About the teaching of radio navigation theory

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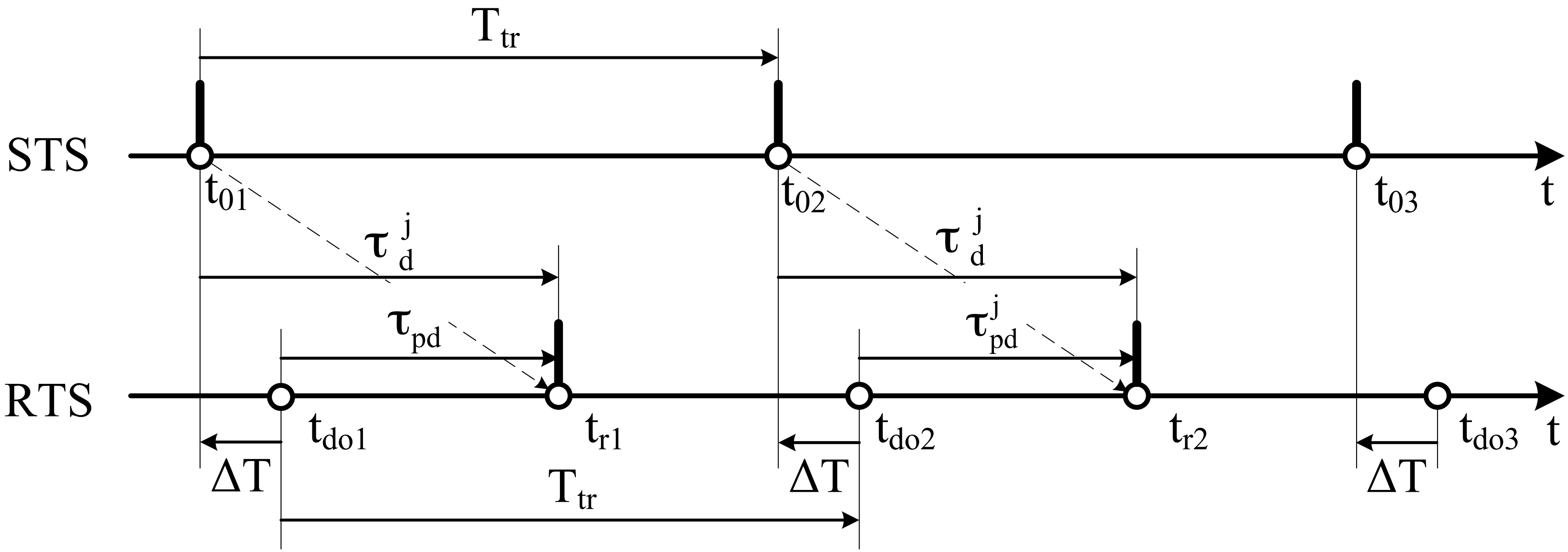
Krasnoyarsk, 20 may 2015 г

Reviewed literature

1. GLONASS. Global satellite radionavigation system. Edited by A.I. Petrov, V.N. Kharisov.- M.: Radiotechnica.- 2005.
2. Malishev V.V., Kurshin V.V., Revnivykh S.G. Introduction to satellite navigation. Text edition. M.: Publishing house MAI-PRINT. – 2008.
3. Information technology in radiotechnical systems. Text edition. Edited by Fedorov I.B. Second edition, revised and corrected edition. M.: MSTU Bauman Publishing house.- 2004.
4. Solovyov Y.A. Systems of satellite navigation. Monograph. M.: EKO-TRENDZ.- 2000.
5. Boriskin A.D., Weitzel A.V., Weitzel V.A., Jodzishskiy M.I., Milutin D.S. High-precision positioning equipment on the signals of global navigation satellite systems: receivers – navigation data users. Scientific publication. - M.: MAI-PRINT.- 2010.
6. Bakulev P.A., Sosnovskiy A.A. Radionavigation systems. Course manual. - M.: Radiotechnics.- 2011.
7. Guide to GPS Positioning. Prepared under the leadership of David Wells. Canadian GPS Associates. Second printing, with corrections, May 1987

