

Static and Dynamic Monitoring of Civil Engineering Structures by Microwave Interferometry

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IBIS range

PRODUCTS



IBIS - FL



IBIS - FM



IBIS - FS

APPLICATIONS



LANDSLIDE & DAM MONITORING



SLOPE STABILITY IN MINING



STRUCTURE MOVEMENTS

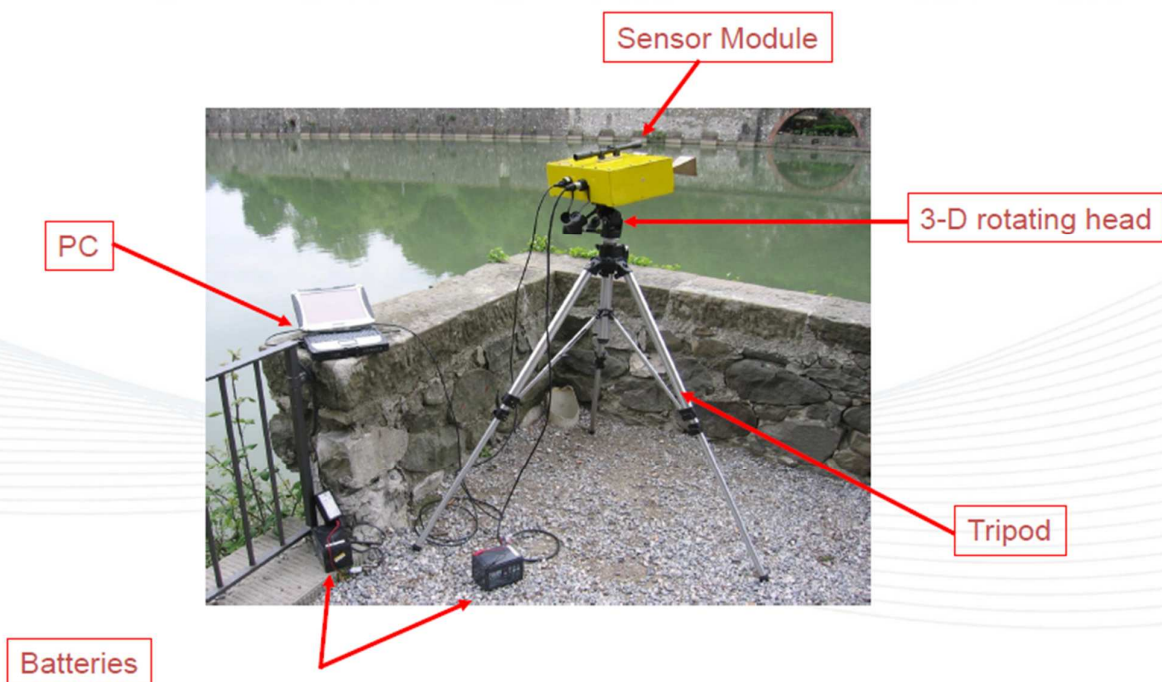


IBIS-FS characteristics

- Measures from remote
 - Direct displacement measure
 - Several points simultaneously
 - Operates day-night in every weather conditions
 - Easy and quick setup
- Range resolution:
 - 0.75m (CE and FCC limit)
 - 1.1 m (Japan limit)
 - 1.5 m (IC limit)
 - Max sampling frequency: 200 Hz
 - Max operating distance: 1 km
 - Accuracy: 0.01 mm



IBIS FS Hardware



Techniques behind the IBIS FS system

The IBIS FS product utilises two radar techniques:

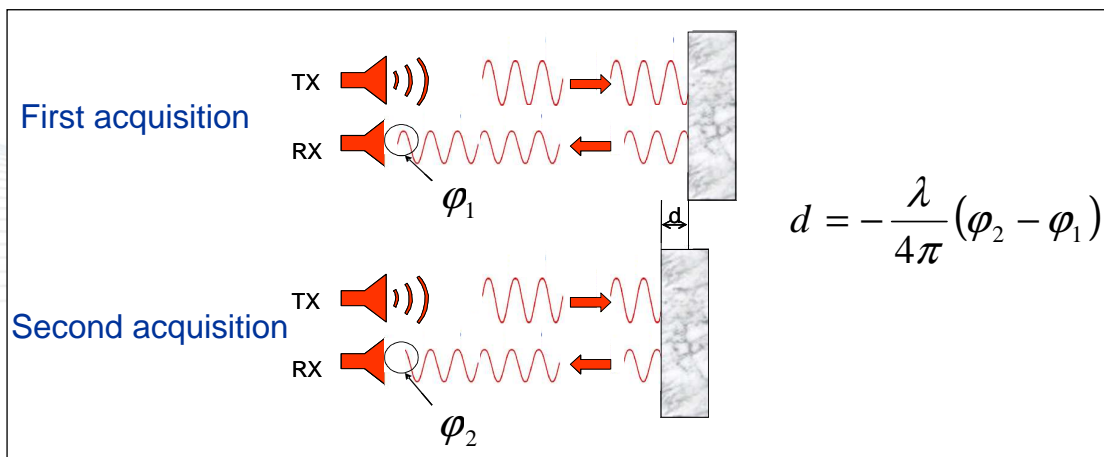
1. **Frequency Modulated - Continuous Wave (FM-CW)** technique for obtaining the 1-Dimensional Range Profile with Range Resolution.



