Contents

Zusammenfassung i

Abstract iii

1 Introduction 1
- 1.1 Overview . . . 1
- 1.2 Clinical Requirements . . . 3
- 1.3 Thesis Objectives . . . 5
- 1.4 Thesis Structure . . . 6

2 Background in EM Tracking 9
- 2.1 Chapter Overview . . . 9
- 2.2 Background Theory . . . 9
- 2.3 Extensions and the State of the Art in EM Tracking . . . 13
  - 2.3.1 EMTS Prototypes Proposed by Research Groups . 13
  - 2.3.2 Commercial EMTS . . . 16
- 2.4 The Experimental Setup . . . 19
- 2.5 Chapter Discussion . . . 22

3 Reduction of Metallic Distortions 25
- 3.1 Chapter Overview . . . 25
- 3.2 Classifications of Metallic Distortions . . . 25
- 3.3 Related Work . . . 26

Bibliografische Informationen
http://d-nb.info/1154619400

digitalisiert durch DEUTSCHE NATIONAL BIBLIOTHEK

3.3.1 Increasing Source Distance 27
3.3.2 Calibration Technology 27
3.3.3 Magnetic Shielding 29
3.3.4 Paused DC Tracking 32
3.3.5 Ultra–low Frequency Input Signals 32
3.3.6 Quadratic–Rectangular Excitation Based Method . 34
3.4 The Ramp Excitation 37
3.4.1 Equivalent Circuit 37
3.4.2 System Analysis with Ramp Excitation 38
3.4.3 Simulation 41
3.4.4 Time Constant Measurement 44
3.5 System Implementation 46
3.6 Experiment and Evaluations 47
3.6.1 Measurement of Refresh Rate 47
3.6.2 Measurement of Tracking Latency 47
3.6.3 Measurement of Tracking Precision 48
3.6.4 Test of Free–hand Mobile Distortion 50
3.6.5 Test of Distance-dependant Distortions 52
3.6.6 Measurement of Distortions from Different Sources 53
3.7 Results 54
3.8 Chapter Discussion 60
3.9 Future Work 62
3.10 Chapter Conclusion 63

4 System Implementation **65**
4.1 Chapter Overview 65
4.2 Signal Generation and Data Acquisition 65
4.2.1 Time Division Multiplexing 65
4.2.2 Frequency Division Multiplexing 68
4.2.3 The Improved TDM 72
4.3 DDS Waveform Generation in FPGA 74

4.3.1 DDS Principle 74
4.3.2 Frequency, Phase, and Amplitude Adjustment . . . 76
4.4 Data Acquisition in FPGA 80
4.5 Analysis of the Generated and Measured Signals 81
4.6 Chapter Conclusion 85

5 Advanced Error Analysis using an EMTS Simulator 87
5.1 Chapter Overview 87
5.2 Sources of Errors 88
5.2.1 Errors in Voltage Measurement 88
5.2.2 Errors in Voltage Estimation 89
5.2.3 Errors in Algorithm Convergence 90
5.2.4 Errors in Over–speed Sensor Movement 91
5.2.5 Errors in the Registration Processes 92
5.3 Methods in Accuracy Evaluation 93
5.3.1 Phantom Based Assessment 94
5.3.2 Modular Bricks Based Assessment 95
5.3.3 Robotic Based Assessment 96
5.3.4 Optical–tracking Based Assessment 97
5.3.5 Section Discussion 97
5.4 The Simulator Development 98
5.5 Accuracy Evaluation Using the Developed EMTS Simulator 101
5.6 Advanced System Analysis Using the Simulator 102
5.6.1 Accuracy Variations with the Changes in the Spatial Arrangement of the Transmitter Coils 102
5.6.2 Optimization of the Spatial Arrangement of the Transmitter Coils 104
5.6.3 Testing the Performance of the Calibration algorithm 110
5.6.4 Testing of Kalman Filter Performance 115
5.6.5 Testing of Updating Initial Guess of the Pose Estimation Algorithm 119

5.7 Chapter Discussion 121
5.8 Chapter Conclusion 123

6 Summary and Future Work **125**

A Documentation of Designed Simulator **129**
A.1 The GUI Design 129
A.2 Quick Start Guide 132
A.3 Optimization of the Transmitter Coils Arrangement . . . 133

Acknowledgement **134**

Bibliography **149**

Nomenclature **150**

List of Publications **151**