# Resonators and their Applications for Monitoring Blood Sugar

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**Abstract –** *Diabetes is considered one of the most dangerous, common and life threatening diseases. Due to its serious side-effects on human health , monitoring of blood sugar has become very important . This paper includes detailed study of Resonators, its types and its applications for monitoring blood sugar. Besides various new inventions in Science and Technology, Resonators are considered a fundamental aspect for frequency based analysis and applications. Resonators are mainly known for their wide-ranging applications based on resonant frequency. These properties are considered very useful for calculation and monitoring of blood sugar. This paper not only describes the latest modern blood monitoring techniques but also gives an idea about the progress made right from the invasive techniques to non-invasive techniques .*

***Key Words***: Diabetes, Resonators, invasive, non-invasive

## 1.INTRODUCTION

Diabetes Mellitus is considered one of the most common life threatening diseases in the world. Diabetes Mellitus, commonly referred to as diabetes, is a chronic disease in which the human body is unable to produce adequate amounts of insulin for maintaining normal glucose level in the blood [1] . The International Diabetes Federation states that the number of diabetic patients in 2011 was 366 million worldwide and this number is expected to rise to 552 million by 2030 [2]. Major causes of diabetes mellitus are closely related to body weight, gender, diet, genetic and physical activities. Therefore blood glucose measurement has become important for health and monitoring purposes.

The three basic blood glucose measurement techniques are categorized as invasive, minimally invasive, and non-invasive. In glucose meters, invasive techniques are widely used because the results obtained are very accurate for the measurement. The most common and cheapest invasive method is a finger puncture wound, which requires blood to be drawn from the finger with a lancet. The disadvantage of this method is that it causes pain to the patient when collecting blood samples and the results obtained by this method differ from the actual measurements. Therefore, this method was not considered very reliable. The latest non-invasive technology has been introduced as an alternative to reduce the deprivation of pain during blood draws and insulin injections. Various methods such as infrared, photoacoustic, ultrasound, and flash are used to measure blood glucose. The main reason for the ongoing research efforts in the field of non-invasive glucose monitoring is that this is the only way to develop a painless glucose monitoring system. Absorption spectroscopy, photoelectron spectroscopy, polarization spectroscopy, fluorescence and dielectric spectroscopy are one of the commonly used methods for non-invasive techniques.

Diabetics are advised to continuously monitor their blood glucose levels within typical limits. A self-monitoring system is needed to ensure that blood glucose is always within normal limits, and it also helps regulate diet and physical activity [7]. Microwave resonators can be used to measure parameters in the volume non-destructively. This property suggests that microwave resonators can be applied to non-invasively measure glucose levels in human blood. The shift in the resonant frequency of the resonator and the corresponding change in dielectric properties form an important relationship for blood glucose monitoring purposes.

### 1.1 Fundamentals of resonators:

A Resonator is a device or circuit that is capable of storing both frequency dependent electric energy and frequency dependent magnetic energy. The frequency at which the energy stored in an electric field equals the energy stored in the magnetic field, is called the resonant frequency of a resonator. Resonators are considered to be the basic building blocks of any bandpass filter. An example, where the magnetic energy is stored in the inductance L and the electric energy is stored in the capacitance C is an LC resonator. Resonators can take various shapes and forms at microwave frequencies. The electric field distribution is affected by the shape of the microwave structure that affects the stored electrical and magnetic energy. The inherent resonance frequency is present in all microwave structures determined by its physical properties and dimensions. The most important design considerations for microwave cavities are cavity size, no-load Q, spurious power, and power processing. The higher the loss, the lower the Q value. Therefore, it is desirable to use a resonator with a high Q value. This reduces the insertion loss of the filter and improves its selection performance. Similarly, the one port S parameter analysis is very useful in measuring the resonant frequency. A simple S11 measurement provides direct information about the resonator's resonant frequency and its interference behavior.

The main uses of resonators are filters, oscillators, tuned amplifiers, and frequency meters. The resonator has a wide range of frequencies to choose from and can be used as a frequency selection device that can be used in the microwave range. The resonator also functions as an oscillator. Here, crystals and ceramics (used in the manufacture of ceramic resonators) are the two main materials used. A ceramic resonator is an electronic circuit or device used to generate an oscillation frequency output using ceramic as a piezoelectric resonant material. A material can have more than one electrode, and when connected to an oscillator circuit, it receives mechanical vibrations, resulting in an oscillation signal of a particular frequency.

