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Organic-Based Microwave Frequency Absorbers Using Corn Stover

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***Abstract*—Commercial antenna test chambers (anechoic) currently use polyurethane foam absorbers on chamber interiors to eliminate undesired radio-frequency (RF) reflections. While effectively absorbing microwave signals, polyurethane material particulates over time adding contaminants to clean rooms and reducing absorber lifetime. These absorbers also release toxic gas when operating under high temperatures and pose a health risk to direct-contact personnel. This paper presents reflectivity analysis and performance of alternative organic-based (corn stover) microwave frequency absorbers for use in anechoic chambers. These absorbers are composed of renewable materials and eliminate the toxic gas release problem for polyurethane materials under high power test conditions. Preliminary results show that the organic absorbers perform at levels comparable to commercially-available absorber panels.**

Keywords–Microwave RF absorbers; organic radar absorbing materials; alternate anechoic chamber lining.

I. Introduction

Present-day antenna test chambers are lined with RF absorbers made of polyurethane which contains hazardous materials (toxic gas release under high power conditions), particulate (crumble) over time, and are petroleum-based (unsustainable). These characteristics represent potential fire hazards, prohibit long-term use in clean room environments, and consume non-renewable resources.

Alternate organic absorber materials include corn stover, rubber particles, and organic binder compounds. Rice grain mixture processing, absorber shape formation, and reflectivity characterization are described in [1]. Corn stover (husk, leaves and stalks), due to its wider availability in the U.S., is considered in this paper. Binding materials [1] form absorbers for characterization relative to commercial absorbers.

II. Materials

Corn stover and rubber dust were combined with non-toxic Isophathalic Polyester Resin (IPR) and hardening agent Methyl Ethyl Ketone Peroxide (MEKP), commonly used in the composites industry. These compounds are also USDA-approved for food container production [2].

Corn stover stock was supplied by the Applied Biotechnology Institute (Cal Poly campus). The U.S. corn industry produces substantial corn stover: 10.8 billion corn bushels were produced on 87.4 million acres in 2012 [3] making this America's largest crop.

Rubber dust (20 lbs) was donated for absorber fabrication [4]. The U.S. scraps 300 million tires annually [5]; 18 million are converted to rubber dust for recycled product production.

III. Formation Procedure

RF absorbers were formed in cake pans; 9" x 12" flat panels, 1" thickness in three corn stover-rubber composition ratios; 25%:75%, 50%:50%, 75%:25%. Fig. 1 shows the 75%:25% ratio.

Fig. 1. Corn-Rubber RF Absorber, 75%:25% ratio.

Absorber formation (2kg total mass) through compression molding was completed in the Cal Poly Composites Lab. Polyester (400gm) was added to the mixture (1600gm) in 20gm increments. MEKP and polyester mixing was completed quickly to ensure binder reactions occurred within the molder, and then transferred to cake pans. Square metal plates over each absorber distributed five tons of molder pressure at 350^{o}F for 25 minutes each. The RF absorbers were cooled to room temperature to complete MEKP hardening.

IV. Absorber Characterization Procedure

NRL (Naval Research Lab) arch testing [6] in the Cal Poly Anechoic Chamber includes transmit and receive horns connected to an HP8720C network analyzer, Fig. 2.

The blocking screen (flat absorber panel) between horn antennas blocks direct path interference (possible error). Three horn pairs were used for the 5.4-8.2GHz, 7.05-10GHz, and 12-18GHz ranges. The test configuration was calibrated using a metal plate and commercial flat panel absorber at incident angles 20^{o} to 60^{o} (10^{o} increments). The three fabricated absorber panels were characterized; 150 total test sets.

Metal plate $|S_{21}|$ measurements establish a reference for perfect reflection. Absorber measurements are compared to this reference ($|S_{21(absorber)}| - |S_{21(metal)}|$). Values greater than 0dB represent reflected power.