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

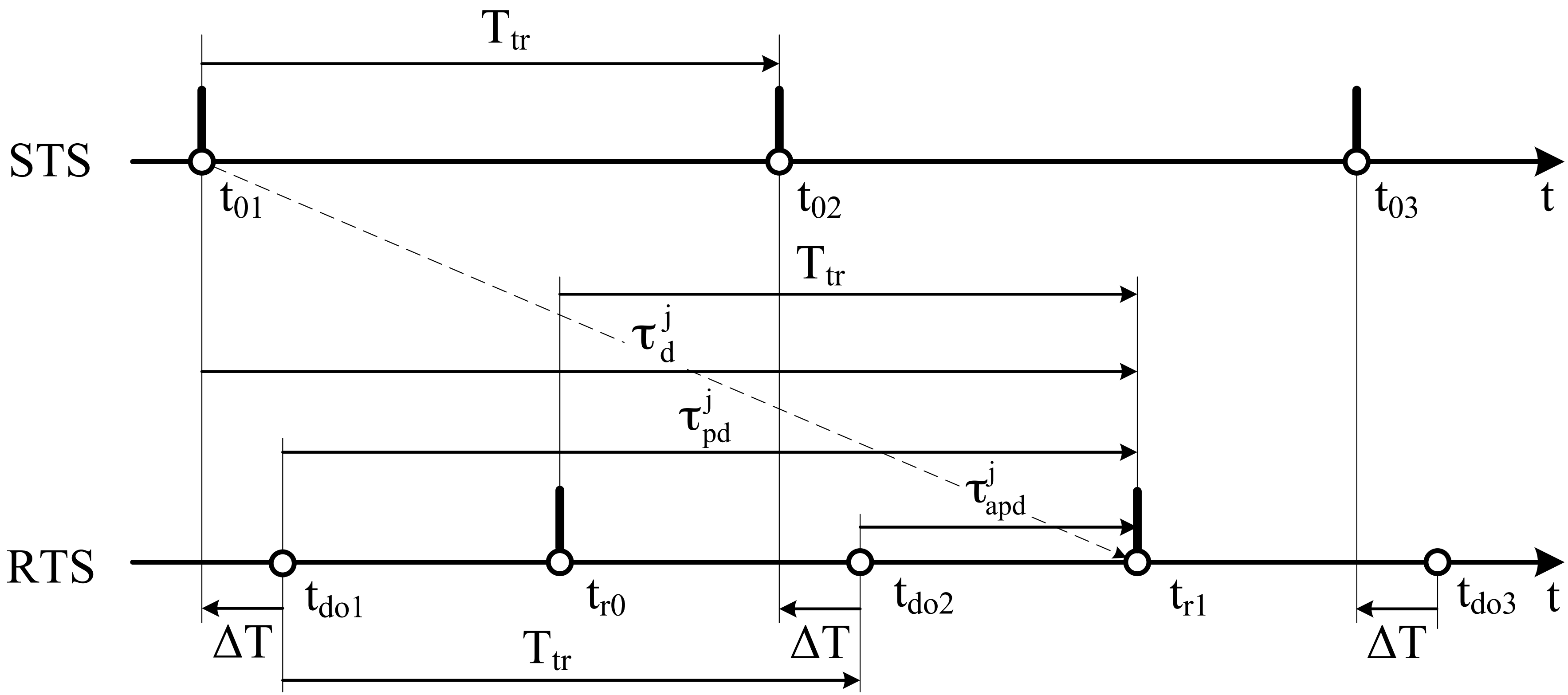


t_{01}, t_{02}, t_{03}, … is called "a priori known" [3, 4], or moments with nominal time of transmission [5]

$$\Delta T = t_{0i} - t_{doi} \qquad \tau_{pd}^j = \tau_d^j + \Delta T$$

$$\rho^j = c\tau_{pd}^j = c\left(\tau_d^j + \Delta T\right) = \sqrt{\left(x_r - x^j\right)^2 + \left(y_r - y^j\right)^2 + \left(z_r - z^j\right)^2} + \Delta R_r$$

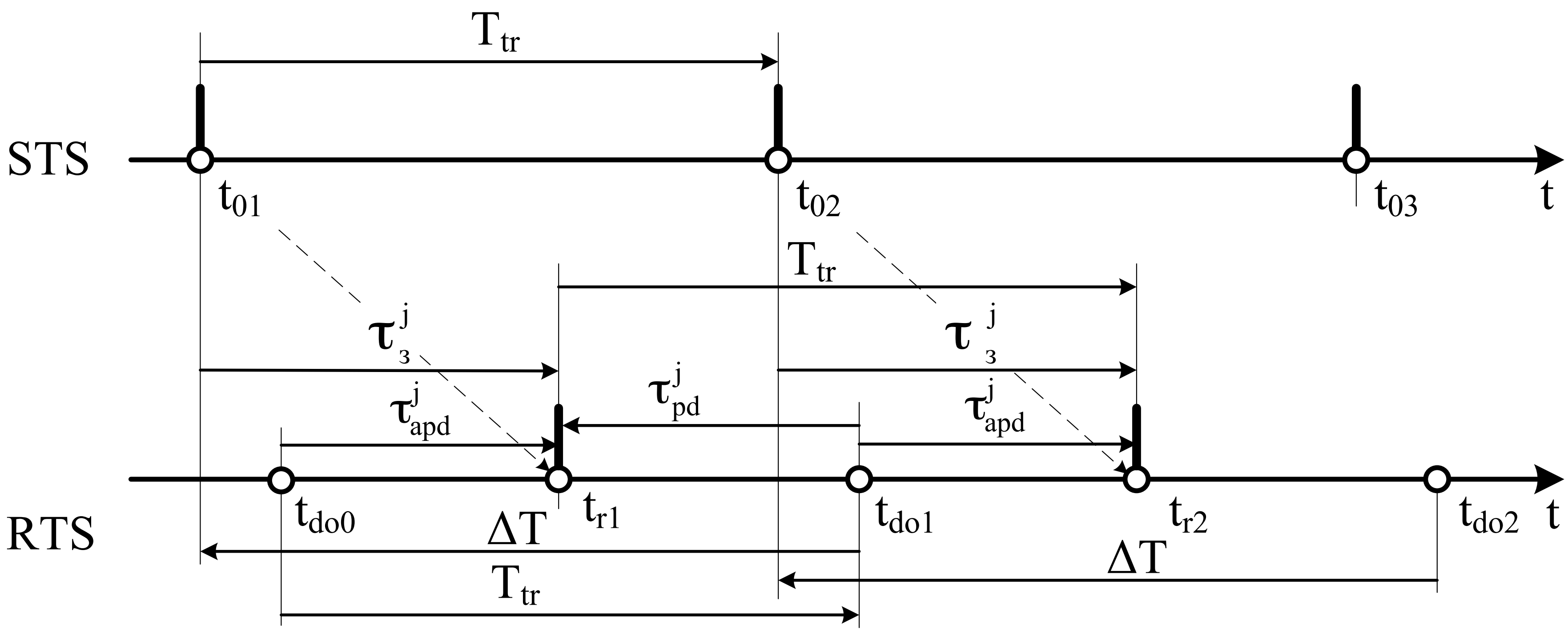
Kriticism of ideas used in modern scientific and teaching literature for GNSS activity description (1)



