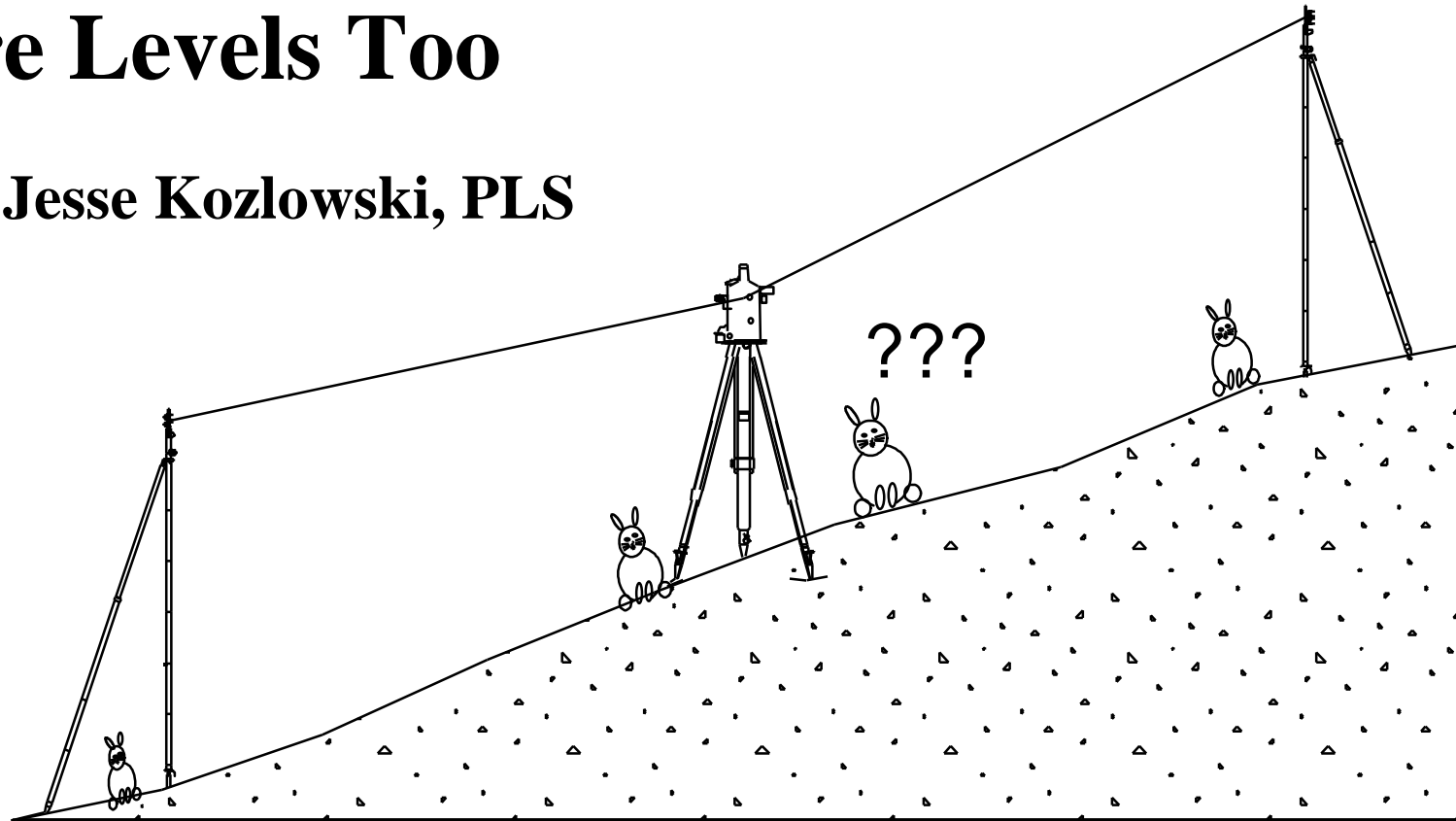


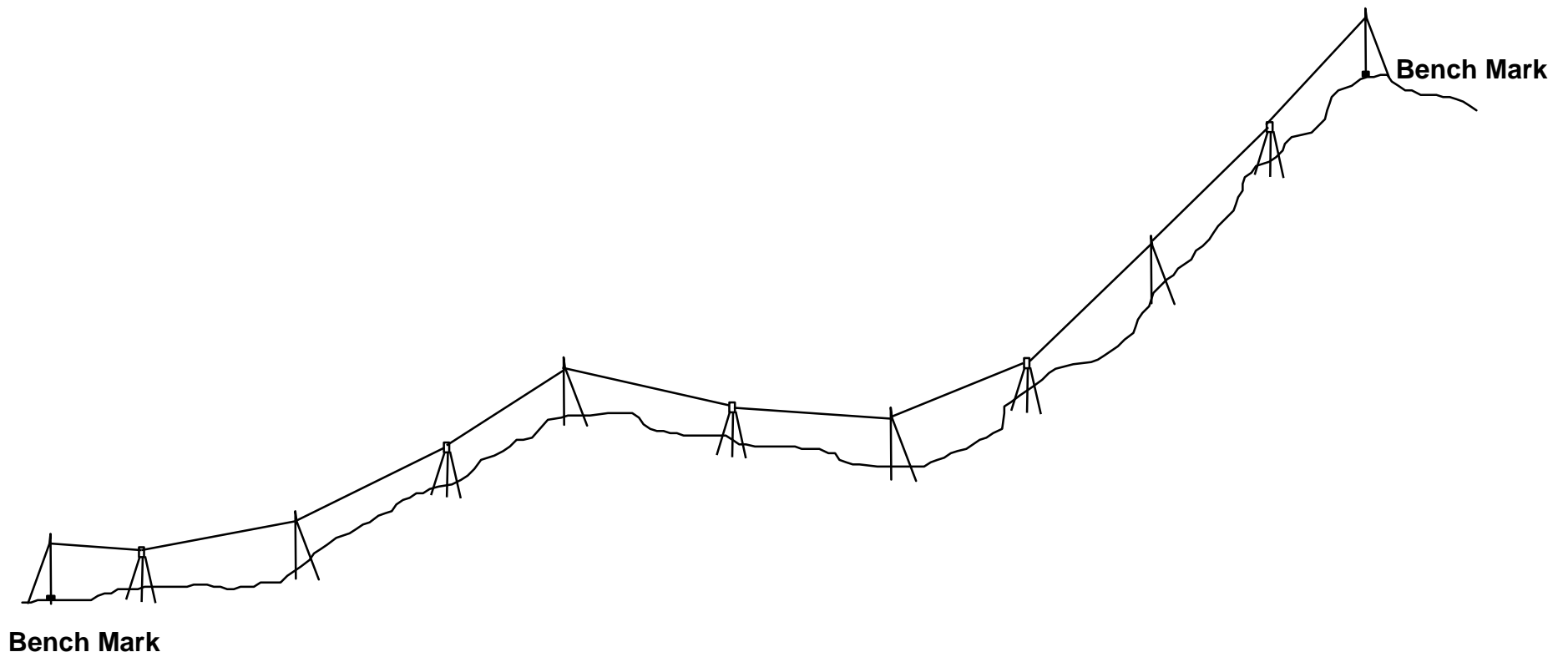
Electronic Total Stations Are Levels Too

