ARC BENCHMARKING EQUIPMENT

VERSION 1.27

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1. TEST EQUIPMENT

1.1 Design and Description

The test equipment was designed and developed to produce accurate, consistent, and repeatable RF measurements. A layout of the test equipment is shown in Figure 1. The major components of the setup are the anechoic chamber, the rotating test platform, the antennas, the cables, and the measurement unit. The test equipment can measure performance of RFID inlays for a variety of use cases.

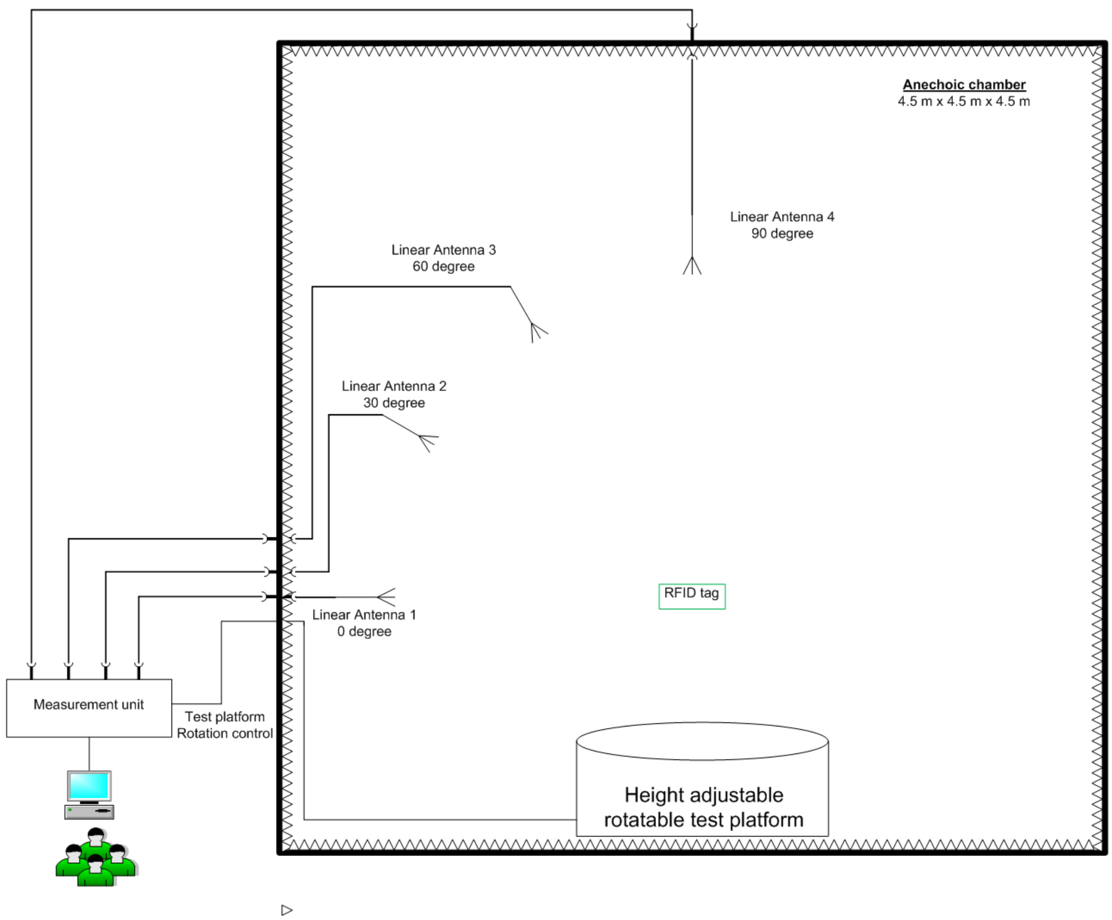

Figure 1: High Level Layout of Test Equipment

1.1.1 Anechoic chamber

The anechoic chamber was designed to eliminate reflections of electromagnetic waves and provide an environment to accurately measure performance of RFID inlays. The chamber is made of steel and sealed with copper lining to prevent any external interference. All the internal surfaces of the chamber are lined with pyramidal radio absorbent material which prevents RF waves from reflecting in the test environment. The height of the pyramidal radio absorbent material used in the chamber is 0.3048 meters. The antennas are mounted in the chamber using a frame made of a low dielectric material commercially available as 80/20. The 80/20 is assembled using plastic nuts and bolts. The fiber optic cable for the test platform passes through a wave guide on the wall of the anechoic chamber. Antenna cables attach to connectors through the chamber wall. The height adjustable test platform is located in the center of the chamber. All the other components of the test equipment are kept outside the anechoic chamber.

