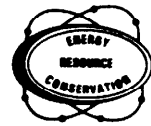


INTERDEPARTMENTAL CORRESPONDENCE



TO: Manny Olmedo
ORG: 14-53-22

J.B. Adams
J.N. Bruner
cc: M.A. Dalla Valle
L.D. Hall
D.S. Schenk
P.R. VonBurke

DATE: September 20, 1983
REF: 83/1453.22/54

SUBJECT: FSD Fast Frequency Synthesizer

FROM: J.A. Crawford
BLDG: 600 MAIL STA.: G156
EXT: 2-1294 ORG. CODE: 14-53-22

Design philosophy for the frequency translation scheme used in the synthesizer has converged upon the design addressed here in. In an attempt to reduce the parts count external to the Timing Sample and Hold (TS&H) hybrid, the VCO coarse tune circuitry has also been redesigned. Design rationale and breadboard test results are included in the discussion.

J.A. Crawford, Head
Synthesizer Group
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JAC/dr

Frequency Translation. The frequency synthesizer mix-down scheme must reliably translate the VCO band of frequencies at L-Band (1275-1530 MHz) down to the operating window of the 11C90 dual modulus counter (this is the fastest 10/11 dual modulus counter presently available). The mix-down operation has traditionally been done by a high side mixing operation using a Local Oscillator (LO) at 1872 MHz. This resulted in the 11C90 divider seeing frequencies from 342 to 597 MHz. However, over temperature, (-55° to +125° C) the 11C90 is guaranteed to only work up to 550 MHz. In actual tests, very low yields over the full temperature will result if the 11C90 must operate at the 597 MHz frequency extreme.

A decision was made in June, 1983 to lower the LO frequency to 1800 MHz so that the frequency window as seen by the 11C90 would be reduced to 270 to 525 MHz. Comments made to support this change were made to M.S. Olmedo in the form of an AVO. Portions of this AVO and other supportive material are provided in Appendix I.

The candidate mix-down scheme is given in Figure 1. Notable changes to the earlier design are:

1. inclusion of pads in the filters to reduce VSWR mismatches
2. inclusion of limiting amplifier to solidify the power window excursions into the 11C90 divider

Temperature tests of 7 FSD Prime Mission Equipment (PME) divide-by-N hybrids with the imbedded 11C90 were done to insure that the required power window requirements were accurately known. In general, and without exception, the power window width permissible into the 11C90 for proper operation widens at lower temperature. From a production standpoint, it would be invaluable to know how this power window behaves over frequency and temperature. Statistical measures seem applicable.

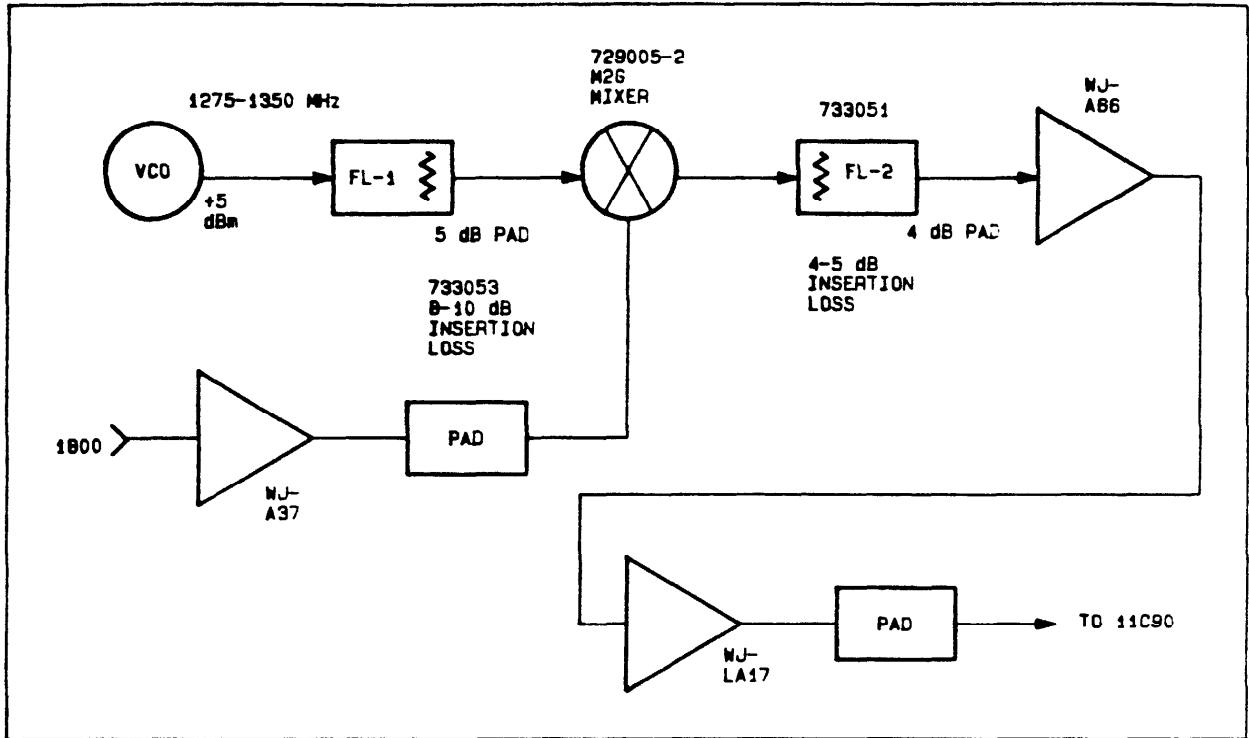


Figure 1. Improved Frequency Translation Scheme for the Fast Frequency Synthesizer

The permissible power window widens sharply for low frequency use and therefore, the low frequency extreme is not at issue (See Fairchild ECL data book). Measurements for the 7 divider units follow:

TABLE I. DIVIDE-BY-N POWER WINDOW BOUNDARIES FOR OPERATION
AT 105°C AIR TEMPERATURE AND INPUT FREQUENCY 525 MHz; MIN
AND MAX POWER LEVELS READ FROM HP8662 SOURCE PANEL

Window Boundaries, dBm				
S/N	Min	MAX	Center	Width
6	1.3	7.5	4.4	6.2
20	-0.2	6.1	3.0	6.3
23	0.0	5.7	2.9	7.2
24	-0.7	6.5	2.9	7.2
27	1.3	6.8	4.1	5.5
28	-0.2	6.5	3.2	6.7
29	0.9	6.5	2.8	5.6

The data in Table I was arrived at by exciting the hybrid while in its test fixture using an HP8662 source and noting when proper device operation ceased. The data accuracy depends upon the accuracy of the HP8662 power readings (± 1 dB absolute level accuracy) and the 3 ft. approximately of RG coax between the source and test fixture. Although the absolute power levels have an uncertainty of ± 1 dB over the full range of the HP8662, relative accuracy over the 0-7 dB range here is anticipated from brief evaluation to be significantly better. Improved accuracy would demand the use of a power meter.

First and second order statistics for Table 1 data provide the following useful information:

- 1) $\overline{\text{window center}} = 3.33 \text{ dBm}$
- 2) $\sigma^2 [\text{window center}] = E(x^2) - (\bar{X})^2 = 0.3497$
- 3) $\sigma_{wc} = 0.59 \text{ dBm}$
- 4) $\overline{\text{window width}} = 6.17 \text{ dBm}$
- 5) $\sigma^2 [\text{window width}] = 0.354$
- 6) $\sigma_{ww} = 0.59 \text{ dBm}$

If the statistics are assumed to be normal, 95.5% of the devices will lie within 2σ of the mean. With a high degree of confidence, most of the devices will have

$$\text{center of window} = 3.33 \text{ dBm} \pm 1.2 \text{ dB}$$

$$\text{width of window} = 6.17 \text{ dB} \pm 1.2 \text{ dB}$$

To insure that a low window maximum level rarely occurs with a high window minimum level, the window width statistic is adequate. It is insightful however to examine the window edge statistics too.

$$\left. \begin{array}{l} 7) \overline{\text{window min}} \\ 8) \sigma [\text{window min}] \\ 9) \overline{\text{window max}} \\ 10) \sigma [\text{window max}] \end{array} \right\} \begin{array}{l} = 0.343 \text{ dBm} \\ = 0.75 \text{ dB} \\ = 6.51 \text{ dBm} \\ = 0.57 \text{ dB} \end{array} \quad \begin{array}{l} @ 105^\circ\text{C} \\ 525 \text{ MHz} \end{array}$$

Data on the same devices was taken at the low temperature extreme to guarantee that the window did not move with temperature. This data is given in Table II.

TABLE II. DIVIDE-BY-N POWER WINDOW BOUNDARIES AT
-55°C AIR TEMPERATURE AND INPUT FREQUENCY OF 525 MHz

S/N	Window Boundaries, dBm			
	MIN	MAX	Center	Width
6	-2.8	8.0	2.6	10.8
20	-4.9	6.4	0.75	11.3
23	-5.0	5.9	0.45	10.9
24	-4.5	6.7	1.1	11.2
27	-3.9	6.9	1.5	10.8
28				
29	-4.6	6.5	0.95	11.1

← failed at -45°C

The same statistical measures may be applied to Table II. In this case,

11)	<u>window center</u>	= 1.23 dBm	} @ -55°C f _{in} = 525 MHz
12)	σ[window center]	= 0.68 dB	
13)	<u>window width</u>	= 11.02 dB	
14)	σ[window width]	= 0.18 dB	
15)	<u>window min</u>	= -4.28 dBm	
16)	σ[window min]	= 0.77 dB	
17)	<u>window max</u>	= 6.73 dBm	
18)	σ[window max]	= 0.68 dB	

The situation is best presented in graphical form as in Figure 2.

Based upon the results given in Figure 2, a 96 percent yield will be possible provided that the mixdown can reliably provide $3.62 \text{ dBm} \pm 1.78 \text{ dB}$ to the 11C90.

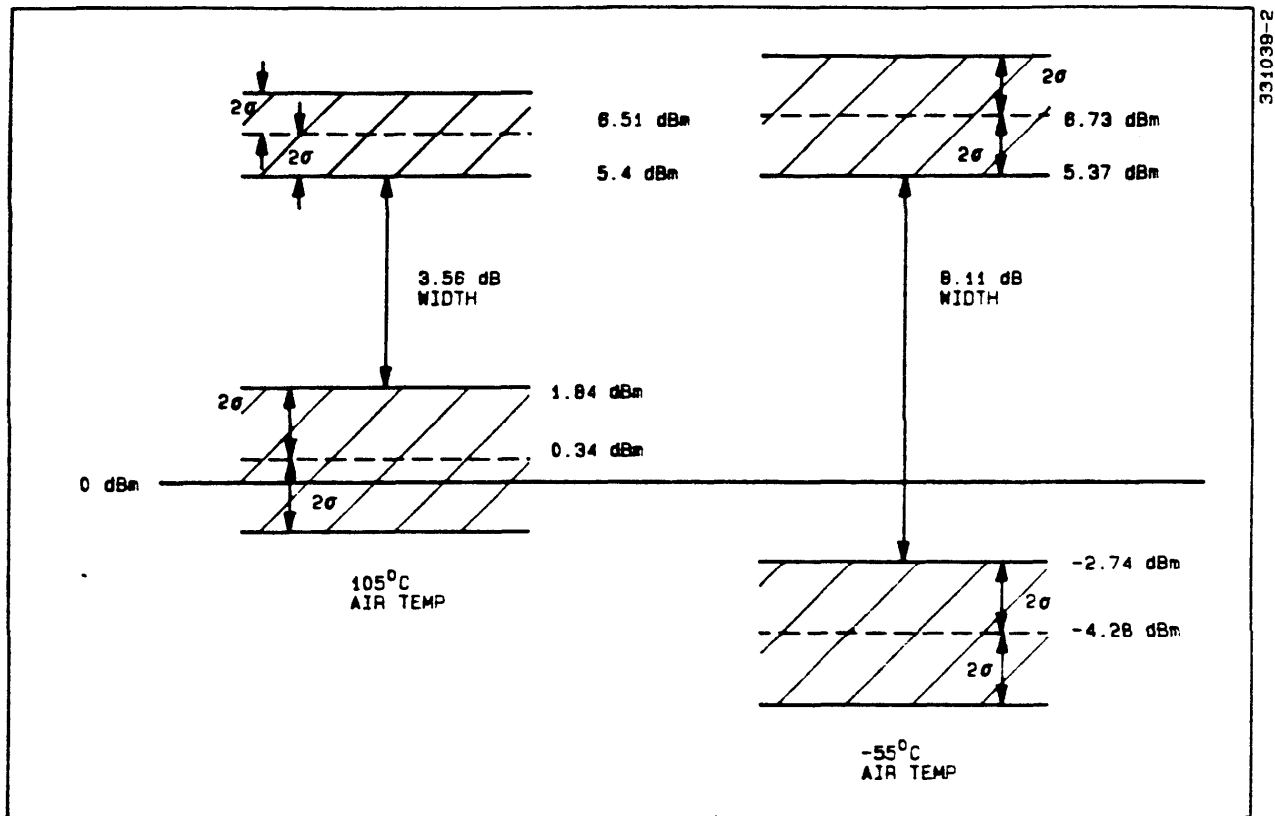


Figure 2. The Permissible Power for the %N Clearly Widens at Low Temperature. The upper boundary is quite constant with temperature.

