Low Cost Microwave Power Meter Device

Muhanned AL-Rawi

***Abstract*:** Radio frequency power measurement is a broad topic that has been of importance to designers, operators and users. With today's complex modulation schemes, increased popularity of wireless transmission and pulsed communication modes, the need to accurately and efficiently measure RF power has become crucial to achieve certain regularity steps to restrict and to prevent the usage of communication devices in prohibited places like exam holes and for data securing purposes. Therefore, the objective of the paper is to develop and to implement a low cost microwave frequencies signal power measuring device with a frequency range of 100MHz-2.5GHz which covers the communications bands of VHF, UHF, CDMA, GSM 900, GSM 1800, Bluetooth and Wi-Fi. The development and the implementation is achieved by utilizing AD8313 IC, LM9314, Arduino Uno, Arduino Liquid Crystal Display (LCD), vibrator motor and solar cell power supply. The developed microwave signal power measurement system works successfully with the detection range greater than 10 m with detection sensitivity to the power of signal ranging from -70 dbm to +10 dbm.

***Keywords*: Low cost; microwave power meter; detection**

I. INTRODUCTION

In the communication and wireless industries, there are usually a number of regulatory specifications that must be met by any transmitting device, and maximum transmitted power is almost always near the top of the list. The Federal Communications Commission (FCC) and other regulatory agencies responsible for wireless transmissions place strict limits on how much power may be radiated in specific bands to ensure that devices do not cause unacceptable interference to others. Although the real need is usually to limit the actual radiated energy, the more common and practical regulatory requirement is to specify the maximum power which may be delivered to the transmitting antenna [1].

A microwave power meter is an instrument which measures the electrical power at microwave frequencies typically in the range 100 MHz to 40 GHz that is used for communications applications. Usually, a microwave power meter consists of a measuring head which contains the actual power sensing element or an antenna, connected via a cable to the meter prober, which displays the power reading. The head may be referred to as a power sensor or mount. Different power sensors can be used for different frequencies or power levels [2].

Historically, the means of operation in most power sensor and meter combinations were that the sensor would convert the microwave power into an analogue voltage which would be read by the meter and converted into a power reading. Several modern power sensor heads contain electronics to create a digital output and can be plugged via Universal Serial Bus(USB) into a PC which acts as the power meter. Microwave power meters have a wide bandwidth, so they are not frequency-selective. To measure the power of a specific frequency component in the presence of other signals at different frequencies, a spectrum analyzer is required [3].

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There are a variety of different technologies which have been used as the power sensing element. Each has advantages and disadvantages. Thermal sensors can generally be divided into two main categories, thermocouple power sensors and thermistor-based power sensors. Thermal sensors depend on the process of absorbing the Radio Frequency (RF) and microwave signal energy, and sense the resulting heat rise. Therefore, they respond to true average power of the signal, whether it is pulsed, or any complex modulation. Thermocouple power sensors make up the majority of the thermal power sensors sold at present. They are generally reasonably linear and have a reasonably fast response time and dynamic range. The microwave power is absorbed in a load whose temperature rise is measured by the thermocouple. Thermocouple sensors often require a reference DC or microwave power source for calibration before measuring; this can be built into the power meter. Thermistor-based power sensors such as the Agilent 8478B are generally only used in situations where their excellent linearity is important, as they are both much slower and have a smaller dynamic range than either thermocouple or diode-based sensors. Thermistor-based power sensors are still the sensor of choice for power transfer standards because of their DC power substitution capability. Other thermal sensing technologies include microwave calorimeters and bolometers, and quasi-optic pulsed microwave sensors [4].

As with power measurements, there are different types of power detectors. It is necessary to have a basic understanding of how power detectors work in order to be able to choose the most appropriate one for the measurement at hand. In addition to learning about the detectors, it is important to understand how the electronic packages associated with the detectors work (the "power meters"). Due to the difficulty of measuring waveforms and power directly at higher frequencies, the techniques used to measure power modify the microwave signal in some manner to allow it to be measured more easily. The three main types of detectors are bolometric, thermoelectric, and diode [2].

