NATIONAL RADIO ASTRONOMY OBSERVATORY
P. O. Box O
Socorro, New Mexico

VLA Electronics Memorandum No. 201

IF TRANSMISSION COMPRESSION ERRORS AND PRECISION COMPRESSION MEASUREMENT

W. E. Dumke
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1.0 INTRODUCTION

A system investigation into reduction of IF transmission compression has resulted in discovery of a number of problems difficult to solve. The reduction of compression required to facilitate accurate direct Front End noise temperature measurement after the final narrow band filters in the spectral line mode is shown to be impractical because of cumulative compression errors, measurement errors, amplitude changes versus filter selected, and IF transmission signal plus noise to noise ratio errors. An alternative indirect method is required.

A precision compression measurement system with repeatable errors on the order of a few tenths of a percent is also presented. An automated system for general application is proposed.

2.0 DEFINITION OF TERMS

The relationships of measured voltages to the Front End T_{SYS}/T_{CAL} ratio is presented for both the F4 and T5C baseband driver systems. When dealing with compression the reduction in percent increase in power is more convenient than the inverse T_{SYS}/T_{CAL} ratio.

WED 6/3/80 -1

SYNCHRONOUS DETECTOR DEFINITIONS

F4

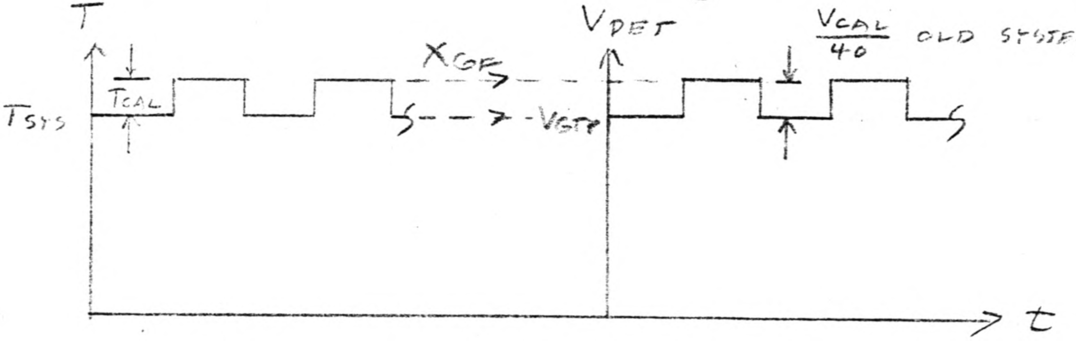
$P = NKTB$

$\therefore P \propto T$

SQUARE LAW DETECTORS ARE USED

$\therefore V_{DCS} \propto P \propto T$

FOR F4 MODULE,



T_{SYS} = SYSTEM TEMPERATURE WITH CALIBRATION SOURCE OFF

T_{CAL} = CHANGE IN SYSTEM TEMPERATURE DUE TO CALIBRATION SOURCE

G_F = TOTAL SYSTEM GAIN INCLUDING DETECTOR (FRONT END ONLY)

$V_{CAL} = G_F \cdot T_{CAL} \cdot 40$ = OLD F4 SYNCHRONOUS DETECTOR VOLTAGE [redacted]

$V_{CAL} = G_F \cdot T_{CAL} \cdot 15$ = NEW F4 SYNCHRONOUS DETECTOR VOLTAGE [redacted]

$V_{STP} = G_F \cdot T_{SYS}$ = DETECTOR VOLTAGE [redacted] WITH NOISE SOURCE OFF

WED 6/3/80 - 2

F4 (CONT'D)

$$\therefore \quad T_{SYS} = \frac{V_{GTP}}{G_F}$$

$$\therefore \quad T_{CAL} = \frac{V_{CAL}}{40\,G_F} \qquad \text{OLD SYSTEM}$$

$$\therefore \quad T_{CAL} = \frac{V_{CAL}}{15\,G_F} \qquad \text{NEW SYSTEM}$$

$$\therefore \quad \frac{T_{SYS}}{T_{CAL}} = \frac{\frac{V_{GTP}}{G_F}}{\frac{V_{CAL}}{40\,G_F}} = \frac{V_{GTP} \times 40}{V_{CAL}} \qquad \text{OLD SYSTEM}$$

$$\therefore \quad \frac{T_{SYS}}{T_{CAL}} = \frac{\frac{V_{GTP}}{G_F}}{\frac{V_{CAL}}{15\,G_F}} = \frac{V_{GTP} \times 15}{V_{CAL}} \qquad \text{NEW SYSTE}$$

$$\text{\% INCREASE IN POWER} = \frac{T_{CAL}}{T_{SYS}} \times 100\,\%$$

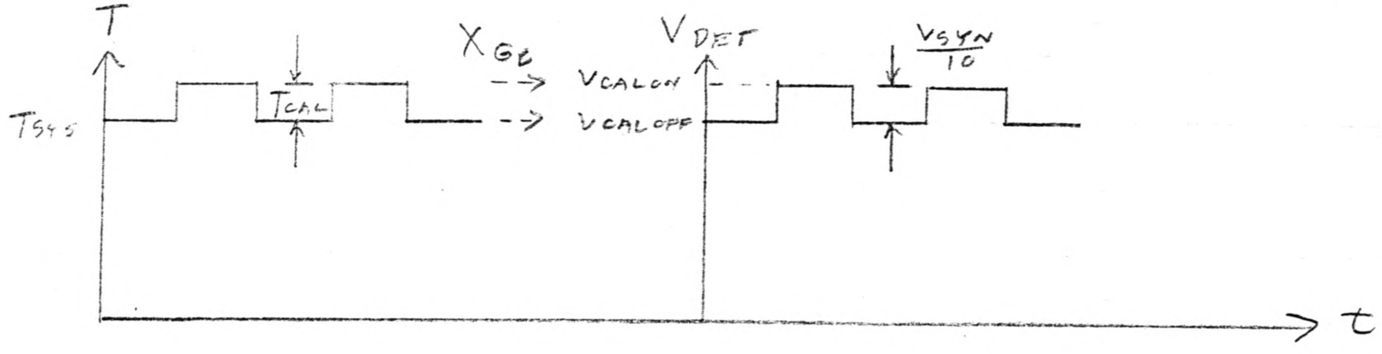
$$= \frac{V_{CAL}}{V_{GTP} \times 40} \times 100\,\% \qquad \text{OLD SYSTE}$$

$$= \frac{V_{CAL}}{V_{GTP} \times 15} \times 100\,\% \qquad \text{NEW SYSTE}$$

$$= 3\,\% \text{ TO } 10\,\%$$

T5B

FOR T5B MODULE,



T_{SYS} = SYSTEM TEMPERATURE WITH CALIBRATION SOURCE OFF

T_{CAL} = CHANGE IN SYSTEM TEMPERATURE DUE TO CALIBRATION SOURCE

G_B = TOTAL SYSTEM GAIN INCLUDING DETECTOR (FRONT END + IF TRANSMISSION + BASEBAND)

$V_{SYN} = G_B \cdot T_{CAL} \cdot 10$ = BASEBAND SYNCHRONOUS DETECTOR VOLTAGE

$V_{CAL\,OFF} = G_B \cdot T_{SYS}$ = DETECTOR VOLTAGE WITH NOISE SOURCE OFF

$V_{CAL\,ON} = G_B \cdot (T_{SYS} + T_{CAL})$ = DETECTOR VOLTAGE WITH NOISE SOURCE O

WED 6/3/80 -4

T5B (CONT'D)

$$\therefore\ T_{SYS} = \frac{V_{CAL\ OFF}}{G B}$$

$$T_{CAL} = \frac{V_{SYN}}{10\ G B}$$

$$\therefore\ \frac{T_{SYS}}{T_{CAL}} = \frac{\frac{V_{CAL\ OFF}}{G B}}{\frac{V_{SYN}}{10\ G B}} = \frac{V_{CAL\ OFF} \times 10}{V_{SYN}}$$

$$\%\ \text{INCREASE IN POWER} = \frac{V_{SYN}}{V_{CAL\ OFF} \times 10} \times 100$$

