Sparsity in Touchstone 2.n

"labels" and "index-pairs"

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SIGRITY

Concept

- **Many S-parameter matrices have**
  - <u>sparsity</u>
    many very small values that could be set to zero
  - <u>redundancy</u>
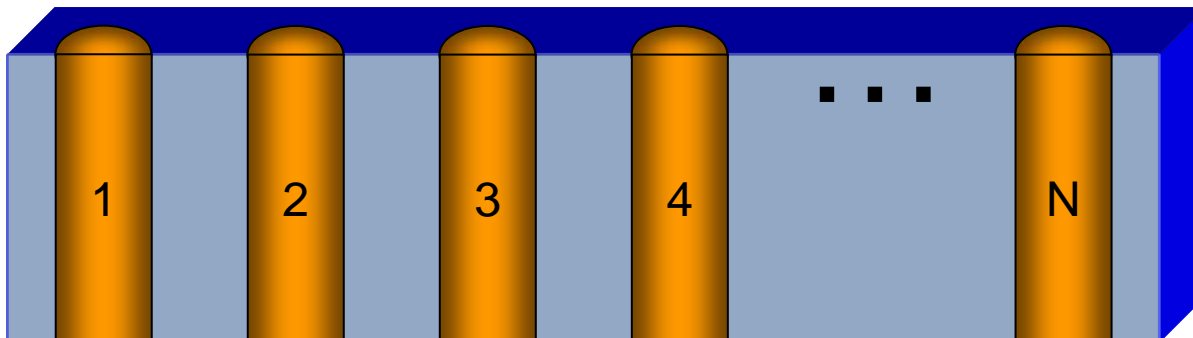   many similar values that could be defined to be identical

- **Accounting for sparsity and redundancy can significantly reduce the size of a Touchstone data file**
  - the structure of sparse data is assumed to be frequency independent
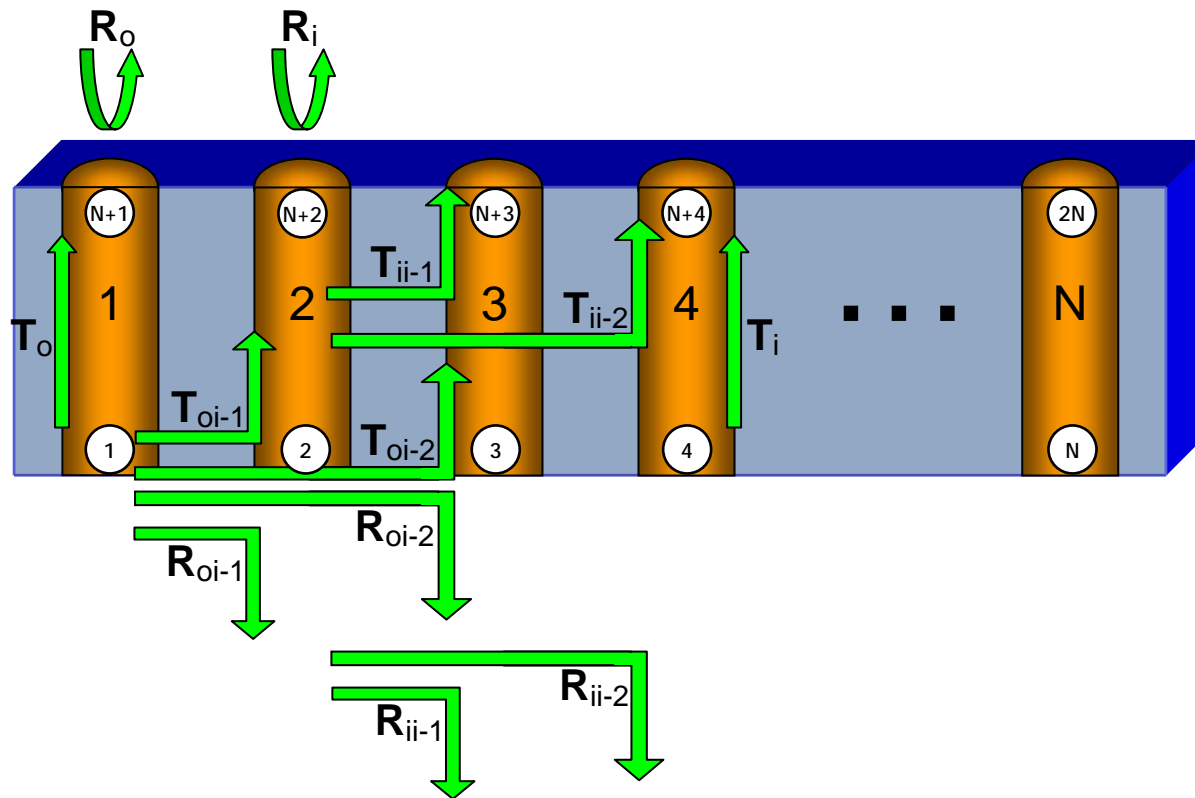
<u>NOTE</u>:

Redundancy is not intended as a numerical data compression scheme to recognize and eliminate similar numerical values, but rather a topology-based attribute of the device that may be exploited by the creator of the data to exploit symmetry or translational invariance.

A collinear connector example

- ▪ **Assume**
  1. collinear N-pin connector with identical pins
     - ▪ though outside pins may be unique electrically due to asymmetry
  2. nearest and next-nearest neighbor coupling
     - ▪ $S(i,j) = 0$ for $j<((i-2)$ and $j>(i+2)$
- ▪ **S-parameters**
  - • 2N-by-2N matrix with 12 unique values
    1. many identical values due to translational invariance
    2. many zero values

Unique values

S-parameter matrix for N=8

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Ro	Roi-1	Roi-2	0	0	0	0	0	To	Toi-1	Toi-2	0	0	0	0	0
2	Roi-1	Ri	Rii-1	Rii-2	0	0	0	0	Toi-1	Ti	Tii-1	Tii-2	0	0	0	0
3	Roi-2	Rii-1	Ri	Rii-1	Rii-2	0	0	0	Toi-2	Tii-1	Ti	Tii-1	Tii-2	0	0	0
4	0	Rii-2	Rii-1	Ri	Rii-1	Rii-2	0	0	0	Tii-2	Tii-1	Ti	Tii-1	Tii-2	0	0
5	0	0	Rii-2	Rii-1	Ri	Rii-1	Rii-2	0	0	0	Tii-2	Tii-1	Ti	Tii-1	Tii-2	0
6	0	0	0	Rii-2	Rii-1	Ri	Rii-1	Roi-2	0	0	0	Tii-2	Tii-1	Ti	Tii-1	Toi-2
7	0	0	0	0	Rii-2	Rii-1	Ri	Roi-1	0	0	0	0	Tii-2	Tii-1	Ti	Toi-1
8	0	0	0	0	0	Roi-2	Roi-1	Ro	0	0	0	0	0	Toi-2	Toi-1	To
9	To	Toi-1	Toi-2	0	0	0	0	0	Ro	Roi-1	Roi-2	0	0	0	0	0
10	Toi-1	Ti	Tii-1	Tii-2	0	0	0	0	Roi-1	Ri	Rii-1	Rii-2	0	0	0	0
11	Toi-2	Tii-1	Ti	Tii-1	Tii-2	0	0	0	Roi-2	Rii-1	Ri	Rii-1	Rii-2	0	0	0
12	0	Tii-2	Tii-1	Ti	Tii-1	Tii-2	0	0	0	Rii-2	Rii-1	Ri	Rii-1	Rii-2	0	0
13	0	0	Tii-2	Tii-1	Ti	Tii-1	Tii-2	0	0	0	Rii-2	Rii-1	Ri	Rii-1	Rii-2	0
14	0	0	0	Tii-2	Tii-1	Ti	Tii-1	Toi-2	0	0	0	Rii-2	Rii-1	Ri	Rii-1	Roi-2
15	0	0	0	0	Tii-2	Tii-1	Ti	Toi-1	0	0	0	0	Rii-2	Rii-1	Ri	Roi-1
16	0	0	0	0	0	Toi-2	Toi-1	To	0	0	0	0	0	Roi-2	Roi-1	Ro

