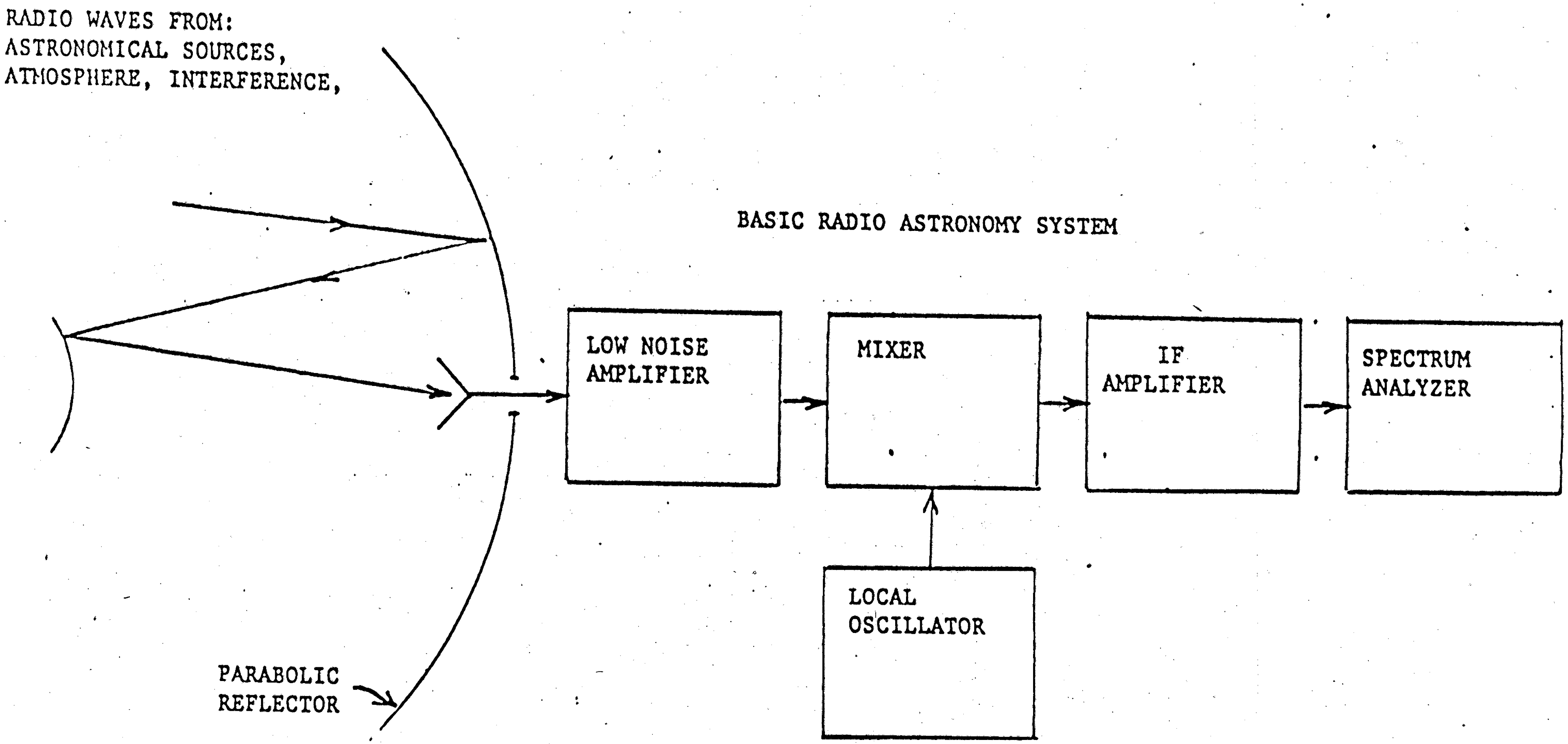
BASIC RADIO ASTRONOMY SYSTEM



PROBLEM AREAS

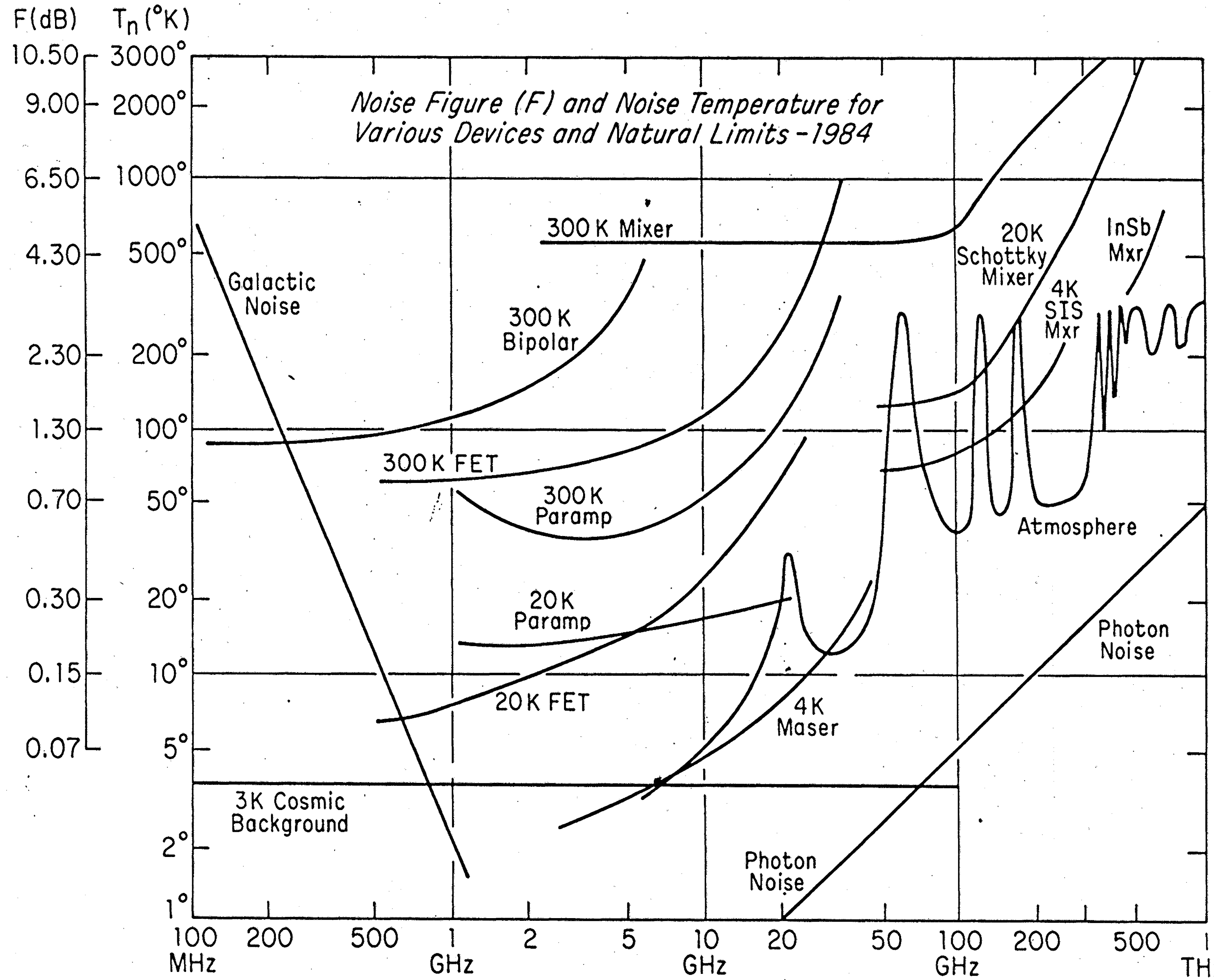
1) IN CM RANGE LOW-NOISE AMPLIFIERS LIMIT SENSITIVITY AND TEND TO BE UNRELIABLE.

2) IN MM-λ RANGE LOW-NOISE AMPLIFIERS DO NOT EXIST; EFFICIENT MIXERS MUST BE DEVELOPED.

