[illegible]

[illegible]

[illegible] extremely sensitive receive systems to communicate with deep space probes and to perform radio science experiments. They incorporate sensitive high-electron mobility transistors(HEMT) or masers with very low noise temperatures as their front-end amplifiers. Radio frequency interference(RFI) can significantly degrade the performance of these receive systems. Out-of-band RFI can result in gain compression, noise temperature increases, and in the case of masers, spurious output signals.

Low loss bandpass filters fabricated from high temperature superconducting(HTS) materials can provide RFI protection for these amplifiers. The low loss that these filters exhibit allow them to provide protection without significantly degrading the noise temperature or microwave performance(return loss, group delay variation, etc.) of the receive system.

Superconducting Technologies Incorporated in Santa Barbara, California, designed and fabricated a 2.3 GHz(S-band) and a 8.45 GHz(X-band) bandpass filter for JPL. Both prototype filters incorporate a five-resonator, stripline structure with Tl-Ca-Ba-Cu-O thin film resonators. They were designed to have a bandwidth of 60 MHz and 150 MHz, respectively, with a desired insertion loss of less than 0.5 dB.

The filters were characterized by JPL at 12 Kelvin in a closed cycle refrigerator. The lowest insertion loss measured was 0.21 dB (including connector losses) with a return loss of greater than 15 dB. The insertion loss appears to be dominated by extrinsic factors such as joint losses and impedance matching, and not by the superconducting material losses.

Introduction

The Jet Propulsion Laboratory(JPL) uses extremely sensitive receive systems to communicate with deep space probes and to perform radio science experiments. Radio frequency interference(RFI) can significantly degrade the receive system performance. Low loss bandpass filters fabricated from High Temperature Superconducting(HTS) materials will provide out of band RFI protection for HEMT low noise receivers without degrading their noise and microwave' performance. The objective of this work is to demonstrate HTS RFI filters for cryogenic: HEMT LNAs at 2.3 and 8.45 GHz.

Insertion Loss Measurements

An automatic microwave network analyzer test set was used to measure the insertion and return loss of the filters((see figure 1). To measure the losses at 12 K the filters and the necessary microwave circuits were cooled in a two stage closed cycle refrigerator (CCR).

Two **low loss** “/mm coaxial transmission lines with APC7 with end on SIS [illegible] input [illegible] [illegible] 03 [illegible] line [illegible] the frequency [illegible] input [illegible]

[illegible] Measurements

[illegible] Y, [illegible] amplifier [illegible] were [illegible] temperature [illegible] used [illegible] ohm [illegible]

The noise sources are amplified by a HEMT amplifier, down converted and detected by a power meter (see figure 3). The ratio of measured noise powers are then substituted into the following expression to obtain the receiver noise temperature (T_r):

$$T_r = T_h + T_f \, (T_{am} \, [illegible]) / (Y - 1) \qquad (3)$$

where T_h = noise temperature of the amplifier, T_f = noise temperature of the down converter, T_{am} = temperature of the ambient load, and Y = ratio of the system noise power with hot load to the noise power with cold load.

The [illegible] between [illegible] and the noise [illegible] frequencies [illegible]

[illegible] and loss [illegible]

[illegible]

[illegible] filter [illegible]

[illegible] (dB) [illegible] (MHz)

[illegible] bandwidth, [illegible] and

[illegible] given by [illegible] and ripple [illegible]

The filters were designed to have a bandwidth of 60 MHz at S-band and 150 MHz at X-band with an inband ripple of less than 0.05 dB for both. Using an optimistic estimate of the unloaded Q (~10,000) the midband insertion loss at 2.3 GHz is expected to be 0.17 dB, and 0.24 dB at 8.45 GHz. However, the measured insertion loss is expected to be higher because the filters use normal metal SMA connectors which can contribute up to 0.2 dB of additional loss.

At 12 K the S-band filter exhibited a bandwidth of 75 with a passband peak-to-peak ripple of 0.874 dB. The maximum insertion loss of -1.07 dB corresponded exactly with the poorest return [illegible] dB. See [illegible] for and return loss results. However, at frequencies where the filter was well matched, the insertion loss was approximately 0.30 dB.

This being a prototype filter their were problems that occurred that caused the poor match near the center frequency. They arose because of stresses that damaged the substrate during its manufacturing. Those problems were solved for the X-band amplifier which is reasonably matched across the band.

The X-band filter exhibited a passband peak to peak ripple of 0.31 dB with a maximum insertion loss of -0.658 dB and a band width of 360 MHz. Figure 5 shows a plot of the insertion and return loss results for this filter.

Taking into account the losses contributed by the connectors the filter losses agree reasonably well with the measured results.

The filters' insertion loss as a function of temperature responses exhibited very similar responses. There was very little change in the insertion loss below 50 K while very dramatic changes were observed from 100-115 K > 50 K.

Noise Temperature Contribution

For an extremely low loss and reasonably matched filter the

... approximately by the following ... on:

(...) / (...) (2)

... by ... freq ... the ... in

... the ... amplifier, an ... ion

... ficie...

Thus ... 0.2 ... 1 ... dB

... 20 K ... temperature ... contribution ...

... and 7 show ...

contributions of ... 3 and 8.4 GHz ... X ... and ...

... and X ... and ... respectively ... frequencies ...

... will ... (0 ...)

... com... lowest

...

... has been ... the ...

... potential benefit to provide ... and ...

... ver ... would

... the receiver reliability ... by degrading

... receive performance

The ... of the ...

... HEMT ... in ... hybrid ...

[illegible] the [illegible] come to [illegible].

[illegible] applications of [illegible] filters are the High Resolution Microwave Survey (HRMS) formerly Search for Extra-terrestrial Intelligence [illegible] all sky mapping at microwave frequencies from 1 to 10 GHz using JPL's low noise receivers [illegible] bandpass filters [illegible] will allow significant [illegible] from the unwanted terrestrial RFI.

References

1. [illegible] Otoshi, "The Effect of Mismatched Components on Microwave Noise Temperature Calibrations," IEEE Trans. on Microwave Theory and Techniques, Vol. MTT-16, No. 9, [illegible] 686, Sept. [illegible] 68.

2. J.J. Bautista and S.M. Petty, "Superconducting [illegible] and [illegible] Bandpass Filters", IEEE Trans. on Magnetics, Vol. Mag-21, NO.2, [illegible]