About the teaching of radio navigation theory

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Reviewed literature

Review of ideas, used in modern scientific and teaching literature for GNSS activity description

\( t_{01}, t_{02}, t_{03}, \ldots \) is called “a priori known” \([3, 4]\), or moments with nominal time of transmission \([5]\)

\[
\Delta T = t_{0i} - t_{d oi}
\]

\[
\tau^j_{pd} = \tau^j_d + \Delta T
\]

\[
\rho^j = c \tau^j_{pd} = c(\tau^j_d + \Delta T) = \sqrt{(x_r - x^j)^2 + (y_r - y^j)^2 + (z_r - z^j)^2 + \Delta R_r}
\]
Kriticism of ideas used in modern scientific and teaching literature for GNSS activity description (1)

\[ \tau_{pd}^j = \tau_{apd}^j + k^j T_{tr} \]

Ambiguous pseudodelay measurements under \( \tau_{d}^j > T_{tr} \)
Kriticism of ideas used in modern scientific and teaching literature for GNSS activity description (2)

\[ \tau_{pd}^j = \tau_{apd}^j + k^j T_{tr} \]

Ambiguous pseudodelay measurements under \( |\Delta T| > T_{tr} \)
Kriticism of ideas used in modern scientific and teaching literature for GNSS activity description (3)

Arrival times of j-th and k-th satellites signals
Kriticism of ideas used in modern scientific and teaching literature for GNSS activity description ГНСС (4)

Measurement moment $t_{\text{meas}}$ and appropriate for it transmission times for $j$-th $t_{tr}^j$ and $k$-th $t_{tr}^k$ satellites.
Meaning content of harmonic signal phase \( \phi(t) \) definition

\[
\varphi(t) = \int_0^t \omega(x) \, dx + \varphi_0
\]

\[
a(t) = A(t) \cos \varphi(t)
\]
Meaning content of PRN signal phase definition
Time scale and time on the scale meaning content definition

Clock indication (clock process full phase) or scale time

Clock indication (first clock process full phase) or the time on first scale

Clock indication (first clock process full phase) or the time on second scale

Shift of first scale relative to second scale in the moment defined on the second scale

Moments, appropriate for two different time scales
Satellite clock indication resolution

\[ \xi_j(t_{\text{изм}}) = \frac{b}{a} - \text{fraction phase} \]

\[ \hat{T}_j(t_{\text{пр}}) = 10^{-3} \left( \xi_j + n_j + \xi_j(t_{\text{изм}}) \right) \]
Visual navigational receiver model and pseudorange idea definition

satellite code signals

\[ T_{\text{chan}}^j(t_{\text{meas}}) = \hat{T}^j(t_{\text{tr}}) = 10^{-3}(\xi_{\text{mc}} + n^j + \hat{\xi}^j(t_{\text{meas}})) \]

\[ \hat{\Pi}^j(t_{\text{meas}}) = T_r(t_{\text{meas}}) - \hat{T}^j(t_{\text{tr}}) = T_r(t_{\text{meas}}) - T_{\text{chan}}^j(t_{\text{meas}}) \]
OMEGA system navigational frame

10.2 (0.09804 mc) 13.6 34/3 KHz

Least common multiple is 60/17 mc

OMEGA frame duration 10 c, hence least common multiple is 30 c
L. Fey. definitions


\[
\hat{T}^j(t_{tr}) = N_{day} \cdot 86400 + N_{hour} \cdot 3600 + N_{min} \cdot 60 + N_{30} \cdot 30 + \xi^j(t_{meas})
\]
Summary

• Primary radionavigation concept is “time on scale”, for which stands moments of physical time, indicated by clock, basic for every scale. Clock reading is a full phase of a signal given by a clock generator.

• “Time on scale” concept is used to determine a pseudo-delay, as well as for calculating in a receiver a satellite coordinates in the moment of emission.

• A pseudodelay is secondary concept formed as the difference between the readings of the receiver clock and the channel clock in the moment of measurement.

• In radionavigation systems pseudodelay ambiguity resolution is made by ambiguity resolution of satellites (stations) clock ambiguity in the moment of emission (channel clock readings).
Summary (continuation)

• Reading of curriculum a on bases of radionavigation systems functioning should be started from:

- Definition of “time on scale” as full phase of a periodical signal, lying in a basis of every scale (clock).

- Transmission of the radionavigation stations clock readings with use of emitted signals phase.

- Use in a receiver a received signal phase for calculating a satellites coordinates in the moment of emission and for forming a pseudodelay measurements as a difference of full phases (difference of a receiver clock readings in the moment of measurement and a moment of emission)
Summary (continuation)

• After presenting the general principles of radionavigation systems functioning one should move to the illustration how these principles are implemented in specific terrestrial systems (OMEGA, ALPHA, Loran-C, Chaika) and GNSS.

• Examine characteristics of a common functioning principles in exact GNSS: GPS, GLONASS, BDS, Galileo. Example: in GPS, satellites migration is binded to the system scale time, whereas in GLONASS -- to the Moscow decreed time. In GLONASS, board timescale is the phase of a signal transmitted in L1, whereas in GPS it is ionospherefree combination of signal phases, transmitted by satellites in L1 and L2. Etc…
Thanks for your attention.

Questions?