Bolometric detectors use a temperature-sensitive resistor to measure the microwave power. The most common form of bolometric detector is the thermistor detector. Simply put, when microwave power is applied to a thermistor sensor, the resistive element heats up and as a result changes its resistance. By measuring the change in resistance, you can determine the amount of microwave power that was applied.

Thus, the microwave power level of the signal being measured is ultimately determined by a DC resistance measurement [2]. Of course, it is not really that simple. There are other steps in the process that must be considered. The DC blocking capacitor, if used, rejects any DC signal coming into the detector from the microwave connector. This is important, as the sensing element reacts to any signal and a DC signal would give a false microwave power level. The sensing element is some form of temperature-sensing resistor. There are many resources that discuss the different types of sensing elements. For this discussion, we consider a thermistor bead sensing element. Thermistor sensors are small beads of metallic oxides with two very small wire leads. The common type of bead is a negative-temperature-coefficient bead which refers to the effect that as the temperature of the bead goes up the resistance of the bead goes down. The resistance of the thermistor is monitored by a power meter circuit. To make sure that there is minimal leakage of the microwave signal beyond the bead, there are filters designed to block any microwave signal, in the operating range of the detector, from leaking out of the DC leads to the power meter circuit [2].

Thermoelectric detectors use a different method for detecting a microwave signal. However, like the bolometric detector, temperature is the medium of the method. For this detector, the microwave signal is applied to a terminating resistor. This is a fixed value resistor. The microwave signal causes the resistor to heat up. In close proximity to the resistor, on a thermally isolated “island” is the hot junction of a thermocouple. Thermocouples are based on the fact that dissimilar metals generate a voltage due to temperature differences at a hot and a cold junction of the two metals [2].

Diode detectors use a method for determining power that is very different from the thermistor and thermocouple detectors. Diodes convert AC signals to DC by way of their rectification properties. These arise from the nonlinear current-voltage (I-V) characteristics of a semiconductor diode. Metal-semiconductor junctions, exemplified by point-contact technology, exhibit a low potential barrier across their junction, with a forward voltage of about 0.3 V. They have superior RF and microwave performance, and were popular in earlier decades. Low-barrier Schottky diodes, which are metal semiconductor junctions, succeeded point-contacts and vastly improved the repeatability and reliability[2].

II. DESIGN AND IMPLEMENTATION

A. Connection of power meter circuit

The microwave power meter circuit shown in Fig.1 is implemented by connecting the Omni directional antenna to utilize its spherical radiation pattern to receive microwave signal from all directions, two 1N5711 diodes are connected to realize the principle of RF protection of the circuit, the received signal is then fed to the logarithmic amplifier IC AD8313. The power level of the signal is then determined by using LM3914 IC. Nine output levels of power signal ranging from -70 dBm to +10 dBm, are then connected to the digital pins of Arduino Uno (D2 – D10) in order to display the power level digitally on I^{2}C LCD serial display.

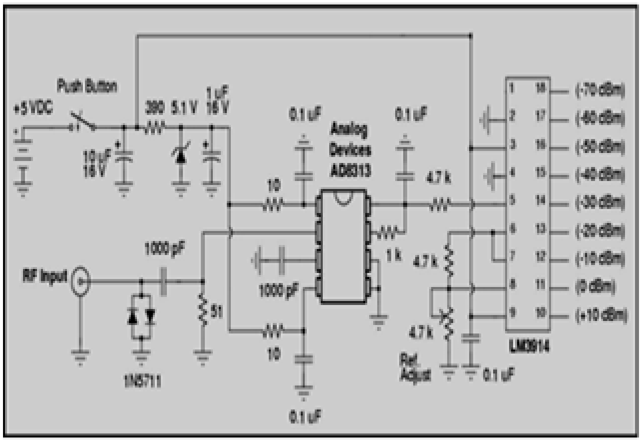

Fig.1 Connection of the microwave power meter circuit

B. Connection of the serial I^{2}C LCD

The serial I^{2}C LCD is used to display the signal power level in a digital form. The connection of I^{2}C LCD requires only four pins on the Arduino board which are 5V, GND, A4, A5 as shown in Fig.2 to be ready to display the data produced by the Arduino microcontroller.

