Performance evaluation of two RF power limiters based on PIN diodes

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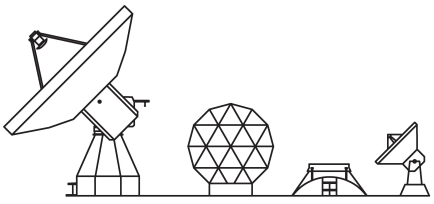

1 Introduction

In this report two Herotek's PIN diode limiters, model LS2018 (serial numbers 594619 and 594620), were tested in order to evaluate their performance as RF power limiters, because they are planned to be installed in the 13.2-m Yebes VGOS receiver to limit the input power to the RF over fiber transmission system, which can be very high in the presence of RFI signals and may damage this equipment.

The frequency range of these limiters span from 2-18 GHz.

Firstly, the measurement setup will be described together with the instrumentation required for this purpose.

Finally, several measurements will show the performance of these devices in terms of output power versus input power. In addition, other parameters given in the data-sheet, like maximum insertion losses, input and output matching will be tested in order to evaluate the performance of these devices. The last measurement will show how fast the devices are when limiting the input power (rise time).

2 Measurement setup

Three different measurements were carried out on the 13^{th} of December, 2017. The instrumentation used consists of the following elements:

- 3 Hz - 50 GHz PXA signal analyzer from Keysight, model N9030A.
- 250 kHz - 67 GHz PSG signal generator form Agilent Technologies, model E8257D.
- Low loss SMA coaxial cable.
- Two pin diode limiters from Herotek, model LS2018 (see Apendix A for details).
- SMA adapter.
- 10 MHz - 67 GHz PNA network analyzer from Keysight, model N5277A.
- Digital oscilloscope from Tektronix, model TDS 3052B.
- Power meter from Rohde & Schwarz.

PIN diode limiters are shown in Figure 1.

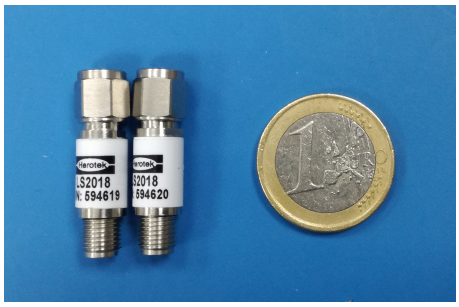

Figure 1: The two Heterotek's PIN diode limiter, model LS2018 (serial numbers 594619 and 594620).

The first measurement procedure is shown in Figure 2 where the PIN diode input is connected at the output of the generator and its output connected to the spectrum analyzer by means of one coaxial cable.

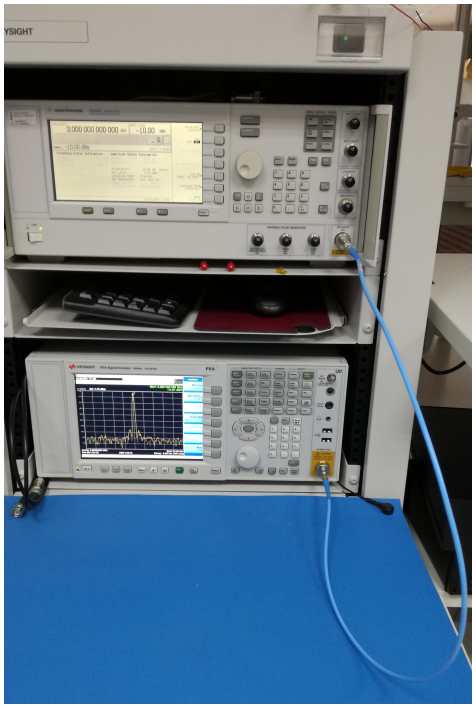

Figure 2: First measurement setup.

The purpose of this measurement is to verify the proper operation of the PIN diode along its frequency range. For that, a CW signal was generated at

different frequencies (1-18 GHz, 1GHz step) and at different power levels (-30 to +16 dBm) and it is compared with the level received at the signal analyzer.

The second measurement procedure is shown in Figure 3 where the PIN diode is connected at the two ports of the network analyzer, previously calibrated up to 40 GHz and -20 dBm output power for each port.

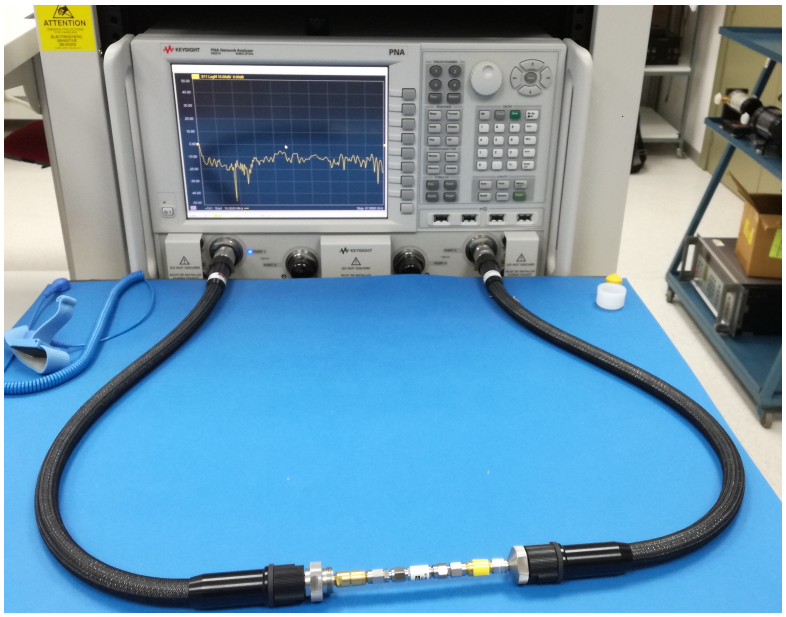

Figure 3: Second measurement setup.

The purpose of this measurement is to verify that input and output matching are suitable.

In the last measurement procedure, the PIN diode is connected at the output of the signal generator and its output carried to the power meter. The DC output of the power meter, proportional to the input power, is sent to the oscilloscope.

The purpose of this measurement is to check the rise time the PIN diode limiters when RF input power is toggled from -20 dBm to +10 dBm.

All these processes were carried out in the same way for both limiters.

3 Measurement results

In this section the results from these measurements are shown.

Figures 4 to 21 show the operation curve of the PIN diode limiters from 1 to 18 GHz at 1 GHz steps. The graphs are in terms of output power (dBm) versus input power (dBm). The coaxial cable and adapters losses have been

taken into account, so they have been removed from the measurements. The red color corresponds to PIN diode serial number 594619 and the blue one to serial number 594620.

