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Araştırma Makalesi Research Article

DETERMINATION OF OLIVE OIL PURITY BY S PARAMETER

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Keywords

Oil Adulteration, Pure Oil, Mixed Oil, Olive Oil, Sunflower Oil, Electromagnetic Analysis, Helical Antenna.

Abstract

Vegetable oils are one of the products used in our daily lives, and the originality and purity of the oil used is important. Olive oil is highly preferred by people. Mixing different oils such as canola oil, sunflower oil, soybean oil, and other seed oils into olive oil to reduce its cost reduces its purity and leads to fraud. It is very difficult to detect these oils mixed with olive oil, and to understand whether the olive oil is pure or not when viewed visually. For the quality of the oil, values such as fluidity, base number, refractive index, acid numbers, and density must be measured, and analyzed. Extensive laboratory environments are required to control these chemical changes in oil. Instead of these laboratory environments, an easy-to-install, practical, and cost-effective electromagnetic analysis method has been proposed to determine the purity of oil. The S parameters of olive oil, sunflower oil and a mixture of the two were measured with a helix antenna between 2-4 GHz.Pure olive oil was determined by evaluating the reference S_{11} value of the antenna, and the change in S_{11} value, and resonance frequency shift when pure oil and impurity oil were present in the container. Due to mixed oil, a 12.5MHz frequency shift toward lower frequencies is observed, which shows that the proposed system can differentiate standard oil from non-standard.

ZEYTİNYAĞI SAFLIĞININ S PARAMETRESİYLE BELİRLENMESİ

Anahtar Kelimeler

Yağ Tağşişi, Saf Yağ, Karışım Yağ, Zeytin Yağı, Ayçiçek Yağı, Elektromanyetik Analiz, Helix Anten.

Öz

Bitkisel yağlar günlük hayatımızda kullandığımız ürünlerden biri olup, kullanılan yağın orijinalliği ve saflığı önemlidir. Zeytinyağı insanlar tarafından oldukça fazla tercih edilmektedir. Kanola yağı, ayçiçek yağı, soya yağı ve diğer tohum yağları gibi farklı yağların zeytinyağına karıştırılarak maliyetinin düşürülmesi saflığını azaltır ve sahtekarlığa yol açar. Zeytinyağına karışan bu yağları tespit etmek ve gözle bakıldığında zeytinyağının saf olup olmadığını anlamak oldukça zordur. Yağın kalitesi için akışkanlık, baz numarası, kırılma indisi, asit sayısı, yoğunluk gibi değerlerin ölçülüp analiz edilmesi gerekir. Yağdaki bu kimyasal değişimlerin kontrol edilebilmesi için geniş laboratuvar ortamlarına ihtiyaç vardır. Bu laboratuvar ortamları yerine, yağın saflığının belirlenmesi için kurulumu kolay, pratik ve uygun maliyetli bir elektromanyetik analiz yöntemi önerilmiştir. Zeytinyağı, ayçiçek yağı ve bu ikisinin karışımından oluşan S parametreleri 2-4 GHz arası helis anten ile ölçülmüştür. Saf zeytinyağı, antenin referans S_{11} değeri ve S_{11} değerindeki değişim değerlendirilerek belirlenmiştir. Karışık yağ nedeniyle, daha düşük frekanslara doğru 12.5MHz'lik bir frekans kayması gözlemlenmiştir, bu da önerilen sistemin standart yağı standart olmayandan ayırt edebildiğini göstermektedir.

Alıntı / Cite

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Highlights

- A preliminary study was carried out to determine oil purity without the need for a complex laboratory environment and instruments.
- Helix antenna was designed to measure the mixing effect of oils.
- Oil adulteration was detected by looking at S_{11} parameters there is a 12.5 MHz resonance frequency difference between olive oil and mixed oil.

