Fieldwork Surveying FS01

5. Lecture

Distance measurement

Presentation was supported by 105 1052201A003 FCE CTU in Prague Internal Project

Base unit of length

Physical unit = **metre** (m) = the length of the path travelled by light in vacuum during a specific fraction of a second (1/299 792 458 s).

kilo-	km	10^{3}	**hecto-**	hm	10^{2}
milli-	mm	10^{-3}	**deci-**	dm	10^{-1}
micro-	µm	10^{-6}	**centi-**	cm	10^{-2}
nano-	nm	10^{-9}			

Distance measurement methods

1. measurement with a tape

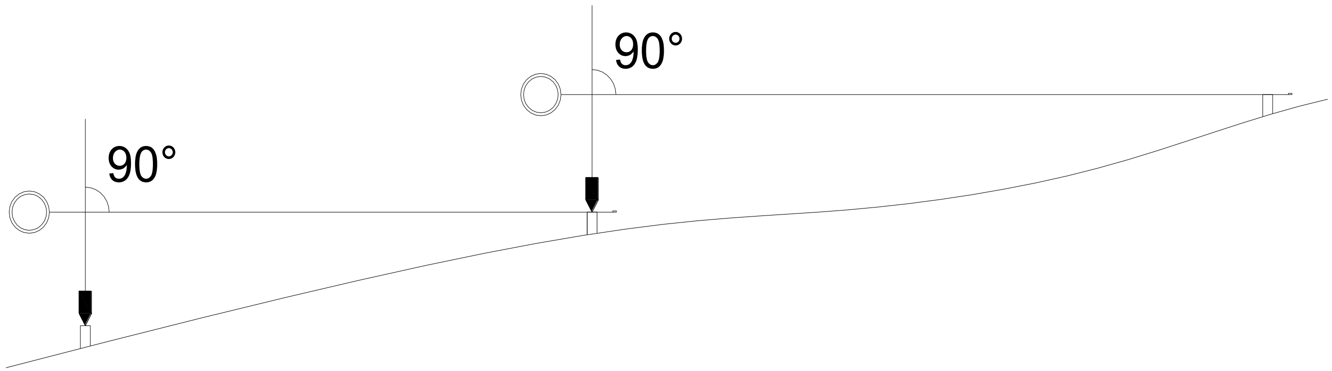
2. optical methods
   a) measurement of a parallactic angle
   b) stadia range finder

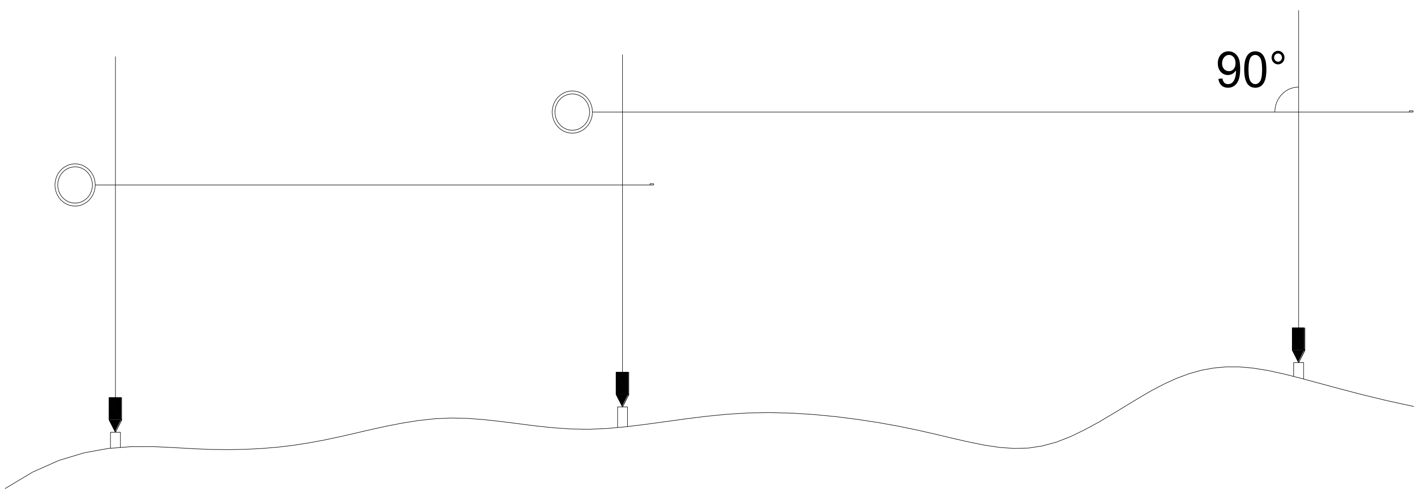
3. electro-optical methods
   a) phase distance meter
   b) distance meter measuring transit time

