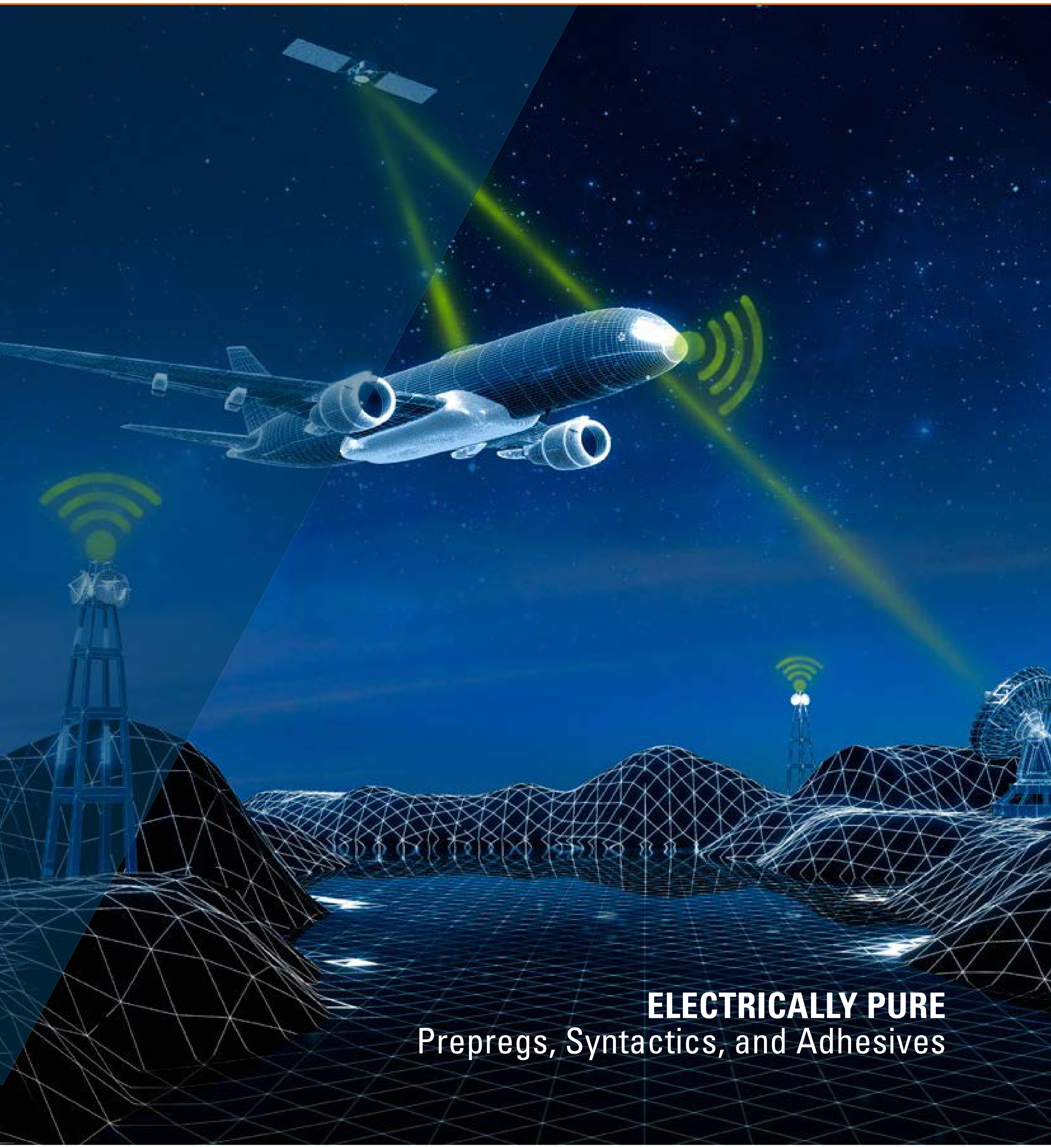
RADOME ANTENNA SYSTEMS

Advanced Composite Materials Selector Guide



ELECTRICALLY PURE

Prepregs, Syntactics, and Adhesives

TORAY

Toray Advanced Composites

MATERIALS FOR HIGH PERFORMANCE, RELIABLE RADOMES AND ANTENNAS

The Science of Communication

WORLD-LEADING RADOME COMPOSITE MATERIALS

Toray Advanced Composites is the world's leading supplier of advanced composites and resin systems for the radome and antenna industry. Applications include use on radomes for military and civil aircraft, ship, rail, and ground-based systems, including conformal and patch antennas.

