Hardware and software development for cryogenic detector measurement

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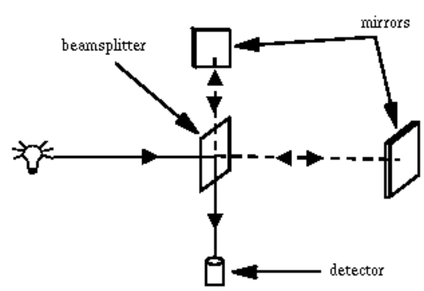
ABSTRACT

For many years, a goal in detector development has been the realization of both high energy resolution and high efficiency within the same detector. It has become apparent that to achieve this aim it will be necessary to operate the detector at very low temperatures, as close to 0° K as possible. Cryogenics is the study of the production of very low temperatures. It involves how to produce them, and how materials behave at those temperatures. Cryogenic particle detectors are radiation sensors that operate at very low temperature, typically only a few degrees above absolute zero. The most commonly cited reason for operating any sensor at low temperature is the reduction in thermal noise.

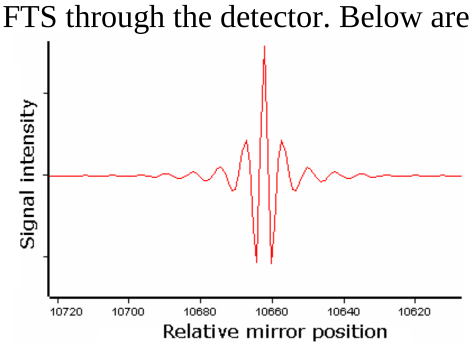
In this paper, cryogenic detectors and cooling technologies are presented. The improved performance of cryogenic devices, such as sensors and cold electronics, has opened new science applications. One of the main aims is to develop future refrigerators for the utilization of cryogenic detectors in space.

SUMMARY AND RESULTS

FTS stands for Fourier Transform Spectrometer. It is used to study the light spectrum. Below is a diagram showing how it works.

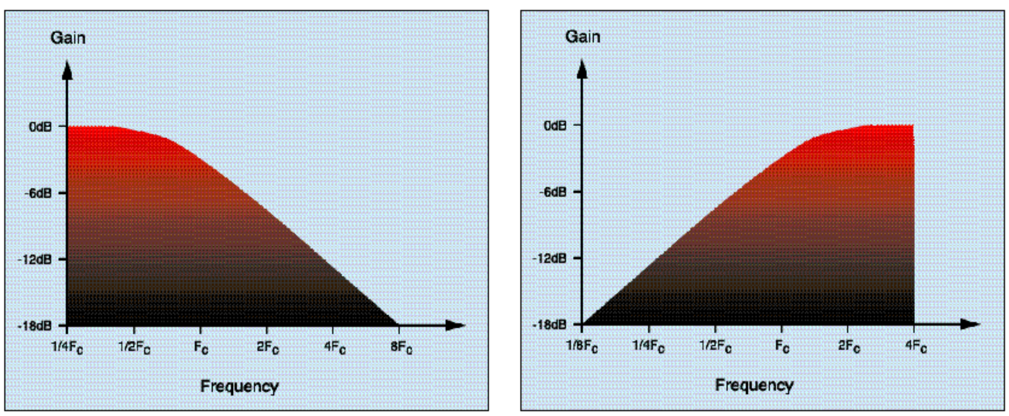


A beam of light will travel through the FTS and hit a beamsplitter that sits at a 45 degree angle. The beam of light is split into two beams, each hitting a mirror. The mirrors make a 90 degree angle, one mirror is fixed and one is mobile. The two mirrors will reflect the beams of light back to the beamsplitter where they interfere and leave the FTS through the detector. Below are the results.

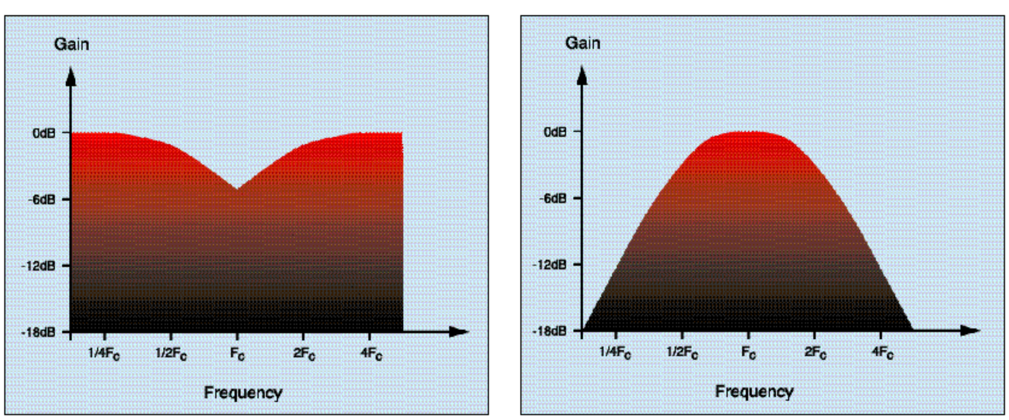


The peak at the center is the ZPD position ("Zero Path Difference"). Here, all the light passes through the interferometer because its two arms have equal length. As the two beams cancel each other out, the signal becomes a straight line.