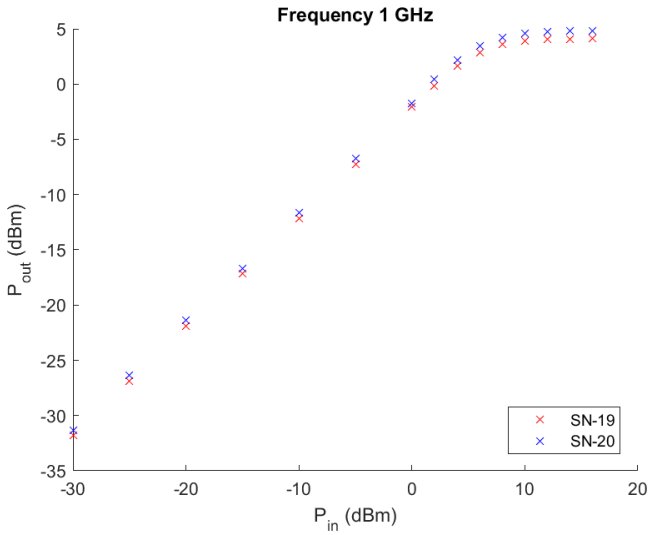

Figure 4: Performance at 1 GHz frequency.

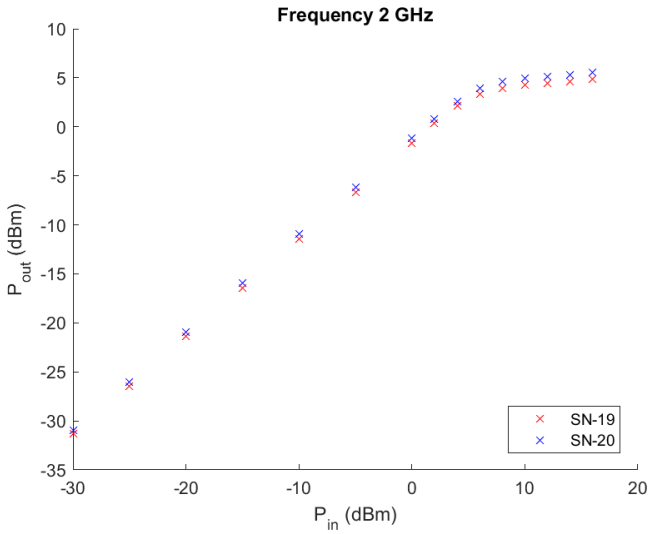

Figure 5: Performance at 2 GHz frequency.

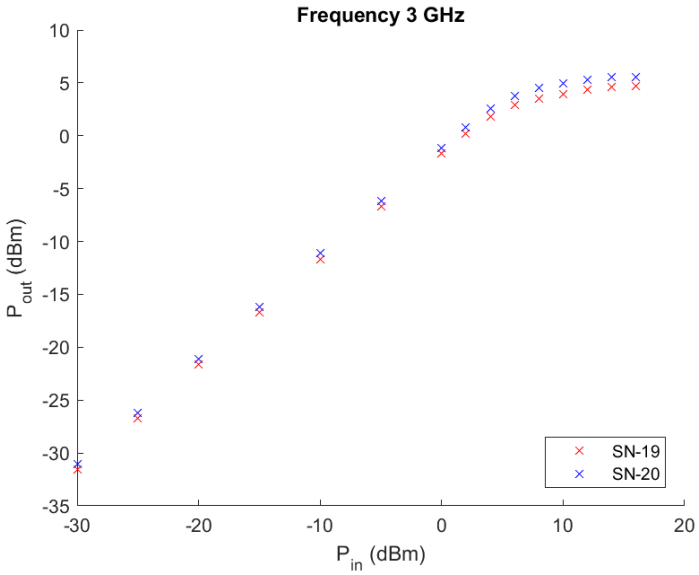

Figure 6: Performance at 3 GHz frequency.

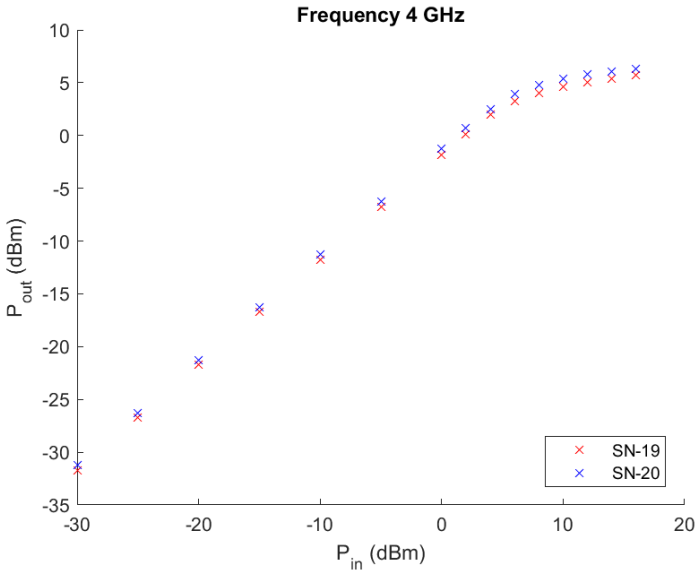

Figure 7: Performance at 4 GHz frequency.

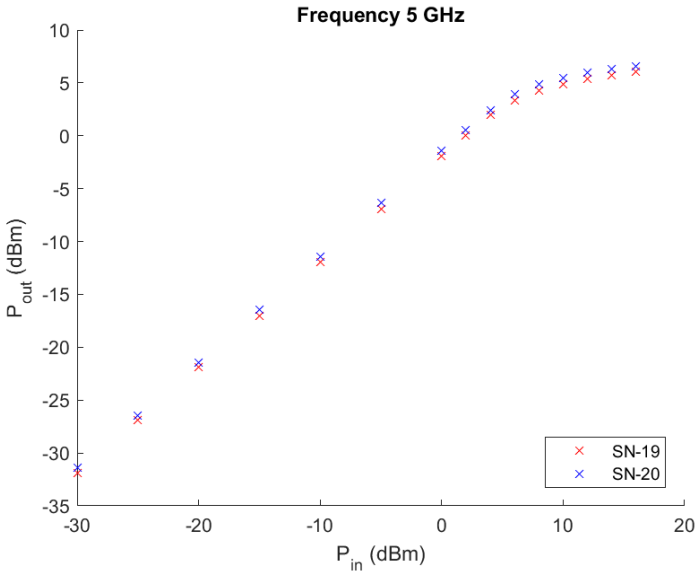

Figure 8: Performance at 5 GHz frequency.

