



شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم

بسم الله الرحمن الرحيم



HANAA ALY



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شبكة المعلومات الجامعية التوثيق الإلكتروني والميكروفيلم



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جامعة عين شمس

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HANAA ALY



**AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING**

Electronics and Communication Engineering Department

**Antenna Designs for Recent Millimeter and THz
Applications**

A Thesis

Submitted in Partial Fulfillment of the Requirements

**For the Degree of Doctor of Philosophy in Electrical Engineering
(Electronics and Communication Engineering)**

Submitted By

Eng. Kamel Salah Kamel Sultan

Supervised By

Prof. Dr. Esmat Abdel-Fattah Abdallah

Prof. Dr. Hadia Mohamed Saied El Hennawy

Prof. Haythem Hussien Abdullah

Assoc. Prof. Mohamed Ali Basha

Egypt

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Antenna Designs for Recent Millimeter and THz Applications

By

Kamel Salah Kamel Sultan

Doctor of Philosophy in Electrical Engineering
(Electronics and Communications Engineering)
Faculty of Engineering, Ain Shams University, 2021

Examiners' Committee

Approved by:

Name and Affiliation

Signature

1- Prof. Mostafa Elsaïd Mostafa

.....

Electronics and Electrical Communications Department,
Faculty of Engineering, Cairo University.

(Examiner)

2- Prof. Amr Mohamed Ezz Safwat

.....

Electronics and Communications Department,
Faculty of Engineering, Ain Shams University.

(Examiner)

3- Prof. Esmat Abdel-Fattah Abdallah

.....

Microstrip Department,
Electronics Research Institute.

(Supervisor)

1- Prof. Hadia Mohamed Saïed El Hennawy

.....

Electronics and Communications Department,
Faculty of Engineering, Ain Shams University.

(Supervisor)

Date: 13/12/2021

STATEMENT

This dissertation is submitted as a partial fulfillment of the degree of Doctor of Philosophy in Electrical Engineering (Electronics and Communications Engineering) Faculty of Engineering, Ain Shams University.

The work included in this thesis was carried out by the author at the Electronics and Communications Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

No part of this thesis was submitted for a degree or a qualification at any other university or institution.

Student Name: Kamel Salah Kamel Sultan

Signature:.....

Date:

RESEARCHER DATA

Name:	Kamel Salah Kamel Sultan
Date of birth:	6 th of January 1988
Place of birth:	Cairo, Egypt.
Last academic degree:	Master of Science in electrical Engineering
Field of specialization:	Microwave Engineering
University issued the degree	Cairo University
Date of issued degree:	26 th of January 2014
Current job:	Assistant Research in the Microstrip Dep., Electronics Research Institute

ABSTRACT

Antenna Designs for Recent Millimeter and THz Applications

by

KAMEL SALAH KAMEL SULTAN

DOCTOR OF PHILOSOPHY IN ELECTRICAL ENGINEERING THESIS

AIN SHAMS UNIVERSITY

Over the previous few years, the millimetre wave frequency range and sub-THz range have been received a lot of attention as they include unused frequency spectrum resources that are appropriate for providing a lot of applications such as automotive radars, short communication, medical imaging, security, and 5G communications to provide end-user access to Multi-Gbit/s services. On the other hand and because of the restrictions on the communication systems in these ranges such as power, path losses, and attenuation, the present RF antennas can't be used for millimeter and THz applications. The needed antennas should have low-profile, high-gain, acceptable technology, high efficiency and low cost to compensate these ranges restrictions.

Although there are some antenna designs for millimeter and sub THz ranges through the last decay, the antenna designs in these ranges still under investigation and studies to complete the vision of the proposed designs for the aforementioned applications. Thus, they cannot be carried by the optimum response and efficiency for these applications. This thesis aims to introduce a comprehensive study for the main applications that occupy these ranges of frequencies. In addition to introduce efficient antennas for each application with acceptable technology for it.

As the automotive radar sensors play an important role in driver safety and assist him in the actions, the antennas that are used in this application is a key component in the sensor because they need to provide high gain to increase the radar range and to provide wideband to increase the radar resolution. The virtual antenna array (VAA) concept is introduced to provide low profile radar antenna array with high gain and serve the long range radar (LRR) and medium range radar (MRR). The analysis of VAA are introduced and verified. The antenna is fabricated and measured. Furthermore, hybrid linear antenna arrays with two different configurations are introduced to achieve a suitable

range and HPBW for LRR. The frequencies that can be used for automotive radar sensors are 24 GHz and 76 GHz and the two bands are covered in this thesis.

