

THE COMPUTER CODE BPERM FOR WAKEPOTENTIAL & IMPEDANCE CALCULATIONS

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Abstract

The program **bperm** is a 2-dimensional code for wakepotential and impedance calculations based on an analytic method of boundary perturbation. It can be employed for periodic structures with rotational symmetry and is useful for structures with small discontinuities such as shielded bellows and valves, tapered transitions, weldments, etc. One principle used in developing the code is portability. It is written in Fortran 77 and is entirely self-contained, with no machine-dependent calls and with simple file input not relying on the namelist extension. The post-processor **gnuplot** has been used for plotting.[1] The code runs on UNIX as well as on VMS computers. It is currently stored on the Common File System (CFS) at the National Energy Research Supercomputer Center (NERSC). A user's guide can be found in Reference [2].

I. INTRODUCTION

The computer code **bperm** is a generalized version of an earlier code using the boundary perturbation method for calculating wakepotentials and impedances for periodic structures.[3] The fundamentals of this method can be found in References [3-6] and are briefly introduced below.

When a rigid Gaussian bunch of rms length σ traverses a periodic structure of period length L and mean radius b_0 , the longitudinal and transverse wakepotentials calculated by the boundary perturbation method are, respectively,

$$W_{\parallel}(s)^{m=0} (V/pC) = -1.8\pi \sum_{p=1}^{\infty} p |2c_p|^2 \cdot \sum_{n=1}^{\infty} k_{0n} \operatorname{Re} \left[\frac{1}{2} e^{-s^2/2\sigma^2} w \left(\frac{k_{0n}\sigma}{\sqrt{2}} - j \frac{s}{\sqrt{2}\sigma} \right) \right], \quad (1)$$

$$W_{\perp}(s)^{m=1} (V/pC \cdot m) = -\frac{360\pi}{b_0^2} \sum_{p=1}^{\infty} p |2c_p|^2 \cdot \sum_{n=1}^{\infty} \left\{ \frac{1}{1-x'_{1n}} \operatorname{Im} \left[\frac{1}{2} e^{-s^2/2\sigma^2} w \left(\frac{k'_{1n}\sigma}{\sqrt{2}} - j \frac{s}{\sqrt{2}\sigma} \right) \right] - \operatorname{Im} \left[\frac{1}{2} e^{-s^2/2\sigma^2} w \left(\frac{k_{1n}\sigma}{\sqrt{2}} - j \frac{s}{\sqrt{2}\sigma} \right) \right] \right\}, \quad (2)$$

in which s is the distance between the bunch head and the point where the wakepotentials are being calculated, w the complex error function, and

$$k_{mn} = \frac{\pi p}{L} + \frac{L x_{mn}^2}{4\pi p b_0^2}, \quad (3)$$

$$k'_{mn} = \frac{\pi p}{L} + \frac{L x'_{mn}{}^2}{4\pi p b_0^2}, \quad (4)$$

where x_{mn} and x'_{mn} are the n^{th} root of the Bessel functions J_m and J'_m , respectively. All the lengths on the r.h.s. of Eqs. (1)-(4) are in centimeters. The parameter c_p is the Fourier coefficient of the given periodic structure. For a simple geometry it may have an analytic expression. For example, for the structure shown in Figure 1, one has

$$c_p = -j \frac{2\epsilon}{\pi b_0} \frac{\sin(p \frac{\pi q}{L})}{\frac{\pi q}{L}} \frac{1}{p^2} \quad \text{for } p = \pm 1, \pm 3, \dots \quad (5)$$

$$= 0 \quad \text{otherwise.}$$

But in general, c_p has to be computed by a Fast Fourier Transform (FFT), as is done in the code **bperm**.

In order to convert the wakepotentials computed by Eqs. (1) and (2) to impedances, one needs to set the time origin correctly. For this purpose, the code shifts the time zero point from the bunch head to the bunch center, and moves the part of the wakepotentials between the bunch head and center to the tail of the wake. The shifted wakepotentials are then Fourier-transformed to impedances.

Since the code is based on analytical formulae, it consumes much less CPU and memory than that by numerical integration codes such as TBCI or ABCI.[7,8] In addition, it can be applied to more general types of geometries (provided that the perturbation is not too big) than some other analytical methods (*e.g.*, the field matching method).

