IJCSI International Journal of Computer Science Issues, Vol. 10, Issue 2, No 1, March 2013
ISSN (Print): 1694-0814 | ISSN (Online): 1694-0784
www.IJCSI.org

Modeling of a Microstrip Low- Pass Filter by the Scattering-Bond Graph Formalism

Sameh Khmailia[1], Hichem Taghouti[1] and Abdelkader Mami[1,2]

[1]Department of Electrical Engineering, National Engineering School of Tunis
P.O. Box 37, 1002 Tunis, Tunisia

[2] Department of Physics, Sciences Faculty of Tunis, Company
2092 El Manar Tunis, Tunisia

Abstract

Low pass filters play an important role in wireless systems. At the reception and the transmission, the signal has to be filtered at a certain frequency with a specific band width. In this paper we present a design of microstrip low- pass filter. The bond graph and the scattering formalism are used jointly to give an explicit model of filer.

The representations of transmission and reflection coefficients of filter are derived from the obtained model.

Keywords: *Low Pass Microstrip Filter, Bond Graph Model, Scattering Formalism, Transmission and Reflection Characteristics.*

1. Introduction

Electronics filters are required in all radio- frequency communication techniques. They are used to execute signal processing functions specifically to enhance the wanted frequency component, to remove the unwanted one [1]. There are four filter types: Low Pass Filters, High Pass Filters, Band Pass Filters and Band Stop Filters [2,3]. Depending on the characteristics and the conditions of application, the electronic filter can be designed by distributed or lumped elements [4].

In order to describe the physical behavior of a low pass microstrip filter, we will use a procedure which links the bond graph formalism to the scattering formalism. Firstly, we will develop a bond graph model of microstrip filter. Secondly, we will derive the scattering matrix from the reduced bond graph model. Finally, we will use the scattering parameters to extract the transmission and reflection characteristics by maple program.

2. Bond Graph Model

The Bond graphs are a kind of graphical language and systematic representation.

They were applied in physical multidiscipline domains, such as mechanics, electronics and hydraulics… They include elements and constitutive relations which can used to express the common energy transfer or transform behavior underlying the several physical domains.

The characteristics of bond graphs include:

- being able to obtain important qualitative information as a conceptual model.
- being able to reveal the relationships among system, subsystems, and elements.
- not only being able to represent the topology of subsystems or elements of different physical domains, but also being able to represent the relationships of their products among them.

The concepts of bond graphs include port and bond, elements, variables, constitutive relations and causality.

Fig.1 shows the concept of the basic bond graph component.

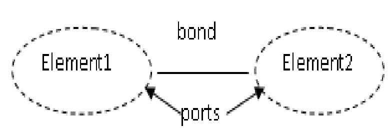

Fig. 1 Bond and ports of bond graph.

Between two elements, there is always a bond. Every bond has two power variables, one is effort (e), and the other is flow (f) associated with it. Energy will flow through the bond in either direction.

Bond graphs consist of nine types of elements, they are source of effort(Se), source of flow(Sf), inductor(I), capacitor(C), resistor(R), transformer(TF), gyrator(GY), 0-junction and 1- junction.

3. Proposed Structure and Bond Graph Model

The chosen structure, given by Fig 2, is a low pass microstrip filter formed by an alternating of high and low impedance transmission lines which are linked in cascade.

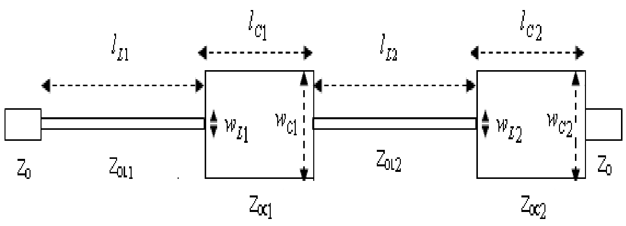

Fig. 2 Low pass microstrip filter

The physical characteristics of the filter are:

$$l_{L1} = l_{L2} = 9.81mm,\ l_{C1} = l_{C2} = 7.11mm$$

$$w_{C1} = w_{C2} = 4mm,\ w_{L1} = w_{L2} = 0.2mm$$

The specifications of the filter are:
Cut off frequency: fc=1.3GHz
Pass band ripple=0.1 dB
Source/load impedance: Z0=50Ω
The characteristic impedances of high and low impedance lines are chosen as Z0Li=93Ω and Z0Ci=24Ω.
The substrate is characterized by a relative dielectric constant $\varepsilon_r = 10.8$ and a thickness $h = 1.27mm$.

