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CONTENTS

From Editor

Engineering Faculty of Istanbul Aydın University has started to publish an international journal on Electronics, Mechanical and Mechatronics Engineering, denoted as "International Journal of Electronics, Mechanical and Mechatronics Engineering (IJEMME)". We have especially selected the scientific areas which will cover future prospective engineering titles such as Robotics, Mechanics, Electronics, Telecommunications, Control systems, System Engineering, Biomedical, and renewable Energy Sources.

We have selected only a few of the manuscripts to be published after a peer review process of many submitted studies. Editorial members aim to establish an international journal IJEMME, which will be welcomed by Engineering Index (EI) and Science Citation Index (SCI) in short period of time.

Prof. Dr. Zafer UTLU
Editor

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Future of the 'Street': Reading from William J. Mitchells's Csity of Bits

Derya Güleç Özer[1]

Abstract - In the end of twentieth century starting with 1970s, the world was introduced to a brand new concept of digital communication and information system. It is obvious that developments in computer technology have caused rapid transformations in various fields including technology-based processes and related daily activities [1]. Especially with the invention of the internet, the transformation accelerated. In this article, −focusing in the field of architecture−it was questioned how this new concept reconstructed the way of designing, perceiving and experimenting the space. In a larger −urban− scale, what is public and what is private were being questioned. One of the public city elements;−a place,space is allocated for both public and private use,for buildings and for open spaces [2]− 'streets' will be transformed into what? To realize the future of the city transformation, William J. Mitchell's City of Bits: Space, Place and the Infobahn [3] was the key source of this research, and relative references supported as well.

Keywords - *City of Bits, digital communication, street*

1. Introduction

The book 'City of Bits: Space, Place and the Infobahn'[3] posits some of the social, legal, and philosophical consequences of revolutionary advances in electronic communication and computer technology. Mitchell addresses the impact that the electronic information highway is making on traditional definitions of space, time, and human interaction. The Internet challenges old ways of viewing "workspace," "homespace," and "cityspace" and demands a redefiniton of architecture and urbanism for the twenty-first century [4].

Before focusing on the book, let us check the situation depending on sociology and its effects to societies. We may consider the revolution of agricultural society and then *industrial* society to *informational* society happened in around 1970s.

In sociology, industrial society refers to a society with a modern societal structure. Such a structure developed in the west in the period of time following the industrial revolution. It is argued that we are located in the middle of a transformation or transition from industrial societies to post-modern societies. The triggering technology for the change from an agricultural to an industrial organization was steam power, allowing mass production and reducing the agricultural work necessary. Identified as catalyst or trigger for the transition to post-modern or informational society is global information technology. Depending on that an informational society is a society in which the creation, distribution and manipulation of information is a significant economic and cultural activity. Information technology is not only internet, and there are discussions how big the influence of specific media or specific modes of production really is [5].

Development of worldwide telecommunications infrastructure began in 1837, when the telegraph was demonstrated and patented. The telephone followed in 1876. Long-distance telegraph and telephone networks had developed by the dawn of the twentieth century. By the 1950s extensive analog telecommunications networks employed wire,cable, and microwave links together with crossbar switching technology. Fiber optic cables became increasingly commonplace in the 1980s. By mid 1994 Internet can be accessed from homes, and it was clear that

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existing, largely separate, telephone,radio, television and data networks would eventually evolve into a worldwide, broadband digital service [3].

Fiber-optic network system is analogically the *street network* of 'cyber' world, so called *infobahn* and reconfiguring space and time relationships in ways that promised to change our lives forever [3]. With the use of internet, you don't need to go to work anymore, or shopping, or hanging out with friends, or many other daily life routines. Going outside is when you really want to be socialized, physically *to be* with someone. Mitchell points out that homes will be places with network addresses as well as street addresses. The functions of the various interior spaces will be established. And, as networks and information appliances deliver expanding ranges of services, there will br fewer occasions to go out [3].

2. Streets

Streets are not the dividing elements within the city. They are to be communal rooms and passages.

Pattern − A single given street is always to be part of a street network [6]. Connectedness and continuity of movement within such a network will encourage the mixing of uses in the city.

Hierarchy − There is to exist a variety of streets based on their pedestrian and vehicular loads.

Figure − The architectural character of streets is to be based on their configuration in plan and section [2].

3. Networks

The most significant of all oppourtunities that the developing computer technology is the concept of networking. In order to share the sources(software), information and hardware, a domain of computers are connected to each other. Connection provides data transfer and communication, with such tools as direct cable-to-cable connection, fiber optic cables and infrared connections,utilizing radio transmission instead of any physical device. Networking had presented a new medium to interact [1].

Consequently, the digital revolution of the networking technology offered new ways of communication and socialization. It is a new medium, occupied by a community which has a different sense of communication, socialization and visualization, so a different perception of space.

It is now a network community. Although the participants of this community are the same, the network community has a different inner structure. Logging on the network, the participants transform themselves into faceless identities [1].

Mitchell reminds us to update Churchill's bon mot: Now we make our networks, and our networks make us.

"Click, click through cyberspace; this is the new architectural promenade" [3].

The worldwide computer network, subverts, displaces and redefines our notions of gathering place, community, and urban life [3]. MSN Messenger is my usual gathering place with friends, who are America, Italy, England or all over Turkey. When it is kind of impossible to meet in one 'physical' place with all those friends, internet became an alternative way of keeping in touch. As in city scale, it will play a crucial role in twenty-first-century urbanity as the centrally located,spatiallly bounded, architecturally celebrated agora did in the life of Greek polis [3]. At an urban scale, streets and public places interconnect buildings. Classical architects of the eighteenth and nineteenth centuries handled the task of putting spaces together by creating hierarchies of great and small spaces around axial, symmetrical circulation systems connected to grand, formal entries and public open spaces. With the aim of being as logical and efficient as possible, functionalist modernists of the twentieth century have often derived their less regular layouts directly from empirically established requirements of adjacency and proximity among the necessary spatial elements.

But when telecommunications through lickety-split bits on the infobahn supplements or replaces movement of bodies along circulation paths, and when telepresence subtitudes for face-to-face contact among participants in actvities, the spatial linkages that we have come to expect are loosened… we will find compelling advantages to putting together spaces- like living spaces and work space- that were once thought to belong in different buildings located in different zones of the city. In any case, the old bonds break down and new groupings can begin to form [3].

Peter Anders explains the contributional relation of architecture to cyberspace with the following words:

"The architectural metaphor of cyberspace validates the designer's work: just as spatial cues help to orient us in a real building, they also offer a visual structure for abstract information, revealing relationships and hierarchy. Although cyberspace will never replace traditional architectural work, the electronic realm opens up a huge territory for architectural expertise at a time when conventional career paths are hard to find." [7].

So what is it that, architects should derive from the book? There are serious problems that might occur, because of this juxtaposition of real-world phenomena and their cyber equivalents. It most probably will cause human disorientation and alienation as the machines take control. Martin Pearce answers the crucial question:

"The massage for architects is to realise how these changes will affect what we do and to engage ourselves in designing the city of bits." [3].

How the architects will adapt the designs to the rapidly changing electronic world? How will the elements of a city will be affected from it? As the life changes, can they keep their form or function as it is? As an example library shelves are becoming data servers and art works are digitised and exhibited in virtual galleries [3]. In Magill's Literary Annual, it is addressed that such institutional and social functions are being severed from physical architecture in the world of communication [8]. So is it the same space to read a book or enjoy an art work, that we need as before? Probably not. The question is how should the architectural elements be designed, flexible in a way, to be adaptable the new 'cyber' world. It is given as an example in the annual, that in British Museum London, centering library stacks around a large room, does not allow for electronic information servers of the future or the evolution of reading material from paper to computer screen [8]. It means our buildings are not ready for the necessary transformation.

In the book 'City Of Bits', it is argued that how digital technology is turning traditional architectural theory and planning upside down. According to the book's review in Publishers Weekly; transcending geographic boundries, online communities and social contexts, offer new ways of thinking about urban design, private and public space, the separation of work and home life and personal identity [9].

The street network in a city was used to be the public interface between home-work, home-social life, home-home etc. But in its 'cyber' replica, World Wide Web (WWW) is an electronic network of streets providing access between one building and another, between one activity and another. As well, Multi-User Dungeons(MUDs) are electronic neighborhoods in which residents create their own personas or characters in order to participate in on-line role-playing games [1]. As an example ,two people I know were married in the game 'cyber' life, infact their physical 'world' identities were sitting next in the class, without knowing each other. This sort of games are offering an 'alternative' life more than we can imagine and control as a human being.

There were there important issues that changed our level of perception of the world. One was the use of perspective - renaissance discovery of perception- , second was the invention of the camera which was an alternative to the eye level perception with different angles and different heights, and the third was the speed. It was a measurement system in terms of *walking speed* related to human, later become *car speed* related to vehicles, then soon transformed to *internet speed* related to computers;

Walking speed: Man power is used. Speed is average 5 km/hour, 120 steps in a minute.
Car speed: Vehicle power is used (named as horse power). Speed is average 60 km/hour.
Internet speed: Electricity and modem connection is used. Speed is 100 mbps (megabit per second).

How does this change in 'speed' concept results? How does the physical affected?

One such transformation concerns human perception of space. On the Internet, spatial becomes antispatial. Face-to-face contact yields to forms of communication in which location does not matter.

4. Conclusion

We use our 5 senses; seeing,hearing,touching,smelling and feeling to perceive an object. City of Bits suggests a different 'cyber' world, which is senseless. The only sensing organ active is the 'eye', fingers help eye to see. This new phenomena is a new perception of world, without the help our sensing organs. Then how do we 'perceive' now,

without our most used instruments. Are they going to die? Is it only 'eye', which will exist in the next generation? Is it the evolution human facing in the world of City of Bits? Is it end of human being?

While you are imprisoned to your computers at home, you may travel Champs Elysees, enjoy the city from bird eye level and come back without paying a bit. Or make your reserach from a library, download your documents, read them. Chat with your friends, and your family in MSN, invite them to a game for fun. Buy your ingredients for tonight's dinner.Why do you need to go outside? Our public life, street network, is still existing physically for what purpose? Is the City of Bits, destroyed the infrastucture of the street life? What is left for us to be 'social' again?

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Forward and Inverse Kinematic Analysis and Validation of the ABB IRB 140 Industrial Robot

Mohammed Almaged[1]

Abstract - The main goal of this paper is to derive the forward and inverse kinematic model of the ABB IRB 140 industrial manipulator. Denavit-Hartenberg analysis (DH) is presented to write the forward kinematic equations. Initially, a coordinate system is attached to each of the six links of the manipulator. Then, the corresponding four link parameters are determined for each link to construct the six transformation matrices (${}^{i-1}_{i}T$) that define each frame {i} relative to the previous one {i-1}. While, to develop the kinematics that calculates the required joint angles ($\theta_1 - \theta_6$), both geometrical and analytical approaches are used to solve the inverse kinematic problem. After introducing the forward and inverse kinematic models, a MATLAB code is written to obtain the solutions of these models. Then, the forward kinematics is validated by examining a set of known positions of the robot arm, while the inverse kinematics is checked by comparing the results obtained in MATLAB with a simulation in Robot Studio.

Keywords - *Robotics, forward kinematics, inverse kinematics, ABB IRB 140 manipulator*

1. Introduction

'Kinematics is the science of geometry in motion' [1]. This means it deals only with geometrical issues of motion such as the position and orientation regardless the force that causes them. There are two types of kinematics, the forward and inverse kinematics. Forward kinematic analysis is concerned with the relationship between the joint angle of the robot manipulator and the position and orientation of the end-effector [2]. In other words, it deals with finding the homogeneous transformation matrix that describes the position and orientation of the tool frame with respect to the global reference frame. On the other hand, inverse kinematics is used to calculate the joint angles required to achieve the desired position and orientation. The same transformation matrix which resulted from the forward kinematics in order to describe the position and the orientation of the tool frame relative to the robot base frame is used here in the inverse kinematics to solve for the joint angles.

The IRB 140, shown in Figure 1 below, is compact six axes (6 DOF) industrial manipulator. It is designed with six revolute joints providing a flexible use at an outstanding accuracy to be suitable for a wide range of applications such as welding, packing, assembly, etc.

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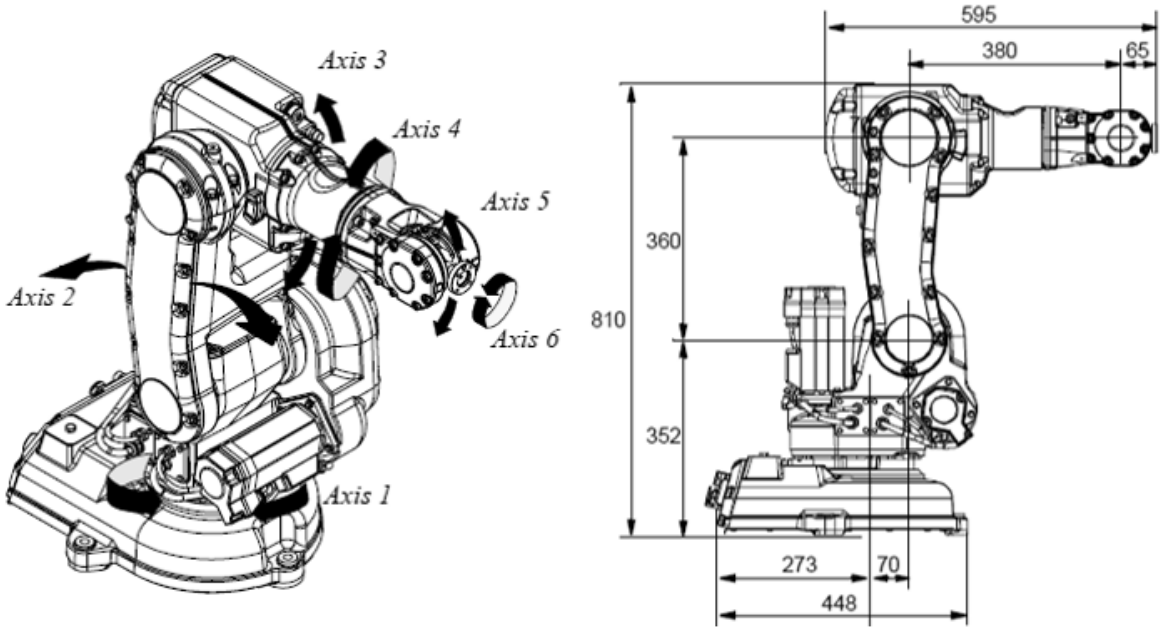

Figure 1. The ABB IRB 140 manipulator

2. Forward Kinematics

To mathematically model a robot and hence determine the position and orientation of the end effector with respect to the base or any other point, it is necessary to assign a global coordinate frame to the base of the robot and a local reference frame at each joint. Then, the Denavit-Hartenberg analysis (DH) is presented to build the homogeneous transformations matrices between the robot joint axes [3]. These matrices are a function of four parameters resulted from a series of translations and rotations around different axes. The illustration of how frame {i} is related to the previous frame {i −1} and the description of the frame parameters are shown in Figure 2 below.

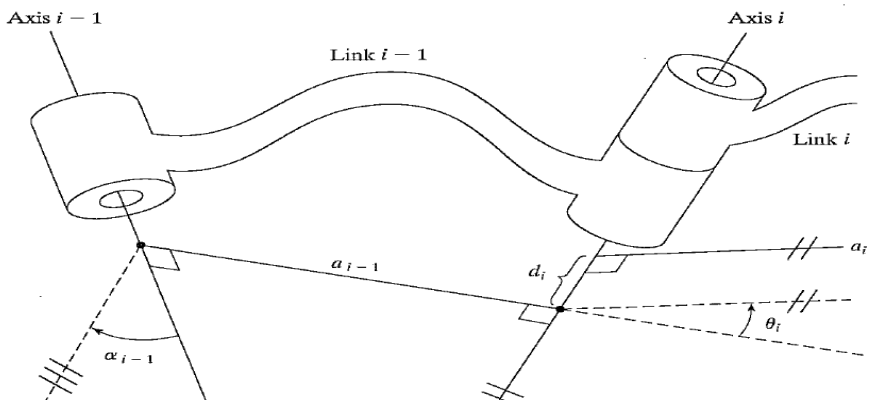

Figure 2. The description of frame {i} with respect to frame {i −1} [3]

From Figure 2, the modified D-H parameters can be described as:

- α_{i-1}: Twist angle between the joint axes Z_i and Z_{i-1} measured about X_{i-1}.
- a_{i-1}: Distance between the two joint axes Z_i and Z_{i-1} measured along the common normal.
- θ_i: Joint angle between the joint axes Xi and Xi-1 measured about Zi.
- d_i: Link offset between the axes Xi and Xi-1 measured along Zi.

Thus, the four Transformations between the two axes can be defined as:

$$^{i-1}_{i}T = Rot\left(X_{i-1}, \alpha_{i-1}\right) \text{ x } Trans(X_{i-1}, a_{i-1}) \text{ x } Rot\left(Z_i\,, \theta_i\right) \text{ x } Trans(0,0,d_i)$$

After finishing the multiplication of these four transformation, the homogeneous transform can be obtained as:

$$^{i-1}_{i}T = \begin{pmatrix} c_{\theta_i} & -s_{\theta_i} & 0 & a_{i-1} \\ s_{\theta_i}c_{\alpha_{i-1}} & c_{\theta_i}c_{\alpha_{i-1}} & -s_{\alpha_{i-1}} & -d_i s_{\alpha_{i-1}} \\ s_{\theta_i}s_{\alpha_{i-1}} & c_{\theta_i}s_{\alpha_{i-1}} & c_{\alpha_{i-1}} & d_i c_{\alpha_{i-1}} \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad \textbf{(1.1)}$$

The ABB IRB140 frames assignment is shown below in Figure 3.