The external length, width and height of the chamber are 4.5 meters, 4.5 meters and 4.5 meters respectively. The chamber size is designed so that the tagged product will be in far field of the test antennas for test products up to the size of a pallet. The anechoic chamber is accessible through a steel door measuring 1.22 meters wide and 2.13 meters high. The interior of the door is lined with radio absorbent material. The edges of the chamber and the door are lined with copper strips to prevent external interference when the door is closed. An exterior view of the anechoic chamber is shown in Figure 2.

Figure 2: Anechoic Chamber

1.1.2 Test platform

The anechoic chamber has a height-adjustable and rotating testing platform. The platform has a low dielectric constant, and was chosen for its ability to support heavy test products with minimum electromagnetic interference. The platform has a diameter of

1.22 meters and thus has a surface area of 1.17 square meters. The height of the platform can be adjusted from 0.6 meters to 1.2 meters above the floor of the chamber, and is adjusted depending upon the dimensions of the test product.

To further minimize the interference of the turntable test platform, a smaller platform made of 80/20 topped with Styrofoam blocks (dielectric constant of 1.05) is used. This additional platform is placed on the larger platform when the test products are of low weight and size.

The rotation of the test platform is performed using a stepper motor, which is directly controlled by the measurement unit. As a result, the test platform can be rotated 360 degrees, in increments of 1 degree, with variable dynamically adjustable acceleration and velocity.

1.1.3 Antennas and cables

Four linearly polarized patch antennas are used in the test setup. The antennas' vertical linear polarizations have been rotated and mounted horizontally, so that they are in parallel with the floor of the chamber. The antennas have an average gain of 8 dBi in 800 MHz to 1000 MHz frequency range. The antennas have VSWR less than 1.4 in the 800 MHz to 1000 MHz frequency range. The antennas are commercially available and manufactured by HUBER+SUHNER. Detailed antenna parameters can be found in Appendix B.

The antennas are mounted at angles of 0 degrees, 30 degrees, 60 degrees and 90 degrees with respect to the floor of the chamber. The 0 degree, 30 degree, 60 degree and 90 degree antennas are named Antenna 1, Antenna2, Antenna 3 and Antenna 4, respectively. Antenna 1 is mounted with its horizontal polarization plane parallel to the floor of the anechoic chamber. The rest of the three antennas—Antenna 2, Antenna 3 and Antenna 4—are mounted in a similar way, with their horizontal polarization parallel to the horizontal polarization of Antenna 1. The antenna configuration with respect to the inlay and the test platform is shown in Figure 3. A photograph of the antennas and the test platform is shown in Figure 4.

The antennas are directed at a single incident point. This incident point is where the inlay to be tested is positioned, and can be seen in Figure 3. The antennas are mounted and the test platform height is adjusted such that the incident point is exactly above the center of the testing platform, which causes the center of the RFID inlay under test to be at the incident point throughout the entirety of the test platform rotation. Inlays are aligned to the antennas' incident point using laser cross levels.

