Advanced Bridge Monitoring Strategies by Polarimetric GB-SAR

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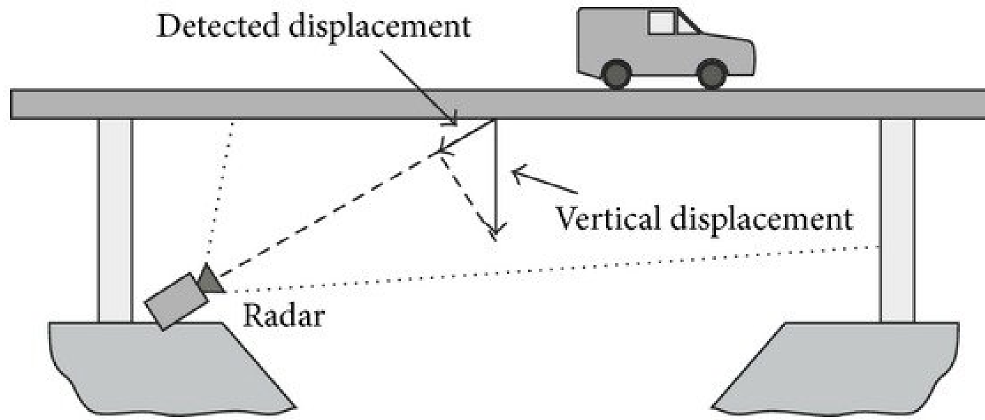
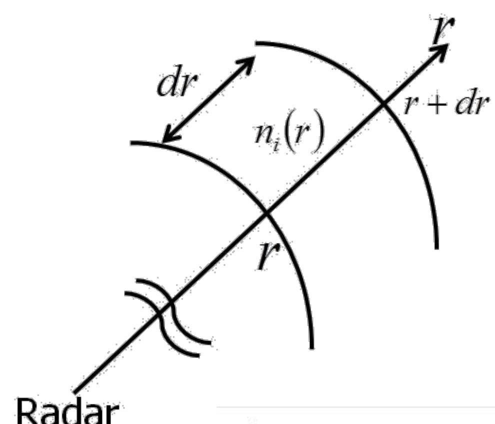
Motivation and Objective

Bridge collapses (Italy, 2018)

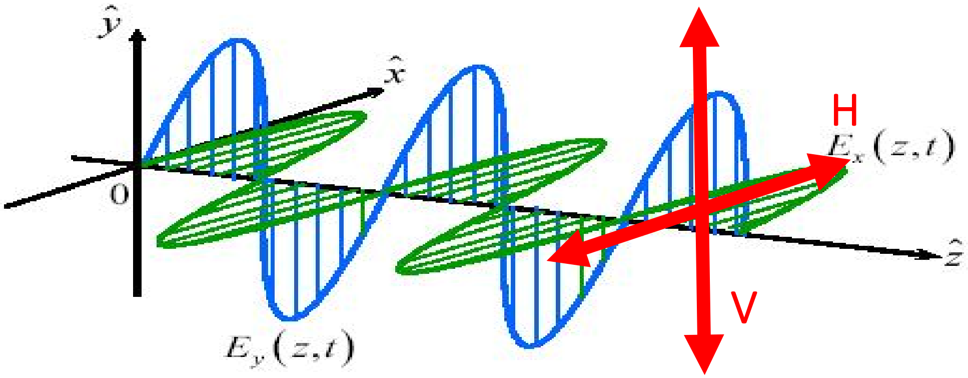


Bridge monitoring by Interferometry Radar (M. Pieraccini, 2013)



