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Blura Radome for Radio Telescope: Design, Material, and Performance

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Abstract

This paper presents the design and material selection of a protective geodesic dome for the 5-meter radio telescope at Princess Nourah bint Abdulrahman University (PNU). A 7-meter geodesic dome with a height-to-diameter ratio (y/d) of 0.5 was chosen for its structural stability, aerodynamic efficiency, and low material requirements. The dome is covered with a thin protective layer of Ethylene Tetrafluoroethylene (ETFE), selected for its excellent radio signal transparency, lightweight properties, cost-effectiveness, and durability in various weather conditions. The primary objective of the dome is to shield the telescope from environmental factors while ensuring minimal signal attenuation, particularly at the hydrogen line frequency of 1420 MHz.

Keywords:
Geodesic dome, radio telescope, Hydrogen Line, Radio Transparency, ETFE, wind tunnel test, pressure coefficient value, height-to-diameter ratio.

Introduction

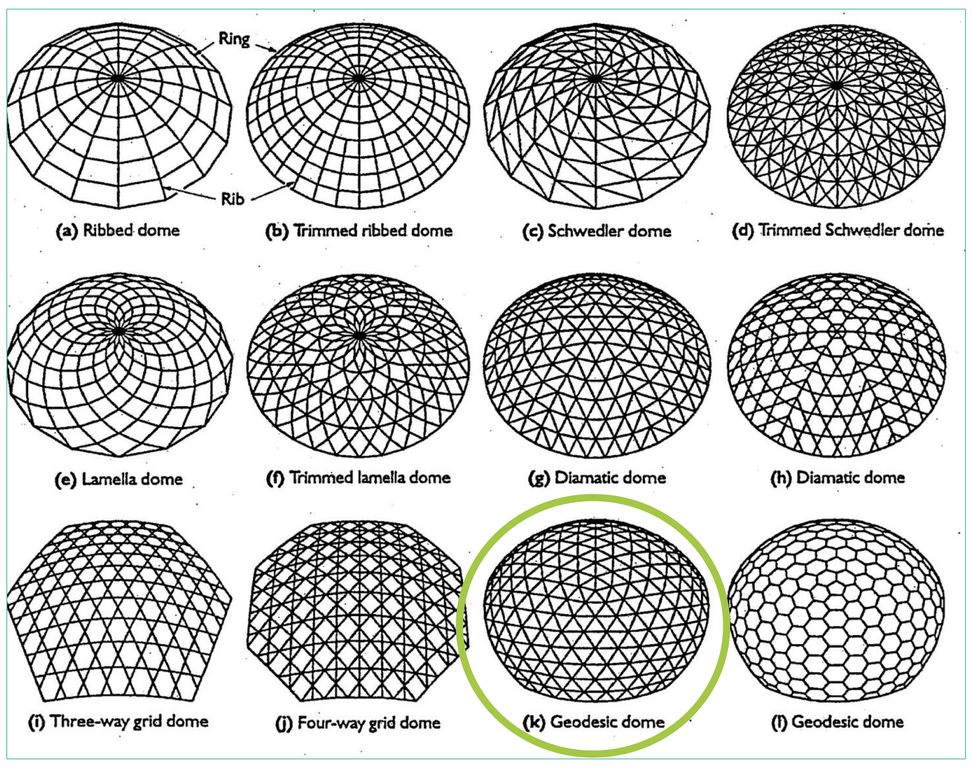
Radio telescopes are very sensitive tools and require protection from atmospheric factors such as rain, wind and fine particles to maintain their performance of the highest quality. Protective domes (a.k.a. Radomes) are used to achieve this goal so that protection is made available for the telescope while reducing the impact on the received electromagnetic signals. The aerobic performance of Radomes is greatly affected by its engineering composition, especially the aspect-to-diameter ratio (y/d). Studies indicate that the ratio of (y/d) is close to 0.5 provides an ideal balance between structural stability and aerodynamic efficiency, which reduces the pressures resulting from the wind and improves performance. In addition, geodesic dome designs are preferred in view of their lightness, the distribution of loads efficiently and their structural strength, which makes them suitable for different weather conditions.

Methodology

The project adopts a quantitative analytical approach, focusing on the radio telescope located at PNU as the study's primary subject. The dimensioning and material selection of the proposed Radome design were optimized to balance aerodynamic stability, structural integrity, and environmental durability, guided by state-of-the-art engineering literature.

Data collection methods included:

- A literature review on engineering studies specializing in dome design.
- Scientific interviews with domain experts—Dr. Walid Al-Rasheed and Dr. Adnan Zaman at KACST—to assess the most suitable materials based on practical performance and cost.
- A comparative analysis of material properties, including ETFE, FEP, PFA, PTFE, and Kapton.
- Development of a physical prototype to embody the proposed design.