Graphical Abstract

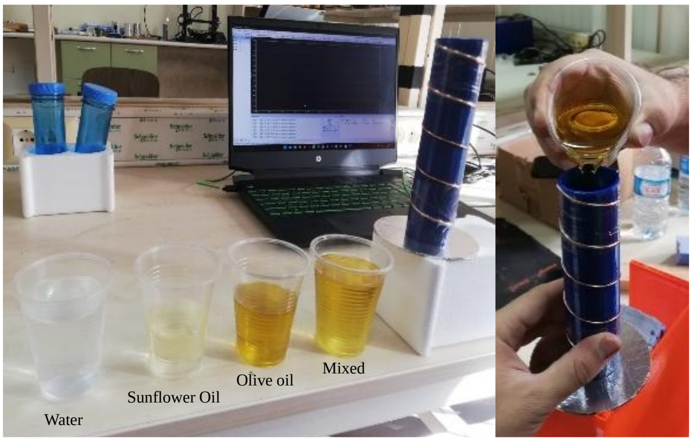

Figure. Measurement Setup

Purpose and Scope

Mixing different types of oils and liquids with pure oils causes problems in human health and economy. Preliminary studies have been carried out to develop an accessible, short, and easy analysis method to solve this problem.

Design/methodology/approach

In the system considered for the purity measurement of oils, a method that is simple and does not require complex analysis has been considered. In the proposed study, the change in the S parameters of the oils was observed with the container placed in a helix antenna operating between 2-4 GHz.

Findings

Using a helical antenna operating at 2-4 GHz specifically designed for fraud detection, an investigation was conducted to determine whether olive oil was a mixture. Initially, S11 parameters were measured with a Vector Network Analyzer (VNA) for sunflower oil, followed by olive oil, and then a mixture of the two oils. The resonance frequencies of the oils at S_{11} values were found to be different, indicating a distinction between the S_{11} parameter of the mixed oil and that of pure olive oil.

Practical implications

The resonance frequency shift in the S parameter with the helix antenna used was a preliminary study on oil purity, and the resonance differences of pure olive oil and mixed oil were obtained. In practice, it is thought that it can contribute to economical systems that can be developed to eliminate the need for advanced laboratory environments, devices, and sensors in terms of application. This will make it easier for the consumer to access pure oil. In future studies, with the method to be developed, it will be tried to predict which oil is the mixed oil and what percentage of the mixture it is.

Originality

There are studies on the purity of materials in various laboratories, but this study is thought to be a very accessible study in terms of applicability and ease.

