The Eurasia Proceedings of
Educational & Social Sciences (EPESS)
ISSN: 2587-1730

The Eurasia Proceedings of Educational and Social Sciences (EPESS), 2025

Volume 46, Pages 163-169

IConETE 2025: International Conference on Education in Technology and Engineering

Impact of VSWR Network Analyzer and Advanced Program Interface on User Performance

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Abstract: The present study investigates the frequency measurement process of mobile phone antennas utilizing a VSWR (Voltage Standing Wave Ratio) network analyzer, and the impact of an automatic measurement program interface developed in this process on user performance. Prior to the study, the antennas of the phones were measured manually with the support of the network analyzer, and the results were calculated by the test engineer. The development of a program in C# has enabled the automation of the measurement process, enhanced measurement accuracy, and improved user interaction. In this study, the structural features of mobile antennas are examined, along with their importance, the measurement principles of the network analyzer device, and the effects of program interface design on performance. Consequently, the development of a program and test jig has led to the automation and acceleration of the testing process for mobile phone antennas. The configuration files were compiled using data obtained from 600 tests conducted on each phone model produced. The improved interface design increased operator efficiency, allowing more time for high-value tasks. Consequently, the developed software and test jig automated and accelerated the testing process for mobile phone antennas. With the improved system, the analysis and sorting process, which previously took one hour, was reduced to 20 seconds, resulting in an annual profit of 25,000$.

Keywords: Antenna structures, VSWR, Fixture design, Interface design with C#

Introduction

The accelerated evolution of mobile communication technologies has elevated the performance and efficiency of mobile phone antennas to a position of paramount importance. The gradual replacement of older mobile communication methods, which were first introduced with the advent of 1G, by the more advanced technological framework of 5G has accelerated. This phenomenon can be attributed to the progressive development of technology. The term '5G' is used to denote a set of standard applications and much faster wireless internet technologies. It has been demonstrated that users of 5G experience significantly enhanced internet speeds and reduced latency. Furthermore, 5G represents the fifth generation of mobile network technology, offering enhanced connectivity, reduced latency, and increased device connectivity capacity. As mobile communication methods evolve, there is an attendant change in the structure and number of antennas used in mobile phones. The utilization of antennas that are compatible with mobile communication methods has been demonstrated to enhance communication efficiency and quality.

Accurate and precise measurement of antenna parameters such as frequency, efficiency and SAR (specific absorption rate) is critical for both device quality and user safety (Kivekas et al., 2004). Conventional

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

measurement techniques are predominantly reliant on manual procedures, whereas the automation of measurement processes has been demonstrated to enhance efficiency with regard to both temporal and labor requirements. In this context, the discussion focuses on the optimization of measurements made with the Network Analyzer through the utilization of an automated test program interface (Taniguchi & Kobayashi, 2003). The program developed to automate many of the operations performed during the testing process was developed through the C# program. Following the development of the program, the interface design underwent modifications to enhance its efficiency in terms of usability and comprehensibility.

Previous Studies

Ollikainen et al., introduce Bandwidth, SAR, and efficiency of internal mobile phone antennas conducted a comprehensive study that investigated the effects of various parameters related to the phone case—length, width, thickness, and distance between the head and the phone—on the bandwidth, efficiency, and specific absorption rate (SAR) characteristics of internal cell phone antennas. The antenna-case combinations that were the focus of the study were positioned in close proximity to an anatomical head model, with the model positioned in the same location as the phone during usage. The influence of the user's hand is also studied with two different hand models. (Ollikainen et al., 2004).

Chen et al., in the study, introduce Limitations of the Free Space VSWR Measurements for chamber validations. Free Space VSWR measurement has been the de facto standard method for anechoic chamber performance evaluation for over 50 years. In this method, a probe antenna is initially positioned parallel to the boresight angle while traversing a linear trajectory. The reception pattern is then documented. Subsequently, the probe antenna is rotated to a different angle, and a standing wave pattern is recorded along the same path. The reflectivity employed as a metric for evaluating room performance is derived from the VSWR fluctuations as a function of the probe rotation angle. It has been demonstrated that the reflectivity obtained in this manner is equivalent to the ratio of the reflections perceived by the probe antenna relative to the incident field on the probe antenna. The findings demonstrate that the reflectivity is influenced by the probe antenna's antenna pattern. The reflectivity measured using a higher gain probe antenna typically yields a lower reflectivity compared to that measured using a lower gain probe antenna (Chen et al., 2016).

