LOW NOISE RECEIVERS AND THEIR CALIBRATION*

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Low noise microwave receiving systems are particularly important for deep space communications systems, radio astronomy and some sensitive laboratory measurement systems[1] such as transmission spectroscopy[2]. Dramatic improvements in microwave receivers have reduced noise figures from the range of 10 dB to tenths of dB's in the last 15 to 20 years[3]. Although cooled parametric amplifiers[4] provide a very practical performance compromise for ultra low noise, wide bandwidth and low cost, the maser has the lowest noise temperature of any practical microwave amplifier.

	Freq.	T_{op}(K)	T_e(K)	T_m(K)
Goldstone 64m Antenna	2295 MHz	15.6	4.3	4.1
"	8415 MHz	20.0	6.1	6.0
"	15.3 GHz	27.0	8.5	8.4
Minimum Horn/Maser*	2295 MHz	10.7	4.3	4.2
"	8465 MHz	12.4	6.1	6.0
"	15.3 GHz	18.5	8.7	8.4

*System located on ground

Examples of Some JPL 1972 Ultra Low Noise Maser Receiving Systems[5] Pointed at Zenith

Although the system operating noise temperatures can be determined by accounting for the individual system components, it is usually most accurately determined from a direct measurement. This is a key parameter required to determine system sensitivity and can be conveniently measured by switching the receiver input between an ambient termination and the antenna (or other source). With this technique[6]

$$T_{op} = \frac{T_p + T_e}{Y_{ap}}$$

where

T_e = receiver effective noise temperature, K.

T_p = ambient termination physical temperature, K.

Y_{ap} = the output noise power ratio obtained when switching between the antenna and the ambient termination.

This requires a separate calibration of T_e but is especially convenient if $T_e \ll T_p$.

Calibration of the noise contributions of the individual system components is important from the standpoint of component specification and system performance prediction and verification. The most accurate calibration of T_e can be obtained by switching the receiver between two precision thermal noise standards[7,8,9]. The amplifier effective noise temperature is given by[10]

$$T_e = \frac{T_{hot} - YT_{cold}}{Y - 1}$$

D. Wait[7] itemizes 7 important sources of error:

1. Uncertainty in the value of T_{hot}.
2. Uncertainty in the value of T_{cold}.
3. Uncertainty in the measurement of Y.
4. Amplifier nonlinearity and instability during the measurement of Y.
5. Mismatched System[7,11].
6. Non ideal connectors.
7. "Cascade" error.

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