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1. Introduction

The escalation in human population has also increased consumption, and the limited world resources, and increased competition between companies have also led to rise in imitation of products. Due to the demand for olives, which have been produced and consumed since ancient times, their value in world trade is growing day by day. Olive oil production varies from year to year and is limited, so its price is quite high compared to other oils, this high price causes olive oil to be adulterated with other cheap oils, especially in producing countries, and it is considered the most adulterated food in the world (Dıraman and Tüğen, 2022). Hippocrates, the father of medicine, called olive oil "the great healer" and Homer, the famous poet of ancient Greece, called it "liquid gold" (Dıraman and Tüğen, 2022). Increasing health awareness in the world has increased the tendency towards pure foods, and olive and olive oil trade has gained importance in world trade (Ağır et al., 2018). Adulteration plays a deceptive role in unfair competition, making a low quality food product look like high quality in terms of health, adulteration has worse consequences, and has a very important ethical dimension, especially negatively affecting babies, young children, the elderly, and patients, creating a cycle of malnutrition that affects all humanity and generations (İçyer and Durak, 2019). Consumer awareness and demand for pure products in a healthy way also necessitate controls in olive oil production. Natural olive oil is obtained from the olive tree using unique techniques, only mechanically, without compromising its purity, and can be consumed without undergoing any refining process. In this case, the refined and pomace olive oil available in the market is not pure olive oil. Pure olive oil is adulterated by adding seed oils (rapeseed, sunflower, soybean, cotton, corn, peanut, mustard, sesame, poppy, etc.) or vegetable refined blend oils (oils such as hazelnut oil, avocado oil, etc.) (Türkmen and Ataseven, 2020). Identifying these impure olive oils is important for the consumer. It is important to perform these analyzes economically and quickly, without the need for advanced laboratories and test environments. There are testing devices such as spectrometry, but they are expensive and difficult to access. Spectra obtained with this method contain the vibrations (wavenumber) of molecular bonds in the mid-infrared region 4000 to 400 cm^{-1}, since each component has its own fingerprint region, samples with different molecular bonds can be detected with different vibration frequencies (İçyer and Durak, 2019). When the literature was examined, the electrical properties of sunflower oil were obtained in real and imaginary parts of the electrical conductivity value at different temperatures between 5 MHz and 0.5 MHz (Ulrych and Mentlik, 2016). Temperature-dielectric spectroscopy of flaxseed, sunflower, mustard, rapeseed, and olive oil at 25–70°C and 25 Hz–1 MHz frequency was obtained and a mechanism for hardening was proposed (Agaev et al., 2020). In another adulteration study, the dielectric properties of binary oil mixtures at different ratios were examined in the frequency range of 101 Hz to 1 MHz, and the results showed that as the concentration of oils increased, the dielectric spectrum of the binary mixture of olive oil added with other oils also increased (Lizhi, 2010). In addition, in this study, the relative dielectric constant of olive oil at 1 MHz was shown to be 3.041 ±1.6e04 and 3.049 ±3.1e04, varying depending on the olive species. However, the dielectric constant of sunflower oil was reported as 3.037 ±2.0e04 (Lizhi, 2010). In another study, the obtained results demonstrated the feasibility of detecting adulterations of olive oil with percentages of at least 10% of sunflower and red palm oils (Xu, 2014). A rapid and simple luminescence method combined with advanced chemometric tools has been developed to characterize and classify edible vegetable oils with good predictive ability (Domínguez, 2019). In addition, a capacitive probe study was conducted based on the fluidity change in the oil to show the effects of changes in the quality of frying oil on human health (Liu et al., 2019). Besides vegetable-based edible oils, there are studies in the literature that analyse industrial oils (Yıldırım and Gözel, 2023), alcohols (Akgöl, 2018), or water mixtures of chemicals such as acetone with special targets using antenna-based sensors (Hossain et. al., 2024). As expected in all of the studies, the frequency with the lowest reflection aka resonant frequency, shifts depending on the mixture of the relevant substances. In this context, when compared with this study, it is seen that different structures designed with similar hypotheses give compatible results.

Nowadays, with the developing technology, information can be obtained about the characterization of many simple or complex substances by using electromagnetic methods. Each substance has its own electrical characteristics. The identity information of substances as electrical characteristics is carried on their electrical permittivity and magnetic permeability values. In the literature, it has been observed that the relative dielectric constant for olive oil varies between 2.92 and 3.05 at 2.50 GHz levels and between 25-180 °C (Delgado et al., 2021). Depending on the magnetic permeability and electrical permittivity values, the reflection coefficient and transmission coefficient values of the substances are calculated. The scattering parameter carries these transmission coefficient and reflection coefficient values. For this reason, material characterization can be determined based on the scattering parameter. In this paper, when the olive oil placed inside the antenna and whose purity was measured was mixed, that is, its purity was impaired, its dielectric properties changed, and this change caused a shift in the resonance frequency.

In this study, pure water, sunflower oil, olive oil and a 50% mixture of sunflower and olive oil were placed in the container inside the helical antenna and scattering parameters were measured with VNA. According to these measurement results, the purity of the oil was determined depending on the resonance frequency shift in the S_{11}

parameters. In this preliminary study, it is predicted that the proposed method to understand the purity of the oil will be accessible, easy to apply and economical.

