Leica TDA5000 - Short Range Performance Tests using Corner Cube and Tooling Ball Reflectors

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1. INTRODUCTION

In Fall 1996 Leica Inc. introduced the successor to the famous T2000/TC2002 instruments family - the TPS5000. Today the following high precision instruments are available :

- TM5000 Motorized Theodolite
- TDM5000 Motorized Total-Station
- TDA5000 Motorized Total-Station with *A*utomated *T*arget *R*ecognition System (ATR)
- TM5100 Motorized Theodolite with panfocal telescope (T3000)

The most important specifications are [5] :

Angle Measurements
Standard deviation according
to DIN 18723 (HZ & V) 0.2 mgon

Drives
motorized, positioning
accuracy (HZ & V) 0.2 mgon

Range-Finder (EDM)
Standard deviation 1 mm + 2ppm

Special Axyz-communication interface

Fig.1 Leica TDA5000

This paper summarizes the results of EDM and ATR test measurements using a variety of special Leica glass reflectors within a distance range of up to 40 m. The following types of reflectors were used :

Table 1 Type of Glass Reflector Prisms used for the test Measurements

Reflector	Abbreviation
Leica standard geodesy prism	GPR1
1.5" Corner Cube Reflector	TBCC15
0.5" Tooling Ball Corner Cube Reflector	TBCC05
0.5" Tooling Ball Prism Reflector	TBPR05

Fig. 2 1.5" Corner Cube Reflector TBCC15 | 0.5" Tooling Ball Corner Cube Refl. TBCC05 | 0.5" Tooling Ball Prism Reflector TBPR05

Additional tests with different types of retro tape targets have also been performed, but are not finished yet [4]. These results will be published in the German Surveying Magazine 'AVN' in early 1998.

2. RANGE FINDER (EDM)

Most of the Measurements were performed with two TDA5000 instruments (No. 437735/FHBB and No. 437742/Leica PMU). Due to the results of the integral short range performance test (see 2.3) additional measurements were made with a TDM5000 (No. 437722/Leica PMU).

2.1 Shortest measuring Distance

Table 2 Shortest measuring distance

Reflector	Shortest measuring distance [m]
GPR1	~0.9
TBCC15	~0.9
TBCC05	~6.0
TBPR05	~4.0

2.2 Offset Correction

This correction was determined by using a 'Rüeger'-type of calibration baseline with unknown distances. The 5 baseline-points were marked with Kern forced centering tripods.

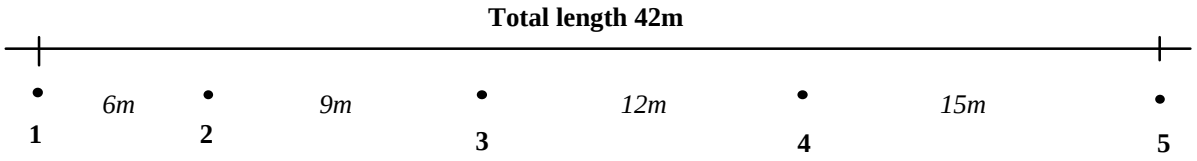


Fig.3 Configuration of the Rüeger-type calibration baseline

Table 3 Offset Correction c

		Offset Correction c			
Instrument Type	No.	GPR1 [mm]	TBCC15 [mm]	TBCC05 [mm]	TBPR05 [mm]
TDA5000	437735	-0.46 ± 0.08	+33.81 ± 0.12	+33.92 ± 0.16	+28.98 ± 0.30
TDA5000	437742	-0.07 ± 0.10	+34.30 ± 0.11	not determ.	+28.57 ± 0.30

2.3 Integral Short Range Test

These test measurements were carried out on the Interferometer Baseline at Basel Institute of Technology.

