spdc user manual

1. Introduction

1.1. What is spdc

spdc stands for simulation program for distributed circuit.

spdc is a simulator for 3D linear time-invariant isotropic distributed circuit. Given 3D distributions of circuit parameters such as electro/magnet conductance and capacitance, and stimuli such as voltage and current source, spdc will figure out the 3D distributions as well as the waveform/spectrum of responses such as voltage, current, and so on.

1.2. With Spice

Classical circuit simulators that can work with distributed circuit, such as the well-known Spice, Simulation Program for Integrated Circuit Emphasis, mainly focus on 1D uniform-distributed transmission line.

However, spdc is a full-3D arbitrary-distributed circuit simulator. In fact it is like an electromagnet field simulator in some degree.

1.3. With Field Simulator

Electromagnet field simulators mainly work on the field view, figuring out electric field and magnetic field.

Although spdc can also calculate electromagnet field, it is designed to provide a circuit view, focusing on such as voltage and current, which might be more familiar to circuit designers.

2. Getting Start

2.1. Running spdc

spdc is based on GNU Octave, but is designed to be close to Spice so that it is easy for circuit designers who are familiar with Spice.

Open a terminal and type spdc followed by an optional netlist file to run simulation, after that you will get into an interpreter, like some Spice programs such as Ngspice. What's more, you can also pass any Octave's options to spdc at start.

```
$ spdc [octave-options] [your-circuit-netlist-file]
```

2.2. Writing Netlist

The netlist which spdc reads is close to Spice netlist, though it is difficult to be totally as the same as Spice since spdc has to describe 3D objects while Spice mainly describes lumped circuit.

As seen by Octave, an spdc netlist is actually an Octave script. In the netlist you can use spdc-provided Spice-style commands, as well as any Octave's statements you like.

The spdc commands are implemented as a set of Octave functions but their usages appear to be Spice-style. All of them begin with “sp_” in order to be different from Octave's native function or command names to prevent from overloading. You will see that usually replacing the prefix dot “.” of a Spice command with “sp_” will get the corresponding spdc command.

Each spdc command accepts either string or number argument where it excepts a number. This makes it possible to write your netlist using Octave's command format (which just accepts string arguments) like Spice netlist style. For example, the following statements will perform the same “ac” simulation.

```
sp_ac dec 10 1e+3 1e+9
sp_ac('dec','10','1e+3','1e+9')
sp_ac('dec',10,1e+3,1e+9)
sp_ac dec n=10 fstart=1e+3 fstop=1e+9
sp_ac('dec','n=10','fstart=1e+3','fstop=1e+9')
n=10;fstart=1e+3;fstop=1e+9; sp_ac('dec',n,fstart,fstop)
```

Octave's native statements are helpful, for example, to process data or figures, to perform parameter sweep simulation using loop or conditional branch, and so on.

Octave's syntax supports the Sha-Bang “#!”. Thus you can even make your spdc netlist a standalone executable by adding the following line to the head of netlist and adding executable permission to the file.

