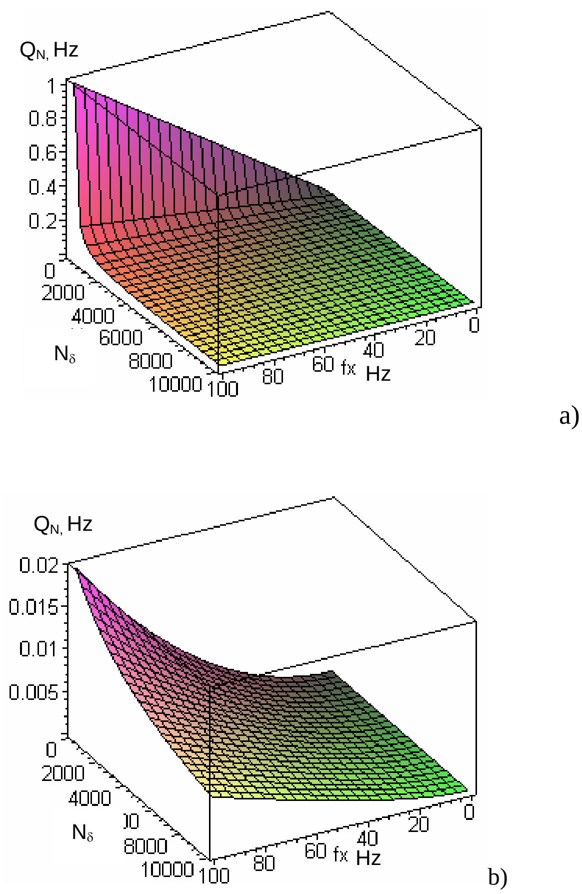

Fig. 3. Modeling results for $\Delta N=0$ (a) and $\Delta N=\Delta N_{max}$ (b)

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