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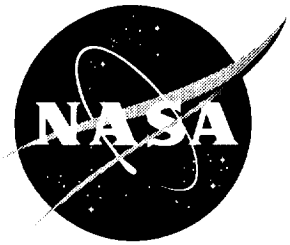

Complex Permittivities of Candidate Radome Materials at W-band

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Introduction

This report presents the results of w-band complex permittivity measurements performed in NASA Langley's Electromagnetics Research Branch (ERB). The test articles included in the permittivity study were flat panels of materials which are under consideration for use in a radome for the Passive Millimeter Wave Camera (PMMWC) flight experiment. This experiment is scheduled to fly on the Air Force's "Speckled Trout" aircraft in late 1997. The radome design is very important because the PMMWC can tolerate only a small amount of electromagnetic loss through the radome.

The measurement setup and calibration procedure used for this study is described in detail in a separate report [1]. Briefly, a free space measurement system was used to obtain complex reflection and transmission coefficients of the samples. The frequency of interest was 89 GHz, so measurements were performed over a range of 79 to 99 GHz (time domain gating was used to reduce errors from multiple reflections, so corruption of the data at the band edges was expected). The transmission and reflection coefficients were used, along with the measured sample thickness, to calculate complex permittivity over the frequency range. This was accomplished with the Hewlett-Packard (HP) 85071A Material Measurement Software [2].

The material samples measured in this study can be divided into four categories: skin materials, core materials, coating materials, and layered samples. The samples will be described in more detail in the next section. The algorithms used in the HP 85071A software assume a homogeneous sample for computation of the dielectric properties. The core materials, which were honeycomb samples, obviously do not meet this assumption; however, for validation purposes with the layered sample, a permittivity was calculated anyway and should be interpreted as some sort of "average" permittivity for the sample. For the layered sample, composed of one of the honeycomb cores with a skin material bonded to either side, transmission and reflection coefficients only were measured (no permittivity calculation was attempted). This measurement allows for

comparison of measurement with transmission and reflection coefficients calculated using the permittivity values measured for the individual layer materials.

Material Samples

Table 1 contains a list of the different flat panel materials for which the complex permittivity was measured, along with their measured thickness values. The four skin samples measured in this study consisted of cynate ester resins with different fiber reinforcement for each sample: DuPont Kevlar, J.P Stevens, Inc. AstroQuartz (2) and Allied Signal PT Spectra. The two core samples were two different Hexcel honeycomb materials. The coating measured was a rain erosion coating from PM Research, Inc. All samples except the rain erosion coating were provided by Composite Optics, Inc.

Material sample	Sample details	Sample Thickness (inches)
Skin samples		
Kevlar 49 LMR 120 / EX1515	0.0045" per ply	0.025
4581 AstroQuartz iii / BTCy-1	0.018" per ply	0.08
4503 AstroQuartz / EX1515	0.004" per ply	0.018
955 PT Spectra / BTCy-3A	0.0045" per ply	0.067
Core samples		
Hexcel HRH	1/4" cell size 2.1 lb. density	0.255
Hexcel Korex	1/8" cell size 6 lb. density	0.495
Coating sample		
PM Research rain erosion coating		0.014

Table 1: Candidate Radome Material Samples

The layered sample for which reflection and transmission coefficients were measured was composed of 0.250" Hexcel HRH honeycomb material with 0.008" - 0.010" thick 0.0045" ply Kevlar skin material bonded to each side. The total thickness for the final layered material was measured as 0.265".

Results

In Figures 1-5, the permittivity results for the skin materials are presented. For each plot, the different traces correspond to different tests of the material, and a plot for real and imaginary permittivity is included for each material. Also, for the 0.004" ply quartz material, a direction was specified on the sample, so two different sets of measurements were taken - with the E-field oriented parallel to the direction on the sample (co-pol) and the E-field oriented perpendicular to the direction on the sample (cross-pol). The other skin samples did not show any polarization dependence.

In Figues 6-9, permittivity plots are given for the honeycomb core samples. As mentioned in the introduction, the permittivity calculation assumes a uniform sample, so the values must be interpreted as some sort of "average" permittivity value for the sample. The samples were each measured for two different polarizations, and the sample orientation is indicated on the plots.

In Figure 10, the results for the rain erosion coating from PM Research, Inc. are given.

In Figure 11, transmission and reflection coefficients for the layered sample described in the previous section are presented.

References

1. Fralick, D. T., "W-band Free Space Permittivity Measurement Setup for Candidate Radome Materials", NASA Contractor Report CR 201720, August 1997.
2. HP 85071A Materials Measurement Software User's Manual, Edition 1, June 1989.

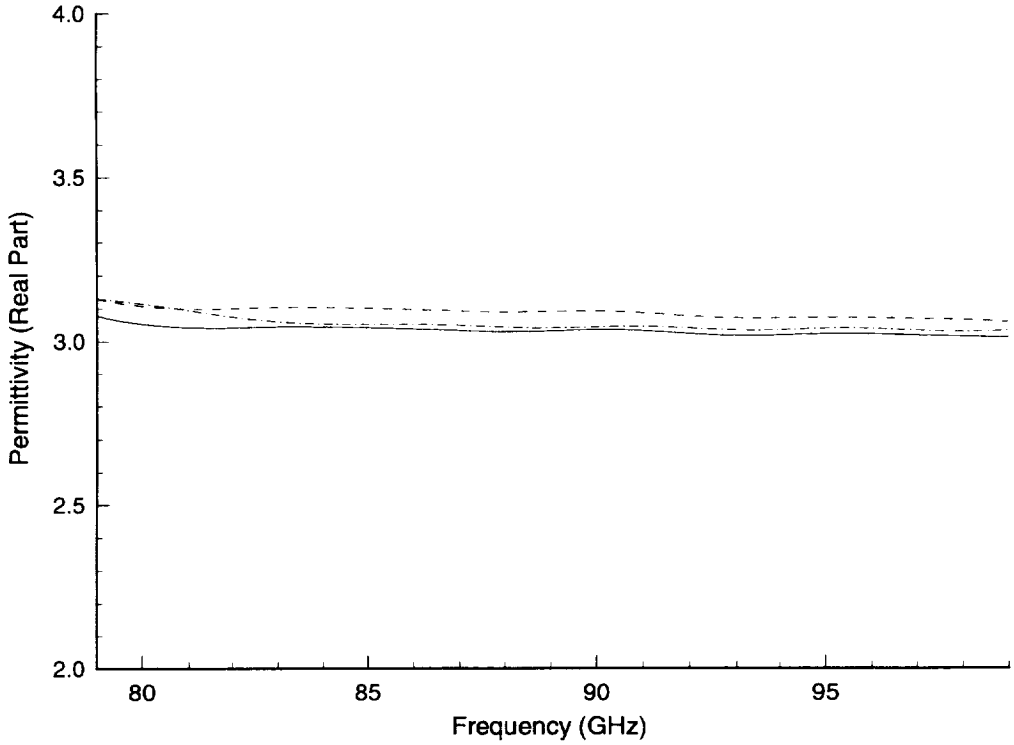

Figure 1(a). Real Part of Permittivity for Kevlar 49 LMR 120 / EX1515 0.0045" per ply