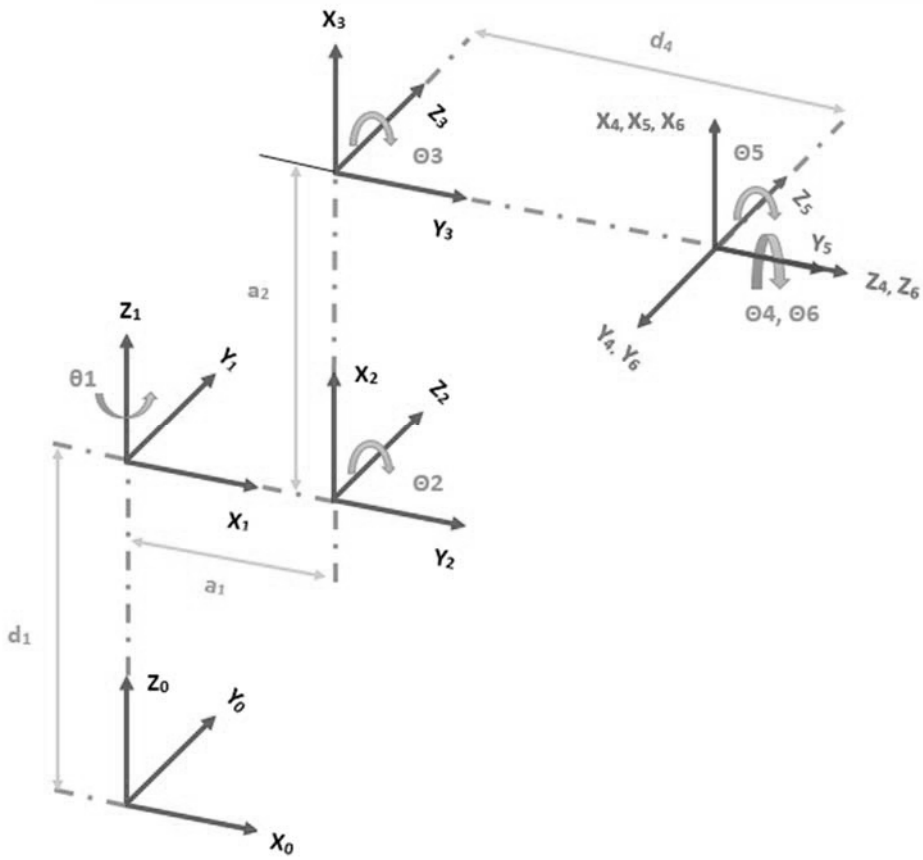

Figure 3. ABB IRB140 frames assignment

According to our particular frame assignment, the modified D-H parameters are defined in Table 1 below.

Table 1. Hata! Belgede belirtilen stilde metne rastlanmadı.**.** The ABB IRB 140 D-H parameters

Axis (i)	α_{i-1}	a_{i-1}	d_i	θ_i
1	0	0	$d_1 = 352$	θ1
2	-90	$a_1 = 70$	0	θ2-90
3	0	$a_2 = 360$	0	θ3
4	-90	0	$d_4 = 380$	θ4
5	90	0	0	θ5
6	-90	0	0	θ6

For the simplicity of calculations and matrix product, it can be assumed that $s_2 = \sin(\theta 2\text{-}90)$, $c_2 = \cos(\theta 2\text{-}90)$. After achieving the D-H Table 1, the individual transformation matrix for each link is achieved by substituting the link parameters into the general homogeneous transform derived above in (1.1).

$$ {}^{0}_{1}T = \begin{pmatrix} c_{\theta_1} & -s_{\theta_1} & 0 & a_0 \\ s_{\theta_1}c_{\alpha_0} & c_{\theta_i}c_{\alpha_{01}} & -s_{\alpha_0} & -d_1 s_{\alpha_0} \\ s_{\theta_1}s_{\alpha_0} & c_{\theta_1}s_{\alpha_0} & c_{\alpha_0} & d_1 c_{\alpha_0} \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad {}^{0}_{1}T = \begin{pmatrix} c_1 & -s_1 & 0 & 0 \\ s_1 & c_1 & 0 & 0 \\ 0 & 0 & 1 & d_1 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

$$ {}^{1}_{2}T = \begin{pmatrix} c_{\theta_2} & -s_{\theta_2} & 0 & a_1 \\ s_{\theta_2}c_{\alpha_1} & c_{\theta_2}c_{\alpha_1} & -s_{\alpha_1} & -d_2 s_{\alpha_1} \\ s_{\theta_2}s_{\alpha_1} & c_{\theta_2}s_{\alpha_1} & c_{\alpha_1} & d_2 c_{\alpha_1} \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad {}^{01}_{2}T = \begin{pmatrix} c_2 & -s_2 & 0 & a_1 \\ 0 & 0 & 1 & 0 \\ -s_2 & -c_2 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

$$ {}^{2}_{3}T = \begin{pmatrix} c_{\theta_3} & -s_{\theta_3} & 0 & a_2 \\ s_{\theta_3}c_{\alpha_2} & c_{\theta_3}c_{\alpha_2} & -s_{\alpha_2} & -d_3 s_{\alpha_2} \\ s_{\theta_3}s_{\alpha_2} & c_{\theta_3}s_{\alpha_2} & c_{\alpha_2} & d_3 c_{\alpha_2} \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad {}^{2}_{3}T = \begin{pmatrix} c_3 & -s_3 & 0 & a_2 \\ s_3 & c_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

$$ {}^{3}_{4}T = \begin{pmatrix} c_{\theta_4} & -s_{\theta_4} & 0 & a_3 \\ s_{\theta_4}c_{\alpha_3} & c_{\theta_4}c_{\alpha_3} & -s_{\alpha_3} & -d_4 s_{\alpha_3} \\ s_{\theta_4}s_{\alpha_3} & c_{\theta_4}s_{\alpha_3} & c_{\alpha_3} & d_4 c_{\alpha_3} \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad {}^{3}_{4}T = \begin{pmatrix} c_4 & -s_4 & 0 & 0 \\ 0 & 0 & 1 & d_4 \\ -s_4 & -c_4 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

$$ {}^{4}_{5}T = \begin{pmatrix} c_{\theta_5} & -s_{\theta_5} & 0 & a_4 \\ s_{\theta_5}c_{\alpha_4} & c_{\theta_5}c_{\alpha_4} & -s_{\alpha_4} & -d_5 s_{\alpha_4} \\ s_{\theta_5}s_{\alpha_4} & c_{\theta_5}s_{\alpha_4} & c_{\alpha_4} & d_5 c_{\alpha_4} \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad {}^{4}_{5}T = \begin{pmatrix} c_5 & -s_5 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ s_5 & c_5 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

$$ {}^{5}_{6}T = \begin{pmatrix} c_{\theta_6} & -s_{\theta_6} & 0 & a_5 \\ s_{\theta_6}c_{\alpha_5} & c_{\theta_6}c_{\alpha_5} & -s_{\alpha_5} & -d_6 s_{\alpha_5} \\ s_{\theta_6}s_{\alpha_5} & c_{\theta_5}s_{\alpha_5} & c_{\alpha_5} & d_6 c_{\alpha_5} \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad {}^{5}_{6}T = \begin{pmatrix} c_6 & -s_6 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -s_6 & -c_6 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} $$

Once the homogeneous transformation matrix of each link is obtained, forward kinematic chain can be applied to achieve the position and orientation of the robot end-effector with respect to the global reference frame (robot base).

$${}^{0}_{2}T = {}^{0}_{1}T \text{ X } {}^{1}_{2}T$$

$${}^{0}_{2}T = \begin{pmatrix} c_1 & -s_1 & 0 & 0 \\ s_1 & c_1 & 0 & 0 \\ 0 & 0 & 1 & d_1 \\ 0 & 0 & 0 & 1 \end{pmatrix} \text{X} \begin{pmatrix} c_2 & -s_2 & 0 & a_1 \\ 0 & 0 & 1 & 0 \\ -s_2 & -c_2 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} c_1c_2 & -c_1s_2 & -s_1 & c_1a_1 \\ s_1c_2 & -s_1s_2 & c_1 & s_1a_1 \\ -s_2 & -c_2 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^{0}_{3}T = {}^{0}_{2}T \text{ X } {}^{2}_{3}T$$

$${}^{0}_{3}T = \begin{pmatrix} c_1c_2 & -c_1s_2 & -s_1 & c_1a_1 \\ s_1c_2 & -s_1s_2 & c_1 & s_1a_1 \\ -s_2 & -c_2 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{pmatrix} X \begin{pmatrix} c_3 & -s_3 & 0 & a_2 \\ s_3 & c_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^{0}_{3}T = \begin{pmatrix} c_1c_2c_3 - c_1s_2s_3 & -(c_1c_2s_3 + c_1s_2c_3) & -s_1 & c_1c_2a_2 + c_1a_1\,) \\ s_1c_2c_3 - s_1s_2s_3 & -(s_1c_2s_3 + s_1s_2c_3) & c_1 & s_1c_2a_2 + s_1a_1\,) \\ -(s_2c_3 + c_2s_3) & s_2s_3 - c_2c_3 & 0 & -s_2a_2 + d_1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^{0}_{3}T = \begin{pmatrix} c_1c_{23} & -c_1s_{23} & -s_1 & c_1(c_2a_2 + a_1\,) \\ s_1c_{23} & -s_1s_{23} & c_1 & s_1(c_2a_2 + a_1\,) \\ -s_{23} & -c_{23} & 0 & -s_2a_2 + d_1 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^{4}_{6}T = {}^{4}_{5}T \text{ X } {}^{5}_{6}T$$

$${}^{4}_{6}T = \begin{pmatrix} c_5 & -s_5 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ s_5 & c_5 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} X \begin{pmatrix} c_6 & -s_6 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -s_6 & -c_6 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} c_5c_6 & -c_5s_6 & -s_5 & 0 \\ s_6 & c_6 & 0 & 0 \\ s_5\,c_6 & -s_5\,s_6 & c_5 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^{3}_{6}T = {}^{3}_{4}T \text{ X } {}^{4}_{6}T$$

$${}^{3}_{6}T = \begin{pmatrix} c_4 & -s_4 & 0 & 0 \\ 0 & 0 & 1 & d_4 \\ -s_4 & -c_4 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} X \begin{pmatrix} c_5c_6 & -c_5s_6 & -s_5 & 0 \\ s_6 & c_6 & 0 & 0 \\ s_5\,c_6 & -s_5\,s_6 & c_5 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^{3}_{6}T = \begin{pmatrix} c_4c_5c_6 - s_4s_6 & -c_4c_5s_6 - s_4c_6 & -c_4s_5 & 0 \\ s_5\,c_6 & -s_5\,s_6 & c_5 & d_4 \\ -s_4c_5c_6 - c_4s_6 & s_4c_5s_6 - c_4c_6 & s_4s_5 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^{0}_{6}T = {}^{0}_{3}T \text{ X } {}^{3}_{6}T$$

$${}^{0}_{6}T = \begin{pmatrix} c_1c_{23} & -c_1s_{23} & -s_1 & c_1(c_2a_2 + a_1\,) \\ s_1c_{23} & -s_1s_{23} & c_1 & s_1(c_2a_2 + a_1\,) \\ -s_{23} & -c_{23} & 0 & -s_2a_2 + d_1 \\ 0 & 0 & 0 & 1 \end{pmatrix} X \begin{pmatrix} c_4c_5c_6 - s_4s_6 & -c_4c_5s_6 - s_4c_6 & -c_4s_5 & 0 \\ s_5\,c_6 & -s_5\,s_6 & c_5 & d_4 \\ -s_4c_5c_6 - c_4s_6 & s_4c_5s_6 - c_4c_6 & s_4s_5 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$${}^{0}_{6}T = \begin{pmatrix} r11 & \text{r12} & \text{r13} & \text{x} \\ \text{r21} & \text{r22} & \text{r23} & \text{y} \\ \text{r31} & \text{r32} & \text{r33} & z \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

$r_{11} = c_1 c_{23}\,(c_4 c_5 c_6 - s_4 s_6) - c_1 s_{23} s_5\, c_6 + s_1(s_4 c_5 c_6 + c_4 s_6)$
$r_{12} = c_1 c_{23}(-c_4 c_5 s_6 - s_4 c_6) + c_1 s_{23} s_5\, s_6 - s_1(s_4 c_5 s_6 - c_4 c_6)$
$r_{13} = -c_1 c_{23} c_4 s_5 - c_1 s_{23} c_5 - s_1 s_4 s_5$
$r_{21} = s_1 c_{23}\,(c_4 c_5 c_6 - s_4 s_6) - s_1 s_{23} s_5\, c_6 - c_1(s_4 c_5 c_6 + c_4 s_6)$
$r_{22} = s_1 c_{23}(-c_4 c_5 s_6 - s_4 c_6) + s_1 s_{23} s_5\, s_6 + c_1(s_4 c_5 s_6 - c_4 c_6)$
$r_{23} = -s_1 c_{23} c_4 s_5 - s_1 s_{23} c_5 + c_1 s_4 s_5$
$r_{31} = -s_{23}\,(c_4 c_5 c_6 - s_4 s_6) - c_{23} s_5\, c_6$
$r_{32} = -s_{23}\,(-c_4 c_5 s_6 - s_4 c_6) + c_{23} s_5\, s_6$
$r_{33} = s_{23} c_4 s_5 - c_{23} c_5$
$x = -d_4 c_1 s_{23} + c_1(c_2 a_2 + a_1)$
$y = -d_4 s_1 s_{23} + s_1(c_2 a_2 + a_1)$
$z = -s_2 a_2 + d_1 - d_4 c_{23}$

Now, it is also possible to find the position of the tip (TCP) with respect to the robot base. According to the robot frame assignment, it is simply a transition along the z axis of frame {6} by d6 (65 mm). Therefore, the final position of the end effector with respect to the robot global reference frame can be expressed as:

$$\text{Ptip} = {}^0_6T\ X\ P^6$$

$$\text{Ptip} = \begin{pmatrix} r11 & r12 & r13 & x \\ r21 & r22 & r23 & y \\ r31 & r32 & r33 & z \\ 0 & 0 & 0 & 1 \end{pmatrix} X \begin{pmatrix} 0 \\ 0 \\ d6 \\ 1 \end{pmatrix} = \begin{pmatrix} d6\ X\ r13 + x \\ d6\ X\ r23 + y \\ d6\ X\ r33 + z \\ 1 \end{pmatrix}$$

3. Forward Kinematic Validation

After finding the homogeneous transformation matrix (${}^0_6T$) that describes the end effector position and orientation with respect to the robot global reference frame, the position of the robot in space is expressed by the vector ${}^0P_{6ORG}$ which gives the values of x, y and z vectors as follow:

$x = -d_4 c_1 s_{23} + c_1(c_2 a_2 + a_1)$
$y = -d_4 s_1 s_{23} + s_1(c_2 a_2 + a_1)$
$z = -s_2 a_2 + d_1 - d_4 c_{23}$

n that: $S_2 = \sin(\theta 2\text{-}90)$, $C_2 = \cos(\theta 2\text{-}90)$, d1 = 352 mm, d4 = 380 mm, a1 = 70 mm and a2 = 360 mm.

These equations are programmed in Matlab and a set of eight positions, illustrated below in Figure 4, were chosen randomly to validate the forward kinematic model. The joint angles of each position are entered manually by the user to obtain the x, y and z vectors as shown in Table 2 below. It can be clearly seen that there is no y component corresponding to these particular positions because Θ1 is always given to be zero. The same joint angle values were entered through the robot operating software in the lab and the results were similar to the x, y and z vectors obtained from Matlab which proves the validity of this model.

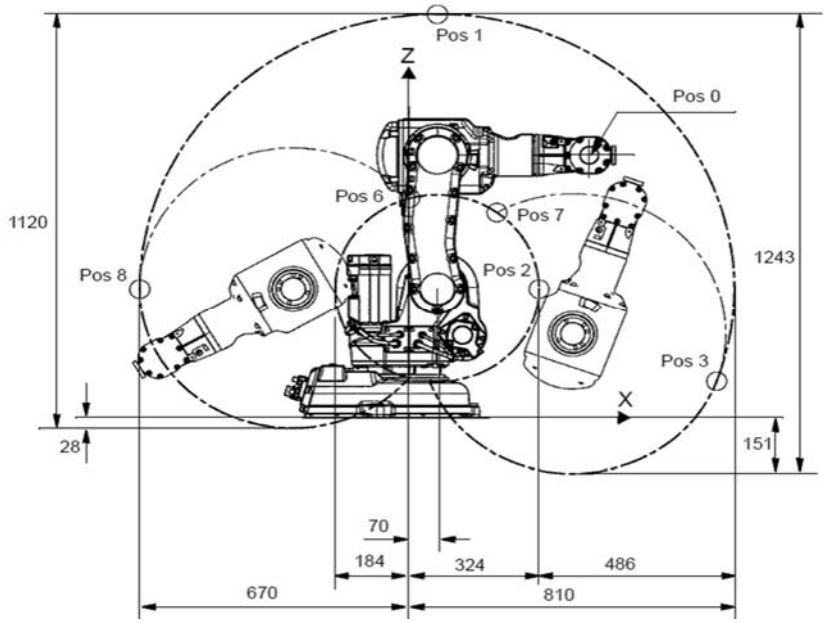

Figure 4. Set of different robot positions

4. Inverse Kinematics

Inverse kinematics is used to calculate the joint angles required to achieve the desired position and orientation in the robot workspace. In general, there are two methods of solution, the analytical and geometrical approaches. Since three consecutive axes of the robot intersect at a common point, Pieper's solution can be applied. Pieper's approach works on the principle of separating the position solution for Θ1, Θ2 and Θ3 from the orientation solution to solve for Θ4, Θ5 and Θ6 [4]. Therefore, a geometrical approach is initially implemented to find the joint variables Θ1, Θ2 and Θ3 that define the end effector position in space, while an analytical solution is applied to calculate the angles Θ4, Θ5 and Θ6 which describe the end-effector orientation.

4.1 Geometrical solution

According to the frame assignment shown in Figure 1, x and y components of frame {1} is the same as frame {0} because there is only a Z-directional offset between the two frames.

