DESIGN AND CONSTRUCTION OF THE COSMIC MICROWAVE RADIOMETER

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HOW CAN I DETECT THE COSMIC MICROWAVE BACKGROUND?

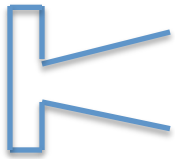
- Difficult to find the important design elements from popular magazines or websites.

- How big of an antenna?
- How good must the receiver be ?
- What frequency?
- What bandwidth?
- How much amplification?
- How do I calibrate the temperature response?

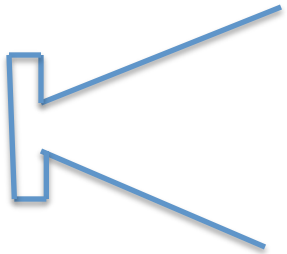
Basically we want to find a device that can detect a microwave noise, which acts as if it was radiated by a 2.7 K black body

HOW BIG SHOULD MY ANTENNA BE ?

Size Does Not Matter !!



A small horn has a large field of view

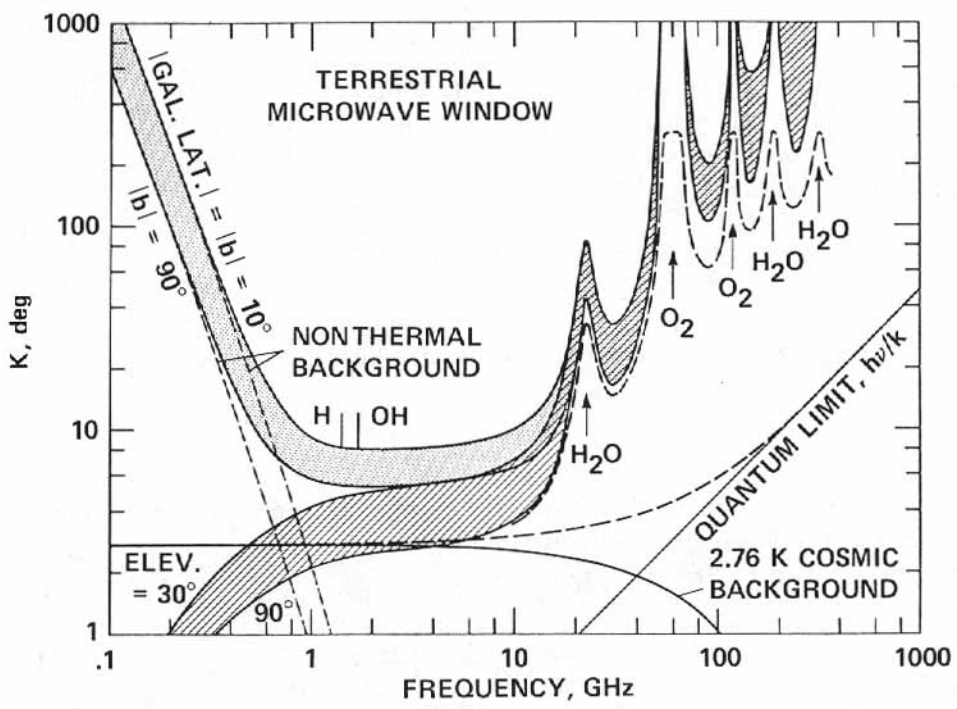


A large horn has a small field of view

These two factors exactly cancel by the second law of thermodynamics.

Discussed in Hannany et al., CMB Telescopes and Optical Systems, Pg 9 (2012) in Bibliography