Observations for Touchstone files

- ## For N=8 collinear connector

  - apply upper/lower symmetry
    - reduces from **256** to **136** values   (2X reduction)
  - eliminate values identically zero
    - reduces from **136** to **76** values   (3.3X reduction)
  - eliminate redundancy
    - reduces to **12** unique values   (21X reduction)

- ## Greater than 10X reduction versus using only symmetry

  - larger reductions for larger N
    - no matter how large N, there are only 12 unique values

Proposed syntax

```
[Version] 2.0
# GHz S RI R 50
[Number of Ports] 16
[Number of Frequencies] 1
[Matrix Format] Lower
[Number of Sparse Labels] 12
[Sparse Matrix Mapping]
1: (1,1) (8,8) (9,9) (16,16)
2: (2,2) (3,3) (4,4) (5,5) (6,6) (7,7) (10,10) (11,11) (12,12) (13,13) (14,14) (15,15)
3: (9,1) (16,8)
4: (10,2) (11,3) (12,4) (13,5) (14,6) (15,7)
5: (2,1) (8,7) (10,9) (16,15)
6: (3,1) (8,6) (11,9) (16,14)
7: (9,2) (10,1) (15,8) (16,7)
8: (9,3) (11,1) (14,8) (16,6)
9: (3,2) (4,3) (5,4) (6,5) (7,6) (11,10) (12,11) (13,12) (14,13) (15,14)
10: (4,2) (5,3) (6,4) (7,5) (12,10) (13,11) (14,12) (15,13)
11: (10,3) (11,2) (11,4) (12,3) (12,5) (13,4) (13,6) (14,5) (14,7) (15,6)
12: (10,4) (11,5) (12,2) (12,6) (13,3) (13,7) (14,4) (15,5)
[Network Data]
F1  S1R S1I S2R S2I S3R S3I ... S12R S12I
[End]
```

Proposed syntax
with arbitrary text-labels rather than sequential integer-labels

```
[Version] 2.0
# GHz S RI R 50
[Number of Ports] 16
[Number of Frequencies] 1
[Matrix Format] Lower
[Number of Sparse Labels] 12
[Sparse Matrix Mapping]
Ro: (1,1) (8,8) (9,9) (16,16)
Ri: (2,2) (3,3) (4,4) (5,5) (6,6) (7,7) (10,10) (11,11) (12,12) (13,13) (14,14) (15,15)
To: (9,1) (16,8)
Ti: (10,2) (11,3) (12,4) (13,5) (14,6) (15,7)
Roi-1: (2,1) (8,7) (10,9) (16,15)
Roi-2: (3,1) (8,6) (11,9) (16,14)
Toi-1: (9,2) (10,1) (15,8) (16,7)
Toi-2: (9,3) (11,1) (14,8) (16,6)
Rii-1: (3,2) (4,3) (5,4) (6,5) (7,6) (11,10) (12,11) (13,12) (14,13) (15,14)
Rii-2: (4,2) (5,3) (6,4) (7,5) (12,10) (13,11) (14,12) (15,13)
Tii-1: (10,3) (11,2) (11,4) (12,3) (12,5) (13,4) (13,6) (14,5) (14,7) (15,6)
Tii-2: (10,4) (11,5) (12,2) (12,6) (13,3) (13,7) (14,4) (15,5)
[Network Data]
F1  S1R S1I S2R S2I S3R S3I ... S12R S12I
[End]
```

NOTE:
Arbitrary text labels.
The ':' character is separator and may not be part of a label.