2. Material and Method

Helix antennas are antennas mounted on the ground plane surface, wrapped in a helix from one or more wires. In this study, a ground plane surface-mounted helical antenna operating in single-wire angular mode was constructed. Geometric parameters of helix antenna as shown Figure 1 usually turn N, diameter D, each turn space S. L, C, L_0, L_n where Helix antenna total length, circumference, each turn length, wire total length are given in the following equations (1)-(4). Pitch angle (α) which is a line tangent to the helix antenna wire and a plane perpendicular to the helix axis is given equation (5).

$$L = NS \tag{1}$$

$$C = \pi D \tag{2}$$

$$L_0 = \sqrt{S^2 + C^2} \tag{3}$$

$$L_n = NL_0 \tag{4}$$

$$\alpha = \tan^{-1}\left(\frac{S}{\pi D}\right) = \tan^{-1}\left(\frac{S}{C}\right) \tag{5}$$

In axial mode helix design for circular polarization circumference C of the helix must be in $3/4 < C/\lambda_0 < 4/3$ range (with $C/\lambda_0 = 1$ near optimum), and the spacing about $S \cong \lambda_0/4$. The pitch angle is usually $12° \leq \alpha \leq 14°$ (Balanis, 2012). Although as a ground plane like cupped ground plane, conical ground plane, a flat ground plane is generally used. Flat ground plane diameter is at least $\lambda_0/2$ (Kraus, 1988). (λ_0 is given operating wavelength.) In axial mode the dimensions of the helix are not critical. Therefore, parameters can be adjusted according to the desired bandwidth to get better results.

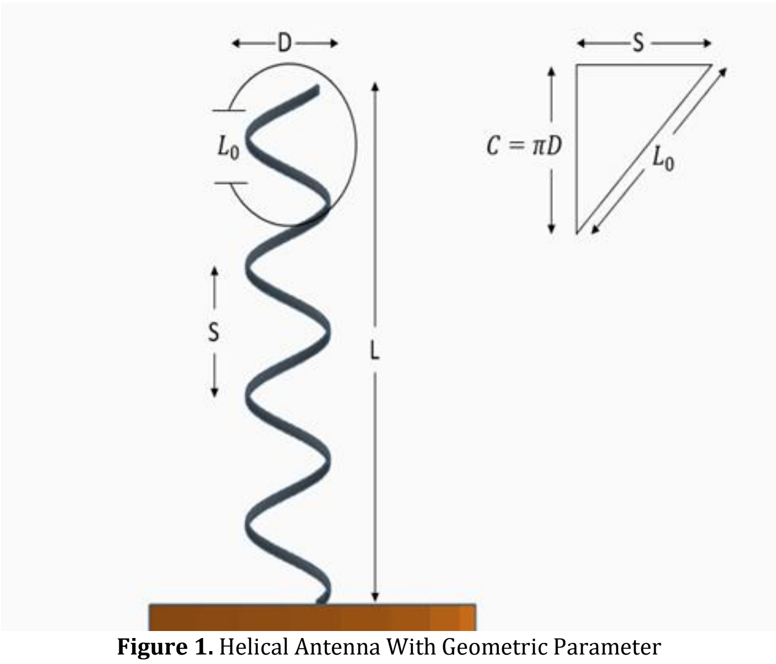

Figure 1. Helical Antenna With Geometric Parameter

The terminal resistance of the helix antenna is between 100 and 200 ohms. Since the resistance of the supply line is generally 50 ohms, impedance mismatch occurs. The purely resistive input impedance given equation (6) (Balanis, 2012).

$$R \cong 140\left(\frac{C}{\lambda_0}\right) \tag{6}$$

In order to ensure impedance matching by eliminating the inductive reactance that occurs due to the structure of the helical antenna, a cylindrical balun with a height of $\lambda_0/8$ and a diameter of 5 mm was designed between the ground plane and the pin. The half-power beamwidth which is accurate to about ±20%, the directivity and the axial ratio are given in the following equations (7)-(9) (Balanis, 2012).

$$HPBW(degrees) \cong \frac{52\lambda_0^{\frac{3}{2}}}{C\sqrt{NS}} \quad (7)$$

$$D_0(dimensionless) \cong 15N\frac{C^2S}{\lambda_0^3} \quad (8)$$

$$AR = \frac{2N+1}{2N} \quad (9)$$

According to the given equations, the helix antenna operating between 2 GHz - 4 GHz was realized by adjusting the parameters to be at the optimum level in the simulation environment. The parameters of the antenna are given in Table 1.