LIMITS OF DETECTION OF THE CMB AT SEA LEVEL

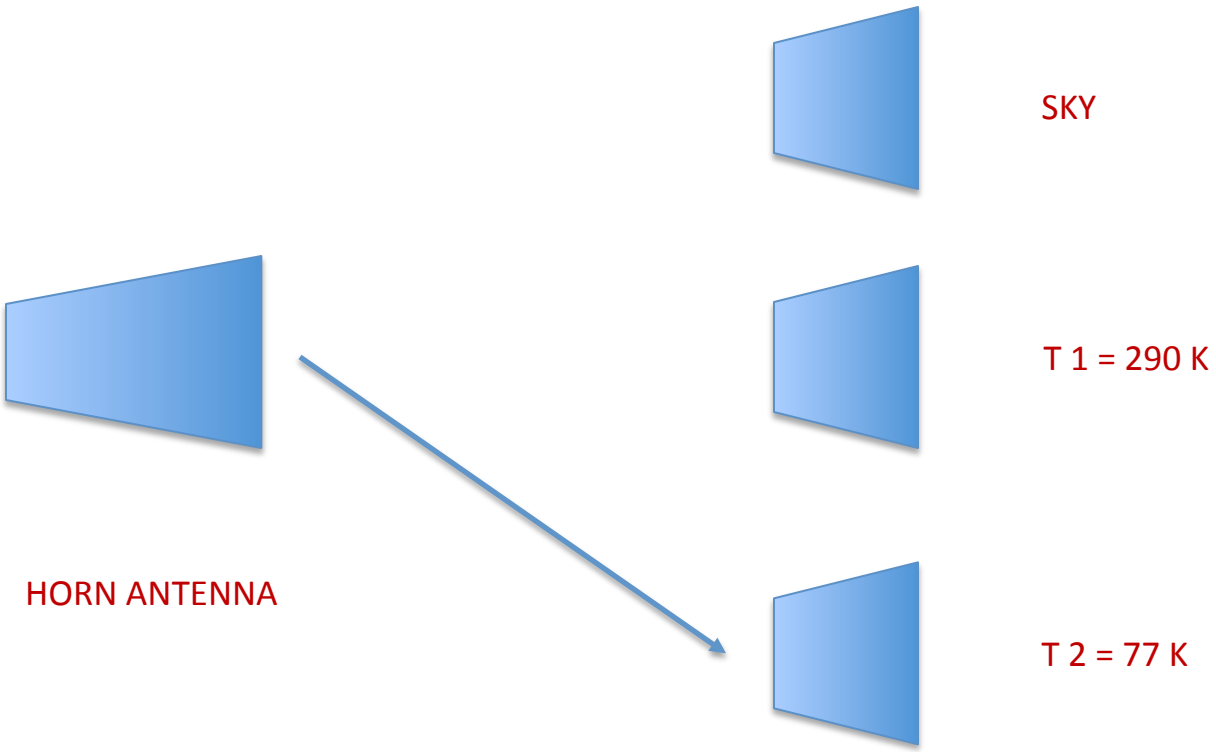


Detection is limited at low frequencies by galactic noise. Above 20 GHz, background noise from water and oxygen emission in the atmosphere limits detection. A frequency of 10 GHz has a clear window and is compatible with inexpensive electronics.

MICROWAVE RADIOMETER

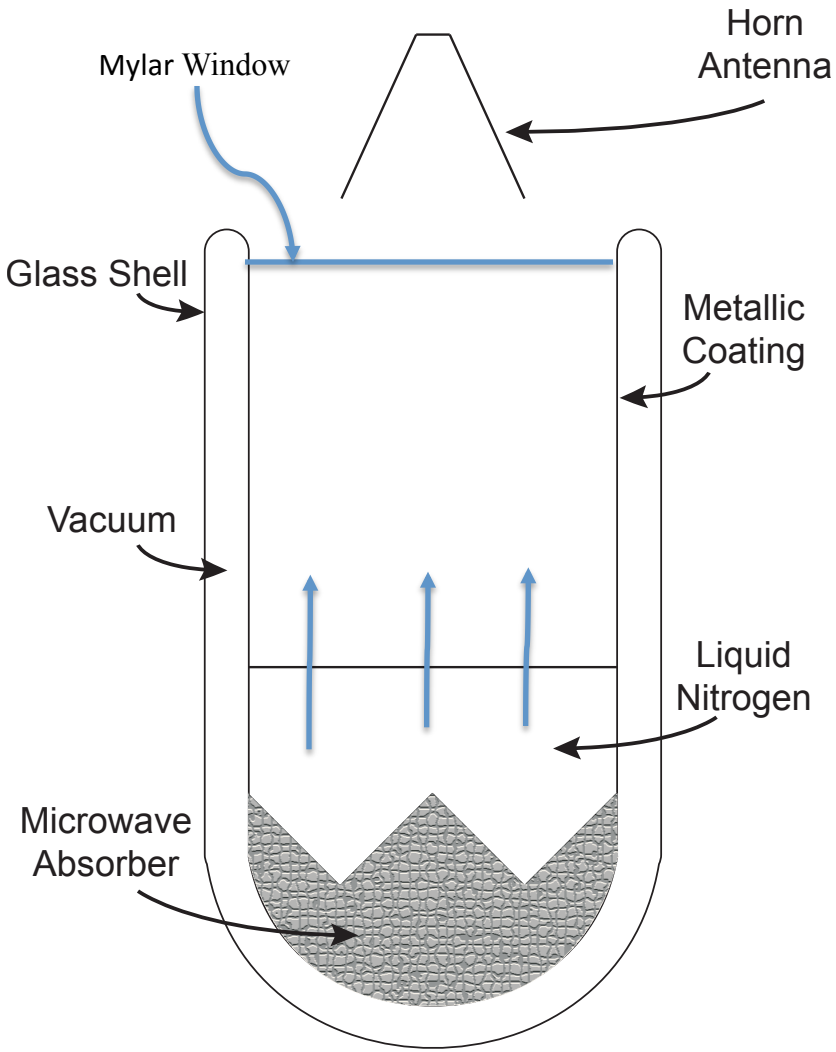
Measures microwave noise power

- Noise radiated is linearly proportional to temperature of source
- Uses calibration loads
  - Two temperatures plus signal



