OVLBI-ES MEMO NO. 67

COMPATIBILITY TESTS BETWEEN JPL DATA GENERATOR AND USUDA TRACKING STATION

L. D'Addario, 96/12/23

During the week of 16-20 December 1996, major components of the Usuda tracking station were located at the Sagamihara campus of ISAS for final tests of the VSOP spacecraft. During breaks in that testing (amounting to about two working days), the recently developed JPL VSOP Data Generator (JPL-DG) [1] was used with the Usuda station electronics to establish the validity of the Data Generator's output. Note that similar tests had been done earlier with the Goldstone and Green Bank [2] stations. As time permitted, additional tests of the characteristics of the Usuda station were also carried out.

In summary, no difficulties were encountered. The Usuda equipment was able to decode both the header portion and the data portion of the frames produced by the JPL-DG. Baseband signals consisting of tones of variable amplitude and frequency were used to do bit-level tests of the digitization format. Broadband noise signals (from a JPL noise generator assembly) were used to check the sample statistics vs. power. The Usuda correlator was used to derive autocorrelation spectra for various baseband signals. In all cases, the results were as expected. Finally, a recording on VSOP tape was made using a variety of baseband signal combinations; it is planned that this will be copied to VLBA tape and sent to Socorro for study.

SETUP

A block diagram of the equipment configuration is shown in Figure 1. All of it was set up in the "checkout room" of the satellite test building at ISAS, with the actual VSOP spacecraft present in an adjacent clean room.

We provided for a variety of inputs to the JPL-DG, including the "prompt" and "delayed" noise outputs of the JPL noise generator, and a synthesizer that was coherent with the data clock. Each of these three signals could be connected to either the A or B input, as shown. The noise levels were varied by the front panel attenuator of the noise generator (labeled \alpha in Fig 1), and the tone level was varied by an HP step attenuator (labeled \beta). Absolute levels were checked on a power meter and spectrum analyzer.

The digital outputs of the JPL-DG drove the QPSK modulator in the Japanese VSOP Simulator. (The Simulator has its own data generator, which was not used.) The modulator includes differential encoding, so the encoding feature of the JPL-DG was always turned off. The Simulator was coupled at 14/15 GHz via coax to an upconverter and downconverter like those of the tracking station; these were part of a test rack being used with the satellite, since the actual RF electronics of the Usuda station remained at Usuda. The resulting IF downlink signal (140 MHz carrier) was brought into the first of three racks of actual tracking station hardware.

Frame synchronized bitstreams are sent in parallel to the TLM (telemetry) Extractor, Tone Detector, and recorder interface. Only the VSOP recorder (not the VLBA) was on hand. The Tone Detector can measure one frequency at a time, but it can do both channels simulaneously (in 2-channel modes). It has a front-panel readout of amplitudes and phases, but it was also connected to a PC for control and data recording. The VSOP recorder is also controlled by a PC, which can capture large segments of the data stream for analysis. Software was available for such things as display by channel and bit, computation of digitizer state statistics, and soft sync detection; this proved to be very valuable. Finally, a real-time correlator receives the same bitstreams via the VSOP recorder. It is really a 1-baseline VLBI cross-correlator, but here it was used only for autocorrelations. It has another PC for control, output data collection, spectrum computation, and display.

Control and monitoring of the tracking station modules was dependent mainly on front-panel buttons and displays because the station control computers also remained in Usuda. The available indicators are shown in Figure 1. The main ones used were "Carrier Lock" and "Clock Lock" on the QPSK Demodulator; "Lock On" (frame sync) on the Frame Synchronizer; and "Fr Cntr Error" and the hex display of header data contents on the TLM Extractor. The latter displays data from any two selected IDs.

BASIC TESTS

The JPL-DG and noise generator were operated from the local AC line without adapters or transformers. Line voltage in the "checkout room" of the Environment Test Building, where everything was set up, measured 104 Vrms (cf. 100 V Japanese standard).

With data supplied by the JPL-DG, and with its inputs driven by the JPL noise generator, the Usuda demodulator achieved carrier and clock lock immediately, and the Usuda decoder achieved frame sync immediately. Lock was retained in all three modes, with only a few frame sync errors being noted during the mode changes.

HEADER DATA VALIDITY

The Usuda TLM Extractor module provides front panel hexidecminal displays of the contents of any two header data types; by cycling through all 16 types, the fixed pattern of the JPL-DG was found to be correctly decoded. The TLM Extractor also has a front panel LED to indicate errors in the frame counter byte (W4); it is not clear exactly what this indicator means, but no error was indicated.

This provides a fairly good indication that the header data format is correct. It does not show directly whether the 25-frame repetition or the 2-sec cycle through all data types conforms exactly to the specification, but such detailed checks were made at Green Bank [2], so there is little doubt.

The Usuda Frame Synchronizer module passes the entire data stream, with headers, to the K4/VLBA Interface module. The latter normally replaces the header portion with pseudo-random noise, but optionally it can pass the header data unchanged to the recorder. This was done during parts of these tests, and short segments of data were recorded. During playback, blocks of data can be captured by a computer and analyzed. In this way, some headers were checked bit-by-bit; although an exhaustive verification of the format was not attempted, the general pattern was as expected, including the frame count (W4) and ID (W5) bytes.

SIGNAL SAMPLES

The data portion of the frames, containing the digitized signals, was checked in numerous ways.