Table 2. Numerical calculation for the values x, y and z of each positions

Position	Joint angles	X vector	Y vector	Z vector
0	Θ1 = 0, Θ2 = 0, Θ3 = 0	450	0	712
1	Θ1 = 0, Θ2 = 0, Θ3 = -90	70	0	1092
2	Θ1 = 0, Θ2 = 0, Θ3 = 50	314	0	420.9
3	Θ1 = 0, Θ2 = 110, Θ3 = -90	765	0	98.9
6	Θ1 = 0, Θ2 = -90, Θ3 = 50	1.1	0	596
7	Θ1 = 0, Θ2 = 110, Θ3 =-230	218	0	558
8	Θ1 = 0, Θ2 = -90, Θ3 = -90	-670	0	352

Therefore, the projection of the wrist components on x-y plane of frame {0} has the same components on frame {1} [5, 6]. In addition, since both link two and three are planar, the position vector in y direction changes with respect to θ1 only. Thus, two possible solutions for θ1 can be achieved by simply applying the arctangent function.

$$\theta 1 = \text{atan2}\,(Py, Px), \quad \textbf{(4.1)}$$
$$\theta 11 = \Pi + \theta 1. \quad \textbf{(4.2)}$$

The solutions of θ2 and θ3 are obtained by considering the plane, shown in Figure 5, formed by the second and third planar links with respect to the robot global reference frame.

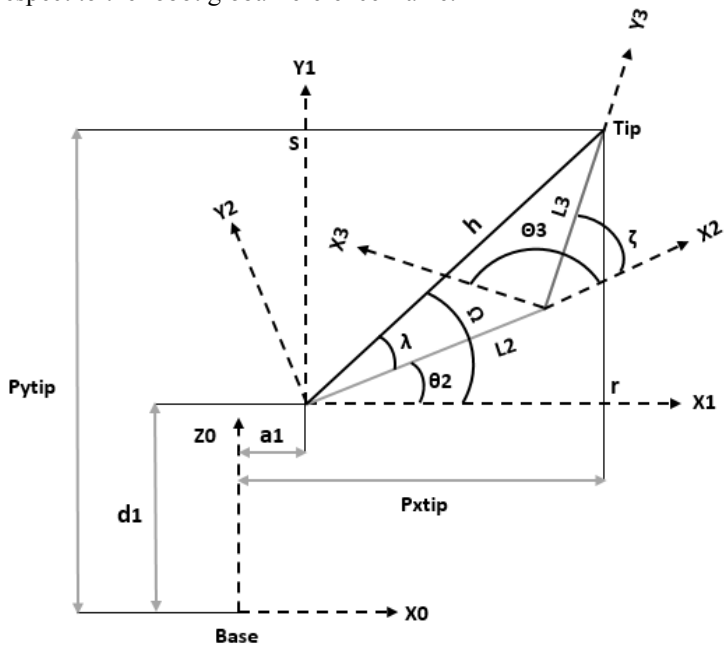

Figure 5. Projection of links two and three onto the x y plane

The cosine low is used to solve for θ3 as follow:

$$h^2 = (L_2)^2 + (L_3)^2 - 2 \times L_2 \times L_3 \cos(180 - \zeta)$$

Since the position is given with respect to the robot tip (TCP), L_3 should be equal to d4 + d6.
While, $L_2 = a_2$, $h^2 = s^2 + r^2$, $\cos(180 - \zeta) = -\cos(\zeta)$.

$$s^2 + r^2 = (a_2)^2 + (d_4 + d_6)^2 + 2 \times a_2 \times (d_4 + d_6) \cos(\zeta)$$
$$\text{Cos}(\zeta) = \frac{[s2 + r2 - (a2)2 - (d4 + d6)\,2]\,]}{2 \times a2 \times (d4 + d6)} \quad \textbf{(4.3)}$$

Now, we should have the value of (**s**) and (**r**) in term of $\mathbf{P_{xtip}}$, $\mathbf{P_{ytip}}$, $\mathbf{P_{ztip}}$ and **θ1**.
$S = (P_{ztip} - d1)$

$r = \pm\sqrt{(\text{Pxtip} - \text{a1}\cos(\theta 1))2 + (\text{Pytip} - \text{a1}\sin(\theta 1))2}$, Sub. (**s**) and (r) in (4.3) yield:

$$\text{Cos}(\zeta) = \frac{[(\text{Pztip} - \text{d1})2 + (\text{Pxtip} - \text{a1}\cos(\theta 1))2 + (\text{Pytip} - \text{a1}\sin(\theta 1))2 - (\text{a2})2 - (\text{d4} + \text{d6})\,2]}{2 \times \text{a2} \times (\text{d4} + \text{d6})}$$
$$\text{Sin}(\zeta) = \pm\sqrt{1 - \text{Cos2}(\zeta)}$$

$$\zeta = \text{atan2}\,(\text{Sin}(\zeta), \text{Cos}(\zeta))$$

Finally, $\theta 3 = -(90 + \zeta)$ **(4.4)**

The negative sign in θ3 indicates that the rotation occurred in the opposite direction. Likewise, we can follow the same procedure to solve for θ2 using similar trigonometric relationships.

$\theta 2 = \Omega - \lambda$
$\Omega = \text{atan2}\ (s, r)$
$\lambda = \text{atan2}\ ((d_4+d_6) \sin(\zeta), a_2 + (d_4+d_6) \cos(\zeta))$
$\theta 2 = \text{atan2}\ (s, r) - \text{atan2}\ [(d_4+d_6) \sin(\zeta), a_2 + (d_4+d_6) \cos(\zeta)]$, sub the values of (s) and (r) yield:
$\theta 2 = \text{atan2}\ [(P_{ztip} - d1), \pm\sqrt{(Pxtip - a1 \cos(\theta 1))2 + (Pytip - a1 \sin(\theta 1))2})]$
$- \text{atan2}\ [(d_4+d_6) \times \sin(\zeta), a_2 + (d_4+d_6) \cos(\zeta)]$.

Again the rotation occurred in the opposite direction of the z axis as well as there are an initial rotation of 90^0 between axis 1 and axis 2. Therefore, the final value of θ2 equal to:

$$\theta 2 = -((\Omega - \lambda) - 90). \quad \textbf{(4.5)}$$

It is important to say that any position within the robot workspace can be achieved with many orientations. Therefore, multiple solutions exist for the variables Θ1, Θ2 and Θ3 due to the nature of trigonometric functions.

As noticed above, every solution step resulted in two values that will be used in the next step, and so on. For example, there are four solutions for ζ that resulted from two different values of θ1 (θ1 and θ11), this procedure gives four solutions for θ3, each solution corresponds to different robot configurations of elbow-up and elbow-down representations. These solutions can be listed in Table 3 below to illustrate all the possible solution set.

Table 3. Possible solution set

Solution	THETA1	THETA3	THETA2	Set
1	Θ1	Θ3	Θ2	SET 1
2	Θ1	Θ3	Θ22	
3	Θ1	Θ33	Θ2i	SET 2
4	Θ1	Θ33	Θ22i	
5	Θ11	Θ3i	Θ2j	SET 3
6	Θ11	Θ3i	Θ22j	
7	Θ11	Θ33i	Θ2k	SET 4
8	Θ11	Θ33i	Θ22k	

4.2 Analytical solution

After solving the first inverse kinematic sub-problem which gives the required position of the end effector, the next step of the inverse kinematic solution will deal with the procedure of solving the orientation sub-problem to find the joint angles Θ4, Θ5 and Θ6. This can be done using Z-Y-X Euler's formula. As the orientation of the tool frame with respect to the robot base frame is described in term of Z-Y-X Euler's rotation, this means that each rotation will take place about an axis whose location depends on the previous rotation [3]. The Z-Y-X Euler's rotation is shown below in Figure 6.

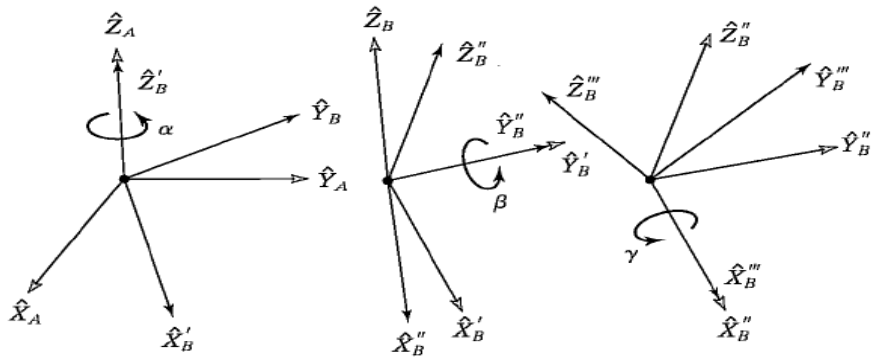

Figure 6. Z—Y—X Euler rotation [3]

The final orientation matrix that results from these three consecutive rotations will be as follow:

$${}^0_6R = R_{z'y'x'} = R_z(\alpha)\, R_y(\beta)\, R_x(\gamma)$$

$${}^0_6R = \begin{pmatrix} c_\alpha & -s_\alpha & 0 \\ s_\alpha & c_\alpha & 0 \\ 0 & 0 & 1 \end{pmatrix} X \begin{pmatrix} c_\beta & 0 & s_\beta \\ 0 & 1 & 0 \\ -s_\beta & 0 & c_\beta \end{pmatrix} X \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_\gamma & -s_\gamma \\ 0 & s_\gamma & c_\gamma \end{pmatrix}$$

$${}^0_6R = \begin{pmatrix} c_\alpha c_\beta & c_\alpha s_\beta s_\gamma - s_\alpha c_\gamma & c_\alpha s_\beta c_\gamma + s_\alpha s_\gamma \\ s_\alpha c_\beta & s_\alpha s_\beta s_\gamma + c_\alpha c_\gamma & s_\alpha s_\beta c_\gamma - c_\alpha s_\gamma \\ -s_\beta & c_\beta s_\gamma & c_\beta c_\gamma \end{pmatrix}$$

Recall the forward kinematic equation,

$${}^0_3R = \begin{pmatrix} c_1 c_{23} & -c_1 s_{23} & -s_1 \\ s_1 c_{23} & -s_1 s_{23} & c_1 \\ -s_{23} & -c_{23} & 0 \end{pmatrix}$$

$${}^3_6R = ({}^0_3R)^T \; {}^0_6R$$

$${}^3_6R = \begin{pmatrix} c_1 c_{23} & s_1 c_{23} & -s_{23} \\ -c_1 s_{23} & -s_1 s_{23} & -c_{23} \\ -s_1 & c_1 & 0 \end{pmatrix} x \begin{pmatrix} c_\alpha c_\beta & c_\alpha s_\beta s_\gamma - s_\alpha c_\gamma & c_\alpha s_\beta c_\gamma + s_\alpha s_\gamma \\ s_\alpha c_\beta & s_\alpha s_\beta s_\gamma + c_\alpha c_\gamma & s_\alpha s_\beta c_\gamma - c_\alpha s_\gamma \\ -s_\beta & c_\beta s_\gamma & c_\beta c_\gamma \end{pmatrix}$$

$${}^3_6R = \begin{pmatrix} g_{11} & g_{12} & g_{13} \\ g_{21} & g_{22} & g_{23} \\ g_{31} & g_{32} & g_{33} \end{pmatrix}$$

However, it can be concluded that the last three intersected joints form a set of ZYZ Euler angles with respect to frame {3}. Therefore, these rotations can be expressed as:

$$R_{z'y'z'} = {}^3_6R = R_z(\alpha)\, R_y(\beta)\, R_z(\gamma)$$

$${}^3_6R = \begin{pmatrix} c_\alpha & -s_\alpha & 0 \\ s_\alpha & c_\alpha & 0 \\ 0 & 0 & 1 \end{pmatrix} X \begin{pmatrix} c_\beta & 0 & s_\beta \\ 0 & 1 & 0 \\ -s_\beta & 0 & c_\beta \end{pmatrix} X \begin{pmatrix} c_\gamma & -s_\gamma & 0 \\ s_\gamma & c_\gamma & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$${}^3_6R = \begin{pmatrix} c_\alpha c_\beta c_\gamma - s_\alpha s_\gamma & -c_\alpha c_\beta s_\gamma - s_\alpha c_\gamma & c_\alpha s_\beta \\ s_\alpha c_\beta c_\gamma + c_\alpha s_\gamma & -s_\alpha c_\beta s_\gamma + c_\alpha c_\gamma & s_\alpha s_\beta \\ -s_\beta c_\gamma & s_\beta s_\gamma & c_\beta \end{pmatrix}$$

Where ${}^3_6R$ is given above as

$$ {}^{3}_{6}R = \begin{pmatrix} g_{11} & g_{12} & g_{13} \\ g_{21} & g_{22} & g_{23} \\ g_{31} & g_{32} & g_{33} \end{pmatrix} $$

It is possible now to use the ZYZ Euler's angles formula to obtain the solutions for Θ4, Θ5 and Θ6 where

$$ \theta_5 = \beta = atan2\left(+\sqrt{g_{31}^2 + g_{32}^2}, g_{33}\right) $$

$$ \theta_4 = \alpha = atan2\left(\frac{g_{32}}{s_\beta}, \frac{-g_{31}}{s_\beta}\right) $$

$$ \theta_6 = \gamma = atan2\left(\frac{g_{23}}{s_\beta}, \frac{g_{13}}{s_\beta}\right) $$

For each of the eight solutions achieved from the geometric approach for Θ1, Θ2 and Θ3, there is another flipped solution of Θ4, Θ5 and Θ6 that can be obtained as:

$\theta_{55} = \beta' = atan2\left(-\sqrt{g_{31}^2 + g_{32}^2}, g_{33}\right)$, Or simply Θ55 = − Θ5

$\theta_{44} = \alpha = atan2\left(\frac{g_{32}}{s_{\beta'}}, \frac{-g_{31}}{s_{\beta'}}\right)$, Or simply Θ44 = 180 + Θ5

$\theta_{66} = \gamma = atan2\left(\frac{g_{23}}{s_{\beta'}}, \frac{g_{13}}{s_{\beta'}}\right)$, Or simply Θ66 = 180+ Θ6

Now, if β = 0 or 180, this means that the robot in a singular configuration where the joint axes 4 and 6 are parallel. This results in a similar motion of the last three intersection links of the robot manipulator.

Alternatively:

If β = θ_5 = 0, the solution will be

$\theta_4 = \alpha = 0$

$\theta_6 = \gamma = atan2\ (-g12, g11)$

If β = θ_5 = 180, the solution will be

$\theta_4 = \alpha = 0$

$\theta_6 = \gamma = atan2\ (g12, -g11)$

5. Inverse Kinematic Validation

The home position of the robot in space is chosen to check the validity of the inverse kinematic solution. This position can be represented by a point (P_{tip}) in the robot workspace. This point describes the position of the end effector (TCP) with respect to the robot base frame. By applying the inverse kinematic equations derived above, a set of joint angles is achieved. However, some of these angles do not yield a valid solution which is simply due to the fact that not all the joints can be rotated by 360^0.

P_{tip} (Home Position) = $[pxtip\ \ pytip\ \ pztip]^T$ = $[515\ 0\ 712]^T$

After performing the calculations in MATLAB, four sets of solution were obtained as follow:

Table 4. Inverse kinematic solution sets

Θ1	Θ3	Θ2	Set
0	-180	102	SET 1
0	-180	0	
0	0	0	SET 2
0	0	**-102**	
180	-153	93.7	SET 3
180	-153	-23	
180	-27	23	SET 4
180	-27	**-93.7**	

However, because of the limitation on the joint angle range of movement [7], especially joints 2 and 3, some of these solutions (marked in **red**) are not valid. The ABB IRB 140 joint angle limits are listed below in Table 5.

Table 5. ABB IRB 140 joint angle limits [7]

Joint Angle	MAX	MIN
Θ1	180	-180
Θ2	110	-90
Θ3	50	-230
Θ4	200	-200
Θ5	115	-115
Θ6	400	-400

After checking all the possible solutions with joint angle limitation table, only three valid solutions [(0, 0, 0), (180, -23, -153), (0, 102, -180)] were achieved which represent different robot configurations of the home position, elbow-up and elbow-down representations. The elbow-up configuration that corresponds to joint angles (180, -23, -153) is shown in Figure 7 below, while Figure 8 shows the elbow-down configuration that corresponds to joint angles (0, 102, and 180). Finally, the set (0, 0, 0) represents the home position by default. It is important to note that the position vector in Robot Studio is given for the TCP with respect to the robot global reference frame. Thus to match our solution with the simulation in Robot Studio, the inverse kinematics was solved with respect to the robot TCP.

