INNEGRA HYBRID MATERIALS FOR LOW DIELECTRIC RADOME APPLICATIONS

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BACKGROUND

Radomes are protective housings for antennae, used in a wide variety of terrestrial, marine, and airborne communications applications. Shifts to higher frequency communications bands are driving an expanded need for lower dielectric materials, as system losses increase with frequency. Radome design must take into consideration not only electronic performance, but also mechanical performance, weather/impact damage resistance, system weight, and cost targets. When a radome is damaged by impact, the nature of the damage can alter the electrical transmission characteristics of the structure. Structures that have greater damage tolerance, where the stress of an impact can be absorbed and/or distributed without compromising the integrity of the structure, are thus of high value. Structures designed using high-density materials, such as glass or quartz are increasingly under scrutiny to determine if a material substitution can be made to reduce the system weight. Lower density, low dielectric materials therefore offer an additional advantage to designers. Using a hybrid system of fiber reinforcement offers the opportunity to optimize the FRP composite system based on mechanical, electrical, and cost criteria. Previous mechanical studies of FRP composites reinforced with hybrids of Innegra S and glass have demonstrated improvements in impact resistance and damage tolerance, which would be an additional benefit in radome applications.

EXPERIMENTAL

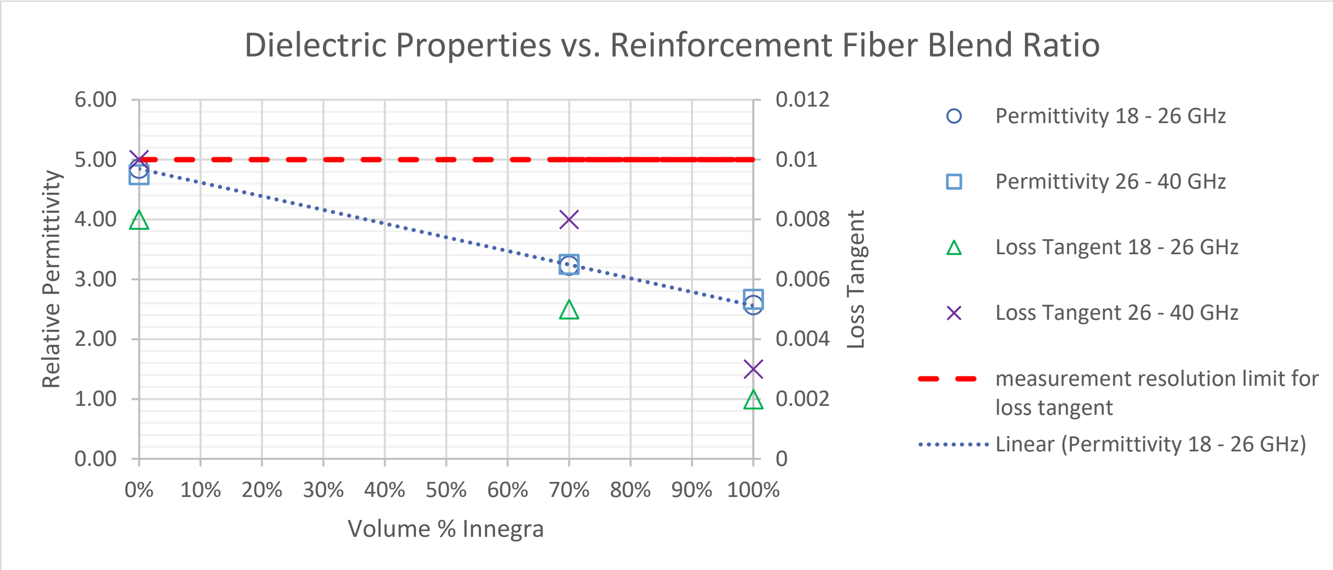
Three fabrics were chosen for this study: 100 % E-glass, used as a benchmark material; 100 % Innegra S; and a hybrid E-glass / Innegra S fabric, constructed of Innegra HIG06 hybrid E-glass/Innegra S yarns, chosen to represent a test point in composition between the two pure fiber fabrics. The composition of the hybrid fabric was approximately 70 % Innegra S / 30% E-glass by volume. Prepregs of the sample fabrics were prepared with a low-dielectric epoxy resin system, type AX3201, by Axiom Materials in a solvent-free hot-melt application process. Composite laminate panels were fabricated by the University of Delaware Center for Composite Materials from prepreg materials supplied by Axiom Materials. Each panel was composed of eight plies of prepreg with a stacking sequence of $[0]_8$. Panel laminate quality was verified by ultrasound C-scan prior to testing. Measurement of the dielectric properties of the test panels was made over a frequency range of 18 GHz – 40 GHz by the University of Delaware Center for Composite Materials using the free space focused beam transmission method. Complex permittivity was calculated from the measured transmittance and reflectance using methodologies based on transmission of electromagnetic waves through a dielectric slab.