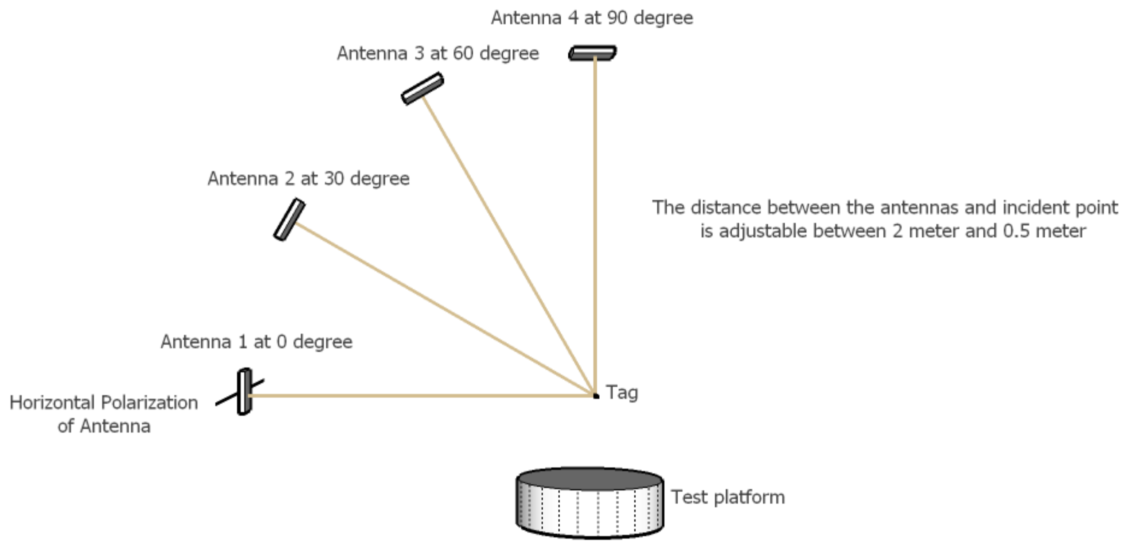

Figure 3: Antenna Configuration

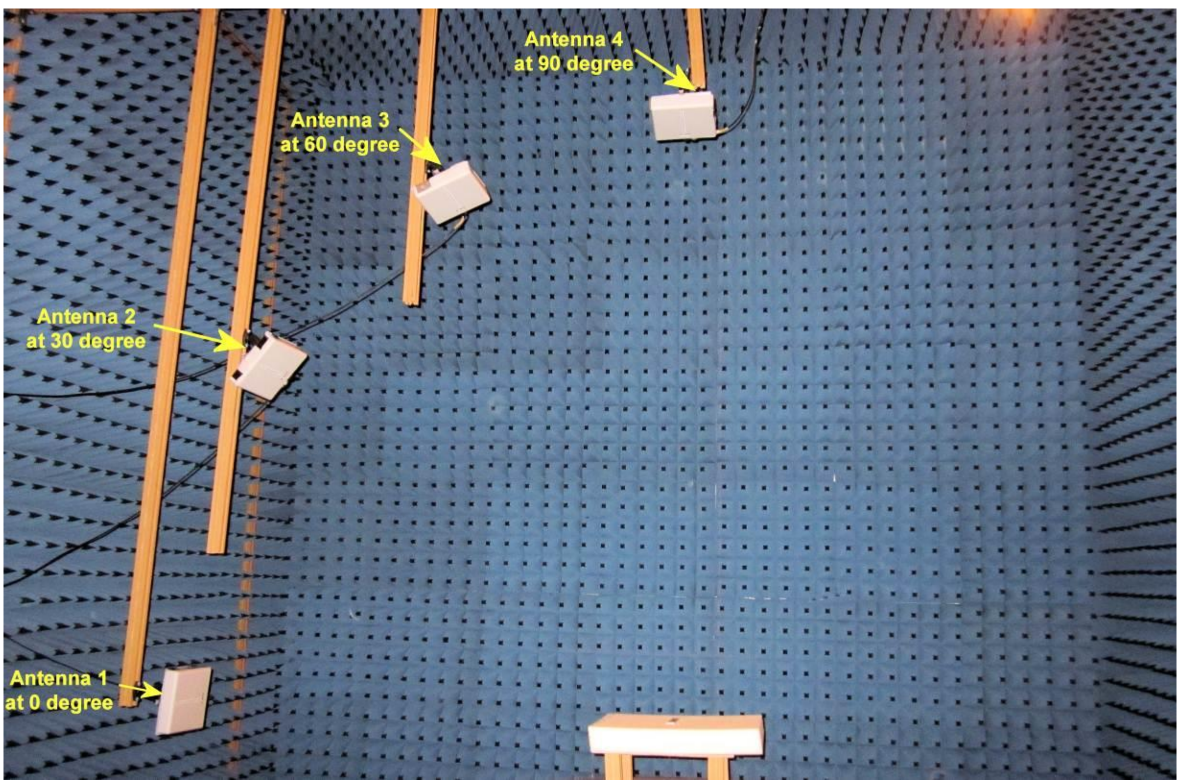

Figure 4: Antenna Configuration

The distances of the antennas from the incident point are individually adjustable between 0.5 meters and 2 meters. The distance from antenna to incident point is based on two considerations: the distance must be short enough that the inlay can be read by the antennas, and the inlay must also be in the electromagnetic far field of each of the test antennas for all measurements. Once an optimal distance is determined, all the antennas are mounted at the same distance from the incident point.

Orientation of the inlay on the test platform with respect to Antenna 4 is shown in Figure 5. The 0 degree position is when the horizontal polarization of the inlay is parallel to the polarization of antenna 4. The 90 degree position is when the horizontal polarization of the inlay antenna is perpendicular to the polarization of antenna 4.

The antennas are monostatic; the forward and return communication happens through the same antenna. The measurement unit can dynamically multiplex between antennas if required during the measurement of an inlay.

