

RF and Microwave Wireless Systems

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To my parents and my family

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Preface

Wireless personal mobile and cellular communications are expected to be one of the hottest growth areas of the 2000s and beyond. They have enjoyed the fastest growth rate in the telecommunications industry—adding customers at a rate of 20–30% a year. Presently, at least six satellite systems are being developed so that wireless personal voice and data communications can be transmitted from any part of the earth to another using a simple, hand-held device. These future systems will provide data and voice communications to anywhere in the world, using a combination of wireless telephones, wireless modems, terrestrial cellular telephones and satellites. The use of wireless remote sensing, remote identification, direct broadcast, global navigation, and compact sensors has also gained popularity in the past decade. Wireless communications and sensors have become a part of a consumer's daily life. All of these wireless systems consist of a radio frequency (RF) or microwave front end.

Although many new wireless courses have been offered at universities and in industry, there is yet to be a textbook written on RF and microwave wireless systems. The purpose of this book is to introduce students and beginners to the general hardware components, system parameters, and architectures of RF and microwave wireless systems. Practical examples of components and system configurations are emphasized. Both communication and radar/sensor systems are covered. Many other systems, such as, the global positioning system (GPS), RF identification (RFID), direct broadcast system (DBS), surveillance, smart highways, and smart automobiles are introduced. It is hoped that this book will bridge the gap between RF/microwave engineers and communication system engineers.

The materials covered in this book have been taught successfully at Texas A&M University to a senior class for the past few years. Half of the students are from RF and microwave areas, and half are from communications, signal processing, solid-state, optics, or other areas. The book is intended to be taught for one semester to an undergraduate senior class or first-year graduate class with some sections assigned to

students for self-study. The end-of-chapter problems will strengthen the reader's knowledge of the subject. The reference sections list the principal references for further reading.

Although this book was written as a textbook, it can also be used as a reference book for practical engineers and technicians. Throughout the book, the emphasis is on the basic operating principles. Many practical examples and design information have been included.

I would like to thank all of my former students who used my notes in class for their useful comments and suggestions. I would also like to thank Mingyi Li, Paola Zepeda, Chris Rodenbeck, Matt Coutant and James McSpadden for critical review of the manuscript. Michelle Rubin has done an excellent job in editing and preparing the manuscript. Taehan Bae has helped to prepared some of the art work. Finally, I wish to express my deep appreciation to my wife, Suh-jan, and my children, Peter and Nancy, for their patience and support.

KAI CHANG

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Acronyms

AF	array factor
AGC	automatic gain control
AM	amplitude modulated
AMPS	advanced mobile phone service
APTS	advanced public transit systems
ASK	amplitude shift keying
ATIS	advanced traveler information system
ATMS	advanced traffic management system
AUT	antenna under test
AVCS	advanced vehicle control system
AVI	automatic vehicle identification
BER	bit error rate
BPF	bandpass filter
BPSK	biphase shift keying
BSF	bandstop filter
BW	bandwidth
CAD	computer-aided design
CDMA	code division multiple access
CEP	circular probable error
CMOS	complementary MOS
CP	circularly polarized
CPL	cross-polarization level
CRTs	cathode ray tubes
CT1/2	cordless telephone 1/2
CTO	cordless telephone O
CVO	commercial vehicle operations
CVR	crystal video receiver
CW	continuous wave

DBS	direct broadcast satellite
DC	direct current
DECT	digital european cordless telephone
DR	dynamic range
DRO	dielectric resonator oscillator
DSB	double side band
DSSS	direct-sequence spread spectrum
ECCMs	electronic counter- countermeasures
ECMs	electronic countermeasures
EIRP	effective isotropic radiated power
EM	electromagnetic
ESM	electronic support measure
EW	electronic warfare
FCC	Federal Communications Commission
FDD	frequency division duplex
FDM	frequency division multiplexing
FDMA	frequency division multiple access
FETs	field-effect transistors
FFHSS	fast frequency- hopping spread spectrum
FHSS	frequency-hopping spread spectrum
FLAR	forward-looking automotive radar
FMCW	frequency-modulated continuous wave
FM	frequency modulated
FNBW	first-null beamwidth
FSK	frequency shift keying
GEO	geosynchronous orbit
GMSK	Gaussian minimum shift keying
GPS	global positioning system
GSM	global system for mobile communication
G/T	receiver antenna gain to system noise temperature ratio
HBTs	heterojunction bipolar transistors
HEMTs	high-electron-mobility transistors
HPA	high-power amplifier
HPBW	half-power beamwidth
HPF	high-pass filter
IF	intermediate frequency
IFM	instantaneous frequency measurement
IL	insertion loss
IMD	intermodulation distortion
IM	intermodulation
IMPATT	impact ionization avalanche transit time device
IM3	third-order intermodulation
IP3	third-order intercept point
I/Q	in-phase/quadrature-phase
IVHS	intelligent vehicle and highway system

JCT	Japanese cordless telephone
J/S	jammer-to-signal
LAN	local area network
LDMS	local multipoint distribution service
LEO	low earth orbit
LNA	low-noise amplifier
LO	local oscillator
LOS	line-of-sight
LPF	low-pass filter
LP	linearly polarized
MDS	minimum detectable signal
MEO	medium-altitude orbit
MESFETs	metal–semiconductor field-effect transistors
MIC	microwave integrated circuit
MLS	microwave landing system
MMIC	monolithic microwave integrated circuits
MSK	minimum shift keying
MTI	moving target indicator
NMT	Nordic mobile telephone
OQPSK	offset-keyed quadriphase shift keying
PAMELA	pricing and monitoring electronically of automobiles
PA	power amplifier
PAE	power added efficiency
PCM	pulse code modulation
PCN	personal communication networks
PCS	personal communication systems
PDC	personal digital cellular
PHS	personal handy phone system
PLL	phase-locked loops
PLO	phase-locked oscillators
PM	phase modulation
PN	pseudonoise
PRF	pulse repetition frequency
PSK	phase shift keying
8-PSK	8-phase shift keying
16-PSK	16-phase shift keying
QAM	quadrature amplitude modulation
QPSK	quadriphase shift keying
RCS	radar cross section
RF	radio frequency
RFID	radio frequency identification
RL	return loss
SAR	synthetic aperture radar
SAW	surface acoustic wave
SEP	spherical probable error

SFDR	spurious-free dynamic range
SFHSS	slow frequency- hopping spread spectrum
SLL	sidelobe levels
SMILER	short range microwave links for european roads
SNR	signal-noise ratio
SOJ	stand-off jammer
SPDT	single pole, double throw
SPST	single pole, single throw
SP3T	single pole, triple throw
SQPSK	staggered quadriphase shift keying
SS	spread spectrum
SS-CDMA	spread spectrum code division multiple access
SSJ	self-screening jammer
SSMI	special sensor microwave imager
STC	sensitivity time control
TACS	total access communication system
TDM	time division multiplexing
TDMA	time division multiple access
TE	transverse electric
TEM	transverse electromagnetic
TM	transverse magnetic
TOI	third-order intercept point
T/R	transmit/receive
TWTs	traveling-wave tubes
UHF	ultrahigh frequencies
VCO	voltage-controlled oscillator
VHF	very high frequency
VLf	very low frequency
VSWR	voltage standing-wave ratio
WLANs	wireless local-area networks