Spurious Analysis. The mixdown output signal is intended to drive a digital divide-by-N device, ideally a threshold device. Spurious signals in this realm will be time coherent with the desired signal. Problems can occur if the spurious level causes periodic double clocking, or missed counts by the $\frac{1}{N}$.

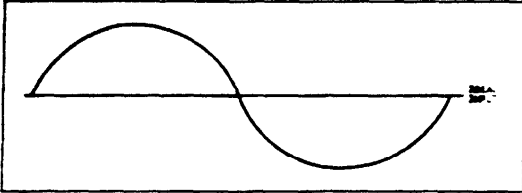


Figure 3.

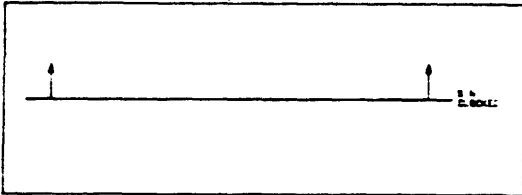


Figure 4.

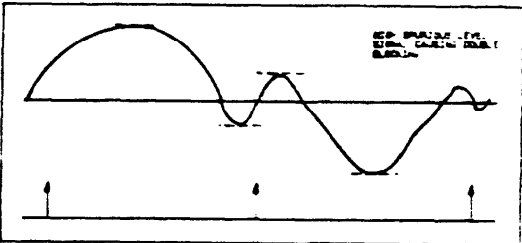


Figure 5.

Double clocking can be examined by counting the number of and location of derivative sign changes. Consider the following (see Egan)

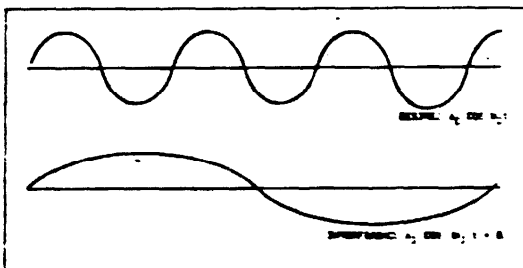


Figure 6.

The sum of the two is then

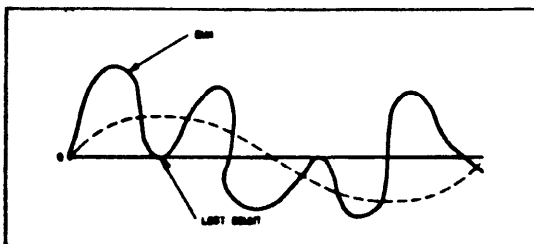


Figure 7.

Lost counts will occur wherever

i) function value is zero

and

ii) function slope is zero

$$19) V_s(t) = A_D \cos(\omega_D t) + A_I \cos(\omega_I t + \theta)$$

$$20) \frac{A_D}{A_I} = \frac{\cos(\omega_I t + \theta)}{\cos(\omega_D t)} \text{ with } V_s(t) \equiv 0$$

$$21) -\frac{dV_s}{dt} = A_D \omega_D \sin(\omega_D t) + \omega_I A_I \sin(\omega_I t + \theta) \equiv 0$$

$$22) \frac{A_D \omega_D}{A_I \omega_I} = -\frac{\sin(\omega_I t + \theta)}{\sin(\omega_D t)}$$

or

$$23) \frac{A_D}{A_I} = -\frac{\omega_I \sin(\omega_I t + \theta)}{\omega_D \sin(\omega_D t)}$$

Using equations 20) and 23), lost counts will occur for

$$24) \left(\frac{A_D}{A_I}\right)^2 = 1 + \left[\left(\frac{\omega_I}{\omega_D}\right)^2 - 1\right] \sin^2(\omega_I t + \theta)$$

This basically boils down to the fact that counts can be corrupted if the time derivative of the interfering signal is greater than that of the desired signal.

If the divider "threshold" is non zero, an interfering signal will more easily corrupt a zero crossing.

The bandwidth out of the bandpass filter is roughly 250 MHz to 550 MHz, so at most,

$$25) \frac{W_I}{W_D} \leq 2$$

Since the maximum value of $\sin(\cdot)$ is 1, a spur can corrupt the ideal zero crossing provided

$$26) \left(\frac{A_D}{A_I} \right)^2 > 1 + \left[\left(\frac{W_I}{W_D} \right)^2 - 1 \right]$$

$$> 1 + [4 - 1]$$

$$> 4$$

i.e., interfering signal must be greater than -6 dBc

The spurious analysis is included in Appendix I. Under no circumstances will any spur be even close to -6 dBc so we can be sure of system spur integrity inside the synthesizer mixdown. We must only keep the divider threshold as near to the sine wave mid-point as possible.

Consider Figure 8. If the interfering signal is not quite as large, no counts will be lost, yet the zero crossings will still be time modulated. If this modulation time period (period of interfering signal) is not

i) exactly $1/n * T_{REF}$ where n is an integer > 0

ii) $n > 1$, divider ratio

the modulation will be seen at the divider output

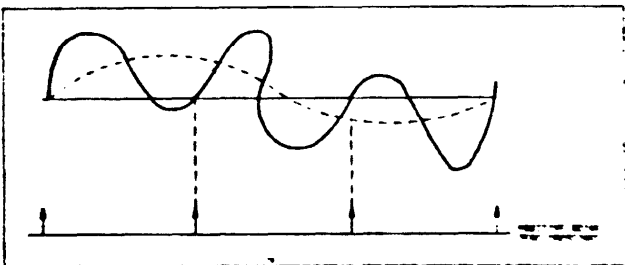


Figure 8.

The signal in Figure 8 may be written once again as

$$27) V_s(t) = A_D \cos(W_D t) + A_I \cos(W_I t + \theta)$$

$$28) \quad = A_D \left[\cos(W_D t) + \left(\frac{A_I}{A_D} \right) \cos(W_I t + \theta) \right]$$

Lets look at conditions i) and ii) above.

$$29) \quad \begin{array}{ll} \text{SIG} & \equiv \text{Synthesizer output frequency} \\ (\text{LO-SIG}) & \equiv \text{frequency of desired mixing product} \end{array}$$

$$30) \quad N = \frac{\text{LO-SIG}}{3 \text{ MHz}} \quad \equiv \text{feedback divider ratio}$$

$$31) \quad [\pm n \text{ LO } \pm m \text{ sig}] \quad \equiv \text{frequency of all possible spurs from 29)}$$

$$32) \quad \text{LO} = \text{Desired} + \text{SIG}$$

Substituting equation 32) into 31)

$$33) \quad \text{Spur frequency} = \pm n (\text{desired} + \text{SIG}) \pm m \text{ sig}$$

$$34) \quad = \underbrace{(\pm n \pm m) \text{ sig}}_{\substack{\uparrow \\ \text{a perfect} \\ \text{multiple of} \\ 3 \text{ MHz}}} \quad \underbrace{\pm n \text{ Desired}}_{\substack{\uparrow \\ \text{a perfect} \\ \text{multiple of} \\ 3 \text{ MHz}}}$$

all spurs @ perfect multiples of 3 MHz

Based upon item ii), as long as the spur frequency is not < 3MHz, there is no problem. The only possible spur frequency below 3MHz from (33) is 0 MHz which presents no problem. It is very fortunate that all sources in the system are perfect multiples of 3MHz. For the more general problem of Figure 8, the zero crossings could be found by passing $V_S(t)$ through an ideal limiter.

Another way to look at the divider situation is that of ideal impulse sampling. If we assume that a divider can be modeled as

Fig. 9 $\theta_i \boxed{\frac{1}{N}} \rightarrow \frac{\theta_i}{N}$

then the output from the ideal sampling θ -detector would be

$$35) \quad V_{out}^*(S) = \frac{1}{T} \sum_{n=-\infty}^{\infty} V_S(S + jnW_s)$$

This clearly indicates that if any frequency component is not an exact multiple of the reference frequency, it will be folded in about zero frequency and its presence felt.

Literature indicates that the division process of Figure 9 reduces spurious components more typically by $2N^2$ compared to the anticipated N^2 (IEEE AES-10 July, 74 p. 436).

As mentioned earlier, the presence of an interfering signal will effect the zero crossings into a divider but under certain constraints i) and ii) and the fact that all signals are coherently related to 3 MHz, the effects can be ignored.

Since the zero crossings are the prime concern because they carry all of the frequency information as far as the divider is concerned, we could compute the output spectrum if we knew where all of the zero crossings were. This is in general, not an easy task. It is more expedient to compute the time correlation function of the extreme clipping case and then calculate the spectral density using the Wiener-Kinchin theorem.

The result of extreme clipping is to make the output correlation function $2/\pi$ times the arc sine of the original correlation function before clipping (Van Vleck Proc. IEEE 54(1) 1966).

$$36) R(t) = \frac{2}{\pi} \text{Sin}^{-1} (r)$$

This approach could be further pursued, but is not needed at this time.

In conclusion, spurious terms resulting from the mixing operation should cause no problems whatsoever since they will be perfect harmonics of the reference frequency, and at least -40dBc.

IN Input Impedance. The return loss for 6 PME IN was measured on a network analyzer. The measurements were all done at room temperature. The poorest return loss occurred at the high frequency end, worse case being ~ 9.5 dB. This translates to a worse case VSWR of ~ 2.01. The incurred "loss" is included in all the previous window measurements.

Efforts to match the input better at high frequency did improve the VSWR, but the power window was left unchanged.

Based upon the worse-case 2:1 VSWR and the fact that the mismatch loss is embedded in the earlier window measurements, no problems are anticipated due to the 11C90 input impedance mismatch.

Gain Profiles. Gain profiles are the subject of the next several pages. The source data for these calculations was:

VCO	Output VSWR < 1.5	assumed
	Output power + 5dBm + 1.5dB	assumed
	(power window hypothetically widened to relieve spec)	

FL-1	Insertion Loss 9dB + 1dB Input VSWR \leq 1.4 Output VSWR \leq 1.4	733053 733053 733053
M2G	Max. Conversion Loss 8.5dB Min. Conversion Loss 7dB Input VSWR 1.9-2.6 Output VSWR 1.9-2.6	729005-2 assumed 729005-2 729005-2
FL-2	Insertion Loss 4.5dB + 0.5dB Input VSWR \leq 1.5 Output VSWR \leq 1.5	733051 733051 733051
A-66	Gain min 22dB max 28dB Input VSWR \leq 1.8 Output VSWR \leq 1.8 Compression Point 14dBm	725122 assumed 725122 725122 725122
LA-17	Input VSWR \leq 2	assumed

The min-max again profile is given in Figure 10. This figure does not include any VSWR mismatch losses.

Mismatch loss calculations require some additional care. The loss due to a mismatch between source and load is worse case

$$37) \frac{(1 - |\Gamma_L|^2)(1 - |\Gamma_S|^2)}{(1 + |\Gamma_L \Gamma_S|)^2}$$

where Γ is the respective load or source reflection coefficient. The mixer case is a bit more involved and it is best to refer back to the general equation for transducer gain.

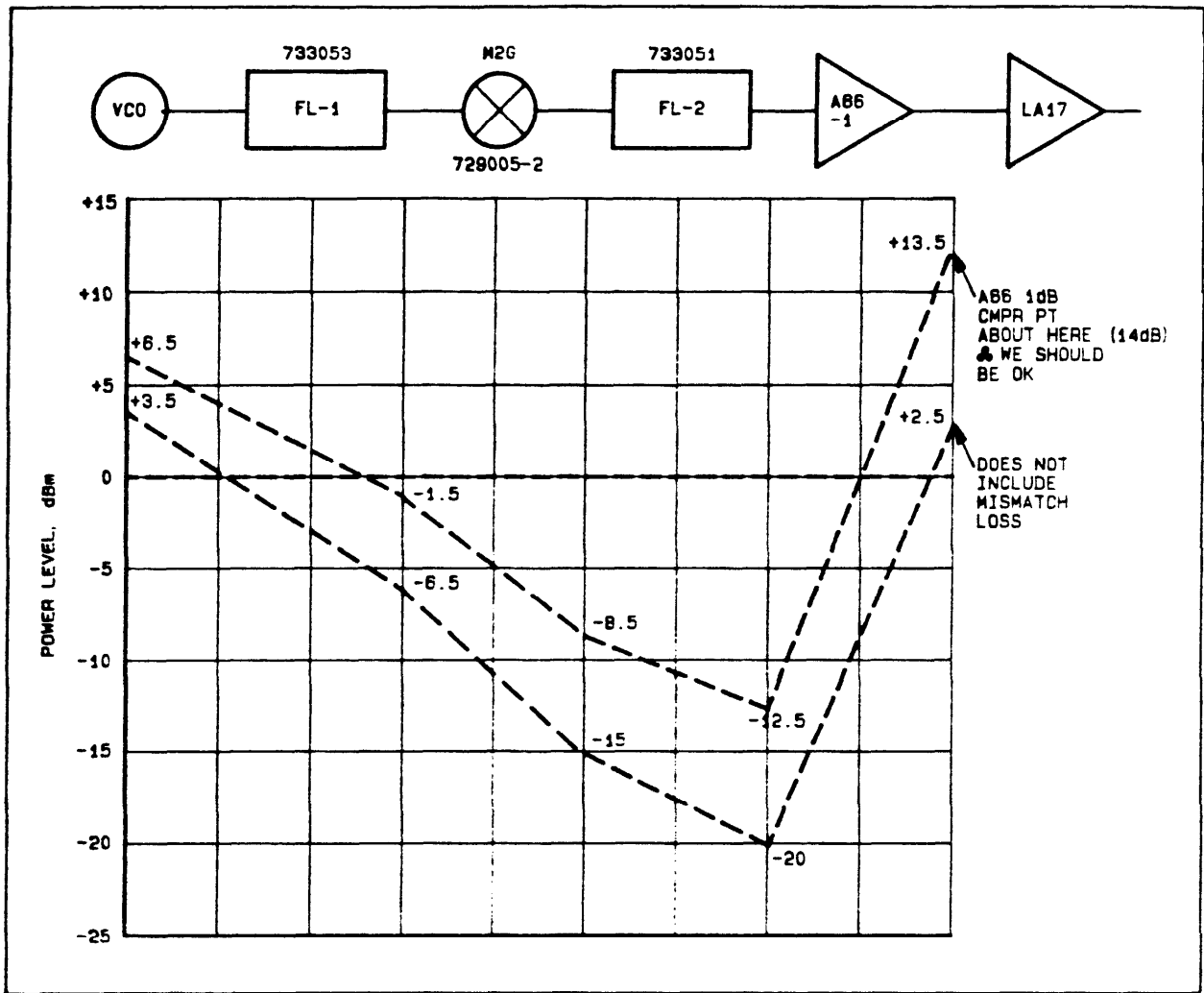
$$38) G_T = \frac{|S_{21}|^2 (1 - |\Gamma_S|^2)(1 - |\Gamma_L|^2)}{|(1 - S_{11}\Gamma_S)(1 - S_{22}\Gamma_L) - S_{12}S_{21}\Gamma_L\Gamma_S|^2}$$



