

Steffen Schön
Institut für Erdmessung
Leibniz Universität Hannover



Klaus Strauch
GEObasis.NRW
Bezirksregierung Köln



Ringversuch 2009

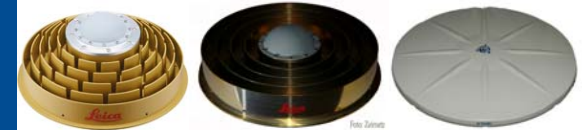


Lambert Wanninger
Volker Frevert
Geodätisches Institut
TU Dresden



Philipp Zeimetz
Heiner Kuhlmann
Institut für
Geodäsie und Geoinformation
Uni Bonn



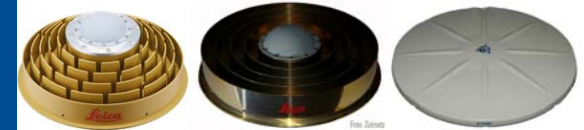


Kalibrierverfahren:

- **Relative Kalibrierung**
 - Geodätisches Institut, TU Dresden
- **Absolute Kalibrierung mit Roboterarm**
 - Institut für Erdmessung, Uni Hannover
 - Senatsverwaltung für Stadtentwicklung Berlin
- **Absolute Laborkalibrierung**
 - Institut für Geodäsie und Geoinformation, Uni Bonn
 - Bezirksregierung Bonn – GEObasis.NRW

Berücksichtigte Antennen:

- Leica AR25
- Leica AT504GG
- 2 Trimble Zephyr Geodetic Modell 2



Vergleiche

- Vergleich identischer Antennen
- Berücksichtigung des vollständigen Modells: PCO + PCV
- Frequenzen: L1, L2, R1, R2 (R1, R2 gemessen nicht aus GPS abgeleitet)

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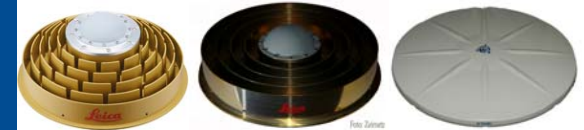
Fragen:

- Wie groß sind die Differenzen zwischen den Verfahren?
- Handelt es sich um zufällige oder systematische Abweichungen?
- Wie groß ist der Einfluss auf die Positionsbestimmung?

Besondere Schwierigkeit:

Derzeit kann keinem der existierenden Kalibrierverfahren eine übergeordnete Genauigkeit zugeschrieben werden! →...

Allgemeine Hinweise



Für die Vergleiche muss eine Bezugslösung definiert werden!

Kalibriermittel (Mittel aus allen/ausgesuchten Verfahren)

Problem: Auftretenden Differenzen sind nur schlecht interpretierbar, da stets alle Kalibrierverfahren einen Anteil zu den Differenzen beitragen.

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4

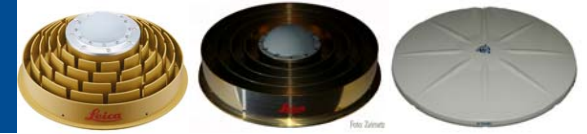
Einzellösung

Problem: Anteil der Vergleichsmessung an sichtbaren Differenzen ist ebenfalls nicht bekannt. Die Wahl suggeriert dem ausgewählten Verfahren eine übergeordnete Genauigkeit.

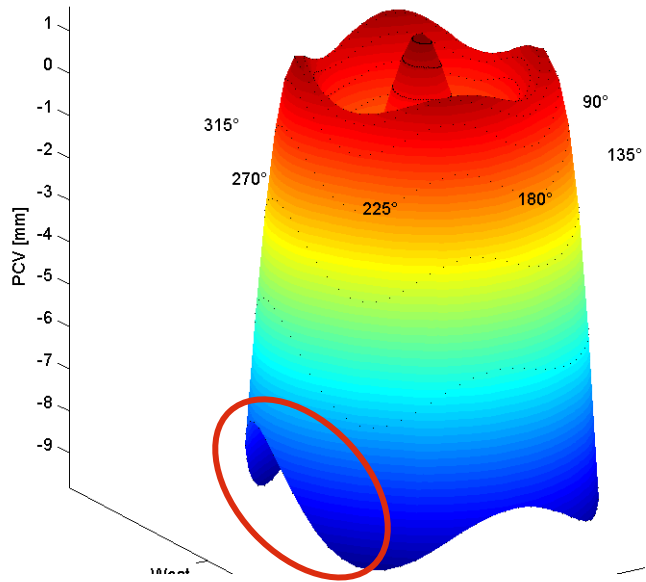
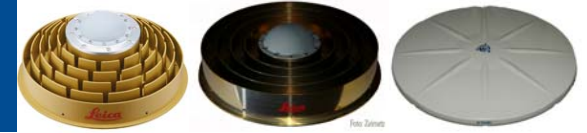
Vorteil: Eine eindeutig schlechte Wahl wird unmittelbar sichtbar, wenn mehrere Vergleiche gleiche Systematiken aufweisen.

Gewählter Ansatz: Roboterkalibrierung (IfE) als Bezugslösung

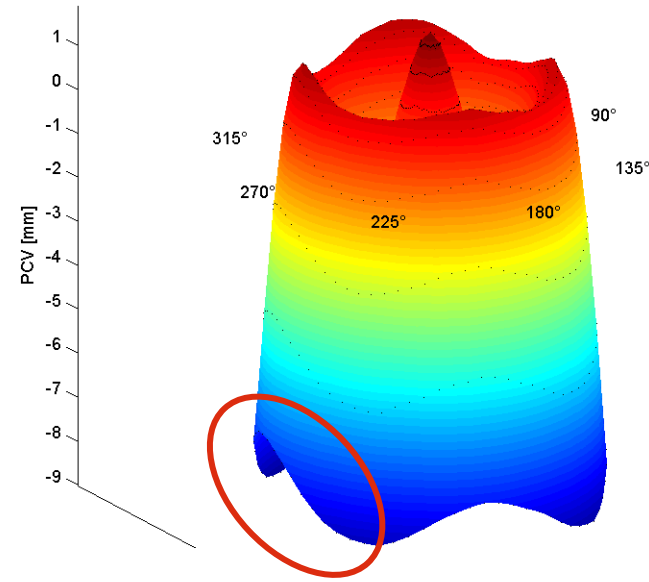
Leica AR25



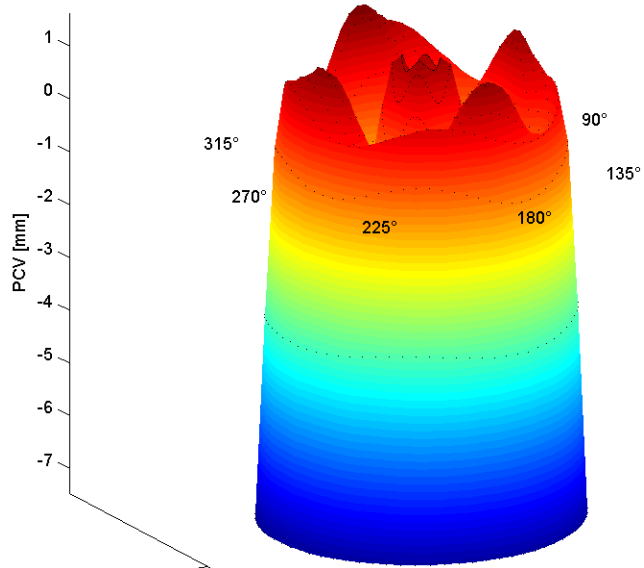
Leica AR25 (L1)



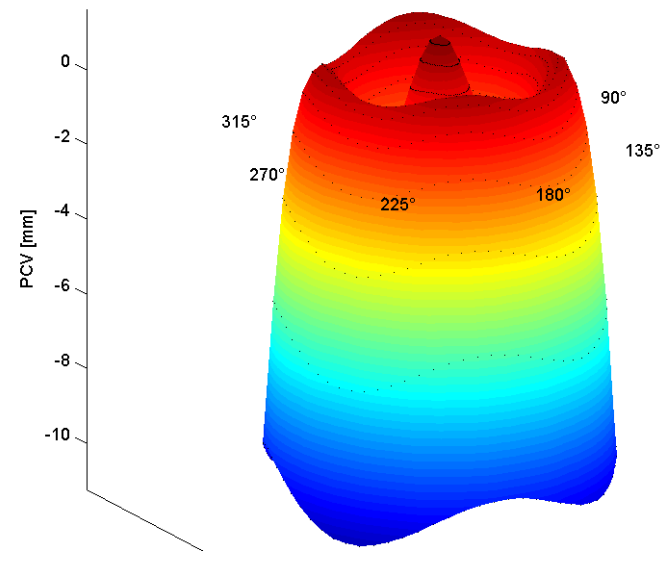
IfE



AMK Bonn

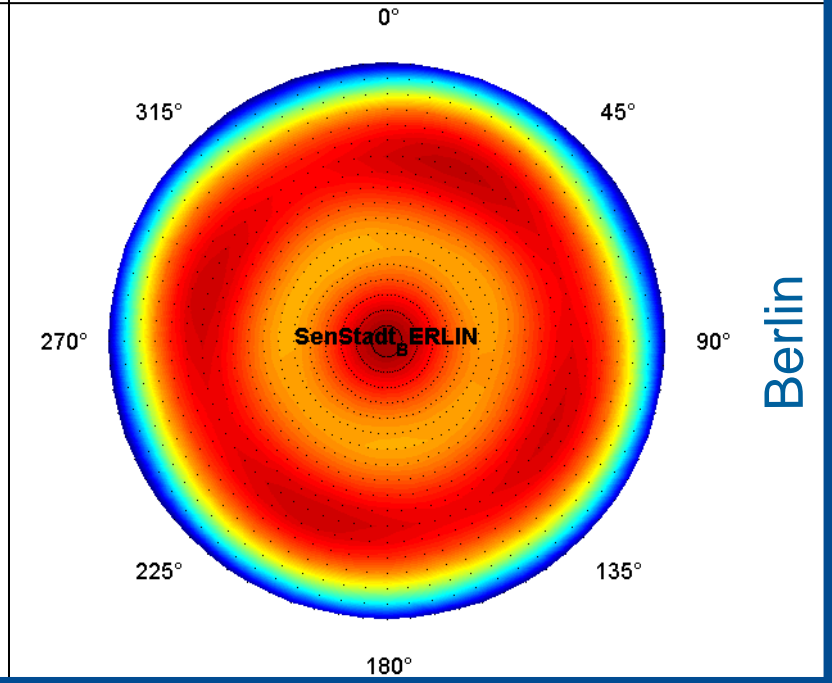
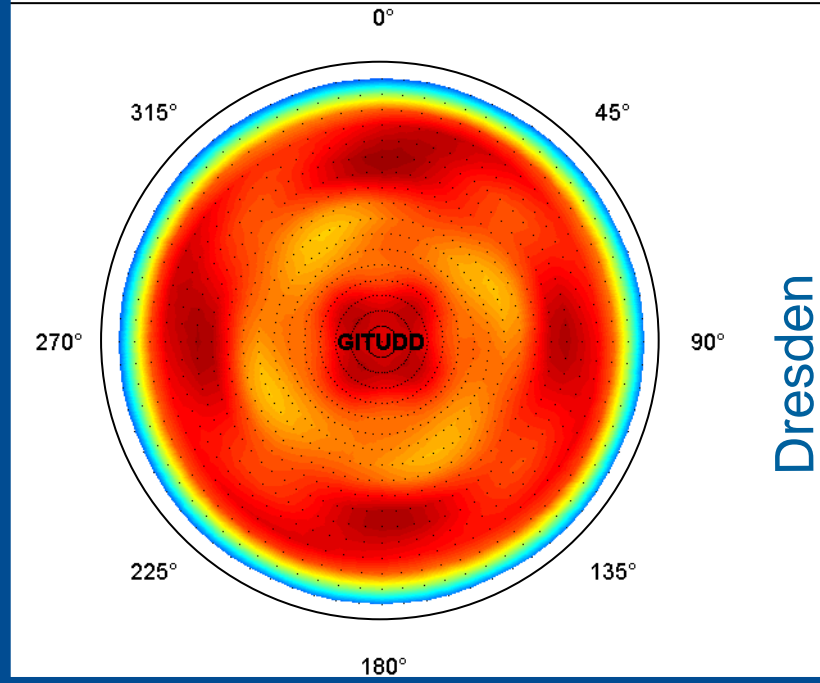
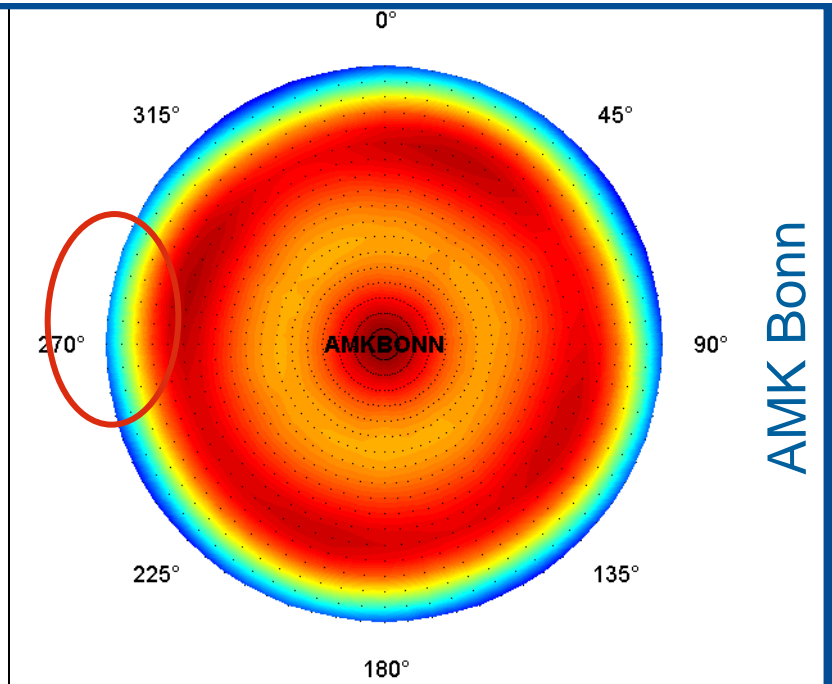
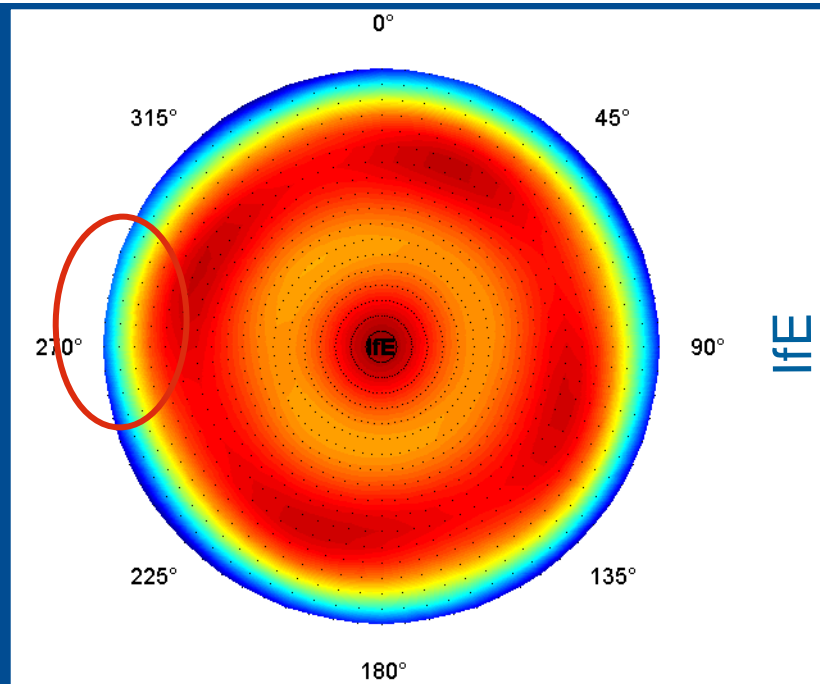
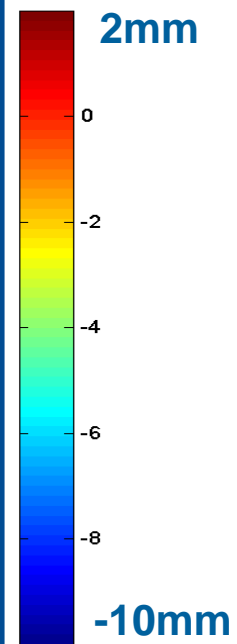


Dresden

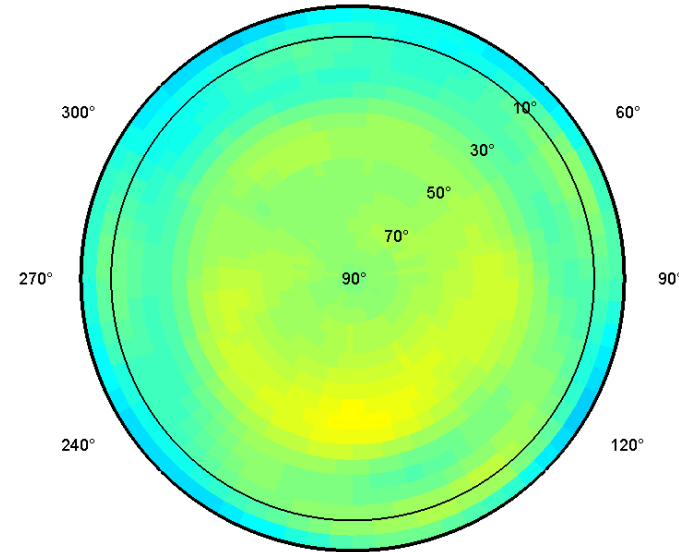
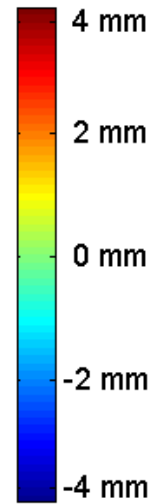
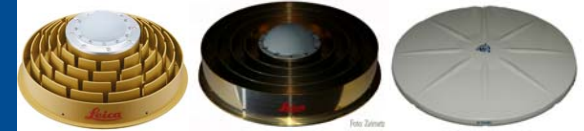


Berlin

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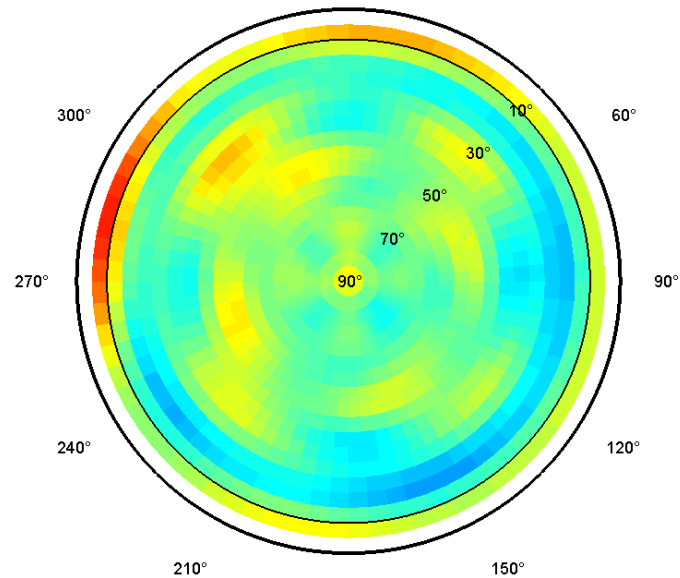


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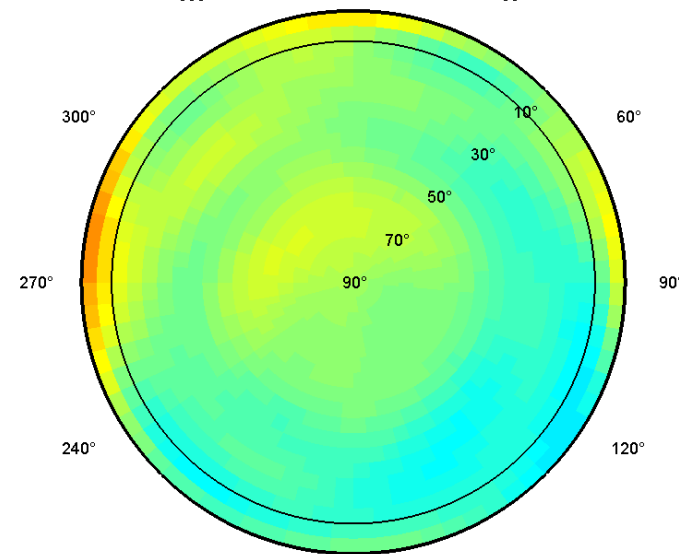


IfE vs. Bonn

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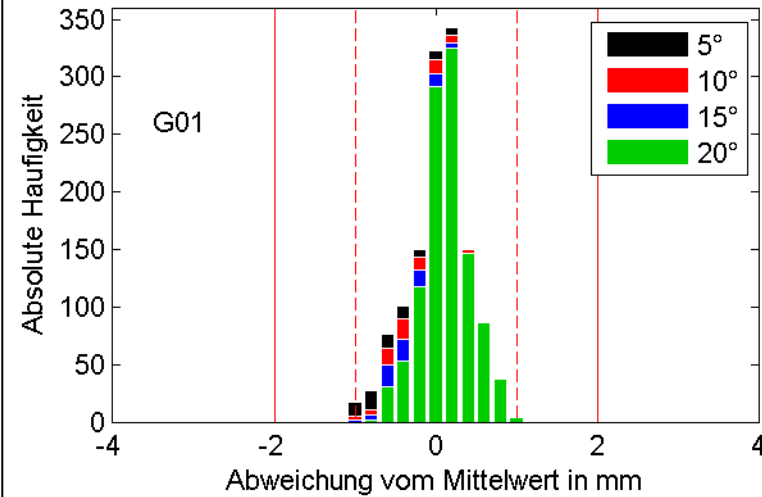
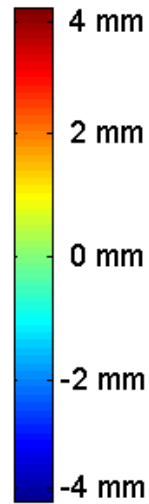
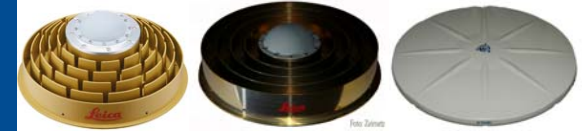


IfE vs. Dresden



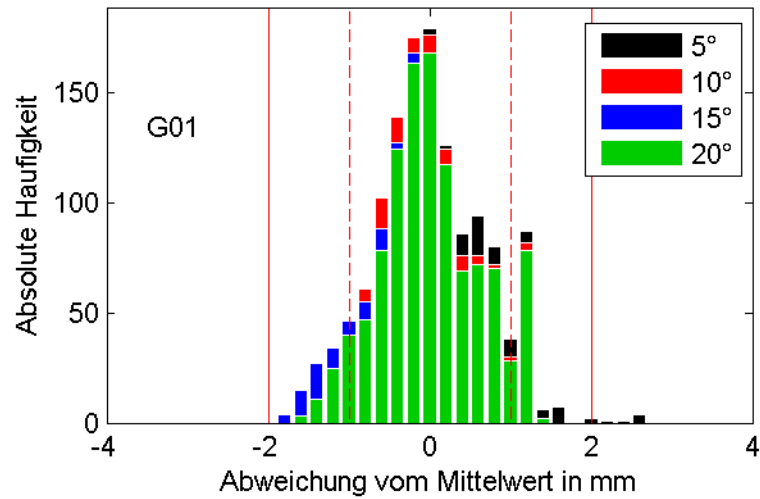
IfE vs. Berlin

Leica AR25 (L1)

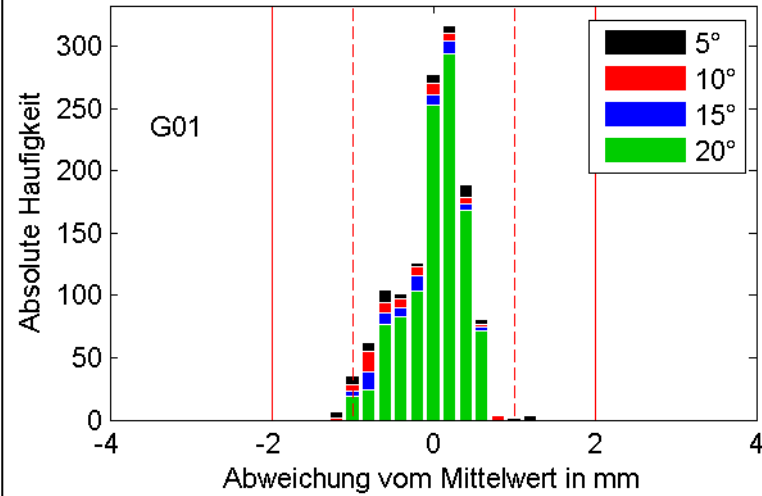


IfE vs. Bonn

9

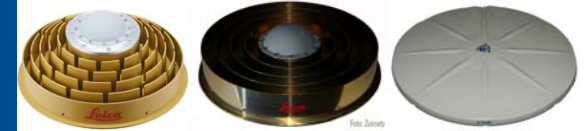


IfE vs. Dresden

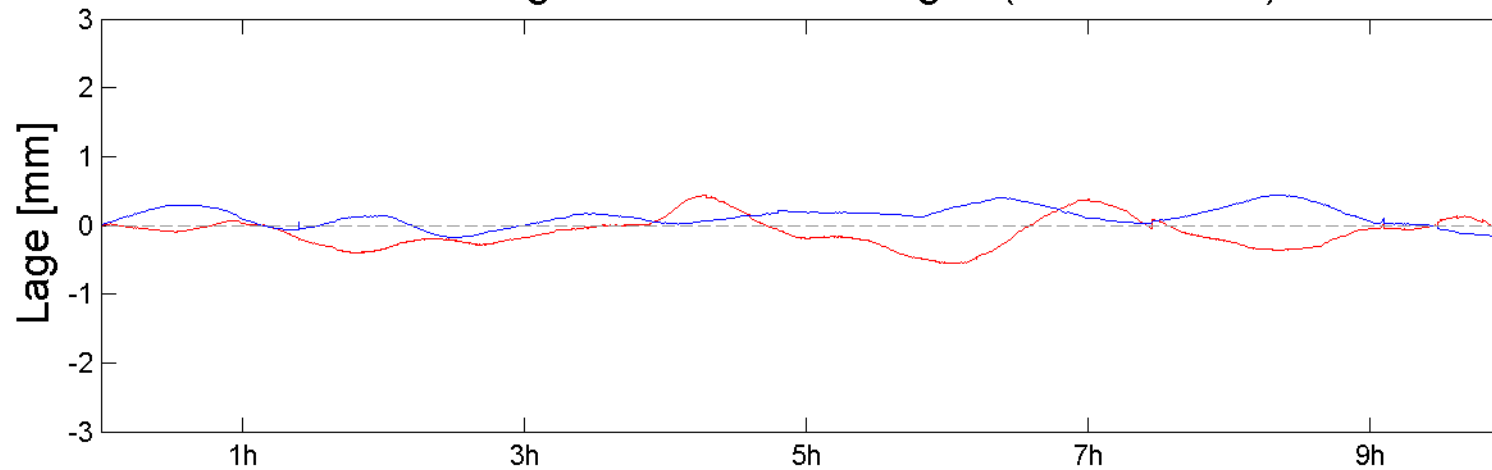


IfE vs. Berlin

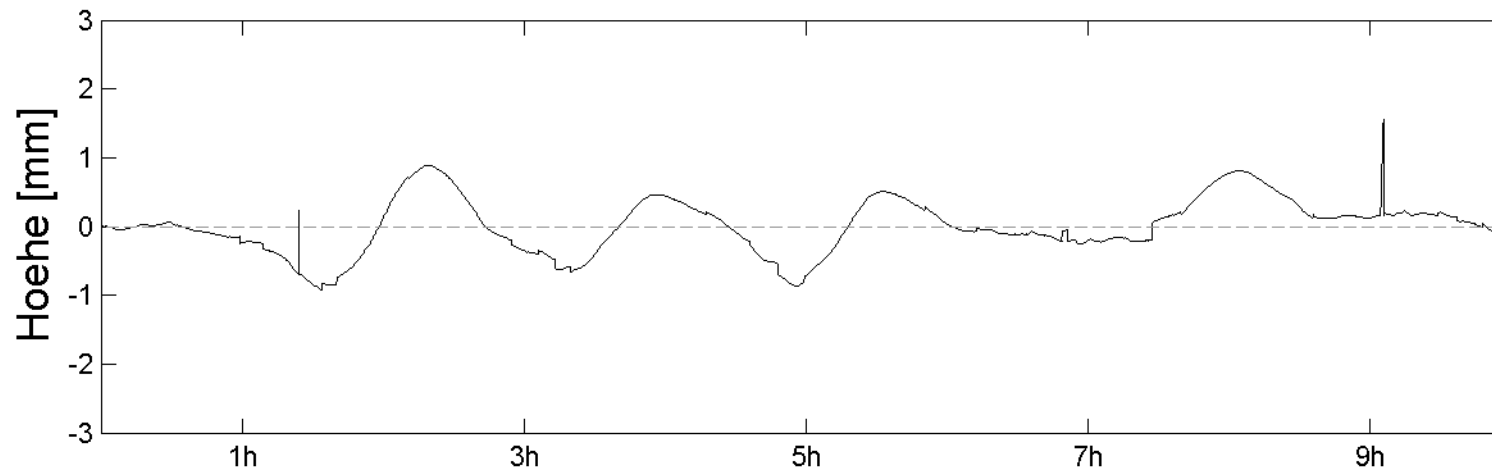
Leica AR25 (L1)