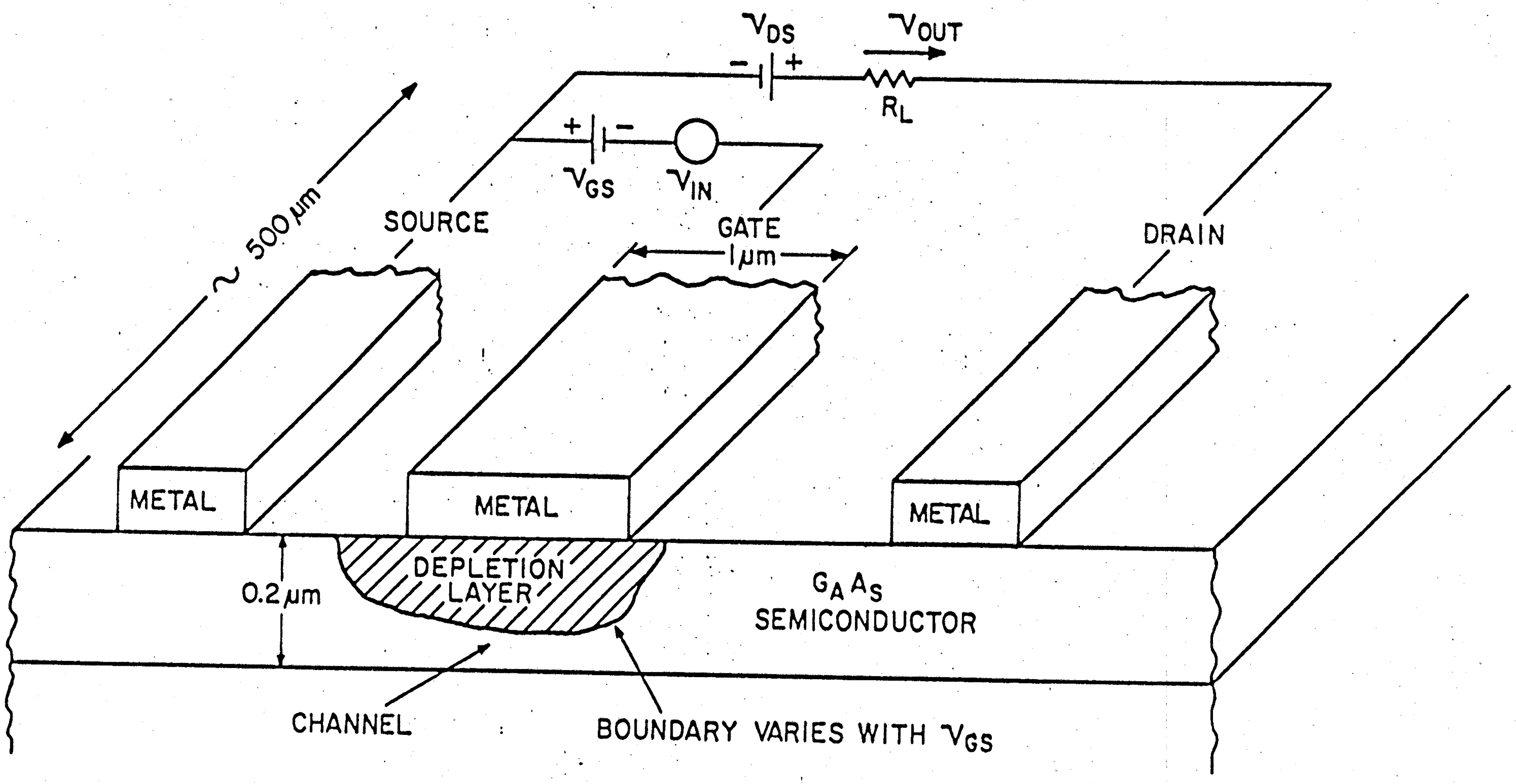
3) MM-λ LOCAL OSCILLATORS ARE EXPENSIVE, UNRELIABLE AND DO NOT EXIST FOR SHORT MM-λ RANGES.

4) SPECTRUM ANALYZERS COVERING GHZ BANDWIDTHS WITH $\sim 10^4$ CHANNELS ARE NEEDED.