Table 1. Parameters Of Helix Dimensions

PARAMETERS OF HELIX	DIMENSION
D (diameter of helix)	39,47 mm
C (circumference of helix)	124 mm
S (spacing between turns)	31 mm
N (number of turns)	5
α (pitch angel)	14º
Ground diameter	93 mm
Balun diameter	5 mm
Balun height	20 mm
HPBW	55º
Directivity	9.96 dB

$$f = \frac{c}{\sqrt{\varepsilon_r}\lambda_0} \quad (10)$$

The propagation of an electromagnetic wave within the material is affected by the dielectric properties of the material and the frequency of the wave is found from the given equation (10). As seen in the equation, changing the frequency also affects the wavelength. In this case, S_{11} of the antenna is also affected because in the given equation, C/λ_0 should be approximately 1 for optimum operation of the helix, where C is circumference of helix, λ_0 is wavelength. And since this value will change, shifts in the S_{11} parameter of the antenna will occur.

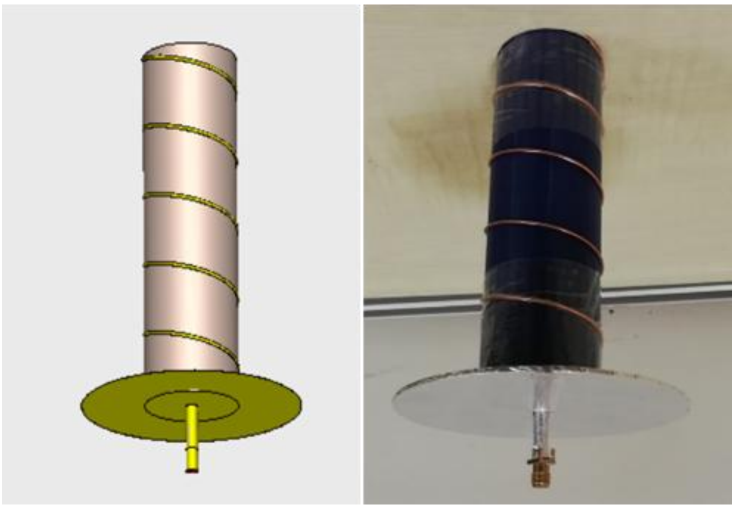

Figure 2. Designed And Realized Helix Antenna.

A helix antenna was preferred since a portable container can be placed in the middle of the helix. In this study, the modes of the antenna are not the subject of study, but the axial mode helix selection was chosen to have a container size that can be placed. A container that can be printed from a 3D printer in a simulation environment was added to the design to guide the winding of the helix antenna and to serve as a container into which olive oil can be poured. This designed and realized antenna are shown in Figure 2. When the S_{11} results of the helix antenna and the results obtained with the container added to this antenna are evaluated, while the scattering parameter of the antenna decreases by approximately 10 dB in the majority of the results, there is a slight shift in the resonance frequencies and the amplitude is improved. S_{11} results of the actual measurement taken with this design are given in Figure 3. The S_{11} parameter of the helix antenna produced with the container was measured with Libre VNA. As seen in Figure 3, despite of the losses caused by the manufacturing error, the S_{11} values are like the results obtained in the simulation.

