# Diffracted Wave Field And Coherency Analysis: An Example From Dense Array Network In Argotostoli Basin, Cephalonia, Greece

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## Abstract :

The Koutavos-Argostoli area is a relatively small-size shallow sedimentary basin, situated on the Cephalonia Island (Western Greece) in the Ionian Sea. The island is situated in the north-western boundary of the Aegean Plate where the seismic activity is high and dominated by the Cephalonia transform fault. This 3 km long and 1.5 km wide valley is surrounded by hills of limestone and marl. Soft to stiff sediments cover the valley up to 40-50 m depth (Protopapa et al., 1998). As part of a temporary seismological experiment that took place in Argostoli basin within the FP7 EU-NERA (Network of European Research Infrastructures for Earthquake Risk Assessment and Mitigation) 2010-2014 project, a dense array consisting of 21 velocimetric stations was deployed close to the centre of the basin. The array was operational from mid-September 2011 to mid-April 2012. The 21 stations of the array were arranged in concentric circles of 5 m, 15 m, 40 m and 80 m radii around the reference station. From noise measurement, fundamental frequency at the centre of the valley has been observed to be slightly lower than 2 Hz. All the array stations are located on the same geological unit and exhibit resonance frequencies close to 1.8 Hz.

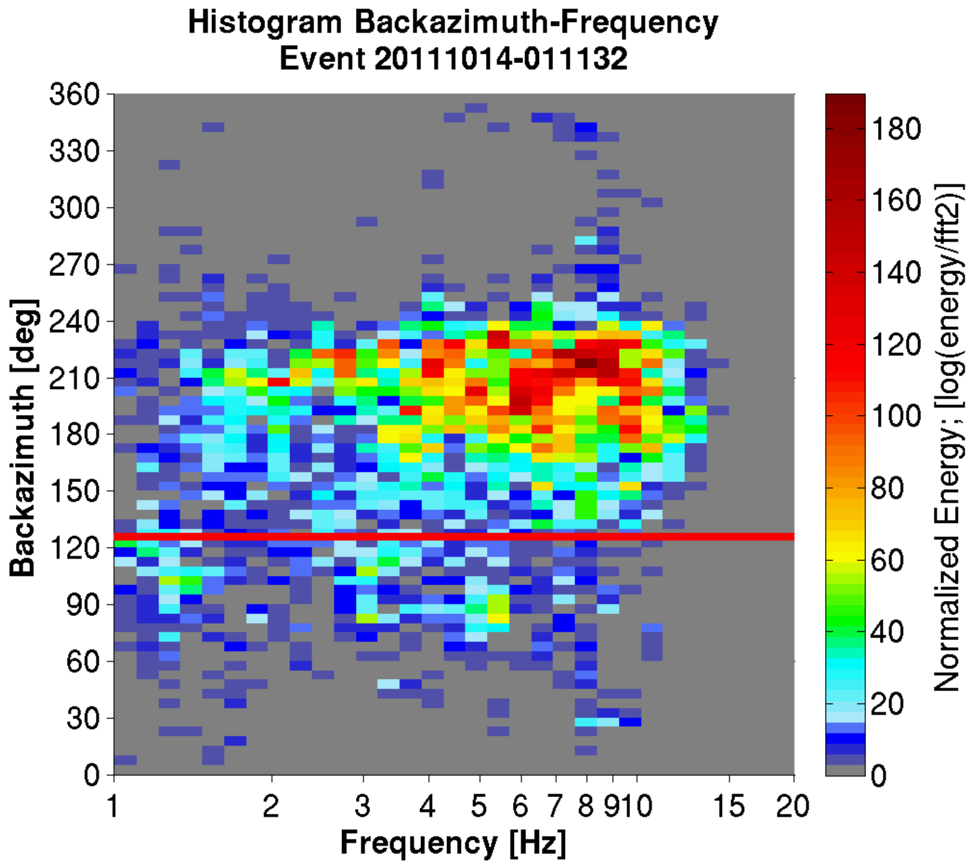
As well-known, the local geological structure and geometry of a site can strongly modify the seismic wave propagation and can lead to large amplifications and strong spatial variations over short distances. These effects are generally associated with a significant proportion of surface waves in the seismic wave-field, which are generally caused by lateral variation of material properties of the site. Due to the complexity of these effects as well as the limitations of geophysical investigations and numerical simulation techniques, such effects could not be incorporated so far in routine seismic hazard assessment and risk mitigation; in fact, the majority of building codes do not include any provision for basin and surface topography effects. In addition, the coherency models from the existing literature are derived on the basis of ground motions recorded at very few arrays, with limited number of sites and events, and generally a poor knowledge of the underground conditions. It is therefore uneasy to capture the whole physics and mechanics of spatial variability, and to extrapolate those models to other sites with different subsoil conditions. Since the Argostoli array is deployed at a very small scale (a few meters of separation distance between the stations), it allows the combined study of local site effects, spatial variability of ground motion and coherency, and can provide very useful information for the design of long structures. The main goals of the Argostoli array data analysis are (1) to understand the key parameters that locally control the ground motion spatial variability and amplification, which require the identification of the seismic wave field composition and underground structure, and, (2) to derive coherency models in order to link spatial coherency to velocity structure and diffracted wave fields as well as to investigate its dependency on magnitude, distance and azimuth in the near fault region. The present article focuses on the preliminary results obtained from the array analysis of a few tens of carefully selected events, which include the identified diffracted wave fields and evaluation of coherency.

