

A DMAP Alter to Calculate the Contributions of Individual Modes In a Modal Complex Eigenvalue or Frequency Response Solution

by

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Abstract:

In this paper, a DMAP alter is presented which will calculate and print the Contributions of individual modes to a solution at user-selected locations. The alter allows you to chose from several different formats for the output: Magnitude/phase, real/imaginary, projection on solution, fraction of solution, and others.

Introduction:

The approach implemented in this paper uses a DMAP alter to calculate the contributions of each mode to the displacement at selected dof in the model in either SOL 110 (Modal Complex Eigenvalues) or SOL 111 (Modal Frequency Response). The alter was developed based on requests from several clients and the results of a discussion between myself and several members from MSC's Southfield, Michigan office technical support staff. The alter is available in the sssalter directory for V70.5 as modconta.v705.

1. Overview

This DMAP was developed in response to a "simple" client request, "Can you print modal participation factors for me?". That request is one which is frequently heard by MSC support engineers throughout the world. The biggest problem which we encounter when responding to this question is "what is meant by participation factor"? It seems that each engineer has a different definition of this term. Among these definitions, we have:

A) The civil engineering definition is:

$$= {}^tM_r$$

where:

= participation factor

= elastic mode

r = a rigid-body vector

M = Mass matrix

The civil engineering "participation factor" has the interesting property that if the summation of the participation factors for all modes multiplied by the acceleration of gravity is equal to the total weight of the model. In fact, many people call the civil engineering "participation factor" the "modal effective mass". This is a popular tool in dynamics and is available in the sssalter directory in either checka.v705 or effmassa.v705. (The sssalter directory and files contained therein are documented in the MSC/NASTRAN Common Questions and Answers¹)

B) The modal force = tP

Where:

P is the applied force vector

This is a measure of how much of the physical loading is transformed into the modal coordinate. The problem with this is that it does not have a physical meaning, it simply lets us know if a loading is likely to "excite" a mode. This can be printed with a simple DMAP alter as follows (SOL 111) :

```
COMPILE SEMFREQ
ALTER 'CALL . *FREQRS . *CASEF '
MATPRN PHF// $
```

C) The contribution of a single mode to the displacement at any selected dof in the model –

$$ij_i$$

Where

i is the solution in modal coordinates for mode I and

ϕ_{ij} is the mode shape for mode I, dof j

and, of course, there are many more.

During a meeting in Southfield, this topic came up and I tried to get a simple definition of what was really wanted by the client. As a first step, it was decided to select only one type of participation factor, the displacement resulting from a single mode. Of course, then the question came up, "What format would you like that in"? In the course of the discussion, we came up with 6 possible formats, each with a reasonable argument for having it be the format. These formats were (not listed in any particular order):

1 = each mode's response (magnitude/phase)

2 = projection of modal response on the solution (magnitude)

3 = fraction of total displacement per mode (option 2 divided by total displacement magnitude)

4 = scaled magnitudes (option 2 divided by largest term in option 3 per dof)

5 = modal displacements (real /imaginary)

6 = modal response for each mode - magnitude and phase(wrt total displacement at point)

Of course, since each engineer seems to have a different definition of participation factor, it was decided to call the output "modal contributions", which seems less likely to be misinterpreted.

The alter allows the results to be printed in any of the above 6 formats and has a seventh option, which combines options 1 and 3.

2. What the Alter Does

In a separate subDMAP called PARTFAC, the alter calculates and stores the modal contributors (participation factors). The alter uses parameters ZUZRR1 and ZUZRC1, which may be stored on the database) to store the solution at user-selected dof for each mode. ZUZRC1 is used for the complex eigenvalues, the total solution for the selected dof, and for the solution for each mode for the selected dof. ZUZRR1 is used to store the excitation frequencies, the eigenvectors for the chosen dof, the magnitude of the solution for each mode, the phase angle of the solution for each mode, the projected magnitude of the solution for each mode upon the total solution, the relative phase angle between the solution for each mode and the total solution, the magnitude of the total solution, and the phase angle of the total solution.

The way this is done is by using different values of the qualifiers ZUZRI1, ZUZRI2, and ZNAME. All of these parameters are defined in the NDDL and are not used by any of the standard solutions. They are provided for use in user-DMAP, such as this one. For a detailed description of how these parameters are defined and how the qualifiers are used, see the MSC/NASTRAN DMAP Module Dictionary.

The results are printed in tabular form based on the format selected by you.