Line-of-sight displacement

Radar polarimetric and polarimetric orientation angle

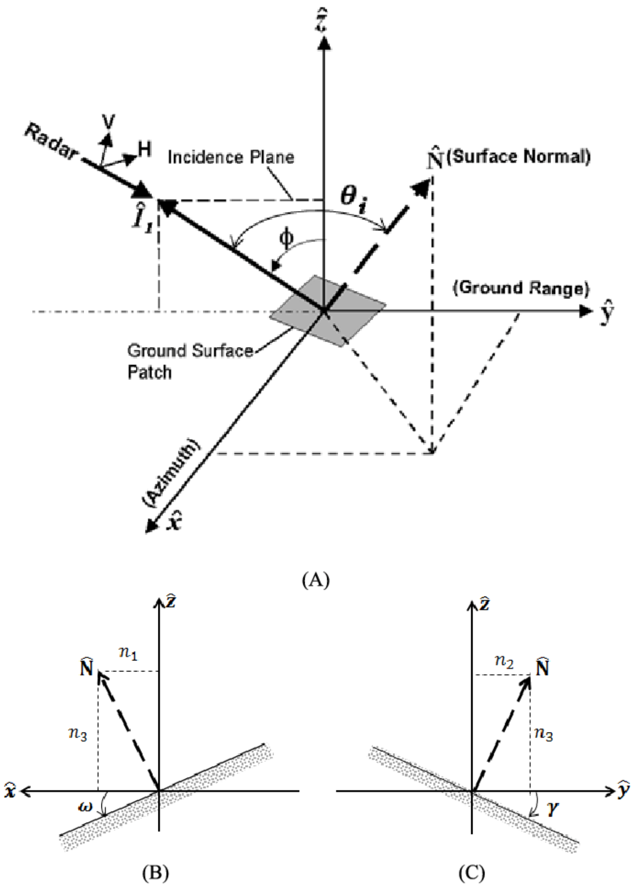


Polarimetric wave

$$\begin{bmatrix} E_H^R \\ E_V^R \end{bmatrix} = \frac{e^{-j2kr}}{\sqrt{4\pi r^2}} \begin{pmatrix} S_{HH} & S_{HV} \\ S_{VH} & S_{VV} \end{pmatrix} \begin{bmatrix} E_H^T \\ E_V^T \end{bmatrix}$$

$$\mathbf{E}^R \qquad \mathbf{S} \qquad \mathbf{E}^T$$

[S]: Scattering matrix



Polarimetric orientation angle
(Jong-Sen Lee et. al 2018)

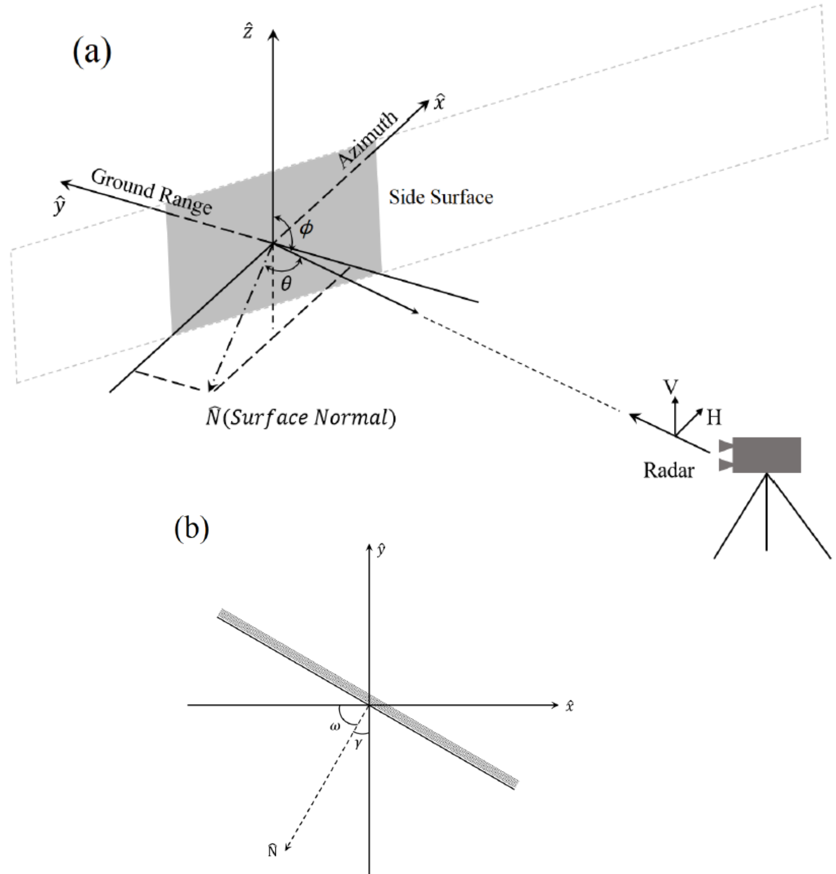
FASTGBSAR System

Polarimetric GB-SAR system

Parameter	Value
Operating frequency	17.2 GHz (Ku Band)
Range resolution	Up to 0.5 m
Maximum range	4 km
EIRP power	19 to 42 dBm
Operating temperature range	-25 ^{o}C to 60 ^{o}C
Sensor weight	10 kg
Accuracy	± 0.01 mm
Power consumption	70 W

Field Measurement

Bridge monitoring by polarimetric GB-SAR system (Sendai, Japan)



(a) Radar imaging geometry of the side surface. (b) The side surface projection in both azimuth and ground range direction.