By Jesse Kozlowski, PLS

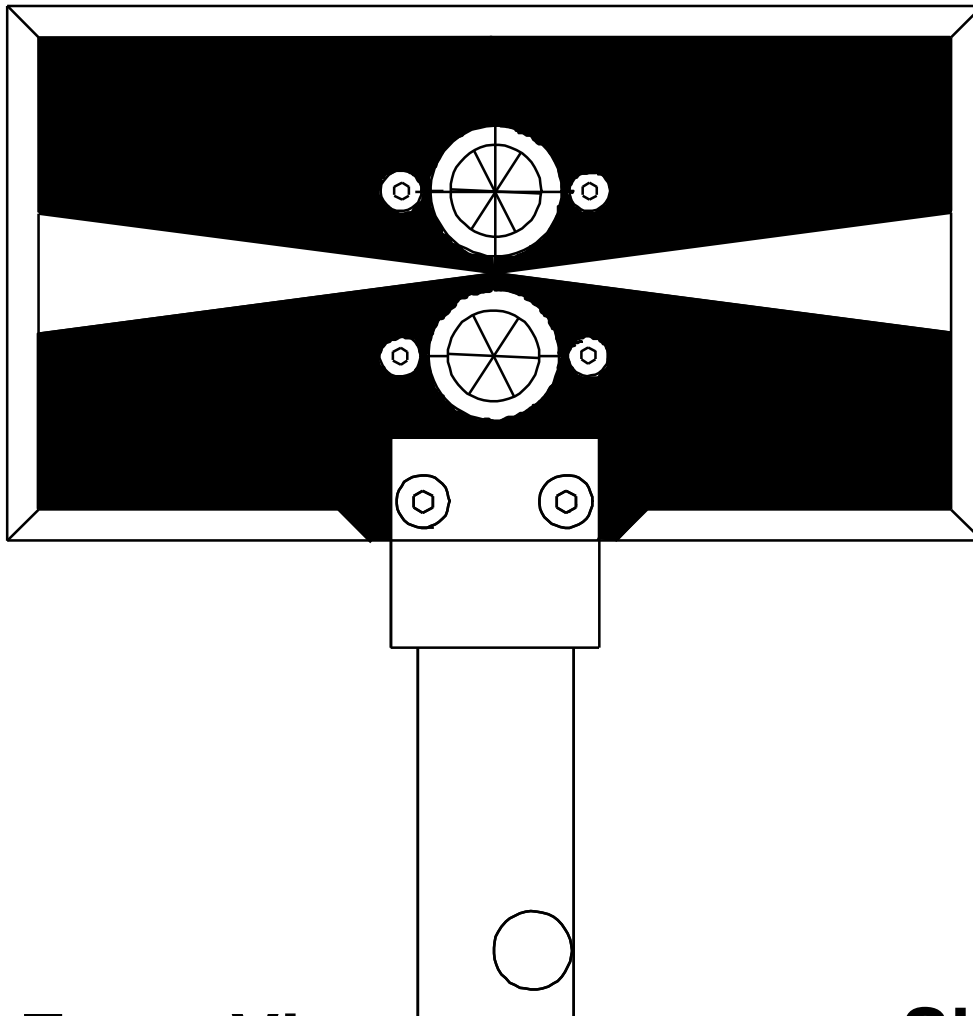


*Precise Trigonometric Leveling Using
Modern Total Station Instruments*

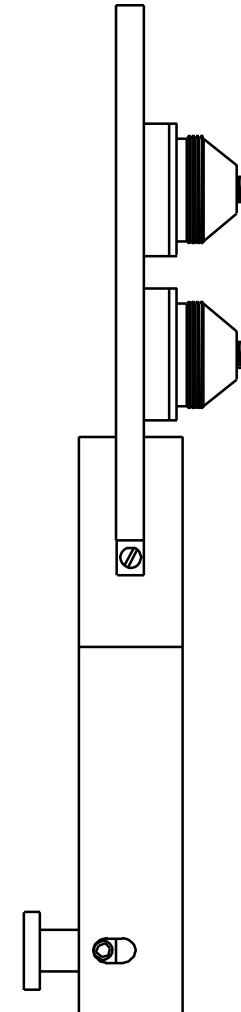
Trigonometric Leveling



Trigonometric Leveling Target



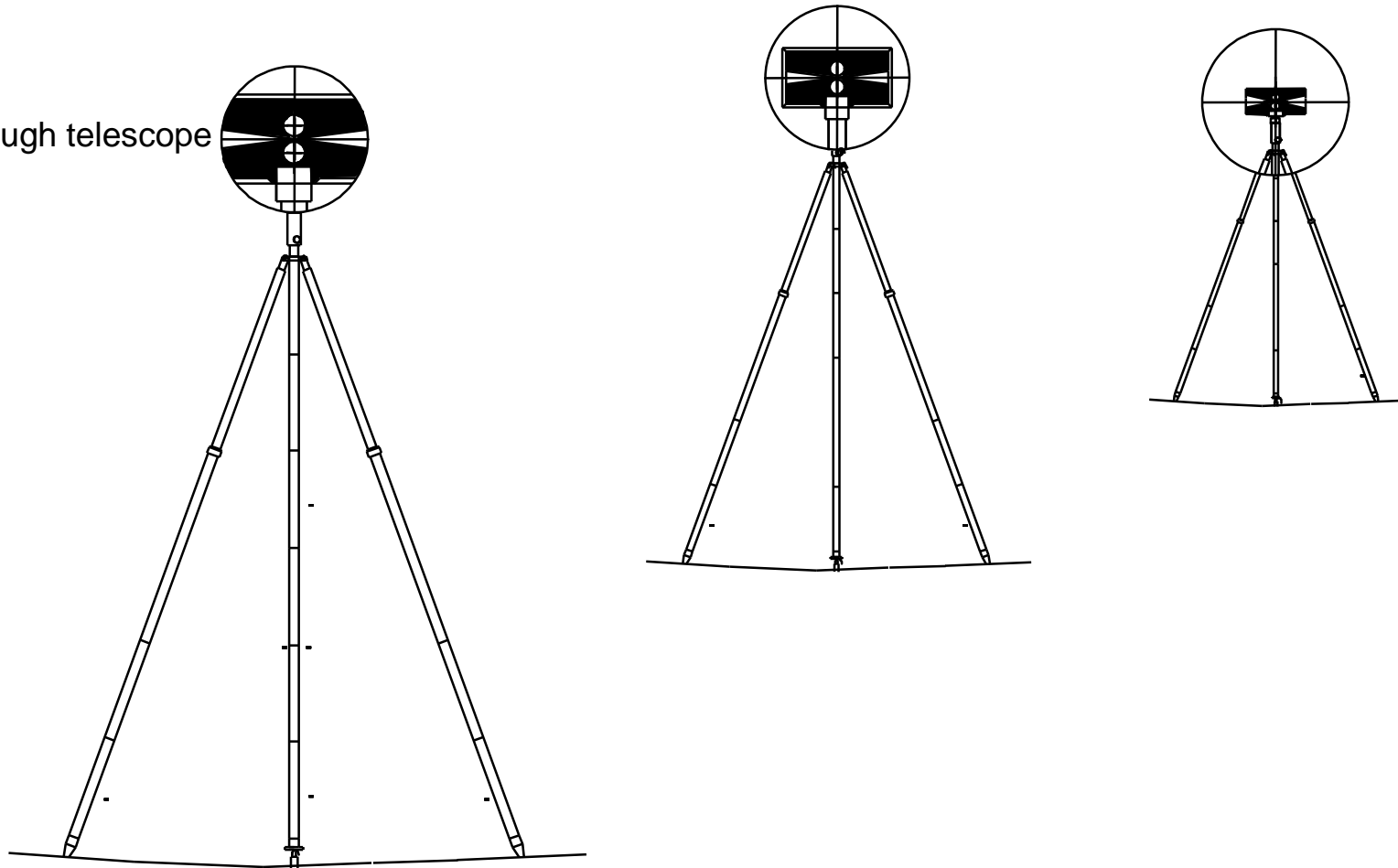
Front View



Side View

Trig-Target Views At Various Distances

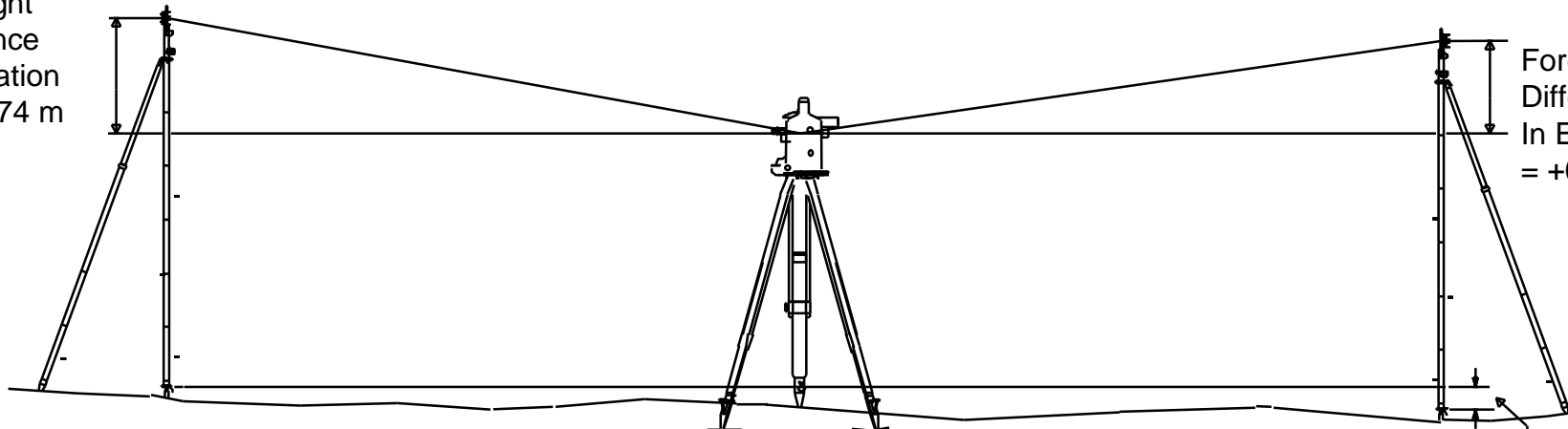
View through telescope



Trigonometric Leveling

Level Ground

Backsight
Difference
In Elevation
= + 1.174 m



Foresight
Difference
In Elevation
= +0.752 m

Difference In Elevation (DE)
Backsight (BS) To Foresight (FS)
 $DE = FS - BS$
 $= + 0.752 - (+1.174)$
 $= - 0.422$ meters

Observation Procedure

Pointings - 2 Sets of D&R ZA

- 1 Direct on Backsite
- 2 Swing Alidade
- 3 Direct on Foresite
- 4 Plunge Scope
- 5 Reverse on Foresite
- 6 Swing Alidade
- 7 Reverse on Backsite
- That completes one set of
Direct and Reverse Pointings*
- 8 Re-point on Backsite in Reverse
- 9 Swing Alidade
- 10 Reverse on Foresite
- 11 Plunge Scope
- 12 Direct on Foresight
- 13 Swing Alidade
- 14 Direct on Backsite

What Gets Recorded?

**Vertical Distances to the millimeter
or tenth of a millimeter.**

Be sure to record the algebraic sign!!!

