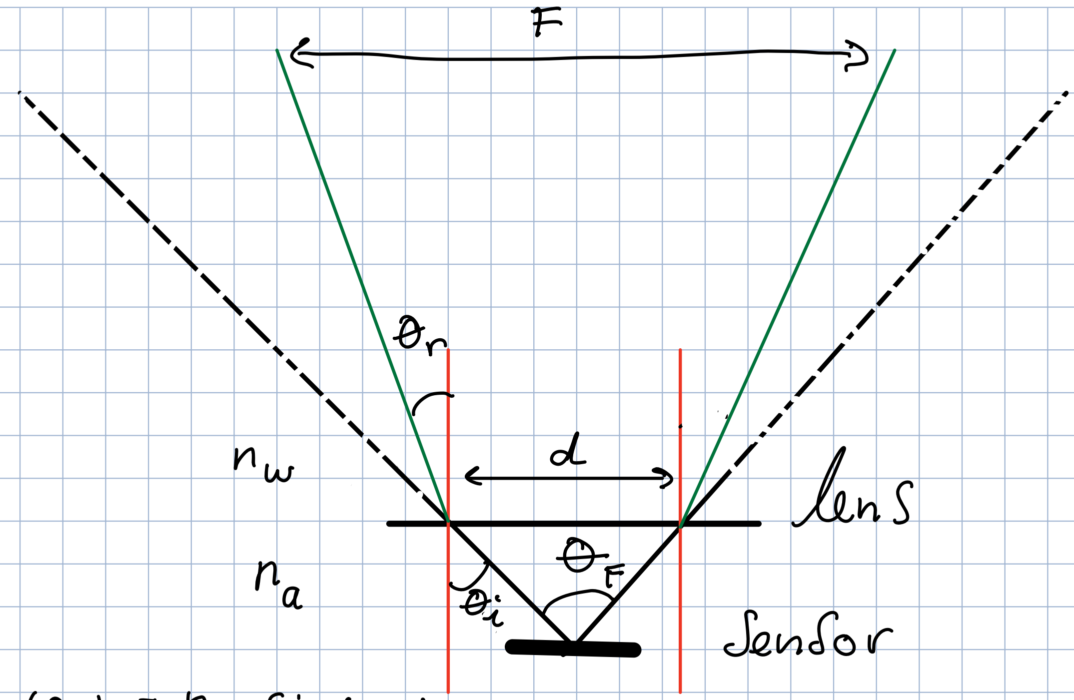
θ_F = Field of view on land



Snell's law: $n_a \cdot \sin(\theta_i) = n_w \cdot \sin(\theta_r)$

$$\theta_r = \sin^{-1}\left(\frac{n_a}{n_w} \cdot \sin(\theta_i)\right)$$

$$= \sin^{-1}\left(\frac{n_a}{n_w} \cdot \sin\left(\frac{\theta_F}{2}\right)\right)$$

when $d \ll F$ the field of view is equal to

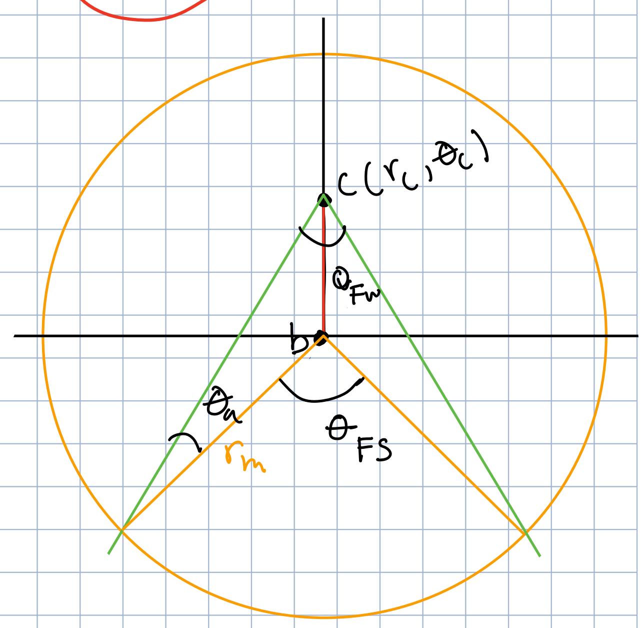
$$\boxed{FOV_{water} = 2 \cdot \theta_r = 2 \cdot \sin^{-1}\left(\frac{n_a}{n_w} \cdot \sin\left(\frac{\theta_F}{2}\right)\right)}$$

$$FOV_{water} = 2 \cdot \sin^{-1}\left(\frac{1}{1,33} \cdot \sin\left(\frac{120}{2}\right)\right) = 81,3^\circ$$

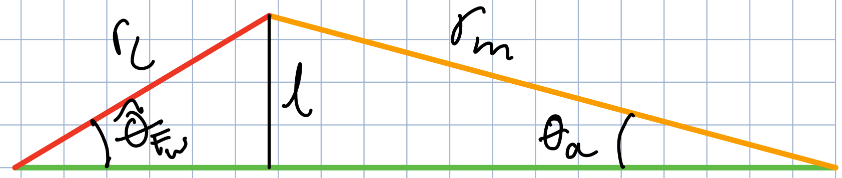
We place a camera at $[r_c, \theta_c]$ in a polar coordinate system

Next, we want to find the segment of the circle with radius r_m which is in the field of view

To do so, we want to find the shifted field of view angle θ_{FS} from the field of view angle θ_{FW}



r_c and r_m span a triangle



where

$$\hat{\theta}_{Fw} = \frac{1}{2} \cdot \theta_{Fw}$$

and

$$r_c \cdot \sin(\hat{\theta}_{Fw}) = r_m \cdot \sin(\theta_a)$$

$$\theta_{Fw} + 2\theta_a + \cancel{2\pi} - \theta_{Fs} = \cancel{2\pi}$$

$$\boxed{\theta_{FS} = \theta_{Fw} + 2\theta_a = \theta_{Fw} + 2 \cdot \sin^{-1}\left(\frac{r_c}{r_m} \cdot \sin\left(\frac{\theta_{Fw}}{2}\right)\right)}$$