

# Broadband ambient seismic noise recorded with submarine telecom DAS along the Texas Gulf Coast: spectral levels and spatial variability

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## Summary

Distributed Acoustic Sensing (DAS) measurements obtained from telecommunication fiber-optic networks provide new opportunities for passive seismic imaging and monitoring in offshore environments. In this study, we analyze ambient seismic noise recorded along a 65-km submarine telecommunication fiber-optic DAS cable offshore Freeport, Texas, to evaluate broadband noise characteristics and suitability for passive seismic applications. The dataset includes more than 5,000 DAS channels with  $\sim 12.8$  m spacing, providing dense spatial sampling of the ambient wavefield along the cable. DAS optical phase measurements are converted to axial strain and then transformed to equivalent ground acceleration. Acceleration spectral densities are computed and compared with Peterson global seismic noise models, with observations from a nearby broadband seismometer, and with previously published ocean-bottom seismograph studies. The recorded wavefield is dominated by ocean-generated microseisms, with stable spectral peaks near  $\sim 0.08$  Hz and  $\sim 0.16$  Hz corresponding to primary and secondary microseisms, respectively. These signals are interpreted as ocean-wave-generated microseisms produced by pressure forcing at the seabed, which generate seismic wave motion recorded by the DAS cable as axial strain. DAS-derived acceleration spectra fall within Peterson noise bounds across the 0.01–10 Hz band and show strong agreement with broadband seismometer observations in the microseism band. Noise amplitudes vary spatially along the cable, while spectral shapes remain consistent, indicating that amplitude variations are primarily controlled by seabed stiffness and site amplification rather than changes in the wavefield itself. The results demonstrate that submarine telecommunication DAS can reliably record broadband ambient seismic noise and ocean-generated surface waves and can serve as a dense offshore seismic array for passive imaging, ambient noise interferometry, dispersion analysis, and velocity model building.

## Introduction

Offshore seismic imaging and monitoring have always been logistically and economically challenging. While traditional seismic methods remain the standard for subsurface imaging, real-time monitoring requires permanent placement of seismic instrumentation to obtain long, continuous recordings. This is particularly challenging in offshore settings, where the industry typically relies on active-source methods and ocean-bottom nodes. These methods are often expensive and limited in spatial and temporal resolution. As a result, continuous broadband observations in marine environments remain substantially more difficult and less common than on land (Cheng et al.,

2021). Emerging seismic imaging technologies such as Distributed Acoustic Sensing (DAS) are therefore being actively explored to expand offshore passive seismic imaging capabilities.

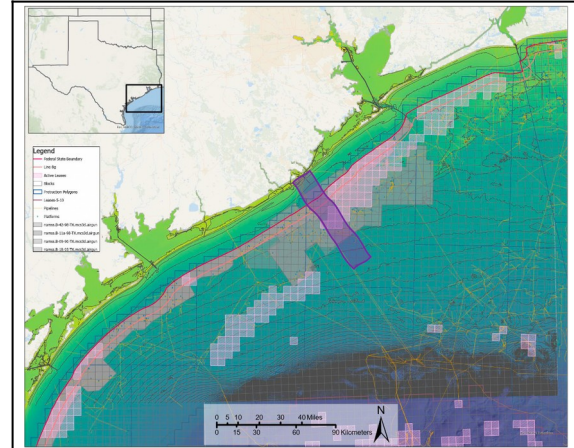


Figure 1: Location of the submarine telecom fiber cable offshore Freeport, Texas, used for ambient seismic noise analysis. The cable route is shown by the purple polygon.

DAS measures axial strain averaged over the gauge length, which represents the spatial derivative of displacement along the fiber direction rather than point ground motion. Although DAS has been primarily applied in borehole Vertical Seismic Profiling (VSP), it is now expanding into surface seismic acquisition, ambient noise interferometry, and real-time monitoring of natural hazards. Recent studies have investigated the broadband performance and instrument response of DAS systems in both onshore and offshore environments (Lindsey et al., 2020; Zhai et al., 2025).

