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# Broadband Dielectric Properties Evaluation of Catharanthus Roseus Leaf, Flower and Stem Using Open Ended Coaxial Probe Technique

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**ABSTRACT**

Dielectric properties (i.e. permittivity and loss tangent) are measured for Catharanthus Roseus plant species using open ended coaxial probe technique at 25 º C temperatures. Measured data are useful in SAR (Specific Absorption Rate) evaluation in different parts of the same plant due to RF (Radio Frequency) exposure from different wireless sources like GSM and CDMA cell phone towers. Dielectric properties (of the species taken) are measured and illustrated in graphs within a frequency range of 200 MHz to 8.5 GHz. Permittivity and loss curves are presented for Catharanthus Roseus leaf, flower and stem samples at 25ºC.

***Keywords:*** Catharanthus Roseus, Dielectric properties, Loss tangent, Open ended coaxial probe technique, Permittivity, Plant and Vegetable

## 1. Introduction

The complex permittivity of a dielectric medium reflects the extent to which that particular medium interacts with electric fields. Permittivity is a measure of how an electric field affects, and is affected by, a dielectric medium. It is determined by the ability of a medium to polarize in response to an electric field. Thus, dielectric constant relates to a medium’s ability to permit the electrostatic lines of flux within that medium. The complex dielectric constant or complex permittivity of any medium can be decomposed in to two parts i.e. the real part of permittivity ($\varepsilon'$) and imaginary part of permittivity ($\varepsilon''$) / loss tangent ($\tan\delta$) and mathematically complex permittivity is defined as $\varepsilon = \varepsilon' - j\varepsilon''$. The real part of dielectric constant ($\varepsilon'$) of a medium is associated with the RF energy storage capability within the medium in presence of an RF field whereas the imaginary part ($\varepsilon''$) is associated with the energy dissipation within the medium i.e. the conversion of RF energy to heat energy in the medium. Both permittivity ($\varepsilon'$) and loss tangent ($\tan\delta$) are having an important aspect in finding out SAR of an object that may be a human head or a Catharanthus Roseus leaf.

There are various available techniques for determining dielectric properties of different materials, among them open ended coaxial probe technique is very popular one as it is a non-destructive measurement technique specially used for biological samples [1]. Open ended coaxial probe technique for dielectric properties determination was invented by Stuchly and Stuchly in 1980 [1]. This particular method calculates permittivity and loss tangent of the MUT (material under test) from the phase and amplitude of the reflected signal ($S_{11}$) at the end of an open-ended coaxial line inserted or immersed into the sample MUT. This technique is extremely useful in measuring the dielectric properties of liquid, semi-solid and solid samples with high loss factor and therefore the same has been used several times to determine dielectric properties of different fruits and crops [1-2]. Hence, this technique is employed in this work to study the dielectric properties of Catharanthus Roseus leaf, flower and stem samples at $25^0$C for further SAR evaluation in the plant due to RF exposure from wireless cell phone towers.

Now-a-days, researchers are well concerned regarding the biological effects of RF radiation on human especially in head due to cell phone usage. On the other hand, the whole plant kingdom is exposed to RF radiation from several wireless sources like GSM and CDMA cell phone towers. The plant leaves, fruits, flowers and twigs are having high water content which results in high permittivity and loss values for different parts of various plants. Consequently, plants are also absorbing huge amount of RF energy from these cell phone towers that may have some possible effects on their growth and other physiological processes. From this point of view, dielectric properties of Catharanthus Roseus plant is measured at $25^0$C for further investigation on SAR evaluation in different parts of Catharanthus Roseus plant due to RF exposure from cell phone base station towers.

In this particular work, dielectric properties of Catharanthus Roseus leaf, flower and stem samples are measured with Agilent 85070E Dielectric Probe Kit and Network Analyzer at 25ºC temperature. Measured permittivity and loss tangent versus frequency curves for different Catharanthus Roseus leaf samples show a minor variation because of difference in their maturity levels and the optimum dielectric curves (curve drawn with the data set that repeats in most of the measurements) are presented for each type of Catharanthus Roseus samples (leaf, flower and stem) at $25^0$C.