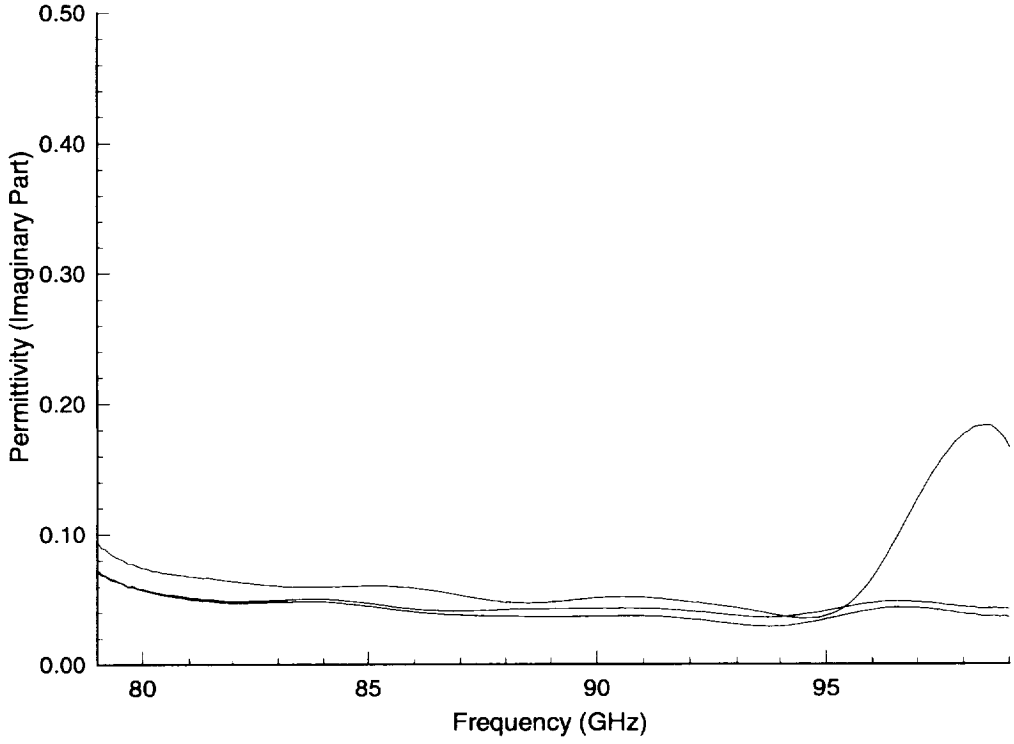

Figure 1(b). Imaginary Part of Permittivity for Kevlar 49 LMR 120 / EX1515 0.0045" per ply

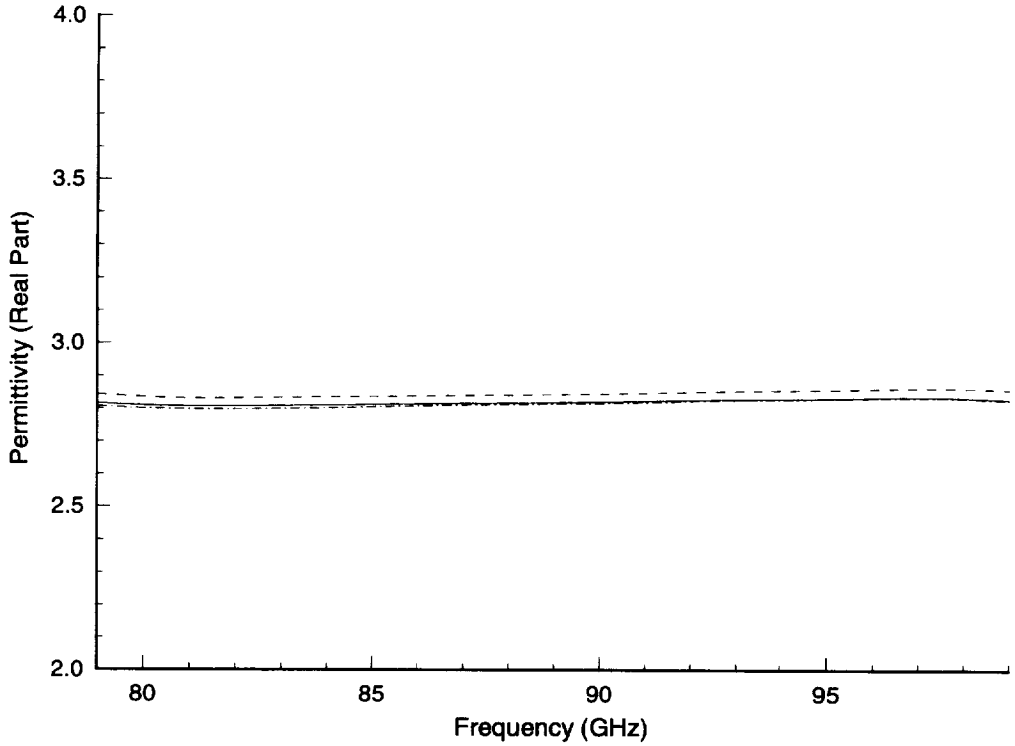

Figure 2(a). Real Part of Permittivity for 4581 AstroQuartz iii / BTCy-1 0.018" per ply

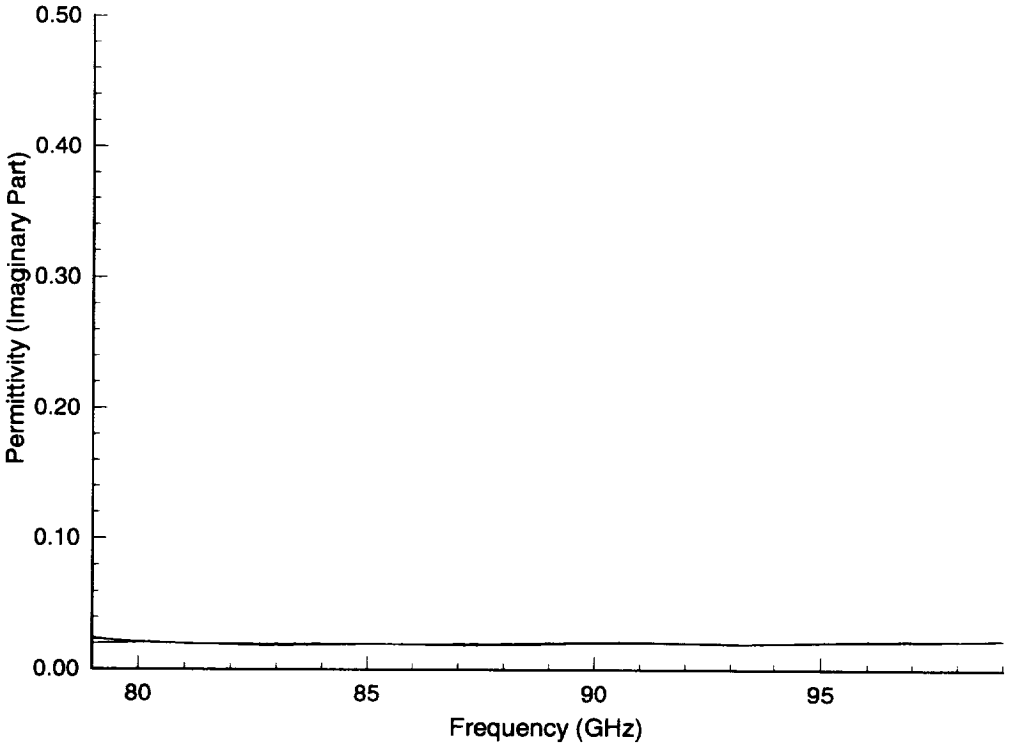

Figure 2(b). Imaginary Part of Permittivity for 4581 AstroQuartz iii / BTCy-1 0.018" per ply

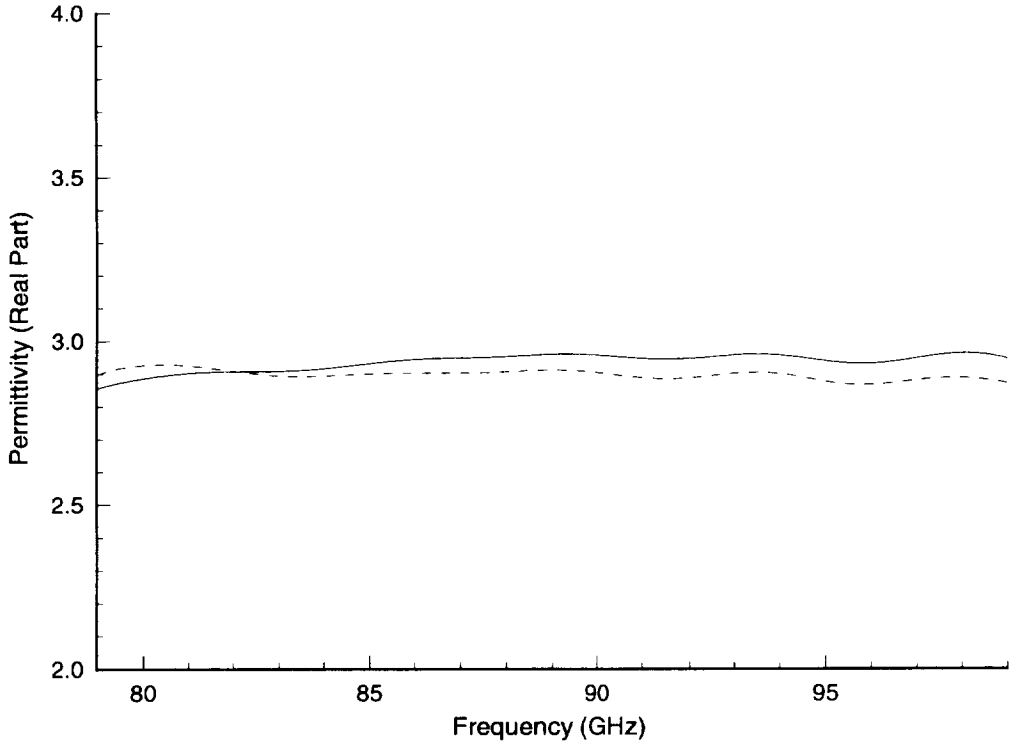

Figure 3(a). Real Part of Permittivity for 4503 AstroQuartz / EX1515 0.004" per ply