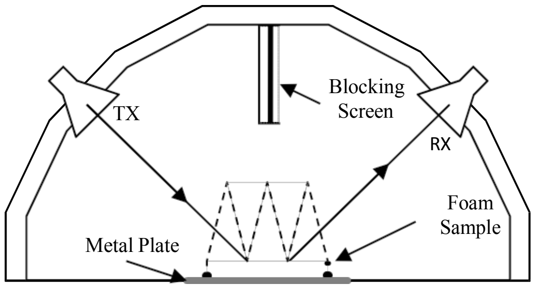

Fig. 2. NRL Arch Test Configuration.

TABLE I. CORN STOVER (1" THICK) VS. COMMERCIAL ABSORBER (4" THICK) REFLECTIVITY PERFORMANCE.

Freq (GHz)	Polarization	θ_{inc} (deg)	Better Reflectivity	Margin (dB)
5.4	H	20-40	Comm	5
	H	40-60	Equal	<5
	V	20-50	Comm	5
	V	50-60	Equal	<5
6.8	H	20-45	Equal	<5
	H	45-60	75:25 C/R	**10**
	V	20-50	Equal	<5
	V	50-60	75:25 C/R	**15**
7.0	H	20-60	Equal	<5
	V	20-60	Equal	<5
8.2	H	20-60	Equal	<5
	V	20-30	Comm	5
	V	30-60	Equal	<5
10	H	20-60	Equal	<5
	V	20-60	Equal	<5
12	H	20-40	Comm	**15**
	H	40-60	Equal	<5
	V	20-40	Comm	7
	V	40-60	Equal	<5
15	H	20-40	Comm	5
	H	40-60	Equal	<5
	V	20-40	Comm	5
	V	40-60	Equal	<5
18	H	20-35	Comm	**10**
	H	35-60	Equal	<5
	V	20-60	Equal	<5

Notes: Polarization: horizontal (H) or vertical (V), corn/rubber (C/R), commercial absorber (Comm).

V. RESULTS AND ANALYSIS

Comparisons between three corn stover/rubber (C/R) compositions (25:75, 50:50, 75:25) and a commercial flat panel absorber (Comm) are presented in Table I.

Nearly 90% of test results indicate comparable corn stover and flat commercial absorber performance ("Equal"); less than 5dB difference. Also, the commercial absorber is four times thicker than the corn stover panels. Reflectivity differences greater than 10dB are highlighted in Table I.

Reflectivity differences of 10dB and 15dB (corn absorber advantage) were measured at 6.8GHz for horizontal and vertical polarizations, respectively. For 1" thick absorber (t) at 50^{o} incidence angle (θ_i), assuming an odd multiple (N) quarter-wave path length ($N\lambda/4$) with refraction effects, the corn stover dielectric constant ($\varepsilon_{r,a}$) is calculated from

$$\varepsilon_{r,a}^2 - \left(\frac{Nc}{4tf}\right)^2 \varepsilon_{r,a} + \left(\frac{Nc}{4tf}\right)^2 \sin^2\theta_i = 0, \quad (1)$$

which yields $\varepsilon_{r,a} = 4.03$ for N = 5, comparable to FR4 printed circuit board substrates. Using equation (1) and 4" absorber thickness, the dielectric constant is 3.85. the polyurethane coating dielectric constant range is 3 to 4 [7].

VI. CONCLUSIONS AND FUTURE WORK

Organic-based RF absorbers represent a potential solution to chamber absorber foam crumbling and sustainability issues. Polyurethane foam's poisonous gas emissions upon ignition (high power testing) and potential health hazards from absorber particulates are eliminated [8]. Additionally, non-toxic compounds – IPR resin combined with hardening agent MEKP – form corn stover and rubber dust into absorbers.

Corn stover absorber experimentation can be extended by fabricating additional shapes (wedge, pyramidal) and comparing test results to commercial absorbers.

VII. ACKNOWLEDGMENTS

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