
Operator GENE_ACCE_SEISME

1 Goal

This operator allows to generate artificial seismic accélérogrammes for transitory dynamic calculations. He makes it possible to generate two types of signals:

1. Nonstationary seismic signals according to the model of spectral concentration of power (DSP) of evolutionary Kanai-Tajimi, option `DSP`
2. Seismic signals compatible with a spectrum of answer of oscillator (SRO) target, option `SPEC_MEDIAN`, `SPEC_UNIQUE` or `SPEC_FRACTILE`

In both cases, one must associate with it a function of modulation which determines the temporal evolution of the seismic signals by the keyword factor `MODULATION`. If one does not wish to apply temporal modulation, it is necessary to choose a “constant” modulation on the time interval. It is advisable to consult R4.05.05 documentation for a detailed description of modelings and parameters to be informed.

Product a concept of the type `table_fonction`.

2 Syntax

```
acce [table_fonction] = GENE_ACCE_SEISME
```

```
◆ DUREE_PHASE_FORTE = TSM [R]
◆ GRAVITY = G [R]
◆ PAS_INST = dt [R]
◇ FREQ_FILTRE = FF [R]
◇ FREQ_CORNER = FC [R]
◇ NB_TIRAGE = Nbt [I]
◇ NB_POIN = nb_poin [I]
◇ INIT_ALEA = nor [I]
◇ FREQ_PENTE = FP [R]
◇ COEF_CORR = rho [R]
```

(rule: one among DSP, SPEC_MEDIANE, SPEC_UNIQUE, SPEC_FRACTILE

```
◆ DSP = _F (
◇ / ◆ AMOR_REDUIT = amo [R]
    ◆ FREQ_FOND = f0 [R])

( ◆ SPEC_MEDIANE = _F (
◇ / ◆ SPEC_OSCI = spec_cible [fonction_sdaster]
    ◆ AMOR_REDUIT = amo [R]
    ◇ NB_ITER = nbiter [I]
    ◇ FREQ_PAS = fpas [R]
    ◇ ERRE_MAX = (cmax, emax) [R]
    ◇ ERRE_ZPA = (czpa, ezpa) [R]
    ◇ ERRE_RMS = (crms, erms) [R]
    ◇ METHOD = /'HARMO' [DEFECT]
    = /'NIGAM' [TXM] ) )

( ◆ SPEC_UNIQUE = _F (
◇ / ◆ SPEC_OSCI = spec_cible [fonction_sdaster]
    ◆ AMOR_REDUIT = amo [R]
    ◇ NB_ITER = nbiter [I]
    ◇ FREQ_PAS = fpas [R]
    ◇ ERRE_MAX = (cmax, emax) [R]
    ◇ ERRE_ZPA = (czpa, ezpa) [R]
    ◇ ERRE_RMS = (crms, erms) [R]
    ◇ METHOD = /'HARMO' [DEFECT]
    = /'NIGAM' [TXM] ) )

( ◆ SPEC_FRACTILE = _F (
◇ / ◆ SPEC_OSCI = spec_med [fonction_sdaster]
    ◆ SPEC_1_SIGMA = spec_sig [fonction_sdaster]
    ◆ AMOR_REDUIT = amo [R]
    ◇ FREQ_PAS = fpas [R] )

◆ MODULATION = _F (
    ◆ TYPE = /'JENNINGS_HOUSNER' [TXM]
    /'GAMMA'
    /'CONSTANT'
```

```
% if TYPE = GAMMA
```

```
        ◆ INST_INIT          = t_ini      [R])
% if DSP:
    ◆ INT_ARIAS              = arias      [R]
    ◆ ACCE_MAX                = pga        [R]
    ◆ ECART_TYPE              = etc.       [R]
◆ INFORMATION                = / 1        [DEFECT]
                               / 2
◆ TITLE                      = title      [l_Kn]

) ;
```

3 Operands

3.1 Keyword DUREE_PHAS_FORT

◇ DUREE_PHAS_FORT = TSM [R]

Duration of the strong phase of the signal to be generated (cf also R4.05.05).