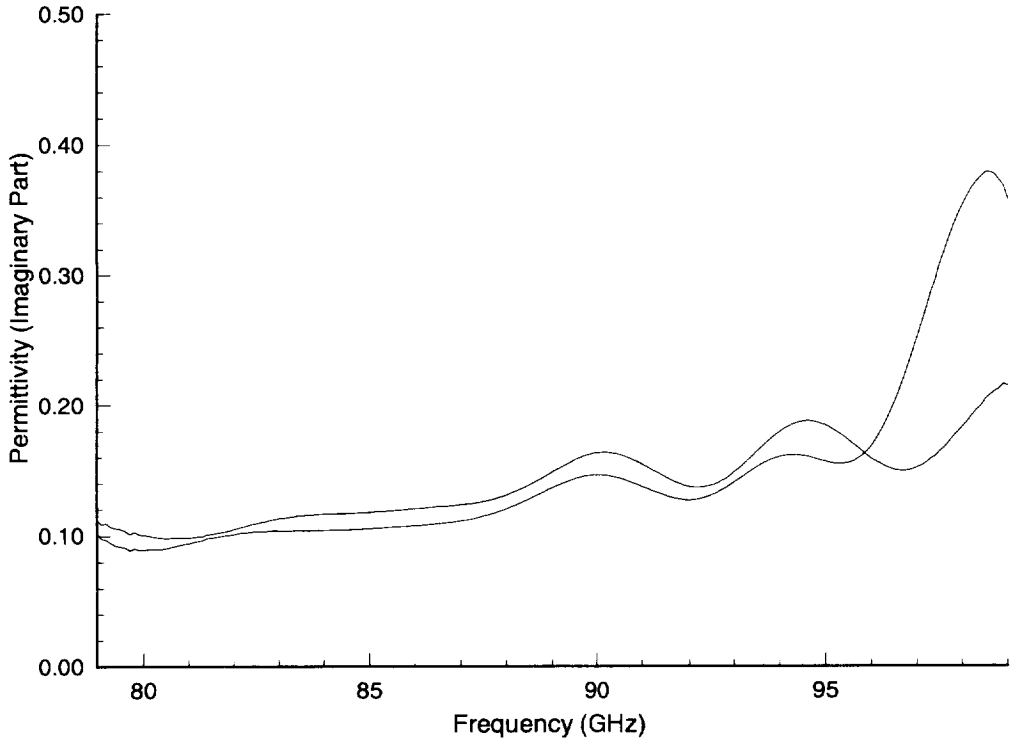

Figure 3(b). Imaginary Part of Permittivity for 4503 AstroQuartz / EX1515 0.004" per ply

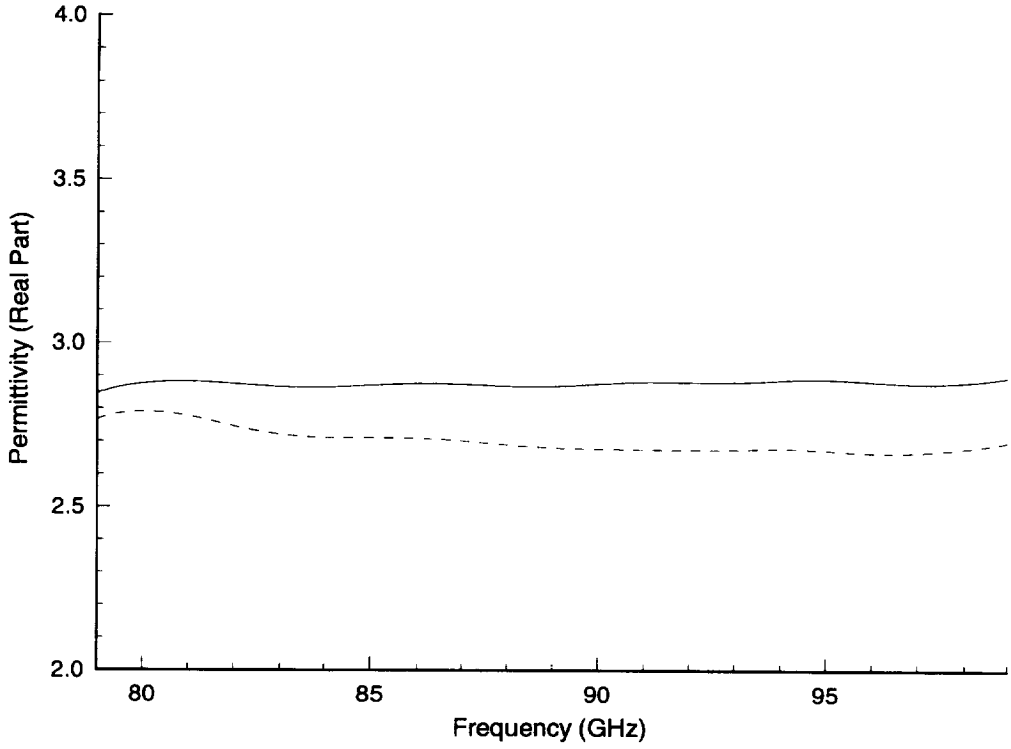

Figure 4(a). Real Part of Permittivity for4503 AstroQuartz / EX1515 0.004" per ply cross pol

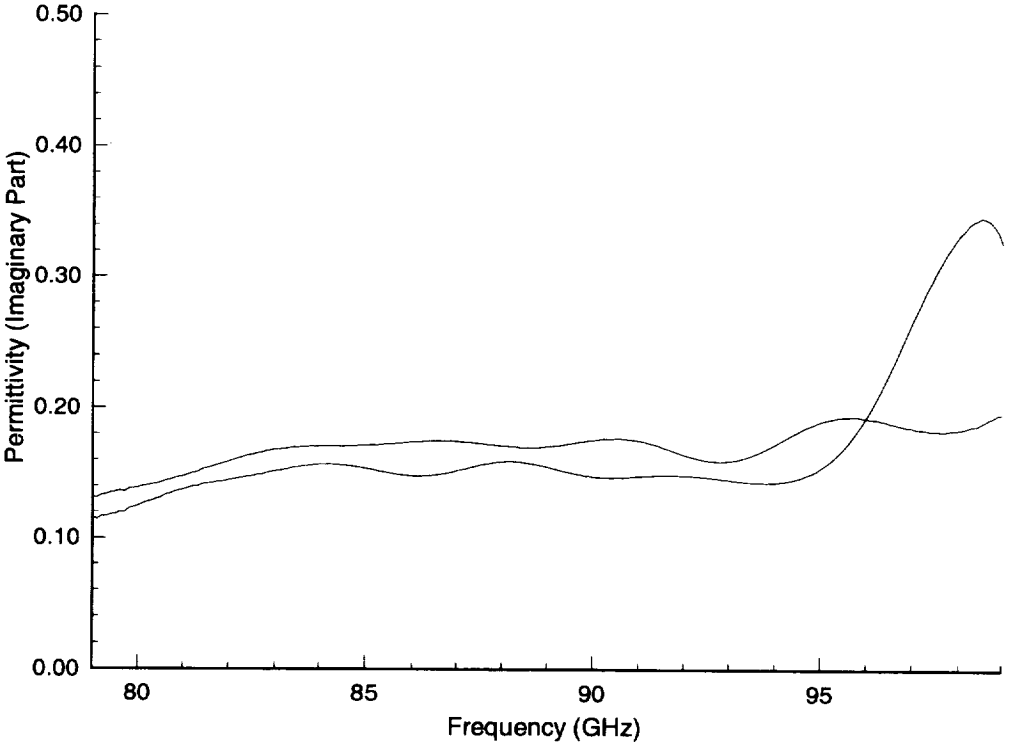

Figure 4(b). Imaginary Part of Permittivity for 4503 AstroQuartz / EX1515 0.004" per ply

