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Solar-Powered Portable 5G Signal Testing Meter with Network Analysis

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Abstract:
Today's era of digital times is based on robust mobile network coverage for proper communication, data sharing, and internet connectivity. However, rural, as well as urban, areas are mostly subjected to interruptions in the strength of the signal as well as network quality because of infrastructural shortages and geographical limitations. To bridge such flaws, this project introduces a light-weighted, cost-effective, and portable 5G Network Tester. The product operates on an ESP32 microcontroller and a SIM card module A7600 which is 5G-capable and able to read and output real-time RSSI signal strength, recognize active operator, and determine current network type (from 2G to 5G. There is also instant feedback output given in the form of dBm on an OLED display screen for users to view in network performance in the field. Power and connectivity with the SIM module is through AT commands in serial communication and a solar-powered power bank, making it energy-friendly and portable. This single device, designed for any environment, performs network field testing in any condition and provides telecom professionals, planners, and researchers with a convenient solution. Keeping real network information on the road, the 5G Network Tester facilitates more efficient connectivity testing, supports planning infrastructure, and helps build better communication networks in rural areas. testers, telecom providers, emergency responders, and general users who need to analyze and optimize 5G connectivity in different locations. [2]

Index Terms - 5G Modem, Microcontroller (ESP32), OLED,5G Antenna,GPS Module,Solar Power Bank

1.INTRODUCTION

With the current digital age, communication, data transfer, and internet access demand reliable mobile network connectivity. Rural and urban regions both have mobile signal intensity and network performance that fluctuates according to varying infrastructure and environmental factors [1]. In order to combat such variations, we present an affordable, portable solution: the 5G Network Tester, using an ESP32 microcontroller and a 5G SIM module (A7600). This equipment is designed to measure the strength of live mobile signal (RSSI), detect the present network operator, and determine the currently utilized network type (2G–5G) in the field conditions [2]. The tester possesses an OLED display for the presentation of signal strength in dBm so that users can analyze network quality in real-time. It transfers commands to the SIM module by issuing AT commands via serial communication, extracting important signal parameters efficiently [3]. The entire system is powered by a solar power bank, rendering it portable and eco-friendly, especially in far-flung regions where conventional power sources might be inaccessible [4]. By using a SIM module that is 5G-capable like the SIM7600, the system gathers diagnostics from the network like RSSI, RSRQ, RSRP, and SINR, and decides on the nature of the network, which in this case is LTE and LTE-Advanced. These values could be shown on various interfaces like a serial monitor, OLED/LCD, or a basic web interface to offer flexibility and convenience in a variety of environments [5]. Though the tester will frequently be in a low-power state, it's rugged enough to be taken into the field. Signal strength in dBm is important: readings near 0 are stronger signals. RSSI above –70 dBm is good, –70 through –90 dBm is fair to good, and weaker than –100 dBm is poor performance. In addition to RSRQ and SINR, these measurements help establish signal clarity, network interference, and data throughput expectations [6]..

2.METHODOLOGY

The method of attaining a 5G network tester design using embedded systems carries the fusion of hardware with signal acquisition through AT commands to real-time display with 5G parameters, location-tagged data logging using GPS, and running on solar power. The basic idea is to give a portable low-power device that scans and presents 5G signal-related details of RSSI, RSRP, RSRQ, and SINR. Signal parameters are acquired from the 5G SIM module by means of a microcontroller and are thence displayed on an LCD screen or logged into the storage device. Power runs the system using a solar-charged power bank, which makes the system highly usable in a field. The design is directed toward portability, reliability, and the ability to judge a signal's quality in several environments. Methodology

2.1 Hardware Setup

a. ESP32 Microcontroller part: The main controller unit interfacing with the 5G SIM module and peripherals.

b. 5G SIM7600 or RM500Q-GL module: Utilized, preferably in RS232 or USB-to-Serial mode to communicate using AT commands to extract signal strength parameters.

c. TFT or 16x2 LCD Display: Work done to present the relevant display of the live 5G signal quality metrics such as RSSI, RSRP, RSRQ and SINR.

d. GPS module (optional): Also integrated to capture the geolocation of each signal acquisition, with the idea of mapping coverage.

e. Solar-powered Power Bank: Provides a cleaned 5v power supply to the entire system where daily renewable energy use is needed, there is deliberately avoided battery integration so that it can be used in the field regularly with ease

2.2 Signal Acquisition and Display

a. Send AT commands from the ESP32 unit to the 5G module to access signal strength and network information.

b. Parse the return functions (i.e. +CSQ, +CESQ or +QENG) to extract the signal RSSI or RSRP and other values when available.

c. Feed the processed data into an LCD screen to present it visually onto a screen in a concise manner, for field engineers and researchers for immediate evaluation in terms of efforts on the scheme.

