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GENERATOR OF BASIC COMMAND SIGNALS FOR QUALITY TESTING OF PAN AND TILT DEVICES SERVOMECHANISMS

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Abstract: *The pan and tilt devices (P&TD) are often used for placement of camera and antenna systems which must track moving objects (targets) precisely and speedily in many applications. For the basic testing of the adjustment and the quality of their positioning servomechanisms, the unit step functions of position or velocity are used as command signals. We have developed the program SNBP for the complex testing. The algorithms description of its foregoer EFG was published in the conference Engineering Mechanics 2004. As time goes on, it has shown the necessity to develop a connecting link – the generator of only basic command signals necessary in the middle phase during servos testing. We have utilized the traditional model of a target movement, i.e. the hypothesis about its uniform straight-line motion. This model is not able to generate a correct command signal for the elevation motion control in the range greater than ± 90°. At present, P&TDs are made with substantially greater elevation ranges. Therefore we have remade completely the model. The simulation model, which we present now, is able to generate the command signal for the unlimited traverse motion and for the elevation motion, too.*

Keywords: ***Pan and tilt device, positional servomechanism, basic command signals generator (simulator).***

1. Target movement model

A basic clarification of the simulation target movement model is in Fig. 1 and 2. A pan and tilt device (P&TD) is placed in the point *B* (Fig. 1). Its traverse (pan) axis is perpendicular to the horizontal plane and it intersects the elevation (tilt) axis just in the point B. Due to simplicity, we assume that the Line-of-Sight (LOS) of the camera objective passes through the same point and that the LOS is directed precisely to the target point T, which represents the target. Consequently, the target point T is identical to the aiming point. The non-simplified description of the configuration is adduced in Cech, V. & Jevicky, J. (2004).

The target is moving uniformly rectilinearly and so its trajectory is determined explicitly by the ground speed vector vT = (vT, αT, λT). The movement proceeds in the vertical target course over ground plane (track plane) (Fig. 2 – a set of T-points, specially T0, TH, TA, T). The target course over ground is given by the unit vector of its speed, consequently by the angles (αT, λT), where αT is the actual track bearing (azimuth), λT is the angle of course pitch over ground (λT = 0 – „constant altitude“, λT > 0 – pitching angle, λT < 0 – diving angle).

The shortest horizontal range dTB from the point B to the track plane (the line segment BPC) is denoted as (azimuthal) course (track) parameter |pA| = min dTB. If pA = 0, then it is called as “coming course (track)”; if pA ≠ 0, then it is called as “crossing course (track)”. It is presumed traditionally, that pA ≥ 0. For simplification of calculations, we will assume that pA is a real number.

Vertically over the point PC there is lying so-called midpoint TA of the target path. Actual path sA is contractually equal to zero in this point, i.e. sA(TA) = 0. It is valid contractually that sA = vT·tA, where tA is contractual time of the target motion. The half-line is denoted as “approaching leg” for $t_A < 0$ and as “receding leg” for $t_A > 0$. In calculations there is used the actual horizontal path $x_A = s_A \cdot \cos \lambda_T$, which lies in the target horizontal course (track). The horizontal increments of topographical coordinates of the system UTM relative to the point *B* are

