

Touchstone Version 2.0

Mixed-Mode Syntax

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Outline

- Background and Overview
- Generalized mixed-mode syntax
- (Abbreviations)
 - **SE:** single-ended
 - **MM:** mixed-mode for differential and common modes such as “Sdd11” or “Sdc12”
 - **GMM:** generalized mixed-mode for combination of SE and MM data

Background

- Touchstone issued in 1984 by EEsof (now part of Agilent Technologies)
- Touchstone is an OPEN, de-facto format supported by nearly all companies supplying or handling S-parameter data
- Older Touchstone “Version 1.0” uploaded as public reference for ICM reference
 - <http://www.eda.org/ibis/connector/>
- Touchstone Version 2.0 extended to remove some format limitations and to add some resistance per port flexibility for PDS applications
 - <http://www.eda.org/pub/ibis/adhoc/interconnect/>



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Eight IBIS-like Keywords (so far)

- Required keywords
 - **[Version]** 2.0
 - **[Number of Ports]** <n>
 - **[Two-Port Data Order]** {2I_12 | 12_2I} (for n=2 only)
 - **[Number of Frequencies]** <nf>
- Optional keywords
 - **[Reference]** <list of n reference resistances in port order>
 - **[Matrix Format]** {Full | Lower | Upper}
 - **[Mixed-Mode Order]** {Di,j, Ci,j, Si,j entries}
 - **[Number of Noise Frequencies]** <nnf>
- Details (except [Mixed-Mode Order]) reported February, 2008
 - <http://www.eda.org/ibis/summits/feb08/ross1.pdf>



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“Version 1.0” Fixed Format Examples

(f = frequency, s = data-pair)

S1P

f s
f s
f s
f ...

S3P

f s s s
s s s
s s s
f s s s
s s s
s s s
f ...

S4P

f s s s s
s s s s
s s s s
s s s s
f s s s s
s s s s
s s s s
f ...

S5P

f s s s s
s
s s s s
s
s s s s
s
s s s s
s
f ...

S6P

f s s s s
s s
s s s s
s s
s s s s
s s
s s s s
s s
s s s s
s s
f ...

Etc ...

S2P

f s s s s
f s s s s
f s s s s
f ...

Formatting, frequency ordering,
and end of file implies number of
ports and frequencies values.

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Version 1.0 Block Arrangement

Option Line
For example, # GHZ S MA R 50

N-port Data Block
(rigid format rules)
SE Data

Optional Noise Data Block
(n=2 only)



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Version 2.0 Block Arrangement