**Slope Distances to the nearest decimeter
just to keep track of the distance traveled.**

**Make sure that all the necessary
corrections are being applied!!!**

Temperature

Pressure

PPM

EDM Constant

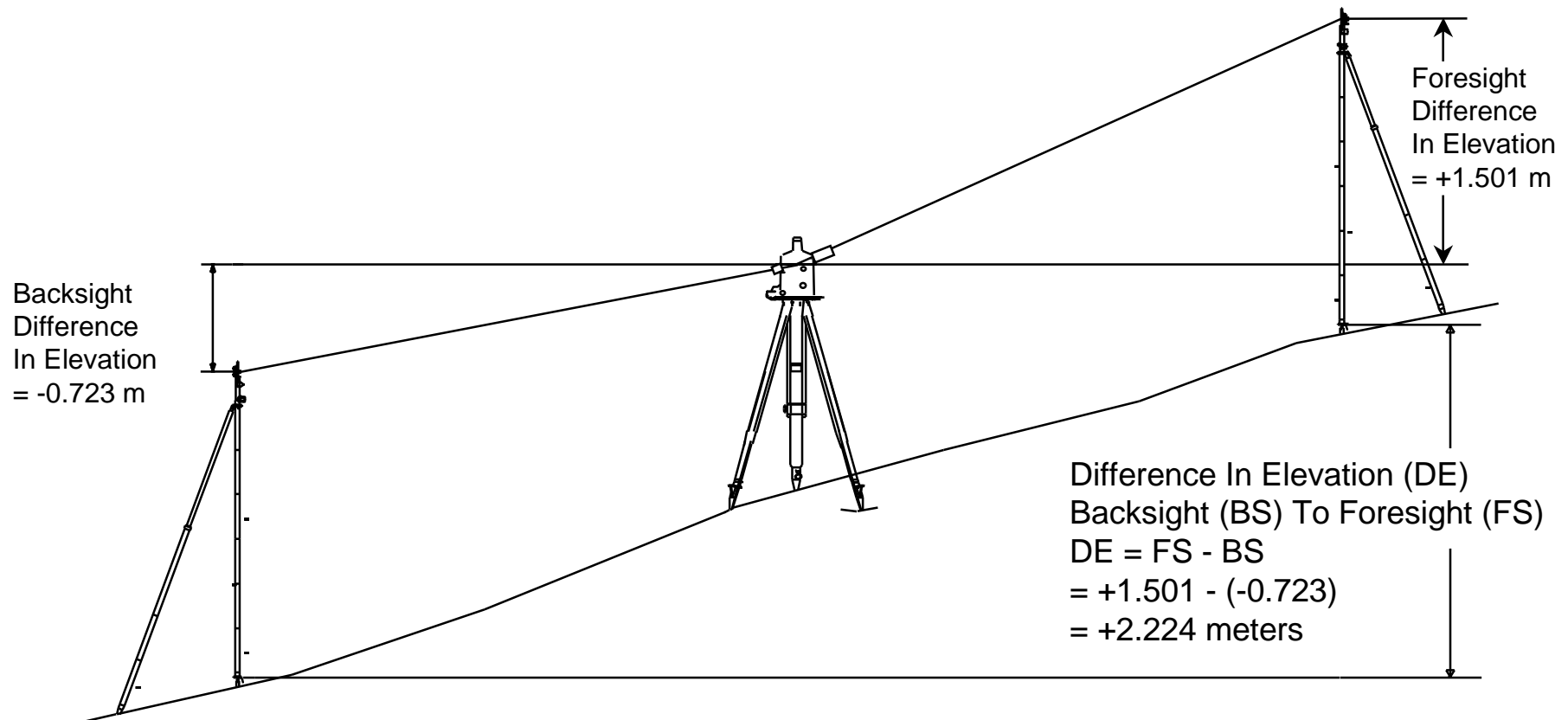
Reflector Constant

Curvature and Refraction

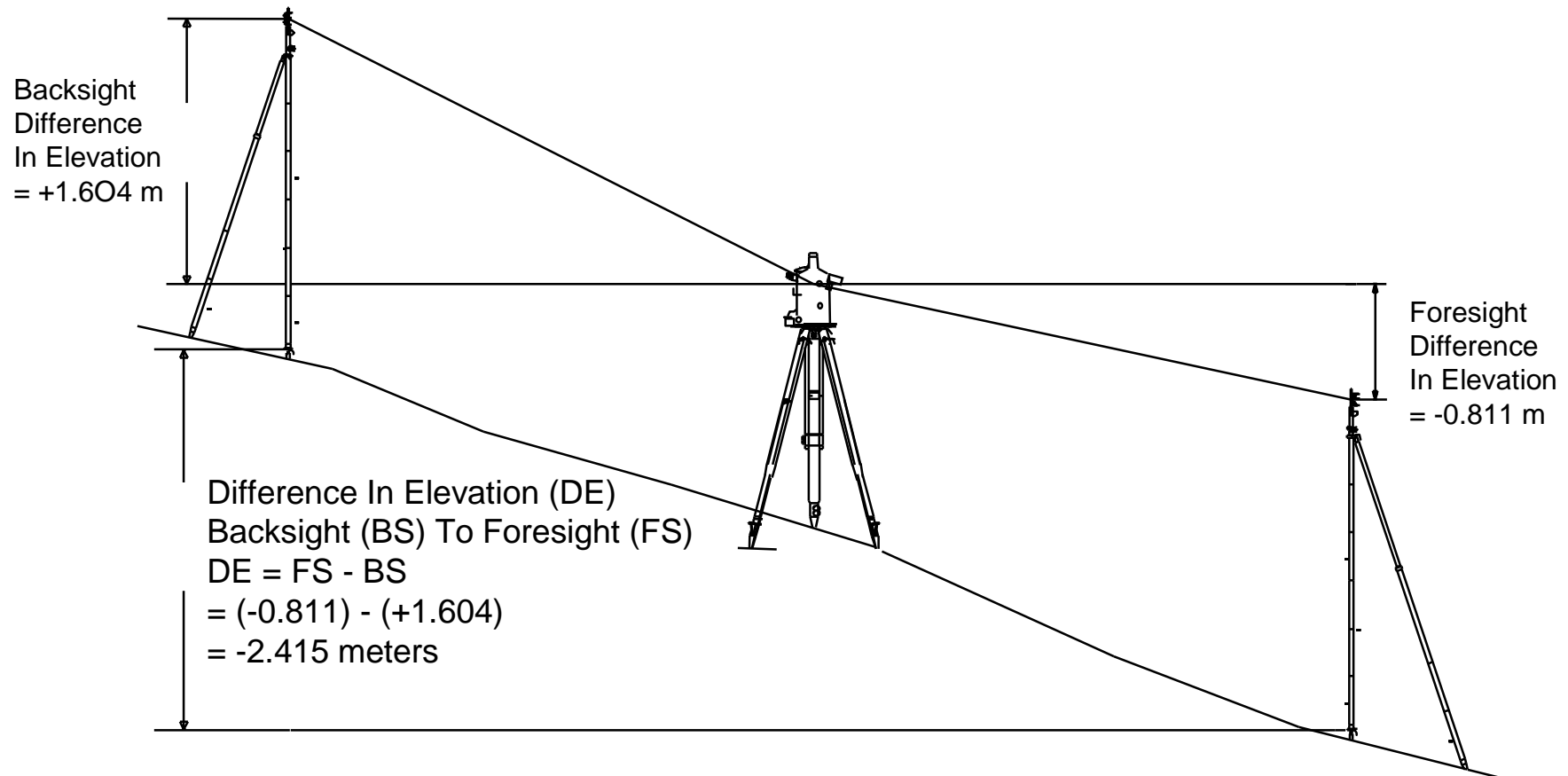
A Data Collector with a Trig Leveling Routine would be great!!!!