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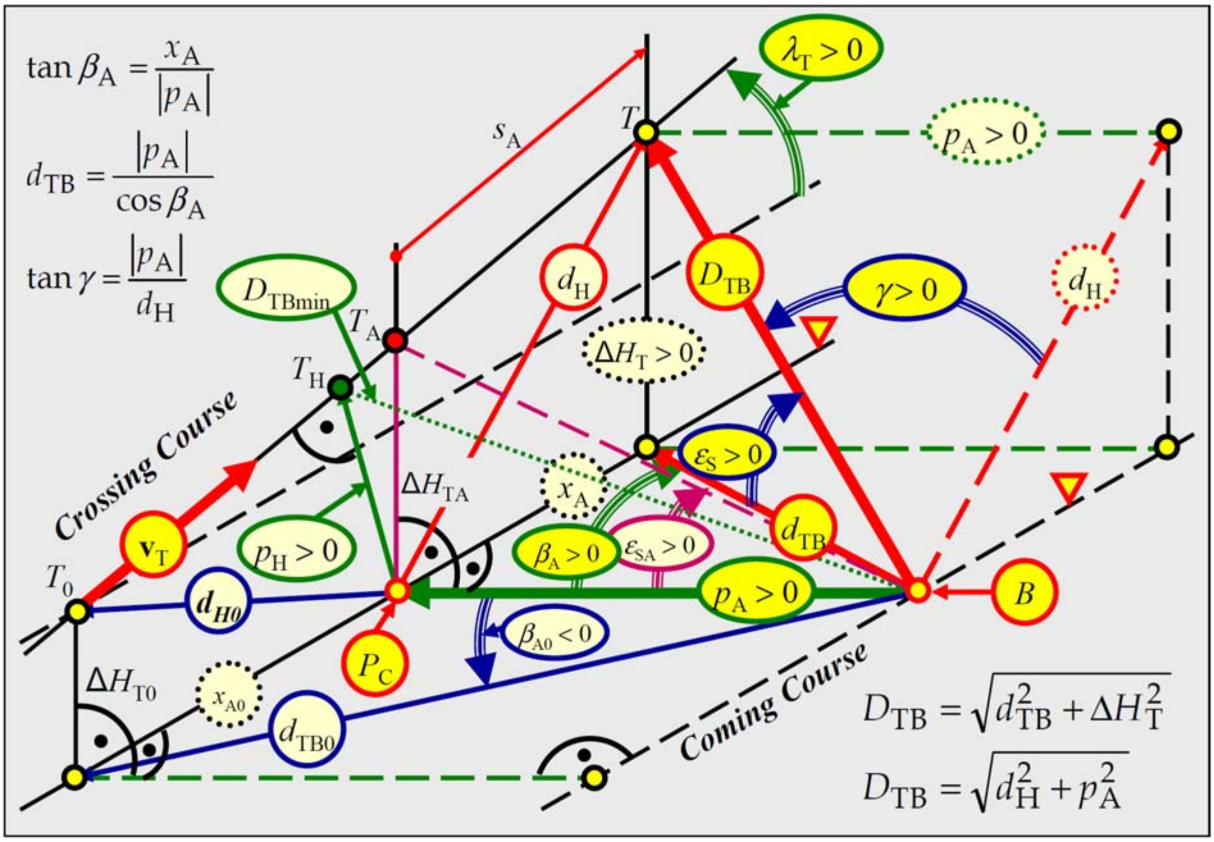

Fig. 1: The first scheme for clarification of geometric relations.