Parameters of the functions of modulation GAMMA and of Jennings & Housner (JENNINGS_HOUSNER), are identified of kind so that the average strong phase of the signals corresponds to that given. In the case of a constant modulation, the total duration of the signal corresponds to the duration of the strong phase well informed.

3.2 Keyword NB_POIN

◇ NB_POIN = nb_poin [I]

Many points of discretization of the interspectre to be used in the algorithm of generation. nb_poin must be an even number.

If NB_POIN is well informed, then the duration of simulation is determined by this value: $T = dt(N - 1)$ and the point of temporal discretization are: $t_j = j dt$, $j = 0, \dots, N - 1$.

If the keyword NB_POIN is not well informed, one takes the duration of simulation equalizes with 4 times the duration of the strong phase more t_{ini} : $T = 3TSM + t_{ini}$. This makes it possible to simulate the accélérogramme over all its length if the variation of the signal is defined by a function of modulation Gamma or of Jennings & Housner. The number of points NB_POIN is then calculated starting from this value. In the case of a constant modulation (TYPE=CONSTANT), one takes $T = TSM$ and NB_POIN is not asked.

3.3 Keyword FREQ_FILTRE

◇ FREQ_FILTRE = FF [R]

Optional keyword to inform a frequency (in [Hz]) to filter the low frequencies of the seismic signals (accelerogrammes) in the temporal field. It is thus about a high-pass filter. This filter makes it possible to remove a possible drift of the signals in displacement obtained by integration of the accélérogrammes. By default, one does not apply temporal filtering (ff=0.0).

Note:

Attention should be paid not to choose too large FF (ff=0.05Hz constitute a reasonable value of reference). If FF is too large, then one does not remove only the drift but one removes also most of the conrenu in low frequencies of the signals.

3.4 Keyword FREQ_CORNER

◇ FREQ_CORNER = FC [R]

This frequency is known in the community of the seismologists by the term "corner frequency". One can observe that the frequential contents of the seismic signals naturalness tend towards 0 very quickly starting from a certain minimal frequency, namely for frequencies lower than "corner frequency".

In the case of the generation of signals compatible with a SRO, one can use this order to optimize the adjustment of the contents in low frequencies of the signals.

In the case of the generation of signals by the DSP of Kanai-Tajimi, it is necessary to apply this filter to obtain a physical model in agreement with the seismological data, in particular the property that the spectral contents must tend towards zero beyond “corner frequency” (without filter, the DSP of Kanai-Tajimi is not worthless in the beginning). By default, one uses a filter with $f_c = 0.05 \times \text{FREQ_FOND}$ for the DSP of Kanai-Tajimi.

3.5 Keyword PAS_INST

◆ PAS_INST = dt [R]

Pas de time of the seismic signals. This value is used to determine the cut-off frequency for simulations by the formula $F = 1/(2 dt)$ (Shannon). It should be taken care that the cut-off frequency is sufficiently large for modelling the phenomenon well.

3.6 Keyword FREQ_PENTE

◇ FREQ_PENTE = F_p [R]

Slope for the evolution of the centre frequency [Hz/s]: $f(t) = f_0 + f_p(t - t_0)$, where t_0 is the moment of reference and f_0 the centre frequency at this moment. In GENE_ACCE_SEISME, the moment of reference is selected like the moment in the middle of the strong phase: $t_0 = 0.5 \text{TSM} + t_{ini}$. One takes constant values before and after the strong phase (it is advised to consult R4.05.05 for more details). It is observed that, generally, the fundamental frequency drops with time. It is necessary in this case to give a negative slope: $f_p < 0$. The code stops in error if the function $f(t)$ product of the negative centre frequencies over the duration of the strong phase. If FREQ_PENTE is not well informed, then one takes a constant fundamental frequency equalizes with f_0 . This one must be indicated for the option DSP, in the case of SPEC_UNIQUE, SPEC_MEDIANE or SPEC_FRACTILE, the centre frequency of the process results from the target spectrum of answer.