In a 50 ohm system, $\Gamma_S = \Gamma_L \equiv 0$ and

$$G_{T50} = |S_{21}|^2$$

which is the specified maximum 8.5 dB conversion loss. (Conversion loss is specified in a 50 ohm system.)



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Figure 10. Mix-Down Gain Profile

For the mixer, $S_{12} \sim S_{21}$ and are both small. Therefore, given that the product $S_{12} S_{21}$ may be ignored, the transducer gain for the mixer is

$$39) G_T = \frac{|S_{21}|^2 (1 - |\Gamma_S|^2) (1 - |\Gamma_L|^2)}{\left| (1 - S_{11}\Gamma_S)(1 - S_{22}\Gamma_L) \right|^2}$$

For the worse case (knowing nothing about the angles of the scattering parameters), the transducer gain is

$$40) G_T = \frac{|S_{21}|^2 (1 - |\Gamma_S|^2) (1 - |\Gamma_L|^2)}{\left[(1 + |S_{11}\Gamma_S|) (1 + |S_{22}\Gamma_L|) \right]^2}$$

Knowing that the M2G mixer is situated as in Figure 10, the appropriate quantities can be substituted into 40) to give the mixer transducer gain as

$$41) G_{T_{M2G}} = 0.6824 |S_{21}|^2$$

The mixer interface mismatches add an additional loss of 1.66 dB.

The remaining device interfaces may be examined using 37) giving

VCO to FL-1	$\Gamma_L = 0.166$	$\Gamma_S = 0.2$	$L < 0.58\text{dB}$
FL-2 to A66	$\Gamma_L = 0.2857$	$\Gamma_S = 0.2$	$L < 1.03\text{dB}$
A66 to LA17	$\Gamma_L = 0.333$	$\Gamma_S = 0.2857$	$L < \underline{1.67\text{dB}}$

3.28dB

The total mismatch loss including the mixer loss, 41), is therefore 4.94dB.

Measured data for the WJ-LA17 Limiter-amplifier is given in Appendix II. The output level remains within 3.5dB of the flat-top maximum output level for input levels greater than roughly 3.0 dBm worse case. From Figure 10, the min gain curve shows an input level to the LA17 of 2.5 dBm, but with worse case mismatch loss, this is further lowered to -2.44 dBm. In order to guarantee operation over all worse case conditions, approximately 5.4 dB more gain is needed ahead of the LA17. With present specmanship, this is not possible.

Conclusion. As shown above, approximately 5.4 dB of additional gain is needed ahead of the LA17 to absolutely insure worse case operation over device variations. Since the A66-1 amplifier is really a 1 GHz device, as supported in the data books, it typically has significantly higher gain at lower frequencies. The requirement may be lowered by 4 dB to 1.4 dB additional gain by simply specifying the A66-1 minimum gain at 270-525 MHz at 26 dB. The remaining 1.4 dB is not worth worrying about but could be made up by perhaps reducing the pad in FL-1 or FL-2.

VCO Coarse Presetting. The VCO coarse presetting has traditionally been performed with a DAC and inverting op-amp. For FSD, the op-amp must be very high performance with a gain-bandwidth product in excess of 30 MHz for rapid settling. The op-amp used to date has been the Burr-Brown 3551. It will be unavailable in the future, is non-hybridizable, consumes more than 12 ma quiescent current, is costly, and requires a number of additional components outside the TS&H hybrid. These factors prompted another approach.

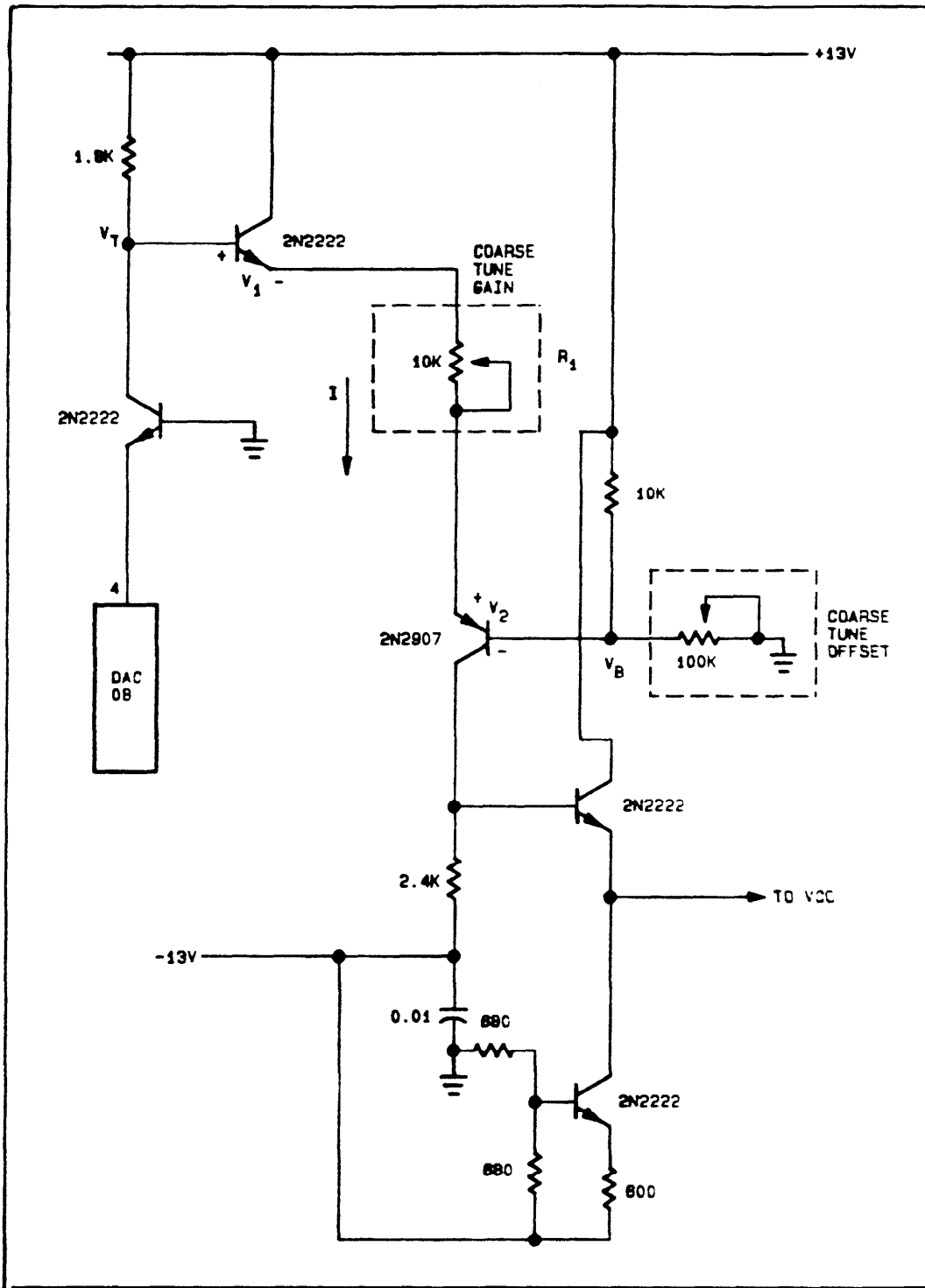
The approach adopted uses simple transistors with heavy local feedback to perform the presetting operation faster than before, with less power drain, lower cost, and most importantly, far fewer external parts. A rough sketch of the new circuit is given in Figure 11. Given solid +13 volt supplies, temperature performance should be very good due to the localized feedback and high β transistors.

For a diode

$$42) \quad v = \frac{KT}{q} \ln \left(\frac{I}{I_S} \right)$$

Assuming that $V_1 = V_2$

$$43) \quad I = \frac{(V_T - V_B) - 2V_1}{R_1 + R_2}$$



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Figure 11. New VCO Coarse Tune Approach

$$44) (R_1 + R_2)I = (V_T - V_B) - \frac{2KT}{q} \ln \left(\frac{I}{I_S} \right)$$

$$\frac{dI}{dT} = - \frac{2K}{q} \frac{\ln(I/I_S)}{R_1 + R_2 + \frac{2KT}{qI}}$$

$$\frac{dI}{dT} = - \frac{2}{T} \frac{V_1}{R_1 + R_2 + \frac{2KT}{qI}}$$

For

$$\begin{aligned} T &= 290 \text{ K} \\ V_1 &= 0.65 \\ R_1 + R_2 &= 1 \text{ K} \\ I &= 5 \text{ mA} \\ \frac{dI}{dT} &= - 4.4 \text{ ppm}/^\circ\text{C very low.} \end{aligned}$$

AVOID VERBAL ORDERS

Appendix I

To: Manny Olmedo
 From: J. A. Crawford
 Subject: FSD Synthesizer Mixdown
 Date: 6/27/83

Earlier concern was raised by Dave Arter in the 1872 MHz scheme used in the FSD Fast Frequency Synthesizer. The choice of L.O. frequency at present requires the 11C90 divider to operate as high in frequency as 597 MHz. Per all available published Fairchild data for the 11C90, the device will not reliably operate at this frequency, particularly over temperature.

Carl Cook and Casey Dinsmoor performed tests on 3 different flight LSI hybrids over temperature. Several other hybrids were also examined but failed to operate at all at 597 MHz, $f_{out} = 3$ MHz, and $T_{AIR} = 105$ C. The test results for the 3 hybrids measured follows:

Hybrid #6

Temp = 105°C

<u>fin</u>	<u>Input Min.</u>	<u>Max</u>	<u>Window</u>
597 MHz	+5.4	+6.6 dBm	1.2 dB
546	+2.5	+7.5	5.0
525	+1.3	+7.5	6.2

Temp = -55 C

<u>fin</u>	<u>Input Min.</u>	<u>Max</u>	<u>Window</u>
597	-0.5	+7.4	7.9
546	-2.4	+7.7	10.1
525	-2.8	+8.0	10.8

Hybrid #23

Temp = 105 C

<u>fin</u>	<u>Input Min.</u>	<u>Max</u>	<u>Window</u>
597 MHz	-	-	None
546 MHz	+1.2	+4.9 dBm	3.7 dB
525	0.0	+5.7	5.7