During the Argostoli experiment, more than 3000 local and regional events with magnitude 2.0 and greater occurred in the broader Aegean area and about 700 of those events have been recorded with a high signal to noise ratio. Among those, a total of 406 events have been re-localized. A subset of 45

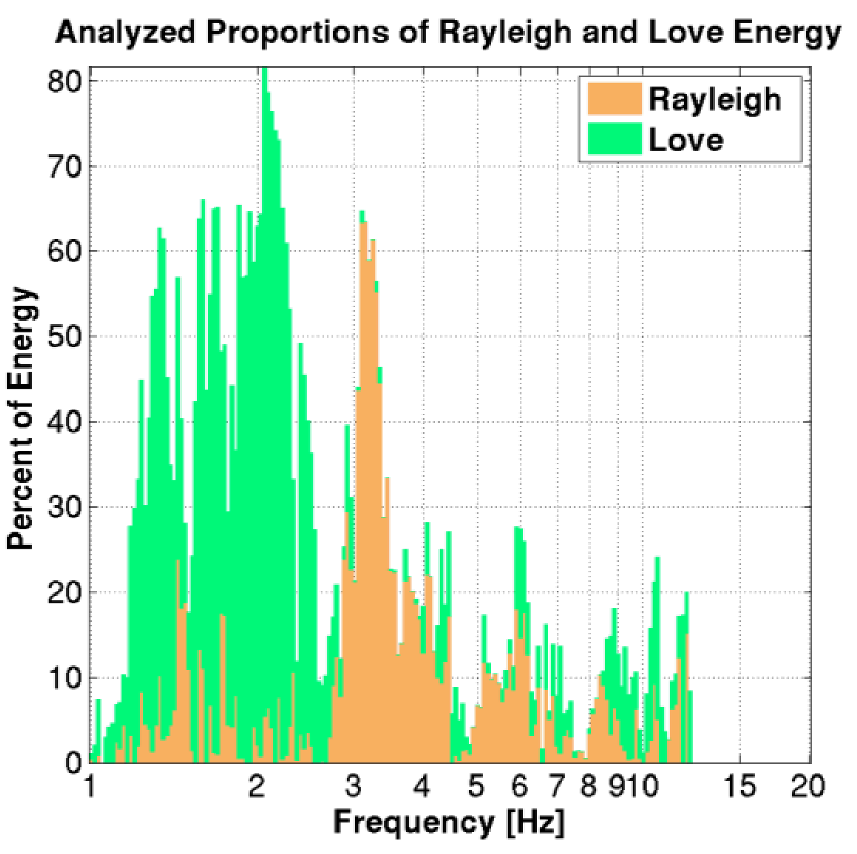
events, with homogeneous azimuth distribution, has been selected in the local magnitude range of 2 to 5 and within the epicentral distance of 0 to 200 km from the array-centre.