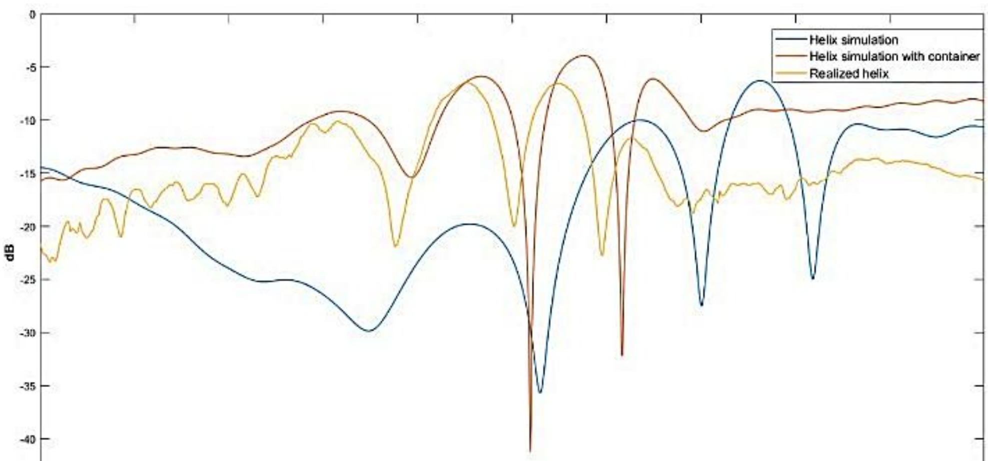

Figure 3. Helix Antenna S_{11} Parameters

Although the designed helix works best in the 2.3 GHz-3.1 GHz frequency band, it operates in the 2 GHz-4 GHz band. (except 3.45-3.58GHz). Various measurements were taken with VNA to determine the purity of olive oil with the designed antenna. These measurements were taken in equal volumes of pure water, pure sunflower oil, pure olive oil and 50% mixed olive oil and sunflower oil, respectively. Pictures of these measurement studies are shown in Figure 4.

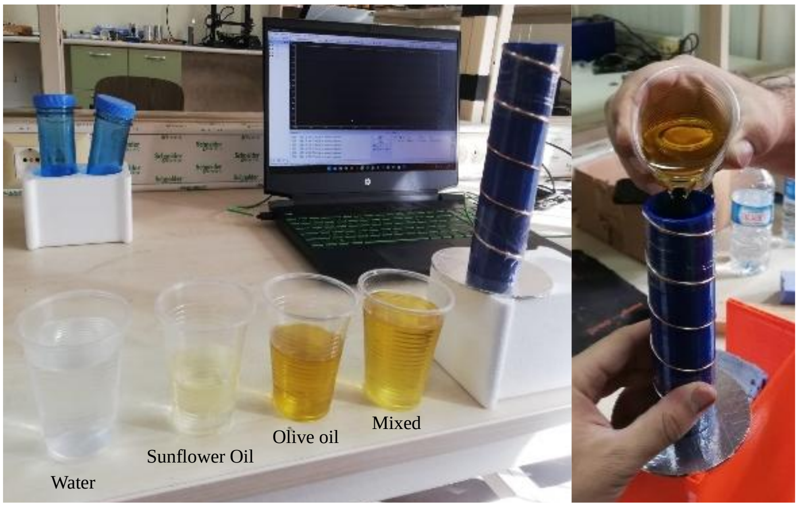

Figure 4. Measurement Setup

3. Results

Oil measurements were carried out with VNA in situations created to detect counterfeiting in olive oil. First, pure water was measured. Then, sunflower oil and then olive oil were measured. Then, olive oil and sunflower oil were mixed and measured. The frequency-dependent change of S_{11} parameters of individual oils were obtained, and then these results were plotted according to frequency, as seen in Figure 5. In this figure, the horizontal axis is frequency, and the vertical axis is dB. As seen in Figure 5, the resonance frequencies of the oils are different. At the 2.62 GHz which is not a resonance frequency of antenna, the resonance frequency that occurred after oil was lowest in mixed oil and the S_{11} parameter was -28.40 dB. At 2.63 GHz, the resonance frequency of sunflower oil occurs and the S_{11} parameter is -33.37 dB. The resonance frequency of pure olive oil was at 2.64 GHz and its S_{11} was -48.82 dB. Here it is clearly seen that different S_{11} values. Different resonance frequencies have occurred between the pure olive oil and the mixed oil. It has been observed that oils shift the resonance frequency of the antenna to the left, and there is a 12.5 MHz difference between the resonance frequency of the mixed oil and the resonance frequency of the pure oil.