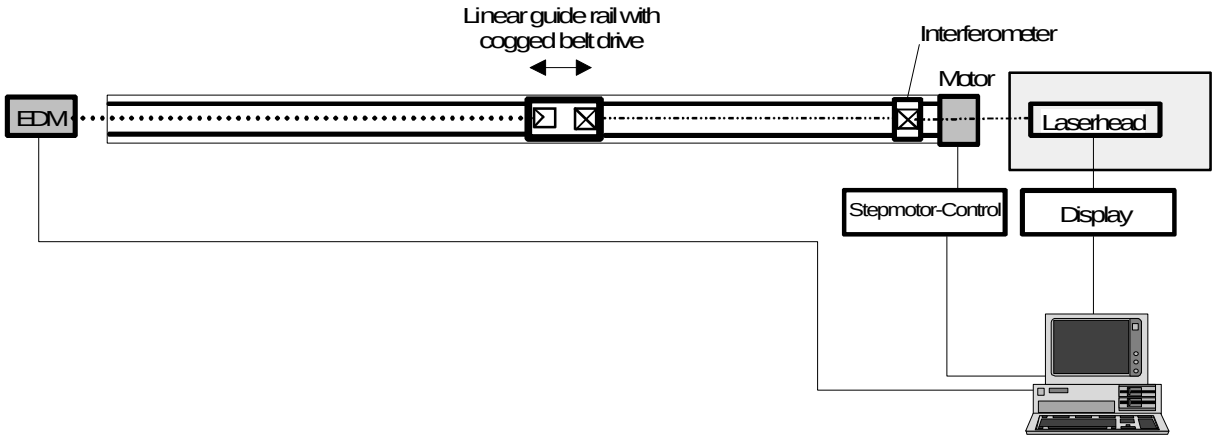


Fig. 4 Interferometer Baseline (Configuration: 'Absolute Distance Comparison')

The reflector of the Interferometer-System (hp5526a) and the reflector of the EDM are mounted on a sliding carriage with a cogged belt drive and a microcomputer controlled step-motor device. To carry out an absolute distance comparison between the interferometer and the EDM, the distance from the vertical axis of the EDM and the interferometer reference point is known to about 0.02 mm. The whole setup is described more in detail in [1].

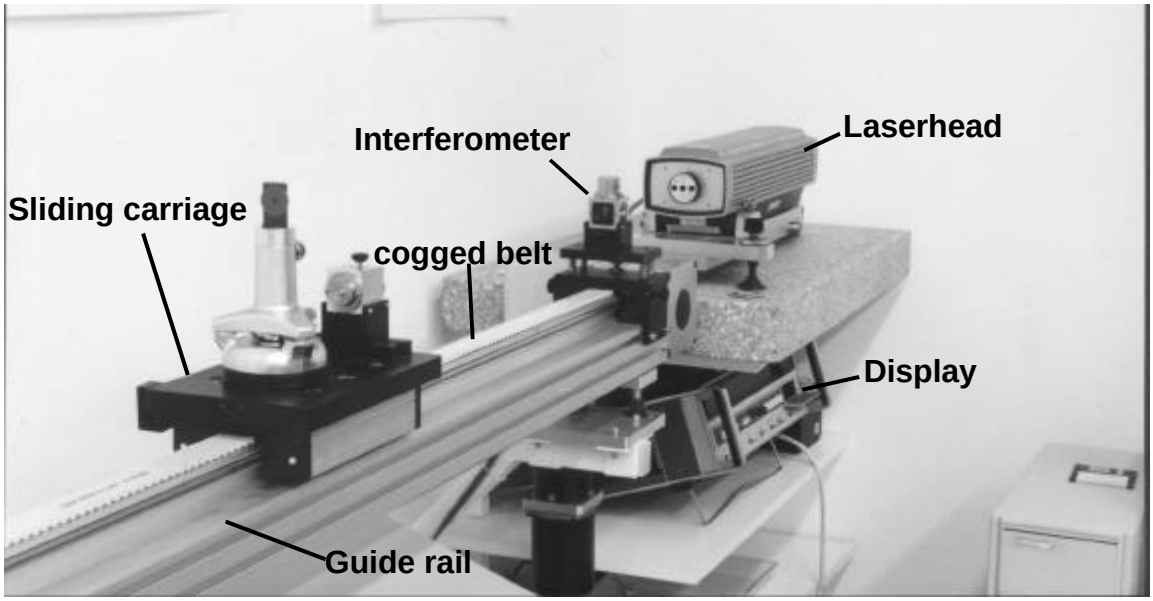


Fig. 5 Part-sectional view of the Interferometer Baseline

The following diagrams show typical results (differences between the nominal values (interferometer) and the actual EDM-values) of the baseline measurements :

