XXVII FIG CONGRESS
11–15 SEPTEMBER 2022
Warsaw, Poland

Volunteering for the future – Geospatial excellence for a better living

Presented at the FIG Congress 2022, 11-15 September 2022 in Warsaw, Poland

Applicability of recent low-cost GNSS receivers to deformation monitoring

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1. MOTIVATION

- Geodetic class equipment allows to achieve accuracy in the order of millimeters. Therefore, it has been usually employed in the applications where high accuracy and precision are needed.
- However, the geodetic receivers imply high costs, what is often a severe constraint for the institutions and research communities with a limited budget and can discourage using the GNSS technique.
- **Can low-cost equipment be the solution to this problem?**
- The goal of this study is to:
  - assess the positioning accuracy of recent multi-frequency low-cost receivers.
- We investigate their applicability to deformation monitoring at a local scale and examine whether, when GNSS observations are processed in the state-of-the-art scientific software, they can achieve a level of accuracy close to that of high-grade receivers.

2. DATA AND METHODS

- **Five low-cost receivers** were used to collect the GNSS observations:
  - pairs of u-blox ZED-F9P and Septentrio MOSAIC-X5 receivers, and a single SkyTraq receiver.
- **Two different antennas** were employed:
  - the Trimble GNSS choke ring antenna TRM59800.00 NONE and the patch u-blox ANN-MB antenna.
- A high-grade Trimble Alloy receiver was also installed and treated as a **benchmark**.

Table 1: Summary of the receiver and antenna sets used in the experiments.

Station name	Receiver type	Antenna type
SEP3	Septentrio MOSAIC-X5 S/N: #1	choke ring TRM59800.00
		u-blox ANN-MB
SEP6	Septentrio MOSAIC-X5 S/N: #2	choke ring TRM59800.00
		u-blox ANN-MB
SKY7	SkyTraq	choke ring TRM59800.00
UBL1	u-blox ZED-F9P S/N: #1	choke ring TRM59800.00
		u-blox ANN-MB
UBL9	u-blox ZED-F9P S/N: #2	choke ring TRM59800.00
		u-blox ANN-MB
TRI2	Trimble Alloy	choke ring TRM59800.00
		u-blox ANN-MB

2. DATA AND METHODS

Three different variants of processing in **Bernese GNSS Software v.5.2**:

1) GPS-only, depicted further as "**G**";
2) GPS + GLONASS, depicted further as "**GR**";
3) GPS + GLONASS + Galileo, depicted further as "**GRE**".

Table 2: Selected GNSS data processing parameters.

Observations	Double-differenced dual-frequency phase and code
Processing model	Relative, geometry-based
Reference station	Permanent OPNT station, 13 km far from the measurement field
Sessions	24 h with the 30 s sampling rate

3. RESULTS OF DATA PROCESSING

(1) Statistics of the combined solution

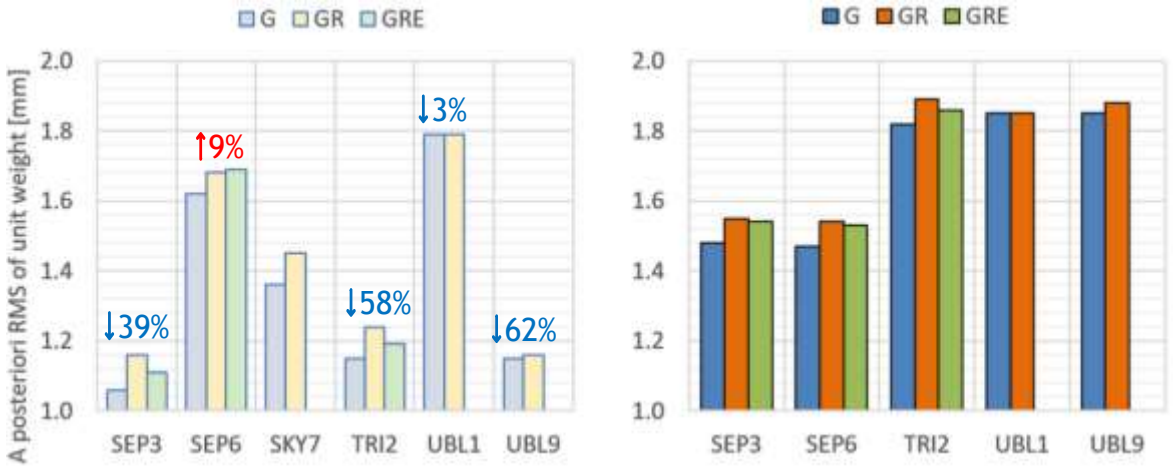

Fig. 1a A posteriori RMS error
receiver + TRM59800.00 choke ring antenna sets (left);
receiver + ANN-MB patch antenna sets (right).