1. Distance measurement with a tape

- tape length 20 – 50 m, the smallest division 1 mm
- material – steel, invar (Ni, Fe), plastic
- measured distance is split into sections which are shorter than the tape length, these sections should be in a straight line
- horizontal distance is measured (it is assured by a plummet)
- measurement is always performed twice – back and forth in a flat terrain or down from the top twice in a slope terrain

Slope and flat terrain





Errors of measurement with a tape

- if the real tape length is not known: the tape should be calibrated,

- if the temperature during a measurement is not the same as the temperature during the calibration: the temperature correction should be introduced

  $o_t = (t - t_0) . \alpha . d$,

  d – measured distance,

  α – thermal line expansion coefficient,

  t – temperature during the measurement,

  t_0 – temperature during the calibration,

- if the sections are not in a straight line,
- if the tape is stretched less than 50 N or more than 100 N,
- if the tape is not horizontal,
- if the tape is sagged: it depends on the tape length
- if a wrong value is read on the tape

Accuracy of the distance measurement with a tape is about 3 cm for 100 m (1: 3000 of a measured distance).

K 2292

KALIBRAČNÍ LABORATOŘ č. 2292

AUTORIZOVANÉHO METROLOGICKÉHO STŘEDISKA

VÝZKUMNÝ ÚSTAV GEODETICKÝ, TOPOGRAFICKÝ A KARTOGRAFICKÝ

250 66 ZDIBY 98

KALIBRAČNÍ LIST č.: 18 393/2002

Datum vystavení: 1. 10. 2002 — List 1 ze 2 listů

Zadavatel: ČVUT v Praze, Fakulta stavební, katedra speciální geodézie

Datum přijetí měřidla: 26. 9. 2002

Měřidlo: Pracovní měřidlo nestanovené, 30 m ocelové pásmo PAR, žluté, s mm dělením, v pouzdře, s nulou v průběhu pásma

Inventární číslo: 4780907

Použitý etalon: Helio – neonový laser 633 nm, Laser Head, Model 5519A, Ser.No. 3627A00792, kalibrační list č. 818-KL-I190/00

Napínací síla: 50,0 N

Předpisy: Kalibrace byla provedena dle následujících předpisů:
Pracovním postupem dle ČSN ISO 8322-2/1994 – Geometrická přesnost ve výstavbě - Určování přesnosti měřicích přístrojů - část 2: Měřická pásma, dle ČSN 251105 – Měřická pásma.
Kalibračním postupem KP - č. 1: Měřická pásma:
B - ocelová, umělohmotná a tkaninová pásma.
EA-4/02 Metodika vyjadřování nejistot měření při kalibracích.

Podmínky pro kalibraci: laboratorní, teplota 20,0° C ± 0,3°C, tlak 973,3 hPa

Kalibrační list může být rozšiřován v celkovém počtu stran beze změn. Změny a doplňky mohou být provedeny pouze laboratoří, která dokument vystavila.