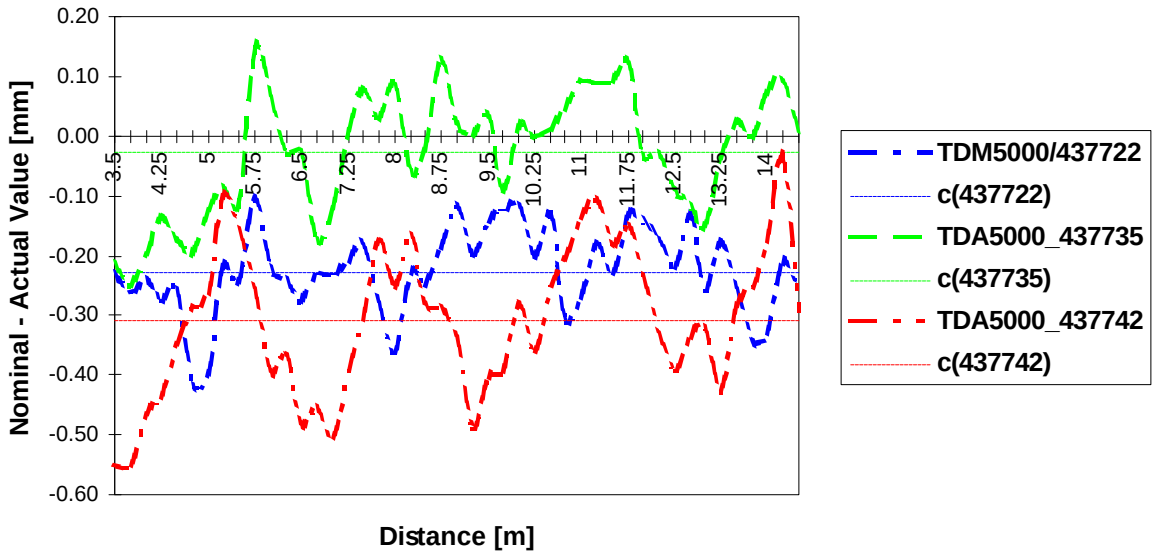


Fig. 6.1 Close Range Performance - GPR1

The scattering of the differences 'Nominal - Actual Values' is more or less accidental. The maximum scattering amplitude is approximately ± 0.3 mm. All tested instruments are performing within the manufacturers sepcifications.

