NAVCOM # 30
3 Nov. 70

INTERVISIBILITY OF SHIPS AT SEA

Notes On

HCBrown

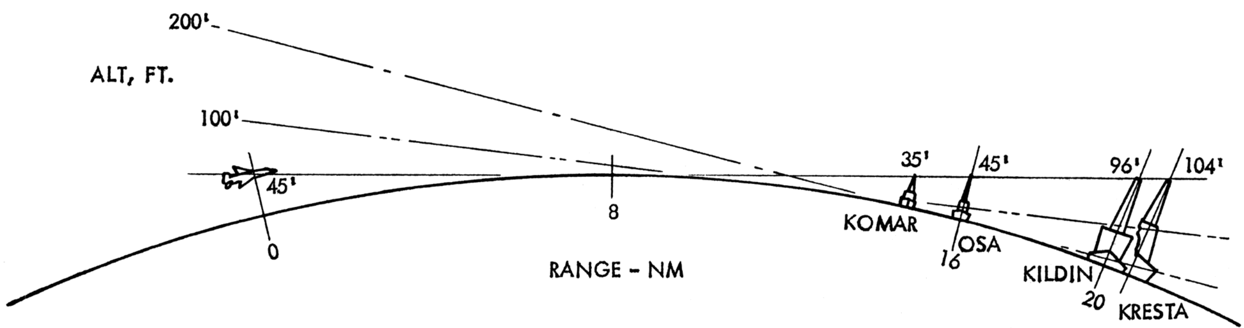
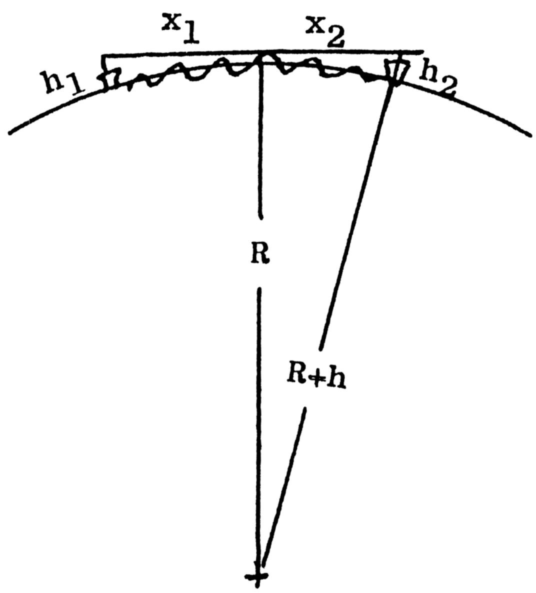


Figure 1 - Target Acquisition Geometry

1. The distance at which the top of one ship can be seen from the top of the other can be calculated as $x_1 + x_2$, which are calculated from the top of the masts to a point where the line of sight is tangent to the sea surface.

2. Now in either case $x = \sqrt{(R+h)^2 - R^2} = \sqrt{2Rh + h^2}$, and since $h << R$ we can call it $\sqrt{2Rh}$. This holds pretty well for optics, though separation does enter the picture under certain meteorological conditions.



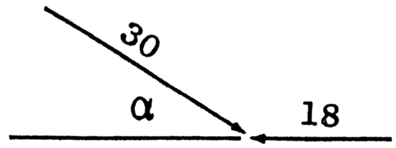
Sketch 1

3. For radar, in which the waves are normally refracted downward, we usually put in a factor of 4/3, making $x = \sqrt{2/3\ Rh}$. In effect we are pretending that the earth is larger than it is, and therefore we can see further. It is important to remember that this is only an assumed "average" refraction. There is about 50% chance that radar can see as far as is calculated

4. Now, when we introduce sea state, it is important to remember that there is virtually always at least one wave crest between observer and target. In fact, if the ships are some miles apart, there is high probability that the critical intervening crest is one of the highest to be anticipated in that sea state.

5. Both ships will rise and fall with the passage of the waves in a pattern sinusoidal in time. The amplitude of the rise and fall is modified by the bridging action across successive crests - only the smallest craft rise to the height of the highest crest. Therefore either h_1 or h_2 must be considered as oscillating sinusoidally (with respect to the intervening wave) between some value less than h_1 or h_2 or some value greater than h_1 or h_2 less the height of the intervening wave. Of course, if one of the "ships" is an aircraft it does not oscillate. It must still, however, look over the top of an intervening wave, and its target will oscillate.

6. If both ships are qoscillating they will not, in general, maintain the same phase relationship. The cyclic frequency of each will be the cycle of the waves relative to the vector velocity of the vessel.



Sketch 2

As an example, suppose we have waves of length 190' and velocity of 18 knots (lower end of state 5 sea, height of wave about 8 1/2 ft). The velocity of a 30 knot craft relative to the wave crests will be $| 30\cos\alpha + 18 |$. The period of oscillation will be 190' divided by that relative speed. The shortest period is:

$$\frac{130\times 60\times 60}{48\times 6080} = 2.34 \text{ sec}.$$

The longest period is ∞, when $\alpha = \cos^{-1}\frac{-18}{30}$. This represents a case in which the ship is maintaining position on a crest (sensor) or in a trough (target). Either tactic may be reasonably feasible, dependent on what are the other constraints on course and speed.