The narrow line with high impedance is equivalent to a lumped- element inductor attached in series.

Fig. 3 Microstrip line and its electric model.

$$L = \frac{Z_{0L}.l_{Li}}{\upsilon_{p1}} \tag{1}$$

The large line with low impedance present a better approximation of lumped- element capacitor connected in parallel.

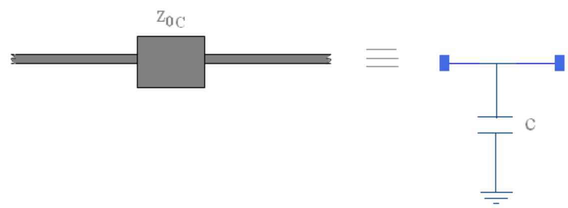

Fig. 4 Large microstrip line and its electric model.

$$C = \frac{.l_{Ci}}{Z_{0C}\upsilon_{p2}}$$

(2)

Where

$$\upsilon_{pi} = \frac{\omega}{\beta i} \tag{3}$$

And

$$\beta i = \frac{2\pi}{\lambda_{gi}} \tag{4}$$

λ_{gi} The guided wavelength

Thus the equivalent circuit constituted by lumped elements is given by Fig. 5.

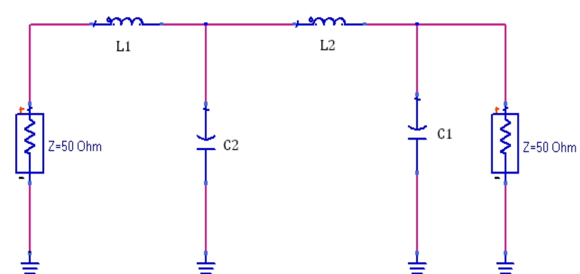

Fig. 5 Lumped elements filter

Applying the above formulas in our structure, we obtain:

The values of inductances: $L1 = L2 = 7.7316\,nH$
The values of capacitances: $C1 = C2 = 2.816\,pF$

So we can easily deduce the bond graph model of the filter. This model describes clearly the exchange of physical energy between the filter elements.

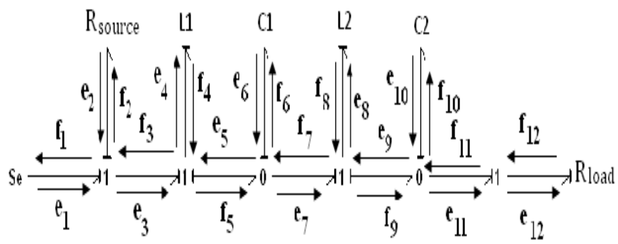

Fig. 6 Bond graph model.

From the bond graph model we can determine the Scattering parameters of filter. This approach is described in the next paragraph.

4. Derivation of the Scattering Matrix from Bond Graph Model

Scattering parameters or S-parameters describe the electrical behavior of linear electrical networks.
The researches of **Abdelkader Mami** and **Hichem Tghouti** [5, 6, 7, 8] have shown that it is possible to determine the scattering matrix of a system from its bond graph model.
In the case of the chosen structure, it is necessary to transform the bond graph model by a reduced bond graph model given by Fig. 7.

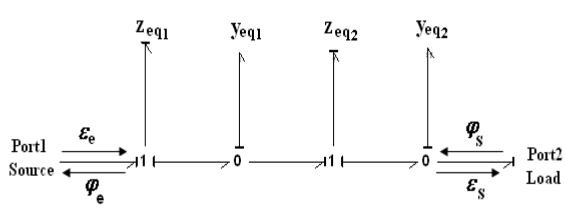

Fig.7 Reduced bond graph model.