Výsledky měření:

Nominální hodnota (m)	Odchylka (mm)	Nominální hodnota (m)	Odchylka (mm)
0	0,0	16	-0,7
1	+0,3	17	-0,6
2	+0,4	18	-0,9
3	+0,1	19	-0,8
4	+0,4	20	-0,8
5	-0,1	21	-0,9
6	-0,1	22	-0,9
7	-0,1	23	-0,9
8	-0,3	24	-1,0
9	-0,2	25	-1,0
10	-0,2	26	-0,9
11	-0,4	27	-0,6
12	-0,3	28	-0,7
13	-0,4	29	-0,6
14	-0,6	30	-0,7
15	-0,5		

Poznámka: znaménko + (-) znamená, že pásmo je delší (kratší) nominální délky.

Rozšířená nejistota měření při **K = 2** je **U ≤ ± [0,3 + 0,007 . L(m)] mm.**

Údaj platí pro koeficient rozšíření K = 2, tj. pravděpodobnost P = 95%.
Rozšířená nejistota byla stanovena v souladu s dokumentem EA-4/02.

Pásmo vyhovuje ustanovení ČSN 251105 pro přesnost měřických pásem.

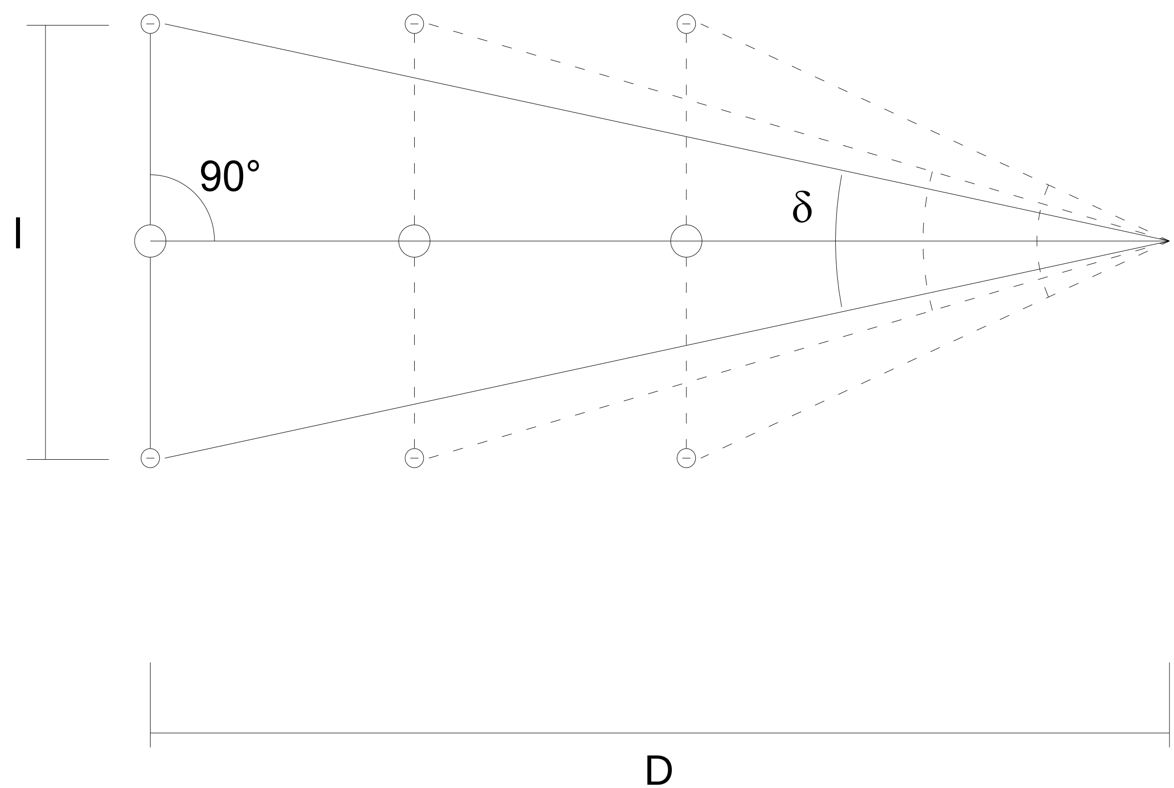
Ve Zdibech dne 27. 9. 2002 kalibraci provedla: D. Lazová

AKREDITOVANÁ KALIBRAČNÍ LABORATOŘ 2292

Ing. J. Lechner, CSc.
vedoucí KL

2a) Measurement of a parallactic angle

Parallactic distance measurement is based on a very precise measurement of the so-called "parallactic angle" δ and a very precisely known base length l.

