G-16

CASCADING (CAS) AND ITS INVERSE (SAC) MATRIX OPERATION

Harold E. Stinehelfer, Sr.
Harold E. Stinehelfer, Jr.
Made-It Associates, Inc.
21 Daniel Drive
Burlington, Mass. 01803

Abstract

The cascading of S-parameters from test areas is described and includes the inverse cascading option "SAC" (CAS backwards). The "SAC" option inverts the matrix before multiplication causing the matrix to be de-embedded from the second matrix.

Introduction

Each test area of the MAMA program contains a complete set of S-parameters which may be either measured or calculated from theory. These sets of S-parameters represent circuits that may contain many elements. The time-domain of each set gives the reflection characteristics when TDR analysis is performed, and transmission characteristics if TDD analysis is performed. This new option allows the measured circuit data or calculated theoretical representation of a circuit to be joined together or separated from another set of S-parameters.

CAScading Test Areas Normally: (CAS)

The normal CAScading option is performed by matrix multiplication. The test areas used are specified by the command:

```
CAS N1,N2,N3  CONT
```

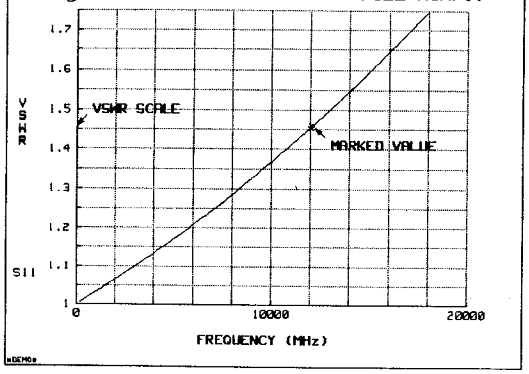
This command will take the S-parameters from the area N1, cascade them with test area N2 and store the cascaded S-parameters in the test area N3. The cascade operation requires the S-parameters to be converted to the T-matrix first, then multiplied together, and the resultant T-matrix converted back into the S-parameter form for storage into the new test area.

This feature has been added to the MAMA-3 program and the demonstration file MCAP1 will be used to illustrate its performance. This demonstration file has a .1 pfd capacitor located at 5 cm on a 10 cm long 50 ohm line.

The VSWR for this file is shown in Figure 1 where the VSWR has a smooth rise with frequency. When plotted as an impedance, the same data has the spiral shape shown in Figure 2. This spiral is clockwise because the reference point is at 0 cm and the location of the capacitor is at 5 cm. Whenever the impedance plot makes a clockwise spiral with increasing frequency the location of the actual discontinuity is further in time-space from the observation point. When this data in frequency is converted to the time-domain, the location of the capacitor is clearly seen and can be identified using the "RLC" function to interpret its location and capacitive or inductive value. Figure 3 shows the impulse time-domain for this lumped capacitance and displays the capacitance and location below the graph.

CAPACITOR OF .1 PF ON A 50 OHM LINE AT 5 CM POINT

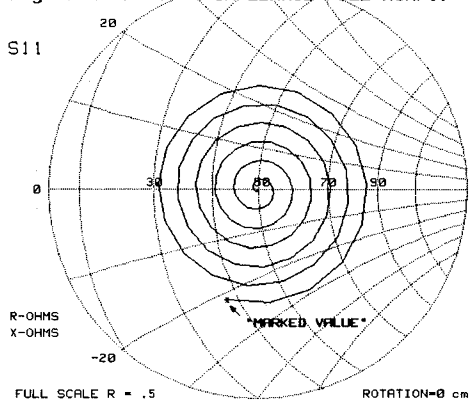
Figure 1 VSWR vs FREQUENCY FILE MCAP1.



MARK	FREQUENCY (MHz)	VSWR
*	12042.375	1.46

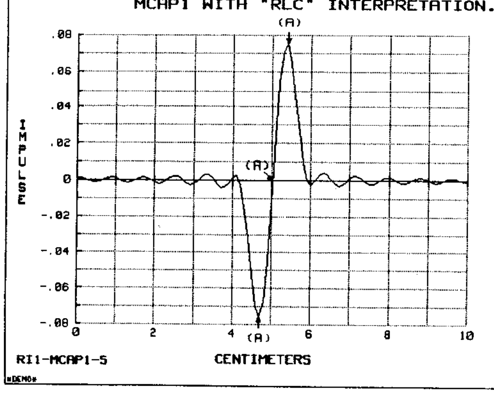
CAPACITOR OF .1 PF ON A 50 OHM LINE AT 5 CM POINT

Figure 2 PLOT OF IMPEDANCE FILE MCAP1.



MARK	FREQUENCY (MHz)	R-OHMS	X-OHMS
*	18000.000	37.89	-21.42

Figure 3 IMPULSE TIME-DOMAIN OF FILE MCAP1 WITH "RLC" INTERPRETATION.