## 2. Dielectric Measurement Methodology

### *A. Sample Preparation for Dielectric Properties Measurement*

Initially 3 Catharanthus Roseus plants are collected from 3 different gardens of Jadavpur University main campus. For dielectric properties determination of Catharanthus Roseus leaf, some standard size (having a minimum width ≥ 20 mm at least in the centre of each leaf sample to avoid air gap in between the centre line conductor and the outer ground conductor of the probe) fresh leaves are picked from those plants and stacked together under the open ended coaxial probe for immediate measurement before the leaves lose any moisture content. A number of leaves are stacked together because the thickness of the MUT should satisfy the criteria illustrated in (1).

$$\text{Thickness of MUT} \geq (20/\sqrt{\varepsilon_{r\_approx}})\ \text{mm} \quad (1)$$

Next a number of Catharanthus Roseus flowers are picked from those three plants. The twig is cut from each flower in such an efficient way so that the five petals of that flower remain in contact with each other. After preparing a number of flower samples, they are also stacked together with caution under the open ended coaxial probe for instant measurement.

At last, an attempt is made to characterize dielectric properties of Catharanthus Roseus stem/twig. To characterize dielectric properties, cross-sectional samples with flat surface are cut from Catharanthus Roseus stem/twig specimen after satisfying minimum thickness criteria illustrated in (1). But, the diameters of those cross-sectional Catharanthus Roseus stem/twig samples are a little bit smaller than 20 mm which has introduced some amount of inaccuracy in the measured data.

### *B. Open Ended Coaxial Probe Technique for Permittivity and Loss Tangent Measurement*

Open ended coaxial probe technique is being used for several years as a non-destructive dielectric properties evaluation method especially for biological specimens and agricultural products [2]. This technique was pioneered by Stuchly and Stuchly in 1980 [1]. In this technique, permittivity and loss tangent of an MUT are evaluated from the phase and amplitude of reflected signal at the open end of a coaxial probe inserted or immersed into solid, semi-solid or liquid MUT [1]. This open ended coaxial probe technique is especially important in case of biological specimens to perform in-vivo dielectric characterization. This method allows the sample to be placed in close contact with the probe without causing any disturbance to the material characteristics. More care should be taken for materials having low value of permittivity and low loss factor because errors are introduced in the measured data especially for those types of materials. This technique is accurate enough for dielectric characterization of different plants as they are having high permittivity along with high loss factor. The amplitude and phase of the reflected signal (at open end of the coaxial probe) is measured with a VNA (vector network analyzer). The VNA with open ended probe is initially calibrated to measure the reflection coefficient at the probe aperture plane. The method uses distilled water (at 25ºC) for direct calibration at the open end of the probe. In the method, all measurements are performed by placing the standards (short, open and distilled water) at the open ended coaxial probe. Next, the measured amplitude and phase of the reflection coefficient are post-processed to obtain the dielectric parameters using Agilent 85070E software.

### *C. Dielectric Properties Measurement Set Up and Graphical Representation of Measured Data*

Dielectric constant and loss tangent evaluation have been obtained with Agilent 85070E open-ended coaxial probe kit and Agilent VNA at ETCE_Microwave lab of Jadavpur University, Kolkata. Agilent 85070E dielectric probe kit contains a high temperature coaxial probe (shown in the left side of Fig. 1) that can measure permittivity and loss factor up to 20 GHz and can withstand up to 200°C temperature. Agilent 85070E open-ended coaxial probe requires to be connected with Agilent VNA with a cable and also must be interfaced to a PC to install 85070E dielectric evaluation software for computing permittivity and loss tangent from the reflection coefficient at active tip of the probe. The frequency range of the VNA present at JU_ETCE_Microwave lab is limited to 8.5 GHz; hence dielectric properties of Catharanthus Roseus samples are studied up to 8.5 GHz at 101 frequency points. Initially the open-ended coaxial-line probe is calibrated with open air, short-circuit block, and distilled water; then dielectric measurements are taken for leaf, flower and stem/twig samples of Catharanthus Roseus plant.

