SODD:
A Computer Code to calculate Detuning and Distortion Function Terms in First and Second Order

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Abstract

The program *SODD* (**S**econd **O**rder **D**etuning and **D**istortion function) calculates the detuning, distortion and Hamiltonian terms for arbitrary complex accelerator structures. Starting from the linear lattice functions and the strength of the multipoles these terms are determined in first order of the multipole strength and in second order of all possible pairs of multipoles.

1 Introduction

Since some time one–turn maps have been used to derive detuning, distortion and Hamiltonian terms via Normal Form [1, 2] to very high orders. To this end É. Forest has been provided the efficient computer tool DALIE [3].

The great advantage of having a map that comprises the integrated information of all nonlinearities around the machine may however also be a disadvantage. In the design phase of an accelerator it is mandatory to understand the effect of each individual element in the ring. It is possible to derive the map with multipole strengths as parameters so that a subsequent Normal Form analysis allows to determine all nonlinear terms as a function of those multipoles. However, it is not possible to have hundreds or thousands of these parameters. Of course, one can derive maps for subsections of the ring, but all this remains a tedious effort.

It is therefore helpful to have a complementary tool that derives these terms for each element directly albeit to low order only. For the SSC the theory for such a tool has been prepared and programmed in part[4]. The FORTRAN program *SODD*, as presented here, is a full implementation of detuning, distortion and Hamiltonian terms in first and second order of multipole strengths to arbitrary multipole order and for all possible combinations of multipoles.

2 Description

The Program *SODD* consists of 3 parts:

- Subroutine Detune calculates the detuning function terms in first and second order in the strength of the multipoles.

- Subroutine Distort1 calculates the distortion function and Hamiltonian terms in first order in the strength of the multipoles. Contrary to the more traditional approach [5] the Normal Form technique needs no restrictions to slowly varying terms.

- Subroutine Distort2 calculates the distortion function and Hamiltonian terms in second order in the strength of the multipoles.

The program uses roughly 50Mbytes which is needed in particular to calculate the second order distortion function due to pairs of multipoles of up to 11th order.

SODD has been successfully compiled and executed on several computer platforms. You will find the documentation, src (source file), bin (executable) and example (example run) directories on afs at the following locations.

- **DEC alpha station**:
  /afs/cern.ch/group/si/slap/share/sodd/.alpha_dux40

- **IBM rsplus**:
  /afs/cern.ch/group/si/slap/share/sodd/.rs_aix42

- **HP–UX slap01**:
  /afs/cern.ch/group/si/slap/share/sodd/.hp_ux102

- **HP–UX hpslap03**:
  /afs/cern.ch/group/si/slap/share/sodd/.hp700_ux90

If you are logged onto one of these platforms you may drop the system name: e.g. on the **DEC alpha station** you type 'cd /afs/cern.ch/group/si/slap/share/sodd/example' to examine the example run.

3 Input

3.1 Description of the Accelerator

As input the program expects a file **fort.34** which contains 8 columns:

- Position of Multipole [m]
- Name of Multipole
- Multipole Type k ($k > 0$ ==> erect Multipole; $k < 0$ ==> skew Multipole); e.g. **k = 3** is an erect sextupole, **k = –5** is a skew decapole
- Single particle strength à la SIXTRACK
- Horizontal Beta function
- Vertical Beta function
- Horizontal Phase advance
- Vertical Phase advance

The last line in this file is special: it contains the lattice functions at the end of the accelerator; the name is **END** and the artificial multipole type **100** is used.

This file can be automatically produced with SIXTRACK when the linear optics parameter are calculated with the <LINE> block [6]. It is also produced directly from MAD [7] with the DOOM program by invoking the MAD–SIXTRACK converter [8]. To this end the script **mad_6t** has been prepared which expects the option **special** (see details at Web location [9]).

3.2 Program Parameters

1. **Program selection:**
   Enter **iprog** (1 to 7)

   - iprog = 1 ==> Run Program Detune
   - iprog = 2 ==> Run Program Distort1
   - iprog = 4 ==> Run Program Distort2

   All combinations of programs can be run by specifying iprog properly.

2. **Order selection:**
   Enter **n1, n2** (–11 to 11)
   Specify low (n1) and high (n2) limit of orders to be studied. Erect and skew elements are denoted with positive and negative values respectively; e.g. (n1 = –4, n2 = 10) ==> the orders (–4, –3, –2) and (3 to 10) will be treated.