Temp = 83 C

<u>fin</u>	<u>Input Min.</u>	<u>Max</u>	<u>Window</u>
597	3.3	4.4	1.1

Hybrid #20

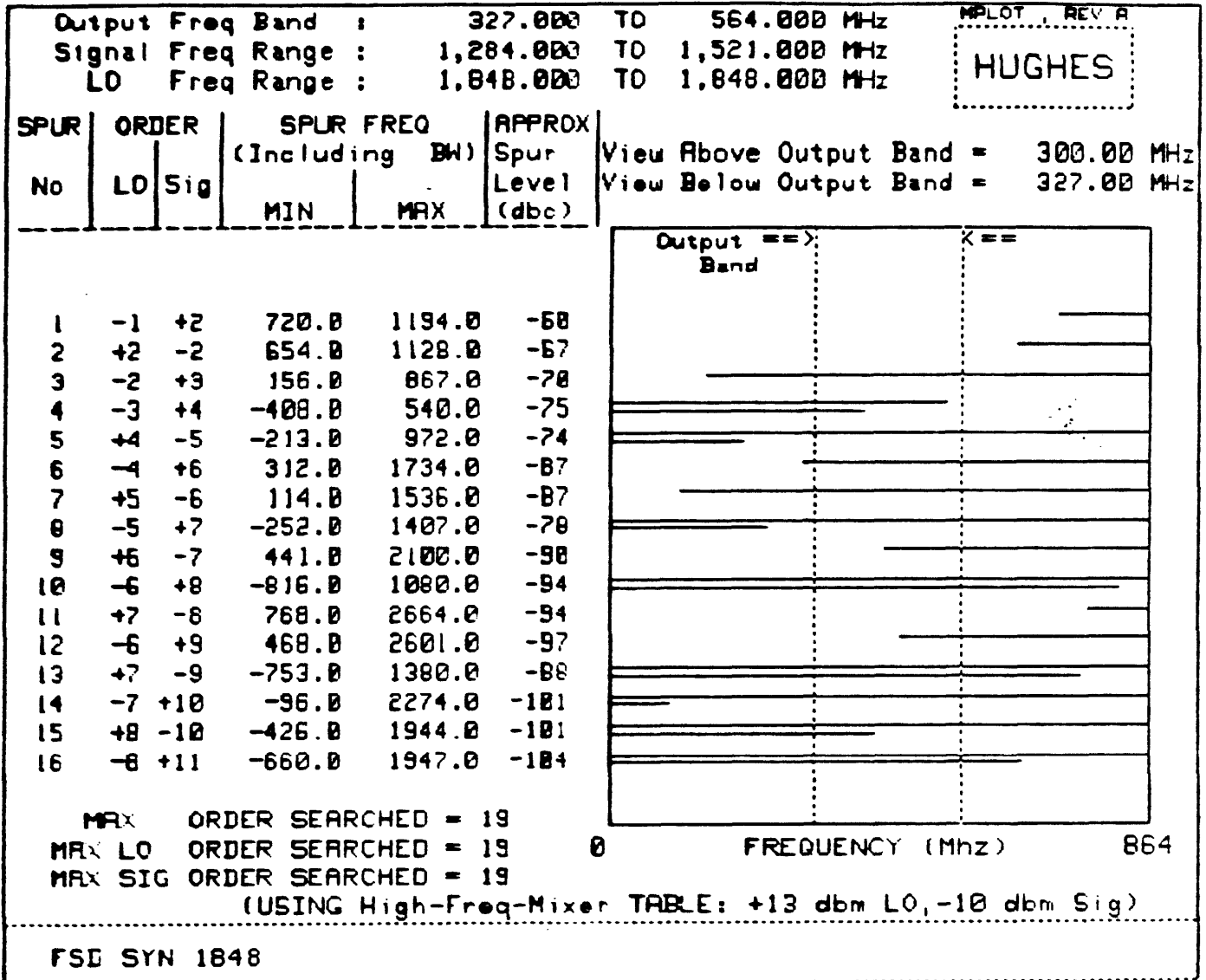
Temp = 105 C

<u>fin</u>	<u>Input Min.</u>	<u>Max</u>	<u>Window</u>
597	+4.4	+4.7	0.3
546	0.9	5.7	4.8
525	-0.2	+6.1	6.3

Observations. First of all, Fairchild data only guarantees reliable operation over the mil temp range for frequencies less than 550 MHz. Fairchild re-iterated this fact in phone conversations last week.

The operating power window based upon available data is from 0 dB to 1.2 dB at 597 MHz and 105 C. This window is too small to provide any design margin and I will not endorse the present mixdown scheme without modification. Alternatives are:

- 1) Be saved by the arrival of the Harris GaAs 10/11 divider. Performance at present is still questionable, as well as compatibility with present LSI hybrid topology.
- 2) Lower the L.O. generator frequency to 1800 MHz. This would make the 11C90 maximum operating frequency 525 MHz which, per presented data, displays a typical 6 dB power window. Spurious analysis was done by S. Schenk and is included at end. Spur levels should not be any worse than for the present mix-down with 1872 MHz. Hardware impact will cause the greatest concern. Two new filters will be needed with (probable slight) modification to the L.O. generator itself. The frequency control words to the synthesizer will also change. The XN ratios will be smaller which will necessitate reduced phase-detector gains in the TS&H hybrid. This will cause no problem, rather, it will provide some synthesizer performance improvement.



NOTE : Double entries on Plot (Spur No 4,5,6,10,13,14,15,16) result from passing thru zero Hz and image spur coming into viewing range.

MPL0T , REV A

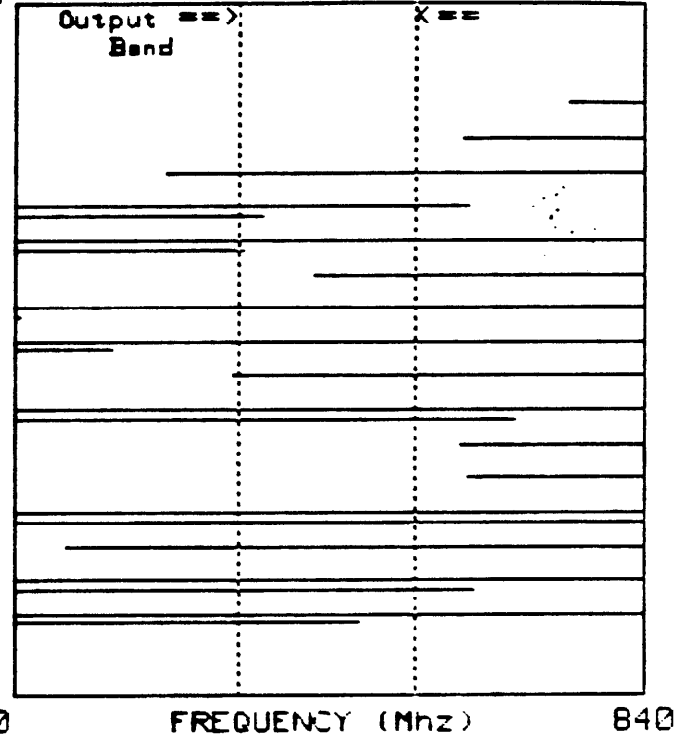
Output Freq Band : 303.000 TO 540.000 MHz
 Signal Freq Range : 1,284.000 TO 1,521.000 MHz
 LO Freq Range : 1,824.000 TO 1,824.000 MHz

HUGHES

SPUR No	ORDER		SPUR FREQ (Including BW)		APPROX Spur Level (dbc)
	LO	Sig	MIN	MAX	

View Above Output Band = 300.00 MHz
 View Below Output Band = 303.00 MHz

1	-1	+2	744.0	1218.0	-60
2	+2	-2	606.0	1080.0	-67
3	-2	+3	204.0	915.0	-70
4	-3	+4	-336.0	612.0	-75
5	+4	-5	-309.0	876.0	-74
6	-4	+6	408.0	1830.0	-87
7	+5	-6	-6.0	1416.0	-87
8	-5	+7	-132.0	1527.0	-70
9	+6	-7	297.0	1956.0	-90
10	-6	+8	-672.0	1224.0	-94
11	+7	-8	600.0	2496.0	-94
12	-6	+9	612.0	2745.0	-97
13	+7	-9	-921.0	1212.0	-88
14	-7	+10	72.0	2442.0	-101
15	+8	-10	-618.0	1752.0	-101
16	-8	+11	-468.0	2139.0	-104

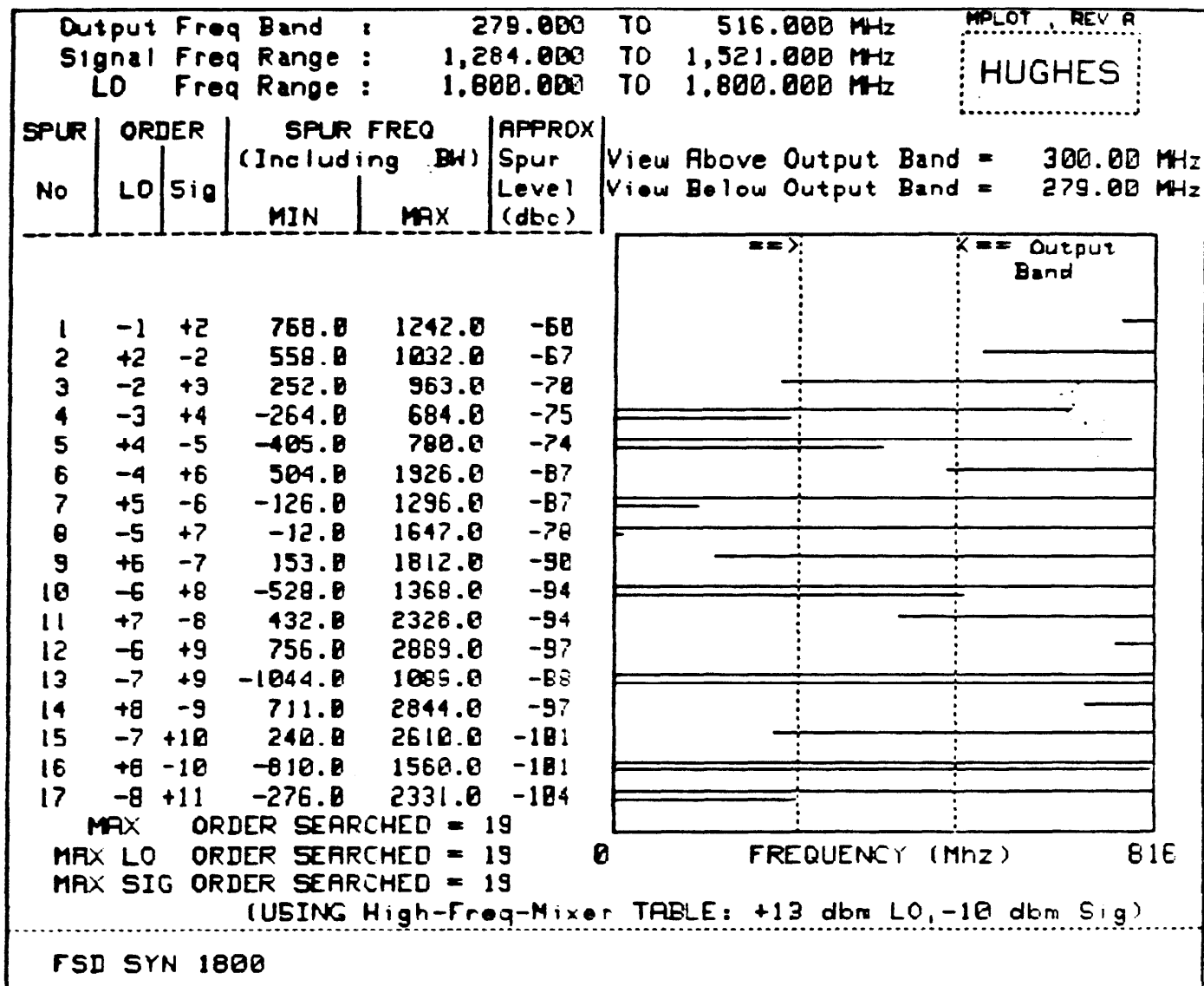


MAX ORDER SEARCHED = 19
 MAX LO ORDER SEARCHED = 19
 MAX SIG ORDER SEARCHED = 19

(USING High-Freq-Mixer TABLE: +13 dbm LO, -10 dbm Sig)

FSD SYN 1824

NOTE : Double entries on Plot (Spur No 4,5,7,8,10,13,15,16)
 result from passing thru zero Hz and image spur coming into viewing range.