7. If neither ship is employing such "optimization" tactics, the intervisibility distance will oscillate between maximum and minimum according to a complex wave produced by summing two sine waves of different frequencies and probably of different amplitudes.

8. It would probably be better to speak in terms of the visible height (from the top) of the target at a given distance - rather than the intervisibility distance.

NAVCOM # 30 - Attachment
26 Oct. 70

EXOCET/KORMORAN TARGET ACQUISITION

Target acquisition from low altitude trajectory can peer over horizon and see the target (clear of clutter).

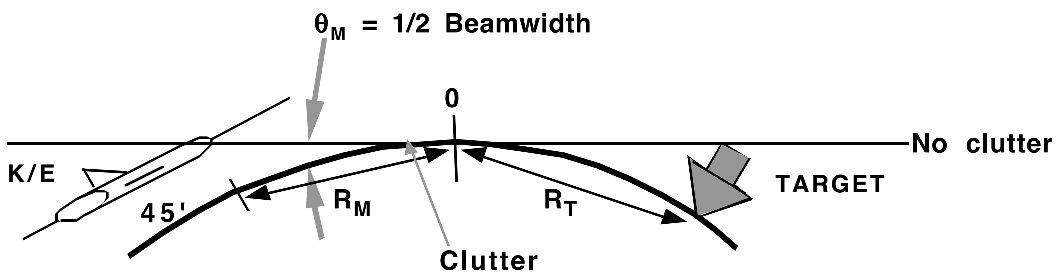


Figure 1 - Geometry

<u>Work Out Geometry</u>

Calculate freespace range of X-Band Fixed Frequency Radar:

		<u>KORMORAN</u>	<u>EXOCET</u>
λ	=	9000 MH (fixed)	upper X-Band (fixed)
P_{ave}	=	30 Watts	-----
P_{peak}	=	60 KW	40 KW
PRF	=	1600 Hz	High
Waveform	-	Shortpulse	100 nanoseconds
Range Gate	-	90 feet deep	----
etc.			etc.

Acquisition Range - Free Space

Claim Acquisition Range 7 nmi / 50 m^2 / 55.5

Reference Weyers –

	DISPL	SPEED	LENGTH	BEAM	DRAFT	HEIGHT (approx.)	
	(tons)	(knots)	(feet)	(feet)	(feet)	TOPMAST	2ND TOPMAST
OSA	200	35	130			45'	30'
KOMAR	75	40	90			35'	20'
KYLDIN (DG)	4000	35	420	42.8	15.9	96'	68'
KRESTA (DG)	7000	36	508	54.6	19.8	104'	78'
DE 1052 (KNOX)	4100	27	438	42.0	18.1	100'	60'

Table 1

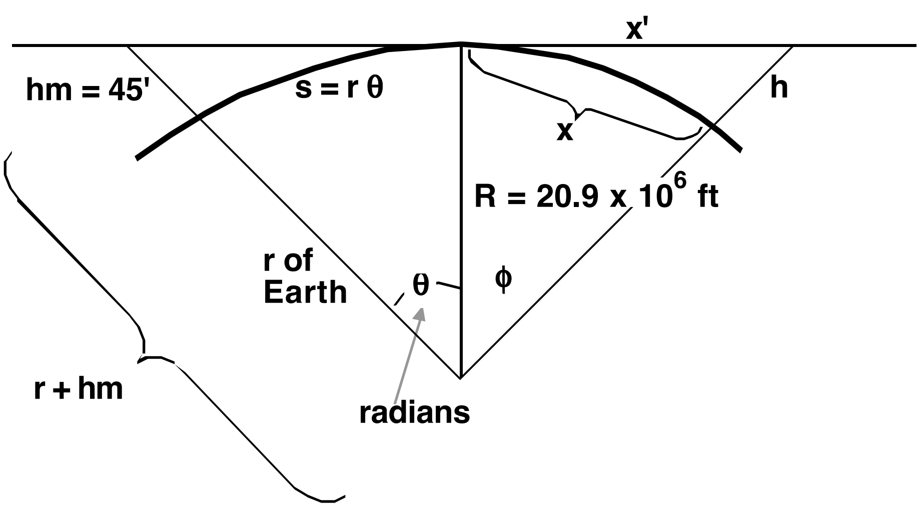


Figure 2

Circumference of Earth = 360(60') = 21,500 nmi

r = 21,500/2Π = 3,410 nmi

$\theta = \cos^{-1} r/(r+hm) = 3410/(3410 + (45/6000)) =$

$x^2 = 4/3(R + h)^2 - (4/3\ R)^2$

$x^2 = h^2 + 8/3\ R\ h$

$x = \sqrt{h^2 + 8/3\ R\ h}$ chord

$h << R$

$\therefore\ x \approx \sqrt{8/3\ R\ h}$

$x = \sqrt{8/3\ (20.9 \times 10^6)}\ \sqrt{h} = \sqrt{55 \times 10^6}\ \sqrt{h} = 7.4 \times 10^3\ \sqrt{h}$ feet

For h = 45'; x = 49,400 feet = 8.2 nmi

For h = 100'; x = 74,000' = 12.2 nmi

Note: this is the 4/3 earth law which includes radar refraction (ave 50% of time)