

# Contents

<b>1</b>	<b>Introduction</b>	<b>1</b>
<b>2</b>	<b>Propagation in the Nonradiative Dielectric Waveguide (NRD-guide)</b>	<b>7</b>
2.1	Longitudinal Section Electric (LSE) Modes . . . . .	10
2.1.1	Even LSE Modes . . . . .	11
2.1.2	Odd LSE Modes . . . . .	13
2.2	Longitudinal Section Magnetic (LSM) Modes . . . . .	15
2.2.1	Even LSM Modes . . . . .	16
2.2.2	LSM Odd Modes . . . . .	17
2.3	Field Solutions for the Fundamental Modes . . . . .	17
2.4	A Graphical Method for Solutions of the Eigenvalue Equations and Determination of Cutoff-Frequencies . . . . .	20
2.5	Loss Calculation . . . . .	25
2.5.1	Time-Average Power Flow . . . . .	26
2.5.2	Transmission Loss due to Imperfect Conductors . . . . .	27
2.5.3	Transmission Loss due to Imperfect Dielectrics . . . . .	30
<b>3</b>	<b>Fixed Beam Antenna for Point-to-Point Applications</b>	<b>39</b>
3.1	Antenna Design . . . . .	40
3.2	Design and Simulation of Components . . . . .	42
3.2.1	Configurations for Excitation of an NRD-guide . . . . .	42
3.2.2	Feeding Network . . . . .	47
3.2.3	T-junctions . . . . .	48
3.2.4	Sub Arrays . . . . .	50
3.3	Complete Antenna Array . . . . .	52
<b>4</b>	<b>Dual Polarization Antennas</b>	<b>57</b>
4.1	Dual Polarization Antenna Fed by a Dual Mode SINRD-guide . .	59
4.1.1	Design and Characterization of a Dual Mode Transition .	62
4.1.2	Design and Simulation of a Transition from Dual Mode NRD-guide to Crossed Microstrip Lines . . . . .	68
4.1.3	Design of the Dual Polarization Radiating Element . . . . .	72
4.1.4	Measurements on the Dual Polarization Antenna . . . . .	73

4.1.5	A Transition Microstrip Line to NRD-guide for Simulta-	
	neous Excitation of Both Modes . . . . .	78
4.2	Dual Polarization Antenna Array with Optimized Feeding Network	79
4.2.1	NRD-guide Circuit Elements . . . . .	81
4.2.2	Measurements of Dual Mode NRD-guide Test Circuits . .	92
4.2.3	Measurements of the Linear Array of $2 \times 2$ Sub Arrays . .	100
<b>5</b>	<b>A Low Cost Low Profile Scanning Receiver Array</b>	<b>107</b>
5.1	Introduction . . . . .	107
5.1.1	Motivation for Automotive Sensors . . . . .	107
5.1.2	Comparison of Sensor Types . . . . .	107
5.1.3	Applications of Radar Sensors . . . . .	108
5.1.4	System Requirements . . . . .	108
5.1.5	Beam Switching and Steering Approaches with Increased Angular Resolution . . . . .	109
5.2	Antenna Design . . . . .	114
5.3	Design and Simulations of the Components . . . . .	115
5.3.1	Design and Simulations of Hybrid Couplers . . . . .	115
5.3.2	Design of a Balanced Mixer with an NRD-guide LO Feed	121
5.4	Performance of the Scanning Receiver Array . . . . .	125
5.5	Two-path Band-pass Filters for a Steeper Phase Increment . . .	127
<b>6</b>	<b>Summary</b>	<b>131</b>
<b>A</b>	<b>Appendix</b>	<b>135</b>
A.1	Design Details on the Components of the Dual Polarization Antenna	135
A.1.1	Dual Mode Transition from NRD-guide to Microstrip Line	135
A.1.2	Dual Mode NRD-guide T-junction . . . . .	137
A.1.3	Dual Mode Transition from NRD-guide to Crossed Mi- crostrip Lines . . . . .	138
A.2	Layouts of the NRD-guide Fed Antennas . . . . .	139
<b>Bibliography</b>		<b>143</b>