High-speed raster analyzer

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We propose an original design of a raster analyzer of the screening type that uses pulse-width modulation (PWM) principle of operation. The analyzer allows the coordinates of an object to be determined during a single pulse. Calculations of its shape that should meet the requirements to its time response characteristic are presented and a version of the raster exemplified for the case, when high accuracy of measurement is needed.

A wide variety of current lidar systems include raster analyzers, when determination of coordinates of an object sounded is needed. In this connection it is an urgent problem to improve the rate of angular measurement channel in such systems.

Among the raster analyzers (rasters), pulse-width modulation (PWM) rasters are most widely used. The advantage of the PWM rasters is an easy algorithm for processing electric signals from a photodetector. Concentric single-coordinate and two-coordinate rasters are currently used for the PWM.[1] The former are most simple, but they require additional channel for recording information about the second coordinate of a target. Two-coordinate rasters require application of dividers that rotate synchronously with the main raster. Besides, all concentric raster analyzers have such disadvantages as the zone of insensitivity at the center and very fine alignment with the optical system they are used with.

To eliminate the above disadvantages, we propose to use a two-coordinate eccentric screening raster (with the center lying off the optical axis of the system, see Fig. 1). The new feature of such a design is in utilization of the principle of concentric-to-eccentric coding of raster information in combination with the coding using reference pulses.

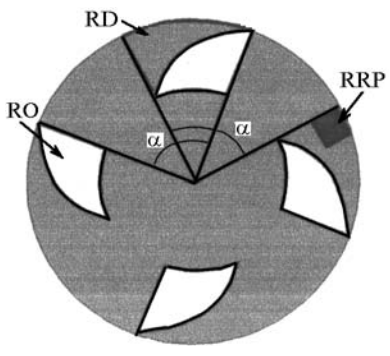

Fig. 1. Two-coordinate screening raster: receiver diaphragm (RD); raster opening (RO); receiver of reference pulses (RRP).

The analyzer proposed has an unbounded *linearity zone*, that is, the modulation parameters (pulse widths) are related to the sighting point coordinates by a *certain* dependence all over the raster field (Fig. 2).

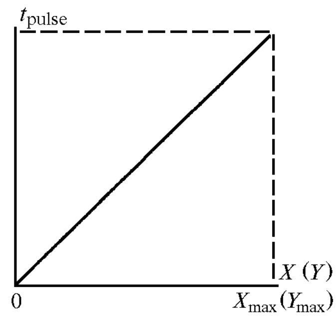

Fig. 2

The time interval between the reference pulse and the leading edge of a return pulse from a target image is proportional to the X coordinate of the target, while the pulse width τ is the measure of a target image deflection along the Y-axis (Fig. 3).

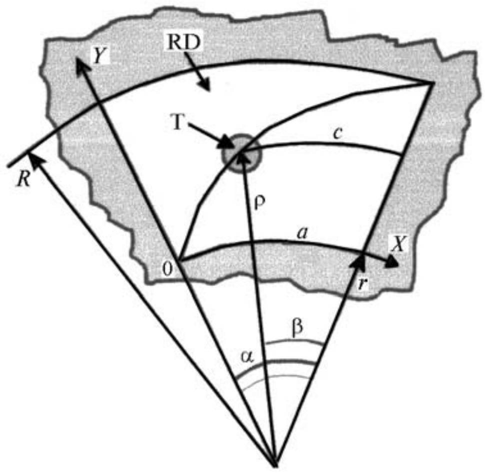

Fig. 3. Analyzer geometry: receiver diaphragm (RD); target image (T); R is the outer radius of the raster; r is the inner radius of the raster; c is the length of the arc, the raster draws on the image of the target being at an arbitrary distance ρ from the raster center.

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Different profiles of the raster aperture shape can provide for different dependence of the pulse width on the deflection angle β of the radius vector ρ from front edge of the raster opening (see Fig. 3).

To make the dependence of τ on Y coordinate linear, the following condition should be satisfied:

$$\tau = \text{const}\ \rho. \tag{1}$$

As the target shifts toward the inner edge of the raster (Y and ρ increase), the pulse width τ decreases due to the decreasing arc length c in the transparent part of the raster (see Fig. 3):

$$\tau = c/V = c/(2\pi\rho f), \tag{2}$$

where V is the speed of movement of an arbitrary raster point at a distance ρ from the center; f is the raster rotation frequency.

