Mechatronic Systems, Mechanics and Materials II

Edited by
Jerzy Garus and Piotr Szymak

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Preface

The current volume of the Solid State Phenomena contains some new results in mechatronic systems, mechanics and materials, as well as in aspects of automatics and robotics in relevant technological applications. Therefore, the book is divided into three main chapters: mechatronics, automatics and robotics, and it contains the latest theoretical and practical experiences of scientists and researchers from universities and research centers.

The main objective of this volume is the dissemination of the scientific knowledge to better understanding of widely considered mechatronic and material systems. Moreover, the aim of the issue is to interconnect diverse scientific fields and exchange current views between scientists and researchers.

The Editors would like to express their appreciation to the Authors for their valuable contributions published in this volume, as well as to the Reviewers for excellent work, which helped us select the papers contained in the issue.

We hope that the volume will be a source of knowledge and inspiration for scientists, researchers and practitioners working in the fields of interest covered by the book.

Jerzy Garus and Piotr Szymak

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Active Impedance Matching

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Keywords: Active impedance matching, negative impedance converter, electrically small antennas

Abstract. Electrically small antenna suffer from the high Q impedance such as narrow bandwidth and poor gain. To improve them, passive impedance matching is often used but it is restricted to a Bode-Fano limit. To skip it, active matching incorporating non-Foster circuits can provide a good solution. Using non-Foster theory, in this paper an active reactance circuit(ARC) design is proposed for application to electrically small antenna prototypes

Introduction

The sizes of the electronics needed for a mobile application have decreased during the years. As they shrank all its components not only have to be size-limited but also have to keep their best functional parameters. Unfortunately, for component such as antenna it is very difficult to fulfill these requirements, so reduction of the dimensions is an actual problem. Antennas can, of course, be made smaller but at the expense of bandwidth, gain, and efficiency. To overcome this problem, antenna engineers take often into consideration the so-called electrically small antennas (ESAs) which have been an important topics of research for many decades [1]-[6].

By the classical definition proposed by Wheeler [7], electrically small antenna is an antenna that satisfies the condition $ka \leq 1$, where k- wave number, a –radius of the minimum size sphere that encloses the antenna. Such a sphere represents the boundary between the near-and-far field radiation.

ESA is characterized by their electrical size *ka*, quality factor Q and bandwidth. Of particular interest is how antenna bandwidth (or Q) is related to the antenna size. This relation is known as a theoretical limit and it was established in the work of Wheeler [7] and Chu[8]. According to this relation the bandwidth decreases with electrical size of antenna. Moreover, ESA impedance is highly reactive. Hence most of the input power will be stored in the near-field region which results in low gain, so ESA needs a matching network.

To decrease Q, increase bandwidth and improve radiation efficiency two kinds of matching network can be used. First, is a commonly used passive matching such as LC network or baluns. Unfortunately, the disadvantage of this solution is the Bode-Fano limit [9,10]. In order to skip it, an active impedance matching is used. It is realized by using non-Foster elements such as negative capacity or negative inductor. Such negative elements can be realized in practice using NICs (negative impedance converters).

An ideal negative impedance converter is usually assumed as an active two-port device in which the impedance at one pair of terminal is the negative of the impedance connected to the other terminal pair (see Fig. 1).

Fig. 1. An ideal NIC scheme

There are two types of NICs. The first case is called a voltage inversion NIC (VINIC) and its hybrid set of equations is:

$$\begin{bmatrix} U_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0 & -K \\ -1 & 0 \end{bmatrix} \begin{bmatrix} I_1 \\ U_2 \end{bmatrix}, \tag{1}$$

where U_1, I_1 are voltage and current at the input of terminal, U_2, I_2 are voltage and current at the output of terminal and K is a conversion coefficient.

The second type of NIC is called a current inversion NIC (CINIC) and it can be defined by the following hybrid set of equations

$$\begin{bmatrix} U_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ K & 0 \end{bmatrix} \begin{bmatrix} I_1 \\ U_2 \end{bmatrix}. \tag{2}$$

NICs can be realized via a combination of active devices (amplifiers) and lumped loads (capacitors and inductors). Several configurations of NICs can be found in [11,12], with some simple one presented in Fig. 2.