2.3 Documentation and Data Storage

a. Another option is if the ESP32 has an SD card module acquired data can be sent to that, it should record the timestamp, signal values and GPS coordinates if applicable.

b. Data is expected to be in a format that can be imported into data analysis software later (i.e. CSV format) for subsequent evaluation or visualization

2.4 Real-Time function and portability

a. The device will only have to be powered on and it should, boot itself up and start scanning for available signals.

b. The system should be lightweight and packaged in a sturdy portable housing in order to be used outdoors.

c. An LED indicator should be used to give an indication of system status (e.g.. Scanning, error, standby).

2.5 Assessing and Testing

a. Carry out tests across other environments (urban, suburban, rural) so that signal strength can be measured and also measure their general compatibility with different bands of 5G.

b. Compare manualreadings alongside maps, provided fromtelecomproviders or by using apps jointly, to check validity.

c. Perform a stress test on the solar supply to the device so you can see if it stays powered on the device under different light conditions.

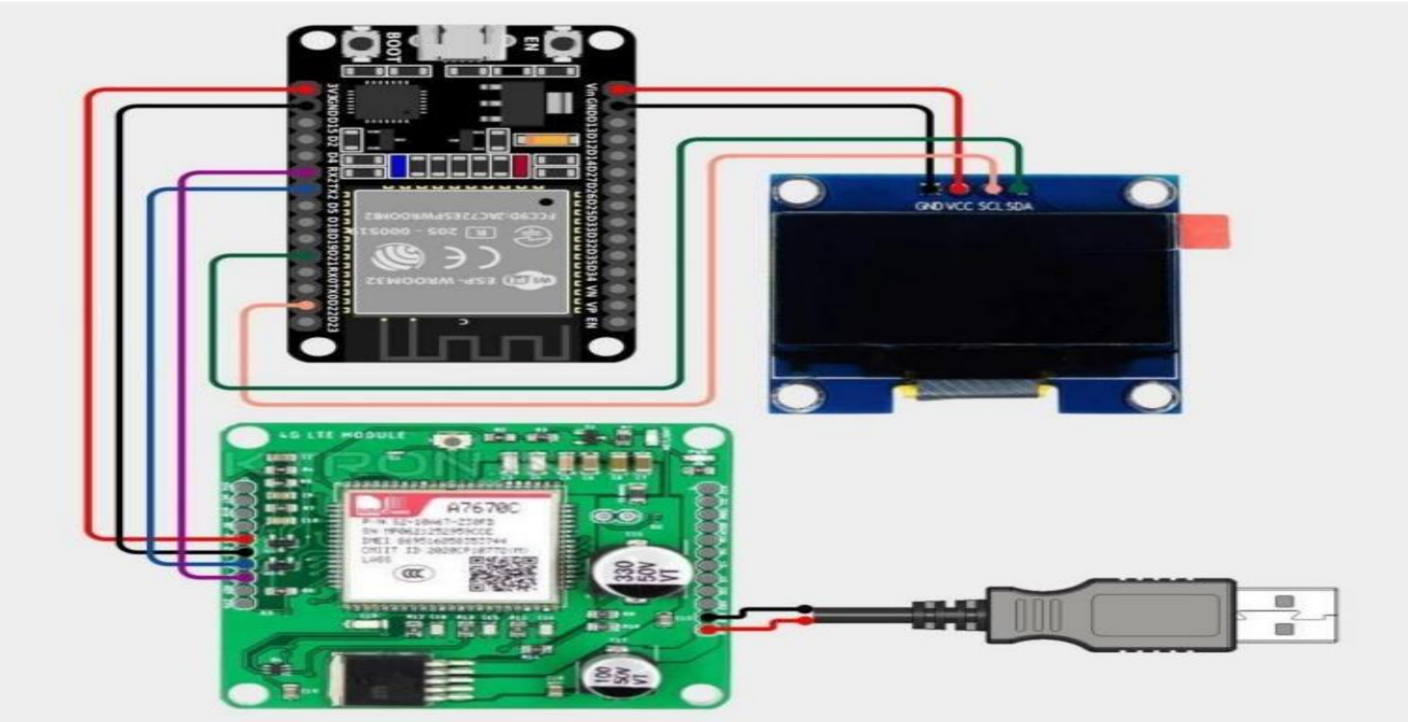

Fig.2.1: System architecture

3.RESULT AND DISCUSSION

This 5G/4G Network Tester is operated using an ESP32microcontroller with the SIM7600/A7670C module. This unique instantaneous analysis ensures that cellular signal strengths, network types (2G/4G/5G), and mobile officers in the vicinity could be observed. This portable application allows easy data visualization using an OLED screen, while the AT command set is used as the communication standard between the ESP32 and the network module.

Following are some major components of this implementation:

- Real-Time application-development signal-strength detection using the AT+CSQ command.
- Identifying the operator using AT+COPS command
- Determining network type via AT+CNSMOD commands.
- Connecting an OLED display that shows dynamic signal bars.
- Fully portable set-up with a power bank being charged by solar energy.
- Compact low-powered solution for field-use and testing.The zoomed-in portion of the figure further accentuates the accuracy of the EKF predictions, particularly during periods of rapid voltage fluctuations. This visual representation provides compelling evidence of the EKF's ability to accurately estimate the battery's internal state and predict its future behavior.

Table 3.1 Performance Summary

Feature	**Expected**	**Result**
Signal Strength	CSQ between 0–31	Accurate values shown
Network Type	Detect 2G/4G/5G	**Correct type identified**
Operator Name	Show Carrier name	**Displayed correctly**
OLED Display	Live info updates	**Real time updates working**

The Solar-Powered Portable 5G Signal Meter of this project is an innovative, independent, and green way of on-time mobile signal measurement. The independence from a power source is what gives it the utility of being best adapted in areas out of reach or outdoors where typical power sources won't be used. Its solar power option enhances its utility, enabling users to obtain signal strength readings anywhere, anytime. The inclusion of features like real-time signal analysis, logging functionality, and GPS support makes it a handy tool for contemporary telecom and connectivity applications. The work not only solves the increasing demand for portable network test solutions but also fosters green engineering practices and is therefore a worthy contribution to wireless communication and infrastructure testing