The integration of DAS with telecommunication fibers has been an active area of investigation. Lindsey et al. (2020) demonstrated that telecommunication DAS can transform fiber networks into dense seismic arrays that approximate ground motion over long periods, with amplitude responses consistent with conventional broadband seismometers in the frequency range of 0.01–10 Hz. In a similar onshore study, Zhai et al. (2025) evaluated telecom fiber-optic DAS and compared it with nearby broadband seismic stations, showing comparable noise levels across the same frequency band. Ugalde et al. (2022) conducted an ambient noise assessment on a submarine telecommunication cable across the Canary Islands and showed that poor coupling caused by irregular bathymetry and cable suspension can significantly increase DAS noise levels. While these studies demonstrate DAS capabilities for passive imaging, they also emphasize

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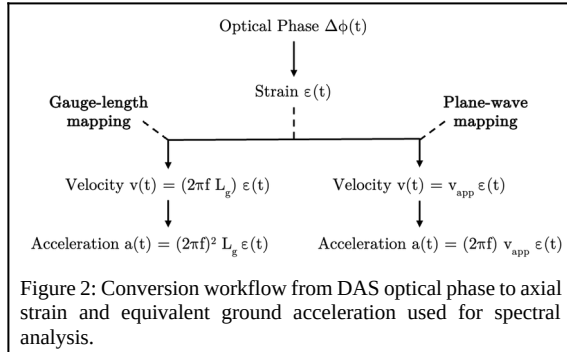
the importance of site-specific coupling and seabed conditions, which are key aspects investigated in this study.

Building on previous work demonstrating the viability of submarine DAS for ambient noise interferometry and surface-wave inversion (Cheng et al., 2021), we extend a similar framework to a submarine telecommunication DAS installation along the Texas Gulf Coast in the Gulf of Mexico.

### Methods

The DAS system records time-varying optical phase changes along the fiber, which represent spatially averaged axial strain over the gauge length. These phase changes are converted to strain as a function of time and position along the cable, forming a dense spatiotemporal sampling of the wavefield. Axial strain is obtained using the standard strain–phase relationship:

where  $\lambda = 1.55 \mu\text{m}$  is the laser wavelength,  $n = 1.4685$  is the refractive index of the fiber,  $L_g = 23.93 \text{ m}$  is the gauge length, and  $K = 0.78$  is the photoelastic scaling factor for longitudinal strain in silica.



DAS optical phase measurements are first converted to axial strain. Standard preprocessing is applied to the strain time series, including detrending to remove the DC component while preserving the broadband signal. The strain records are then transformed to equivalent ground acceleration using the relationships illustrated in Figure 2. Power spectral densities (PSD) are subsequently estimated from the equivalent acceleration time series using the Welch overlapping method, in which the signal is divided into overlapping windows, transformed to the frequency domain, and averaged to reduce variance in the spectral estimates (Welch, 1967). As shown in Figure 2, strain spectra are converted to acceleration using both gauge-length mapping and plane-wave mapping with representative apparent velocities to illustrate the effect of wavefield assumptions on inferred noise levels.

The analyzed dataset was acquired along a 65-km submarine telecommunication fiber-optic cable deployed on the seabed

off the coast of Freeport, Texas (Figure 1). The cable lies in a shallow-water environment where seabed conditions enable efficient strain transfer and support surface-wave propagation along the fiber. Continuous 1-minute DAS records were acquired with 12.76 m channel spacing, 23.93 m gauge length, and 333.33 Hz sampling frequency. The continuous recordings provide dense spatial coverage along the full cable length, enabling analysis of both spectral content and spatial variability of the ambient wavefield.