-70

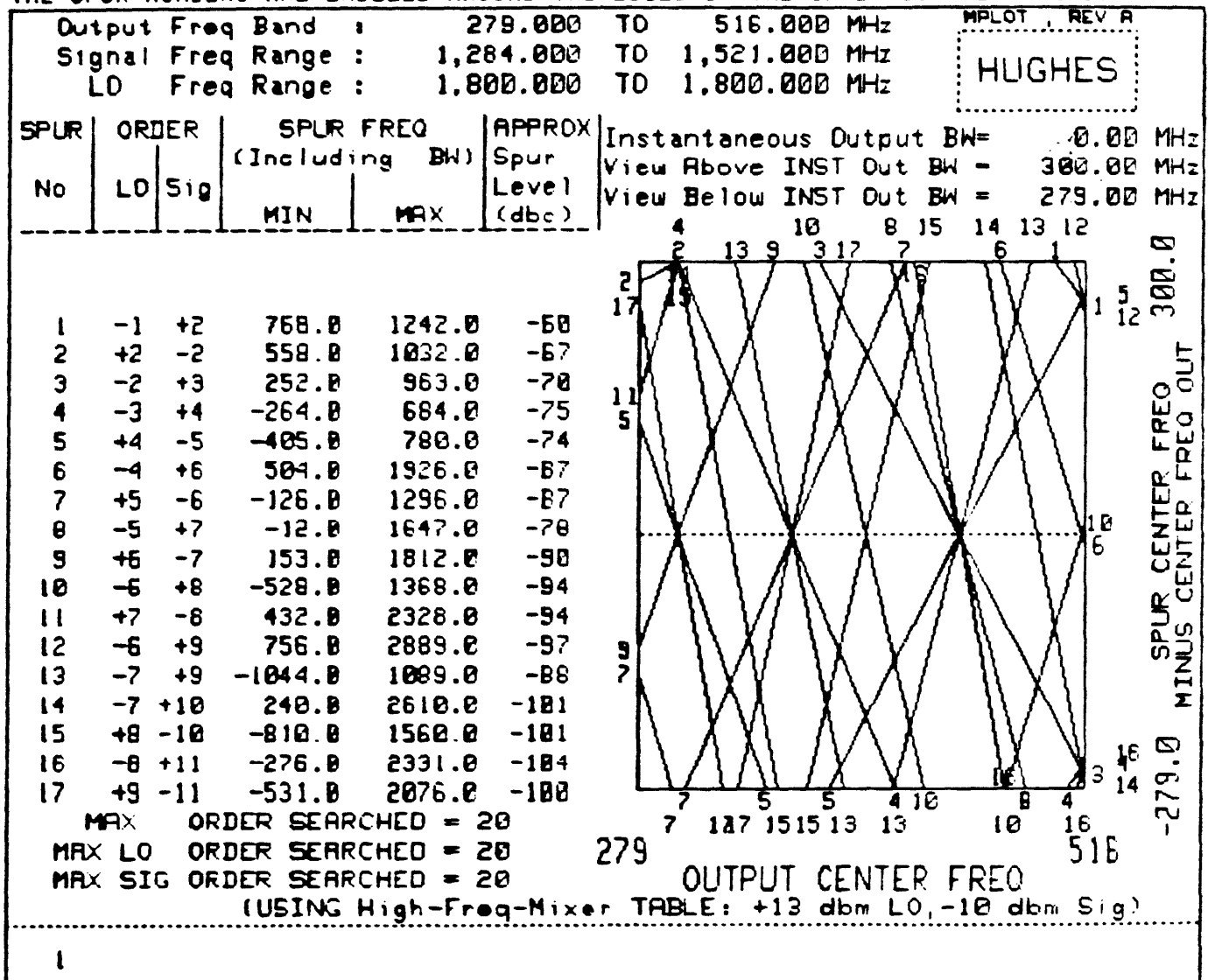
NOTE : Double entries on Plot (Spur No 4,5,7,8,10,13,16,17) result from passing thru zero Hz and image spur coming into viewing range.

	CENTER FREQ (MHz)		INSTANTANEOUS BANDWIDTH (MHz)
	MIN	MAX	
OUTPUT :	279.000	516.000	0.000
INPUT SIGNAL :	1284.000	1521.000	0.000
LO :	1800.000	1800.000	0.000

VERTICAL SCALE IS DIFFERENCE BETWEEN SPUR CENTER FREQUENCY AND THE OUTPUT CENTER FREQUENCY.
 THE INSTANTANEOUS OUTPUT BAND(WIDTH) LIES BETWEEN THE DOTTED LINES.

THE HORIZONTAL SCALE IS THE VARYING CENTER FREQUENCY OF THE OUTPUT SIGNAL.

THE SPUR NUMBERS ARE LABELED AROUND THE EDGES OF THE INNERMOST RECTANGLE.

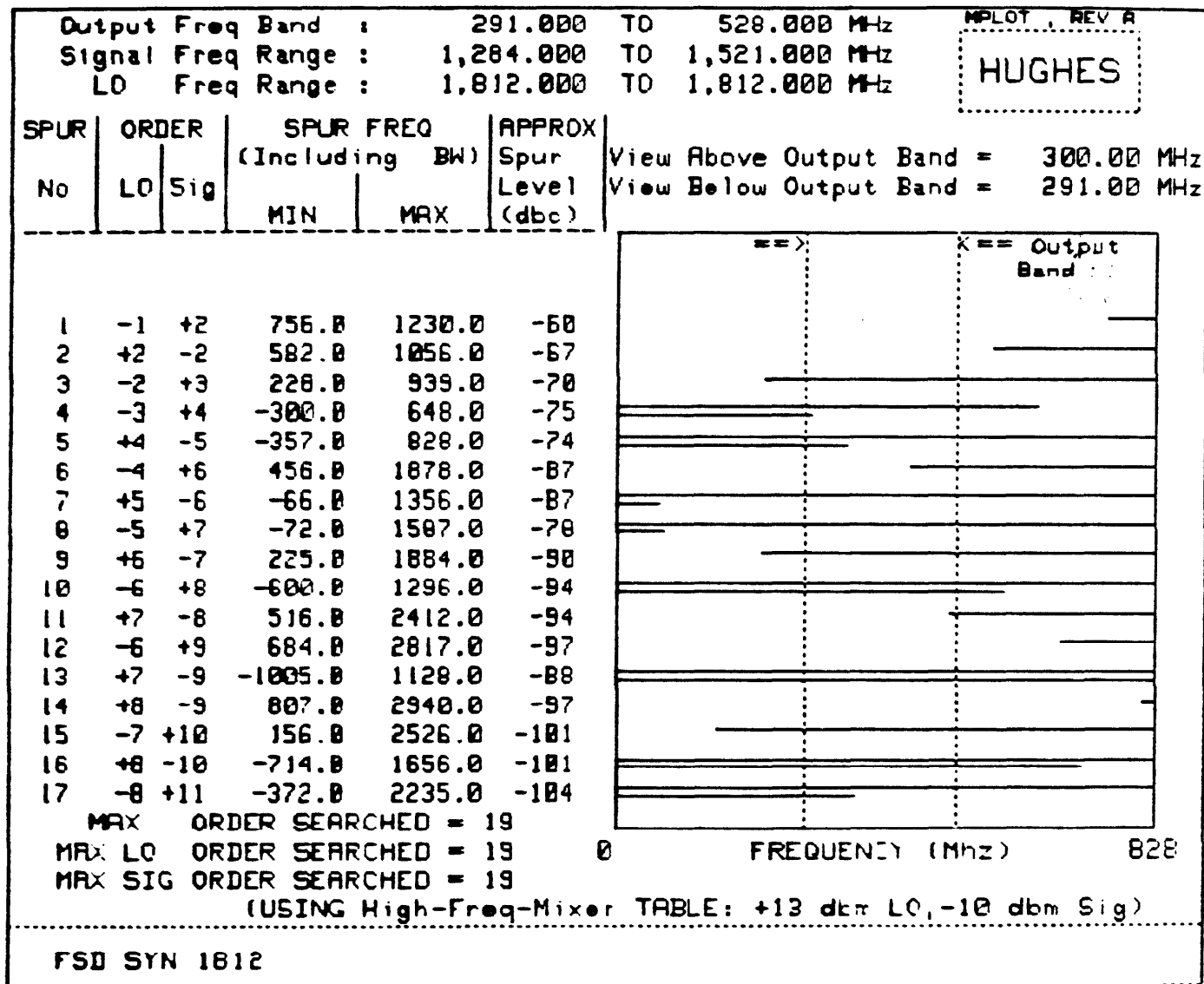


ALL SPURS UP TO THE ORDERS INDICATED ON THE GRAPH ARE PLOTTED IF THE CENTER FREQUENCY GOES INTO THE VIEWING AREA.
 OTHER SPURS WHICH ARE TABULATED ARE THOSE (UP TO THE ORDER SPECIFIED) WHOSE INSTANTANEOUS FREQUENCY EXTENDS INTO THE INSTANTANEOUS OUTPUT BAND (AREA BETWEEN THE DASHED LINES).

1

	CENTER FREQ (MHz)		INSTANTANEOUS BANDWIDTH (MHz)
	MIN	MAX	
OUTPUT :	279.000	516.000	0.000
INPUT SIGNAL :	1284.000	1521.000	0.000
LO :	1800.000	1800.000	0.000

SPUR Number	SPUR CENTER FREQUENCY		SPUR Instan- taneous Band- width	WHERE SPUR FREQ IS NEAREST TO CENTER OF INSTANTANEOUS OUTPUT FREQUENCY BAND			
	MIN	MAX		SPUR CENTER FREQ MINUS OUTPUT CENTER FREQ	SPUR FREQ	OUTPUT FREQ	SIG FREQ
1	768.00	1242.00	0.00	252.000	768.000	516.000	1284.000
2	558.00	1032.00	0.00	279.000	558.000	279.000	1521.000
3	252.00	963.00	0.00	0.000	450.000	450.000	1350.000
4	-264.00	684.00	0.00	0.000	360.000	360.000	1440.000
4				-252.000	-264.000	516.000	1284.000
5	-405.00	780.00	0.00	0.000	450.000	450.000	1350.000
5				0.000	-300.000	300.000	1500.000
6	504.00	1926.00	0.00	0.000	514.286	514.286	1285.714
7	-126.00	1296.00	0.00	0.000	360.000	360.000	1440.000
7				-153.000	-126.000	279.000	1521.000
8	-12.00	1647.00	0.00	0.000	450.000	450.000	1350.000
9	153.00	1812.00	0.00	0.000	300.000	300.000	1500.000
10	-528.00	1368.00	0.00	0.000	400.000	400.000	1400.000
10				0.000	-514.286	514.286	1285.714
11	432.00	2328.00	0.00	153.000	432.000	279.000	1521.000
12	756.00	2889.00	0.00	240.000	756.000	516.000	1284.000
13	-1044.00	1089.00	0.00	0.000	360.000	360.000	1440.000
13				0.000	-450.000	450.000	1350.000
14	240.00	2610.00	0.00	0.000	490.909	490.909	1309.891
15	-810.00	1560.00	0.00	0.000	400.000	400.000	1400.000
15				0.000	-327.273	327.273	1472.727
16	-276.00	2331.00	0.00	0.000	450.000	450.000	1350.000
16				-240.000	-276.000	516.000	1284.000
17	-531.00	2076.00	0.00	0.000	360.000	360.000	1440.000
17				0.000	-300.000	300.000	1500.000



NOTE : Double entries on Plot (Spur No 4,5,7,8,10,13,16,17)
result from passing thru zero Hz and image spur coming into viewing range.

PERMANENT RECORD OF TELEPHONE CONVERSATION

Dave Arter Called Hank Miller of Fairchild, June 23, 1983 from Hughes (Fullerton). Call related to Performance of 11C90 10/11 Prescaler.

Called Fairchild in Mountain View, Calif. and talked with Hank Miller an application engineer. I told Hank our application of 11C90 and our problem of the upper frequency window at +125°C. Hank said that the performance we were experiencing was not out of the ordinary. I asked Hank about the P-P MV of operational window indicated in the Fairchild Data Book compared to our measured smaller window. His response was that the data was taken in 1977 and was not sure of test set-up at the time the data was taken. Hank stated that the window was typical, not the worse case. Hank recommended checking RCA for an equivalent device.

LATER COMMENTS ON MIX-DOWN SCHEME 6-29-83

FSD Mix-Down. A problem focusing on the maximum operating frequency of the 11C90 over temperature was addressed in an AVO to M. Olmedo 6-27-83. Briefly, two alternatives exist at present:

- 1) use a different 10/11 device
- 2) alter the mix-down scheme such that the 11C90 does not have to operate at such a high frequency.

Approach 1. Fairchild voiced no methods for dealing with the problem we are facing. The 11C90 is a known quantity, and its performance non-negotiable. A divider which will reliably operate at 600 MHz over mil temperature is needed.

Plessey's SP8680 (10/11) appears identical to the 11C90. I have not been able to talk to them directly about my problem (in part due to relations between Hughes & Plessey at this time I believe).

Motorola has nothing in the required frequency range except the MC12013 which is really a 500 MHz part over temperature.

Other work is being done at present with high speed dividers. Rockwell claims to have dual modulus devices in GaAs that work up to 1.84 GHz with 70% yield at 1.0 GHz (no temperature data given).

IEEE MTT-30, No. 7 July, 1982 p. 1020-1025
IEEE MTT-28, No. 5 May, 1980 p. 466-472

One particular Torrance 10/11 device which we evaluated 7-82 (Ping Kwok) operated up to 960 MHz with care. No specific tests were done to examine its role as a replacement for the 11C90. In phone conversation (6-29-83), he claims that his new material works better and is less temperature sensitive. We will get working samples of this device shortly and will perform a thorough characterization of it.

Phone conversations with Ed Kelley (RSG) (6-29-83) produced interesting results also. He said that Fairchild will soon announce a new 11 HS__ device line with performance improvement over the 11C family by factors of 3 to 4. He claims to have heard about their 11 HS05 a year ago which operated up to 3.5 GHz. This I sincerely doubt. He also claims that RSG has a bipolar 10/11 due July 20 which should operate at 2 GHz over Mil temp. This I doubt also. Furthermore, he said that Avantek will soon release a prescaler using their own processing and an outside design. Other activity is apparent, but the reliability of these performance estimates is certainly questionable.

In talking with Fairchild sales people (Santa Ana 557-7350), they had no knowledge of the new HS line of devices.

We will evaluate the new Torrance devices, but in general, the devices are not available now for replacing the 11C90 with a better device. This avenue may present itself at a later date, but cannot be considered as a viable alternative at this time.

Approach 2: Fast Synth. Impact.

This approach requires that the L.O. frequency must be reduced from 1872 MHz to ideally 1800 MHz. This new choice would make the maximum 11C90 frequency 525 MHz which is within the guaranteed operating range over mil temperatures.