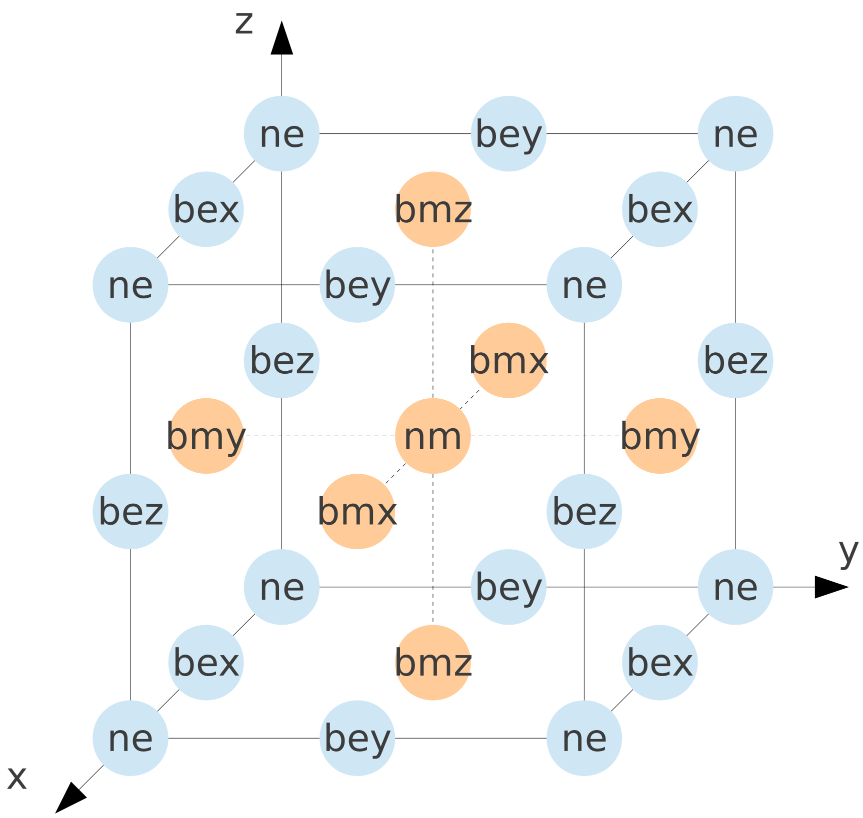
```
#!/usr/bin/env spdc
```

Then you can run simulation by either of the following shell commands.

```
$ spdc your-circuit-netlist-file
$ ./your-circuit-netlist-file
```

3. Modeling 3D Distributed Circuit

In spdc, 3D distributed circuit in a cuboid zone is discretized to repeated cubic circuit cells. The following figure shows one of the cubic cells, where “n” means circuit node, “b” means circuit branch, “e” means electric circuit, “m” means magnetic circuit.



In this model, electric circuit and magnetic circuit are interlaced, the cell size (branch length) is 2 grids, so each cell contains 8 grids which are listed below.

Grid type	Symbol	Position in the cell
Electric circuit node	ne	[0 0 0]
Electric circuit branch (along x-direction)	bex	[1 0 0]
Electric circuit branch (along y-direction)	bey	[0 1 0]
Electric circuit branch (along z-direction)	bez	[0 0 1]
Magnetic circuit node	nm	[1 1 1]
Magnetic circuit branch (along x-direction)	bmx	[0 1 1]
Magnetic circuit branch (along y-direction)	bmy	[1 0 1]
Magnetic circuit branch (along z-direction)	bmz	[1 1 0]

Thus, in spdc each node or branch can be identified by its unique 3D coordinate, compared with Spice in which node or branch is identified by its name. This is a main difference between spdc netlist and Spice netlist.

3.1. Circuit Parameters

In spdc, the circuit's cuboid size (sc) should be set first of all, which specifies the whole simulate zone. Then every object's 3D coordinate (x, y, z) should be limited in the range of the cuboid size, i.e. 1≤x≤scx, 1≤y≤scy, 1≤z≤scz.

The boundary condition (bc) also should be given. spdc provides two types of boundary condition, including short electro circuit (open magnet circuit) and open electro circuit (short magnet circuit). Other types of boundary condition can be realized by set circuit parameters near the boundary to proper values.

Circuit parameters include the following.

Parameter	Symbol	Position	Value
Electro branch conductance	gc	[1 0 0] [0 1 0] [0 0 1]	$\sigma_e(2\cdot dx)$
Electro branch capacitance	cc		$\epsilon_0\epsilon_r(2\cdot dx)$
Magnet branch conductance	rc	[0 1 1] [1 0 1] [1 1 0]	$\sigma_m(2\cdot dx)$
Magnet branch capacitance	lc		$\mu_0\mu_r(2\cdot dx)$

Magnet capacitance can be set to zeros if you do not want to take account of “inductance” in simulation.

Magnet conductance can be set to zeros if magnetic medium's loss can be ignored (and if there is no “magnetic monopole” in the world).