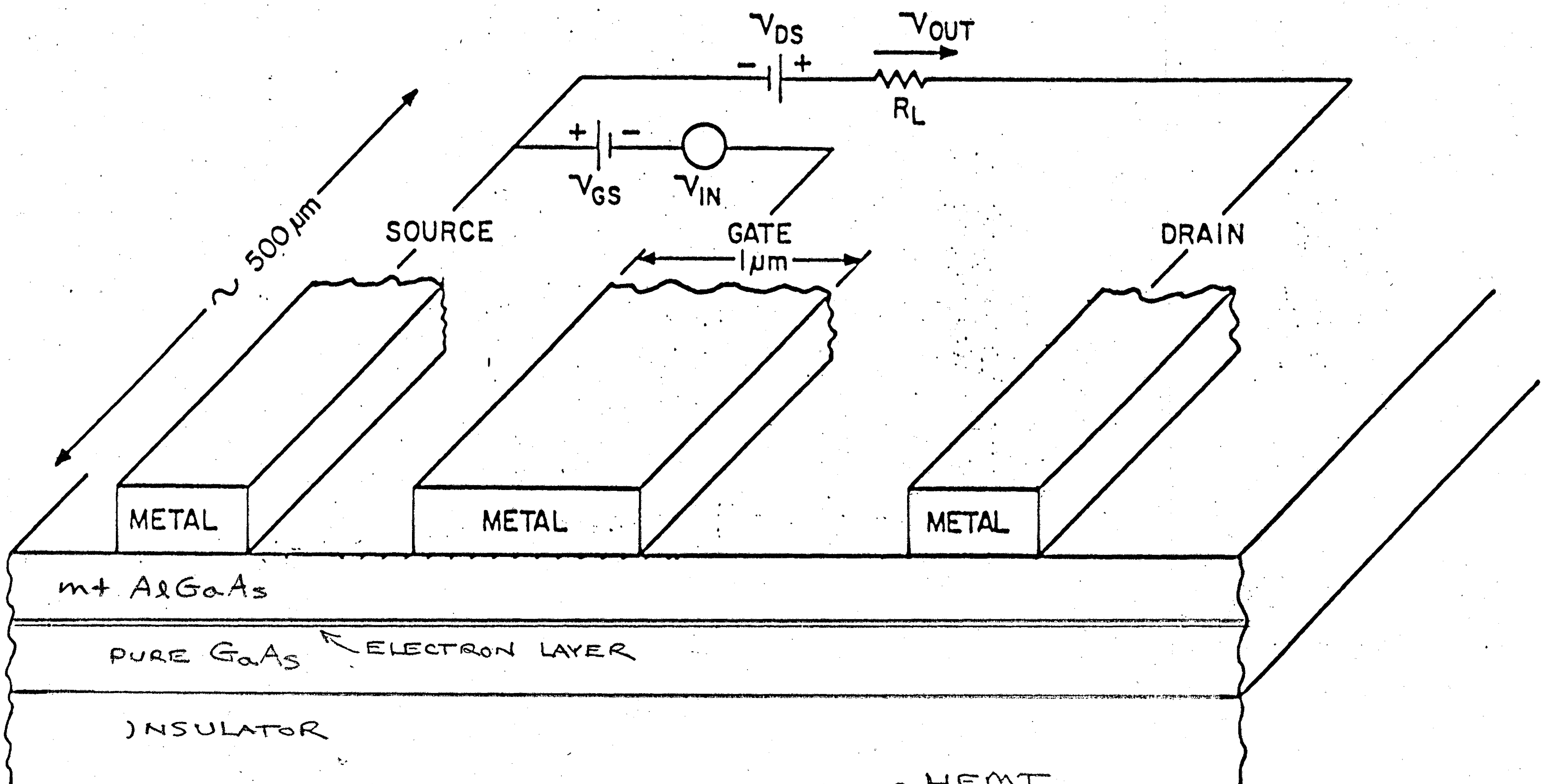
LECTURE NOTES
S. WEINREB
6/25/84



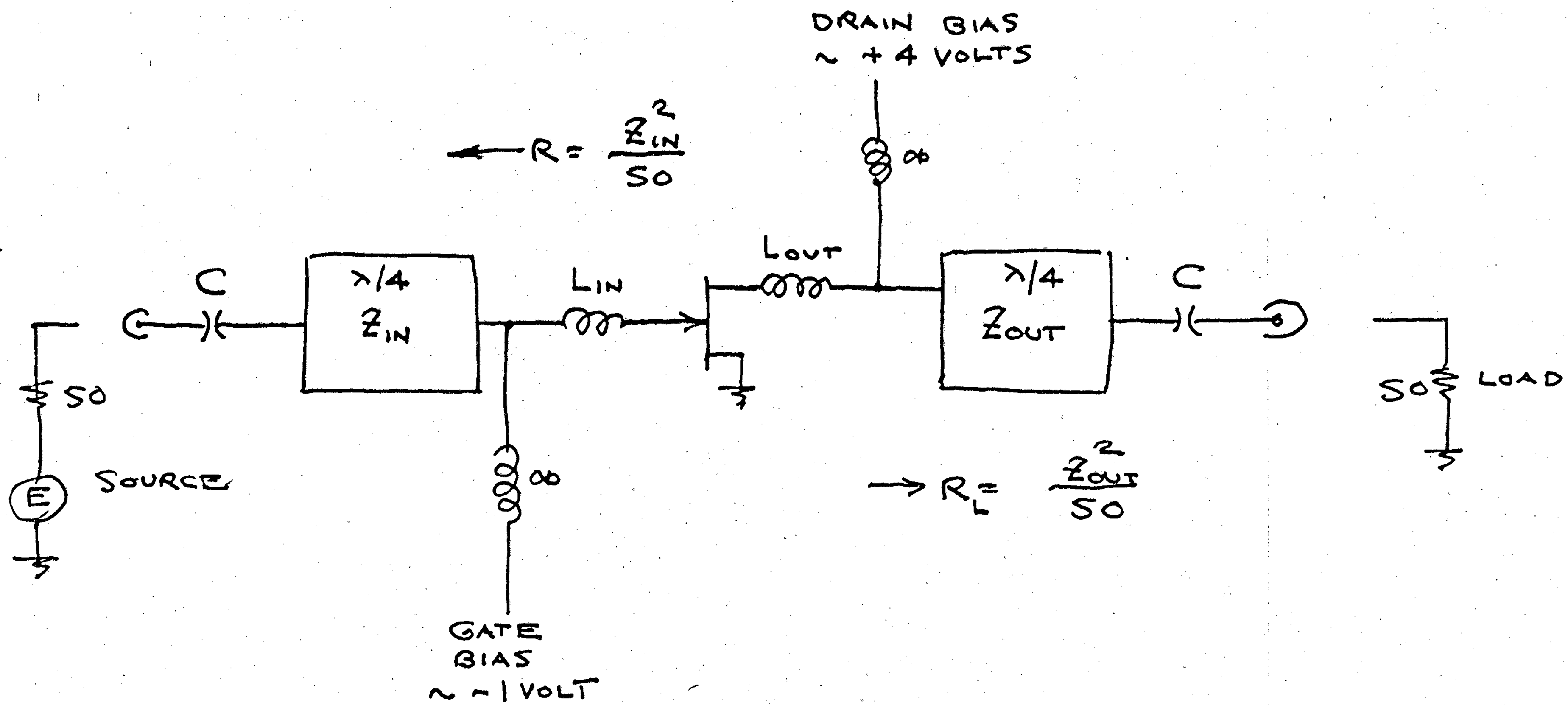
Noise Figure (F) and Noise Temperature for
Various Devices and Natural Limits - 1984
F(dB)
Tn (°K)
10.50
3000°
9.00
2000°
6.50
1000°
4.30
500°
2.30
200°
1.30
100°
0.70
50°
0.30
20°
0.15
10°
0.07
5°
2°
1°
300 K Mixer
Galactic
Noise
300 K
Bipolar
300 K FET
300 K
Paramp
20 K
Paramp
20 K FET
4 K
Maser
3 K Cosmic
Background
Photon
Noise
20 K
Schottky
Mixer
4 K
SIS
Mxr
InSb
Mxr
Atmosphere
Photon
Noise
100
MHz
200
500
1
GHz
2
5
10
GHz
20
50
100
GHz
200
500
THz