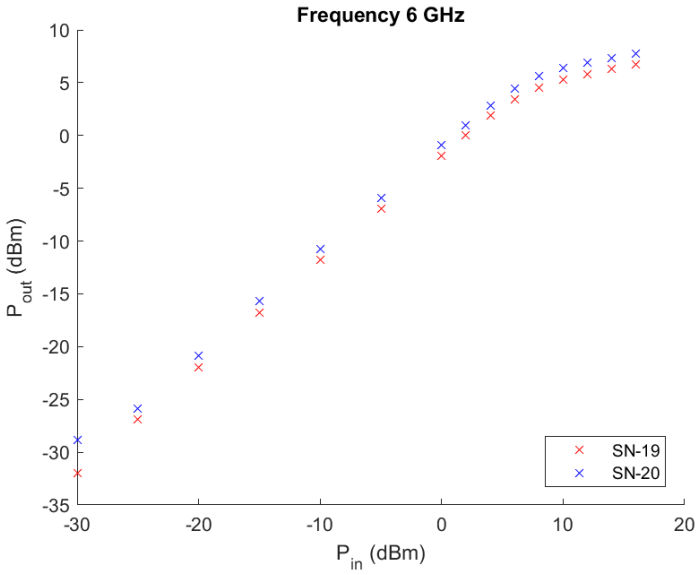

Figure 9: Performance at 6 GHz frequency.

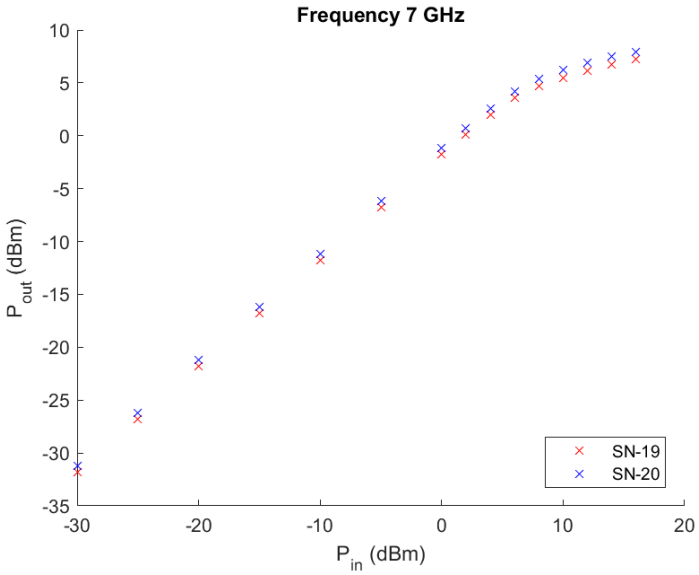

Figure 10: Performance at 7 GHz frequency.

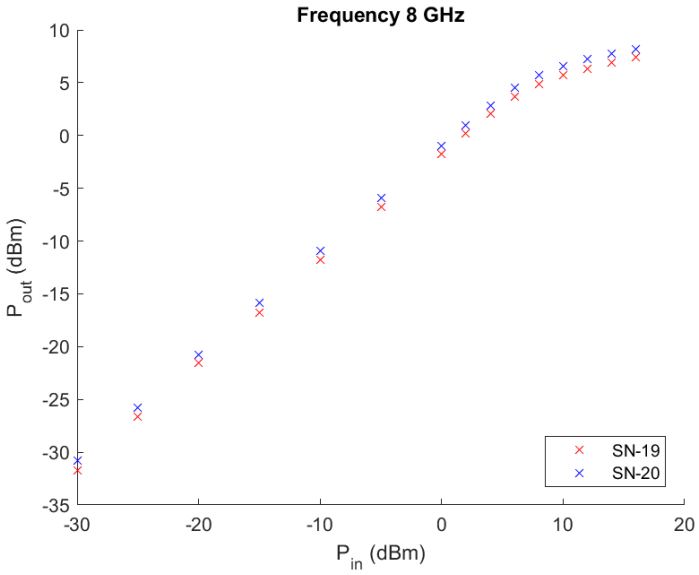

Figure 11: Performance at 8 GHz frequency.

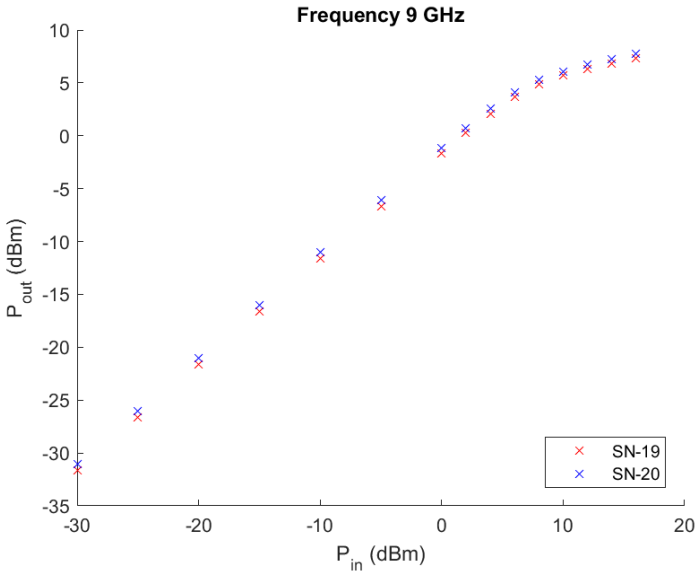

Figure 12: Performance at 9 GHz frequency.

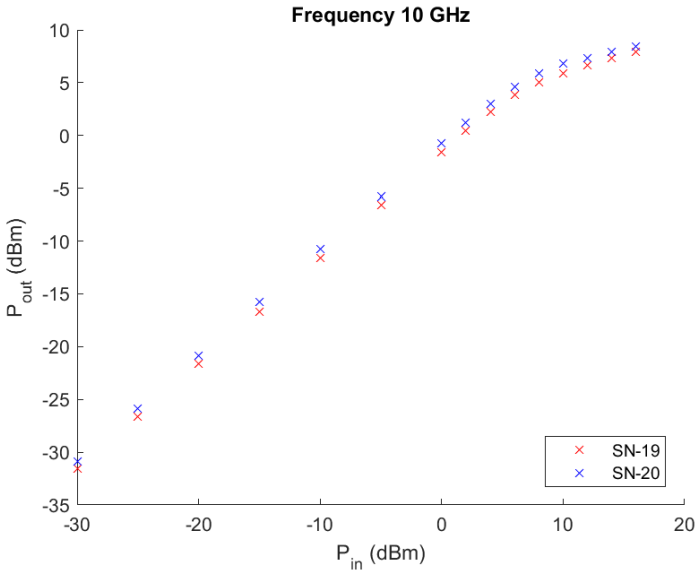

Figure 13: Performance at 10 GHz frequency.