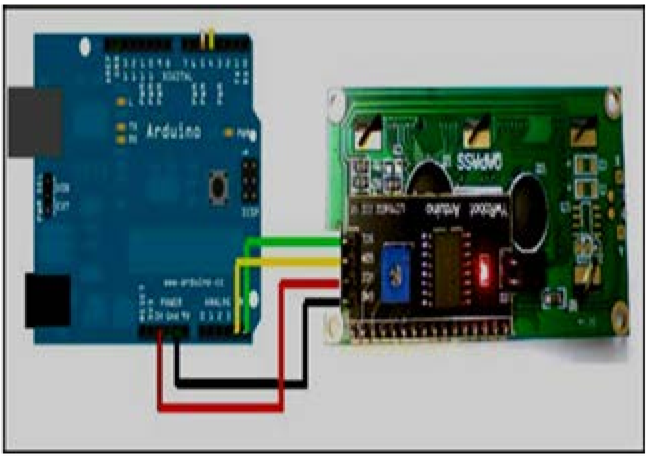

Fig.2 Connection of the I^{2}C LCD

C. Connection of vibration motor

A vibration motor provides the ability to alert the carrier of the microwave signal power meter, a notification that the power meter device is very near from the source of the signal silently.

The connection of the vibration motor is implemented by using 2N2222 transistor to amplify the current of the vibrator motor, 1N4001 to protect the vibrator and to provide a suitable voltage, 0.1µf capacitor to ease the movement of the motor rotor from the static. The motor voltage is supplied by Arduino Uno microcontroller and the motor is activated by digital pin number 11, the connection of vibrato motor is shown in Fig.3.

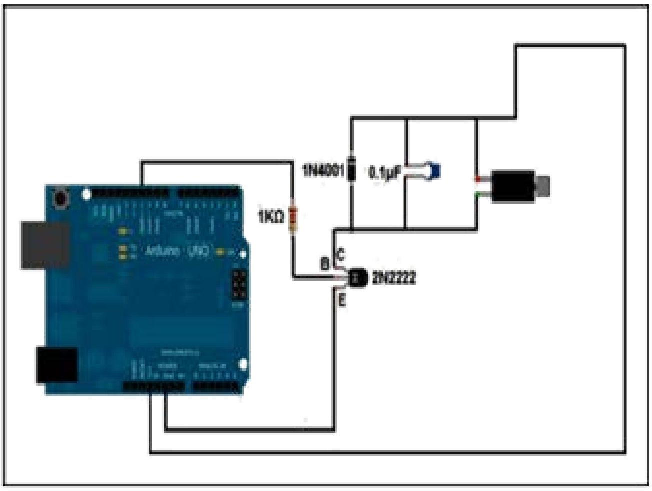

Fig.3 Connection of the vibration motor

D. Solar battery charger

To eliminate the need of using DC power supply, a solar battery charger is used which leads to reduce the cost of the whole design. Solar power is a very fast growing industry. As a result, there has been a long running shortage of silicon for solar panels, which has traditionally led to high solar panel prices. Based on volume purchasing power, BatteryStuff.com is proud to offer competitive pricing for smaller solar panel battery charger items that are often in short supply, as shown in Fig.4.

Fig.4 Solar battery charger

III. EXPERIEMENTAL RESULTS

A. Tests of signal power

In order to test the efficiency of the power measurement device, the microwave signal power at a Bluetooth frequency of 2.4GHz is measured in three different positions where the first position is about 10 meter from the device, the measured power is -60 dBm as shown in Fig.5. The second position is about 5 meter from the device, the measured power is - 30 dBm as shown in Fig.6. The third position is about 1 meter from the device, the measured power is -10 dBm as shown in Fig.7.

