Machine Learning for Transmission and Classification of Radar Satellite Data

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Satellite Communications

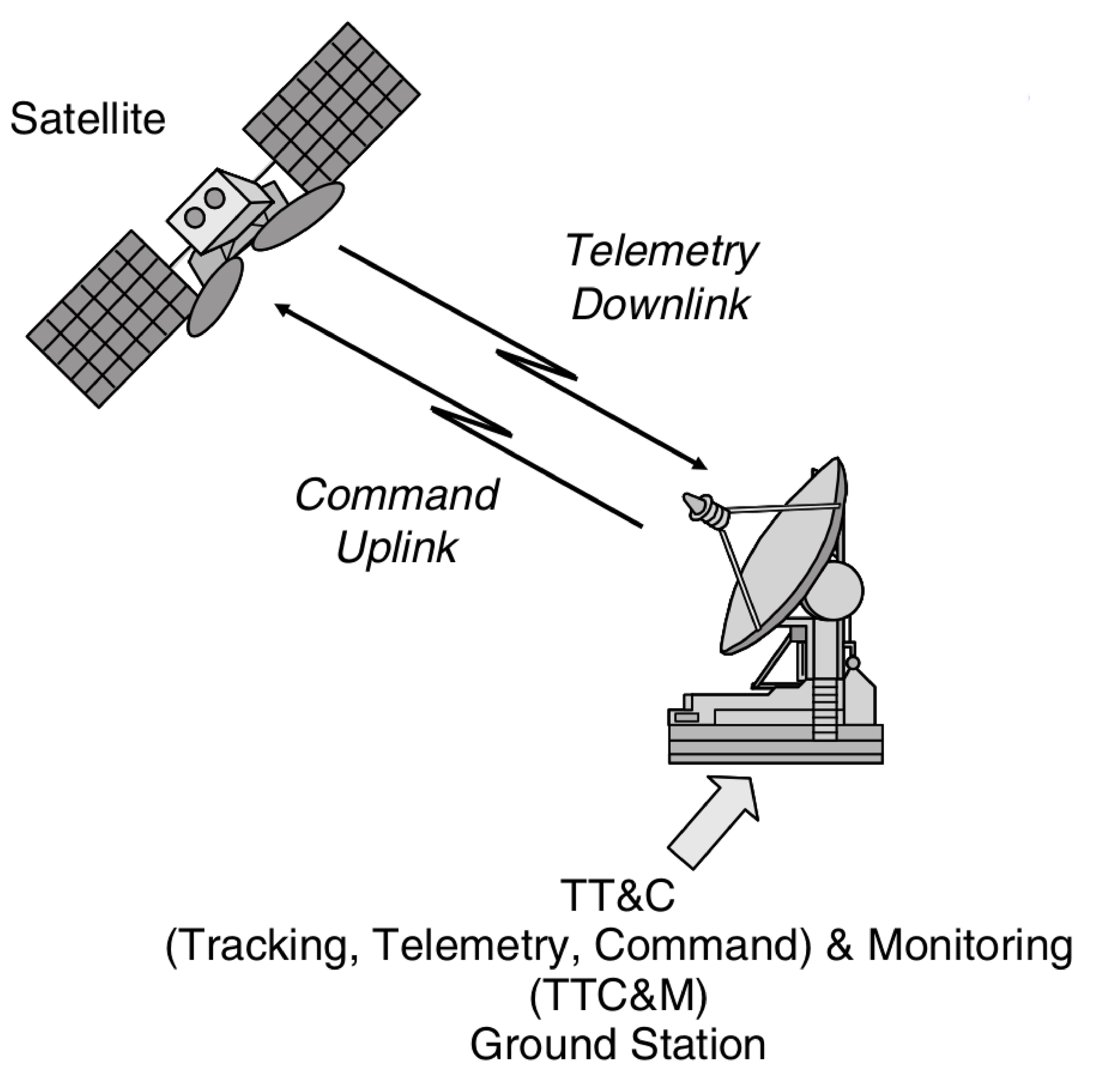


Figure: Ippolito, figure 1.2, p9 [1]

