

List of Figures

Figure 1. 1: The mind map used in this thesis.	4
Figure 2. 1: Range of rocks and minerals resistivity [36].....	9
Figure 2. 2: Basic principle of geoelectrical resistivity methods.....	10
Figure 2. 3: Current injection at the surface.	11
Figure 2. 4: Current injection by a pair of current electrodes through the subsurface and potential difference measurement on the surface relate to equipotential field superposition due to current injection on current electrodes.....	12
Figure 2. 5: The arrangement of electrodes in wenner configuration [38].	13
Figure 2. 6: The arrangement of electrodes in schlumberger configuration [38].	14
Figure 2. 7: The arrangement of electrodes in dipole-dipole configuration [38].	15
Figure 2. 8: The distance of potential electrodes to current electrodes in dipole-dipole configuration.....	15
Figure 2. 9: Dipole-dipole configuration as a multi-channel system on resistivity method. .	17
Figure 2. 10: VES technique on electrical resistivity method.....	18
Figure 2. 11: ERT technique on electrical resistivity method.....	18
Figure 2. 12: Computer-controlled multielectrode systems on conventional equipment of resistivity method using dipole-dipole configuration.	19
Figure 2. 13: Potential divider circuit.	20
Figure 2. 14: Controlling, Monitoring and Controlling-Monitoring in WSN.....	22
Figure 2. 15: Types of nodes and network topology on Wireless Sensor Network.....	22
Figure 2. 16: Comparison of Wireless Communication Technology.	25
Figure 3. 1: System design of Resistivity meter multinode.	28
Figure 3. 2: Scheme of the main unit.	28
Figure 3. 3: 3D scheme of the main unit.....	29
Figure 3. 4: Injection current selection block circuit.	30
Figure 3. 5: Diagram Control of Main Unit Block.	31
Figure 3. 6: Circuit model when injecting current to the ground. (a). The earth is directly connected to the 400VDC Boost Converter (b). The earth is connected to a particular power resistor.....	32
Figure 3. 7: The scheme of Multinode block.	34
Figure 3. 8: 3D circuit of node on Multinode block.	34
Figure 3. 9: Data Acquisition during the measurement in land field.....	36

Figure 3. 10: Datum point from Wireless GERM System with total nodes are 5 nodes.	37
Figure 3. 11: Architecture of Wireless communication between main unit block and multinode block on Wireless-GERM System.....	38
Figure 3. 12: Time series on Wireless-GERM System to ensure Potential Difference measurement on multinode is due to Current Injection on Main Unit.....	39
Figure 3. 13: Block diagram of Geo-electric Resistivity Meter Multinode system.	40
Figure 3. 14: Format of the research data (apparent resistivity) is adjusted to requirement of Multinode.....	40
Figure 3. 15: Flowchart of optimization algorithm for Wireless-GERM System on Main Unit Block.....	42
Figure 3. 16: Flowchart of optimization algorithm for Wireless-GERM System on Multinode Block.....	43
Figure 4. 1: TTGO LoRa ESP32 V2.1.....	45
Figure 4. 2: Packet delivery testing on TTGO LoRa ESP32 V2.1.	46
Figure 4. 3: Testing scheme for checking the availability of current injection selection.	47
Figure 4. 4: Testing scheme for Lab Scale CRM mode testing.	49
Figure 4. 5: Resistance measurement on CRM mode using INA219.	50
Figure 4. 6: Testing scheme for field scale CRM mode testing.....	51
Figure 4. 7: Comparisons of Earth resistance measurement using Contact Resistance Measurement (CRM) mode with INA219 in dry and hydrated soils.....	52
Figure 4. 8: Testing scheme to validate current sensor WCS1800 on Lab Scale.	54
Figure 4. 9: Current measurements by WCS1800 sensor on lab scale measurement for each resistance value (20 ohms, 50.91 ohms, 80 ohms, and 100 ohms) with 12 volts, respectively, yield the average currents of 643.7 mA, 246.0 mA, 162.1 mA, and 143.2 mA.	54
Figure 4. 10: Testing scheme to validate current sensor WCS1800 on Field Scale	56
Figure 4. 11: Current measurement by WCS1800 sensor on field scale measurement.	57
Figure 4. 12: Temperature of power resistor on Main unit block after injection. (Rx is a dummy resistor that is connected to the model).	58
Figure 4. 13: Testing scheme to define the accuracy and variability of INA219 sensor readings.....	60
Figure 4. 14: Voltage Measurement's Absolute Error on INA219 Sensors Readings.	60
Figure 4. 15: Voltage Measurement's Relative Error on INA219 Sensors Readings.	61
Figure 4. 16: Current Measurement's Absolute Error on INA219 Sensors Readings.....	62
Figure 4. 17: Current Measurement's Relative Error on INA219 Sensors Readings.....	63
Figure 4. 18: The testing scheme of estimating resistance between potential electrodes on CRM mode.....	65

Figure 4. 19: Estimating Resistance on CRM mode Between Potential Electrodes.	66
Figure 4. 20: The accuracy and variability of the estimation resistance between potential electrodes testings.	67
Figure 4. 21: The difference in relative errors for nodes between properly connected electrodes and non-connected properly electrodes.	68
Figure 4. 22: The scheme of potential difference measurement testing on multinode block.	69
Figure 4. 23: Mean Absolute Percentage Errors of Potential Difference Measurement Mode by INA219 on Multinode.	69
Figure 4. 24: Relative Errors of Potential Difference Measurement Mode by INA219 on Multinode.	71
Figure 4. 25: Time series in the Geo-electrical resistivity meter multinode communication.	72
Figure 4. 26: Given model with a certain resistor on each layer.	73
Figure 4. 27: The testing scheme for evaluating the performance of the GERM system in measuring resistivity.	73
Figure 4. 28: The stored data of the GERM system in measuring resistivity.	74
Figure 4. 29: The inverted measurement data resistivity of Wireless-GERM using Res2DInv.	74
Figure 4. 30: The latency of transmitting data on Geo-electrical Resistivity Meter Multinode.	75
Figure 4. 31: Field scale testing location at Cikeruh river in the East Bandung Basin.	78
Figure 4. 32: Validating Wireless GERM system on Geophysical exploration (a) comparison of its physical setup with commercial instruments, Supersting R8, (b) comparison of the size of main controller on the system.	79
Figure 4. 33: The example of measurement results at the node; (a) CRM mode and (b) Potential difference measurement mode.	80
Figure 4. 34: The stored data of field scale testing at Cikeruh River on East Bandung Basin.	81
Figure 4. 35: Profile resistivity comparison of Wireless Geo-Electrical Resistivity Meter and AGIS Supersting R8.	82
Figure 4. 36: Absolute and relative error on WCS1800 sensor readings in lab scale measurement.	84
Figure 4. 37: Absolute and relative error on WCS1800 sensor readings in field scale measurement.	85