Auswirkung Kalibrierabweichungen (zero-baseline)

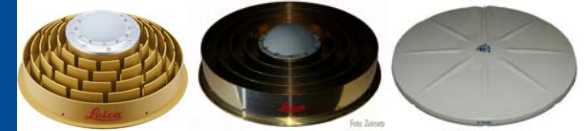


Zero-Baseline: IfE vs. Bonn

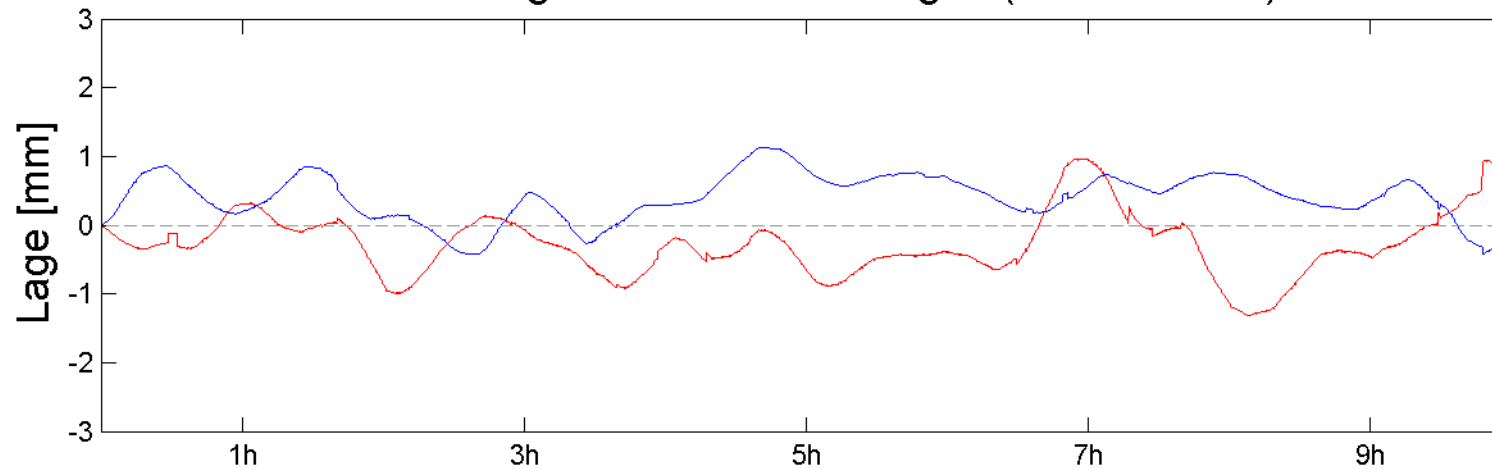


zero-baseline: L1-Frequenz, 5° Elevation, 5sec Sampling

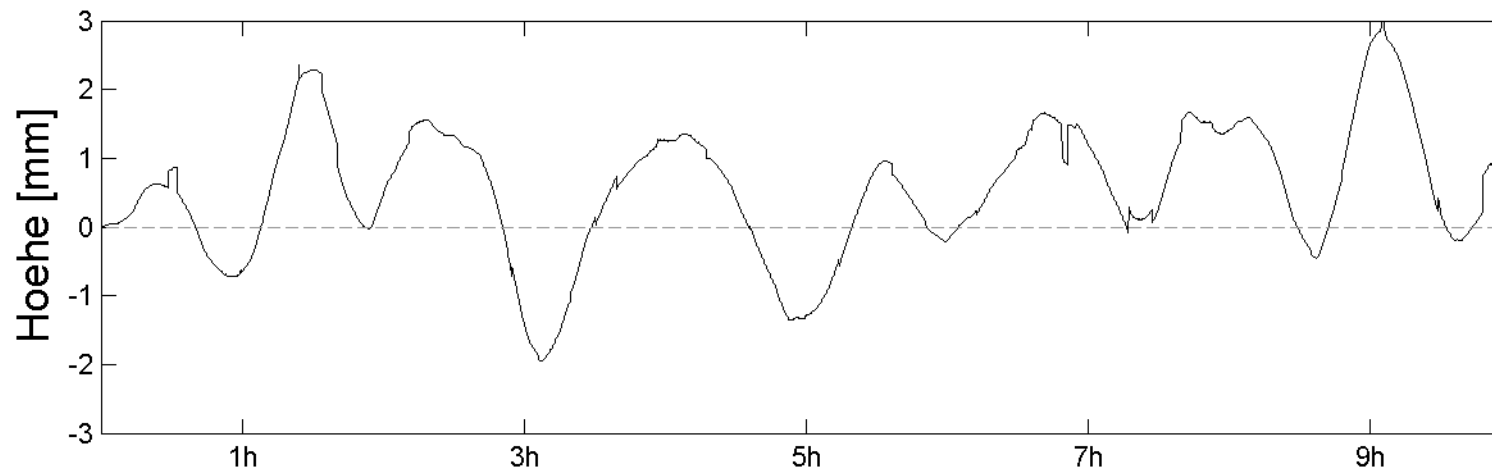
Leica AR25 (L1)



Auswirkung Kalibrierabweichungen (zero-baseline)

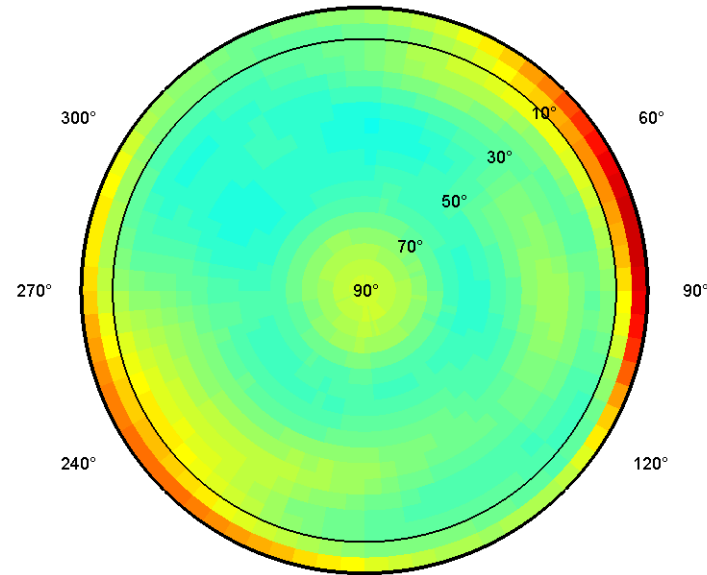
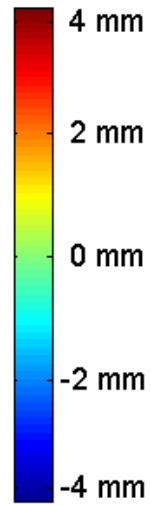
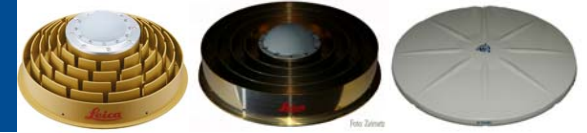


Zero-Baseline: IfE vs. Dresden



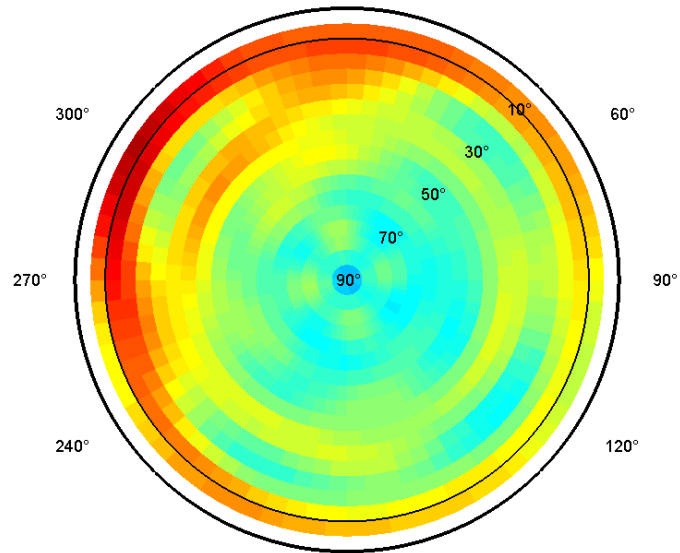
zero-baseline: L1-Frequenz, 5° Elevation, 5sec Sampling

Leica AR25 (L2)

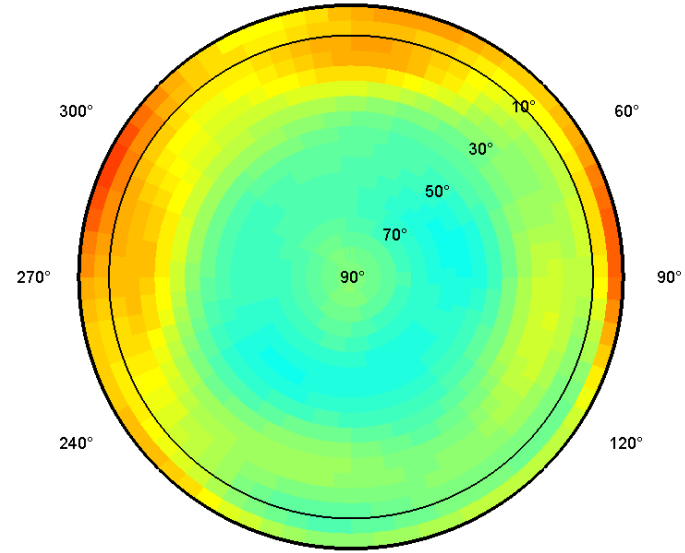


IfE vs. Bonn

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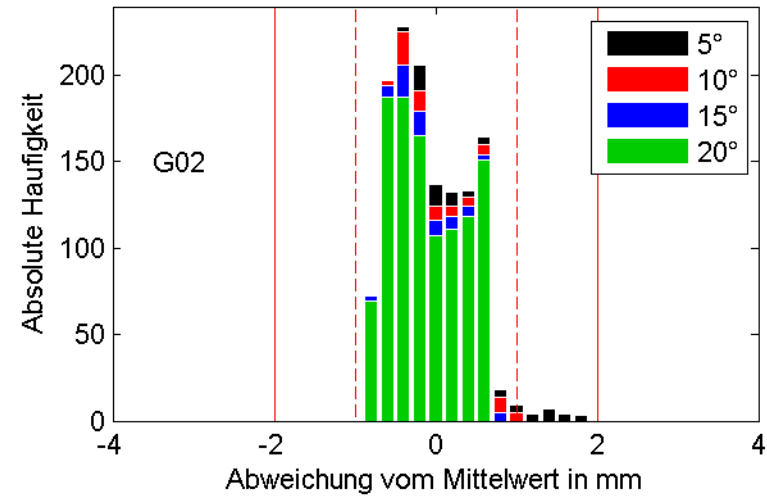
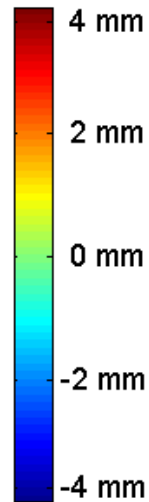
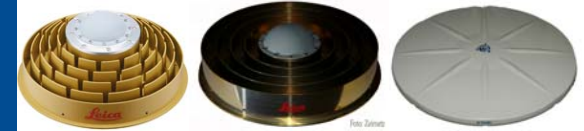


IfE vs. Dresden



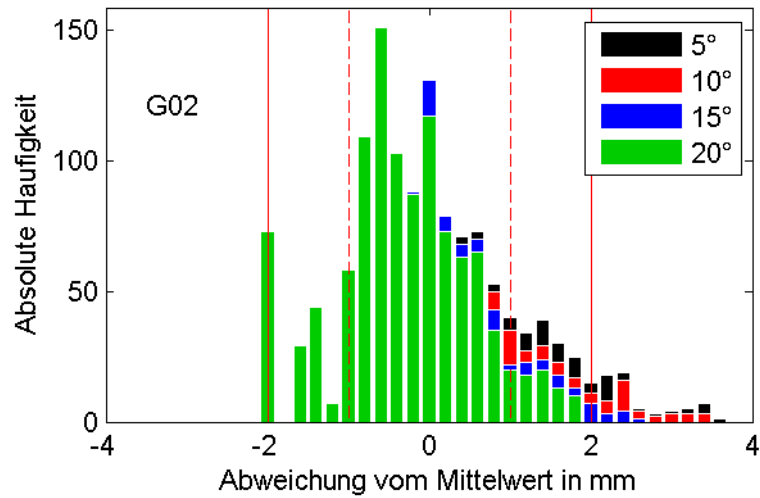
IfE vs. Berlin

Leica AR25 (L2)

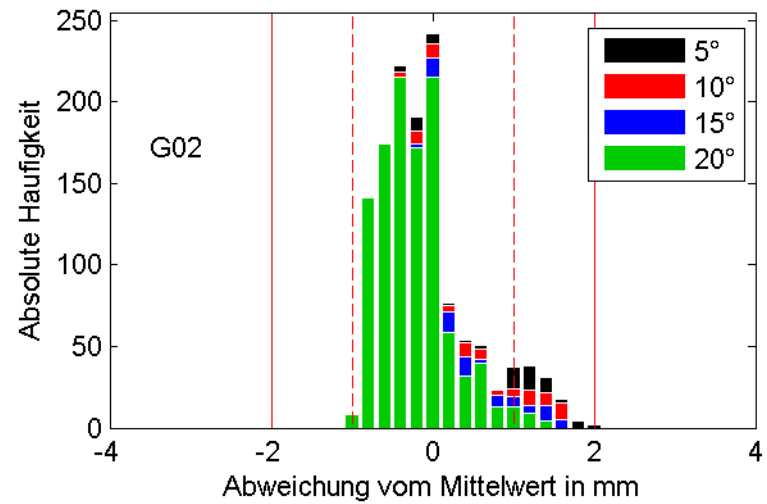


IfE vs. Bonn

13

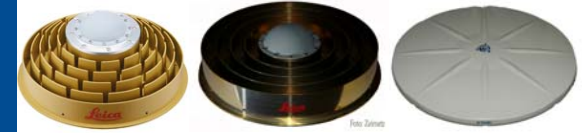


IfE vs. Dresden

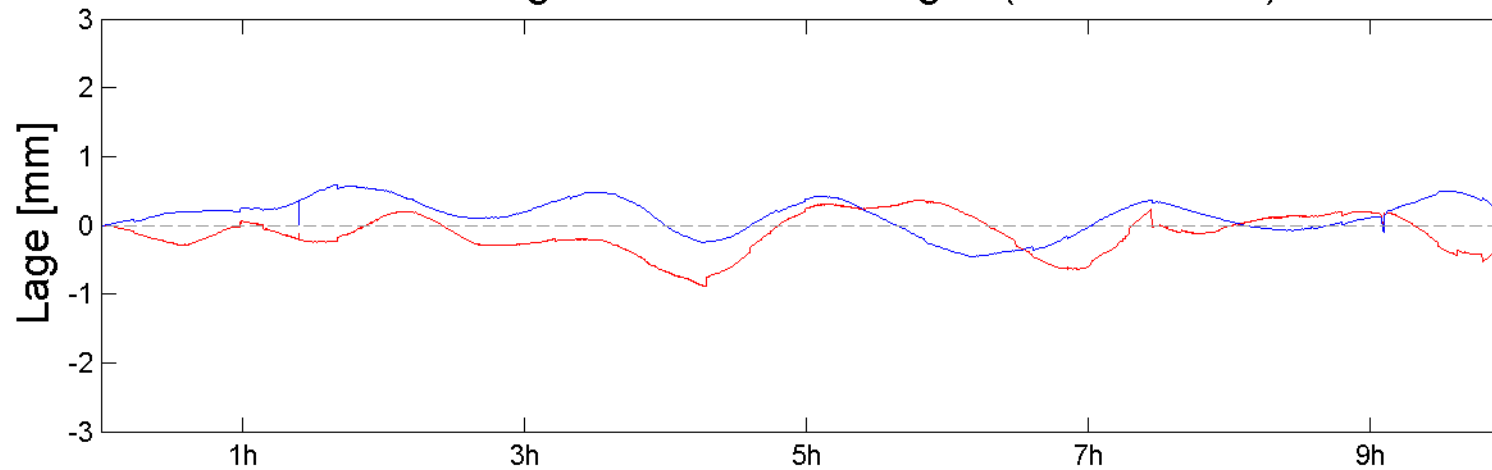


IfE vs. Berlin

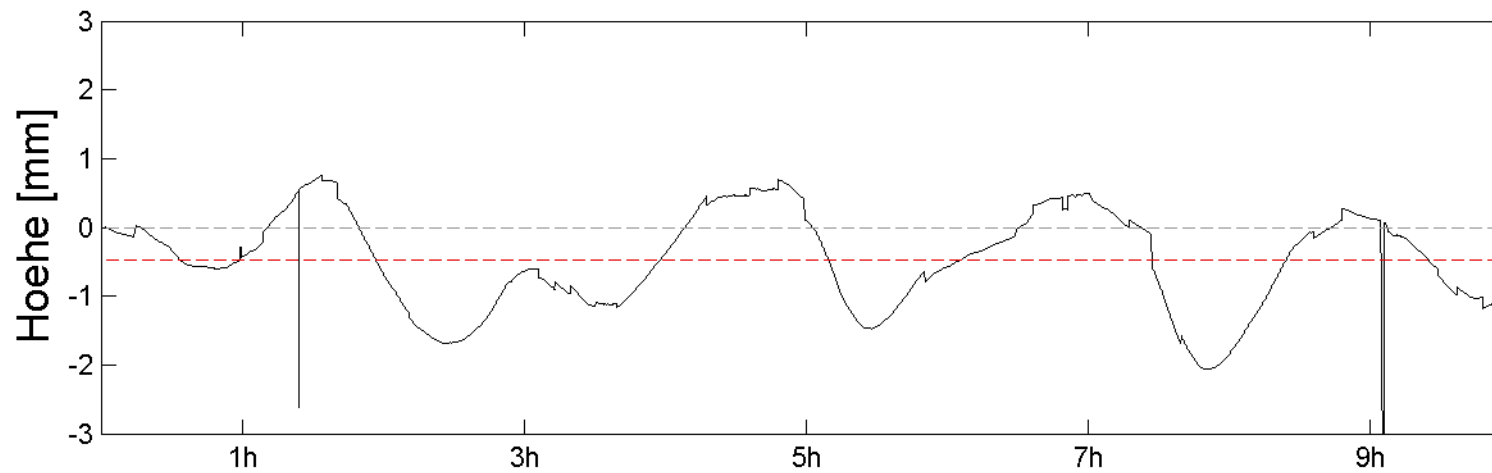
Leica AR25 (L2)



Auswirkung Kalibrierabweichungen (zero-baseline)

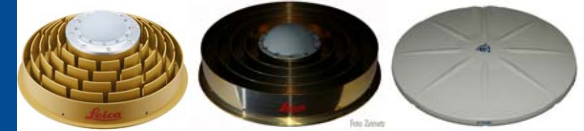


Zero-Baseline: IfE vs. Bonn

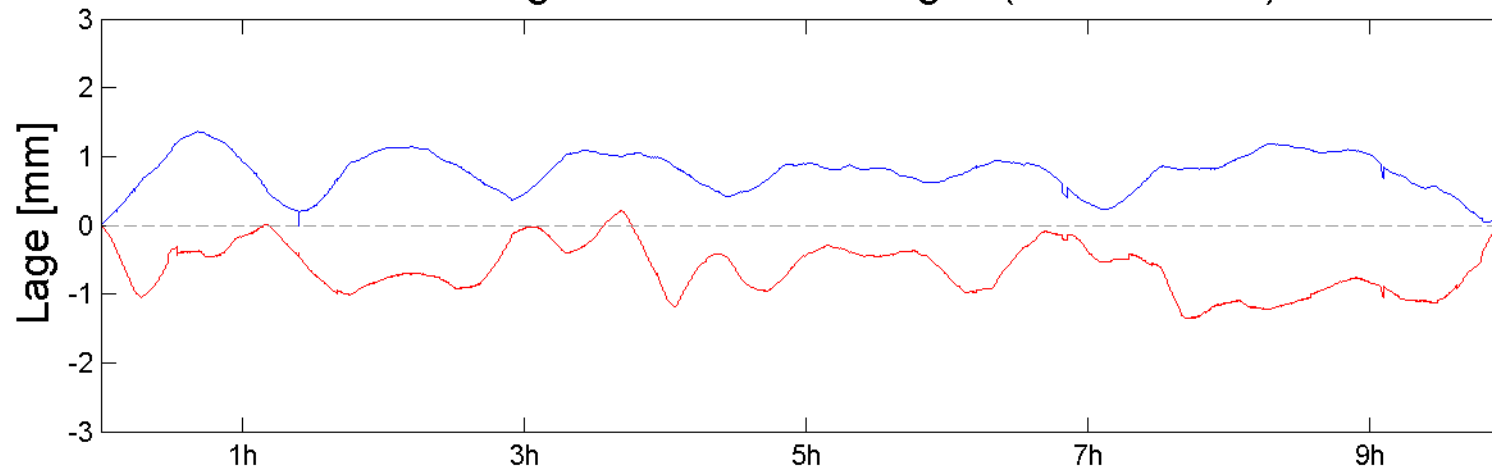


zero-baseline: L2-Frequenz, 5° Elevation, 5sec Sampling

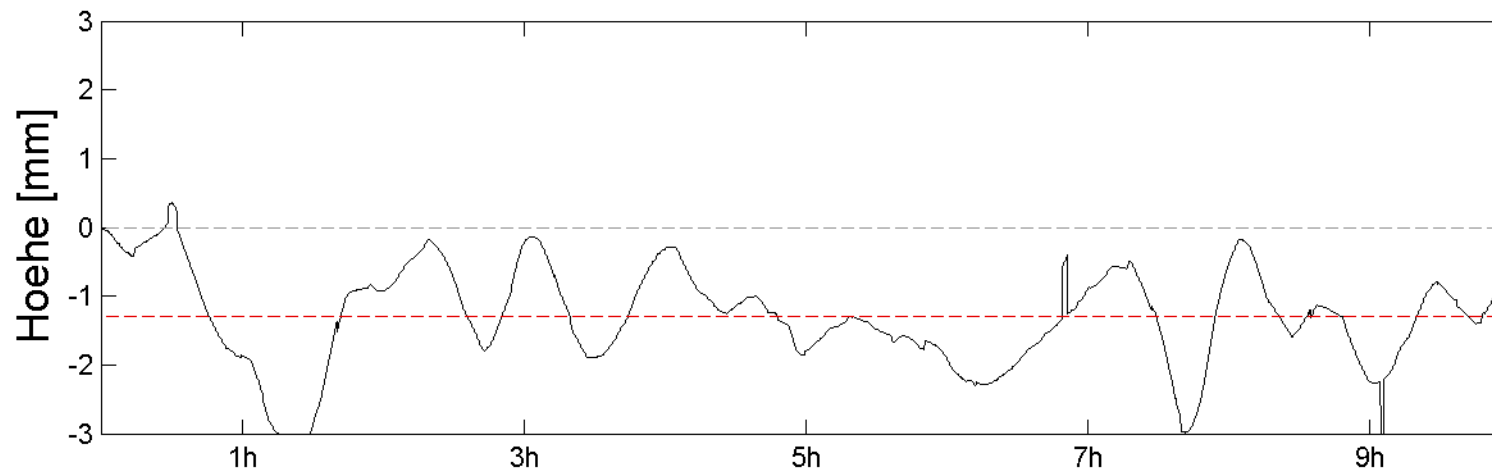
Leica AR25 (L2)



Auswirkung Kalibrierabweichungen (zero-baseline)

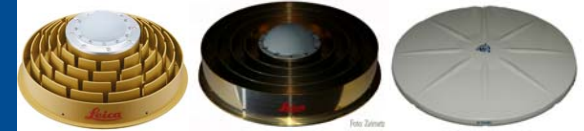


Zero-Baseline: IfE vs. Dresden

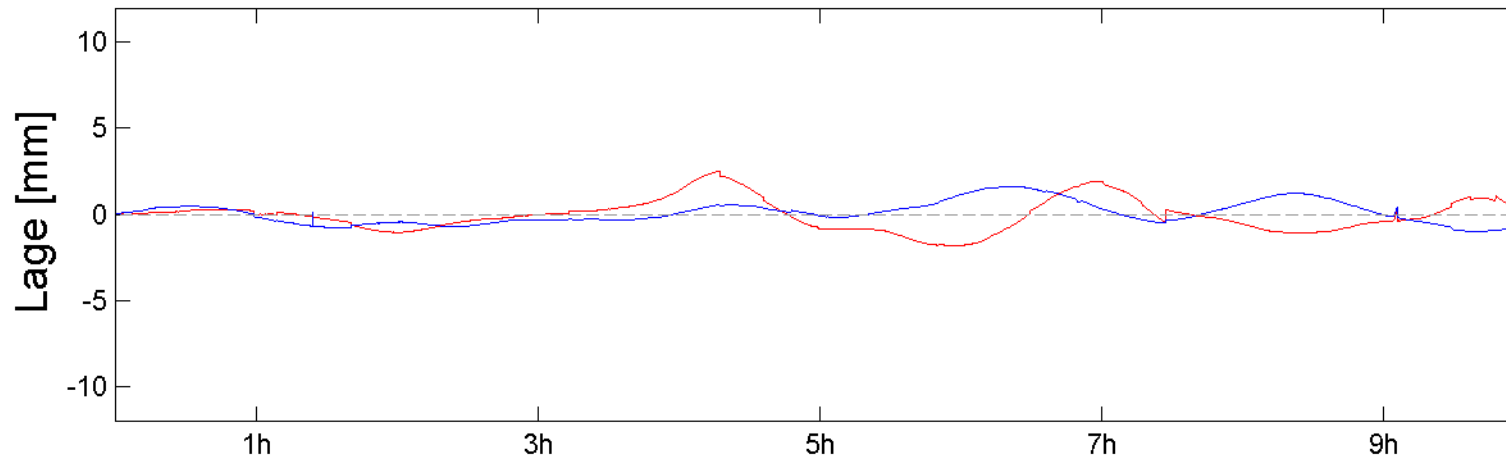


zero-baseline: L2-Frequenz, 5° Elevation, 5sec Sampling

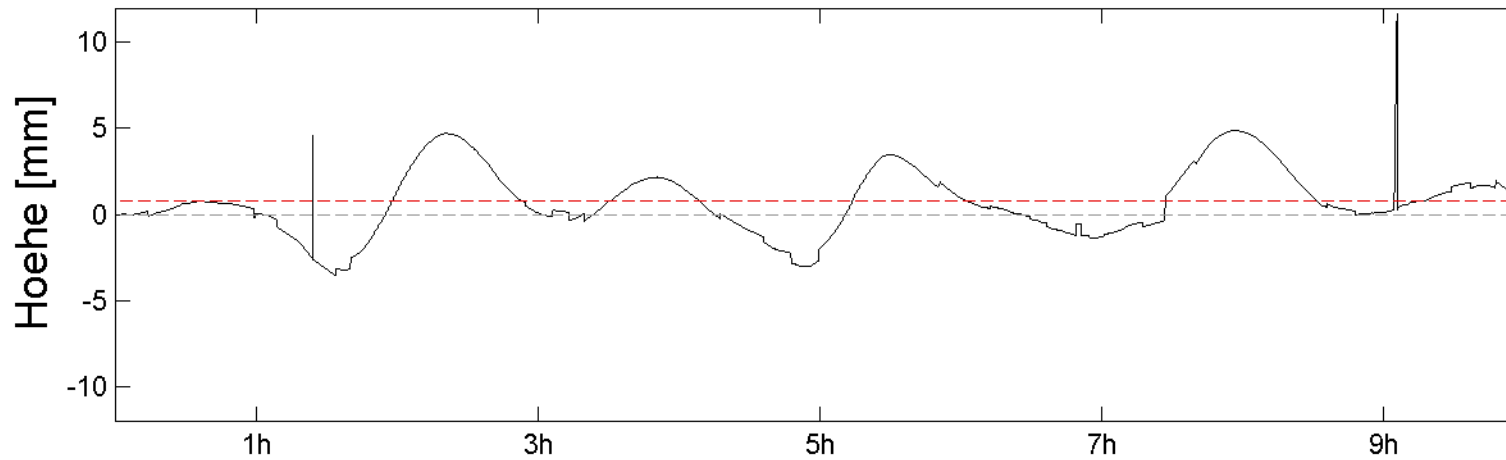
Leica AR25 (L3)



Auswirkung Kalibrierabweichungen (zero-baseline)