Synthetic-Aperture Radar (SAR)

Basic principle: a larger *aperture* or antenna increases the range and resolution of a radar system
Challenge: antennas on satellites can not be constructed arbitrarily large
Solution: use satellite movement to *synthesize* a larger aperture

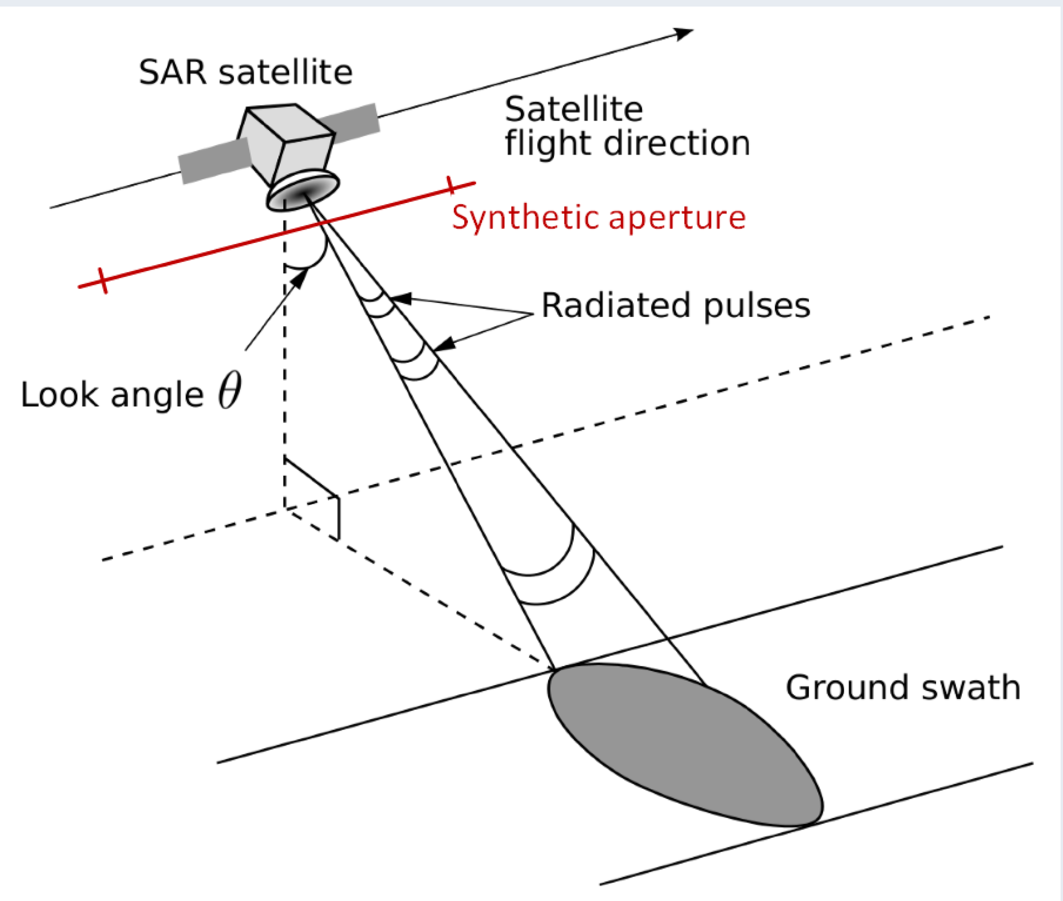


Figure: Laukness, figure 2.1, p12 [3]

