# FREQUENCY DEPENDENCE OF ATTENUATION CONSTANT OF DIELECTRIC MATERIALS

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**Different dielectric materials have been studied for frequency dependence of attenuation constant. The sensitive cathode-ray-oscillograph method has been used to evaluate the dielectric constant and loss factor, and from these attenuation constants have been calculated. The temperature remaining constant, a regular increase has been observed in attenuation constant, at higher frequencies of electromagnetic propogating wave.**

For defence purposes and for security reasons, it is sometimes necessary to install the transmitting antenna system inside a building or even underground. As the electrical properties of environment and other nonconducting materials have a marked effect on the propagation of electromagnetic waves, the behaviour of dielectric materials, under the influence of variable frequency wave has been studied.

The method suggested is suitable for determining the electrical constants of a large number of dielectric materials, fairly quickly with high degree of precision.

## THEORETICAL CONSIDERATION

The method involves the relation between the attenuation constant, conductivity and dielectric constant of the medium. This is as follows.

The general equation[1] for the propagation of electromagnetic waves, with the electrical intensity $E$ may be written as

$$\nabla^2 E = \mu\sigma \frac{dE}{dt} + \mu\epsilon \frac{d^2E}{dt^2} \tag{1}$$

Since the field is varying sinusoidally with time (1) in terms of phasors will be given as :

$$\nabla^2 E - jw\,\mu\,(\sigma + jw\,\epsilon)\,E = 0 \tag{2}$$

where

$E$ = Electrical intensity

$w = 2\,\pi f$ rad/sec

$f$ = Frequency $Hz$

$\sigma$ = Conductivity

$\epsilon$ = Permitivity or dielectric constant

$\mu$ = Permiability

$$\nabla^2 E - \gamma^2 E = 0 \tag{3}$$

where

$\gamma$ = Propagation Constant $= jw\mu\ (\sigma + jw\,\epsilon)$

Now $\gamma$ being complex quantity, it can be expressed as

$$\gamma = \alpha + i\,\beta$$

where $\alpha$ and $\beta$ are attenuation and phase constants respectively.

On simplification and expressing the electrical constant in e.s.u

$$\alpha = \frac{2\pi\sigma}{3 \times 10^{10}} \sqrt{\frac{1}{\epsilon}} \tag{4}$$

Moreover $\sigma$, $\epsilon$, and $f$ (frequency) are related[2] by

$$\sigma = w\, \epsilon \tan \delta \tag{5}$$

$$= 2\,\pi f \epsilon \tan \delta$$

where $\tan \delta =$ loss factor

from (4) & (5) we have

$$\alpha = 0{\cdot}0013\, f \tan \delta \sqrt{\epsilon} \tag{6}$$

It is obvious from (6) that if we measure the conductivity ($\sigma$), dielectric constant ($\epsilon$), we can find out the attenuation constant ($\alpha$) at different frequencies of propagating electromagnetic wave.

## EXPERIMENTAL PROCEDURE

In the present investigation, the loss factor ($\tan \delta$) and dielectric constant ($\epsilon$), have been determined, at room temperature as a function of frequency over the range, 10 *Hz* to 10 *KHz* by using cathode-ray-oscillograph method. An audio frequency oscillator Fig. 1, with variable frequency was used as signal feeder. The fed signal is divided into two parts. One part is directly applied to *X*-plate and other after amplification to *Y*-plate, of the cathode-ray-oscillograph. A specially prepared parallel plate condenser, with plane faces was used for measurement of dielectric constant and loss angle, of samples. Two different ellipses were obtained on the screen of cathode-ray-oscillograph, with and without samples, in condenser AB. Measurement of loss angle $\delta$ and permitivity constant $\epsilon$ were made in accordance with the procedure suggested by Jackson[3] (see Fig. 2 & 3). The values of loss factor are shown in Table 1. The values of attenuation constant obtained from the (6) are given in Table 2.

## RESULTS AND DISCUSSION

Tables 1 & 2 provide the study regarding the behaviour of materials at different frequencies of electromagnetic waves. Fig. 4 shows that the bakelite and rubber behave as almost perfect dielectric with minimum attenuation loss and the conductivity of glass and wood are large in comparison to

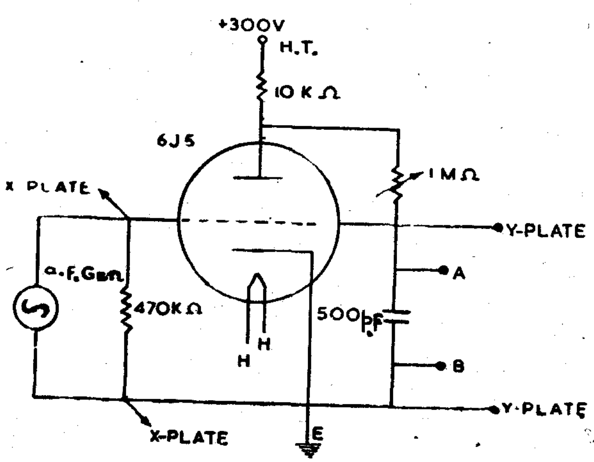


FIG. 1—Experimental setup.