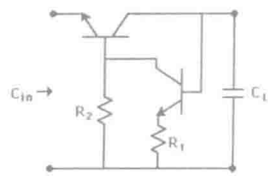

Fig. 2. Negative impedance converter[11]

Basically, the idea of using Non-Foster matching is simple and based on the reduction of the reactive part of antenna input impedance by connecting the antenna terminals to active matching circuit that consists of converters. Doing so, the bandwidth can increase as it is shown in [13] where the bandwidth of microstrip antenna increase from 12% to 24%.

Overall, non-Foster matching can improve bandwidth significantly as it is not limited by Bode-Fano limit. Hence, active matching can allow for small broadband antennas.

The work purpose is research of problem of the input matching of an ESA by using Non-Foster reactance that can be realized using active reactance circuits(ARC), the operation of which resembles negative impedance converters (NICs). Therefore, we report in this article on design and measurement of ARC. The simulation and measurement results of ARC prototype are presented and discussed.

Active impedance matching design

A circuit model for ESA

In our investigation, we consider a wire antennas presented in fig. 3. We called it antenna "A" and "B". Their shape was found by our design method called "M2" [14]. Antennas resemble monopole. Each antenna consists of four wire segments connected in series. Segments lengths are equal.

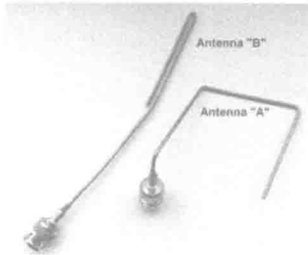

Fig. 3. ESAs taken into investigation

Before, the design of Non-Foster matching network is begun, it is important to obtain an equivalent lumped model for the reactance of the input impedance. For our experiment, the simulated input impedance for antenna "A" and "B" is Z_A=30.7-j136 and Z_B=54.7-j118.2 respectively. Using these data we can get equivalent circuit model of our antennas, as it is shown in Fig. 4.

ARC design for non-Foster matching

In order to cancel ESAs reactance we design transistor ARC that acts as a negative inductor. All the necessary simulation were done using PSpice and the schematic of the antenna with its impedance matching network is shown in Fig. 5.

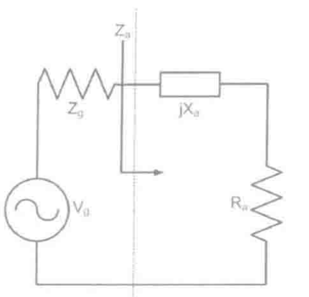

Fig. 4. Equivalent circuit model of ESAs

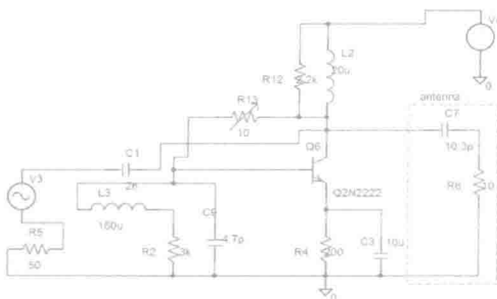

Fig. 5. ARC design scheme

ARC presented in Fig. 5 is a single-stage amplifier, where transistor works in the OE system. The collector of the transistor is powered by a choke L2 isolating the power supply from high frequency signal. Operating point of the transistor and hence the transconductance is determined by the potentiometer. The nature of the circuit is determined by the feedback parameters. In our researches ARC acts as an inductance. What is more, this circuit was taken due to the nature of the antenna, which would work in transmitting and receiving mode. In our case, antenna works in transmitting mode.

To verify our ARC design several simulation were performed and its results for AC sweep and transient analysis are presented in Fig. 6(a), 6(b) respectively. Notice that Fig. 6(a) shows that the resonance is achieved for 600 MHz and Fig. 6(b) shows that there is no current phase shift between collector current and antenna current(I(R6)), which means that the ARC was design properly.