By Ying, has been introduced Antennas in cellular phones for mobile communications. In this study, examines the evolution of the mobile industry, highlighting its remarkable growth trajectory. The progression of wireless communication systems is marked by a transition from analog to digital 2G (GSM), followed by the emergence of high-speed data transmission methods such as 3G (WCDMA), and culminating in the development of packet-optimized 3.5G (HSPA) and 4G (LTE and LTE-Advanced) systems. The primary challenges associated with the design of contemporary cell phone antennas pertain to their diminutive dimensions, integrated configuration, and the necessity of catering to an array of system requirements across multiple bands. These bands encompass not only all cellular 2G, 3G, 4G, and 5G frequencies but also a plethora of non-cellular radio frequency (RF) bands. Additionally, there is an imperative to adhere to all prevailing standards and criteria, including aesthetic considerations, specific absorption rates (SARs), hearing aid compatibility (HAC), and over-the-air (OTA) compliance. This paper provides an overview of some of the major antenna designs and advances in mobile phones over the last 15 years. It also presents recent developments in new antenna technology for LTE and compact multiple-input-multiple-output (MIMO) terminals (Ying, 2012).

Material and Method

Mobile Phone Antennas

In the context of mobile phones, the antenna constitutes the primary hardware component responsible for transmitting and receiving radio frequency (RF) signals. Mobile antennas facilitate wireless communication by transmitting and receiving electromagnetic signal waves. A high-performance antenna has been demonstrated to improve signal quality, reduce connection interruptions, and support overall communication efficiency (Kivekas et al., 2004). Consequently, the quality and accuracy of the antenna employed directly impact communication and signal quality.

The configuration of mobile antennas typically encompasses compact integrated circuits and multiband designs. In contemporary designs, the geometrical configuration of the antenna elements and the utilized materials are optimized to ensure maximal signal transmission efficiency (Kivekas et al., 2004).

VSWR Network Analyzer

A VSWR (voltage standing wave ratio) network analyzer is a measurement device that facilitates the evaluation of the efficiency of antenna systems by quantifying the reflections that occur within these systems. The device under scrutiny employs a meticulous analysis of wave ratios at the points where the signal undergoes transmission and subsequent reflection. During the measurement process, the network analyzer determines the extent to which the signal transmitted to the antenna is reflected. A low VSWR value is indicative of a coherent and efficient antenna operation, while a high VSWR value signifies a mismatch condition, which can potentially result in a performance decline (Taniguchi & Kobayashi, 2003). This fundamental principle underlies the design and optimization of antennas.

Test and Improvement Process

The experimental studies were performed using a Keysight N9923A vector network analyzer (VNA). The measurements were conducted over a frequency range of 2 MHz to 6,000 MHz, with both manual and jig-assisted measurements being performed for each antenna. The test environment was configured within an isolated RF cabinet, with the objective of minimizing environmental interference. The jig body is covered with aluminum material, and there are 50 ohm-compatible connectors for RF input and output. The mechanical stabilizer located on the upper portion of the device is interchangeable with adapters that are compatible with various antenna models. The image of the test machine is presented in Figure 1.

Figure 1. Test machine

The ports on the jig are connected to the port of the VNA device via the switch box, and the measurements are triggered under software control. The system has the capacity to facilitate automatic frequency assignment through the utilization of an IP connection. As illustrated in Figure 2, the jig is composed of multiple connections. A comparative analysis was conducted on ten distinct antennas, with measurements being taken both manually and with the aid of a jig. In the jig measurement, the VSWR value is precisely the desired value at the frequencies of interest, indicating enhanced impedance matching and consistency. The circuit board utilized in the Jig's infrastructure is meticulously engineered to facilitate uninterrupted and distortion-free frequency measurement. A series of tests have been conducted to ascertain the security of the measurement results transmission process. These tests entailed the implementation of resistors at the connection point of each individual pin.