3. User Interface

In addition to the standard output requests, the alter uses one parameter to determine the format for the additional output and a user-defined set of dof to determine the dof for which the output is desired. A description of these is provided below:

PARAM,PARTFAC = parameter determining the format of the output from the alter

1 = each mode's response at each dof selected (magnitude/phase) = default

2 = projection of modal response on solution for each dof selected(magnitude)

3 = fraction of total displacement per mode (option 2 divided by total displacement)

- 4 = scaled magnitudes (option 2 divided by largest term in option 3 per dof)
- 5 = modal displacements (complex solution at each dof by mode number)
- 6 = modal response for each mode - magnitude and phase(wrt total displacement at point)
- 7 = combination - output from both options 1 and 3

USET,U3,...

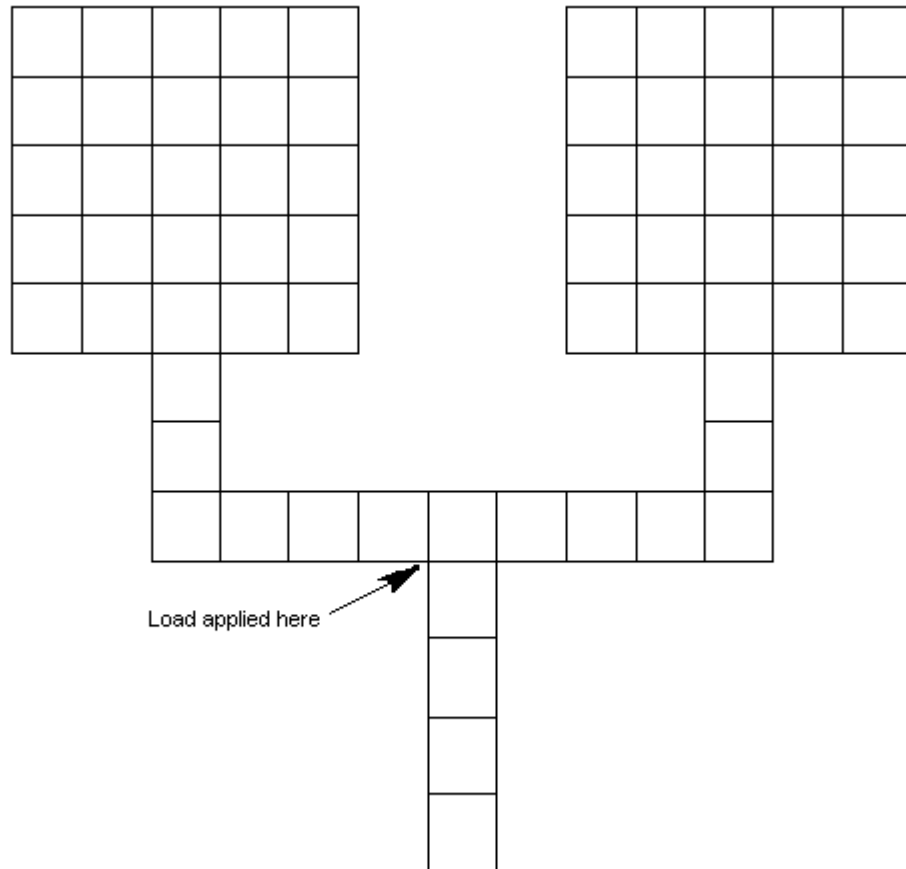
And/ Or

USET1,U3,...

Any dof placed in the U3 set by USET and/or USET1 entries will have the modal contributions printed using the format requested by PARAM,PARTFAC.

Sample Problem

The sample model is the “two-headed flyswatter” model used in the MSC/NASTRAN Superelement seminar notes². The loading consists of an oscillating out-of-plane point load on the indicated grid point.



This loads is applied a frequencies between 1.0 and 20.0 Hz. I am using SOL 111 and getting modes up to 200.0 Hz. In order to assure accuracy, I used one residual vector^{4,5}.

Results

Step 1: Evaluate modes – using modevala.v705

The first step is to see which modes we expect to be active in the solution by using “modevala.v705”^{1,7}. This involves two runs, first a static run using “pchdispa.v705”¹, second an eigenvalue solution using “modevala.v705”

As a residual vector was requested, the run provides two EIGENVALUE SUMMARY TABLES. The original set of normal modes follows.