Notice that:

z_{eqi}: The reduced equivalent impedance

y_{eqi}: The reduced equivalent admittance

So we have:

$$z_{eq1} = r_1 + \tau_{L1}.s \quad (5)$$

$$y_{eq1} = \tau_{C1}.s \quad (6)$$

$$z_{eq2} = \tau_{L2}.s \quad (7)$$

$$y_{eq2} = \tau_{C2}.s + r_2 \quad (8)$$

s: The Laplace operator.

$$r_1 = \frac{R_{souce}}{R_0}$$

$$r_2 = \frac{R_{load}}{R_0}$$

$$\tau_{Ci} = Ci.R_0 \quad (9)$$

$$\tau_{Li} = \frac{Li}{R_0} \quad (10)$$

$$R_0 = 50\Omega$$

The reduced bond graph model is easier to study by dividing it into two sub models.

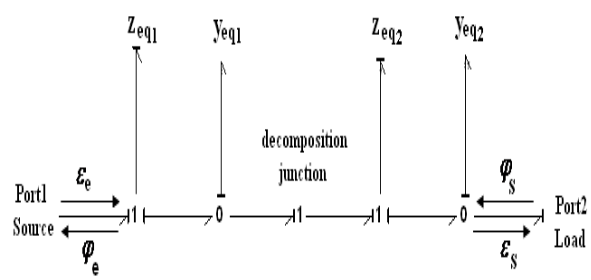

Fig. 8 Decomposition of the reduced bond graph model into two sub-

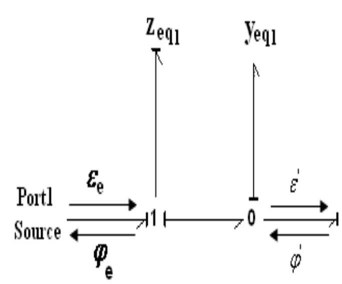

Fig. 9 Sub- model1

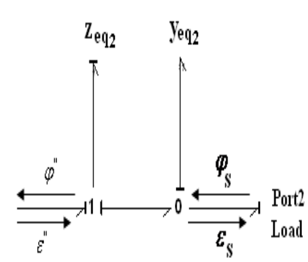

Fig. 10. Sub- model2

$B1 = -\frac{1}{z_{eq1}.y_{eq1}}$ (11): Loop gain of the algebraic loop given by the first sub-model .

$B2 = -\frac{1}{z_{eq2}.y_{eq2}}$ (12): Loop gain of the algebraic loop given by the second sub-model

$\Delta 1 = 1 + \frac{1}{z_{eq1}.y_{eq1}}$ (13): Determinant of causal bond graph of the first sub-model.

$\Delta 2 = 1 + \frac{1}{z_{eq2}.y_{eq2}}$ (14): Determinant of causal bond graph of the second sub-model.

The all integro- differentials [9,10] operators of the first sub model are:

$$\begin{cases} H_{11}[1] = \frac{y_{eq1}}{z_{eq1}.y_{eq1}+1} \\ H_{12}[1] = \frac{1}{z_{eq1}y_{eq1}+1} \\ H_{21}[1] = \frac{1}{z_{eq1}.y_{eq1}+1} \\ H_{22}[1] = -\frac{z_{eq1}}{z_{eq1}.y_{eq1}+1} \\ \Delta(s)[1] = -\frac{1}{z_{eq1}.y_{eq1}+1} \end{cases} \quad (15)$$

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

$$\begin{cases} H_{11}[2] = \frac{y_{eq2}}{z_{eq2}.y_{eq2}+1} \\ H_{12}[2] = \frac{1}{z_{eq2}y_{eq2}+1} \\ H_{21}[2] = \frac{1}{z_{eq2}.y_{eq2}+1} \\ H_{22}[2] = -\frac{z_{eq2}}{z_{eq2}.y_{eq2}+1} \\ \Delta(s)[2] = -\frac{1}{z_{eq2}.y_{eq2}+1} \end{cases} \quad (16)$$

From these operators, we can deduce directly the wave matrix of the first and the second sub-model [11, 12,13].

$$W[1] = \begin{bmatrix} W_{11}[1] & W_{12}[1] \\ W_{21}[1] & W_{22}[1] \end{bmatrix} \quad (17)$$

$$W[2] = \begin{bmatrix} W_{11}[2] & W_{12}[2] \\ W_{21}[2] & W_{22}[2] \end{bmatrix} \quad (18)$$

.