Notice : If one does not inform FREQ_PENTE and if one chooses a function of constant modulation, one obtains a stationary process. This process corresponds to the DSP of Kanai-Tajimi classic (but filtered in low frequencies).

3.7 Keyword NB_TIRAGE

◇ NB_TIRAGE = Nbt [I]

The number of signals to be simulated. The value of defect is 1.

3.8 Keyword INIT_ALEA

◇ INIT_ALEA = nor [I]

If the keyword INIT_ALEA is well informed, one initializes the germ of the random continuations by this value. Two calculations consecutive with same initialization produce the same seismic signal then.

3.9 Keyword COEF_CORR

◇ COEF_CORR = rho [R]

This keyword makes it possible to inform a coefficient of correlation for the generation of correlated signals. The coefficient of correlation can take the values between -1 and +1: $-1 < rho < 1$.

If COEF_CORR is informed, then one simulates pairs of correlated signals, with coefficient of correlation rho. These signals can represent the two components of correlated horizontal seismic signals or then of the temporal loadings for studies in multi-support.

In TABLE_FONCTION at exit of the operator, the two components are listed by 'NOM_PARA' who is worth 'ACCE1' for the first and 'ACCE2' for the second signal.

3.10 Keyword GRAVITY

◆ GRAVITY = G [R]

In general, one takes GRAVITY = 9.81 (m/s^2) (cf. too §3.8.2). In this case, IL is necessary to inform ACCE_MAX (PGA), and ECART_TYPE or, if necessary, the spectrum targets (SPEC_OSCI) in g. This size of standardisation is also used for the calculation of the intensity of Arias. By way of an example, to give ACCE_MAX = 0.2 corresponds to a PGA of 0.2g with $g = 9.81 m/s^2$. The generated accélérogrammes will be then accelerations in m/s^2 .

3.11 Keywords factor DSP

The earthquake is modelled by a nonstationary stochastic process. The spectral concentrations of power (DSP) evolutionary make it possible to take account of a nonstationary phenomenon in amplitude and frequential contents like the earthquake. The variation of the amplitude is taken into account by a function of modulation whereas the evolution of the frequential contents is modelled by the evolutionary DSP of Kanai-Tajimi. The DSP of Kanai-Tajimi moreover is filtered in order to very remove the frequential contents in low frequencies which can lead to digital problems (nonworthless drifts for the integrated signals).

The parameters related to the variation of the amplitude are the intensity of Arias, the duration of the strong phase and the moment of beginning of the strong phase. The parameters related to the DSP and the evolution of the frequential contents are the damping and the fundamental frequency of the DSP of Kanai-Tajimi as well as the slope describing the evolution of the latter in the course of time. These parameters can be given starting from a given acélérogramme, and/or of a SRO (spectrum of answer of oscillator) and/or by calling on the available data in the literature. Moreover, the model being parameterized, it is possible to take account of the variability and the uncertainty of these parameters using random pullings.

The algorithm of simulation and the model are described with more detail in the reference material R4.06.04.

3.11.1 Operands AMOR_REDUIT, FREQ_FOND

◆ AMOR_REDUIT = amo [R]

Value of the rate of depreciation criticizes DSP of Kanai-Tajimi.

◆ FREQ_FOND = F₀ [R]

Centre frequency of the DSP of Kanai-Tajimi, it is the frequency where the most energy is concentrated.

3.12 Keywords factor SPEC_MEDIANE, SPEC_UNIQUE and SPEC_FRACTILE

This keyword factor makes it possible to inform given of a SRO targets in order to generate seismic signals in agreement with the target SRO. It is then necessary to determine a "compatible" DSP with the data of the target SRO. There are two options

- Generation of a seismic signal to which the SRO is very close to the target SRO: it is necessary to proceed to iterations as well as possible to adjust the spectral contents of the signal. If one asks for several signals (`NB_TIRAGE`), then the adjustment is done by generated signal.
- Generation of `Nbt` signals whose median spectrum respects the target. If the median SRO is a physical spectrum, then the whole of the generated signals has a median SRO in general near to the target. One can however make iterations to improve the adjustment of the median SRO.
- Generation of `Nbt` signals whose median spectrum and the spectrum with a sigma respect the target. It is about a method for the studies "best-estimate". The generated signals have a variability close to that of the signals real available in the databases, in particular with regard to variability between the achievements (*record-to-record variability*). For that, it is necessary to inform the median spectrum as well as the spectrum with a sigma. The median spectrum as well as the spectrum with a sigma are generally provided by the laws of attenuation.