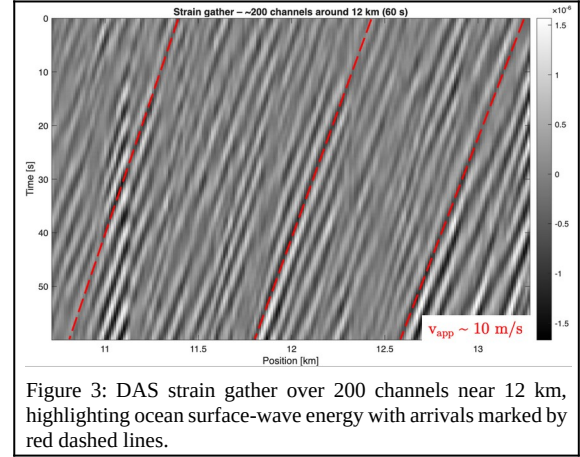


Figure 3 shows an example strain gather centered on a reference channel located 12 km from the interrogator, with 100 neighboring channels on each side. The red dashed lines indicate ocean waves propagating along the fiber, appearing coherently across multiple channels with an apparent velocity of approximately 10 m/s.

As a key step in our noise assessment workflow, we compare DAS acceleration ASD spectra with the New Low Noise Model (NLNM) and New High Noise Model (NHNM) introduced by Peterson (1993), which define the lower and upper bounds of seismic background noise. These models were derived from land-based measurements and serve as a reference for benchmarking DAS noise performance and broadband fidelity. We restrict the interpretation of this comparison to the frequency range 0.01–10 Hz, which captures ocean-generated energy of interest. It is the range where broadband seismometers are stable and representative of true ground motion. Ambient noise outside this range is often dominated by non-seismic trends, such as cultural noise (>10 Hz) and atmospheric pressure and temperature variations (<0.01 Hz) (Besedina & Tubanov, 2023).

### Results

We first characterize the spectral content of the ambient wavefield and then examine how noise levels vary spatially along the cable. The ambient wavefield recorded along the

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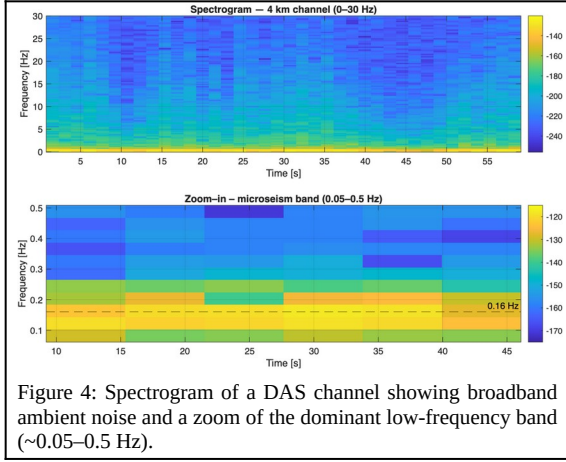


Figure 4: Spectrogram of a DAS channel showing broadband ambient noise and a zoom of the dominant low-frequency band ( $\sim 0.05$ – $0.5$  Hz).

DAS cable is illustrated in Figure 4 using a spectrogram from a representative channel located approximately 4 km from the interrogator. Most of the observed energy is concentrated at low frequencies, with strong energy in the microseism band below  $\sim 0.3$  Hz and additional shallow-water noise extending to higher frequencies up to  $\sim 15$  Hz. The spectrogram shows dominant energy near  $\sim 0.12$ – $0.14$  Hz (7–8 s periods), characteristic of secondary microseisms generated by ocean wave interactions and associated pressure forcing at the seabed.

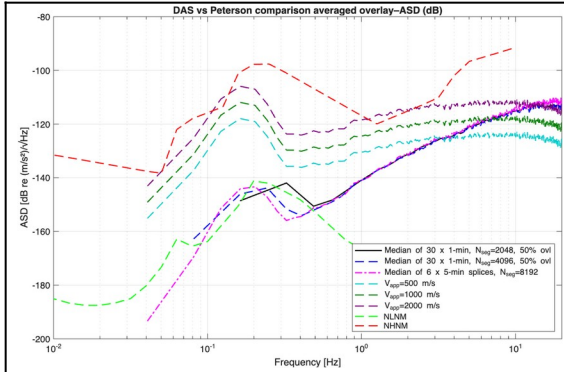


Figure 5: DAS noise spectra computed using 1-minute averages and 5-minute spliced records with different Welch parameters, including apparent-velocity-scaled spectra.