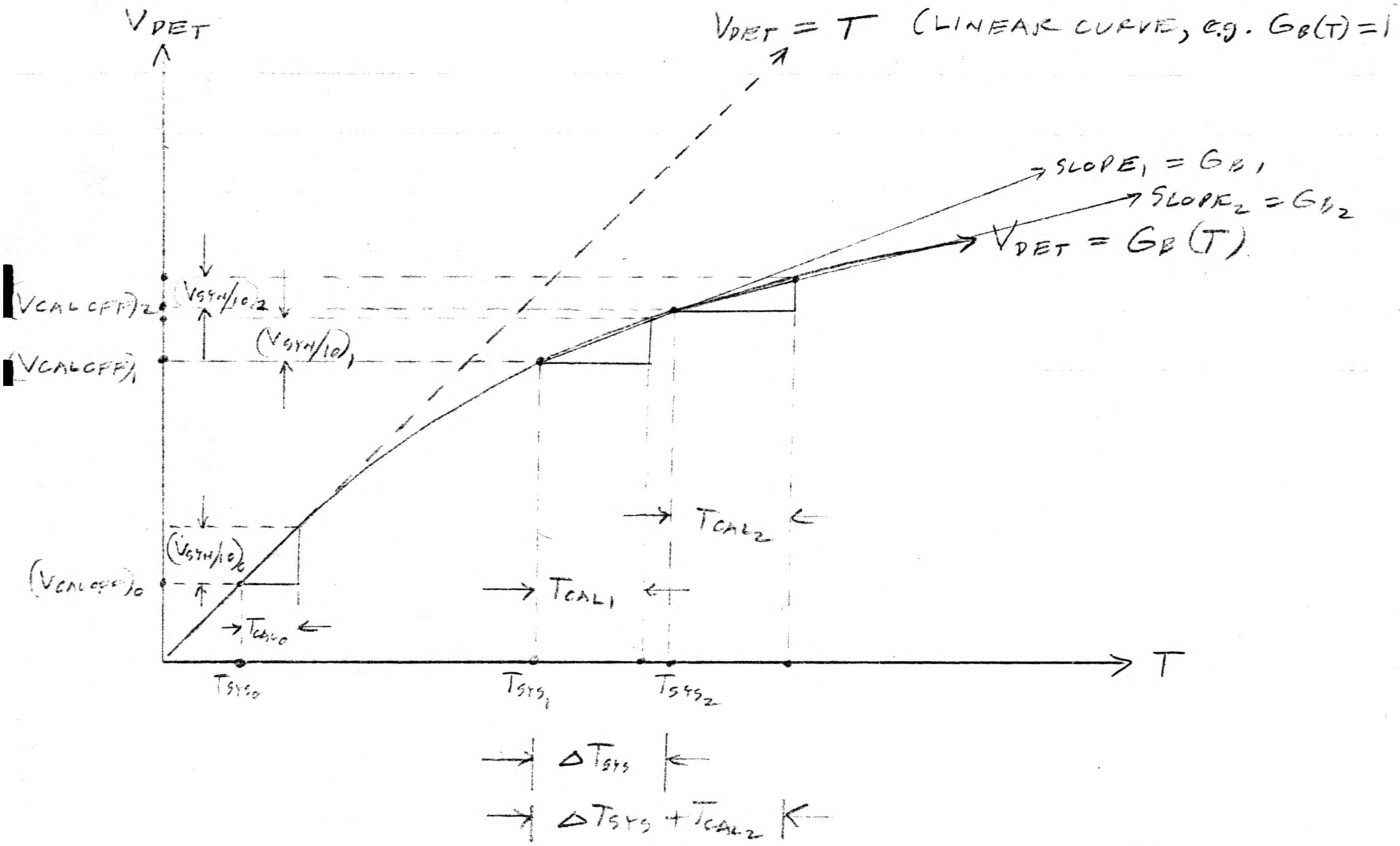
$$= \frac{V_{SYN}}{V_{CAL\ OFF}} \times 10\ \%$$

3.0 COMPRESSION EFFECTS

The effect of compression on the measurement of Front End noise temperature is described.

WED 6/3/80 - 5

COMPRESSION CURVE



LET T_{SYS_0}, T_{CAL_0}, $(V_{SYN}/10)_0$, $(V_{CALOFF})_0$ BE IN LINEAR REGION.

$$\frac{(V_{SYN}/10)_0}{(V_{CALOFF})_0} \times 100\% = \text{\% INCREASE IN DETECTOR VOLTAGE IN LINEAR REGION}$$

$$\frac{T_{CAL_0}}{T_{SYS_0}} \times 100\% = \text{\% INCREASE IN NOISE TEMP. IN LINEAR REGION}$$

NOTE THAT $V_{DET} = T$ IN LINEAR REGION.

$$\therefore \quad \frac{(V_{SYN}/10)_0}{(V_{CALOFF})_0} \times 100\% = \frac{T_{CAL_0}}{T_{SYS_0}} \times 100\%$$

WITH $G_{B_0} = 1$

IF THE TOTAL COMPRESSION $\geq 1\%$, IT WOULD STILL BE POSSIBLE TO OBTAIN THE DESIRED ACCURACY BY USING THE COMPUTER TO CALCULATE A CALIBRATION FACTOR TO COMPENSATE FOR G_{B1}.

IF $\frac{G_{B1} - G_{B2}}{G_{B1}} \times 100\% \leq 0{,}1\%$ WITH TIME, THEN THE DESIRED ACCURACY WOULD STILL HOLD.

THIS REQUIRES $\leq 0{,}1\%$ CHANGE IN SLOPE OVER $\Delta T_{SYS} + T_{CAL_2}$ RANGE IN LEVEL.

$G_B(T)$ = NONLINEAR FUNCTION OF T DUE TO COMPRESSION (ASSUMES FRONT END COMPRESSION IS NEGLIGIBLE FOR PURPOSES OF IF SYSTEM REQUIREMENTS, ONLY)

$$\frac{T_{SYS_2} - T_{SYS_1}}{T_{SYS_1}} \times 100\% = \frac{\Delta T_{SYS}}{T_{SYS_1}} \times 100\%$$

= MAXIMUM PEAK TO PEAK CHANGE IN OPERATING POINT RELATIVE TO COMPRESSION CURVE.

EVEN THOUGH WITH ALC, $(V_{CAL\ OFF})_1 = (V_{CAL\ OFF})_2$, ASSUMING NO CHANGES IN TSU/DI LINE, AN ERROR WILL EXIST DUE TO THE INPUT POWER CHANGING RELATIVE TO THE COMPRESSION CURVE. THE CHANGE IN OPERATING POINT MAY BE DUE TO CHANGES IN COMPONENT CONVERSION LOSS AND WAVEGUIDE LOSS WITH TIME.

$$\frac{(V_{SYN}/10)_1}{(V_{CAL\,OFF})_1} \times 100\% = G_{B_1}\left[\frac{T_{CAL_1}}{T_{SYS_1}} \times 100\%\right]$$

$$\frac{(V_{SYN}/10)_2}{(V_{CAL\,OFF})_2} \times 100\% = G_{B_2}\left[\frac{T_{CAL_2}}{T_{SYS_2}} \times 100\%\right]$$

WHERE:

$(1-G_{B_1}) \times 100\%$ = % COMPRESSION AT LOWEST OPERATING POINT

$= (1 - SLOPE_1) \times 100\%$

$(1-G_{B_2}) \times 100\%$ = % COMPRESSION AT HIGHEST OPERATING POINT

$= (1 - SLOPE_2) \times 100\%$

IT IS DESIRED TO HAVE 1% ACCURACY IN THE MEASUREMENT OF $\frac{T_{CAL}}{T_{SYS}}$ AT THE OUTPUT OF THE BASEBAND SYSTEM

THUS $(1-G_B) \times 100\% \leq 1\%$

$$1.00 \geq G_B \geq 0.99$$

FROM LARRY D'ADDARIO'S MEMO OF [illegible], IT IS ALSO DESIRABLE TO HAVE $\frac{G_{B_1} - G_{B_2}}{G_{B_1}} \leq .001$ FOR

0.1% ACCURACY ACROSS THE RANGE

OF VARIATION OF $\frac{T_{CAL}}{T_{SYS}} \times 100\%$.

$$\frac{T_{CAL}}{T_{SYS}} \times 100\% \text{ MIN.} = 3\%$$

$$\frac{T_{CAL}}{T_{SYS}} \times 100\% \text{ MAX.} = 10\%$$

THE MAXIMUM VARIATION IN INPUT TEMPERATURE = $\Delta T_{SYS} + T_{CAL_2\,MAX}$. WHERE ΔT_{SYS} = CHANGE IN OPERATING POINT DUE TO CONVERSION LOSS AND WAVEGUIDE LOSS WITH TIME, AND WHERE $T_{CAL_2\,MAX}$ = MAXIMUM VARIATION DUE TO CALIBRATION SOURCE EXCESS NOISE.