2. **Interferometric technique**

Interferometric Technique

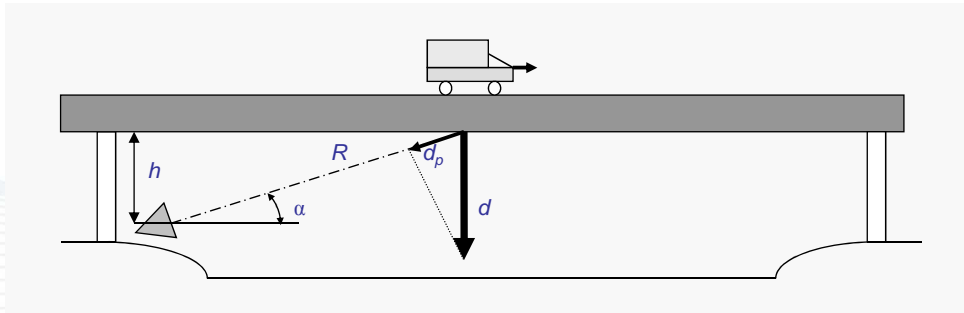
The **interferometric analysis** provides data on object displacement by comparing phase information, collected in different time periods, of reflected waves from the object, providing a measure of the displacement with an accuracy of less than 0.01mm (intrinsic radar accuracy in the order of 0.001 mm.)



1-D Interferometric technique

The displacement is measured in the direction of the **line of sight** of the system.

To calculate the real displacement is needed to know the acquisition geometry



$$d = \frac{d_p}{\sin(\alpha)} \quad \rightarrow \quad \sin(\alpha) = \frac{h}{R} \quad \rightarrow \quad d = d_p \cdot \frac{R}{h}$$

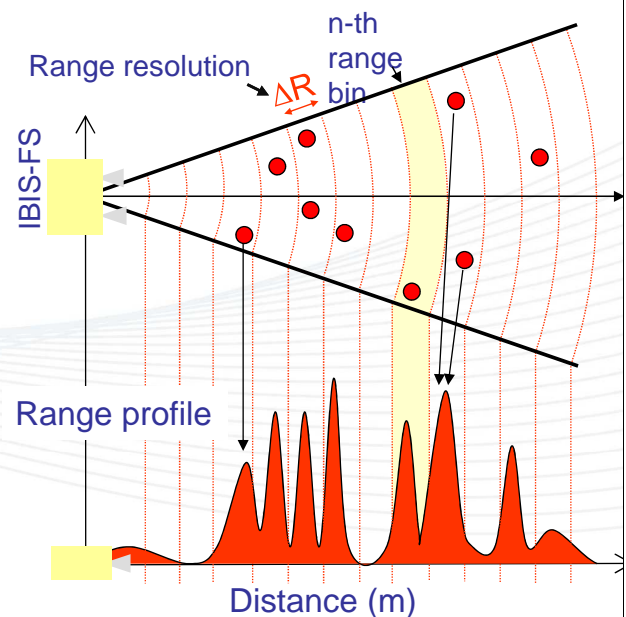
The distance **R** is measured by IBIS-S

IBIS-FS Acquisition Mode

IBIS-FS measured scenario is determined by

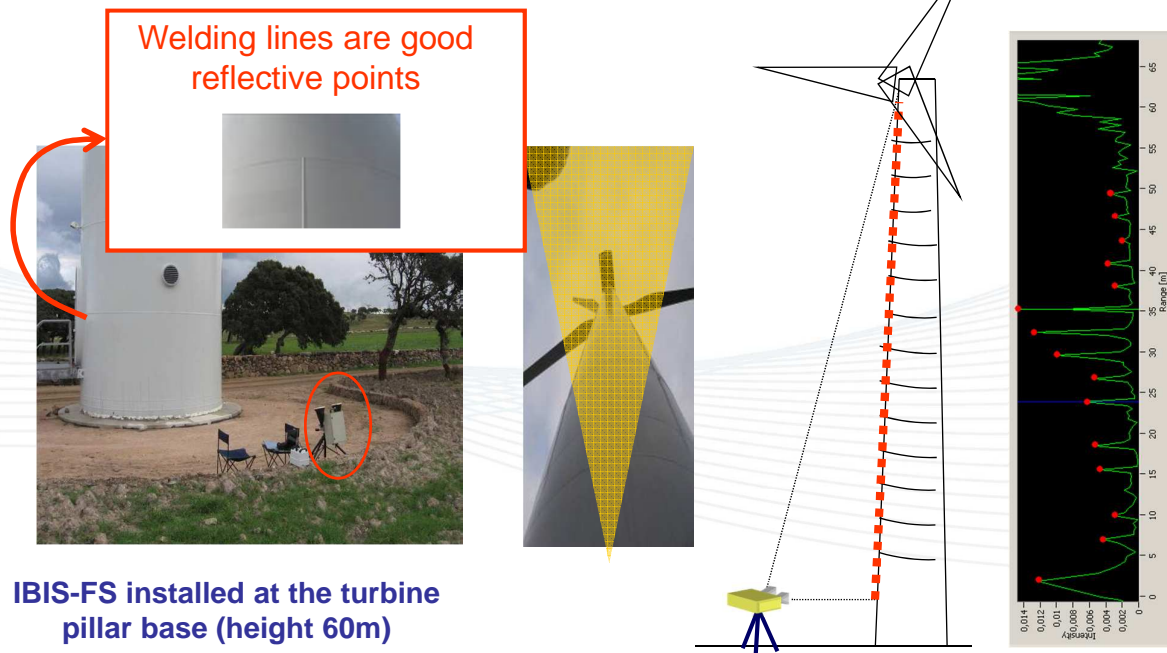
- **Antenna beamwidth** (depending on the model, from 10° to 50°).
- User's defined **maximum range** (up to 1 Km)

The measured scenario is divided into range bins, whose number depends on the **range resolution** (0.75 m minimum, constant with distance). Two targets at the same distance from the radar fall on the same range bins.



