OUTLINE

I. Radar imaging - Spatial resolution

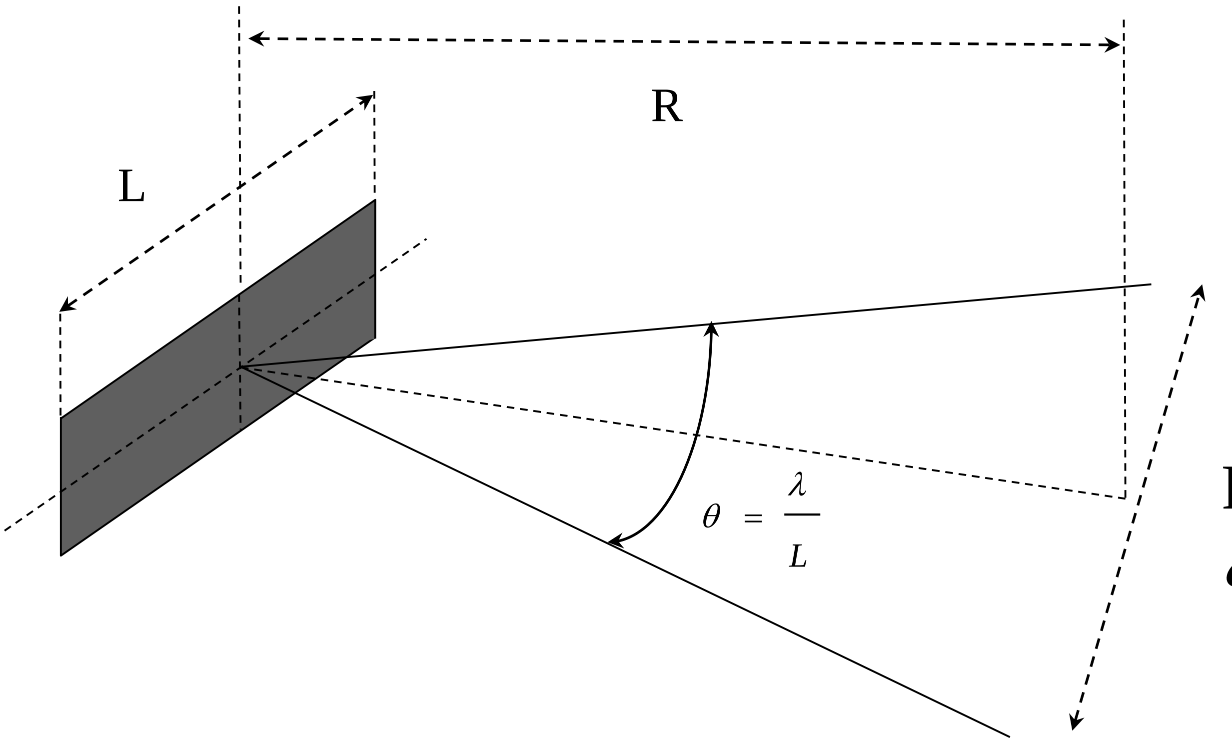
II. Polarization - Polarimetry

III. Radar response sensitivity

IV. Relief effects

V. Speckle and Filtering

ANTENNA APERTURE



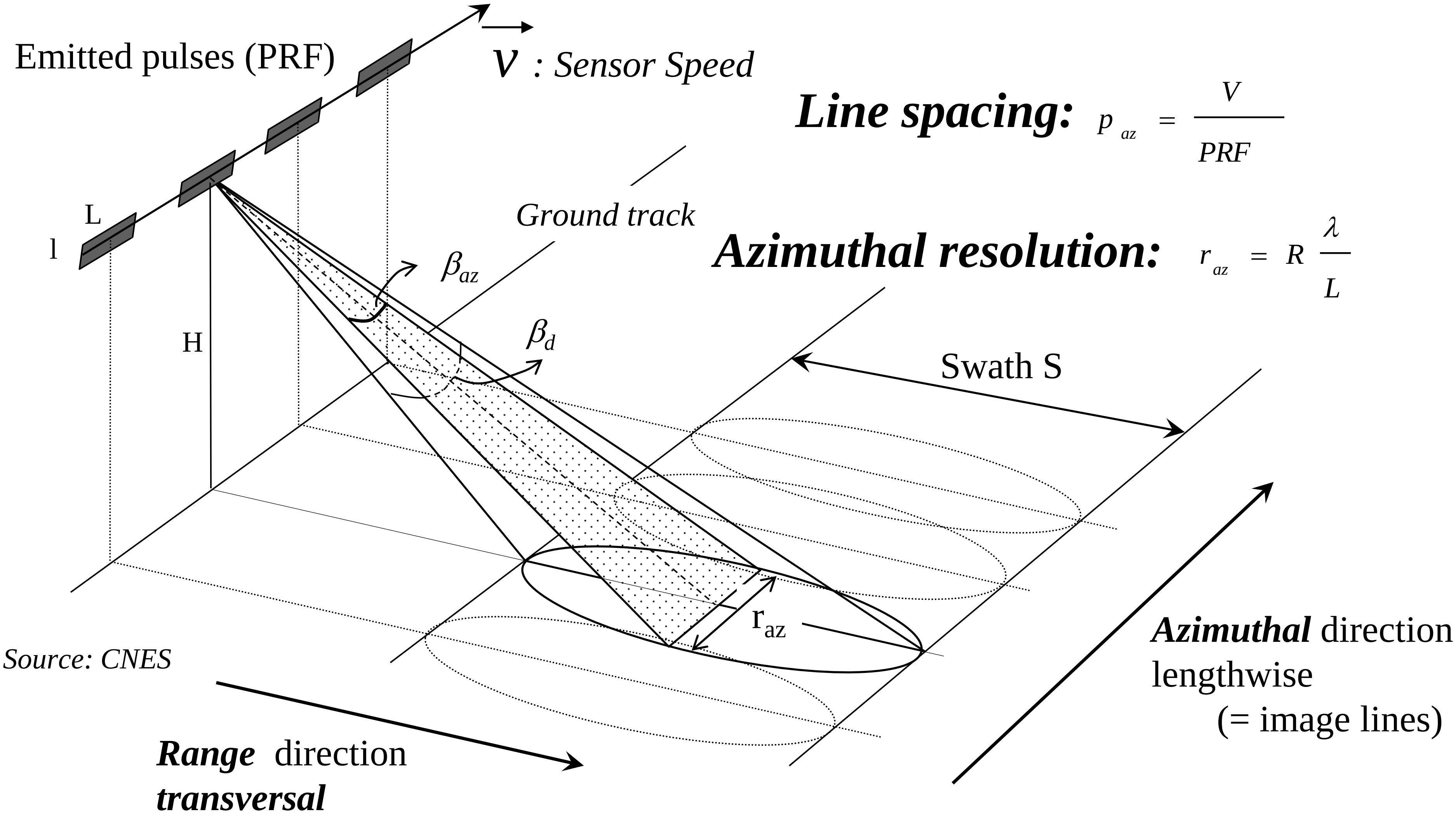
Resolution

$\delta r = \theta \, . \, R$

Ex.: L = 4 m, R = 4 km (airborne), λ = 3 cm (X band) δr = ***30 m***

L = 10 m, R = 800 km (spaceborne), λ = 6 cm (C band) δr = ***4,5 km***

Radar Imaging – spatial resolution



Line spacing: $p_{az} = \frac{V}{PRF}$

Azimuthal resolution: $r_{az} = R\frac{\lambda}{L}$

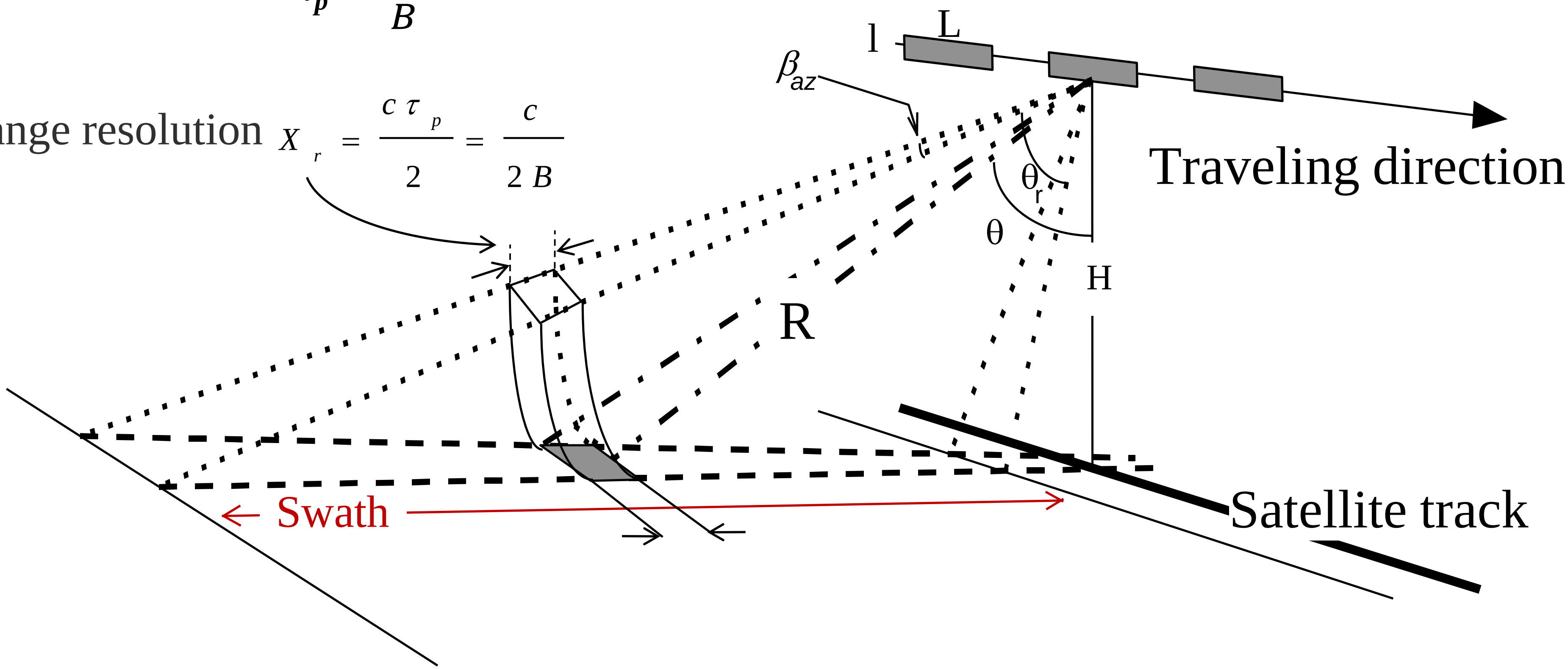
Numerical Application (ERS):

