



AFC's Radome Technology

Maximum Protection Minimum Transmission Loss



AFC's Two 68-ft diameter thin membrane wall DSF radomes for the Defense Satellite Communications System (DSCS), Okinawa, Japan.

Antennas for Communications (AFC) high technology radome capability combines the expertise of materials science, geodesic domes, structures and electromagnetics. AFC manufactures four types of Dielectric Space Frame (DSF) radomes. The four types identify themselves primarily by the radome wall construction. Depending on radome wall structure, the adjacent panel flange framework may also serve as environmental load bearing beams or struts. Each panel is a molded one piece unit without bonds or seam lines. When assembled to the other panels, the panel array forms a truncated spherical surface. Individual panels may be doubly curved or flat yielding a faceted geodesic or spherical smooth appearance. Foam insulation is often added to the wall producing a 2 or 3-layer sandwich configuration. As required by sophisticated electrical performance requirements. Impedance matching circuits may be inserted into the dielectric flanges to reduce scattering loss. The superior performance and advantages of DSF Radome technology are evident in the worldwide Defense Satellite Communications System (DSCS). Weather satellite and radar, air surveillance radar and Intelsat communications.

Features

MAXIMUM ENVIRONMENTAL PROTECTION

- ◆ Radome panel and frame in one molded piece
- ◆ Stainless steel hardware is inside to prevent corrosion
- ◆ Self supporting without any air pressure
- ◆ Pretensioned thin membrane panels to prevent wind flutter noise
- ◆ Optional full hydrophobic coating
- ◆ Fungus resistant
- ◆ Large panel segments can be removed for equipment movement
- ◆ Sandwich 2-layer and 3-layer radomes for thermal insulation and optimal performance

MINIMUM TRANSMISSION LOSS

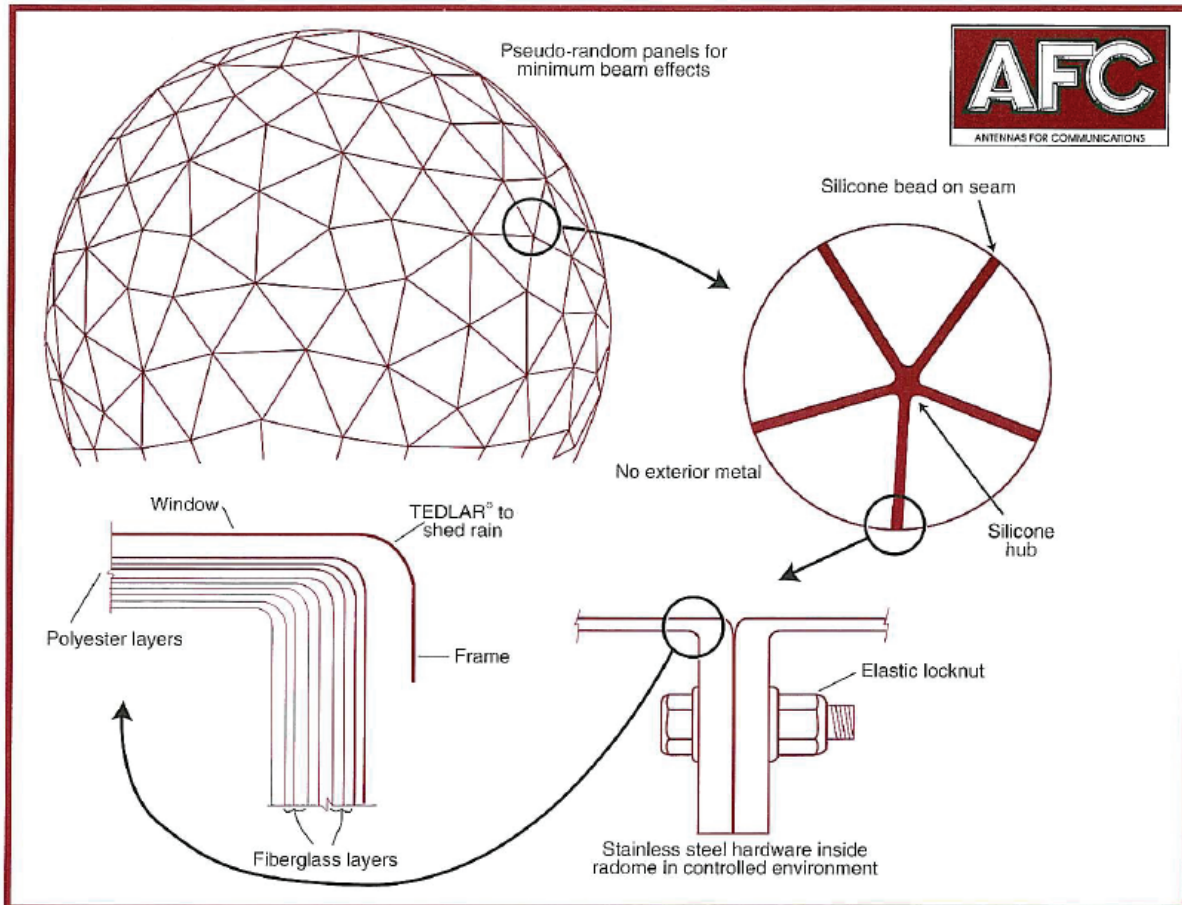
- ◆ Pseudo-random panels prevent coherent scattering
- ◆ Dielectric space frame has no low frequency cutoff
- ◆ Minimum wall insertion loss and framework scattering loss
- ◆ Optional impedance matching network eliminates dielectric framework scattering loss
- ◆ No framework metal/ dissimilar metals corrosion to produce intermodulation
- ◆ No dissimilar metals to produce intermodulation