IBIS-FS: 1-dimensional range profiles

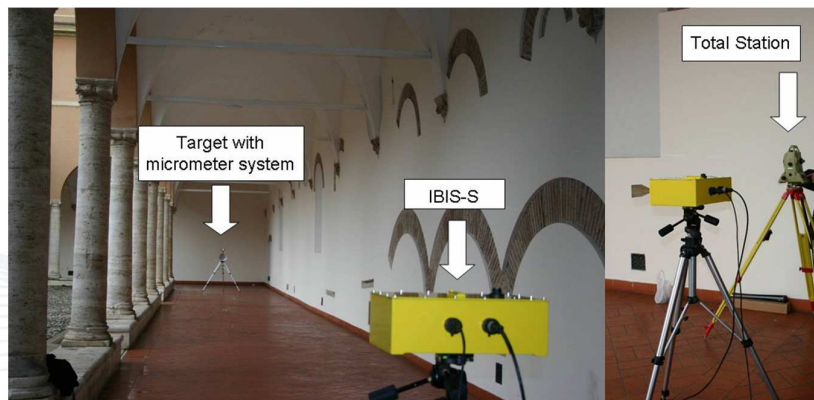
Range Profile: one dimensional image with 0.5m range resolution



IBIS-FS installed at the turbine pillar base (height 60m)

Measurement accuracy: IBIS vs. Total Station

Test objective: comparison between IBIS-S results and a high-performance Total Station in measuring a target displacement

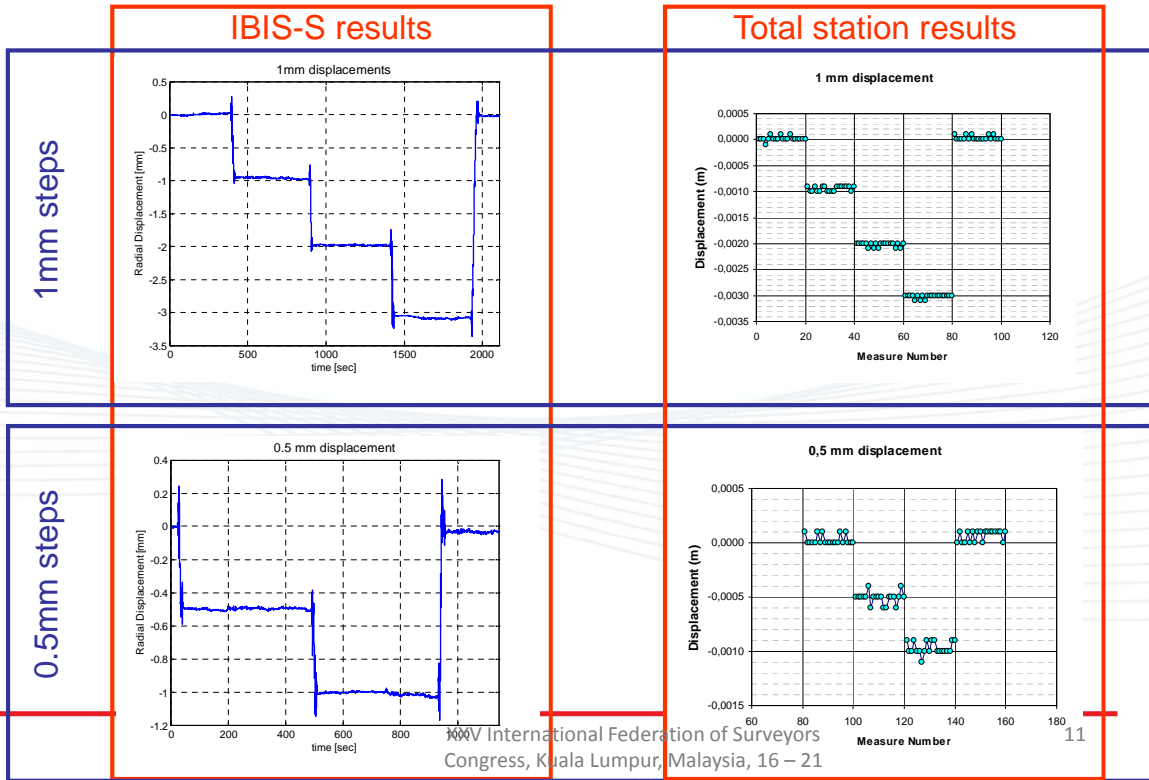


Target distance: 33m

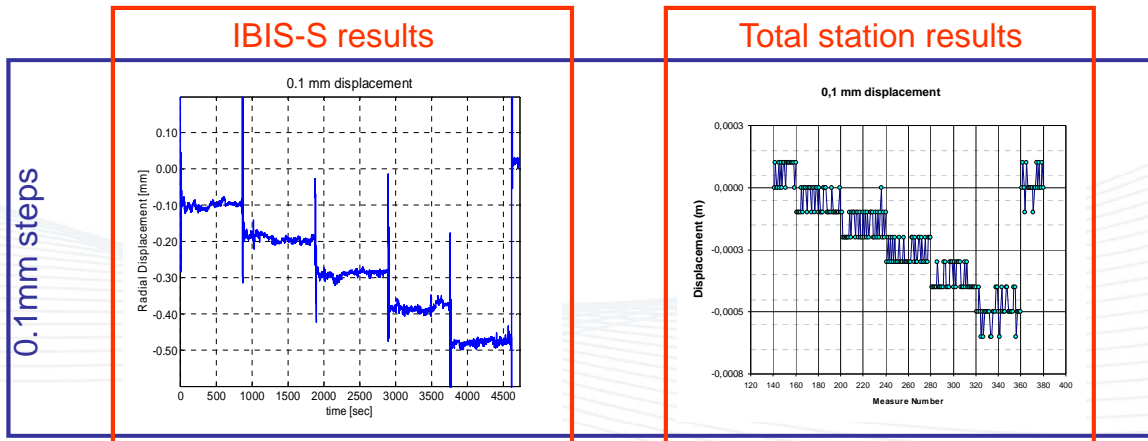
Forced displacement:

- 3 x 1mm step towards IBIS-S and -3mm back
- 2 x 0.5mm step towards IBIS-S and -1mm back
- 5 x 0.1mm step towards IBIS-S and -0.5mm back

