Recent research achievements in the field of satellite navigation in Croatia

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Agenda

• Motivation
• Aim of the project
• Project team
• Project description
• Obtained results
• International collaboration
• Conclusion
Motivation – project “Environment for Satellite Positioning”

- Increased importance of satellite positioning systems requires analysis and control of GNSS performance
- Satellite signal propagation environment is the major source of positioning errors
- Ionospheric, tropospheric and multipath impacts give the largest contribution to satellite positioning error budget and satellite positioning reliability
- Existence of local ionospheric processes, dynamics and patterns is confirmed
- No local satellite positioning ambient error model for Croatia and south-eastern Europe exists so far
Project team

• **Prof. Tomislav Kos**, PhD FRIN, Faculty of Electrical Engineering and Computing, University of Zagreb – leading scientist

• **Prof. Ivan Markežić**, PhD MRIN, Faculty of Traffic and Transport Sciences, University of Zagreb

• **Renato Filjar**, PhD FRIN, Faculty of Maritime Studies, University of Rijeka

• **Jakov Kitarović**, MSc MRIN, Faculty of Maritime Studies, University of Rijeka – PhD student

• **Prof. Ante Tičac**, Faculty of Maritime Studies, University of Rijeka – retired professor

• **Mladen Viher**, PhD, Croatian Air Force Headquarter, Expert collaborator in atmospheric physics, meteorology and remote sensing research
Aim of the project

- Identification of particularities of local GNSS signal propagation environment in Croatia and surrounding region that make impact on the quality of satellite positioning in the area
- Focus on ionospheric, tropospheric and multipath propagation
Aim of the project

- Proposal, development and validation of local and regional ionospheric, tropospheric and multipath error correction models for satellite positioning (GPS, GLONASS, Galileo)
Project procedures

- Experiments, field campaigns
- Numerical analysis of experimental data sets
- Computer simulations
- Knowledge transfer
Research protocol

- Development of local ambient correction models for satellite positioning
- Verification of models through computer simulations and by comparison with experimental data sets
- Knowledge transfer
  - Student and young researcher education, students diploma work in GNSS related topics
  - Professional advancement
  - Seminars and workshops
  - Consultancy
Research protocol

• Research papers
  – Journal papers (Journal of Navigation)
  – Conference papers (NAV, ENC, ICECom, ELMAR, Baska GNSS Vulnerabilities and Solutions conference)

• Project presentation
  – Technical reports
Research results

Ionospheric research

- **Definition of related space weather indices and ionospheric behaviour**

Time series of space weather indices in 2003

A HALLOWEEN EVENT CASE STUDY

ssn – sunspot number,

flux – solar flux,

Ap – planetary geomagnetic Ap index)
Research results

Ionospheric research

- Correlation between the space weather indices and GPS positioning error

![Graphs showing correlation between space weather indices and GPS errors]
Research results

Ionospheric research

- Daily dynamic of ionospheric delay with seasonal effects in periods of quiet space weather conditions for a Croatian coastal region of the northern Adriatic in 2007

Modification of a Klobuchar-like approach for quiet space weather conditions was proposed

- night-time GPS ionospheric delay is not constant, but rather modelled by a linear function with the minimum during dawn
- the width and the amplitude of the cosine component is linearly related to the season of the year

![Graphs showing daily dynamic of ionospheric delay with seasonal effects in summer and winter.](image)
Research results

Tropospheric research

• Analysis of available models for tropospheric delay

Two types of tropospheric delay models exist:

Models that use actual meteorological data:
- Saastamoinen model
- Hopfield model

Global models that use yearly averages of meteorological data and their seasonal variation data:
- WAAS/EGNOS model
Research results

Tropospheric research

• *Analyses of annual tropospheric delay changes at different latitudes*

• WAAS/EGNOS parameters are dependent on the receiver’s height, latitude and day-of-year
Research results

Multipath propagation effects

• Analyses of positioning performance in a typical urban environment
## Research results

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Research results

**Typical intervals without multipath:**
DOP factor < 6
95% positions within 10 to 15 meter

**Typical intervals with multipath:**
DOP factor < 6, position shift by 30-35 meter
Research results

Student diploma works

• Attenuation of GNSS signals by different kind of trees
• Comparision with the data from similar published measurement results
Research results

Student diploma works

• Influence of urban environment
Research results

Student diploma works

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Research results

Student diploma work

Positioning performance with multipath propagation
International collaboration

- Joining the COST 296 MIERS (Mitigation of Ionospheric Effects on Radio Systems) in 2008
- Published journal and conference papers
- Organisation of annual GNSS Vulnerabilities and solutions conference every year since 2007
- Participation on FP7- PEOPLE-2010-ITN project TRANSMIT (Training Research and Applications Network to Support the Mitigation of Ionospheric Threats) – Marie Curie Actions – Initial Training Network
- Scientific researcher exchange
International collaboration

- TRANSMIT (Training Research and Applications Network .....)

+ Placements
+ Training
+ Networking

13 ESR
3 ER
International collaboration

- TRANSMIT (......to Support the Mitigation of Ionospheric Threats)
Conclusion

• This was the first project in Croatia aimed to systematically research the local ionospheric impact and other environmental influences on satellite positioning quality

• A competent project team developed and validated local and regional ionospheric and tropospheric error correction models and multipath influence on GNSS positioning performance

• We successfully extended the project towards international collaboration
Thank you for your attention