The minimum synthesizer ΣN number would be 90 (formally 114) at 1530 MHz which is also the lower bound on legal ΣN numbers. Some careful attention has been given to this change in terms of impact and the expectations are:

- | | | |
|------------------|---|--|
| Perform-
ance | } | 1) a theoretical decrease in Fast Synth. reference phase noise of 1.12 dB |
| | | 2) slightly better speed due to decreased values of K_D |
| | | 3) larger phase detector capture range due to smaller K_D |
| | | 4) new bandpass filter required. At present (1872), filter must pass 342-597 MHz [56.43 % bandwidth] |
| Hard-
ware | | with new frequency (1800), filter must pass 270-525 MHz [67.73 % Bw] |

$$\frac{f_H - f_L}{\sqrt{f_H f_L}} = \lambda$$

- 5) Frequency word portion of command word must be changed to reflect new %N numbers.

The present fast synthesizer BP filter description follows:

5 pole
 $f_c = 470 \text{ MHz}$
 0.25 dB Bw = 350-588 MHz
 Delay @ 470 M = 3-4 nsec
 0.5 dB Bw = 597-342 MHz

From the spur analysis - ala Stuart, no in band spur exists greater than -70 dBc (levels will be checked in hardware to confirm). Given a 5 pole filter with same 255 MHz Bw at $f_c = 398 \text{ MHz}$, no spur greater than -70 dBc will in the passband of interest. Owing to the same bandwidth, the group delay characteristics will remain largely unchanged.

Anticipate no spur or delay problems in fast synthesizer due to changed mix-down scheme.

	Definite Change	Investigate	No Change	Vendor Involved	Change Existing Spec	Prob- able
● Change Frequency control word to Fast Synthesizer	X				X	
● Fast Frequency Synthesizer ϕ -noise. Capture range improve						X
● Fast Synth. P.C. Board			X			
● Fast Synth. Mixdown filter change	X			X	X	
● L.O. Generator P.C. Board	X					
● L.O. Generator VCO - respecify part	X			X	X	
● ϕ -noise improve slightly						X
● L.O. Generator filter change	X			X	X	
● L.O. Generator parts less VCO			X			

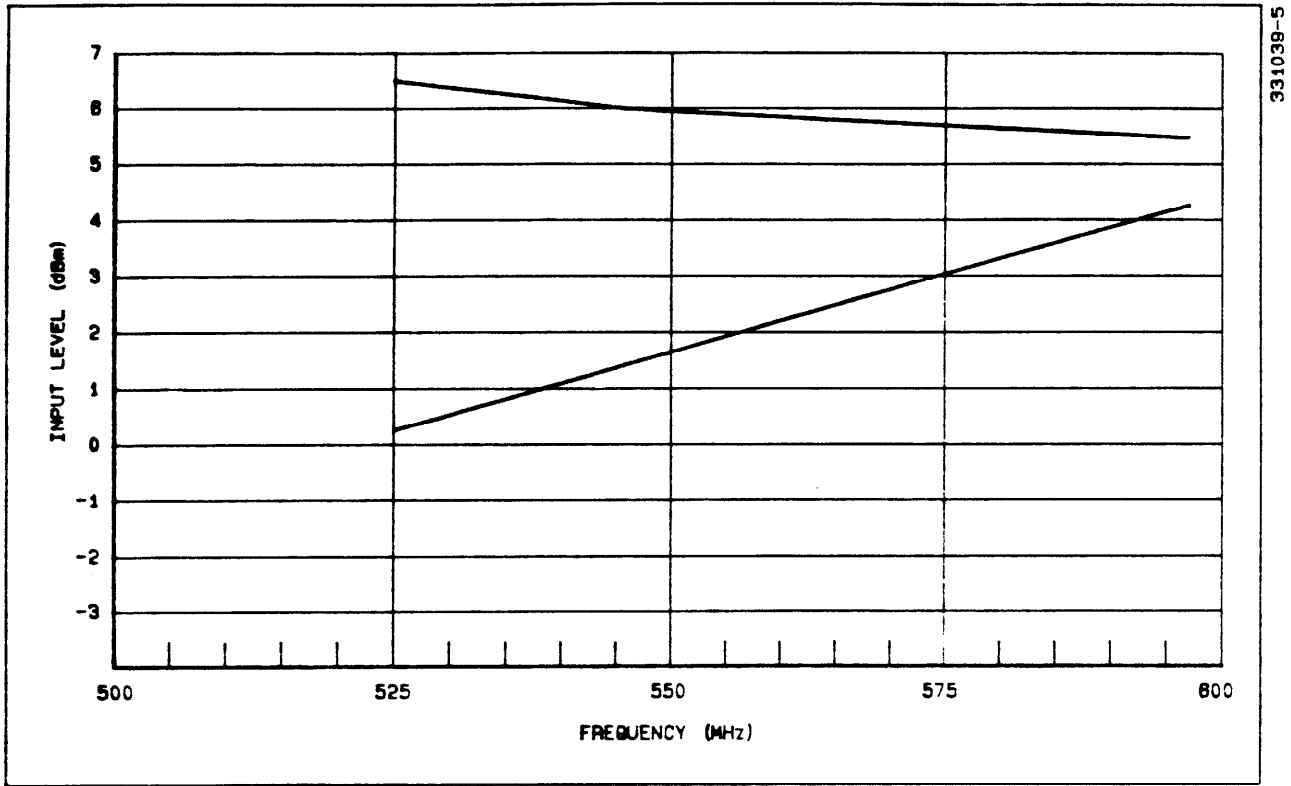
Plan of ActionDone

1. Insert 1800 MHz L.O into Fast Synthesizer, hunt and confirm spur levels with previous analysis.
- ✓ 2. Alter L.O Generator per attached description to operate at 1800 MHz (room temp at present) Breadboard.
- ✓ 3. Confirm that 11C90 operating window is adequate (~ 6 dB) in LSI hybrid over temperature and frequency extremes.
4. Contact WJ about VCO, 900 MHz. EMC Simulator L.O. generator will use an 1872 MHz VCO so this 900 MHz VCO (multiplied by 2) will have its own part number.
5. Respecify filters 1 - Bandpass on L.O. Gen.
(specs) 1 - Bandpass on Fast Synth.
6. Re-do specification for L.O. Generator 900 MHz VCO.
7. L.O. Generator documentation
8. Design Review of L.O. Generator/perhaps catch 8 other items now.
9. Fast Synth. documentation/specification update.
10. Re-do test box prompts with new frequency word table.
11. Get J. Bruner's blessing on new mix down area (L.O. Gen and Fast Synth.)

Divide By N Hybrid - Temperature Test Results	Temperature = 105°C			Temperature = -55°C		
	597 MHz	546 MHz	525 MHz	597 MHz	546 MHz	525 MHz
% Functioning	44.4	77.8	77.8	55.6	66.7	66.7
Average Maximum Input Level	5.6 dBm	6.0 dBm	6.5 dBm	6.0 dBm	6.2 dBm	6.7 dBm
Average Minimum Input Level	4.3 dBm	1.4 dBm	0.3 dBm	-2.1 dBm	-4.8 dBm	-4.3 dBm
Average Window	1.3 dBm	4.6 dBm	6.2 dBm	6.2 dBm	8.1 dBm	11.0 dBm
Lowest Maximum Input Level	4.7 dBm*	4.9 dBm	5.7 dBm	5.0 dBm	5.4 dBm	5.9 dBm
Highest Minimum Input Level	5.4 dBm*	2.5 dBm	1.3 dBm	-0.5 dBm	-2.4 dBm	-2.8 dBm
Worst Case Window	Non- existent	2.4 dBm	4.4 dBm	5.5 dBm	7.8 dBm	8.7 dBm

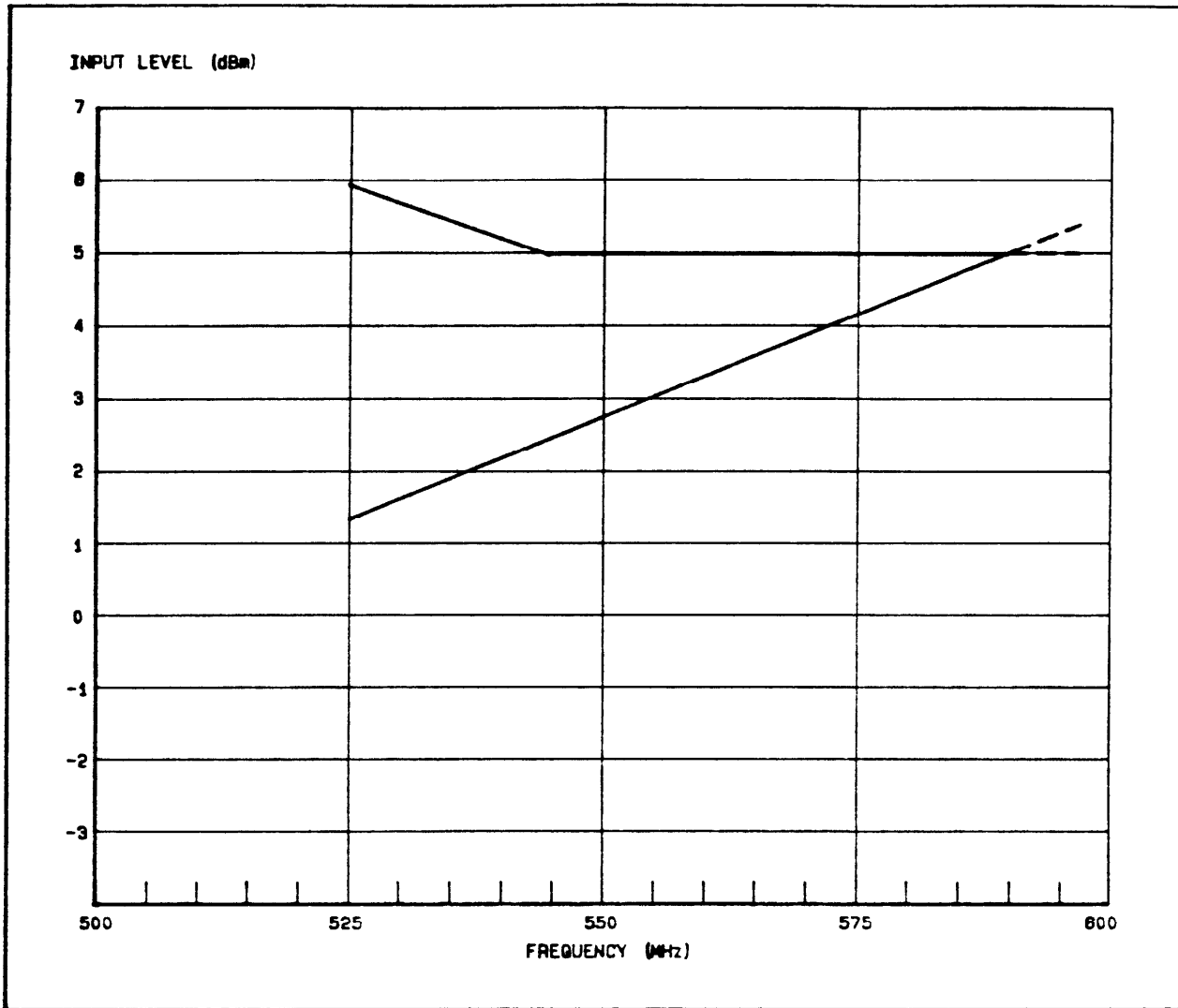
*These values overlap and no window exists in the worst case condition