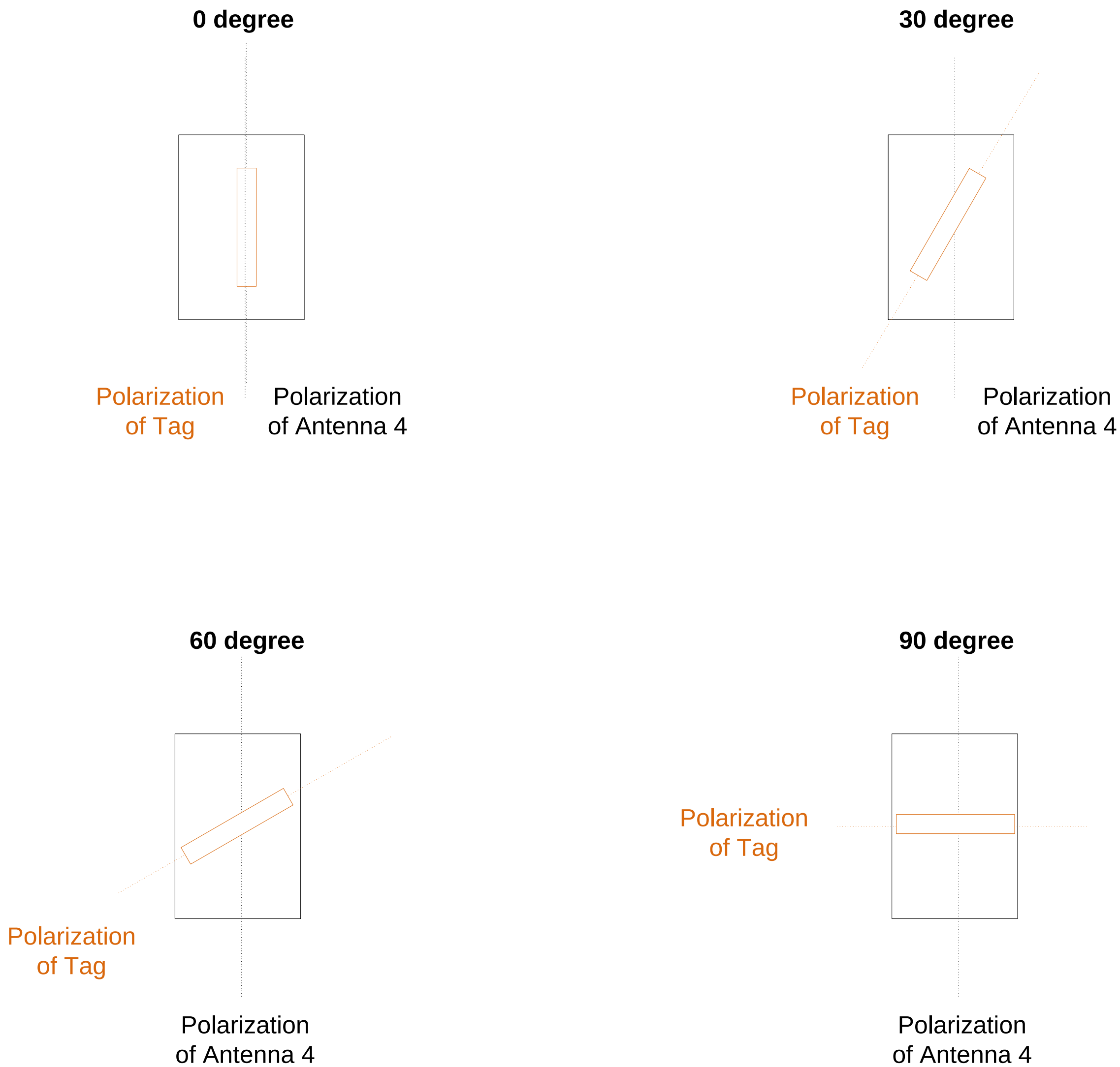

Figure 5: Table Position from Top of Chamber

Coaxial cables are used to connect the antennas to the test equipment. A set of four cables connects the ports of the multiplexer to the through panel on the chamber wall, and another set of four cables connects from the through panel inside of the chamber wall to the antennas.

1.1.4 Measurement Unit

The test equipment can generate, transmit, receive, and process UHF RF communication. The configuration of the measurement unit is shown in Figure 6. The transmitter of the measurement unit is connected to an amplifier to increase the maximum power output offered by the measurement unit. The amplifier is dynamically controlled by the measurement unit to achieve the desired level of power output. The return path has two attenuators with a total attenuation of 9 dBm, which keeps the receiver within its linear dynamic range. Both the transmitter and the receiver of the measurement unit are connected to the multiplexer through a wideband circulator. The circulator has an isolation of at least 20 dB between transmit and receive ports with a 50 ohm load. The circulator is connected to a multiplexer, which interfaces with the measurement unit to the four antennas. The multiplexer is also dynamically controlled by the measurement unit to dynamically switch between antennas during the measurement process.