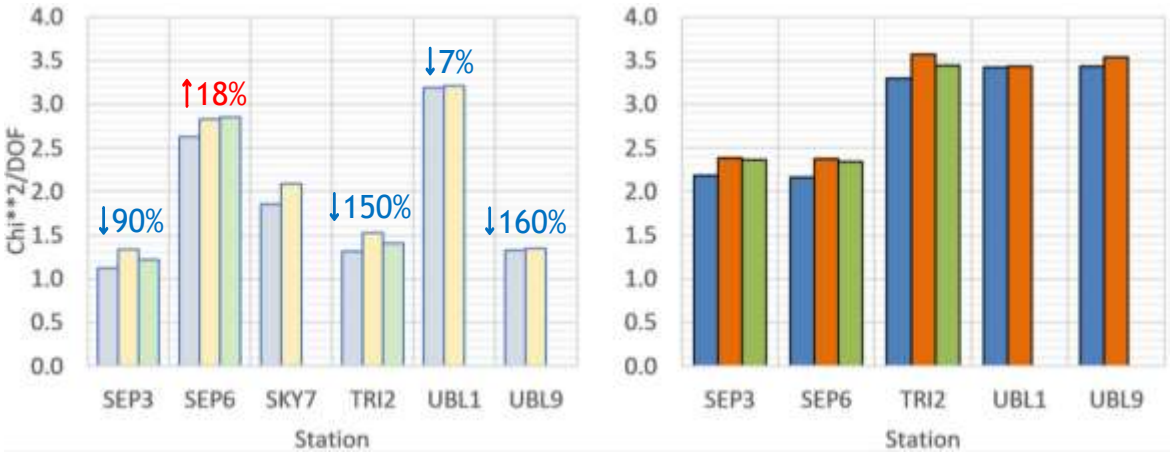

Fig. 1b Chi-square per degree-of-freedom
receiver + TRM59800.00 choke ring antenna sets (left);
receiver + ANN-MB patch antenna sets (right).

3. RESULTS OF DATA PROCESSING

(2) Ambiguity resolution success rate (ASR)

Table 3: L1/L2 SIGMA ASR, mean over all daily sessions for each station [%].

Receiver + TRM59800.00 choke ring antenna sets									
Processing variant		G	GR			GRE			
Baseline	Constellation	G	G	R	GR	G	R	E	GRE
OPNT-SEP3		93.4	**94.4**	74.0	86.4	**94.2**	73.7	**100.0**	89.6
OPNT-SEP6		92.5	**94.0**	68.4	83.1	**95.1**	68.7	**95.5**	86.8
OPNT-SKY7		**99.5**	99.1	96.8	**97.8**	-	-	-	-
OPNT-TRI2		87.9	89.6	97.4	92.5	89.8	96.7	98.7	93.8
OPNT-UBL1		**90.1**	90.1	81.2	**88.7**	-	-	-	-
OPNT-UBL9		**85.5**	86.3	94.9	**87.4**	-	-	-	-
Receiver + ANN-MB patch antenna sets									
Processing variant		G	GR			GRE			
Baseline	Constellation	G	G	R	GR	G	R	E	GRE
OPNT-SEP3		95.1	**95.1**	73.9	85.9	**94.8**	73.0	**98.3**	88.8
OPNT-SEP6		95.1	**95.5**	73.5	85.9	**94.8**	73.0	**98.3**	88.6
OPNT-TRI2		95.9	96.5	96.5	96.5	96.2	95.1	93.0	94.9
OPNT-UBL1		**90.7**	91.0	98.6	**92.2**	-	-	-	-
OPNT-UBL9		**91.7**	90.2	80.5	**88.8**	-	-	-	-