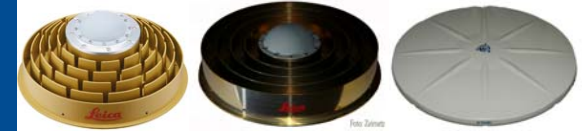


Zero-Baseline: IfE vs. Bonn

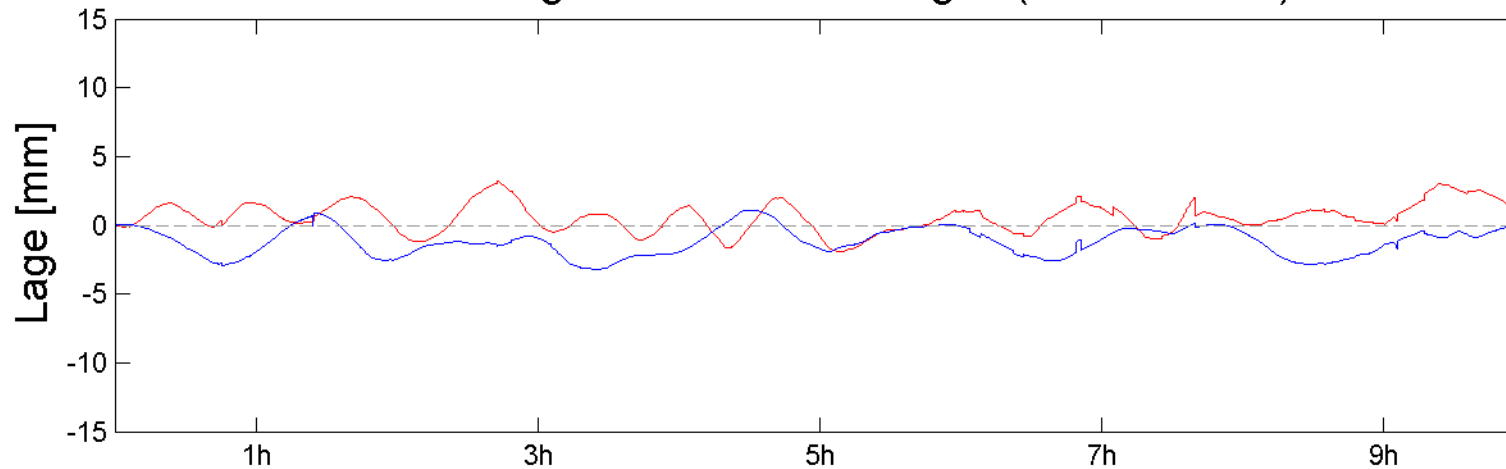


zero-baseline: L3-Frequenz, 5° Elevation, 5sec Sampling

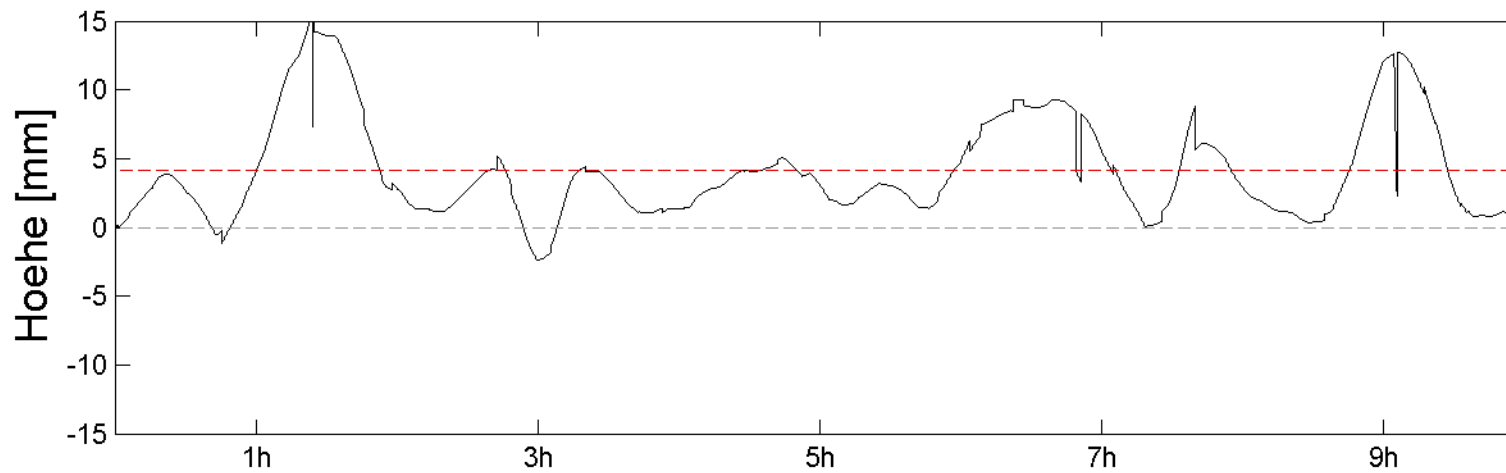
Leica AR25 (L3)



Auswirkung Kalibrierabweichungen (zero-baseline)

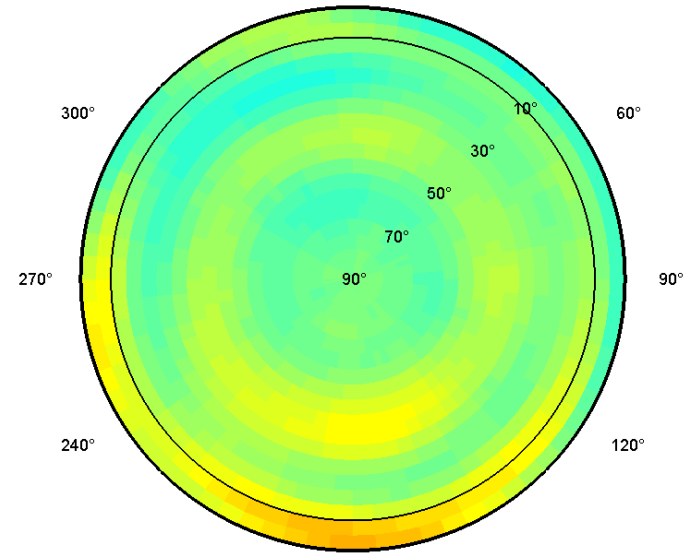
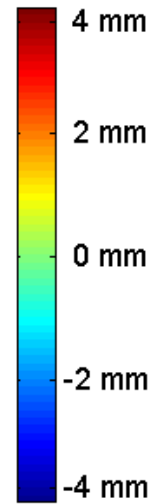
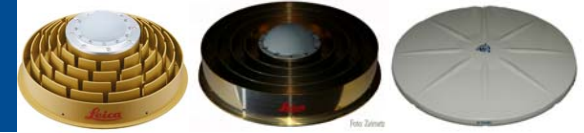


Zero-Baseline: IfE vs. Dresden



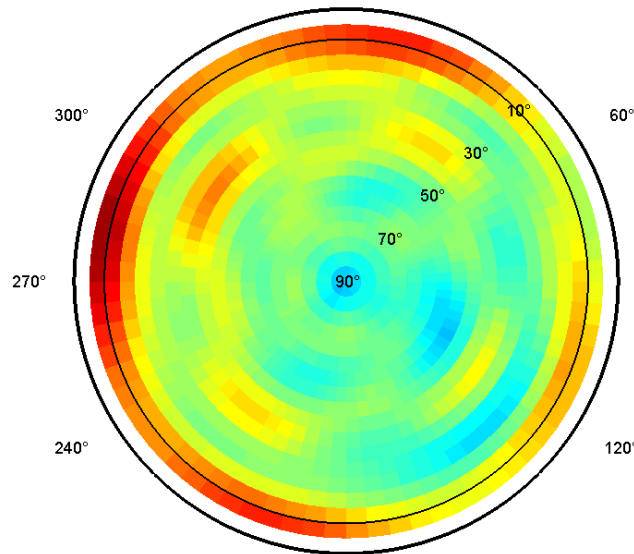
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Leica AR25 (R1)

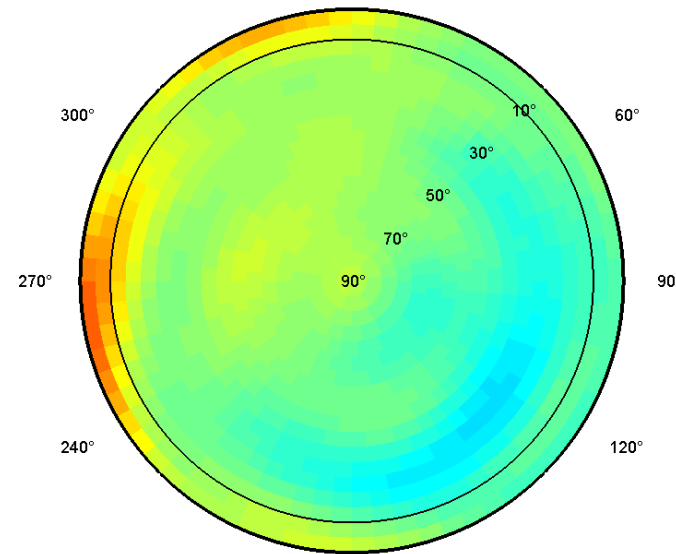


IfE vs. Bonn

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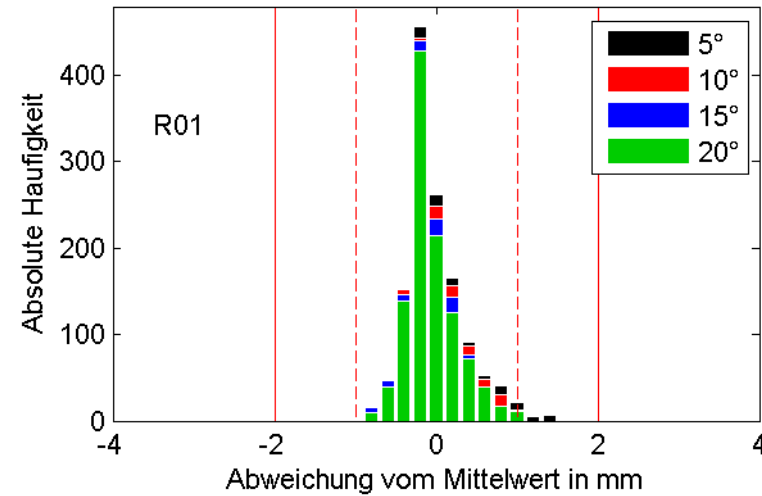
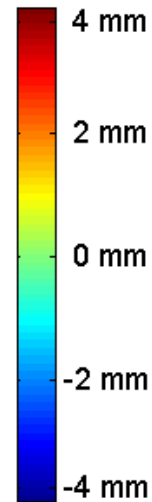
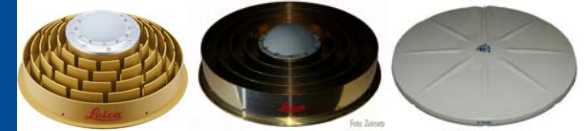


IfE vs. Dresden



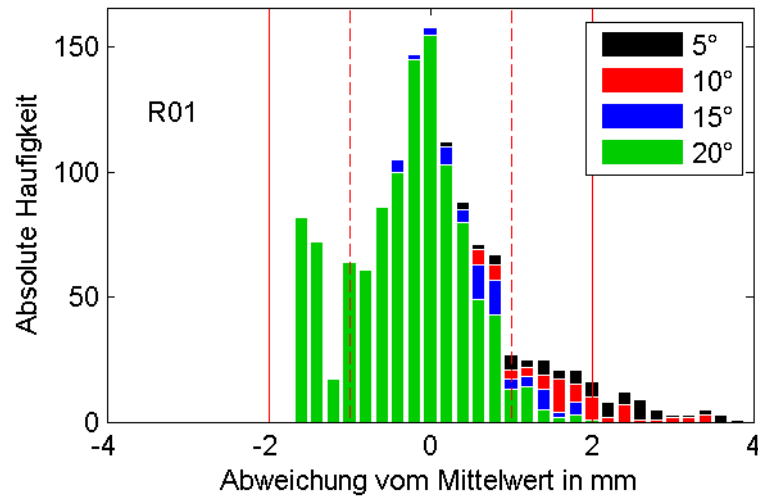
IfE vs. Berlin

Leica AR25 (R1)

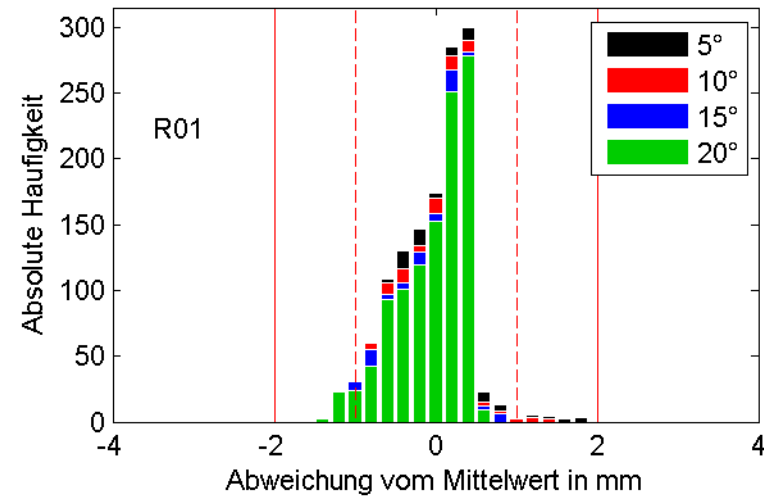


IfE vs. Bonn

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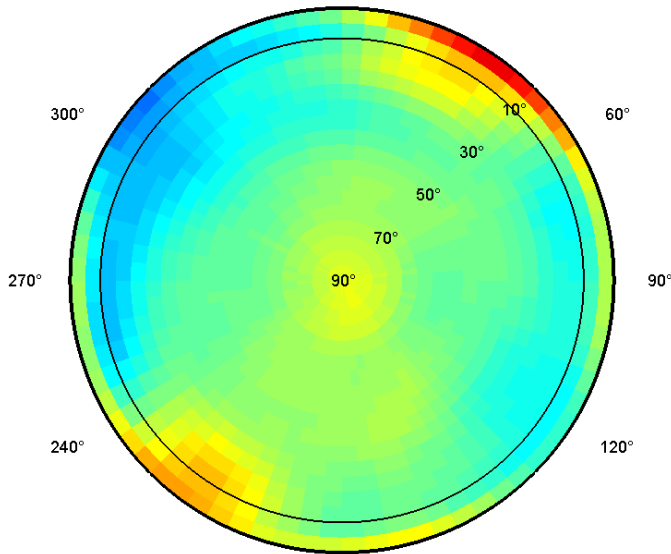
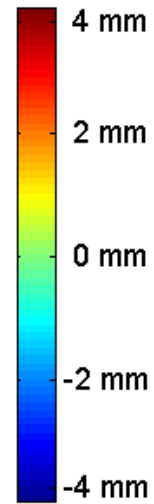
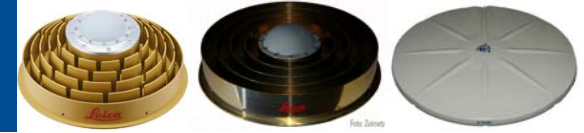


IfE vs. Dresden



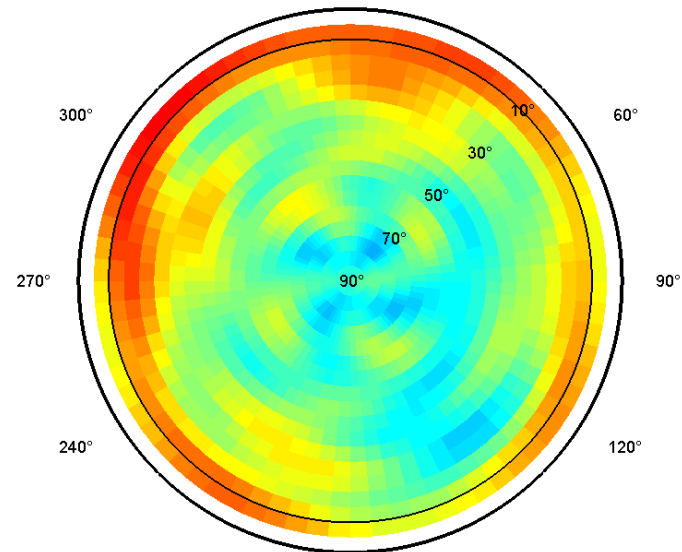
IfE vs. Berlin

Leica AR25 (R2)

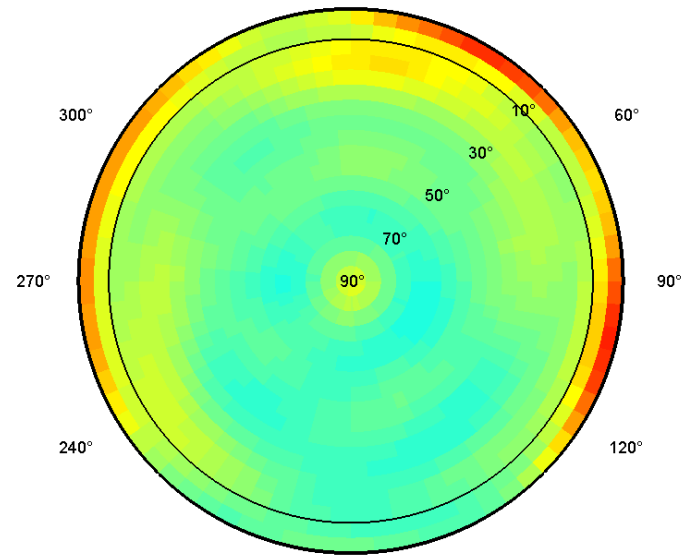


IfE vs. Bonn

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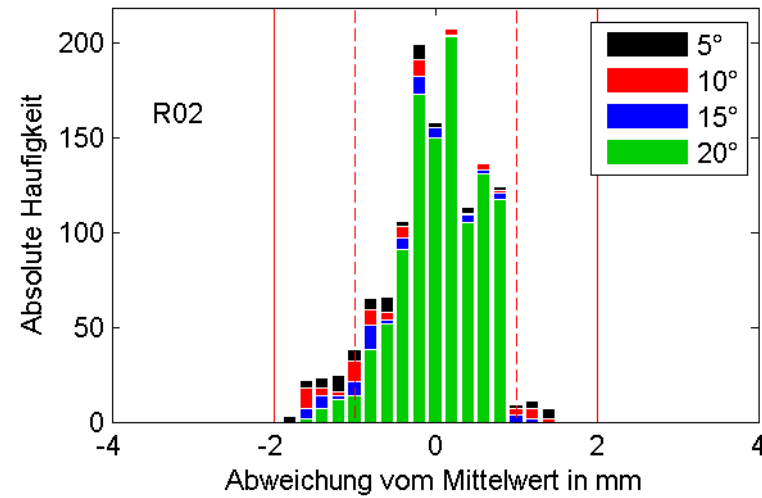
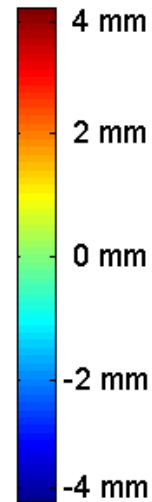
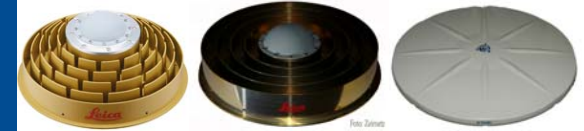


IfE vs. Dresden



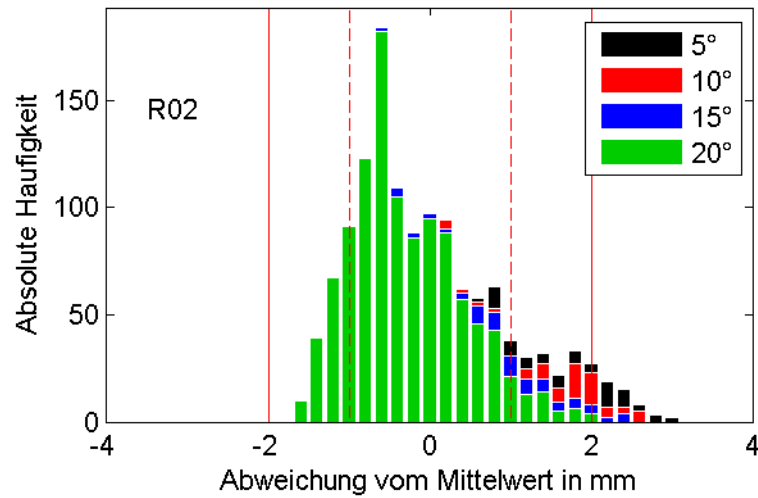
IfE vs. Berlin

Leica AR25 (R2)

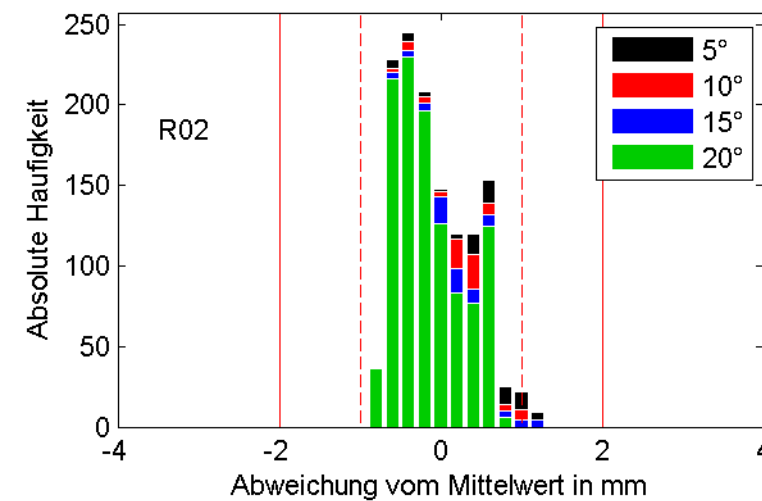


IfE vs. Bonn

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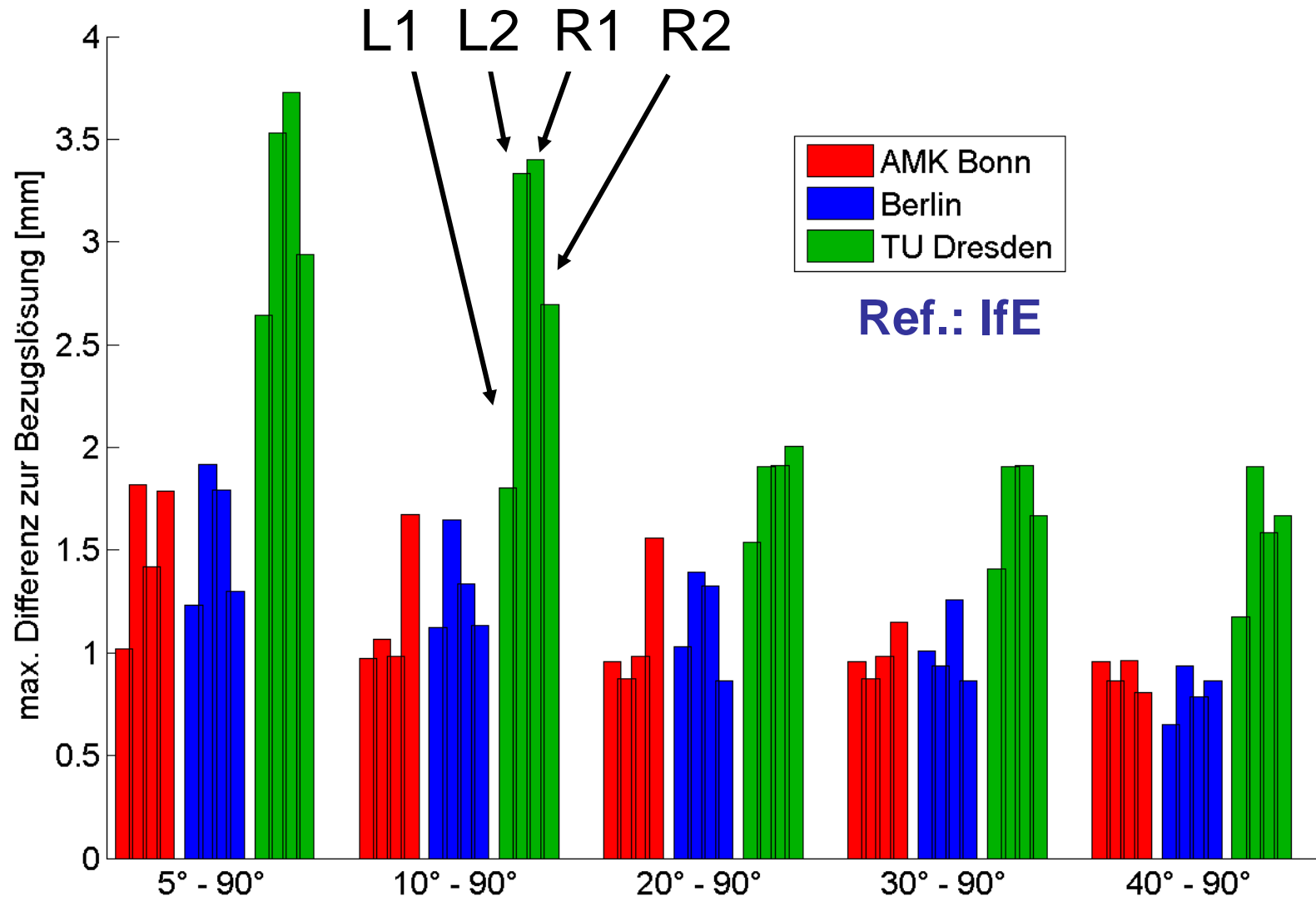
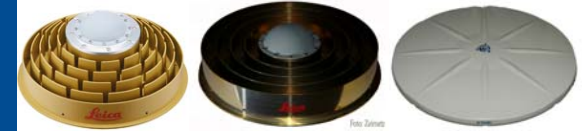


IfE vs. Dresden

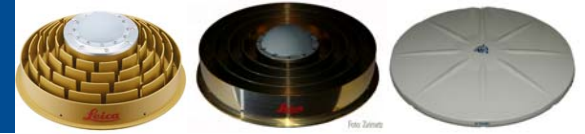


IfE vs. Berlin

Leica AR25

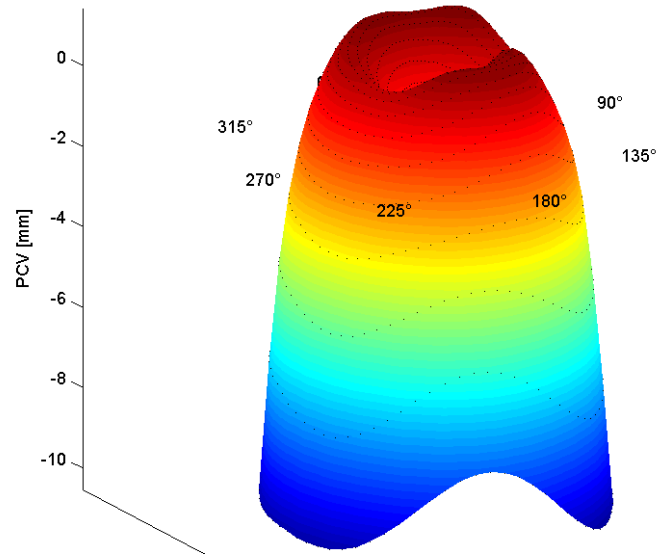
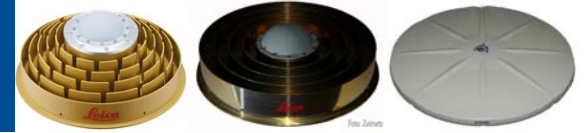


Trimble Zephyr Geodetic 2

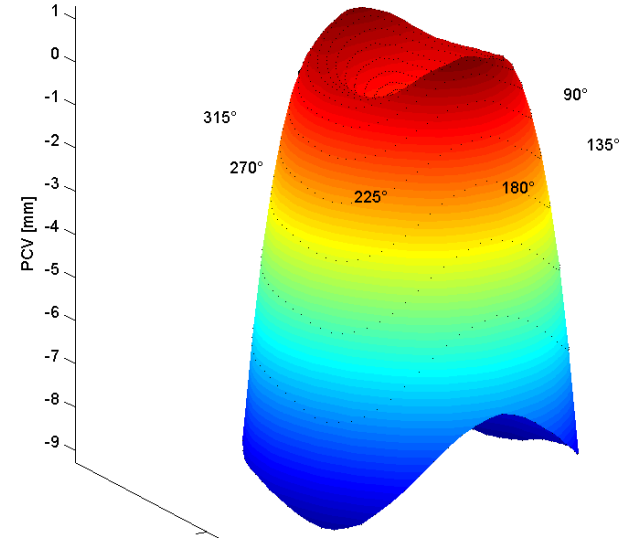


SN: 30573939

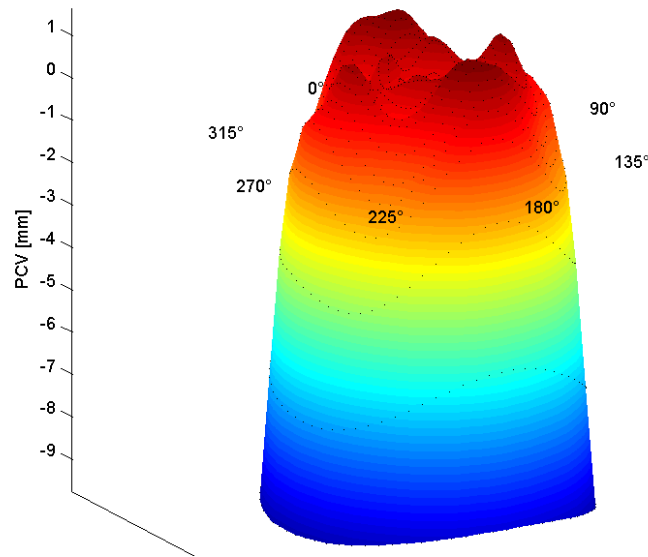
Trimble Zephyr Geodetic 2 (L1)