Trigonometric Leveling

Leveling Up Hill

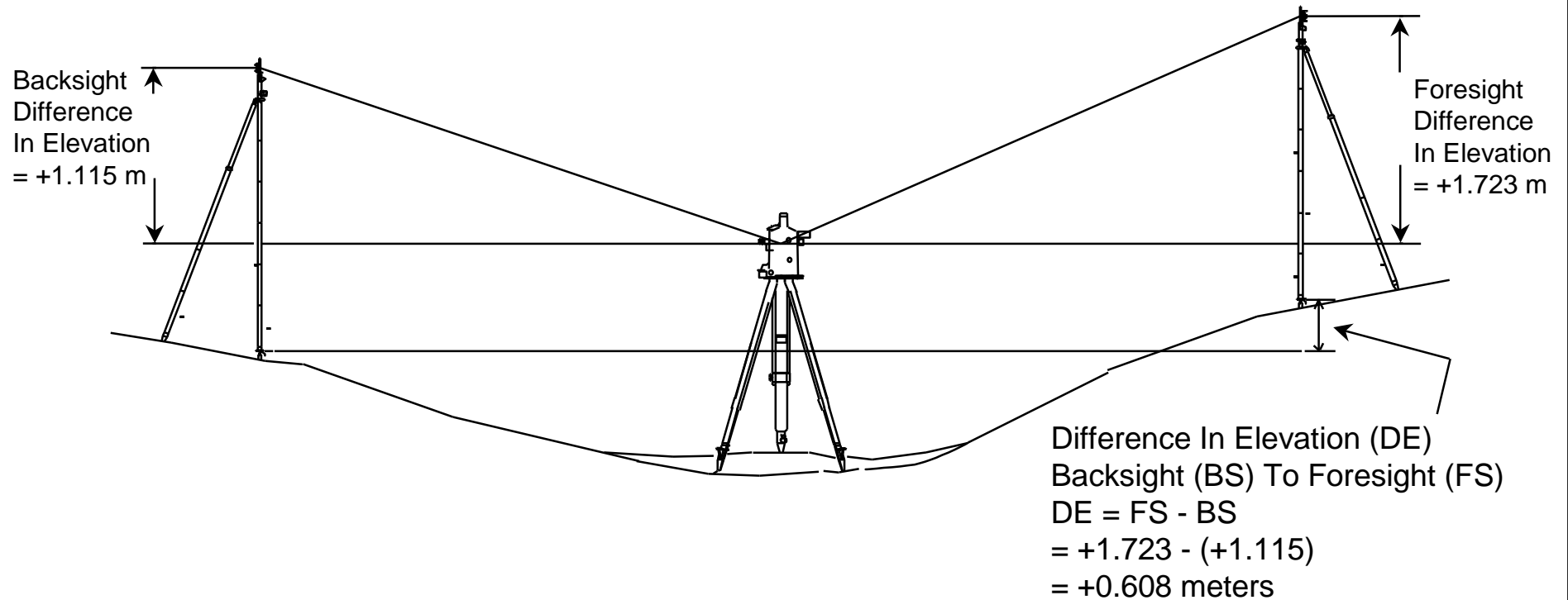


Trigonometric Leveling Leveling Down Hill



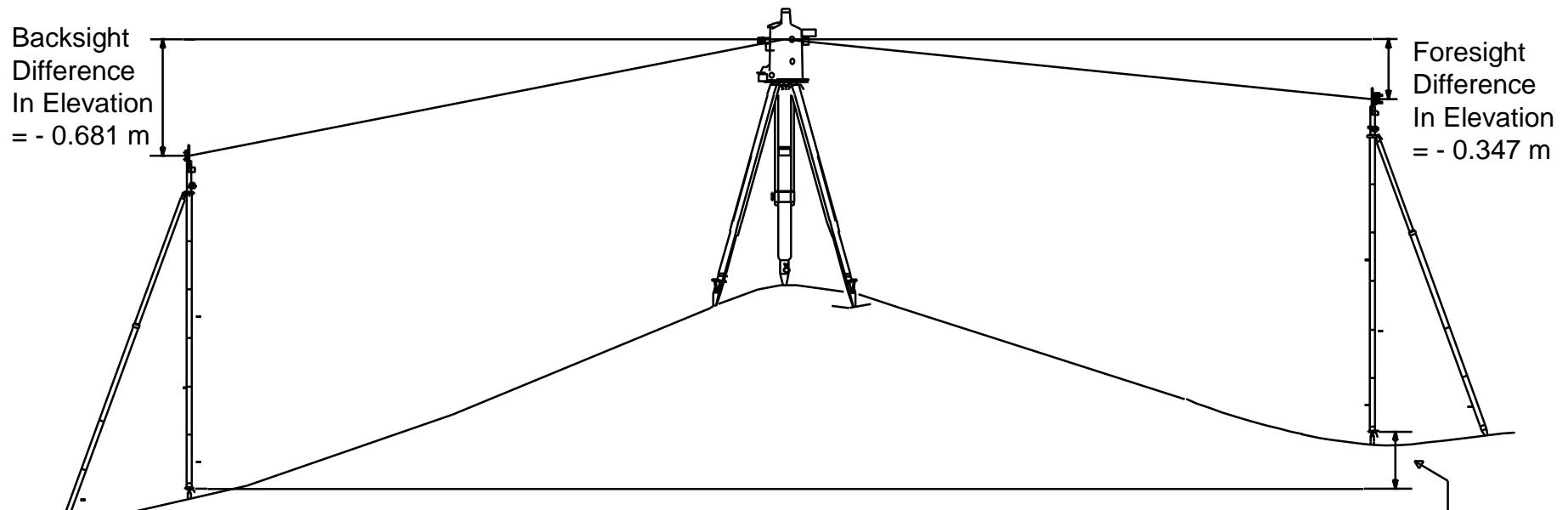
Trigonometric Leveling

Leveling Down and Up Hill



Trigonometric Leveling

Leveling Up and Down Hill

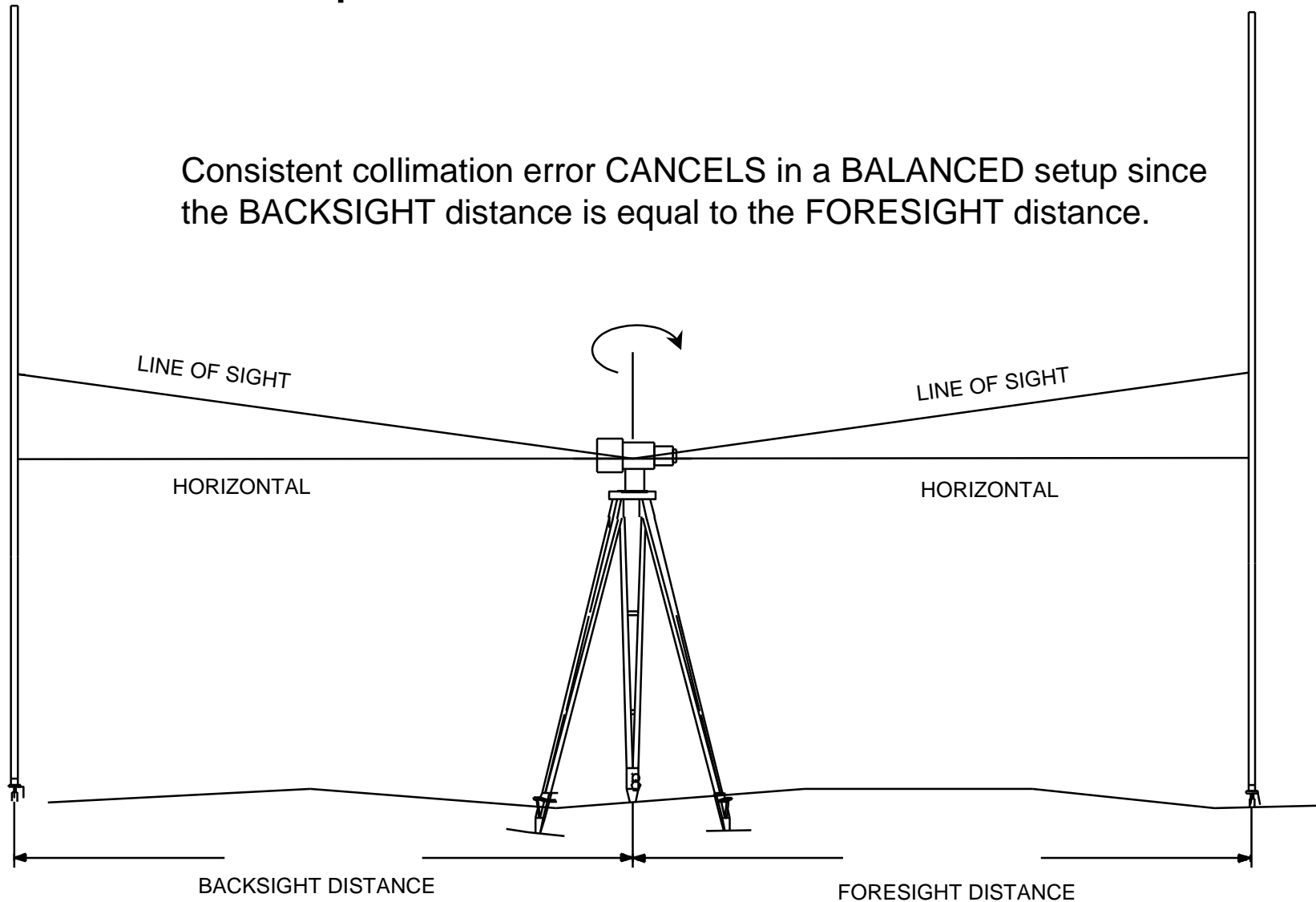


Difference In Elevation (DE)