An additional proposal

- **Allow blank integer labels under [Sparse Matrix Mapping]**
  - allows "data re-use"

- **Example**
  - for previous 8-pin connector, if we <u>assume only nearest neighbor coupling</u>
    - 4 of the previous 12 unique values are zero
      - Roi-2 = Rii-2 = Toi-2 = Tii-2 = 0
    - 24 more matrix elements are zero, yielding 52 index-pairs

- **The same [Network Data] section could be re-used, as on the following page**
  - it was suggested this saves model developers or EDA tools much effort
  - is it potentially confusing?
  - does it extends beyond the storage of data to implement something the user or EDA tool might better or more logically support?

Additionally proposed syntax

```
[Version] 2.0
# GHz S RI R 50
[Number of Ports] 16
[Number of Frequencies] 1
[Matrix Format] Lower
[Number of Sparse Labels] 12
[Sparse Matrix Mapping]
1: (1,1) (8,8) (9,9) (16,16)
2: (2,2) (3,3) (4,4) (5,5) (6,6) (7,7) (10,10) (11,11) (12,12) (13,13) (14,14) (15,15)
3: (9,1) (16,8)
4: (10,2) (11,3) (12,4) (13,5) (14,6) (15,7)
5: (2,1) (8,7) (10,9) (16,15)
6:
7: (9,2) (10,1) (15,8) (16,7)
8:
9: (3,2) (4,3) (5,4) (6,5) (7,6) (11,10) (12,11) (13,12) (14,13) (15,14)
10:
11: (10,3) (11,2) (11,4) (12,3) (12,5) (13,4) (13,6) (14,5) (14,7) (15,6)
12:
[Network Data]
F1  S1R S1I S2R S2I S3R S3I ... S12R S12I
[End]
```

NOTE:
Simply delete all index-pairs no longer required for nearest-neighbor coupling.

Additionally proposed syntax
with arbitrary text-labels rather than sequential integer-labels

```
[Version] 2.0
# GHz S RI R 50
[Number of Ports] 16
[Number of Frequencies] 1
[Matrix Format] Lower
[Number of Sparse Labels] 12
[Sparse Matrix Mapping]
Ro: (1,1) (8,8) (9,9) (16,16)
Ri: (2,2) (3,3) (4,4) (5,5) (6,6) (7,7) (10,10) (11,11) (12,12) (13,13) (14,14) (15,15)
To: (9,1) (16,8)
Ti: (10,2) (11,3) (12,4) (13,5) (14,6) (15,7)
Roi-1: (2,1) (8,7) (10,9) (16,15)
Roi-2:
Toi-1: (9,2) (10,1) (15,8) (16,7)
Toi-2:
Rii-1: (3,2) (4,3) (5,4) (6,5) (7,6) (11,10) (12,11) (13,12) (14,13) (15,14)
Rii-2:
Tii-1: (10,3) (11,2) (11,4) (12,3) (12,5) (13,4) (13,6) (14,5) (14,7) (15,6)
Tii-2:
[Network Data]
F1  S1R S1I S2R S2I S3R S3I ... S12R S12I
[End]
```

NOTE:
Simply delete all index-pairs with '2' in the label. More intuitive, an advantage for the model developer.

Required changes
without additionally proposed syntax

```
[Version] 2.0
# GHz S RI R 50
[Number of Ports] 16
[Number of Frequencies] 1
[Matrix Format] Lower
[Number of Sparse Labels] 12
[Sparse Matrix Mapping]
1: (1,1) (8,8) (9,9) (16,16)
2: (2,2) (3,3) (4,4) (5,5) (6,6) (7,7) (10,10) (11,11) (12,12) (13,13) (14,14) (15,15)
3: (9,1) (16,8)
4: (10,2) (11,3) (12,4) (13,5) (14,6) (15,7)
5: (2,1) (8,7) (10,9) (16,15)
6: (9,2) (10,1) (15,8) (16,7)
7: (3,2) (4,3) (5,4) (6,5) (7,6) (11,10) (12,11) (13,12) (14,13) (15,14)
8: (10,3) (11,2) (11,4) (12,3) (12,5) (13,4) (13,6) (14,5) (14,7) (15,6)
[Network Data]
F1  S1R S1I S2R S2I S3R S3I ... S8R S8I
[End]
```

> **NOTE:**
> The requirement that index-label be consecutive integer mandates modification of the labels.

