レーダ開口と分解能

実開口レーダ　（**Real　Aperture Radar)**

方位分解能 (Azimuth Resolution)

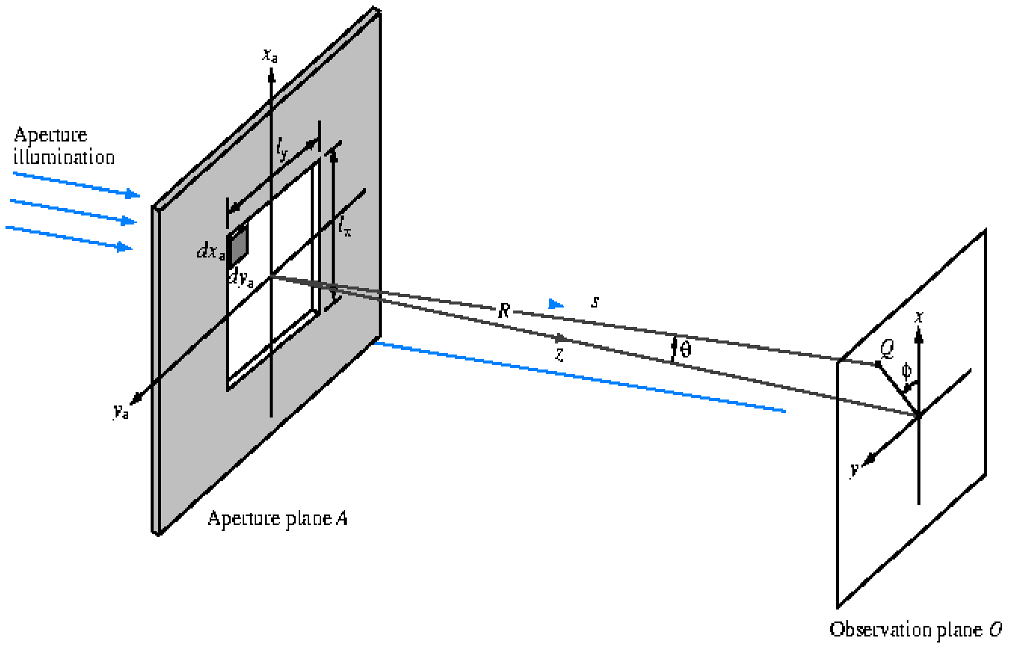
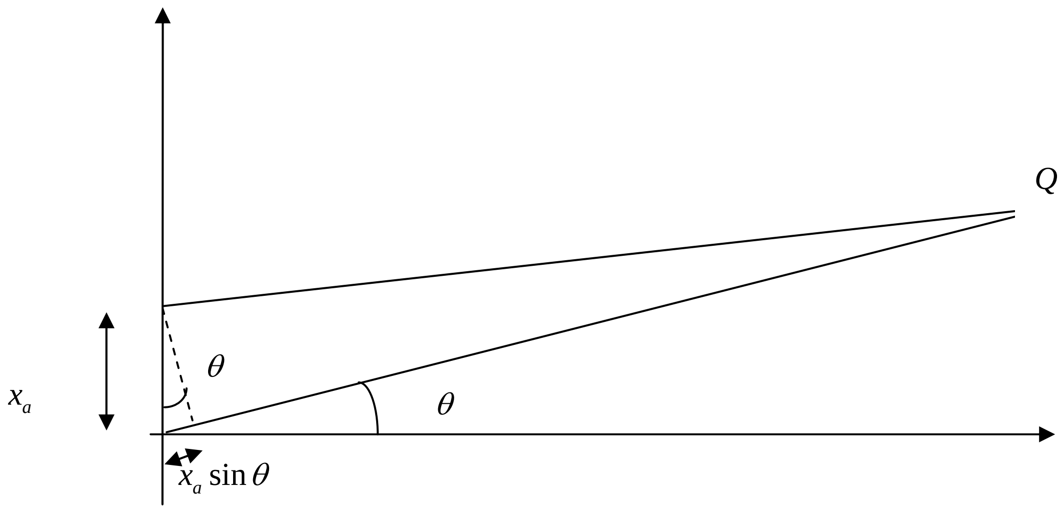


Figure 9-22

Fig.1.1 Antenna aperture (Ulaby 2001)



The antenna radiation pattern at far region, from an aperture shown in Fig.4.1 can be given by assuming the field strength on the aperture as:

$$E_a(x_a, y_a) = \begin{cases} E_0 & \text{for } -\ell_x/2 \le x_a \le \ell_x/2 \text{ and } -\ell_x/2 \le y_a \le \ell_x/2 \\ 0 & \textit{Otherwise} \end{cases} \qquad (7.3.1)$$

Then the radiation pattern in x-z plane ($\phi = 0$)is given by:

$$\begin{aligned} h(\theta) &= \int_{-\ell_y/2}^{\ell_y/2} \int_{-\ell_x/2}^{\ell_x/2} E_0 \exp(jkx_a \sin\theta) dx_a dy_a \\ &= E_0 \ell_x \ell_y \frac{\sin(\pi \ell_x \sin\theta/\lambda)}{\pi \ell_x \sin\theta/\lambda} \qquad (7.3.2) \\ &= E_0 \ell_x \ell_y \sin c(\pi \ell_x \sin\theta/\lambda) \end{aligned}$$