**Option Line and All Keywords
(first entry is [Version] 2.0)**

**N-port Data Block
(flexible format, new line only for
each frequency)**

SE, MM or GMM data

**Optional Noise Data Block
(n=2 only)**

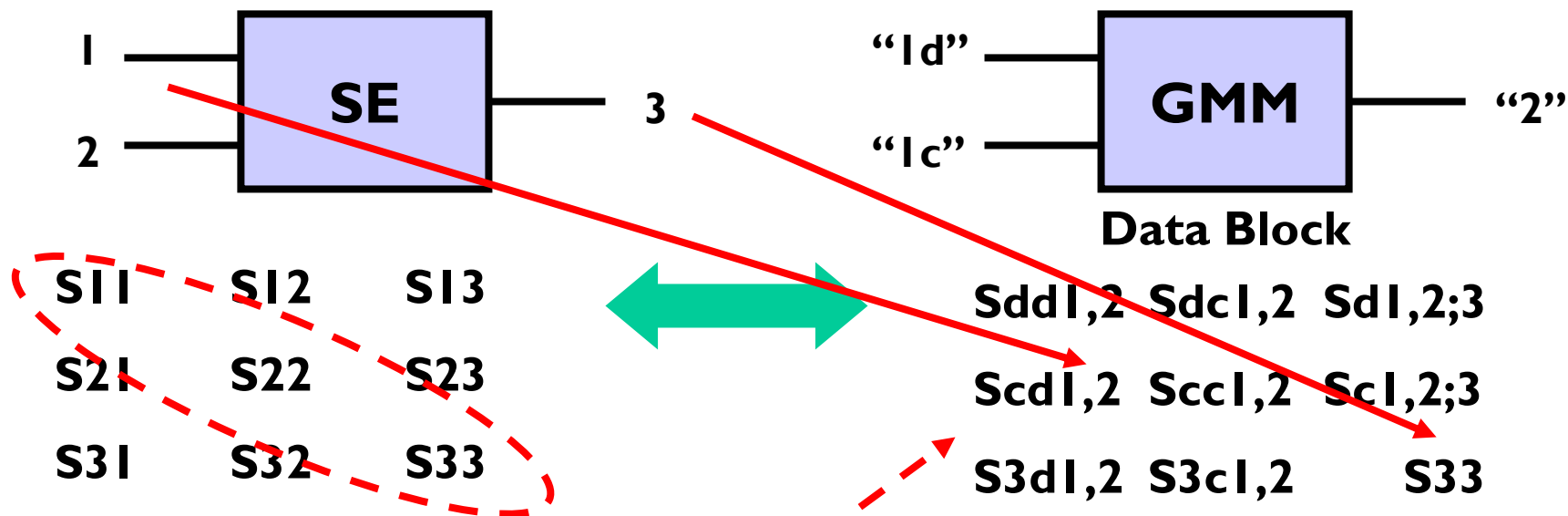


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[Mixed-Mode Order] Keyword

- Applies for **S**, **Y**, **Z** n-port matrices
- Allows general **re-ordering** of ports (SE, MM, GMM)
- Main document (3 pages) and Appendix A (6+ pages) gives mathematical details
- Argument **port indices** are for new **SE ports**
 - **S<k> C<i,j> D<i,j>** for single-ended, common mode, and differential mode port numbers (1, ..., n)
- Argument **positions** apply to **data block**

[Mixed-Mode Order] DI,2 CI,2 S3 (balun, splitter, op. amp. example)



"S" above means
n-port entry (S, Y,
or Z)

"S" argument
means Single-
ended

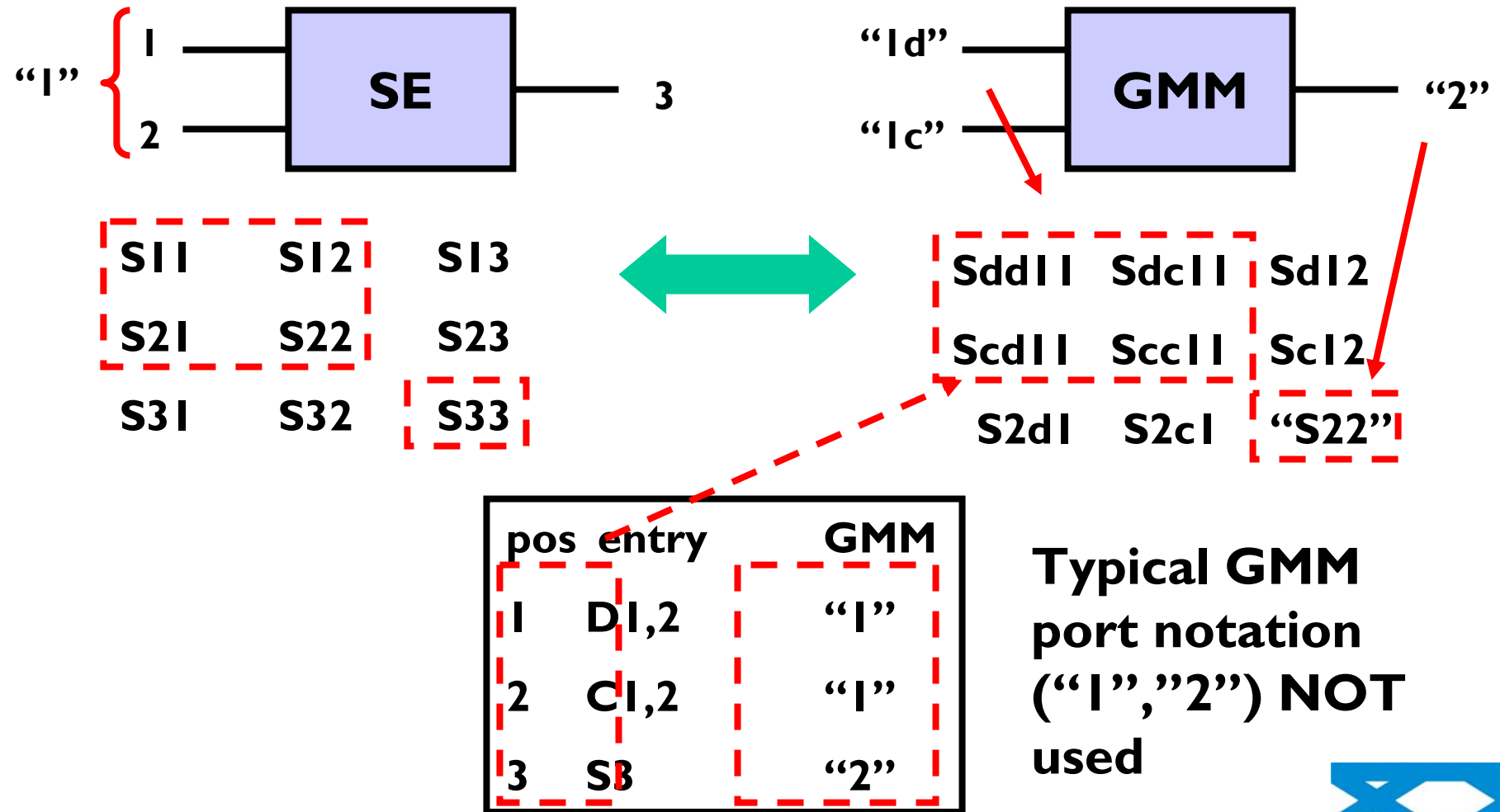
pos	entry	GMM
1	DI,2	1,2
2	CI,2	1,2
3	S3	3