Backsight (BS) To Foresight (FS)
 $DE = FS - BS$
 $= - 0.347 - (-0.681)$
 $= + 0.334 \text{ Meters}$

Conventional Differential Leveling

Balanced Setup

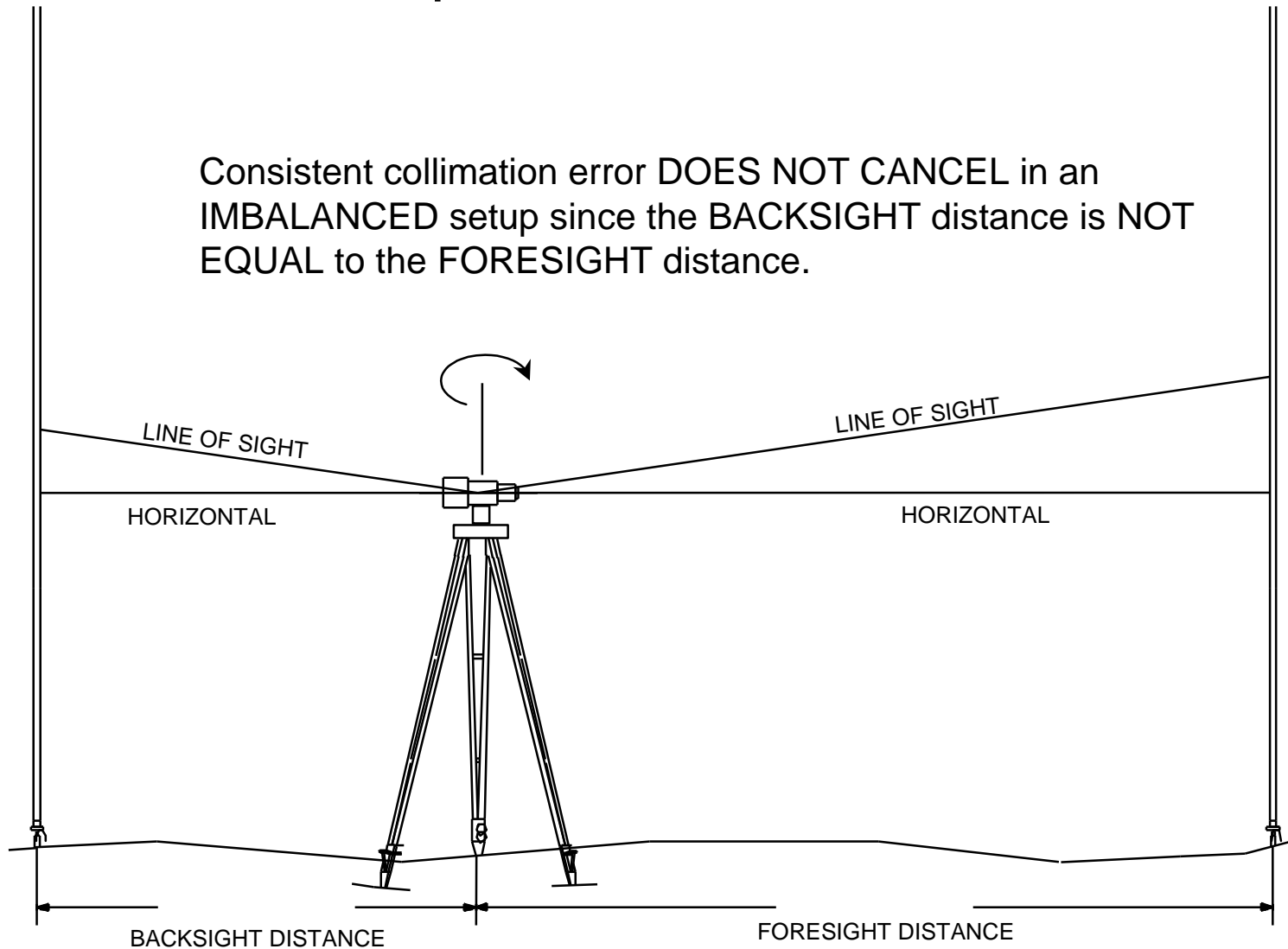
Consistent collimation error CANCELS in a BALANCED setup since the BACKSIGHT distance is equal to the FORESIGHT distance.