Then the power density of the radiation pattern is given by

$$S(R,\theta) = S_0 \sin c^2(\pi \ell_x \sin\theta/\lambda) \quad (x - z \quad plane) \qquad (7.3.3)$$

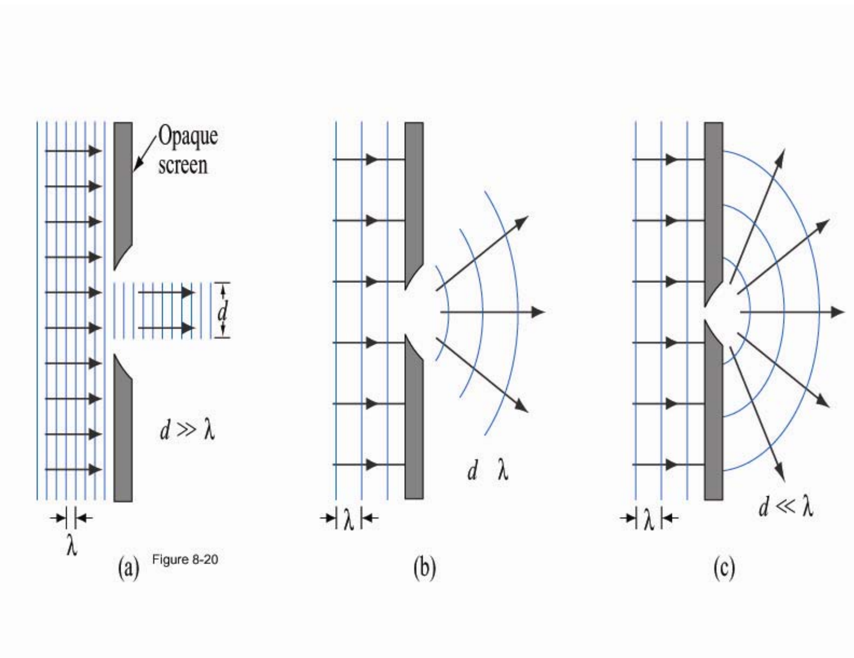
By the definition of radiation pattern, it is given by:

$$F(\theta) = \frac{S(R,\theta)}{S_{\max}} = \sin c^2(\pi \ell_x \sin\theta/\lambda) \qquad (7.3.4)$$

By using (1.4) we can find the beam width of the radiation pattern by solving

$$F(\theta_2) = \sin c^2(\pi \ell_x \sin\theta_2/\lambda) = 0.5 \qquad (7.3.5)$$

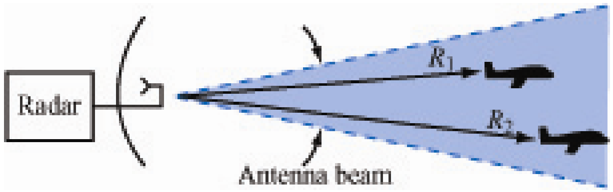
$$2\theta_2 \approx 2\sin\theta_2 = 0.88\frac{\lambda}{\ell_x} \approx \frac{\lambda}{\ell_x} \qquad (7.3.6)$$



地表でのアジマス分解能

$$\triangle(azimuth) = 2\theta_2 h = \frac{\lambda}{\ell_x} h$$

距離分解能　（レンジ分解能）　Range resolution



$$\triangle(range) = R_1 - R_2 = \frac{c\tau}{2}$$

Where τ is the pulse length.

The spectrum of the rectangular pulse having the pulse length τ is given by:

$$F(\omega) = \int_{-\frac{\tau}{2}}^{\frac{\tau}{2}} e^{-j\omega t} dt = -\frac{\sin\frac{\omega}{2}\tau}{\frac{\omega}{2}}$$ which has the dominant frequency spectrum $-\frac{1}{\tau} \le f \le \frac{1}{\tau}$, and the frequency bandwidth is $B = 2f = \frac{2}{\tau}$

$$\triangle(range) = \frac{c\tau}{2} = \frac{c}{B}$$

7.4 Radar resolution

When an antenna is equipped on a spacecraft or an airplane, the radiation pattern from this antenna determines the area of the radar signal. This area is called “foot print” of radar system, and it determines the resolution of radar system.