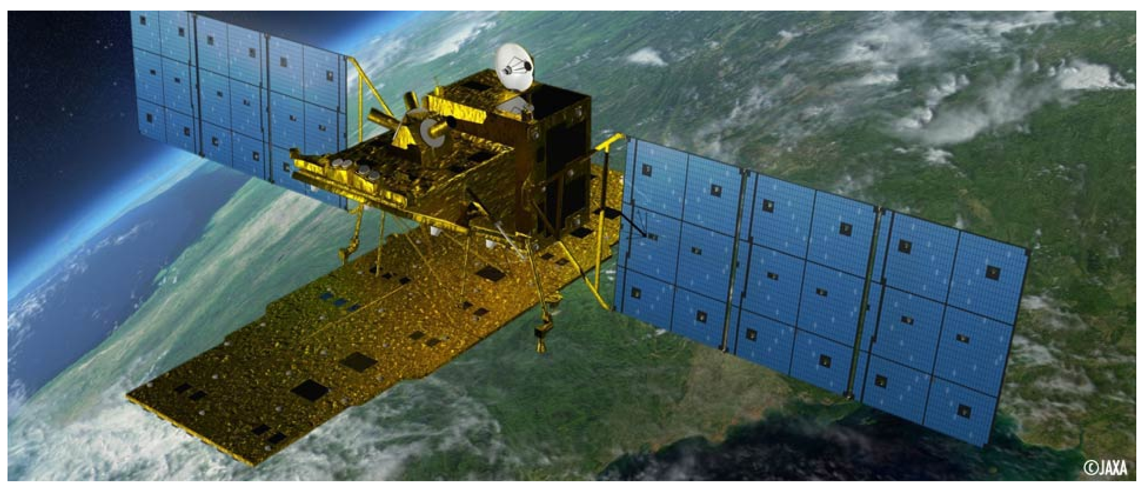


Figure: Advanced Land Observing Satellite (ALOS) 2 operated by JAXA [2]