ASSUME $10\,dB\,LOG_{10}\left(\frac{\Delta T_{SYS_1}}{T_{SYS_1}}\right) = 1\,dB$ MAXIMUM FOR THE IF TRANSMISSION SYSTEM.

$\frac{T_{CAL_2\,MAX}}{T_{SYS_2}} \times 100\% = 10\%$ MAXIMUM FOR THE NOISE CALIBRATION SOURCE.

$\therefore$ TOTAL VARIATION (dB) $= 10\,dB\,LOG_{10}\left[\frac{\Delta T_{SYS}}{T_{SYS_1}} + \frac{T_{CAL_2}}{T_{SYS_2}}\right]$

TOTAL VARIATION (dB) $= 1\,dB + 0,4\,dB = 1.4\,dB$

WED 6/3/80-9

IF THE TOTAL COMPRESSION CANNOT BE KEPT UNDER THE 1% DESIRABLE, IT WOULD STILL BE POSSIBLE TO OBTAIN THE DESIRED ACCURACY BY USING THE COMPUTER TO CALCULATE A CALIBRATION FACTOR TO COMPENSATE FOR G_{B1}.

IF $\frac{G_{B1} - G_{B2}}{G_{B1}} \times 100\% \leq 0.1\%$

WITH TIME, THEN THE DESIRED ACCURACY WOULD STILL HOLD.

THIS REQUIRES $\leq 0.1\% / 1.4dB$

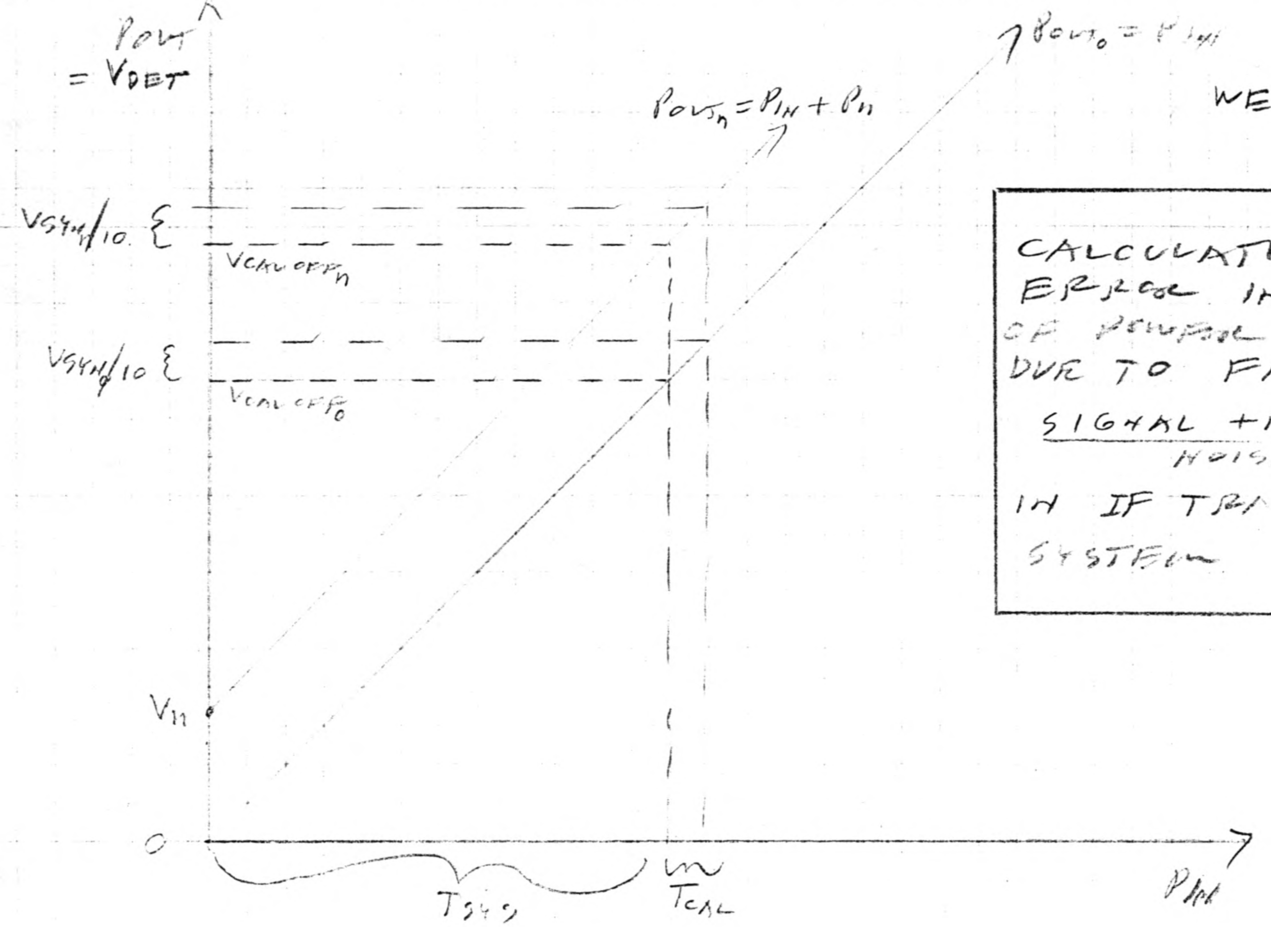
CHANGE IN COMPRESSION SLOPE, PER CHANGE IN TOTAL POWER VARIATION, WITH TIME AND TEMPERATURE

4.0 SIGNAL PLUS NOISE TO NOISE RATIO EFFECTS

Although it is desirable to include $\frac{S + N}{N}$ degradation due to the IF transmission system in the overall antenna noise temperature measurement, it is required to treat it as a seperate error for system diagnostics. It will have an effect on measurement similar to that of compression.

WED 6/11/80 -

CALCULATION OF ERROR IN % INCREA OF POWER MEASUREME DUE TO FINITE $\frac{\text{SIGNAL + NOISE}}{\text{NOISE}}$ RATIO IN IF TRANSMISSION SYSTEM



$P_{OUT_0} = P_{IN}$ FOR ∞ S/N RATIO AND [illegible]
UNITY

$P_{OUT_n} = P_{IN} + P_n$

LET $\frac{T_{CAL}}{T_{SYS}} \times 100\% =$ % INCREASE IN F.E. NOISE POWER

FOR $P_{OUT_0} = P_{IN}$ (INFINITE S/N RATIO IN IF SYSTEM)

$$\frac{V_{SYN_0}/10}{V_{CALOFF_0}} \times 100\% = \frac{T_{CAL}}{T_{SYS}} \times 100\%$$

FOR $P_{OUT_n} = P_{IN} + P_n$ (FINITE S/N RATIO IN IF SYSTEM)

$$\frac{V_{SYN_n}/10}{V_{CALOFF_n}} \times 100\% = \frac{T_{CAL}}{T_{SYS}} \times 100\% + \epsilon\%$$

AFTER SOME ALGEBRA:

$$\epsilon\% = -\left(\frac{V_n}{V_{CAL\ OFF_0} + V_n}\right) \times 100\%$$

$$\epsilon\% = -\left(\frac{NOISE}{SIGNAL + NOISE}\right) \times 100\%$$

WED 6/11/80 - 2

BUT $V_{S44n}/10 = V_{S44o}/10$

$V_{CALOFFn} = V_{CALOFFo} + V_n$

FIND % ERROR IN TWO RATIOS. $= \in$

$$\therefore \frac{\frac{V_{S44o}/10}{V_{CALOFFo} + V_n} \times 100\% - \frac{V_{S44o}/10}{V_{CALOFFo}} \times 100\%}{\frac{V_{S44o}/10}{V_{CALOFFo}} \times 100\%} \times 100\% = \in\%$$

$$\therefore \frac{\frac{(V_{S44o}/10)(V_{CALOFFo}) - (V_{S44o}/10)(V_{CALOFFo} + V_n)}{(V_{CALOFFo} + V_n)(V_{CALOFFo})}}{\frac{V_{S44o}/10}{V_{CALOFFo}}} \times 100\% = \in\%$$

$$\therefore \frac{\frac{V_{S44o}/10\left[V_{CALOFFo} - (V_{CALOFFo} + V_n)\right]}{V_{CALOFFo}\left[V_{CALOFFo} + V_n\right]}}{\frac{V_{S44o}/10}{V_{CALOFFo}}} \times 100\% = \in\%$$

$$\therefore \boxed{\in\% = -\left(\frac{V_n}{V_{CALOFFo} + V_n}\right) \times 100\% \text{ DUE TO FINITE S+N/N RATIO IN IF SYSTEM.}}$$

FROM LARRY D'ADDARIO'S MEMO OF JULY 1978, IT WAS DESIRABLE TO HAVE 0.1% ACCURACY ACROSS THE RANGE OF VARIATION

WED 6/11/80 - 3

FIND REQUIRED STN/N RATIO FOR 0.1% ACCURACY ACROSS THE RANGE OF VARIATION OF SIGNAL LEVELS.