(A)
CAPACITANCE .1014 pFd
IMPEDANCE CHANGE FACTOR: .999
FOR 50 Ohms Zr = 49.93 Ohms
LOCATION APPROXIMATELY 5.03 cm

0149-645X/83/0000-0187 $01.00 © 1983 IEEE

CHANGING REFERENCE PLANE LOCATION USING DRP OPTION

The terminals of this capacitance can be changed using the DRP (Displace Reference Plane) option and choosing which terminal port is to be moved. Moving both reference planes 2.5 cm closer to the capacitor gives the impedance plotted in Figure 4. The impedance spiral is still clockwise but makes fewer revolutions for this range of frequency. The impulse time-domain for this shortened line and capacitor is shown in Figure 5 where the location of the capacitor is now at 2.5 cm.

CASCADING TWO TEST AREAS TOGETHER (CAS)

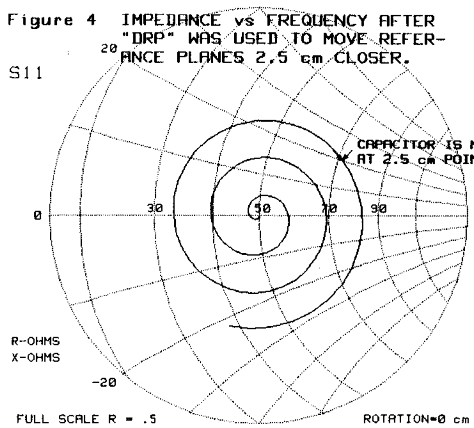
This shorter (5 cm) line with the capacitor at 2.5 cm is cascaded with itself to form a 10 cm line having two capacitors 5 cm apart. The command:

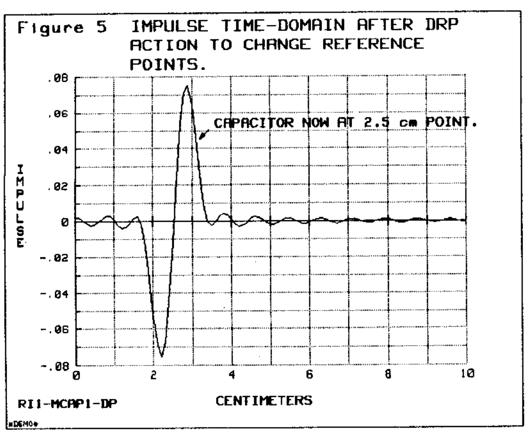
CAS 2,2,3

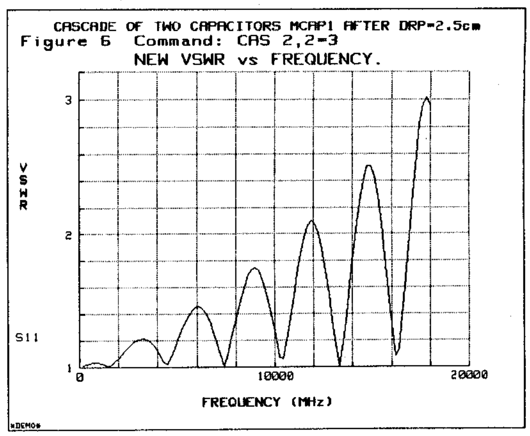
will result in the test area #2 being joined to itself and the results stored into test area #3. The VSWR for test area #3 is given in Figure 6, where the two capacitors now add and cancel giving the maximum and minimum values of VSWR vs frequency. This now can be converted to the time-domain to show in Figure 7, both capacitors and their location along the 10 cm line. Each capacitor has been evaluated by the RLC function and the location of each capacitor is noted below the graph.

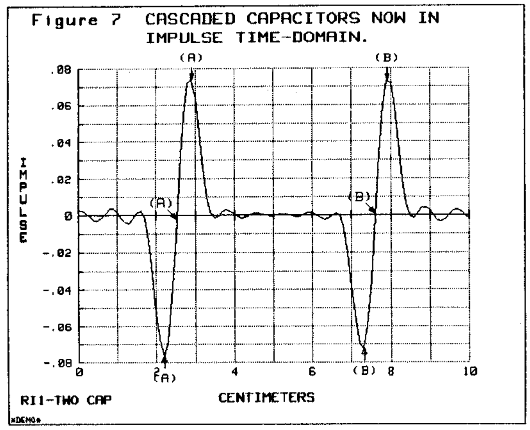
Figure 8 shows the admittance of these two capacitors with reference plane S11 rotated to the first one (2.5 cm).