Additionally proposed syntax
with arbitrary text-labels rather than sequential integer-labels

```
[Version] 2.0
# GHz S RI R 50
[Number of Ports] 16
[Number of Frequencies] 1
[Matrix Format] Lower
[Number of Sparse Labels] 12
[Sparse Matrix Mapping]
Ro: (1,1) (8,8) (9,9) (16,16)
Ri: (2,2) (3,3) (4,4) (5,5) (6,6) (7,7) (10,10) (11,11) (12,12) (13,13) (14,14) (15,15)
To: (9,1) (16,8)
Ti: (10,2) (11,3) (12,4) (13,5) (14,6) (15,7)
Roi-1: (2,1) (8,7) (10,9) (16,15)
Toi-1: (9,2) (10,1) (15,8) (16,7)
Rii-1: (3,2) (4,3) (5,4) (6,5) (7,6) (11,10) (12,11) (13,12) (14,13) (15,14)
Tii-1: (10,3) (11,2) (11,4) (12,3) (12,5) (13,4) (13,6) (14,5) (14,7) (15,6)
[Network Data]
F1  S1R S1I S2R S2I S3R S3I ... S8R S8I
[End]
```

NOTE:
Simply delete all rows with '2' in the label. No label changes are required, an advantage for the model developer.

TS 2.0 file

8-pin connector
lower matrix

frequency samples
for 136 values

TS 2.0 file

8-pin connector
nearest and next-nearest
neighbor coupling,
lower, 76 index pairs

frequency samples
for 12 unique values

TS 2.0 file

8-pin connector
only nearest
neighbor coupling,
lower, 52 index pairs

frequency samples
for 8 unique values

TS 2.0 file

8-pin connector
only nearest
neighbor coupling,
lower, 52 index pairs

frequency samples
for 12 unique values

?

Inquiry

- Does anyone have an opinion concerning support for this construct of labels having zero index-pairs associated with them?
  - Is the complexity and potential confusion due to this additional syntax worth the benefit?
- Should we consider arbitrary text labels?

NOTE:

The example applied here was a collinear connector. The same concept could equally well be applied to a set of coupled serial channels. The same superset type of data could be applied with only minor Touchstone file level changes to simulate coupled or uncoupled channels. The file representing the least amount of coupling amongst channels could have labels with no index-pairs in the [Sparse Matrix Mapping] section.

Comments
  - One advantage cited by committee participants of allowing this additional syntax is that a superset of data (more fully-coupled, as in this example) could be leveraged to quickly generate a reduced model (less-coupled).
  - Having a superset of data in the [Network Data] section increases storage requirements. For this syntax to yield a data storage advantage it would require an "include" construct for the superset of data to be saved only once in an external file and then be referenced by multiple Touchstone files. It may not be logical to consider this additional syntax without also considering the "include" construct.
  - Such changes to the model as supported by this additional syntax may just as easily be made programmatically by the model developer when creating the [Network Data] section because explicit knowledge of the physical topology of the device is required. Possibly, the only advantage of this additional syntax is the potential for reduced storage.
  - The committee may wish to quantify storage benefits due to this additional syntax through specific examples.

  - The application of arbitrary text-labels instead of sequential integer-labels may be advantageous for model developers and users who examine the ASCII Touchstone file.
  - Application of such would require a separator character (e.g. ':') that could not be used in the text labels.
  - With arbitrary text labels, sequential integer-labels could still be applied if desired. Blank labels could also be applied.

Thank You!