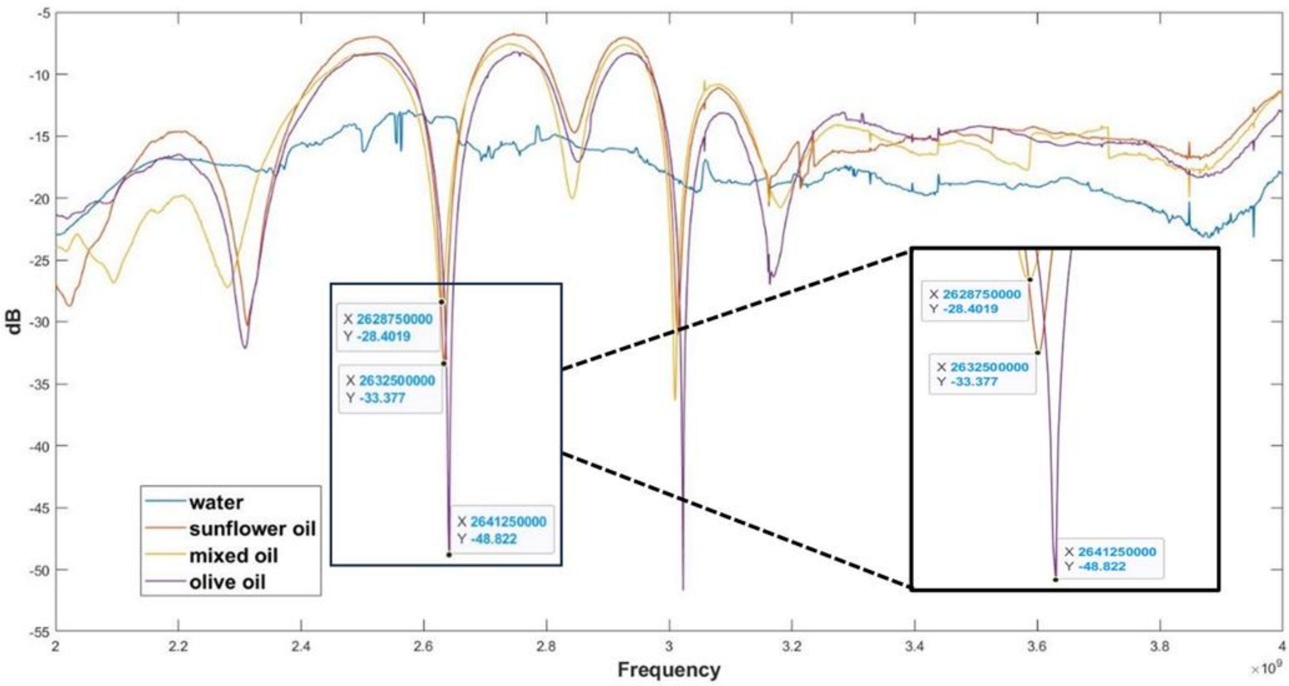

Figure 5. Measurement S_{11} Results.

4. Discussion and Conclusions

Due to limited oil resources and increasing demand for oil, olive oil counterfeiting has risen recently. Detecting this fraud is essential for the financial situation and health of the consumer. It was determined whether olive oil was a mixture with the container placed in a helical antenna operating at 2-4 GHz designed for fraud detection. First, sunflower, olive, and impure oil were obtained by mixing the two. S_{11} parameters were reached with VNA, and according to the results, the resonance frequencies of the oils at S_{11} values were different. This shows that the S_{11} parameter of the mixed oil is different from pure olive oil. According to the results obtained, the resonance frequency of pure olive oil was 2641.25 MHz, the resonance frequency of sunflower oil was 2632.50 MHz, and the resonance frequency of the oil that was a mixture of the two was 2628.75 MHz. It can be seen from here that there is a difference of 12.5 MHz between the resonance frequencies of pure olive oil and mixed oil. The resonance of olive oil is shifted to the left by 12.5 MHz.

In summary, these differences can help determine whether it is pure or not. Since it was desired to examine the limit conditions and an observable difference between the mixture and pure olive oil, the mixture ratio was chosen as half. In future work, oils other than sunflower will be added to olive oil, and dielectric studies will be carried out on them. Based on the differences, predicting which oil is added is envisaged.

Acknowledgement

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