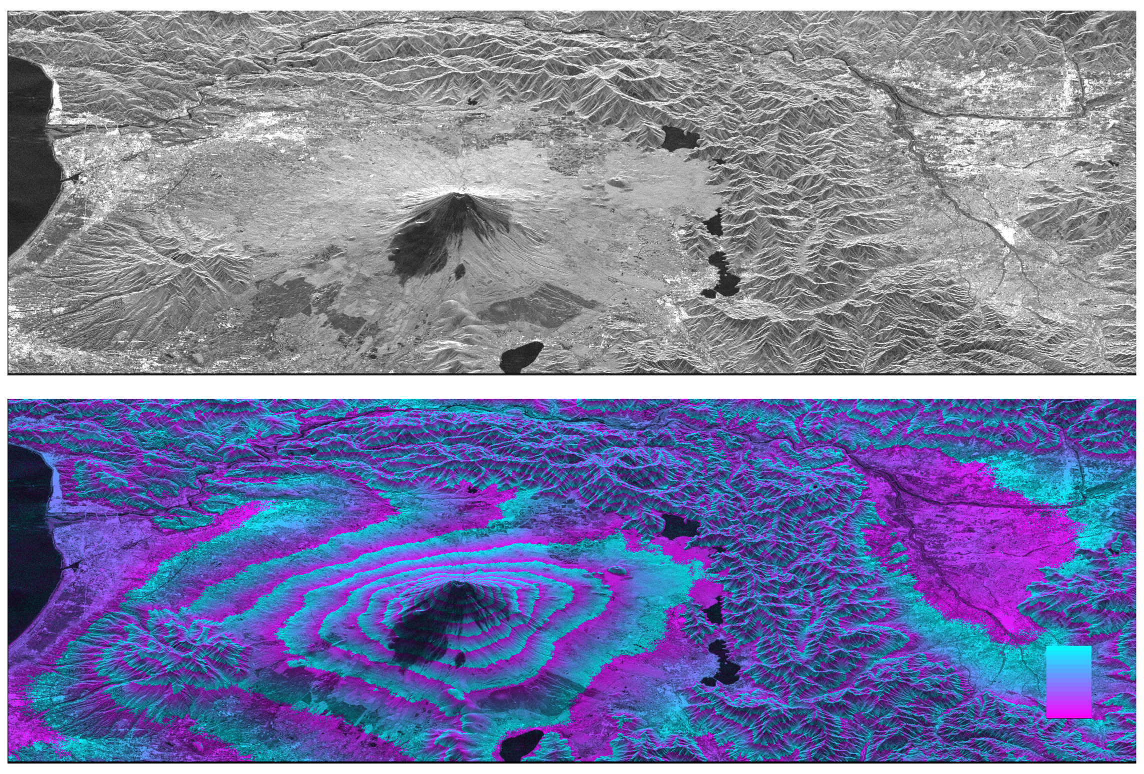
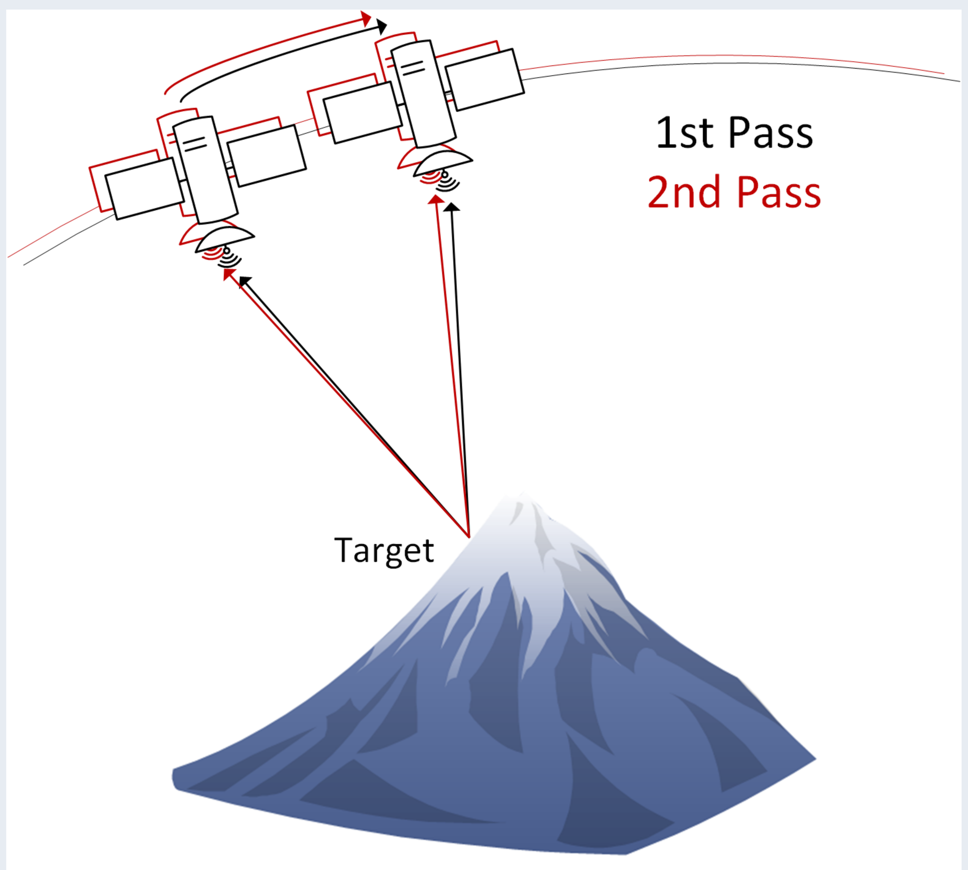


Figure: Interferogram of Mt Fuji area

Interferometric SAR (InSAR)

Main idea: combining two SAR images of the same target to obtain a radar interferogram



Two SAR images can be obtained by:

- Large satellite with two separated radar systems (e.g. Spacehuttle mission)
- Two satellites in close formation (e.g. TanDEM-X)
- One satellite passing two times (e.g. ALOS)

