Application of the Fault Tolerance of Reduced Bond Graph Approach of Parallel Computing of a Matching Network

Shiv Kumar Gupta, Rajiv Kumar, Krishna Kumar Verma

Abstract— In this paper we present a new method for modeling high frequency systems. This method combines the scattering formalism with the bond graph model in a new technique called scattering bond graph model. This method allows describing explicitly the distribution of electromagnetic waves of any high frequency system. We applied this method to deduce the reflection and transmission coefficient as function as frequency of a parallel computing matching network of a Planar Inverted F Antenna.

Index Terms—Matching network, scattering matrix, scattering formalism, bond graph modeling, scattering bond Graph model, PIFA.

I. INTRODUCTION

The scattering formalism which results in a matrix noted S can be used to study linear or nonlinear, multi-energy representations of physical system [1]. It’s an appropriate method to describe the behavior of microwave structure. This method represents the relations of transmission and reflection waves between different ports of structures. At the same, Bond graph is a graphical representation of a physical dynamic system. This technique is based on exchange of energy and can give concise description of complex systems. By this approach, a physical system can be represented by symbols and lines, identifying the power flow paths [2]. Many researchers proved the possibility of using bond graph model jointly with scattering formalism to study physical systems [3],[4]. The feasibility and efficiency of using formalism scattering jointly with bond graph approach as the representation technique of high frequency systems will be verified in our experiment with matching Network of Planar Inverted F Antenna. We will start this work by the description of the scattering method. Then we will show the relationship between the scattering formalism and the bond graph method. Finally, we will use the two methods jointly to study a matching network of Planar Inverted F Antenna. By a simple maple programme, we will extract the representation of reflection and transmission coefficient in Edges of Antenna. And to validate the found results, we will compare them by the results of simulation circuit obtained by advanced design system (ADS).

II. SCATTERING FORMALISM

Scattering parameters or S-parameters (the elements of a scattering matrix or S-matrix) describe the electrical behavior of linear electrical networks, they may describe large and complex network. S-parameters are useful for electrical engineering, electronics engineering, and communication systems design, and especially for microwave engineering. Scattering matrix, are frequently used to characterize multiport networks, especially at high frequencies. They are used to represent microwave devices, such as amplifiers and circulators, and are easily related to concepts of gain, loss and reflection. S-parameters are readily represented in matrix form and obey the rules of matrix algebra. The S-parameter matrix for the 2-port network is probably the most commonly used and serves as the basic building block for generating the matrix of one port network or multi port networks. Consider a circuit or device inserted into a T-Line as shown in the Figure 1, we can refer to this circuit or device as a two-port network.

Figure 1: Two port network

The scattering matrix is written as follows:

\[
[S] = \begin{bmatrix}
S_{11} & S_{12} \\
S_{21} & S_{22}
\end{bmatrix}
\]

The scattering parameters represent ratios of voltage waves entering and leaving the ports:

\[
V_1^- = S_{11}V_1^+ + S_{12}V_2^+.
\]

[2]

Manuscript received on April 26, 2012.

Shiv Kumar Gupta, Research Scholar Dept. of Computer Science, Manav Bharti University Solan, (H.P.) India, +919816081782, (e-mail: shivku2003@gmail.com).

Rajiv Kumar, Asst. Professor Dept. of ECE, Jaypee University of Inf. Tech. Wakanghat Solan (H.P.) India, +919816365801, (e-mail: rjv.ece@gmail.com).

Krishna Kumar Verma, Krishna Kumar Verma Dept. of Computer Science Awadhesh Pratap Singh University Rewa, (M.P.) India, +919229502568 (e-mail: krishnamscit.verma@gmail.com).

Retrieval Number: B0617042212/2012@BEIESP

Published By: Blue Eyes Intelligence Engineering & Sciences Publication

\[ V_- = S_{21}V_1^+ + S_{22}V_2^+. \]

In matrix form this is written as:

\[ \begin{bmatrix} V_-^1 \\ V_-^2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} V_1^+ \\ V_2^+ \end{bmatrix}, \]

\[ [V] = [S][V^*]. \]

\[ S_{11} = \frac{V_-^1}{V_1^+}, \quad V_1^+=0 \]

\[ S_{12} = \frac{V_-^1}{V_2^+}, \quad V_2^+=0 \]

\[ S_{21} = \frac{V_-^2}{V_1^+}, \quad V_1^+=0 \]

\[ S_{22} = \frac{V_-^2}{V_2^+}, \quad V_2^+=0 \]

\[ S_{22}^*: \text{is the output port voltage reflection coefficient.} \]

A network is reciprocal if it is equal to its transpose:

\[ [S] = [S]^T, \]

In terms of scattering parameters, a network is lossless if:

\[ [S]^T[S]^T = [U], \]