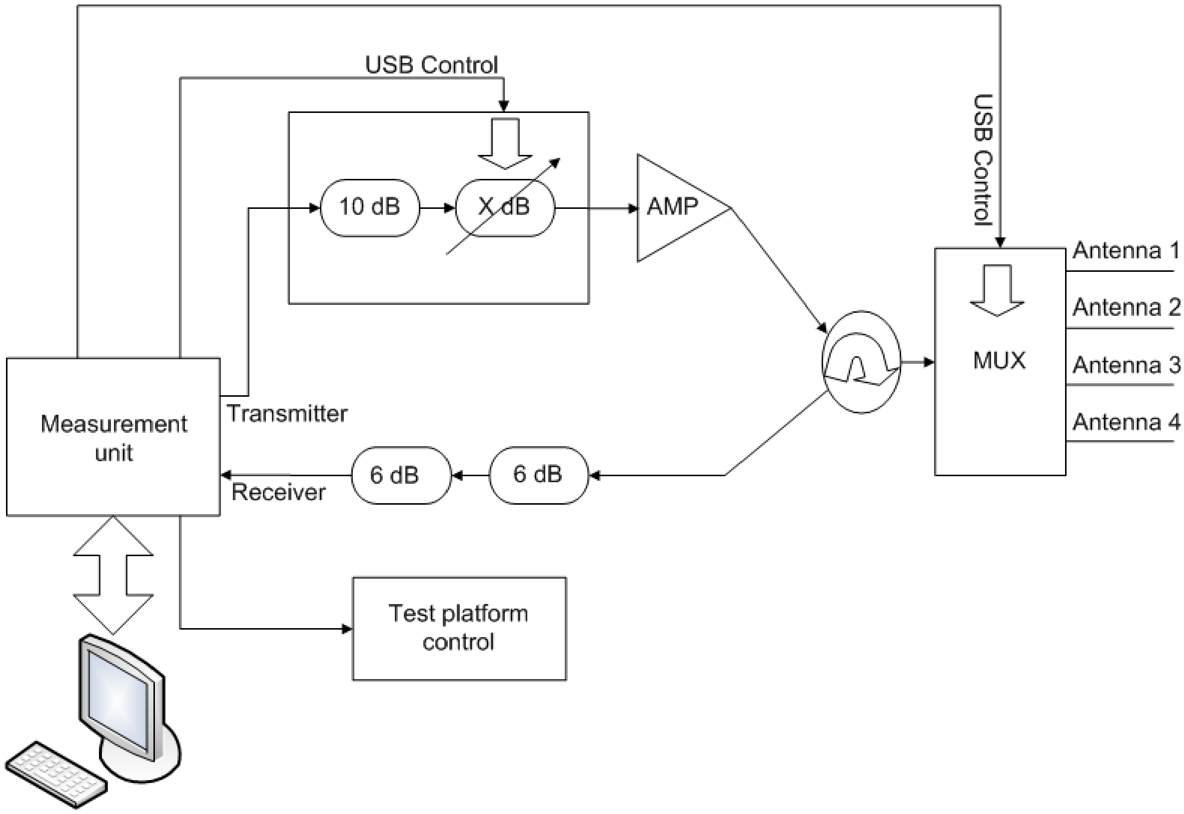

Figure 6: Configuration of Measurement Unit

The measurement unit can operate in the 800 MHz to 1000 MHz frequency range, and the frequency of operation can be dynamically controlled in increments of 1 MHz. The accuracy of the transmitter's oscillator is 10 ppm. The output power range of the measurement unit is 0 dBm to 40 dBm, and can be dynamically controlled in increments of 0.1 dBm. The absolute power accuracy is 1 dBm with an output power uniformity of 0.5 dBm.

The modulator in the measurement unit supports double-sideband amplitude shift keying (DSB-ASK) modulation and phase-reverse amplitude shift keying (PR-ASK) modulation. The receiver has a sensitivity of -80 dBm with an absolute maximum input power of 40 dBm.

The Select, Query, and Write commands can be used for measuring inlay performance. A combination of Select and Query commands can be used to individually test a specific inlay ID number in a population of multiple inlays present in the test environment. As shown in Figure 7, the measurement unit sends a Select command with the ID value of the inlay to measure. The Select command is followed by a Query command for which the inlay should reply with a random number. The random number response is used to validate the inlay response, and thus measure the inlay performance. The write command is used for measurement by attempting to rewrite the first 16 bits of the inlay ID with the value of 1010101010101010.

A graphical user interface is used to configure and control the test equipment. The measurement unit also has a scripter-based interface where multiple tests can be done automatically with all test parameters like frequency, power, antenna, and table position controlled dynamically. The scripter and software is designed with a focus to minimize user interaction.

The test equipment can measure the transmitted power, backscattered power and relative backscatter phase. The equipment can also calculate and store parameters such as theoretical read range based on the three measured parameters and the test setup parameters. The equipment and the controller software were built by Voyantic Ltd.