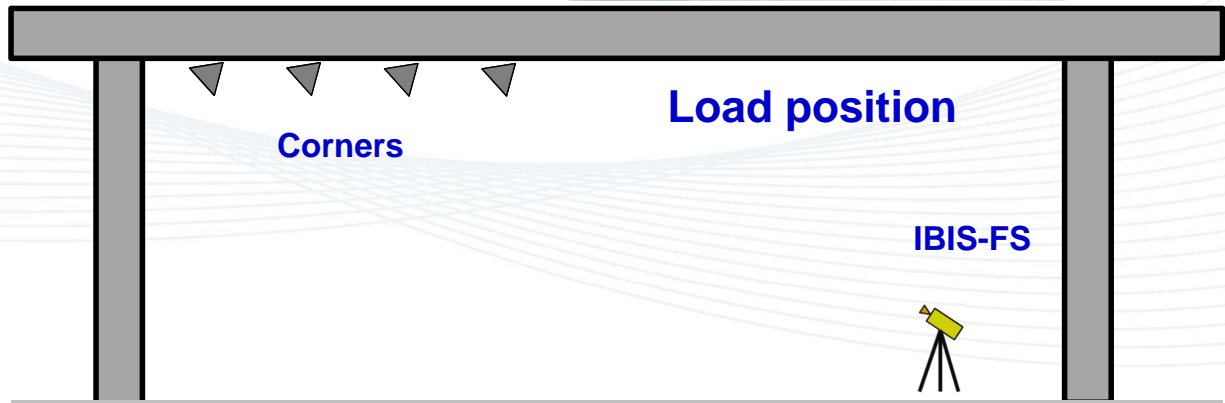
Measurement accuracy : IBIS vs. Total Station



Measurement accuracy : IBIS vs. Total Station

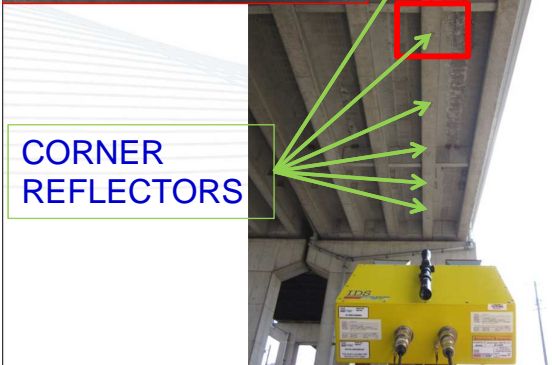


Static Monitoring

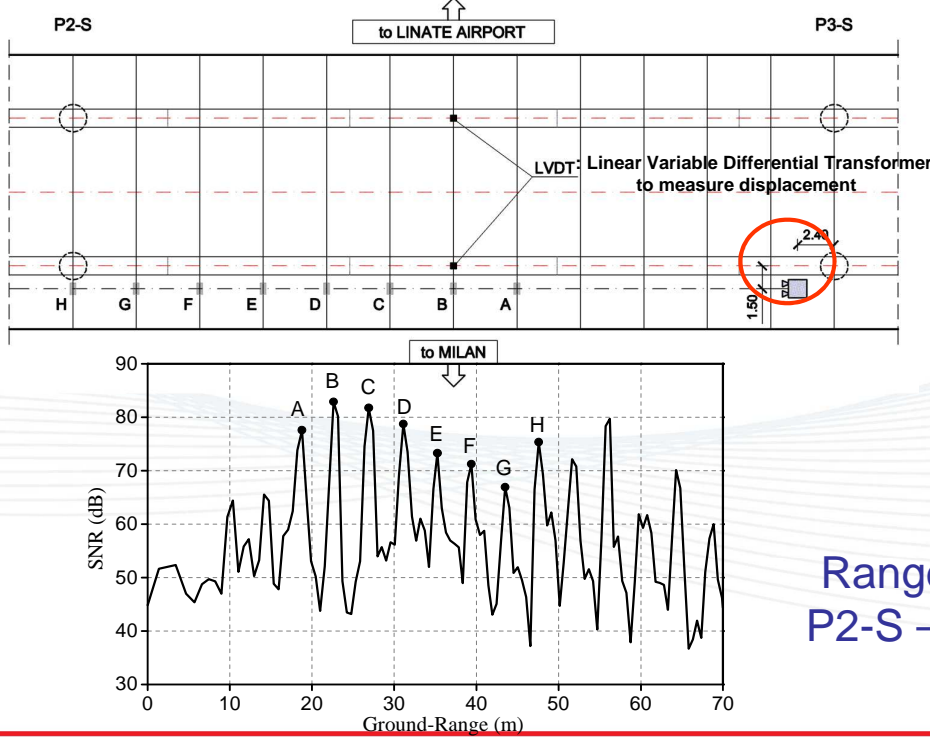


IBIS-FS corner reflectors

From the structure plan is possible to determine whether reflectors are needed or not.