SE port notation
in both blocks,
position gives
mapping

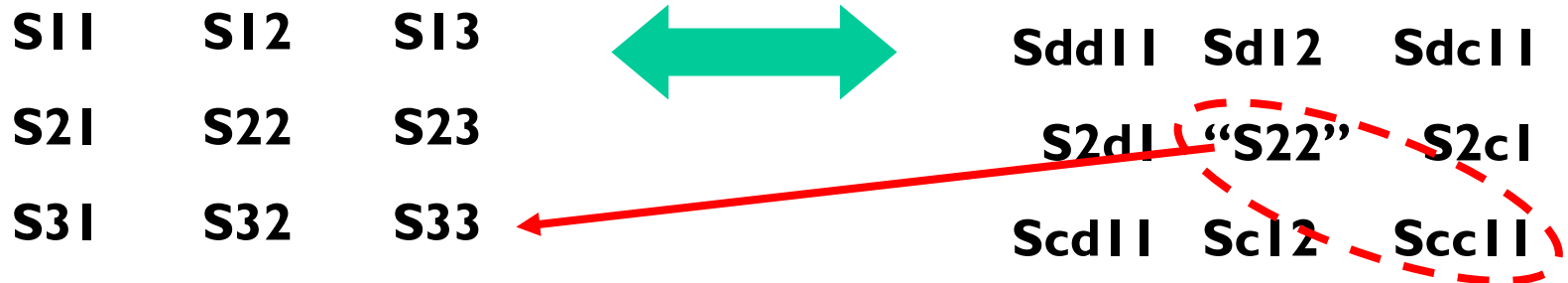
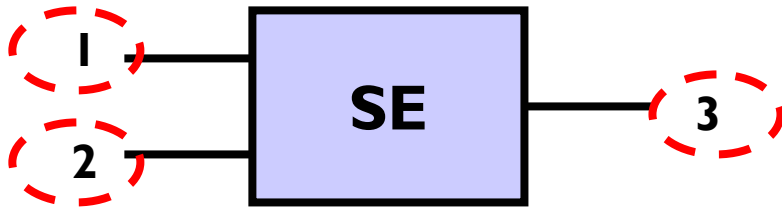