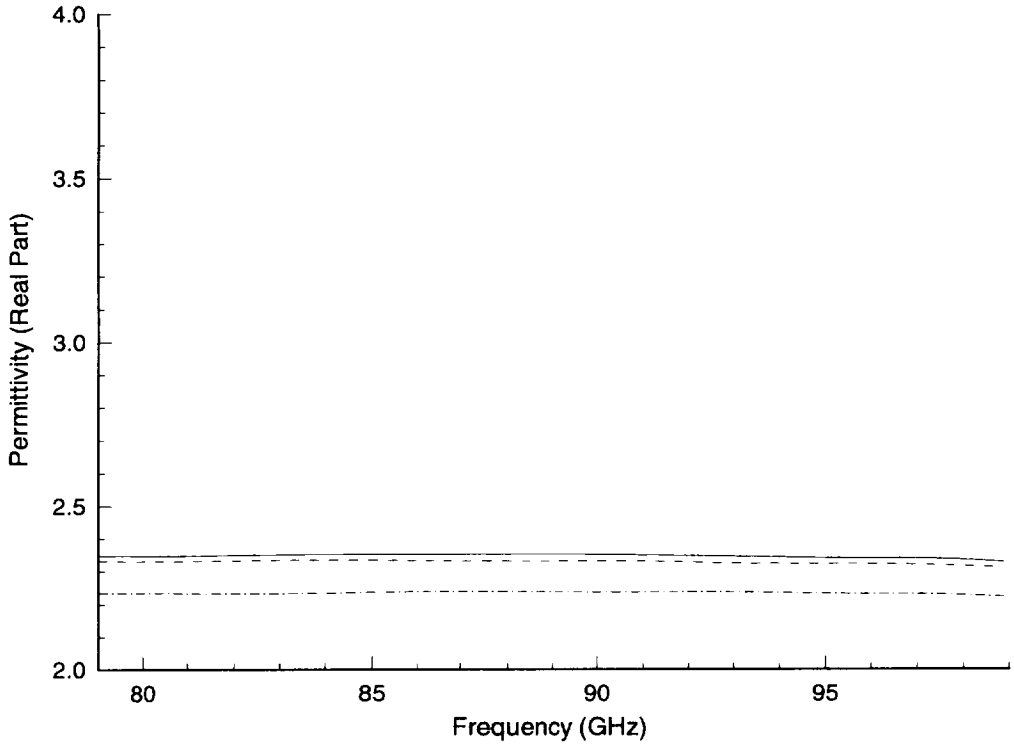

Figure 5(a). Real Part of Permittivity for 955 PT Spectra / BTCy-3A 0.0045" per ply

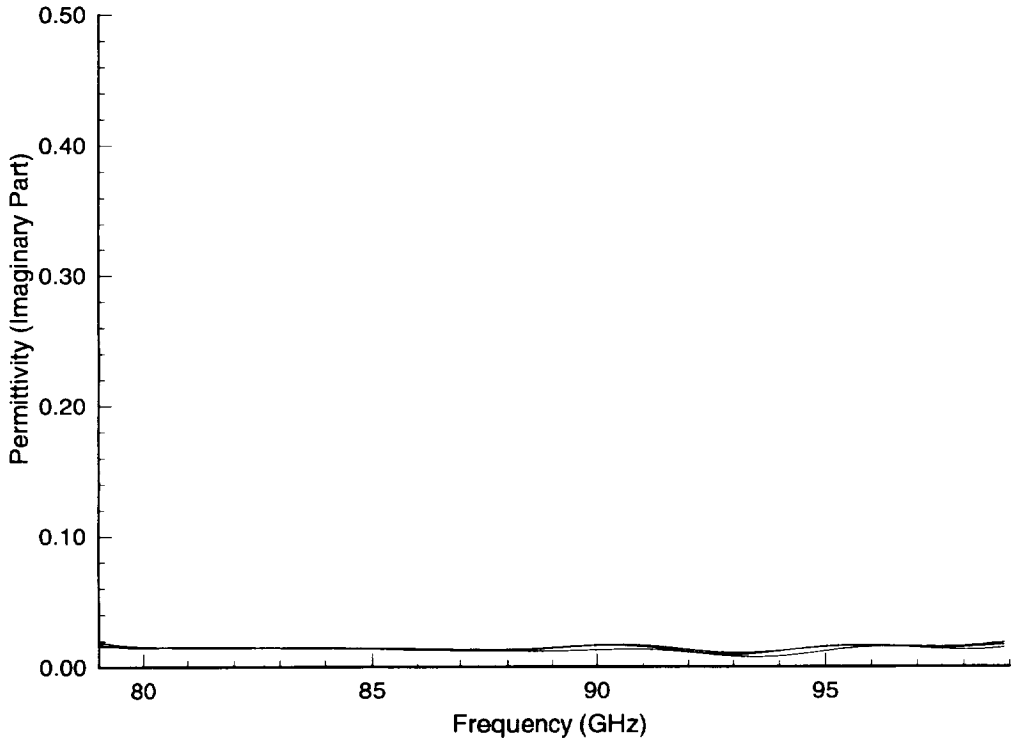

Figure 5(b). Imaginary Part of Permittivity for 955 PT Spectra / BTCy-3A 0.0045" per ply