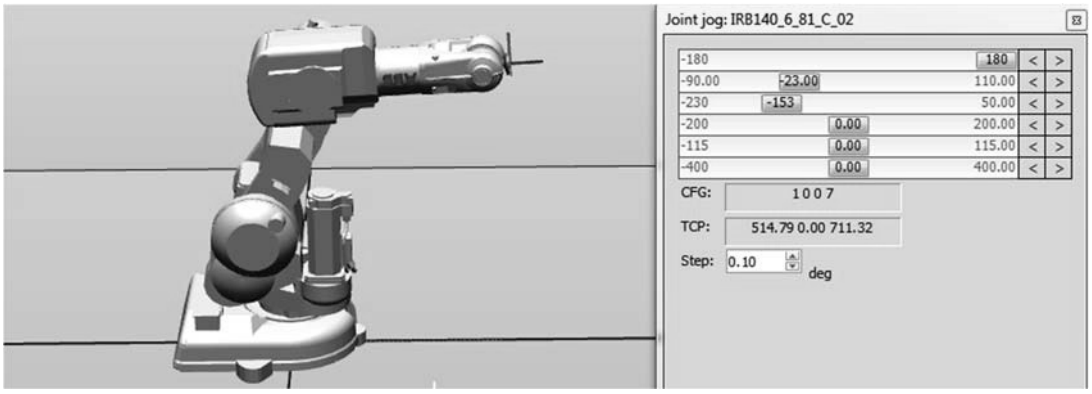

Figure 7. Elbow-up configuration

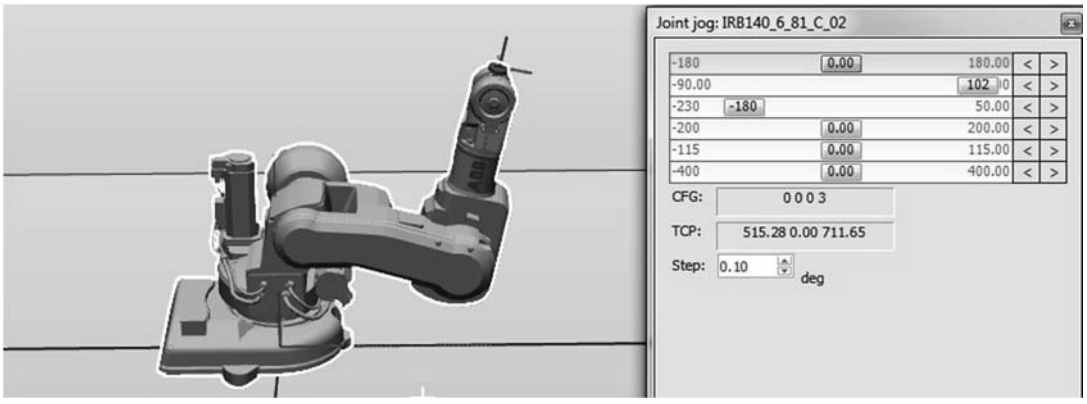

Figure 8. Elbow-down configuration

6. Conclusion

This work was undertaken to build the forward and inverse kinematic models of the ABB IRB 140 industrial manipulator. The Denavit-Hartenberg analysis (DH) is introduced to form the homogeneous transformation matrices. From the derived kinematic equations, it can be concluded that the position of the robot is given as a function of Θ1, Θ2 and Θ3 only, while the three last intersection joint angles (Θ4, Θ5 and Θ6) are used to give the desired orientation in space. The position vectors (x, y and z) obtained from the kinematic equations were matched with the actual robot position in the lab for the same joint angle input. Therefore, it can be declared that the kinematic derivation was carried out successfully. Two approaches have been presented to solve the inverse kinematic problem. Those were the geometrical and analytical approaches. Multiple solutions have been produced due to the nature of trigonometric functions. However, it has been shown that not all the solutions that resulted from the inverse kinematics were valid. This is basically due to the physical restrictions on the joint angle range of movement. A simulation of the manipulator in Robot Studio has been introduced to prove the validity of the inverse kinematic model. It is also used to validate the written Matlab code.

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[6] D. B. Vicente, *Modeling and Balancing of Spherical Pendulum Using a Parallel Kinematic Manipulator*, 2007.
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Appendices

I. Forward kinematics script

```
% THIS PROGRAM IS USED TO SOLVE THE FORWARD KINEMATIC OF THE ABB IRB140

% NON RETURN FUNCTION OF THE MAIN PROGRAM TO COMBINE ALL THE FUNCTIONS
    TOGETHER IN ONE SCRIPT

function [ NONRETURNFN ] = FORWARD( )

% DECLARATION OF THE MDH PARAMETERS

a0 = 0;      d1 = 352;     alpha0 = 0;
a1 = 70;     d2 = 0;       alpha1 = -pi/2;
a2 = 360;    d3 = 0;       alpha2 = 0;
a3 = 0;      d4 = 380;     alpha3 = -pi/2;
a4 = 0;      d5 = 0;       alpha4 = pi/2;
a5 = 0;      d6 = 0;       alpha5 = -pi/2;

% USER INTERFACE

theta1 = input ('PLEASE ENTER THE VALUE OF THETA1 IN DEGREE = ');
theta2 = input ('PLEASE ENTER THE VALUE OF THETA2 IN DEGREE = ');
theta3 = input ('PLEASE ENTER THE VALUE OF THETA3 IN DEGREE = ');
```

```
theta4 = input ('PLEASE ENTER THE VALUE OF THETA4 IN DEGREE = ');
theta5 = input ('PLEASE ENTER THE VALUE OF THETA5 IN DEGREE = ');
theta6 = input ('PLEASE ENTER THE VALUE OF THETA6 IN DEGREE = ');

% CALL THE DH FUNCTION TO CALCULATE THE HOMOGENOUS TRANSFORMATION MATRICES

T10 = DHFUNCTION(a0,alpha0,d1,theta1*pi/180)
T21 = DHFUNCTION(a1,alpha1,d2,(theta2-90)*pi/180)
T32 = DHFUNCTION(a2,alpha2,d3,theta3*pi/180)
T43 = DHFUNCTION(a3,alpha3,d4,theta4*pi/180)
T54 = DHFUNCTION(a4,alpha4,d5,theta5*pi/180)
T65 = DHFUNCTION(a5,alpha5,d6,theta6*pi/180)
T20 = T10*T21;
T30 = T20*T32;
T64 = T54*T65;
T63 = T43*T64;
T60 = T30*T63

% THE POSTION OF THE END EFEECTOR AT JOINT 6

Xw = T60(1,4);
Yw = T60(2,4);
Zw = T60(3,4);
P6 = [Xw;Yw;Zw]

% THE POSTION OF THE END EFEECTOR AT THE TCP

PTCP= T60*[0;0;65;1]

% Modifed DH TRANSFORM FUNCTION

function T = DHFUNCTION(ai,alphai,di,thetai)

T = [ cos(thetai),                    -1.*sin(thetai),                    0,                    ai ;

      sin(thetai).*cos(alphai),       cos(thetai).*cos(alphai),       -1.*sin(alphai),       1*di.*sin(alphai);

      sin(thetai).*sin(alphai),       cos(thetai).*sin(alphai),       cos(alphai),       di.*cos(alphai);

      0,                              0,                              0,                              1          ];

end

end
```

II. Inverse kinematics script

```
% THIS PROGRAM IS USED TO SOLVE THE INVERSE KINEMATIC OF THE ABB IRB 140

% DEFINE A NON RETURN FUNCTION TO COMBINE ALL THE INVERSE FUNCTIONS TOGETHER
  IN ONE SCRIPT

function [ NONRETURNFUNCTION] = INVERSE(  )
```

```
% DECLERATION OF THE ROBOT PARAMETER
d1 = 352;
a1 = 70;
a2 = 360;
d4 = 380;
NOSOLUTION=1000;

% THIS PROGRAM IS DESIGNED TO SOLVE THE INVERSE WITH RESPECT TO Porg6 OR TCP
ACCORDING TO USER SELECTION
sel = input ('TO SOLVE THE INVERSE WITH RESPECT TO FRAME6 PRESS 1 WHILE, TO SOLVE THE
INVERSE WITH RESPECT TO TCP ENTER 2: ');
if (sel == 1)
d6 = 0;
elseif (sel == 2)
d6 = 65;
else
d6= 65;
end

% USER INTERFACE

xtip = input ('PLEASE ENTER THE GOAL POSTION X = ');
ytip = input ('PLEASE ENTER THE GOAL POSTION y = ');
ztip = input ('PLEASE ENTER THE GOAL POSTION z = ');
alpha= input ('PLEASE ENTER THE VALUE OF alpha IN DEGREE = ');
beta = input ('PLEASE ENTER THE VALUE OF beta IN DEGREE  = ');
gama = input ('PLEASE ENTER THE VALUE OF gama IN DEGREE  = ');

% CALCULATING ALL THE POSSIBLE VALUES FOR THETA1

theta1= atan2 (ytip,xtip);
theta11= pi + theta1;
THETA1 = theta1 * 180/pi;
THETA11= theta11 * 180/pi;

% CALCULATING ALL THE POSSIBLE VALUES FOR THETA3

s = (ztip - d1);
r =  sqrt((xtip - a1*cos (theta1))^2 +(ytip - a1*sin(theta1))^2);
czeta = (r^2 + s^2  - (a2)^2 - (d4 + d6)^2)/(2 * a2 *(d4 + d6));

% SINGULARTIY CONDTION, CHECK IF THE POSTION WITHIN THE WORKSPACE OR NOT

if (abs(czeta) <= 1)
szeta = sqrt(1-(czeta)^2);
szeta1 = -szeta;
zeta= atan2(szeta,czeta);
zeta1= atan2(szeta1,czeta);
theta3 = -(pi/2 + zeta);
theta33 = -(pi/2 + zeta1);
THETA3 = conversion( theta3,50,-230);
THETA33 = conversion( theta33,50,-230);
else
theta3 = NOSOLUTION;
```

```
theta33= NOSOLUTION;
THETA3 = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR THETA3');
THETA33 = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR  THETA33');
End

s = (ztip - d1);
r =  sqrt((xtip - a1*cos (theta11))^2 +(ytip - a1*sin(theta11))^2);
czetai = (r^2 + s^2  - (a2)^2 - (d4 + d6)^2)/(2 * a2 *(d4 + d6));

% SINGULARTIY CONDTION, CHECK IF THE POSTION WITHIN THE WORKSPACE OR NOT

if (abs(czetai) <= 1)
szetai = sqrt(1-(czetai)^2);
szeta1i = -szetai;
zetai= atan2(szetai,czetai);
zeta1i= atan2(szeta1i,czetai);
theta3i = -(pi/2 + zetai);
theta33i = -(pi/2 + zeta1i);
THETA3i = conversion( theta3i,50,-230);
THETA33i = conversion( theta33i,50,-230);
else
theta3i=NOSOLUTION;
theta33i=NOSOLUTION;
THETA3i = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR THETA3i');
THETA33i = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR  THETA33i');
end

% CALCULATING ALL THE POSSIBLE VALUES FOR THETA2

if (theta3 == NOSOLUTION)
THETA2 = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR THETA2');
THETA22 = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR  THETA22');
else
theta2 = THE2(xtip,ytip,ztip,theta1,zeta);
theta22 = THE2COMP(xtip,ytip,ztip,theta1,zeta);
THETA2 = conversion( theta2,110,-90);
THETA22 = conversion( theta22,110,-90);
end

if (theta33 == NOSOLUTION)
THETA2i = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR THETA2i');
THETA22i = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR  THETA22i');
else
theta2i = THE2(xtip,ytip,ztip,theta1,zeta1);
theta22i = THE2COMP(xtip,ytip,ztip,theta1,zeta1);
THETA2i = conversion( theta2i,110,-90);
THETA22i = conversion( theta22i,110,-90);
end

if (theta3i == NOSOLUTION)
THETA2j = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR THETA2j');
THETA22j = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR  THETA22j');
else
theta2j = THE2(xtip,ytip,ztip,theta11,zetai);
```

```
theta22j = THE2COMP(xtip,ytip,ztip,theta11,zetai);
THETA2j = conversion( theta2j,100,-90);
THETA22j = conversion( theta22j,100,-90);
end

if (theta33i == NOSOLUTION)
THETA2k = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR THETA2k');
THETA22k = ('GOAL OUT OF WORKSPACE, THERE IS NO VAILD VALUS FOR  THETA22k');
else
theta2k = THE2(xtip,ytip,ztip,theta11,zeta1i);
theta22k = THE2COMP(xtip,ytip,ztip,theta11,zeta1i);
THETA2k = conversion( theta2k,110,-90);
THETA22k = conversion( theta22k,110,-90);
end

% DISPLAY ALL THE POSSIBLE EIGHT SOLUTIONS, NOTE THAT EVERY TWO SOLUTIONS FORM
   ONLY ONE SOLUTION SET

disp ( ' THETA 1,2,3 SOLUTIONS')
disp ( ' SET 1')
SOL1 =[ THETA1, THETA2, THETA3]
SOL2 =[ THETA1, THETA22, THETA3]
disp ( ' SET 2')
SOL3 =[ THETA1, THETA2i, THETA33]
SOL4 =[ THETA1, THETA22i, THETA33]
disp ( ' SET 3')
SOL5 =[ THETA11, THETA2j, THETA3i]
SOL6 =[ THETA11, THETA22j, THETA3i]
disp ( ' SET 4')
SOL7 =[ THETA11, THETA2k, THETA33i]
SOL8 =[ THETA11, THETA22k, THETA33i]

% SOLVING THE SECOND KINEMATIC SUB-PROBLEM (ORIENTATION)

alpha = alpha * pi/180;
beta = beta * pi/180;
gama = gama * pi/180;

R60 = [cos(alpha).*cos(beta),          (cos(alpha).*sin(beta).*sin(gama))- sin(alpha).*cos(gama),
        (cos(alpha).*sin(beta).*cos(gama)) + sin(alpha).*sin(gama) ;

         sin(alpha).*cos(beta),          (sin(alpha).*sin(beta).*sin(gama)) + cos(alpha).*cos(gama),
        (sin(alpha).*sin(beta).*cos(gama)) - cos(alpha).*sin(gama) ;

        - sin (beta),                    cos (beta).*sin (gama),          cos (beta).*sin (gama)]


R30 = [cos(theta1).*cos(theta2+theta3),          -cos(theta1).*sin(theta2+theta3),                    sin(theta1);

        sin (theta1).*cos(theta2+theta3),          -sin(theta1).*sin(theta2+theta3),                    cos(theta1);

       -sin(theta2+theta3),                        -cos(theta2+theta3),                                  0     ] ;
```

```
RT30= transpose (R30);
R63 = RT30 * R60 ;
g11 = R63 (1,1);
g12 = R63 (1,2);
g23 = R63 (2,3);
g31 = R63 (3,1);
g32 = R63 (3,2);
g33 = R63 (3,3);

% THETA 4,5,6 CALCULATION

theta5 = atan2 ( sqrt((g31)^2 +(g32)^2), g33);
if(theta5 == 0)
THETA4=  0
THETA5=  0
theta6 = atan2 (-g12, g11);
THETA6=  theta6*180/pi
elseif (theta5 == pi)
THETA4=  0
THETA5=  0
theta6 = atan2 (g12,-g11);
THETA6=  theta6*180/pi
else
theta4 = atan2 (g32/ sin (theta5), - g31/ sin (theta5));
theta6 = atan2 (g23/ sin (theta5), g31/ sin (theta5));
THETA4=  conversion( theta4,200,-200);
THETA5=  conversion( theta5,115,-115);
THETA6=  conversion( theta6,400,-400);

% FLIPPED POSTION

theta44 = theta4 + pi;
theta55 = -theta5;
theta66 = theta6+pi;
THETA44=  conversion( theta44,200,-200);
THETA55=  conversion( theta55,115,-115);
THETA66=  conversion( theta66,400,-400);
disp ( ' THETA 4,5,6 SOLUTIONS')
Solution1 = [THETA4,THETA5,THETA6]
Solution2 = [THETA44,THETA55,THETA66]
end

% FIRST POSSIBLE SOLUTION OF THETA2 FUNCTION

function RES = THE2(xtip,ytip,ztip,theta1,zeta)
 s = (ztip - d1);
 r =  sqrt((xtip - a1*cos (theta1))^2 +(ytip - a1*sin(theta1))^2);
omega = atan2 (s, r);
lenda = atan2 (( d4+d6) * sin (zeta) , a2+( d4+d6)* cos (zeta));
RES =  - ((omega - lenda)- ( pi/2)) ;
End
```

```
% SECOND POSSIBLE SOLUTION OF THETA2 FUNCTION

function RES1 = THE2COMP(xtip,ytip,ztip,theta1,zeta)
s = (ztip - d1);
r =  - sqrt((xtip - a1*cos (theta1))^2 +(ytip - a1*sin(theta1))^2);
omega = atan2 (s, r);
lenda = atan2 (( d4+d6) * sin (zeta) , a2+( d4+d6)* cos (zeta));
RES1 = - ((omega - lenda) - ( pi/2));
end

% JOINT ANGLES LIMIT FUNCTION

function OUT = conversion( theta,upperlimit,lowerlimit)
upperlimit = upperlimit * pi / 180;
lowerlimit = lowerlimit * pi / 180;
if (theta > upperlimit)
OUT = (' THE SOLUTION OUT OF JOINT ANGLE LIMIT ');
elseif (theta < lowerlimit)
OUT = (' THE SOLUTION OUT OF JOINT ANGLE LIMIT ');
else
OUT = theta * 180 / pi;
end

end

end
```

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Examination of Electrical Energy Usage in Terms of Thermodynamic Efficiency and Sustainability in the Residential and Commercial Sector

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Abstract - Energy usage is vital for social life and sustainability in the residential sector. This study examines the electrical energy utilization and efficiency of the Turkish residential and commercial sector in terms of sustainable energy and efficiency in 2013 by using energy and exergy analyses. The total energy input that was produced as 27.55% while the rest was obtained by imports in 2013. In this year, 35.02% of Turkey's total end-use energy was consumed by the residential - commercial sector. Annual fuel consumptions in space heating, water heating and cooking activities as well as electrical energy used by appliances are determined for 2013. It is clear from this figure that the energy efficiencies in the year studied range from 56.60 to 86.15%, while the exergy efficiencies vary from 5.05 to 24.76%. Additionally, researches on electrical household appliances efficiency indicated an efficiency of 86.15% for the first law of thermodynamic and 24.76% for the second law of thermodynamics.

Keywords - *Analysis, efficiency, electrical usage, thermodynamic, sustainability, residential-commercial sector*

1. Introduction

Energy is an important factor, in terms of social, economic and technological development of countries and the protection of the environment. The basic ways to increase energy efficiency is to reduce energy consumption. Approximately 35% of the energy consumption in our country and the world are used in the building. In about 80% of the energy used in buildings is spent for heating, cooling, air conditioning and hot water supply. The average residential energy consumption in Europe is 100 kWh /m^2 in Turkey is found normally 200 kWh/m^2. The average energy consumption in passive house building design is criteria consumed under of 15 kWh / m^2 [1]. Values are investigated when energy consumption in homes nationwide, and it reached twice the amount of energy consumed is compared with households in Europe. This energy consumption gives that short and outstanding information about our buildings sector.

The residential and commercial sector (RCS) used about 38-40% of primary energy consumption in the developed countries. However, in this sector, share of the electricity use is 68-70%, and of atmospheric emissions are 40% in these countries [1]. Total amount of energy usage in RCS is 20-30% of primary energy usage and emissions all over the world.