Such as:

$$W_{11}[i] = \frac{1 - H_{11}[i] + H_{22}[i] - \Delta H[i]}{2H_{21}[i]} \quad (19)$$

$$W_{12}[i] = \frac{1 - H_{11}[i] - H_{22}[i] + \Delta H[i]}{2H_{21}[i]} \quad (20)$$

$$W_{21}[i] = \frac{1 + H_{11}[i] + H_{22}[i] + \Delta H[i]}{2H_{21}[i]} \quad (21)$$

$$W_{22}[i] = \frac{1 + H_{11}[i] - H_{22}[i] - \Delta H[i]}{2H_{21}[i]} \quad (22)$$

$$\Delta H[i] = H_{11}[i]H_{22}[i] - H_{12}[i]H_{21}[i] \quad (23)$$

The global Wave matrix W_g is given by the product of $W[1]$ and $W[2]$ [14,15,16]:

$$W_g = W[1]*W[2] = \begin{bmatrix} W_g[11] & W_g[12] \\ W_g[21] & W_g[22] \end{bmatrix} \quad (24)$$

Then we can determine the S matrix[17]:

$$S = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \quad (25)$$

$$S_{11} = -\frac{W_g[12]}{W_g[22]} \quad (26)$$

$$S_{12} = \frac{1}{W_g[22]} \quad (27)$$

$$S_{21} = \frac{W_g[22]W_g[11] - W_g[12]W_g[21]}{W_g[22]} \quad (28)$$

$$S_{22} = \frac{W_g[21]}{W_g[22]} \quad (29)$$

A simple programming and simulation of the above scattering parameters equations, gives the Figures11- 14 which represent respectively the reflection and transmission coefficients of the studied filter.