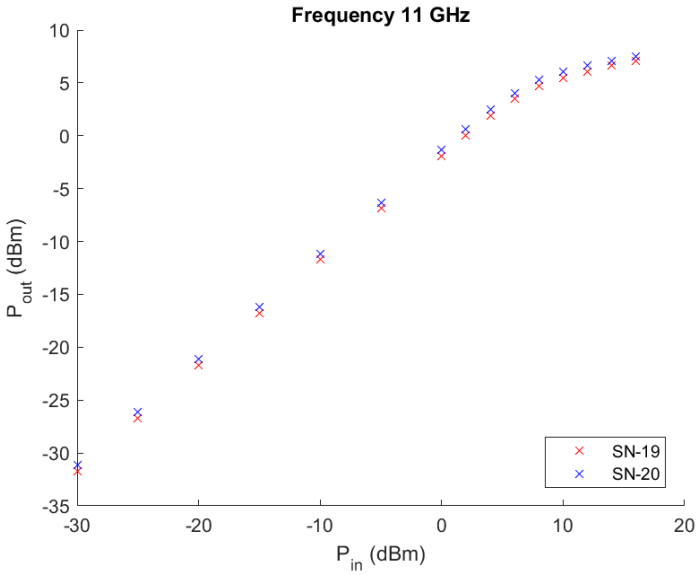

Figure 14: Performance at 11 GHz frequency.

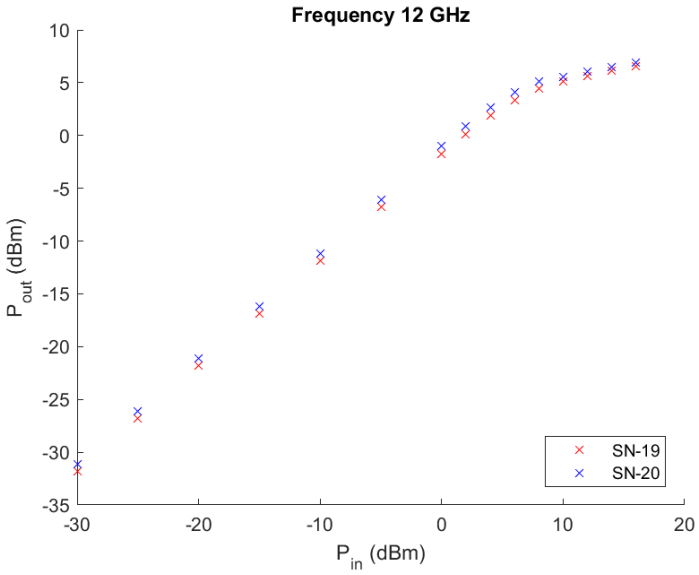

Figure 15: Performance at 12 GHz frequency.

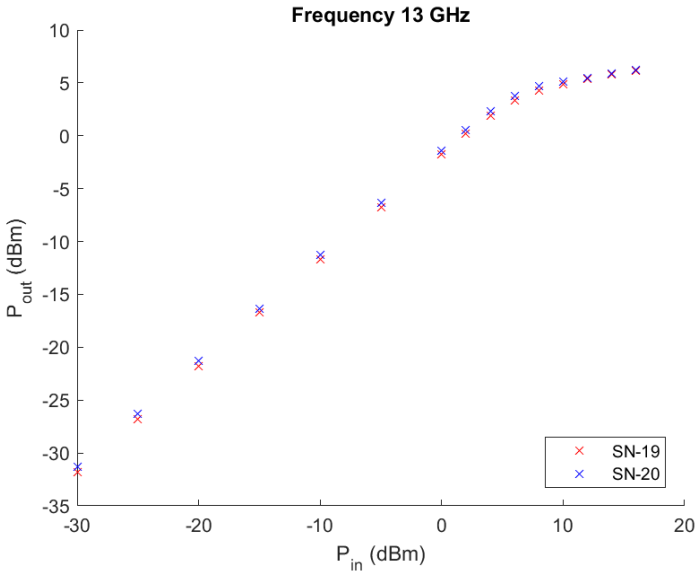

Figure 16: Performance at 13 GHz frequency.

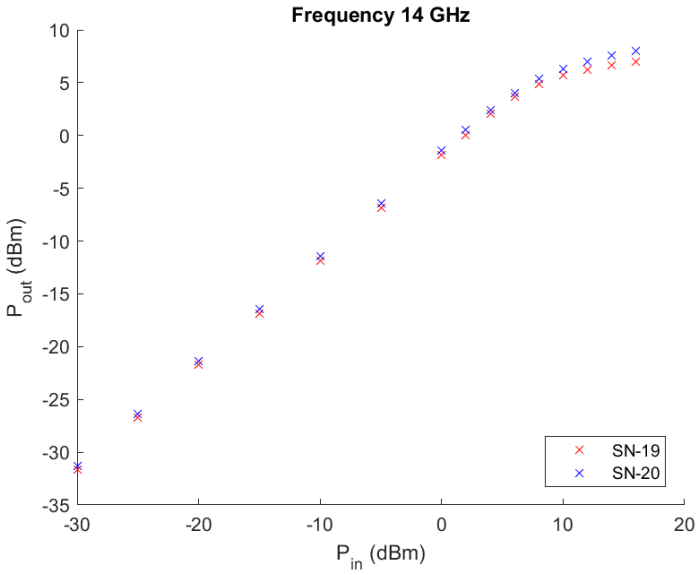

Figure 17: Performance at 14 GHz frequency.

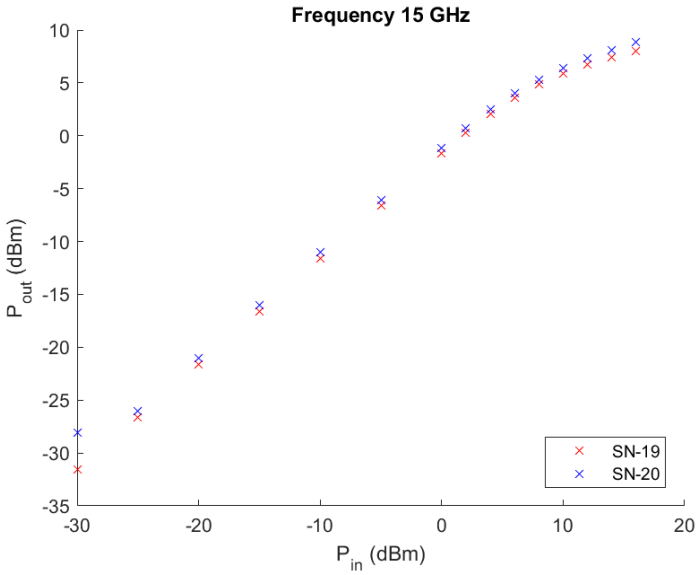

Figure 18: Performance at 15 GHz frequency.