ASSUMPTIONS: ASSUME 0.1%/1.4 dB MAXIMUM ERROR WITH CHANGE IN SIGNAL LEVEL BEFORE ADDITION OF NOISE POWER. (FROM WED 6/3/80 - 9)

$$\therefore \epsilon_{0dB} - \epsilon_{+1.4dB} = 0.1\%$$

LET P_n = NOISE POWER

$P_{CAL\,OFF\,0dB}$ = LOWEST SIGNAL POWER

$P_{CAL\,OFF\,+1.4dB}$ = HIGHEST SIGNAL POWER

$$\therefore 0.1\% = \left(-\frac{P_n}{P_{CAL\,OFF_{0dB}} + P_n}\right) \times 100\% - \left(-\frac{P_n}{P_{CAL\,OFF_{+1.4dB}} + P_n}\right) \times 100\%$$

$$\therefore 0.1\% = \left[\frac{P_n}{P_{CAL\,OFF_{+1.4dB}} + P_n} - \frac{P_n}{P_{CAL\,OFF_{0dB}} + P_n}\right] \times 100\%$$

BUT $P_{CAL\,OFF\,+1.4dB} = 1.38\, P_{CAL\,OFF\,0dB}$

$$\therefore 0.001 = \left[\frac{P_n}{P_{CAL\,OFF_0} + P_n} - \frac{P_n}{1.38\, P_{CAL\,OFF_0} + P_n}\right]$$

WED 6/11/80 - 4

$$0.001 = \frac{P_n(1{,}38 P_{CALOFF_0} + P_n) - P_n(P_{CALOFF_0} + P_n)}{(P_{CALOFF_0} + P_n)(1{,}38 P_{CALOFF_0} + P_n)}$$

$$0{,}001 = \frac{P_n(0{,}38 P_{CALOFF_0})}{1{,}38(P_{CALOFF_0})^2 + P_n P_{CALOFF_0} + 1{,}38 P_n P_{CALOFF_0} + P}$$

$$0{,}001 = \frac{P_n(0{,}38 P_{CALOFF})}{1{,}38(P_{CALOFF_0})^2 + 2{,}38 P_n P_{CALOFF} + P_n^2}$$

$$0{,}00138(P_{CALOFF_0})^2 + 0{,}00238 P_n P_{CALOFF} + 0{,}001 P_n^2 = 0{,}38 P_n P_{CAL}$$

$$0{,}00138(P_{CALOFF_0})^2 - 0{,}37762 P_n P_{CALOFF} + 0{,}001 P_n^2 = 0$$

NOW SOLVE FOR PCAL OFF IN TERMS OF P_n.

$$P_{CALOFF} = \frac{+0{,}37762 P_n \pm \sqrt{0{,}14260 P_n^2 - 4(,00138)(,001 P_n}}{2(,00138)}$$

$$= \frac{0{,}37762 P_n \pm \sqrt{P_n^2(0{,}14259)}}{2(,00138)}$$

$$= \frac{0{,}37762 P_n \pm 0{,}37762 P_n}{2(,00138)}$$

$$P_{CALOFF} = \frac{.75524}{2.76 \times 10^{-3}} P_n = 274 P_n$$

$$\frac{\text{SIGNAL + NOISE}}{\text{NOISE}} = \frac{P_{CALOFF} + P_n}{P_n}$$

$$\frac{\text{SIGNAL + NOISE}}{\text{NOISE}} = 275 \Rightarrow \boxed{+24.4\,dB}$$

WED 6/11/80 -5

∴ A $\frac{\text{SIGNAL + NOISE}}{\text{NOISE}}$ RATIO OF +24.4 dB IS REQUIRED FOR 0.1 % ERROR PER 1.4 dB INCREASE IN POWER.

5.0 REQUIRED INTEGRATION TIMES

Because of the narrow bandwidths in the spectral line mode, averaging times on the detector output voltage measurements have a significant effect on a precision measurement of antenna noise temperature.

WED 6/17/80 -1

CALCULATION OF MINIMUM TIME CONSTANT REQUIRED FOR 0.1% ERROR BETWEEN % INCREASE IN POWER AT FRONT END AND MEASUREMENT OF % INCREASE IN POWER AT BASEBAND OUTPUT FOR FILTER #7

ALLEN AVIONICS BASEBAND FILTERS

L.P.F.'s (#0-#6) N = 9 POLE

B.P.F (#7) N = 18 POLE (L.P.F. + H.P.F.)

0.1 dB RIPPLE CHEBYSHEV CONSTRUCTION

FILTER #	-3dB BANDWIDTH
0	46 MHz
1	23
2	11.5
3	5.75
4	2.88
5	1.438
6	0.719
7	0.189 (0.201 — 0.390 MHz)

BECAUSE OF LARGE NUMBER OF POLES PER FILTER ASSUME PREDETEC. EQUIVALENT NOISE BANDWIDTH = -3dB BANDWIDTH.

ASSUME 0.1 % MAXIMUM RMS ERROR BETWEEN FRONT END AND BASEBAND PER CENT INCREASE IN POWER

ASSUME 3 % MINIMUM PER CENT INCREASE IN POWER DUE TO FRONT END NOISE SOURCE AND SYSTEM TEMPERATURE.

ASSUME FRONT END CONTRIBUTION TO ERROR IS NEGLIGIBLE DUE TO BROADER BANDWIDTH.

WED 6/17/80 – 2

FROM DEFINITION OF BASEBAND TERMINOLOGY,

$$\%\ \text{INCREASE IN POWER} = \frac{\text{VSYN}}{\text{VCAL OFF}} \times 10\%$$

$$= \frac{\text{VCAL ON} - \text{VCAL OFF}}{\text{VCAL OFF}} \times 100\%$$

LET VCAL ON AND VCAL OFF HAVE RMS NOISE VOLTAGES OF VCAL ONn AND VCAL OFFn

∴ % INCREASE IN POWER WITH MAXIMUM ERROR =

$$= \frac{(\text{VCAL ON} + \text{VCAL ON}n) - (\text{VCAL OFF} - \text{VCAL OFF}n)}{\text{VCAL OFF} - \text{VCAL OFF}n} \times 100$$

FOR 3% MINIMUM INCREASE IN POWER,

$|\text{VCAL ON}| = 1.03\,|\text{VCAL OFF}|$

ALSO ASSUME VCAL OFF >> VCAL OFFn

∴ MAXIMUM % ERROR IN % INCREASE IN POWER AT BASEBAND OUTPUT =

$$= \frac{\dfrac{1.03(\text{VCAL OFF} + \text{VCAL OFF}n) - (\text{VCAL OFF} - \text{VCAL OFF}n)}{\text{VCAL OFF}} \times 100\% - }{3\%}$$

SINCE VCAL OFFn AND VCAL ONn ARE UNCORRELATED RMS NOISE VOLTAGES,

$$= \frac{3\% + \dfrac{\sqrt{(1.03\,\text{VCAL OFF}n)^2 + (\text{VCAL OFF}n)^2}}{\text{VCAL OFF}} - 3\%}{3\%}$$

WED 6/17/80 - 3

$$= \frac{1{,}436 \ \mathrm{VCAL\,OFF_n}}{3\% \ \mathrm{VCAL\,OFF}} \times 100\%$$

BUT 3 % = 0,03

∴ MAXIMUM % ERROR IN % INCREASE IN POWER AT BASEBAND OUTPUT =

$$= \frac{1{,}436}{0{,}03} \ \frac{\mathrm{VCAL\,OFF_n}}{\mathrm{VCAL\,OFF}} \times 100\%$$

$$= 47{,}85 \ \frac{\mathrm{VCAL\,OFF_n}}{\mathrm{VCAL\,OFF}} \times 100\%$$

IF MAXIMUM % RMS ERROR IN % INCREASE IN POWER AT BASEBAND OUTPUT = 0,1 % = 0,001 × 100 %, THEN

$$0{,}001 \times 100\% = 47{,}85 \ \frac{\mathrm{VCAL\,OFF_n}}{\mathrm{VCAL\,OFF}} \times 100\%$$

$$\therefore \ \frac{\mathrm{VCAL\,OFF_n}}{\mathrm{VCAL\,OFF}} = 2{,}09 \times 10^{-5}$$