$PRF=1680\ Hz,\ V=7km/s$ $\mathbf{p_{az} \approx 5\ m}$	$L=10\ m,\ \lambda=5.6\ cm,\ H=700\ km,\ \theta=23°$ $\mathbf{r_{az} \approx 4.2\ km}$

Radar Imaging – spatial resolution

Pulse duration = $\tau_p = \dfrac{1}{B}$

Range resolution $X_r = \dfrac{c\,\tau_p}{2} = \dfrac{c}{2B}$



☞ ***Increase the pulse B***

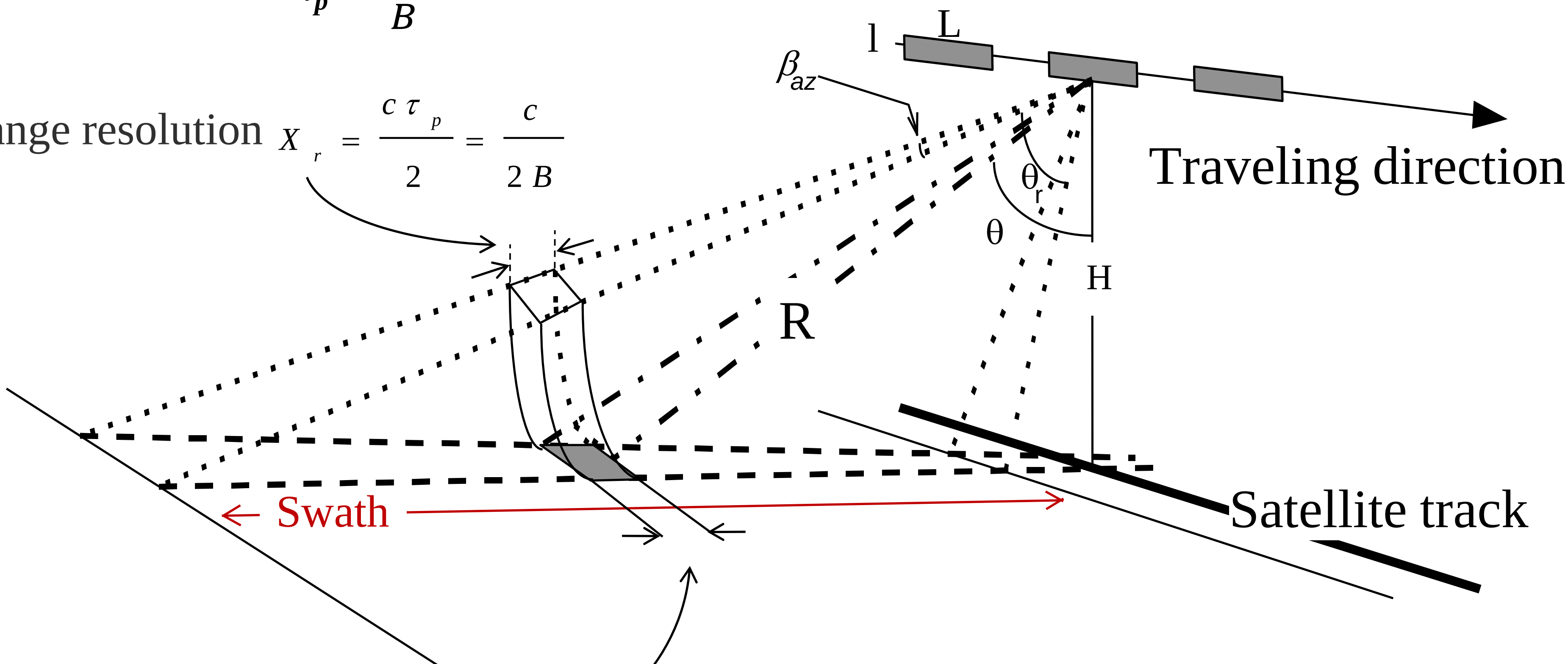
Num. Appl. (ERS): $\tau_p = 37\ \mu s$ $B \approx \cancel{30\ kHz}$ $15.5\ MHz$

$X_r \approx 10\ m$

Radar Imaging – spatial resolution

Pulse duration = $\tau_p = \dfrac{1}{B}$

Range resolution $X_r = \dfrac{c\,\tau_p}{2} = \dfrac{c}{2B}$



Ground Range resolution:

$$X_{gr} = \frac{c\,\tau_p}{2\sin\theta} = \frac{c}{2B\sin\theta}$$

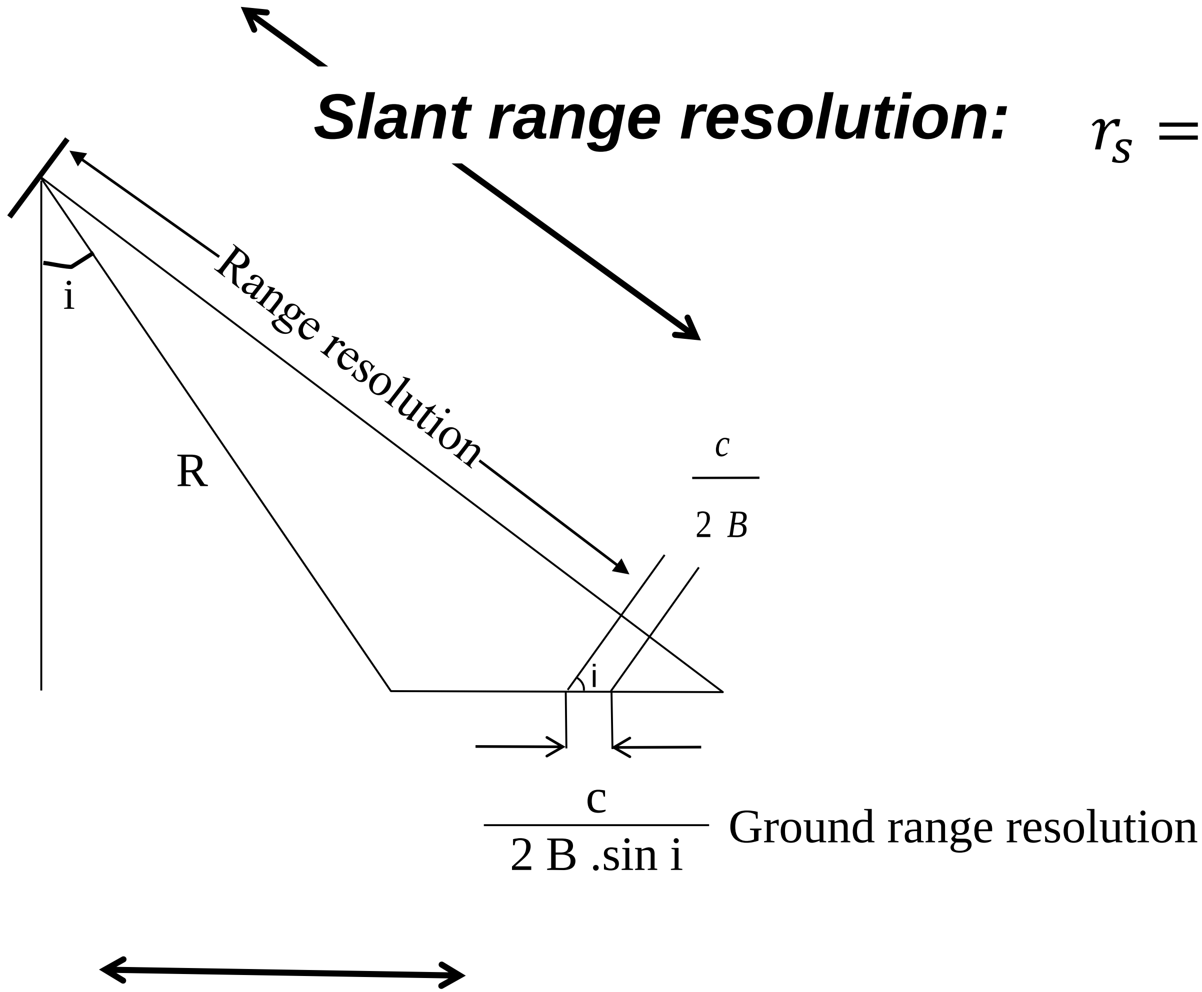
☞ ***Increase the pulse B***

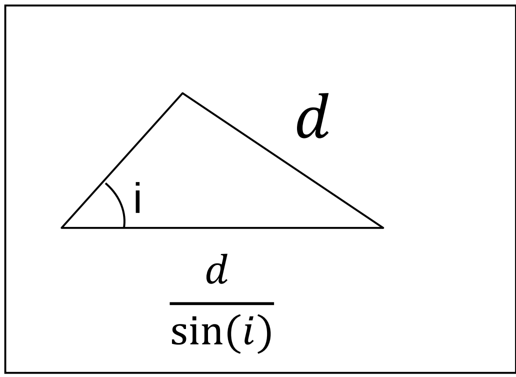
Num. Appl. (ERS): $\tau_p = 37\ \mu s \quad B \approx \cancel{30\ kHz}\quad 15.5\ MHz$