Divide by N output was held at 3.0 MHz

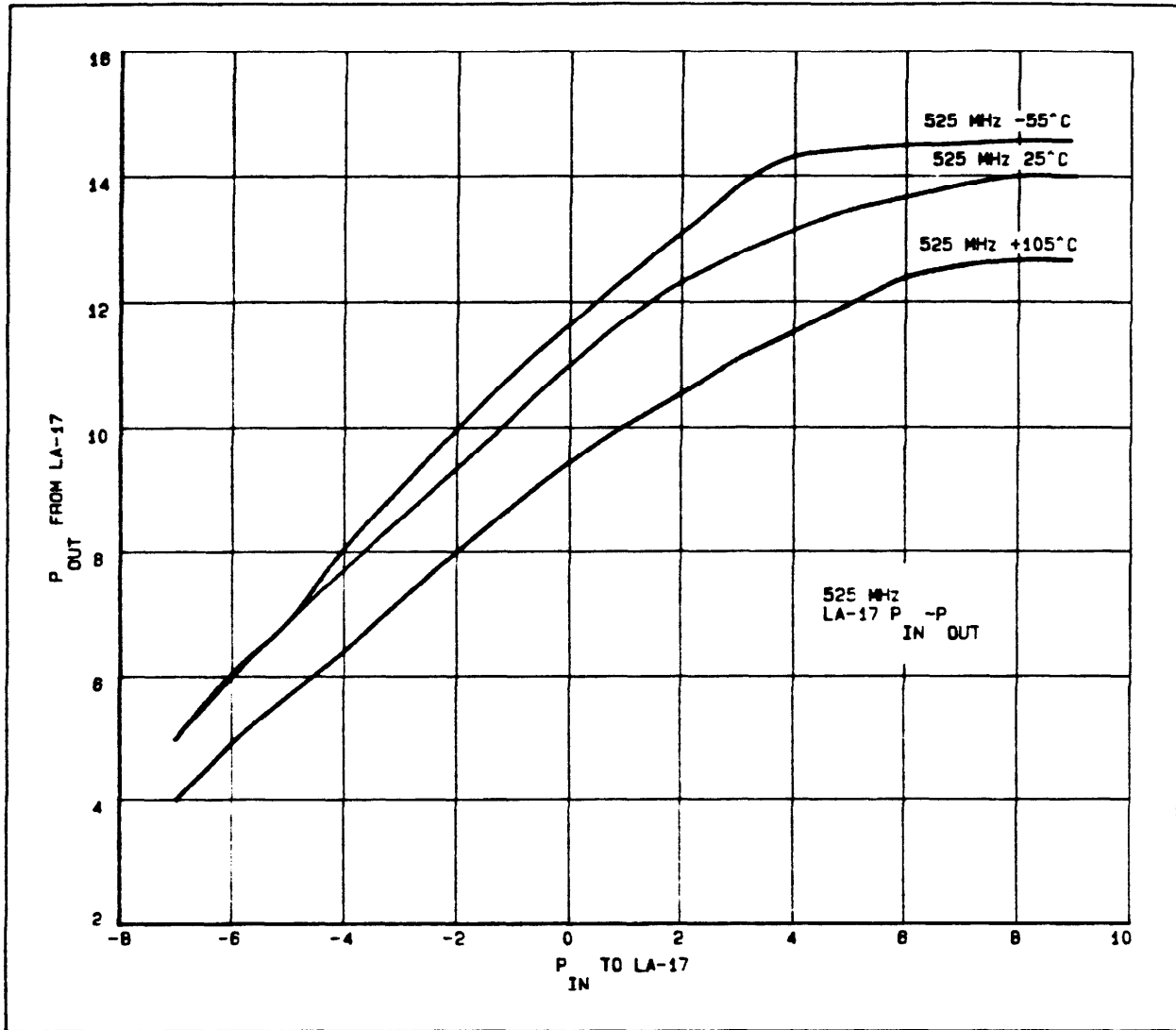


Divide by N Hybrids - Temperature Test Sample of 9 (Average Values at 105 C)

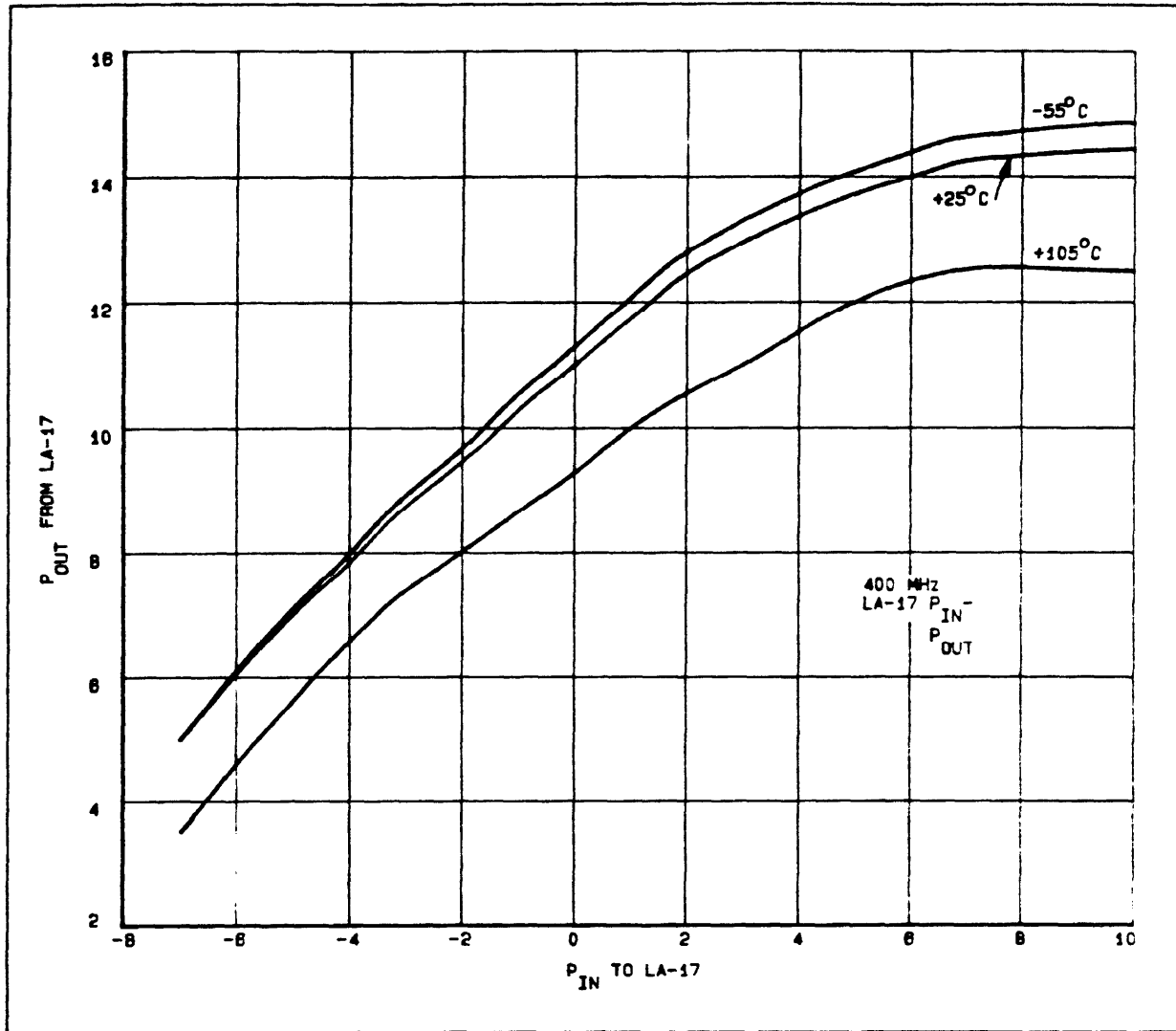
331039-B



Divide by N Hybrids - Temperature Test - Sample of 9 (Worst Case Values at 105 C)

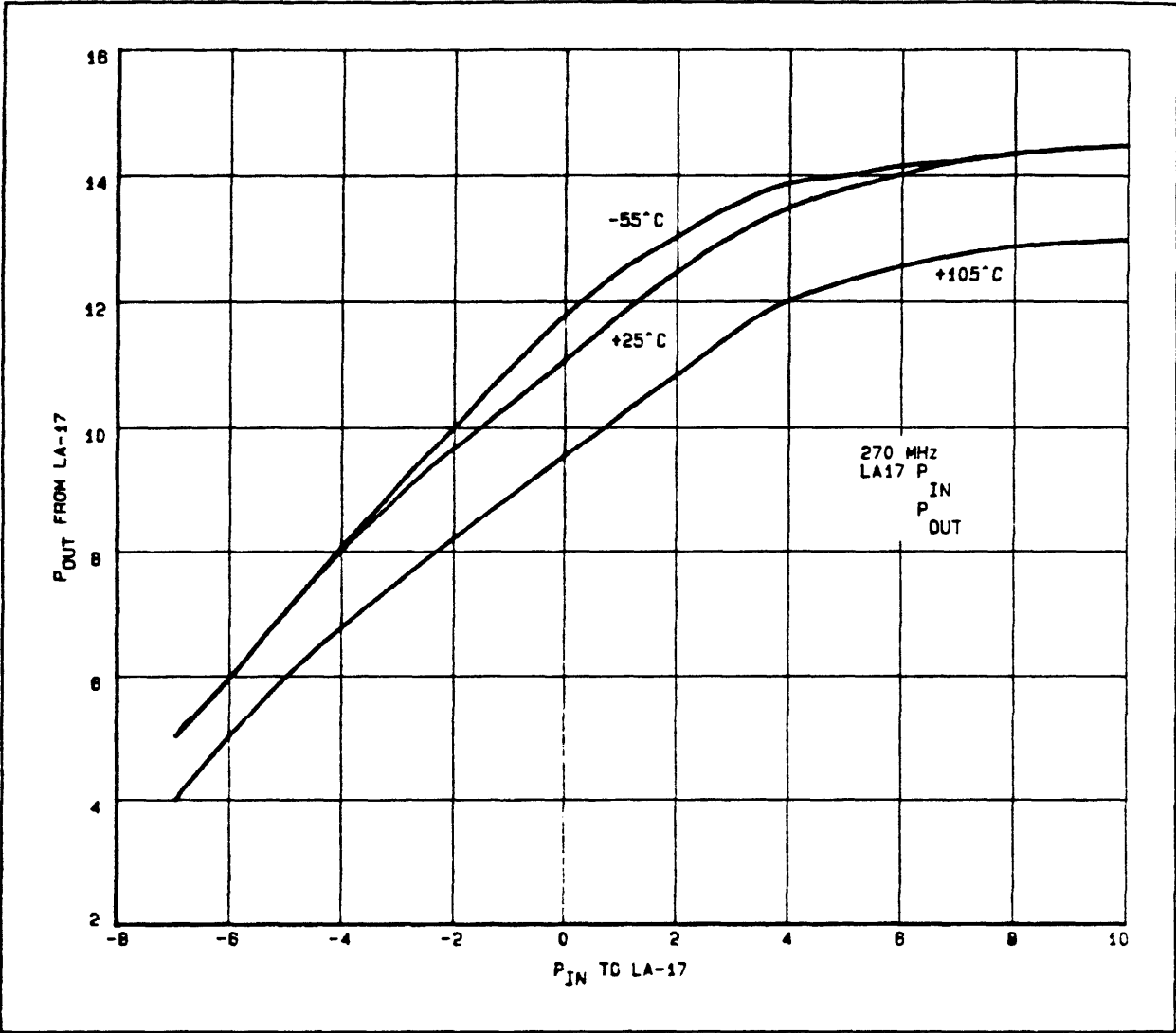


331039-7



331038-B

331038-8



Air: -61°C
 Case: -56 Temp°C
 Red: 270 MHz Freq.

IN	A	B	OUT
+20	+10	+14.6	+4.6
19	9	14.5	+4.5
18	8	14.4	+4.4
17	7	14.3	+4.3
16	6	14.2	+4.2
15	5	14.0	+4.0
14	4	13.7	+3.7
13	3	13.4	+3.4
12	2	13	+3.0
11	1	12.4	+2.4
10	0	11.7	+1.7
9	-1	10.8	+0.8
8	-2	9.8	+0.2
7	-3	8.9	-1.1
6	-4	7.9	-2.1
5	-5	6.9	-3.0
4	-6	5.9	-4.1
3	-7	+4.9	-5.1

Air: +25 Temp°C
 270 Freq.

IN	A	B	OUT
+20	+10	+14.5	+4.5
19	9	+14.5	+4.5
18	8	+14.4	+4.4
17	7	14.3	+4.3
16	6	14.1	+4.1
15	5	13.9	+3.9
14	4	13.5	+3.5
13	3	13.1	+3.1
12	2	12.6	+2.6
11	1	11.9	+1.9
10	0	11.3	+1.3
9	-1	10.5	+0.5
8	-2	9.7	-0.3
7	-3	8.9	-1.1
6	-4	8.0	-2.0
5	-5	7.0	-2.9
4	-6	+6	-4.0
3	-7	+5	-5.0

Air: 101°C
 Case: 105 Temp°C
 Blue: 270 MHz Freq.

IN	A	B	OUT
+20	+10	+13.1	+3.1
19	9	+13.0	+3.0
18	8	+12.9	+2.9
17	7	12.7	+2.7
16	6	12.5	+2.5
15	5	12.3	+2.3
14	4	11.9	+1.9
13	3	11.5	+1.5
12	2	11.0	+1.0
11	1	+10.3	+0.3
10	0	+9.7	-0.3
9	-1	9.0	-1
8	-2	8.3	-1.7
7	-3	7.5	-2.5
6	-4	6.7	-3.3
5	-5	+6	-4.0
4	-6	+5	-5.0
3	-7	+4	-6.0

Air: -61°C
 Case: -56 Temp°C
 Red: 400 MHz Freq.

IN	A	B	OUT
+20	+10	14.6	+4.6
19	9	14.6	+4.6
18	8	14.5	+4.5
17	7	14.4	+4.4
16	6	14.3	+4.3
15	5	14.1	+4.1
14	4	13.8	+3.8
13	3	13.5	+3.5
12	2	13.0	+3.0
11	1	12.3	+2.3
10	0	11.5	+1.5
9	-1	10.6	+0.6
8	-2	9.7	-0.3
7	-3	8.7	-1.3
6	-4	7.8	-2.2
5	-5	6.9	-3.1
4	-6	5.8	-4.2
3	-7	4.8	-5.2

Air: +25° Temp°C
Green: 400 MHz Freq.