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

Ambiguous pseudodelay measurements under $\tau_{d}^{j} > T_{tr}$

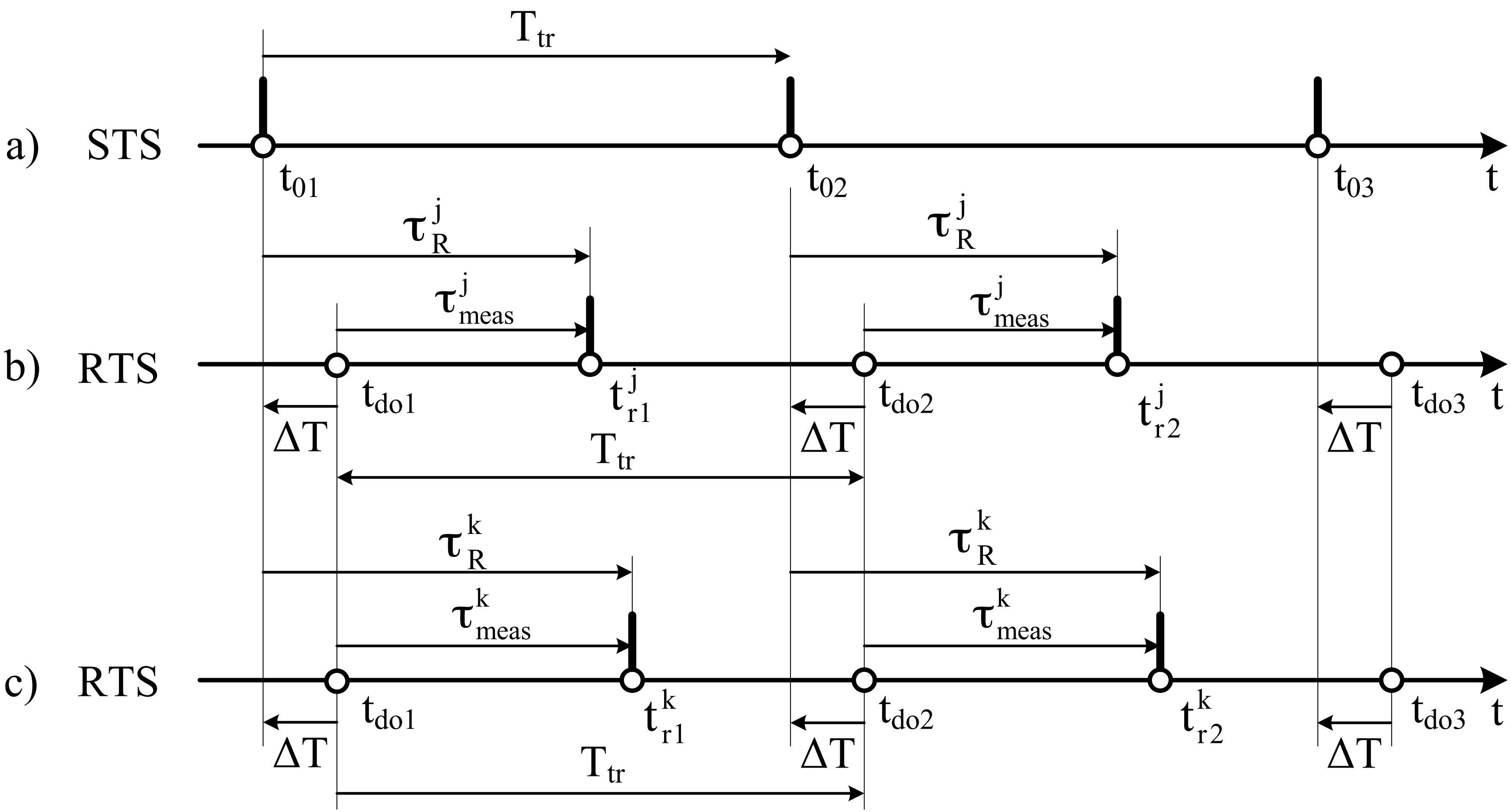
Kriticism of ideas used in modern scientific and teaching literature for GNSS activity description (2)



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

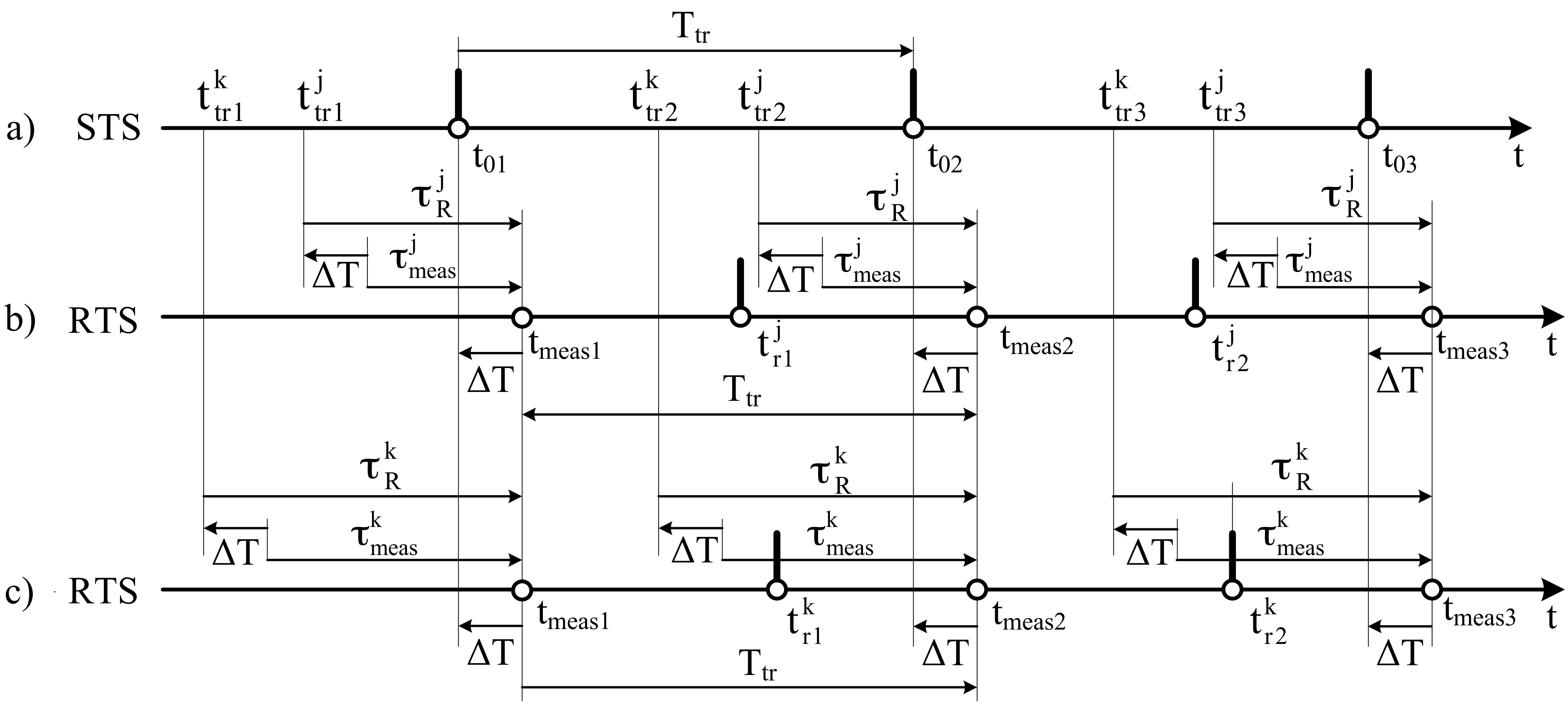
Ambiguous pseudodelay measurements under $|\Delta T| > T_{tr}$