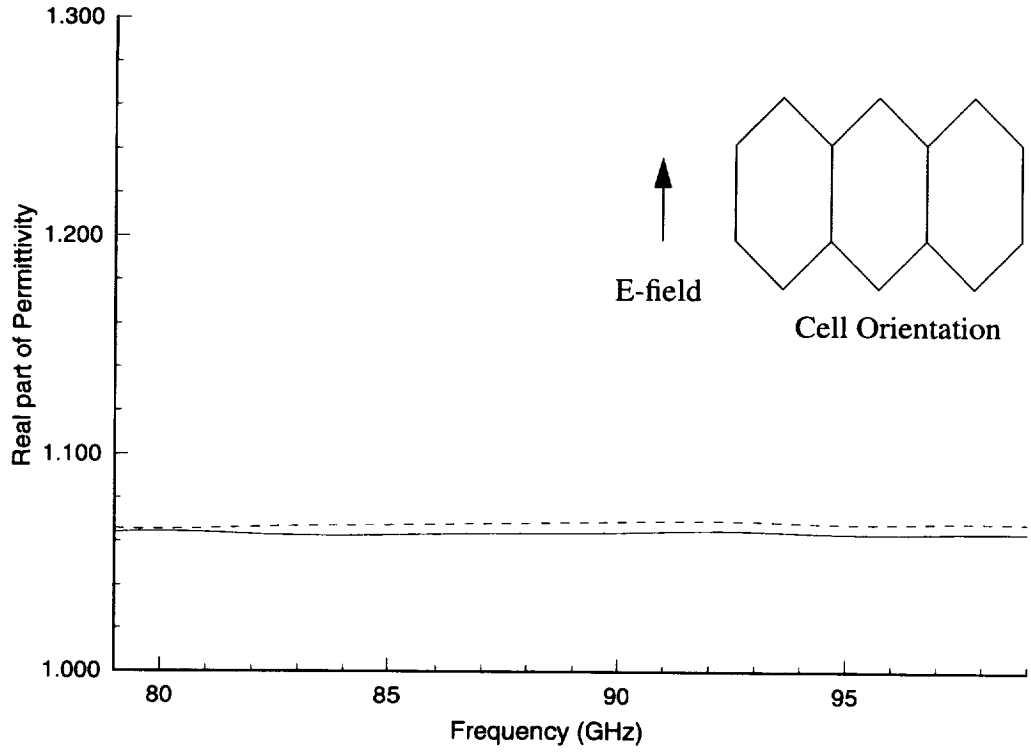

Figure 6(a). Real Part of Permittivity for 1/4" cell size Hexcel HRH co pol

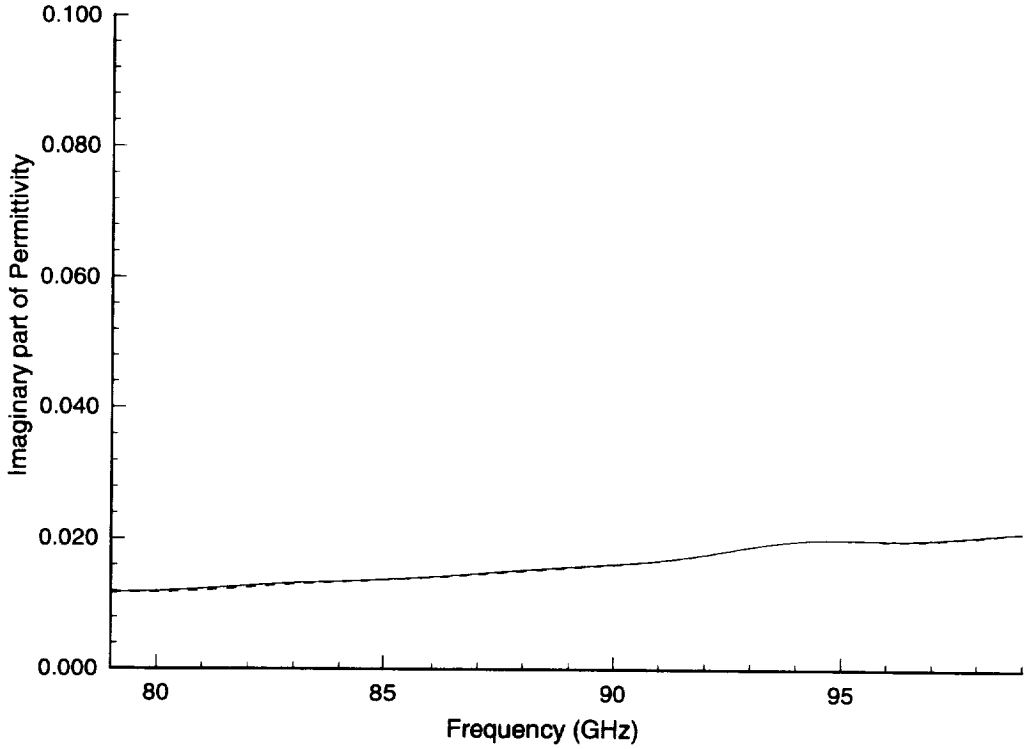

Figure 6(b). Imaginary Part of Permittivity for 1/4" cell size Hexcel HRH co pol

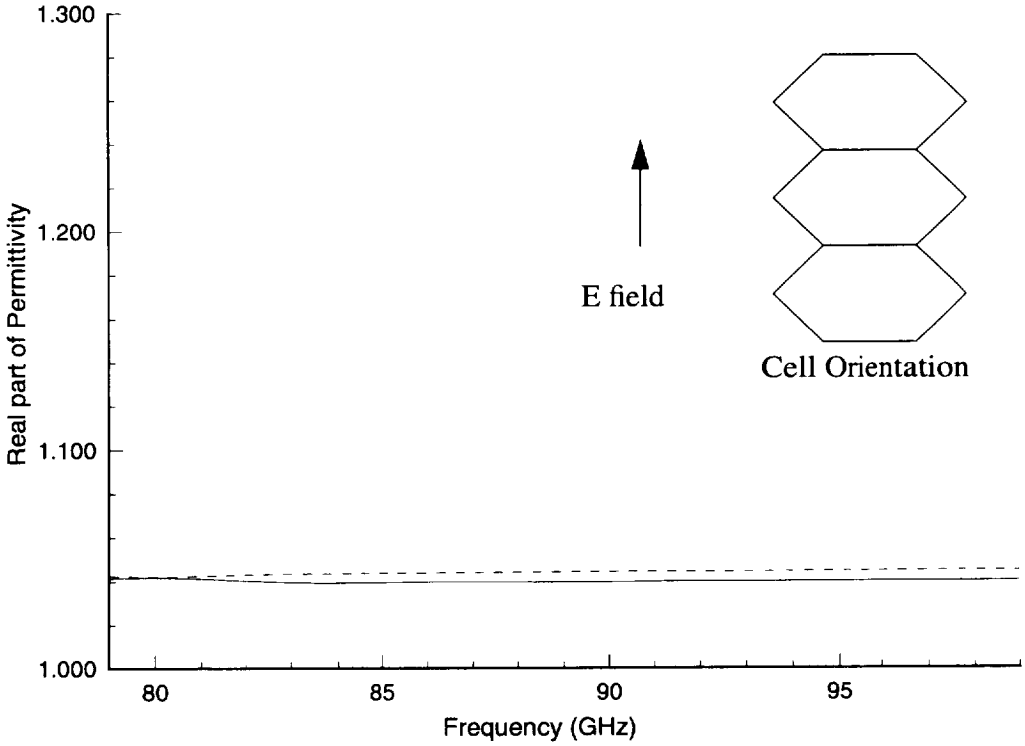

Figure 7(a). Real Part of Permittivity for 1/4" cell size Hexcel HRH cross pol

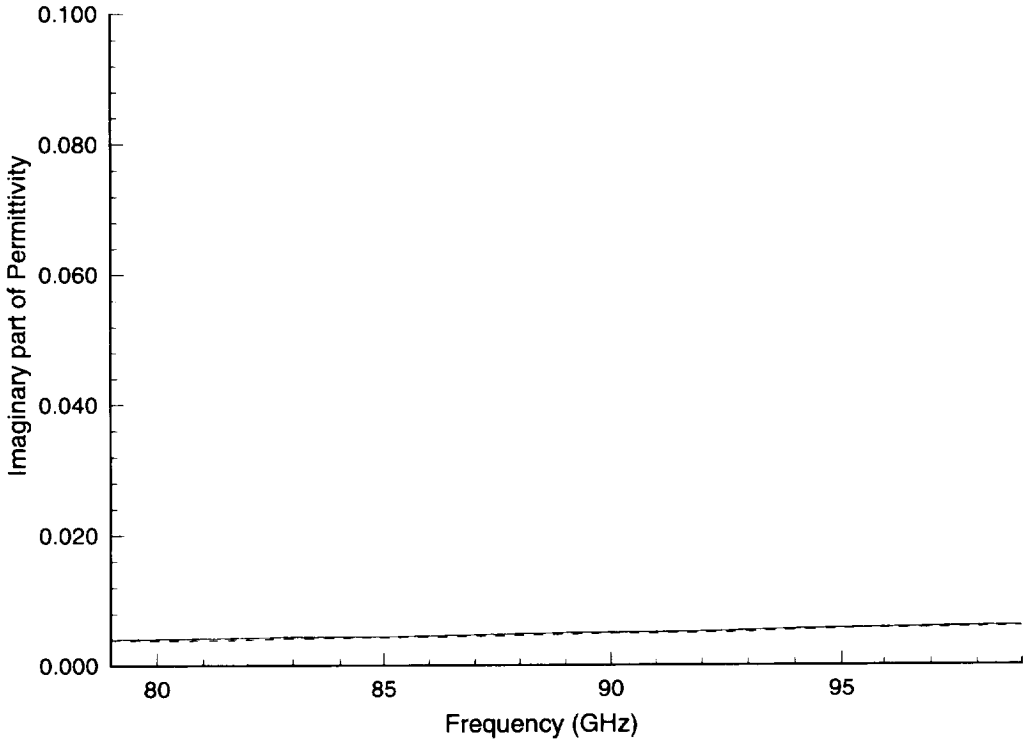

Figure 7(b). Imaginary Part of Permittivity for 1/4" cell size Hexcel HRH cross pol

