AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Electronics and Communications Engineering Department

RF Components Using Nanoparticles

A Thesis

Submitted in partial fulfillment of the requirements of the degree of Doctor of Philosophy in Electrical Engineering

(Electronics and Communications Engineering)

Submitted by:

Shaimaa Ali Mohammed Beeh Mohassieb

M.Sc. in Electrical Engineering

(Electronics and Communications Engineering)

Ain Shams University

Supervised By

Prof. Hadia Mohammed Said El-Hennawy

Prof. Khaled Abdelwahab Kirah

Cairo 2017

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STATEMENT

This dissertation is submitted to Ain Shams University in partial fulfillment for the degree of Doctor of Philosophy in Electrical Engineering (Electronics and Communications Engineering), 2017.

The work included in this dissertation was carried out by the author at the Electronics and Communications Engineering 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.

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ABSTRACT

Inkjet printing is a low-cost technique suitable to fabricate flexible electronic devices using solutions of conductive nanoparticles on a large variety of substrates without material waste as in conventional etching techniques. In this dissertation, low-profile wideband coplanar waveguide-fed monopole antennas operating at 20 GHz are designed and printed using Copper Oxide and Silver nanoparticles inks on flexible substrates. Polyethylene Terephthalate and Epson paper were the chosen flexible substrates. The effects of altering the drop spacing of the ink on the conductivity of the printed films as well as on the antenna parameters were fully investigated by numerical simulations and by measurements. A conductivity of $2.8{\times}10^7\Omega^{-1}\mathrm{m}^{-1}$ was found for the Copper Oxide nanoparticles films printed on Polyethylene Terephthalate using a drop spacing of 20 µm leading to superior antenna performance with an achieved gain and efficiency of 1.82 dB and 97.6%, respectively. On the other hand, antennas on Epson paper substrate show a -10 dB return loss, bandwidth which extends from 17.9 GHz up to 23.3 GHz, leading to a fractional bandwidth of 26.0%.

Thin films printed using Silver nanoparticles on Polyethylene Terephthalate substrate have shown a conductivity of $1.8{\times}10^7\ \Omega^{-1}\mathrm{m}^{-1}$ using a drop spacing of 30 µm. The corresponding coplanar waveguide feed monopole antennas achieved a gain and efficiency of 1.67 dB and 96%, respectively. In addition, the size reduction reached 99% relative to bulk material. Experiments showed that smaller drop spacings lead to bulging of the printed lines while the antenna performance decreases for longer ones. At the same drop spacing, antennas printed on Epson paper substrate showed a -10 dB return loss bandwidth which extends from 17.18 GHz up to 24.3 GHz, leading to a fractional bandwidth of 34.34 %.

Keywords: Inkjet printing, Silver nanoparticles, Copper oxide nanoparticle ink, Drop spacing, Coplanar waveguide monopole antenna, Conductivity.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

IBM	International Business Machines
RF	Radio Frequency
CNT	Carbon Nanotubes
CPW-MA	Coplanar Waveguide Monopole Antenna
CST	Computer System Technology
MWS	Microwave Studios
CVD	Chemical Vapor Deposition
PVD	Physical Vapor Deposition
SEM	Scanning Electron Microscope
TEM	Transmission Electron Microscope
AFM	Atomic Force Microscope
AC	Alternative Current
DC	Direct Current
FIT	Finite Integration Technique
PE	Printed Electronic
RFID	Radio Frequency Identification
UHF	Ultra High Frequency
OLED	Organic Light-Emitting Diode
PCB	Printed Circuit Board
MOD	Metallic Organic Decomposition
DoD	Drop-on-Demand
MEMS	Micro-electromechanical systems
DMP	Dimatix Materials Printed
PET	Polyethylene Terephthalate
SNP	Silver Nanoparticle
VSWR	Voltage Standing Wave Ratio
LPDA	Log Periodic Dipole Array
SLL	Side Lobe Level
AMC	Artificial Magnetic Conductor
BLC	Branch Line Coupler
WBAN	Wireless Body Area Network
HFSS	High Frequency Structure Simulator
IPL	Intense Pulsed Light
XRD	X-ray Diffraction
TL	Transmission Line
BW	Bandwidth
IJPT	Inkjet Printing Technology
DS	Drop spacing
CuONP	Copper Oxide Nanoparticle
VNA	Vector Network Analyzer
DAAD	Deutscher Akademischer Austausch Dienst