3.2. Ports and Stimuli

Stimuli include branch voltage source and branch current source as Spice does.

Instead of directly adding stimuli to the circuit branches, the electro/magnet circuits together are first labeled with several voltage ports and several current ports (see below tables), each port is then defined with a direction vector, and finally add stimuli to each port. As a result, all the zones which belong to the same port will be added with the same stimulus along the same direction. This makes it easy to set stimuli because the port number is usually much smaller than the branch number.

Parameter	Symbol	Position	Value
Electro branch voltage port index	vpe	[1 0 0] [0 1 0] [0 0 1]	voltage port index
Electro branch current port index	ipe		current port index
Magnet branch voltage port index	vpm	[0 1 1] [1 0 1] [1 1 0]	voltage port index
Magnet branch current port index	ipm		current port index

Parameter	Symbol	Index	Value
Branch voltage port direction vector	vd	vpe,vpm	[vdx, vdy, vdz]
Branch current port direction vector	id	ipe,ipm	[idx, idy, idz]

Parameter	Symbol	Index	Value
Branch voltage port source	vs	vpe,vpm	$E_s(2\cdot dx)$, $H_s(2\cdot dx)$
Branch current port source	is	ipe,ipm	$J_{es}(2\cdot dx)^2$, $J_{ms}(2\cdot dx)^2$

3.3. Responses

Responses include the following.

Parameter	Symbol	Position	Value
Electro node voltage	ve	[0 0 0]	φ_E
Electro branch motiveforce	fe	[1 0 0]	$E_A(2 \cdot dx)$
Electro branch voltagedrop	de	[0 1 0] [0 0 1]	$E_\varphi(2 \cdot dx)$
Electro branch current	ie		$J_e(2 \cdot dx)^2$
Magnet node voltage	vm	[1 1 1]	φ_H
Magnet branch motiveforce	fm	[0 1 1]	$H_A(2 \cdot dx)$
Magnet branch voltagedrop	dm	[1 0 1] [1 1 0]	$H_\varphi(2 \cdot dx)$
Magnet branch current	im		$J_m(2 \cdot dx)^2$

The node voltage is the scalar potential of branch voltagedrop which satisfies KVL, while branch motiveforce can also be considered as the vector potential of branch current which satisfies KCL. spdc's simulate command only gives those potentials which are less redundant. All the other data will be got by post-simulation data process method.

Besides, voltagedrop plus motiveforce just equals the total field ($E_\varphi + E_A = E$, $H_\varphi + H_A = H$) which is concerned by electromagnet field simulators, while spdc mainly concerns voltage and current as Spice does.

4. spdc Commands

Once you start spdc and get into the interpreter, begin with the following command to list all spdc commands, and then see the separate help text for each command for detail.

```
sp_help
```

4.1. Circuit Description

These commands correspond to Spice's instantiation statements.

```
sp_circ sc SCX [SCY SCZ]
sp_circ bc 0|1
sp_circ gc|rc|cc|lc X Y Z VALUE
sp_circ vpe|vpm|ipe|ipm X Y Z PORT
sp_circ vd|id PORT DIRX DIRY DIRZ
sp_stim vs|is PORT [ac [MAG [PHASE]]] [dc [VALUE]]
sp_stim vs|is PORT [ac [MAG [PHASE]]] [pwl T1 V1 [T2 V2 ...]]
sp_stim vs|is PORT [ac [MAG [PHASE]]] [pulse V1 V2 [TD [TR [TF
[PW [PER]]]]]]
sp_stim vs|is PORT [ac [MAG [PHASE]]] [sin VO VA [FREQ [TD [THETA
[PHASE]]]]]
```

spdc also provides the following commands to help you draw complex geometric patterns conveniently.

```
sp_draw ls|rm ...
sp_draw mv|cp PARAM VALUE ...
sp_draw im X Y Z FILE ...
sp_draw ex Z FILE ...
sp_draw all ...
sp_draw new X Y Z ...
sp_draw [mov|ext][drw] shf N DIST TX TY TZ ...
sp_draw [mov|ext][drw] rot N PHASE PX PY PZ TX TY TZ ...
sp_draw [mov|ext][drw] pnt N SCALE PX PY PZ ...
sp_draw [mov|ext][drw] axs N SCALE PX PY PZ TX TY TZ ...
sp_draw [mov|ext][drw] pln N SCALE PX PY PZ NX NY NZ ...
```