Sustainable energy can be defined as energy which provides affordable, accessible and reliable energy services that meet economic, social and environmental needs within the overall developmental context of society, while recognising equitable distribution in meeting those needs [2]. In practice, sustainable energy has different meanings to people. Some consider it as the energy related to renewable energy and energy efficiency. Some include natural gas under the heading of sustainable energy because of its more favourable environmental quality. Whatever approach is used, sustainable energy always implies a broad context covering resource endowment, existing energy infrastructure, and development needs.

In this study; electrical energy usage in terms of thermodynamic efficiency and sustainability will be analysed in the residential and commercial sector. Firstly, general evaluation will be done with regard to energy usage and sustainability. Secondly, the perspective of energy usage of Turkey will be presented, and energy utilization in the

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RCS will be explained followingly. Efficiency values of electric usage will be calculated. Finally, progression of efficiency in the RCS will be discussed in both findings and discussion sections.

2. The Perspective of Energy Usage in Turkey

Energy production and consumption values of Turkey is increasing constantly over the last thirteen years. The value of energy consumption in 2000 which was 3527.2 PJ has dramatically raised to 5077.16 PJ in 2013. When this increase is examined through electric consumption depending on technological development and economic growth, the total electric consumption measured as 128.29GWh in 2000 increased to 229.39GWh in 2013 [3,4]. The rate of meeting consumption through production is 27.20%, thus rest of the consumption which is 72.80% is met through imports in 2013.

Furthermore, whilst total greenhouse gas emission of Turkey was 298 million tons in 2000, it reached out 422.41 million tons in 2013 by increasing 5.9% annually. While 71% of the total emission in 2013 stemmed from energy sector, the rates of other sectors given as: 9% from waste product, 13% from industrial and 7% from agriculture sectors. Greenhouse gas emission potential shall be reduced with activities carried out within the scope of the energy efficiency studies. Particularly efficiency of the second law is considered as a cornerstone in efficiency thus efficiency is low and research projects increasing efficiency should be carried out. Considering aforementioned particularities, Researches and Development projects and projects increasing the efficiency of EHA which are recommended within the scope of the project are compulsory and should be seen as an opportunity.

Table 1. Values of energy and exergy inputs Turkey and RCS during 2013

			TRCS			Turkey	
Types of energy	toe/q*		Input (PJ)	Sector (%)	Turkey (%)	(PJ)	(%)
Hard coal	0.61	Energy	172.70	13.88	3.55	668.76	13.76
	1.03	Exergy	177.88	14.94	3.77	688.82	14.64
Lignite	0.21	Energy	61.23	4.92	1.26	648.98	13.36
	1.04	Exergy	63.68	5.35	1.35	674.94	14.35
Asphaltite	1.03	Energy	6.56	0.53	0.14	15.54	0.32
	0.97	Exergy	6.76	0.57	0.14	15.07	0.32
Petroleum	1.05	Energy	52.01	4.18	1.07	1274.17	26.22
	0.99	Exergy	51.49	4.32	1.09	1261.43	26.81
Natural gas	0.91	Energy	446.18	34.26	8.77	1870.68	35.00
	0.92	Exergy	412.08	32.92	8.30	1710.63	33.26
Wood	0.30	Energy	102.06	8.21	2.10	102.25	2.10
	1.05	Exergy	107.17	9.00	2.27	107.36	2.28
Bio – Mass	0.23	Energy	42.89	3.45	0.88	45.61	0.94
	1.05	Exergy	45.03	3.78	0.95	47.89	1.02
Hydro-power	0.09	Energy	316.54	25.45	6.51	188.14	3.87
	1.00	Exergy	316.54	26.58	6.70	188.14	4.00
Geothermal	0.86	Energy	45.19	3.63	0.93	86.09	1.77
	0.29	Exergy	13.10	1.10	0.28	24.97	0.53
Solar	0.86	Energy	18.43	1.48	0.38	26.33	0.54
	0.93	Exergy	17.14	1.44	0.36	24.49	0.52
Wind	0.09	Energy	0.00	0.00	0.00	16.98	0.35
	1.00	Exergy	0.00	0.00	0.00	16.98	0.36
Coke	0.70	Energy	0.00	0.00	0.00	68.99	1.42
	1.05	Exergy	0.00	0.00	0.00	72.44	1.54
Petrocoke	0.77	Energy	0.00	0.00	0.00	16.64	0.34
	1.04	Exergy	0.00	0.00	0.00	17.31	0.37
Total		**Energy**	**1298.65**	**100.00**	**26.40**	**5077.16**	**100**
		Exergy	**1243.45**	**100.00**	**26.20**	**4937.79**	**100**

* (toe/q)(tons oil of equivalent/ quality factor)

The values of energy and exergy inputs for 2013 according to energy carriers are indicated in Table 1. As can be shown in this table, total energy and exergy inputs of the Turkish sector were 5077.16 and 4937.79PJ, respectively, whilst RCS was determined as 1298.65PJ and 1243.45 PJ in 2013, respectively. In 2013, 34.47% of total ultimate energy usage of Turkey was used up by the RSC. The other sectors were calculated as; the industrial, with 36.25%; the transportation, with 19.15%; the agricultural, with 6.2% and out of energy, with 5.3%. In the analysed year, in terms of consumption of the thirteen energy sources, natural gas had the largest share, with 35.02%, followed by petroleum, with 26.20%.

2.1 Energy utilization in the Turkish residential commercial sector

The RCS includes space heating, water heating, cooking and electrical appliances for energy consumption. In the following subsections, the utilization of energy and exergy in the RCS in the year of 2013 was analysed. The specific electrical applications for energy and exergy consumptions were determined for 2013. Table 1 illustrates the use of energy and exergy as well as the shares of the resources in this sector for the year of 2013. Share of the energy utilization in the residential commercial modes are: space heating with 45%, water heating with 25%, cooking with 12% and electrical appliances with 18% in studied year. Table 1 shows energy and exergy utilization values for the year studied in the RCS. The highest contributions came from renewable resources (includes wood) with 41.50 %, fuel with 38.70 and electric with 19.80 in this year. Natural gas constituted 446.18 PJ of used energy in RCS in 2013. Moreover, usage of renewable energy became widespread in TRCS.

2.2. Estimation of overall efficiency values for electric utilization

Growth in living standards has been influencing the usage of electrical appliances; thus there is an emerging considerable increase in electricity demand day by day. According to a survey conducted by Turkish Statistical Institute in Turkey on 2013, there were 19,681,255 residences in Turkey. The average household appliances in a residence are refrigerator, air conditioning (AC), washing machine, dishwasher, television (TV), iron, vacuum cleaner, computer, oven, microwave oven; which means electrical energy is used for various purposes in this sector. Energy utilization and the saturation values of electrical appliances for the RCS are indicated in Table 2. Refrigeration had the largest ratio of electricity consumption as 29.4% in the analysed year, followed by lighting with 28.4%.

Table 2. Energy utilization and saturation values of components in Turkey in 2013

Components	Consumption (kW/year)	Electrical (%)	Fuels (%)	Renewables* (%)	Saturation values
Lighting	936	28.4			100
Refrigerator	917.28	29.4			99
Water heating		*	30	54	100
Cooking	272.48	8.3	18		100
Space heating	*	*	50	46	100
Washing machine	187.2	5.7			95
Vacuum Cleaner	78	2.4			93
Dishwasher	171.6	5.2			76
AC		4			14.50
TV	498,8	14.8			99
Iron	130	4			98
Computer	109.2	15			45
Total	**3290,56**	100	100	100	

2.3. Examining of electrical appliances and lighting efficiency

In Turkey, the average household appliances and lighting energy consumption by class of energy are given in the Table 3[4].

Table 3. Energy consumption values of some household appliances in housing sector

Type of appliances	Class B consumption of device	Class A consumption of device
Fridge	917.28 kW	733.82 kW
Washing machine	187.2 kW	149.76 kW
Dishwasher	171.6 kW	137.28 kW
TV	296.4 kW	237.12 kW
Lighting	936 kW	748.8 kW

2.4. Energy class labelling of household electrical appliances

Energy efficiency classification are grouped in seven categories; A, B, C, D, E, F and G is composed of these groups. Class-A shows the lowest energy consumption. Values of energy efficiency index (Z) are stated depend on the energy efficiency class values, and are shown in Table 4 [4].

Table 4. Energy efficiency index values in connection with energy efficiency class

(Z)	**Class**
$Z < 55$	A
$55 \leq Z < 75$	B
$75 \leq Z < 90$	C
$90 \leq Z < 100$	D
$100 \leq Z < 110$	E
$110 \leq Z < 125$	F
$125 \leq Z$	G

Energy Efficiency Index (Z) is estimated as follows as stated in percent (%).

$$Z=E/E\ ST \tag{1}$$

E: Annual energy consumption of the device in accordance with the standards specified kWh / year terms (24 hours consumption x 365) will be provided and it will be measured according to Turkish Standard (TS-EN 153).

Est: The standard annual energy consumption of device as expressed in kWh / year

$$Est = M \times DH + N \tag{2}$$

DH = Adjusted net volume (liter)

M and N values are taken from Table 5.

Table 5. Values of M and N according to class of devices [4]

Electrical Appliances	M	N
Refrigerator	0.233	245
Fridge-chiller	0.233	245
Starless fridge	0.233	245
One star refrigerator *	0.643	191
Double stars fridge **	0.450	245
Three stars fridge ***	0.657	235
Deep-freezer *(***)	0.777	303
Vertical-freezer	0.472	286
Horizontal-freezer	0.446	181
Other refrigerating appliances	(1)	(1)

M and N values for these electrical appliances are calculated by considering the low-temperature chamber and the number of stars as given Table 5. The differences between the classes of A, A+ and A++ is because of energy consumption hence class A++ is more efficient in terms of energy consumption. In Table 6 it is compared to the energy consumption of this class. Class A+ + Energy level is consumed energy of 0.5 kWh in a day. Thus consumption is equivalent to 0.5kWh is equivalent 40W lighting lamp 12.5 hours a day.

Table 6. Electricity consumption of electrical appliances depend on energy class for per day

Class	Consumption (kWh/24hour)
B	1.70
A	1.23
A+	1.07
A++	0.50

2.5. Evaluation of electrical appliances terms of efficiencies

Lighting; Lighting used approximately 35-38% of all electrical usage [8]. Annual electricity consumption of dwelling unit for lighting is assumed to change linearly from 138 kWh in 1990, 180 kWh in 2001 and 235 kWh in 2013 [9,10]. Lighting is assumed to be 60% incandescent and 40% fluorescent with first and second law efficiencies of about 5 and 4.5%, and 20 and 18.5% in 2013, respectively [9,10]. Combining the relevant first and second law efficiencies for lighting, we calculated **η** =9.5-15.5% and Є=8.70-14.3% for the year considered, as mentioned in Table 7.

Refrigerator; Refrigerators consume big share of electricity. Usage of electricity for refrigeration was 30-35% out of all electrical use in TBS [4,6]. Electricity consumption is projected to decrease by using new technologies for refrigerators. Average annual consumption was determined to be 346 kWh in 1990, 328 kWh in 1995 and 300 kWh in 2001, and 285 kWh in 2013 [9-10].

The second law efficiency of refrigeration was estimated from;

$$Є = \eta\,[(T_0/T_3) - 1] \tag{3}$$

It is presumed that the temperatures inside the freezers and the refrigerators are approximately 8°C, the coefficient of performance (COP) is 1.0, and the room temperature near the refrigerator coil is 20°C. Using Eq. (3), these assumptions yield Є = 11.60% in 2013, while exergy efficiencies are mentioned in Table 7 for 2013.

Water heating; In 2013, usage of electricity purposes of water heating was 4% out of all electrical use in TBS. Energy efficiencies of electrical use for water heating are assumed to be 90% [4]. The assumed-temperatures of hot

water and ambient are 60°C and 20 °C, whilst quality factor (q_{fuel}) is 1.0 for electrical use. The exergy efficiency for water heating was calculated from Eq. (3) and was found to be 10.8%, as demonstrated in Table 6.

Cooking; in 2013, usage of electricity purposes of cooking appliances (electric oven, hob, cooker, kettle etc.) was 3-4% out of all electrical use in RCS. It is presumed that energy efficiency of electrical use is 80%, and the cooking and ambient temperatures are 120°C and 20°C, respectively [5]. Using Eq. (3), these assumptions yield Є= 17.2% for cooking.

Table 7. Energy and exergy efficiency values of electrical components

Components	2013	
	η	ε
Lighting	15.5	14.3
(Incandescent)	5	45
(Fluorescent)	20	18.5
Refrigerator	150	15.7
Water heating	90	10.8
Cooking (electric oven, hob, cooker, kettle etc.)	80	17.2
Space heating	98	8.22
Washing machine	90	90
Vacuum-cleaner	80	80
AC	200	14
TV	85	85
Iron	98	30
Others	90	70
Total	**86.15**	**24.76**

Space heating; Usage of direct electrical purposes of space heating was 2-3% out of all electrical use in this Turkish building sector. It is determined that, energy efficiency is 98%, the supply temperature for the space heating equipment is 50°C and the ambient temperature is 20°C [6,10] using Eq. (3), the numerical values and the first law efficiencies estimated, it is calculated exergy efficiency 8.22% for space heating.

Air conditioning; Considering the COP value of the AC unit is 2, the unit extracts heat from air at 14°C and the outside temperature is 35°C and using Eq. (3) in a similar manner, it is calculated Є = 14% in the year studied.

Television; Usage of electric for TV and computer was *6,* 7% out of all electrical use in this sector. Electricity consumption of TV per year has increased compared to previous years; since the number and the usage of television and TV channels as well as computers and computer appliances have been increased over the last decade. Energy and exergy efficiencies are estimated to be 85%.

Others; Other electrical appliances are washing-machine, dishwasher, iron, computer and vacuum-cleaner and electricity consumption values of these appliances are given in Table 3. Whilst the energy and exergy efficiencies of these appliances are stated in Table 7. Substituting the relevant numerical values into Eqs. (4)-(5), it is found **η** = 86.15% and Є= 24.76% for electrical use in 2013.

Total energy and exergy efficiencies ($\eta_{,orc}$ and $Є_{,orc}$) for the entire TRCS were calculated by collecting used electrical energy (e_{rc}), direct fuel (f_{rc}), and renewable energy (r_{ec}) use as follows:

$$\eta_{,orc}= [(\eta_{oe}*e_{rc}) + (\eta_{of}*f_{rc})+ (\eta_{r}*r_{rc})] / (e_{rc} + f_{rc} + r_{rc}) \quad (4)$$

$$\epsilon_{,orc}= [(\epsilon_{oe}*e_{rc}) + (\epsilon_{of}*f_{rc})+ (\epsilon_{r}*r_{rc})] / (e_{rc} + f_{rc} + r_{rc}) \quad (5)$$

The weighted mean of overall energy and exergy efficiencies for TRCS were calculated to be $\boldsymbol{\eta}_{orc}$=67.35%, and ϵ_{orc} =11.05 % in 2013 by using the numerical data given in Table 7. The overall calculated efficiency values of RCS in 2013 is shown in Table 8.

Table 8. Energy and exergy efficiency values of RCS in 2013 (%)

Sub-sectors	η	Є
Space heating	62.15	5.05
Water heating	63.65	7.60
Cooking	56.60	11.80
Fuel use of all sub-sectors	61.02	7.05
Electrical energy use of all sub-sectors	86.15	24.76
Total	**67.35**	**11.05**

3. Results and Discussion

Energy and exergy utilization efficiencies of electrical appliances in RCS in 2013 were analysed. Energy and exegy consumption values of RCS and Turkey in total were calculated. Consumption and saturation values and efficiency indexes of electrical appliances used in RCS were examined. Energy and exergy efficiency of electrical appliances were investigated by utilizing from the obtained data. Finally, the energy and exergy inputs were compared by identifying losses and efficiencies of electrical appliances.

3.1. Development of energy and exergy efficiencies in the RCS

Energy and exergy efficiency values for the RCS is compared in this study. It can be understood through the values that the energy efficiencies in the year studied range from 56.60 to 86.15%, while the exergy efficiencies vary from 5.05 to 24.76%. This sector shows considerably important and comparable losses of energy and exergy. In terms of exergy loses, this sector ranks rather differently, accounting for about 75.24% of all exergy loses.

The study stated that exergy utilization in Turkey was even worse than energy utilization. As a result of this, there is big potential for increasing the exergy efficiency in this sector. It can be seen that a conscious and planned effort is needed to improve exergy utilization.

Electric energy saving shall be increased in RCS thus electric energy consumption and greenhouse gas emissions shall be reduced by transforming the market towards EEA with high energy efficiency and accelerating the replacement of old and non-efficient products with highly energy-efficient products. In the other hand, main approach in National Climate Change Strategy Document states that Turkey aims to extend energy efficiency, increase use of clean and renewable energy resources and integrate climate change policies with development policies in order to become a country offering high quality of life and wealth to all citizens with low carbon emissions.

4. Conclusion

It is essential to use exergy analysis along with the energy analysis for determination of the efficiency of the system. Exergy analysis is considerable significant in terms of detecting irrevibilities occurring in the system. Also, exergy is a suitable and necessary concept in the development of a sustainable energy and efficiency, and future research of exergy and its applications must be further directed towards the development of a sustainable society [9]. The obtained results in this study are summarized below;

- There are big potential for development of energy and exergy efficiency in Turkey. This potential can be used to eliminate environmental emissions.
- A common language shall be created with the purpose of improving effective energy use, energy efficiency in this sector and greenhouse gas emissions shall be reduced in Turkey by providing trainings and courses at every stage of education corporate capacity shall be improved towards developing and implementing energy policies.
- To reduce electrical energy consumption in RCS and greenhouse gas emissions caused by this consumption by accelerating market circulation towards electrical household appliances with high energy efficiency and replacement of old and non-efficient products with highly efficient products.
- Awareness of end users and members of the supply chain shall be raised by improving capacity of producers in developing and implementing special promotional activities in education and course environments with the purpose of increasing sales of products with high-energy efficiency.
- The energy efficiency labelling for electrical appliances such as air-conditioning either does not exist or is now under development.
- Led and compact fluorescent lights are efficient types of lighting. The lights spread more widely. Efficient lighting practices should be applied.