3.12.1 Operand `SPEC_OSCI`

◆ `SPEC_OSCI = spec_cible`

One informs here the target SRO in the form of a function with in X-coordinate the frequencies and ordinate acceleration spectral (the last must be normalized according to `GRAVITY`). One can use `DEFI_FONCTION` to build it. If the option were chosen `SPECTRE_FRACTILE`, then this spectrum must correspond to the median spectrum (as defined by the laws of attenuation).

3.12.2 Operand `SPEC_1_SIGMA`

◆ `SPEC_1_SIGMA = spec_cible`

Obligatory keyword for the option `SPEC_FRACTILE`. One informs here the SRO with a target sigma in the form of a function with in X-coordinate the frequencies and ordinate spectral accelerations (the last must be normalized according to `GRAVITY`). One can use `DEFI_FONCTION` to build it. The spectrum with a sigma, for example, is provided by the laws of attenuation which suppose a lognormal distribution of spectral accelerations and thus of the values of the SRO. That implies that the SRO with a sigma corresponds to the fractile with 84% of the SRO. It is advised to consult the reference material R04 .05.05 for more details on this modeling.

3.12.3 Operand `AMOR_REDUIT`

◆ `AMOR_REDUIT = amo` [R]

Value of the reduced damping of the SRO indicated under `SPEC_OSCI`.

3.12.4 Operands `ERRE_ZPA`, `ERRE_RMS` and `ERRE_MAX`

◇ `ERRE_MAX = (cmax, emax)` [R]
◇ `ERRE_ZPA = (czpa, ezpa)` [R]
◇ `ERRE_RMS = (crms, erms)` [R]

These keyword are optional, one can inform the weighting coefficients as well as the maximum error wished by the user for the three criterion of adjustment: maximum error on the waveband, error on the ZPA (*zero period acceleration*) and error RMS. It is possible to inform weighting coefficients (`cmax`, `czpa`, `crms`) but not of target maximum error (`emax`, `ezpa`, `erms`). On the other hand, three weightings should be informed together. The calculated error is the relative error, namely the difference between the value of the spectrum carried out and the value of the target spectrum divided by the value of the target spectrum. If the desired maximum error (`emax`, `ezpa`, `erms`). If one of the errors is larger than the indicated value, an alarm is emitted. The weighting coefficients are used to determine an multi-objectives error balanced for each iteration. This criterion is used to choose, among the results of the iterations, the accélérogramme (or accélérogramme) at exit of calculation which respect the criterion as well as possible (it is not always the last iteration).

3.12.5 Operand `NB_ITER`

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◇ NB_ITER = nbiter [I]

One informs the iteration count to improve the adjustment of the accélérogramme to spectrum (SRO) target. This keyword is optional: by default, one does not make iterations. With the option SPEC_FRACTILE, one cannot reiterate.

3.12.6 Operand METHOD

◇ METHOD = / 'HARMO' [DEFECT]
= / 'NIGAM' [TXM]

This optional keyword makes it possible to choose the method for calculation of the spectrum of answer. They are the same methods as those available for calculation of SRO with CALC_FONCTION [U4.32.04]. By default, one uses the method 'HARMO'. The spectrum of answer is then obtained by successive harmonic calculations (for different Eigen frequencies from oscillator) via a FFT/IFFT of the signal as starter. Method 'NIGAM' is detailed in the document [R5.05.01].