$X_r \approx 10\ m$

Radar Imaging – spatial resolution

Slant range resolution: $r_s = \dfrac{c}{2\,B}$



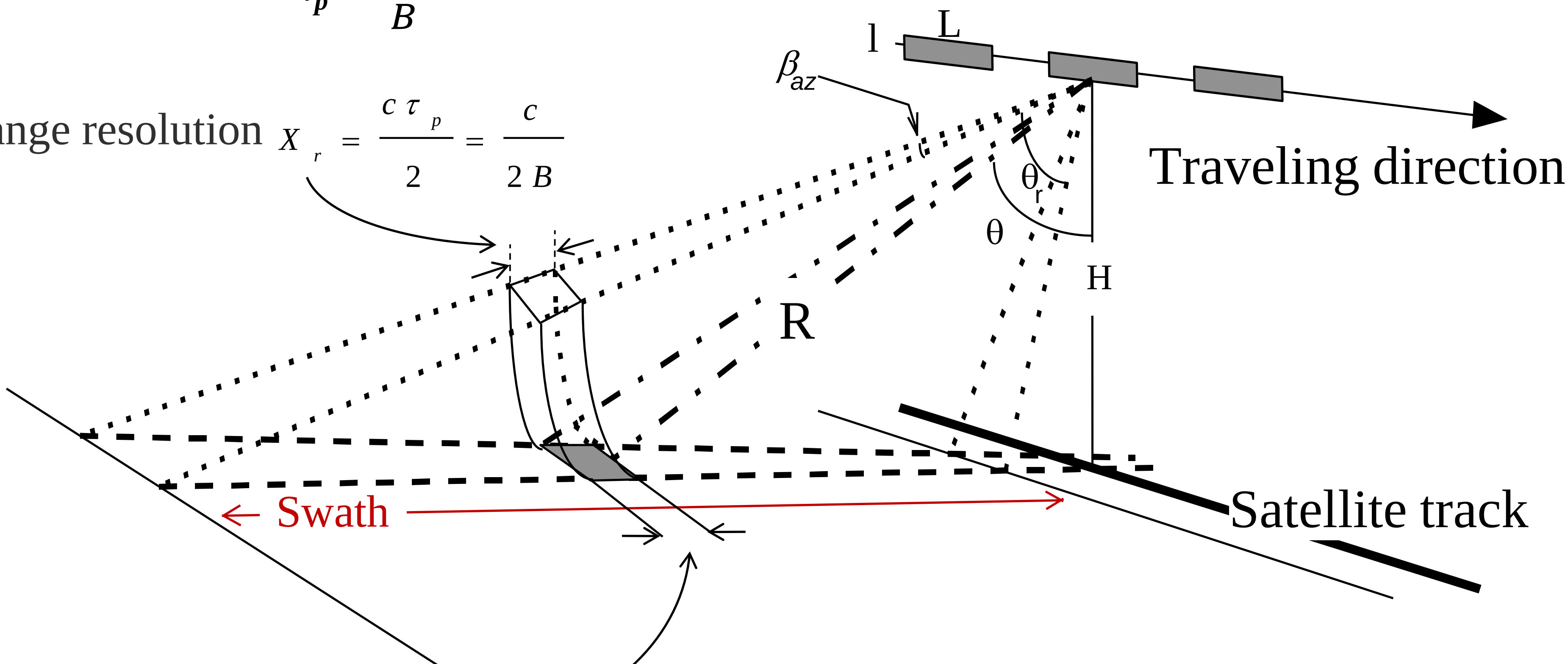


Ground range resolution: $X_{gr} = \dfrac{c}{2\,B\,\sin\,(i)}$

Radar Imaging – spatial resolution

Pulse duration = $\tau_p = \dfrac{1}{B}$

Range resolution $X_r = \dfrac{c\,\tau_p}{2} = \dfrac{c}{2B}$



Ground Range resolution:

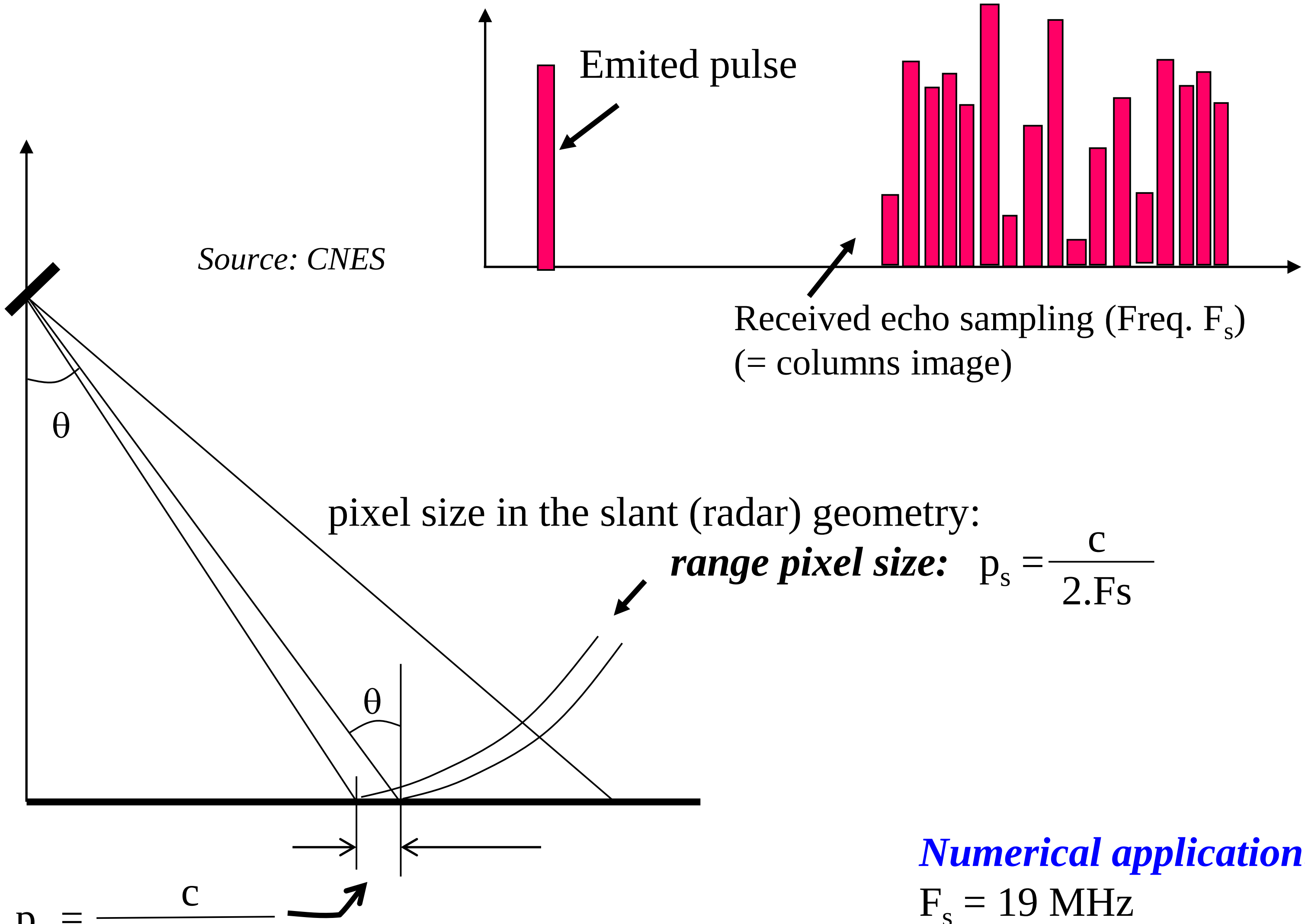
$$X_{gr} = \frac{c\,\tau_p}{2\sin\theta} = \frac{c}{2B\sin\theta}$$

☞ ***Increase the pulse B***

Num. Appl. (ERS): $\tau_p = 37\ \mu s$ $B \approx$ ~~30 kHz~~ 15.5 MHz

$X_r \approx 10\ m$ $X_{gr} \approx 25\ m$

Radar Imaging – spatial resolution



pixel size in the slant (radar) geometry:

range pixel size: $p_s = \dfrac{c}{2.Fs}$

$p_g = \dfrac{c}{2.Fs.\sin\theta}$

Ground pixel size

Numerical application: ERS

F_s = 19 MHz

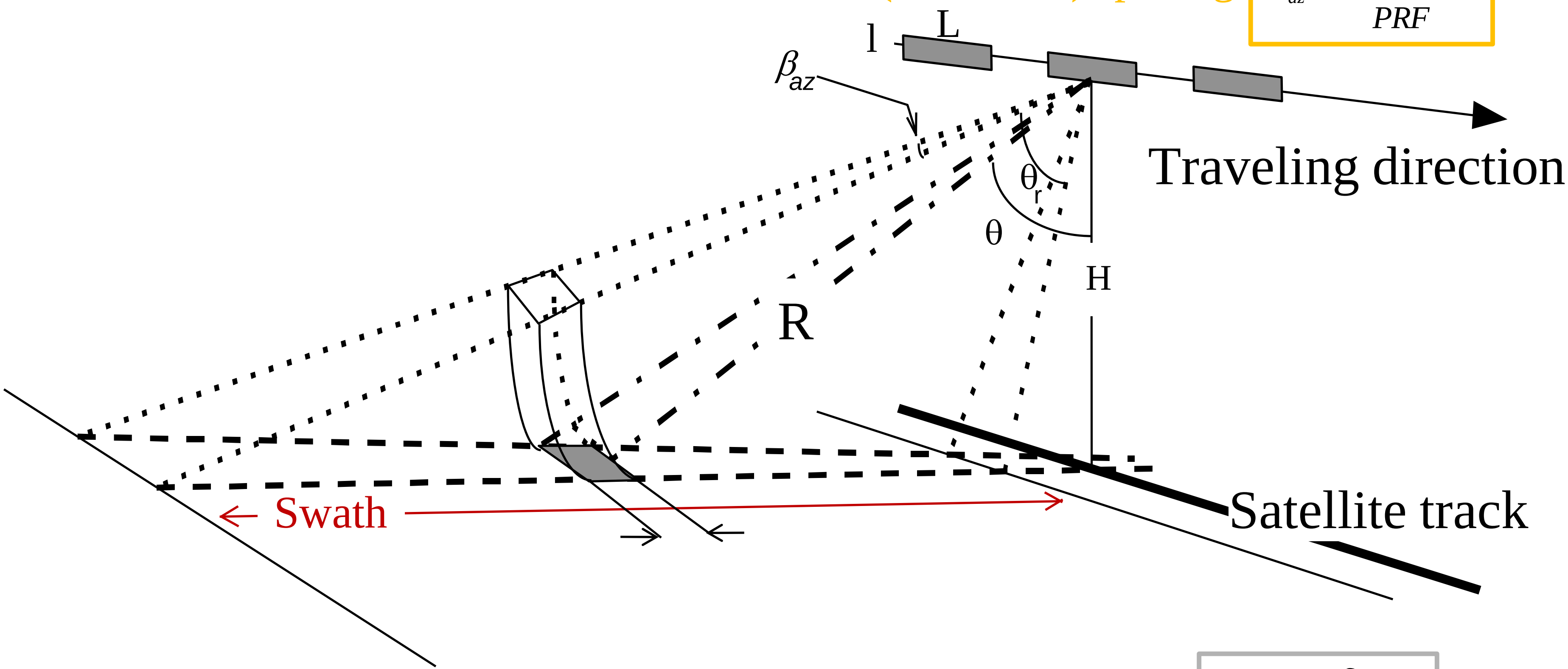
$\boldsymbol{p_s \approx 8\ m}$

$\boldsymbol{p_g \approx 20\ m}$

Radar Imaging – spatial resolution

Line (azimuthal) spacing

$$p_{az} = \frac{V}{PRF}$$



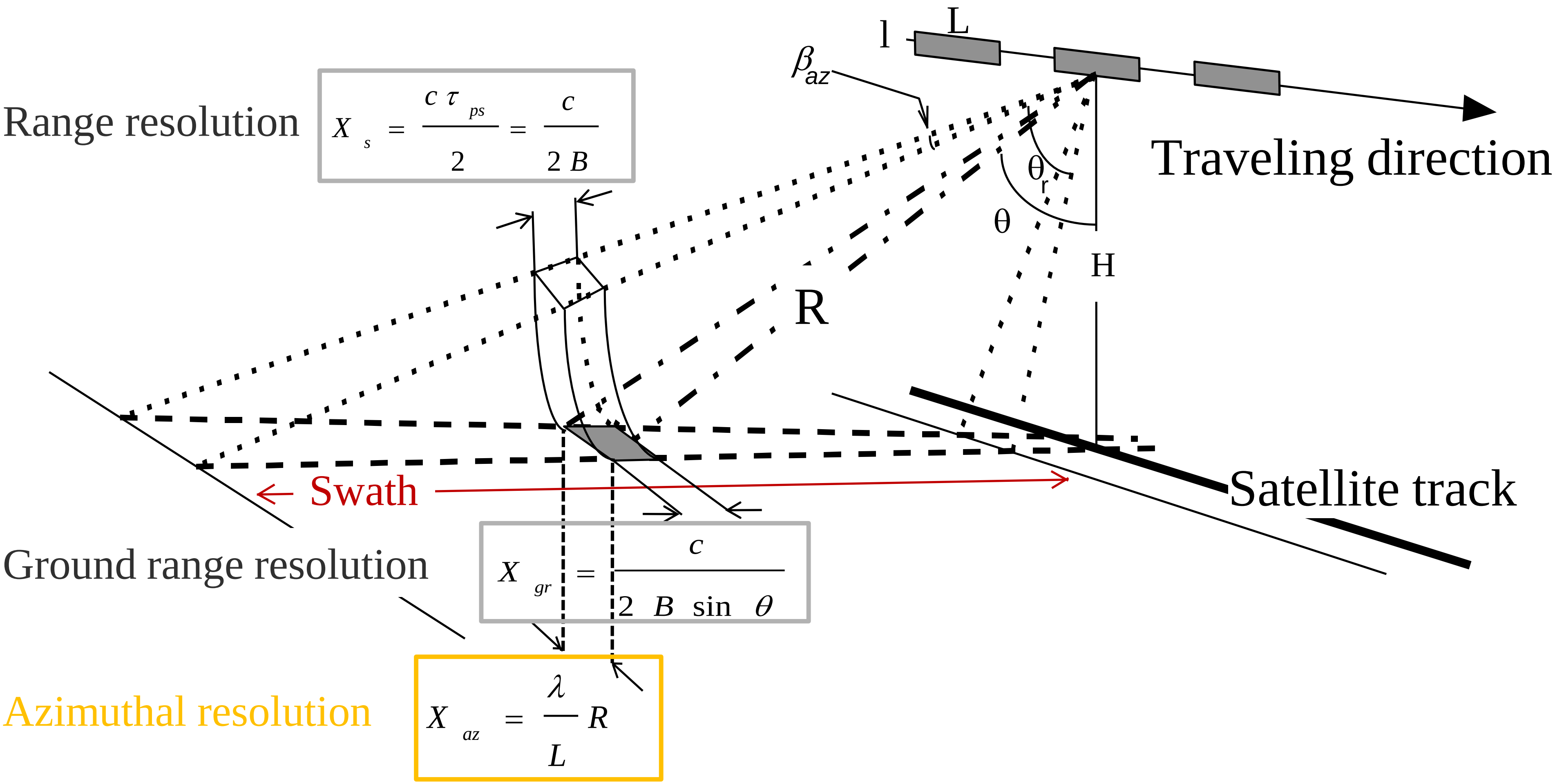
Range pixel (column) size

$$p_s = \frac{c}{2 F_s}$$

Ground range pixel size

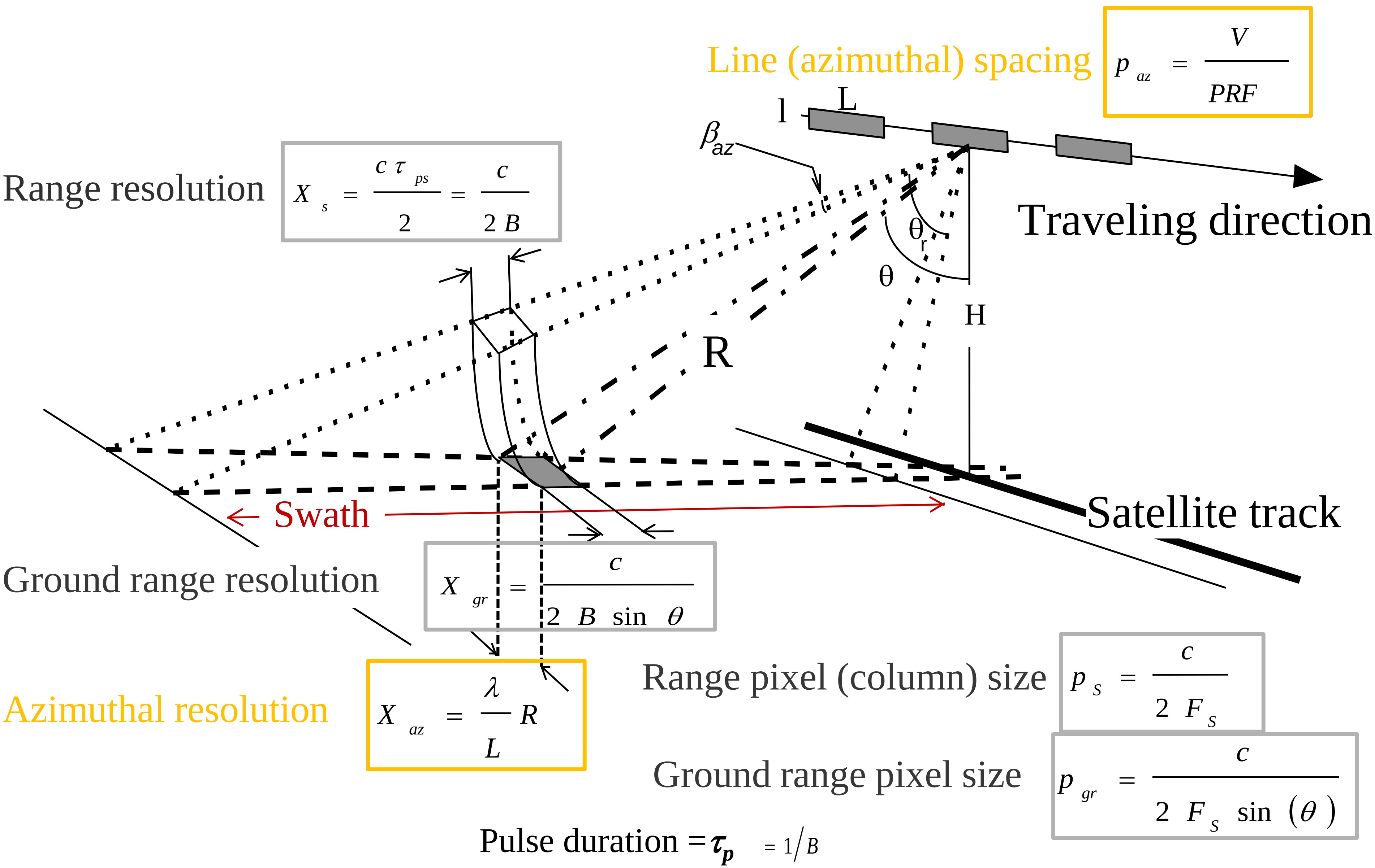
$$p_{gr} = \frac{c}{2 F_s \sin(\theta)}$$