Measured dielectric properties like permittivity and loss tangent parameters (at 101 frequency points) are saved as data file with the help of 85070E software. There after those data files are converted to excel files and imported to MATLAB software for plotting the data on 2D graphs.

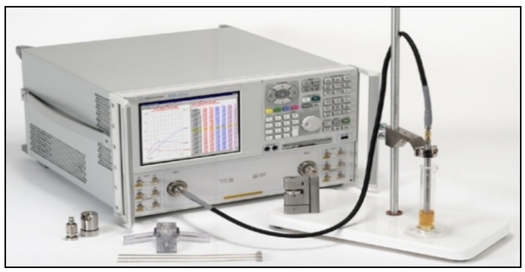


**Figure 1:** Agilent 85070E Dielectric Probe Kit (courtesy: home.agilent.com)

## 3. Results

Dielectric properties measurement of Catharanthus Roseus leaf, flower and stem/twig samples are performed using Agilent 85070 E dielectric probe kit and Agilent VNA at 25ºC ambient temperature. A computer is interfaced along with the measurement set up to record the permittivity and loss parameters. After measurement is done, the excel data sheets containing dielectric properties of Catharanthus Roseus leaf, flower and stem/twig samples are imported to MATLAB software for plotting the dielectric curves for each sample. The permittivity and loss curves are presented for each of the measured samples.

- ✓ *Real part of permittivity vs. frequency*
- ✓ *Loss tangent vs. frequency*

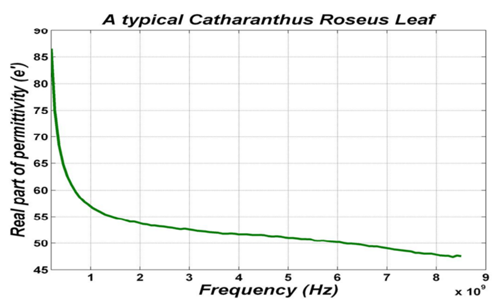
[a] [b]

**Figure 2 [a] and [b]:** Dielectric Constant measurement set up for Catharanthus Roseus Leaf samples with Agilent 85070E Dielectric Probe Kit and VNA

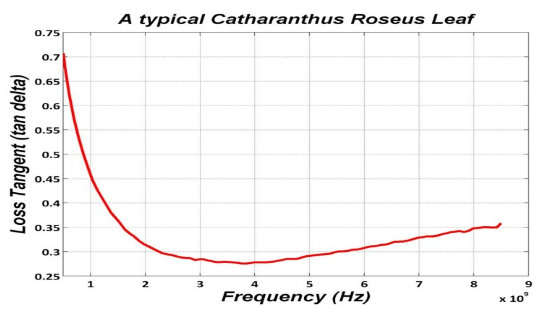
### *A. Dielectric Properties Measurement of Catharanthus Roseus Leaf Samples*

The permittivity measurement set up for typical medium size fresh Catharanthus Roseus leaf samples is shown in Fig. 2 [a] and [b]. In the figures, high temperature dielectric measuring probe is pressed on the stack of 8-10 Catharanthus Roseus leaf samples so that there is no air gap in between them and most importantly, the overall thickness of leaf samples satisfies the criteria illustrated in (1) for obtaining accurate dielectric measurement of the leaf samples. The optimal dielectric curves for Catharanthus Roseus leaf samples are presented in Fig. 3 [a] and [b] after repeating the measurement process for several times.

As seen from Fig. 3[a], real part of dielectric constant decays almost in an exponential manner with frequency at 25ºC ambient temperature. The real part of permittivity of Catharanthus Roseus leaf is around 75 at lowest measured frequency which reduces to 48 at 8.5 GHz. The permittivity of Catharanthus Roseus leaf is so high because of the presence of enough water molecules within Catharanthus Roseus leaves. In adition, it is also clear from Fig. 3 [a] that the energy storage capability within Catharanthus Roseus leaf reduces as the frequency of exposure increases. The loss tangent curve is having very high value close to 0.7 at lowest measured frequency whereas the minimum loss ($\tan\delta = 0.28$) is observed at around 4 GHz as illustrated in Fig. 3[b]. High values of permittivity and loss tangent for Catharanthus Roseus leaves in CDMA 800 MHz, GSM 900 MHz and 1800 MHz along with Wi-Fi 2400 MHz would result in huge RF power absorption and SAR in Catharanthus Roseus plants that might have some possible physiological effects on their growth.