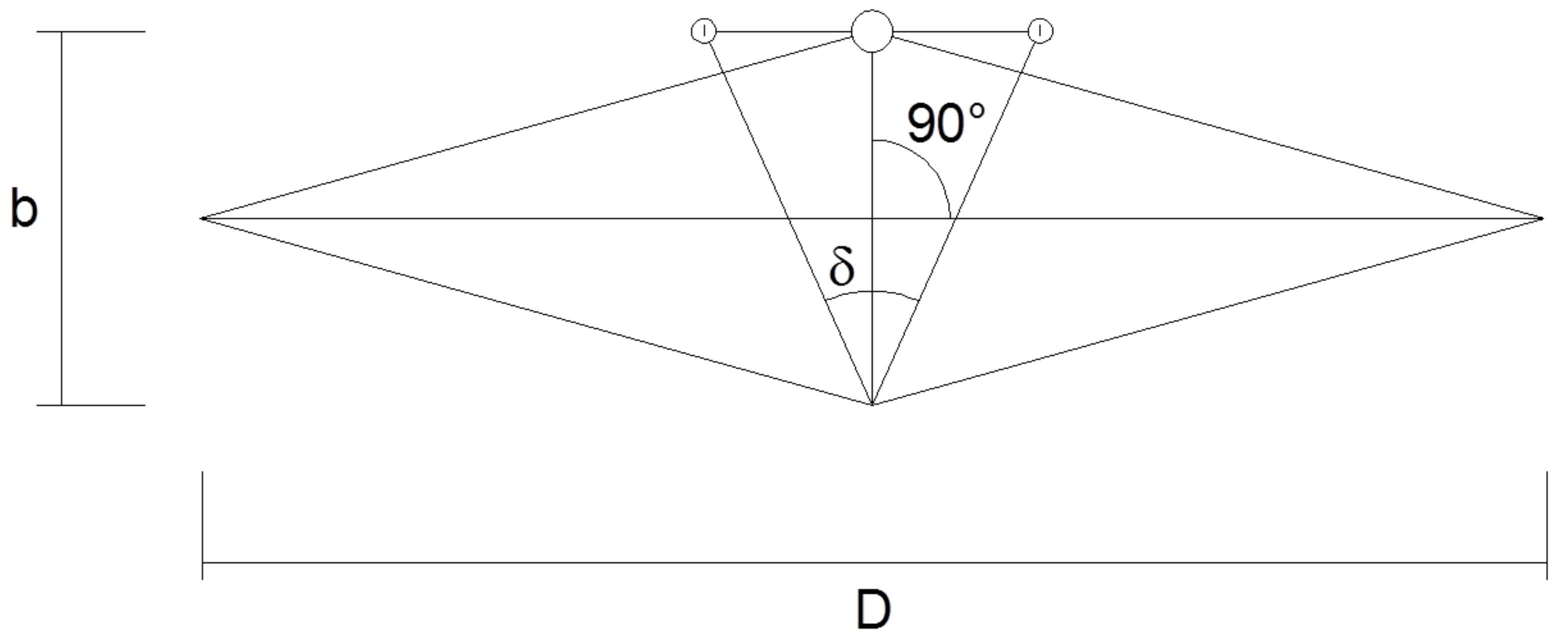


- horizontal stadia rod of known length *l* is placed perpendicular to the measured distance *D*
- horizontal angle δ is measured by a theodolite
- horizontal distance is calculated

