# ON THE ERRORS IN TELEMETERING OF THE MOVEMENT FEATURES WITH DOPPLER RADIOTELEMETRY SYSTEM

**Popa Dan[1], Toma Corneliu[2], Tănase Mihail[3]**

(1) S.C. Auto Europa S.R.L., Str. Miresei no. 1, 300642 Timisoara, Romania,
(2, 3) "Politehnica" University of Timisoara, Departments of Communications and of Applied Electronics, Bd. V. Parvan no 2, 300223 Timisoara, Romania (e-mails: danpopa@mail.dnttm.ro, ctoma@etc.utt.ro, mtanase@etc.utt.ro).

**Abstract:** This paper is a result of the work done by the authors in the field of movement evaluation at low speed in the atmosphere and low costs of the movement execution. Theoretical and constructive solutions offered by telemetering the following features of the movement: instant speed and movement sense, average speed and distance in a interval of given time. Being an indirect determination and taking into account the interfering physical phenomenon it is relationally evaluated the interfering errors, emphasizing the random errors. Their evaluation, with direct implication into the determination precision, represents the contributions of the authors in this paper.

**Keywords:** Doppler signal, Doppler telemetry, systematic and random errors.

## 1. INTRODUCTION

The authors have proposed in [3] the general structure for a Doppler radio-telemetry system with active fixed referential – Figure 1. The main contribution consists in the selection

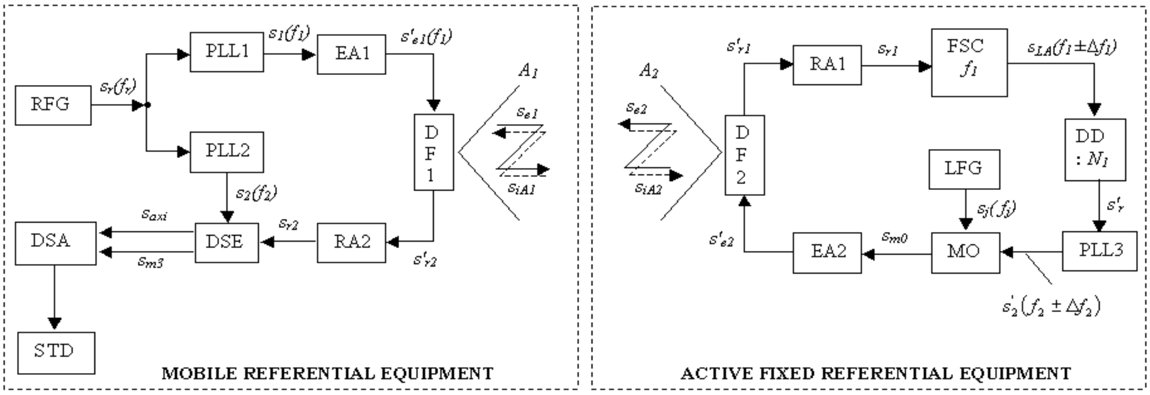


Fig.1. The general structure for the Doppler radio-telemetry system with active fixed referential: RFG – reference frequency signal generator; LFG – low frequency signal generator; PLL1, 2, 3 – frequency synthesizers; EA1, EA2 – emission amplifiers; DF1, DF2 – diplex filters; RA1, RA2 – reception amplifiers; FSC$f_1$ – $f_1$ frequency selection circuit; DD – digital frequency divider; MO – DSB-SC modulator; DSE – Doppler signal extractor; DSA – Doppler signal analyzer; STD – block for showing and transmitting data.

of the movement to be evaluated from other movements taking place simultaneously in the same space by the activation of the fixed referential in that it produces the change of frequency $f_1$ into $f_2$ and its modulation in SSB-SC with the low frequency $f_j$.

The signal $s_{e1}(2\pi f_1 t + \varphi_0)$ emitted by the antenna $A_1$ is phase modulated by the Doppler effect and is received by the antenna $A_2$. The Doppler shift in frequency, $\pm\Delta f_1$, is retrieved into the signal $s_2'[2\pi(f_2 \pm \Delta f_2)t + \varphi_0]$ through $\Delta f_2 = (f_2 \Delta f_1)/f_1$ and is emitted by the antenna $A_2$ as the signal $s_{e2}[2\pi(f_2 \pm \Delta f_2)t \pm 2\pi f_j t \pm \varphi_j + \varphi_0]$. This signal is again phase modulated by the Doppler effect and is received by the antenna $A_1$. At the output of the Doppler signal extractor DSE the signals: $s_D$ - Doppler signal and $s_{axi}$ - Doppler shift in frequency axing signal are obtained. Their expressions are represented by (1).

$$s_D = A_D \sin(8\pi\Delta f_2 t) \quad \text{and} \quad s_{axi} = 2A_m \cos[2\pi(f_j \pm 2\Delta f_2)t + \varphi_j] \qquad (1)$$

## 2. DISCUSSION AND EXPERIMENTAL RESULTS

The telemetering of the following features of movement – instant speed, average speed and distance in the time interval $\Delta t$, is actually an indirect measurement, through the relations (2). The determination errors consists in systematic errors, random errors and gross errors.

$$v = \frac{v_f}{f_2} \cdot \frac{1}{8\pi} \cdot \frac{\partial}{\partial t}\left[\arcsin\left(\frac{s_D}{A_D}\right)\right], \quad v_{\text{med}} = \frac{v_t + v_0}{2} \quad \text{and} \quad D = v_{\text{med}} \cdot \Delta t \qquad (2)$$

**The systematic errors** contain instrumental and methodological errors. The instrumental errors are taking into account that $v$, $v_{\text{med}}$, $D$ are determined numerically, which means that, besides the errors in knowing the $f_2$ frequency, the propagation speed of the electromagnetic wave in the air $v_f$ and the time interval $\Delta t$, the analog/digital conversion error $\gamma_{ad}$ also interferes. Taking into account the used A/D converter into the Doppler signal analyzer DSA and that $f_2$ and $f_1$ are obtained through the frequency synthesizer with PLL loop, it is appreciated that $\gamma_v$ and $\gamma_D$ are measured with a precision better than 0,5 %.