Where \([U]\) is the unitary matrix:

\[ [U] = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}. \]

For a 2-port network, the product of the transpose matrix and the complex conjugate matrix yields:

\[ [S][S^*] = \begin{bmatrix} \{S_1, S_2\}^T \{S_1^*, S_2^*\} \\ \{S_1, S_2\}^T \{S_1^*, S_2^*\} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \]

If the network is reciprocal and lossless:

\[ |S_{11}|^2 + |S_{22}|^2 = 1 \]

\[ S_{11}S_{22}^* + S_{22}S_{11}^* = 0 \]

\[ \begin{bmatrix} b_1 \\ a_1 \end{bmatrix} = \begin{bmatrix} W_{11} & W_{12} \\ W_{21} & W_{22} \end{bmatrix} \begin{bmatrix} a_2 \\ b_2 \end{bmatrix} \]

However, they could be defined differently, as follows:

\[ \begin{bmatrix} a_1 \\ b_1 \end{bmatrix} = \begin{bmatrix} W_{11} & W_{12} \\ W_{21} & W_{22} \end{bmatrix} \begin{bmatrix} b_2 \\ a_2 \end{bmatrix} \]

\[ a_1 = V_1^+ \quad a_2 = V_2^+ \]

\[ b_1 = V_1^- \quad b_2 = V_2^- \]

\[ W_{11} = -\frac{\det(S)}{S_{21}} \]

\[ W_{12} = \frac{S_{11}}{S_{21}} \]

\[ W_{21} = -\frac{S_{22}}{S_{21}} \]

\[ W_{22} = \frac{1}{S_{21}} \]

\[ \text{From } W \text{ to } S: \]

\[ S_{11} = \frac{W_{12}}{W_{22}} \]

\[ S_{12} = \frac{\det(W)}{W_{22}} \]

\[ S_{21} = \frac{1}{W_{22}} \]
\[ S_{22} = \frac{-W_{21}}{W_{22}} \] 

Where \( \text{det}(S) \) indicates the determinant of the matrix \( S \).

### III. RELATION BETWEEN SCATTERING FORMALISM AND BOND GRAPH APPROACH

Generally, any physical system exists in the form of a quadripole inserted between two particular ports \( P_1 \) and \( P_2 \) which respectively represent the entry (source) and the exit (load) of the total system. \([6] \).

This system can be represented by a generalized bond graph model transformed and reduced as the Figure 2 indicates it.

\[ W = \begin{bmatrix} \frac{1-H_{11}+H_{22}-\Delta H}{2H_{21}} & \frac{-1-H_{11}-H_{22}-\Delta H}{2H_{21}} \\ \frac{-1-H_{11}-H_{22}-\Delta H}{2H_{21}} & \frac{1-H_{11}+H_{22}-\Delta H}{2H_{21}} \end{bmatrix} \]  

\[ \Delta H = H_{11}H_{22} - H_{12}H_{21} \]  

**B. Case 2: Effort-flow causality**

\[ \begin{bmatrix} \varphi_1 \\ \varphi_2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} \]  

\[ W = \begin{bmatrix} \frac{1-H_{11}+H_{22}-\Delta H}{2H_{21}} & \frac{-1-H_{11}-H_{22}-\Delta H}{2H_{21}} \\ \frac{-1-H_{11}-H_{22}+\Delta H}{2H_{21}} & \frac{1-H_{11}+H_{22}+\Delta H}{2H_{21}} \end{bmatrix} \]  

**C. Case 3: Flow-flow causality**

\[ \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} \begin{bmatrix} \varphi_1 \\ \varphi_2 \end{bmatrix} \]  

\[ W = \begin{bmatrix} \frac{-1+H_{11}-H_{22}+\Delta H}{2H_{21}} & \frac{-1+H_{11}+H_{22}-\Delta H}{2H_{21}} \\ \frac{1+H_{11}+H_{22}+\Delta H}{2H_{21}} & \frac{1+H_{11}-H_{22}-\Delta H}{2H_{21}} \end{bmatrix} \]  

**D. Case 4: Effort-effort causality**

\[ \begin{bmatrix} \varphi_1 \\ \varphi_2 \end{bmatrix} = \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \end{bmatrix} \]  

All title and author details must be in single-column format and must be center aligned.
\[
\begin{bmatrix}
\varphi_1 \\
\varphi_2
\end{bmatrix} = \begin{bmatrix}
H_{11} & H_{12} \\
H_{21} & H_{22}
\end{bmatrix}
\begin{bmatrix}
\varepsilon_1 \\
\varepsilon_2
\end{bmatrix}
\]