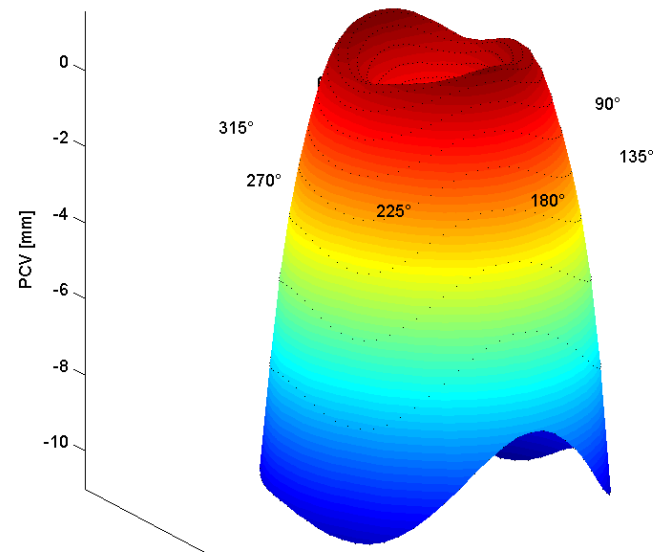
IfE



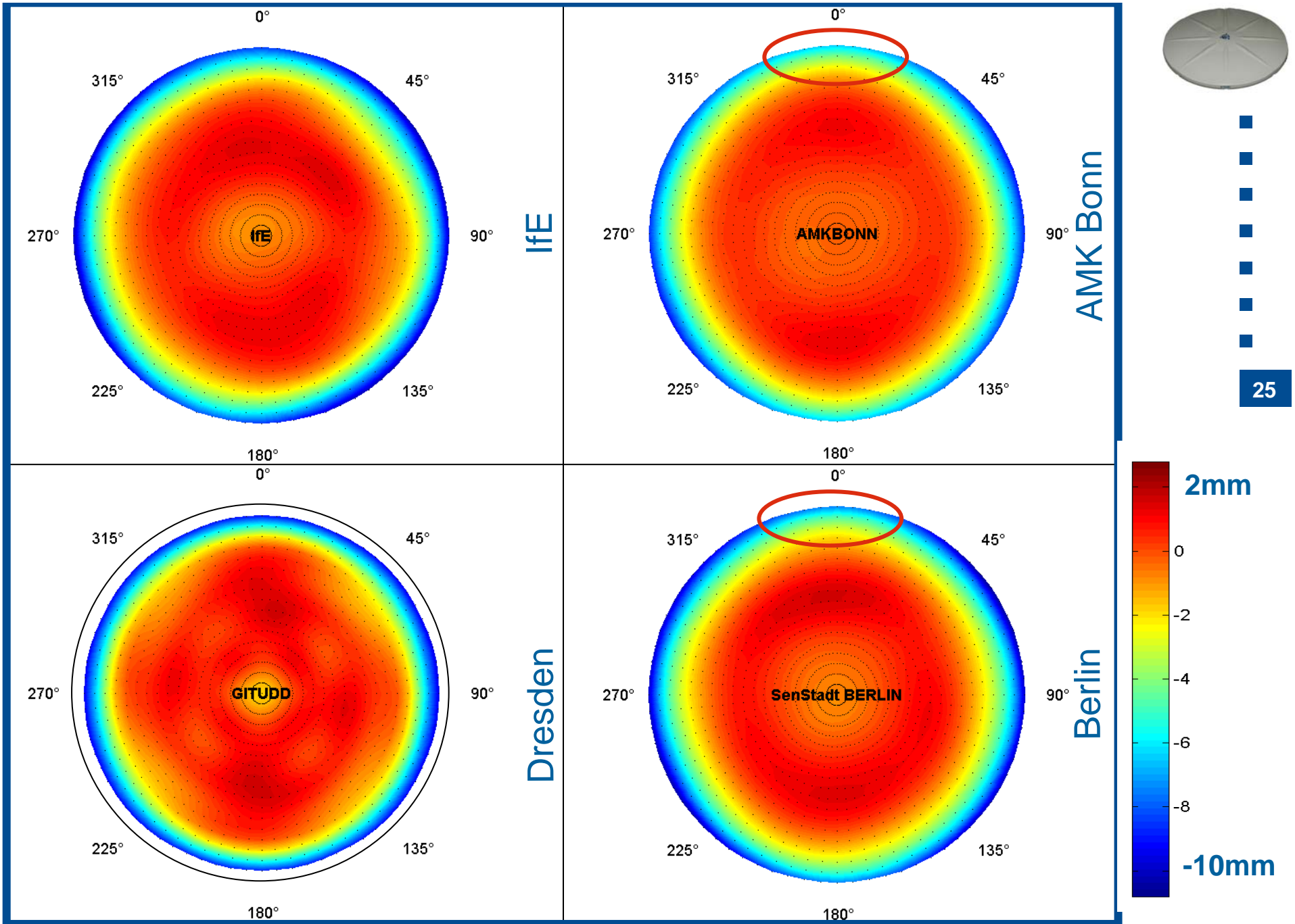
AMK Bonn



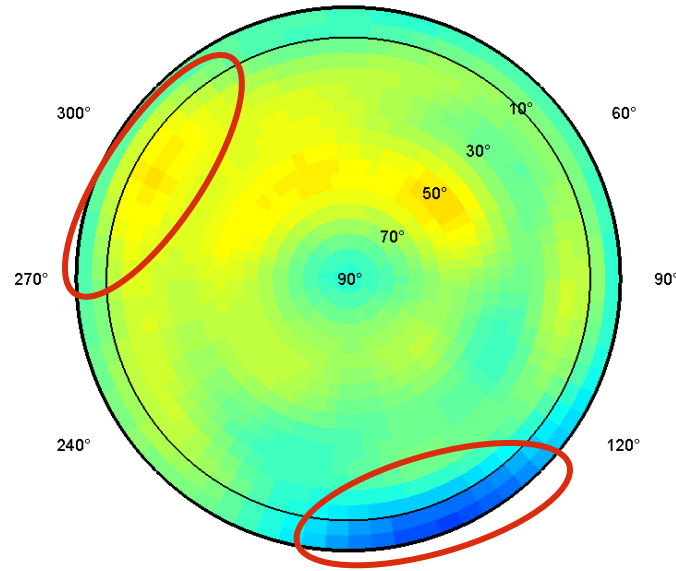
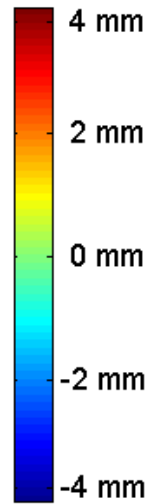
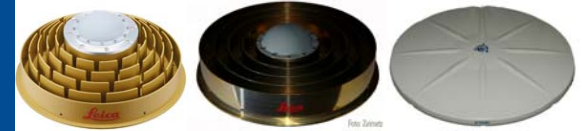
Dresden



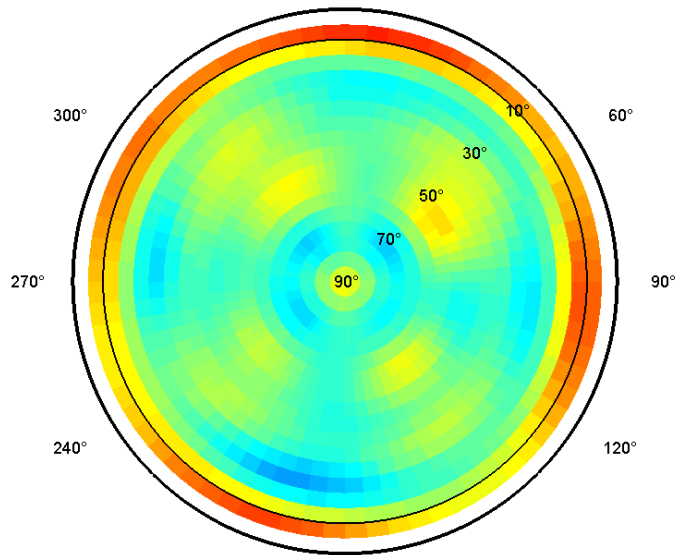
Berlin



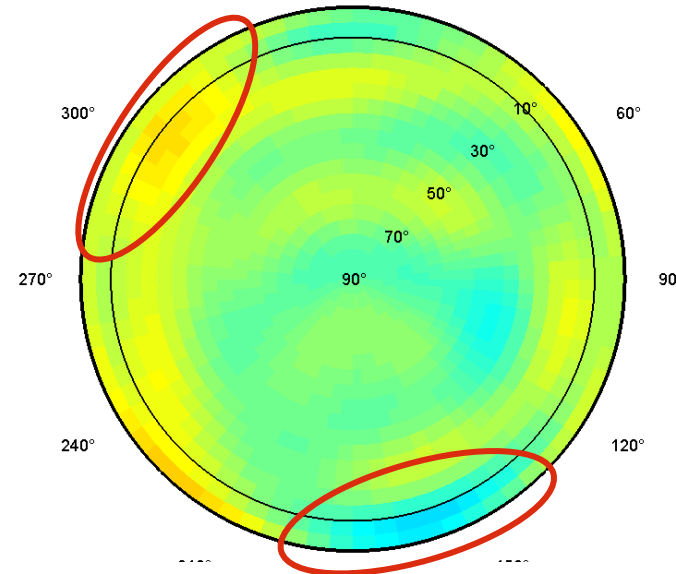
Trimble Zephyr Geodetic 2 (L1)



IfE vs. AMK Bonn



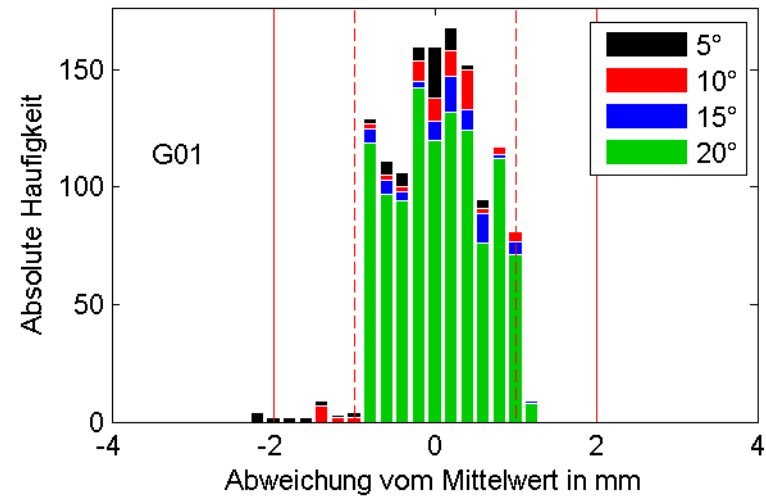
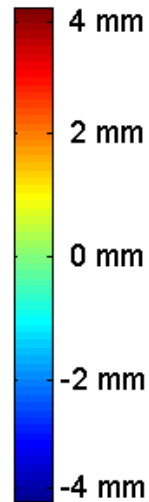
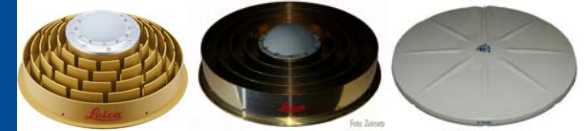
IfE vs. Dresden



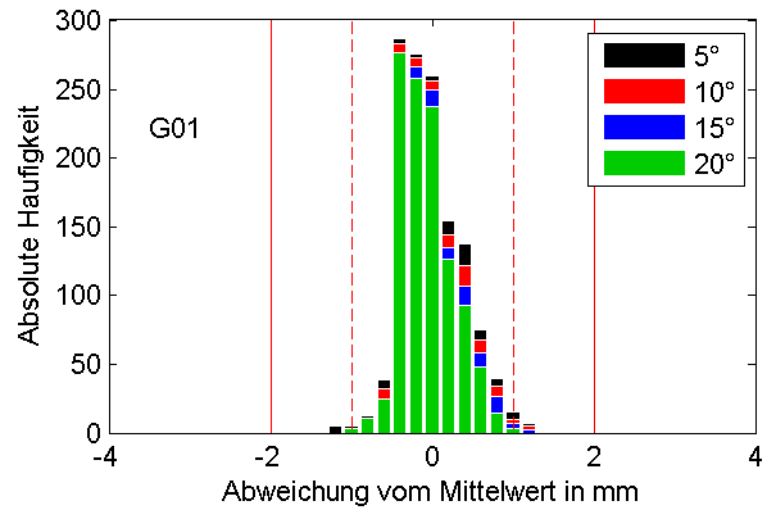
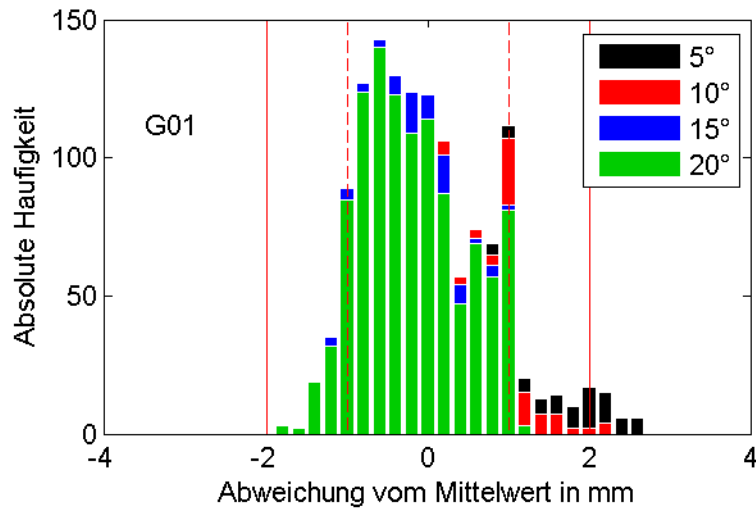
IfE vs. Berlin

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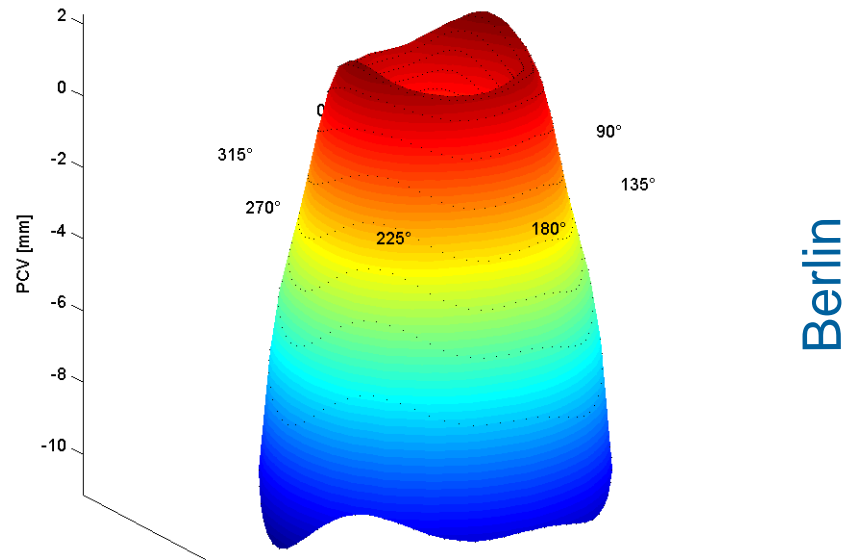
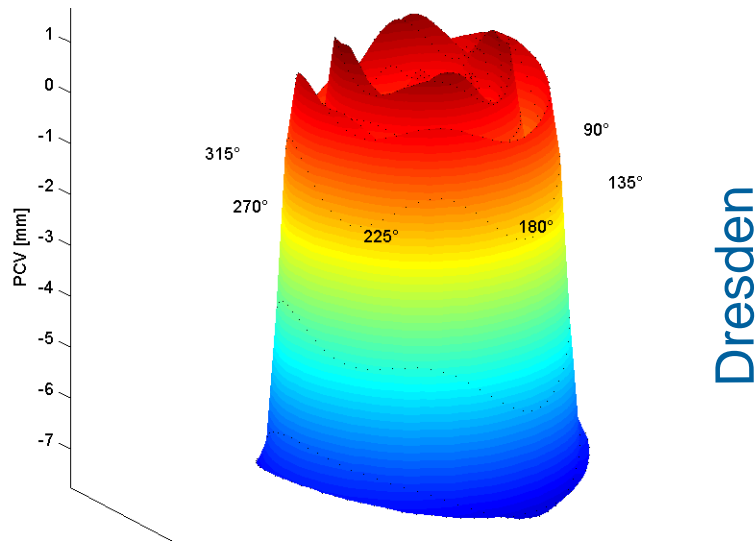
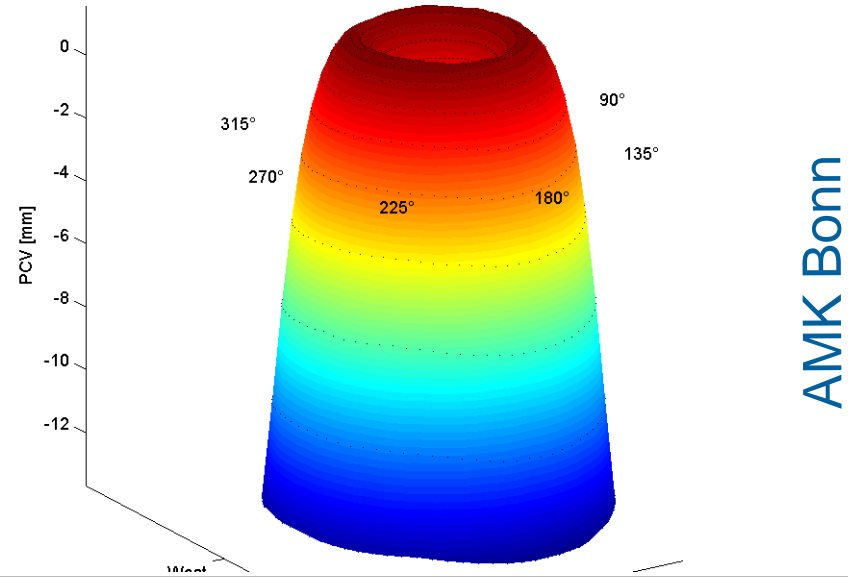
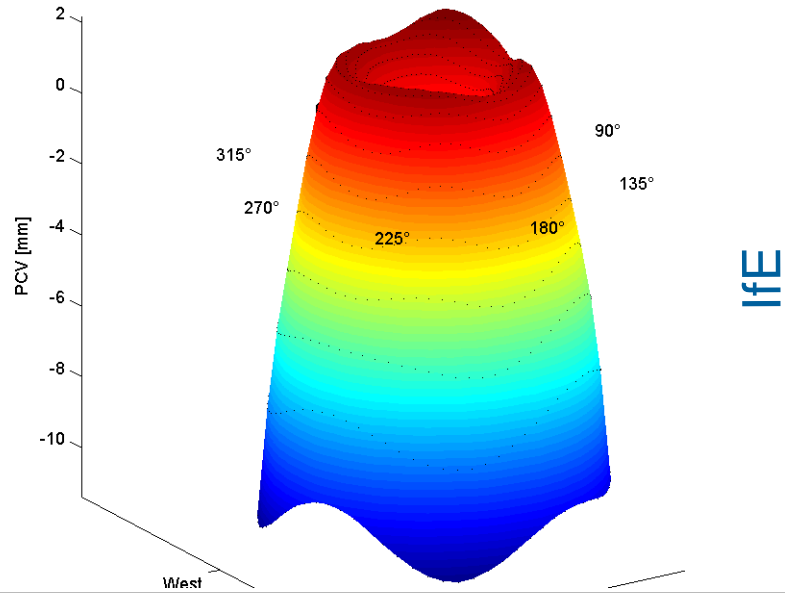
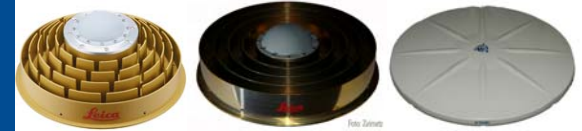
Trimble Zephyr Geodetic 2 (L1)

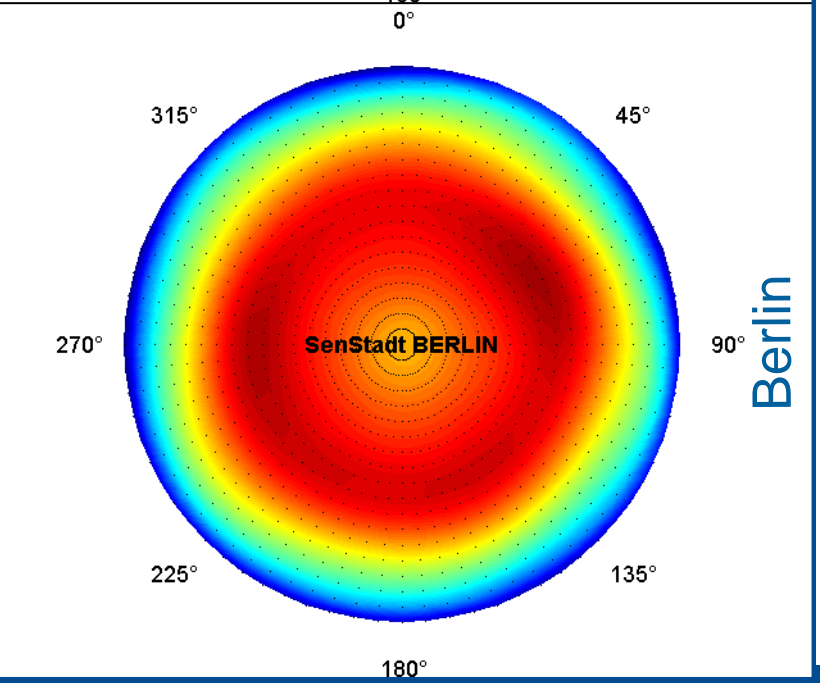
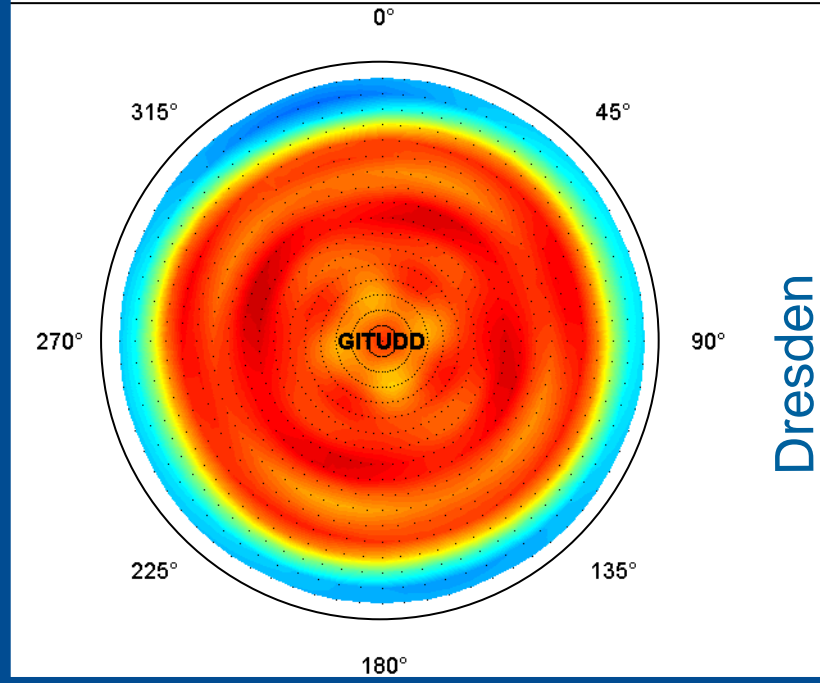
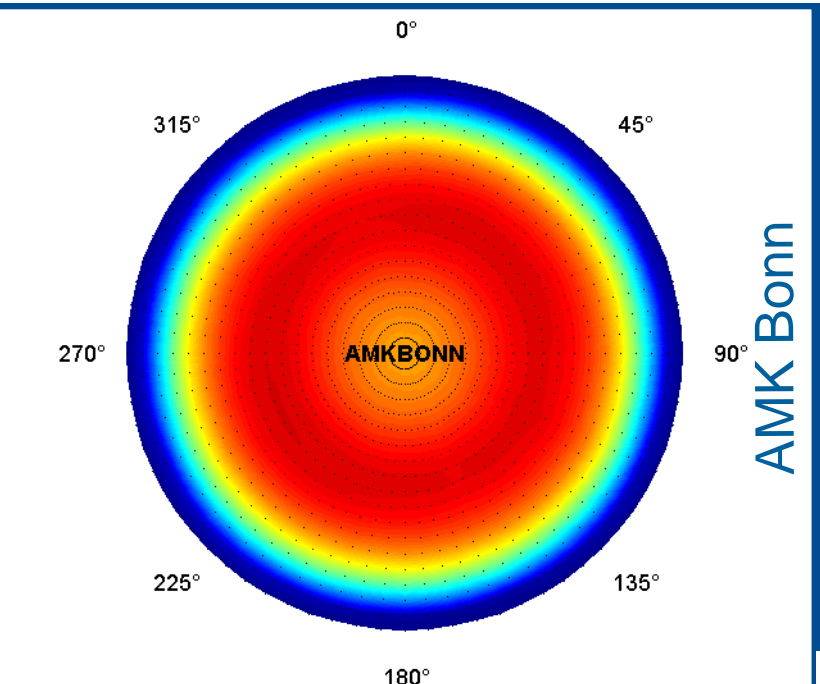
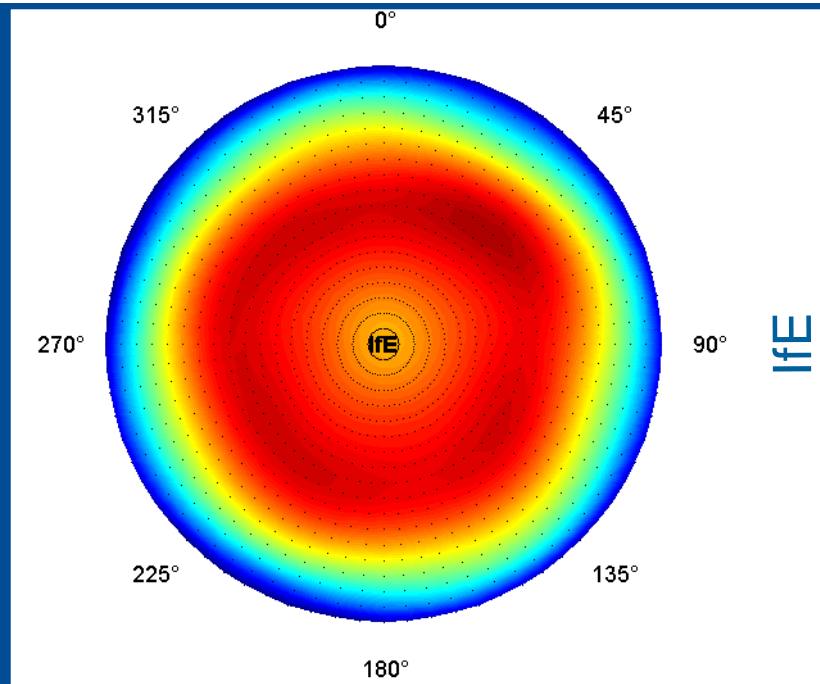
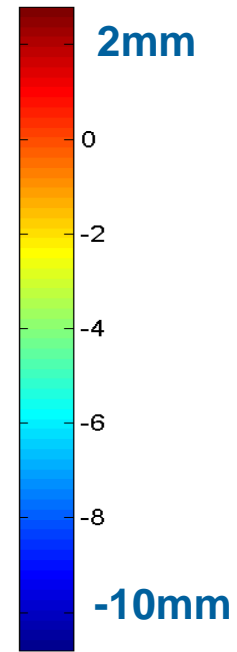


