

Evaluation of Antenna Performance using a Novel Measurement Device: Methodology and Results

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Abstract

In the last decade, the field of On Chip Antennas (OCA) has experienced unprecedented growth due to the introduction of small, low-cost, low-power System-on-Chip (SoC) wireless communication devices. OCAs are superior to conventional off-chip antennas in a number of ways. They first reduce the overall size of the wireless communication system since the presence of an OCA eliminates the need for an impedance matching network between the antenna and RF front-end. Second, OCA-based systems offer improved repeatability and bandwidth, easier system integration, and increased productivity. Thirdly, OCA-based wireless communication systems are power-efficient since they don't lose a lot of power as a result of reflections and dielectric losses. In the end, they provide designers with flexibility by allowing the co-design of transceiver and antenna components, which saves important design time and chip space. In this research, a low-cost antenna parameter measurement system utilizing the AD9850 DDS signal generator and the AD8302 logarithmic amplifier/phase detector is proposed. It makes antenna testing and analysis easier by improving signals up to 6 GHz and evaluating Return Loss and SWR Ratio.

Keywords: Antenna parameters, AD8302, RF power measurement, gain, radiation pattern, return loss, logarithmic amplifier

INTRODUCTION

When measuring the radiation efficiency of electrically tiny antennas, the wheeler cap method is frequently employed and yields more accurate results than radiometric and directivity/gain approaches [1]. If the equivalent circuit of an antenna consists of a series circuit with a resistor, capacitor, and inductor, Wheeler computed the radiation efficiency of an antenna [2].

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Later, Johnston introduced the Improved Wheeler Cap (IWC) technique, an extended model that did away with Wheeler's method's drawbacks by representing the antenna as a two-port device [1]. The radiation efficiency and complete S-matrix for an antenna represented as a two-port device were computed using Thal's Spherical Wheeler Cap (SWC) approach [3]. Accurate radiation efficiency has been experimentally determined by [4] using the S-parameters acquired using the SWC method. Over the past ten years, the field of On Chip Antennas (OCA) has advanced at a rate never seen before thanks to the development of tiny, low-power, and inexpensive System-on-Chip (SoC) wireless communication devices. OCAs have a

number of benefits over traditional off-chip antennas. Since there is no longer a requirement for an impedance matching network between the antenna and RF front-end when an OCA is present, they firstly minimize the size of the entire wireless communication system [1].

Second, OCA-based systems provide easy system integration, higher production, and enhanced repeatability and bandwidth [2], [3]. Thirdly, because OCA-based wireless communication systems don't lose a lot of power due to reflections and dielectric losses, they are power-efficient [3, 4, 6, 7]. Ultimately, they give designers flexibility by enabling the co-design of antenna and transceiver components, saving valuable chip space and design time [2, 7].

Since the size of an antenna element is virtually small at these frequencies and they produce fewer reflections than a modular configuration, OCAs are extremely promising for Millimeter Wave (MM-Wave) frequency applications [8]. OCAs are equally advantageous for applications involving Terahertz (THz) frequencies due to the availability of low-cost Silicon-based technologies; numerous research studies have already been published in this area [2, 8–13]. The following are some recently investigated application areas of OCAs: measurement of MM-Wave ICs and devices, power combining, amplitude mono-pulsed radar, wireless system bandwidth enhancement, biomedical implant devices, detection and imaging in THz region, Radio Frequency Identification (RFID) based SoC, 3-D imaging, next generation wireless mobile terminal, power combining, amplitude mono-pulsed radar, wireless system bandwidth enhancement and beam steering. These are just a few examples of recently explored application areas for OCAs. OCAs have a number of benefits and applications in a number of cutting-edge research fields, but they also present some difficulties that should be carefully considered. Among these is the decline in performance caused by lossy silicon substrates in CMOS and SiGe-BiCMOS designs, which are the best available technologies for contemporary SoC integration [8]. It's also crucial to note that OCA's layout violates technological process design guidelines [6, 8].

Furthermore, another important issue pertaining to OCAs is the electromagnetic interaction with surrounding passives [1]. For the purpose of designing and researching antennas, precise and trustworthy measurements of radiation patterns and impedance are essential. These are often carried out with the use of a network analyzer. When conducting measurements, coaxial cables are typically used to connect the measurement ports of a network analyzer and an antenna. An imbalanced current may be created on the outside of coaxial cables if they are linked to an antenna. The results of the initial measurement, in which no coaxial cable was connected, are impacted by this unbalanced current. Coaxial cables have an especially obvious effect when the antenna is asymmetric and tiny in relation to the wavelength. As an example, we will now concentrate on a tiny antenna mounted on a small housing. Numerous studies have examined how coaxial cables affect a tiny antenna's measured radiation properties [1–3].