ISOMETRIC VIEW OF GASFET



ISOMETRIC VIEW OF HEMT / MODFET / TEGFET



ONE - STAGE FET AMPLIFIER

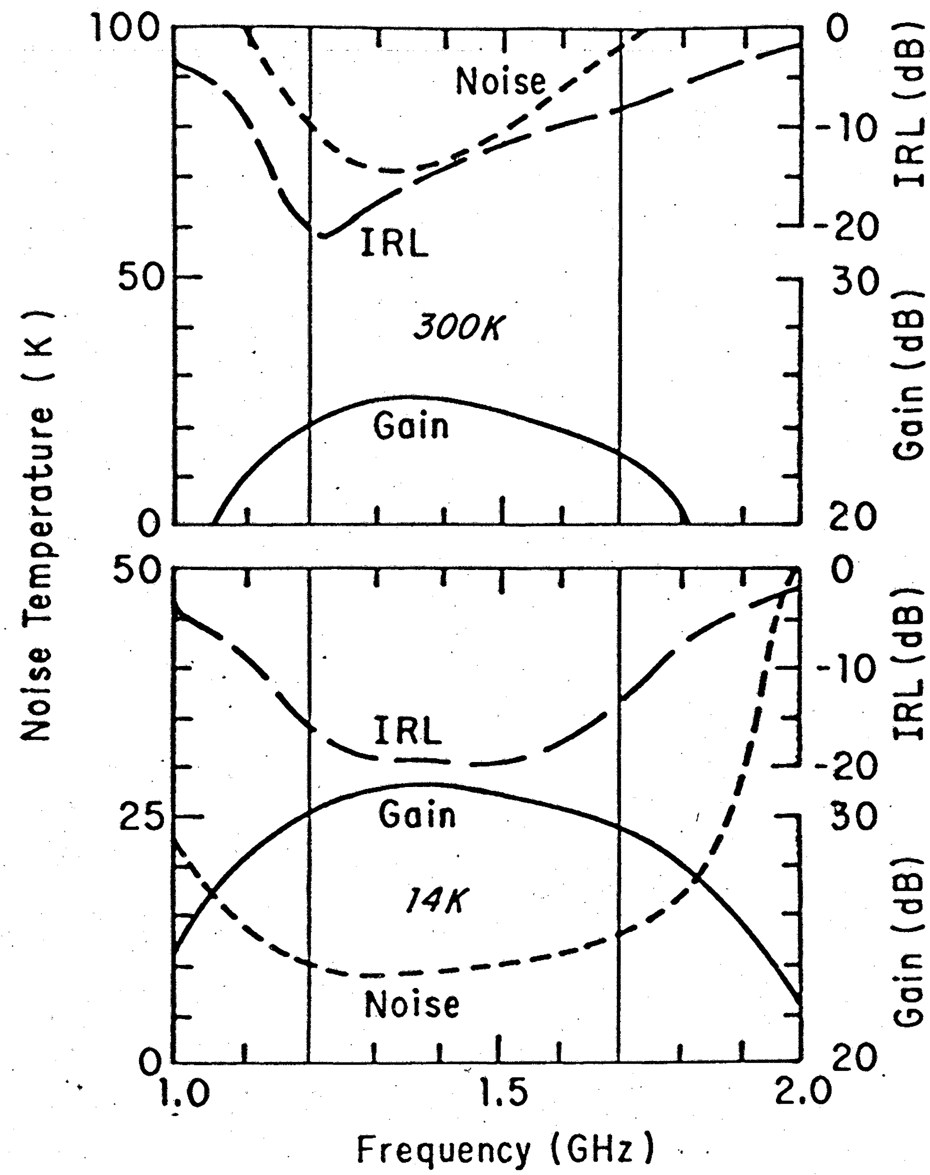
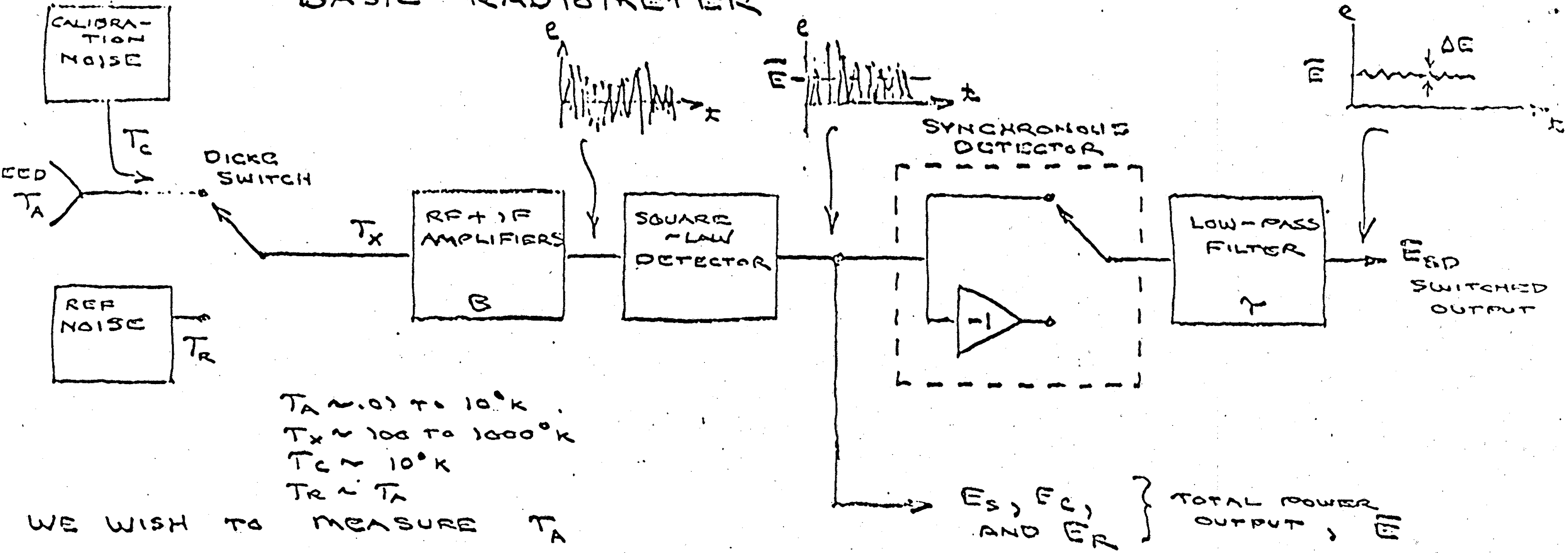