[33]

\[
W = \begin{bmatrix}
\frac{-1 + H_{11} - H_{22} + \Delta H}{2H_{21}} & \frac{1 - H_{11} - H_{22} + \Delta H}{2H_{21}} \\
\frac{-1 - H_{11} - H_{22} - \Delta H}{2H_{21}} & \frac{1 + H_{11} - H_{22} - \Delta H}{2H_{21}}
\end{bmatrix}
\]

[34]

We note that \( H_{ij} \) are the integro-differentials operators which are based in their determination, on the causal ways and algebraic loops present in the associated bond graph model.

\[
H_{ij} = \sum_{k=1}^{N} \frac{G_k \Delta_k}{\Delta}
\]

[35]

\[
\Delta = 1 - \sum L_i + \sum L_i L_j - \sum L_i L_j L_k + \ldots + (-1)^{m} \sum \ldots + \ldots
\]

[36]

Where: \( \Delta \) = the determinant of the causal bond graph.

\( H_{ij} \) = complete gain between \( P_j \) and \( P_i \)

\( P_i \) = input port.

\( P_j \) = output port.

\( N\) = total number of forward paths between \( P_i \) and \( P_j \)

\( G_k \) = Gain of the \( k^{th} \) forward path between \( P_i \) and \( P_j \)

\( G_i \) = Gain of the \( k^{th} \) forward path between \( P_i \) and \( P_j \)

\( L_i \) = Loop gain of each causal algebraic loop in the bond graph model.

\( L_i L_j \) = Product of the loop gains of any two non touching loops (no common causal bond).

\( L_i L_j L_k \) =product of the loop gains of any three pair non-touching loops.

\( \Delta_k \) = the factor value of \( \Delta \) for the \( k^{th} \) forward path, with the loops touching the \( k^{th} \) forward path removed; i.e., Remove those parts of the causal bond graph which form the loop, while retaining the parts needed for the forward path.

**IV. APPLICATION TO A MATCHING NETWORK OF A PLANAR INVERTED F ANTENNA**

The low bandwidth is one of the main disadvantages of micro strip antenna. One of the most reliable methods to increase the bandwidth of micro strip antenna is to introduce multiple resonances by introducing parasitic elements or reactive matching circuit between the generator and the antenna.

This technique allows increasing the bandwidth not only for a single-band antenna, but also for a multi-band antenna. In this work we propose a circuit of PIFA antenna that resonates at 0.9GHz and 1.8GHz. This antenna is preceded by a matching circuit.

From the scattering bond Graph method we extract the different variation of reflection and transmission coefficient of the matching circuit.

The complete circuit is given below:
The reduced equivalent impedance of the element i put in

decomposition junction

\[ \tau_{L_1} = \frac{L_1}{R_0}, \quad \tau_{L_2} = \frac{L_2}{R_0} \]

\[ \tau_{L_3} = \frac{L_3}{R_0}, \quad \tau_{C_1} = C_1R_0 \]

\[ \tau_{C_2} = C_2R_0, \quad \tau_{C_3} = C_3R_0 \]

By decomposition the reduced bond graph given by

Figure 9: The reduced and transformed bond graph model

\[ B_1 = -\frac{1}{z_1y_1} : \text{Loop gain of the algebraic loop by the first sub-model} \]

\[ B_2 = -\frac{1}{z_2y_2} : \text{Loop gain of the algebraic loop by the second sub-model} \]

\[ \Delta_1 = 1 + \frac{1}{z_1y_1} : \text{Determinant of causal bond graph of the first sub-model} \]

\[ \Delta_2 = 1 + \frac{1}{z_2y_2} : \text{Determinant of causal bond graph of the second sub-model} \]

\[ \begin{align*}
H_{11} &= \frac{z_1}{z_1y_1 + 1} \\
H_{12} &= \frac{1}{z_1y_1 + 1} \\
H_{21} &= \frac{1}{z_1y_1 + 1} \\
H_{22} &= -\frac{y_1}{z_1y_1 + 1} \\
\Delta(s) &= -\frac{1}{z_1y_1 + 1}
\end{align*} \]

: The all integro- differentials operators of the first sub-model

\[ \begin{align*}
H_{11} &= \frac{z_2}{z_2y_2 + 1} \\
H_{12} &= \frac{1}{z_2y_2 + 1} \\
H_{21} &= \frac{1}{z_2y_2 + 1} \\
H_{22} &= -\frac{y_2}{z_2y_2 + 1} \\
\Delta(s) &= -\frac{1}{z_2y_2 + 1}
\end{align*} \]

: The all integro- differentials operators of the second sub-model

From these operators, we can deduce directly the wave matrix of the first and second sub-model by taking into account to equations 30 of the reduced bond graph model with effort-flow causality:

\[ W^{(1)} = \frac{1}{2} \begin{bmatrix}
-z_1y_1 - z_1 - y_1 + 2 & -z_1y_1 + z_1 + y_1 \\
-z_1y_1 - z_1 + y_1 & z_1y_1 + z_1 + y_1
\end{bmatrix} \]

Notice that:

* \( z_i \): the reduced equivalent impedance of the element i put in series.
* \( y_i \): the reduced equivalent admittance of the element i put in parallel.