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[Mixed-Mode Order] D1,2 C1,2 S3 (with GMM port notation)



[Mixed-Mode Order] D1,2 S3 C1,2 (GMM data with new S3 C1,2 positions)



Interchange
2 and 3

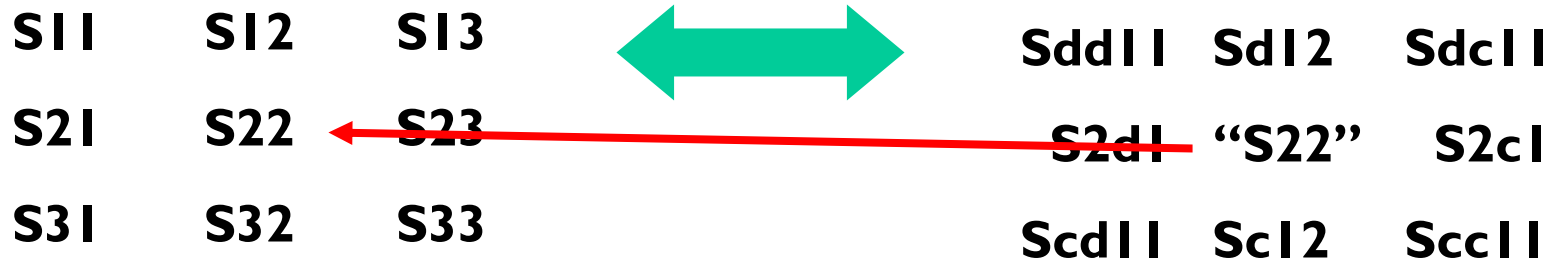
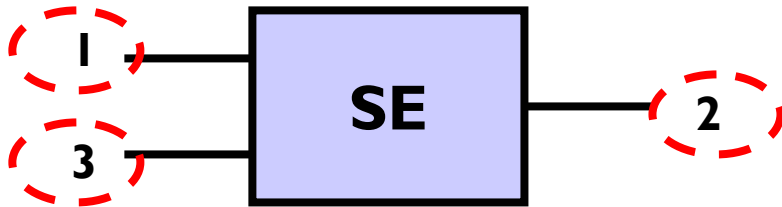
pos	entry	GMM
1	D1,2	"1"
2	S3	"2"
3	C1,2	"1"

GMM data block
with different
positions "S22"
and "Sccl11"



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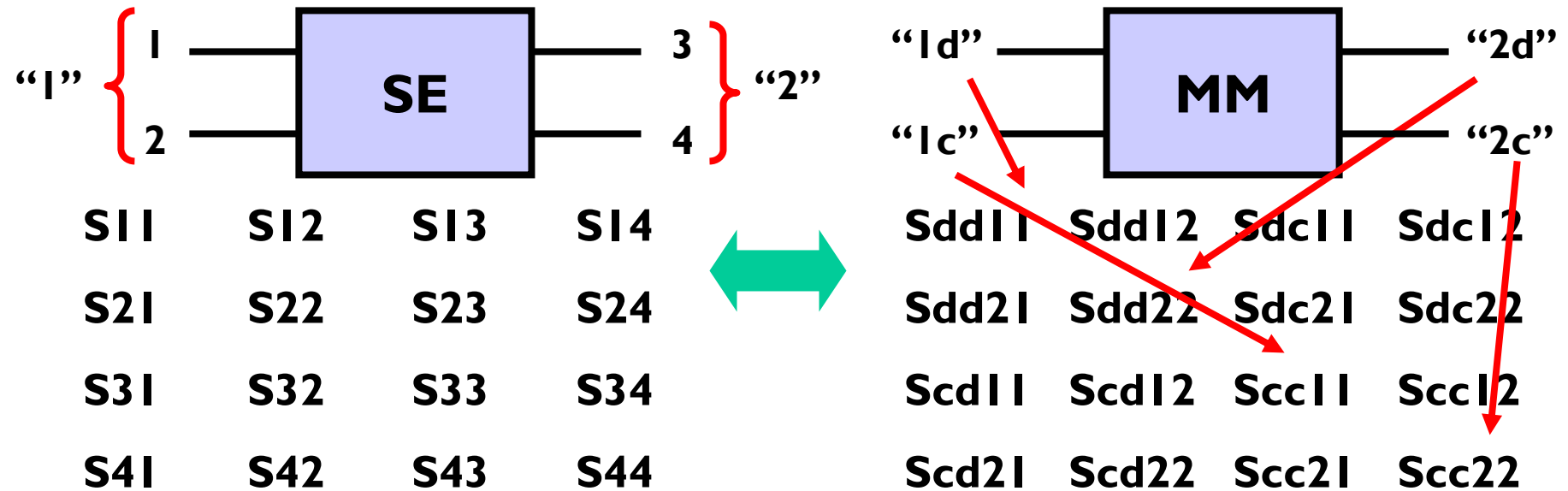
[Mixed-Mode Order] D1,3 S2 C1,3 (SE defined with new order)