A radome (radar dome) is a cover designed to protect an antenna system from the environment, preserve vehicle aerodynamics, provide lightning strike protection, and maintain stealthy attributes. The optimum composite material is a crucial component of a reliable and highly functional radome antenna system.

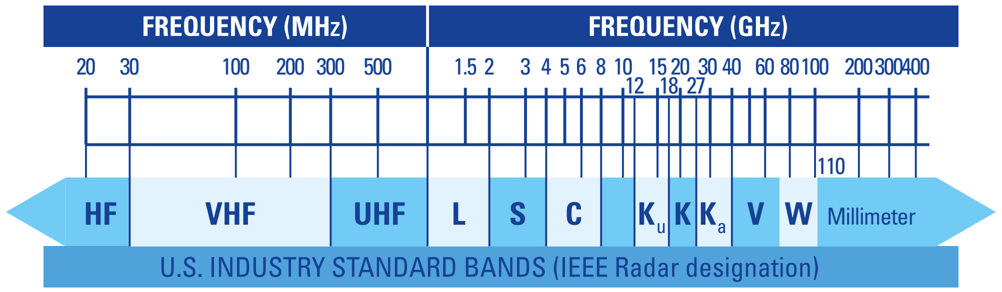
In flight, it is not uncommon for a military aircraft to operate more than fifteen antennas with multiple functions such as weather detection, satellite communications (satcom), ground communication and imagery, target acquisition, fire control, jammer pods, altitude monitoring, and so on. Superior materials are required to ensure optimal output. Toray delivers optimal output in this complex signal environment.

TREND TOWARD HIGHER FREQUENCIES AND MULTIBAND COMMUNICATIONS

Antenna systems are increasingly multiband and multifunctional, operating "broadband" over a number of different frequencies, with trends toward higher frequencies. Not only are the lower frequency bands filling up, but operation at higher frequencies and multiple bands enables high data rates and nearly instantaneous exchange of "big data" packages. Airlines can send and transmit data enabling the "connected aircraft" in real time. Passenger streaming of video onboard is now feasible with Ku, K, and Ka-band communications.

Increased antenna system sophistication drives complexity in the radome design, requiring C-sandwich and B-sandwich constructions for satcom Wi-Fi radomes. Such complexity necessitates higher performance advanced materials such as cyanate ester/quartz, or epoxy/quartz prepregs in place of E-glass/epoxy.

Toray cyanate ester and epoxy prepregs, MicroPly™ syntactic and adhesive films, and RTM/infusion resin systems feature the low density, low dielectric constant and loss tangent, low moisture absorption, low coefficient of thermal expansion, and precise weight and thickness control needed to enable peak performance.



UNDERSTANDING DIELECTRIC CONSTANT AND LOSS

Signal attenuation, or dielectric loss, occurs either through absorption of electromagnetic energy resulting in matrix heating or by reflection of the signal from the surface or within the composite.

The dielectric constant (D_k) gives an indication of the reflective and refractive properties of a material. Simplistically, the signal can be thought of as slowing down as it travels through the composite (compared with air). When the signal hits a surface at an angle, it is deflected. This deflection is referred to as "boresight error" or "beam deflection."

Dielectric constant and loss determine the transmission efficiency of a radome/antenna system and are best measured at the intended operating frequencies. Lower dielectric constant and loss permit the antenna system to operate at lower power and minimizes the effect of the radome on antenna performance. Toray Advanced Composites has an extensive database of materials tested over many different frequencies to facilitate radome design. This data when input into computer-aided electromagnetic modeling packages is a powerful tool to help determine the performance of a proposed radome/antenna system design.

