Millimeter Wave Dielectric Measurement of Sand for Sand Cloud Attenuation Estimations

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The objective of this project is to study the attenuation effects due to sand clouds at millimeter wave frequencies. Attenuation due to the presence of sand in the propagation path is important for both military and environmental applications. The military is concerned about any adverse effects sand clouds might have on radar and communication systems for both aircraft based and satellite based systems. Aircraft landing and take off as well as climate conditions can create such clouds. For environmental applications, it is of interest to determine the air quality remotely, and the attenuation through dust in the air provides such a measure.

Sand clouds can be modeled as a discrete random medium, where each sand particle has a probability density function for its size and position in the cloud. Such models have been developed for vegetation and rain before, and can be applied to sand as well (O. Kilic, R. H. Lang, "Scattering of a pulsed beam by a random medium over ground," J. of Electromagnetic Waves and Appl., Vol. 15, No. 4, pp. 481-516, 2001.). Each sand particle will be treated as a perfect sphere with complex permittivity. As a first order approximation, an equivalent propagation constant can be calculated inside the medium for a mean wave. This effective propagation constant provides information on the attenuation levels, and is a function of the medium parameters such as particle size distribution, particle density, total volume, and the dielectric properties of sand particles in the air. While the medium parameters are random and need to be statistically defined, the dielectric constant for sand can be measured.

This paper discusses the dielectric measurements of various types of sand (for different moisture levels) at millimeter wave frequencies by using a coaxial sample holder. The holders are filled with sand and connected to a network analyzer for S-parameter measurements. A full 2-port calibration is carried out before the measurements to identify the reference plane. Dielectric measurements of sand using this approach have been carried out before at lower frequencies, such as 45 MHz-26GHz ("A Durable Laboratory Apparatus for the Measurement of Soil Dielectric Properties," John O. Curtis, IEEE I&M, Vol. 50, No. 5, 2001). This paper extends this method to 40-60 GHz range, and discusses the extension of the data via extrapolation techniques to higher frequencies such as 100 GHz, where the sand particles may resonate more with the wavelength.