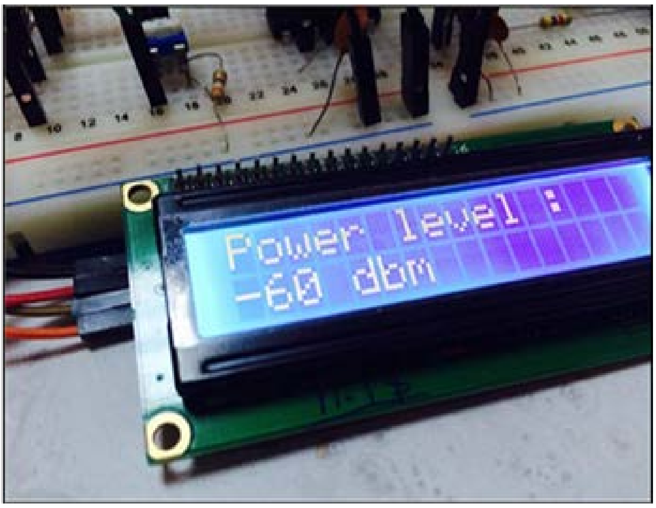

Fig.5 Measured power when the distance is 10 meters

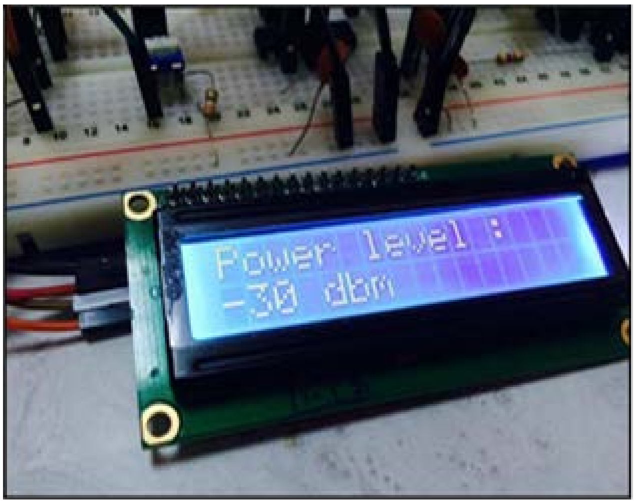

Fig.6 Measured power when the distance is 5 meters

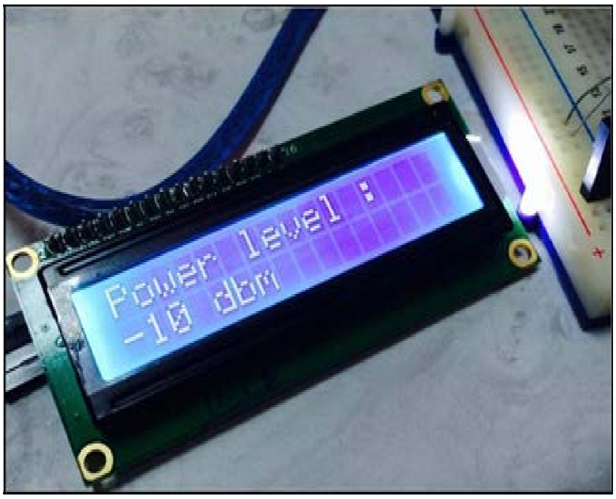

Fig.7 Measured power when the distance is 1 meter

IV. CONCLUSION

The developed power meter device works successfully as it designed and implemented. The measurement circuit of signal power works efficiently and measures electromagnetic signals power from -60 dBm to +10 dBm for the range of 100MHz-2.4GHz. Furthermore the circuit could cover more than seven bands and finally the power level that represents actual signal power is displayed on LCD serial monitor. Additionally, the detection system is designed and implemented to be in small size and light weight and with solar battery charger in order to eliminate the need of using DC power supply source. Also, the vibrator motor works successfully when a signal of highest power level (+10 dBm) is detected to indicate that the developed power meter is very near from the source of the microwave signal.

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