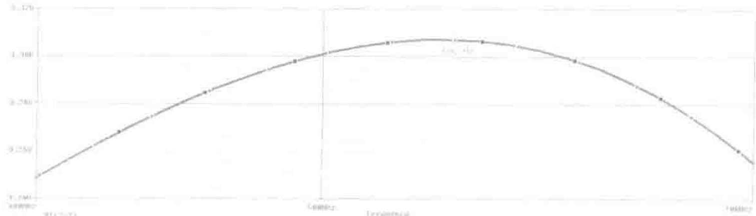

Fig. 6(a). Simulation results for AC sweep analysis

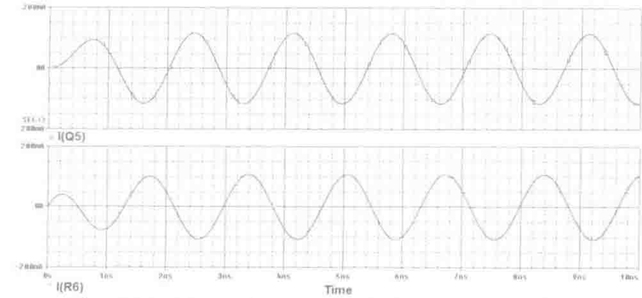

Fig. 6(b). Simulation results for Transient analysis

In order to verify the performance of the active matching, a board design was completed. The prototype is shown in Fig. 7. Next, we measure VSWR, input impedance and return loss of the antennas with and without active matching. In our experiment all parameters mentioned above were measured with antenna analyzer AA-1000. All measurement results are presented in Table 1 and Table 2.

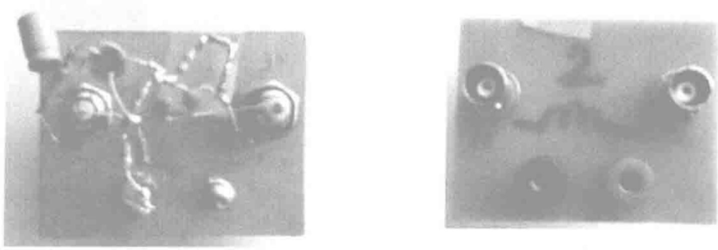

Fig. 7 Prototype of active impedance matching

Table 1. VSWR, input impedance and return loss of antennas without ARC

	VSWR	Input impedance	RL[dB]
Antenna "A"	16,8	27.5-j141.2	1,2
Antenna "B"	6,6	55.6-j114.3	2,6

Table 2. VSWR, input impedance and return loss of antennas with ARC

	VSWR	Input impedance	RL[dB]
Antenna "A"	2,7	133.5+j0.1	6,8
Antenna "B"	3,3	164.4	5,5

Taking into consideration results from Table 1 it is clearly seen that VSWR for both antennas is high and the reactive component of input impedance dominates. In turn, results from Table 2 indicate that active impedance matching significantly reduced VSWR values to values more acceptable. Moreover, to achieve full match i.e. VSWR=1, the real part of the antenna input impedance should be equal to the characteristic impedance of the transmission line (Z_0= 50 Ω). It could be accomplished by choosing an appropriate length of the transmission line. Therefore simulation was performed and the results are presented in the Fig. 8(a) and Fig 8(b). As it can be seen from Fig. 8(a) it is possible to choose a suitable length of the transmission line, which in our case is 0.206 m. Unfortunately, it is not possible to match the real part of the antenna input impedance to the transmission line with line reactance equal to 0. Hence, the transmitter should have correction system that could protect it from the reactance part of the input impedance of the transmission line.