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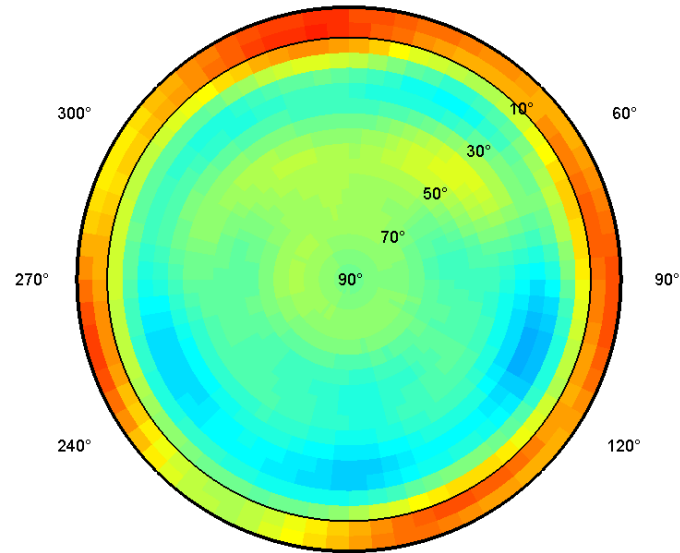
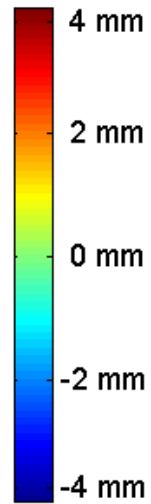
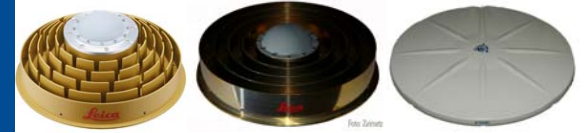


Trimble Zephyr Geodetic 2 (L2)

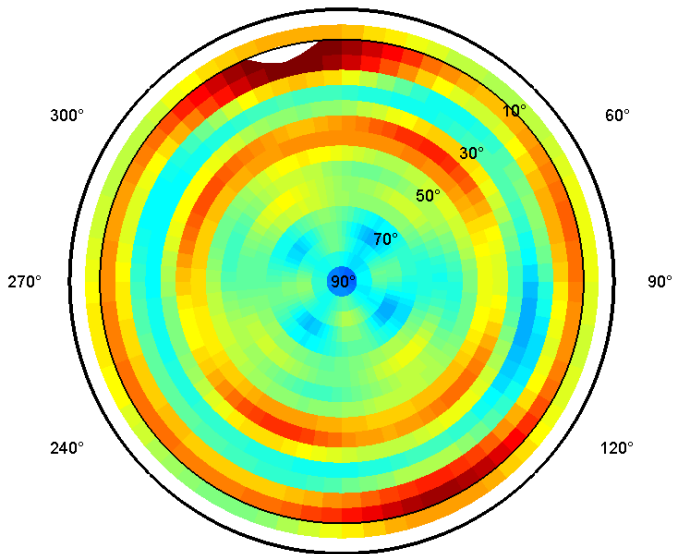




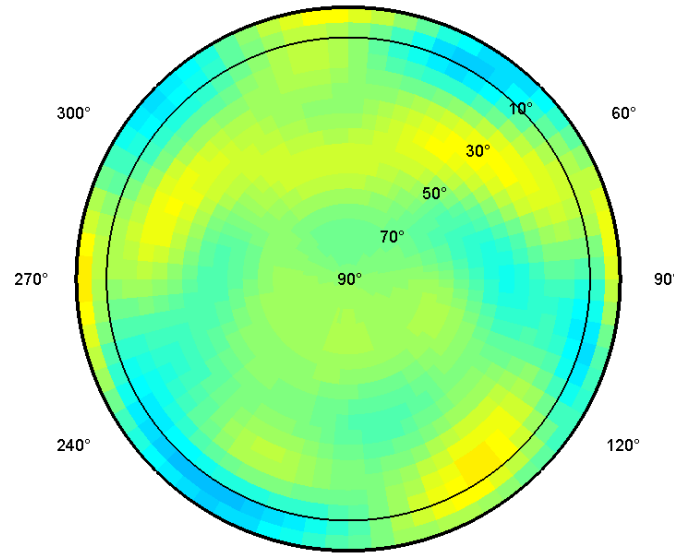
Trimble Zephyr Geodetic 2 (L2)



IfE vs. AMK Bonn

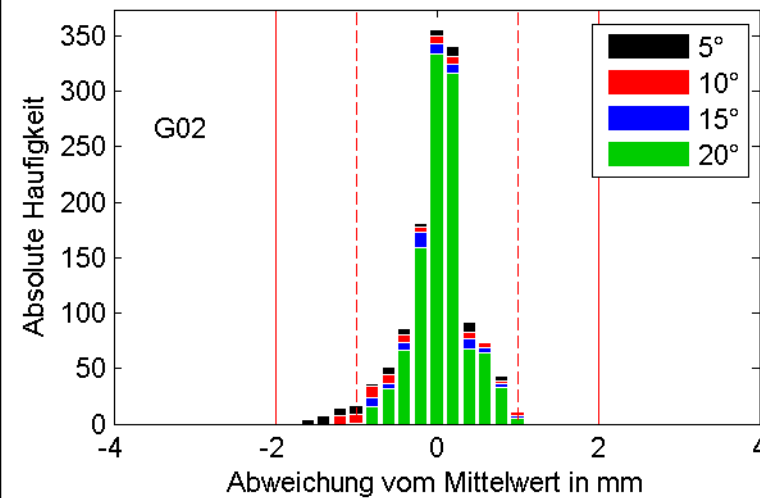
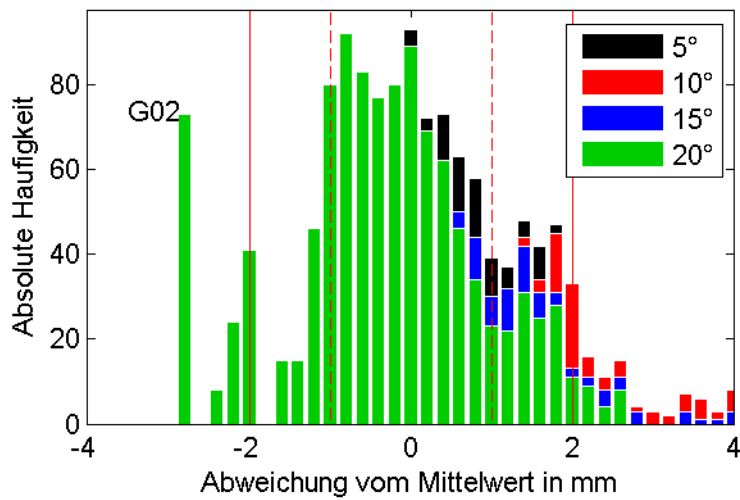
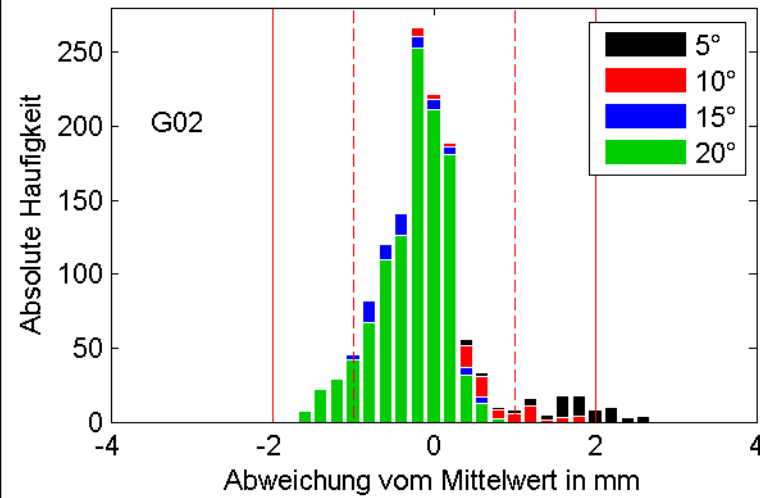
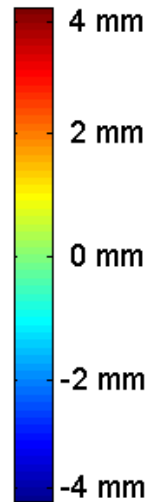
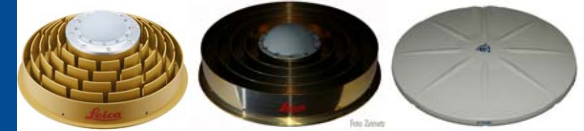


IfE vs. Dresden

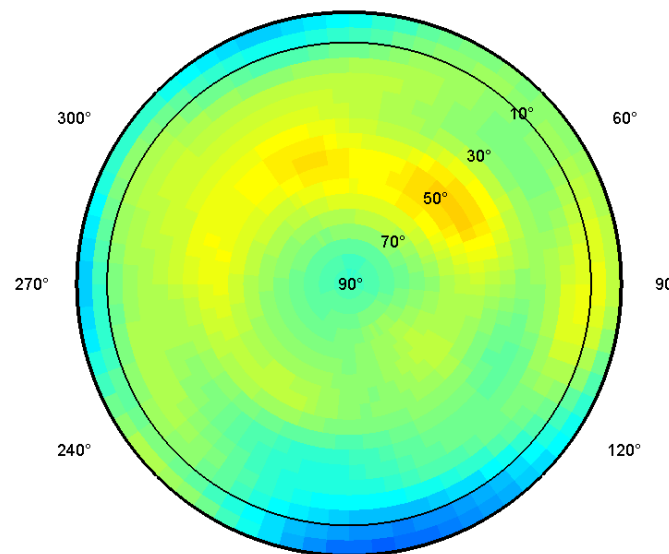
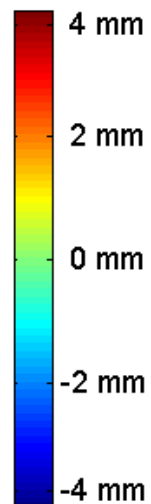
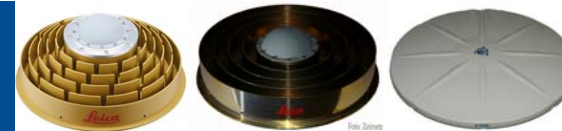


IfE vs. Berlin

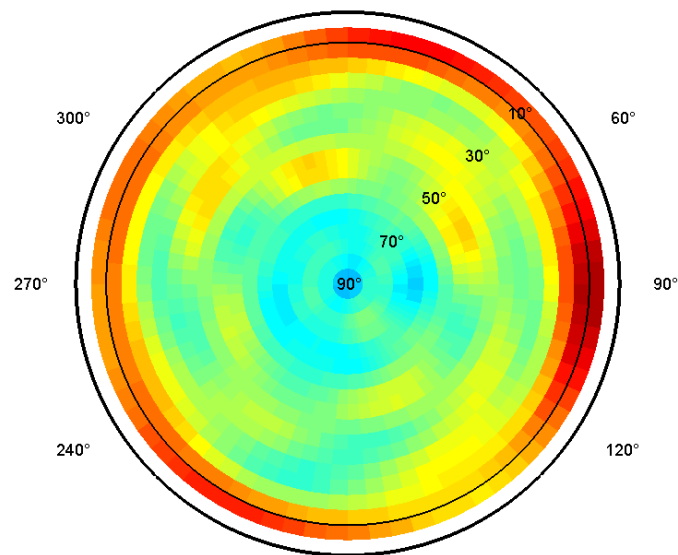
Trimble Zephyr Geodetic 2 (L2)



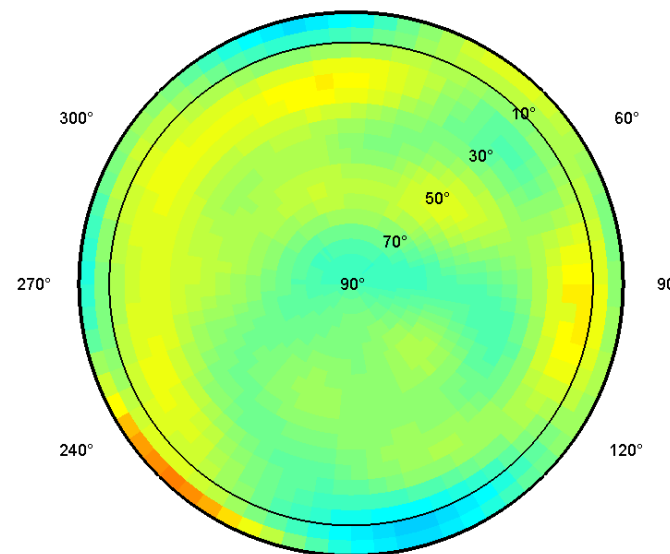
Trimble Zephyr Geodetic 2 (R1)



Berlin vs. AMK Bonn

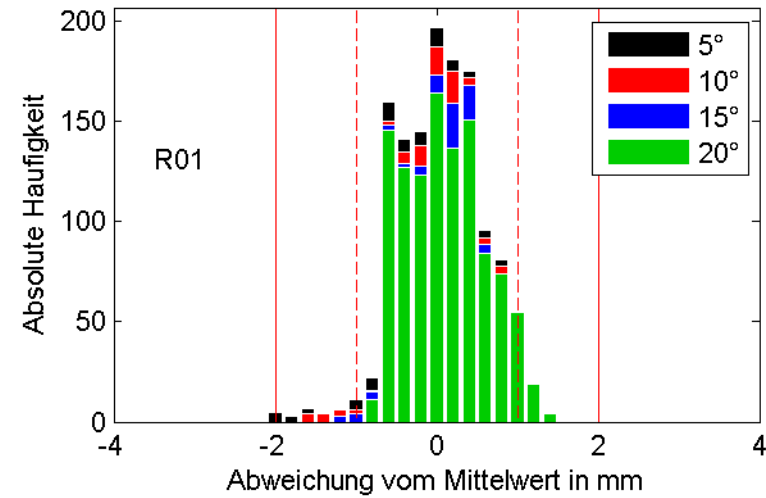
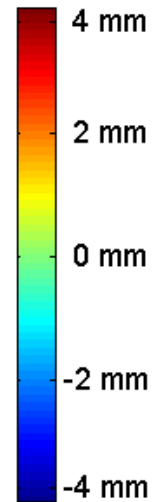
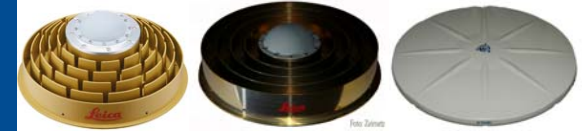


Berlin vs. Dresden



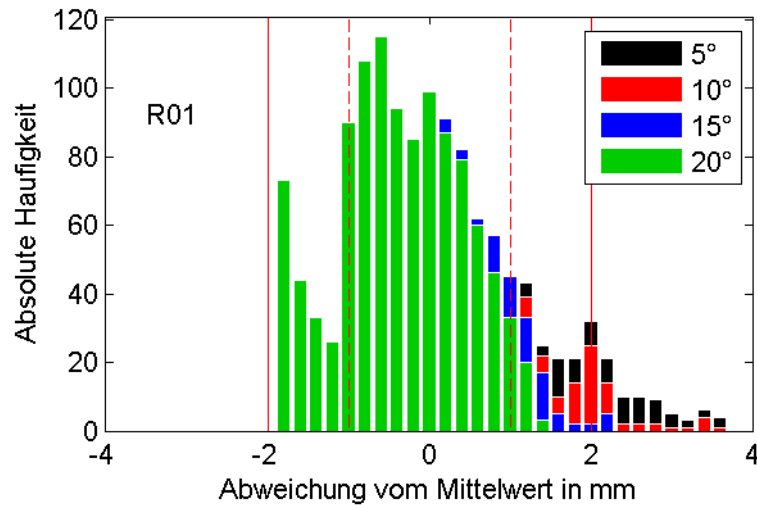
Berlin vs. IfE

Trimble Zephyr Geodetic 2 (R1)

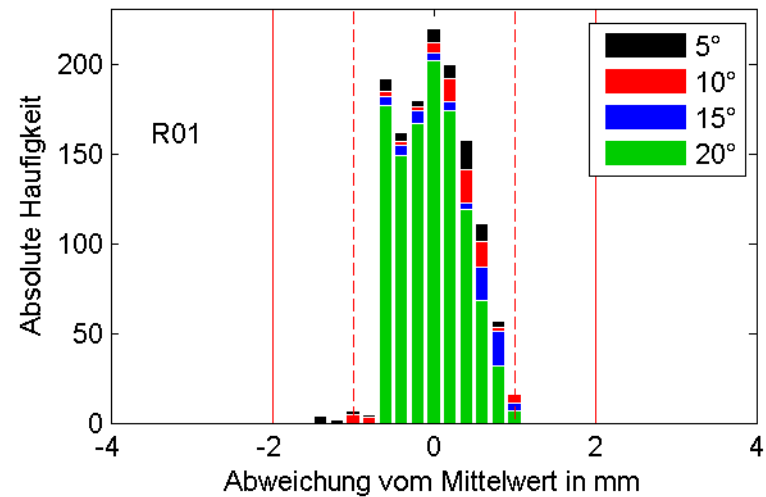


IfE vs. Bonn

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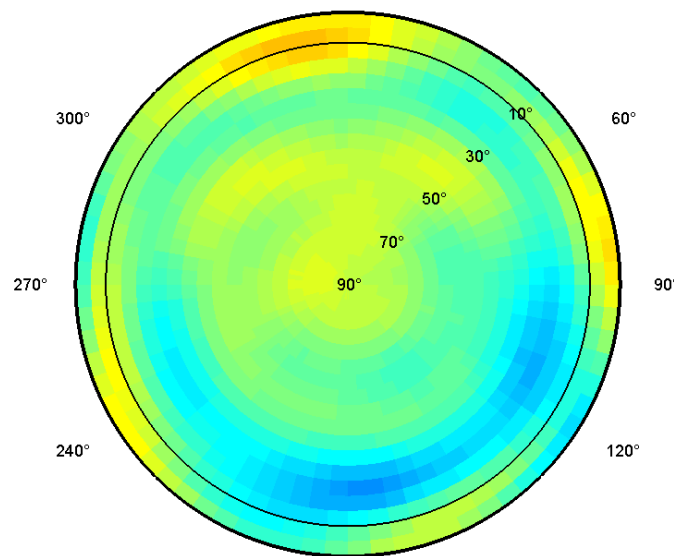
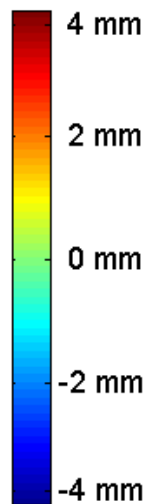
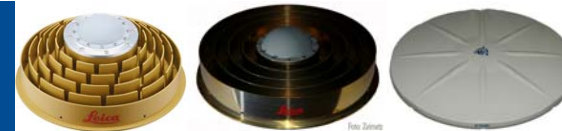


IfE vs. Dresden

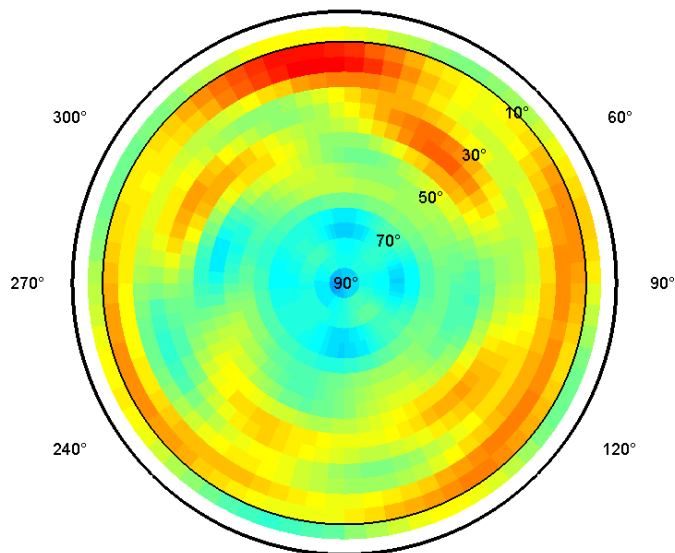


IfE vs. Berlin

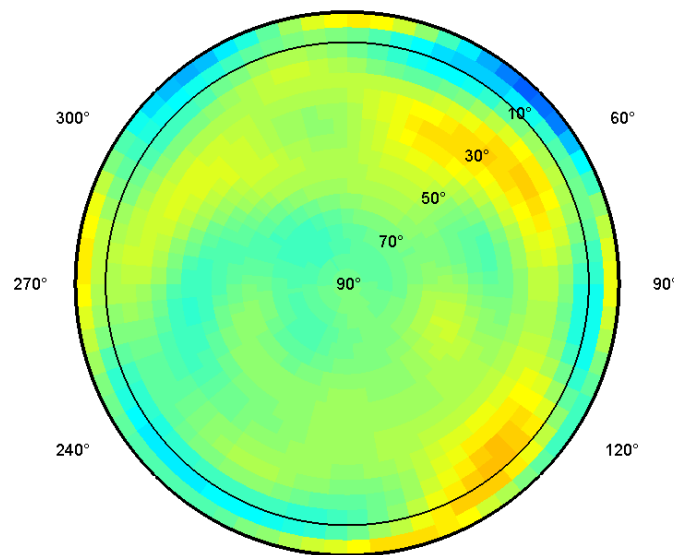
Trimble Zephyr Geodetic 2 (R2)



Berlin vs. AMK Bonn

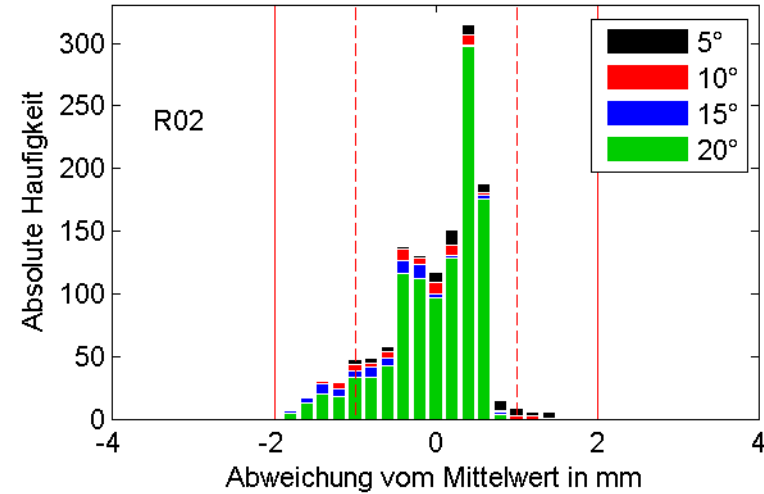
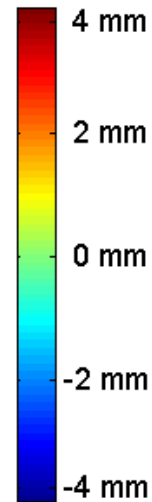
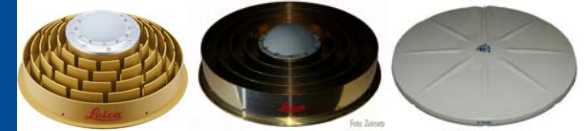


Berlin vs. Dresden



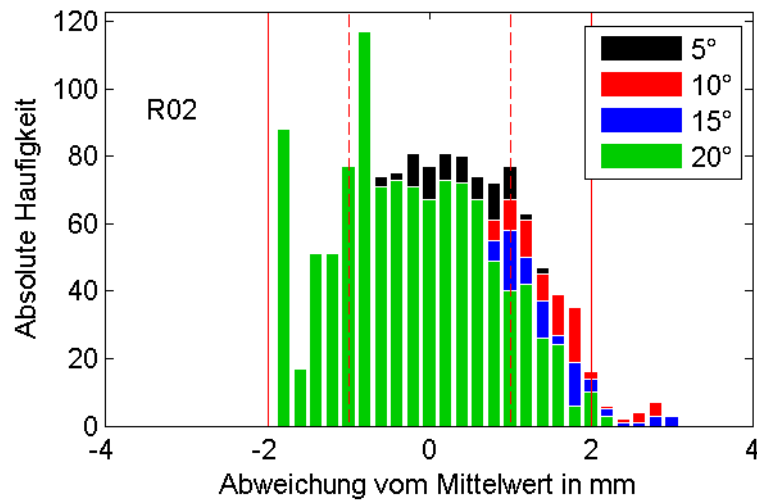
Berlin vs. IfE

Trimble Zephyr Geodetic 2 (R2)

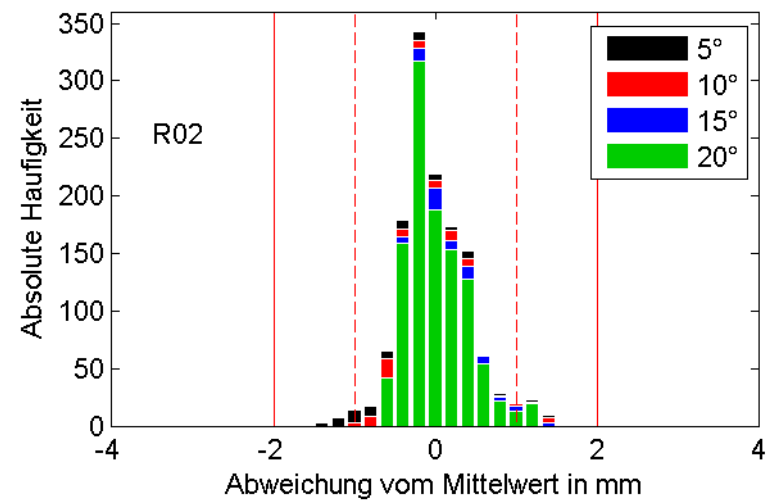


IfE vs. Bonn

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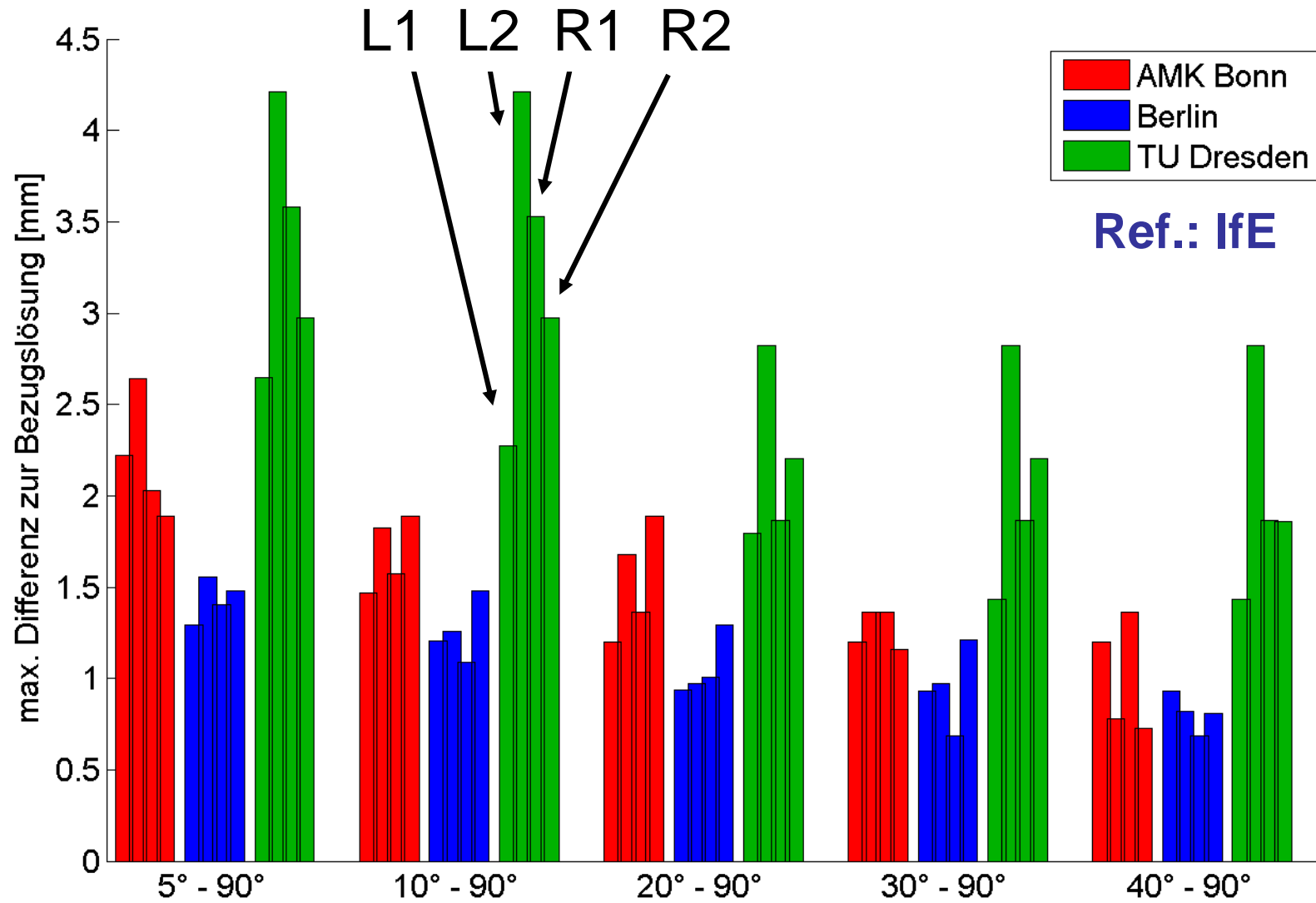
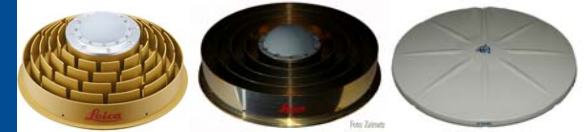