Figure 5 compares DAS-derived noise spectra with Peterson bounds to evaluate broadband performance. The plot shows two versions of the gauge-length-derived acceleration ASD estimates using both 1-minute records and concatenated 5-minute segments over a 30-minute recording period. The 1-minute estimates provide stable spectral levels across the mid-frequency band ( $\sim 0.1$ – $10$  Hz) but exhibit a low-frequency cutoff near  $\sim 0.017$  Hz due to limited record length. To demonstrate DAS low-frequency sensitivity, consecutive 1-minute records are concatenated into 5-minute splices, a single linear detrend is applied, and spectra are

averaged using longer Welch windows with  $N_{seg} = 8192$ , which extends the low-frequency range down to  $\sim 0.003$  Hz. The spectra are first shown without apparent-velocity scaling to provide a baseline comparison with global seismic noise models. Applying representative apparent velocities of  $0.5$ – $2$  km/s shifts the spectra upward by  $\sim 6$ – $12$  dB in the  $0.05$ – $1$  Hz range while preserving the spectral shape. In both cases, DAS-derived ASD spectra remain within the Peterson noise bounds across the  $0.01$ – $10$  Hz band, with the strongest agreement observed in the microseism frequency range.

Unlike the land-based telecom DAS study by Zhai et al. (2025), where DAS self-instrumental noise caused noise levels to exceed the NHNM at long periods, the spectra observed in this study exhibit well-defined microseism peaks while remaining consistent with the Peterson bounds. This suggests that submarine telecom DAS noise levels within the microseism band are dominated by environmental wavefield energy rather than instrumental self-noise.

### Spatial variability of DAS noise along the cable

Figure 6a shows the RMS noise level per DAS channel computed from the full ambient wavefield over approximately two hours of continuous records. The RMS

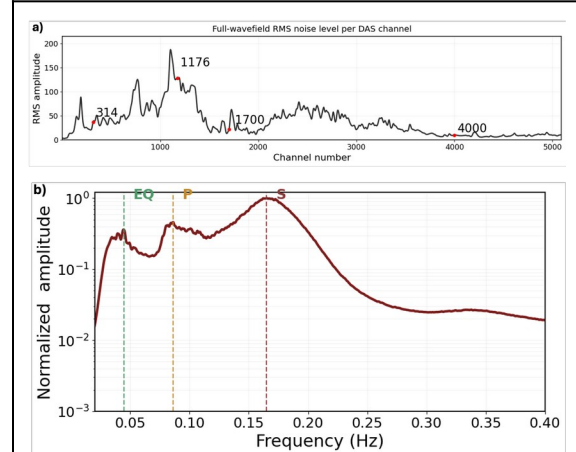


Figure 6: (a) RMS noise amplitude per DAS channel computed from the full ambient wavefield over approximately two hours of continuous records. Four representative channels used for spectral analysis are indicated by red markers. The RMS amplitudes show strong spatial variability along the cable. (b) Average amplitude spectrum computed along the entire cable from the same two-hour record, resolving teleseismic energy near  $\sim 0.04$  Hz (EQ), the primary microseism peak ( $\sim 0.08$  Hz, P), and the secondary microseism peak ( $\sim 0.16$  Hz, S). The consistent spectral peaks indicate that spatial variability primarily affects amplitude rather than spectral shape.

amplitudes exhibit strong spatial variability along the cable. Based on this variability, four representative channels (314, 1176, 1700, and 4000) were selected for detailed spectral analysis. The observed spatial variability is interpreted as a

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seabed stiffness amplification effect rather than simple coupling variability, where softer sediments amplify ocean-generated wave energy while stiffer seabed sections produce lower amplitudes (Bakulin et al., 2026). Figure 6b shows the average amplitude spectrum of the same two-hour DAS record computed along the entire cable. The spectrum consistently resolves teleseismic energy near  $\sim 0.04$  Hz, the primary microseism peak near  $\sim 0.08$  Hz, and the secondary microseism peak near  $\sim 0.16$  Hz. Despite the spatial variability observed in RMS amplitudes along the cable, the spectral character of the ambient wavefield remains consistent, indicating that spatial variability primarily affects amplitude rather than spectral shape.