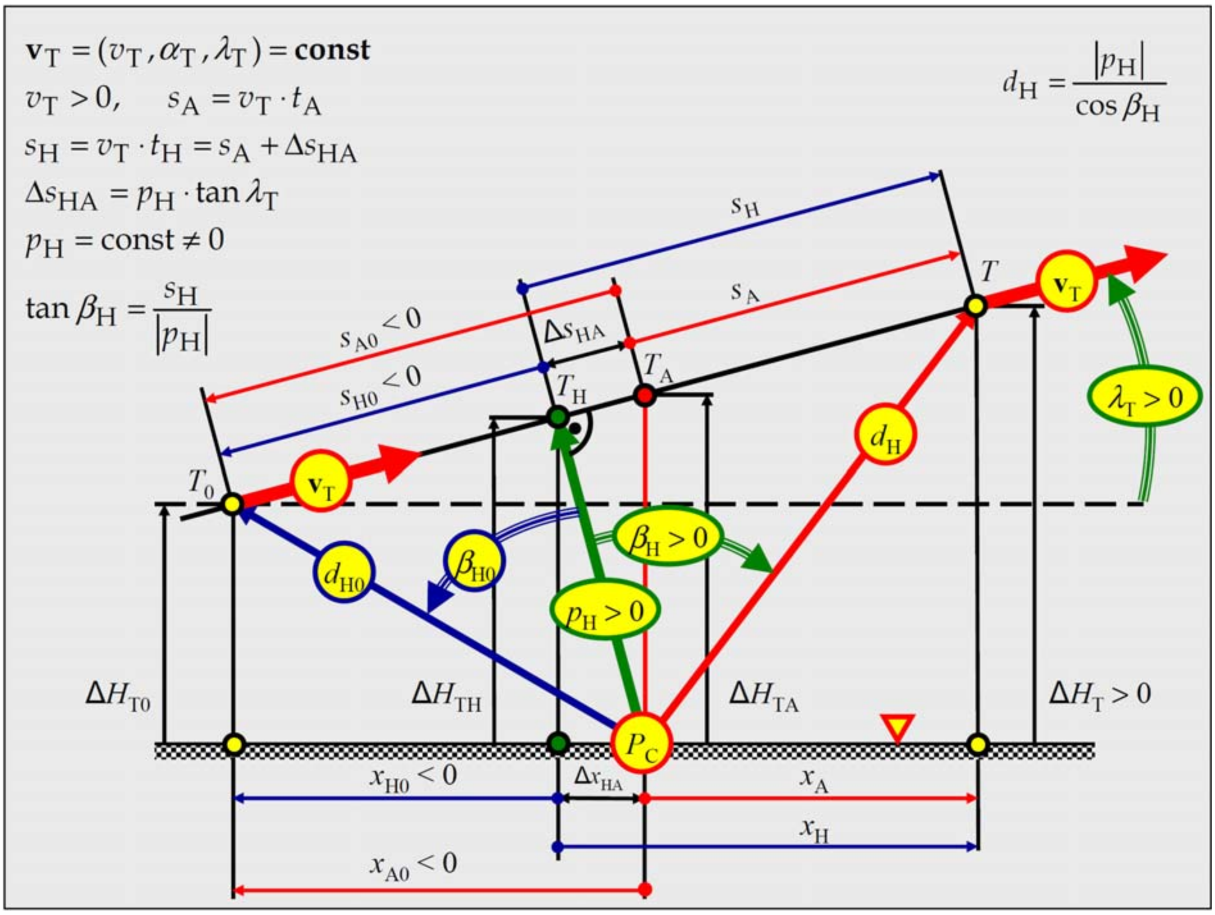

Fig. 2: The second scheme for clarification of geometric relations.

$$\Delta E_T = x_A \cdot \sin\alpha_T + p_A \cdot \sin(\alpha_T + 270°),$$
$$\Delta N_T = x_A \cdot \cos\alpha_T + p_A \cdot \cos(\alpha_T + 270°). \tag{1}$$

In contrast to traditional procedures, we will use the slant range d_H of the point T to the point P_C. We denote its minimal size as the elevation course (track) parameter $|p_H|$ = min d_H (the line segment $T_H P_C$). For simplification of calculations, we will assume that p_H is a real number, $p_H \neq 0$. It is valid for the altitude of the target point T

$$\Delta H_T = \Delta H_{TA} + s_A \cdot \sin\lambda_T, \quad \Delta H_{TA} = p_H / \cos\lambda_T. \tag{2}$$

This introduction of the parameter $p_H \neq 0$ and the slant range d_H allows to use the universal relation for the slant range to target point T

$$D_{TB} = \sqrt{d_H^2 + p_A^2}, \quad d_H = |p_H| / \cos\beta_H. \tag{3}$$

2. Usage of model of target movement for generating command signals ε_S, ψ_a

An instantaneous position of the target point T is determined by the pair of angles $\beta_A \in \langle -90°; +90° \rangle$, $\beta_H \in \langle -90°; +90° \rangle$ (Figs. 1, 2). Their sizes can be calculated easily from values (v_T, λ_T, p_H, p_A), which determine simulated movement of the target, and from the chosen time t_A. It can be determined consequently with the use of angles β_A, β_H:

a) Traditional value of the bearing (azimuth) of the target point T

$$\alpha_{TB} = \begin{cases} (\alpha_T + 270°) + \beta_{AE0} & \text{if } p_A = 0, \\ (\alpha_T + 180°) + (\beta_A + 90°) \cdot \mathrm{sgn}(p_A) & \text{otherwise,} \end{cases} \quad \alpha_{TB} \in \langle 0°, 360°), \tag{4}$$

where β_{AE0} is defined below in (9).

b) The absolute traverse (pan) angle

$$\psi_a = (\alpha_{TB} - \alpha_{MD}) \in \langle 0°, 360°), \tag{5}$$

where α_{MD} is the bearing (azimuth) of main direction of pan and tilt device (its orientation is towards the north in the horizontal plane). It must be for simulations $\psi_a \in (-\infty, +\infty)$.

c) The angular height of the target point T angle detected by an elevation (tilt) angle sensor

$$\varepsilon_S = \begin{cases} [\beta_H + (90° - \lambda_T)] \cdot \mathrm{sgn}(p_H) & \text{if } p_A = 0, \\ \arctan\left(\dfrac{\Delta H_T}{d_{TB}}\right) & \text{otherwise,} \end{cases} \quad \varepsilon_S \in \langle -180°, +180° \rangle, \quad d_{TB} = |p_A| / \cos\beta_A. \tag{6}$$

d) Traditional angular height of the target point T

$$\varepsilon_{TB} = \begin{cases} \arcsin(\sin\varepsilon_S) & \text{if } p_A = 0, \\ \varepsilon_S & \text{otherwise,} \end{cases} \quad \varepsilon_{TB} \in \langle -90°, +90° \rangle. \tag{7}$$

e) Hereafter, it is valid for $p_A = 0$:

$$\dot{\varepsilon}_S = \dot{\beta}_H \cdot \mathrm{sgn}(p_H), \qquad \dot{\varepsilon}_{TB} = -\dot{\varepsilon}_S \cdot \mathrm{sgn}(\beta_H - \lambda_T),$$
$$\ddot{\varepsilon}_S = \ddot{\beta}_H \cdot \mathrm{sgn}(p_H), \qquad \ddot{\varepsilon}_{TB} = \left[|\ddot{\beta}_H| - \delta(\beta_H - \lambda_T) \right] \cdot \mathrm{sgn}(p_H), \tag{8}$$

where $\delta(\beta_H)$ is the Dirac delta function.