Radar Imaging – spatial resolution



Pulse duration $= \tau_p = 1/B$

Radar Imaging – spatial resolution



Radar Imaging – spatial resolution

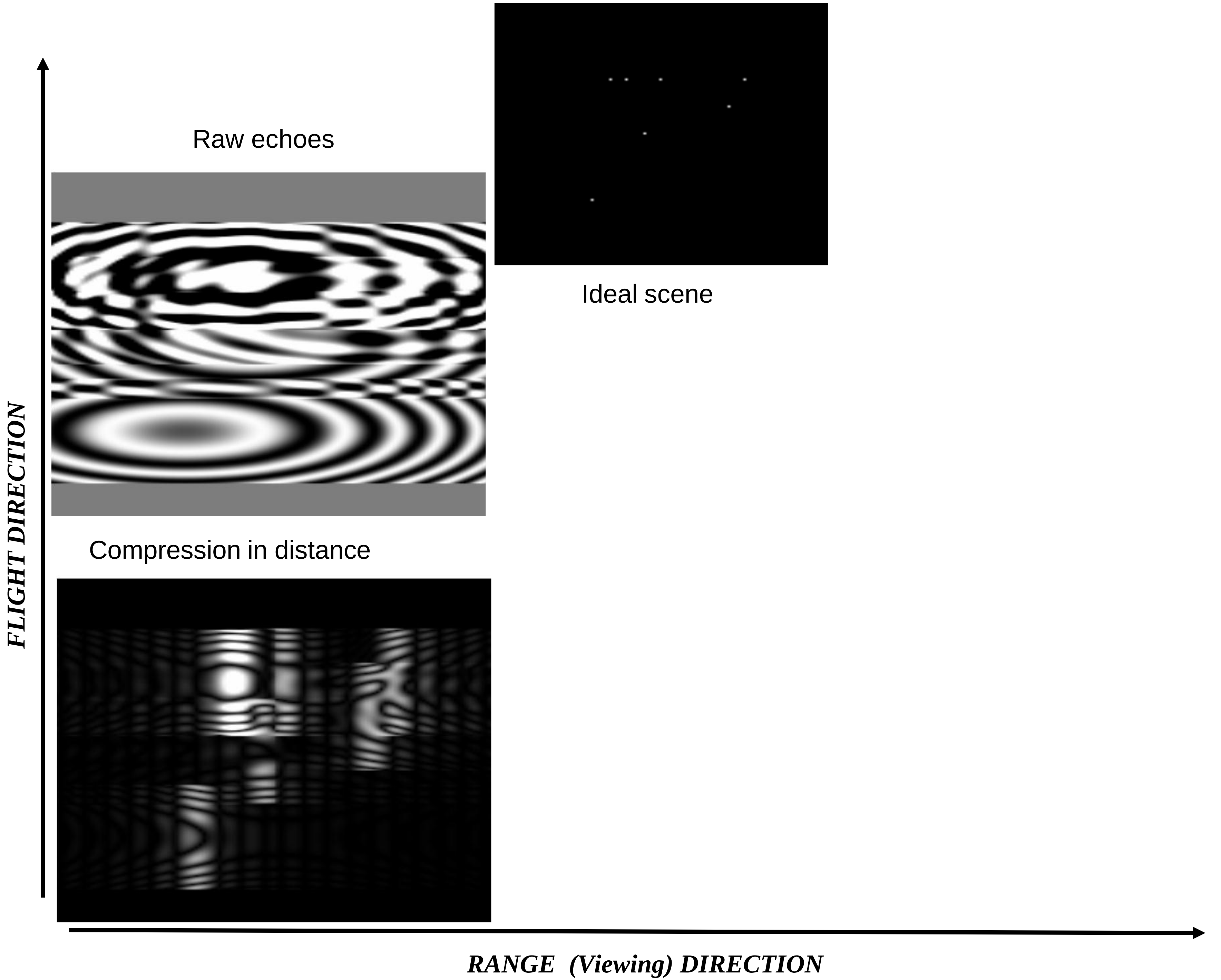
Case of ERS

	Range		Azimuth
	Slant (radar)	Ground	
Resolution	$X_s = \frac{c}{2B}$ ***= 10 m***	$X_{gr} = \frac{c}{2B\sin(\theta)}$ ***= 25 m - 32 m***	$X_{az} = \frac{\lambda}{L}R$ ***~5 km***
Pixel size	$p_s = \frac{c}{2F_s}$ ***= 8 m***	$p_{gr} = \frac{c}{2F_S\sin(\theta)}$ ***= 20 m - 26 m***	$p_{az} = \frac{V}{PRF}$ ***= 4 m***

λ = 5.6 cm
V = 7 km/s
PRF =1680 Hz

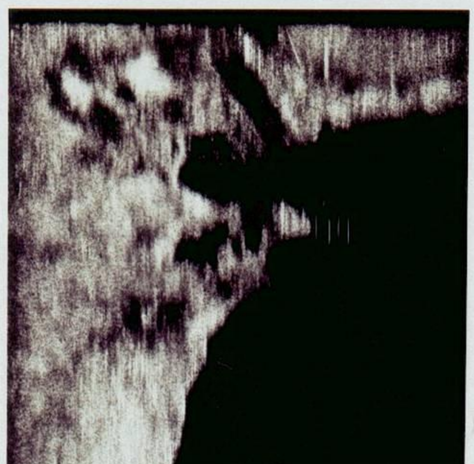
F_s = 19 MHz
θ = 18-24°
B =15.5 MHz

R = 15.5 MHz
L = 10 m


Raw echoes
Ideal scene
Compression in distance
FLIGHT DIRECTION
RANGE (Viewing) DIRECTION

NON COMPRIME DISTANCE
NON COMPRIME AZIMUT

Document

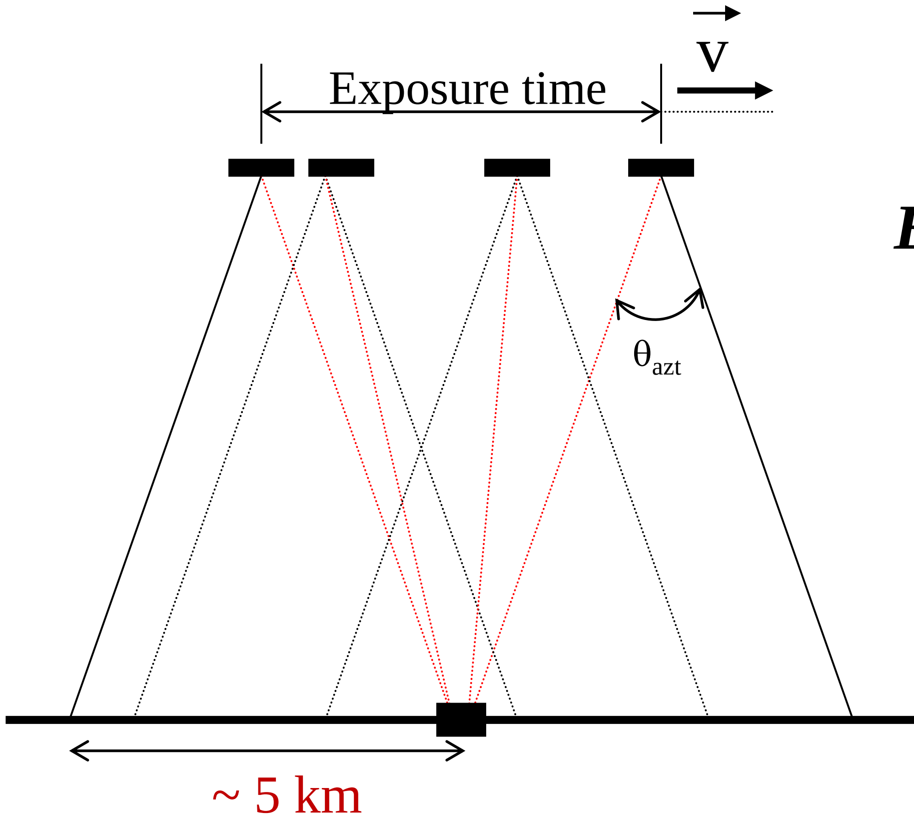


COMPRIME DISTANCE
NON COMPRIME AZIMUT

Radar Imaging – spatial resolution

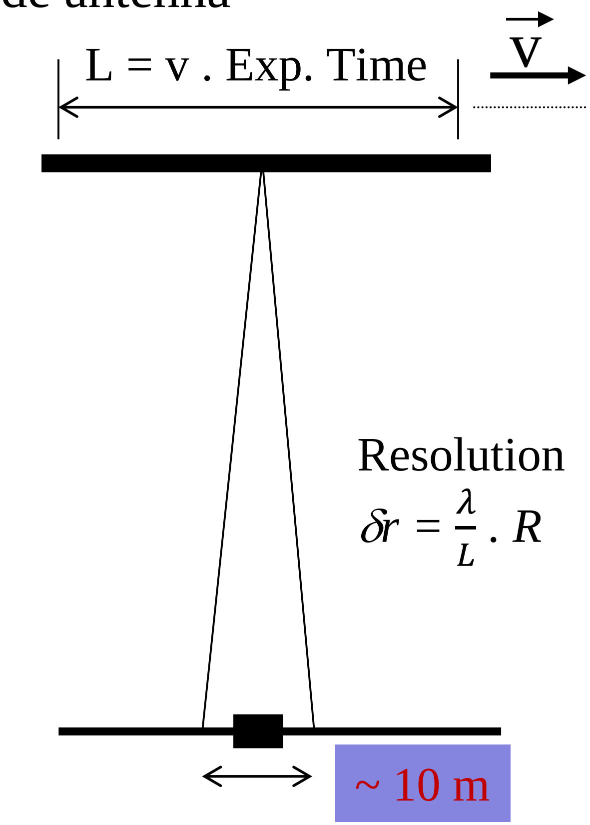
***Synthetic Aperture Radar*: (i.e. improvment of azimuthal resolution)**

