Response to review

Editor:

Please find below the comments submitted in the webform by Reviewer A and B at the bottom of this email. In addition, I read through your manuscript and I have some minor grammatical / wording suggestions to improve readability. Please see these notes in the attached annotated pdf. Please let me know if you have any issues finding these.

Thank you for the reviews and the points raised on the manuscript.

I have made expansion of the text at several points, not picked up by the reviewers, where explanations had been unduly brief.

In response to the points you raised, I have tried to indicate the nature of 'leaking modes' at the beginning before using the term explicitly in connection with the position of singularities.
I have also moved the sentence beginning "I here bring together …" to the end of the Introduction, as you suggested.

I have also tried to follow up all the very sensible suggestions made by the reviewers, and most have been incorporated into the revised form.
Changes are indicated in red and moved material in blue.

Reviewer A:

Recommendation: Revisions Required

The author presented an important issue for understanding the modal interactions. This issue exists in seismological observations of different scales, but rarely mentioned. I also thought about this issue several years ago, but more on the observations. Thus, I have some extended questions from the observation. (The observation results depend on the observation method. Here, I do not intend to ask the author to discuss different observation methods but the different scales of observations.) The paper is written by a senior expert and the expression is very clear. I only have some minor comments for the convenience of reading.

Extended questions:

1. Can the dispersion curves of the interacting waveguides directly calculated and be shown on figure 2 and 3? As far as I understand, the dispersion curves we observe from seismic waves should be a kind of blurring of the kernel, which leads to multimodal theoretical dispersion curves in one observed dispersion curve. Directly calculate dispersion curves after interacting waveguides may be useful for the inversion.

When all modes are considered the dispersion curves become very complicated and if superimposed on figures 2 and 3 would completely obscure the features under discussion.

Whereas the direct frequency-slowness approach automatically covers all modes, with a resolution set by the frequency interval, the tracking of more than a hundred modes presents a very significant computational challenge because of the tight spacing of roots.

A second Appendix is now provided showing the dispersion curves out to 5.3 km/s for both Rayleigh and love waves. Beyond this the density of modes is too high (over 200 modes) to allow meaningful plotting for this frequency band.

2. Usually, we set different half-space depths and layer thicknesses for different scale network observations, which is also shown in Appendix. How much does the half-space depth affect the accuracy of the inversion? Can we quantify the error introduced by the half-space? For example, the phase speed above 2.2 km/s, there is a significant difference on dispersion. According to my experience, for the model in figure 1, we may set the half-space depth within 500m for sediment observations. Would the difference come in lower phase speed? And how to deal with this difference?

   In addition, with the shallower half-space, the P-dominated modes will occur at lower phase speed zones, which may coincide with the S-dominated modes in figure 2.

   Additional comments have been made on the influence of truncated structures at the end of Appendix A.

   The nature of the influence of truncation is model dependent, and thus difficult to quantify in general terms. Error will be at a minimum for lower phase speeds and increase as the wavespeed in the underlying half space is approached.

Minor Comments:

1. Line 139. Should be c > alpha_L
   Corrected

2. Line 144. “The dependence of the seismic response to a surface source on structure at depth (1)” I think the (1) may be after seismic response?

   Rearranged for clarity with the reference to equation (1) after the response expression

3. Line237-238. I suggest to mark it in the figures so that it is easier for readers to understand.

   Crustal markers are already present in the figures, so an extra sentence has been added to draw attention to their significance

4. Line 344. Maybe it is better to mark the depth of the half-space in the subfigure in figure 1.

   The 1 km depth line is already marked in Figure 1. Again a sentence has been added to draw attention to this feature

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Reviewer B:

Valérie Maupin

Recommendation: Revisions Required

This manuscript analyses the characteristics of the modal content of the elastic wavefield in a rather broad range of phase velocity and frequency, with emphasis on how coupling between P and S waves, and between propagation in shallow and deeper structures, form characteristic features in the dispersion curves. The analysis is restricted to 1D vertically varying structures. The full response of the structure is displayed as amplitude in the frequency-phase velocity domain, which gives a much more robust approach than picking individual modes. This provides beautiful images of the response, where the different features discussed in the paper are clearly illustrated. This gives useful insight in how the complexity of dispersion curves is a normal feature of layered structures.

The paper is rather theoretical and a few additional details in the derivation of the equations would not hurt. Here are some suggestions:

- define all the terms in R_F and R_D^0L and write them in matrices instead of in equation 6.

Now defined in new equations (2) and (3)

- I did not see the point in defining X^PP and equation 8, as, as far as I could see, all the following derivations derive directly from equation 5. Equation 8 is not quoted in the rest of the manuscript. Anyway, if equation 8 should be kept, intermediate derivation steps are required.

This material has been removed since I agree it was distracting

- I didn't manage to understand the logic of what is kept and what is neglected in deriving equation 10, and if you keep for example first order but neglect second order terms. Write some more details, with some intermediate equations.

The description has been improved and the equation rewritten to make it clear that single conversions have been retained. All terms with purely P reflection are neglected in this regime.

- equation 11 derives directly from the first term in equation 5, but the terms are shuffled around. I guess this is to give some new physical insight, but warn the reader about it, and explain why you do this.

The expressions have been rearranged to take the same form throughout.

Although the features described in the theoretical parts are illustrated in the examples figures, this comes late. Would it be possible to make one or several sketches to explain features discussed in the theoretical part, for example the paragraph starting line 171.

I now include a figure showing schematically the crossing of modal branches associated with shallow and deeper waveguides, together with an expansion of the associated text.

line 256-257: what do you mean by P or SV excitation? are the sources different? which kind of source mechanism have you used?

A comment has been made after new equation (3) to explain how aspects of the seismic wavefield can be extracted by choice of the components of the reflection matrix for the structure employed.

There are no annotation of the modes on the figures. Either put annotation with reference to what is discussed in the text, or add more precise information in the text about the frequency-phase velocity position of the features you are discussing.

The lower order modes and the P-dominated Rayleigh modes have now been annotated. The descriptions in the text of the various frequency-slowness regimes have been taughtened.

This is a purely theoretical study in a laterally homogeneous structure with no noise. The discussion could include some remarks about the expected robustness of the conclusions in the presence of lateral heterogeneities and noise.

Comments have been added to the conclusions about the effect of lateral heterogeneity.

Minor comments:

- line 46: "the three sets": be more specific

The structural elements have been made specific

line 71: "on" twice

corrected

line 94: "less", isn't it "more"?

Yes - corrected

line 220: remove "a" before "strong"

removed

line 236: "base" --> "case"

corrected

line 263: "the" twice

corrected