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UWB Microstrip Antenna Design for Microwave Imaging Systems

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Abstract - In this work, an ultra-wide band (UWB) microstrip antenna is designed which can be used for microwave imaging applications such as breast cancer detection. Proposed antenna is operating in between 2.01GHz to 7.64GHz with a Fractional Bandwidth (FBW) of 116%. Antenna is using low cost low profile substrate with 38 × 40mm^2 dimensions and thickness of 1.6mm. This antenna can provide maximum gain of 9.4dB, which is considerably a good result for microwave imaging purpose.

Keywords - *Ultra-wide band (UWB), microstrip antenna, microwave imaging, breast cancer detection*

1. Introduction

Recently, many researchers are focusing on the wide use of ultra-wide band (UWB) antennas because of ability for using in many applications such as Medical and Military Purpose, Radar and Communication Systems. According to the Federal Communication Commission (FCC) that device where the fractional bandwidth is greater than 109% (3.1GHz – 10.6GHz) while according to European Telecommunications Standards Institute (ETSI) the fractional bandwidth is more than 85.7% (3.4GHz – 8.5GHz) is considered as ultra-wide band devices. Designing UWB antenna, we are required to keep several parameters in specific range and values. For instance, the most important parameter is frequency bandwidth, voltage standing wave ratio (VSWR), gain, and directivity. Even in some applications, we require to have good penetration depth such as through-wall imaging systems [1-2] and [14-15].

UWB antennas are widely used in microwave imaging for cancer detection purposes [3]. Compact antennas exhibiting ultra-wide bandwidth is considerably possessing low gain and omni-directional radiation pattern which is commonly used for short distance and low resolution [4]. This type of antenna could be used in the Ground-Penetrating Radar (GPR) application also [16-21]. While on the other hand, use of UWB antennas for detection purpose in microwave imaging systems, requires somewhat better gain and radiation pattern.

Microwave imaging is considered as one the most interested field in terms of research, as they have many advantages such as detecting cancerous tissues. In medical purpose, microwave imaging basically finding out the electrical property distribution of body [5]. The difference between normal tissues and cancer affected tissues helps in detection of cancer. It is moving towards popularity for cancer detection and other medical purposes at the present time because of easy layout and simplicity in configuration.

In this paper, we proposed the microstrip patch antenna designed which is applicable in ultra-wide band. This frequency range is considered as a better solution for detecting breast cancer. Also, we improved the gain and directivity to get high resolution data. High frequency structure simulator (HFSS) is used for simulation to design the antenna structure and analyze the measurement and properties.

In section 2, we discussed the design of antenna thoroughly, which includes size and dimensions. Section 3 includes simulation results and detailed discussion while in the end; we conclude the paper with conclusion.

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2. Geometry of Proposed Antenna

Ultra-wide band can be obtain by keeping a specific dimension of radiating patch such that length and width, also we used different slits and extended stubs to get considerable simulation results. Proposed microstrip antenna consist of optimal substrate thickness (FR4) substrate thickness of 1.6mm with the relative permittivity, ε_r=4.4 and loss tangent δ=0.02. The length and width of substrate is 40mm and 38mm respectively.

Radiating patch is most important part of every antenna because the design parameters of patch manage the properties of antenna. Resonant frequency is depending on the length of patch while width of patch gives us good radiation efficiencies [6], which are the reasons that we focus on the calculated and compact size of patch. The length of patch, denoted by L_p, is 23.5mm and width, W_p size is 12mm. In the beginning, we designed a very simple structure of patch without having any gaps and slits in the patch which later on improved by adding I shaped slits in the right side of patch [7]. First of all, we used a simple design to observe the changes in radiation pattern and S11, which is mentioned in Figure 1(a), (b), (c) and (d).

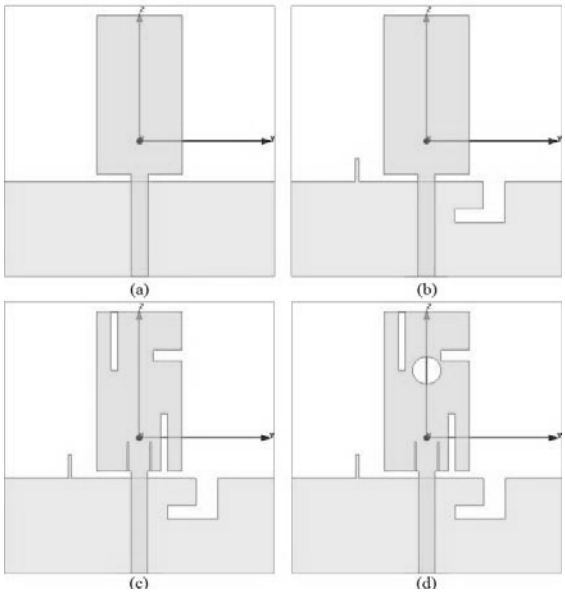

Figure 1. (a) Simple design (b) I shaped stub and L shaped slit in ground (c) Modified patch (d) Proposed antenna design

Changes occurred because of altering and modification in antenna design effect the return loss, S11 parameter of antenna which can be observed in Figure 2.

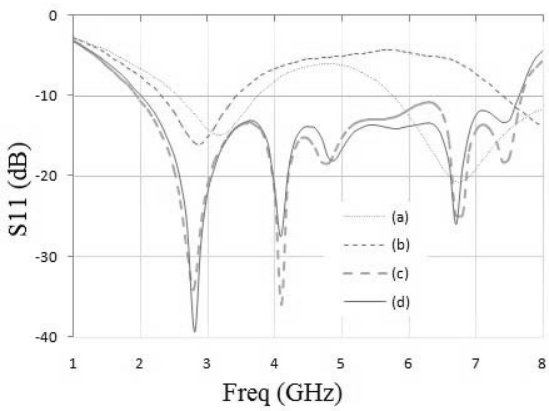

Figure 2. Variation in S11 with changing design of Antenna i-e; (a), (b), (c) and (d)

There is very slight difference in S11 of antenna (c) and (d) but we can find out a huge difference in gain. Gain of proposed antenna with the varying design (a), (b), (c) and (d) is shown in Figure 3.

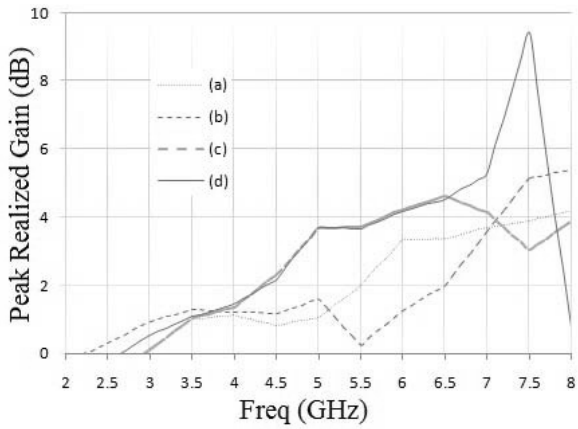

Figure 3. Gain (dB) with the varying design of antenna (a), (b), (c) and (d)

Ground is on the lower side of substrate with the length, L_g and width of $14\times38mm^2$, while from the Figure 1, it is quite visible that there is I shaped stub on the left side which is inserted on the particular place to increase the bandwidth and gain for ultra-wide band purpose. I shape stub has the size of $3.5\times0.5mm^2$, also there is L shaped slit on the right side of the ground. Figure 4 shows the complete design parameters of antenna.

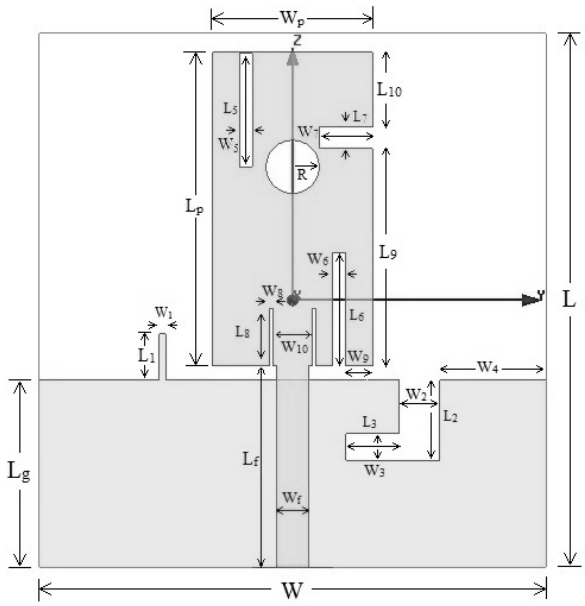

Figure 4. Complete Design Parameters of Antenna

From Figure 4, Patch structure can be seen clearly as its shape is consisting of rectangular shape. L_p denotes the length of patch and W_p is width of patch, which is responsible for the bandwidth. Inset feed of width, W_f and length, L_f is used to achieve 50Ω impedance. Effect of inset feed is discussed briefly in the section 3. The structure has been simulated in high frequency structure simulator (HFSS) which helped us to understand the detailed characteristics of antenna.

Table 1. Values of Antenna Parameters

Parameter	Values (mm)	Parameter	Values (mm)
L	40	W_4	8
W	38	L_5	8.5
Height	1.6	W_5	1
L_g	14	L_6	8.5
L_1	3.5	W_6	1
W_1	0.5	L_7	1.6
L_2	6	W_7	4
W_2	3	L_8	4.3
L_3	2	W_8	0.2
W_3	4	L_9	16.3
L_p	23.5	W_9	2
W_p	12	L_{10}	2.3
L_f	15.1	W_{10}	3
W_f	2.4		

In references, there are few antennas which are compared with our proposed antenna in terms of dimensions and the operating frequency range which is listed below in Table 2.

Table 2. Proposed Antenna Dimension Comparison with Reference Antennas

References	Dimensions (mm^3)	Freq Range (GHz)	Gain
[3]	50×50×1.6	3.1–11 (112%)	9 dB
[9]	35×30×1.6	3.2–12 (115.7%)	5 dB
[10]	34×36×1.6	4.6–9.6 (70%)	5 dB
[12]	35×30×1.6	3.2–15.7 (132%)	7.5 dB
[13]	50×30×1.57	4.8–6.1 (23.8%)	11 dB
Proposed Antenna	38×40×1.6	2.01–7.64 (116%)	9.4 dB

3. Results and Discussion

Proposed antenna is designed in high frequency structure simulator (HFSS). Operating frequency is in between 2.01GHz to 7.64GHz which is considered as better frequency range for microwave imaging purpose. The most important part is fractional bandwidth (FBW), formula used for FBW is shown in equation (1).

$$FBW = \frac{f_h - f_l}{f_h + f_l}\ 200\% \tag{1}$$

Antenna has 116% fractional bandwidth, as lower frequency f_l is 2.01GHz while higher frequency f_h is 7.64GHz. Return loss, S11 of designed antenna is shown in Figure 5.

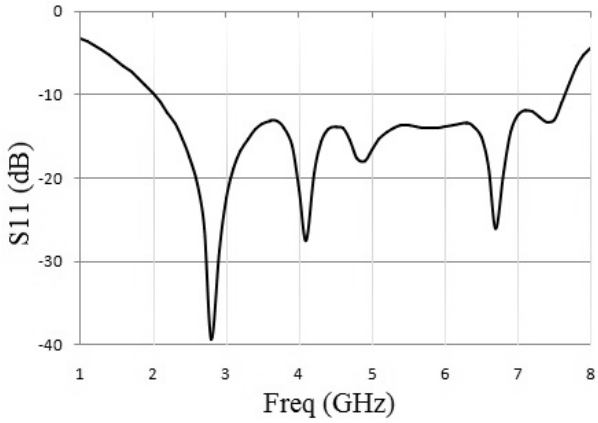

Figure 5. Return Loss, S11 of Proposed Antenna

After simulating the designed antenna, we got several results that are important to show and discuss in this paper. Voltage standing wave ratio (VSWR) is basically describes the power reflected from antenna and should be less than 2 [8], as we can see in Figure 6, in between the range of 2.01GHz to 7.64GHz.

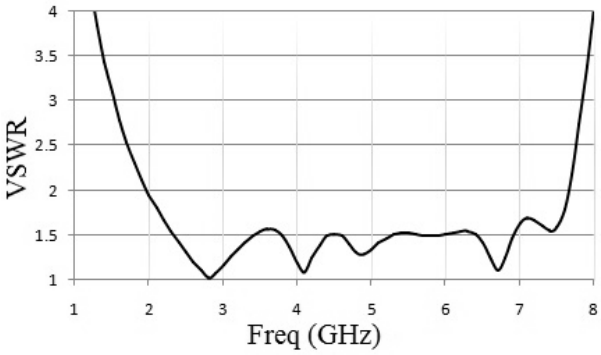

Figure 6. Voltage Standing Wave Ratio (VSWR) of Proposed Antenna

Antenna pattern give us more detail about the radiation characteristics. The pattern of designed antenna at frequency of 5.9GHz is shown in Figure 7.

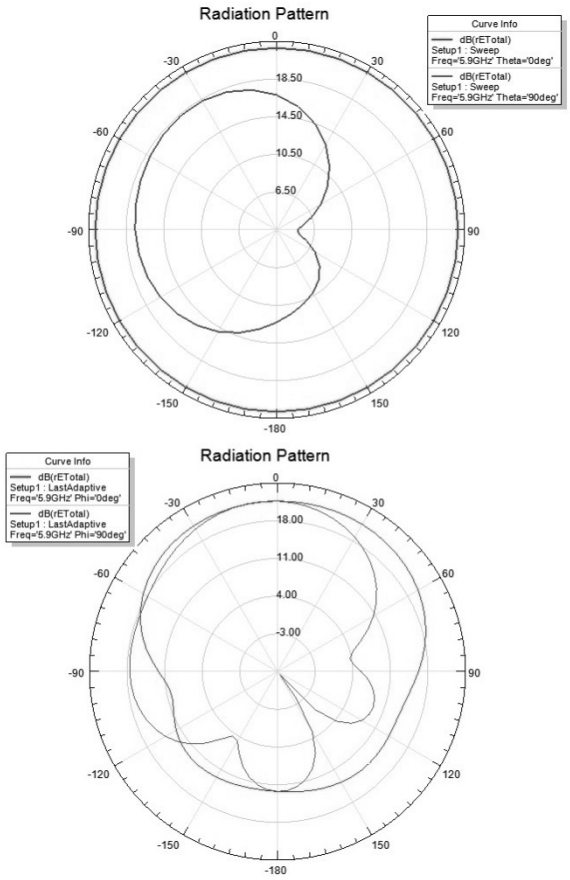

Figure 7. Radiation pattern at 5.9 GHz at phi=0˚ and theta=90˚

Also, we focused on increasing the gain as much as possible with the compact size of antenna. The maximum gain is 9.4dB at frequency 7.5GHz, which is quite better result. Figure 8 shows graphical representation of antenna gain.

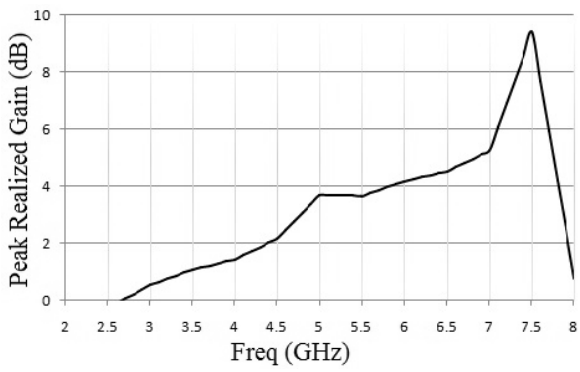

Figure 8. Graphical representation of Antenna Gain

4. Conclusion

In this paper, we designed a simple ultra-bide band (UWB) microstrip patch antenna with the fractional bandwidth (FBW) of 116%. Substrate used in proposed antenna is FR4 with the thickness of 1.6mm having relative permittivity, ε_r of 4.4 and loss tangent, δ equals to 0.02. Dimension of the substrate is 38 × 40mm^2 which is low profile

comparatively to other antennas. Microstrip feed line is used to provide 50Ω High frequency structure simulator (HFSS) is used for designing and simulation. Return loss, S11 is lesser than -10dB in the range 2.01GHz to 7.64GHz with the improved maximum gain of 9.4dB, which is considered as sufficient results. In short, a very compact design of antenna is proposed to use in microwave imaging applications such as breast cancer detection. As compared to other cancer detection techniques it is considered as one of the most efficient technique because of high sensitivity.

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Removal of Bitterness by Using of Amberlite in Orange Juices

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Abstract - In this study, the removal of bitterness in Washington (navel) orange juice due to limonin was examined by using "Amberlite XAD-7HP" adsorbent. In the meanwhile, the changes on some chemical properties of orange juices such as (pH, titratable acidity, brix) were investigated. It had been determined that the adsorbent was successfully removed the bitterness in Washington navel orange juice. The results showed that bitterness caused from limonin was decreased from 90% to %96 at 30°C and 40°C, respectively. The bitterness of orange juice caused due to limonin was decreased up to %96 during using Amberlite XAD-7HP polymeric resin.

Keywords - *Washington (navel), removal bitterness, limonin, Amberlite XAD-7HP*

1. Introduction

Orange juice should have a typical flavor of mature oranges, orange color and free from any flavor defects. Factors such as color, ascorbic acid content, taste balance (arthritis / acid ratio), bitterness (flavonoids), essential oil content, pulp content and turbidity are important properties in orange juice in terms of the qualities of fruit juice in orange juice [1-4]. The color characteristic in orange juices is one of the most important quality criteria. The dark and natural bright orange color which is formed by carotenoids in fruit juice vials and by the coloring of flavedo is preferred [5-7]. It has been reported as the main carotenoids in the orange juices as α-carotene, β-carotene, γ-carotene, α-cryptoxanthin, β-cryptoxanthin, lutein, zeaxanthin, antherxantine and violaxanthin. B-carotene and β-cryptoxanthin are the main pigments that give color to fruit juice and shell color [5,7,8]. Most of the ingredients that provide orange flavors are shell fat-derived and lipid-like, together with many volatile substances, which are predominantly bitterness, sourness and sweetness [9].