The four DSF radome types are:

- ◆ The thin membrane wall DSF radome, where adjacent panel flanges carry all the environmental loads. Wall thickness is usually 0.040 inch or less.
- ◆ The solid laminate wall DSF radome. Wall thickness is typically 0.090 inch.
- ◆ Adding a layer of foam to the inside thin wall DSF radome forms a 2-layer sandwich. Foam thickness is chosen primarily for thermal insulation.
- ◆ The composite 3-layer sandwich foam core wall radome. Core thickness is chosen as 1/4 wavelength for the highest RF signal frequency.

High Degree of Flexibility

AFC engineers have developed a family of dielectric space frame radomes based on a range of required radome diameters. A set of radomes within a given range of radii will have identical panel count, panel shape and overall geometric layout. Individual panel size and the flange angles, which are radius dependent, will differ to accommodate the radome's overall shape factors. Spherical truncation is also radome specific, and is accommodated by sub panels unique to each requirement. Radome accessories customize a radome to suit particular requirements. Accessories may include lightning protection, obstruction lights, ventilation, base collar, personnel door, indoor lights and power outlets. Other enhancements could include hydrophobic coating and impedance matching. AFC has combined its extensive experience in fiberglass antenna manufacturing with its radome experience to produce the dielectric space frame radome. DSF radomes combine strength and weather resistance with minimal effect on microwave frequency signals.