$$D = \frac{l}{2} cot\left(\frac{\delta}{2}\right)$$

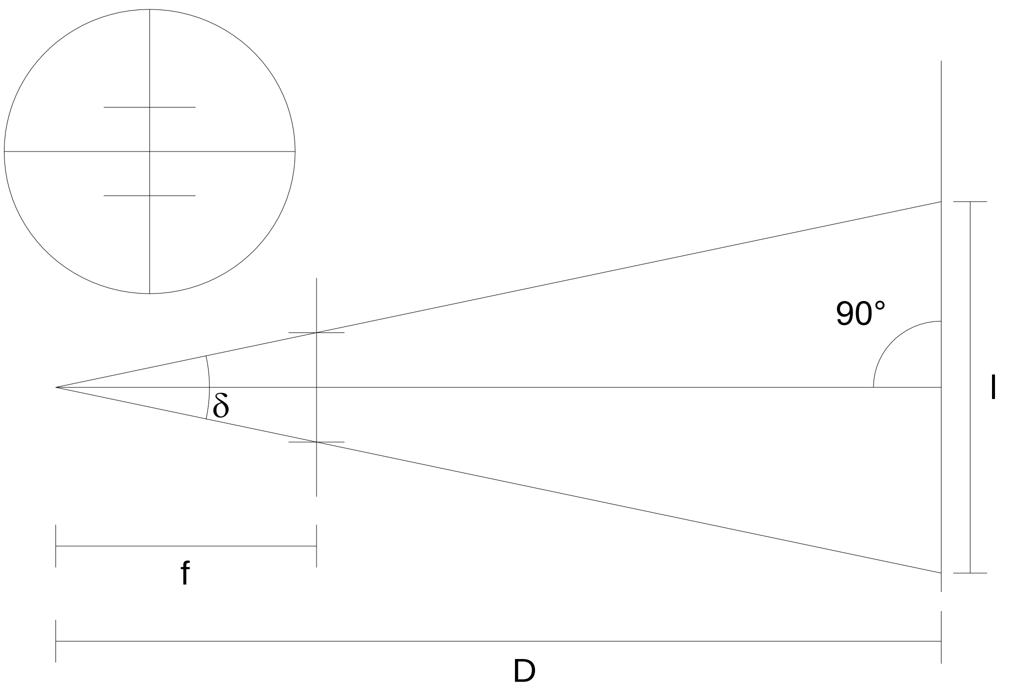
- accuracy – 1 mm for 100 m (1:100 000)

The applicable measured distance is approximately 100 m, longer measurement distance can be divided into several sections or the so-called parallactic cell procedure can be used.



2b) Stadia range finder – horizontal line of sight

It is part of practically all theodolites and levelling instruments



- there are 2 short lines = stadia lines in the field of view of all theodolites and levelling instruments

- angle δ is invariable (it is given by the distance between stadia lines and by the focal distance *f*), a rod interval *l* is measured (it is read on a levelling rod)

$$D = \frac{l}{2}\cot\left(\frac{\delta}{2}\right), k = \frac{1}{2}\cot\left(\frac{\delta}{2}\right)$$