**The methodological errors** are deduced from the measuring function $y = F(x, l, m, ..., q)$ where $y$ is the result of the measurement, $x$ is the measured quantity and $l$, $m$, …,$q$ are physical quantities that can vary during the measurement process. Based on the detailed knowledge of the whole telemetering strain, the quantities that can vary have been established, compensating measures have been taken and the methodological error has been minimized under 0,5 %.

**The random errors** are due to different causes whose individual influence is not easy to see, the experiments putting into evidence only their random appearance. For the case of telemetry, those errors are very important and this is why they have been carefully researched. The random errors are grouped around the zero value and they are according to the known statistical laws [1].

Starting from the apparent measuring error $u_i = v_i - v_0$ with $v_0 = \frac{1}{n}\sum_{i=1}^{n} v_i$ the probability of the random errors repartition $f(u_i)$ is determined, as well as the error function $\overline{\Phi}(v)$, according to the relations:

$$f(u_i) = \frac{1}{r\sqrt{2\pi}} \cdot \exp\left(-\frac{u_i^2}{2r^2}\right) \quad \text{and} \quad \overline{\Phi}(v) = \frac{2}{\sqrt{\pi}}\int_0^v \exp\left(-u_i^2\right)\mathrm{d}u \tag{3}$$

The constant $h = 1/\left(r\sqrt{2}\right)$ is known as the precision module and it interferes into the normal repartition function $N\left(m, r^2\right)$. Choosing the interval for the variation of the random errors [–3r, +3r), the probability that this error will be inside this interval is $P\left(-3r \le u_i \le +3r\right) = 0{,}9972$.

The mean square error $\sigma_v$ of the measurements, taking into account the random variable $\xi$ is:

$$\sigma_v = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(v_i - v_0\right)^2} = r \tag{4}$$

It is deduced that the true value of the instant speed is inside the interval $(v_0 \pm r)$ with $r$ equal to the mean square error of the measurements.

In reality, $v$ is not directly determined, but through the measurement of the Doppler signal $s_D$ and of its amplitude $A_D$. Because it has been supposed that for an instant speed, $n$ individual measurements are made, it is possible to say that $v_i$ has been obtained through direct measurement $s_{Di}$ and $A_{Di}$ with $i$ = 1, 2,…, $n$. It is determined $s_{D0} = \frac{1}{n}\sum_{i=1}^{n} s_{Di}$ and $A_{Do} = \frac{1}{n}\sum_{i=1}^{n} A_{Di}$ as well as the mean square errors:

$$\sigma_{SD} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(s_{Di} - s_{D0}\right)^2} \quad \text{and} \quad \sigma_{AD} = \sqrt{\frac{1}{n}\sum\left(A_{Di} - A_{D0}\right)^2} \tag{5}$$

Based on the first relation in (2) it is obtained $v_i = V\left(s_{Di}, A_{Di}\right)$ and $V\left(s_{D0} + \alpha_i, A_{D0} + \beta_i\right)$.

In case that the $\alpha_i$ and $\beta_i$ errors have values smaller than 1, it is obtained :

$$\sigma_{pv} = \sqrt{s_{D0}^2 \cdot \sigma_{pSD}^2 + A_{D0}^2 \cdot \sigma_{pAD}^2} \quad \text{and} \quad v = V\left(s_{D0}, A_{D0}\right) \pm \sigma_{pv} \tag{6}$$

The Doppler radio-telemetry equipment with active fixed referential (Fig.1), has been test under real conditions on the sheep for lift the graph of the background of the Danube around the Iron–Gates 1 water power station, near Drobeta Turnu Severin. Starting from the active fixed referential, on a distance of 400 meters and going back to the referential, DSA indicated zero at 0,7 meters from the referential. The total error resulted better than 1 %.

## 3. CONCLUSIONS

The theoretical consideration of the systematic and random errors, through experimentation proved to be correct and it demonstrated the good knowledge of the performing electronic equipment used, as well as the correct choice of the structure of the Doppler radio-telemetry system with active fixed referential for the telemetering of the small speed movements characteristics.

## REFERENCES

[1] Iarlîkov M.S., 1985, "Statisticeskaia teoria radionavigaţii", Izd. "Radio I sviaz", Moskva.
[2] Popa D.T., 2003, "Contributions to the realization of the distance evaluation systems for low speed movements, executed at low costs", Ph.D. Dissertation, 'Politehnica" University of Timisoara, Romania.
[3] Tănase M.E., Toma C.I., Popa D.T., 2004, "Doppler telemetry system for the evaluation of low speed movement in the atmosphere", Facta Universitatis (Niš), Ser.:Elec. Energ., Vol. 17, No. 3, pp.313 – 324.