IfE vs. Dresden

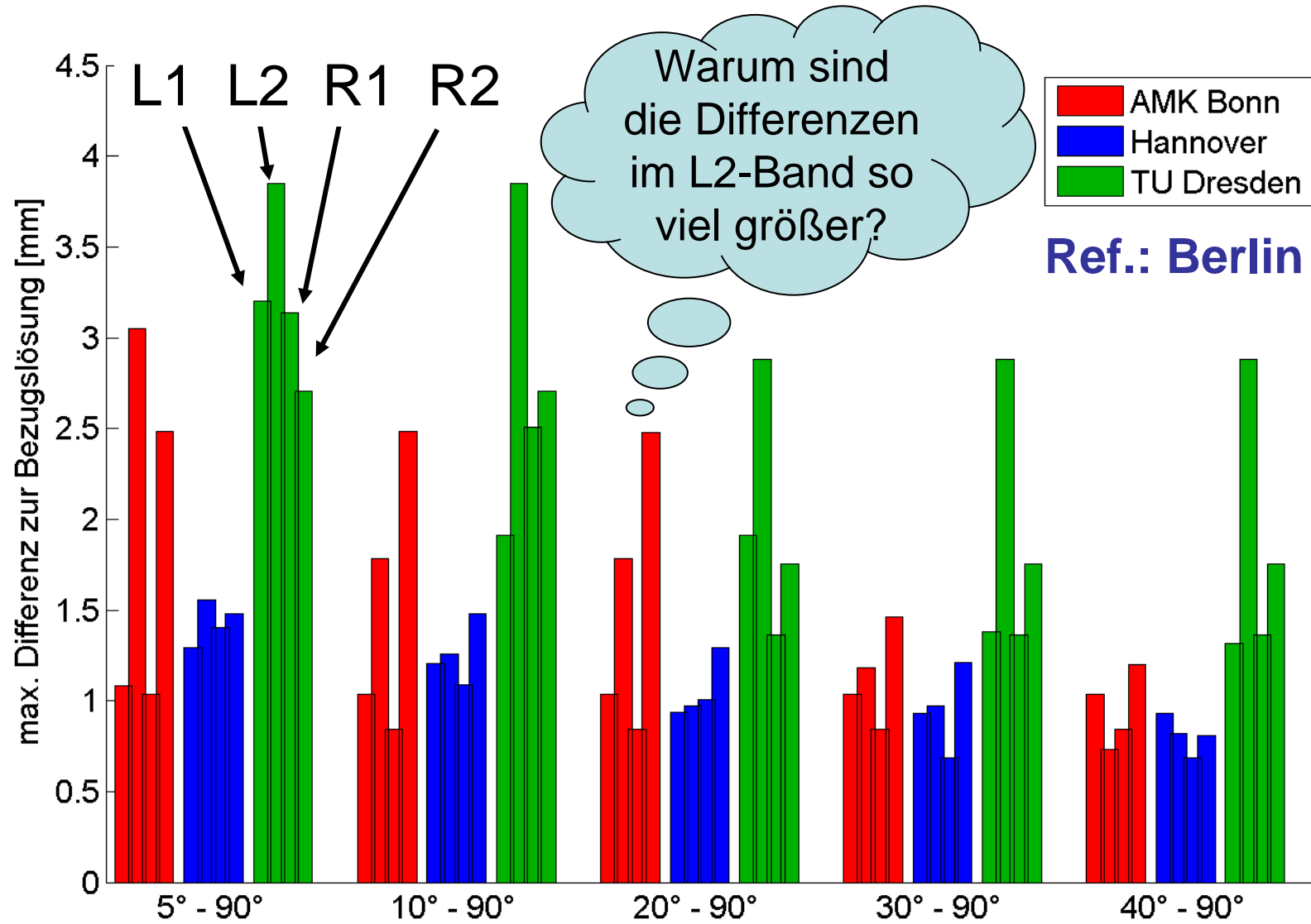
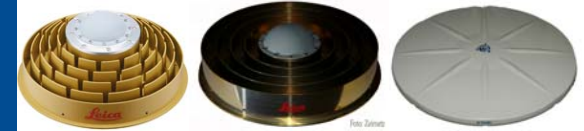


IfE vs. Berlin

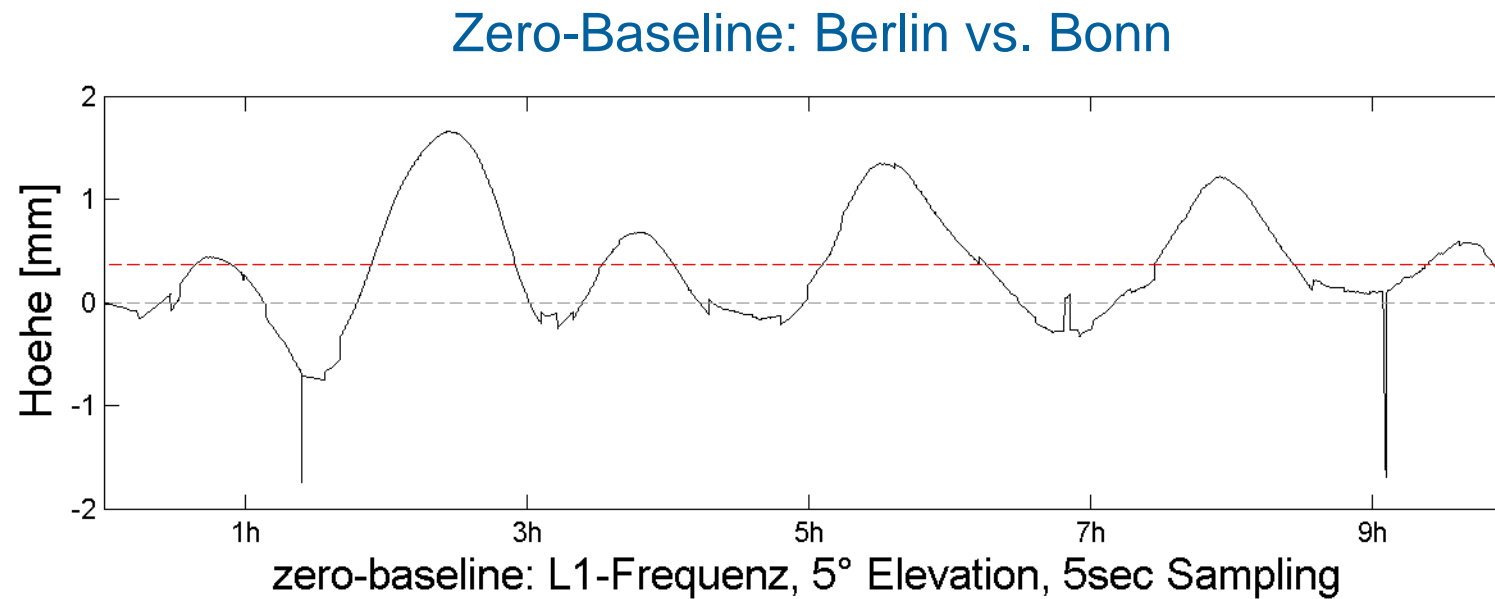
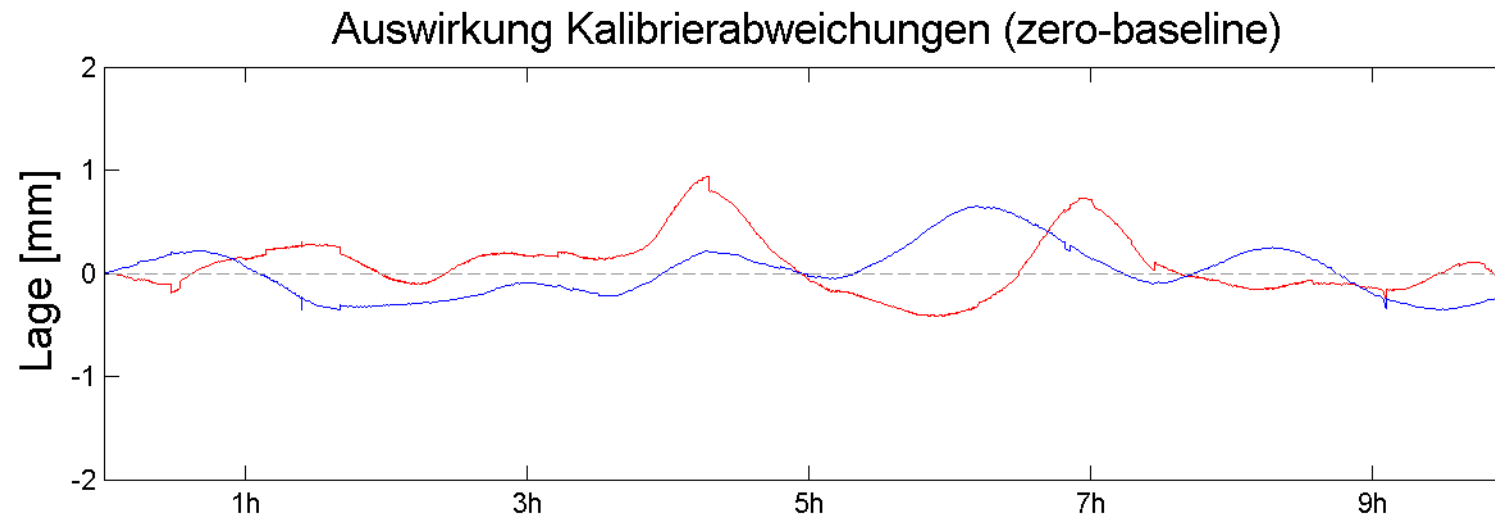
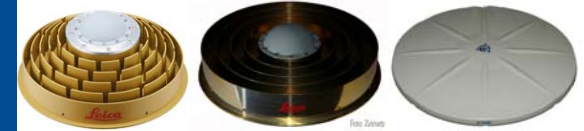
Trimble Zephyr Geodetic 2



Trimble Zephyr Geodetic 2

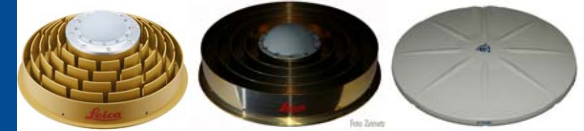


Trimble Zephyr Geodetic 2 (L1)

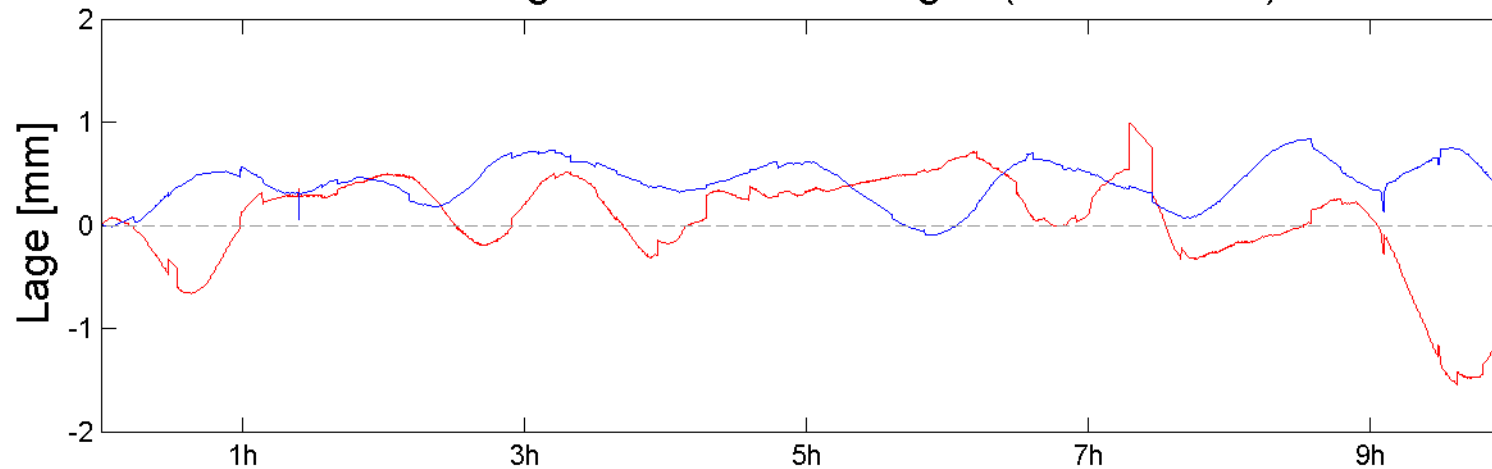


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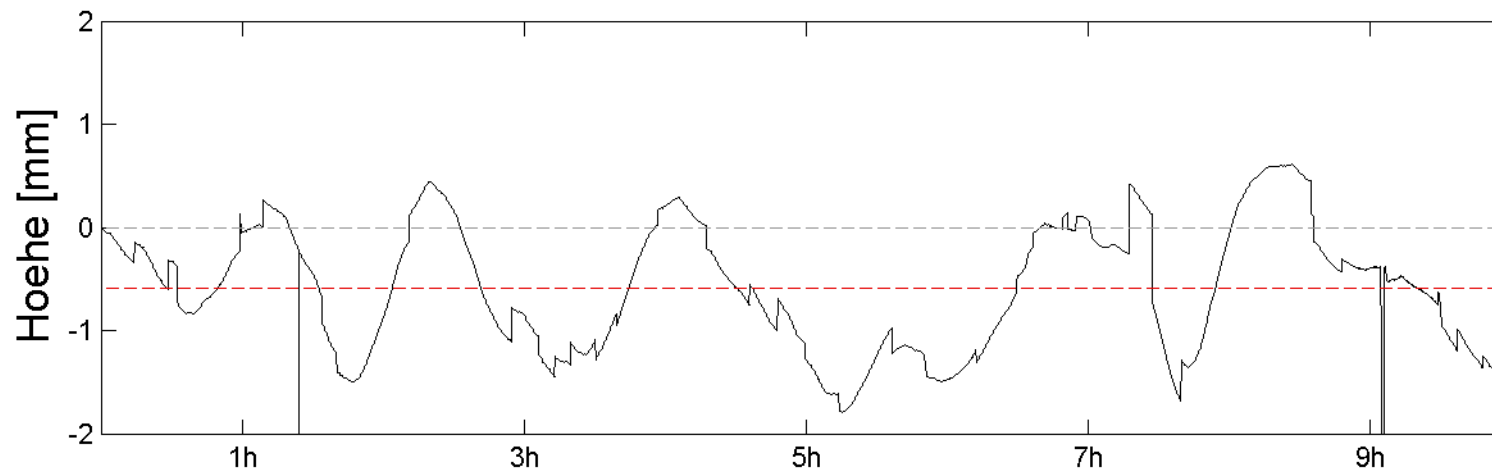
Trimble Zephyr Geodetic 2 (L2)



Auswirkung Kalibrierabweichungen (zero-baseline)

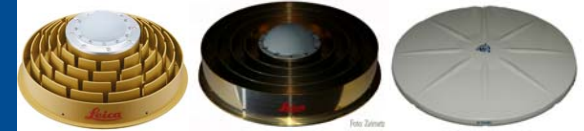


Zero-Baseline: Berlin vs. Bonn

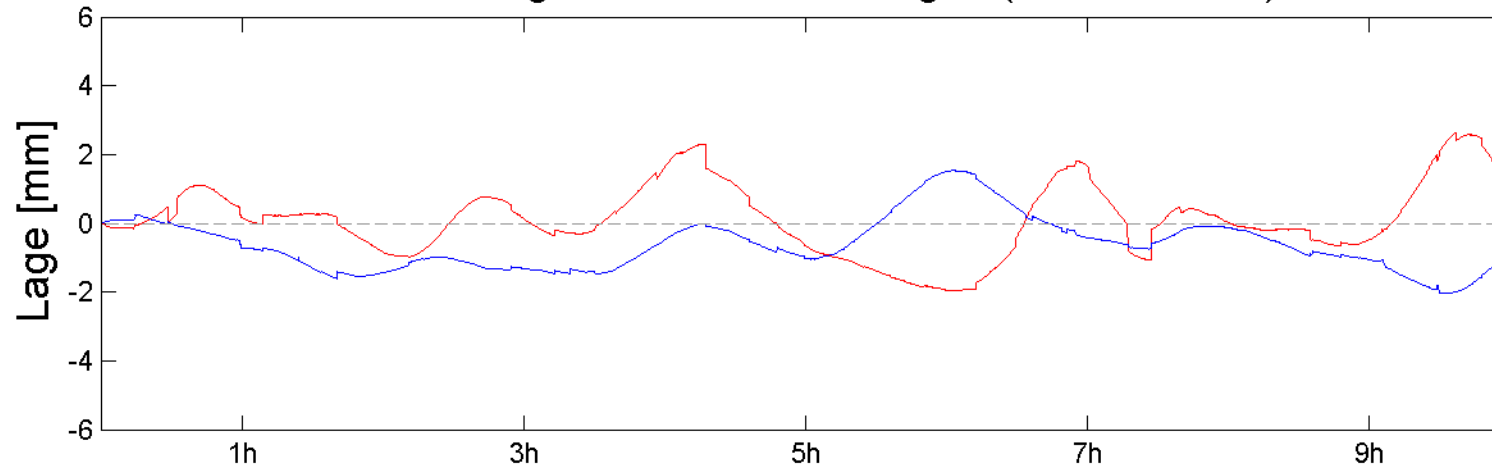


zero-baseline: L2-Frequenz, 5° Elevation, 5sec Sampling

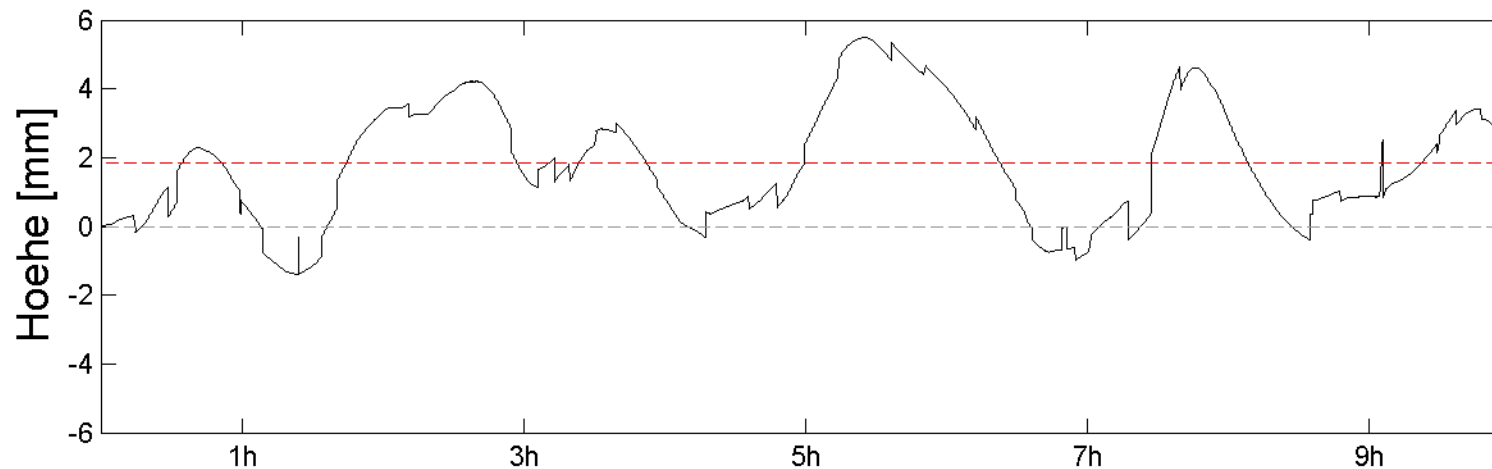
Trimble Zephyr Geodetic 2 (L3)



Auswirkung Kalibrierabweichungen (zero-baseline)

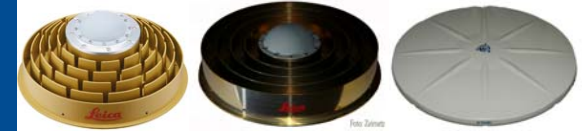


Zero-Baseline: Berlin vs. Bonn

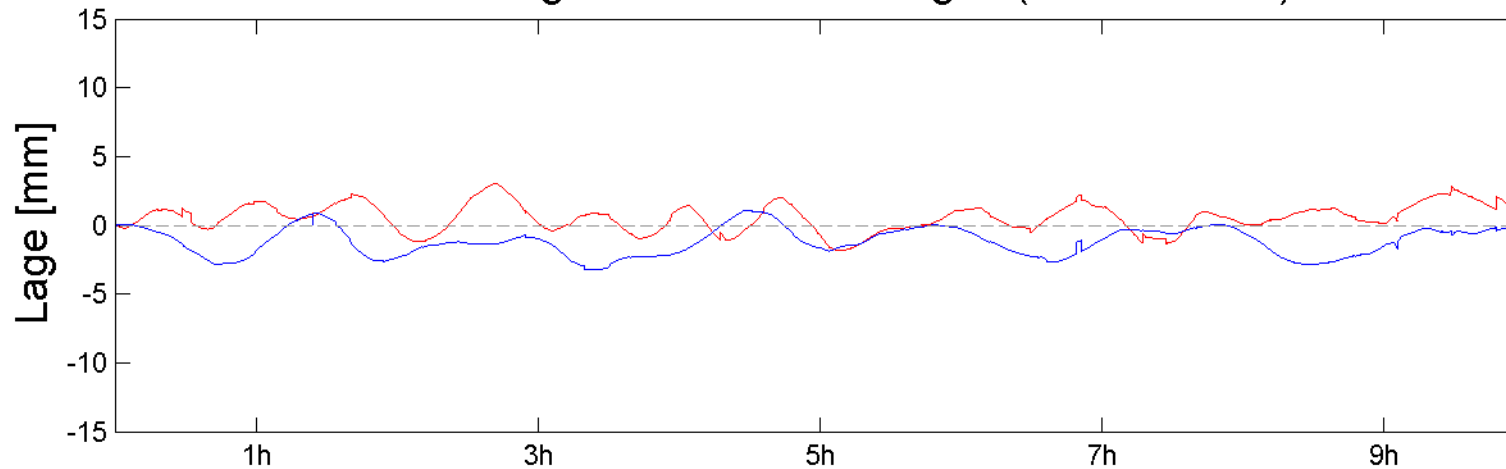


zero-baseline: L3-Frequenz, 5° Elevation, 5sec Sampling

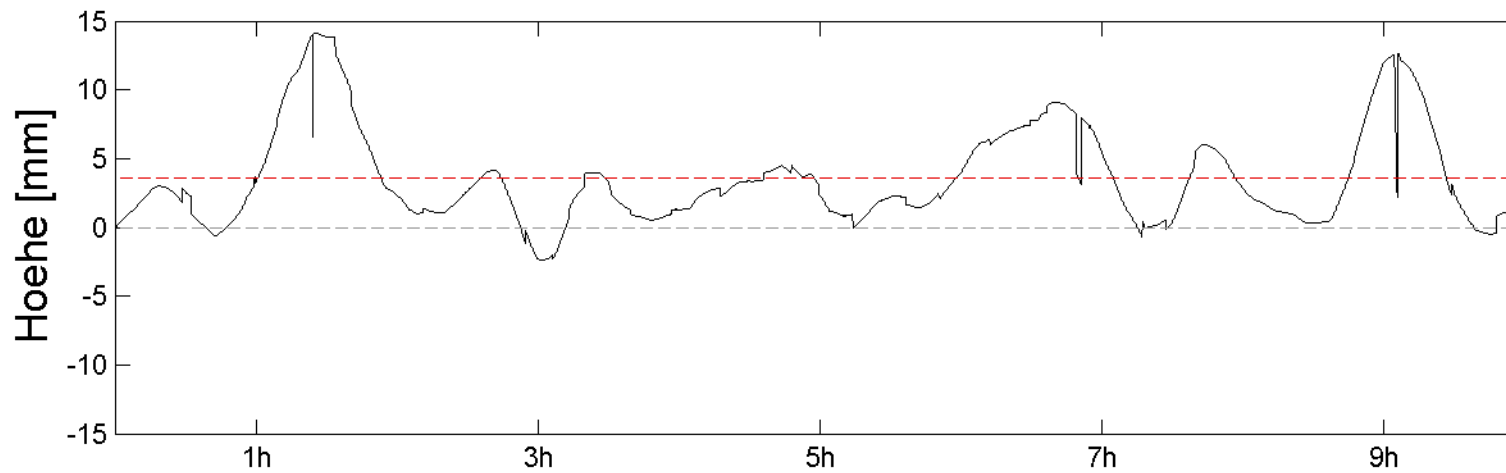
Trimble Zephyr Geodetic 2 (L3)



Auswirkung Kalibrierabweichungen (zero-baseline)

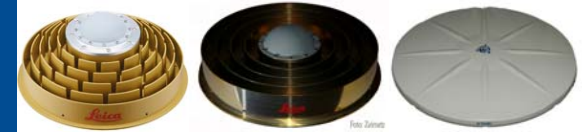


Zero-Baseline: Berlin vs. Dresden



zero-baseline: L3-Frequenz, 5° Elevation, 5sec Sampling

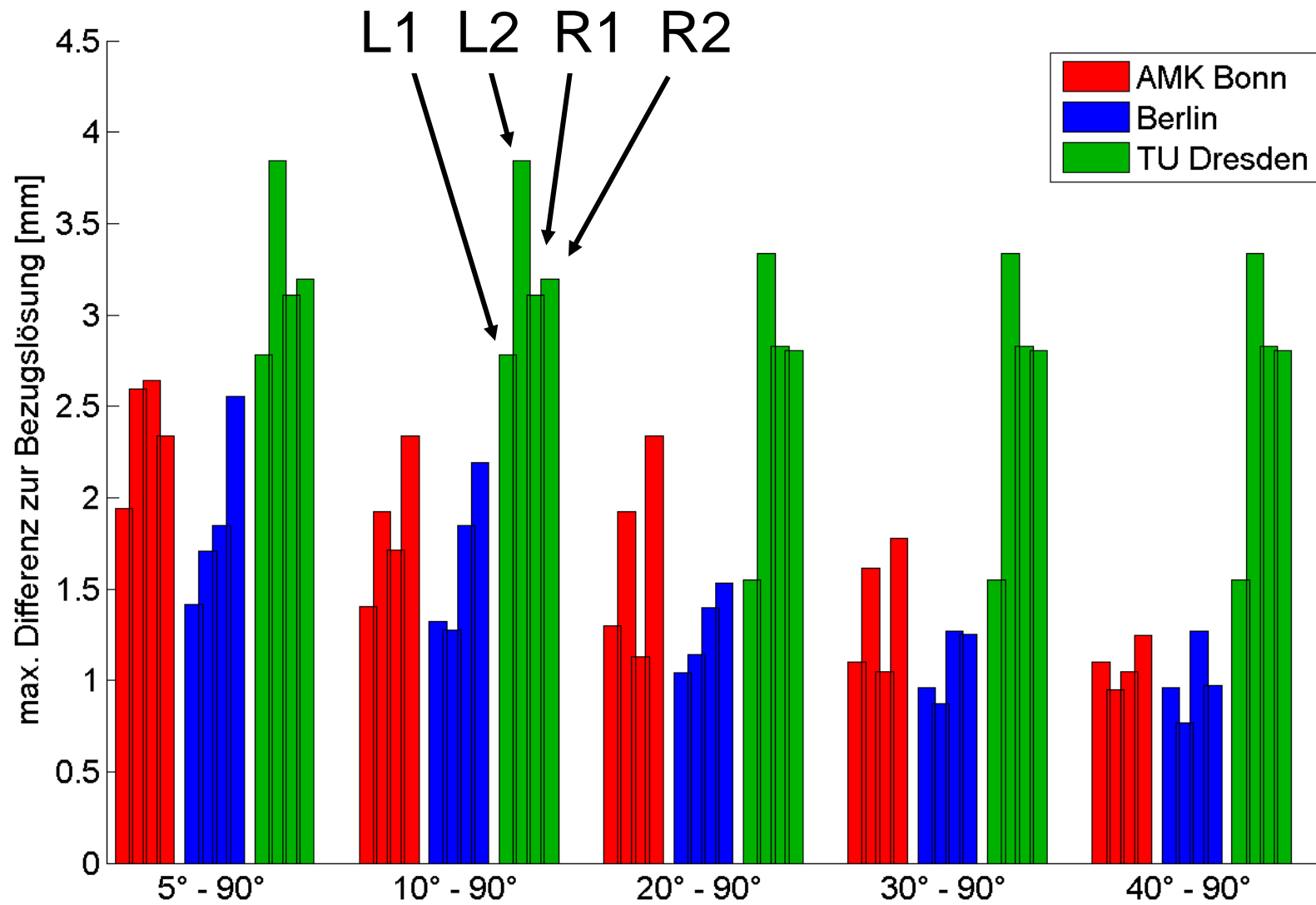
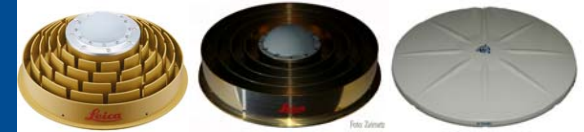
Trimble Zephyr Geodetic 2