Kriticism of ideas used in modern scientific and teaching literature for GNSS activity description (3)



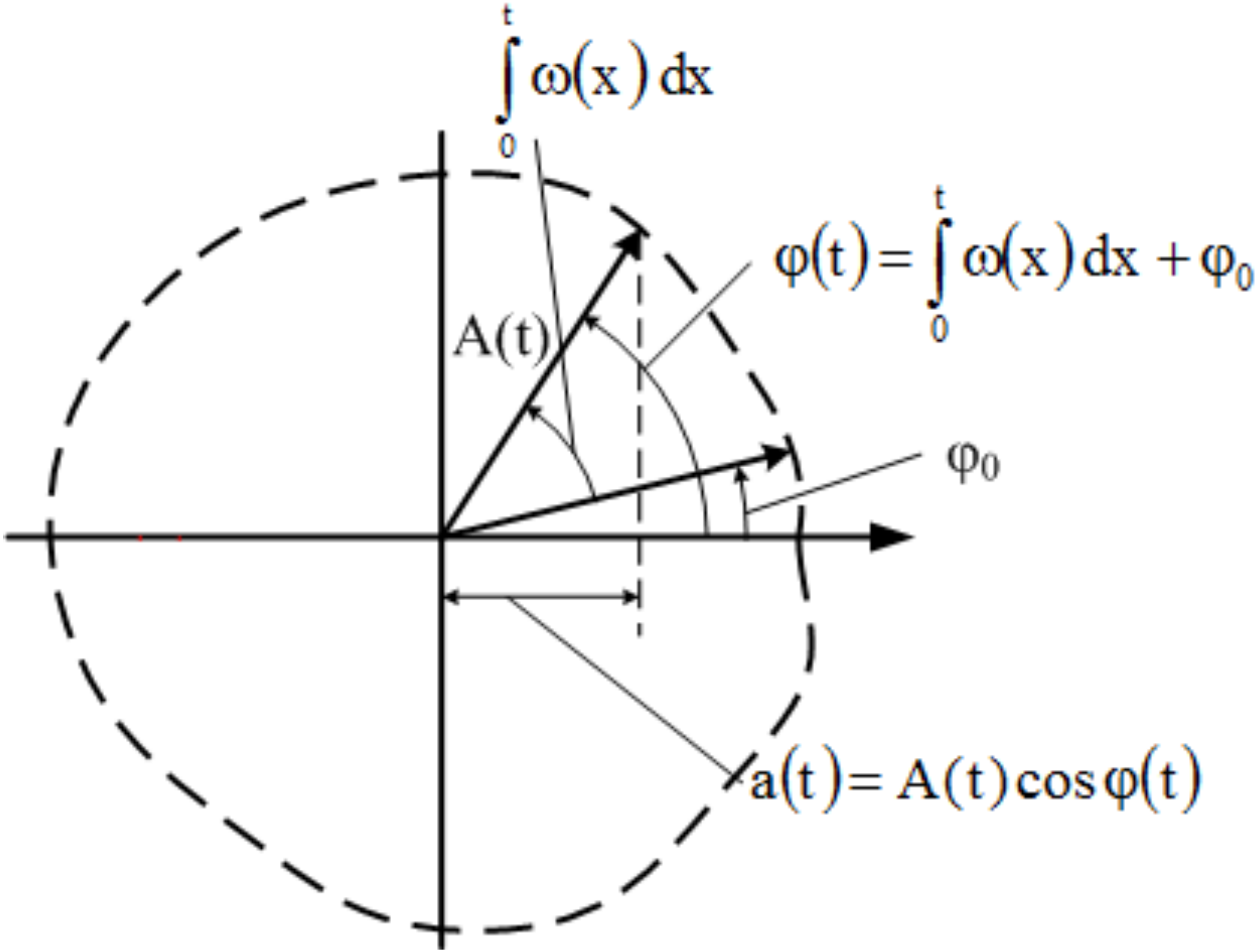
Arrival times of j-th and k-th satellites signals

Kriticism of ideas used in modern scientific and teaching literature for GNSS activity description ГНСС (4)

