AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electronics Engineering and Electrical Communications

Microwave Circuits and Systems for UWB Applications

A Thesis submitted in partial fulfilment of the requirements of the degree of

Master of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

by

Shaimaa Abdelaziz Mahmoud Osman

Bachelor of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

Faculty of Engineering, Helwan, 2006

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Statement

This thesis is submitted as a partial fulfilment of Master of Science in Electrical Engineering Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

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Abstract

Ultra-wideband (UWB) applications have captured attention as a high-speed secured wireless communications with extremely low power consumption. There are many challenges when dealing with these new applications. One of them is how to design a power divider (PD) that can perform effectively in the entire UWB frequency range from 3.1 GHz to 10.6 GHz. This thesis mainly focused on designing power dividers for UWB systems. The performance criteria of power divider such as insertion loss, output ports isolations and return loss are discussed as well as PD different design methodologies and technologies. Different techniques to enhance the performance of power divider are investigated and tested, such as bandwidth broadening, isolation enhancement and matching improvement.

A novel N-way power divider design for UWB systems is developed. The design is realized using two cascaded sections of Wilkinson PD of equal characteristic impedances and unequal electrical lengths with inserted open stub on each section to enhance the isolation, matching and to broaden the bandwidth. The analytical solution for the designed N-way power dividers is based on two approaches namely "Even-Odd Mode Method" and the "ABCD Matrix" Method. Simple design equations and guidelines are proposed to facilitate the design procedure and limit the usage of CAD simulators and optimizers. To verify the proposed design methodology, 2-way, 3-way and 4-way PD for UWB are designed, simulated and implemented.

The 2-way power divider for UWB systems is tested using EM-Circuit Co-Simulation then fabricated, measured and compared with similar published PD. It has an isolation of better than 13.5 dB within the entire UWB frequency band and has a compact area of 22 * 15 mm^2. Measurement and simulation results agrees well, which verifies the proposed design equations as well as the design procedure. In addition, the proposed circuit is compared to conventional published ones to show the enhancement percentage in different performance parameters, where the 2-way proposed circuit achieves 23% isolation enhancement and better than 45 % of return loss enhancement. The 3-way and 4-way power dividers design equations are introduced along with the suggested planar microstrip implementation. Another 4-way power divider is proposed using three 2-way PD. This method is more realistic in planar microstrip fabrication. This proposed 4-way PD is fabricated, measured and compared to published available ones. It has an isolation of better than 12.5 dB and a return loss of better than 10 dB through the whole UWB range. Furthermore, the exceeded insertion loss is less than 1.8 dB and the occupied area is 40*34 mm^2. Finally, the proposed structures as well as the developed design procedure are very useful for UWB applications.

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Table of Contents

List of Symbols

[S]	Scattering Matrix
μ	Permeability
B	Bandwidth
B_1, B_2	Stub Susceptances
C	Channel Capacity
C	Capacitance
C_L	Left handed Capacitance
C_R	Right handed Capacitance
dB	Decibel
ε_r	Dielectric Constant
f	Frequency
f_c	Center Frequency
F_L	Lower Edge Frequency
F_U	Upper Edge Frequency
GHz	Giga-Hertez, 10^9 Hz
h	Substrate Thickness
IL	Insertion Loss
L	Inductance
l	Physical Length of Transmission Line
L_L	Left handed Inductance
L_R	Right handed Inductance
MHz	Mega-Hertez, 10^6 Hz
N	Number of output ways
n	Refractive Index
NF	Noise Floor
Pi	Incident Power
Pn	Input or Output Port number n where n $\in \{1,2,3,\ldots N+1\}$
Pt	Transmitted Power
R	Resistance
S_{11}	Input Return Loss (Reflection Coefficient)
$S_{21} = S_{31} = S_{41}$	Insertion Loss (Transmission Coefficient)
$S_{22} = S_{33} = S_{42}$ ….	Output Return Loss
$S_{23} = S_{32} = S_{42}$ ….	Output Ports Isolation

S_{nn}^{e}	The Even-mode S-Parameter at port n (Pn) where n ∈{1,2,3,…N+1}
S_{nn}^{o}	The Odd-mode S-Parameter At Pn where n ∈{1,2,3,…N+1}
SNR	Signal to Noise Ratio
t	Conductor Thickness
tanδ	Loss Tangent
V	Voltage
VSWR	Voltage Standing Wave Ratio
Y	Admittance of Transmission line
$Y_{n,in}^{e}$	The Even-mode input admittance at port n, where n ∈{1,2,3,…N+1}
$Y_{n,in}^{o}$	The Odd-mode input admittance at port n, where n ∈{1,2,3,…N+1}
$Y_{n,l}^{e}$	The Even-mode load admittance at port n, where n ∈{1,2,3,…N+1}
$Y_{n,l}^{o}$	The Odd-mode load admittance at port n, where n ∈{1,2,3,…N+1}
Z_{1_oc}	Open-Circuited Stub characteristics impedance
Z_{1_sc}	Short-Circuited Stub characteristics impedance
Z_o	Characteristic Impedance of External Load
Z_{s1}, Z_{s2}	Characteristic Impedance of stub
β	Phase Constant
θ	Electrical length of Transmission Line
λ	Wavelength
ϕ	Equivalent Total Electrical length of Transmission Lines
Ω	Ohm
ω_{se}	Series Resonance
ω_{sh}	Shunt Resonance

List of Abbreviations

ADS	Advanced Design System
BPF	Band Pass Filter
CMOS	Complementary Metal Oxide Semiconductor
CPLD	Complex Programmable Logic Device
CPW	Co-planar Waveguide
CRLH	Composite Right-Left Handed
CST	Computer Simulation Technology
DC	Direct Current
DGS	Defected Ground Structure
DPA	Digital Pulse Amplifier
DRA	Dielectric Resonator Antenna
DTR	Differential Transmit Reference
EM	Electromagnetic
FCC	Federal Communication Commission
GPS	Global Positioning System
HFSS	High Frequency Structural Simulator
IEEE	Institute of Electrical and Electronics Engineers
IR	Impulse Radio
LH	Left Handed
LNA	Low Noise Amplifier
LPD	Low Probability of Detection
LPI	Low Probability of Intercept
LTCC	Low Temperature Co-fire Ceramic
LTCF	Low Temperature Co-fire Ferrite
MCM	Multi-Chip Module
MIC	Microwave Integrated Circuit
MMR	Multiple Mode Resonator
MTM	Meta-Material
NRI	Negative Refractive Index
OC	Open Circuit
OFDM	Orthogonal Frequency Division Multiplexing
PBG	Photonic Band Gap
PCB	Printed Circuit Board

PD	Power Divider
PMGA	Parallel Micro-Genetic Algorithm
PPM	Pulse Position Modulation
PRH	Pure Right Handed
PSD	Power Spectral Density
QPS	Quadrature Phase Splitter
RF	Radio Frequency
RFID	RF Identification
RH	Right Handed
SC	Short Circuit
SoC	System on Chip
SRD	Step Recovery Diode
SRSSLR	Square Ring Short Stub Loaded Resonator
SIW	Substrate Integrated Waveguide
TL	Transmission Line
UWB	Ultra Wide Band
WBAN	Wireless Body Area Network
WLAN	Wireless Local Area Network
WPD	Wilkinson Power Divider
WPS	Wilkinson Power Splitter

List of Figures