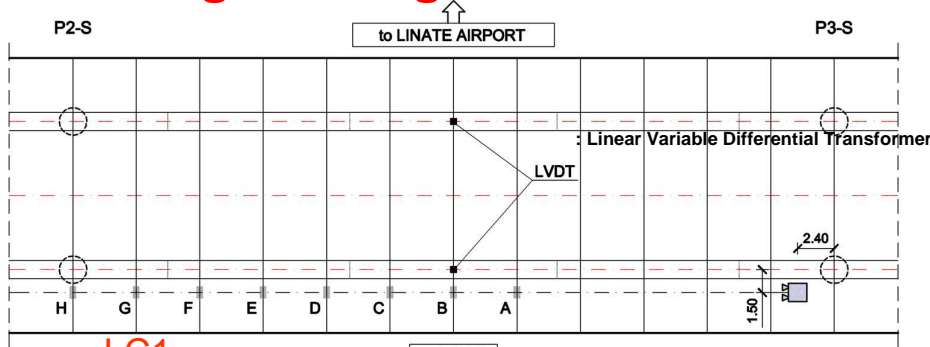
Bridge testing: static live load test



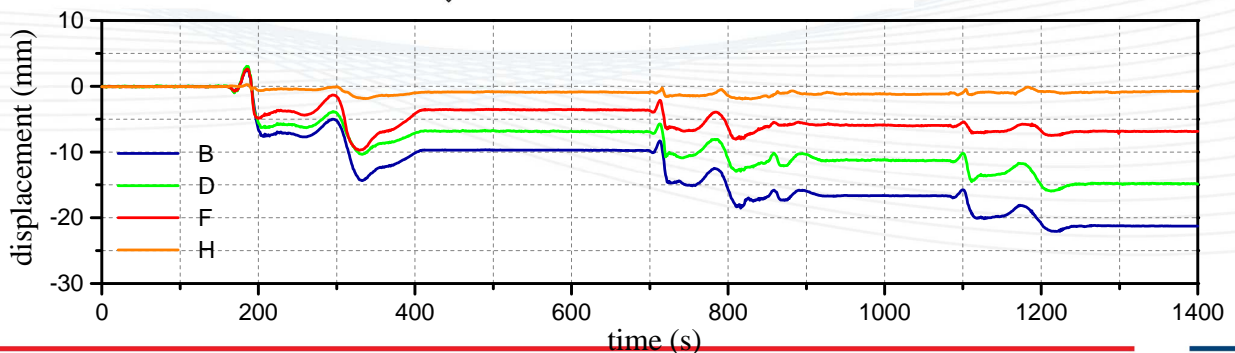
IBIS-FS
installation

Range profile of
P2-S – P3-S span

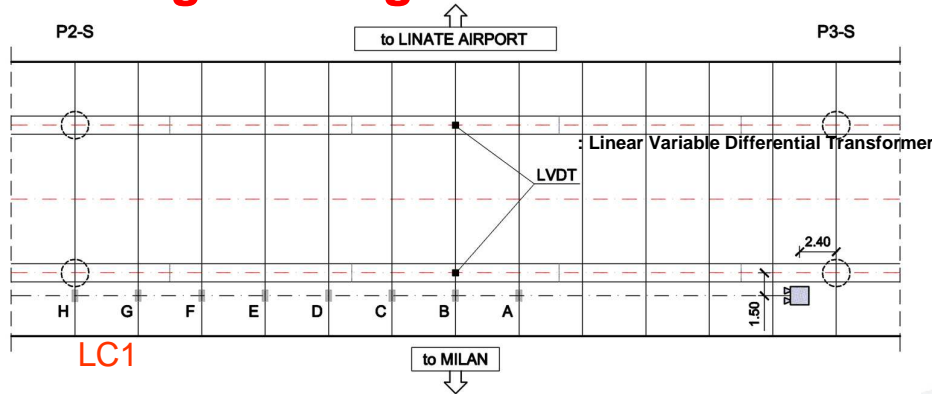
Bridge testing: static live load test



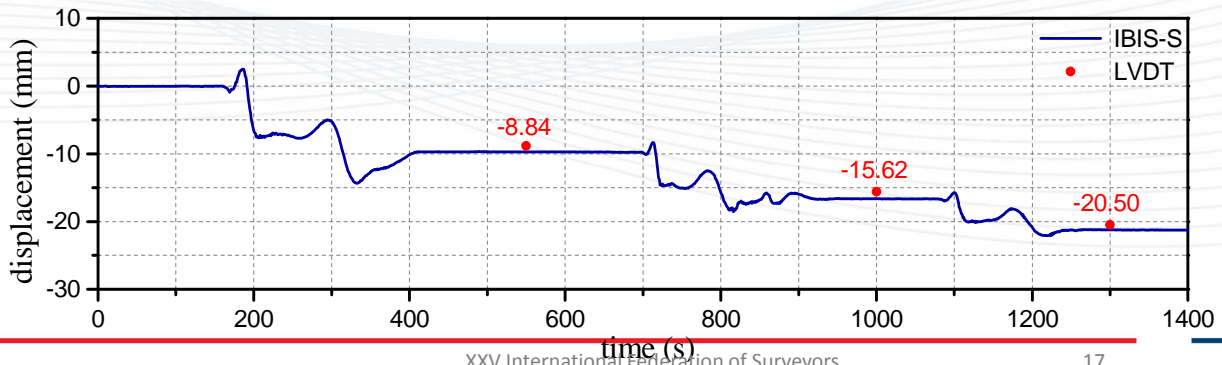
LVDT



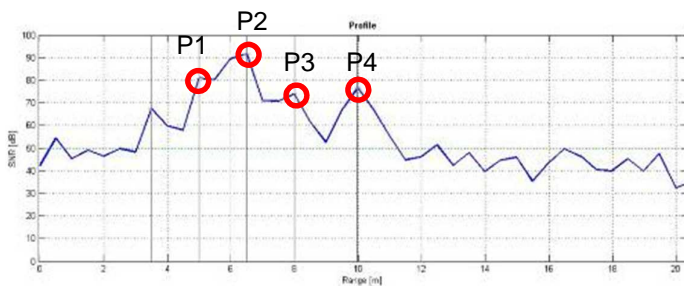
Bridge testing: static live load test



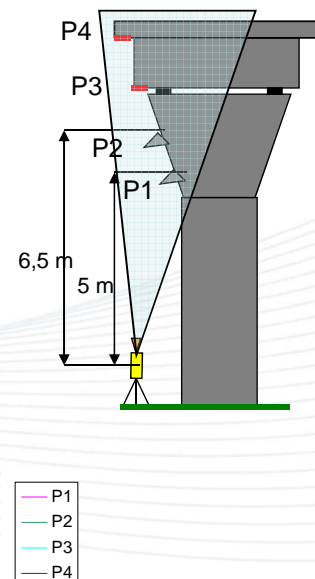
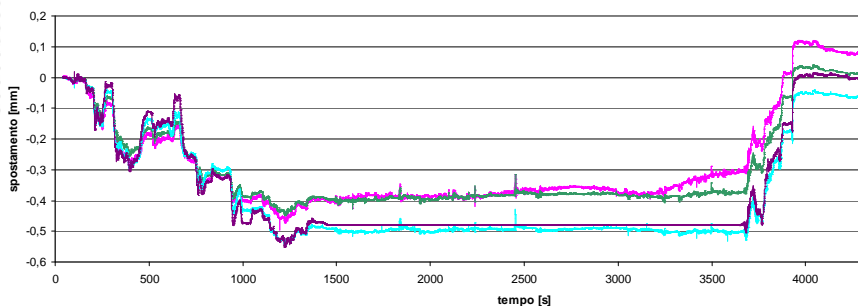
LVDT