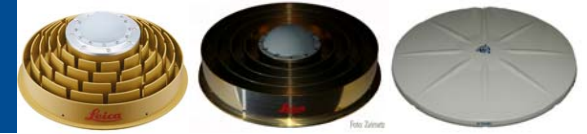
SN: 30520325

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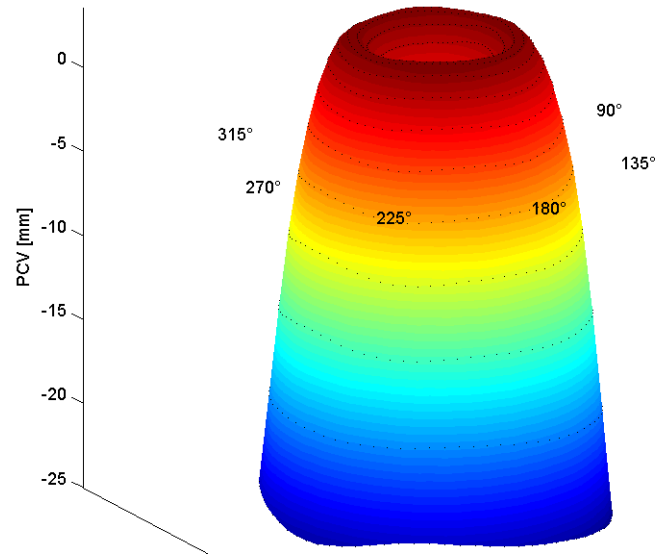
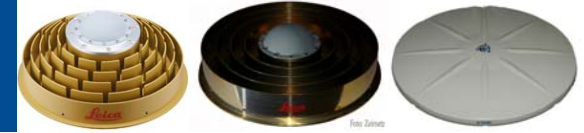
Trimble Zephyr Geodetic 2



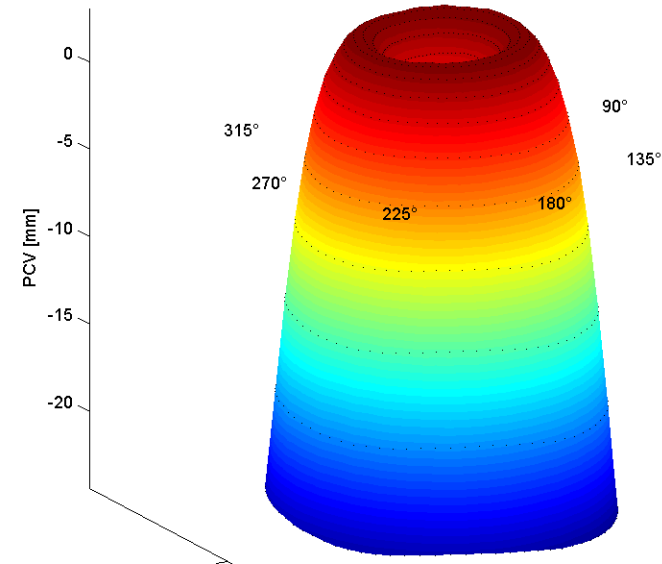
Leica AT504GG



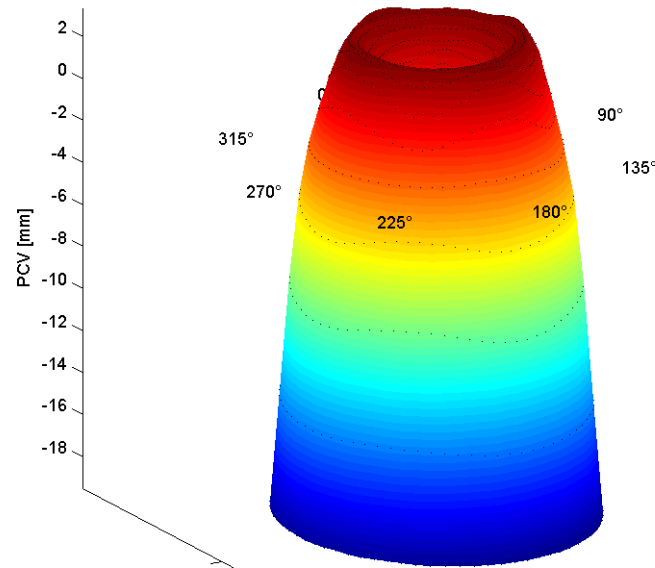
Leica AT504GG (L1)



IfE



AMK Bonn



Dresden

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Leica AT504GG (L1)

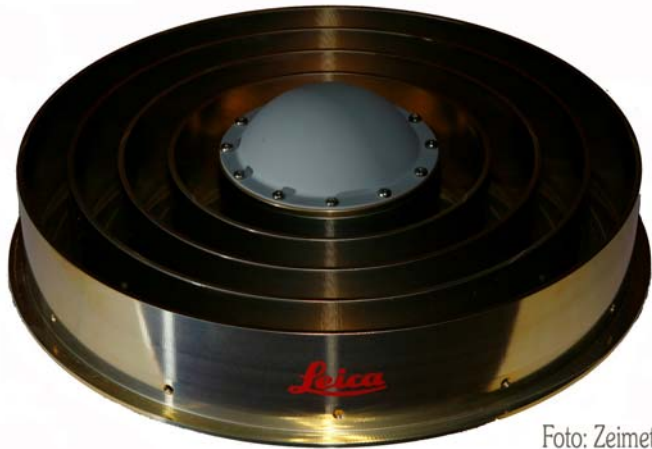
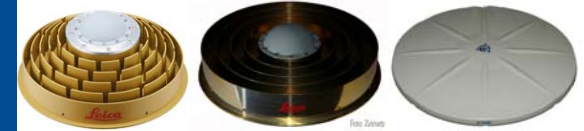
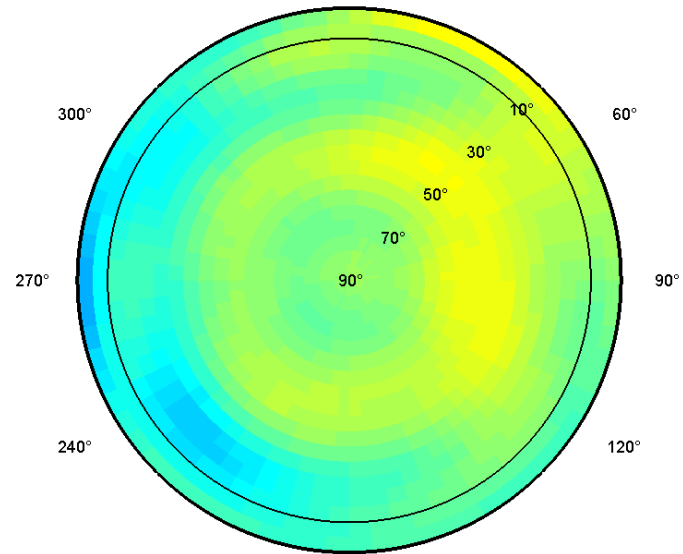
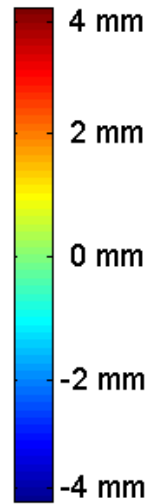
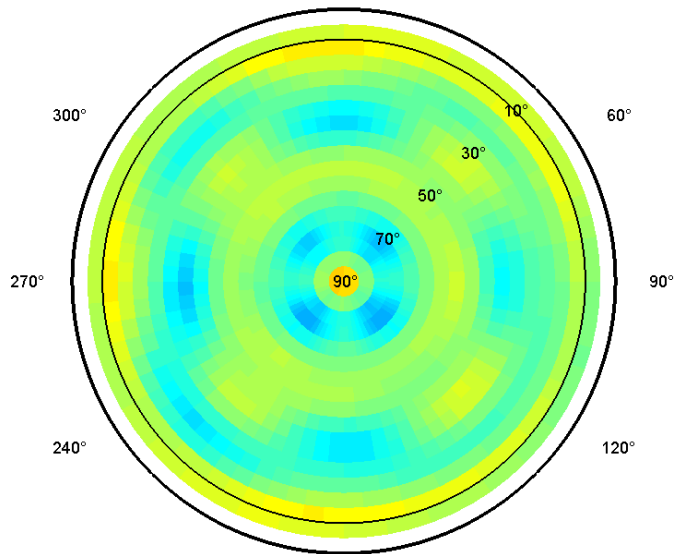


Foto: Zeimetz



IfE vs. Bonn

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IfE vs. Dresden

Leica AT504GG (L1)

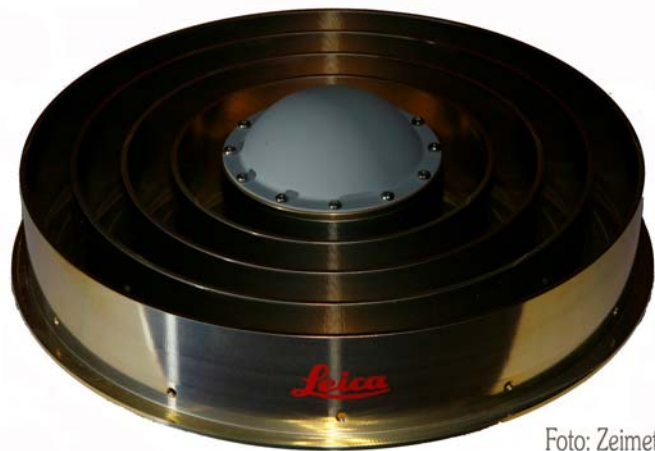
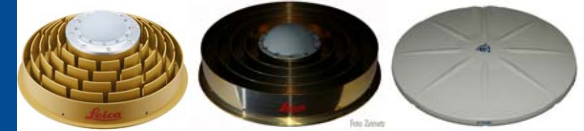
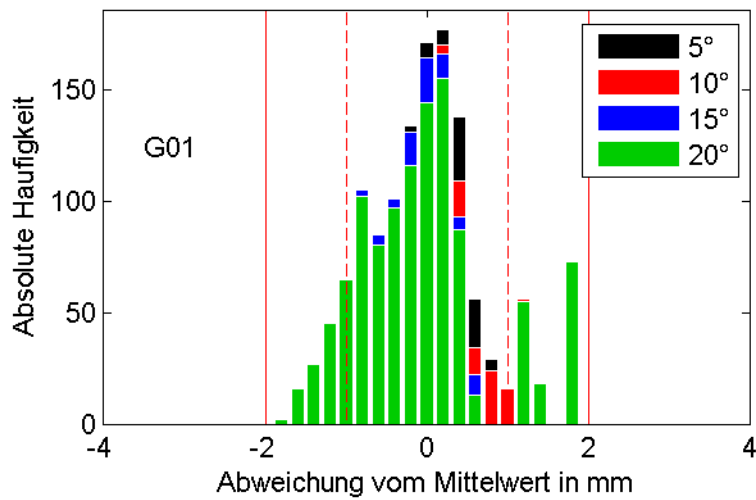
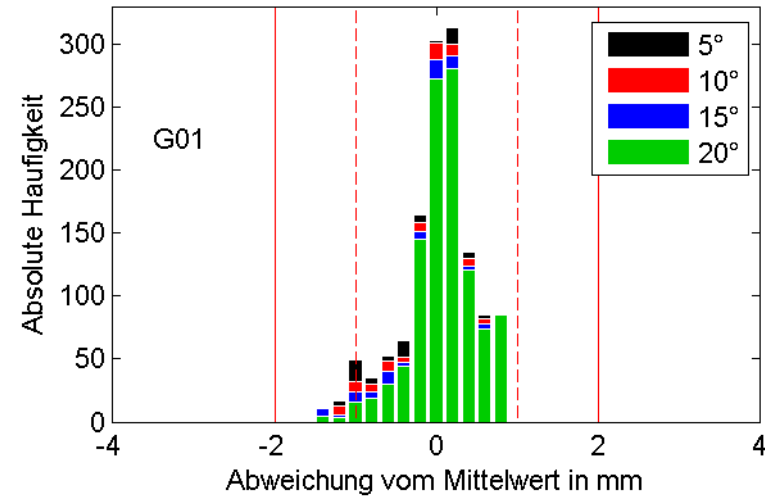
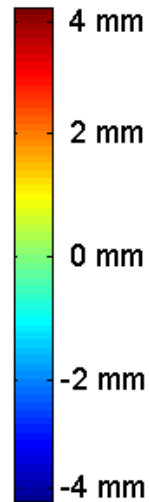


Foto: Zeimetz



Leica AT504GG (R1)

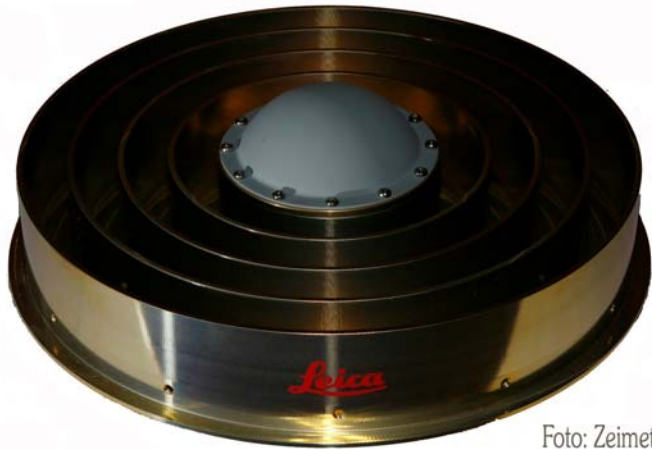
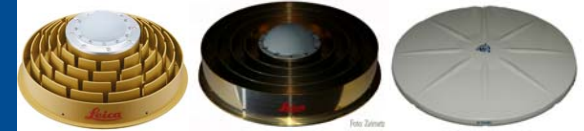
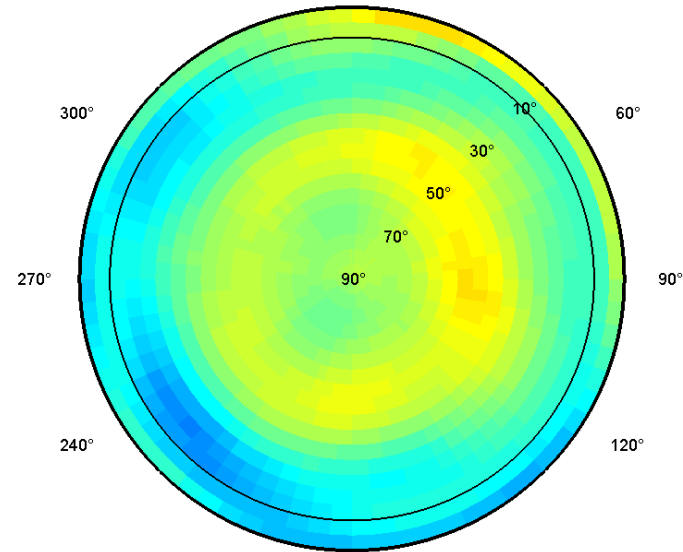
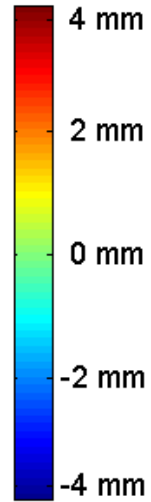
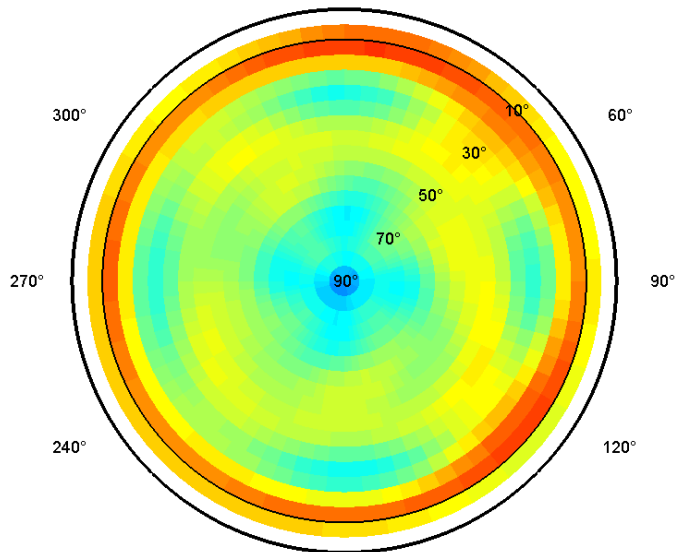


Foto: Zeimetz



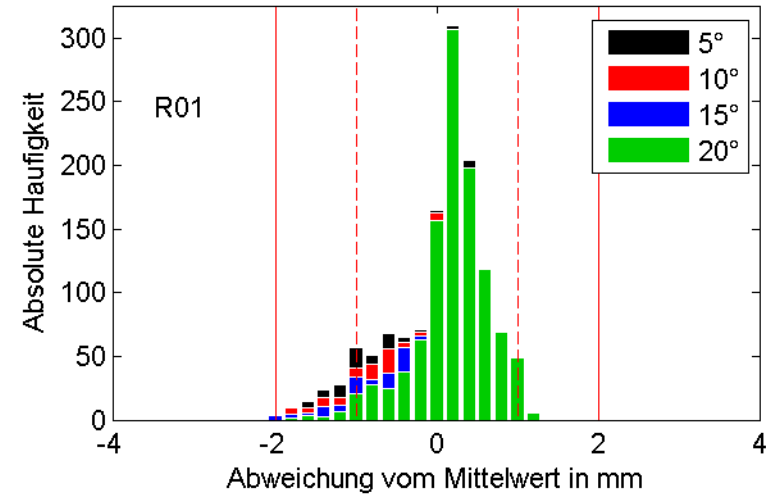
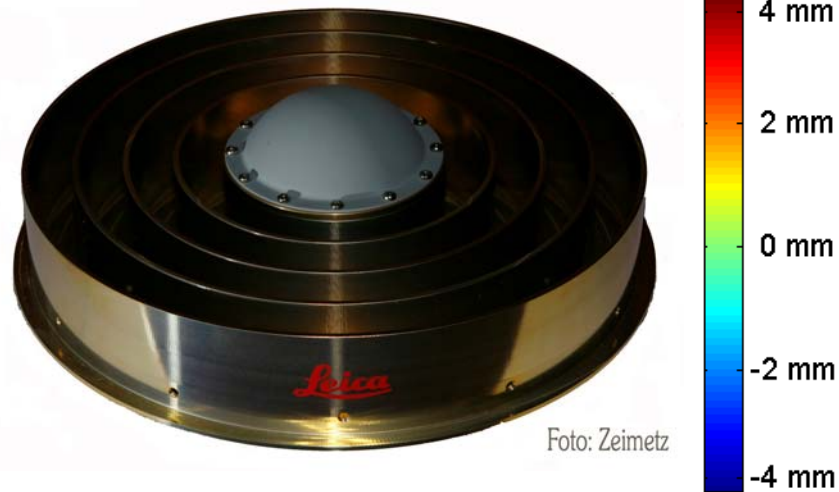
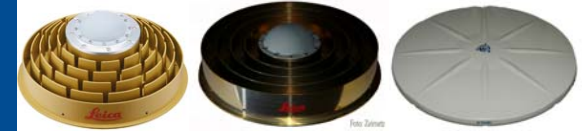
IfE vs. Bonn

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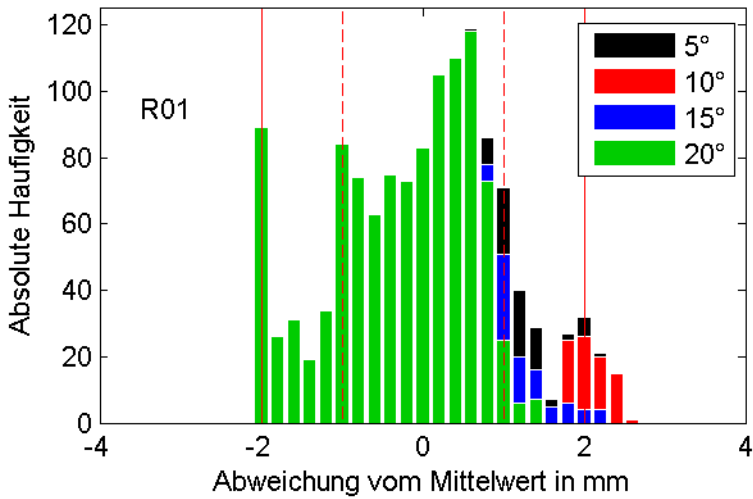


IfE vs. Dresden

Leica AT504GG (R1)



IfE vs. Bonn



IfE vs. Dresden

Leica AT504GG (L2)

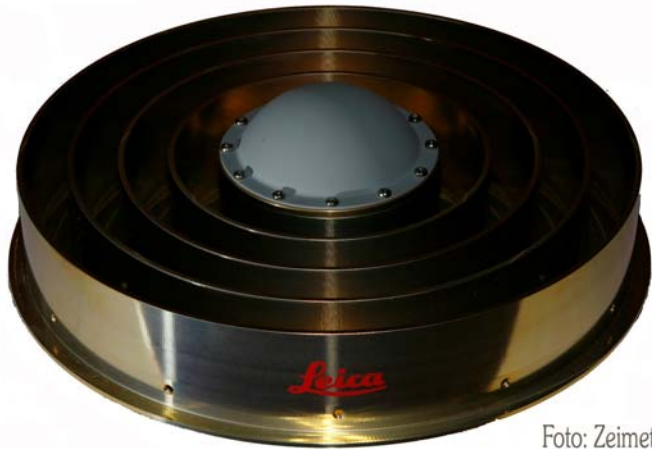
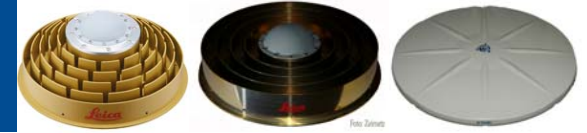
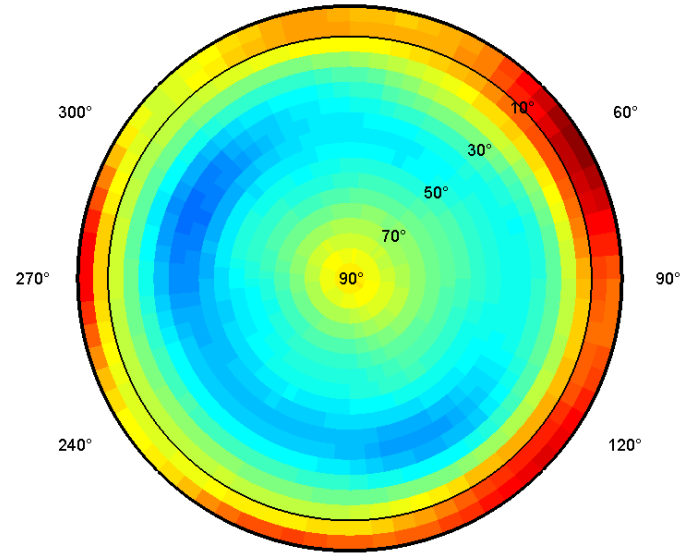
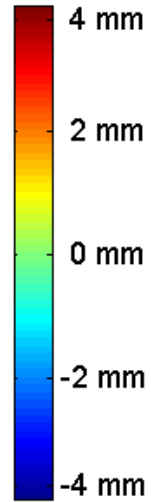
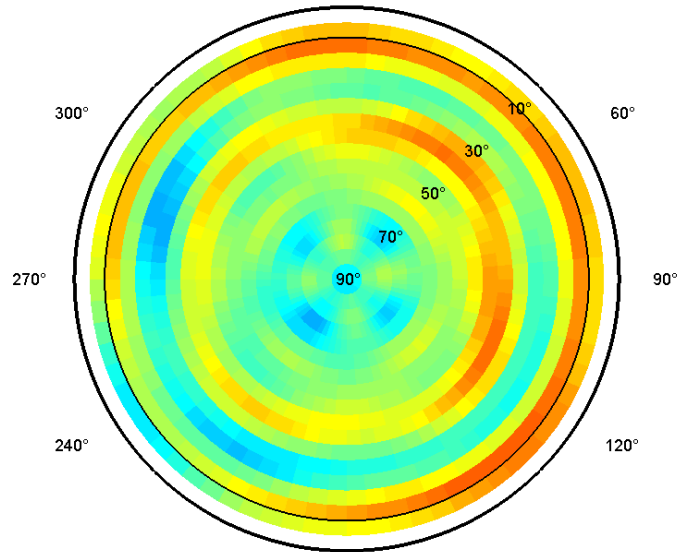


Foto: Zeimetz



IfE vs. Bonn



IfE vs. Dresden

Leica AT504GG (L2)

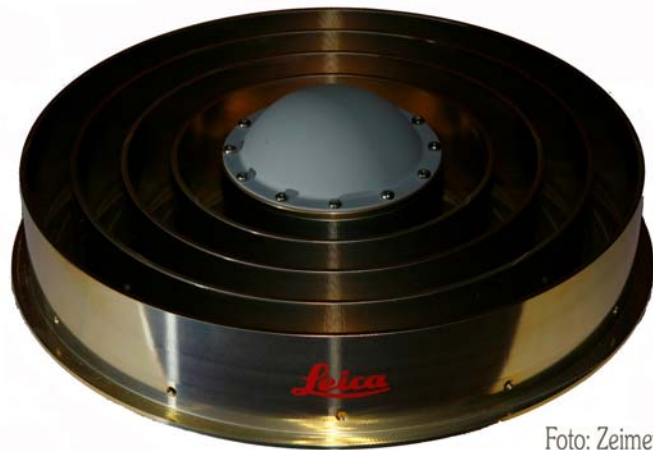
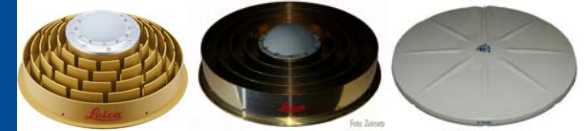
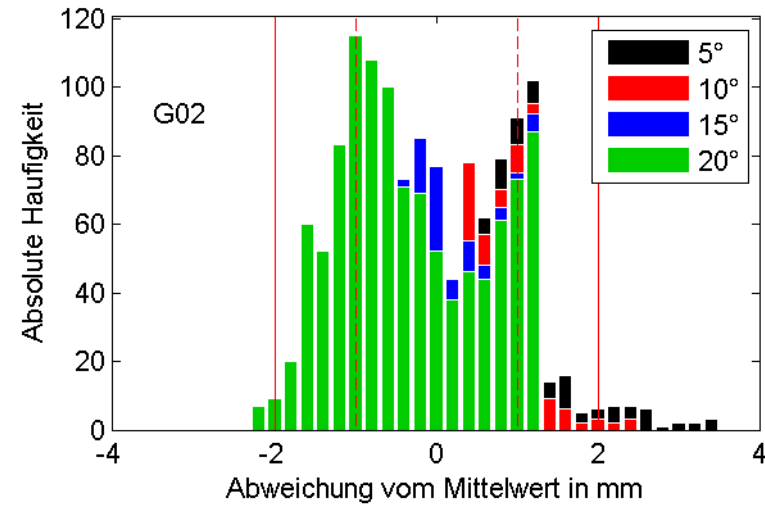
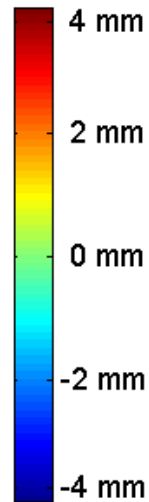
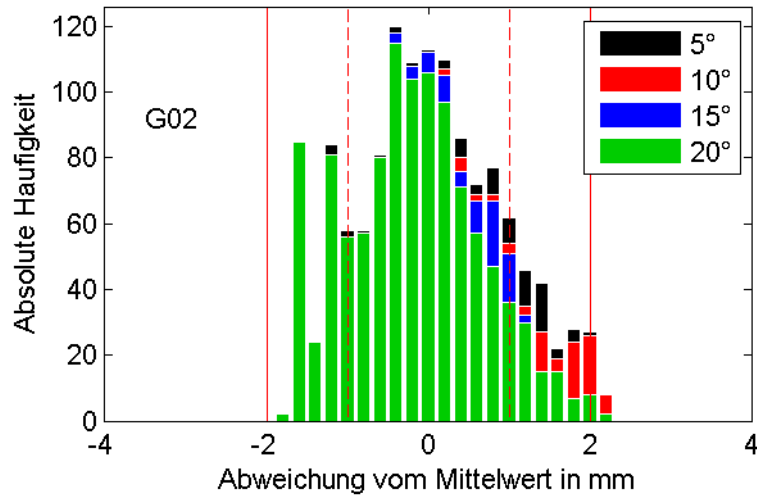


Foto: Zeimetz



IfE vs. Bonn

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IfE vs. Dresden

Leica AT504GG (R2)