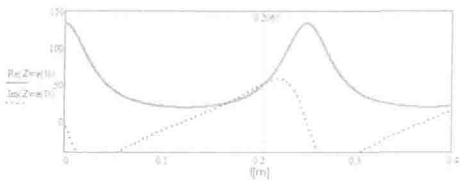

Fig. 8(a) Input impedance of the transmission line as a function of its length

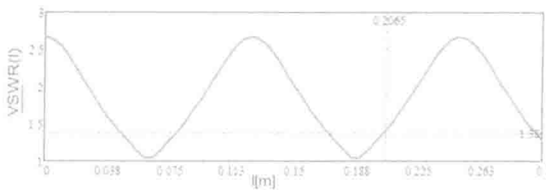

Fig. 8(b) VSWR change as a function of the transmission line length

The last stage of our research was to estimate the power budget in case of match and mismatch. We calculated it using measured values of VSWR. In case of mismatch only 21% of the power was delivered to the antenna, whereas using ARC 79% of the power was delivered.

Summary

This paper has presented the design of the active impedance matching. We have demonstrated an active reactance circuit(ARC) which the operation resembles negative impedance converters (NICs). Using ARC we have shown the non-Foster impedance matching concept by reducing a large portion of the reactance of an electrically small antenna.

The proposed active matching circuit is effective and can be used in place of mounting the antenna and supplied from a central supply system. The simplicity and high performance technology secures high reliability of it operation. Moreover, we are going to perform the above ARC in the structure of the integrated circuit.

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Analysis of Possibilities of Using Membrane Electrolyser in a Closed-Circuit Power Supply System

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Keywords: fuel cell PEM, power system, hydrogen.

Abstract. The issue of using hydrogen as an "energy source of the future" raises greater and greater interest and lively discussions. Frequently, leaving aside complexity of the problem, these discussions focus exclusively on fragmentary analyses. This presentation is a description of practical and comprehensive assessment of an actual efficiency of a system using hydrogen for supplying energy in mobile arrangements of a power in the region of a dozen watts. In our discussion, emphasis was placed on the analysis of advantages and disadvantages taking into consideration all these aspects that are necessary for the correct and safe operation of the system. Research described in this paper has been financed with founds for science in years 2013-2015 under Contract No DOBR /0061/R/ID2/2012/03.

Introduction

Dynamic technological development of our civilisation within the last few decades has led to an increased need for energy sources. Their limited amount is a well-known, global issue and a reason for looking towards alternative energy sources. Recently attention of many most prestigious scientific-research centres has focused on hydrogen technologies. The scope of research covers issues concerning production, transport, storage and application for using this gas as an energy source. Particularly great expectations have built up towards development of technologies of fuel cells that, in concert with hydrogen as an energy carrier create a vision of an "energy revolution" at least in the industry sectors connected with mobile sources of energy. Hydrogen technology functions on different principles of energy generation, processing and storage than technologies based on fossil fuels. This is a reason for certain ambiguity in the evaluation of this technology, particularly if criteria defined for the processing of crude oil, the major mobile source of energy, have been applied selectively. The criticism mainly relates to a low efficiency of the hydrogen generating process currently achieved on an industrial scale when compared with crude oil recovery. I think that such evaluation is a result of applying outdated comparative data relating to the costs and amounts of produced crude oil. The time of the world's peak production of crude oil, i.e. historical moment of its highest production figures is over. We should be aware of the fact that "the age of cheap and easily acquired energy sources" has come to the end. We enter the new age where crude oil production – the source of energy essential for the functioning of our civilisation model – will be systematically falling down. Geological figures are clear: 54 out of 65 oil producing countries have achieved or are in progress of achieving their peak phase of crude oil production. Current data relating to the costs of one barrel of crude oil are carefully protected. What is more, they depend whether they are recovered from oil bearing sands of Canada, from the Santos basin depths or in Saudi Arabia. Nevertheless, basing on data gathered some years ago by Cambridge Energy Research Associates (CERA)[5], and keeping in mind that the cost of production increases each year, the following question is worth posing: Is the energetic balance of technologies based on recovery and combustion of crude oil still positive?

In 2007, the world's daily consumption of oil amounted to 86 million barrels, while the price of one barrel oscillated around 40 USD. CERA presents the costs of individual sources of crude oil, making up the daily production [5]. The above-mentioned data clearly indicate that half of daily production took place at the cost that was lower than the sale price, on the understanding that in oil