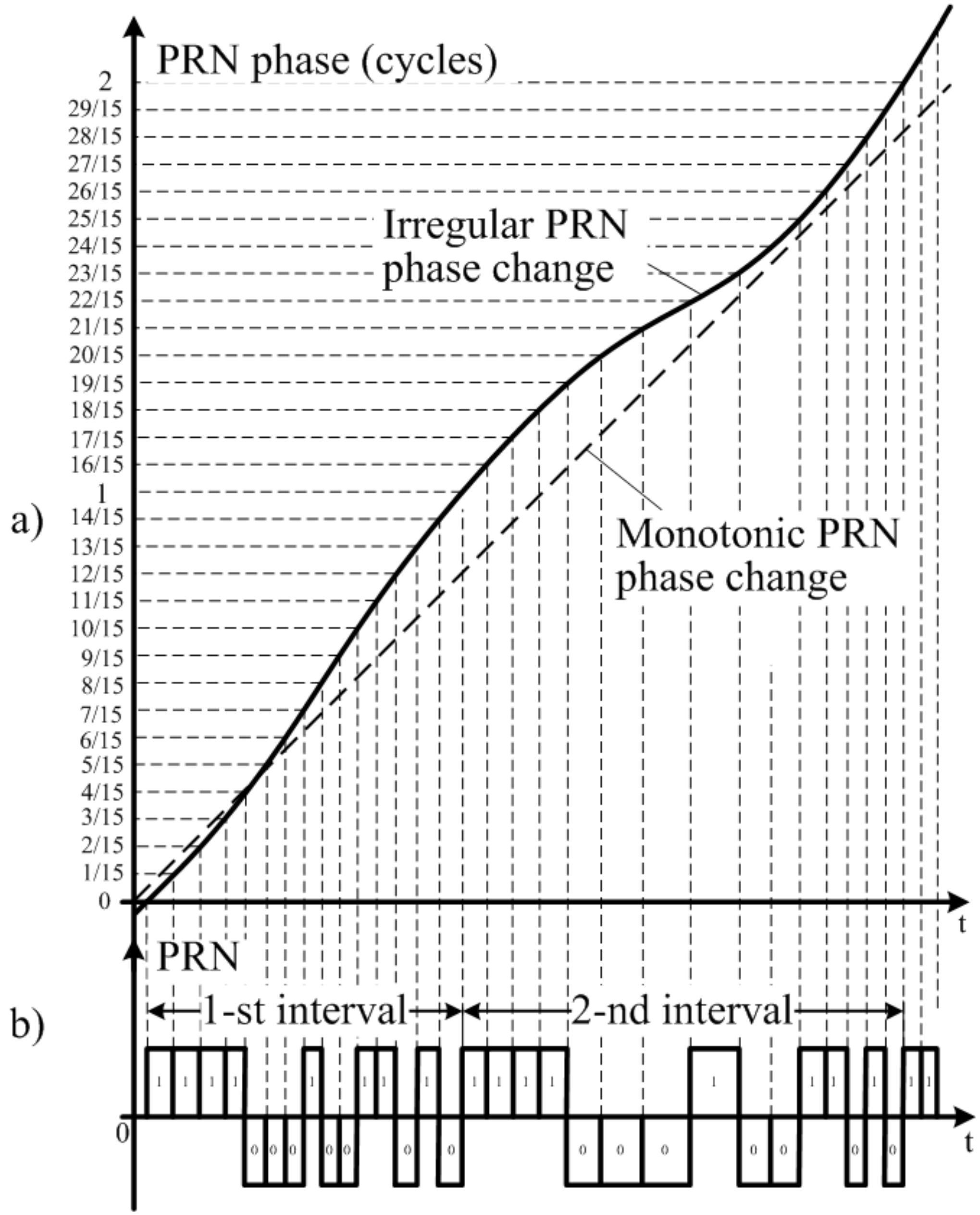


Measurement moment t_{meas} and appropriate for it transmission times for j-th t^j_{tr} and k-th $t^к_{tr}$ satellites.

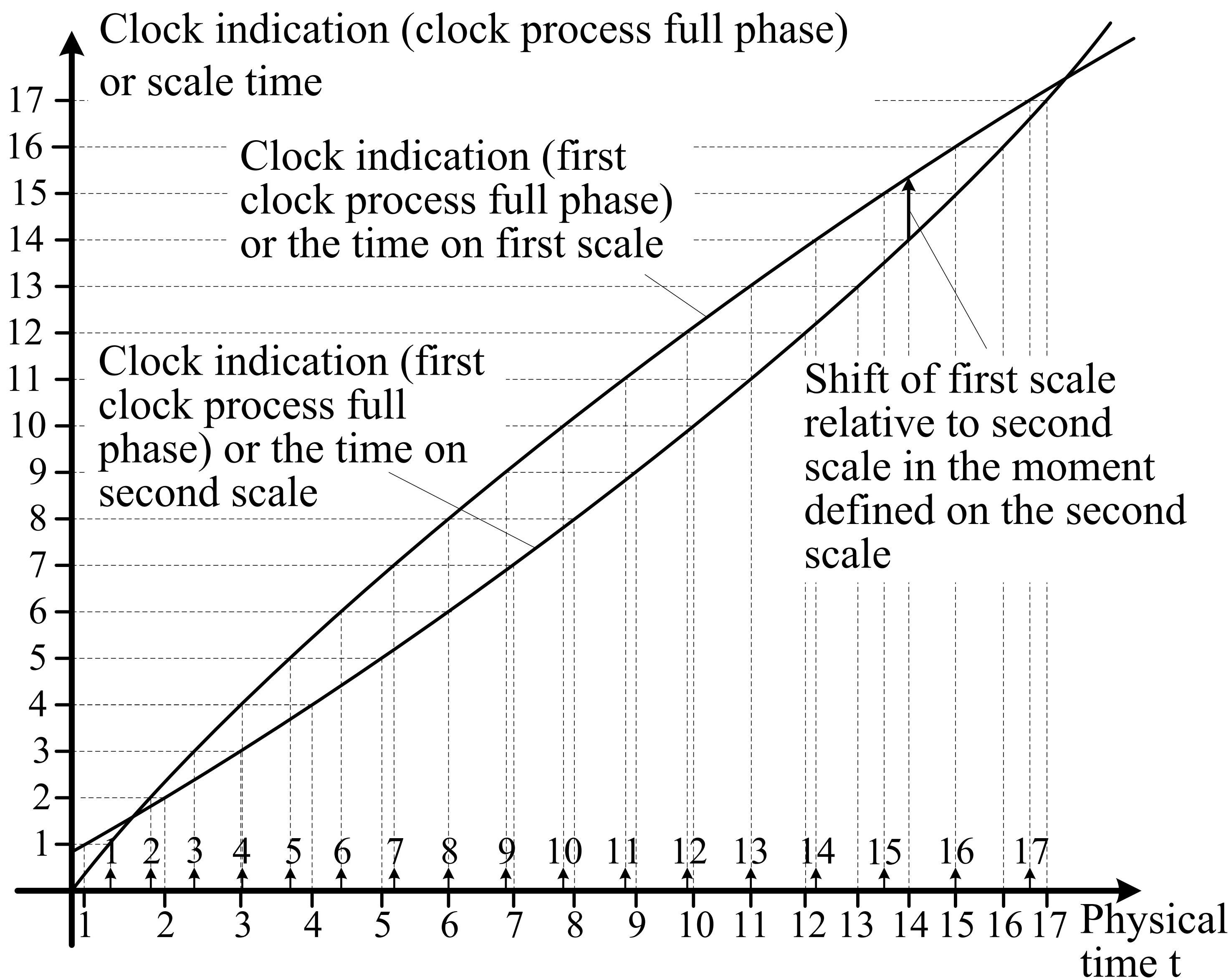
Meaning content of harmonic signal phase φ(t) definition