CAPACITOR OF .1 PF ON A 50 OHM LINE AT 5 CM POINT





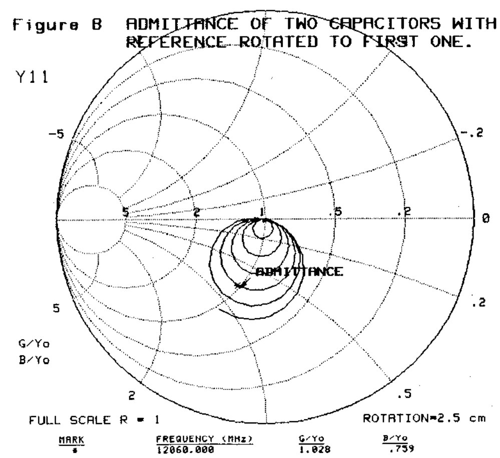




(A)
CAPACITANCE .1016 pFd
IMPEDANCE CHANGE FACTOR: .996
FOR 50 Ohms Zr = 49.78 Ohms
LOCATION APPROXIMATELY 2.53 cm

(B)
CAPACITANCE .0982 pFd
IMPEDANCE CHANGE FACTOR: 1.002
FOR 50 Ohms Zr = 50.09 Ohms
LOCATION APPROXIMATELY 7.61 cm

CASCADE OF TWO CAPACITORS MCAP1 AFTER DRP=2.5cm



Reverse Cascading (SAC) Operation

This operation is the de-embedding of the two S-parameter data files. The first S-parameter matrix is inverted and then multiplied into the second. This makes the first de-embed itself from the second and remove its effect completely. To illustrate this de-embedding operation we will SAC the original file containing only one capacitor in the center of a 10 cm line from this newly created 10 cm line with two capacitors.

The "SAC" operation using two sets of S-parameters both 10 cm long moves the input reference plane 10 cm to the output reference location. The single capacitor from file #1 (MCAP1) now appears to be missing in the center of the newly created set of S-parameters. The VSWR after this operation is given in Figure 9 where the maximum and minimum values of VSWR are not evenly increasing as in Figure 6, but now have some new maximum and minimum values. The conversion of the modified S-parameters into the time-domain shows the original two capacitors with an inductance (negative capacitance) at the center. The time scale has now been scanned from -10 to 0 cm because the SAC operation has moved the reference plane for zero-time 10 cm inside the second set of S-parameters making the capacitors now appear before the zero reference plane. Using the port #2 for analysis, which has not been shifted by this operation, shows that the three reflections are at 2.5, 5.0 and 7.5 cm of time as shown in Figure 11. Figure 12 is an overlay of Figures 10 and 11, showing that the "SAC" operation has modified both S11 and S22 reflection parameters.

Conclusions

This analysis shows the new operation of CAScading and its reverse operation of SAC (CAS reversed) which de-embeds the first set of S-parameters from the second set. If the operation of SAC had been applied to the modified file having the single capacitor on a 5 cm line and the file having two capacitors with a 10 cm line, then the first capacitor would have been removed and the new reference plane would have been moved only 5 cm making the second capacitor appear at 2.5 cm from this new reference plane. This operation would have removed the first capacitor completely and it would not appear even when port #2 was used for analysis.

Figure 10 "SAC" operation removed capacitor from "MCAP1" file from combined cascaded capacitors.

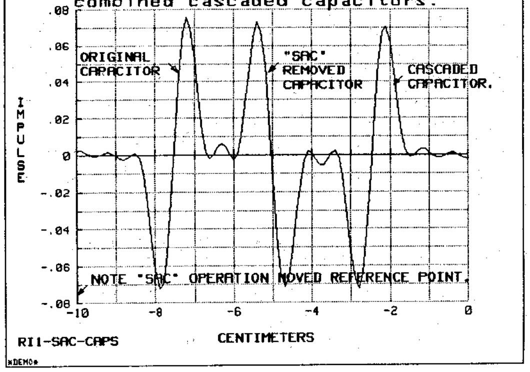
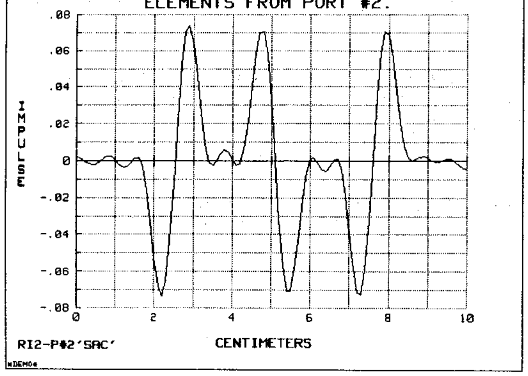


Figure 11 REVERSE TIME-DOMAIN AFTER "SAC" OPERATION SHOWS ALL THREE ELEMENTS FROM PORT #2.



SAC CAP MCAP1 FROM TWO CAPS AT 2.5 &7.5 CM.
Figure 9 VSWR after "SAC" operation single capacitor from two caps}

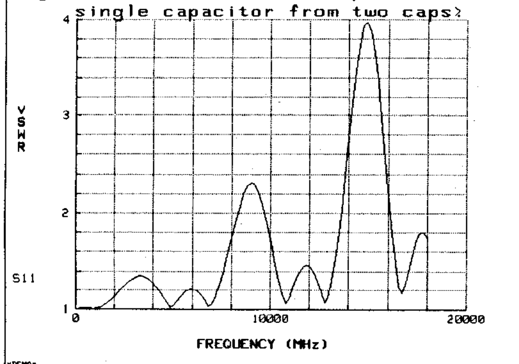


Figure 12 OVERLAY OF PORT #1 & #2 TIME-DOMAINS AFTER "SAC" OPERATION.