R E A L E I G E N V A L U E S				
(BEFORE AUGMENTATION OF RESIDUAL VECTORS)				
MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES
1	1	1.171679E+03	3.422980E+01	5.447843E+00
2	2	3.460238E+03	5.882379E+01	9.362097E+00
3	3	3.991923E+04	1.997980E+02	3.179883E+01
4	4	6.105859E+04	2.471004E+02	3.932724E+01
5	5	1.187518E+05	3.446039E+02	5.484541E+01
6	6	2.308826E+05	4.805024E+02	7.647433E+01
7	7	2.439876E+05	4.939510E+02	7.861474E+01
8	8	1.288677E+06	1.135199E+03	1.806726E+02
9	9	1.448988E+06	1.203739E+03	1.915810E+02

A single residual vector was added by using PARAM,RESVEC,YES. The second EIGENVALUE SUMMARY TABLE included this mode as mode 10 and has one additional line as follows:

10	10	5.089070E+06	2.255897E+03	3.590371E+02
----	----	--------------	--------------	--------------

This high frequency mode represents any portion of the static solution under the applied load, which the original modes cannot represent. Therefore, this set of modes is capable of exactly representing the “static” solution. The output from modevala.v70 indicates this.

```
^^^
^^^ RESULTS FOR LOADING NUMBER          1
^^^
^^^ STRAIN ENERGY FRACTIONS FOR EACH MODE
^^^ MODE NO          1 =    9.921062E-01
^^^ MODE NO          2 =    4.968143E-03
^^^ MODE NO          3 =    2.099547E-04
^^^ MODE NO          4 =    7.233973E-06
^^^ MODE NO          5 =    2.621694E-03
^^^ MODE NO          6 =    1.903540E-05
^^^ MODE NO          7 =    1.953301E-30
^^^ MODE NO          8 =    6.357280E-05
^^^ MODE NO          9 =    4.724291E-33
^^^ MODE NO         10 =    4.191349E-06
^^^
^^^ TOTAL STRAIN ENERGY IN INPUT VECTOR      =    7.758314E-05
^^^ TOTAL STRAIN ENERGY REPRESENTED BY MODES =    7.758315E-05
^^^
^^^ TOTAL FRACTION FOR ALL MODES =    1.000000E+00
```

From the above, it is apparent that the residual vector is not necessary for this model and loading. That is, the first 9 elastic modes are capable of representing 99.999% of the static solution, so we expect that they should be able to accurately represent the dynamic solution. From looking at this, we make expect that modes 7 and 9 will not contribute to the dynamic solution, as their contributions here are numeric zero. We

would expect mode 1 to be the dominant mode and modes 2, 3, and 5 to be contributing. When loaded near or at resonance, we would expect modes 4, 6, or 8 to contribute.

Step 2: Run Frequency Response using modconta.v705

Now it is time for the SOL 111 run using the new alter. The input file for this run (abbreviated) is shown below:

```
SOL 111
$
$ STATIC LOADS APPLIED TO UPSTREAM SUPERELEMENTS 1 & 2
$   USED LOADSET,LSEQ, AND DLOAD TO APPLY THEM DYNAMICALLY
$
TIME 25
include 'modconta.v705'
CEND
TITLE = SAMPLE PROBLEM 1 - MODAL FREQ RESP
SUBTITLE = DYNAMICS - FREQ RESP
LOADSET = 10 $ Used to define dynamic load and to generate residual vector
set 999 = 101
disp(phase)=999
LABEL = FORCE AT POINT 13
METHOD = 2
DLOAD = 15
FREQ = 100
SDAMP = 101
BEGIN BULK
$
$ select dof for output from the alter and the format for the output
$
uset1,u3,3,101
param,partfac,7
$
$ add residual vector
$
PARAM,RESVEC,YES
$
FREQ1      100      1.      1.      19
FREQ4      100      1.      20.     .1      5
$
TABDMP1,101,CRIT,,,,,,+DAMP
+DAMP,0.,.01,200.,.01,ENDT
$
TABLED1,15
,0.,1.,200.,1.,ENDT
RLOAD1      15      100
LSEQ      10      100      12
FORCE,12,13,,2.,0.,0.,1.
$
EIGRL,2,,200.
include MODEL.DAT
ENDDATA
```

In this file, the “include” command is adding the DMAP alter to the file. In the BULK DATA section, the USET entry is defining GRID point 101(the upper right-hand corner point), dof 3 as belonging to the “U3” set (the set the alter will print results for), and PARTFAC is set to 7 (combined printout for forms 1 <each mode’s response at each dof selected (mag/phase)> and 3 <fraction of total disp per mode>).