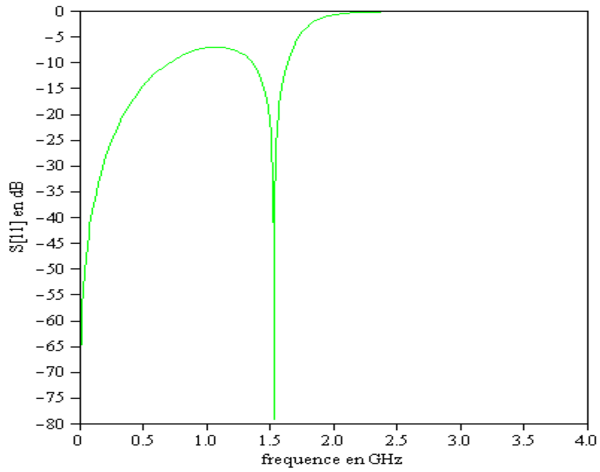

Fig. 11 Reflection coefficient S11

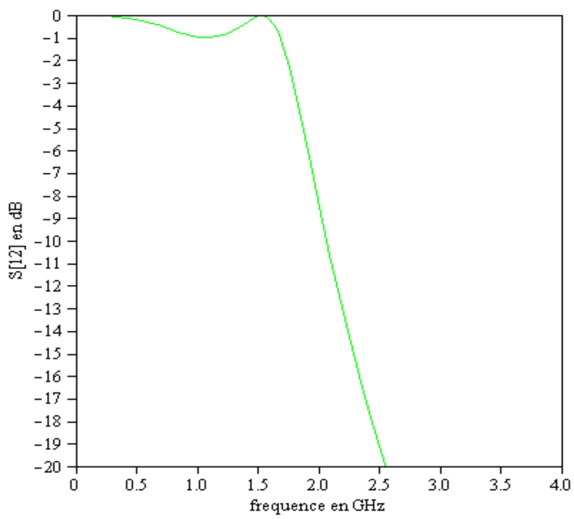

Fig. 12 Transmission coefficient S12

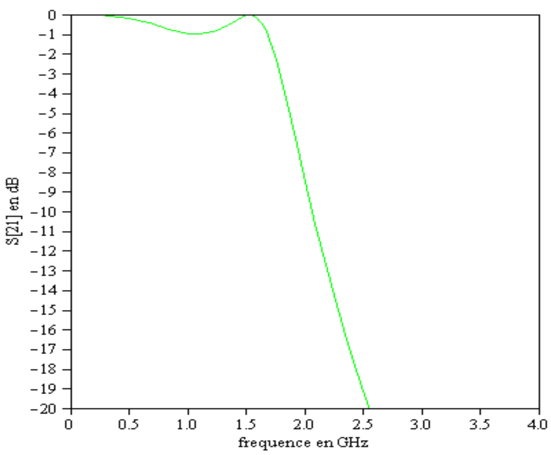

Fig. 13 Transmission coefficient S21

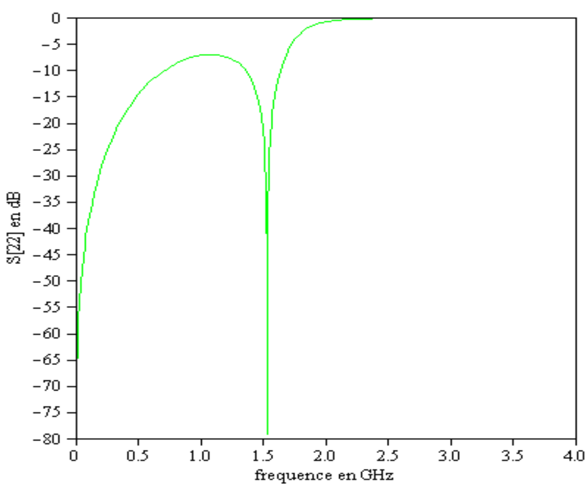

Fig. 14 . Reflection coefficient S22

The obtained results are in accordance with the characteristics of the filter, which proves the validity of the scattering bond graph formalism to analyze the linear systems.

5. Conclusions

In this article, we have used a procedure which links the bond graph formalism to the scattering formalism to analyze a low pass microstrip filter. Firstly, we have explained the method to find the bond graph model from the filter. Then, we showed the steps to obtain the S matrix. Afterwards, we have developed a maple program from the scattering parameters which has allowed us to represent the transmission and reflection characteristics.

Acknowledgments

We would like to thank Mr MAMI Abdelkader, professor in Faculty of Sciences of Tunis (FST); Dr. TAGHOUTI Hichem, Assistant Professor of Electrical Engineering in Superior Institute of Sciences and Technologies of Environment of BORJ-SEDRIA Tunis and researcher in Laboratory of Analysis and Command Systems, National Engineering School of Tunis for the time and guidance given during this work, without forgetting the members of the unit of electronics and high frequency circuits specially; Mr. MEHOUACHI Riadh, doctoral researcher in Laboratory of Analysis and Command Systems, National Engineering School of Tunis and all those who contributed and aided in this study in particularly L.A.C.S members (Laboratory of analysis and command systems), ENIT.

References

[1] Richa Gupta, Onkar Chand," Analysing Chebyshev Filter For Displaying Radar Target Track", International Journal of Engineering Research and Applications.
[2] Gheorghe Todoran, Rodica Holonec, Nicolae D.Dragomir and Ioan G. Tarnovan,"A Modeling Method for Analog High- Pass and Band- Stop Type Filter by Using Stripline Operators ", ACTA Electrotechnica
[3] K.V.Puglia, " A General Design Procedure for Bandpass Filters derived from Low Pass Prototype Elements", Microwave journal 2000, 12.
[4] Bruce E.Carey- Smith, Paul A, Mark A, Associate Member, IEEE, and Tayfun Nesimoglu,"Wide Tuning- Range Planar Filters Using Lumped- Distributed Coupled Resonators", IEEE Transaction on microwave theory and techniques, VOL.53, NO.2, February 2005.
[5] Taghouti Hichem, 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.
[6] Taghouti Hichem, Mami Abdelkader, "How to Find Wave-Scattering Parameters from the Causal Bond Graph Model of a High Frequency Filter", American Journal of Applied Sciences 7 (5): 702-710, 2010, ISSN 1546-9239
[7] Taghouti Hichem, Mami Abdelkader, "Modeling Method of a Low-Pass Filter Based on Microstrip T-Lines with Cut-Off Frequency 10 GHz by the Extraction of its Wave-Scattering Parameters from its Causal Bond Graph Model", American J. of Engineering and Applied Sciences 3 (4): 631-642, 2010.
[8] Mehwachi Riadh, Taghouti Hichem, Sameh Khmailia, Abdelkader Mami "Modeling and Simulation of the Patch Antenna by Using a Bond Graph Approach", International Journal of Advances in Engineering & Technology, Jan 2012.
[9] Hichem TAGHOUTI and Abdelkader MAMI :''Discussion around the Scattering Matrix Realization of a Microwave Filter using the Bond Graph Approach and Scattering Formalism''. American Journal of Applied Sciences Volume 9, Issue 4 Pages 459-467, April 2012.