Notice each type of data's cell position; to set value to a datum out of its position(s) will take no effect. One method to avoid this is to extend your pencil size to at least the cell size, 2×2×2.

4.2. Analyses

These commands are as the same as the corresponding Spice commands (.op, .ac, .tran).

```
sp_op
sp_ac lin|oct|dec N FSTART FSTOP
sp_tran TSTEP TSTOP [TSTART]
```

4.3. Output Control

Not only spdc can plot curves of waveform/spectrum as Spice's .plot command does, but also it can plot 3D distributions of data like field simulators.

```
sp_plot tran vs|is PORT [UNIT] ...
sp_plot tran ve|vm X Y Z [UNIT] ...
sp_plot tran fex|fey|fez|fmx|fmy|fmz X Y Z [UNIT] ...
sp_plot tran dex|dey|dez|dmx|dmy|dmz X Y Z [UNIT] ...
sp_plot tran iex|iey|iez|imx|imy|imz X Y Z [UNIT] ...
sp_plot ac vs|is(r|i|m|p) PORT [UNIT] ...
sp_plot ac ve|vm(r|i|m|p) X Y Z [UNIT] ...
sp_plot ac fex|fey|fez|fmx|fmy|fmz(r|i|m|p) X Y Z [UNIT] ...
sp_plot ac dex|dey|dez|dmx|dmy|dmz(r|i|m|p) X Y Z [UNIT] ...
sp_plot ac iex|iey|iez|imx|imy|imz(r|i|m|p) X Y Z [UNIT] ...
sp_plot [linlin|linlog|loglin|loglog] ...

sp_plot3 dc|tran|ac gc|rc|cc|lc|vpe|vpm|ipe|ipm[n] [UNIT] ...
sp_plot3 dc fe|fm|de|dm|ie|im[n] [UNIT] ...
sp_plot3 tran fe|fm|de|dm|ie|im[n] T [UNIT] ...
sp_plot3 ac fe|fm|de|dm|ie|im[n](r|i) F [UNIT] ...
```

spdc's set circuit and simulate commands only give basic (packed) data, since this can save memory and all the other data can be calculated from them. Therefore, you should calculate (unpack) the data before plotting them. The following commands manipulate the unpacked data.

```
sp_post [gc|rc|cc|lc|vpe|vpm|ipe|ipm ...]
sp_post [ve|vm|fe|fm|de|dm|ie|im ...]

sp_reset [gc|rc|cc|lc|vpe|vpm|ipe|ipm ...]
sp_reset [ve|vm|fe|fm|de|dm|ie|im ...]
```

Notice each type of data's cell position; to evaluate a datum out of its position(s) will get zero values.

4.4. Miscellaneous

The following command is as the same as Spice's .include command.

```
sp_include FILE
```

You may want to save your circuit or simulation results so as not to spend cputime on it again later. The following commands manipulate the basic (packed) data.

```
sp_save FILE [c|r|a]

sp_load FILE [c|r|a]

sp_clear [c|r|a]
```

4.5. Ngspice Interactive

The above commands are similar to Spice's command set.

Furthermore, spdc can also export distributed circuit to Ngspice netlist, edit it for stimuli and analysis type, call Ngspice simulator, and then import the corresponding Ngspice simulation result. All of these can be done without exiting spdc, but this needs Ngspice installed on your system.

```
sp_nglist FILE
sp_ngrun FILE
sp_ngload FILE
```

You may want to view or edit any text file without exiting spdc, then the following command does.

```
sp_edit FILE
```