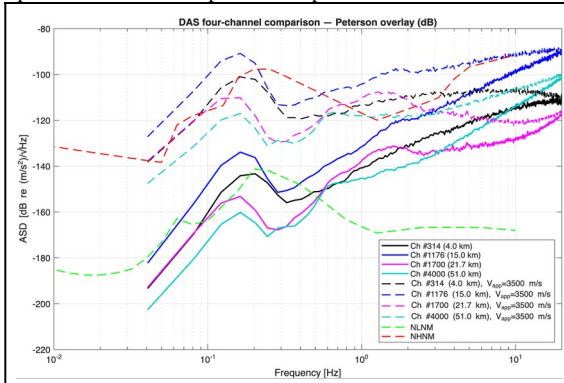


Figure 7: Acceleration ASD spectra for four representative DAS channels (314, 1176, 1700, and 4000) selected based on RMS amplitude variability. Gauge-length-derived spectra and velocity-scaled spectra ( $V_{app} = 3500$  m/s) are compared with Peterson noise models. All channels exhibit similar spectral shapes with consistent microseism peaks, while spectral levels vary systematically between channels, reflecting spatial variability along the cable.

Figure 7 compares the acceleration ASD spectra from the four representative DAS channels identified from the RMS analysis. These channels represent different noise regimes along the cable, ranging from quieter to noisier segments. In addition to gauge-length-derived spectra, we show velocity-scaled spectra using a representative surface-wave velocity of 3500 m/s, near the upper bound of Rayleigh-wave group velocities reported for the microseism band ( $\sim 5$ – $30$  s), which range from  $\sim 2.1$  to  $3.7$  km/s in the ambient-noise surface-wave dispersion study by Muhumuza (2020).

While all channels show the characteristic secondary microseism peak near  $\sim 0.16$  Hz, they exhibit systematic differences in overall spectral levels. Channels with higher RMS amplitudes consistently produce higher spectral levels, while quieter cable segments approach the lower Peterson noise bound. This consistent ordering between RMS amplitudes and acceleration ASD spectra indicates that spatial variability along the cable reflects local seabed amplification effects rather than changes in the wavefield itself.

The spectral peak near  $\sim 0.16$  Hz observed in this dataset is consistent with the strong peak reported in submarine DAS strain spectra by Glover et al. (2026) at a dominant period of  $\sim 6$  s ( $\sim 0.17$  Hz), which they attributed to near-bed dynamic pressure generated by ocean waves. The relatively limited variation observed in spectral shape among channels suggests generally consistent wavefield conditions along the cable, whereas amplitude variations are primarily controlled by seabed mechanical properties.

### Comparison with onshore broadband seismic observations

Additionally, we compared the noise response from the HKT station (IU Network, Houston, Texas), which was processed over the same one-hour period as the DAS dataset and is shown in Figure 8. The HKT station uses a Trillium 360 broadband seismometer recorded at 40 Hz sampling frequency. The sensor records waveforms along three components (BH1, BH2, and BHZ). The horizontal components were rotated by  $149^\circ$  azimuth to obtain a radial component (BHR) approximately parallel to the DAS cable.

