For a 3m diameter aperture horn antenna designed for the 1420.4 MHz hydrogen line (21.1 cm wavelength), the "best" dimensions are determined by maximizing gain while maintaining single-mode operation in the waveguide throat.

Optimal Pyramidal Horn Dimensions

A 3m aperture is exceptionally large for a standalone horn, providing high gain and a narrow beamwidth.

- **Aperture Size:** 3000 mm x 3000 mm (for a square aperture) or scaled based on your preferred aspect ratio.
- **Flare Length (Slant Length):** To minimize phase errors at the aperture, the flare length should be at least **3.5 to 5 meters**. A shorter flare will result in significant gain loss and distorted beam patterns.
- **Waveguide Throat (WR-650 Standard):**
  - **Internal Width (a):** 165.1 mm.
  - **Internal Height (b):** 82.55 mm.

Feed Probe Placement (Waveguide)

The waveguide section (the tube behind the flared horn) must be tuned to the guided wavelength (λ_g) at 1420 MHz.

- **Probe Length:** Approximately **52.7 mm** (1/4 of the free-space wavelength).
- **Distance from Backwall: 84–100 mm**. This is typically $1/4$ of the guided wavelength (λ_g) inside the waveguide to ensure constructive interference.
- **Waveguide Total Length:** Minimum **300–350 mm** to allow the signal to stabilize before the probe.

Critical Construction Targets for 2026

- **Surface Accuracy:** For 21.1 cm wavelengths, the surface deviations must be less than **±10 mm** ($\lambda/20$) to maintain peak efficiency.
- **Material:** Conductive materials like copper or aluminum sheet are ideal. If using wire mesh for a 3m structure, the hole size must be smaller than **12 mm** to reflect the signal effectively.
- **Beamwidth:** At 3m diameter, expect a narrow **Half Power Beam Width (FWHM) of ~4° to 5°**, which is highly directional and excellent for mapping specific regions of the Milky Way.