Next, low pass, high pass, and band pass filters were studied and the frequency of each filter was measured using the network analyzer. A low-pass filter is a filter that passes low frequency. Figure 1(a) below shows the results of a low pass filter. Most low pass filters have a cut-off point of about 2 GHz. These particular filters allow all signals below 2 GHz to pass through. Any signal above 2 GHz is blocked from the filter. A high-pass filter's task is just the opposite of a low-pass filter: to offer easy passage of a high-frequency signal and difficult passage to a low-frequency signal as shown in Figure 1(b).   Most of the filters used had a cut off frequency of about 40 GHz. This means the filter pass signals only if the frequency is 40 GHz or above. If any frequencies below 40 GHz entered the filter, the signal would be blocked. There are applications where a particular band, or spread, or range of frequencies need to be filtered from a wider range of mixed signals. Filter circuits can be designed to accomplish this task by combining the properties of low-pass and high-pass into a single filter. The result is called a band-pass filter as shown in Figure 1 (d). Band pass filters pass signals within a range of frequencies. The band pass filters have a high and a low cut-off point. Most of the filters that were measured had a frequency range from 3.1 to 3.9 MHz. All signals with frequencies below 3.1 and above 3.9 are blocked from the filter.

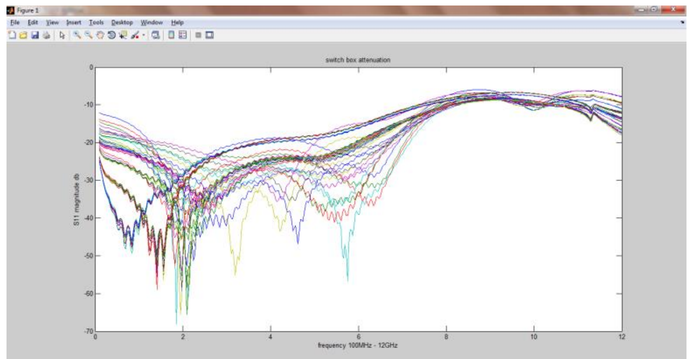


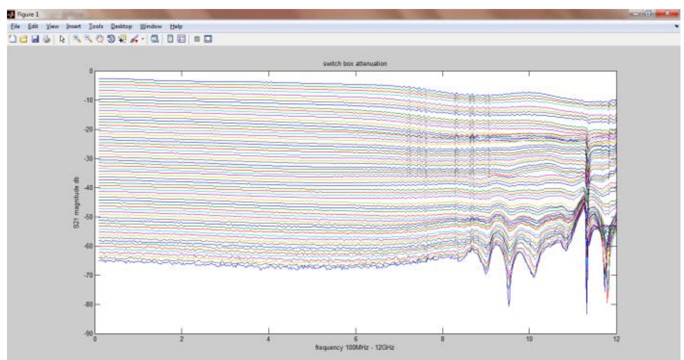
Figures 1(a) and 1(b): 6dB/octave (one-pole) low-pass and high pass filters.

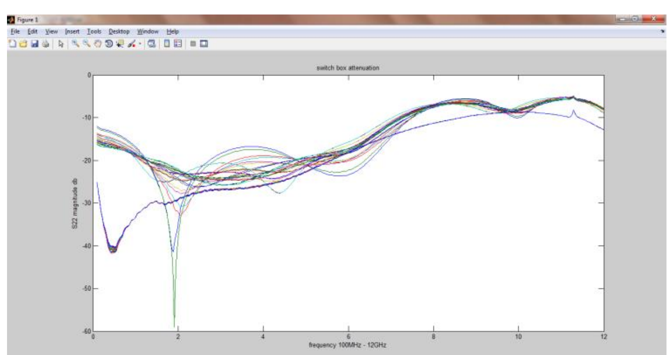


Figures 1(c) and 1(d): Band-reject and band-pass filters.

The third and final way to detect sound is with an attenuator and a control mechanism. A control box for a programmable attenuator was built. An attenuator is an electronic device that reduces the amplitude or power of a signal without appreciably distorting its waveform. An attenuator is effectively the opposite of an amplifier, though the two work by different methods. While an amplifier provides gain, an attenuator provides loss (gain less than 1). The box was designed for the attenuator has six switches and six LEDs. Each switch represents a power of two and the binary range is from 0 to 63 dB, in addition, there is a main switch that controls all of the other switches. Each switch is connected to an LED and to each pin of the attenuator. The box is then connected to a power supply measuring 5 volts. The attenuator is connected to the box and to the network analyzer. From the network analyzer, one can measure loss of the attenuator. The programmable attenuator has an attenuation level of 3.5 dB. After the other switches were turned on, the attenuation levels began to change. Below are the graphs for each s-parameter.







CONCLUSION

In conclusion, cryogenic detectors and cooling technologies have made a remarkable amount of progress over the last 20 years. The increased reliability and simplicity of operations of cryogenic equipment have allowed operation on spacecrafts, while the improved performance of cryogenic devices, such as sensors and cold electronics, has opened new science applications. One of the main aims is to develop future refrigerators for the utilization of cryogenic detectors in space.