Using tiny oscillators for antenna feeding, such as voltage-controlled oscillators (VCOs), is one efficient technique to reduce the impact of coaxial cables [1, 4]. The primary foci of this work are antenna array S-parameters and radiation efficiency modeling and measurement. Antennas are important components in many radio frequency (RF) applications, such as satellite communications, radar, and wireless communications, where accuracy is essential for best results. Conventional techniques for measuring antenna parameters usually need network analyzers or other large, bulky, expensive equipment. However, integrated circuits (ICs) like the AD8302 provide useful features for measuring RF power. The AD8302 functions as a power meter and multi-logarithmic amplifier, helping to determine the RF power levels required for antenna building and performance assessment [1–8].

PROPOSED METHOD

The first step in the Antenna Parameter Measurement project is choosing the components, which include the Arduino Nano, AD9850 IC, Bluetooth HC-05 module, and device. Correct connections are ensured via a thorough circuit schematic. Data processing and transmission between components are

made easier by the Arduino Nano. Bluetooth offers real-time data analysis, frequency configuration, and calibration (Blue VNA smartphone app). Calibration, frequency setup, data processing, and parameter computation are all included in algorithm development. System functionality and user guidance are ensured by comprehensive testing and documentation.

COMPONENTS

Arduino Nano

The Arduino Nano is a smart development board made to produce prototypes more quickly and in the smallest possible size. The eldest member of the Nano family, the Arduino Nano, has enough power for your projects. The ATmega328 microcontroller, which is clocked at 16 MHz and functions largely similarly to the Arduino Duemilanove, is in the center of the board. The board includes a small USB connection, eight analog pins, and twenty input/output pins [9].

HC-05 Bluetooth Module

The Bluetooth module that was used for this project has a sensitivity of -80dBm, which makes communication dependable. It guarantees powerful signal transmission with a strong RF transmit capacity of up to +4dBm. The module facilitates energy-efficient performance by functioning effectively within a low power range of 1.8V and 1.8 to 3.6V I/O. Its edge connector allows for flexible device placement by extending the communication range from 10 to 100 meters. This Bluetooth module functions on the commonly used 2.4 GHz band, making it a dependable and adaptable part that allows for smooth control and connectivity in our project[10].

AD8302

A logarithmic amplifier and controller module, the AD8302 is intended to measure the power of microwave and radio frequency (RF) signals. Measures phase and gain/loss up to 2.7 GHz. Phase detector and dual demodulating log amplifiers. Input Range for a 50 System: -60 dBm to 0 dBm Accurate Scaling of Gain Measurement (30 mV/dB). Nonlinearity on average < 0.5 dB. Precise Phase Measurement Scaling at 10 mV per degree. Normal Nonlinearity < 1 Degree. Modes for Measurement, Controller, and Level Comparators. Runs on Supply Voltages Between 2.7 and 5.5 V. stable reference voltage output of 1.8 volts. DC to 30 MHz Small Signal Envelope Bandwidth[11].

AD9850

The high-performance DAC and comparator on the Analog Devices AD9850 125 MHz CMOS DDS synthesizer have an on-chip DAC SFDR > 50 dB @ 40 MHz AOUT. For easier control, it provides a 32-bit frequency tuning word and supports serial or parallel byte loading formats. It also has the ability to modulate phase, runs on a single 3.3 V or 5 V supply, uses little power (155 mW at 110 MHz, 3.3 V; 380 mW at 125 MHz, 5 V), and has a power-down feature. With its ultrasmall 28-lead SSOP package, it is perfect for applications that need accurate frequency synthesis[12].

Proteus Software

Version 8.14 of Proteus Software continues to be a popular electrical design automation (EDA) tool for PCB design and circuit modeling. Most likely, this version keeps the essential elements that have made Proteus a top choice for engineers and designers. Proteus enables users to visually create and assess electronic circuits before they are physically realized thanks to its wide voltage range capabilities. Proteus simplifies the creation of embedded software by offering useful code visualization and debugging capabilities, especially for projects using microcontrollers. Although users may need to consult the official documentation for accurate insights into version 8.14's features, they may expect an improved and adaptable tool for electronic designing as well as for usage in electrical and mechanical modeling [13].

Arduino IDE

All Arduino microcontroller boards can be programmed using the Arduino IDE software tool. It offers a straightforward interface for writing, compiling, and installing code. Using the built-in libraries

and examples makes development simple. The IDE is compatible with Windows, Mac OS, and Linux and offers debugging help as well.

RF Amplifier ADL5611

An adaptable RF/IF gain block amplifier, the ADL5611 operates between 30 MHz and 6 GHz. It has a wide dynamic range thanks to its high OIP3 of 40.0 dBm and extremely low noise figure of 2.1 dB. It is simple to apply in a variety of applications thanks to its consistent gain of 22.2 dB over frequency, temperature, and power supply fluctuations. The amplifier requires few extra components because it is internally matched to 50 Ω and is housed in an industry-standard SOT-89 box. Along with its wide temperature range of -40°C to +105°C, it functions reliably and has a high ESD rating of ± 1.5 kV[14].