Fig. 6. Input return loss (IRL), gain, and noise temperature of amplifier #74 at 300K (top) and 14K (bottom). Note scale change for noise temperature.

BASIC RADIOMETER



$T_A \sim .01$ to $10°K$

$T_X \sim 100$ to $1000°K$

$T_C \sim 10°K$

$T_R \sim T_A$

WE WISH TO MEASURE T_A

BASIC INPUT-OUTPUT RELATION ⟶ (AVERAGE DETECTOR OUTPUT VOLTAGE, $\bar{E}$) = $\Big(\underbrace{k\ B\ G'}_{=G}\Big)$ × (TOTAL INPUT NOISE TEMPERATURE)

k: 1.38×10^{-23}; B: NOISE BANDWIDTH; G': TOTAL POWER GAIN

SWITCH UP, CAL OFF ⟶ $\bar{E}_S = G(T_X + T_A)$ SIGNAL VOLTAGE

SWITCH UP CAL ON ⟶ $-\bar{E}_C = G(T_X + T_A + T_C)$ CALIBRATION VOLTAGE

SWITCH DOWN CAL OFF OR ON ⟶ $\bar{E}_R = G(T_X + T_R)$ REFERENCE VOLTAGE

3 EQUATIONS, 3 UNKNOWNS (T_A, G, T_X)

SENSITIVITY LIMITATIONS

①

$$\frac{rms}{mean} = \frac{\Delta E}{\bar{E}} = \frac{\Delta T_A}{T_X + T_A} = \frac{1}{\sqrt{B\tau}}$$