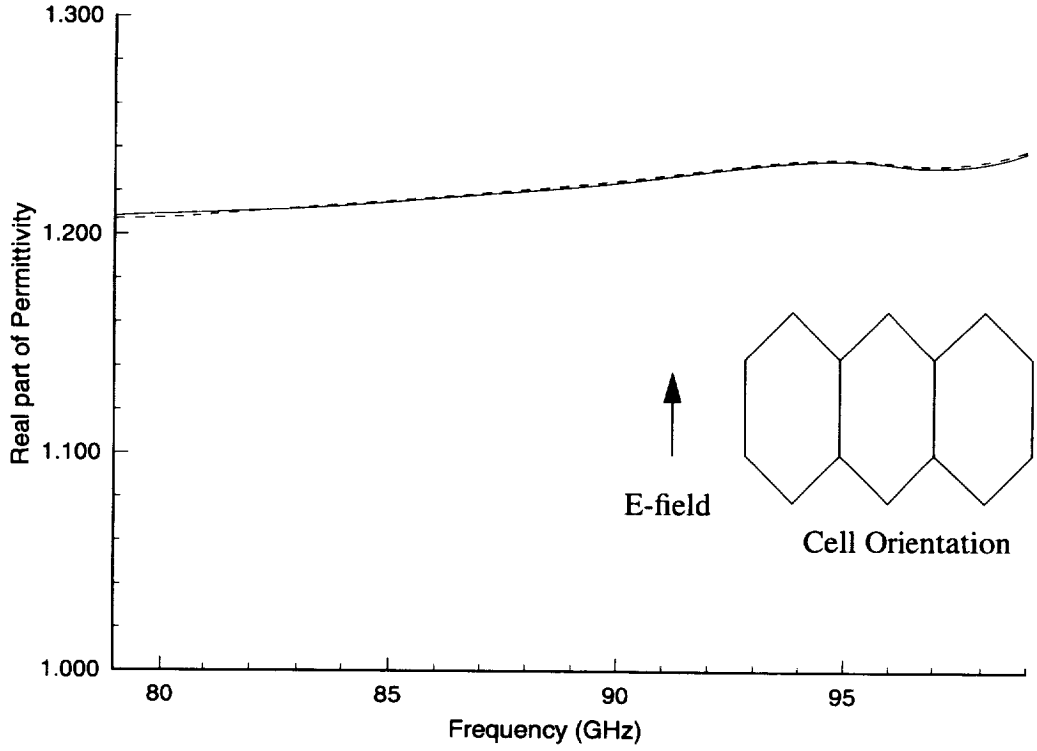

Figure 8(a). Real Part of Permittivity for 1/8" cell size Hexcel Korex co pol

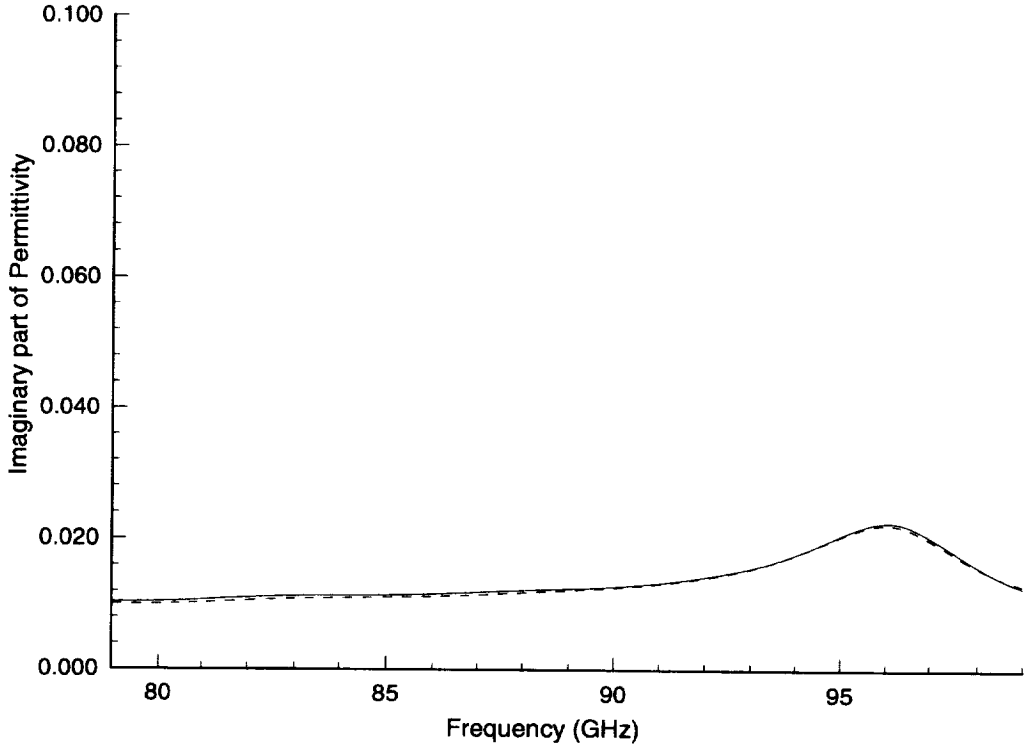

Figure 8(b). Imaginary Part of Permittivity for 1/8" cell size Hexcel Korex co pol

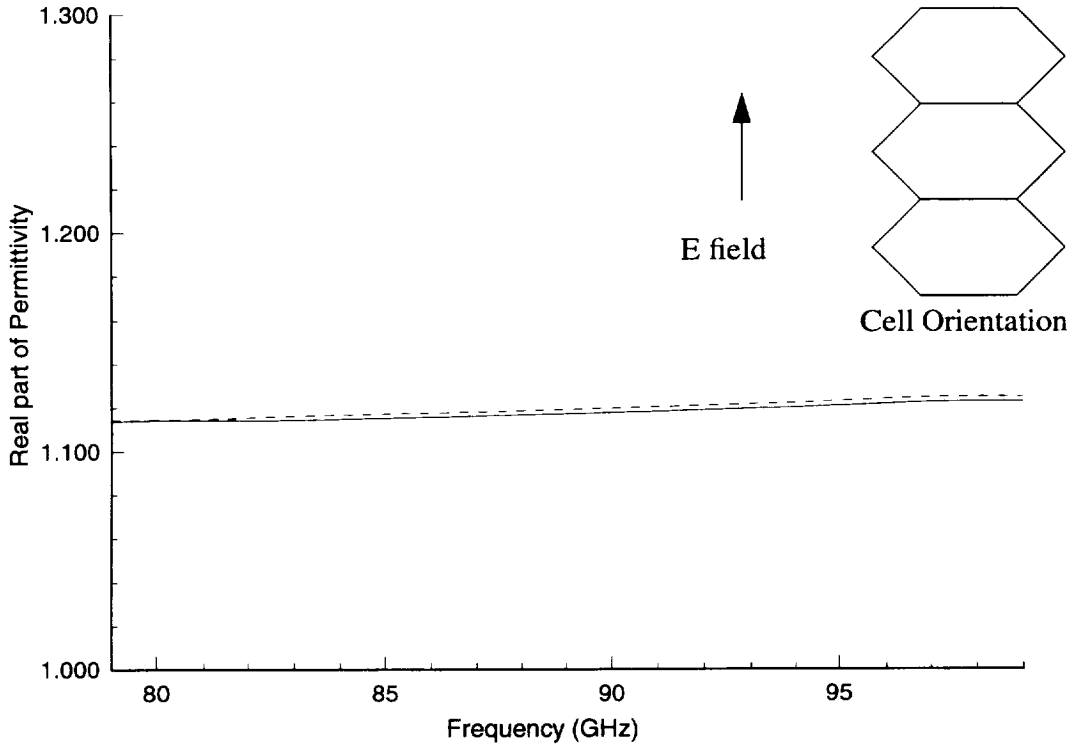

Figure 9(a). Real Part of Permittivity for 1/8" cell size Hexcel Korex cross pol

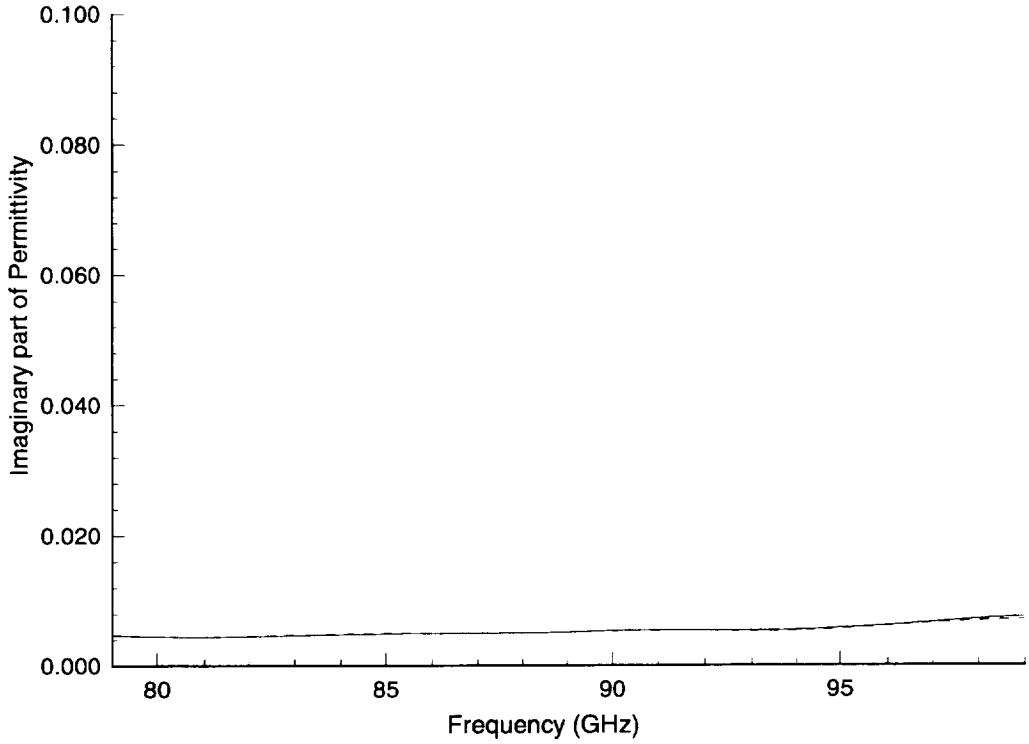

Figure 9(b). Imaginary Part of Permittivity for 1/8" cell size Hexcel Korex cross pol

