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Ultraviolet Aging on the Electromagnetic Transparency of Polymeric Radomes at 24 GHz

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Introduction

Polymeric materials are extensively used in electromagnetic systems because of their low density, mechanical robustness, and cost-effectiveness [1]. In radar systems operating near 24 GHz, such as automotive sensors and satellite communication antennas, these materials commonly serve as radome structures, where high transmission and low reflection are essential [2]. This work investigates the influence of ultravioletal aging exposure on the electromagnetic transparency of polymeric radome materials operating in the K-band.

Methodology

Seven commercial polymers were evaluated: high-density polyethylene (HDPE), polyvinyl chloride (PVC), polypropylene (PP), acrylonitrile butadiene styrene (ABS), polycarbonate (PC), polymethyl methacrylate (PMMA) and polytetrafluoroethylene (PTFE). The materials were experimentally characterized using a vector network analyzer connected to a WR-42 rectangular waveguide. The scattering parameters were measured across the K-band and used to determine the reflectance, transmittance, and absorptance responses of each polymer [3]. The complex dielectric properties were extracted using the Nicolson–Ross–Weir method, enabling the calculation of the radome thickness required to minimize reflection at the design frequency of 24.125 GHz [3], as show in Figure 1.

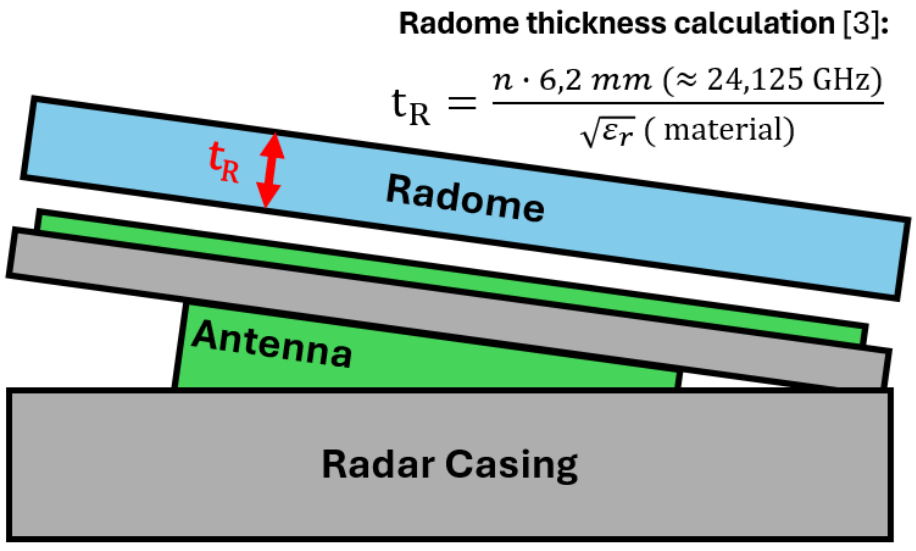


Figure 1. Schematic configuration of the radar assembly indicating the radome thickness (t_R) above the antenna.

Results and Discussions

The polymer samples were subjected to controlled aging conditioning. After UV exposure, the electromagnetic measurements were repeated and compared with the initial results to assess the influence of UV aging on dielectric properties and transmission performance, as shown in Figure 2 and Table 1.

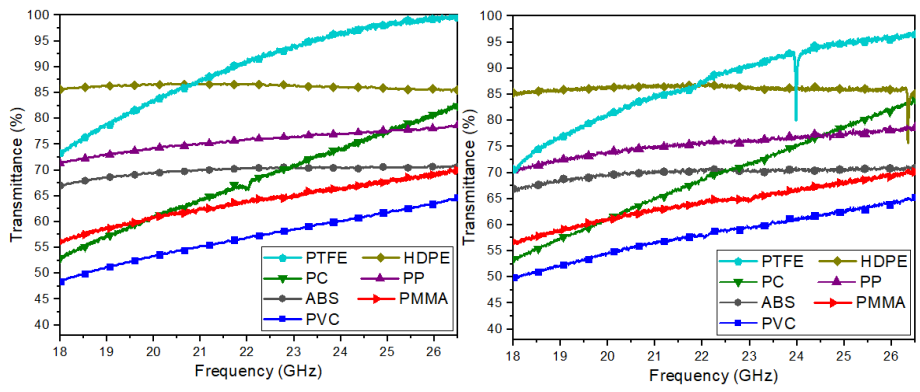


Figure 2. Transmittance measured by VNA at the original sample thickness (a) before and (b) after UV exposure.

Samples	ε'r	ε'r after UV	tR (mm)	tR (mm) after UV	Considering Radome Effect in 24 GHz (%)			Considering Radome Effect in 24 GHz (%) after UV exposure		
					R	T	A	R	T	A
PTFE	1.88	1.87	4.52	4.53	1.64	98.38	0.02	2.63	93.46	3.91
HDPE	2.31	2.30	4.08	4.09	2.06	97.81	0.12	2.24	96.18	1.58
PP	2.21	2.22	4.17	4.16	2.31	97.28	0.42	2.41	97.15	0.44
PMMA	2.78	2.73	3.72	3.75	2.12	96.10	1.78	2.79	94.39	2.81
ABS	2.78	2.75	3.72	3.74	2.23	95.97	1.79	2.88	93.83	3.29
PC	2.67	2.67	3.79	3.79	2.95	95.31	1.74	3.42	93.95	2.64
PVC	3.20	3.07	3.47	3.54	2.75	94.76	2.49	3.59	94.42	1.99

Table 1. Electromagnetic properties of the polymers before and after UV exposure.

Conclusions

After UV exposure, ε'r changed by at most 0.13 (≈ 4%), shifting the optimized radome thickness by less than 0.1 mm. Transmittance at 24.125 GHz decreased for all polymers (by 0.1 to 4.9 points). In most cases the main cause was increased absorptance, indicating that UV aging acts mainly through dielectric losses rather than through detuning of the half-wavelength condition. PP was the most stable material (T = 97.15%, A = 0.44%), while PTFE showed the largest degradation (T: 98.38% → 93.46%). Only PP, HDPE and PMMA still met the previous criteria (T > 94% and R < 3%); PC and PVC exceeded 3% reflectance. Aging must be considered together with initial transparency when selecting radome materials.

References

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