LIMIT DUE TO STATISTICAL FLUCTUATIONS OF NOISE

NOISE BANDWIDTH

INTEGRATION TIME

②

$$\frac{\Delta G}{G} \sim 1\%$$

LIMIT DUE TO RECEIVER GAIN STABILITY

MODIFICATIONS TO BASIC RECEIVER

① DICKE SWITCHING – SYNCHRONOUS DETECTION

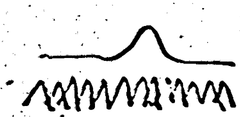
$$\bar{E}_{SD} = E_S - E_R = G(T_A - T_R)$$

② COMPUTER SYNCHRONOUS DETECTION

$$T_A = \frac{\bar{E}_S - \bar{E}_R}{\bar{E}_C - \bar{E}_S} \cdot T_C + T_R$$

③ MULTICHANNEL LINE RECEIVER

– COMB FILTERS AND MULTIPLE DETECTORS



← SPECTRAL LINE

← COMB FILTER BANK

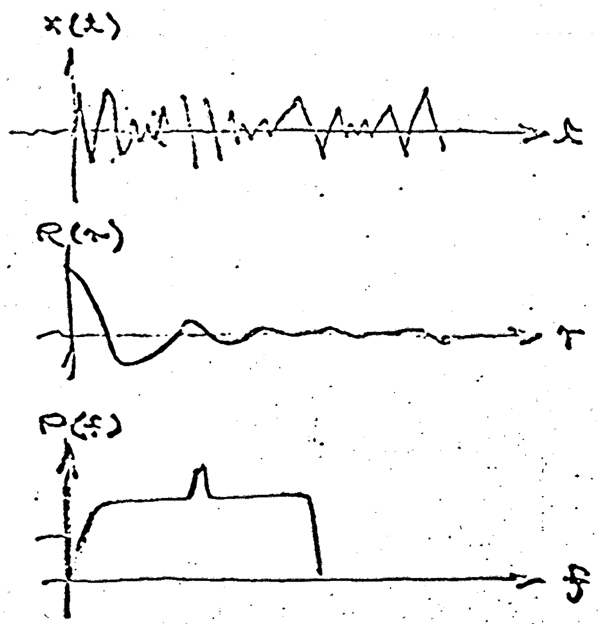
AUTOCORRELATION RECEIVERS

$$T(f) = \int_{-\infty}^{\infty} R(\tau) \cos 2\pi f \tau \, d\tau$$

TEMPERATURE SPECTRUM $T(f)$ AS FOURIER TRANSFORM OF AUTOCORRELATION FCN; $R(\tau)$

$$R(\tau) = \lim_{T \to \infty} \frac{1}{2T} \int_{-T}^{T} x(t)\, x(t+\tau)\, dt$$

DEFINITION OF $R(\tau)$ IN TERMS OF SIGNAL TIME FUNCTION, $x(t)$.



MODIFICATIONS TO THEORY

MODIFICATION	EFFECT
τ CANNOT $\to \infty$	FREQUENCY RESOLUTION $B \sim \frac{1}{\tau_{MAX}}$
T CANNOT $\to \infty$	STATISTICAL FLUCTUATION $\frac{\Delta T}{T} = \frac{1}{\sqrt{BT}} \sim \sqrt{\frac{\tau_{MAX}}{T}}$
$R(\tau)$ IS SAMPLED IN STEPS OF $\Delta\tau$	$f_{MAX} = \frac{1}{2\Delta\tau}$
$x(t)$ IS SAMPLED IN STEPS OF Δt	NO EFFECT IF $f_{MAX} = \frac{1}{2\Delta t}$
$x(t)$ IS QUANTIZED IN N BITS	$\frac{\Delta T}{T}$ SLIGHTLY INCREASED