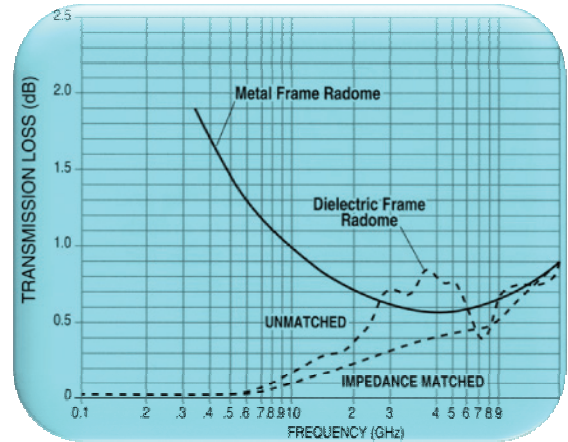
Monolithic Segments

AFC's thin membrane wall dielectric space frame radomes are constructed of flat panel segments which combine a composite multi-layer polyester window with a fiberglass frame in one monolithic piece. DSF radome panel frameworks are completely inside so there is nothing to trap water in puddles or to launch ice adhesion. The only metal parts are stainless steel nuts and bolts holding the panel segments together. There are no metal components on the outside of the radome to corrode in harsh environments or to discolor or stain radome panels. Without corrosion induced oxide diode mixers, DSF radomes are virtually intermodulation product free in the presence of modern multi-carrier communication systems and Radars. The only exterior maintenance required is an occasional washing to remove dirt. No air pressure is required to support the radome. Even without pressurizing the radome, the polyester panel windows are pretensioned to minimize audible flutter, microphonics or "oil canning." Sandwich DSF panels add an internal low density closed cell foam and skin layer forming a thicker 2-layer or 3-layer wall. 3-layer sandwich panels are very rigid. They may be molded into spherical doubly curved or flat surface shaped panel units. For flat DSF panels, such as used in the thin membrane wall geodesic radome, the entire exterior of the radome is covered with TEDLAR®. Tedlar is a unique long-lasting material with a proven weather-resistant 20-year lifetime. Curved panel shapes use gelcoat as the exterior surface. An optional hydrophobic coating may be applied to either the gelcoat or Tedlar surface. This hydrophobic coating causes water to bead and run off in rivulets instead of sheeting. Hydrophobicity also serves as effective anti-ice protection for the radome and reduces rain-related transmission loss.

Low Transmission Loss

Radome transmission loss is composed of two major loss contributions. The first and usually the smallest contribution is the ordinary insertion loss of a microwave signal passing through the radome wall. The second and largest contribution is the scattering loss off the radome panel framework blocking the antenna aperture. Scattering loss is typically 4 to 10 times larger than the wall insertion loss. The use of a dielectric space frame greatly reduces the scattering loss associated with metal frames. This reduces the transmission loss, beam distortion and boresight error that can be caused by a metal frame. Use of a dielectric frame also eliminates the Faraday cage

effect which inhibits the use of metal space frame radomes at lower frequencies. Every DSF radome exhibits the RF property that the total transmission loss, scattering plus wall insertion loss, approaches zero dB at low frequencies (as opposed to metal space frame radomes, whose loss increases without limit. This property is important for UHF/VHF emergency radio communications contained within the radome).



Transmission Loss Comparison between dielectric frame and metal frame 55' diameter radomes

Virtually Invisible

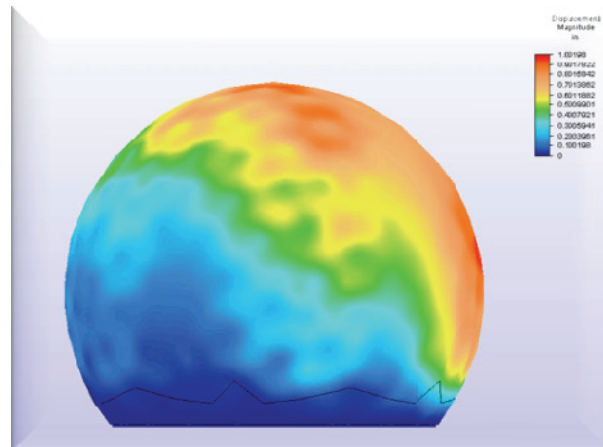
The dielectric space frame radome is divided into several large sections. To eliminate the possibility of coherent scattering from panel framework blocking the antenna, the sections are divided into random sizes of triangular segments. Combining the sections produces a pseudo-randomly segmented radome which has proven to be Virtually invisible to microwave scattering.

Scattering loss can also be greatly reduced in a dielectric space frame radome by a process known as impedance matching. The capacitive reactance of the radome framework is removed by adding inductive circuits into the frame. The inductance offered by the impedance matching circuits "tunes out" the capacitance of the radome framework, to reduce the scattering loss and the phase distortion with its associated boresight shift and sidelobe perturbation. The use of stainless steel hardware with a dielectric space frame avoids any dissimilar metal contact which could increase the intermodulation distortion.

Experts in Structural Analysis

Wind, snow and ice loads place stringent demands on the structural properties of the radome. To support these environmental forces and make shipment possible worldwide, radome structures are composed of panels, which when assembled, form a truncated spheroid. To enable adjacent panel assembly, each panel is surrounded by a flange, which creates a radome framework characteristic of the different panel shapes. This framework also has structural properties, which is the case for space frame geodesic radome designs.

AFC's radome designs are based on accurate structural analysis carried out using time dependent Finite Element Analysis. We have tools that can accurately determine the safety factors such as Critical General Buckling in the presence of severe environmental conditions for reliable and fail-safe operation over a 20 year life-time. Our designs always consider Critical Buckling wind speed significantly higher than the typical wind speed requirement of 150 mph. We can accurately determine the effect of rain and snow load on the structural integrity of the radome.