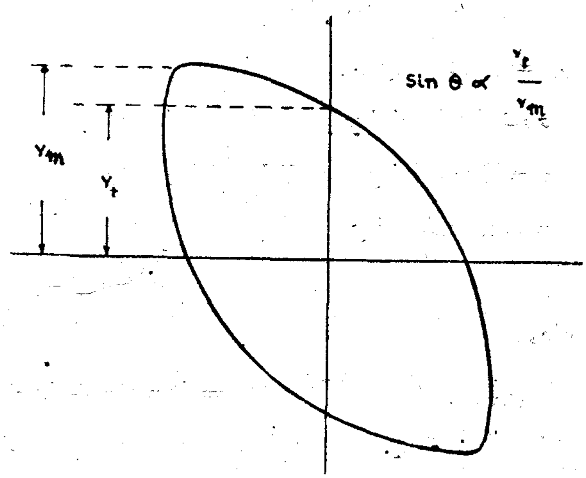


FIG. 2—Ellipses at different working points (frequency) as seen on C.R.O.

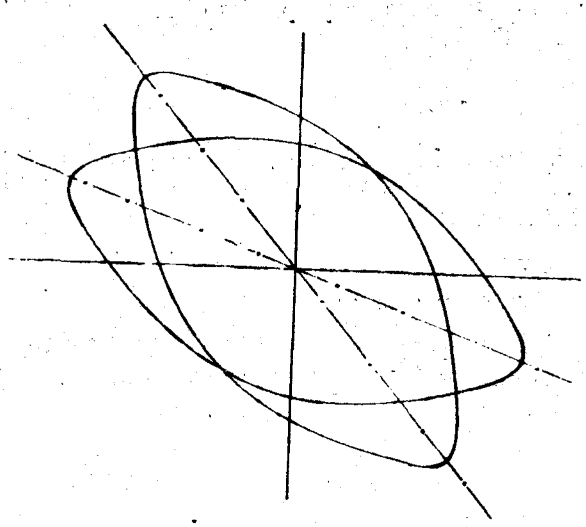

FIG. 3—Ellipses at different working points (frequency) as seen on C.R.O.

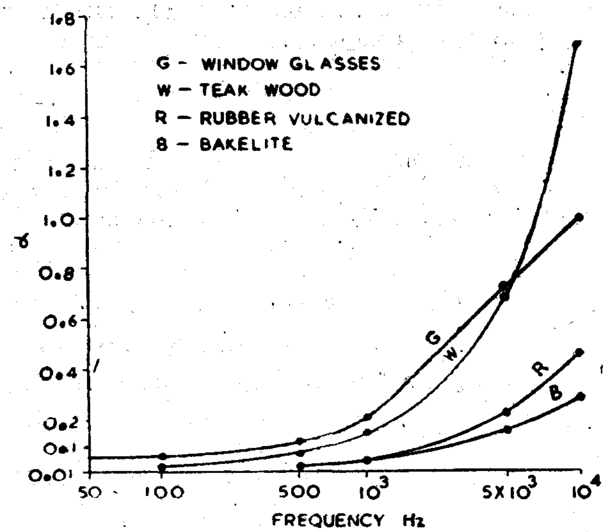


FIG. 4—Variation of attenuation constant ($a$) with frequency.

corresponding value of bakelite and rubber which may be explained due to presence of metallic structure in the body of material.

Thus the knowledge of the dielectric properties and attenuation constants of materials, can serve as a good guide for installation of antenna systems. The above results are in accordance with the findings of other authors[2]. The experiment are in progress in respect of the building materials like, soils cements

TABLE 1

VALUES OF DIELECTRIC CONSTANT ($\epsilon$) AND LOSS ANGLE ($\delta$) AT DIFFERENT FREQUENCY

(Tem p. 303 $\pm$ 1 °$k$)

| Frequency (Hz) | Window Glass (G) $\epsilon$ | tan $\delta$ | Bakelite (B) $\epsilon$ | tan $\delta$ | Teak Wood (W) $\epsilon$ | tan $\delta$ | Rubber (R) $\epsilon$ | tan $\delta$ |
|---|---|---|---|---|---|---|---|---|
| 50 | 8·20 | 0·160 | 5·00 | 0·015 | 3·53 | 0·041 | 4·10 | 0·011 |
| 100 | 8·20 | 0·150 | 4·96 | 0·014 | 3·40 | 0·043 | 4·09 | 0·013 |
| 500 | 7·95 | 0·061 | 4·95 | 0·013 | 3·32 | 0·052 | 4·06 | 0·014 |
| 1000 | 7·90 | 0·055 | 4·90 | 0·012 | 3·30 | 0·061 | 4·04 | 0·015 |
| 5000 | 7·80 | 0·045 | 4·85 | 0·011 | 3·22 | 0·064 | 4·03 | 0·016 |
| 10000 | 7·50 | 0·030 | 4·75 | 0·010 | 3·20 | 0·072 | 3·92 | 0·018 |

TABLE 2

ATTENUATION CONSTANT ($a$)

| Frequency (HZ) | Window Glass (G) | Bakelite (B) | Teak Wood (W) | Rubber (R) |
|---|---|---|---|---|
| 50 | 0·029 | 0·002 | 0·005 | 0·001 |
| 100 | 0·055 | 0·004 | 0·010 | 0·003 |
| 500 | 0·111 | 0.018 | 0·061 | 0·018 |
| 1000 | 0·204 | 0.034 | 0·144 | 0·039 |
| 5000 | 0·816 | 0.157 | 0·746 | 0·208 |
| 10000 | 1·068 | 0·283 | 1·674 | 0·464 |

etc. Moreover this method is useful in determining the other dielectric properties of materials quickly and precisely as compaired to other techniques, viz., fixed and variable cell method, resonance method, etc.

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