RESULTS

The dielectric permittivity and loss tangent were obtained for the FRP composite panels over two frequency ranges, 18 – 26 GHz and 26 - 40 GHz, representing Ka, and Ku communication bands. The relative permittivity (dielectric constant) was found to be consistent over the frequency range studied within the limits of measurement error. The loss tangent also did not show a measurable change with frequency over the range studied, although is difficult to measure accurately at the low values obtained. The focused beam testing method has reduced accuracy below 0.010 loss tangent values.

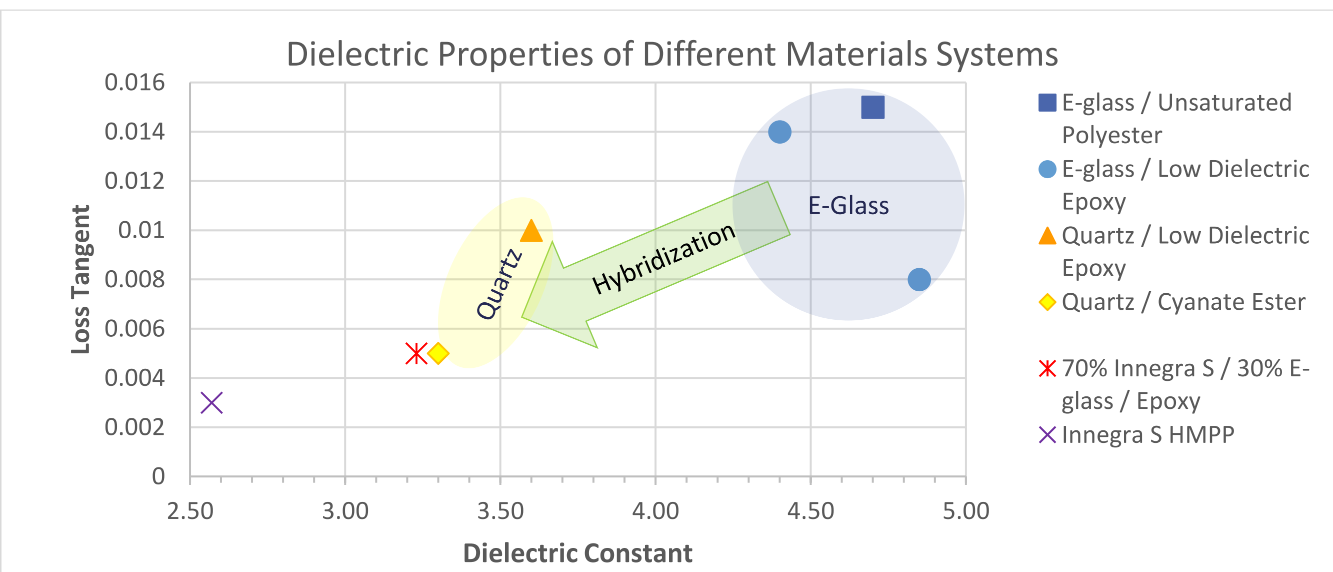
Panel	Thickness (mm)	Areal Weight (g/m^2)	Average Density (g/cc)	18-26 GHz		26 – 40 GHz	
				Relative Permittivity	Loss Tangent	Relative Permittivity	Loss Tangent
E-glass / AX 3201	1.95 ± 0.08	472.9 ± 7.3	1.835	4.85	<0.01 (0.008)	4.75	0.01
Hybrid Innegra / E-Glass / AX3201	2.23 ± 0.07	267.7 ± 3.1	1.002	3.23	<0.01 (0.005)	3.25	<0.01 (0.008)
Innegra / AX 3201	2.70 ± 0.08	459.1 ± 3.4	1.299	2.57	<0.01 (0.002)	2.67	<0.01 (0.003)

Permittivity and loss tangent were evaluated as a function of fiber content and permittivity was found to follow a linear rule-of-mixtures relationship based on volume fraction, which was expected. The loss tangent values were all below the detection accuracy limit of the measurement method so it is not possible to draw any reliable conclusions about the relationship between loss tangent and constituent volume fraction; further study using a different measurement method will be required to clarify the relationship.



DISCUSSION

Those skilled in the art of electronic design will recognize that different hybridization methods may be used to tune the electronic properties of a hybrid FRP structure, just as they can be used to modify the mechanical properties. Hybridization of E-glass with Innegra S fibers is an effective way to reduce the relative permittivity of a FRP composite structure, potentially achieving permittivity values in the range of that achieved with quartz fibers. The use of a reinforcement fabricated from a hybrid yarn results in a uniform distribution of fiber types throughout the plane of the fabric. Other strategies for creating hybrid FRP composites, such as using hybrid woven (co-woven) fabrics or hybridization at a ply level, are also possible.



Innegra S hybrid FRP composites have previously been shown to have higher impact resistance and damage tolerance than composites made from brittle reinforcement fibers alone. Hybridization of a FRP composite with Innegra S fibers can therefore allow designers to create a composite radome structure that is better able to satisfy the full range of requirements.