### 1.2 Types of Resonators

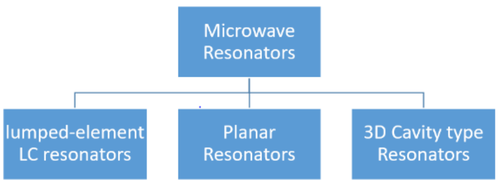


**Fig -1**: Types of Resonators

Microwave resonators are divided into three major categories: lumped-element LC resonators, planar resonators, and three-dimensional (3D) cavity-type resonators.

A. Lumped Element LC Resonators

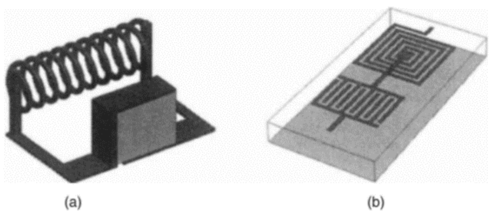


**Fig -2**: Lumped Element LC Resonators

A lumped-element resonator constructed by using a chip inductor and a chip capacitor is shown in Figure (a). The lumped-element resonator can be printed on a dielectric substrate in the form of a spiral inductor and an interdigital capacitor, as shown in Figure (b). They are considered to be extremely small in size and offer a wide spurious-free window; however, they have a relatively low value of Q. A typical Q value for lumped-element resonators is between 10 and 50 at 1 GHz. 11.5. Generally, lumped-element filters are employed in low-frequency applications.

B. Planar Resonators

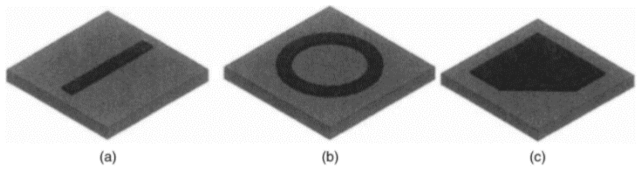


**Fig -3**: Planar Resonators

Planar resonators can be seen in the form of a length of microstrip transmission line terminating in a short or open circuit, or they can take the form of a meander line, folded line, ring resonator, patch resonator, or other arrangement. In the above figure , configurations: (a) half-wavelength resonator; (b) ring resonator; (c) rectangular patch resonator are some examples of Microstrip Resonators. Planar resonators can conveniently be classified as transmission line resonators and patch resonators. The length of its line is always proportional to the wavelength. Transmission line resonators have a physical length equal to some fraction of the wavelength of the guided wave. A closed ring geometry, in which the electrical length is equal to an integral multiple of the wavelength, also acts as a resonator. In open-ended planar resonators, fringe field effects at the open end result in effective line strain and thus reduce the resonant frequency. This effect must be taken into account in the calculation. Therefore, it can be assumed that the resonant modes of such resonators have approximately one-dimensional dependency. The situation is quite different for the resonance condition of a patch resonator, which depends on both the length and the width of the patch (a two-dimensional problem).

The overall performance of a patch resonator, inclusive of resonance frequency and high quality factor, is noticeably dependent on the dielectric parameters of the diverse substances contained in its structure. For microwave system applications, substrates and super straight dielectrics are achieved with very low loss materials to achieve the best performance. When used as a sensor, part of the dielectric layer may be made of an unknown material. Changes in resonator parameters, mainly frequency shifts and increased quality coefficients, are related to the complex permittivity of this unknown material. In this particular application, a patch sensor is used to determine the permittivity of a particular layer by comparing the parameters measured in the patch using a reference structure with the parameters obtained using an unknown material. You can evaluate it. Accuracy between structural modeling and measurement data is urgently needed to obtain good values for the dielectric parameters of unknown materials by solving the inverse problem, or to emphasize local variations in permittivity.

Planar resonators are usually employed in wideband, compact, and low-cost applications. The typical Q value for planar filters is in the range of 50–300 at 1 GHz. In particular, there have been tremendous innovations in planar resonator configurations.

C. 3D cavity-type resonators

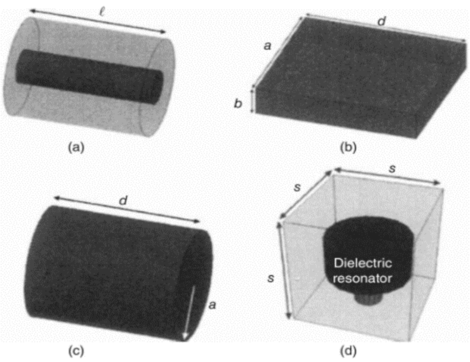


**Fig -4**: 3D cavity-type resonators

Figures (a), (b), (c), and (d) show examples of 3D coaxial, square waveguides, circular waveguides, and dielectric resonators. A coaxial resonator consists of the length of a coaxial line with both ends shorted. Waveguide resonators are rectangular and circular waveguides that are short-circuited at both ends. The dielectric resonator cavity consists of a high-k dielectric resonator mounted in a low-k support structure within the lower metal housing. 3D resonators are bulky. However, they do provide a very high Q factor. In addition, they can handle high RF power levels. 3D resonators are widely employed to construct filters for low loss wireless and space communication applications. The dielectric resonator technology, in particular, is emerging as the technology of choice for miniature high Q filters.