Conventional Differential Leveling

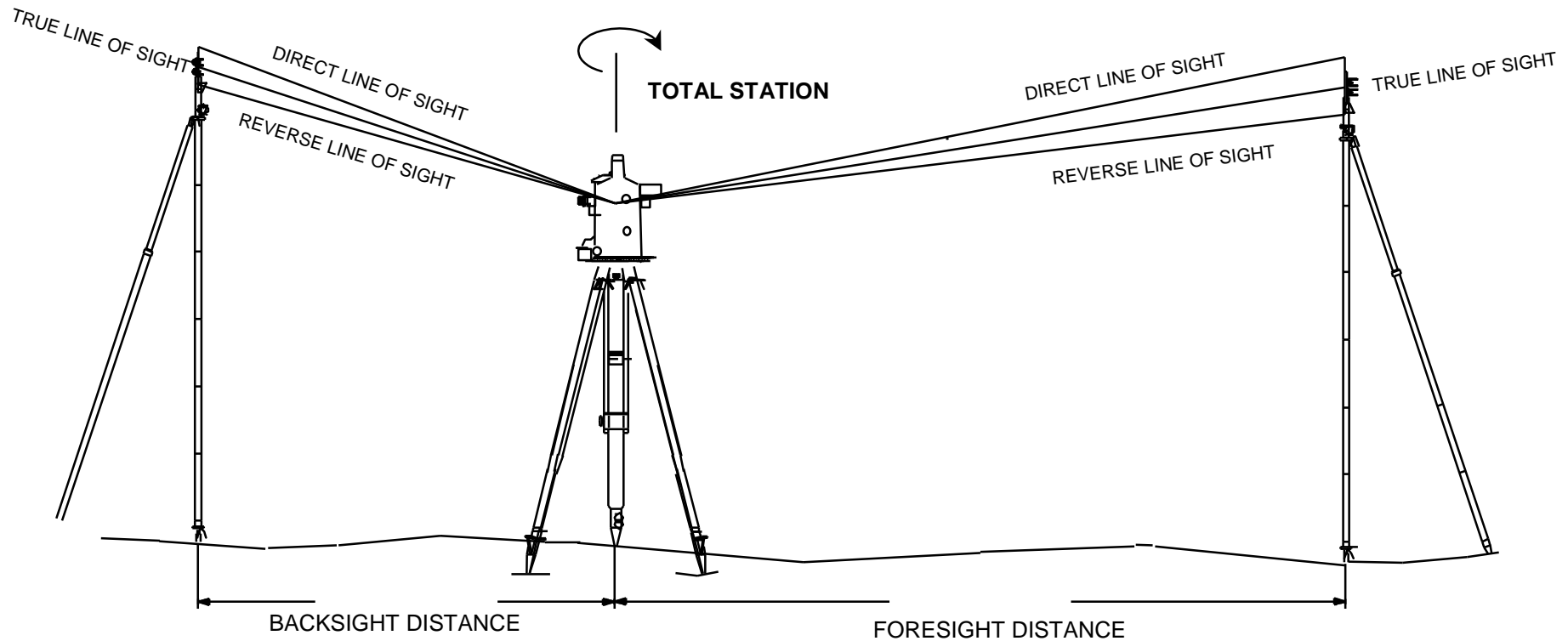
Imbalanced Setup

Consistent collimation error DOES NOT CANCEL in an IMBALANCED setup since the BACKSIGHT distance is NOT EQUAL to the FORESIGHT distance.



Trigonometric Leveling

Imbalanced Setup

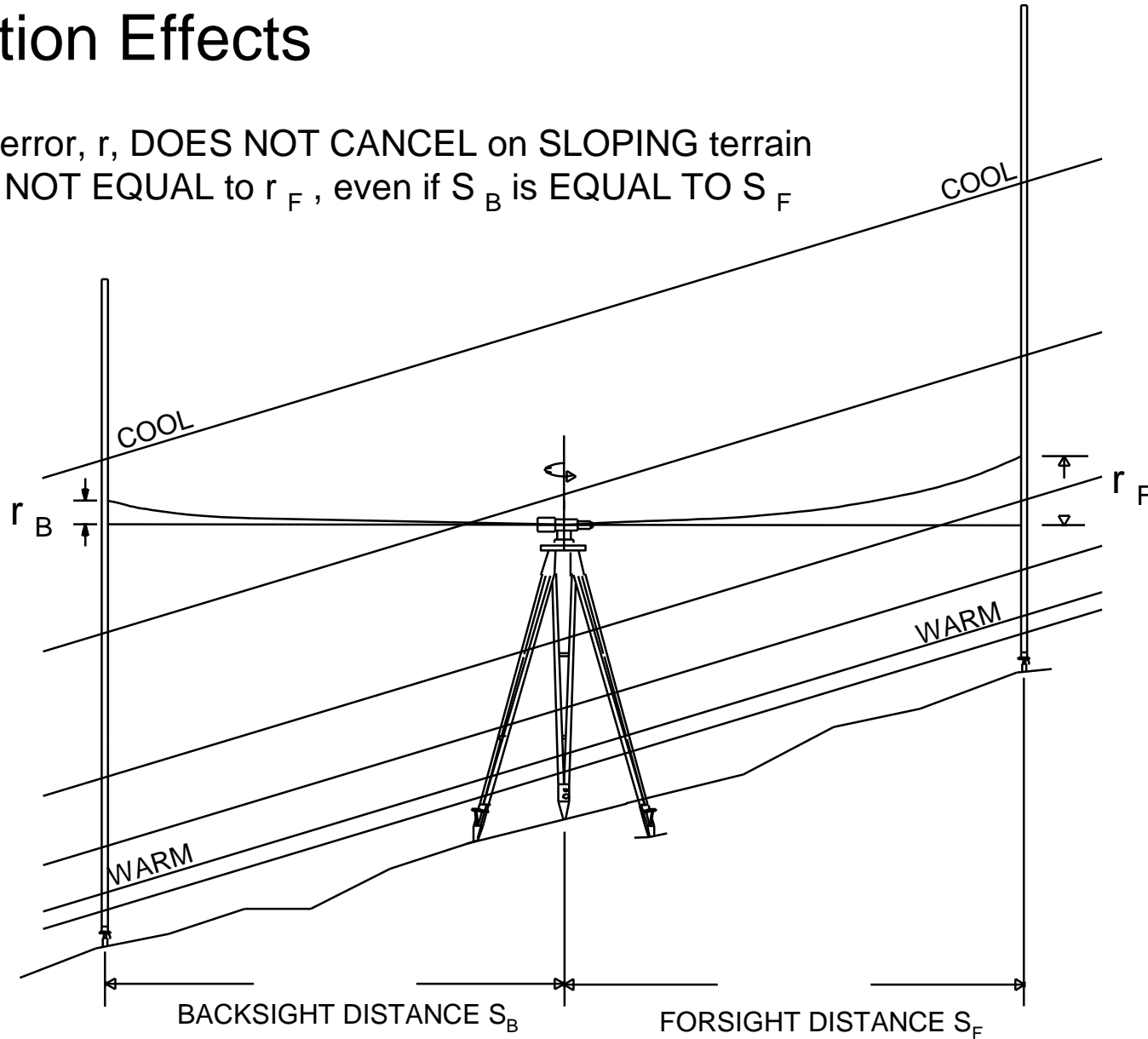


Collimation ERROR CANCELS in a BALANCED or IMBALANCED SETUP in TRIGONOMETRIC LEVELING

