



Fundamentals of Dielectric Properties Measurements and Agricultural Applications

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ABSTRACT

Dielectrics and dielectric properties are defined generally and dielectric measurement methods and equipment are described for various frequency ranges from audio frequencies through microwave frequencies. These include impedance and admittance bridges, resonant frequency, transmission-line, and free-space methods in the frequency domain and time-domain and broadband techniques. Many references are cited describing methods in detail and giving sources of dielectric properties data. Finally a few applications for such data are presented and sources of tabulated and dielectric properties data bases are identified.

KEYWORDS: Dielectric properties, permittivity, dielectric constant, dielectric loss factor, measurement methods, dielectric mixtures, dielectric properties applications.

INTRODUCTION

Dielectrics are a class of materials that are poor conductors of electricity, in contrast to materials such as metals that are generally good electrical conductors. Many materials, including living organisms and most agricultural products, conduct electric currents to some degree, but are still classified as dielectrics. The electrical nature of these materials can be described by their dielectric properties, which influence the distribution of electromagnetic fields and currents in the region occupied by the materials, and which determine the behavior of the materials in electric fields. Thus, the dielectric properties determine how rapidly a material will heat in radio-frequency or microwave dielectric heating applications. Their influence on electric fields also provides a means for sensing certain other properties of materials, which may be correlated with the dielectric properties, by nondestructive electrical measurements.

A few simplified definitions of dielectric properties are necessary for meaningful discussion of their measurement and applications. They have been defined previously in terms of electrical circuit concepts [Nelson 1965] and electromagnetic field concepts [Nelson 1973a]. More detailed discussions and definitions are available in any number of good references, among which the following have been particularly useful to the author [Bottcher and Bordewijk 1978, Brown, et al. 1947, Metaxas and Meredith 1983, Nyfors and Vainikainen 1989, von Hippel 1954a, 1954b]. There are also many useful references on dielectric measurement techniques [Baker-Jarvis 1990; Bussey 1967; Altschuler, 1963; Redheffer, 1964; von Hippel 1954a]. A fundamental characteristic of all forms of electromagnetic energy is their propagation through free space at the velocity of light, c . The velocity of propagation v of electromagnetic energy in a material other than free space depends on the electromagnetic characteristics of that material and is given as

$$v = \frac{1}{\sqrt{\mu \epsilon}} \quad (1)$$