$$\Rightarrow D = k \cdot l$$

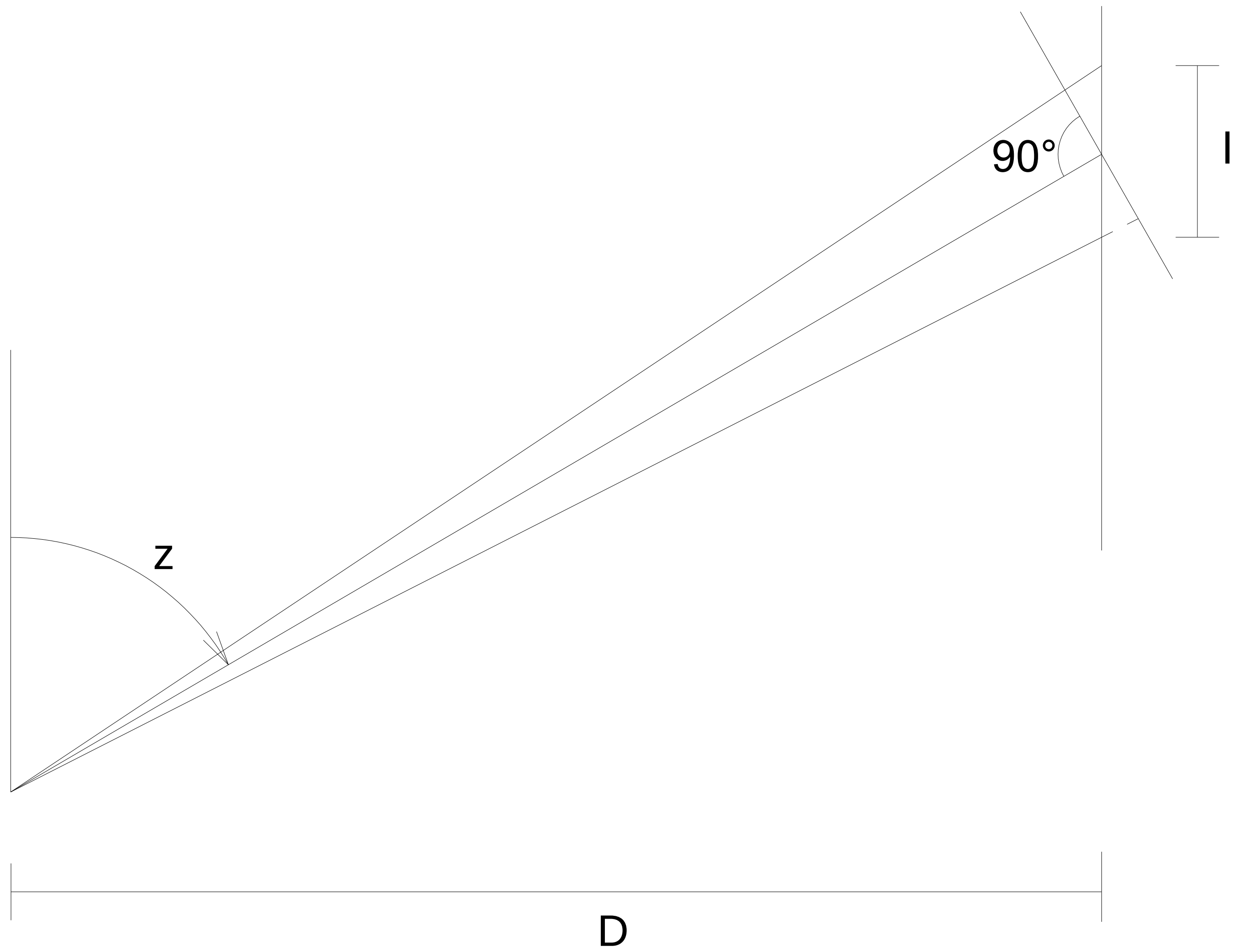
- measured distance D is horizontal
- usually k = 100

- if the line of sight is not horizontal, a rod interval *l* and a zenith angle *z* are measured and then

$$D = k \cdot l \cdot \sin^2 z$$

- accuracy – 0,1 m for 60 m (1:600)

Stadia range finder – slope line of sight



3. Electro-optical distance measurement

- there is a transmitter of electromagnetic radiation on a point and a reflector on another one

- reflector: 1. trigonal reflector / prism
  2. arbitrary diffuse surface

- principles of distance measurement:
  1. evaluation of a phase or frequency of modulated electromagnetic radiation,
  2. signal emission and transit time measurement.

- slope distance is measured with an electronic distance meter = length of a join between the instrument and the prism (target)

- **additive constant** of the instrument and the target set = systematic difference between measured and true distance given by the positions of instrument’s and target’s reference points. The additive constant is given by the producer of the instrument and it should be introduced to a measurement.

