

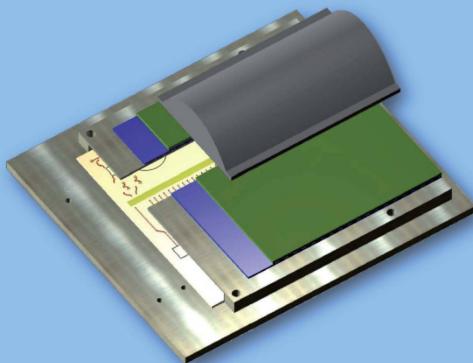


Peter Feil (Autor)

Broadband mm-Wave Sensors for Industrial and Security Applications

Peter Feil

**Broadband mm-Wave Sensors for
Industrial and Security Applications**



Cuvillier Verlag Göttingen

<https://cuvillier.de/de/shop/publications/6298>

Copyright:

Cuvillier Verlag, Inhaberin Annette Jentzsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen,
Germany

Telefon: +49 (0)551 54724-0, E-Mail: info@cuvillier.de, Website: <https://cuvillier.de>



Contents

1	Introduction	1
2	Fundamentals of Radar Principles and Signal Processing	5
2.1	Radar Principles	6
2.1.1	Coherent Pulse Radars	6
2.1.2	Analytical Description of the Radar Channel	7
2.1.3	Pulse Compression	8
2.2	Theory of FM-CW Radars	10
2.2.1	Mathematical Description of FM-CW Radars	12
2.2.2	Comparison to SF-CW radars	14
2.3	Fundamentals of Spectral Estimation	15
2.3.1	Processing of Time Limited Datasets	16
2.3.2	Model-Based Spectral Estimation	21
2.3.3	Spectral Estimation of Deterministic Signals	23
2.3.4	Enhancing the Resolution using Linear Prediction	24
2.3.5	Eigenanalysis-based Techniques	27
2.4	Wideband Calibration of FM-CW Sensors	28
2.4.1	Calibration of the Sensor Ringing or Offset	29
2.4.2	Correction of the Signal Dispersion	29
2.5	Doppler Processing and Velocity Measurement	32
2.5.1	Resolving Range Doppler Ambiguities by Triangular Modulation	33
2.5.2	Phase Processing of Pulse Trains	34
2.6	Digital Beamforming	37
2.6.1	Narrow Band Data Model	38
2.6.2	Conventional Beamformers	39
2.6.3	Correlation Matrix in Beamforming Applications	41
2.6.4	Adaptive Beam Formers	42
2.6.5	Two-Dimensional Imaging	48
2.6.6	Broadband True Time Delay Beamformer	49
3	Broadband FM-CW Sensor at 78 GHz	53
3.1	Overview and Operating Modes	53



Contents

3.2	Processing Technology and Interconnects	55
3.2.1	Microstrip Line-to-Waveguide Transition	56
3.2.2	Planar mm-Wave Components	59
3.3	FM-CW Synthesiser	60
3.3.1	Modelling and Performance of Direct Digital Synthesisers	61
3.3.2	Phase-Locked Loop Design	63
3.4	Analogue DC and Baseband Electronics	65
3.4.1	Intermediate Frequency Filtering Stage	66
3.5	Comprehensive FM-CW Model and Simulation Results	68
3.6	Performance Evaluation	73
3.7	Advanced Operating Modes	76
3.7.1	Heterodyne Reception with Periodically Modulated LO .	76
3.7.2	Leakage Phase Noise Suppression	77
3.7.3	Phase Noise Cancellation Using a Dual Channel Mixer .	79
4	Imaging Sensor with Switched Transmit Antenna Array	81
4.1	Switching Network and Patch Array	82
4.2	Cylindrical Lens Design and Farfield Characteristics	83
4.3	Coarray-based Beamforming for not Fully Populated Arrays . . .	90
4.4	Measurement Results Obtained with the Switched DBF Sensor .	92
4.4.1	Measurement of Point Scatterers	92
4.4.2	Measurement of a Complex Environment	95
4.5	Imaging of Moving Targets using a Switched Sensor Array . . .	98
4.5.1	Optimised Switching Sequence for Reduced Doppler Sensitivity	99
4.5.2	ESPRIT-based Subarray Approach for Doppler Mitigation	103
5	Applications Investigated with the Developed Sensors	105
5.1	Runway Surveillance	105
5.1.1	Antenna Concept	105
5.1.2	Signal Processing	110
5.1.3	Experimental Results	111
5.2	MM-Wave Synthetic Aperture Radar	115
5.2.1	SAR Demonstrator Setup	115
5.2.2	Modes of Operation and Signal Processing	116
5.2.3	Performance Evaluation in Stripmap Mode at 77 GHz .	116
5.2.4	Spotlight Operation at 24 GHz	119
5.2.5	Three Dimensional Combined SAR and DBF Processing at 24 GHz and 77 GHz	120
5.2.6	Further Applications	126

6 Summary and Conclusion	127
A Appendix	129
A.1 Noise Modelling Using Rice's Second Model	129
A.2 Single Sideband Phase Noise Spectrum	129
A.3 Phase Noise Cancellation Factor	130
A.4 Correlation Sequence and Matrix	131
Bibliography	135