pos	entry	GMM
1	D1,3	"1"
2	S2	"2"
3	C1,3	"1"

Mapping data
block to new SE
port order

[Mixed-Mode Order] D1,2 D3,4 C1,2 C3,4 (1,2 and 3,4 port-pairs)



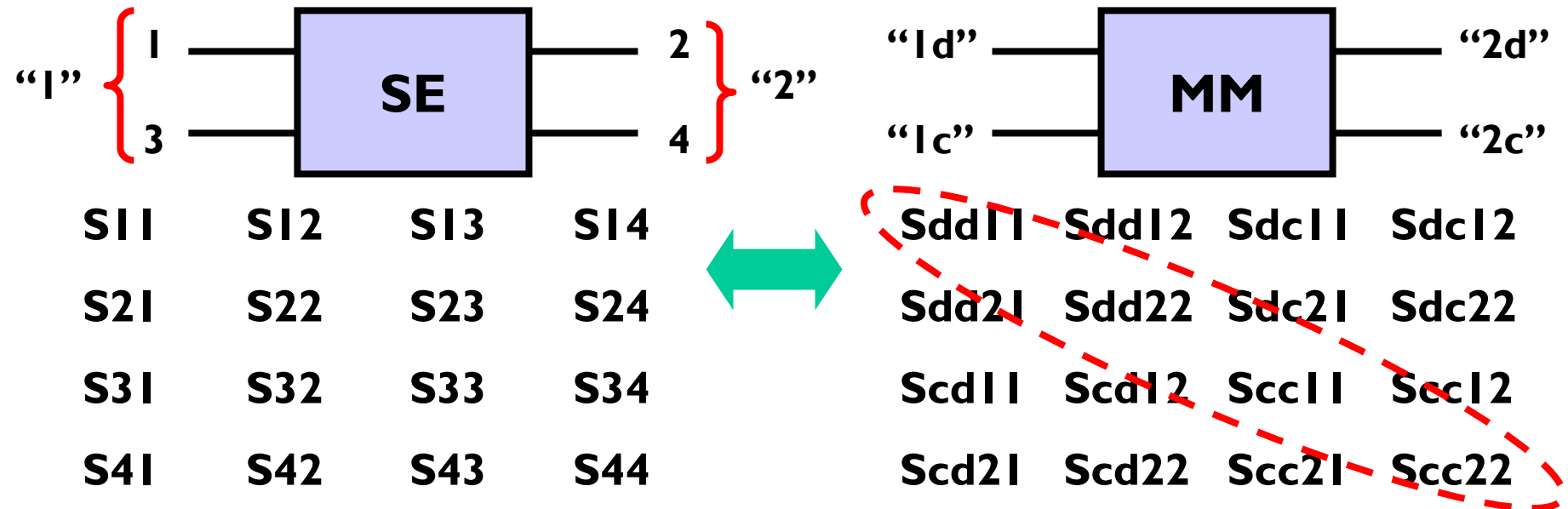
S11 S12 S13 S14
S21 S22 S23 S24
S31 S32 S33 S34
S41 S42 S43 S44