The loading frequencies are between 1.0 and 20.0 Hz. In order to be sure to capture the peak response, a FREQ1 and a FREQ4 entry are used. The FREQ1 entry selects uniformly spaced frequencies starting at

1.0Hz and incrementing by 1.0Hz. The FREQ4 (new in V69) automatically places loading frequencies at the resonant frequencies and nearby. This guarantees that we will capture the peak responses. Selected output from this run follows:

First the solution for the displacement of GRID 101, dof 3 -

FREQ(HZ)	MAG	PHASE
1.000	0.445	359.77
2.000	0.500	359.49
3.000	0.628	359.06
4.000	0.966	358.12
4.903	2.389	354.50
5.000	2.881	353.26
5.175	4.631	348.87
5.448	23.233	269.88
5.720	4.492	191.43
5.993	2.255	185.81
6.000	2.225	185.73
7.000	0.784	181.90
8.000	0.513	180.41
8.426	0.488	179.24
8.894	0.566	175.08
9.000	0.629	172.42
9.362	1.420	99.95
9.830	0.070	45.79
10.000	0.028	108.85
10.298	0.057	168.68
11.000	0.085	178.27
12.000	0.085	179.75
13.000	0.076	180.07
14.000	0.068	180.18
15.000	0.060	180.22
16.000	0.053	180.24
17.000	0.048	180.25
18.000	0.043	180.26
19.000	0.039	180.28
20.000	0.035	180.32

Looking at the above table, you can see the additional loading frequencies created by the FREQ4 entry. As we expected, the peak responses occur at the resonant frequencies.

Now for selected output from the DMAP alter. Since we requested output format 7 (using PARTFAC), we obtain two sets of output. The first is the solution at GRID 101, dof 3 for each mode in Magnitude/Phase format. The second is the projection of each modes contribution upon the total solution at GRID 101, dof 3.

Selected Magnitude/Phase Output:

```

^^^LOADING FREQ = 1.000000E+00 HZ
^^^
^^^ RESPONSE FOR MODE      1 = 4.808677E-01 3.597823E+02

```

^^^ RESPONSE FOR MODE	2 =	2.837745E-02	1.798762E+02
^^^ RESPONSE FOR MODE	3 =	6.942533E-03	3.599639E+02
^^^ RESPONSE FOR MODE	4 =	8.365434E-04	1.799708E+02
^^^ RESPONSE FOR MODE	5 =	1.629345E-02	1.799791E+02
^^^ RESPONSE FOR MODE	6 =	8.853520E-04	3.599850E+02
^^^ RESPONSE FOR MODE	7 =	0.000000E+00	1.799854E+02
^^^ RESPONSE FOR MODE	8 =	2.404034E-03	3.599937E+02
^^^ RESPONSE FOR MODE	9 =	0.000000E+00	1.799940E+02
^^^ RESPONSE FOR MODE	10 =	8.485030E-04	1.799968E+02

The above is from the solution with the applied loading acting at 1.0Hz. At this frequency, the total solution is .445 units. Mode 1 is furnishing more than that, or .48 units. Modes 2 and 5 actually reduce the magnitude of the response. If we desired to reduce the response at this location to this loading, we would wish to somehow increase the contribution of modes 2 and 5, or decrease the contribution of mode 1.

Limitations

Although two clients are known to have been using this alter, it has not been extensively tested. The following Known limitations exist:

- 1) The alter has not been tested using superelements and may not support superelements.
- 2) The alter does not support the mode-displacement method of data recovery. If you have set PARAM,DDRMM,-1, then the alter will print a warning and the run will continue as if the alter were not included

At the present time, I do not know of any other limitations, if you should discover a limitation or an error in the alter, please contact me and I will try to correct it.

Summary and Conclusions

A DMAP alter was developed to allow engineers to determine the contribution of individual modes to the total displacement at selected dof. This information should assist you in identifying which areas of your model should be modified to improve the design by reducing the contribution of modes which make the results unacceptable, or by increasing the results of modes which actually reduce the response.

The goal of this and many of the other alters in the sssalter directory is to allow you to be able to modify your models more efficiently to improve your results. My hope is that this, along with many of the other alters in the sssalter directory, will become a helpful tool in your design process.

References

1. MSC/NASTRAN Common Questions and Answers, Second Edition, John Lee (editor), The MacNeal-Schwendler Corporation, Los Angeles, Ca., 1993
2. "MSC/NASTRAN Superelement Seminar Notes", The MacNeal-Schwendler Corporation, Los Angeles, Ca., Feb., 1997
3. MSC/NASTRAN Release Guide Version 69, The MacNeal-Schwendler Corporation, Los Angeles, Ca, 1996
4. Using Residual Vectors in MSC/NASTRAN Dynamic Analysis to Improve Accuracy
5. MSC/NASTRAN Release Guide Version 70, The MacNeal-Schwendler Corporation, Los Angeles, Ca, 1997

6. Using Strain Energy to Identify Modal Participation in a Dynamic Response Analysis, a presentation at the 1994 MSC World Users' Conference.
7. Some Suggestions for Evaluating Modal Solutions,