EFFECT OF SONAR BEAMWIDTH AND SLOPING SEA BED ON THE ACCURACY OF BATHYMETRIC SURVEY

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INTRODUCTION

- Sonar systems are used everywhere in the world for bathymetric survey purposes
- The beamwidth of the sonar system determines the extent of the instrument coverage of the sea bed
- Pre-analysis is a good tool for Survey accuracy assurance
- Special Interest should be attached to the beamwidth of Single beam echo sounders employed in bathymetric Surveys
- To achieve results within the limits of IHO specification, the beamwidth of transducers employed in bathymetric Surveys within the IHO Special Order and Order 1(a & b) should not be more than 6° and 12° respectively

OVERVIEW OF IHO S-44 STANDARDS

- The International Hydrographic Organization (IHO) has developed a means of determining the accuracy standards of bathymetric surveys, These are;

— **Special Order -** for berthing areas, harbours and critical areas of shipping channels where the depth of water is not more than 40 metres

— **Order1a -** 1a surveys may be limited to water shallower than 100 metres

— **Order1b** - for areas shallower than 100 metres where a general depiction of the seabed is considered adequate for the type of surface shipping expected to transit the area and

— **Order 2 -** surveys are limited to areas deeper than 100 metres.

IHO S-44 STANDARDS

- Summarized Table

Order	SPECIAL	1a	1b	2
Description	**Dept: 0-40m (Underkeel clearance critical)**	**Dept: < = 100m (Underkeel Clearance less Critical)**	**Dept: < = 100m(Underkeel clearance not cosidered to be an issue)**	**Dept: > 100m (General description of the sea bed accepted)**
Maximum allowable THU	**2 metres**	**5m + 5% of depth**	**5m + 5% of depth**	**20m + 10% of depth**
Maximum allowable TVU	**a = 0.25m b = 0.0075**	**a = 0.5m b = 0.013**	**a = 0.5m b = 0.0013**	**a = 1.0m b = 0.023**
Full sea floor Search	**Required**	**Required**	**Not required**	**Not required**

WHY THIS?

- For these different classifications of Survey, it is a very big challenge to determine which sonar instrument will be adequate for use in these areas to meet their respective accuracy standards.
- This work is to investigate and recommend the ranges of sonar beam widths suitable for the accuracy standards of bathymetric surveys as specified by IHO

  — Evaluate the accuracy of standard

  — Determine the ranges of beam widths in single beam echo-sounders.

  — Compute allowable minimum vertical and horizontal uncertainties using the parameters and

  — Recommend the range of sonar beam width to be employed in bathymetric survey of a specified range of sea bed slopes that will conform to the IHO standard at 95% confidence level.