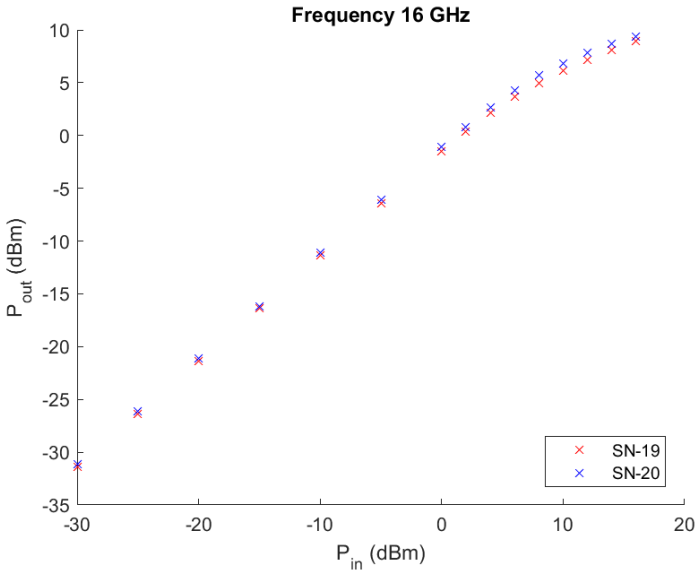

Figure 19: Performance at 16 GHz frequency.

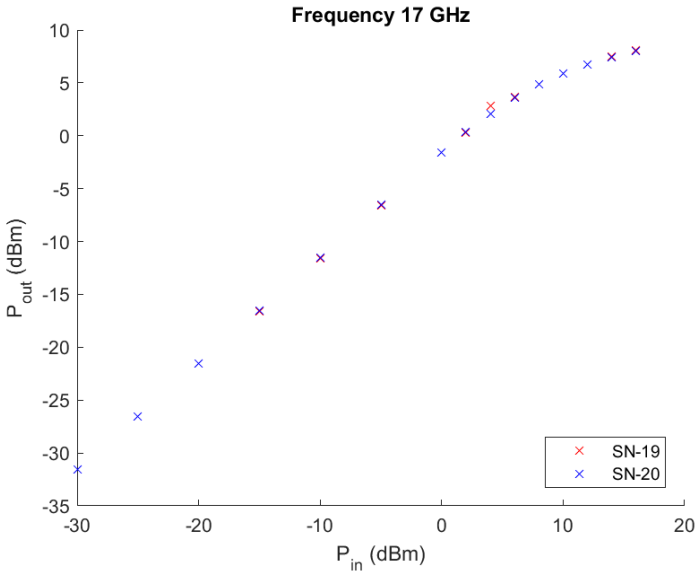

Figure 20: Performance at 17 GHz frequency.

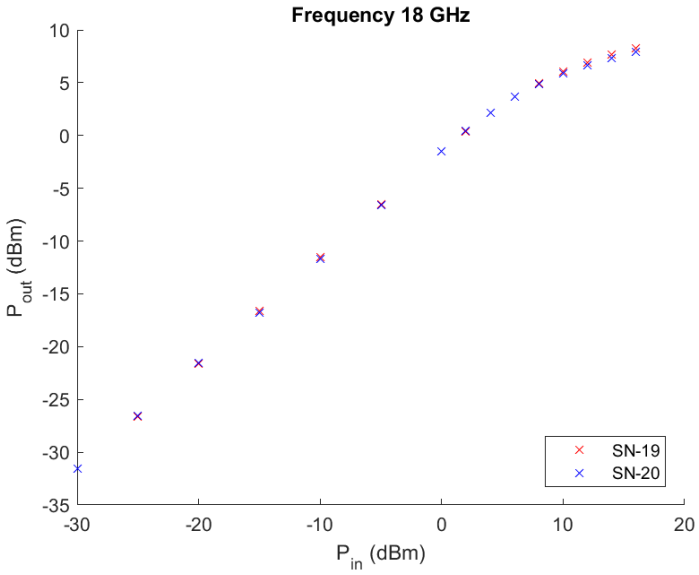

Figure 21: Performance at 18 GHz frequency.

Table 1 shows PIN diode limiters' insertion losses in lineal range (up to +6 dBm). Considering this threshold value according with the previous results.

Freq. (GHz)	**Insertion losses in lineal range (dB)**	
	SN594619	**SN594620**
1	2.08	1.59
2	1.54	1.08
3	1.73	1.19
4	1.80	1.30
5	1.94	1.45
6	1.94	0.68
7	1.84	1.24
8	1.76	0.91
9	1.69	1.14
10	1.61	0.82
11	1.83	1.26
12	1.83	1.16
13	1.81	1.40
14	1.81	1.43
15	1.66	0.82
16	1.50	1.15
17	1.56	1.59
18	1.61	1.63
Mean	1.75	1.21
Std	0.15	0.28

Table 1: Insertion losses from PIN diode limiters (SN 594619 and SN 594620) in lineal and regime at different frequencies.

Losses in the lineal regime are below the value given in the data-sheet, which is 2 dB maximum. At 1GHz this value is higher for one of them (sn. 594620), but it has to be considered that the devices are specified from 2 - 18 GHz only.

Another way to evaluate this power limitation process is through the best-fitting of the linear range to a straight line and finding the input power for which the output power departs by 1 dB from the linear performance (ΔP in Table 2). An example is shown in Figure 22 at 3 GHz for PIN diode SN 594619.

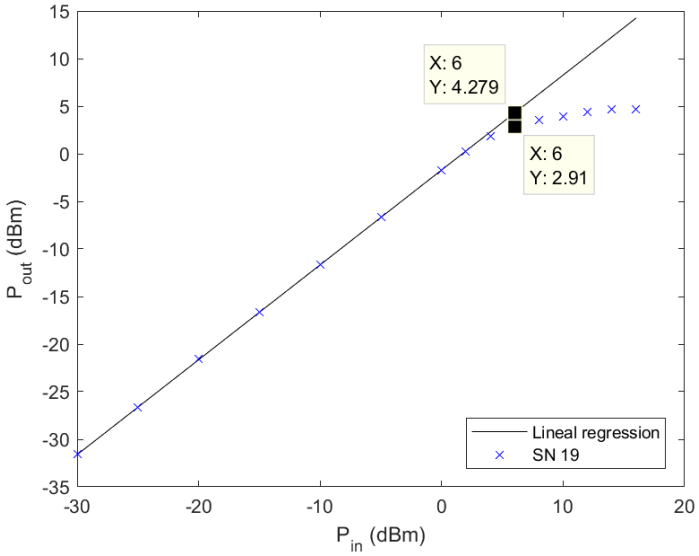

Figure 22: Performance at 3 GHz frequency with linear for PIN diode SN 594619.