Meaning content of PRN signal phase definition

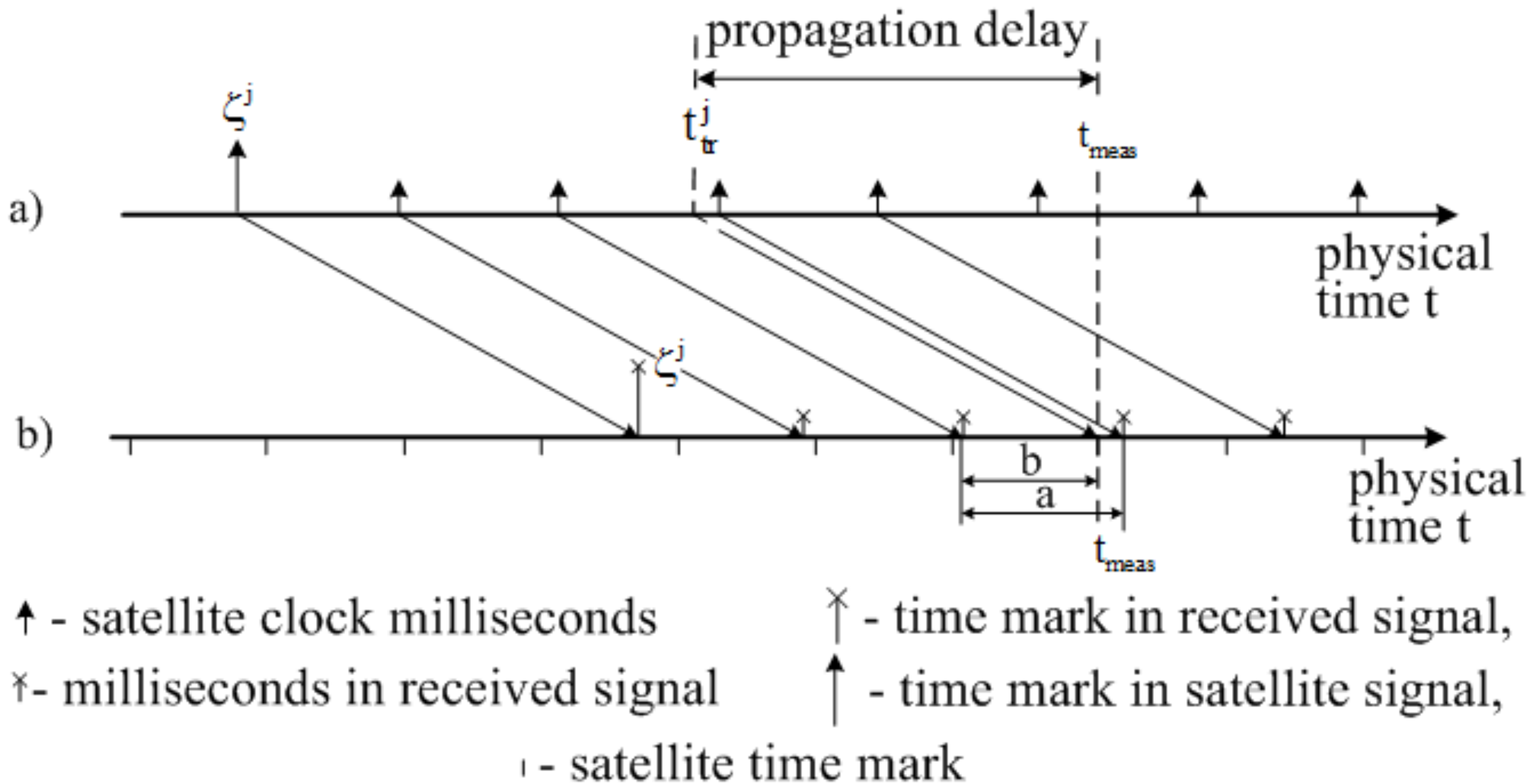


Time scale and time on the scale meaning content definition



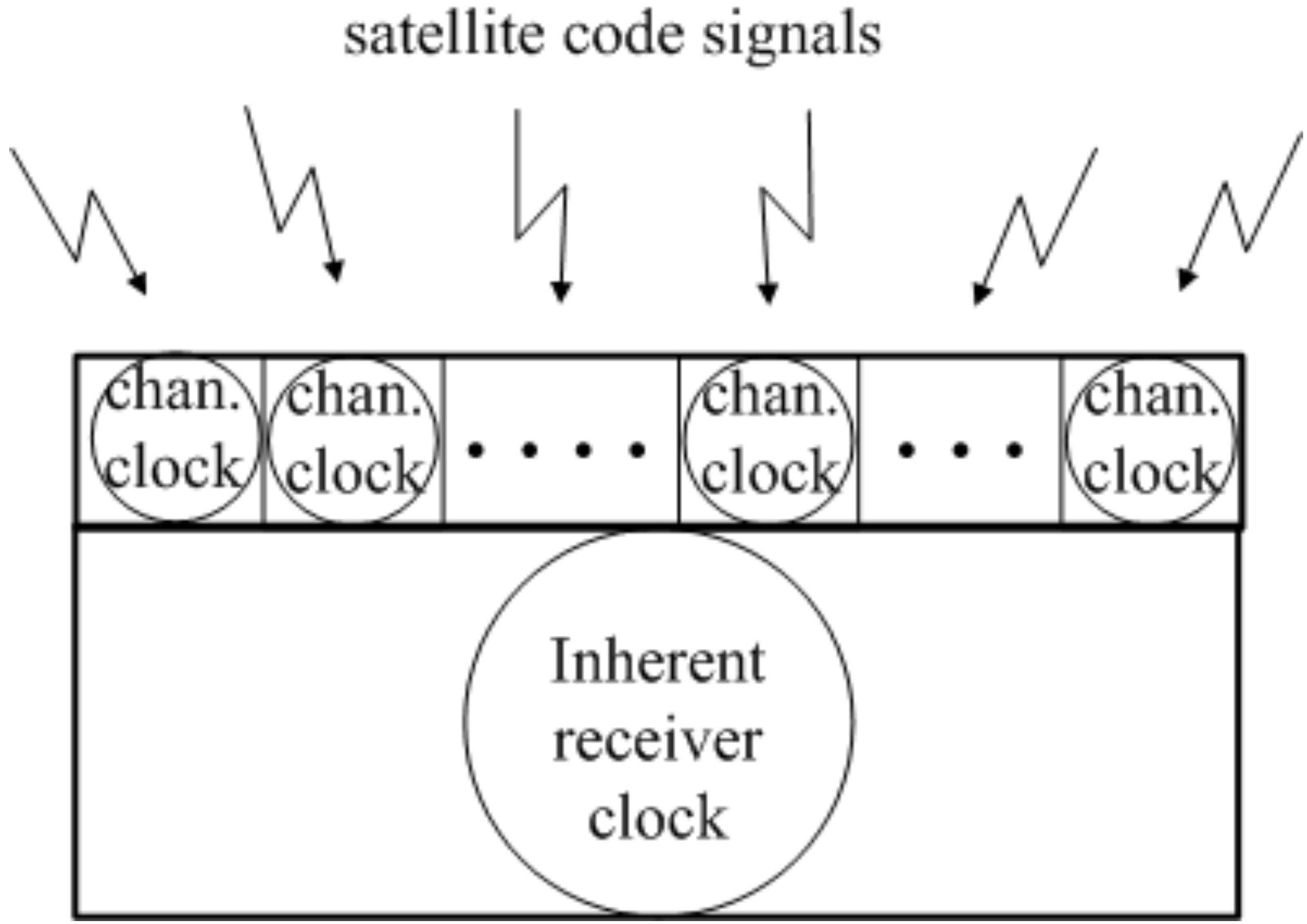
Moments, appropriate for two different time scales

Satellite clock indication resolution