Dielectric resonators can be used to replace the resonant cavities of components such as filters and oscillators. It is typically a disc shaped material with a high εr value. This high εr value provides a significant advantage, enabling the size of a circuit designed with a dielectric resonator to be significantly smaller than when an air filled cavity resonator is employed. Since the electromagnetic field is mainly confined in the dielectric resonator, very low radiation loss and high quality factor (Q) can be achieved.

## 2. MECHANISM OF RESONATORS FOR MONITORING BLOOD SUGAR:

It is useful to study the same because differences in the conductivity of aqueous glucose solutions can change in amplitude due to changes in the concentration of electrolytes contained in them. The ratio of the frequency shift to the change in the dielectric constant of an aqueous glucose solution for a given volume is defined as its sensitivity. Therefore, the resonator captures changes in the permittivity of the surrounding medium (glucose solution) as the glucose level in the solution changes [3]. The electromagnetically excited annular gap resonator can be used for glucose monitoring. First, the frequency shift of the resonator is studied by loading different concentrations of glucose in a constant amount of water onto the surface of the resonator. The analysis can be further extended by examining frequency shifts using human blood samples with known glucose levels. Glucose levels can be measured using the lancet by inserting a glucose meter and lancet into the fingertips and collecting blood samples. The blood glucose level of an unknown blood sample can be predicted from the frequency shift of the resonator sensor. Resonators can be simulated using the HFSS simulator. The Agilent Vector Network Analyzer E5080A is used for measurement purposes. The resonator response can be analyzed by dripping pure water on the coupling edge, changing the resonant frequency of the open-loop resonator. As a result, when a fluid is introduced in consideration of the dielectric change of the ring resonator, the resonance frequency shifts. Response fluctuation analysis is performed by changing the glucose concentration at a constant water concentration. The resonance frequency fc shifts due to the interaction between the fringe field and the dielectric. As the concentration of glucose in the water increases, a positive shift in the resonant frequency is observed. Knowing the relationship between the resonant frequency and the permittivity allows us to identify the permittivity of an unknown sample. A split ring resonator lowers the combination of glucose and water while keeping the substrate concentration high. This concept can be used to determine blood glucose levels in people facing incurable diabetes. Normal fasting blood glucose is 80-130 mg / dL and should not exceed the 180 mg / dL mark above even after eating. A human blood sample can be taken from the fingertips and the blood glucose level is measured with a glucose meter. When the blood glucose level of the specimen varies, the corresponding frequency shift is studied. Thus, the glucose level of blood samples can be predicted with known resonant frequency. [1]

Ultra-wideband microwave sensors can be used to check sensitivity, accuracy, and reliability by changes in signal energy at a particular frequency of a blood glucose solution in a concentration range specified by a defined step value. Blood glucose levels in diabetics can be monitored using a planar microwave sensor made of a honey cell-shaped, complementary split rectangular resonator.

The glucose stage of one μL of solution may be measured with the assistance of a biosensor composed of a single metamaterial asymmetric resonator. The glucose solution is positioned on the gap of the resonator which results in a semicircle shape. The interplay of the glucose with the power of the electrical field generated from an LC resonator made it feasible to design a microwave sensor with a complementary asymmetric single split resonator with a high quality factor. By setting the samples on the spot of a maximum electric field, the wave–matter interaction between the confined electric field within the single resonator and the glucose molecules is maximized. Asymmetric resonators that assist Fano-like high quality factor resonance result in the improvement of the biosensor shape used for the glucose level monitoring. In a single asymmetric split resonator (SASR) based system. The design footprint depends on the operating frequency. To provide a clean change in permittivity with the change in glucose, the resonator frequency may be set close to the molecular resonance of glucose, which is the terahertz (THz) frequency. The four main features of this technique are: (i) Use of a single primary metamaterial-based total resonator instead of the traditional full two-dimensional resonator array. (ii) Analyze a trace amount (1 µl) of glucose response. (iii) A custom resonator with a semi-circular design to trap the bullet and keep the low response at a positive point. (iv) Existence of induction environment in rectangular waveguide. For each measurement, a 1 µL drop of glucose response is placed in the semicircular portion of the resonator. Even if the SASR consists of single resonators, the shift within the resonant frequency is obvious and important.