		SN 594619		SN 594620	
		P_{in}^{1dB} (dBm)	ΔP (dBm)	P_{in}^{1dB} (dBm)	ΔP (dB)
Frequency (GHz)	1	8	2.08	8	1.88
	2	8	2.34	8	2.21
	3	6	1.37	6	1.04
	4	8	2.11	8	1.96
	5	8	1.75	8	1.74
	6	8	1.60	10	1.86
	7	8	1.49	8	1.39
	8	8	1.27	8	1.27
	9	8	1.47	8	1.59
	10	8	1.37	8	1.46
	11	8	1.41	8	1.40
	12	8	1.78	8	1.80
	13	8	2.04	8	1.93
	14	8	1.17	8	1.18
	15	8	1.47	10	1.31
	16	8	1.50	8	1.23
	17	8	1.53	8	1.59
	18	8	1.52	8	1.53

Table 2: Power limitation threshold (P_{in}^{1dB}) where PIN diode limiters begin to limit the input power, and difference between limited power and non limited power from straight line (ΔP) for PIN diode SN 594619 and SN 594620.

Input and output matching has been measured using the vector network analyzer. This is shown by terms of S-parameters in Figure 23. Figure 24 compares both PIN diode limiters.

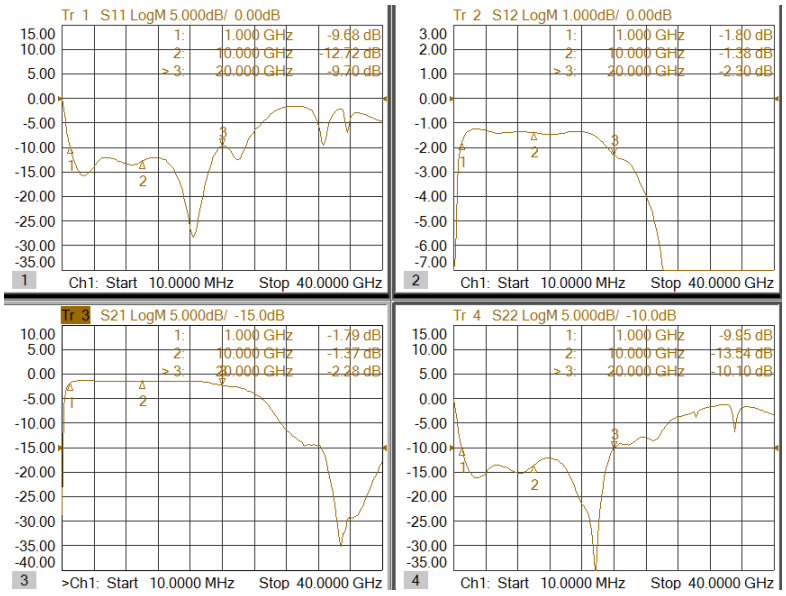

Figure 23: S parameters of the PIN diode SN 594619.

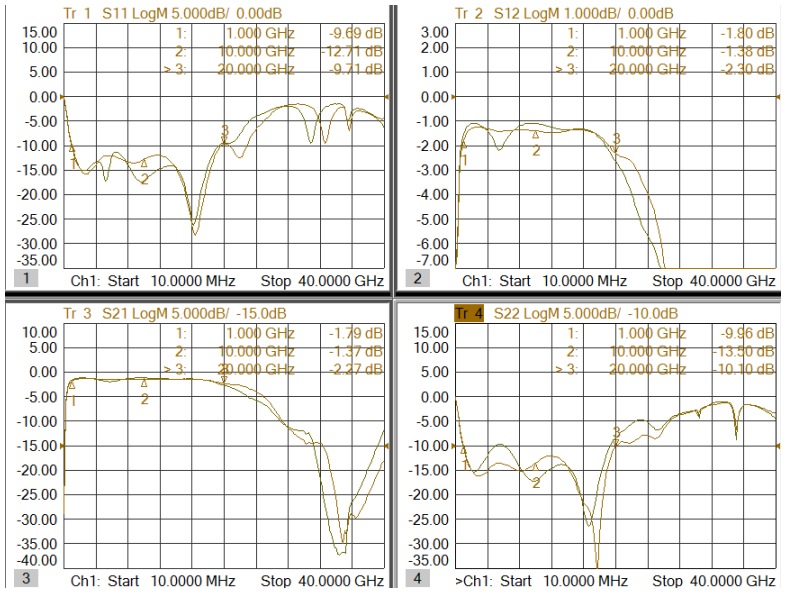

Figure 24: S parameters of the PIN diode SN 594619 (red) and SN 594620 (yellow).

The maximum VSWR given in the data-sheet is 2:1, which translated to return losses is 9.54 dB. As we can see in Figure 24, measured values for all frequency range are better than this value.

Another parameter which has been measured is the rise time that PIN diode needs to limit the output power when the input power toggles from the linear to the saturation range. For that, the RF signal generator, the power detector and the oscilloscope were needed.

A threshold value is set in the oscilloscope to get an image when the input level exceeds it. This process were carried out for both PIN diode limiter at 2, 10 and 18 GHz to determine if this rise time is dependant on the frequency. The level input changes from -20 dBm (lineal range) to +10 dBm (saturation range). Figures 21-26 show the rise time under these conditions. Results are summarized in table 3. However, it must be mentioned that this measurement is also including the response time of the power detector.

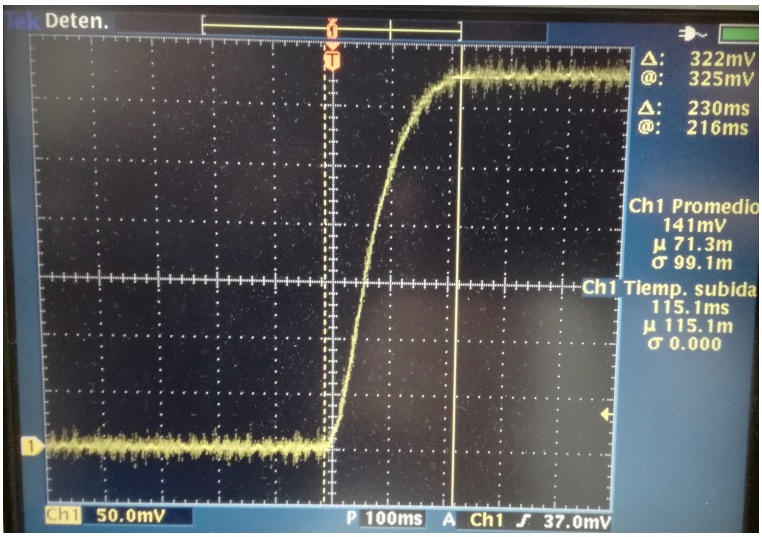

Figure 25: Rise time of PIN diode SN 594619 at 2GHz.