OMRON Relay G6-S-2Y 24DC

This component's surface mounting terminal variants have an inside-L terminal design that saves space and long terminals that are perfect for soldering and mounting dependability. The distinctive terminal construction is designed especially to endure IRS soldering procedures. This component guarantees strong electrical performance with a high dielectric strength of 2,000 VAC and an impulse withstand voltage of 2,500 V, meeting Telcordia specifications. Even with its minuscule dimensions of 9.4 mm (H) \times 7.5 mm (W) \times 15 mm (L), it nonetheless exhibits remarkable dependability. For further safety assurance, some models also include BSI (EN62368-1) supplementary insulation certification.

FORMULAE

Measurements at two sites along a transmission line are required in order to compute the Voltage Standing Wave Ratio (VSWR) and Return Loss (RL) using voltage magnitude (Vmag) and voltage phase (Vphase). Let Vmag1 and Vphase1 at the first point and Vmag2 and Vphase2 at the second point represent the voltage magnitude and phase, respectively.

1. Reflection coefficient (R): $R = (V_{mag2}/V_{mag1})e^{i(V_{phase2}-V_{phase1})}$
2. Voltage standing wave ratio: $VSWR = 1 + |R|/1 - |R|$
3. Return loss: $RL (db) = -20\log_{10}(|R|)$

BLOCK DIAGRAM

Block diagram of proposed system is shown in Figure 1.

LITERATURE SURVEY

The creation of two different phase measurements for the heterodyne two-wave “precision” interferometer—which measures the tokamak COMPASS plasma flow—is presented in this study. The purpose of this project is to build a power meter that can measure the phases and quick changes in each wave that is measured. Two microwave signals of different wavelengths that are going in the same direction to collide can be used to detect plasma in this instance. Three channel level meters are used to

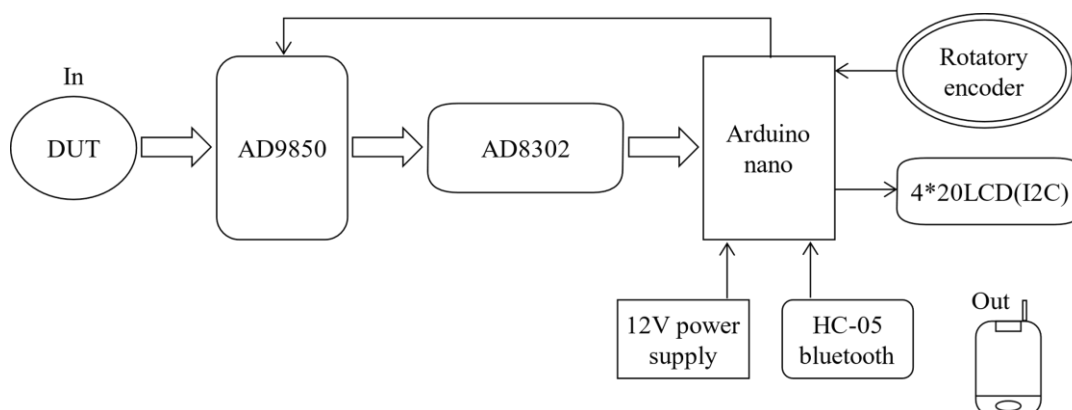


Figure 1. Block Diagram.

measure the precise level of each monitoring signal: two of them are based on a Field Programmable Gate Array (FPGA), while the third one is based on the AD8302 pair. Idea of circuit time. [1] Investigations on the Direction of Arrival (DOA) determination of underwater acoustic waves through the use of an amplitude and phase comparison passive sonar interferometer. Thus, in order to estimate the DOA of the audio signal, we ran the AD8302 test in this study and employed the results in a sonar interferometer. The apparatus is made and intended for use in laboratory level tank scale testing[1, 5, 7].

Applications

1. Antenna maintenance
2. Antenna testing
3. RF component characterization
4. Antenna parameter measurement

CONCLUSION

All things considered, the Antenna Parameter Measurement System provides a reliable way to measure and examine various antenna properties. The solution enables wireless, real-time data collecting through the seamless integration of hardware components like the Bluetooth HC-05 module and the AD8302 Antenna Parameter Measurement device with the Blue VNA software on a mobile device. Precision is ensured by the calibration process, and the system's versatility and usefulness are increased by the frequency range adjustment feature that supports a variety of antenna designs.

Declaration of Interest

We deeply invested in developing a cost-effective antenna parameter measurement device to revolutionize the accessibility of vector network analysis. By reducing costs significantly, we aim to democratize antenna testing, empowering engineers and researchers to innovate in wireless communication technology. We are committed to leveraging our skills to ensure the success of this project and its potential to transform the industry.

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