	BEST PERFORMANCE		BEST COST
	Cyanate Ester/ Quartz Fabric	**Low Dielectric Epoxy/ Quartz Fabric**	**Low Dielectric Epoxy/ Glass Fabric**
Electrical Performance	**BEST** Dielectric Constant 3.13–3.36 Loss Tangent 0.004–0.013	**BETTER** Dielectric Constant 3.32–3.45 Loss Tangent 0.004–0.011	**GOOD** Dielectric Constant 4.47–4.83 Loss Tangent 0.009–0.020
Laminate Impact Strength	**VERY GOOD**	**VERY GOOD**	**MODERATE**
Laminate Moisture Absorption	**LOWEST** 0.1–0.6%	**VERY LOW** 0.6–0.8%	**MODERATE** 1.2–1.6%

ANTENNA AND RADOME MATERIALS

Product Overview

TORAY COMPOSITE LAMINATE PERFORMANCE OVER C/X, KU/K, KA, AND Q/U BANDS

LAMINATE PERFORMANCE OVER DIFFERENT BAND FREQUENCIES				FREQUENCY															
				C/X Band: 4-8 GHz		X Band: 8-12 GHz		X Band: 8-12 GHz		Ku/K Band: 12-26.5 GHz				Ka Band: 26.5-40 GHz				Q & U Band: 40-60 GHz	
				Open Resonator[3]		Open Resonator[3]		Focus Beam Method		Open Resonator[3]		Focus Beam Method		Open Resonator[3]		Focus Beam Method		Focus Beam Method	
Product Name[1]	Resin Matrix	Dry T_g Onset	Reinforcement	D_k	DF	D_k	DF	D_k	DF	D_k	DF	D_k	DF	D_k	DF	D_k	DF	D_k	DF
BTCy-2	Cyanate Ester	191°C (375°F)	4581 Quartz	N/A	N/A	N/A	N/A	3.17	0.010	N/A	N/A	3.13	< 0.01[2]	N/A	N/A	3.14	< 0.01[2]	3.12	< 0.01[2]
BTCy-1A	Cyanate Ester	207°C (405°F)[4]	4581 Quartz	3.26	0.004	3.27	0.004	3.23	0.013	3.23	0.004	3.18	< 0.01[2]	3.24	0.004	3.19	< 0.01[2]	3.18	< 0.01[2]
EX-1515	Cyanate Ester	174°C (345°F)[4]	4581 Quartz	3.24	0.005	3.24	0.005	N/A	N/A	3.21	0.005	N/A	N/A	3.19	0.005	N/A	N/A	N/A	N/A
TC522 **NEW**	Modified Epoxy	198°C (389°F)	4581 Quartz	N/A	N/A	3.33	0.004	-	-	-	-	-	-	-	-	-	-	-	-
BT250E-1	Epoxy	125°C (257°F)	4581 Quartz	N/A	N/A	N/A	N/A	3.26[1]	0.008[1]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TC420	Cyanate Ester	348°C (658°F)[4]	4503 Quartz	N/A	N/A	3.36	0.005	3.33	< 0.01[2]	N/A	N/A	3.18	< 0.01[2]	N/A	N/A	3.24	< 0.01[2]	3.27	< 0.01[2]
EX-1522	Epoxy	180°C (356°F)	4581 Quartz	3.35	0.005	3.34	0.005	3.35	0.011	3.32	0.005	3.31	0.011	3.32	0.005	3.31	< 0.01[2]	3.31	< 0.01[2]
TC250	Epoxy	180°C (356°F)[4]	4581 Quartz	3.45	0.013	3.45	0.013	3.47	0.015	3.43	0.012	3.43	0.015	3.40	0.012	3.42	0.011	3.40	0.012
TC522	Modified Epoxy	196°C (384°F)	7781 E-glass	N/A	N/A	4.48	0.010	-	-	-	-	-	-	-	-	-	-	-	-
BT250E-1	Epoxy	125°C (257°F)	7781 E-glass	4.61	0.014	4.57	0.015	4.52	0.019	4.47	0.016	4.48	0.018	4.50	0.020	4.45	0.017	4.42	0.016
EX-1522[5]	Epoxy	180°C (356°F)	7781 E-glass	4.68	0.009	4.69	0.010	4.72	0.012	4.65	0.011	4.67	0.013	4.63	0.013	4.66	0.010	4. 64	0.011
TC250	Epoxy	180°C (356°F)[4]	7781 E-glass	4.83	0.016	4.82	0.016	4.73	0.026	4.78	0.016	4.63	0.023	4.73	0.017	4.64	0.016	4.59	0.019

1. In order of laminate Dielectric Constant for X Band using Focus Beam Method except BT250E-1/4581 at 10 GHz.
2. Focused Beam loss tangent results are not precise < 0.010 DF. These materials represent the best Toray candidates for high-energy radome applications.
3. Open Resonator results using ASTM D2520 Method C.
4. With post cure.
5. Lower temperature cure data available for EX-1522