II. CODE DESCRIPTION

The program **bperm** is a 2-dimensional code and can be employed for periodic structures with rotational symmetry. The input is one complete period of the structure described in the **r** (radial) and **z** (axial) plane as an array of points, which are assumed to be connected with straight segments. Input data for **bperm** is in an ASCII file named **bperm.in**. It contains seven keywords: *dataset*, *title*, *pmax*, *smax*, *sigma*, *shape*, and *end*. They are explained in Table 1. The required ones are *shape* and *end*. The former is followed by the **r** and **z** coordinates of the structure, one pair of numerical values per line with the **r** and **z** value separated by either a comma or a space, while the latter ends the geometry description. The other keywords will use the default values if not specified. All

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Table 1. Input file keywords

Keyword	Description
shape	Start of shape (structure) data
end	End of shape data
sigma	RMS bunch length in cm (default 1.75)
pmax	Total number of interpolated coordinates used for the structure (default 128)
smax	Region of the wakepotential calculation in units of sigma (min 6, max 140, default 10)
dataset	Name of the output files (default bperm)
title	Plot subtitle
!	Flag for comments

keywords can be either upper, lower, or mixed cases. Any number of problem cases can be included in one input file, but each problem case must be separated from the next with the keyword end. Output of **bperm** is seven ASCII files including five files with plotting data for the structure, wakes and impedances, an information file and a **gnuplot** command file that will generate 13 plots. Output files are listed in Table 2.

Table 2. Output files

Name	Description
bperm.sh	Structure data
bperm.lw	Longitudinal wake
bperm.tw	Transverse wake
bperm.lz	Longitudinal impedance
bperm.tz	Transverse impedance
bperm.out	Information file
bperm.gp	Input file for gnuplot with commands produced by bperm
bperm.ps	Postscript file with 13 plots of the structure, wakes and impedance generated by gnuplot

Portability was the major principle in the development of **bperm**. The entire code is written in Fortran 77 and is self-contained, with no machine-dependent calls and with simple file input not relying on the namelist extension.

On a UNIX system, the command for creating the plots (which can be displayed on a X11 color window) and the postscript file bperm.ps is:

```
gnuplot bperm.gp
```

Because the post-processor **gnuplot** on a VAX/VMS does not execute properly with a load file created with the Fortran 77 compiler, a file named bplot.com is provided by the authors to fix this problem. The command for generating the plots is:

```
@bplot bperm.gp
```

Even though the code is designed to use **gnuplot** for post processing, any plotting package that uses columns of ordinates and abscissas could be substituted. Also the **gnuplot** input file can be modified to open a display terminal other than X11.

It needs to be noted that all output files are opened with the status 'unknown.' This increases user-friendliness on UNIX

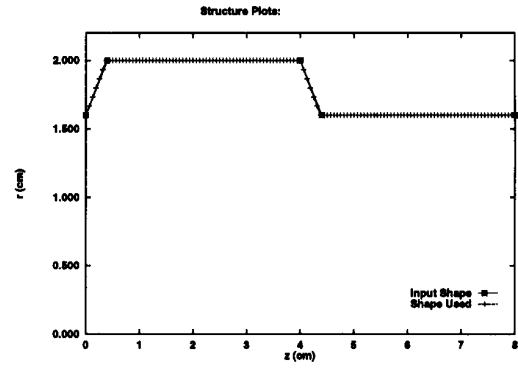


Figure 1. The structure in the example.

workstations by overwriting existing files with the same names. This overwriting also takes place when running **bperm** on a VAX/VMS. The VAX/VMS user needs to be very aware of this feature so that files that need to be saved have names changed before **bperm** makes subsequent runs with identical output dataset names.

III. EXAMPLE

Following is an input file bperm.in for the structure shown in Figure 1.

```
dataset=test
smax=10 sigma=1.75
title=bperm Test Problem
pmax=128 ! pmax stays at the
        default
shape
1.6 0.0
2.0 0.4
2.0 4.0
1.6 4.4
1.6 8.0
end
```

Figs. 2 and 3 are plots of the wakepotentials calculated with **bperm** for this input, plotted with **gnuplot**. As a comparison, the wakes obtained from the MAFIA code, t3210, are also plotted. It is seen that, in the range $[-5\sigma, 2\sigma]$, the two codes give similar results. The differences begin to show up beyond that region. This is probably due to the different boundary conditions used in the two codes — **bperm** assumes a periodic boundary, while MAFIA/t3210 assumes an open boundary.

Figs. 4 and 5 are plots of the real and imaginary longitudinal impedances, and Figs. 6 and 7 the transverse ones.

IV. CODE DISTRIBUTION

Complete packages for **bperm** are available from the CFS at the NERSC and also via anonymous ftp from gateway.ssc.gov, in the /pub directory. The file bperm.tar.Z is the UNIX compressed tar file and bperm.bck.Z is the VMS save set. Both distributions include the **bperm** source code, either a makefile or a command file make.com, inputs and outputs for examples and complete

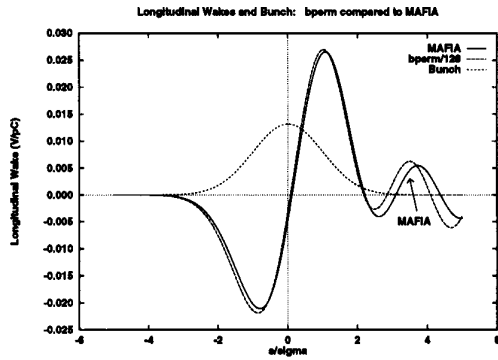


Figure 2. The longitudinal wakepotential.