The bitterness of fruit juices may be caused by bitter fruit or may be caused by faulty processes during processing [10]. There is a marked bitterness in the Washington (navel) oranges after a couple of hours of squeezing and two different views about the bitterness because of waiting on the juices obtained from Washington (navel) oranges [1,11]. The first is the acceptance of a physical change due to the solubility of the bitter item and the second is a chemical change which causes the fruit to be converted into a bitter compound by squeezing the pre-existing bitter substance. One of the most important examples of physical change is given by the fact that the limonene is poorly soluble and is either heated or kept for a long time to increase the concentration and form a bitter taste.

In chemical exchange, pH has a significant effect. While the precursor substances of the whole fruit do not come into contact with the fruit with acid character, the reaction does not occur, whereas the preliminary substances found in the water contents obtained after squeezing are bitterness as a result of reaction with acid type fruit [11]. Limonin bitterness is perceived in about 4 to 6 mg / L of orange juice, causing an unpleasant strong soreness after 12-15 mg / L, and this bitterness is an important problem in making fruit juice in Washington (navel) oranges [2,12,13]. Numerous researches have been carried out with biochemical, physicochemical, chemical and microbiological methods with the purpose of eliminating the limonin which causes the bitterness in all the citrus juices, especially orange juice presented for the time being [14-23].

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In the present study, the removal of limonin bitterness from Washington navel orange juice by using the Amberlite XAD-7HP resin which is a good adsorbent thanks to its aliphatic structure, was investigated. Amberlite XAD resins have physically or chemically been loaded with the various ligands to prepare new chelating resins and explored extensively for metal enrichment. Their attractive features are easy regeneration for multiple sorption-desorption cycles, good mechanical stability and reproducible sorption characteristics. The impregnation of polymer matrices with common chelating ligands is an easy way to design chelating collectors. Amberlite XAD-2 [24–28], Amberlite XAD-4, Amberlite XAD-7, Amberlite XAD-16 [28] and Amberlite IRC-718 [29] have been used as a support for such preparations. During this process, it was aimed to contribute to the literature by investigating the effects of changing the qualitative properties such as taste, aroma, pH, titration acidity, amount of limonin in orange juice to orange juice.

2. Material and Methods

In this study, the orange samples of "Washington (Navel)" were bought from the market in Istanbul in 2015 citrus season and brought to Istanbul Aydin University Food Engineering - Instrumental Analysis Laboratory. The samples were stored in a refrigerator at (+4)°C until analysis required.

Amberlite XAD-7HP (Sigma-Aldrich, 101503324) resin was used to remove limonin in the orange juice with the appropriate adsorbent, and the effect of this resin on the temperature of the limonin was evaluated at the appropriate temperature. Before the orange juice was obtained, the oranges were washed out after separating from the stalk and leaves and cut into two. The orange juice (super mixer) was used to extract the juice of orange. In order to separate the orange juice from the coarse pulp, a 1 mm plastic sieve was poured with the aim. The resulting orange juices were heat treated at 95°C for 15 seconds (Stuart SWBD, Water Bath) and cooled to room temperature. Limonin, water-soluble dry matter (°Brix), pH and titration acidity analyzes were carried out in the heat-treated orange juices. Orange juice was centrifuged (Hettich, Rotofix 32A) at 4000 rpm for 10 minutes during the removal of bitterness of limonin in orange juice to allow separation of serum and pulp. After centrifugation, 100 ml were taken from the serum and the system was supplied with a flow rate of 0.2 ml / min, adjusted with a peristaltic pump (Aqua TEC1), and at 30°C, 40°C, 50°C and 60°C, from the condenser column (Borucam) with adsorbent, 1 cm in diameter, 30 cm in length and 30 ml in volume. The temperature control in the condenser column was provided with a water bath (Julabo F12). Thus, and the serum part was removed with the help of adsorbent by applying different temperature as shown in Figure 1. The sample of orange juice from the column was taken and passed through the 0.45 µm syringe filters and then 20 µL was taken and injected into HPLC (Agilent Technologies 1200 Series) in order to analyze limonin.

This study which is related with the removal of limonin in the orange juice using the adsorbent the procedure was repeated three times for each applied temperature and the amount of limonin were determined as three parallel for each orange juice sample.

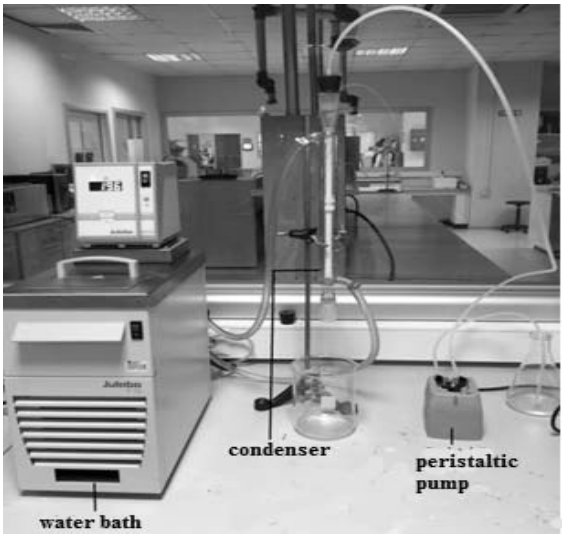

Figure 1. The system installed to eliminate the limonin in orange juice with the adsorbent application

2.1. The Determination of limonin amount

20 µL of the standard limonin (Santa Cruz Biotechnology-1180-71-8) solutions (5 mg/L, 10 mg/L, 15 mg/L, 20 mg/L, 25 mg/L, 30 mg/L, 35 mg/L, 40 mg/L) prepared to generate the standard calibration curve were injected into HPLC (Agilent Technologies 1200 Series) as shown in Figure 2. Post-injection chromatogram results were taken and evaluated. After completion of the analysis, the HPLC was purified with mobile phase aid.

HPLC Analysis Conditions:

- ***Column:*** Agilent Zorbax SB-C18, 5 µm pore diameter, 4.6 mm x 250 mm
- ***Mobile Phase:*** 65 parts Ultra-Pure Water, 17.5 parts Acetonitrile and 17.5 parts Tetrahydrafuran
- ***System Flow Rate:*** *1 ml / min*
- ***Wavelength:*** 207 nm
- ***Analyses Duration:*** 5 min

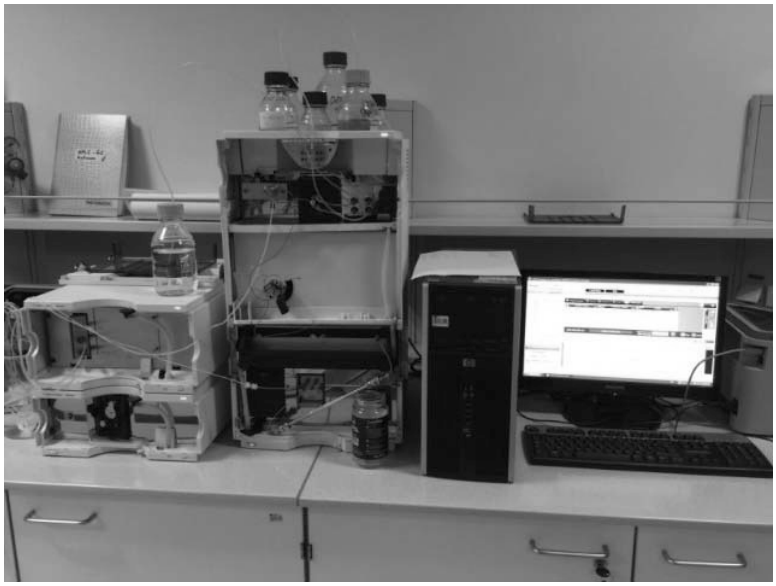

Figure 2. HPLC (Agilent Technologies 1200 Series)

2.2. The Chemical analysis

2.2.1. Titration acidity

The titration acidity was analyzed according to TS 1125 ISO 750 "Fruit and Vegetable Products - Titratable Acid Retention" [30]. 25 mL of pre-treated orange juice was diluted to 250 mL, then 50 mL of diluted orange juice was added and 0.25-0.5 mL of phenolphthalein was added and titrated until a permanent pink color was maintained for 30 seconds with adjusted NaOH solution.

2.2.2. Water soluble matter

The amount of water soluble solids (WSDM) was measured by Abbe refractometer (Reichert). The results were expressed in ° Brix [31].

2.2.3. pH analysis

The pH measurements were determined by pH meter (inoLab WTW pH 720) using orange juice, which was squeezed out and pulverized and heat-treated [26].

2.2.4. The Sensory analysis

In order to determine the changes in the sensory properties of the orange juice samples in the process of eliminating limonin, orange juice samples which had both the juice removed and the juice removed were taken in consideration of "Color-Appearance" and "Bitterness" in the presence of a panelist group of 10 persons. A sorting test was performed according to the sensory evaluation form [32,33].

2.2.5. Statistical analysis

The data obtained from the reduction of citric acid content of orange juice were subjected to analysis of variance with SPSS statistical analysis program (IBM SPSS Statistics 19.0), and the difference data were determined by ANOVA Duncan multiple comparison method. At the end of the statistical evaluation, the data which differ significantly from each other according to the confidence interval of 0.05 was marked with different letters in the respective charts.

2.3. The Calculation of kinetic values

2.3.1. The Calculation of reaction rate (constant k)

In order to calculate the reaction rate constant k, a linear regression analysis was performed according to the curve and the equation of the curve was calculated by placing the limonin changes determined by HPLC on the y-axis and the temperature values on the x-axis. This process was performed for varying the amount of limonin by applying different temperatures, and the reaction rate constant was calculated by determining the gradient by the obtained regression equation [34].

In zero-degree reactions; k= slope (1)

In the first- degree reactions; k=slope*(2.303) (2)

2.3.2. The Calculation of activation energy

The activation energy, which is the effect of the temperature on the reaction rate was calculated by using the Arrhenius equation [35].

$$k= A.e^{(-E_a/R*T)} \quad (3)$$

A= frequency factor constant (the rate of collision and the fraction of collisions with the proper orientation for the reaction to occur)

k= the rate constant
R= the gas constant (1.987 cal/mol. K)
T= Sıcaklık (Kelvin)
E_a= the activation energy (cal/mol or J/mol)

In the reaction, the ln values of k were taken and linear curve was formed by translating the graphs to the y axis, the corresponding temperature values to Kelvin and the reciprocal (1 / T) to the x axis. The regression analysis was performed on the generated curve and the activation energy (Ea) was calculated by multiplying the gradient of the graph by the gas constant [36,37].

$$\text{In } k= - E_a/RT + \text{InA} \quad (4)$$

$$\text{In } k = -(E_a/R)*(1/T) + \text{InA} \quad (5)$$

The Temperature Coefficient (Q_{10}) Determination

The Q_{10} value, which indicates the dependence of the reaction on the temperature, was determined by the Eqn. 6 [36].

$$Q_{10} = (k_2/k_1)^{10/(T2-T1)} \quad (6)$$

T_1 & T_2: Reaction temperatures (K)
k_1: The reaction rate constant at T_1 temperature
k_2: The reaction rate constant at T_2 temperature

3. Results and Discussion

The findings related to sensitivity and sensitivity of application of debittered and fresh orange juice in the study of removal of limonin by application of adsorbent in orange juice were included in this section.

3.1. The Calibration curve of the limonin solution

Before analyzing the debittered and fresh orange juices by using HPLC, limonin standards were prepared at different concentrations and the calibration curve generated was shown in Figure 3.

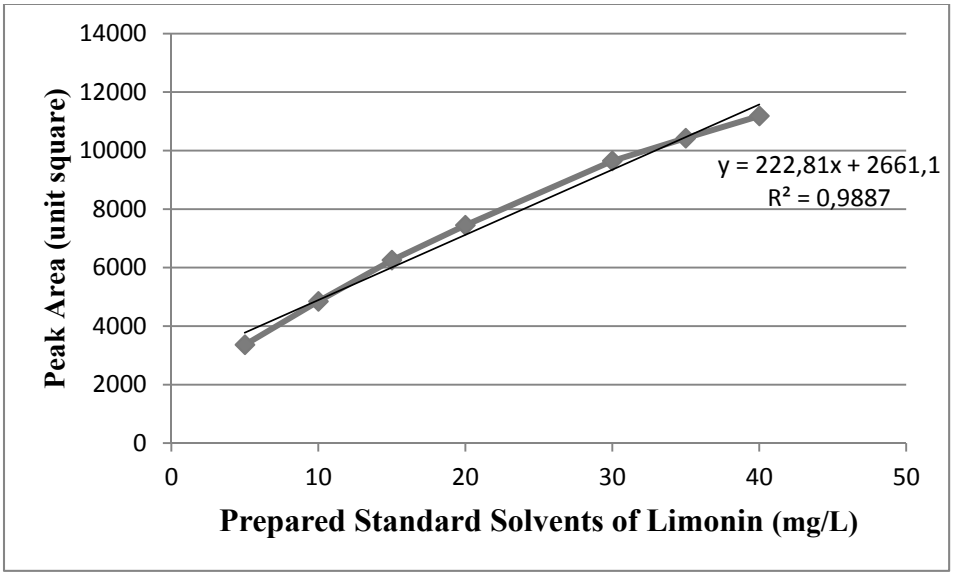

Figure 3. The regression curve and regression equation of prepared limonin solvent

3.2. The Limonin quantity of amberlite applied orange juice

The results of analysis of elimination of limonin sorption by adsorbent of orange juice are given in Tables 1 and 2. The results of the studies performed in different runs (1st and 2nd runs) and at different temperatures (30, 40, 50 and 60ºC) and statistical analyzes by using SPSS program are given in Tables 1 and 2. The amount of limonin in the first run were reduced %90, %89% %80 and %47 at temperature of 30^0C, 40^0C, 50^0C and 60^0C, respectively. It was observed that the treatment of amberlite applied orange juice at 30 ºC significantly differed from the other temperatures by applying different temperatures in the first run to remove limonin bitterness ($p<0.05$) as shown in Table 1. It was determined that the treatments performed at 40ºC, 50ºC, 60ºC, were not caused any significant difference ($p>0.05$). In the second run, 45%, 96%, 84% and 80% reduction at 30ºC, 40ºC, 50ºC and 60ºC, respectively. In the second run, it was concluded that the orange juice applied by amberlite was significantly different from the other temperature applications when applied at 40 ºC ($p<0.05$) as shown in Table 2. It was also determined that the operations performed at 30ºC, 50ºC, 60ºC did not make any significant difference ($p>0.05$).

Table 1. Analysis results of 1st run at different temperatures in removing limonin bitterness with adsorbent applied orange juice

1st Run		
Temp (ºC)	**Amount of limonin in orange juice (ppm)**	**Amount of limonin in Amberlite Applied Orange Juice (ppm)**
30	$3{,}2^a$	$1{,}46^a \pm 1{,}16$
40	$9{,}8^c$	$7{,}98^b \pm 0{,}24$
50	$8{,}2^b$	$7{,}93^b \pm 0{,}41$
60	$8{,}5^b$	$8{,}07^b \pm 0{,}44$

** The same letters in the same column indicate that the difference in the amount of limonin in the orange juice was not statistically significant (p> 0.05) comparing to the ANOVA Duncan test.*

Table 2. The results of the work done in the 2nd run at different temperatures in the process of eliminating the limonin in the orange juice by using the adsorbent

2nd Run		
Temp (ºC)	**Amount of limonin in orange juice (ppm)**	**Amount of limonin in Amberlite Applied Orange Juice (ppm)**
30	11^a	$9{,}8^b \pm 0{,}84$
40	$11{,}4^a$	$5{,}4^a \pm 0{,}59$
50	11^a	$10^b \pm 0{,}84$
60	$12{,}5^b$	$10^b \pm 0{,}43$

** The same letters in the same column indicate that the difference in the amount of limonin in the orange juice was not statistically significant (p>0.05) comparing to the ANOVA Duncan test.*

In addition, the percent reduction curves of orange juice from 1st and 2nd runs in Table 1 and Table 2 are given in Figure 4 for the second run in Figure 4 and Figure 5 for the 1st run. It was determined that the percentage reduction in the amount of limonin at the different temperatures applied was at most 30°C in the 1st run.