The definition of the angle β_A is extended for the case of $p_A = 0$ by the value

$$\beta_{AE0} = \begin{cases} 90° \cdot \mathrm{sgn}(\beta_H - \lambda_T) & \text{in the traditional model (limited elevation, see } \varepsilon_{TB0} \text{ in Fig. 3)}, \\ -90° & \text{in the new model (unlimited elevation, see } \varepsilon_{S0} \text{ in Fig. 3).} \end{cases} \tag{9}$$

The instantaneous size of angle

$$\gamma = \arctan\left(\frac{|p_{\mathrm{A}}|}{d_{\mathrm{H}}}\right) \in \langle -90^\circ, +90^\circ \rangle \tag{10}$$

is important for the choice of control strategy of elevation and traverse movement. We will clarify this problem on some of consequential conferences together with problems of the choice of the target point T_0 initial position (the choice of t_{A0}) for simulations of positional servomechanisms behavior. The work with the time $t_{Asim} = t_A - t_{A0}$ is possible during simulations.

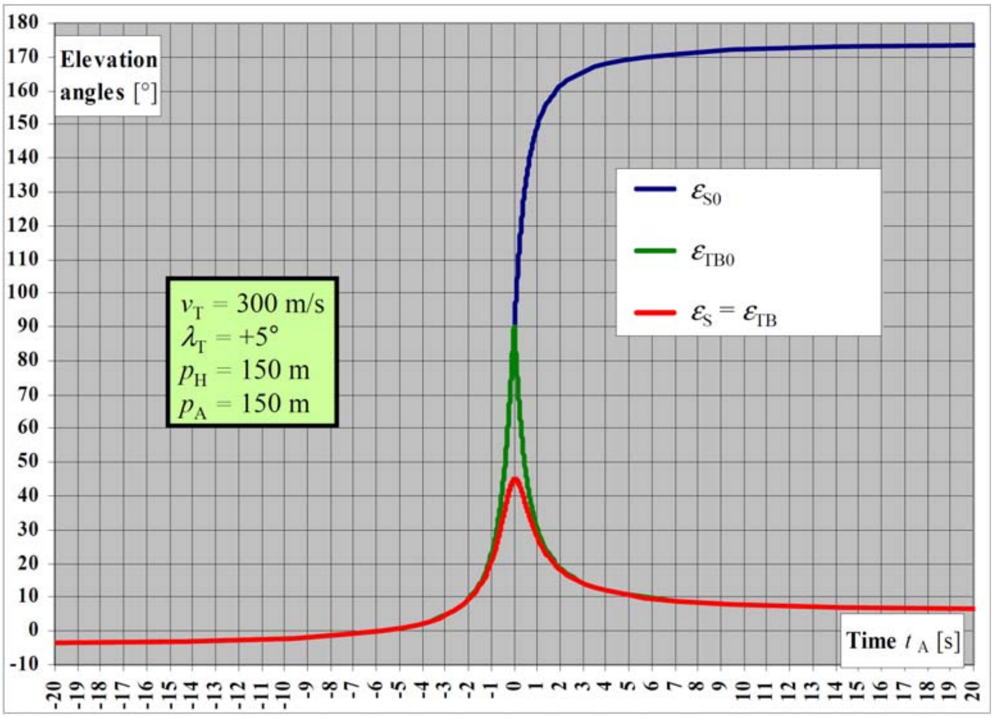

Fig. 3: Courses of angles ε_{S0}, ε_{TB0} for $p_A = 0$ and $\varepsilon_S = \varepsilon_{TB}$ for $p_A \neq 0$.

3. Conclusions

The traditional model had been developed gradually since the end of 19th century and it was finalized in the second half of 1930s (Pchelnikov, N. I. (1940), Curti, P. (1945), Locke, A. S. (1955)). The model does not differentiate between angles ε_S and ε_{TB}. As it is obvious from relations (6), (7), (8) and from the graph in Fig. 3, this simplification represents a serious defect, which fully takes effect during simulations of elevation motions in systems with unlimited elevation. Our asset consists in recognition of this problem and its elimination.

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