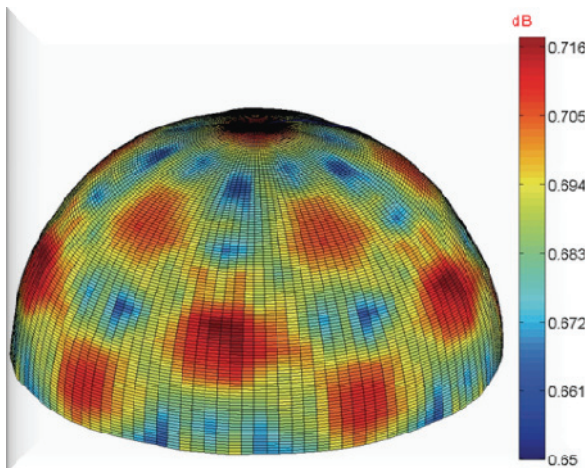


Displacement effects under wind load for a 68ft diameter radome. Analysis was carried out using Finite Element Technique.

Experts in Electromagnetic Analysis

From the electromagnetic perspective, the scattering off the radome framework forms a scattering linear array antenna pattern of those framework elements blocking (shadowing) the antenna aperture. Over the years, AFC has developed in house, accurate electromagnetic analysis tools to design radomes of various sizes and configurations. The EM analysis is based on accurate Finite Difference Time Domain (FDTD) as well as Method of Moments (MoM) to determine the transmission and scattering properties of the radome structure.

AFC has introduced innovative ways of introducing impedance matching in the dielectric flanges, which can offer narrow band or broadband improvement to the scattering loss of the framework. The impedance tuning enables to compensate the dielectric susceptance of the flange with the inductive compensation over a narrow or a broadband and provides greater degree of control in the electromagnetic characteristics of the radome. The impedance tuning network is integrated into the flange framework. With alternate radome technologies, no performance improvements are possible.



Total Transmission loss for a 68ft diameter at 30.5 GHz as a function of the look angle. This demonstrates the transmission loss uniformity throughout the look angle range.



A collection of AFC's radomes of various sizes installed all over the world

Physical

<i>Membrane</i>	PRETENSIONED POLYESTER LAMINATE
<i>Sandwich Wall</i>	INTERNAL CLOSED CELL FOAM CORE
<i>Exterior Surface</i>	TEDLAR ® OR GELCOAT
<i>Air Pressure</i>	NONE REQUIRED
<i>Maintenance</i>	ROUTINE CLEANING
<i>Design Life</i>	20 YEARS

Radome Sizes

Equatorial Diameter		Base Diameter		Radome Height		Center Height		Number of Panels
meters	feet	meters	feet	meters	feet	meters	feet	
0.9	3.0	0.9	3.0	0.9	2.9	0.4	1.4	1
1.8	6.0	1.8	6.0	2.1	7.0	1.2	3.5	1
2.3	7.5	2.3	7.5	3.0	10.0	1.5	5.0	4
2.6	8.4	2.6	8.4	2.6	8.5	1.3	4.3	4
2.9	9.6	2.9	9.6	2.8	9.2	1.3	4.4	4
3.7	12	2.7	8.9	3.0	10.0	1.2	4.0	6
5.5	18.0	3.9	12.7	4.7	15.4	1.9	6.4	12
6.7	22.0	5.6	18.4	5.2	17.0	1.8	6.2	21
8.0	26.4	6.5	21.4	6.4	21.0	2.4	7.7	55
9.5	31.0	6.6	21.8	7.8	25.7	3.1	10.2	75
10.7 3-Layer Sandwich or Solid Laminate	35 3-Layer Sandwich or Solid Laminate	8.3	27.3	8.7	28.5	3.3	11.0	110
12.6	41.4	8.8	28.7	10.9	35.6	4.5	15.0	160
14.9	48.8	11.4	37.3	12.2	40.2	4.8	15.7	275
17.2	56.3	12.2	39.9	14.6	47.8	12.2	19.8	285
18.6	61.0	14.7	48.2	15.0	49.2	5.7	21.5	285
20.7	68.0	16.2	53.1	16.8	55.2	6.5	21.2	425
24.4	80.0	18.5	60.8	20.1	65.8	7.9	25.9	600
28.3	93.0	19.6	64.1	24.4	80.2	10.3	33.7	840
33.5	110.0	23.0	75.5	28.9	94.8	12.4	39.8	1100