

Contents

Kurzfassung	I
Abstract	III
Acronyms	VII
1 Introduction	1
1.1 Organization of this Thesis	4
1.2 Contributions	4
1.3 Radar Fundamentals	5
1.3.1 Pulsed Radar	5
1.3.2 Frequency Modulated Radar	8
2 Noise Modulated Radar	11
2.1 Correlation	12
2.2 Maximum Length Sequences	14
2.3 Effects of Nonlinearities	18
2.4 M-Sequence Radar	22
3 M-Sequence Generation	25
3.1 Discrete Linear Feedback Shift Register (7-Bit CML)	27
3.2 Discrete Sparse LFSR (11-Bit CML)	33
3.3 Shift Register as Integrated Circuit (9-Bit ECL)	37
3.4 Programmable Logic	41
3.5 Conclusions	47
4 Distance Measurement	51
4.1 Design	53
4.2 Implementation	56
4.2.1 Transmitter	56
4.2.2 Receiver	57
4.2.3 Prototype Hardware	60
4.3 Measurement Setup	60



4.4	Prototype Characterization	64
4.4.1	IQ Balance	66
4.4.2	Distance Measurement	68
4.5	Conclusions	74
5	Synchronization System	75
5.1	Synchronization Concept	79
5.2	Implementation	84
5.2.1	Carrier Recovery	87
5.2.2	Demodulation	93
5.3	Characterization and Measurements	93
5.3.1	Characterization in the Lab	95
5.3.2	Real-world Measurements	97
5.4	Conclusions and Future Work	99
6	Ground Penetrating Radar	103
6.1	Introduction to Ground Penetrating Radar	104
6.2	Implementation	107
6.2.1	Analog Front-end	109
6.2.2	Field Programmable Gate Array	111
6.2.3	Clock Generation	113
6.2.4	Prototype Hardware	113
6.2.5	Antennas	114
6.3	Characterization	119
6.3.1	Prototype Performance	119
6.3.2	Real-world Measurements	123
6.3.3	Reference Measurement	127
6.4	Conclusions	130
7	Conclusions and Future Work	131
Bibliography		137