4.5.12. CORRECTION OF THE MAXIMUM POSITION DURING THE PROCESSING OF A DIGITIZED SIGNAL

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Due to the guaranteed accuracy and ideal repeatability of the results, digital signal processing techniques are widely used in the instrument engineering and have "de facto" become an integral part of the non-destructive testing devices. Precise position determination of the analog signal maximum is of great interest in many applications, for instance, in the thickness gauging; meanwhile only the digitally sampled signal can be processed. The present work proposes a method, allowing for a given maximum in a given digitized signal, to improve the accuracy in position determination of the corresponding maximum in the corresponding analog signal.

As generally known, the signal digitization creates a sequence of its values measured in the corresponding analog signal with a pre-set sampling period. Hence, the position of the maximum in the analog continuous signal will be, generally speaking, different from the position of the maximum in the sequence of values of the corresponding digitized signal (fig. 1); the difference between them will be in the interval $\pm T/2$ where T – sampling period. This error can be considerable in some applications, for instance, it is equal to $\pm 12{,}5nS$ at a sampling rate of 40 MHz, so it will constitute about ±0,037 mm in steel for the ultrasonic thickness gauging under usage of longitudinal waves what is comparable with the thickness tolerances.

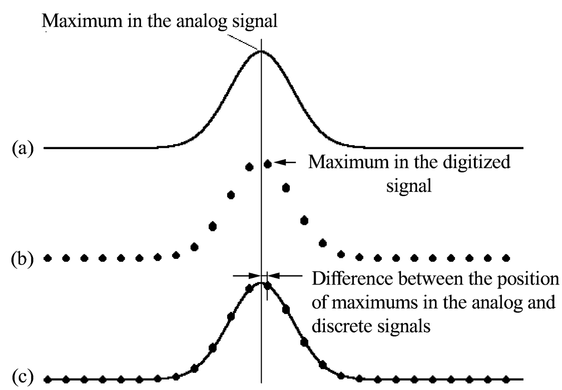

Fig. 1

Let the maximal value $y_0 = Y(n_0T)$ be selected in the digitized signal $Y(nT)$, $n = 0, 1, 2 ...$, where T – sampling period (fig. 1b). The set task is to determine such correction δ to the value n0T that $n_0T + \delta$ sets up the position of maximum in the corresponding analog signal (fig. 1a). Position of the analog maximum is indicated with a vertical line on the fig. 1a. Further, we shall assume that the analog signal peak is convex and symmetric relative to the selected analog maximum in some of its neighbourhood.

Let us suppose that this neighbourhood includes the following $2N + 1$ points of the digitized signal:

– point of the selected discrete maximum, having the y_0 value;

– the nearest N points to the left from the selected discrete maximum with the left-to-right indicated values: $y_{-N}, y_{-N+1}, \ldots, y_{-1}$;

– the nearest N points to the right from the selected discrete maximum with the left-to-right indicated values: $y_1, \ldots, y_{N-1}, y_N$.

Using the least-squares method, we can find the 'a', 'b', 'c' coefficients of a reversed parabola $at^2 + bt + c$, giving the best approach to the above mentioned $2N + 1$ points of the discrete signal. In this case, the following expression will be right for the sought correction δ: $\delta = -b / (2a)$.

As a result of this task solution, the following expression of the correction is obtained:

$$\delta = -\frac{T}{10}(2N+3)(2N-1)\frac{\sum_{k=-N}^{N} k y_k}{\left(3\sum_{k=-N}^{N} k^2 y_k - N(N+1)\sum_{k=-N}^{N} y_k\right)}, \tag{1}$$

where T – sampling period, $y_{-N}, y_{-N+1}, \ldots, y_{-1}, y_0, y_1, \ldots, y_{N-1}, y_N$ – values of the above-mentioned discrete signal points.

As a consequence, (1) is resulted in

$$\text{For } N = 1: \delta = -\frac{T}{2}\,\frac{y_1 - y_{-1}}{y_1 - 2y_0 + y_{-1}}; \tag{2}$$

$$\text{For } N = 2: \delta = -\frac{T}{2}\,\frac{7}{5}\,\frac{2y_2 + y_1 - y_{-1} - 2y_{-2}}{2y_2 - y_1 - 2y_0 - y_{-1} + 2y_{-2}}; \tag{3}$$

$$\text{For } N = 3: \delta = -\frac{T}{2}\cdot 3\cdot\frac{3y_3 + 2y_2 + y_1 - y_{-1} - 2y_{-2} - 3y_{-3}}{5y_3 - 3y_1 - 4y_0 - 3y_{-1} + 5y_{-3}}. \tag{4}$$

The expressions for correction estimation indicated in (2), (3) and (4) are simple and not resource-intensive. Their usage in the software of the “Votum” company devices for different NDT applications in the fields of flaw detection and thickness gauging allows to improve considerably the measurements accuracy.