A SIMPLE MICROWAVE RADIOMETER FOR DETECTING THE COSMIC MICROWAVE BACKGROUND

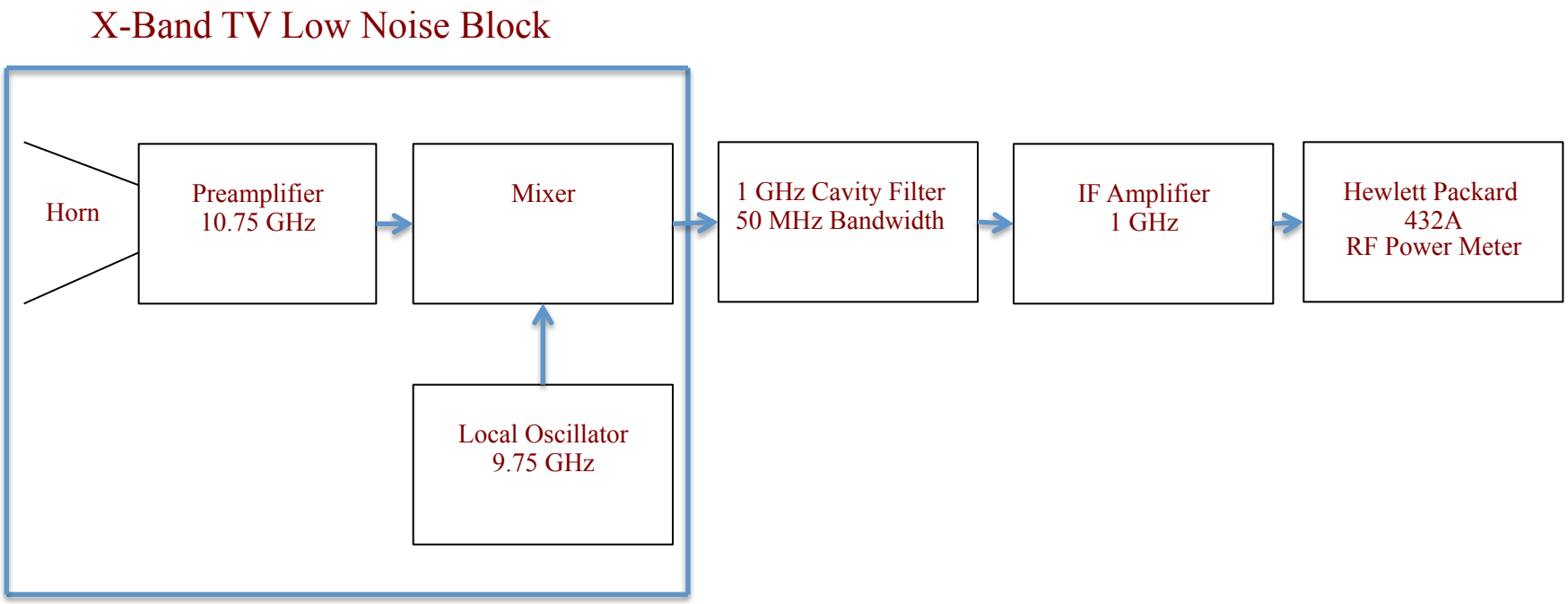
LIQUID NITROGEN TEMPERATURE CALIBRATION



- Dewar Flask
- Acts as a waveguide
- Boiling liquid nitrogen @ 77 K
- Microwave absorber acts as 77K black body
- This calibration source called cold load

This design was described an article by Bensadoun et al. (1992) in Bibliography

MICROWAVE RADIOMETER RECEIVER



This receiver is built with parts purchased on ebay. It is a heterodyne receiver with tuned to 10.75 GHz by the choice of the 1 GHz IF filter and amplifier. There are numerous other configurations that could be used, such as a commercial 1 GHz receiver. Also, the IF section could be replaced by a software defined receiver with a a software sound power detector.

The most important performance criterion for the detector system is linearity. As described in the data analysis section, the radiometer works on the linear extrapolation of the temperature calibration response.

ANTENNA-PREAMPLIFIER-CONVERTER

- Avenger low noise satellite TV antenna/ preamplifier/ converter
- Microwave horn antenna
- 75 degree field-of-view
- 10.7 – 11.7 frequency range
- Converted to 950-1950 MHz range
- Feeds into 1 GHz filter and IF amplifier
- ~ 85K system temp
- $ 11.99 on eBay !!

Microwave Radiometer in Room Temperature (296 K) Reference Position

Antenna pointed into ambient temperature box with microwave absorber material inside.

LN2 77 K Reference Position

Antenna pointed at the Dewar
Flask filled with liquid nitrogen.
Microwave absorber
material in the bottom

Sky Temperature Position

Microwave antenna now pointed at the sky.