- electronic distance meter can be embedded in so called **total station** (electronic theodolite + electronic distance meter)

Accuracy of electronic distance meters

$\sigma = X \text{ mm} + Y \text{ ppm} \cdot D$

X …invariable part of the standard deviation,

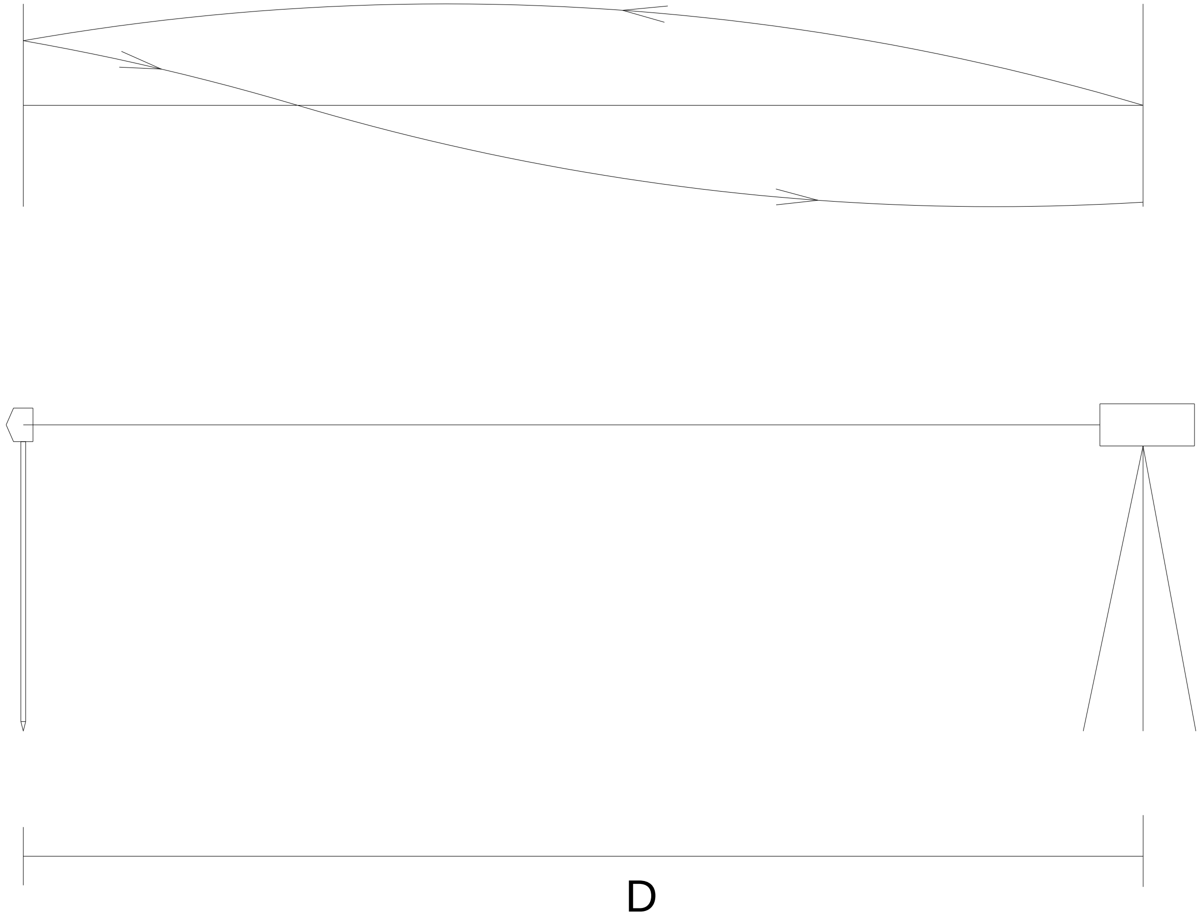
Y …variable part of the standard deviation (it depends on the value of a measured distance)

D ...measured distance in km

E.g. $\sigma = 3 \text{ mm} + 2 \text{ ppm}$

the standard deviation of measured distance is 7 mm for the distance 2 km (= 3 + 2*2)

3a) Phase distance meter



- distance meter signals a modulated wave with the phase ϕ_0 and a wave with the phase ϕ_1 is turned back. The distance is characterized by the phase difference $\Delta\phi$.