Small mobile antenna ⇔ Fixed wide antenna



Equivalence

SAR



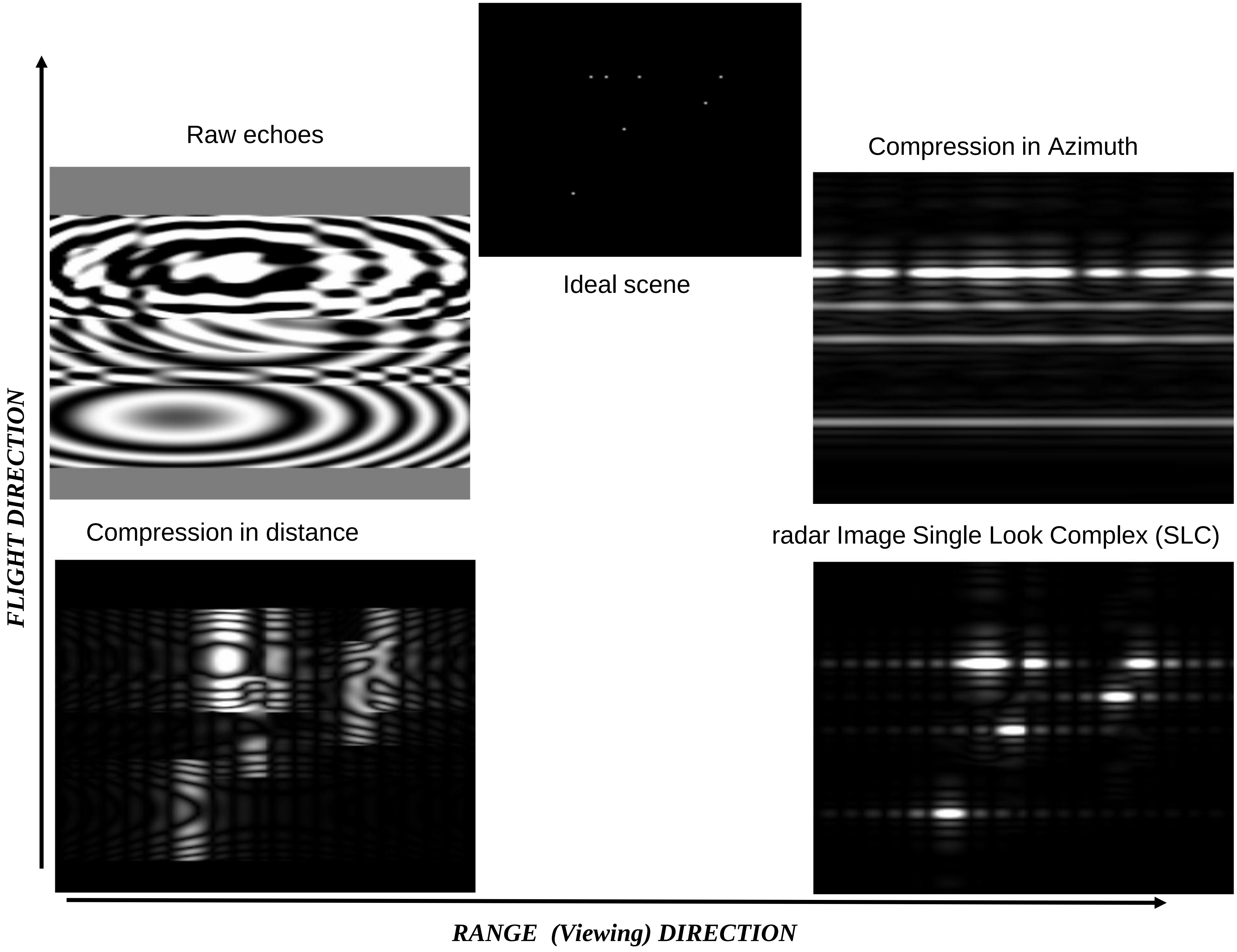
Coherent sum of the successive echoes

Adaptative filtering (Doppler Bandwidth)

$$B_D = \frac{2V}{L}$$

Gain in azimuthal resolution

$$X_{az} = \frac{V}{B_D} \quad => \quad X_{az} = \frac{L}{2}$$

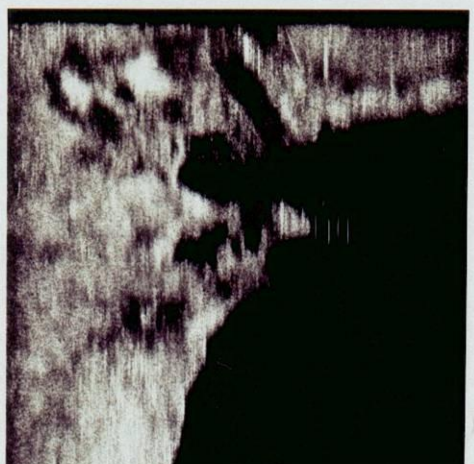

Raw echoes
Ideal scene
Compression in Azimuth
FLIGHT DIRECTION
Compression in distance
radar Image Single Look Complex (SLC)
RANGE (Viewing) DIRECTION

FLIGHT DIRECTION

NON COMPRIME DISTANCE
NON COMPRIME AZIMUT

NON COMPRIME DISTANCE
COMPRIME AZIMUT

Document CNES



COMPRIME DISTANCE
NON COMPRIME AZIMUT

COMPRIME DISTANCE
COMPRIME AZIMUT

RANGE (Viewing) DIRECTION

Radar Imaging – spatial resolution

Case of ERS SAR *(after aperture synthesis)*

	Range		Azimuth
	Slant (radar)	Ground	
Resolution	$X_r = \frac{c}{2B}$ **= 10 m**	$X_r = \frac{c}{2B\sin(\theta)}$ **= 25 m - 32 m**	$X_{az} = \frac{\lambda}{L_{synth}} R$ **= 10 m**
Pixel size	$p_s = \frac{c}{2F_s}$ **= 8 m**	$p_{gr} = \frac{c}{2F_s\sin(\theta)}$ **= 19 m - 26 m**	$p_{az} = \frac{V}{PRF}$ **= 4 m**

Case of TERRASAR-X

	Range		Azimuth
	Slant (radar)	Ground	
Resolution	***1.2 m***	***1.5 m – 3.5 m***	***1.1 m***
Pixel size	***0.6 m***	***0.75 m – 1.75 m***	***0.6 m***