Challenges in Satellite Communication Systems

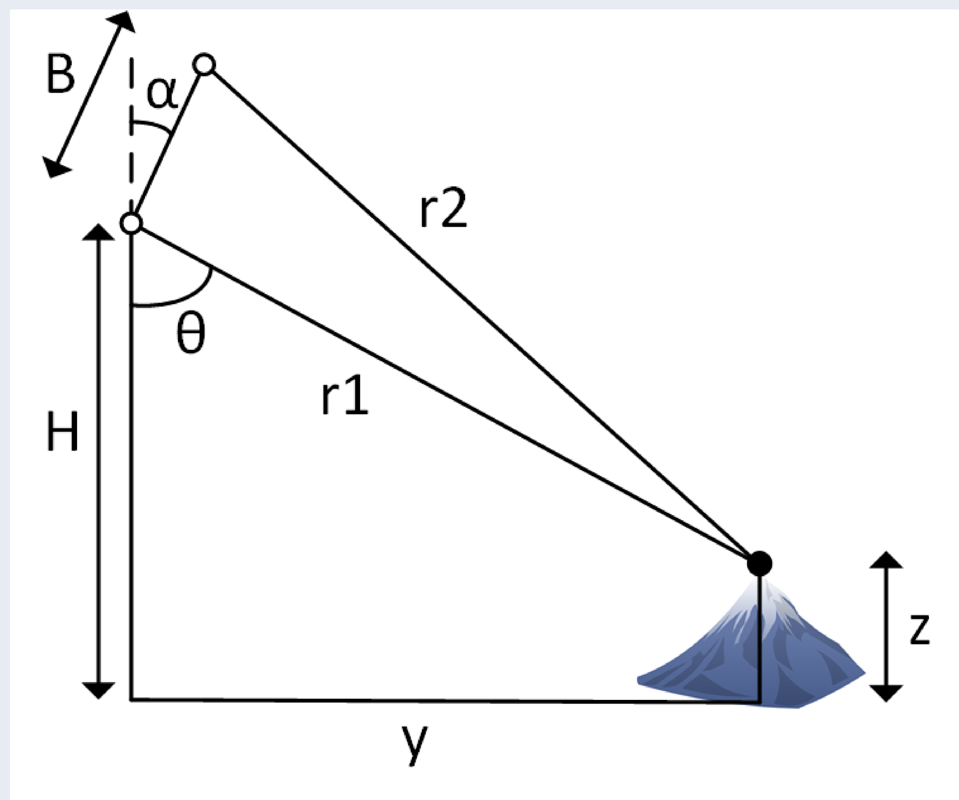
- Large distances (LEO 10^3km to Mars 10^8km)
- Very high signal attenuation (can reach −300dB easily, e.g. link to Mars)
- Low data rates (e.g. 32kbit/s for direct Mars-Earth link)
- But: scientific instruments collecting large amounts of data (e.g. InSAR image of Mt Fuji about 1GB)

➥ Data needs to be compressed and/or specifically selected!

➥ Optimize transmission and compression specifically for the task the data is needed for

InSAR Geometry

- Two SAR images in distances r_1 and r_2
- Baseline distance B, satellite elevation H



For the interferometric phase ϕ under parallel ray approximation ($r \gg B$) follows