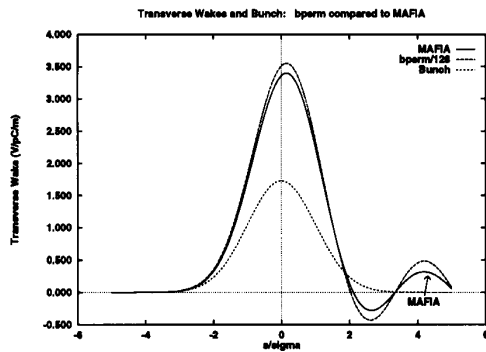


Figure 3. The transverse wakepotential.

documentation including a PostScript file of the User's Guide (i.e., Reference [2]).

References

- [1] The **gnuplot** software is available via anonymous ftp from `dartmouth.edu` in the `/pub/gnuplot` directory in the file `gnuplot3.5.tar.Z`.
- [2] T. Barts and W. Chou, SSCL-MAN-0035, SSC Laboratory (June 1994).
- [3] W. Chou, Light Source Note LS-149, Argonne National Laboratory (1990).
- [4] Z. H. Zhang, Acta Physica Sinica, V 28, p 563 (1979).
- [5] M. Chatard-Moulin and A. Papiernik, Proc. Particle Accelerator Conference, San Francisco, 1979, IEEE Trans Nucl. Sci. V 26, p 3523 (1979).
- [6] R. K. Cooper, S. Krinsky and P. L. Morton, Particle Accelerators, V 12, p 1 (1982).
- [7] T. Weiland, "MAFIA Release 3.1," D6100 Darmstadt, Germany (1991).
- [8] Y. Chin, "User's Guide for New ABCI Version 6.2," LBL-33091, CERN SL/92-49 (AP).

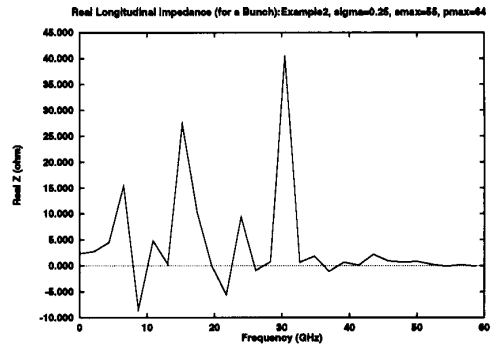


Figure 4. The real longitudinal impedance.

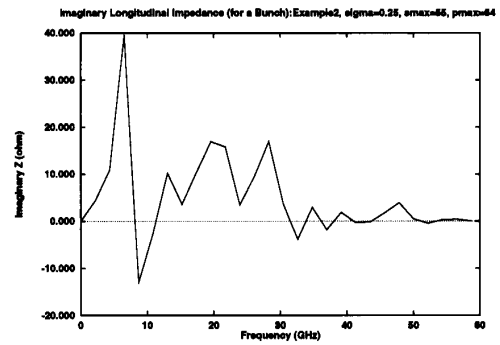


Figure 5. The imaginary longitudinal impedance.

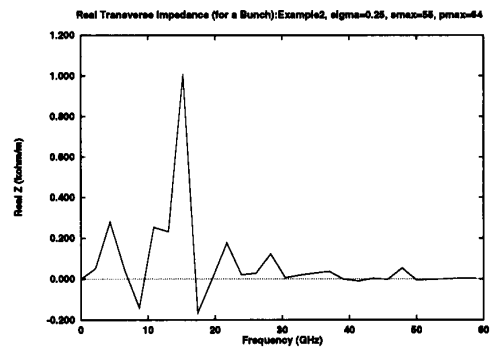


Figure 6. The real transverse Impedance.

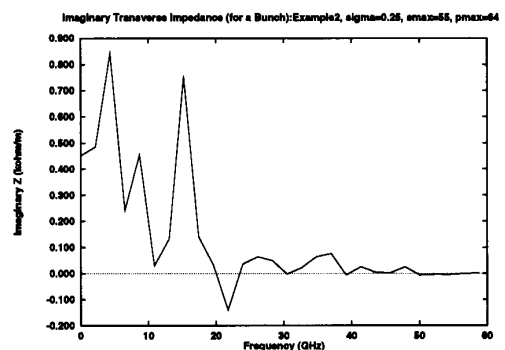


Figure 7. The imaginary transverse impedance.