RADARSAT - Scansar Wide : 27 mars 1999

Spat. res. 150 m

The Ouessant Rail

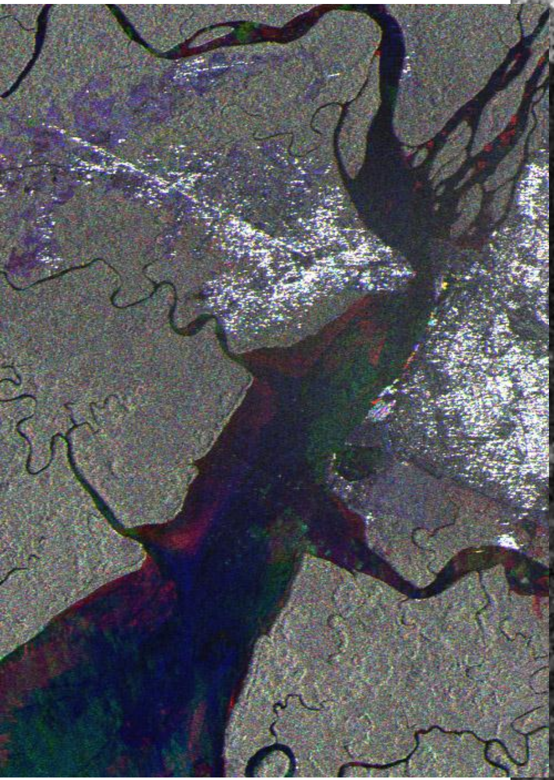
RADARSAT - Standard 6 : 3 Aug.1999

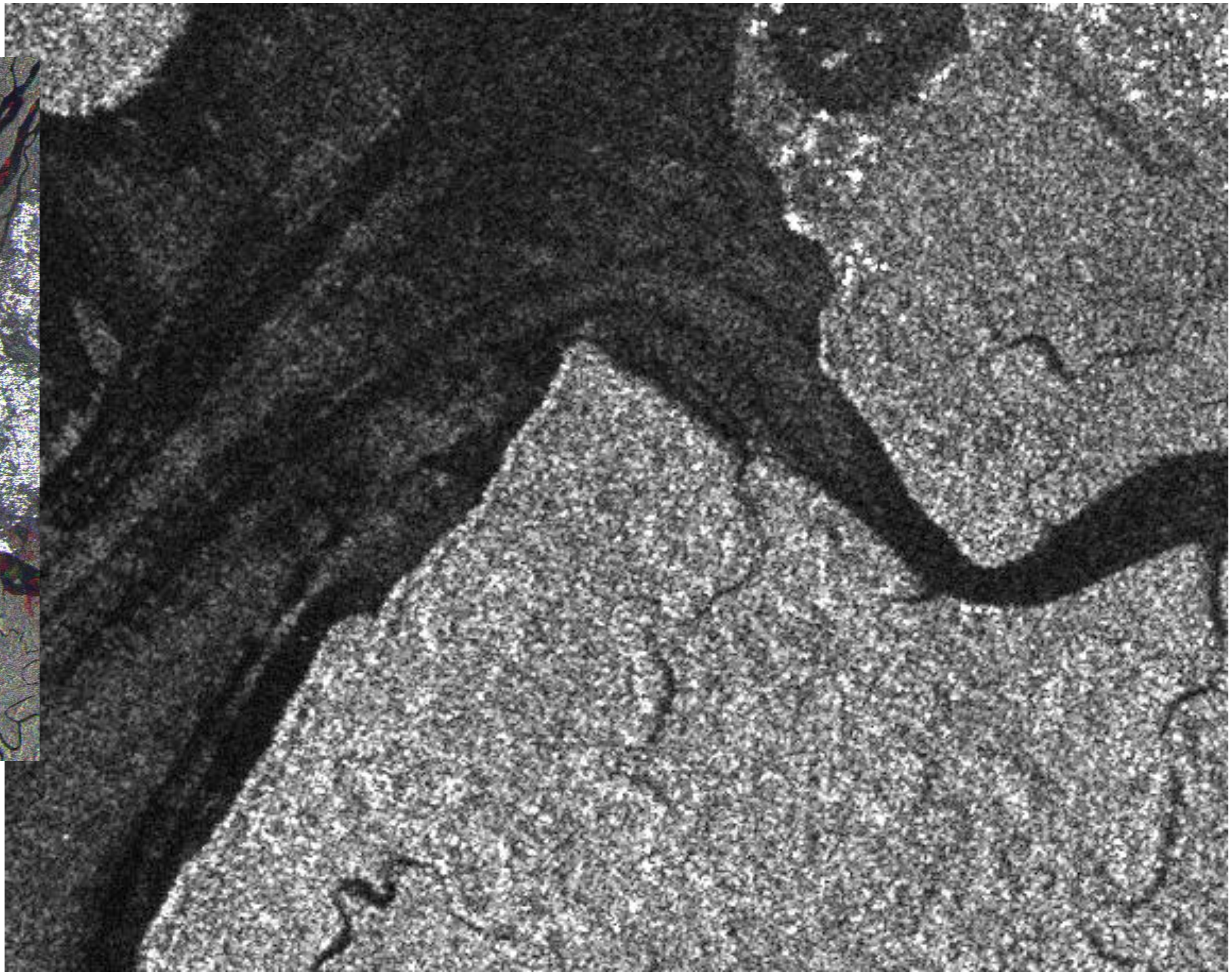
Spat. res. 30 m

The Channel
ASAR
22 novembre 2003

spat. res. 150 m

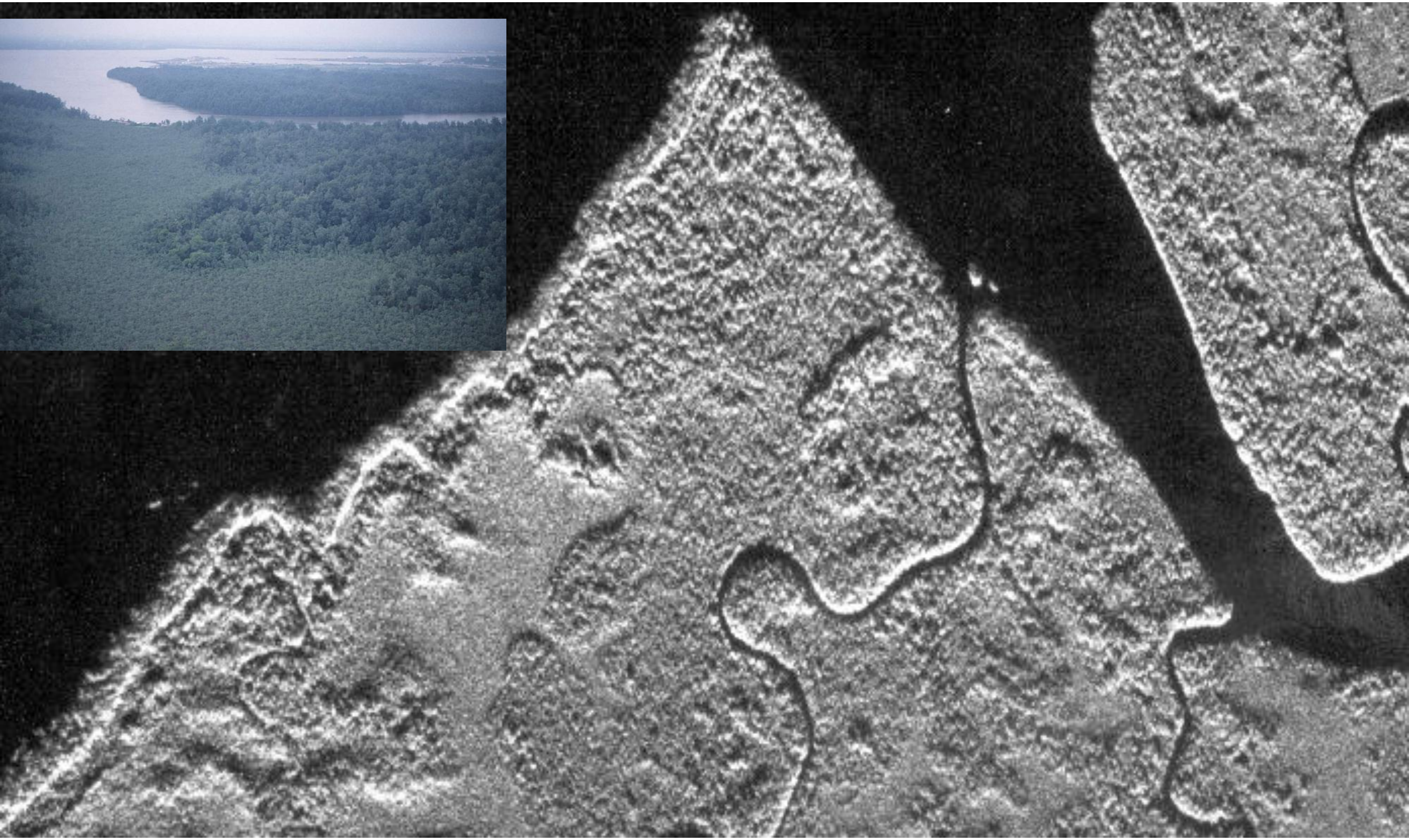
Radar Imaging – spatial resolution





ERS Resolution ~ 25 m, pixel 12,5m

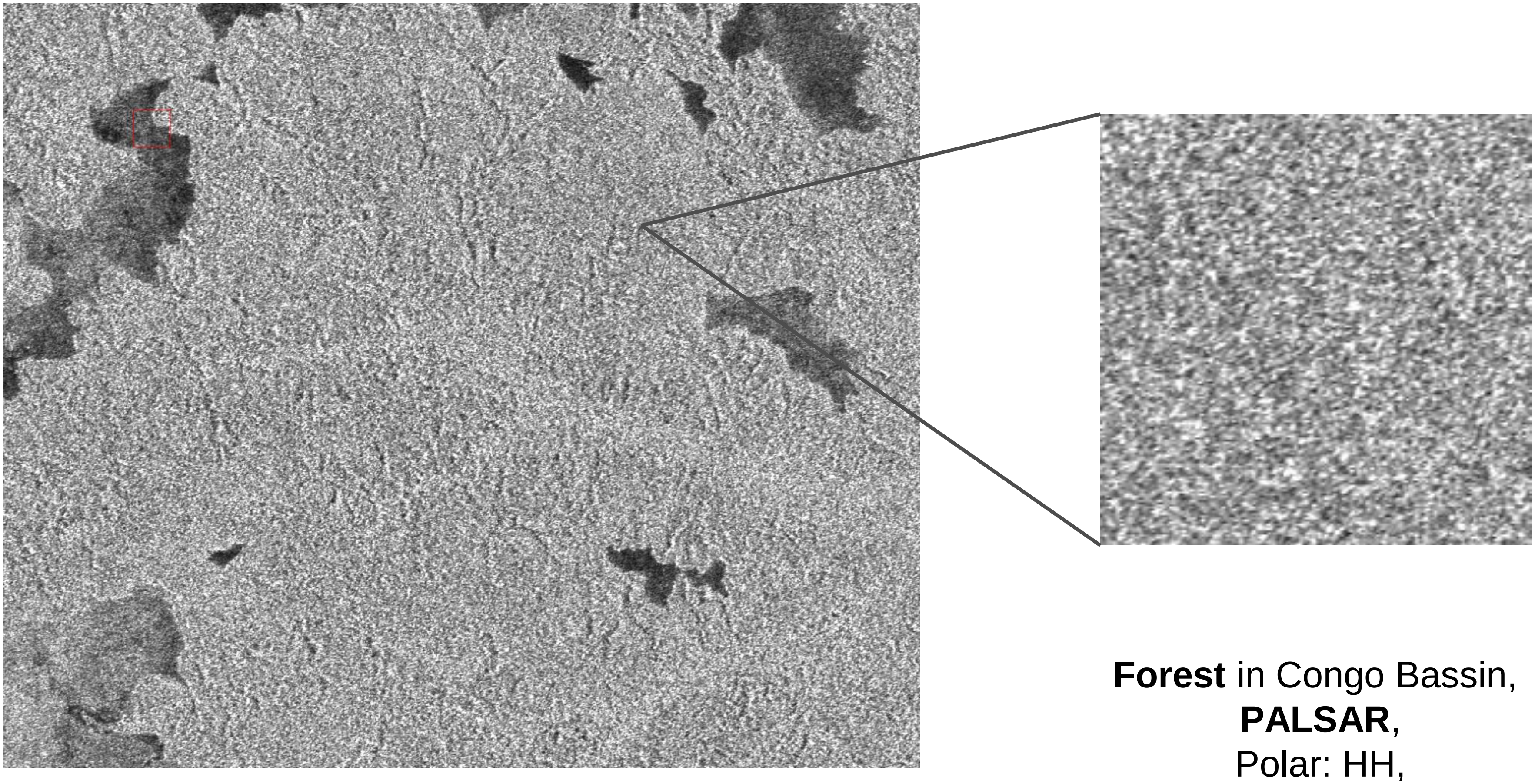
Radar Imaging – spatial resolution



DLR airplane radar resolution ~ 3 m

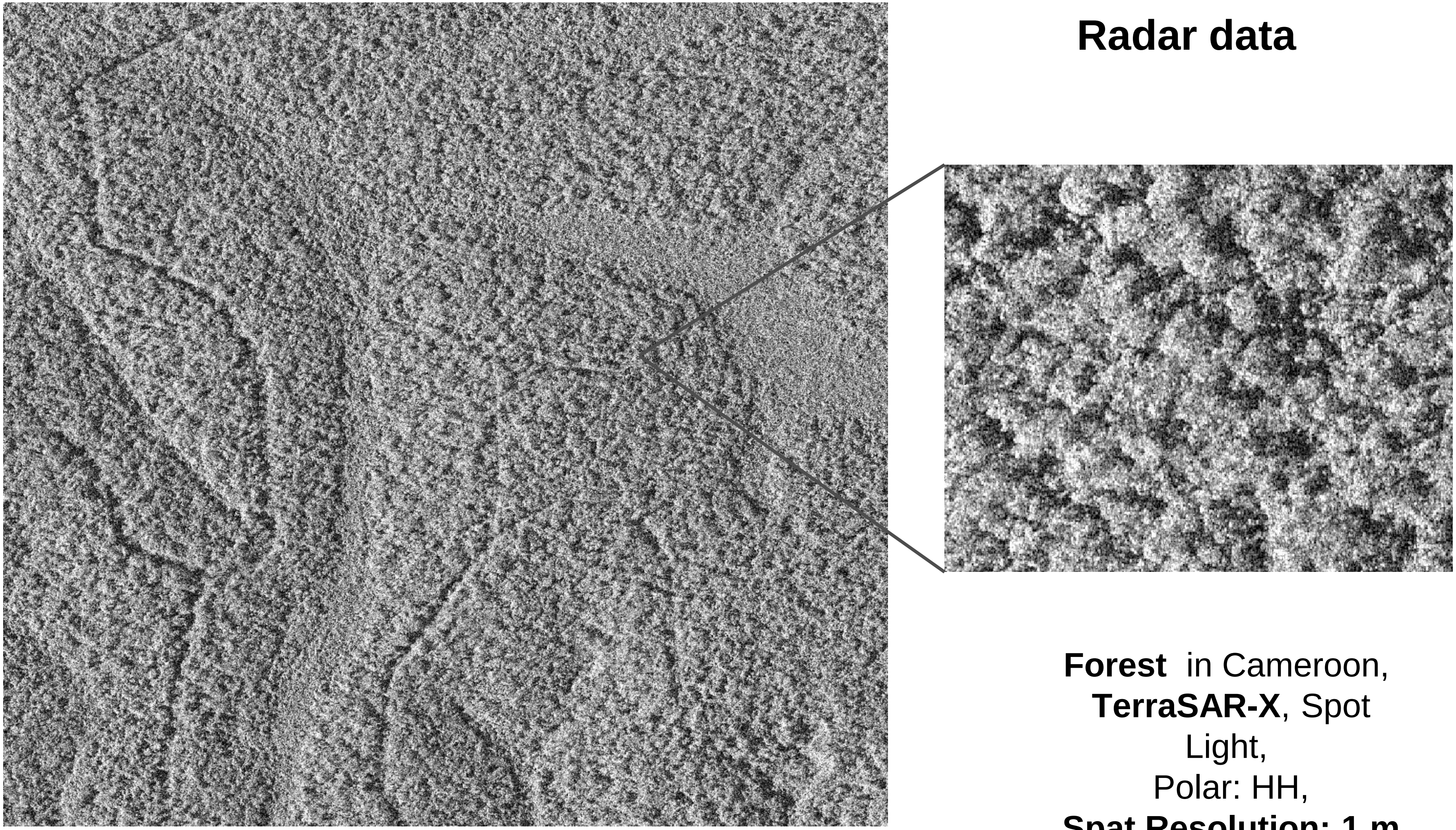
Radar Imaging – spatial resolution

Radar data



Forest in Congo Bassin,
PALSAR,
Polar: HH,
Spat.Resolution: 20 m

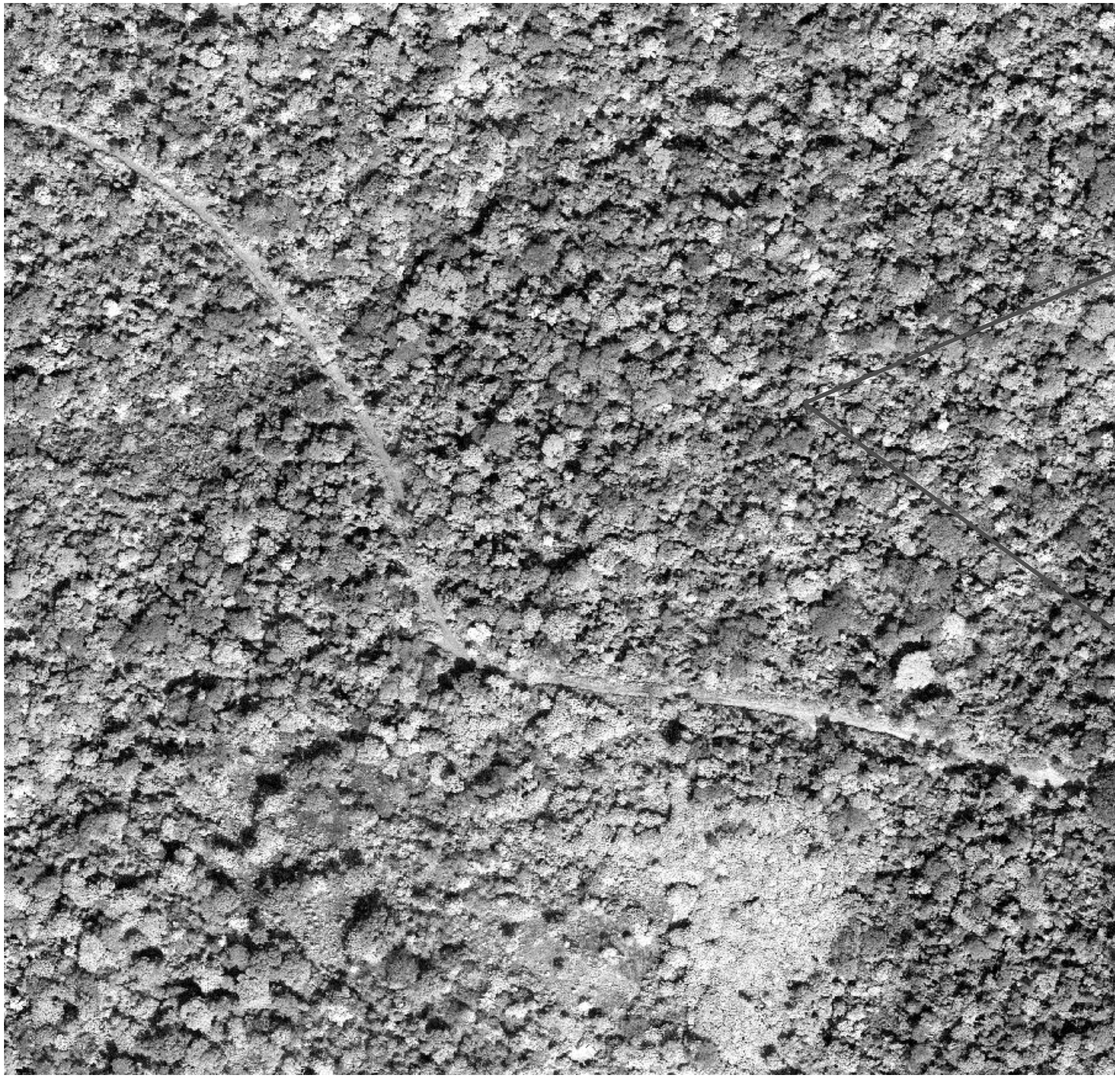