Conventional Differential Leveling

Refraction Effects

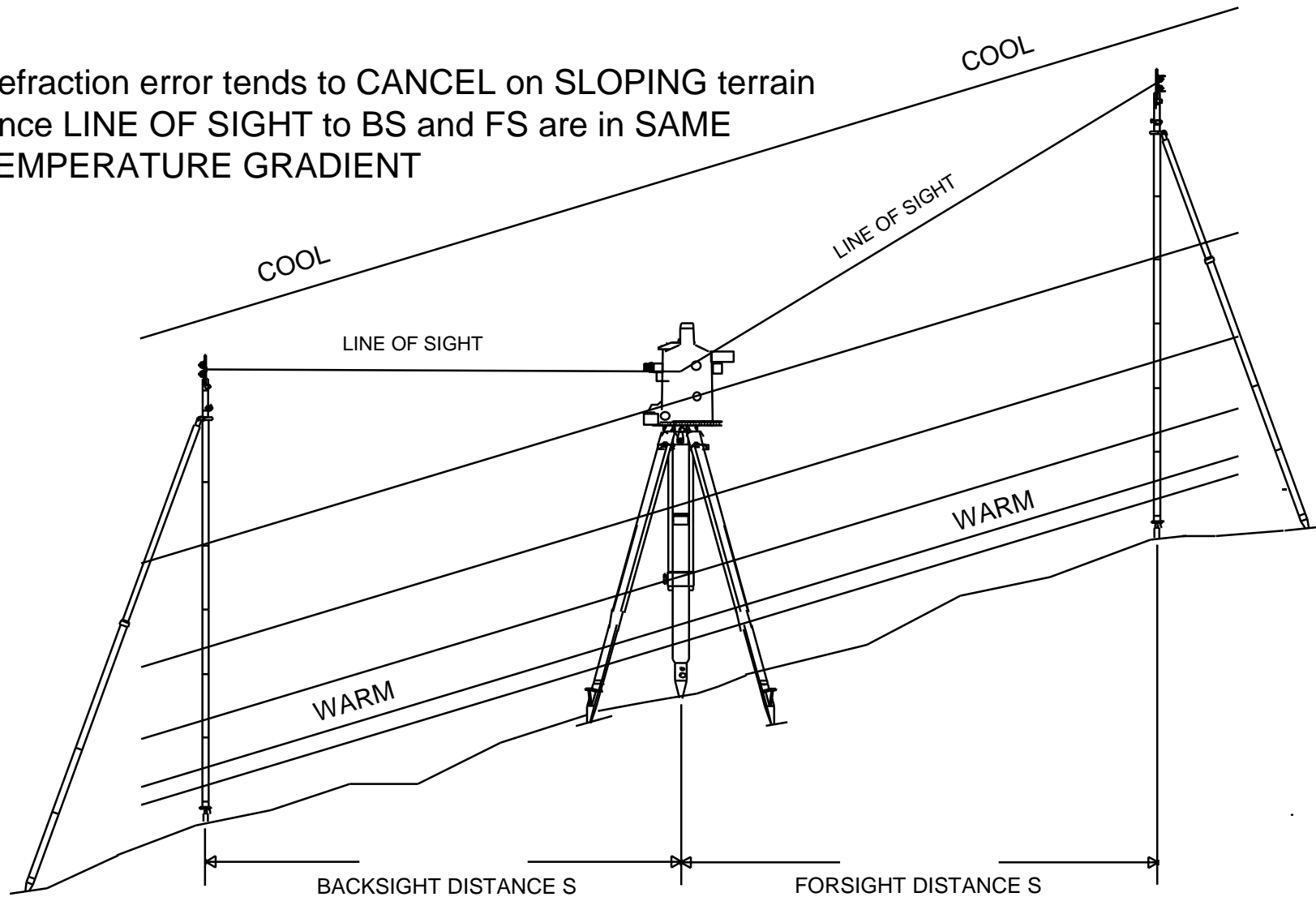
Refraction error, r , DOES NOT CANCEL on SLOPING terrain since r_B is NOT EQUAL to r_F , even if S_B is EQUAL TO S_F



Trigonometric Leveling

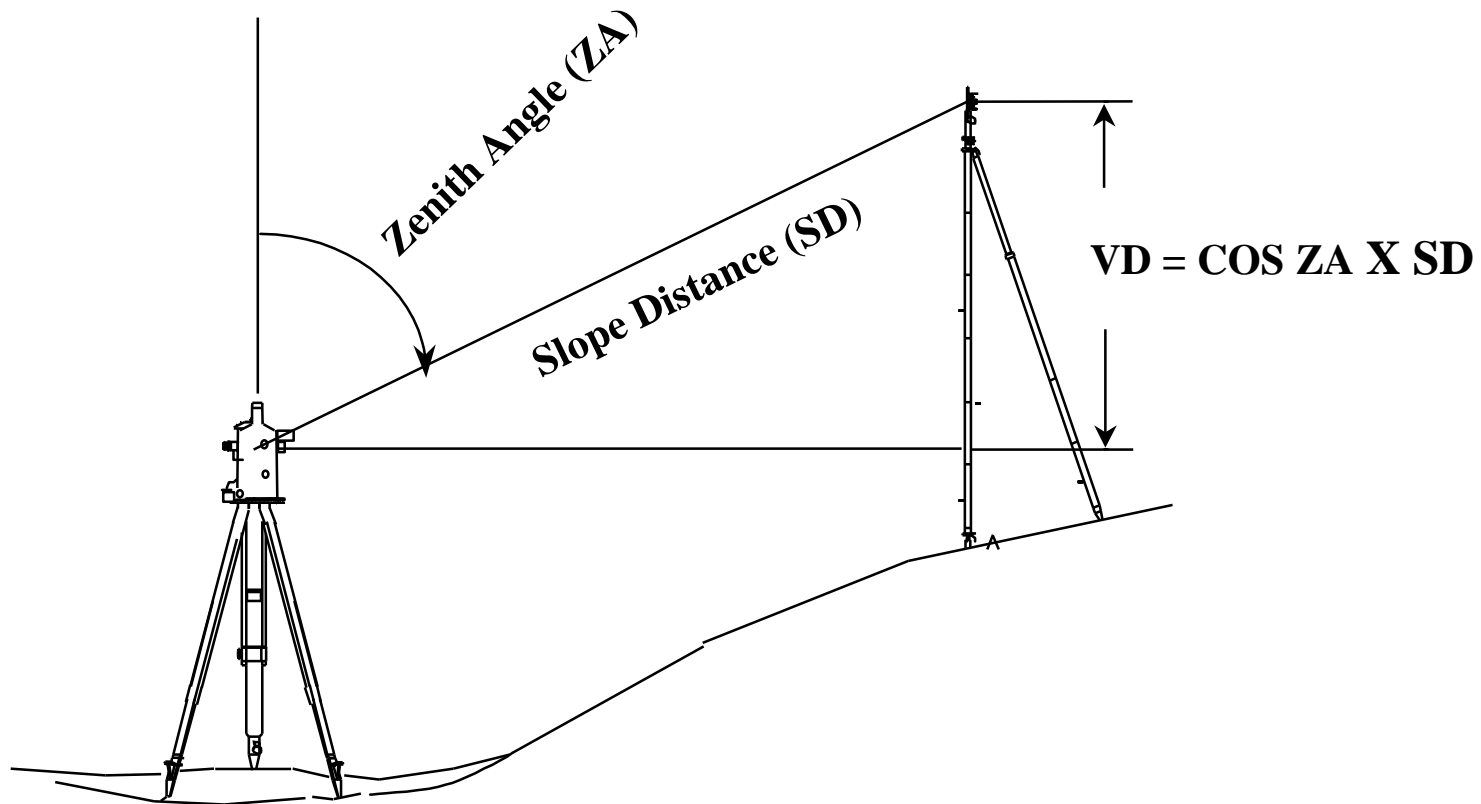
Refraction Effects

Refraction error tends to CANCEL on SLOPING terrain since LINE OF SIGHT to BS and FS are in SAME TEMPERATURE GRADIENT



How Far?