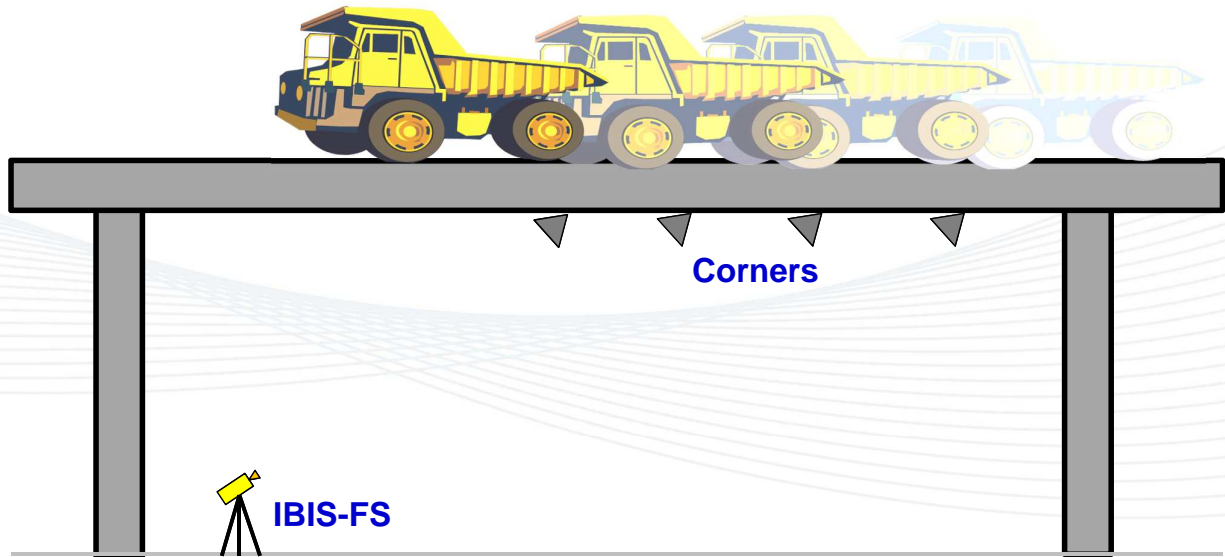
Static settlements of bridge's pier and beam



Vertical movements of the 4 points

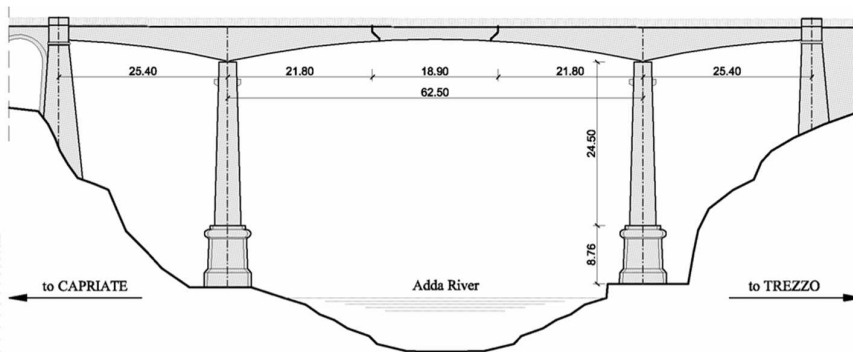


Dynamic Monitoring



Dynamic Monitoring: Capriate bridge

Measurement objective: comparison with accelerometers, resonance frequencies and modal shape retrieval



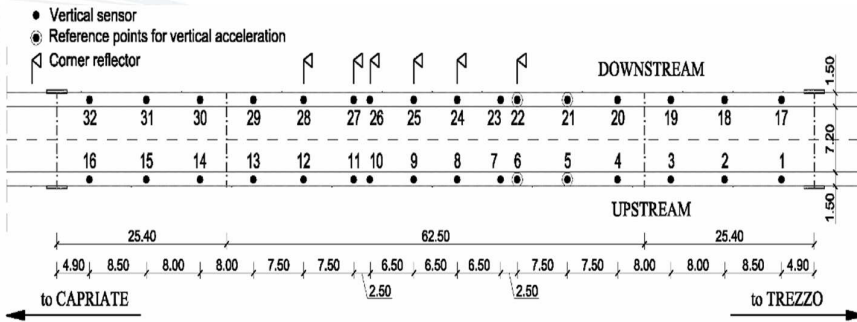
Central arch length (m): 62.5



Dynamic Monitoring: Capriate bridge

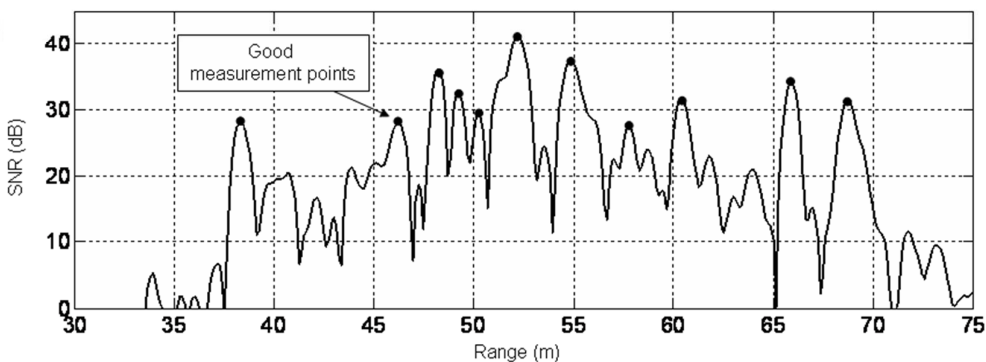


To make a comparison between the results of IBIS-S system and accelerometers system 6 corner reflector were installed at the same position of accelerometers