$\hat{\xi}^j(t_{изм}) = b/a$ – fraction phase $\quad \hat{T}^j(t^j_{пр}) = 10^{-3}\left(\zeta^j_{мс} + n^j + \hat{\xi}^j(t_{изм})\right)$

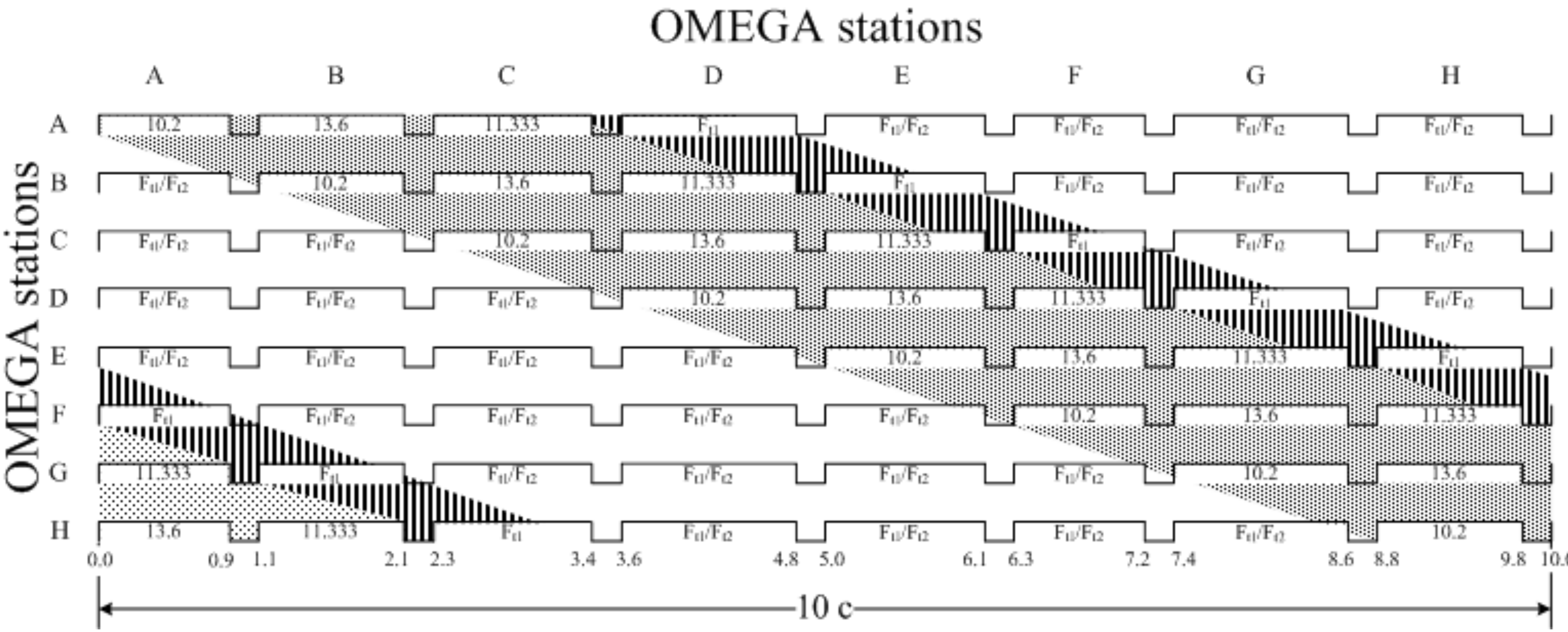
Visual navigational receiver model and pseudorange idea definition