[a]

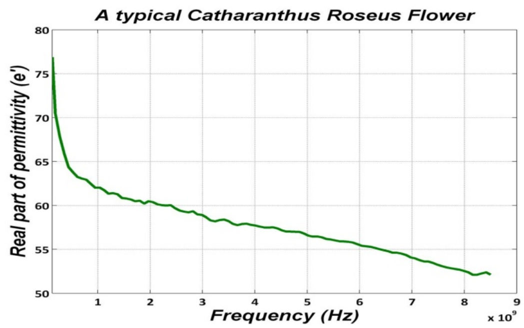



[b]

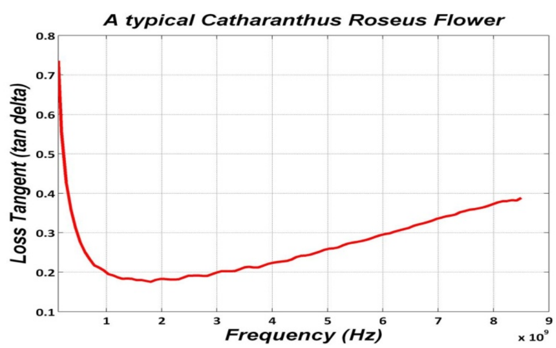
**Figure 3:** A typical Catharanthus Roseus Leaf sample [a] Real part of permittivity (ε') with frequency, [b] Loss tangent with frequency

### *B. Dielectric Properties Measurement of Catharanthus Roseus Flower Samples*

The same dielectric measurement set up (shown in fig. 2) is used for determining permittivity and loss parameters of Catharanthus Roseus flower samples. The green twig is cut from each flower in such an efficient way so that the 5 petals of that flower remain in contact with each other. Next 8-10 of such flower samples are stacked together under the dielectric probe for satisfying (1); finally the probe is pressed upon the stack of the flowers to get an accurate dielectric measurement without any air gap in between the flower petals. The real part of permittivity of Catharanthus Roseus flower samples decays faster in low frequencies up to 500 MHz then the decay rate slows down as observed in Fig. 4 [a]. The measured relative permittivity of typical medium size fresh Catharanthus Roseus flowers is around 70 at 200 MHz which falls to 52 at 8.5 GHz. Dielectric properties of Catharanthus Roseus flower is so high because of the presence of huge water content within Catharanthus Roseus flowers. This also implies the energy storage capability within Catharanthus Roseus flowers reduces with increase in the frequency of exposure. The loss tangent curve for Catharanthus Roseus flowers is having minima at around 1800 MHz as indicated by the red curve illustrated in Fig. 4[B]. The loss tangent at 200 MHz is close to 0.7 that takes a typical value within the range of 0.19 to 0.22 in CDMA 800 MHz, GSM 900 MHz and 1800 MHz along with Wi-Fi 2400 MHz; hence, it is strongly expected that certain amount of RF energy would be absorbed in Catharanthus Roseus flowers in CDMA, GSM and Wi-Fi bands.