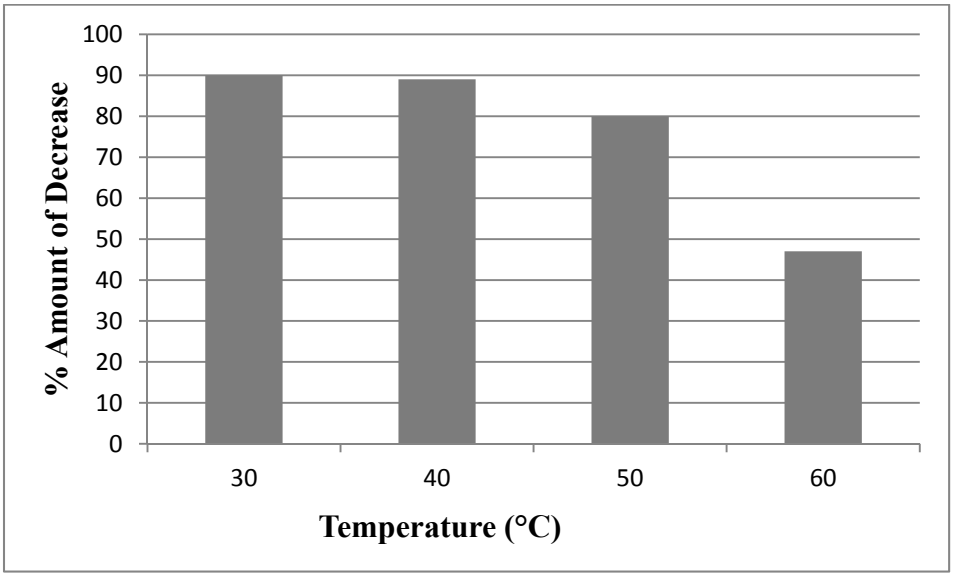

Figure 4. The percentage reduction in the amount of limonin at the different temperatures in the 1st run

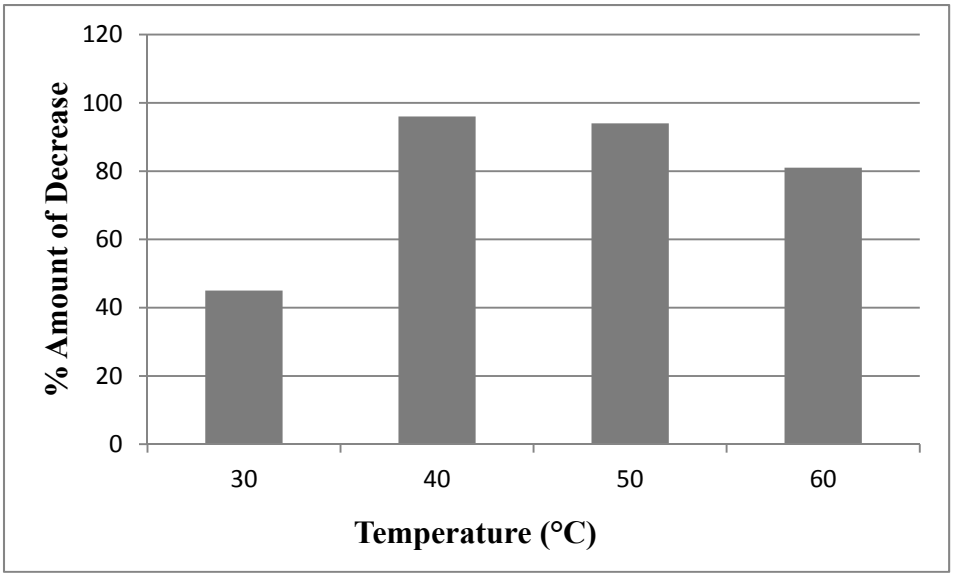

Figure 5. The percentage reduction in the amount of limonin at the different temperatures in the 2nd run

It was observed that the decrease in the amount of limonin was the highest at 40ºC in the experiment of eliminating the bitterness at different temperatures with the experimental adsorbent. It has been reported that Amberlite XAD-4 [38] and Amberlite XAD-16 [39] resins can be used in both citrus juice and low cost juice production. In addition, in the study by Lee and Kim [10], bitterness was tried by using ultrafiltration + polystyrene divinyl benzene in concentrated red grapefruit juice, and the redness of red grapefruit juice decreased by 80-90%. This preferred adsorbent was found to have a linear relationship with adsorption of limonin through its physical properties such as cross-linking ratios, pore diameters and specific surface areas as mentioned by Lee and Kim [10]. In addition, orange juices from Washington (navel) oranges were treated with different adsorbents (Amberlite XAD16 and Dowex Optipore L285) at different temperatures (20ºC, 35ºC and 50ºC) and the amount of limonin were investigated by Kola

et al. [39]. Similar results also had been reported by Kola et.al. [39], as they were found that limonin content was reduced by 95-99%

Table 3. Water Soluble Dry Matter analysis results in the 1st run

1st Run		
Temp (ºC)	**Orange Juice (Brix)**	**Amberlite Applied Orange Juice (Brix)**
30	11,5± 0.0[a]	11,4± 0.05[a]
40	11,5± 0.0[a]	11,5± 0.05[a]
50	11,5± 0.0[a]	11,5± 0.0[a]
60	11,5± 0.0[a]	11,5± 0.0[a]

** The same letters in the same column indicate that the difference in the amount of limonin in the orange juice was not statistically significant (p>0.05) comparing to the ANOVA Duncan test.*

Table 4. Water Soluble Dry Matter analysis results in the 2nd run

2nd Run		
Temp (ºC)	**Orange Juice (Brix)**	**Amberlite Applied Orange Juice (Brix)**
30	12,1± 0.0[a]	12± 0.0[a]
40	12,1± 0.0[a]	12± 0.0[a]
50	12,1± 0.0[a]	12,1± 0.05[a]
60	12,1± 0.0[a]	12± 0.0[a]

** The same letters in the same column indicate that the difference in the amount of limonin in the orange juice was not statistically significant (p>0.05) comparing to the ANOVA Duncan test.*

In this study, it was determined that the orange juice was reduced by 90% at 30ºC in the 1st run and 96% at 40ºC in the 2nd run by using a different form of the adsorbent (Amberlite XAD-16) used (Amberlite XAD-7HP). In addition, despite the use of different forms of adsorbent, approximate results were obtained. Furthermore, it was determined that Q_{10} value was directly proportional to the activation energy. It was concluded that the run was slower because of higher activation energy values. The results of water soluble dry matter analysis of orange juice treated with adsorbent at different temperatures and at different runs in the study of removing orange juice caused by the use of adsorbent were given in Table 3 and Table 4. As shown in Table 3. and Table 3, it was observed that the WSDM values increased with time and no significant change was observed after the adsorbent application. In both runs it was observed that the temperature did not make any significant difference in the dry matter analysis results (p>0.05).

Table 5. The results of titration assay analysis at different temperatures and in the 1st run to eliminate limonin bitterness with adsorbent in orange juices.

1st Run		
Temp (ºC)	**Orange Juice**	**Amberlite Applied Orange Juice**
30	1,43± 0.0[a]	1,40± 0.0[a]
40	1,43± 0.0[a]	1,40± 0.0[a]
50	1,43± 0.0[a]	1,39± 0.0[a]
60	1,43± 0.0[a]	1,40± 0.0[a]

** The same letters in the same column indicate that the difference in the amount of limonin in the orange juice was not statistically significant (p>0.05) comparing to the ANOVA Duncan test.*

Table 6. The results of titration assay analysis at different temperatures and in the 2nd run to eliminate limonin bitterness with adsorbent in orange juices

2nd Run		
Temp (ºC)	**Orange Juice**	**Amberlite Applied Orange Juice**
30	1,33± 0.0[a]	1,30± 0.0[a]
40	1,33± 0.0[a]	1,30± 0.0[a]
50	1,33± 0.0[a]	1,29± 0.0[a]
60	1,33± 0.0[a]	1,29± 0.0[a]

** The same letters in the same column indicate that the difference in the amount of limonin in the orange juice was not statistically significant (p>0.05) comparing to the ANOVA Duncan test*

The titration acidity results of orange juice treated with orange juice at different temperatures for the removal of limonin caused by the adsorbent in orange juice are given in Table 5 and Table 6. Tables 5 and 6 show that the titratable acidity values of the different runs decreased with time in the bittering process at different temperatures by applying adsorbent. It was observed that the acidity values didn't change because of the increasing of temperature. The acidity values changed with the amberlite application. In the first and second runs, it was observed that there was no significant difference in the titration acidity analysis results of the temperature (p>0.05) as shown in Table 7&8.

Table 7. The results of pH analysis at different temperatures and in the 1st run to eliminate limonin bitterness with adsorbent in orange juices

1st Run		
Temp (ºC)	**Orange Juice**	**Amberlite Applied Orange Juice**
30	3,35± 0.0[a]	3,42± 0.0[a]
40	3,34± 0.0[a]	3,40± 0.0[a]
50	3,34± 0.0[a]	3,40± 0.0[a]
60	3,35± 0.0[a]	3,41± 0.0[a]

** The same letters in the same column indicate that the difference in the amount of limonin in the orange juice was not statistically significant (p>0.05) comparing to the ANOVA Duncan test*

Table 8. The results of pH analysis at different temperatures and in the 2nd run to eliminate limonin bitterness with adsorbent in orange juices

2nd Run		
Temp (ºC)	**Orange Juice**	**Amberlite Applied Orange Juice**
30	3,40± 0.0[a]	3,42± 0.0[a]
40	3,40± 0.0[a]	3,41± 0.0[a]
50	3,40± 0.0[a]	3,41± 0.0[a]
60	3,41± 0.0[a]	3,42± 0.0[a]

** The same letters in the same column indicate that the difference in the amount of limonin in the orange juice was not statistically significant (p>0.05) comparing to the ANOVA Duncan test.*

Table 9. Data for the Arrhenius Graph for different temperatures in the 1st run for orange juice

1st Run				
Temp (ºC)	**(K)**	**k**	**-Ink**	**1/Tx10^3**
40	**313**	6,49	1,87	3,19
50	**323**	7,28	1,98	3,09
60	**333**	7,63	2,03	3,00

Finally, the bitterness was removed and the pH was analyzed in the orange juices which had not been relieved, and the results were shown in Table 7 and Table 8. As a result of this study, it was determined that the pH change

increases with time and temperature. In both runs, it was observed that the temperature did not make any significant difference in the pH analysis results (p>0,05).

3.3. The Evaluation of kinetic values of limonin amount

The concentration values of the amount of limonin in the orange juice were calculated in ppm, and a graph was drawn with k constant found as a result of the operations performed.

After the graph was drawn, the comparison of the regression coefficient calculations and the determination (R^2) values was made as shown in Tables 9 and 10.

As a result of these calculations, the increase in the value of k together with the temperature was observed in Tables 9 and 10. The Arrhenius graphs at the different temperatures in the 1st and 2nd runs for orange juice were shown in Figure 6 and Figure 7.

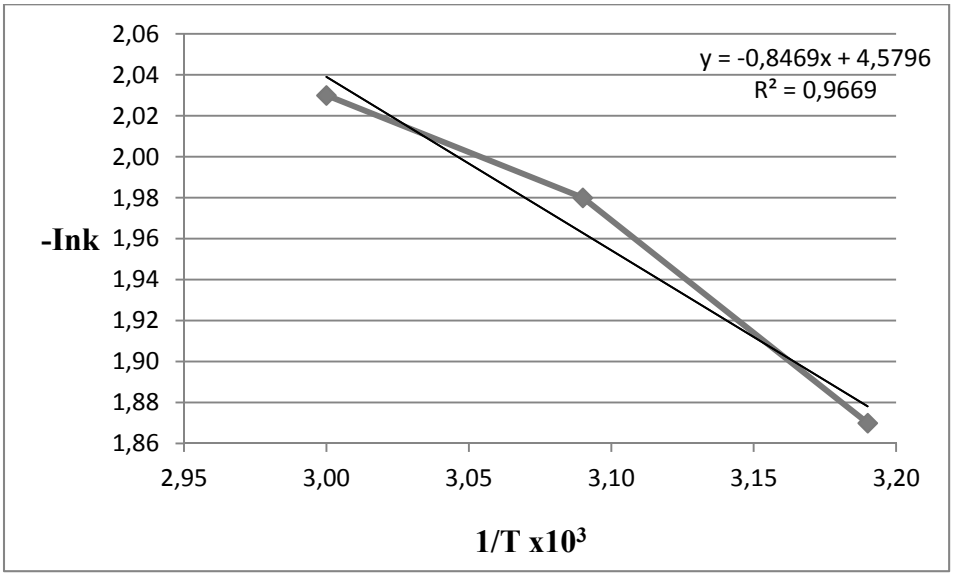

Figure 6. The Arrhenius Graph at the different temperatures in the 1st run for orange juice

Table 10. Data for the Arrhenius graph for different temperatures in the 2nd run for orange juice

2nd Run				
Temp (ºC)	**K**	**k**	**-Ink**	**1/Tx10³**
40	**313**	2,55	0,93	3,19
50	**323**	8	2,07	3,09
60	**333**	9,09	2,2	3,00

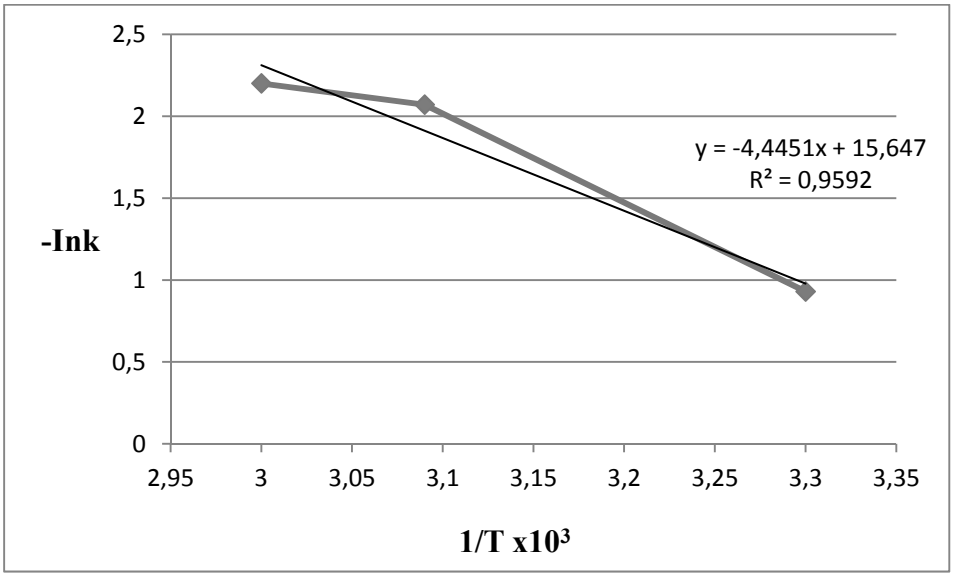

Figure 7. The Arrhenius Graph at the different temperatures in the 1st run for orange juice

3.4. The Q_{10} value results

The effect of the reaction rates on the temperature of 40-60ºC of the orange juices with activation energies was explained while the Q_{10} values were calculated between 40-50ºC and 50-60ºC and the effect of temperature was evaluated and the results are shown in Table 11.

Table 11. Kinetic data on the amounts of limonin in orange juices obtained at different temperatures and times

	E_a		Q_{10}	
	kcal/mol	**kj/mol**	**40-50°C**	**50-60°C**
I. Run	1,68	7,02	0,79	1,05
II. Run	8,83	36,90	3,13	4,13

The changes in the amount of limonin in the orange juices obtained by different temperatures were investigated and the activation energies were found as 1.68 kcal / mol and 8.83 kcal / mol for the first and second runs, respectively. The higher activation energy indicates that the reaction will begin more difficult and progress more slowly. In other words, a slower reaction is observed because the activation energy of the orange juices obtained in the second run is higher than in the first run. Q_{10} values vary between 0.79-1.05 for the first run and 3.13-4.13 for the second run. It was observed that the Q_{10} values caused a 2-fold increase in temperature changes, which was 1 fold. The results indicated that Q_{10} values were directly proportional to the activation energy

4. Conclusion

In this study, the limonin which caused bitter flavor in the orange juices obtained from Washington (navel) oranges was resolved by applying adsorbent at different temperatures. The removal of limonin bitterness was determined as 90% at 30ºC and 96% in 40ºC in this experimental runs. It can be concluded that pH of orange juice and WSDW values were not changed but the acid value was changed related with temperature and time.

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Abstract should not exceed 200 words with the word "Abstract" in 10 pt. bold, abstract text in 9 pt. all in Times New Roman font in Microsoft Word format.

Key Words not exceeding 5 should be in italic.

Document Character: Subtitles should be in 10 pt. bold, small letters and text body 10 pt. both with Times New Roman font in Microsoft Word format. The first letter of the chapter titles should be capital letter and others with lower case and bold. The manuscripts should be written on a single column with single line spacing between paragraphs. Tab should be taken as 0.42 cm. A line must be left blank after the chapter heading. The problem should be clearly stated in the introduction section. The introduction should follow the method, findings, comment / discussion and conclusion sections respectively. It is shown in [1] that there is a need to indicate the source in various places of the text. The rules for how to write the sources are listed at the end of the template where it should be reported.

Each image used must numbered and be named as "Figure". Formulas must be numbered sequentially.

$$Y = a + bX + \varepsilon \quad (1)$$

FRP Area (ft^2) (2)

Conclusion section should have a title written in 10 pt. bold, small letters and the text in 10 pt. all in Times New Roman font in Microsoft Word format.

Reference numbers should be given in brackets as illustrated below and Tab should be taken as 0.42 cm.

Referencing books:

[1]. Özsu M., T, Valduriez, P., *Principles of Distributed Database Systems*, Prentice Hall, New Jersey, 128-136,1991.

Referencing papers:

[2]. G. Altay, O. N., Ucan, "Heuristic Construction of High-Rate Linear Block Codes," *International Journal of Electronics and Communications (AEU),* vol. 60, pp.663-666, 2006.

Page number is to be placed at the top left corner of each page with pencil.

Length of the Manuscript should not exceed 20 pages excluding Figures and Tables.

INSTRUCTIONS ABOUT THE ACCEPTED MANUSCRIPTS

Page Design: Text body area is (195mm x 275mm). 30 mm margin from top, 20 mm from down and 25 mm margins should be left on right/left sides.

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Sections: Formulas should be numbered sequentially. Referring to formulas should be as Eqn (.). Figures and Tables should be placed into the text body and captions for both should be 10 pt. Table numbers and captions should be placed before the Table. If necessary, both columns may be used for large Figures and Tables. Each table should be arranged and numbered so that only the top and bottom horizontal lines appear. The first letter of the subheading must be capitalized and set to bold. One line must be paused between first-degree titles.

Conclusion section should have a title written in 10 pt. bold, capital letters and the text in 10 pt. all in Times New Roman font in Microsoft Word format. Conclusion should not be a version of the Abstract.

References numbers should be given in brackets as illustrated below and Tab should be taken as 0.42 cm.

Referencing books

[1] Özsu M., T, Valduriez, P., *Principles of Distributed Database Systems*, Prentice Hall, New Jersey, 128-136,1991

[2] G. Altay, O. N., Ucan, "Heuristic Construction of High-Rate Linear Block Codes," *International Journal of Electronics and Communications (AEU),* vol. 60, pp.663-666, 2006.

Short Biography of the authors should follow references after a single line space, names in 9 pt. surnames in 9 pt. and the text in 9 pt. The text should not exceed 100 words.

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