HOWEVER, $\frac{\mathrm{VCAL\,OFF_n}}{\mathrm{VCAL\,OFF}} = \frac{1}{\sqrt{B_n T}}$

WHERE B_n = PREDETECTION EQUIVALENT NOISE BANDWIDTH ASSUMED $= B_{-3dB}$ (HZ)

T = POST DETECTION TIME CONSTANT (SEC)

$$\therefore \ 2{,}09 \times 10^{-5} = \frac{1}{\sqrt{(189 \times 10^3)\,T}}$$

$$\therefore \ T = \frac{1}{189 \times 10^3 (2{,}09 \times 10^{-5})^2}$$

∴ T = 12 112,8 SEC OR $\boxed{3{,}36 \text{ HOURS}}$

WED 7/24/80 -1

IF MAXIMUM % RMS ERROR IN % INCREASE IN POWER AT BASEBAND OUTPUT =

1.0% = 0.01 × 100%, THEN

$$0.01 \times 100\% = 47.85 \frac{VCALOFF_n}{VCALOFF} \times 100\%$$

$$\therefore \frac{VCALOFF_n}{VCALOFF} = 2.09 \times 10^{-4}$$

HOWEVER, $\frac{VCALOFF_n}{VCALOFF} = \frac{1}{\sqrt{B_n T}}$

WHERE B_n = PREDETECTION EQUIVALENT NOISE BANDWIDTH ASSUMED $= B_{-3dB}$ (Hz)

T = POST DETECTION TIME CONSTANT (SEC)

FOR 189 KHz BANDWIDTH,

$$\therefore T = \frac{1}{(189 \times 10^3)(2.09 \times 10^{-4})^2}$$

T = 121.1 SEC OR 2.0 MINUTES

WED 6/17/80 -4

SIMILARLY INTEGRATION TIMES FOR OTHER BANDWIDTHS CAN BE DERIVED:

FILTER #	BANDWIDTH	INTEGRATION TIME τ	
		1,0%	0,1% ACCURACY
0	46 mHz	0,5 s	0,829 MINUTES
1	23	1,0 s	1,66 MINUTES
2	11,5	2,0 s	3,32 MINUTES
3	5,75	4,0 s	6.63 MINUTES
4	2,88	7,9 s	13,2 MINUTES
5	1,438	15,9 s	26,5 MINUTES
6	0,719	31,8 s	53,0 MINUTES
7	0,189	121 s	201,9 MINUTES

(FOR $\tau = \dfrac{1}{4{,}37 \times 10^{-10}\, B_{-3dB}}$ FOR 0,1% RMS ACCURACY

$\tau = \dfrac{1}{4{,}37 \times 10^{-8}\, B_{-3dB}}$ FOR 1,0% RMS ACCURACY

6.0 ACTUAL SYSTEM RESULTS

Most of the compression in the VLA IF transmission system occurs in the T1 Modem Mixer when in transmit. This was previously described in VLA Electronics Memorandum No. 197, "Modem T1 Compression, Early Measurements, Optimization of Channel Selection, and Recommendations", W. E. Dumke, October, 1980.

Because of less waveguide loss than originally planned however, this can be reduced by lowering the modem transmit level to allow for 20 dB S + N/N at each D rack for each Front End rack IF signal. This was attempted with antenna 7 (close to the center of the Wye) in an effort to diagnose other errors. Errors were discovered due to a number of causes. Note that in these measurements the F4 is assumed perfect, which it definitely is not, nor will it be stable with time due to detector design.

WED 6/10/80 -2

FROM 6/9/80-1, 6/9/80-2, 6/9/80-3, 6/2/80-1
COMPRESSION SUMMARY BY SUB-SYSTEM

		A	C
(−)	F4 DETECTOR/T2 RCV IF S/H OFFSET	−[≤ +0,8 %]	−[≤ +0,8 %
	F4 DETECTOR LINEARITY ERROR	?	?
	F4 DCS LSB ERROR (TOTAL)	−[≤ ±0,3 %]	−[≤ ±0,4 %
	F4 COMP. ARITHMETIC ERROR → (DEPENDANT ON AVERAGING)	−[0 %]	−[+1,4 %
(+)	T3 N/S ERROR	−5,0 %	−3,0 %
	T5 DET N/S OFFSET ERROR	≤+1,0 %	≤+3,0 %
	T5 EPF	−1,3 %	−1,5 %
	T5 CDET	−2,7 %	−0,7 %
	T5 DCS LSB ERROR (TOTAL)	≤±0,2 %	≤±0.2 %

(ASSUME T1 XMT/T1 RCV AMP/ T2 RCV AMP COMPRESSION NEGLIGIBLE) TOTAL:

A	C
(−.8)	(−.8)
(±.3)	(±0,4)
0	−1,4
−5,0	−3,0
(+1,0)	(+3,0)
−1,3	−1,5
−2,7	−0.7
(±0,2)	(±0,2)
−9,0 %	−6,6 %
(+1,5 −1,3 %)	(+3,6 −1,4 %

CH.	PREDICTED COMPRESSION	ACTUAL COMPRESSION
A	−7,5 % TO −10,3 %	−7,1 %
C	−3,0 % TO −8,0 %	−8,5 %

CH.	PREDICTED Δ COMP./2dB (T5 IN ALGN)	ACTUAL Δ COMP./2dB (T5 IN ALG)
A	3 %/2dB	2 %/2dB
C	2 %/2dB	2,7 %/2dB

7.0 PRECISION COMPRESSION MEASUREMENT

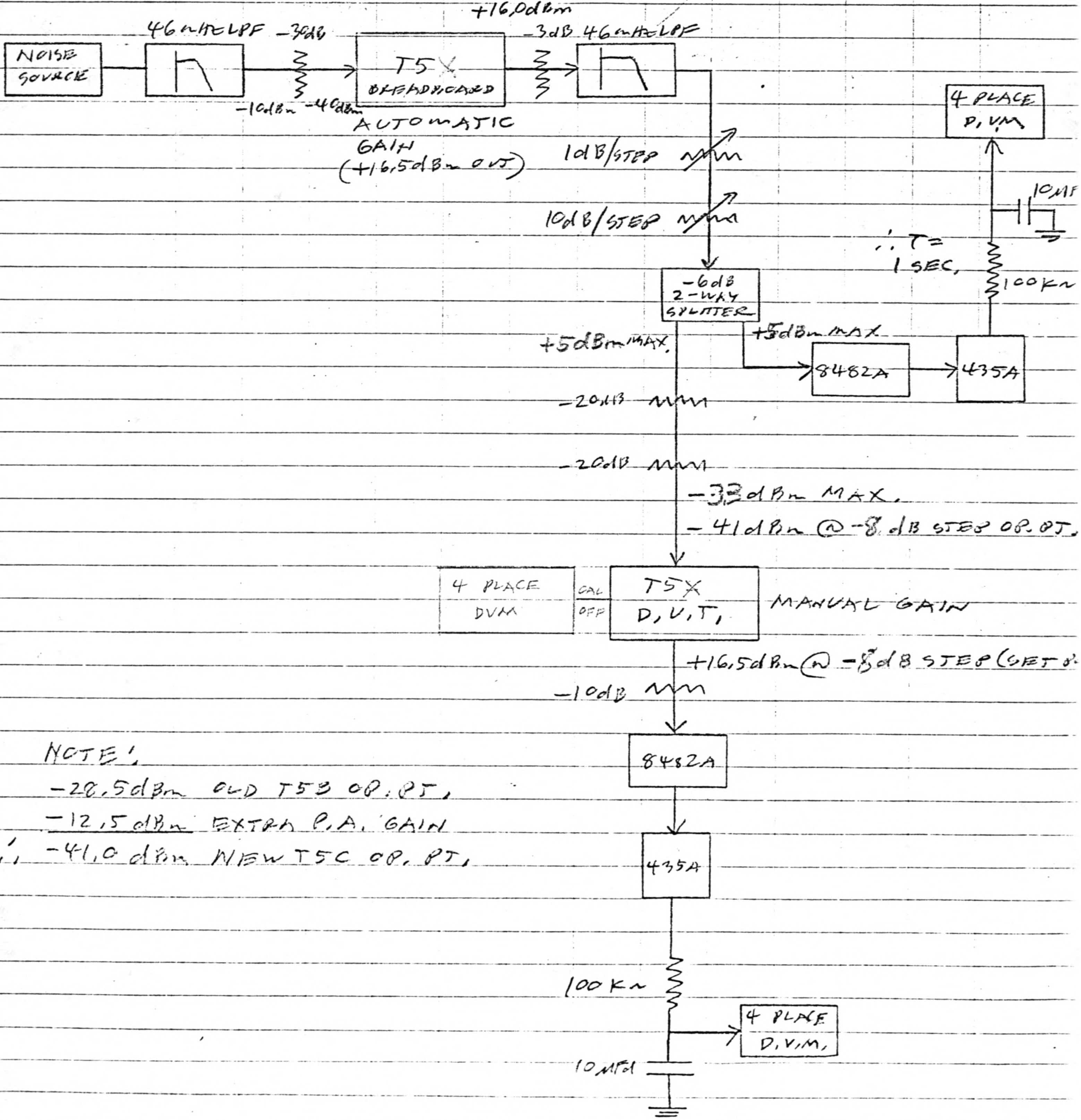
A system was developed for T5 baseband driver compression measurement over a 19 dB dynamic range. Of extreme importance to success are:

1. Linearity in power meters.
2. Simultaneous input and output power measurement.
3. Adequate integration time.
4. Use of broadband noise power rather than sine wave power.
5. Suppression of harmonics from source.
6. Repeatable step attenuators.
7. Accurate absolute power measurement to set reference levels.
8. Adequate input isolation from step attenuators.
9. Four place digital readout for 0.1% maximum error.
10. Operation at high ranges on both power meters.
11. Zero reset of power meters and measurement from lowest level first to minimize drift effects.

An example is given in the following pages. Approximately ½ man/day of calculations are required for one measurement.

~~WED 4/18/80 – 0~~
Tues. 5/13/80 – 3

T5X2 NOISE POWER COMPRESSION TEST SET-UP – ORIG. P.A.
(W/15Ω RESISTOR) – IMPROVED DETECTOR CKT



NOTE:
-28.5dBm OLD T53 OP. PT.
-12.5dBm EXTRA P.A. GAIN
∴ -41.0 dBm NEW T5C OP. PT.

75X21 E/E → 2810 5-13-80

RAW DATA WITH IMPROVED DETECTOR CKT.

ATTENUATOR SETTING		INPUT POWER		INPUT PWR SCALE	OUTPUT POWER		OUTPUT PWR SCALE	
10dB/STEP	1dB/STEP	SCALE A	SCALE B		SCALE A	SCALE B		
0	0		.5122	+10		.8663	+15	13.186
0	-1		.4031	+10		.6961	+15	13.18
0	-2	1.0182	.3215	+5 / +10	.5622	.5622	+15 / +15	13.18
0	-3	.8028		+5	.4476		+15	13.185
0	-4	.6321		+5	.3547		+15	12.22
0	-5	.4982	.4982	+5 / +5	.2809	.8893	+15 / +10	9.783
0	-6		.3974	+5		.7119	+10	7.449
0	-7	.9914	.3131	0 / +5	.5630	.5630	+10 / +10	6.318
0	-8 +16.5dbm output	.7803		0	.4409		+10	5.00
0	-9	.6152		0	.3478		+10	3.966
-10	0	.5070	.5070	0 / 0	.2868	.9049	+10 / +5	3.28
-10	-1		.3993	0		.7131	+5	2.59
-10	-2	1.0077	.3185	-5 / 0	.5698	.5698	+5 / +5	2.081
-10	-3	.7947		-5	.4502		+5	1.648
-10	-4	.6254		-5	.3549		+5	1.303
-10	-5	.4930	.4930	-5 / -5	.2803	.8862	+5 / 0	1.030 1.0320
-10	-6		.3933	-5		.7081	0	.8260
-10	-7	.9824	.3099	-10 / -5	.5592	.5591	0 / 0	.650
-10	-8	.7738		-10	.4413		0	.5138
-10	-9	.6100		-10	.3481		0	.4046

"CAL OFF" OFFSET MEAS.
BY PULLING "RF IN" PLUG

1V SCALE = +.002

10V SCALE = +.0028

5-13-80

②

CALCULATION OF INPUT PWR FACTOR

ATTENUATOR SETTING		INPUT POWER FACTOR TERMS	FACTOR TOTAL
10dB/STEP	1dB/STEP		
0	0		100.578
0	-1		100.578
0	-2	$\times \frac{1.0182}{.3215}$	100.578
0	-3		31.758
0	-4		31.7581
0	-5		31.7581
0	-6		31.7581
0	-7	$\times \frac{.9914}{.3131}$	31.7581
0	-8		10.0297
0	-9		10.0297
-10	0		10.0297
-10	-1		10.0297
-10	-2	$\times \frac{1.0077}{.3185}$	10.0297
-10	-3		3.1701
-10	-4		3.1701
-10	-5		3.1701
-10	-6		3.1701
-10	-7	$\frac{.9824}{.3099}$	3.1701
-10	-8		1
-10	-9		1

5-13-80

CALCULATION OF OUTPUT PWR FACTOR

ATTENUATOR SETTING		OUTPUT POWER FACTOR TERMS	FAC TOTAL
10dB/STEP	1dB/STEP		
0	0		31.581
0	-1		31.5
0	-2		31.58
0	-3		31.5811
0	-4		31.58
0	-5	$\times \frac{.8893}{.2809}$	31.581
0	-6		9.975
0	-7		9.9754
0	-8		9.975
0	-9		9.975
-10	0	$\times \frac{.9049}{.2868}$	9.97
-10	-1		3.161
-10	-2		3.161
-10	-3		3.161
-10	-4		3.1616
-10	-5	$\frac{.8862}{.2803}$	3.161
-10	-6	1	1
-10	-7	1	1
-10	-8	1	1
-10	-9	1	1

5-13-80 ④

NORMALIZATION OF POWER LEVELS

ATTENUATOR SETTING		INPUT POWER	INPUT FACTOR	NORM. INPUT POWER	OUTPUT POWER	OUTPUT FACTOR	NORM. OUTPUT POWER
10dB/STEP	1dB/STEP						
0	0	.5122	100.5788	51.5165	.8663	31.5811	27.3587
0	-1	.4031	100.5788	40.5433	.6961	31.5811	21.9836
0	-2	.3215	100.5788	32.3361	.5622	31.5811	17.7549
0	-3	.8028	31.7581	25.4954	.4476	31.5811	14.1357
0	-4	.6321	31.7581	20.0743	.3547	31.5811	11.2018
0	-5	.4982	31.7581	15.8219	.2809	31.5811	8.8711
0	-6	.3974	31.7581	12.6207	.7119	9.9754	7.1015
0	-7	.3131	31.7581	9.9435	.5630	9.9754	5.6162
0	-8	.7803	10.0297	7.8262	.4409	9.9754	4.3982
0	-9	.6152	10.0297	6.1703	.3478	9.9754	3.4694
-10	0	.5070	10.0297	5.0851	.2868	9.9754	2.8609
-10	-1	.3993	10.0297	4.0049	.7131	3.1616	2.2545
-10	-2	.3185	10.0297	3.1945	.5698	3.1616	1.8015
-10	-3	.7947	3.1701	2.5193	.4502	3.1616	1.4234
-10	-4	.6254	3.1701	1.9826	.3549	3.1616	1.1221
-10	-5	.4930	3.1701	1.5629	.2803	3.1616	.8862
-10	-6	.3933	3.1701	1.2468	.7081	1	.7081
-10	-7	.3099	3.1701	.9824	.5591	1	.5591
-10	-8	.7738	1	.7738	.4413	1	.4413
-10	-9	.6100	1	.6100	.3481	1	.3481

