Decrease in the Error at Elimination of Phase Ambiguity by Method of Equivalent Wavelength

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Abstract – This article describes a method for reducing the phase error in a multifrequency method for eliminating phase ambiguity in digital, including holographic, measuring systems. The proposed method involves obtaining a series of interference patterns with different wavelengths and decoding them by the phase shift method. Reduction in error is ensured by combining the integer values of the phase obtained for an equivalent wavelength with the averaged values of the phase of the original wavelengths, which allows to eliminate the effect of accumulation of errors and, accordingly, to reduce the overall error in determining the phase. This allows us to extend the range of applicability of the method for eliminating phase ambiguity when several wavelengths are used. The method was tested by deciphering test patterns with a given noise level. The method showed stability to phase and amplitude noise.

Keywords – interferogram, analysis, equivalent wavelength, phase ambiguity.

I. INTRODUCTION

Elimination of phase ambiguity is an important component of analysis algorithms of interferograms in digital interferential, including holographic measuring systems. One of popular methods is expansion of dynamic range of phase unambiguity by synthesis of equivalent wavelength from two or more interferograms of the waves of a source of lighting received with different lengths [1]. A lack of such approach is increase in an error of definition of a phase in proportion to the relation of the initial and synthesized lengths of waves. Authors of article have offered a way of elimination of phase ambiguity which allows to eliminate this shortcoming.

II. PROBLEM DEFINITION

The two-frequency method of a holographic interferometry is that two holograms of the same object when lighting with different lengths of waves register in one photographic plate and. Equivalent wavelength is defined as [1]

$$\lambda_{eq} = \frac{\lambda_1 \lambda_2}{|\lambda_1 - \lambda_2|}$$

(1)

The difference between lengths of the used waves is less, the more there will be an equivalent wavelength. From the metrological point of view use of a method of two frequencies is more preferable as lengths of waves decide on a smaller error, than corners or indexes of refraction. The main problem when using this method is the complexity of selection of lengths of waves of the laser radiation used for lighting.

This shortcoming is easily overcome when using projective methods in which it is possible to project easily sinusoidal pictures with various periods [2].

For this purpose we receive two series of sinusoidal pictures with various size of period $$\lambda_1$$ and $$\lambda_2$$.

When using a method of step-by-step phase shift resultant values of a profile will change from 0 to the fringe width. The width of a strip determines object profile size in any units of measure (micrometers, millimeters) at the dynamic range of a phase from 0 to. $$2\pi$$.

The size of a profile can be determined by the following expression

$$C \cdot h(x, y) = \left[\frac{\Phi(x, y)}{2\pi}\right] \lambda$$

(2)

where – $$C$$ the system constant depending on the optical scheme, and $$\Phi(x, y)$$ absolute value of a phase.

Expression which connects a phase $$\Phi$$, the width of a fringe and size of a profile $$h(x, y)$$ has an appearance

$$\Phi(x, y) = \left[C \cdot h(x, y) / \lambda\right] \cdot 2\pi$$

(3)

If we do phase measurements with two lengths of waves $$\lambda_1$$ and $$\lambda_2$$, then the difference of two phases within the period will be defined by the following expression

$$\Delta\Phi_{12} = \Phi_1 - \Phi_2 = \left[C \cdot h(x, y) / \lambda_{eq}^2\right] \cdot 2\pi$$

(4)

where - $$\lambda_{eq}^2 = \lambda_1 \lambda_2 / |\lambda_2 - \lambda_1|$$ equivalent wavelength.

As a result of two phase measurements with different lengths of waves it is possible to receive only the values defined within the period from 0 to for $$\Phi_1$$ and $$\Phi_2$$. The absolute phase 1, is connected with the relation $$\varphi = \Phi \pmod{2\pi}$$. Using this expression from (4) it is possible to receive

$$\Delta\Phi_{12} = \Delta\Phi_{12} \pmod{2\pi} =$$

$$= \left[\Phi_1 - \Phi_2 \right] \pmod{2\pi} = \left\{\varphi_1 - \varphi_2 \right\} \pmod{2\pi} =$$

$$= \left\{\left[C \cdot h(x, y) / \lambda_{eq}^2\right] \cdot 2\pi \right\} \pmod{2\pi}$$

(5)
Thus, if to synthesize equivalent wavelength $\lambda_{eq}$, then the period of the interferential fringe corresponding to it will be more, than the measured range, then a problem of elimination of phase ambiguity will be solved within the range determined by equivalent wavelength.

Expression (5) is as follows:
- determine the phase difference;
- we define the difference of phases $\phi_1 - \phi_2$;
- if $(\phi_1 - \phi_2) < 0$, then to we add $2\pi$.

Let the fringe width (the period size) be expressed in pixels. If to take phase distributions of points $\lambda_1 = 60$ и $\lambda_2 = 90$, then equivalent wavelength will be

$$\lambda_{eq} = \frac{\lambda_1 \lambda_2}{|\lambda_2 - \lambda_1|} = \frac{60 \cdot 90}{(90 - 60)} = 180$$

points (fig. 1).

III. OFFERED THE ALGORITHM

Let us have four interferential pictures with phase shift between them 0, 90, 180 and 270 degrees (fig. 2 at the left) with a margin error 20% of value of amplitude of a sinusoid. The error is modelled by addition of casual noise to value of a sinusoidal picture.

On sinusoidal pictures it is fixable phase distribution (fig. 2 on the right) method of step-by-step phase shift by means of expression

$$\phi(x, y) = \arctan \frac{I_4 - I_2}{I_1 - I_3}.$$  (6)

At 20% of casual noise of amplitude of the set sinusoids the error of definition of a phase will make about 6.64% from at a sinusoid with the period of 60 and 7.2% at a sinusoid with the period 90. (fig. 3). Decrease in an error when determining a phase is explained by the filtering properties of expression (6). For this formula of interpretation decrease in an error makes about 3 times.

Choosing the different period of sinusoids it is possible to receive distribution of phases with various periods. From two sinusoidal sets with the period of 60 and 90 pixels (all field 1024) we will receive two phase distributions $\phi_1$ and $\phi_2$ by which it is possible to determine $\phi_{12} = \phi_1 - \phi_2$, if $\phi_{12} < 0$, then to $\phi_{12}$ it is added $2\pi$ (fig. 4). The period $\phi_{12}$ is equal to the period of equivalent wavelength - 180 pixels.
The phase $\phi_{12}$ is formed by the difference of phases $\phi_1$ and $\phi_2$, her error increases twice in comparison with errors of these phases respectively.

Adding to him value of a profile at the minimum period we will receive (fig.8). At a large number of strips the best results are yielded by an algorithm of elimination of phase ambiguity, with interferential strips the periods of which are coprime \[3\]. Significant increase in area of phase unambiguity is possible when using several phase pictures with various periods.

**IV. CONCLUSION**

The new way of definition of a phase at a multifrequency method of elimination of phase ambiguity is presented. The way is based on combination of integer values of a phase of
the initial lengths of waves received for equivalent wavelength with average values of a phase that allows to eliminate effect of accumulation of an error and to respectively lower the general error of definition of a phase.

REFERENCES


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