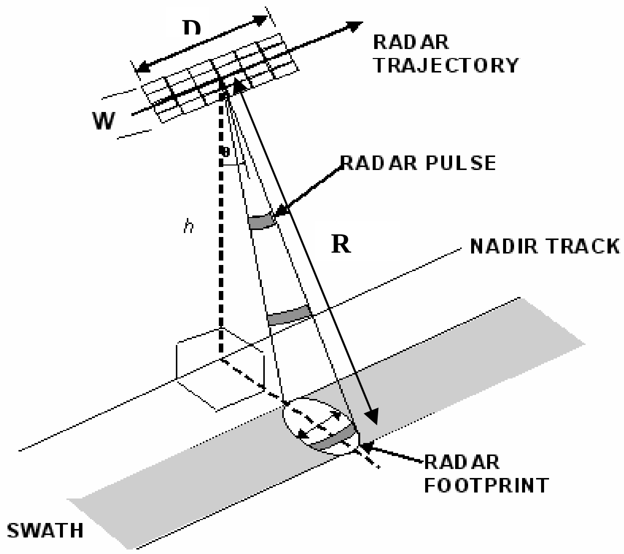
Radar range resolution ρ_{rg} depends on the pulse width τ and it is given by the frequency bandwidth W and is given as:

$$\rho_{rg} = \frac{c\tau}{2} = \frac{c}{2W} \quad (7.4.1)$$

In the azimuth direction, the antenna angle of radiation pattern is approximately given by (7.3.6) and the actual length of the azimuth radiation pattern is

$$\rho_{az} = 2\theta_2 R \simeq \frac{\lambda}{D} R \quad (7.4.2)$$

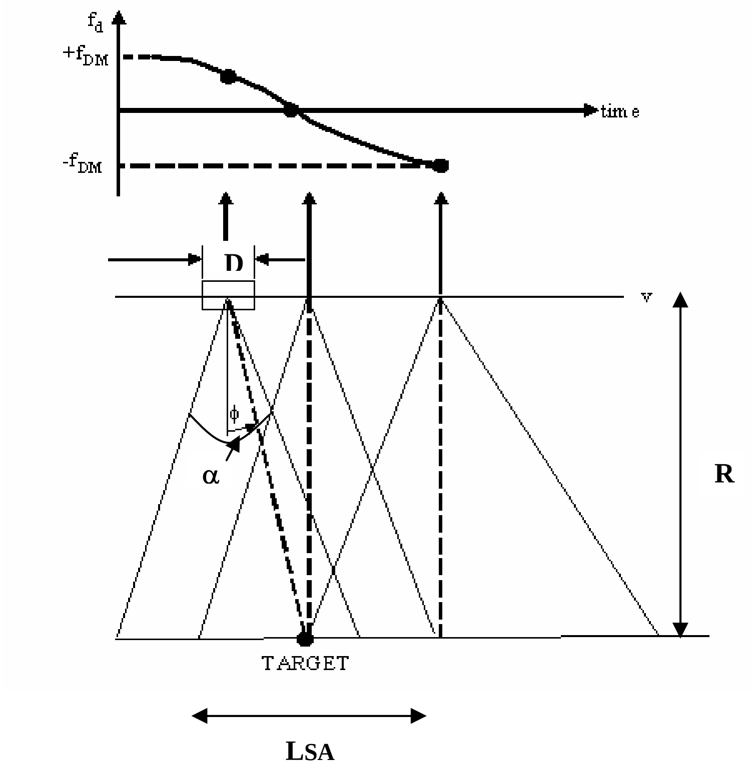
where D is the size of the antenna aperture and R is the range from the antenna to the radar foot print on the ground surface.



The definition above is applied directly for the antenna, and it is called a real aperture radar.

合成開口レーダ　**Synthetic Aperture Radar (SAR)**

On the contrary to the real aperture radar, synthetic aperture radar (SAR) utilizes the radar information during the certain period of flight. When the radar target is stationary and the radar acquires the data while flying the flight path length of L_{SA}, the azimuth resolution of the total data sets are given as;



$$\alpha_{SAR} \simeq \frac{\lambda}{2L_{SA}} \qquad (7.5.1)$$

The factor 2 accounts for the effect of sequential emission of the elements of the synthesized antenna in the case of SAR. The phase difference between equally spaced elements of the synthetic aperture is over the two-way-path difference, and thus it is twice that of a conventional real aperture antenna, where the elements transmit simultaneously.

Using the result obtained for the real aperture antenna, we can derive:

$$L_{SA} = \alpha R = \frac{\lambda}{D} R \quad (7.5.2)$$

and substituting (7.5.2) into (7.5.1) gives:

$$\alpha_{SAR} = \frac{D}{2R} \qquad (7.5.3)$$

and the azimuth resolution is given by:

$$\rho_{AZ} = \alpha_{SAR} R = \frac{D}{2} \qquad (7.5.4)$$

レーダシステムのレーダ分解能比較

	PALSAR	Pi-SAR	Terra-SAR	RADARSAT-1	GPR
h (km)	700	1.2	515	798	0.0001
ℓ_x (m)	8.9	1.7	4.8	15	1
f_c (GHz)	1.27	1.27	9.65	5.3	1
λ (m)	0.23	0.23	0.031	0.056	0.3
B (MHz)	28	50	150	30	500
$\vartriangle(azimuth) = 2\theta_2 h = \frac{\lambda}{\ell_x} h$ (km)	18.1	0.16	3.32	2.98	0.00003
$\frac{\ell_x}{2}$ (m)	4.5	0.85	2.4	7.5	0.5
$\vartriangle(range) = \frac{c\tau}{2} = \frac{c}{B}$ (m)	11	6	2	10	0.6