A three-component array analysis using the Multiple Signal Characterization algorithm, MUSIQUE, proposed by Hobiger et al. (2012) has been performed on the selected events. This algorithm combines the original MUSIC algorithm with a version using quarternions. MUSIQUE analysis allows the extraction of apparent phase velocity, back azimuth and polarization (discrimination between Rayleigh and Love surface waves) of the waves propagating through the array. The array analysis has been performed considering the entire length of the signal for a frequency range of 1 to 20 Hz, dividing them into 5 periods-long windows for each considered frequency. Lagged coherencies were then evaluated for each station-pair using the same time-frequency bands as the MUSIQUE analysis. Figure 1 shows an example of the results obtained from the analysis for one ML 3.5 event. During the post-processing, a filtering of the results has been done based on the selection of wave trains having the highest energy, signal to noise ratio and the highest average coherency over all station pairs.

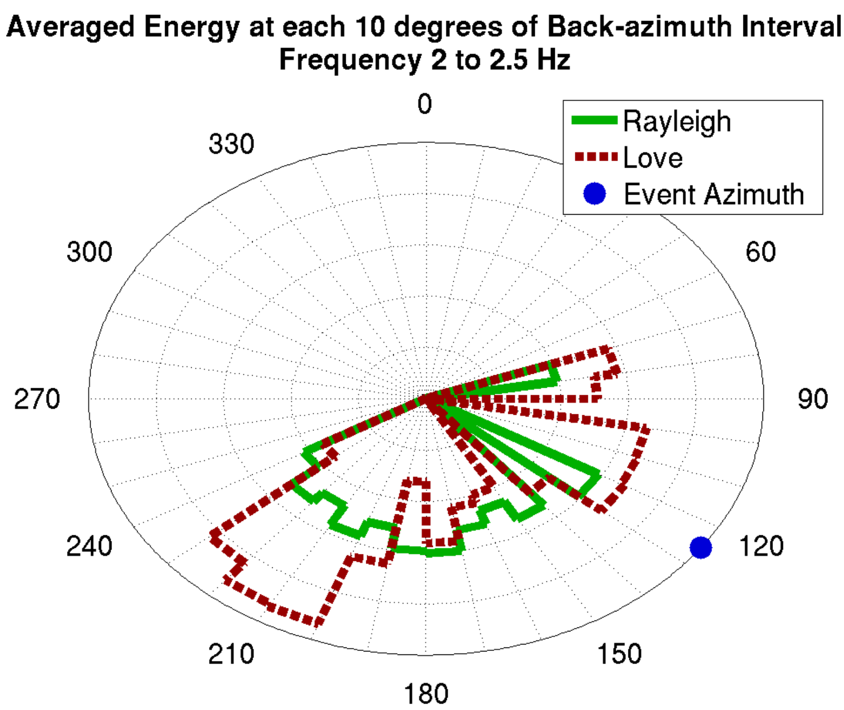
The results of the array analyses clearly indicate a significant scattering corresponding to 2D or 3D effects beyond the fundamental frequency (1.8 Hz) of the basin. The back-azimuth distribution shows that the local scattering comes primarily from the southwest of the basin. The scattered waves are mainly Rayleigh and Love waves, with a significantly higher proportion of Love waves; the corresponding dispersion curves can be measured, indicating frequency dependent phase velocities in the range 250 - 2000 m/s for frequencies 10 to 1 Hz. The spatial coherency exhibits a clear trend to decrease with increasing distance (on the scale of array apertures) and frequency, which can be summarized as a function of the distance over wavelength ratio, and is linked to the local scattering effects. The cumulative summary of the all 45 events confirms again the diffraction from the southwest direction and the robustness of the dominant back-azimuth of the wave arrivals.