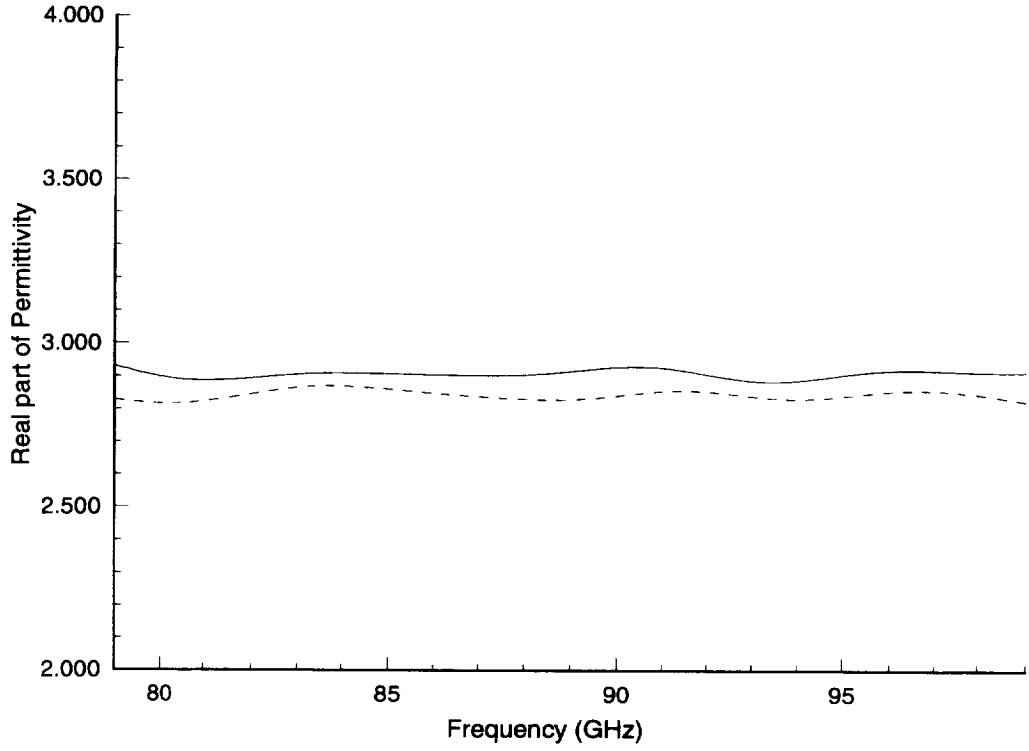

Figure 10(a). Real Part of Permittivity for PM Research Rain Erosion Coating

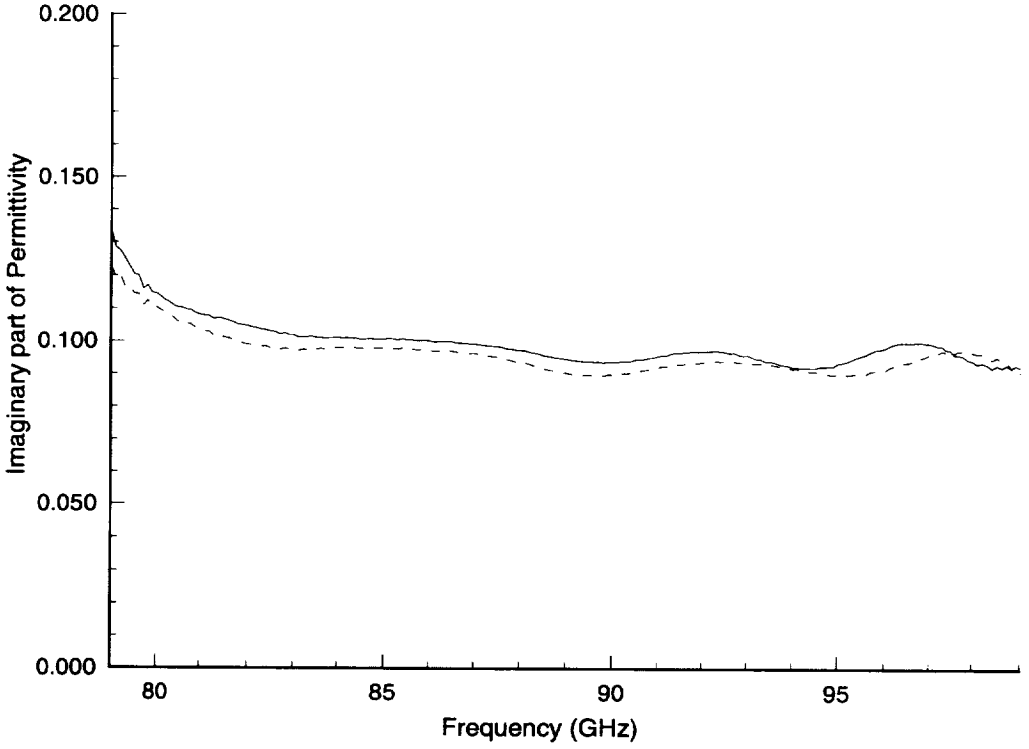

Figure 10(b). Imaginary Part of Permittivity for PM Research Rain Erosion Coating