5-13-80

CALCULATION OF RF COMPRESSION = $\epsilon_{OUT} - \epsilon_{IN}$

ATTENUATOR SETTING		NORM. INPUT POWER	INPUT SHOULD BE:	ϵ_{IN}	NORM. OUTPUT POWER	OUTPUT SHOULD BE:	ϵ_{OUT}	$\epsilon_{OUT} - \epsilon_{IN}$ (ϵ_{RF})
10dB/STEP	1dB/STEP							
0	0	51.5165	48.4540	+6.3	27.3587	27.6506	−1.1	−7.4
0	−1	40.5433	38.4884	+5.3	21.9836	21.9636	+.1	−5.2
0	−2	32.3361	30.5724	+5.8	17.7549	17.4463	+1.8	−4.0
0	−3	25.4954	24.2845	+5.0	14.1357	13.8581	+2.0	−3.0
0	−4	20.0743	19.2899	+3.9	11.2018	11.0079	+1.8	−2.1
0	−5	15.8219	15.3225	+3.3	8.8711	8.7439	+1.5	−1.8
0	−6	12.6207	12.1711	+3.7	7.1015	6.9455	+2.3	−1.4
0	−7	19.9435	9.6678	+2.9	5.6162	5.5170	+1.8	−1.1
0	−8	7.8262	7.6794	+1.9	4.3982	4.3823	+.4	−1.5
0	−9	6.1703	6.1000	+1.2	3.4694	3.4810	−.3	−1.5
−10	0	5.0851	4.8454	+5.0	2.8609	2.7651	+3.5	−1.5
−10	−1	4.0049	3.8488	+4.1	2.2545	2.1964	+2.7	−1.4
−10	−2	3.1945	3.0572	+4.5	1.8015	1.7446	+3.3	−1.2
−10	−3	2.5193	2.4285	+3.7	1.4234	1.3858	+2.7	−1.0
−10	−4	1.9826	1.9290	+2.8	1.1221	1.1008	+1.9	−.9
−10	−5	1.5629	1.5323	+2.0	.8862	.8744	+1.3	−.7
−10	−6	1.2468	1.2171	+2.4	.7081	.6946	+1.9	−.5
−10	−7	.9824	.9668	+1.6	.5591	.5517	+1.3	−.3
−10	−8	.7738	.7679	+.8	.4413	.4382	+.7	−.1
−10	−9	.6100	.6100	0	.3481	.3481	0	0

5-13-80

⑥

CAL OFF
CALCULATION OF ~~INPUT~~ PWR FACTOR

ATTENUATOR SETTING		INPUT POWER FACTOR TERMS	FACTOR TOTAL
10dB/STEP	1dB/STEP		
0	0		1.0019
0	-1		1.0019
0	-2		1.0019
0	-3		1.0019
0	-4		1.0019
0	-5		1.0019
0	-6		1.0019
0	-7		1.0019
0	-8		1.0019
0	-9		1.0019
-10	0		1.0019
-10	-1		1.0019
-10	-2		1.0019
-10	-3		1.0019
-10	-4		1.0019
-10	-5	$\frac{1.0320}{1.030}$	1.0019
-10	-6	1	1
-10	-7	1	1
-10	-8	1	1
-10	-9	1	1

5-13-80

NORMALIZATION OF ~~POWER~~ CAL OFF LEVELS

ATTENUATOR SETTING		INPUT POWER	INPUT FACTOR	NORM. INPUT POWER	~~OUTPUT POWER~~ CAL OFF	CAL OFF ~~OUTPUT~~ FACTOR	NORM. ~~OUTPUT POWER~~ CAL OFF	
10dB/STEP	1dB/STEP							
0	0				13.186	1.0019	13.2111	
0	−1				13.186		13.2111	
0	−2				13.186		13.2111	
0	−3				13.185		13.2101	
0	−4				12.222		12.2452	
0	−5				9.284		9.8016	
0	−6				7.949		7.9641	
0	−7				6.318		6.3300	
0	−8				5.000		5.0095	
0	−9				3.966		3.9735	
−10	0				3.284		3.2902	
−10	−1				2.599		2.6039	
−10	−2				2.081		2.0850	
−10	−3				1.648		1.6511	
−10	−4				1.303		1.3055	
−10	−5				1.030	1.0019	1.0320	
−10	−6				.8260	1	.8260	
−10	−7				.6507	1	.6507	
−10	−8				.5138	1	.5138	
−10	−9				.4046	1	.4046	

5-13-80/

⑧

CAL OFF
CALCULATION OF CAL OFF COMPRESSION = $\epsilon_{OUT} - \epsilon_{IN}$

$\epsilon_{CAL\ OFF}$ =

ATTENUATOR SETTING		NORM. INPUT POWER	INPUT SHOULD BE:	ϵ_{IN}	NORM. ~~OUTPUT~~ ~~POWER~~ CAL OFF	~~OUTPUT~~ SHOULD BE:	CAL OFF ϵ_{OUT}	$\epsilon_{CAL\ OFF}$ $\epsilon_{OUT} - \epsilon_{IN}$
10dB/STEP	1dB/STEP							
0	0			+6.3	13.2111	32.1385	−58.9	−65.2
0	−1			+5.3	13.2111	25.5285	−48.3	−53.6
0	−2			+5.8	13.2111	20.2780	−34.9	−40.7
0	−3			+5.0	13.2101	16.1074	−18.0	−23.0
0	−4			+3.9	12.2452	12.7946	−4.3	−8.2
0	−5			+3.3	9.8016	10.1631	−3.6	−6.9
0	−6			+3.7	7.9641	8.0728	−1.4	−5.1
0	−7			+2.9	6.3300	6.4125	−1.3	−4.2
0	−8			+1.9	5.0095	5.0936	−1.7	−3.6
0	−9			+1.2	3.9735	4.0460	−1.8	−3.0
−10	0			+5.0	3.2902	3.2139	+2.4	−2.6
−10	−1			+4.1	2.6039	2.5529	+2.0	−2.1
−10	−2			+4.5	2.0850	2.0278	+2.8	−1.7
−10	−3			+3.7	1.6511	1.6107	+2.5	−1.2
−10	−4			+2.8	1.3055	1.2795	+1.6	−1.2
−10	−5			+2.0	1.0320	1.0163	+1.5	−.5
−10	−6			+2.4	.8260	.8073	+2.3	−.1
−10	−7			+1.6	.6507	.6412	+1.5	−.1
−10	−8			+.8	.5138	.5094	+.9	+.1
−10	−9			0	.4046	.4046	0	0

5-13-80 /

EDET = ECALOFF – ER

CALCULATION OF DETECTOR COMPRESSION = ~~EOUT~~ = ~~EIN~~

ATTENUATOR SETTING 10dB/STEP	ATTENUATOR SETTING 1dB/STEP	NORM. INPUT POWER	INPUT SHOULD BE:	~~EIN~~ ERF	NORM. OUTPUT POWER	OUTPUT SHOULD BE:	~~EOUT~~ ECAL OFF	ECALOFF – ~~EOUT –~~ EDET
0	0			-7.4			-65.2	-57.8
0	-1			-5.2			-53.6	-48.4
0	-2			-4.0			-40.7	-36.1
0	-3			-3.0			-23.0	-20.0
0	-4			-2.1			-8.2	-6.1
0	-5			-1.8			-6.9	-5.1
0	-6			-1.4			-5.1	-3.7
0	-7			-1.1			-4.2	-3.1
0	-8			-1.5			-3.6	-2.1
0	-9			-1.5			-3.0	-1.5
-10	0			-1.5			-2.6	-1.1
-10	-1			-1.4			-2.1	-.7
-10	-2			-1.2			-1.7	-.5
-10	-3			-1.0			-1.2	-.2
-10	-4			-.9			-1.2	-.3
-10	-5			-.7			-.5	+.2
-10	-6			-.5			-.1	+.4
-10	-7			-.3			-.1	+.2
-10	-8			-.1			+.1	0
-10	-9			0			0	0