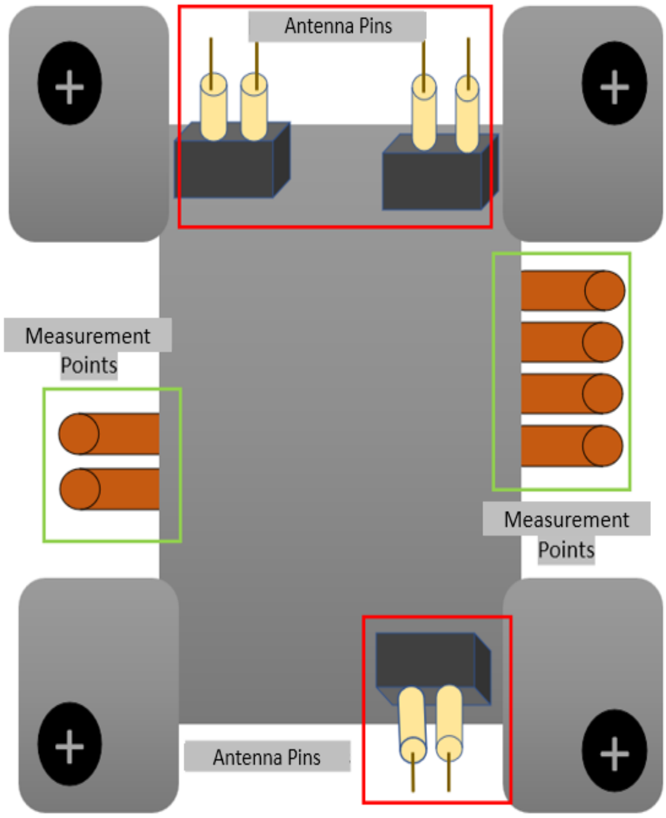


Figure 2. Connection point and pin blocks used for the measurement process on the test fixture

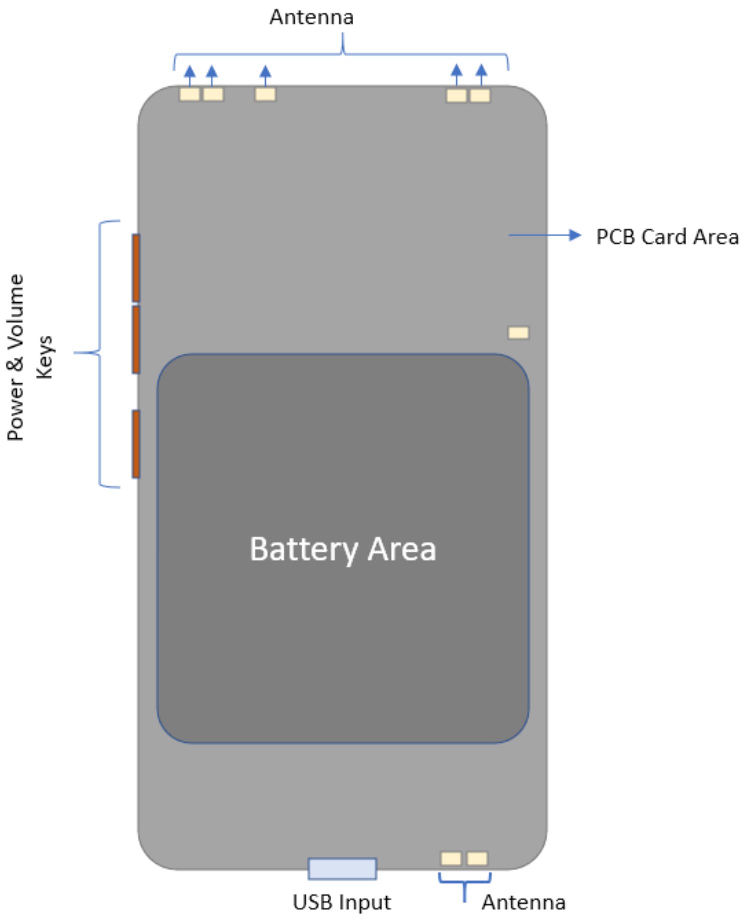


Figure 3. The antenna positions on the front material

Given that the antenna points and structures of each phone are located in different locations, the pin points in the jig were specially calculated and placed. The number of pins added corresponded precisely to the number of antennas to be tested. Given that the configuration of the developed jig is designed with particular relevance to the specific model of telephone, the quantity and spatial distribution of the pin points on the jig undergo modification in accordance with the variation of the model that is to be subjected to evaluation. The antenna positions on the front that were utilized for the measurements, as well as the structure of the front, are illustrated in Figure 3.

In the course of the development process, approximately 1,200 tests were conducted to ascertain the specification values of each control point. Subsequent to the completion of the tests, the calculated measurement values were averaged and appended to the model config file as frequency values. An illustration of the frequency values calculated during the tests is presented in Figure 4.

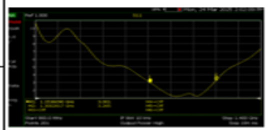
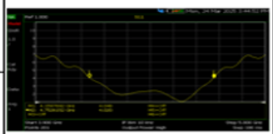
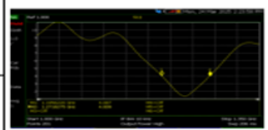
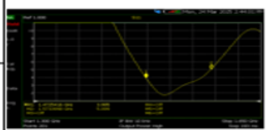
Sample-1												
Port	Port Name	Freq Range		Marker freq (MHz)			Total ABS(Diff)	Marker				Measuremnt Waveform
		Start	Stop	Spec	Meas	Diff	343	LSL	Value	USL	Diff	
1	A	900	1400	1143	1153	10	10	2,5	3	3,5	0,5	
				1281	1300	19	19	2,5	3	3,5	0,5	
2	B	3900	4700 ↓ 5000	4082	4159	77	77	3,5	4	4,5	0,5	
				4550	4752	202	202	3,5	4	4,5	0,5	
3	C	1000	1350	1188	1195	7	7	3,5	4	4,5	0,5	
				1243	1271	28	28	3,5	4	4,5	0,5	
4	D	1300	1650	1473	1472	-1	1	3,5	4	4,5	0,5	
				1526	1573	47	47	4,5	5	5,5	0,5	