The second contribution in this thesis is introducing an antenna for one of the future communication systems (5G). The proposed antenna has a dual polarization to overcome the high losses at 28 GHz (the best recommended band for 5G). Furthermore, the multiple input multiple output (MIMO) antenna for 5G is introduced with a complete study of the MIMO parameters. This antenna is based on characteristic mode analysis to study the performance of the antenna. The metasurface is combined with the slot antenna to enhance its performance and increases the gain. The detailed illustrations of the dual-polarized antenna for handheld 5G systems with the comprehensive study of the interaction of an antenna with the human body and vice versa are taken to our consideration. The antenna is fabricated and measured.

The third contribution in this dissertation mainly focused on the antennas design for short communications and multi-Giga-bit data rate applications. Two different endfire on chip antenna (OCA) using CMOS technology are introduced. These antennas succeeded to achieve high performance compared to the previous published OCAs because of the integration between different techniques to increase the radiation characteristics of these antennas. These antennas are Yagi-uda antenna and tapered slot Vivaldi antenna. Furthermore, to overcome the high losses and high attenuation at 60 GHz, a MIMO on-chip antenna is introduced. Three different configurations from two elements MIMO are introduced in addition to one configuration from four elements MIMO based on diversity technique to increase the isolation between the elements is also introduced. In terms of on-chip antenna, it is observed that the introduced MIMO antenna overcomes high CMOS losses.

The last contribution in this thesis is an antenna array that is based on the dielectric waveguide and silicon on glass technology. The mode analysis, dielectric rod design, a transition between the metallic waveguide and dielectric waveguide, disc dielectric antenna design are introduced to the antenna array design. The antenna meets the high gain and low profile structure requirements for the sub-THz applications. In addition CPW feeding network is used to be compatible with the other components in the THz devices.

The introduced antennas with different techniques and different technologies in this thesis positively contribute to the millimeter and the sub-THz applications and are expected to enhance the performance of the antennas for automotive radars, 5G handheld devices, multi-giga-bit communications devices, short-range networks, and biomedical imaging.

Key Words: Millimeter antennas, sub-THz, automotive radar sensors, virtual antenna arrays, dielectric resonator antenna, on-chip antennas, hybrid antenna array, Yagi-Uda antenna, Vivaldi antenna, dielectric waveguide, dual polarized antenna, metasurface, characteristic mode analysis, Multiple Input Multiple Output (MIMO).

Thesis supervisors:

- Prof. Dr. Esmat Abdel-Fattah Abdallah
Electronics Research Institute,
Giza, EGYPT.
- Prof. Dr. Hadia Mohammed Said El-Hennawy
Ain Shams University,
Cairo, EGYPT.
- Prof. Dr. Haythm Hussien Abdullah
Electronics Research Institute,
Giza, EGYPT.
- Assoc. Prof. Mohamed Basha
Waterloo University,
Canada.

PUBLICATIONS

A. Journals

1. K. S. Sultan, H. H. Abdullah, E. A. Abdallah, and H. El-Hennawy “MOM/GA-based virtual array for radar systems” MDPI, *Sensors* (Basel, Switzerland), vol. 20, no. 3, pp.1-16, 2020.
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B. Conferences

1. K. S. Sultan, H. H. Abdullah, E. A. Abdallah, M.A. Basha and H. El-Hennawy “A 60-GHz CMOS quasi-Yagi antenna with enhancement of radiation properties” 12th European Conference on Antennas and Propagation (EuCAP 2018), pp. 1-3, April 2018.
2. K. S. Sultan, H. H. Abdullah, E. A. Abdallah, M.A. Basha and H. El-Hennawy “A 60-GHz gain enhanced Vivaldi antenna on-chip” 2018 IEEE International Symposium on Antennas and Propagation, pp. 1821-1822, 8-13 July 2018.
3. K. S. Sultan, H. H. Abdullah, E. A. Abdallah, M.A. Basha and H. El-Hennawy “Dielectric resonator antenna with AMC for long range automotive radar applications at 77 GHz” 2018 IEEE International Symposium on Antennas and Propagation, 8-13 July 2018..
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