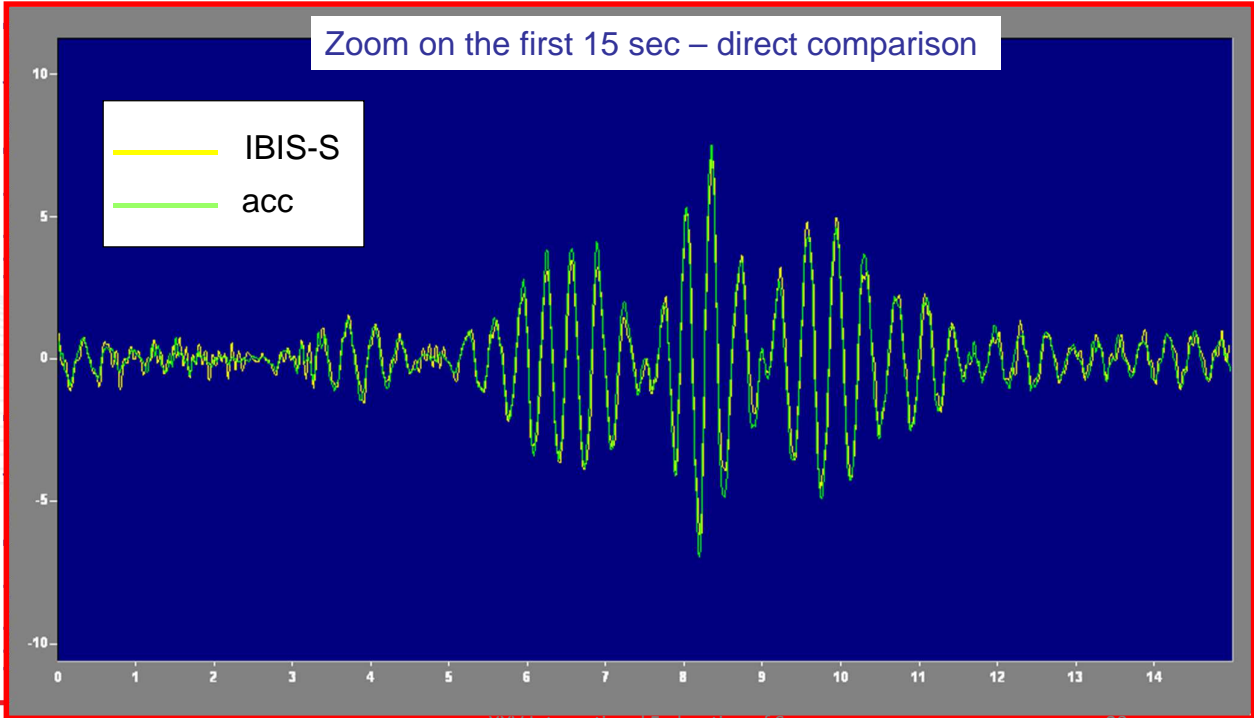
Dynamic Monitoring: Capriate bridge

Bridge photograph and range profile

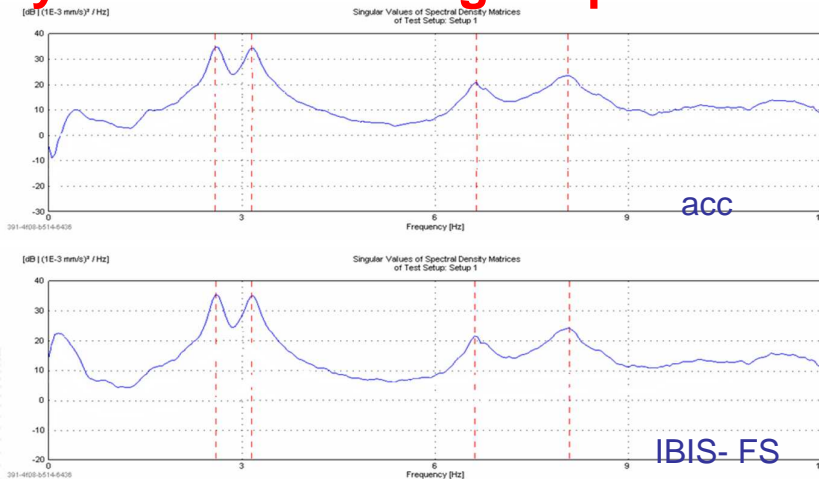


Dynamic Monitoring: Capriate bridge

Velocity comparison for Test Point 22



Dynamic Monitoring: Capriate bridge

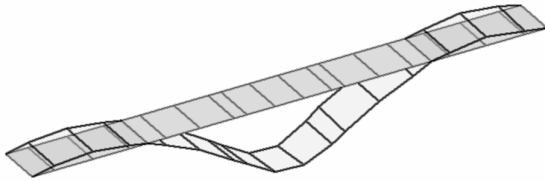


Frequency analysis
comparison on
3000sec
acquisition duration

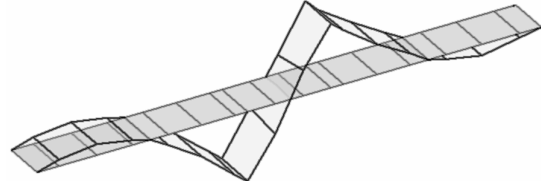
Acc detected frequency	IBIS-S detected frequency	Percentage error
Hz	Hz	%
2,617	2,595	0,84
3,164	3,182	-0,57
6,641	6,608	0,50
8,086	8,077	0,11