Figure 4. An illustration of the test values for 1 phone

Subsequent to the configuration of the frequency values, a series of tests were conducted using 225 distinct phones. This figure encompasses both phones with damaged antennas and phones with undamaged antennas. The antenna points that were identified as defective following the initial testing were subsequently examined manually, and a secondary verification procedure was conducted.

As evidenced by the transmission channel measurement results, it has been observed that the VSWR level in the relevant bandwidth decreases below the specified upper spec in the measurement results with the commonized jig, thereby creating a superior quality transmission environment. The objective of this study was to compare the frequency measurements of mobile antennas obtained using two distinct methods: a VSWR network analyzer and a traditional manual measurement technique, as well as an automatic measurement method.

Test Program Interface and Automatic Measurement Process

The number of antennas, their coverage, and their frequencies vary depending on the level of sophistication of the phones produced. Conventional measurement methods entailed manual adjustment of antenna frequency values, with the resulting data from the network analyzer being contingent on user intervention. Depending on the phone model being tested, the frequency ranges for the antennas to be tested were set individually, and then measurements were made for each antenna individually. While this approach had a margin of error and time loss, thanks to the new program developed:

- It is imperative to note that upper-lower frequency values and mark point values are automatically realized for all antennas to be measured.
- The process of switching between antennas was executed automatically and expeditiously.
- All frequency measurements are performed automatically, and the measurement results are instantly displayed in the system. The measurement results obtained within the system are then compared against the specified specification values. This comparison determines whether the frequency value is adequate. According to the measurement results, the test result is automatically separated into two categories: PASS or FAIL.
- It has been determined that, given the consistent documentation of both the analysis of test results and the test steps, the implementation of retrospective controls is a possibility.
- Given that image logs are also recorded, distortions in the frequency broadcast can be detected and measures can be taken.
- The implementation of an accelerated test mode has enabled the expeditious execution of frequency tests for all antennas on a single mobile device, with a completion time of merely four seconds. This feature enables the rapid testing of thousands of phones, streamlining the preparation process for production.

In the initial phase, the challenges encountered by users during manual measurement were identified, and subsequently, an automatic measurement program was designed with user-friendliness as a priority, informed by these data. The program interface, characterized by its user-friendly design, facilitated the measurement process and enhanced user performance by reducing employee errors. Subsequent to the initial design, the most optimal design was recreated based on the feedback obtained from users' interactions with the interface. During this process, the design of the program interface underwent approximately 15 iterations of modification and evaluation. In the course of the user interactions, a total of 2000 tests were administered, encompassing approximately 300 distinct mobile devices. These evaluations were conducted with the objective of examining the user-program interaction.

The implementation of an automated system has been demonstrated to enhance measurement accuracy while concurrently reducing both time and labor expenditures. This system offers significant advantages in terms of standardization and quality control in antenna measurement processes. The effects of the developed interface on measurement time, error rate, and user satisfaction were experimentally evaluated.The measurements were executed within the designated frequency ranges, and the same equipment and devices were utilized in both methods.

Results and Discussion

The findings of the research indicate that the developed automatic measurement program enhances precision, time efficiency, and user performance. The findings have demonstrated that the automated method exhibits a reduced margin of error and enhanced measurement accuracy in comparison to the manual approach. A substantial decrease in measurement time was observed, attributable to automation. It has been determined that the developed interface contributes to the users' ability to perform measurement operations in a more efficient and reliable manner. These findings underscore the pivotal function of automation in the domains of mobile antenna design and measurement processes.

The integration of automated measurement systems has profoundly impacted the testing and evaluation of mobile phone antennas. The developed program interface has been shown to enhance measurement quality while reducing errors made by employees. In the future, the implementation of analogous automation solutions in additional domains will facilitate the standardization of RF testing processes and enhance efficiency.

Scientific Ethics Declaration

* The author(s) declares that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

Conflict of Interest

* The authors declare that they have no conflicts of interest

Acknowledgements or Notes

* This article was presented as an oral presentation at the International Conference on Education in Technology and Engineering (www.iconete.net) held in Antalya/Türkiye on November 12-15, 2025.

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To cite this article:

Bakis, O. F., Tuna, M., & Sarac, U. (2025). Impact of VSWR network analyzer and advanced program interface on user performance. *The Eurasia Proceedings of Educational and Social Sciences (EPESS), 46,* 163-169.