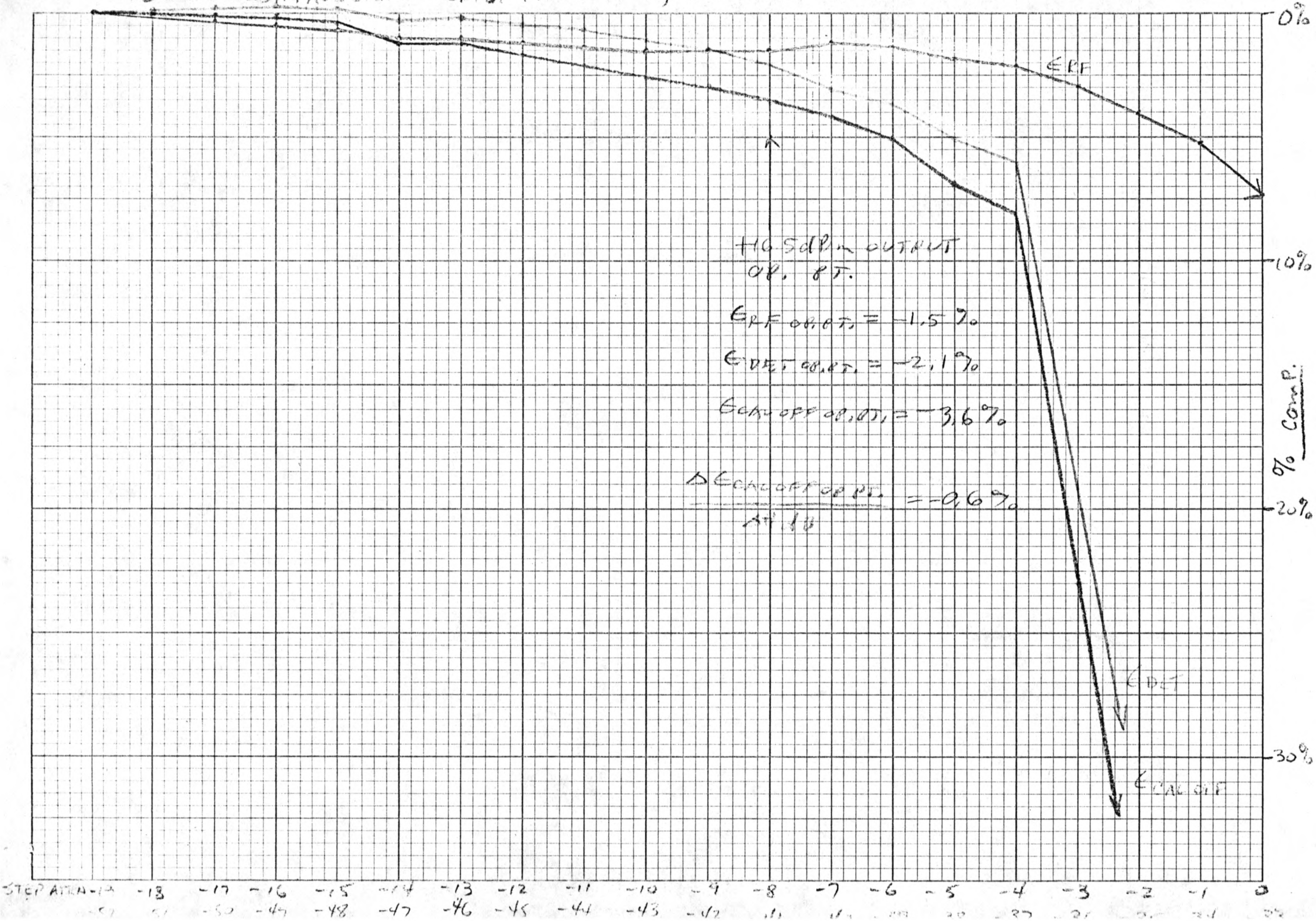
5 - 8

110

10 X 10 TO THE INCH • 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

46 0780

75 x 21 COMPRESSION - OPTS. 10 DB AMP, IMPROVED DETECTOR SET



H6 5dBm OUTPUT
OP. PT.

$\epsilon_{RF\ OP.PT.} = -1.5\%$

$\epsilon_{DET\ OP.PT.} = -2.1\%$

$\epsilon_{CAL\ OFF\ OP.PT.} = -3.6\%$

$\frac{\Delta\epsilon_{CAL\ OFF\ OP.PT.}}{AT\ 18} = -0.6\%$

8.0 AUTOMATED COMPRESSION MEASUREMENT

A proposed system is presented that would be compatable with a number of different RF systems. Interchangeable components are within the dashed lines.

R.F. HDW

*B535	$2850	436A(OP 22)	$2575
*A535	+2850	*432C	$2400
8494G OP. 002	+865		
8495G OP. 002	+720		
8494G OP. 003	+865		
8495G OP. 003	+720		
HP 11667A	+600		
8761B-556	+220		

$14,665 R.F. HDW

INTERFACE

3497A	2450
OP. 1	+1500
OP. 10	+500
OP. 110	+550
OP. 110	+550

$5550 INTERFACE

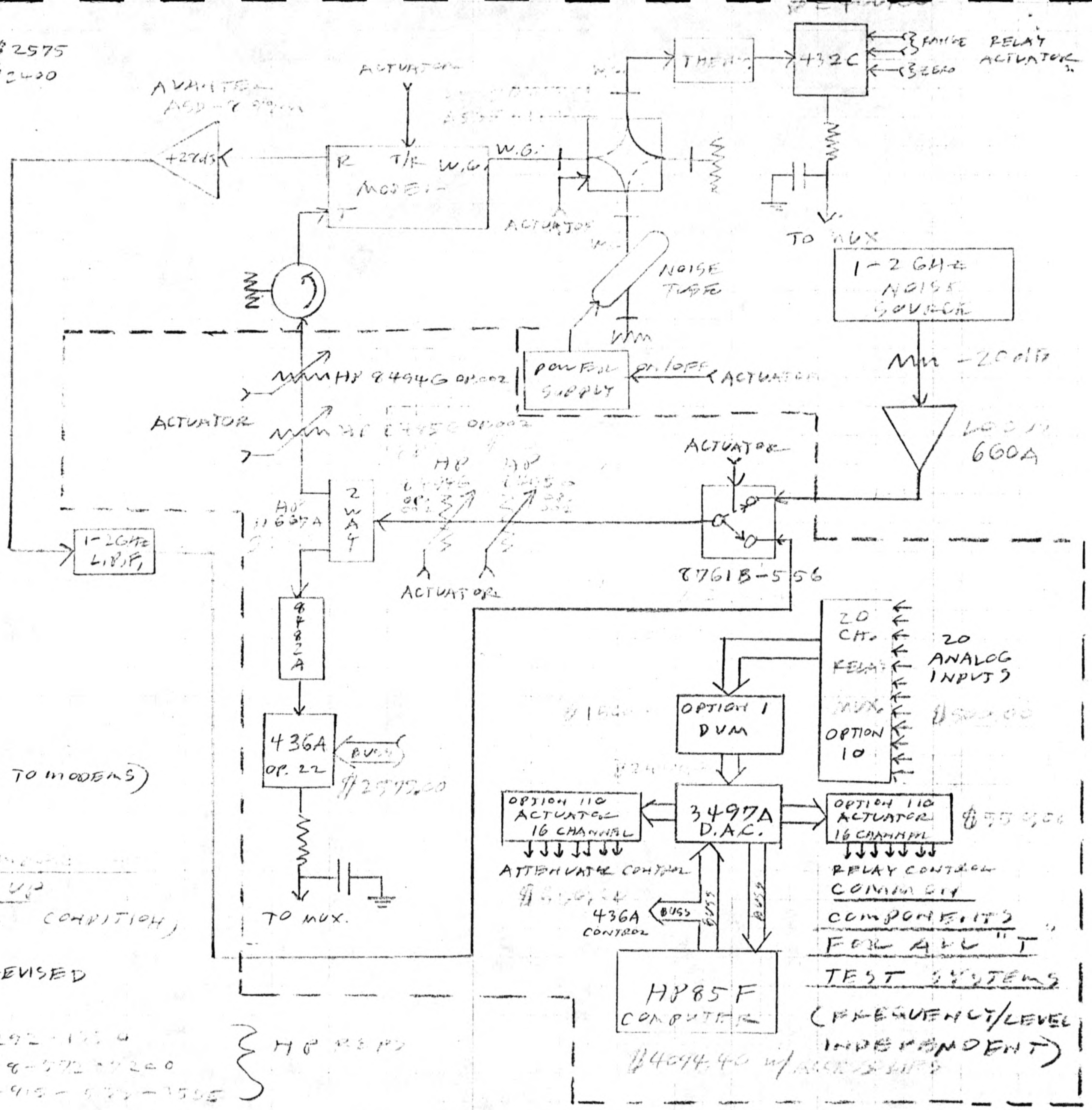
COMPUTER

HP.85F $4094.40 W/ACC.

14,665.00
5,550.00
4,094.40

$24,309.40 TOTAL

(*$8100 OF WHICH IS DEDICATED TO MODEMS)



PROPOSED MODEM

BASE [illegible] COMPARE [illegible]

MEASUREMENT SET-UP

(SHOWN IN NOISE FIGURE CONDITION)

M.S.D, 6/27/80 REVISED

[illegible] [illegible]ETZ [illegible] 292-[illegible]
TOM ACKER [illegible] 8-[illegible]-[illegible]260
1-915-[illegible]-[illegible]

HP REPS