That primarily depends on the precision of the vertical circle.



1mm EDM and 0.5 Second Total Station

Zenith Angle

	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75
10	0.03	0.04	0.06	0.07	0.09	0.11	0.12	0.14	0.16	0.18	0.19	0.21	0.23	0.24	0.26
20	0.05	0.06	0.07	0.08	0.10	0.12	0.13	0.15	0.16	0.18	0.20	0.21	0.23	0.25	0.26
30	0.07	0.08	0.09	0.10	0.11	0.13	0.14	0.16	0.17	0.19	0.20	0.22	0.24	0.25	0.27
40	0.10	0.10	0.11	0.12	0.13	0.14	0.16	0.17	0.18	0.20	0.21	0.23	0.24	0.26	0.28
50	0.12	0.13	0.13	0.14	0.15	0.16	0.17	0.18	0.20	0.21	0.22	0.24	0.25	0.27	0.28
60	0.15	0.15	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.23	0.24	0.25	0.27	0.28	0.29
70	0.17	0.17	0.18	0.18	0.19	0.20	0.21	0.22	0.23	0.24	0.25	0.27	0.28	0.29	0.31
80	0.19	0.20	0.20	0.21	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.31	0.32
90	0.22	0.22	0.22	0.23	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33
100	0.24	0.24	0.25	0.25	0.26	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35
110	0.27	0.27	0.27	0.27	0.28	0.29	0.29	0.30	0.31	0.31	0.32	0.33	0.34	0.35	0.37
120	0.29	0.29	0.30	0.30	0.30	0.31	0.31	0.32	0.33	0.33	0.34	0.35	0.36	0.37	0.38
130	0.32	0.32	0.32	0.32	0.33	0.33	0.34	0.34	0.35	0.36	0.36	0.37	0.38	0.39	0.40
140	0.34	0.34	0.34	0.35	0.35	0.35	0.36	0.36	0.37	0.38	0.38	0.39	0.40	0.41	0.42
150	0.36	0.37	0.37	0.37	0.37	0.38	0.38	0.39	0.39	0.40	0.40	0.41	0.42	0.43	0.44
160	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.41	0.41	0.42	0.43	0.43	0.44	0.45	0.46
170	0.41	0.41	0.41	0.42	0.42	0.42	0.43	0.43	0.44	0.44	0.45	0.45	0.46	0.47	0.47
180	0.44	0.44	0.44	0.44	0.44	0.45	0.45	0.45	0.46	0.46	0.47	0.47	0.48	0.49	0.49
190	0.46	0.46	0.46	0.46	0.47	0.47	0.47	0.48	0.48	0.49	0.49	0.50	0.50	0.51	0.51
200	0.49	0.49	0.49	0.49	0.49	0.49	0.50	0.50	0.50	0.51	0.51	0.52	0.52	0.53	0.54

Expected Accuracy (mm)

1mm EDM and 1.0 Second Total Station

Zenith Angle

	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75
10	0.05	0.06	0.07	0.08	0.10	0.12	0.13	0.15	0.16	0.18	0.20	0.21	0.23	0.25	0.26
20	0.10	0.10	0.11	0.12	0.13	0.14	0.16	0.17	0.18	0.20	0.21	0.23	0.24	0.26	0.28
30	0.15	0.15	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.23	0.24	0.25	0.27	0.28	0.29
40	0.19	0.20	0.20	0.21	0.21	0.22	0.23	0.24	0.25	0.26	0.27	0.28	0.29	0.31	0.32
50	0.24	0.24	0.25	0.25	0.26	0.26	0.27	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35
60	0.29	0.29	0.30	0.30	0.30	0.31	0.31	0.32	0.33	0.33	0.34	0.35	0.36	0.37	0.38
70	0.34	0.34	0.34	0.35	0.35	0.35	0.36	0.36	0.37	0.38	0.38	0.39	0.40	0.41	0.42
80	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.41	0.41	0.42	0.43	0.43	0.44	0.45	0.46
90	0.44	0.44	0.44	0.44	0.44	0.45	0.45	0.45	0.46	0.46	0.47	0.47	0.48	0.49	0.49
100	0.49	0.49	0.49	0.49	0.49	0.49	0.50	0.50	0.50	0.51	0.51	0.52	0.52	0.53	0.54
110	0.53	0.53	0.54	0.54	0.54	0.54	0.54	0.55	0.55	0.55	0.56	0.56	0.57	0.57	0.58
120	0.58	0.58	0.58	0.58	0.59	0.59	0.59	0.59	0.60	0.60	0.60	0.61	0.61	0.61	0.62
130	0.63	0.63	0.63	0.63	0.63	0.64	0.64	0.64	0.64	0.64	0.65	0.65	0.65	0.66	0.66
140	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.69	0.69	0.69	0.69	0.70	0.70	0.70	0.70
150	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.74	0.74	0.74	0.74	0.74	0.75	0.75
160	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.79	0.79	0.79	0.79
170	0.82	0.82	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.84	0.84
180	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
190	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.93	0.93	0.93
200	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97

Expected Accuracy (mm)

2mm EDM and 3.0 Second Total Station

Zenith Angle

	89	88	87	86	85	84	83	82	81	80	79	78	77	76	75
10	0.15	0.16	0.18	0.20	0.23	0.25	0.28	0.31	0.34	0.38	0.41	0.44	0.47	0.50	0.54
20	0.29	0.30	0.31	0.32	0.34	0.36	0.38	0.40	0.42	0.45	0.48	0.50	0.53	0.56	0.59
30	0.44	0.44	0.45	0.46	0.47	0.48	0.50	0.51	0.53	0.55	0.57	0.60	0.62	0.64	0.67
40	0.58	0.59	0.59	0.60	0.61	0.62	0.63	0.64	0.65	0.67	0.69	0.70	0.72	0.74	0.76
50	0.73	0.73	0.73	0.74	0.75	0.75	0.76	0.77	0.78	0.80	0.81	0.82	0.84	0.86	0.87
60	0.87	0.87	0.88	0.88	0.89	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.98	0.99
70	1.02	1.02	1.02	1.03	1.03	1.03	1.04	1.05	1.05	1.06	1.07	1.08	1.09	1.10	1.11
80	1.16	1.16	1.17	1.17	1.17	1.18	1.18	1.19	1.19	1.20	1.20	1.21	1.22	1.23	1.24
90	1.31	1.31	1.31	1.31	1.32	1.32	1.32	1.33	1.33	1.34	1.34	1.35	1.35	1.36	1.37
100	1.45	1.46	1.46	1.46	1.46	1.46	1.46	1.47	1.47	1.47	1.48	1.48	1.49	1.49	1.50
110	1.60	1.60	1.60	1.60	1.60	1.60	1.61	1.61	1.61	1.61	1.62	1.62	1.62	1.63	1.63
120	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.75	1.76	1.76	1.76	1.76	1.76
130	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.90	1.90	1.90	1.90
140	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.04	2.03	2.03	2.03	2.03	2.03
150	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.17	2.17	2.17	2.17
160	2.33	2.33	2.33	2.33	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.31	2.31	2.31	2.31
170	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.46	2.46	2.46	2.46	2.45	2.45	2.45	2.44
180	2.62	2.62	2.62	2.62	2.61	2.61	2.61	2.61	2.60	2.60	2.60	2.59	2.59	2.59	2.58
190	2.76	2.76	2.76	2.76	2.76	2.76	2.75	2.75	2.75	2.74	2.74	2.73	2.73	2.72	2.72
200	2.91	2.91	2.91	2.91	2.90	2.90	2.90	2.89	2.89	2.89	2.88	2.88	2.87	2.86	2.86

Expected Accuracy (mm)