IN	A	B	OUT
+20	+10	+14.3	+4.3
19	9	+14.3	+4.3
18	8	+14.2	+4.2
17	7	14.1	+4.1
16	6	14.0	+4.0
15	5	13.8	+3.8
14	4	13.4	+3.4
13	3	13	+3.0
12	2	12.5	+2.5
11	1	11.8	+1.8
10	0	11.1	+1.1
9	-1	10.3	+0.3
8	-2	9.5	-0.5
7	-3	8.7	-1.3
6	-4	7.8	-2.2
5	-5	6.9	-3.1
4	-6	5.9	-4.1
3	-7	4.9	-5.1

Air: 100°C
Case: 105° Temp°C
Blue: 400 MHz Freq.

IN	A	B	OUT
+20	+10	+12.7	+2.7
19	9	+12.6	+2.6
18	8	12.5	+2.5
17	7	12.4	+2.4
16	6	12.2	+2.2
15	5	12.0	+2.0
14	4	11.5	+1.5
13	3	11.1	+1.1
12	2	+10.6	+0.6
11	1	10	0
10	0	9.4	-0.6
9	-1	8.7	-1.3
8	-2	7.9	-2.1
7	-3	7.2	-2.8
6	-4	+6.4	-3.6
5	-5	+5.6	-4.4
4	-6	+4.6	-5.4
3	-7	+3.6	-6.4

Air: -61°C
Case: -55 Temp°C
Red: 525 Freq.

IN	A	B	OUT
+20	+10	-	-
19	9	14.7	4.7
18	8	14.7	4.7
17	7	14.6	4.6
16	6	14.6	4.6
15	5	14.5	4.5
14	4	14.3	4.3
13	3	13.7	3.7
12	2	13.2	3.2
11	1	12.6	2.6
10	0	11.8	1.8
9	-1	10.8	+0.8
8	-2	10	0
7	-3	+9	-1
6	-4	8	-2
5	-5	7	-3
4	-6	6	-4
3	-7	5	-5

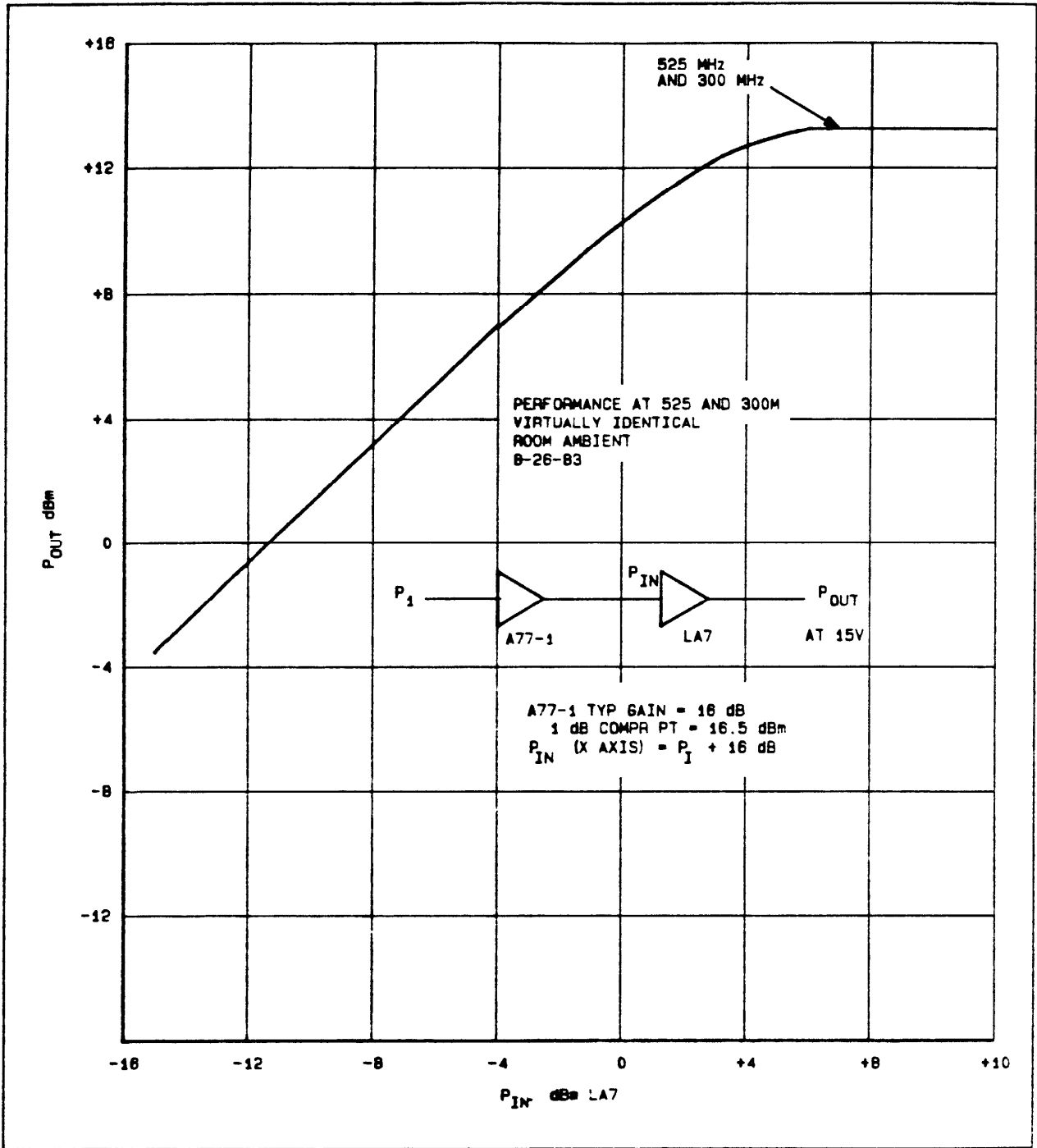
Air: 25 Temp°C
Case: 525 Freq.
Green

IN	A	B	OUT
+20	+10	-	-
19	9	+14.0	4.0
18	8	14.0	4.0
17	7	13.9	3.9
16	6	13.8	3.8
15	5	13.6	3.6
14	4	13.3	3.3
13	3	12.8	2.8
12	2	12.3	2.3
11	1	11.8	1.8
10	0	11.1	1.1
9	-1	10.4	+0.4
8	-2	9.4	-0.6
7	-3	8.7	-1.3
6	-4	7.8	-2.2
5	-5	7.0	-3.0
4	-6	6.1	-3.9
3	-7	5.0	-5.0

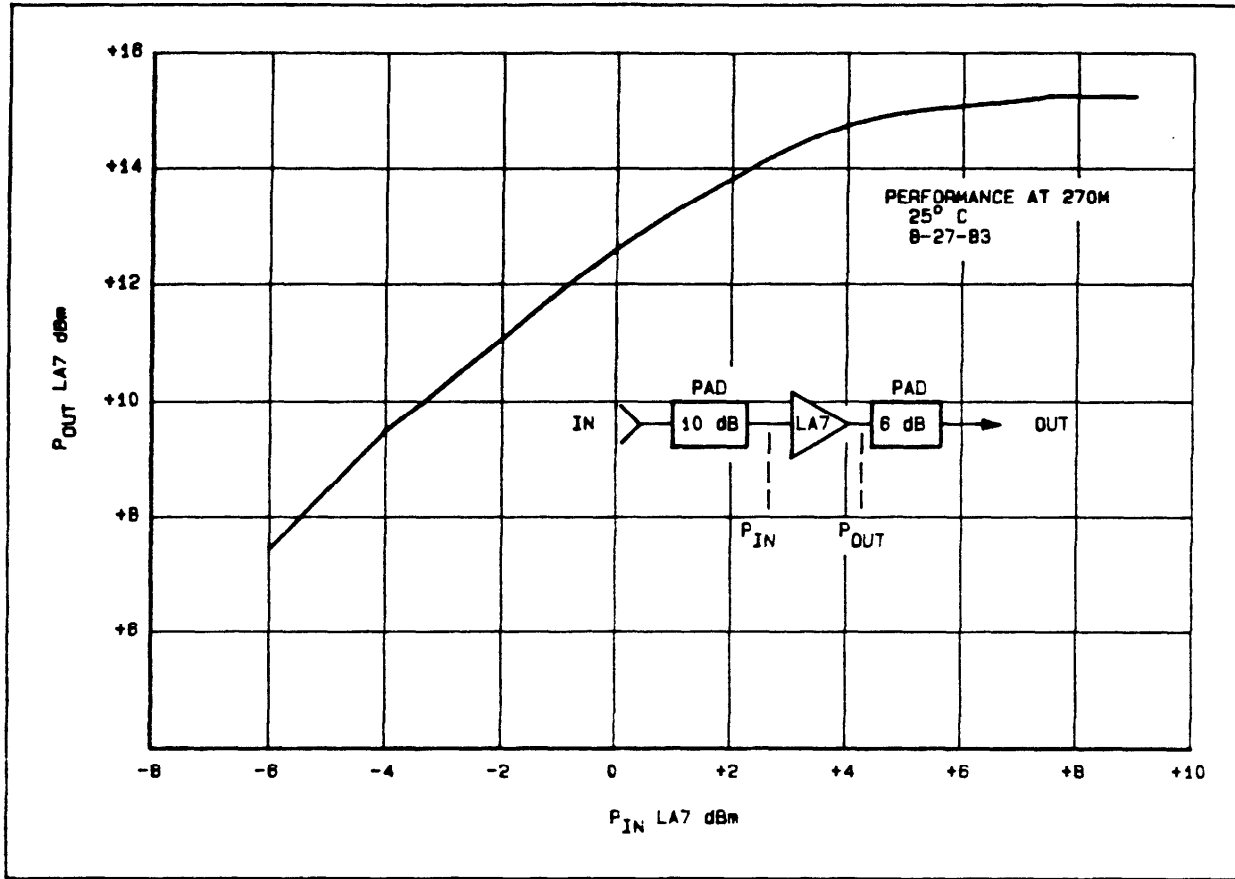
Air: 100°C
Case: 105 Temp°C
Blue: 525 MHz Freq.

IN	A	B	OUT
+20	+10	-	-
19	9	+12.5	+2.5
18	8	+12.5	+2.5
17	7	+12.4	+2.4
16	6	+12.2	+2.2
15	5	+11.9	+1.9
14	4	+11.6	+1.6
13	3	+11.1	+1.1
12	2	+10.5	+0.5
11	1	+10.0	0
10	0	+9.4	-0.6
9	-1	+8.7	-1.3
8	-2	+8.0	-2.0
7	-3	+7.2	-2.8
6	-4	+6.4	-3.6
5	-5	+5.6	-4.4
4	-6	+4.9	-5.1
3	-7	+3.9	-6.1

331038-10



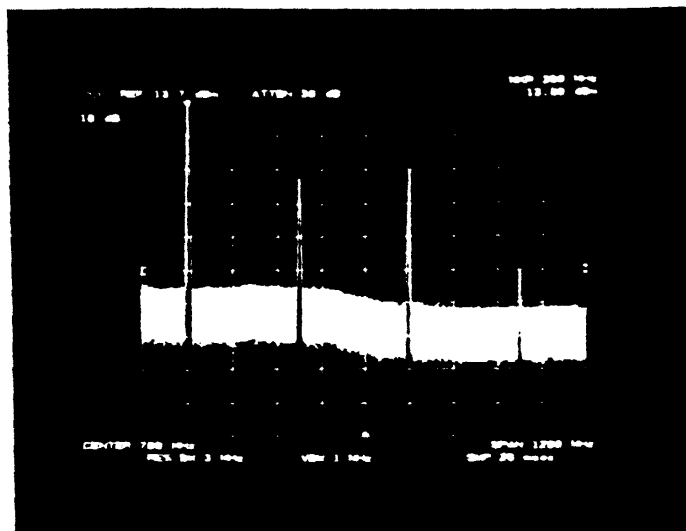
Test Fixture



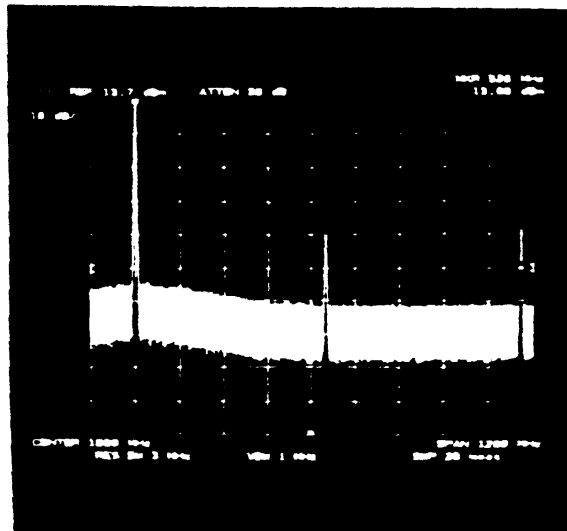
331038-11

Test Fixture

Figure



300 MHz in + 5 dBm
 + 16 dB Pin
 13.2 dBmout



525 MHz + 5dBm
 + 16 dB Pin
 +13.2 dBmout

Spurs generated from LA7 compression are > 22 dBc for 21 dBm input. since compression point of A77-1 is ~ 16.5 dBm, certain that the LA7 is not hit with 21 dBm. The spurs may be generated by the A77-1 more so than the LA7. Nonetheless, analysis shows that very worst case power to the LA7 will be +13.5 dBm. Above spur levels with more Pin than this show no serious spur problems.