D_k - Dielectric Constant
DF - Loss Tangent

TORAY MICROPLY™ ADHESIVES AND SYNTACTICS

	RESIN TYPE	DRY T_g ONSET (DMTA)	CURE TIME AND TEMPERATURE	Material at 10 GHz: DIELECTRIC CONSTANT (D_k)	Material at 10 GHz: LOSS TANGENT (DF)	OOA/VBO	TOUGHENED
SYNTACTIC FILMS							
SF-5	Cyanate Ester	193°C (380°F) or 254°C (490°F) with post cure	2 hours at 120°C (350°F). Optional post cure of 2 hours at 232°C (450°F)	1.70[1]	0.004	○	○
TCF4045	Epoxy	180°C (356°F)	3 hours at 179°C (355°F)	1.57	0.008	○	○
TCF4035	Epoxy	140°C (284°F)	3 hours at 130°C (265°F)	1.94	0.018	○	○
TCF4050	Cyanate Ester	176°C (349°F) or 232°C (450°F) with post cure	2 hours at 177°C (350°F). Optional post cure of 60-90 minutes at 232°C (450°F)	N/A	N/A	○	○
FILM ADHESIVES							
EX-1516	Cyanate Ester	126°C (258°F)	5 hours at 121°C (250°F)	2.6–2.7	0.005–0.006	○	○
EX-1543	Cyanate Ester	191°C (376°F) or 211°C (412°F) with post cure	2 hours at 177°C (350°F) Optional post cure of 2 hours at 204°C (400°F)	2.72	0.009	○	○
TC263	Epoxy	110–115°C (230–239°F)	2 hours at 121°C (250°F)	2.97	0.017	○	○
TC310	Epoxy	157°C (315°F)	2 hours at 177°C (350°F)	3.06	0.013	○	○
RS-4A	Cyanate Ester	203°C (397°F)	2 hours at 177°C (350°F)	N/A	N/A	○	○
TC4015	Cyanate Ester	176°C (349°F) or 321°C (610°F) with post cure	2 hours at 177°C (350°F). Optional post cure for > 60 minutes at 232°C (450°F)	N/A	N/A	○	○
SYNTACTIC PASTES							
EX-1541	Cyanate Ester	227°C (441°F) or 240°C (464°F) with post cure	2 hours at 177°C (350°F). Optional post cure of 2 hours at 232°C (450°F)	1.32	0.009		
TCF4001	Cyanate Ester	176°C (349°F)	2 hours at 177°C (350°F). Optional post cure of 60-90 minutes at 232°C (450°F)	1.55	0.012	○	

1. SF-5 tested at 18 GHz

NEAT RESIN SYSTEM PERFORMANCE

	Resin Matrix	Dry T_g Onset	D_k (10 GHz)	DF (10 GHz)
BTCy-2	Cyanate Ester	191°C (375°F)	2.70	0.001
BTCy-1A	Cyanate Ester	185°C (365°F) or 207°C (405°F) with post cure	2.70	0.003
EX-1515	Cyanate Ester	121°C (249°F) or 174°C (345°F) with post cure	2.79	0.004
EX-1522	Modified Epoxy	180°C (356°F)	2.71	0.007
RS-8HT	BMI	203°C (395°F) or 285°C (545°F) with post cure	3.01	0.0074
RS-3C	Cyanate Ester	191°C (375°F) or 254°C (490°F) with post cure	2.81[1]	0.009[1]
TC522	Modified Epoxy	189°C (372°C)	2.98	0.013
EX-1545	RTM Cyanate Ester	173°C (345°F)	2.89	0.016
TC420	Cyanate Ester	177°C (350°F) or 348°C (658°F) with post cure	3.11	0.016
BT250E-1	Epoxy	125°C (257°F)	3.00	0.017
TC250	Epoxy	140°C (285°F) or 180°C (356°F) with post cure	3.00–3.06	0.020–0.021

Shorted waveguide results using test ASTM D 2520 Method A
1. Sample tested at 10.7 GHz using Open Resonator test ASTM D 2520 Method C

COMMON PREPREG REINFORCEMENTS

	D_k (10 GHz)	DF (10 GHz)	Specific Gravity (g/cc)	Moisture Pickup (% by Wt.)	Maximum Service Temp.
E-glass	6.10	0.004	2.55	nil	371°C (700°F)
S-glass	5.21	0.006	2.49	nil	398°C (750°F)
Quartz	3.78	0.0002	2.20	nil	> 537°C (> 1000°F)
HDPE	2.00	0.0004	0.97	nil	104°C (220°F)
LMR Kevlar® 49[1]	3.85	0.008	1.47	1.9%	176°C (350°F)

1. LMR Kevlar® 49 is a Toray proprietary Low Moisture Regain treatment of the aramid fabric from E.I. de Pont de Nemours and Company.