$$T^{j}_{chan}\left(t_{meas}\right) = \hat{T}^{j}\left(t^{j}_{tr}\right) = 10^{-3}\left(\zeta^{j}_{\text{мс}} + n^{j} + \hat{\xi}^{j}\left(t_{meas}\right)\right)$$

$$\hat{\Pi}^{j}\left(t_{meas}\right) = T_{r}\left(t_{meas}\right) - \hat{T}^{j}\left(t^{j}_{tr}\right) = T_{r}\left(t_{meas}\right) - T^{j}_{chan}\left(t_{meas}\right)$$

OMEGA system navigational frame



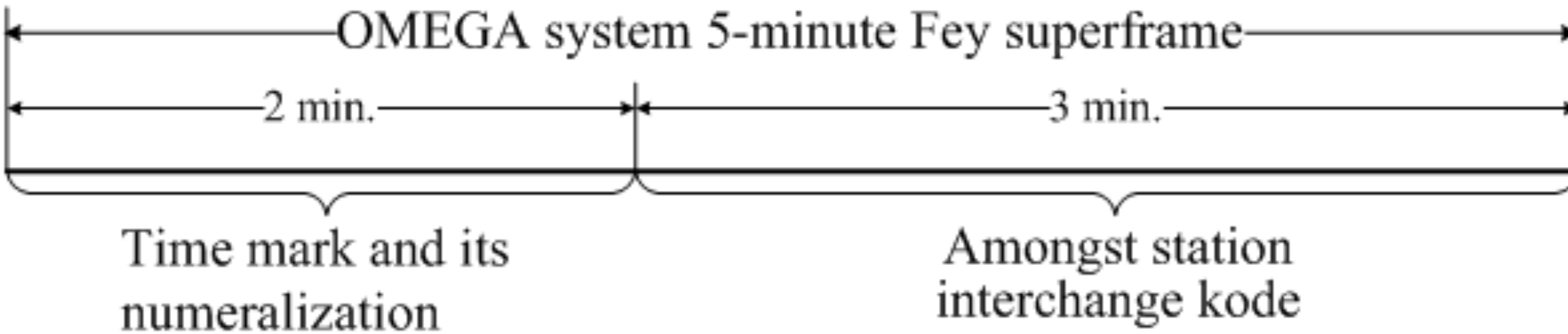
10.2 (0.09804 mc)   13.6   34/3   KHz

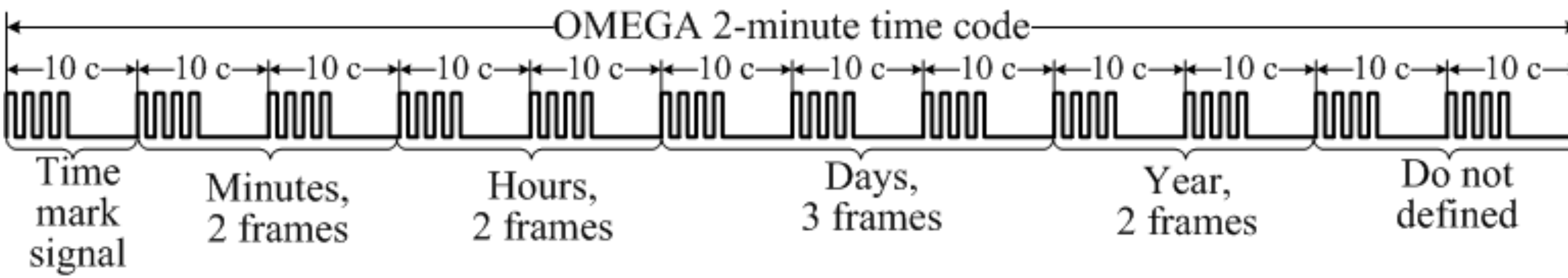
least common multiple is 60/17 mc

OMEGA frame duration 10 c, hence least common multiple is 30 c

L. Fey. definitions

L. Fey. Time Disseminations Capabilities of the Omega System. Pros. 25th Ann. Symp. Frequency Control (Electron. Indust. Ass., Washington, D.C.) pp. 167-170, Apr. 1971





$$\hat{T}^{j}\left(t_{tr}^{j}\right) = N_{day} \cdot 86400 + N_{hour} \cdot 3600 + N_{min} \cdot 60 + N_{30} \cdot 30 + \xi_{c}^{j}\left(t_{meas}\right)$$

Summary

- Primary radionavigation concept is “time on scale”, for wich 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 decret 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 you attention.

Questions?