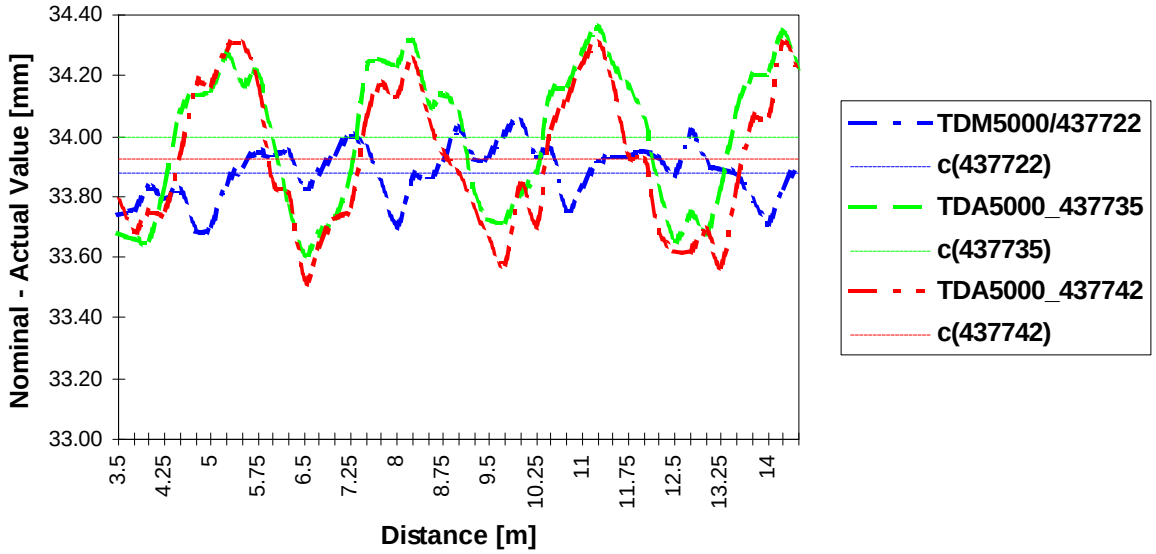


Fig. 6.2 Close Range Performance - TBCC15

TDA5000 Both tested instruments show a typical cyclical behavior. The maximum amplitude is approximately ± 0.4 mm, the length of a cycle period is 3 m (EDM modulation frequency: 50 MHz).

TDM5000 There is no significant change in behavior compared with the GPR1 measurements.

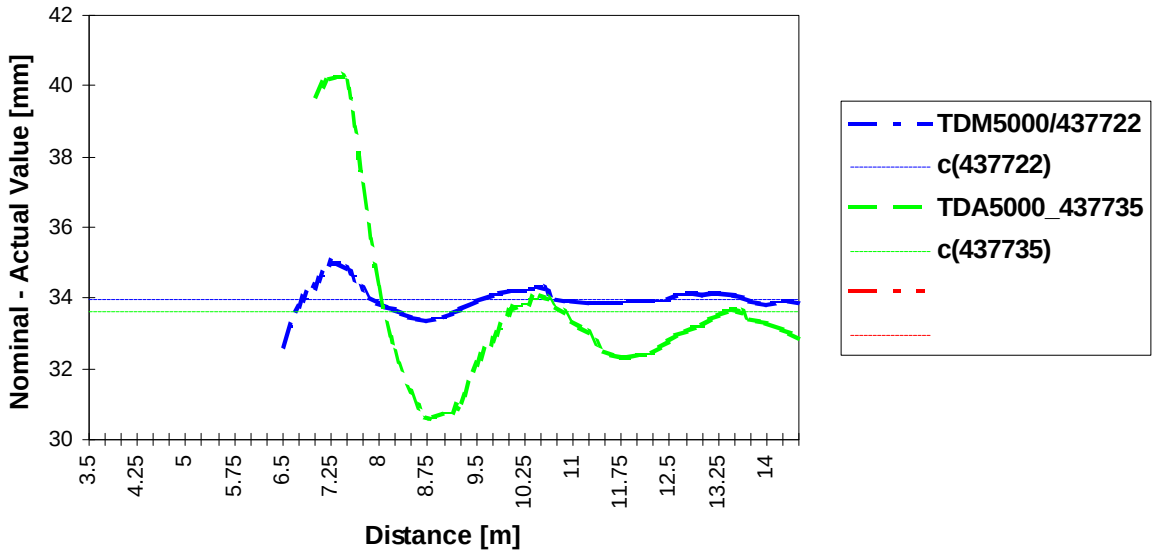


Fig. 6.3 Close Range Performance - TBCC05

TDA5000 This test was performed only with instrument No. 437735. It shows a significant cyclic behavior. The oscillation is decadent. The amplitude is decreasing (1. Cycle: 6 mm, 2. Cycle 3 mm, 3. Cycle 1.6 mm).

TDM5000 Up to 10 m measuring distance there seems to be also a cyclic behavior. The maximum amplitude of the oscillation is approximately 1 mm.