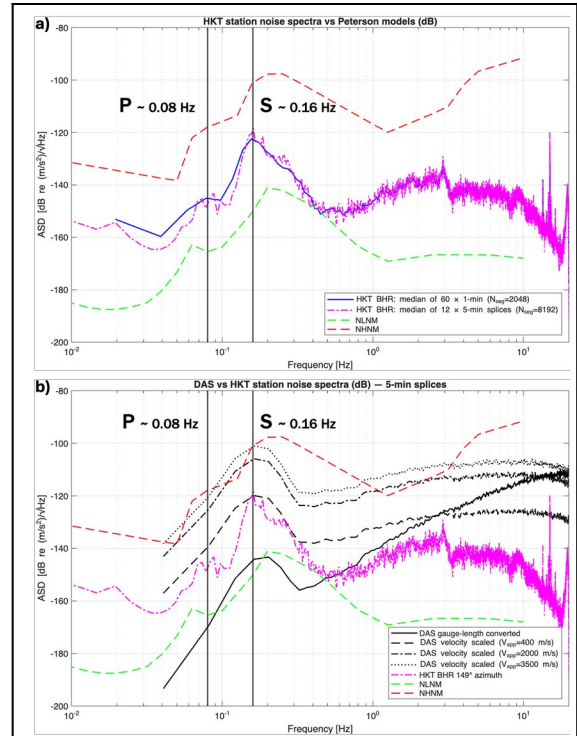


Figure 8: (a) Ambient noise response of the HKT broadband seismometer compared with Peterson noise models. (b) Gauge-length-derived and velocity-scaled DAS noise spectra compared with HKT acceleration ASD and Peterson models. Vertical lines mark the primary (P) and secondary (S) microseism peaks. DAS and broadband seismometer spectra show strong agreement within the microseism band.

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The HKT acceleration ASD estimates were computed using two Welch approaches: 1-minute median spectra ( $N_{\text{seg}} = 2048$ ) and 5-minute spliced median spectra ( $N_{\text{seg}} = 8192$ ). Both spectra, shown in Figure 8a, are consistent across the full frequency band and fall between the Peterson noise bounds. The divergence between the two responses at higher frequencies ( $>1$  Hz) is primarily due to differences in the averaging windows, where the spliced version uses fewer independent windows and therefore exhibits slightly higher variance. These HKT spectra are further compared in Figure 8b with DAS spectra computed using both gauge-length-derived and velocity-scaled conversions discussed earlier. The vertical lines in both figures mark the primary and secondary microseism peaks at  $\sim 0.08$  Hz and  $\sim 0.16$  Hz. Overall, DAS and HKT spectra show strong agreement within the microseism band. Both microseism peaks are clearly resolved by the HKT seismometer, while the DAS response during this hour is dominated by the secondary microseism peak, resulting in a less pronounced primary peak.

The spectral agreement in the microseism band between DAS and HKT is also consistent with the ocean-bottom seismograph (OBS)-HKT comparison by Pulliam et al. (2003), where an OBS deployed in the Gulf of Mexico resolved the same secondary microseism spectral peak as the HKT station. This further supports the validity of the DAS spectral response. The DAS velocity-scaled spectra show elevated noise levels compared to HKT, which is consistent with both the higher noise levels recorded by ocean-bottom seismometers reported by Pulliam et al. (2003) and the theoretical modeling of secondary microseisms by Xu et al. (2025). The latter study demonstrated that ocean-bottom sediments can amplify secondary microseism energy by up to a factor of 100 ( $\sim 20$  dB) relative to land stations and identified the Gulf of Mexico as a region where such amplification occurs, which is consistent with our DAS observations (Xu et al., 2025).

### Conclusions

This study evaluates the feasibility of using DAS coupled with a 65-km submarine telecommunication fiber-optic cable offshore Freeport, Texas, for ambient seismic noise analysis. The results show that the wavefield recorded by DAS is dominated by ocean-generated microseisms and that DAS-derived acceleration spectra fall within Peterson seismic noise bounds across the 0.01–10 Hz band. Spatial variability in noise levels is observed along the cable, while the spectral character of the ambient wavefield remains consistent, indicating that amplitude variations are primarily controlled by seabed stiffness and site amplification effects rather than changes in the wavefield itself. Comparison with the onshore broadband HKT seismometer shows strong agreement within the microseism band, consistent with previous ocean-bottom seismograph observations and

microseism amplification models for the Gulf of Mexico. Despite strong shallow-water noise and spatial amplitude variability along the cable, the spectral characteristics and microseism peak frequencies remain consistent and agree with nearby broadband seismic observations, indicating that the cable records true seismic motion rather than cable-specific noise. These results demonstrate that submarine telecom DAS can reliably record broadband ambient seismic noise and ocean-generated surface waves and can serve as a dense offshore seismic array for passive imaging and surface-wave inversion. Ongoing work will focus on Scholte-wave dispersion and inversion to develop a shear-wave velocity model along the cable.

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