Different types of lattice dome

Conclusions

This project presents an integrated design of a protective geodesic dome for the 5-meter radio telescope at Princess Nourah Bint Abdulrahman University. The proposed solution is a 7- meter geodesic Radome with a height-to-diameter ratio of 0.5, offering optimal aerodynamic performance, structural stability, and sustainable material usage. Following a comparative analysis, the ETFE material was chosen for its superior radio transparency, long service life, and strong tolerance to environmental impacts. Beyond offering physical shield to environmental conditions, the project focused on preserving PNU telescope's sensitivity by maximizing signal transparency, specifically at the Hydrogen line of 1420 MHz. This project lays the groundwork for future dome designs supporting astronomical research in challenging climates.

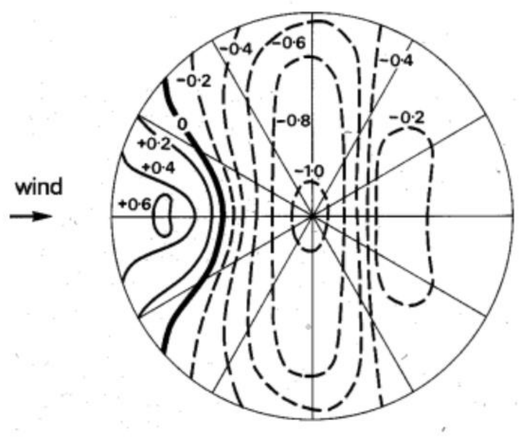
Main Idea

The Blura project aims to design a transparent protective dome for the radio telescope located at PNU. The goal is to shield the telescope from environmental factors such as rain, dust, and moisture, while maintaining the purity and strength of radio signal reception at 1420 MHz (the Hydrogen Line).

The dome structure is based on a geodesic design, which provides excellent wind resistance and structural stability through even load distribution. To optimize aerodynamic performance, The outer membrane will be fabricated from materials such as: ETFE, FEP, or PFA.

A comparative study is conducted to evaluate these materials based on the following criteria: weight, radio transparency, weather resistance, and cost. Blura's core objective is to combine: (1) Physical protection of the telescope, and (2) Maximum signal transparency, avoiding distortion or attenuation of the received electromagnetic waves.

In addition, the dome serves as a protective layer for telescopes with wooden structural components, helping prevent material degradation when exposed to moisture or rain, which leads to problems such as rot and swelling resulting from fungi, thereby extending the operational life of the telescope infrastructure. These domes contribute to maintaining the structural integrity of the telescope and maintain the wooden parts for a longer period.



External pressure coefficient Cp , for y/d=0.5

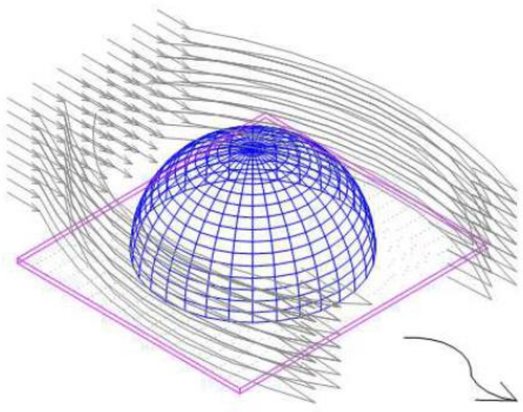


Illustration of wind acting on dome structure

Results

In our project, we compared five materials to determine the best design for a dome that would protect a radio telescope and maintain signal quality. The materials we studied were: ETFE, FEP, PFA, PTFE, and Kapton. We found that the first three (ETFE, FEP, and PFA) exhibit high transparency for radio signals, while PTFE may interfere with signals, and Kapton requires further investigation before being approved. In terms of lifespan, ETFE had the highest lifetime, ranging from 30 to 50 years, while the remaining materials had a lifespan of 20 to 40 years. Regarding resistance to environmental conditions, ETFE demonstrated excellent resistance to ultraviolet radiation and humidity, PFA demonstrated high durability in harsh environments, and Kapton emerged as a suitable choice for extreme conditions. Based on these data, we recommend ETFE because it combines longevity, complete signal transparency, and good resistance, making it the most suitable choice for covering and protecting a radio telescope.

Table - Material Comparison.

Material	Price (USD/m²)	Weight	Radio Transparency	Weather Resistance	Service Life (years)	Max Temp (°C)
ETFE	150–300	Very Light	Fully transparent to radio waves	Excellent – UV & moisture resistant	30–50	200
FEP	120–220	Light	High transparency	Good weather resistance	20–30	205
PFA	200–400	Light	High performance material	Highly durable in harsh conditions	25–40	260
PTFE	100–250	Moderate	Partial – May interfere with signals	Good chemical & corrosion resistance	20–30	260
Kapton	150–300	Light	Unconfirmed – Needs testing	Excellent for extreme environments	20–30	400

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References:

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