So we have:

\[ y_1 = \tau_{C_1}S + \frac{1}{\tau_{L_1}S} \]

\[ z_1 = \tau_{L_2}S + \frac{1}{\tau_{C_2}S} \]

\[ y_2 = \tau_{C_2}S + \frac{1}{\tau_{L_2}S} \]

\[ z_2 = r_1 \text{ with } r_1 = \frac{R_1}{R_0} \]

s: The laplace operator

We have the integro differentials operators by taking into account to the previously equations from the reduced bond graph model with effort-flow causality:
Application of the Fault tolerance of reduced bond graph approach of parallel computing of a matching network

The wave matrix of the complete system can be given by the product of the first and the second wave matrix such as:

\[ W^{(T)} = W^{(1)} \times W^{(2)} = \begin{bmatrix} W_{11} & W_{12} \\ W_{21} & W_{22} \end{bmatrix} \]

V. SIMULATION RESULTS OF THE SCATTERING PARAMETERS

A simple programming and simulation of the above scattering parameters equations, give the figure 12, figure 14, figure 16 and figure 18 below which represent respectively the reflection and transmission coefficients of the studied matching network.

To validate the results of the scattering equations we simulated the circuit of matching network by ADS software, the results obtained are Figure 13, 15, 17 and 19.

![Figure 11: circuit of matching network simulated by ADS](image1)

![Figure 12: Reflection coefficient S11 seen at entry](image2)

![Figure 13: Reflection coefficient S11 seen at entry](image3)

![Figure 14: Transmission coefficient S12 seen from exit to entry](image4)

![Figure 15: Transmission coefficient S12 seen from exit to entry](image5)

![Figure 16: Transmission coefficient S21 seen from entry to exit](image6)
We note that the results obtained from the scattering bond graph method are similar to the results obtained by ADS. That implies the effectiveness of the chosen method.

VI. CONCLUSION

In this work we presented a new method to analyze high frequency systems. This method is based on the combination of scattering formalism with the bond graph model; it is applied scattering bond graph method. We applied it to analyze a matching network circuit of PIFA. To validate the obtained results we compared them with the results of simulation circuit by ADS. The advantage of scattering bond graph method is the simplicity and speed execution. It can also get an idea about a high frequency system before conception step, such as gain, bandwidth, reflection and transmission coefficient.

REFERENCES

2. Mieczyslaw RONKOWSKI, Zhignew KNEBA, “Bond-graphs based modeling of hybrid energy systems with permanent magnet brushless machines”. 
5. Hichem Taghouti,Mami Abdelkader” Extraction, Modelling and Simulation of the Scattering Matrix of a Chebychev Low-Pass Filter with cut-off frequency 100 MHz from its Causal and Decomposed Bond Graph Model”, ICGST-ACSE Journal, Volume 10, Issue 1, November 2010.

AUTHORS PROFILE

Shiv Kumar Gupta has done M. Sc (Mathematics), M.C.A., M. Phil (CS) and currently pursing Ph.D. Computer Science from Manav Bharti University, Solan (H.P.) India. He is life membership of “MATERIALS RESEARCH SOCIETY OF INDIA”.

Rajiv Kumar received his B. Tech. in 1994, in Electrical Engineering, from College of Technology, G.B. Pant University of Agriculture & Technology, Pantnagar and M. Tech. from Regional Engineering College, Kurukshetra (Kurukshetra University) with specialization in Control System. He started his career as a teaching associate from National Institute of Technology (NITT), Kurukshetra. He is presently with the Department of Electronics and Communication Engineering at Jaypee University of Information Technology, Waknaghat, Solan. He obtained his Ph.D in network reliability in the year 2010 from NIT under the supervision of Prof. Krishna Gopal. Rajiv Kumar is member of IEEE and Life Member of ISTE, IETE, Forum of Inter disciplinary Mathematics and System Society of India. His areas of research interests are computing, cyber- physical systems and network reliability.

Krishna Kumar Verma received his M.Sc.(IT) in 2009 and M.Phil. (CS) in 2011 from Department of Computer Science, A.P.S. University, Rewa (M.P.). He started his career as a teaching associate from Department Computer Science at Awadhesh Pratap Singh University, Rewa. Currently He is working with the Department Computer Science at Awadhesh Pratap Singh University, Rewa. His areas of research interests are parallel and distributed computing, load balancing in grid computing and algorithm based fault tolerance.