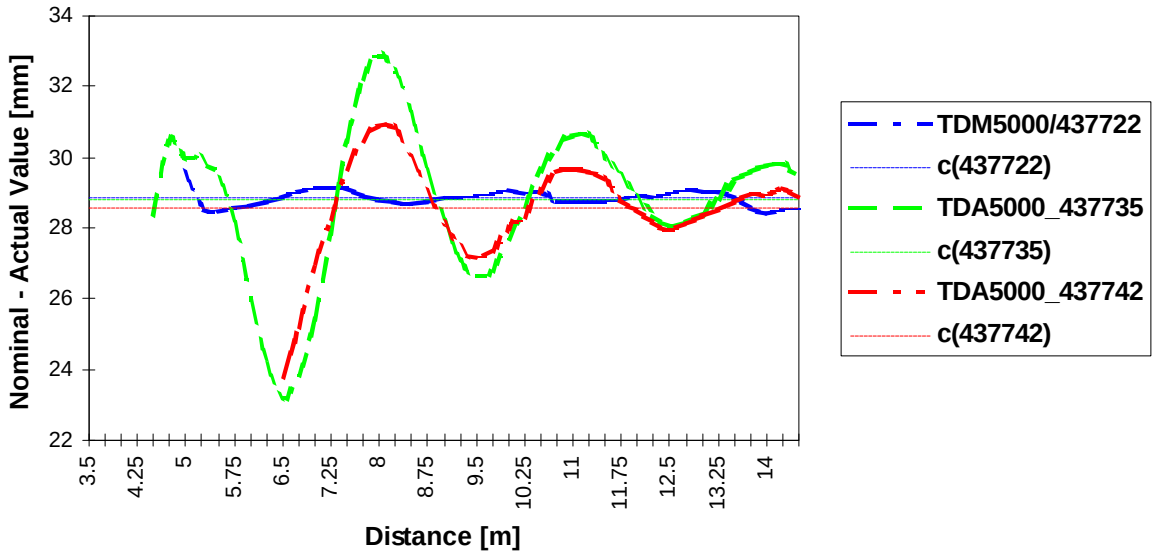


Fig. 6.4 Close Range Performance - TBPR05

TDA5000 Both tested instruments show a significant cyclic behavior. Both oscillations have the same phase relationship. The oscillation is decadent. The amplitude is decreasing :

	No. 437735	No. 437742
1. Cycle	6.0 mm	4.0 mm
2. Cycle	2.5 mm	1.6 mm
3. Cycle	1.1 mm	0.5 mm

TDM5000 There is no significant cyclic behavior. The maximum differences according to the interferometer are ± 0.5 mm.

Attempt at an explanation

It is well known that interferences between the transmitting and the receiving signal on the one hand and the use of peripheral rays on the other hand may cause cyclic errors. The manufacturers of EDM are reducing or eliminating these effects by constructive (optical) and/or electronical countermeasures.

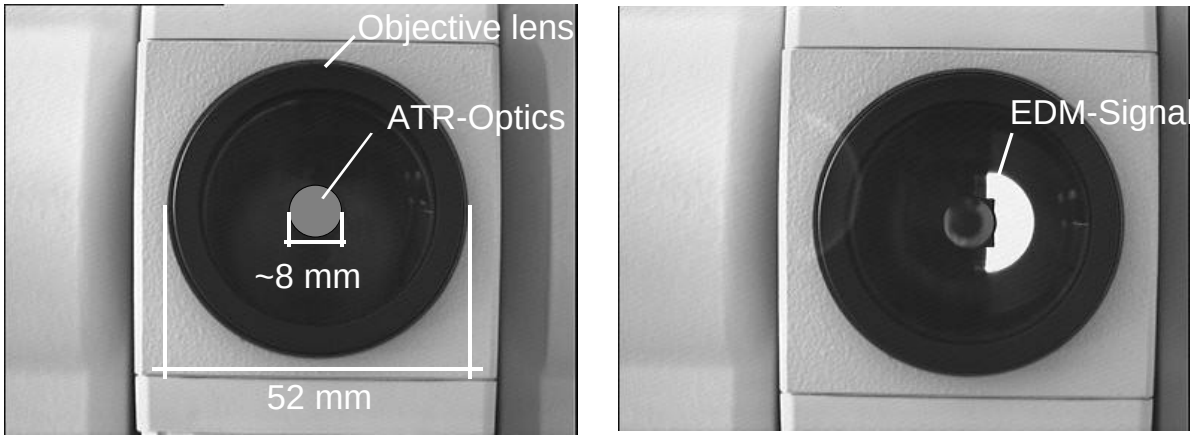


Fig. 7 Front lens area of the TDA5000 telescope. (Left: Dimensions, Right : during a distance measurement)