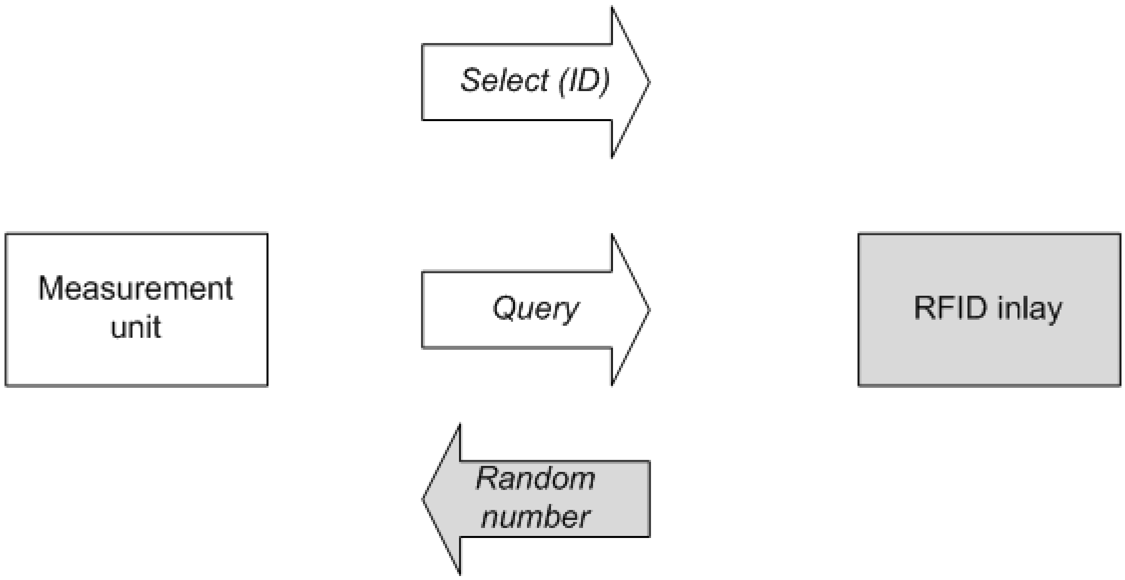

Figure 7: Communication Between Measurement Unit and RFID Inlay

1.2 Equipment Calibration

The transmitter of the test equipment was calibrated using a power meter with a power trace in the entire operational frequency and power range. Both the I and Q channels and their phase difference in the receiver were calibrated through the entire frequency range by connecting the calibrated transmitter to the receiver.

A calibrated two-port network analyzer has been used to measure the S12 parameter of each antenna and cable combinations for the frequency range of 800 MHz to 1000 MHZ in increments of 1 MHz. The free-space loss in the chamber for the distance between the antennas and the incident point is calculated using the Friis equation. The loss of each antenna and cable combination combined with the corresponding free-space loss was used to calculate the total loss between the measurement unit and the incident point.

The final measurement from the calibrated test equipment and calculated total loss was validated and verified by measuring the performance of an externally verified Calibration Inlay.

We measure a Quality Inlay at the beginning and end of measurement each day. The Quality Inlay is measured on all four antennas and the consistency of the measurement is verified to detect any unexpected change in the measurement system.

LIST OF FIGURES

APPENDIX A: DEFINITIONS

Inlay – A specific combination of chipset and substrate antenna in the most finalized format that would affect tagged product performance. Multiple conversions of the same chipset and antenna combination do not constitute a unique ‘inlay’ unless the conversion or application of the tag affects tagged product performance.

Tagged product – The final combination of inlay and product.

Calibration Inlay – The externally verified inlay that is retested and the observed values are used to validate the calibration of the test equipment and calculated path loss in the test setup.

Quality Inlay – An inlay that is measured during the beginning and end of each measurement day to confirm the working condition of the test equipment.

APPENDIX B: EQUIPMENT SPECIFICATION

Antenna Specification

Manufacturer	Huber+Suhner
Model	SPA 8090/75/8/0/V
Impedance	50 ohm
VSWR	1.4 (800 – 1000 MHz)
Polarization	Linear
Gain	8.0 dBi
3dB beam width horizontal	75 degree
3 dB beam width vertical	70 degree
Downtilt	0 degree
Front to back ratio	20 dB
Max. power	75 W (CW) at 25 C

Measurement Unit Specification

Manufacturer	Voyantic Ltd.
Model	Tagformance Lite
Frequency range	800 – 1000 MHz
Frequency resolution	100 kHz
Frequency accuracy	+- 10 ppm

Output power	0 dBm to 40 dBm
Output power resolution	+- 0.1 dBm
Output power absolute accuracy	+- 1 dBm
Output power uniformity	+- 0.5 dBm
Output impedance	50 ohm
Modulation modes	DSB-ASK, PR-ASK (Tari= 25 µs)
Modulation waveform resolution	16-bit, non-linear
Modulation waveform sample rate	1000 kS/s
Receiver usable linear dynamic range	-80 dBm to 10 dBm
Receiver absolute maximum input power	30 dBm
Receiver sensitivity	-80 dBm
Backscattered waveform resolution	16-bit
Backscattered waveform sample rate	1000 kS/s
Input impedance	50 ohm