Radar Imaging – spatial resolution



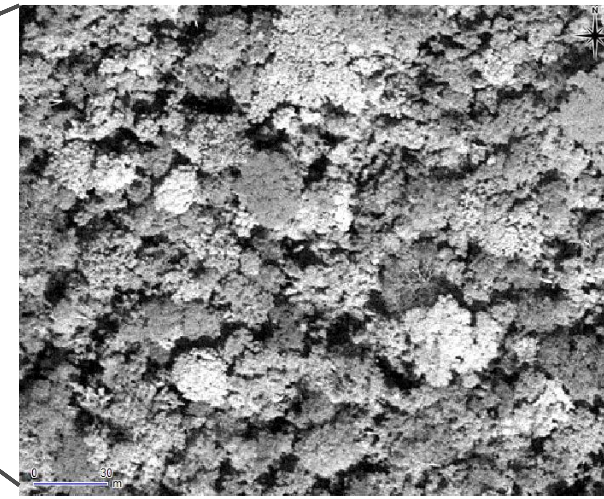
Radar data

Forest in Cameroon,
TerraSAR-X, Spot Light,
Polar: HH,
Spat.Resolution: 1 m

Radar Imaging – spatial resolution



Optical data

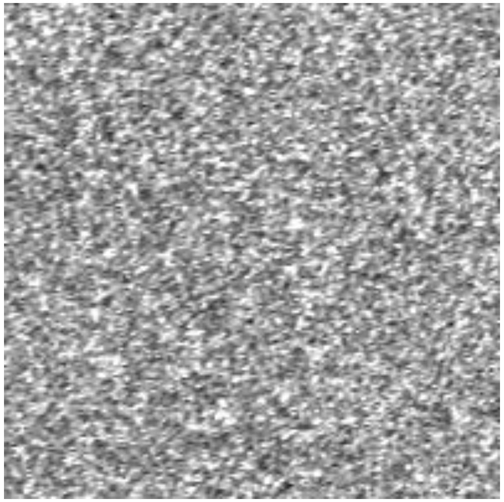


Forest in Cameroon,
Geoeye, Panchromatic,
Spat.Resolution: 0.5 m

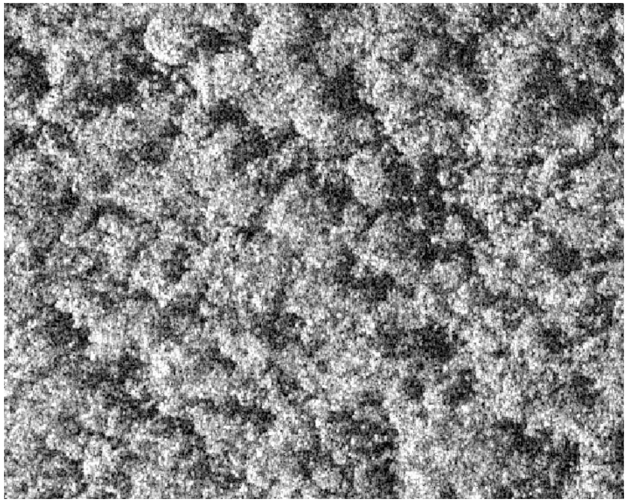
Radar Imaging – spatial resolution

RADAR Data

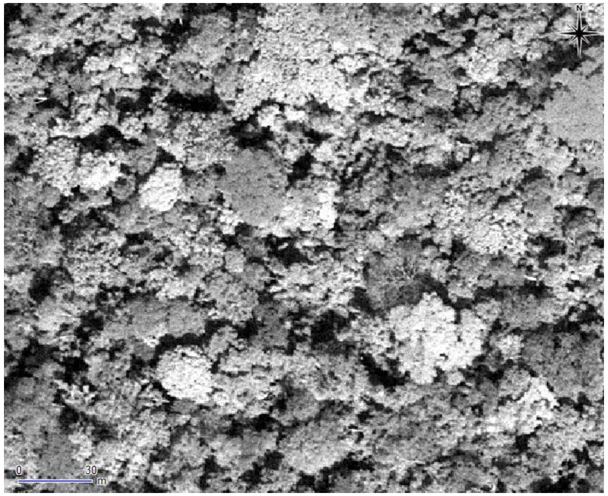
Optical Data



Forest in Congo Bassin,
PALSAR,
Polar: HH,
Spat.Resolution: 15 m



Forest in Cameroon,
TerraSAR-X, Spot Light,
Polar: HH,
Spat.Resolution: 1 m



Forest in Cameroon,
Geoeye, Panchromatic,
Spat.Resolution: 0.5 m