A main difference in the optical system of the TDM5000 and the TDA5000 is the integrated ATR optics (see Fig. 7, left). The diameter of the ATR front lens is approximately 8 mm. The EDM transmitting signal is located slightly eccentric (left telescope side, face 1; see Fig. 7, right). The center of the EDM signal is covered by the ATR optics.

- There might be a possibility of signal reflections at the ATR optics. This might cause interferences between the transmitting and the receiving signal
- The diameter of the TBCC05 and TBPR05 prism is 8 mm
- Measurements to the TBCC05 and TBPR05 prism have to be made in the 'Reflex Tape Mode' with a high intensity of the transmitting signal. This might cause problems in the signal adjustment of the receiving signal (boomerang effect ?)

Recommendation

- Avoid using 0.5" Reflectors for precise distance measurements
- If you need to use 0.5" reflectors, avoid distances below 15 m
- Take into account, that the accuracy of your measurements is reduced

3. AUTOMATED TARGET RECOGNITION SYSTEM (ATR)

The Automated Target Recognition System (ATR) enables an automated acquisition of reflective targets (glass prism). Therefore an infrared beam (IR laser diode) is emitted through a special coaxial optical system (see Fig. 7). If there is a reflective target within the ATR field of view, the signal is reflected back to the telescope. The reflected signal is projected on to a CCD camera which is built into the telescope. Using image processing algorithms, the instrument is moved to a nearly correct position. Vertical and horizontal offsets between the line of sight and the center of gravity of the reflected light are calculated and taken into account to obtain the correct horizontal and vertical angle measurements. A detailed description of the functionality and the performance of the ATR is given in [2] and [6].

3.1 Shortest measuring distance

Depending on the type of Reflector the ATR is operational down to distances between 2.8 m (GPR 1) and 4.0 m (TBCC05). Due to the results of the repeatability tests (see 3.3), the ATR should not be used on distances beyond 5.0 m.

3.2 Reflector Alignment

The tests were carried out for an object distance of 10 m. Based on these test results (see Fig. 8), we recommend aligning the reflector better than ±15° to the line of sight of the ATR.

3.3 Repeatability

These tests were carried out for a distance range between 3.0 m and 40 m either with 'manual' pointing or 'automated' pointing using the ATR.