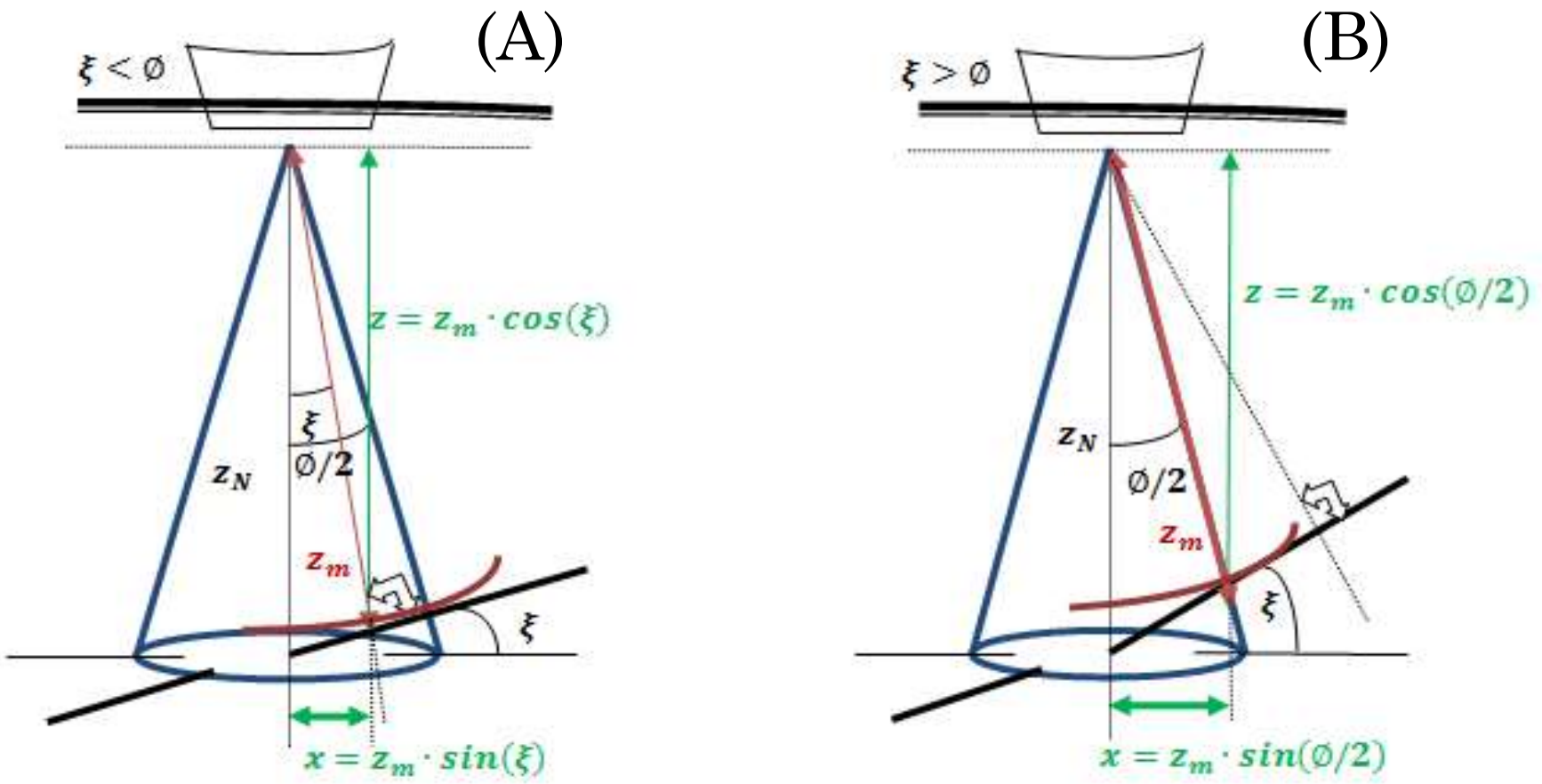
METHOD

- The method involved the IHO S-44 specification and its formula.

- $S = \pm \sqrt{[\, a^2 + (b*d)^2 \,]}$ …….Equation 1

- Where:
- S = Uncertainty in bathymetric Survey
- a = that portion of the uncertainty that does not vary with depth
- b= a coefficient which represents the uncertainty that varies with depth
- d = the depth
- b *d= that portion of the uncertainty that varies with depth

ERROR IN DEPTH MEASUREMENT AND POSITIONING DUE TO SONAR BEAM WIDTH AND SLOPING SEA BED



A = Slope angle is less than one half the beam width

B = Slope angle is greater than one half the beam width

(IHO Manual On Hydrography, 2005)

$$dz = z_m(\sec(\xi) - 1) \text{ if } \xi < \frac{\emptyset}{2}$$ .....Equation 2

$$dz = z_m\left(\sec\left(\emptyset/_2\right) - 1\right) \text{ if } \xi > \frac{\emptyset}{2}$$ .....Equation 3

Where:

ξ = Slope angle

ϕ = Beam width

dZ = Error in depth measurement

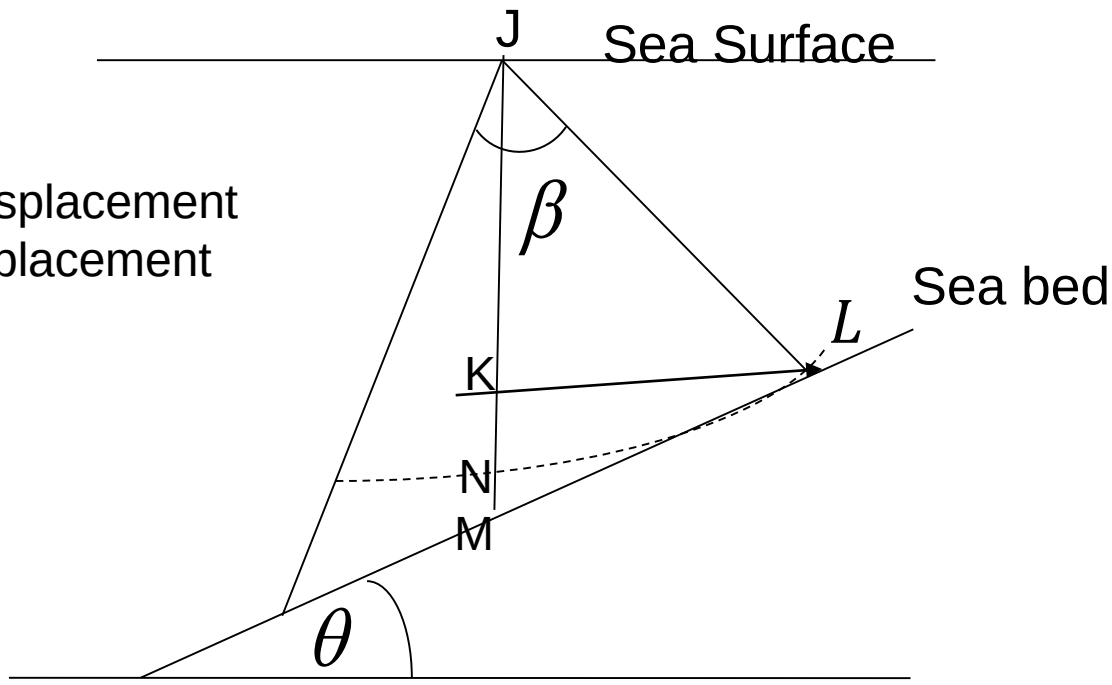
(IHO Manual on Hydrography , 2005)