Dynamic Monitoring: Capriate bridge

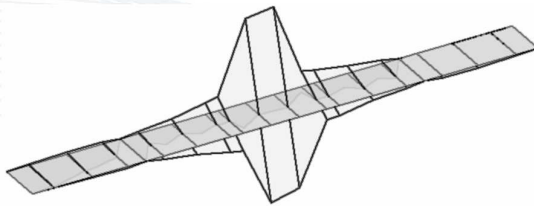
$f = 2.617 \text{ Hz}$



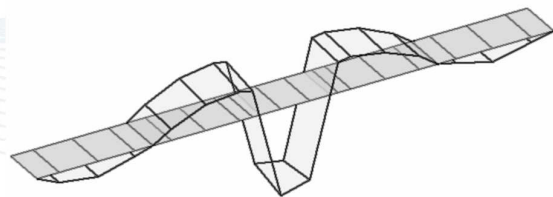
$f = 3.164 \text{ Hz}$



$f = 6.641 \text{ Hz}$



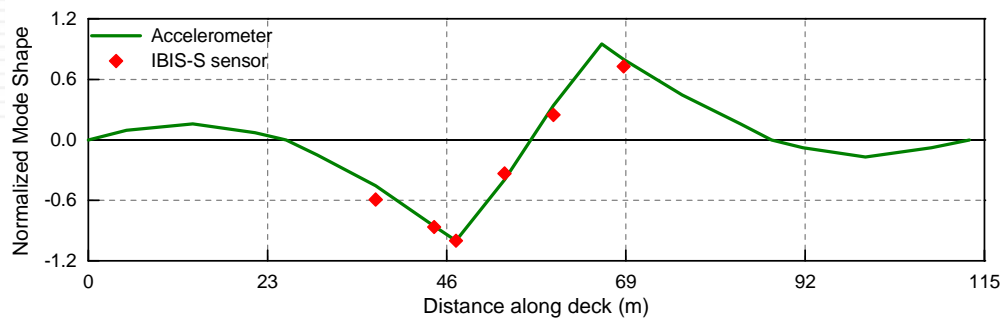
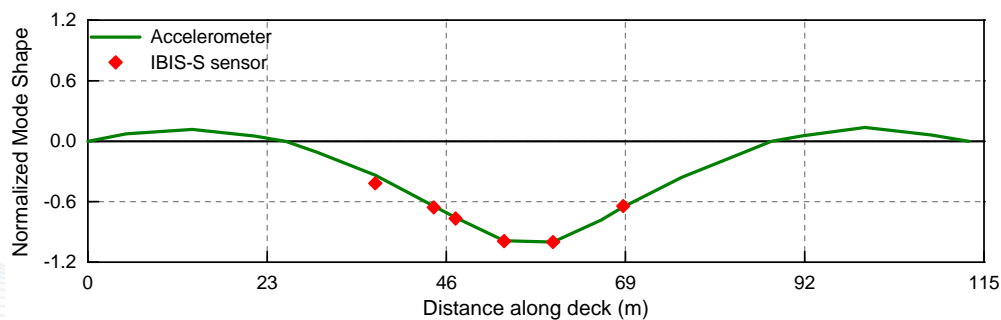
$f = 8.086 \text{ Hz}$



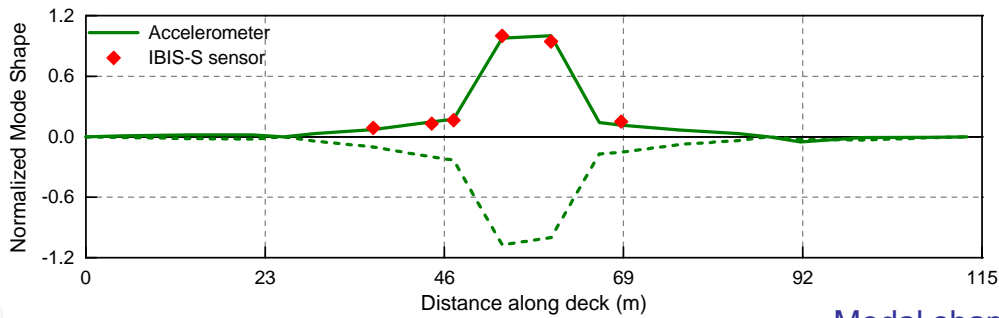
Modal shape obtained by accelerometer data

Dynamic Monitoring: Capriate bridge

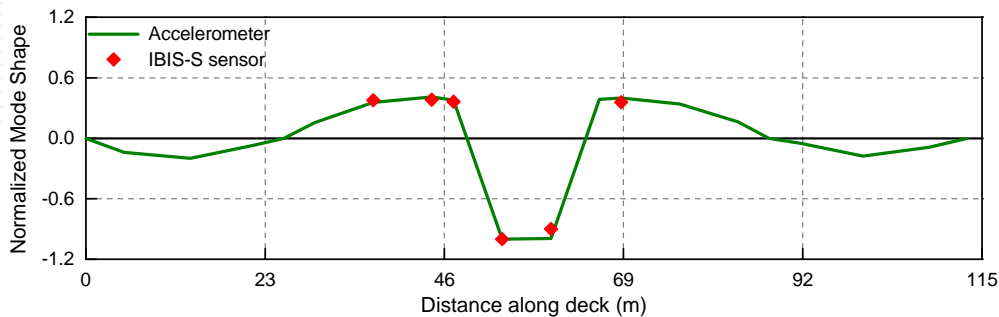
Modal shapes comparison



Dynamic Monitoring: Capriate bridge



Modal shapes comparison



In Summary:

- Interferometry deflection measurements were measured and compared with accelerometer and Linear Variable Differential Transformer fully validating the instrument results.
- The IBIS-FS can be rapidly deployed for short-term displacement and vibration monitoring with complete measurement and set up time being less than one hour
- A great deal of information can be captured from a number of points on a variety of structures very quickly making the unit an excellent alternative for economical static and dynamic surveys

Questions ?

Thanks for your attention