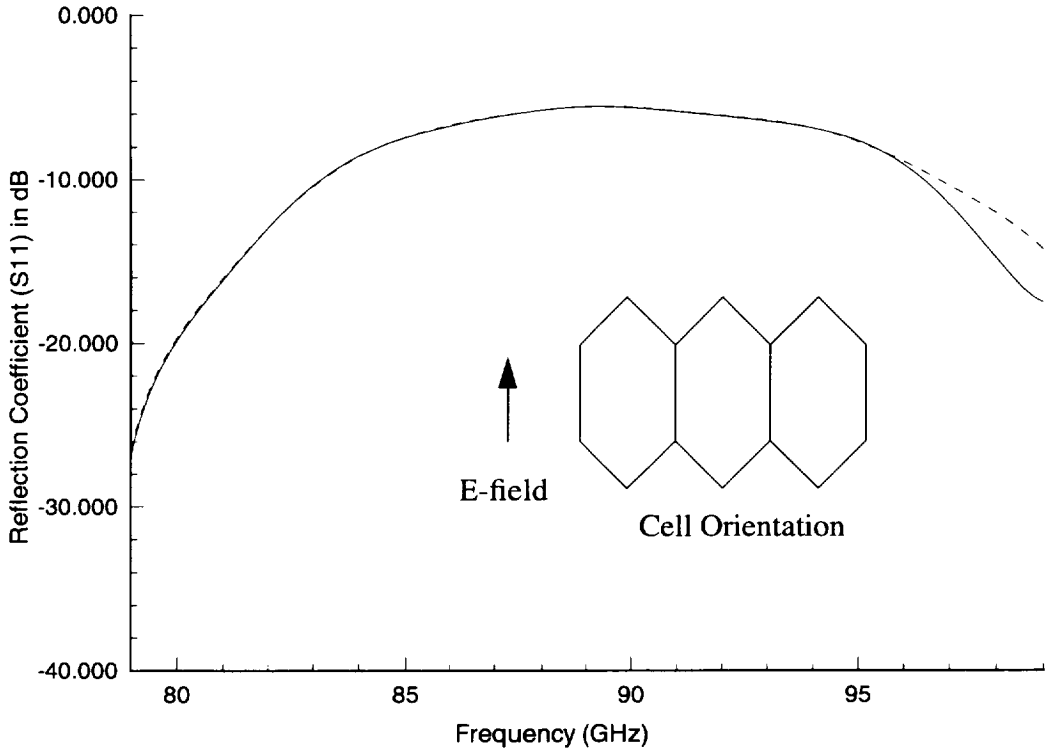

Figure 11(a). Reflection Coefficient (S11) for layered sample co pol

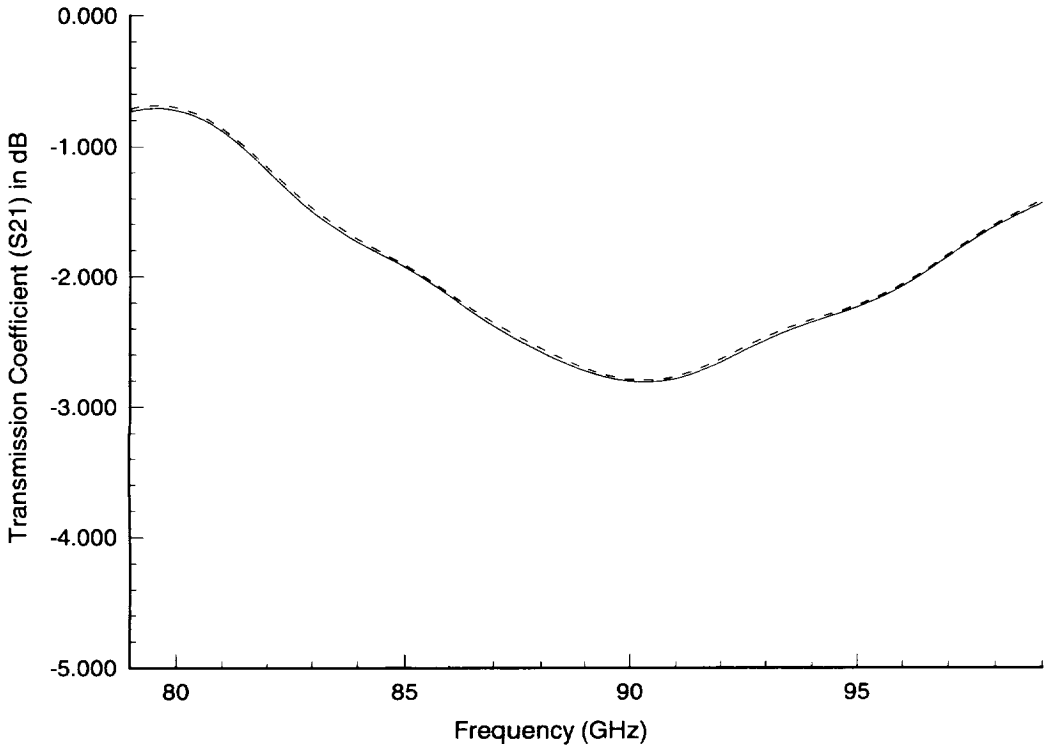

Figure 11(b). Transmission Coefficient (S11) for layered sample co pol

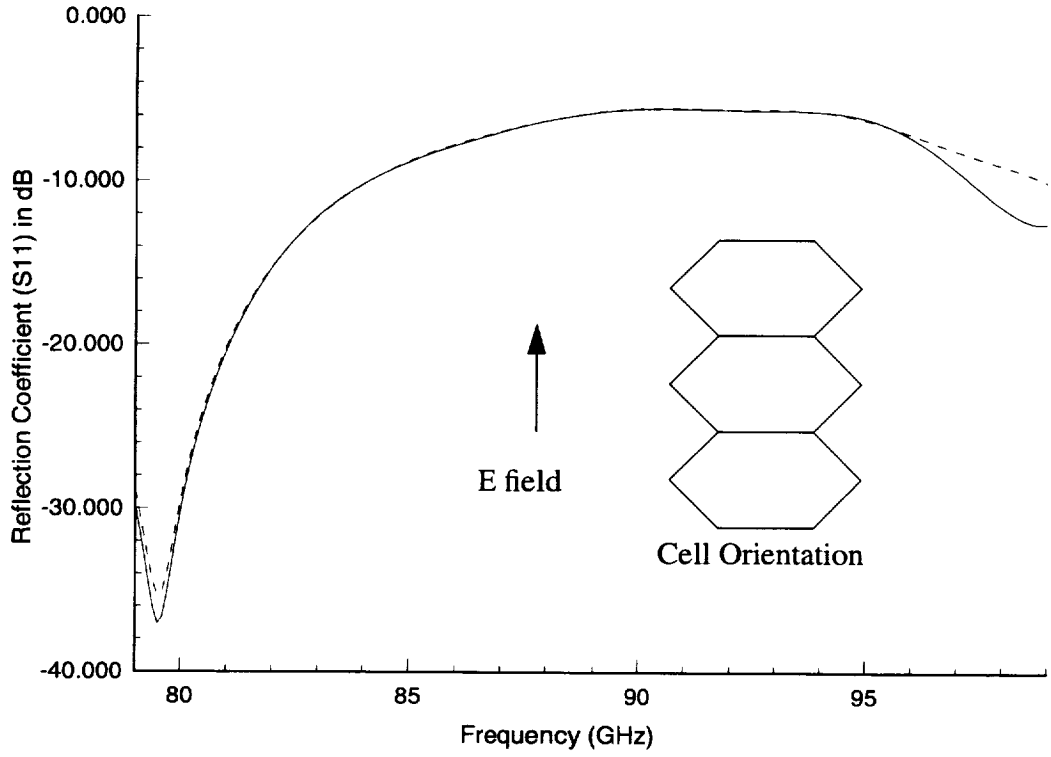

Figure 12(a). Reflection Coefficient (S11) for layered sample cross pol

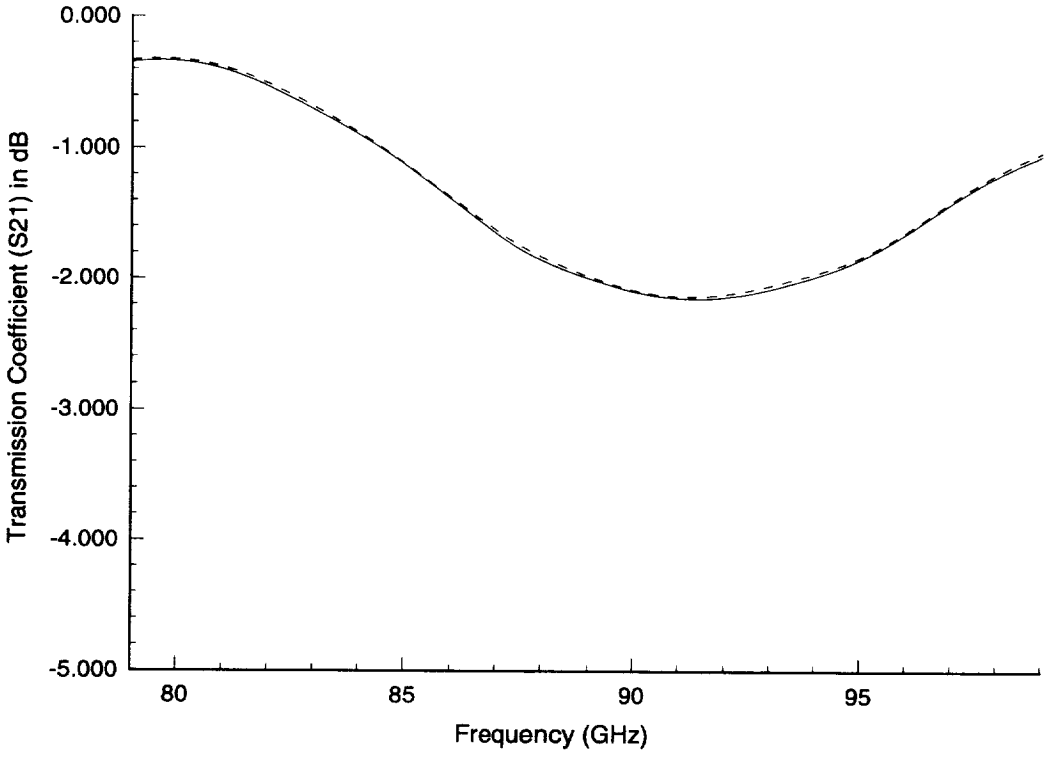

Figure 12(b). Transmission Coefficient (S21) for layered sample cross pol

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13. ABSTRACT ***(Maximum 200 words)***

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