Fig 3.1 Final Protype for Proposed System

4.CONCLUSION AND FUTURE WORK

The Solar-Powered Portable 5G Signal Meter of this project is an innovative, independent, and green way of on-time mobile signal measurement. The independence from a power source is what gives it the utility of being best adapted in areas out of reach or outdoors where typical power sources won't be used. Its solar power option enhances its utility, enabling users to obtain signal strength readings anywhere, anytime. The inclusion of features like real-time signal analysis, logging functionality, and GPS support makes it a handy tool for contemporary telecom and connectivity applications not only solves the increasing demand for portable network test solutions but also fosters green engineering practices and is therefore a worthy contribution to wireless communication and infrastructure testing

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Future Work

In the future, the project can be enhanced by integrating artificial intelligence and machine learning algorithms to enable predictive analysis of signal strength and network performance based on historical data. This would assist in proactive decision-making for network planning and optimization. The system can also be expanded to support multi-band and multi-technology networks such as 4G, Wi-Fi 6, and emerging 6G networks, making it more versatile for various signal environments. To improve usability, a real-time cloud synchronization feature could be implemented, allowing collected data to be accessed and analyzed remotely. Additionally, a mobile application can be developed to provide a user-friendly interface for real-time signal monitoring, control, and data visualization through wireless communication such as Bluetooth or Wi-Fi.

Power efficiency is another critical area for enhancement. Future versions can explore advanced solar panel technologies and battery management systems to ensure longer operational periods, even in low-light conditions. Incorporating environmental sensors such as temperature, humidity, and air quality monitors would enable correlation studies between environmental conditions and network performance. Miniaturization of the device and designing it to be more rugged and weather-resistant would further increase its field applicability, especially in remote or harsh terrains. Moreover, a crowdsourced signal mapping system can be developed where multiple users contribute to a comprehensive coverage map, which would help in identifying network gaps and aiding in infrastructure deployment. Finally, securing data through encryption and working in collaboration with telecom industries and government regulatory bodies will be essential for large-scale deployment and validation of network performance data in sustainable and reliable ways.

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