- the wave has to be longer than measured distance (it is not possible to determine a number of the whole waves)

- more than one wavelength are usually used for measurement, e.g. wavelengths 1000 m, 10 m, 1 m and then the values 382 m; 2,43 m; 0,428 m give the result 382,428 m.

3b) Distance meter measuring transit time

- signal is emitted by the distance meter and transit time *t* is measured

$$2D = v \cdot t \Rightarrow D = \frac{v \cdot t}{2}$$

- high accuracy of the transit time measurement is needed therefore these distance meters are less often used

Corrections of measured distances

1. physical correction of a distance – for measurements with electronic distance meters

2. mathematical reduction of a distance – for coordinate calculations

Physical correction

- wavelength depends on atmosphere which the signal comes through, it depends on atmospheric temperature and pressure mainly

- value of physical correction is set in a distance meter (it is calculated using formulas given by the producer of the distance meter)

- it is possible to enter the temperature and the pressure to the most of modern distance meters and the correction is calculated automatically

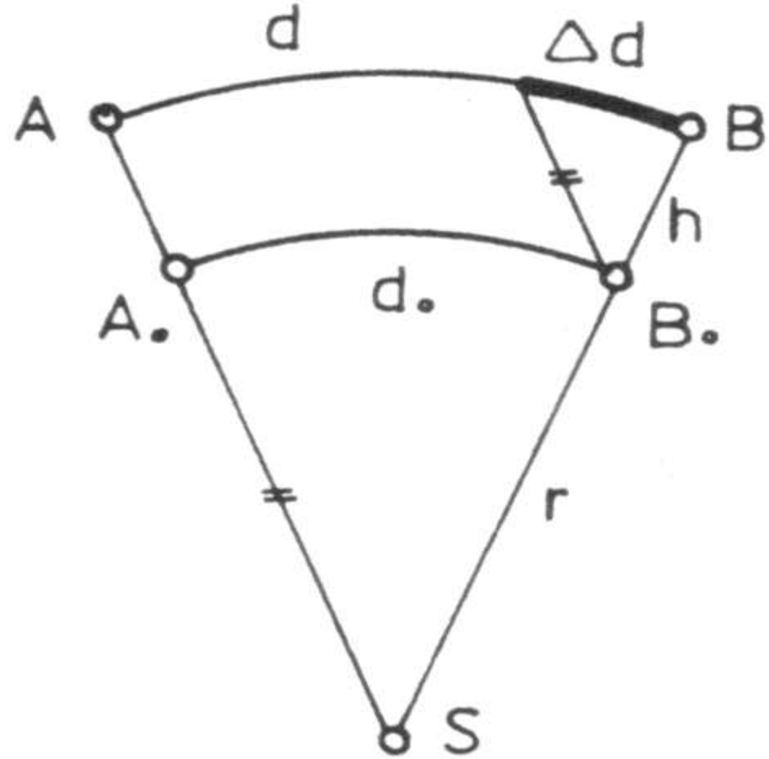
Mathematical reduction

Measured distance *d* which is shorter than 6 km has to be:

1. reduced to a curvature on the reference sphere (to so called „sea level horizon“),

2. reduced to the plane of the cartographic projection (e.g. S-JTSK)

1. Mathematical reduction to the sea level horizon



$$\frac{d}{r+h} = \frac{d_0}{r}$$

$$d_0 = d\,\frac{r}{r+h}$$

r … reference sphere radius (6380 km)

h … sea level height (elevation)

2. Distance projection reduction (S-JTSK)

$$s = d_0 \cdot \frac{1}{2} \cdot \left(m_A + m_B \right)$$

for short distances

$$s = d_0 \cdot m_A$$

The scale error value *m* is calculated or found out using the scale error isolines map.


Leica


SDRbasic
S-OΔHD 0.820m
dHA 0°09'40"
HD 2.480m
ZA 75°20'30"
HA-R 39°05'20"
REC DISP MEAS


DISTO™ D3a
ON DIST
MENU
TIMER
CLEAR OFF

Thank you for your attention!