Sdd11 Sdd12 Sdc11 Sdc12
Sdd21 Sdd22 Sdc21 Sdc22
Scd11 Scd12 Scc11 Scc12
Scd21 Scd22 Scc21 Scc22

pos	entry	MM
1	D1,2	"1"
2	D3,4	"2"
3	C1,2	"1"
4	C3,4	"2"

**Diff Port notation
by position,
numbers for SE
ports**

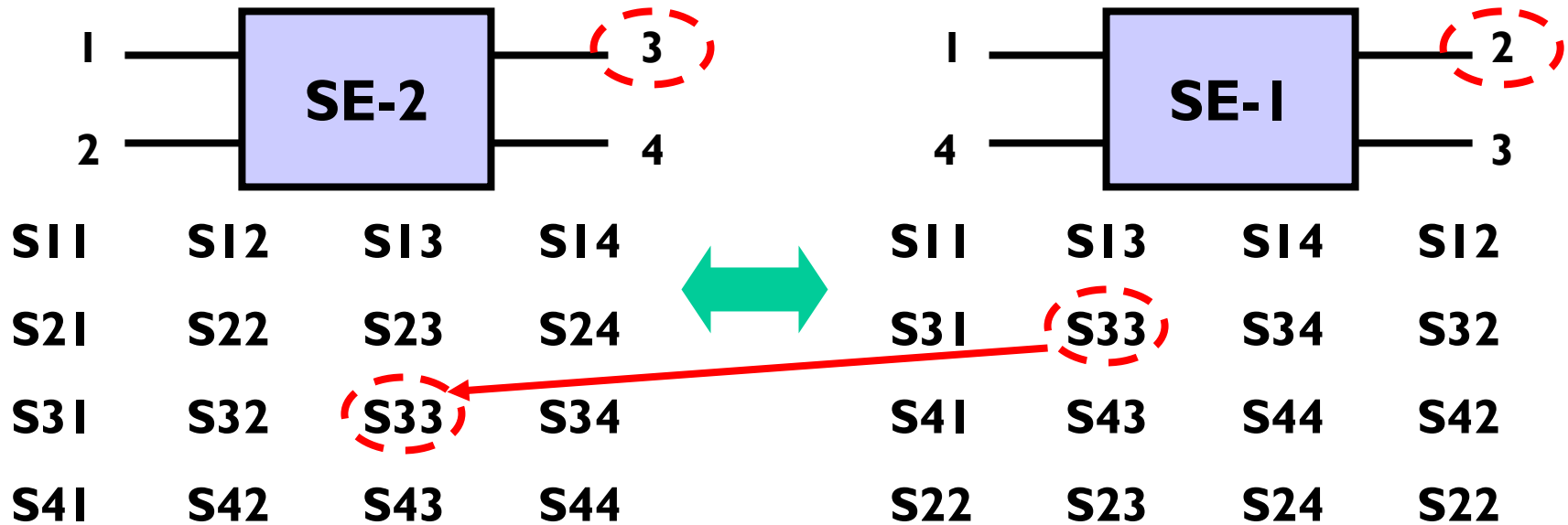
[Mixed-Mode Order] D1,3 D2,4 C1,3 C2,4 (1,3 and 2,4 port-pairs)



pos	entry	MM
1	D1,3	"1"
2	D2,4	"2"
3	C1,3	"1"
4	C2,4	"2"

Diff Ports
reference same
SE positions

[Mixed-Mode Order] S1 S3 S4 S2 (SE-1 data re-ordered to SE-2)



pos	entry	SE-1
1	S1	1
2	S3	3
3	S4	4
4	S2	2

**SE-1 uses SE-2
data notation in
matrix**

Closure

- Several EDA tools already implementing portions of the mixed-mode syntax
 - S, Y, Z parameters for n-ports
 - SE, MM, GMM capability
- Touchstone 2.0 provides standard, interchangeable GMM format when adopted by industry
- Minimal changes from Touchstone “1.0” and Touchstone 2.0 for easy bi-directional migration of tools over several years
- Some minor changes still being considered