3. RESULTS OF DATA PROCESSING

(3) Repeatability of estimated coordinates

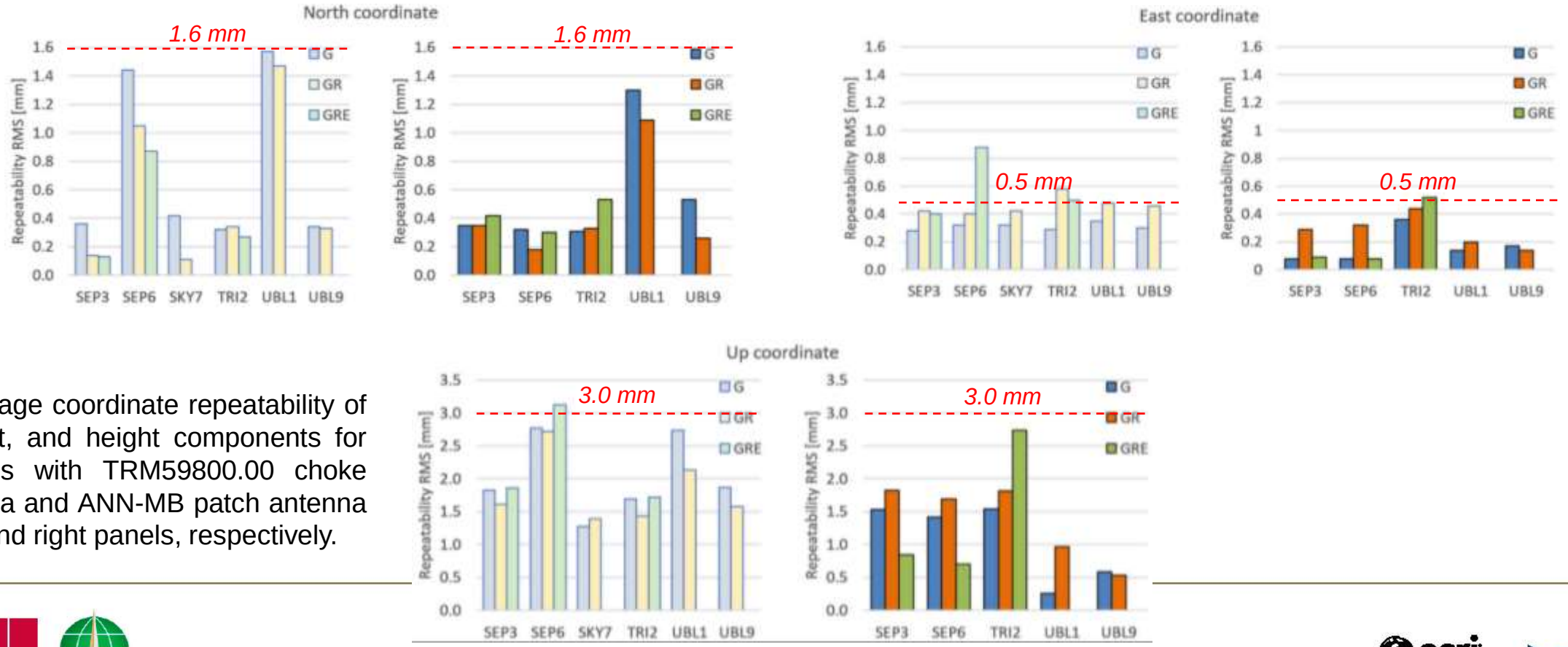

Fig. 2 Average coordinate repeatability of North, East, and height components for the stations with TRM59800.00 choke ring antenna and ANN-MB patch antenna in the left and right panels, respectively.

3. RESULTS OF DATA PROCESSING
(4) Formal coordinate errors

Table 4: Improvement in formal error for SEP3, SEP6, SKY7 and TRI2.