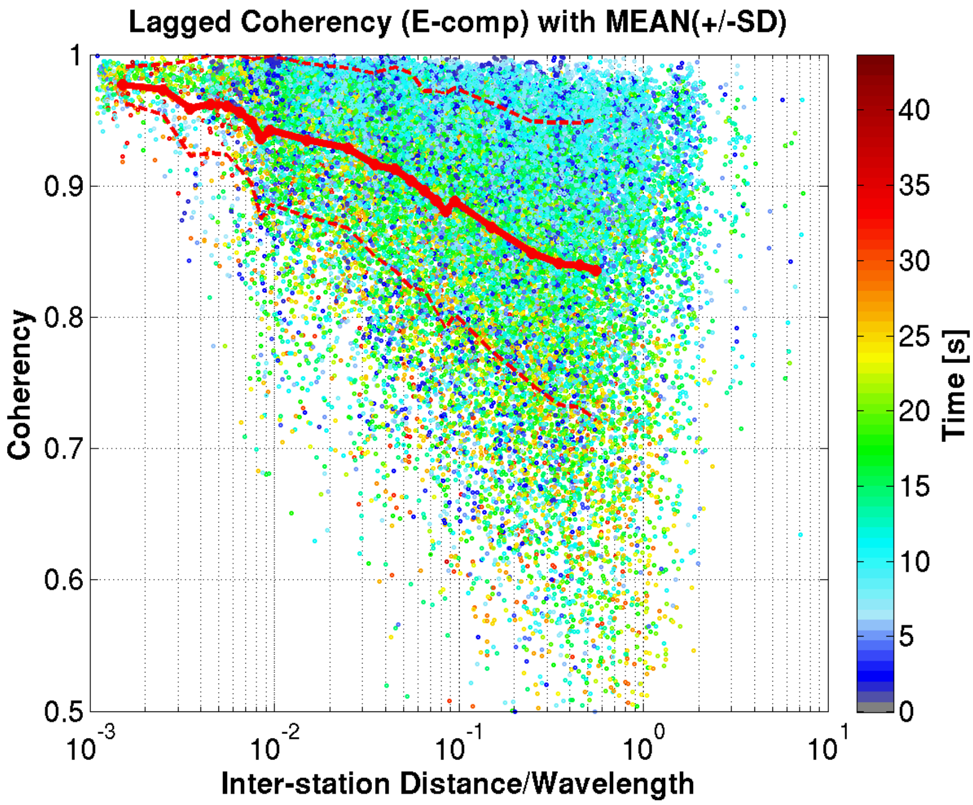

(a)


Analyzed Proportions of Rayleigh and Love Energy
Rayleigh
Love
Percent of Energy
0
10
20
30
40
50
60
70
80
1
2
3
4
5
6
7
8
9
10
15
20
Frequency [Hz]

(b)


Averaged Energy at each 10 degrees of Back-azimuth Interval
Frequency 2 to 2.5 Hz
Rayleigh
Love
Event Azimuth
0
30
60
90
120
150
180
210
240
270
300
330

(c)




(d)

Figure 1. Example of the results from the three-component array analysis for an event with ML= 3.5, at an epicentral distance of 36 km and back-azimuth = 125°. (a) Histogram of back-azimuth with frequency, colorbar indicates the energy level of the wavetrains (b) Radial Distribution of Rayleigh and Love Wave Energy with the back-azimuths (c) Histogram of analyzed proportions of Rayleigh and Love wave energies as a function of frequency (d) Plot of Coherency against the dimensionless ratio Interstation Distance/Wavelength, along with Mean coherency curve with +/-SD, colorbar represents the time of wave.

**References**

[1] Hobiger M, Le Bihan N, Cornou C, Bard P-Y (2012) "Multicomponent Signal Processing for Rayleigh Wave Ellipticity Estimation Application to Seismic Hazard Assessment", IEEE Signal Processing Magazine, 29 (3), p. 29–39

[2] Protopapa E, Papastamatiou D, Michaelidas O, Gazetas G (1998) "The Ionianet Accelerometer Array: Early Results and Analysis", Proceedings of the 11th European Conference on Earthquake Engineering Balkema, Rotterdam, ISBN 90 5410 982 3