[10] Hichem TAGHOUTI and Abdelkader MAMI ''Application of the reduced bond graph approaches to determinate the scattering parameters of a high frequency filter'', Proceeding of the 10th International Conference on Sciences and Techniques of Automatic Control and Computer Engineering (STA'2009), Academic Publication Center Tunisia, 20-22 Dec. 2009, Hammamet Tunisia, pp. 379-391.

[11] Hichem TAGHOUTI, Sameh KHMAILIA, Riadh MEHOUACHI and Abdelkader MAMI '' Using of a New Bond Graph Technology for the Study of a High Frequency Low Pass Filter''. International Journal of Computational Engineering & Management, Vol. 15 Issue 5, September 2012, pp: 9-15.

[12] Hichem TAGHOUTI (2011). ''Utilisation Conjointe de l'Approche Bond Graph et le Formalisme Scattering pour la Modélisation des Systèmes Physiques Applications aux Circuits Electroniques Hautes Fréquences à Eléments Localisés et Distribués''. Thèse de doctorat, faculté des sciences de Tunis, Tunisie.

[13] PAYNTER, H.M., ILENE J. et BUSCH-VISHNIAC ''Wave scattering approaches to conservation and causality'', J. Franklin inst. 1988, Vol. 325, N° 3, pp. 295-313.

[14] Riadh MEHOUACHI, Hichem TAGHOUTI, Sameh KHMAILIA and Abdelkader MAMI ''modeling and simulation of the patch antenna by using a bond graph approach''. International Journal of Advances in Engineering & Technology, Jan 2012, Volume 2, Issue 1, pp: 474-484.

[15] Riadh MEHOUACHI, Hichem TAGHOUTI, Sameh KHMAILIA and Abdelkader MAMI ''Modelling and Determination of the Scattering Parameters Of Wideband Patch Antenna By Using A Bond Graph Approach''. International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 5, September- October 2012, pp.879-884.

[16] Sameh KHMAILIA, Hichem TAGHOUTI, Riadh MEHOUACHI and Abdelkader MAMI. ''analyze of a rectangular micro-strip antenna by the scattering bond graph approach''. International Journal of Electronics and Communication Engineering & Technology (IJECET), Volume 3, Issue 1, January- June (2012).

Sameh KHMAILIA was born in Tunisia. She received the master diploma in electronic (Numeric Analysis and Treatment of Electronics Systems) from the Faculty of Sciences of Tunis (FST) in 2010. During period between February and September 2010, she had been a contractual assistant of Physics-Electronic in Higher Institute of Accountancy and Entrepreneurial Administration of Mannouba in Tunisia. Since September 2010, she has been a contractual assistant of Physics-Electronic in Higher Institute of Applied Sciences and Technology of Gafsa, Tunisia. She is preparing her thesis in National Engineering School of Tunis (ENIT) and faculty of Sciences of Tunis (FST). Her main research areas are the Scattering- Bond Graph modeling and its new Applications in High Frequencies Domain.

Hichem TAGHOUTI Was born in Tunisia in December 1979. He received the master diploma in electronic (Numeric Analysis and Treatment of Electronics Systems) from the Faculty of Sciences of Tunis (FST) in 2005. Since September 2006, he was been an Assistant of Physics-Electronic in Faculty of Sciences of Gafsa in Tunisia. He was preparing his Thesis at National Engineering School of Tunis (ENIT) in Tunisia and faculty of Sciences of Tunis (FST) in Tunisia. His main research areas are the Bond Graph modelling and its new applications in High Frequencies Domain. On April 2011 he received his PhD. Actually he is working as Assistant Professor on Electrical Engineering in Superior institute of sciences and technologies of environment of BORJ-SEDRIA Tunis.

Abdelkader MAMI Was born in Tunisia, he is a Professor in Faculty of Sciences of Tunis (FST). He was received his Dissertation H.D.R (Enabling To Direct of Research) from the University of Lille (France) 2003, he is a member of Advise Scientific in Faculty of Science of Tunis (Tunisia), he is a President of commutated thesis of electronics in the Faculty of sciences of Tunis, He is a person in charge for the research group of analyze and command systems in the ACS- laboratory in ENIT of Tunis and in many authors fields.