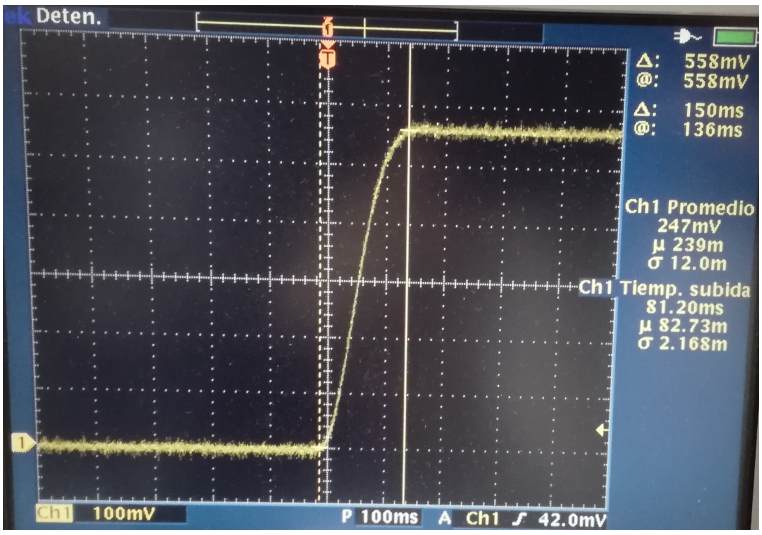

Figure 26: Rise time of PIN diode SN 594619 at 10GHz.

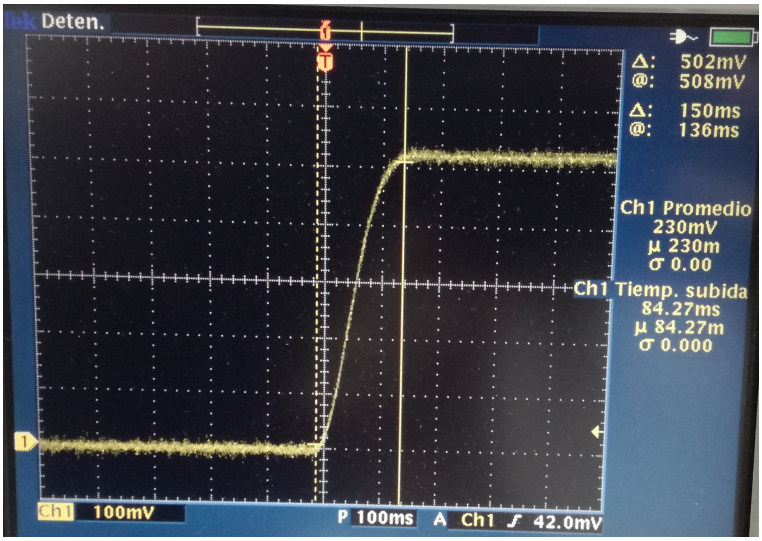

Figure 27: Rise time of PIN diode SN 594619 at 18GHz.

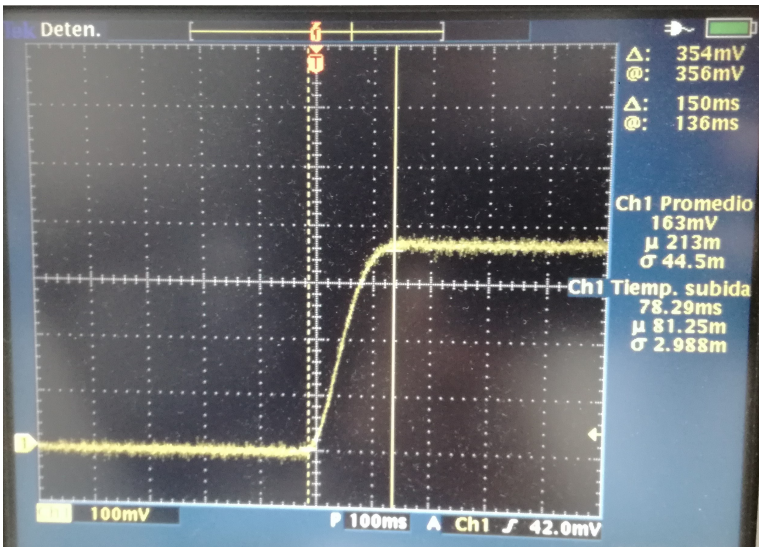

Figure 28: Rise time of PIN diode SN 594620 at 2GHz.

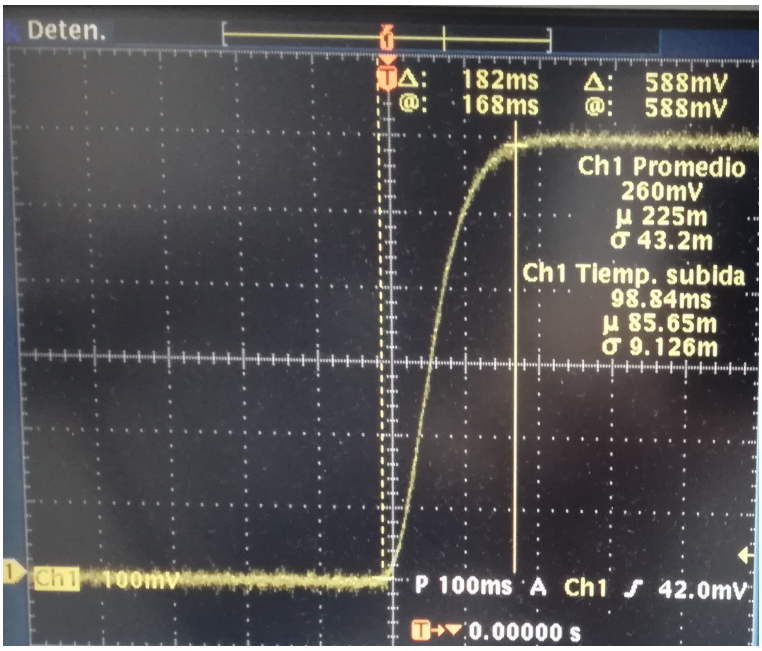

Figure 29: Rise time of PIN diode SN 594620 at 10GHz.