MANUFACTURING FACILITIES

Toray Advanced Composites has over 25 years of experience producing materials for radomes. Even a small carbon fiber contaminant in a radome will heat up in response to an electromagnetic signal, degrading the surrounding matrix with potentially disastrous results. To prevent this, Toray produces our dielectrically sensitive materials in enclosed positively-pressurized rooms with separate air systems and filters, housing carbon-free machines and equipment dedicated solely to the production of radome prepregs and complementary products. Our carbon-free facilities never see a carbon fiber material and are isolated from conductive materials, ensuring superior quality and electrically pure products.

Toray Advanced Composite materials from the carbon-free lines are used worldwide in antennas, reflectors, conformal radomes, components with embedded deicing elements, sonar domes, and microwave transparent and radar absorbing structures. Popular reinforcements such as E-glass, S2-glass, quartz, aramid, HDPE, and HDPP are fully compatible with Toray's advanced resin systems and can be supplied as prepregs, adhesive, and syntactics to satisfy the most demanding electrical, mechanical, and high-temperature applications.

For more product information such as product data sheets, case studies, or technical papers, please use the following resources:

Search for the **Toray TAC Product Selector**

www.toraytac.com
Go to our online resource center for case studies and technical papers

More in-depth technical product data may be available. Please contact your Toray Account Manager or a member of the Expert Services team for more information.

MATERIALS APPLICATION FOCUS

General Dynamic's Fabrication of the Triband Satcom Radome

TECHNOLOGICALLY ADVANCED TRIBAND SATCOM RADOME

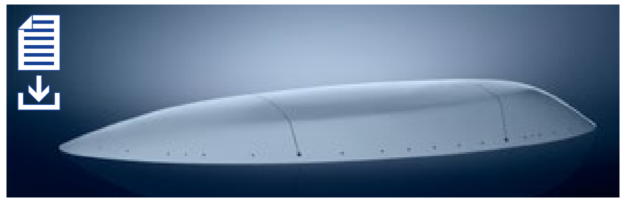
The General Dynamics triband radome is a technologically advanced composite satcom radome. Designed to transmit data across three bandwidths (K, Ku, and Ka), the radome achieves enhanced levels of speed and connectivity for inflight Wi-Fi and two-way communication.

Toray Advanced Composites worked in partnership with General Dynamics, the radome designer and manufacturer, to provide the Toray BTCy-1 material solution, allowing the enclosed antennas to transmit and receive radio frequency signals across a broader range of bandwidths. Other design considerations included consistency in signal transmission across all parts, longevity, and cost-effectiveness.

Toray BTCy-1 is a cyanate ester-based thermoset prepreg that is an industry standard for use on satellite structure and radomes. BTCy-1 offers an outstanding balance of toughness, low dielectrics, mechanical property translation, and hot/wet performance. Combined with a quartz fabric, this advanced composite material solution provides excellent electrical and mechanical performance to deliver the best performance radome antenna system design.

LEARN MORE ABOUT THE USE OF OUR PRODUCTS IN RADOME ANTENNA SYSTEMS

Find this case study, and more at **www.toray**tac.com/success-stories



Composites Aid Connectivity for Commercial Aircraft

To learn more about the fabrication of the General Dynamics triband satcom radome that is used by commercial airlines to bring Wi-Fi to passengers, read the High Performance Composites article at **www.toray**tac.com titled **"Composites Aid Connectivity for Commercial Aircraft."**

LOCATIONS AND CAPABILITIES

SOLUTIONS
- Thermoplastic composites
- Thermoplastic laminates
- Thermoset composites
- Carbon-free manufacturing
- Parts manufacture
- Sales office

CERTIFICATIONS
- ISO 9001:2015
- AS9100D
- ISO 14001:2015
- ISO 45001:2018

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