3.12.7 Operand FREQ_PAS

◇ FREQ_PAS = fpas [R]

With this optional keyword, one can choose the step of discretization of the SRO used to determine the compatible DSP. Values of the SRO indicated via SPEC_OSCI are then interpolated to obtain the step of discretization fpas wished. By default, one takes the same step of frequency as that used for the generation of the signals. This last results from the cut-off frequency and point NB_POIN, cf §3.5.

3.13 Keywords factor MODULATION

Parameters of the functions of modulation GAMMA and of Jennings & Housner (JENNINGS_HOUSNER), are identified of kind so that the strong phase TSM average of the signals corresponds to that given. For a modulation CONSTANT (not of modulation), the duration of the simulated signals corresponds to TSM. One uses the definition being based on the intensity of Arias. One notes $TSM = T_2 - T_1$ where T_1 and T_2 are respectively the moments of time when 5% and 95% of the intensity of Arias (total energy) are carried out. The moment T_1 corresponds to the beginning of the strong phase t_{ini} .

If NB_POIN is given for the modulations Gamma and Jennings & Housner, then the total duration of the signals corresponds to $(NB_POIN-1) * PAS_INST$.

3.13.1 Operand TYPE

◆ TYPE = JENNINGS_HOUSNER [TXM]
GAMMA
CONSTANT

Definition of the type of modulation (cf also R4.05.05).

Modulation CONSTANT corresponds to one signal without amplitude modulation. If one supposes moreover than the fundamental frequency of the DSP is constant, then one brings back oneself to a stationary process.

3.13.2 Operands INT_ARIAS, ACCE_MAX, ECART_TYPE

If the option were chosen DSP, then it is necessary to inform one of the three parameters intensity of Arias, PGA (maximum acceleration on the ground) or standard deviation to define energy contained in

the signals. If one chose one of the three keywords factor SPEC_UNIQUE, SPEC_MEDIANE or SPEC_FRACTILE, then this information is already contained in the target spectrum.

◇ INT_ARIAS = arias [R]

Average intensity of Arias: $Arias = E \left(\frac{\pi}{2g} \int_0^{\infty} X^2(t) dt \right)$ with X the process modelling the seismic movement (acce) and g is gravity.

◇ ACCE_MAX = pga [R]

Maximum acceleration on ground (PGA). One associates this value to the median maximum of the signals to be generated. The standard deviation corresponding is given starting from the factor of peak and for the strong phase TSM.

It is necessary to inform ACCE_MAX (PGA) in g . The value of g is to be informed by the keyword GRAVITY. Thus, ACCE_MAX= 0.2 corresponds to a PGA of 0.2g with $g=9.81m/s^2$. The generated accélérogrammes will be then accelerations in m/s^2 .

◇ ECART_TYPE = etc. [R]

Standard deviation of the subjacent stationary stochastic process. One applies then the amplitude modulation (GAMMA or JENNINGS_HOUSNER).

It is necessary to inform ECART_TYPE in g (confer also above). The value of g is to be informed by the keyword GRAVITY . One must take GRAVITY =9.81 (m/s^2) to obtain accelerations in m/s^2 .

3.13.3 Operand INST_INIT

◆/◇ INST_INIT = t_ini [R]

Moment of beginning of the strong phase in the case of the function of modulation GAMMA.

Parameters of the function of modulation GAMMA are identified (by least squares) so that TSM and t_{ini} are respected.

3.14 Operand INFORMATION

◇ INFORMATION =

/ 1: pas d' impression.

/ 2: impression of the relative information to the model and the discretization (treatment of the signal).

3.15 Operand TITLE

◇ TITLE = title

title is the title of calculation to be printed at the top of the results [U4.03.01].

4 Produced table

The parameters of the produced table are the following

PARAMETER	TYPE	DESCRIPTION
NUME_ORDRE	I	sequence numbers (NB_TIRAGE)
FUNCTION	K24	name of the generated functions
NOM_PARA	K24	ACCE1 and ACCE2 (if COEF_CORR)

5 Examples

One can consult the case test zzzz317.