$$\phi \approx \frac{2\pi}{\lambda} Q B \cos(\theta + \alpha)$$

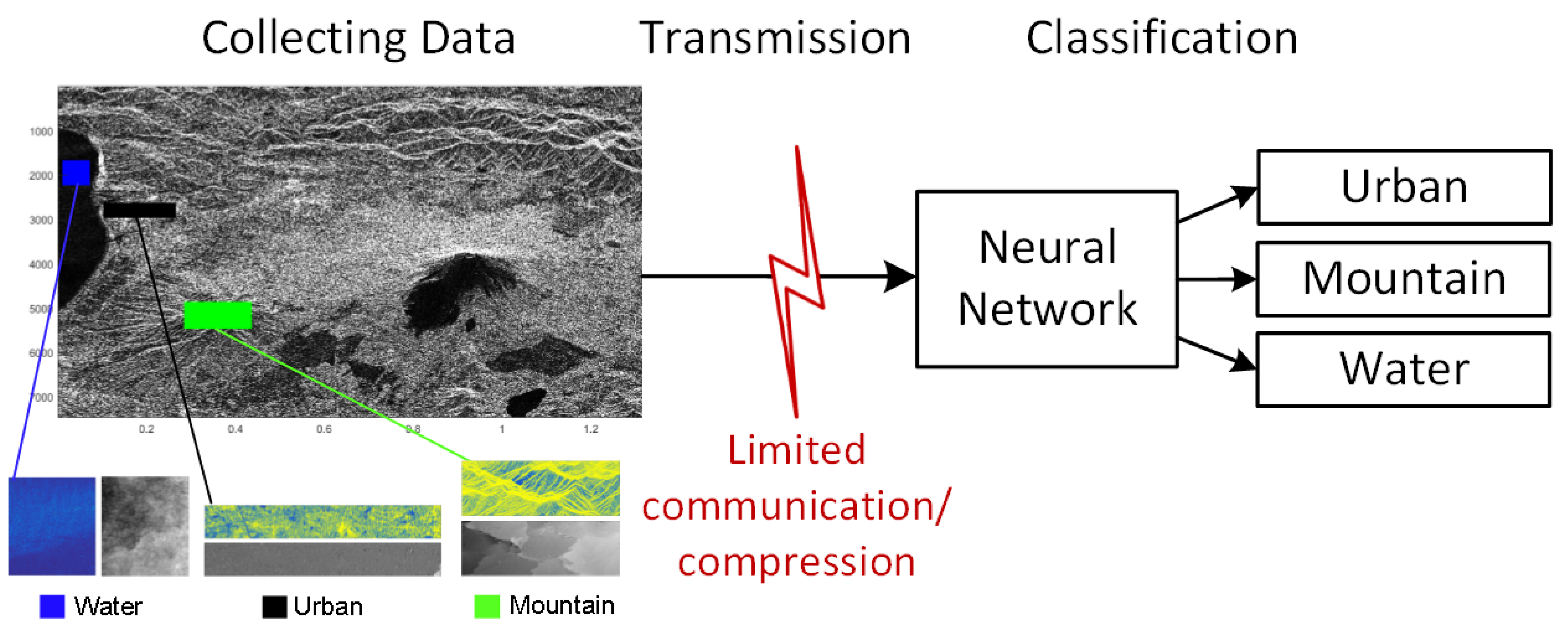
where λ is the radar system's wavelength and $Q = 1$ for a single satellite pass and $Q = 2$ for double pass. As H, r_1 and ϕ are measured and known, r_2 and θ can be computed:

$$r_2 = r_1 + \frac{\phi\lambda}{2\pi}, \qquad \theta = \cos^{-1}\left(\frac{r_2^2 - r_1^2 - B^2}{2Br_1}\right) - \alpha$$

Once θ is known, the target elevation z and target ground range y is given by

$$z = H - r_1 \cos(\theta), \qquad y = \sqrt{r_1^2 - (H - z)^2}$$

Application: InSAR Data Classification with Machine Learning



- Example application: classifying InSAR data according to terrain type
- What needs to be transmitted to guarantee high classification performance?

➥ Extend neural network to also optimize transmitted data

[1] Louis J. Ippolito, "Satellite communications systems engineering", Wiley, 2017.

[2] JAXA 2014 ALOS-2-RESTEC http://alos-2-restec.jp/en/

[3] Tom R. Laukness, "Rockslide Mapping in Norway by Means of Interferometric SAR Time Series Analysis", PhD dissertation, 2011.