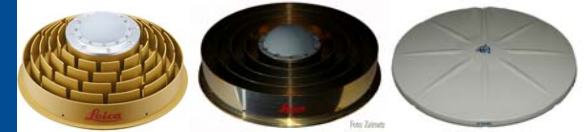
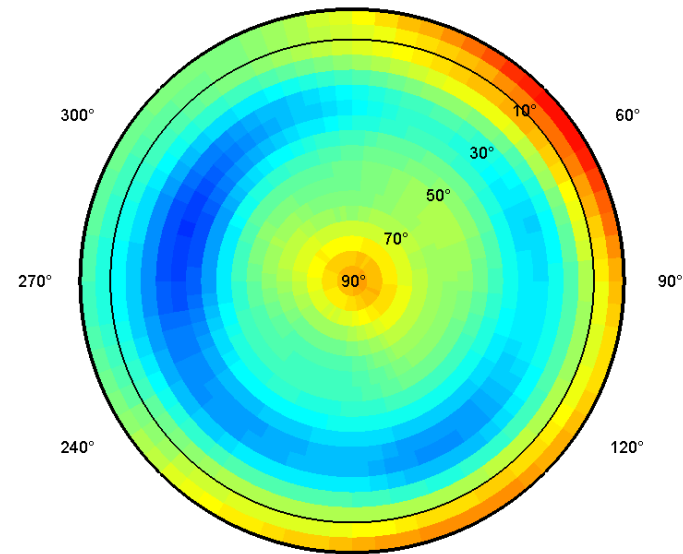
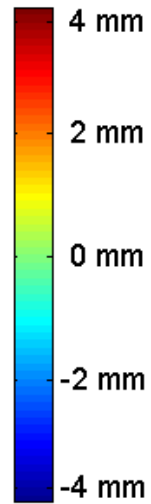
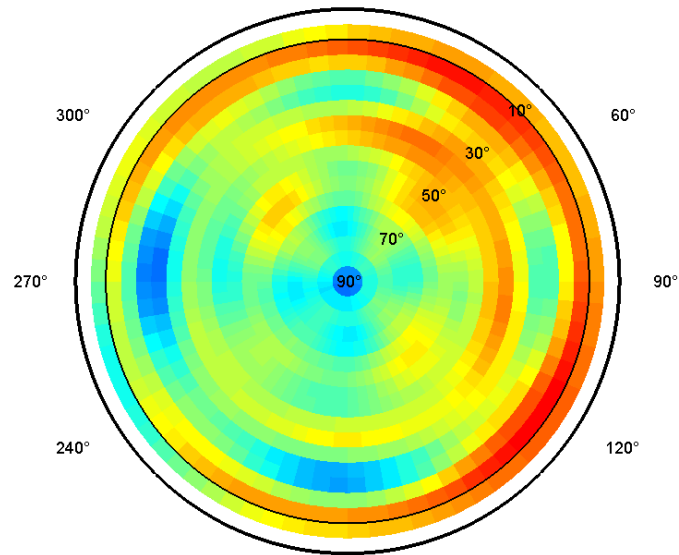


Foto: Zeimetz

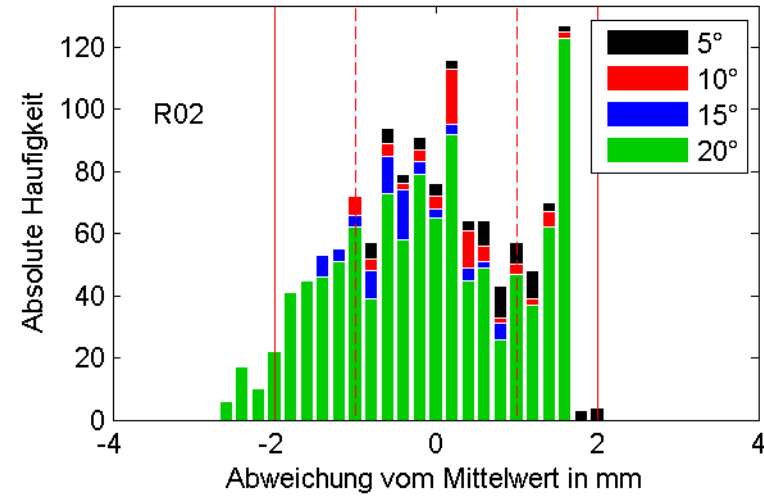
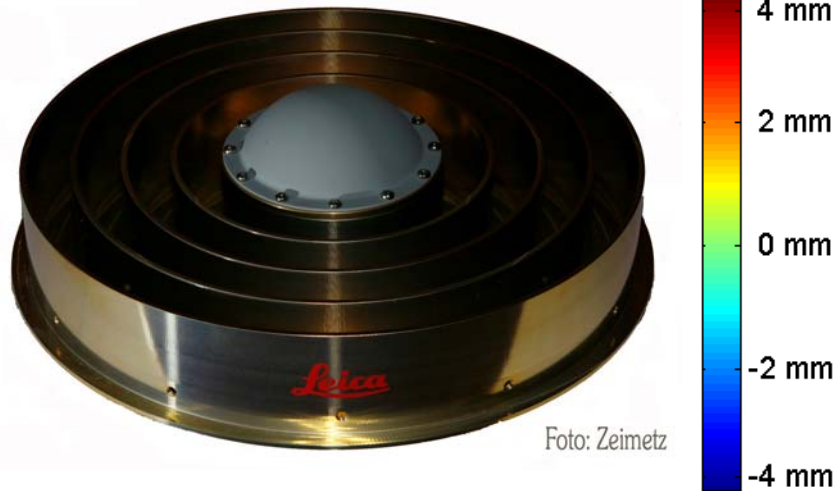
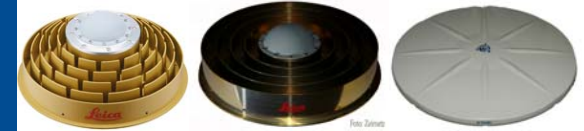


IfE vs. Bonn

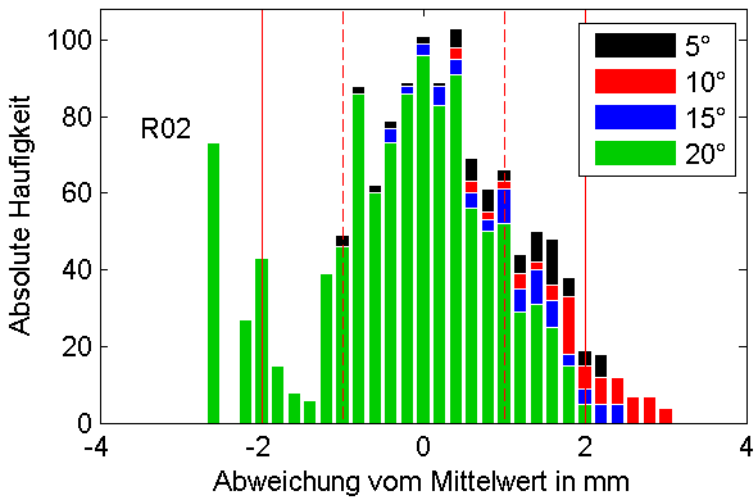


IfE vs. Dresden

Leica AT504GG (R2)

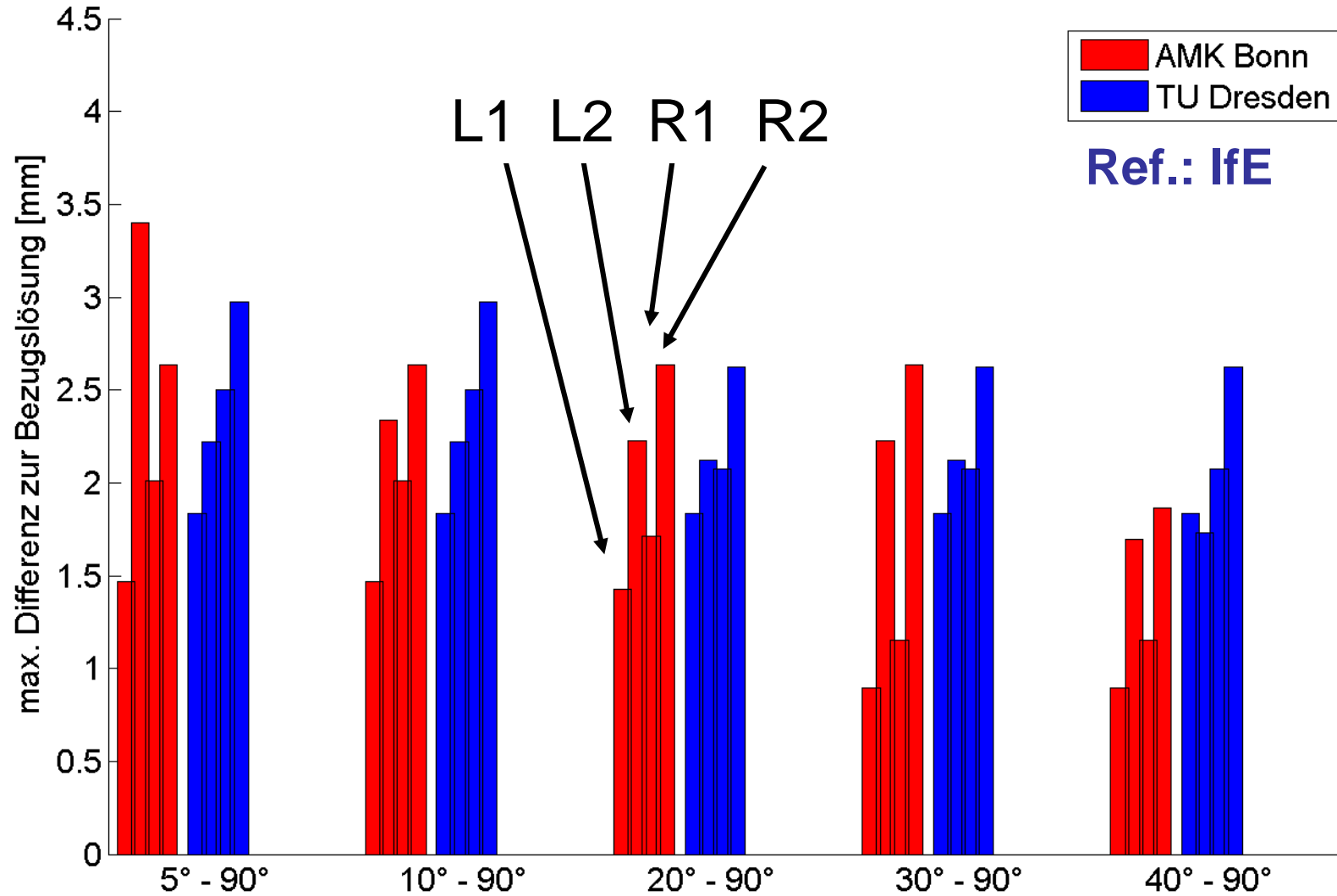
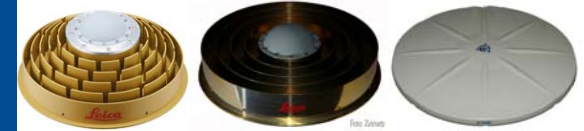


IfE vs. Bonn

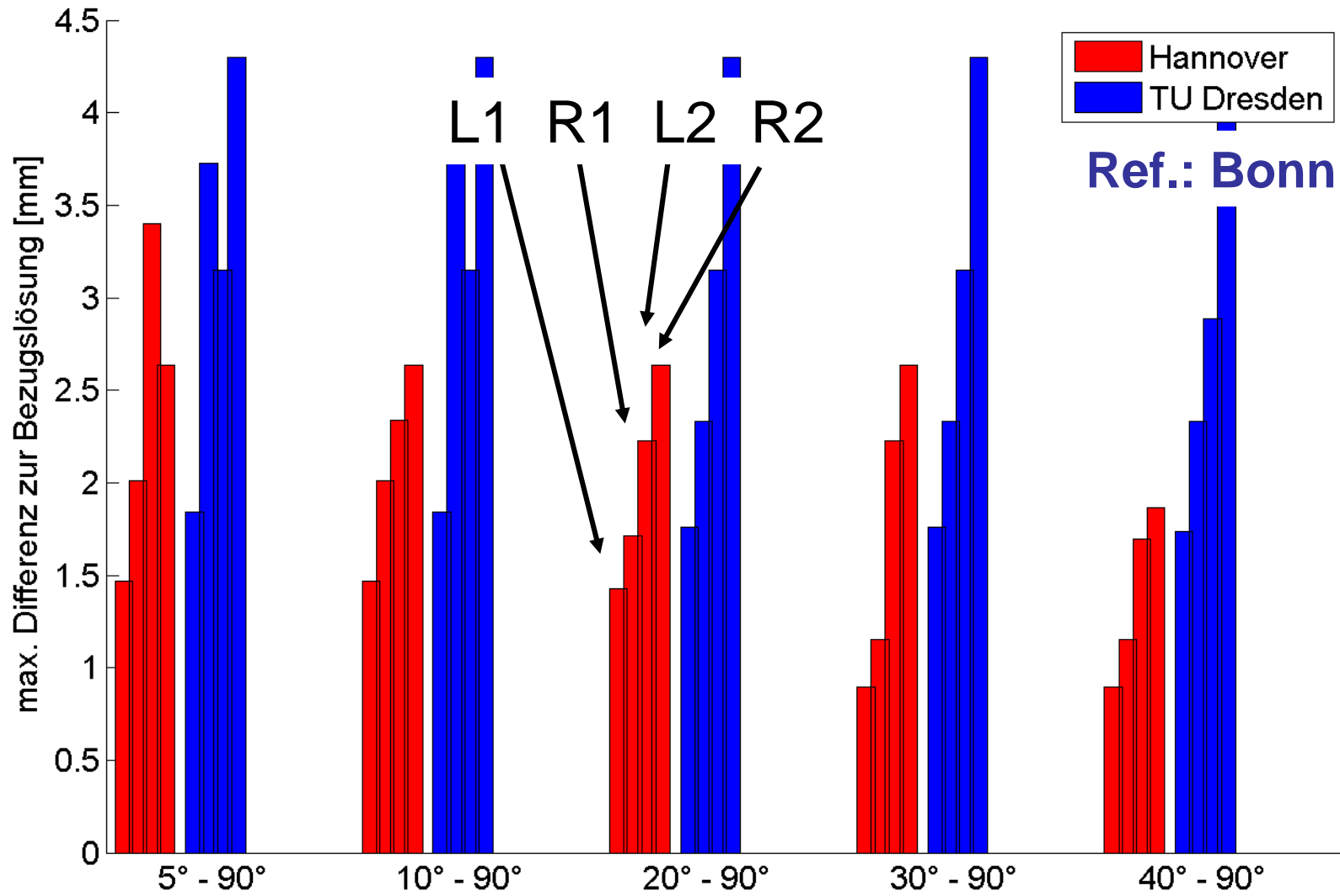
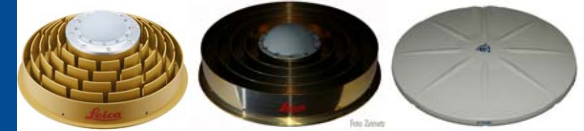


IfE vs. Dresden

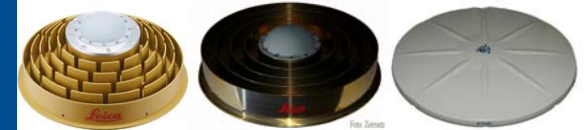
Leica AT504GG



Leica AT504GG



Zwischenfazit



Vergleich der verschiedenen Roboterkalibrierungen zueinander:

- Differenzen im Bereich von 1,0 – 2,5 mm

Vergleich von Roboter- und Laborkalibrierung:

- Differenzen im Bereich von 1,0 – 3,0 mm
(allerdings mit vermehrten Systematiken)

Vergleich von relativer und absoluter Feldkalibrierung:

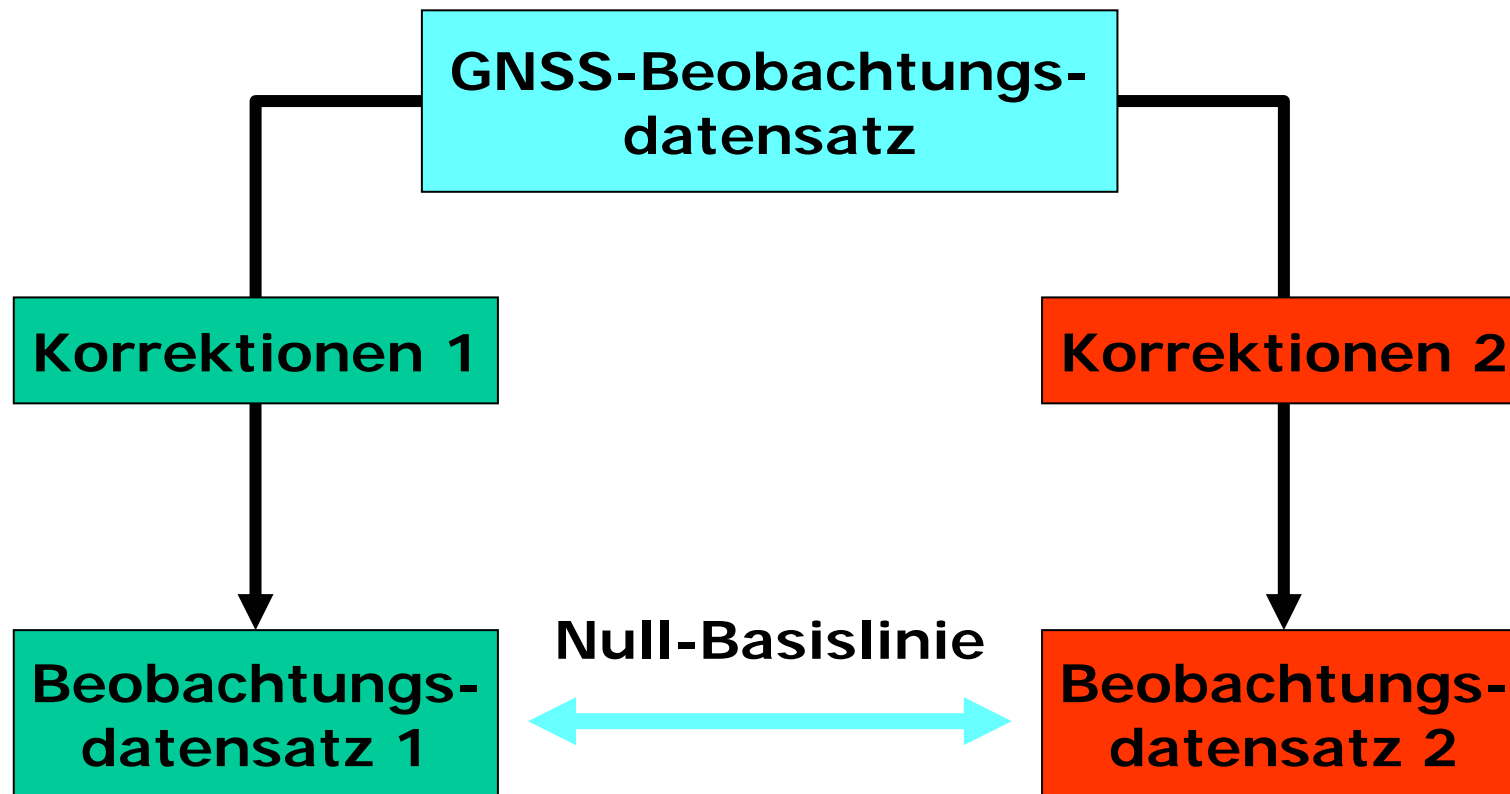
- Differenzen im Bereich von 2,0 – 4,0mm

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Frage:

Sind signifikante Einflüsse bei der Positionsbestimmung zu erwarten?

Vergleich der Kalibrierergeb. auf Koordinatenebene



aber
Koordinatendifferenzen

Vergleich der Kalibrierergeb. auf Koordinatenebene

Aktueller GPS/GLONASS-Beobachtungsdatensatz, 24 h

- **Korrekturen 1:** Mittel aus allen Kalibrierergebnissen für eine Antenne
- **Korrekturen 2:** jeweils einzelne Kalibrierergebnisse

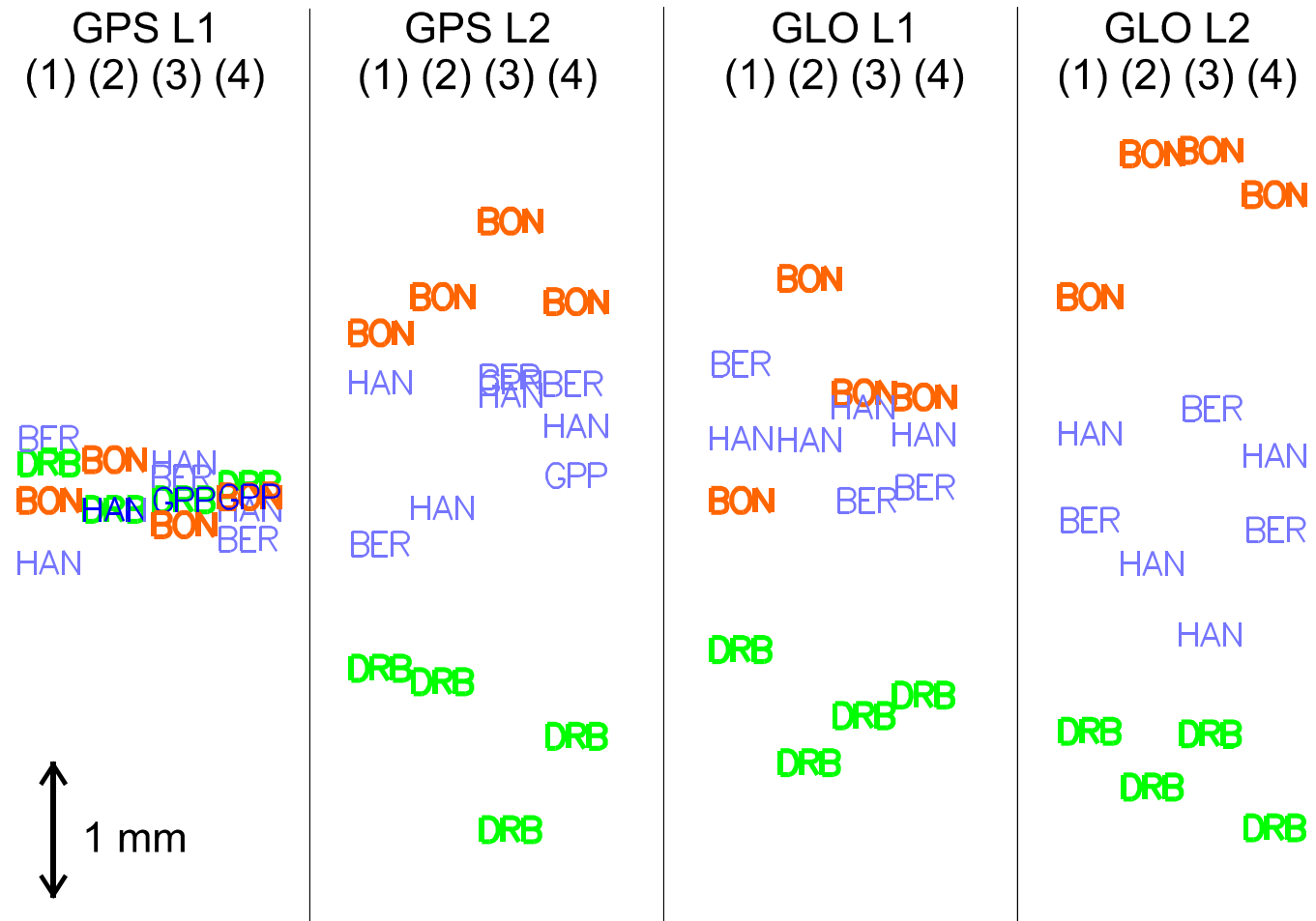
- Basislinienberechnung mit W_{a1} , 10° Elevationsmaske, elev.abh. Gewichtung, ...
- Koordinatensets auf der Basis der gesamten **24 h** Beobachtungsdaten

- Unterschiede in Lagekomponenten so klein, dass sie kaum betrachtet werden müssen,
aber Unterschiede in Höhenkomponenten bis z.T. viele mm

jeweils: (1) LEI AR25, (2) LEI AT504GG, (3)+(4) TRM55971.00 0325 und 3939

Vergleich der Höhenkomponenten

jeweils mit einem mittleren Korrektionsdatensatz



BON Kammer, Bonn
DRB Ant.dreh, Dresden
GPP Roboter: Geo++
HAN IfE, Hannover
BER Berlin

Vergleich der Kalibrierergeb. auf Koordinatenebene

Unterschiede in Höhenkomponenten bis z.T. viele mm:

- sehr gute Übereinstimmung aller Verfahren bei GPS L1
- i. A. gute Übereinstimmung aller Roboterkalibrierergebnisse
- systematische Unterschiede zwischen Kammer und Roboter auf L2
- systematische Unterschiede zwischen DRB und Roboter außer GPS L1
- systematische Unterschiede zwischen Kammer und DRB außer GPS L1
- direkter Zusammenhang zwischen diesen Systematiken!

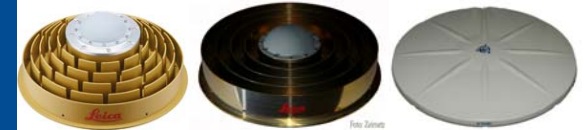
(Mögliche) Ursachen für systematische Höhenabw.:

DRB: Nahfeld-Mehrwege, Referenzantenne und deren Kalibrierung

Kammer: ? Nahfeld-Mehrwege ?

Roboter: ? Nahfeld-Mehrwege ?

Fazit



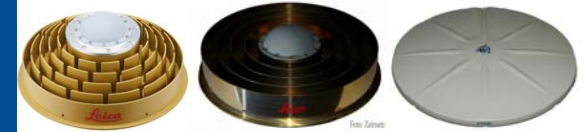
1. Kalibrierungen „Berlin“ und „Hannover“ zeigen gute Übereinstimmung
 - Da es sich um identische Messverfahren handelt, können gemeinsame Systematiken nicht ausgeschlossen werden.
 - + Aber: Die Ergebnisse sind unabhängig von Stationseffekten und äußeren Einflüssen

2. a) Bonner Ergebnisse im Vergleich zu Hannover (L1-Band):
 - + Unterschiede in Größenordnung des Vergleichs „Berlin-Hannover“ (Vergleich Bonn-Hannover evtl. sogar etwas besser)
 - + Erkenntnis: Verfahren liefert prinzipiell gültige Kalibrierergebnisse
 - + GLONASS-R1- und GPS-L1-Kalibrierungen zeigen beim Vergleich mit den Robotermessungen eine vergleichbare Genauigkeit

- b) Bonner Ergebnisse für GPS-L2:
 - Differenzen bei L2 etwa Faktor 2 größer als bei L1 (sowohl beim direkten Vergleich der Pattern als auch auf Koordinatenebene)

- c) Bonner Ergebnisse für R2
 - Abweichungen sind signifikant größer (Ursache ist noch unklar! Nicht erkennbar, welches die „schlechtere“ Lösung ist.)

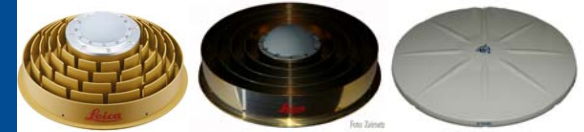
Fazit



3. Dresdener Ergebnisse

- Abweichungen sind insbesondere bei niedrigen Elevationen (5° bis 20°) etwas größer
- + GPS-L1 passt sehr gut zu den anderen Verfahren (besonders auf Ebene der 24h-Koordinatenlösung)
- Bei den übrigen Frequenzen sind größere Abweichungen sichtbar
- + Die Unterschiede wirken sich bei der Positionsbestimmung fast ausschließlich auf die Höhenkomponente aus.

Fazit



4. Nahfeldeinfluss:

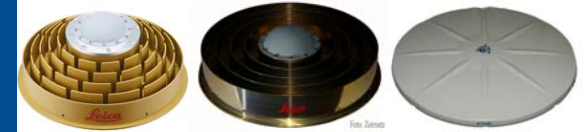
Die bei dem Ringversuch zwischen den Einzellösungen sichtbaren Differenzen liegen in der Größenordnung möglicher Nahfeldeffekte

→ Die Differenzen resultieren nicht zwingend aus den Kalibrierverfahren selber. Die Differenzen können Folge der bei den Kalibrierungen wirkenden Nahfeldeffekte sein.

Aber:

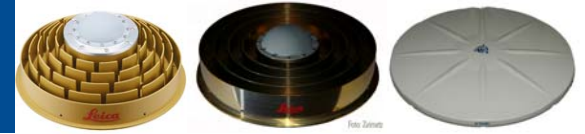
Der Anteil des Nahfeldes muss noch weiter untersucht werden. Es ist nur eine mögliche Erklärung für die gezeigten Unterschiede.

Fazit



Verbleibende Fragen:

- Wie lässt sich der Anteil des Nahfeldes exakt quantifizieren?
- Warum sind die L1-Kalibrierungen stets besser als die L2-Kalibrierungen?
- Wie relevant sind die verbleibenden Kalibrierunsicherheiten im Kontext der übrigen Einflussgrößen bei der GNSS-Positionsbestimmung?
(Kalibrieren wir evtl. schon genau genug?)



Vielen Dank!