The arc length is

$$c = \rho\beta, \tag{3}$$

where β is the sector angle, in radians. Upon substitution of Eq. (3) into Eq. (2), we have

$$\tau = \beta/(2\pi f). \tag{4}$$

From this it follows that for the linearity condition (1) to hold, one should make the shape of the raster opening such that the rotation angle of the raster β be linearly dependent on the radius vector ρ (see Fig. 3):

$$\beta = \text{const}\ \rho. \tag{5}$$

This dependence is a straight line as shown in Fig. 4.

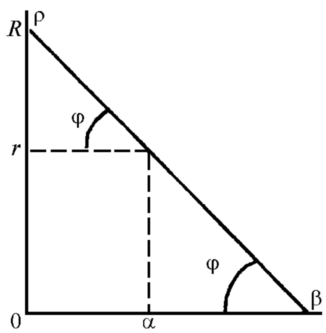

Fig. 4

As β increases, ρ decreases linearly. The straight line has two characteristic points: (0; R) and (α; r), which allow us to present it in the following form:

$$\rho = R - \beta \tan(\varphi) = R - \beta\ (R - r)/\alpha. \tag{6}$$

Expression (6) determines the profile of the raster opening. Let us write expression for β based on the Eq. (6):

$$\beta = \alpha\ (R - \rho)/(R - r). \tag{7}$$

Now transform it to the XnY coordinate system: $\rho = r + Y$, consequently,

$$\beta = \alpha\ (R - r - Y)/(R - r). \tag{8}$$

Substitution of Eq. (8) into the temporal characteristic of the raster given by Eq. (4) yields:

$$\tau = \alpha\ (R - r - Y)/[2\pi f\ (R - r)]. \tag{9}$$

The time characteristic of the raster is presented by a straight line (Fig. 5).

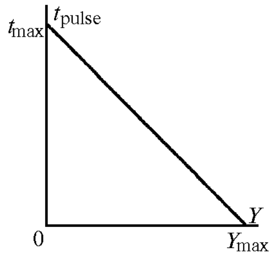

Fig. 5

The characteristics presented are written in the XnY coordinate system, which differs from the rectangular one. This difference decreases, as the raster disc diameter increases and the field of view becomes narrower. Under strict requirements imposed onto the accuracy of measurements, we can avoid this in two ways:

1) by introducing a numerical correction into the finally obtained coordinates,

2) by applying an analyzer with crossed axes, what makes the manufacture of such a raster more difficult (Fig. 6).

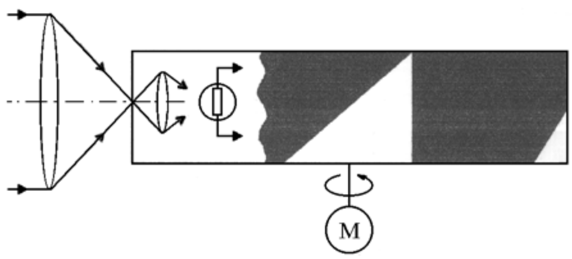

Fig. 6

The raster analyzer proposed allows the information about the target to be obtained from the first measuring pulse, because every pulse bears this information (X and Y coordinates of the target). In some cases, it allows improvement of the system operation rate as compared to similar systems, which determine the coordinates only in a steady process at raster modulation. Numerical estimation of the gain in the system speed due to the use of the raster proposed has shown that the minimum time of pulse presence needed for stable operation of the raster is 20 μs, what is 8 to 10 times (the number of openings in the raster) fewer than in a system determining the coordinates in a steady mode. This result has been obtained experimentally with a coordinate-measuring setup. The setup used employs a semiconductor laser and a semiconductor TsL70339I photoresistor as the detector.

The measurement error of the system supplied with the proposed analyzer is less than a half of the angular size of a target. The error depends on a structure and circuitry of the electronic part of the analyzer. Reference 2 presents estimates of the time position of a pulse depending on the design of the electronic part of the system. The optimal solutions proposed in this paper, enable the measurement error to be reduced to 0.05 of the angular size of a target .

References

1. M.M. Miroshnikov, *Theoretical Grounds of Opto-Electronic Devices* (Mashinostroenie, Leningrad, 1983), 696 pp.
2. B.N. Mityashev, *Determination of a Temporal Position of Pulses under Noise Conditions* (Sov. Radio, Moscow, 1962), 296 pp.