[a]

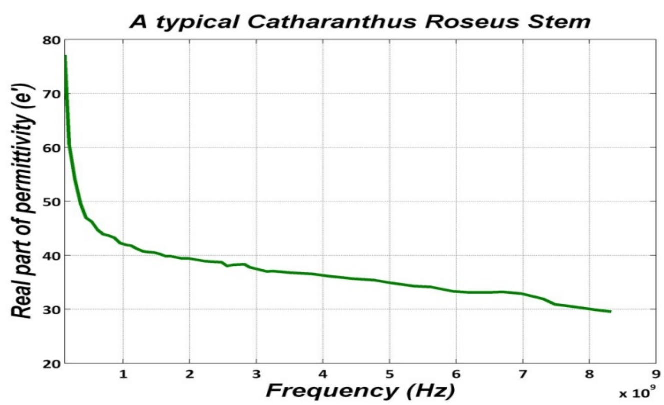



[b]

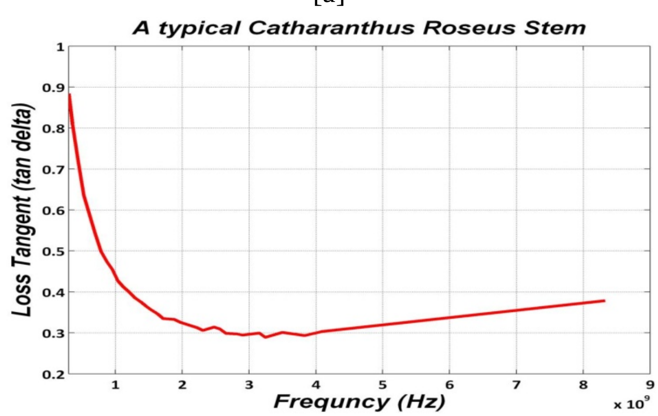
**Figure 4:** A typical Catharanthus Roseus Flower sample [a] Real part of permittivity (ε') with frequency, [b] Loss tangent with frequency

***C. Dielectric Properties Measurement of Catharanthus Roseus Stem/Twig Samples***

A typical standard size fresh Catharanthus Roseus stem is cut in its' cross-sectional side and a cylindrical stem sample is taken out with cross sectional diameter a little bit smaller than 20 mm. Then the dielectric measuring probe is pressed over the circular cross sectional top (diameter is little bit smaller than 20 mm) of the stem sample to get an approximate measurement of dielectric properties of Catharanthus Roseus stem. As illustrated in Fig. 5 [a], real part of permittivity of Catharanthus Roseus stem decays sharply at low frequencies up to 400 MHz, then the decay rate slows down. Measured relative permittivity of Catharanthus Roseus stem is 70 at 100 MHz which saturates down to 30 at 8.5 GHz. This implies the energy storage capability of Catharanthus Roseus stem reduces with increase in frequency of RF exposure. It seems that Catharanthus Roseus stem contains lesser quantity of water than Catharanthus Roseus leaves and flowers; that results in a comparative lower dielectric values for Catharanthus Roseus stem.




[a]




[b]

**Figure 5:** A typical Catharanthus Roseus Stem sample [a] Real part of permittivity (ε') with frequency, [b] Loss tangent with frequency

Measured loss tangent values for Catharanthus Roseus stem is very high at low frequencies whereas that takes values in between 0.3 to 0.45 at CDMA 800 MHz, GSM 900 MHz and 1800 MHz along with Wi-Fi 2400 MHz (shown in Fig. 5 [b]); Therefore, it's definite that certain amount of RF energy would be absorbed within the stem due to the cell phone tower radiation resulting in some possible physiological effects on the growth of Catharanthus Roseus plant.

**4. Conclusion**

In this study, complex dielectric properties of Catharanthus Roseus leaves, flowers and stem/twig are reported probably for the first time. The dielectric properties have been measured several times (10-15 times for each sample) and thereafter the optimal curve is reported for each sample. Higher permittivity is observed for Catharanthus Roseus leaves and flowers than compared to stem samples; it validates that higher water content in plant parts contributes higher permittivity. It is obvious that the whole plant kingdom is exposed to RF radiation from GSM and CDMA cell phone towers as per different national and international RF exposure guideline including revised Indian guideline. It is observed that the Catharanthus Roseus leaves, flowers and stems are having high permittivity and loss values that would result in considerable RF energy absorption / SAR in different parts of the plant due to cell phone tower radiation. Hence, these dielectric data of Catharanthus Roseus may be useful for finding out possible physiological effects on the growth of Catharanthus Roseus due to cell phone tower radiation.

## REFERENCES

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