Uncertainties in vertical and horizontal positions due to sloping sea bed

KL= horizontal displacement
NM = vertical displacement

β = beam width

θ = slope angle



$$NM = JL\left(\tan {}^{\beta}/_{2}\, sin\theta - 1 + \cos {}^{\beta}/_{2}\right) \text{.....Equation 4}$$

$$KL = JL \tan {}^{B}/_{2}\ cos\theta \text{ .....Equation 5}$$

(Oliver Ojinnaka, 2007)

COMPUTATIONS AND MODELLING

❖The NM (vertical displacement) in equation 4 is understood to mean the same thing as dz (error in depth measurment) in equation 2 & 3 and TVU (Vertical Uncertainty) in IHO S-44 table

❖Horizontal uncertainties were given on the IHO table while Vertical uncertainties were computed by substituting the values of “a” , “b” and the specified depth from S-44 table in equation 1

COMPUTATION RESULT

ORDER	DEPTH	THU	TVU
SPECIAL	40.00m	2.00m	0.391m
1(a,b)	100.00m	10.00m	1.393m

THU = Total Horizontal Uncertainty

TVU = Total Vertical Uncertainty

(Results are at 95% confidence level)

MODELLING PROCEDURE

- Compute the values of THU and TVU as explained above
- Set the values of THU and TVU as limits to check the range of acceptable values.
- Model equations 4 and 5 separately in excel worksheet. Equation 4 computes sonar beamwidth (β) while equation 5 computes slope angle (θ)
- Vary the estimated value of one parameter, while the other is constant
- Stop the variation at the point when either THU or TVU reaches maximum value

Summary of the variations of beamwidth at constant slope angle for depth =40.00m (Special Order)

SLOPE ANGLE (deg)	BEAMWIDTH (deg)	DEPTH (m)	TVU(m)	THU(m)
1	5.73	40	-0.020	2.00
2	5.73	40	0.019	2.00
3	5.74	40	0.055	2.00
4	5.74	40	0.089	2.00
5	5.75	40	0.125	2.00
6	5.76	40	0.159	2.00
7	5.77	40	0.195	2.00
8	5.79	40	0.230	2.00
9	5.80	40	0.266	2.00
10	5.82	40	0.302	2.00
11	5.84	40	0.337	2.00
12	*5.86*	*40*	*0.373*	*2.00*

Summary of the Variations of Slope angles at Constant Beam width for depth = 40.00m

Slope Angle (deg.)	Beam width (deg.)	Depth (m)	TVU (m)	THU (m)
34.67	2.00	40	0.391	0.574
22.73	3.00	40	0.391	0.966
17.30	4.00	40	0.391	1.334
14.22	5.00	40	0.391	1.693
12.28	*6.00*	*40*	*0.391*	*2.048*

Summary of the allowable limits of Beam widths computed when beam widths are varied at respective constant slope angles at depth equal to 100.00m (1(a,b))

S/N	Slope Angle (deg)	Beam Width (deg)	Depth (m)	TVU (m)	THU (m)
1	1	11.43	100	-0.322	10.006
2	2	11.43	100	-0.148	10.002
3	3	11.44	100	0.026	10.003
4	4	11.45	100	0.201	10.001
5	5	11.47	100	0.375	10.005
6	6	11.49	100	0.549	10.006
7	7	11.51	100	0.724	10.003
8	8	11.54	100	0.900	10.006
9	9	11.57	100	1.076	10.006
10	10	11.60	100	1.252	10.003
11	*11*	*11.64*	*100*	*1.429*	*10.01*

Summary of the allowable limits of Beamwidth computed at varying slope angles and constant Beamwidth at water depth 100.00m (1(a,b))

S/N	Slope Angle (deg)	Beam Width (deg)	Depth (m)	TVU (m)	THU (m)
1	53.8	2	100	1.393	1.031
2	33.03	3	100	1.393	2.195
3	24.6	4	100	1.393	3.175
4	19.93	5	100	1.393	4.105
5	16.97	6	100	1.393	5.013
6	14.96	7	100	1.392	5.909
7	13.53	8	100	1.392	6.799
8	12.48	9	100	1.392	7.684
9	11.69	10	100	1.392	8.567
10	***11.1***	***11***	***100***	***1.393***	***9.449***
11	10.64	12	100	1.393	10.330

CONCLUSION

At 95% confidence level, the limit of the sonar beam width angles of 6° and 12° are most suitable for IHO Special order and Order 1(a&b) respectively

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