North	East	Up
GPS+GLONASS		
22%	14%	18%
GPS+GLONASS+Galileo		
35%	28%	32%

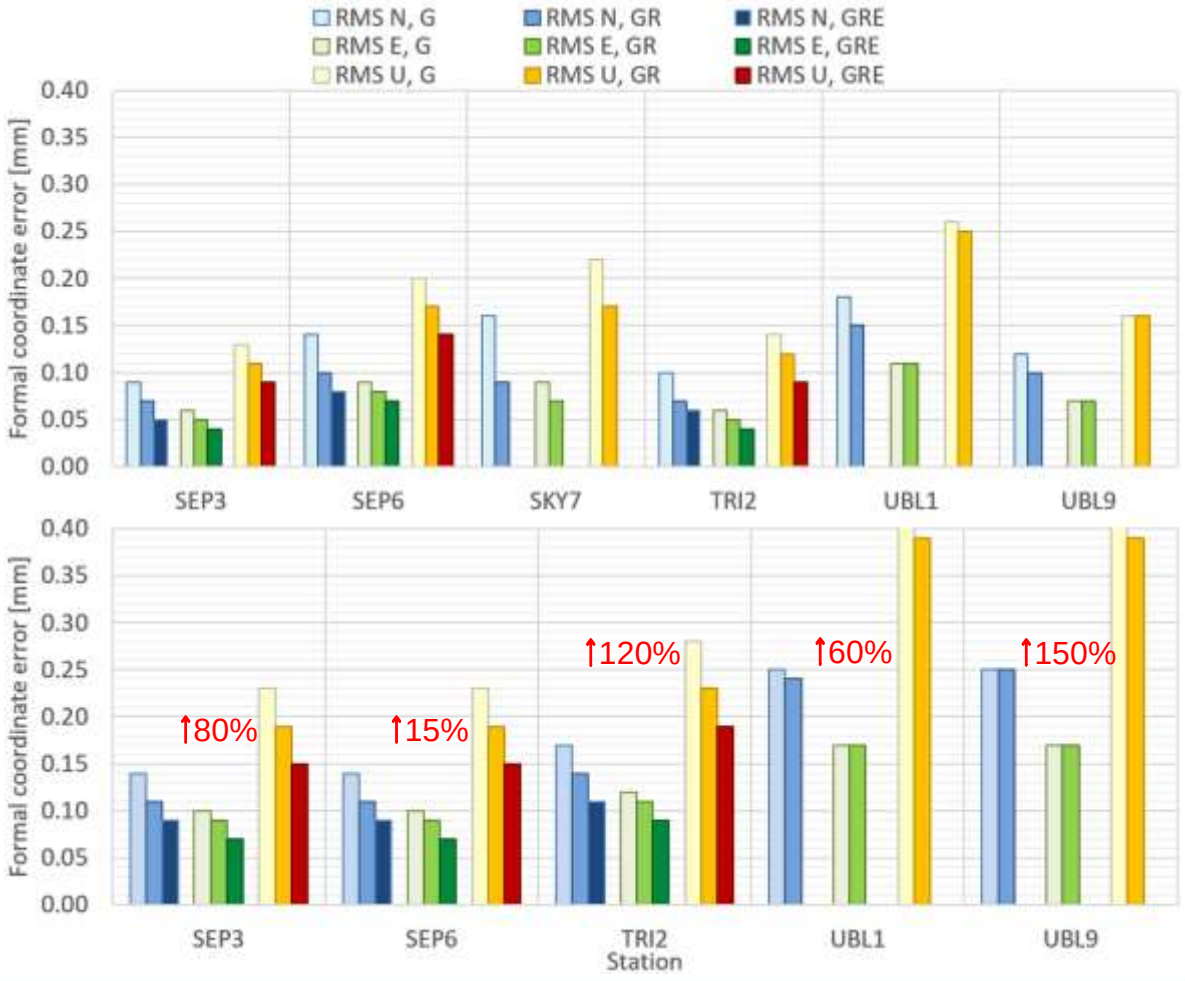

Fig. 3 Formal coordinate error for North, East, Up coordinate component.

In the top panel – TRM59800.00 choke ring antenna;
in the bottom panel – ANN-MB patch antenna.

4. CONCLUSIONS

- The results of this study confirmed that with the optimal GNSS data processing strategy and the state-of-the-art scientific software, the **latest low-cost receivers might be considered a mature complement to high-grade receivers in engineering applications**, such as deformation monitoring.
- We showed the **significant impact of the GNSS antenna type** on the precision and accuracy of the coordinate estimates. We proved that applying a choke ring antenna instead of a patch one to a low-cost receiver can greatly increase the positioning accuracy.
- The experiment also confirmed that the **application of multi-GNSS data processing significantly reduces the error** of estimated coordinates regardless of the employed antenna.

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Thank you for your attention!

Fundusze Europejskie Inteligentny Rozwój
Rzeczpospolita Polska
Unia Europejska Europejski Fundusz Rozwoju Regionalnego

This study was supported by the project "Innovative precise monitoring system based on integration of low-cost GNSS and IMU MEMS sensors", POIR 01.01.01-00-0753/21, co-financed by the European Regional Development Fund within the Sub-measure 1.1.1 of the Smart Growth Operational Program 2014–2020.

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