Saturation behavior is observed in metamaterial resonators at better concentrations. A bare resonator can be used as a reference and the results can be compared to other resonators that used distilled water or aqueous solution as a reference. In this technique, a double asymmetric-split resonator is used as a biosensor to measure the glucose attention zone, which indicates hypoglycemic or hyperglycemic conditions. [4]

## 3. OTHER METHODS FOR BLOOD SUGAR MONITORING

The electrochemical technique is used commonly for blood glucose monitoring, as it gives the most accurate results. The examples of electrochemical techniques are finger pricking method, thin lancet implanted devices etc. Finger pricking method is a self glucose monitoring method as diabetic patients can themselves measure their blood glucose levels using a lancet and a glucometer. The disadvantage of this method is that it causes pain after continuous use and also carries a chance of infecting the patient with outer bacteria as the lancet is pricked into the finger. The thin lancet implanted devices are also required to be pricked frequently, but research is going on in this method since it makes it possible to measure blood glucose continuously. Not only is it painless, but new non-invasive methods that provide highly accurate results, such as the finger stick method, which measures blood glucose levels in direct contact with blood, need to be discovered. Recently, new technologies such as non-invasive optical technology and microwave technology have emerged. Fluorescence spectroscopy is a less invasive, highly sensitive optical method that can accurately measure blood glucose levels, but at the same time can damage tissues after continuous use. Similar to fluorescence spectroscopy, surface plasmon resonance (SPR) technology is a sensitive, minimally invasive optical technology. SPR technology has received less attention due to its bulky size. Because the small design structure requires time. Microwave spectroscopy is a method that can be used for both invasive and non-invasive blood glucose measurements. Microwave spectroscopy is label-free and this method uses non-ionizing radiation. Various methods such as free space, transmission lines, and cavity resonators are described for observing the behavior of different materials in RF / microwave spectroscopy. The resonant cavity method is widely used because of its high sensitivity and narrow bandwidth, which allows it to detect changes in permittivity. [5]

Blood glucose measurement technology using a microstrip split ring resonator sensor is a minimally invasive method.

This method measures the shift in the resonant frequency of a split ring resonator with respect to changes in the permittivity of the surrounding medium (glucose solution). Change in blood dielectric constant with change in glucose

Concentration is the root reason for frequency shifts. The dielectric constant of a solvent is primarily determined using a microstrip resonator sensor. The permittivity is calculated using several configurations of microstrip resonators. The split ring resonator (SRR) has the ability to measure the permittivity of aqueous glucose solutions of various concentrations. This concept is also used to find blood sugar levels. This method allows you to test a variety of blood samples and make effective glucose predictions. This method uses a Vector Network Analyzer, Keysight E5080, to measure the permittivity. Techniques such as resonance, reflection, and transmission / reflection can be used to determine the dielectric properties of a liquid.

Another method, which is a fully implanted telemetry system, is used for continuous monitoring of subcutaneous tissue glucose in people suffering from diabetes. Membranes containing immobilized glucose oxidase are used in sensors and catalase bound to oxygen electrodes, and in telemetry systems integrated together to create implants. The device remains embedded for up to 6 months and the signal is sent to the external receiver every 2 minutes. Glucose clamps and spontaneous glucose spike signaling are present in the data, each adjusted blood glucose and fingertip values are used as references. Dynamic sensor glucose is represented by sensor signals that do not have a separate standard, so it contains a model that explains the relationship between blood glucose and the signal. All model parameter values, including adjacency tissue permeability to glucose, are estimated and comparable to traditional mass transfer parameters. As a group, sensor calibration shows random weekly fluctuations. The strong association between the sensor signal and the reference glucose level is indicated by a statistical correlation. This system allows easy and continuous monitoring of blood glucose levels in diabetics. Till date, glucose monitoring is essential because there is no cure for diabetes and all treatments for diabetes are based on glucose control. With this fully embedded telemetry system, you can continuously monitor your blood glucose levels in new and efficient ways. [6]

## 4. CONCLUSION

In this paper, various types of resonators are analyzed for blood sugar monitoring. Use of resonators turns out to be one of the best non-invasive methods for blood sugar monitoring with respect to its accuracy and cost. The capability of resonators to measure the dielectric parameters of a volume in a non-destructive way is one of the key factors for their usage in blood sugar monitoring. With the use of resonators glucose level of unknown blood samples can be predicted. The concept of shift in frequency of resonators due to change in glucose level of the surrounding medium can also be used for developing devices for monitoring blood sugar.

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