Package ANRAY, version 4.01 [1]

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The new version of the package ANRAY does not differ dramatically from the version 4.00. Nevertheless, limited modifications and corrections should make it, hopefully, more reliable and friendly to a user.

The most important changes are the following:

a) The formulae for the calculation of radiation patterns of waves generated by point sources situated in inhomogeneous anisotropic media were modified according to the corrections of the paper by Pšenčík & Teles (1996), see the Appendix. Modifications based on the formulae proposed by Klimeš (1997) for the evaluation of the KMAH index in inhomogeneous anisotropic media have not yet been finished in this version.

b) A new strategy was used in dealing with problems of shear wave singularities. In the earlier versions, various modifications were used, which were often unreliable. The problem will require substantial modifications of the program in near future. In this version, whenever a ray gets to a region of a shear wave singularity, either inside a layer or at an interface, its calculation stops. In this way, calculation of a ray of a multiply reflected *unconverted* qP wave can be stopped if at some interface, generated qS waves would propagate into a singular direction. Due to this measure, the wavefield at some receivers, although illuminated by the considered wave, is not computed. The code, seems to work now more reliably in such situations.

c) Substantial changes have been made in the specification of input and output files. They should lead to a simpler manipulation with input and output files. In connection with these changes, minor changes in input data (practically only in the first lines) were also made.

d) A possibility to specify a moment tensor source by the elements of the tensor was added to the existing specifications of point sources.

e) Extensive debugging in programs as well as in their documentation was performed. Many confusing statements in the documentation were removed or substituted by, hopefully, more clear explanations.

[1] Seismic Waves in Complex 3-D Structures, Report 6 (Department of Geophysics, Charles University, Prague 1997)

Appendix: Specification of the index of the source (Corrected formulae of Pšenčík & Teles, 1996)

The index of the source can attain the values 0, 1 and 2 in the following situations, see Červený (1997), Klimeš (1997):

$$
\begin{aligned}
&k_S = 0 \text{ if } k_1 < 0,\ k_2 < 0\ , \\
&k_S = 1 \text{ if } k_1 < 0,\ k_2 > 0 \text{ or } k_1 > 0,\ k_2 < 0\ , \\
&k_S = 2 \text{ if } k_1 > 0,\ k_2 > 0\ .
\end{aligned} \tag{1}
$$

Here we show how to use the quantities calculated in the dynamic ray tracing for the determination of the index of the source. For this purpose, we express the principal curvatures of the slowness surface at the source in terms of $\partial\vec{r}/\partial\gamma_I$ and $\partial\vec{p}/\partial\gamma_I$. The principal curvatures k are solutions of the quadratic equation

$$(L-kE)(N-kG)-(M-kF)^2=0, \tag{2}$$

where

$$
\begin{aligned}
&L=v^{-1}\left(\vec{v}\cdot\frac{\partial^2\vec{p}}{\partial\gamma_1^2}\right), \quad M=v^{-1}\left(\vec{v}\cdot\frac{\partial^2\vec{p}}{\partial\gamma_1\gamma_2}\right), \quad N=v^{-1}\left(\vec{v}\cdot\frac{\partial^2\vec{p}}{\partial\gamma_2^2}\right), \\
&E=\left(\frac{\partial\vec{p}}{\partial\gamma_1}\cdot\frac{\partial\vec{p}}{\partial\gamma_1}\right), \quad F=\left(\frac{\partial\vec{p}}{\partial\gamma_1}\cdot\frac{\partial\vec{p}}{\partial\gamma_2}\right), \quad G=\left(\frac{\partial\vec{p}}{\partial\gamma_2}\cdot\frac{\partial\vec{p}}{\partial\gamma_2}\right).
\end{aligned} \tag{3}
$$

We can use the relation

$$\frac{\partial\vec{r}}{\partial\gamma_I}\cdot\frac{\partial\vec{p}}{\partial\gamma_J}=-\frac{r}{v}\vec{v}\cdot\frac{\partial^2\vec{p}}{\partial\gamma_I\partial\gamma_J}, \tag{4}$$

see Pšenčík & Teles (1996), and express L, M and N in terms of the quantities which are solutions of the dynamic ray tracing:

$$L=-r^{-1}\left(\frac{\partial\vec{r}}{\partial\gamma_1}\cdot\frac{\partial\vec{p}}{\partial\gamma_1}\right), \quad M=-r^{-1}\left(\frac{\partial\vec{r}}{\partial\gamma_1}\cdot\frac{\partial\vec{p}}{\partial\gamma_2}\right), \quad N=-r^{-1}\left(\frac{\partial\vec{r}}{\partial\gamma_2}\cdot\frac{\partial\vec{p}}{\partial\gamma_2}\right). \tag{5}$$

Using the solution of Eq.(2) in (1), we get alternative rules for the determination of the index of the source:

$$
\begin{aligned}
&k_S = 0 \quad \text{if} \quad a>0\ ,\ b<0 \text{ and } c>0 \quad \text{or} \quad a<0\ ,\ b>0 \text{ and } c<0\ , \\
&k_S = 1 \quad \text{if} \quad a>0\ ,\ c<0 \quad \text{or} \quad a<0\ ,\ c>0\ , \\
&k_S = 2 \quad \text{if} \quad a>0\ ,\ b>0 \text{ and } c>0 \quad \text{or} \quad a<0\ ,\ b<0 \text{ and } c<0\ ,
\end{aligned} \tag{6}
$$

where

$$a=EG-F^2, \quad b=LG+NE-2MF, \quad c=LN-M^2. \tag{7}$$

The quantity a is proportional to the product and b to the sum of the principal curvatures of the slowness surface at the source.

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References

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