Vertical Deformation Calculation

The polarimetric orientation angle (POA) can be expressed as:

$$\tan(-4\eta) = \frac{-4Re(\langle (S_{HH} - S_{VV})S^*_{HV} \rangle)}{-\langle |S_{HH} - S_{VV}|^2 \rangle + 4\langle |S_{HV}|^2 \rangle}$$

$$\xi = \begin{cases} \eta, & \text{if } n \leq \frac{\pi}{4} \\ -\eta - \frac{\pi}{2}, & \text{if } n > \frac{\pi}{4} \end{cases}$$

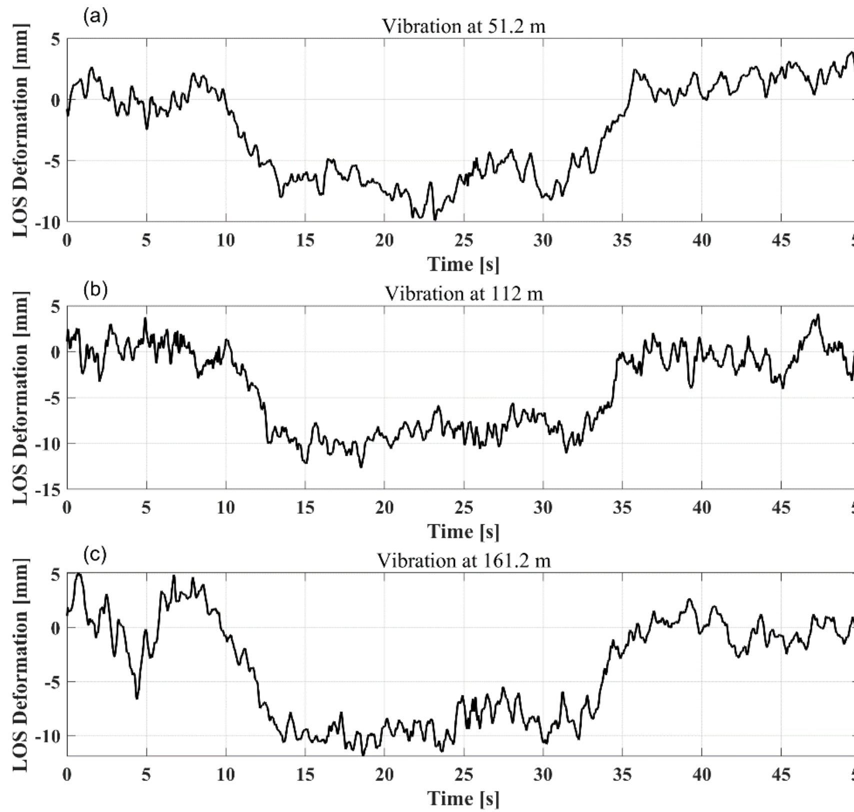
where ξ indicates the POA. The POA can also be obtained from the azimuth slope angle ω, ground range slope angle γ, and radar look angle ϕ based on the imaging geometry by the following equation

$$\tan(\xi) = \frac{\tan\omega}{-\tan\gamma\cos\phi + \sin\phi}, -\frac{\pi}{2} \leq \xi \leq \frac{\pi}{2}.$$

The local incidence angle θ can also be derived in terms of the local slopes and radar look angle, it can be expressed as:

$$\cos\theta = \frac{\tan\gamma\sin\phi + \cos\phi}{\sqrt{1 + \tan^2\gamma + \tan^2\omega}}$$

So that the radar look angle θ can be calculated with the above equations, and the vertical deformation can be known.



Vertical deformation of three different points of the bridge

Thank you for your attention !