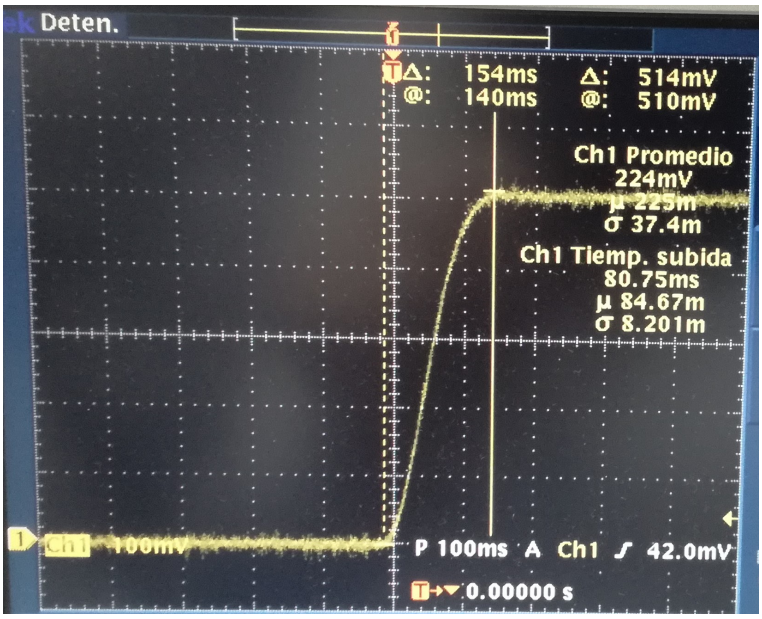

Figure 30: Rise time of PIN diode SN 594620 at 18GHz.

Freq. (GHz)	**Rise time (ms)**	
	SN 594619	**SN 594620**
2	216	136
10	136	168
18	136	140

Table 3: Rise time (ms) for PIN diode limiters SN 594619 and SN 594620 at different frequencies.

4 Conclusion

According to these results, it can be said that all measured values are in agreement with the ones given in the data-sheet, either insertion losses of 2 dB maximum, limit threshold of +6 dBm typical and maximum VSWR.

At input levels higher than +6 dBm the difference between the input and output is higher than 2 dB, meaning that the PIN diode at this level is starting to limit the output power.

According to the rise time measurements, no over-shoot is present in the transition from linear to saturation regime, which could lead to dangerous RF spikes at its output.

As a result, these limiters can be installed at the input of the laser transmitters of the RF over fiber optic links included in the VGOS receiver system of the 13.2 meter VGOS radio telescope in Yebes observatory, whose maximum input power is +20 dBm.

Currently, two 10 dB attenuators are avoiding any damage to the laser transmitters. Once they are changed by the limiters, the link gain will increase by 8 dB, approximately, and the lasers will continue being protected.

A Pin diode limiters specifications

PIN DIODE LIMITERS

LOW LEAKAGE LS SERIES 1W CW, 0.1 - 18 GHz

FEATURES

- Low Limiting Threshold (+6 dBm Typical)
- Low Leakage Level (+13 dBm Typical)
- 1 Watt CW and 200 Watt Peak (1 μsec) Power Handling Capability
- Built-In DC Block @ Input and Output
- Hermetically Sealed Module
- Typical Recovery Time is Less Than 10 μsec

APPLICATIONS

- Front End Protection for LNA's
- Power Leveling (Limiting)
- Receiver Protection

ENVIRONMENTAL RATINGS

Max Input Power……..1 Watt CW & 200 Watt Peak (μsec) Power Handling Capability
Operating Temperature Range…….-55°C to +125°C
Storage Temperature Range……-65°C to +125°C
Shock…….. 50G, 11 msec
Vibration…….. 20G, 100 to 2000 Hz

Specifications: (@ +25°C)

MODEL	FREQUENCY RANGE (GHz)	MAXIMUM INSERTION LOSS (dB)	MAX VSWR	TYP LIM THRESHOLD (dBm)	MAX LEAKAGE @ 1W CW INPUT (dBm)	PACKAGE STYLE
LS0105	0.1 – 0.5	0.4	1.3:1	+6	+14	B, BF, L
LS0110	0.1 – 1.0	0.5	1.4:1	+6	+14	B, BF, L
LS0120	0.1 – 2.0	0.6	1.4:1	+6	+14	B, BF, L
LS0140	0.1 – 4.0	0.8	1.5:1	+6	+14	B, BF, L
LS01012	0.1 –12.0	1.7	1.6:1	+6	+14	B, BF, L
LS01018	0.1 – 18.0	2.2	2.0:1	+6	+14	B, BF, L
LS0510	0.5 – 1.0	0.5	1.4:1	+6	+14	B, BF, L
LS0520	0.5 – 2.0	0.6	1.4:1	+6	+14	B, BF, L
LS0540	0.5 – 4.0	0.7	1.4:1	+6	+14	B, BF, L
LS0560	0.5 – 6.0	1.2	1.5:1	+6	+14	B, BF, L
LS05012	0.5 –12.0	1.6	1.6:1	+6	+14	B, BF, L
LS05018	0.5 –18.0	2.0	2.0:1	+6	+14	B, BF, L
LS1020	1.0 – 2.0	0.6	1.4:1	+6	+14	B, BF, L
LS1060	1.0 – 6.0	1.2	1.5:1	+6	+14	B, BF, L
LS1012	1.0 –12.0	1.6	1.6:1	+6	+14	B, BF, L
LS1018	1.0 –18.0	2.0	2.0:1	+6	+14	B, BF, L
LS2040	2.0 – 4.0	0.7	1.4:1	+6	+14	B, BF, L
LS2060	2.0 – 6.0	1.2	1.5:1	+6	+14	B, BF, L
LS2080	2.0 – 8.0	1.3	1.6:1	+6	+14	B, BF, L
LS2018	2.0 – 18.0	2.0	2.0:1	+6	+14	B, BF, L
LS4080	4.0 – 8.0	1.3	1.5:1	+6	+13	B, BF, L
LS6018	6.0 –18.0	2.0	2.0:1	+6	+13	B, BF, L
LS7012	7.0 –12.0	1.6	1.6:1	+6	+13	B, BF, L
LS8016	8.0 –16.0	1.8	1.8:1	+6	+13	B, BF, L
LS8018	8.0 –18.0	2.0	2.0:1	+6	+13	B, BF, L
LS1118	11.0 –18.0	2.0	2.0:1	+6	+13	B, BF, L

Note 1: Insertion loss and VSWR tested @ -10dBm
Note 2: Minimum power handling capability -1 Watt CW or 200 Watts peak (1 μsec, 0.1% duty) derated to 20%@+125ºC.
Note 3: Standard outline in "B" style add suffix "BF" or "L" to the model number for optional outlines.

Consult factory for higher power limiters (up to 25 Watt CW or 1 KWatt pulse peak power)

For Package Outlines see Outline Drawings Page

HEROTEK, INC. 155 Baytech Drive, San Jose, California 95134
Phone: (408) 941-8399 Fax: (408) 941-8388 Email:info@herotek.com www.herotek.com