3. **Position Range:**
   Enter **etl1, etl2** [m]
   The multipoles located within the position range (etl1, etl2) will be considered in all calculations.

4. **Printout Switch:**
   Enter **iu_on** (0 to 3)
   Output files meant for spreadsheets, i.e. no comments. Human readable output is found in **fort.6** even for (iu_on = 0).

   - iu_on = 0 ==> No printout
   - iu_on = 1 ==> Output at the end of the position range
   - iu_on = 2 ==> At each Multipole in the position range

4 Output

If the printout switch <iu_on> is non zero the programs produce the following output.

Table 1: Output of Program Detune

Unit	iu_on	Multipole Strength Order	Contents in each column
70	1	1	multipole order
			(hor.,ver.) plane => (1,2)
			hor. or ver. detuning
			order of horizontal Invariant
			order of vertical Invariant
71	2	1	multipole order
			(hor.,ver.) plane => (1,2)
			hor. or ver. detuning
			order of horizontal Invariant
			order of vertical Invariant
72	1	2	first multipole order
			second multipole order
			horizontal detuning
			order of horizontal Invariant
			order of vertical Invariant
73	1	2	first multipole order
			second multipole order
			vertical detuning
			order of horizontal Invariant
			order of vertical Invariant

Table 2: Output of Program Distort1

Unit	iu_on	Multipole Strength Order	Contents in each column
74	1	1	multipole order
			cosine part of distortion
			sine part of distortion
			amplitude of distortion
			j
			k
			l
			m
75	1	1	multipole order
			cosine part of Hamiltonian
			sine part of Hamiltonian
			amplitude of Hamiltonian
			j
			k
			l
			m
76	2	1	multipole order
			appearance number in position range
			number of resonance
			position
			cosine part of distortion
			sine part of distortion
			amplitude of distortion
			j
			k
			l
			m
77	2	1	multipole order
			appearance number in position range
			number of resonance
			position
			cosine part of Hamiltonian
			sine part of Hamiltonian
			amplitude of Hamiltonian
			j
			k
			l
			m

Table 3: Output of Program Distort2

Unit	iu_on	Multipole Strength Order	Contents in each column
78	1	2	first multipole order
			second multipole order
			cosine part of distortion
			sine part of distortion
			amplitude of distortion
			j
			k
			l
			m
79	1	2	first multipole order
			second multipole order
			cosine part of Hamiltonian
			sine part of Hamiltonian
			amplitude of Hamiltonian
			j
			k
			l
			m

5 Special Case: Linear Coupling

The case with linear coupling is special in the sense that the skew quadrupoles influence the linear optics so that the beta functions and phase advances are changed. The program *SODD* needs the unperturbed linear lattice functions to evaluate detuning and distortion functions due to skew quadrupoles. It is therefore suggested to reduce the strength of the skew quadrupoles by say 10^{-20} before producing the linear lattice file fort.34. In this way the linear lattice functions stay unperturbed and the skew quadrupoles appear at their proper location in the file fort.34. A simple edit procedure of file fort.34 will allow to multiply all skew quadrupole strengths by the inverse factor 10^{20}. The file fort.34 is then ready to be treated by *SODD*.

References

[1] M. Berz,"Differential–algebraic description of beam dynamics to very high orders", Part. Acc. **24**, pp. 109–124 (1989).

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[3] É. Forest, written in 1986, private communication.

[4] J. Bengtsson and J. Irwin, "Analytical Calculations of Smear and Tune Shift", SSS–232 (1990).

[5] G. Guignard, "A general treatment of resonances in accelerators", CERN 78–11 (1978).

[6] F. Schmidt, "SIXTRACK, version 1.2, single particle tracking code treating transverse motion with synchrotron oscillations in a symplectic manner", CERN SL/94–56 (AP) (1994), http://wwwslap.cern.ch/frs/Documentation/doc.html.

[7] H. Grote and F.C. Iselin, "The MAD Program (Methodical Accelerator Design), Version 8.10, User's Reference Manual", CERN SL 90–13 (AP) (Rev. 4), http://wwwslap.cern.ch/act/mad/mad8/user_guide.ps.gz.

[8] H. Grote, "A MAD–Sixtrack Interface", SL Note 97–02 (AP).

[9] H. Grote, "mad_6t; Script to run the MAD–SIXTRACK converter via the DOOM program", http://wwwslap.cern.ch/ hansg/doom/doom_six.html.