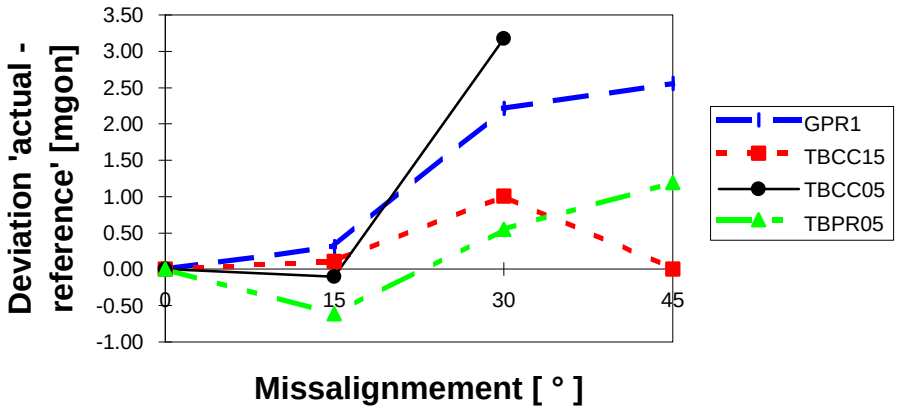
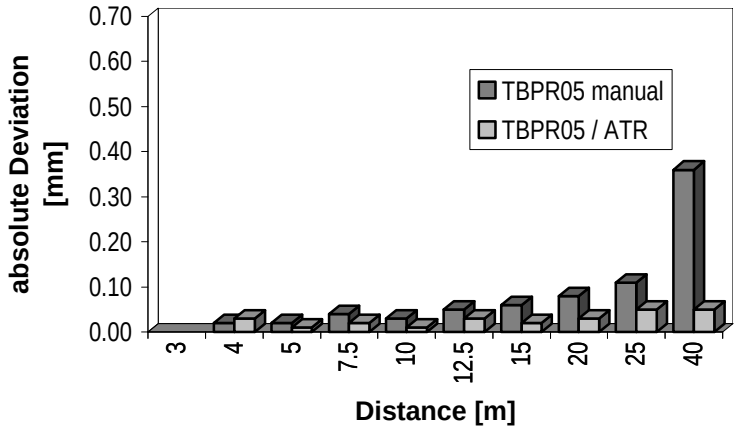
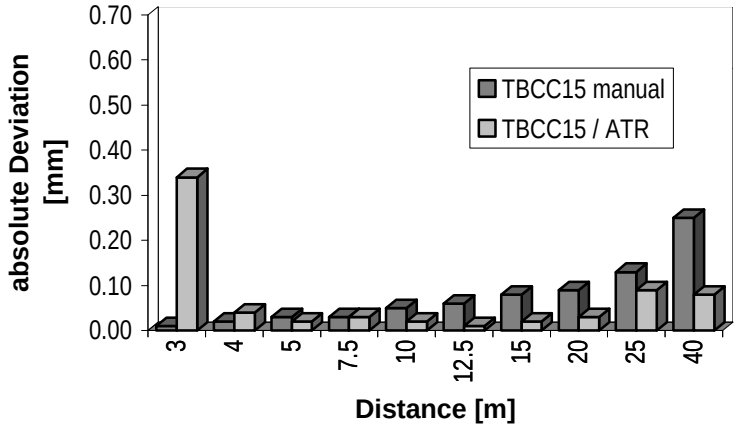


Fig. 8 ATR / Reflector Alignment





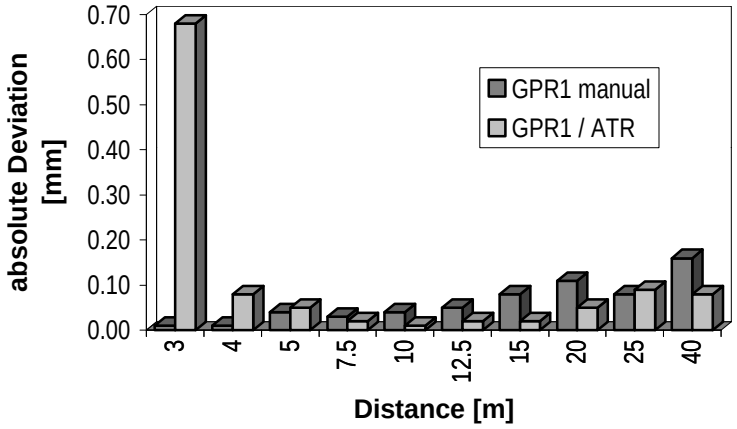


Fig. 9 Absolute transversal Deviation ('manual' pointing versus ATR)

4. CONCLUSION

The TDA5000 is a highly accurate measuring system. The manufacturers specifications (EDM, ATR) could be proved within the tested distance range for the standard geodesy triple-prism GPR1.

The 1.5" Corner Cube Tooling Ball reflector (TBCC15) can be used without a major loss of accuracy. 0.5" Tooling Ball Reflectors (TBCC05, TBPR05) cause a significant cyclic error (EDM). They should not be used for accurate measurements and not below an object distance of about 15 m.

The ATR system performs well independently of the type of glass reflector. It should not be used below an object distance of 5 m.

5. REFERENCES

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[6] Leica. *TPS1000 Total Stations - Automated Target Recognition ATR1, Performance and Calibration,* Leica Product Information (Preliminary Version 2.20) 02/97