A. Sinsoidal signals, bit-level check

First, a 2.0 MHz coherent tone was inserted into one channel, with the other channel's input terminated, and the level was varied, as follows:

Case No.	Chan 1 (A)	Chan 2 (B)	Mode
1	-6.8 dBm	Term	2b,2ch ("3")
2	+6.3	Term	2b,2ch
3	-16.8	Term	2b,2ch
4	Term	-6.8 dBm	2b,2ch
5	-6.8	Term	2b,1ch ("2")
6	-6.8	Term	1b,2ch ("1")

Tape recordings were made and the captured bitstreams were examined in detail upon playback. The analysis software is able to separate the bits by their intended meaning (e.g., in Mode 3, there are four bit types: Chan 1 MSB, 1 LSB, 2 MSB, 2 LSB). Whereas the signal was coherent with the sample clock, the data are periodic. In this way, precise checks of the digitization format were accomplished. Figure 2 shows a listing of a short portion of captured data for each of the above cases.

First, compare cases 1 and 4, which are the same except for swapping the channels. It can be seen that both bits of the channel containing the signal have a period of 16 samples (32MHz/2MHz), and that both bits of the other channel are essentially static. Similarly, in case 6, the signal appears on the chan 1 bits only. This verifies that the format correctly separates the channels.

Next, consider the details of the 1M and 1L bits of case 1, and compare with cases 2 and 3. The MSB is a square wave, with 2 transitions per period, whereas the LSB shows additional transitions, as expected for the intermediate-level signal. This verifies that the MSB and LSB of each sample are assigned to the correct bits in the link stream.

B. Noise signals, statistical check

To further verify the 4-level digitization accuracy, signals from the JPL noise generator were applied to the baseband inputs, the decoded signals were recorded, and the statistics of the played-back streams were analyzed in software provided by H. Kobayashi. The connections were:

Chan 1	prompt	-8.0 dBm at \alpha=4, 16 MHz mode
Chan 2	delayed	-9.2 dBm at \alpha=4, 16 MHz mode

where the levels were measured with a power meter at the JPL-DG's rear panel monitor jacks, and therefore represent the total power into the digitizers. As in Fig. 1, \alpha represents the front panel attenator setting; it was found, unexpectedly, that one step of this attenuator produces 2 dB change in power. The "delayed" noise signal includes about 15 m of RG223 coax, which accounts for the slightly lower level.

Results are shown in Figure 3. We used three signal levels (\alpha=0,4,8, for a range of 16 dB) and both mode 2 (2b,1ch,32MHz) and mode 3 (2b,2ch,16MHz). For mode 3, it can be seen (Fig. 3a,b,c) that the four digitizer values are distributed as expected: the two inner states and the two outer states are about equally populated, with the relative population of the outer levels increasing with signal level. Both channels behave similarly, but the 1.2 dB higher level in channel 1 (A) can be easily seen. For mode 2, only channel 1 is used, and the behavior is almost identical.

C. Spectra

With the same setup as above (noise into 1, delayed noise into 2), spectrum analyzer plots were taken at the JPL-DG's rear panel jacks, and then the digitized and decoded signals were analyzed using the Usuda real-time correlator. Measured autocorrelations were transformed to spectra and plotted. Figure 4 shows the analog and digital spectra for channel 1, and Figure 5 shows the same for channel 2. Notice that the delayed noise has a slope of about 0.2 dB/MHz, whereas the prompt noise is much flatter; this is no doubt due to the attenuation slope of the coax cable.

With a sinusoid at 2.1 MHz and -6.8 dBm into channel 2 in mode 3, we obtained the digital spectrum of Figure 6. It shows a great many lines due to harmonics and aliasing, as expected; the largest is the third harmonic, at about -13 dBc.

TAPE RECORDINGS

A series of six recordings was made on a VSOP tape, each with a different setup, and each lasting about 7 minutes. It is intended that this tape will be copied to a VLBA tape and sent to Socorro for analysis. Some details are given in the log sheet, Figure 7. Here "Ku TLM on/off" refers to whether the downlink headers are included in the data on the tape or replaced by pseudo random noise. For Rec 1 through Rec 5, the noise generator's level setting was \alpha=4 and the tone synthesizer's attenuator was at \beta=13 dB (-6.8 dBm at 2.1 MHz and -7.5 dBm at 11 MHz). In Rec 6, channel A used prompt noise at \alpha=2 and 11 MHz tone at \beta=30 dB into a power combiner (producing a weak tone on normal-level noise), and channel B used the delayed noise signal (\alpha=2) and a 3 dB pad (producing normal-level noise).

With the setup of Rec 6, the tone was observed in the digital autocorrelation spectrum as expected, but a plot was not made. In addition, the tone detector was used to measure the amplitude and phase at 1 MHz intervals; its results (amplitude only) are shown in Figure 8. The desired tone at 11 MHz has amplitude 4.5%; based on the attenuator settings, we expected 10% (-20 dB). The 1.7% response at 10 MHz is the alias of the 22 MHz second harmonic; and the 0.4% response at 1 MHz is the alias of the 33 MHz third harmonic. The 0.8% response at 7 MHz is not understood. The tone was not detected at all in channel B, indicating that the cross-talk is less than 0.1% (-60dB).

ACKNOWLEDGMENTS

The JPL-DG and noise generator were designed and built by Hamil Cooper under the direction of Jim Springett. The SVLBI Project Office at JPL, under the direction of Joel Smith, handled the arrangements for sending the equipment to and from Japan and paid my travel expenses. During the tests at Sagamihara, I received excellent support from N. Kawaguchi, H. Kobayashi, and K. Takahashi.

REFERENCES

[1] J. Springett, "Specification for a VSOP data pattern generator to support verification of VLBA tape compatibility," 23 July 1996.

[2] L. D'Addario, "Tests of JPL's VSOP Data Generator at the NRAO," 4 Dec 1996.

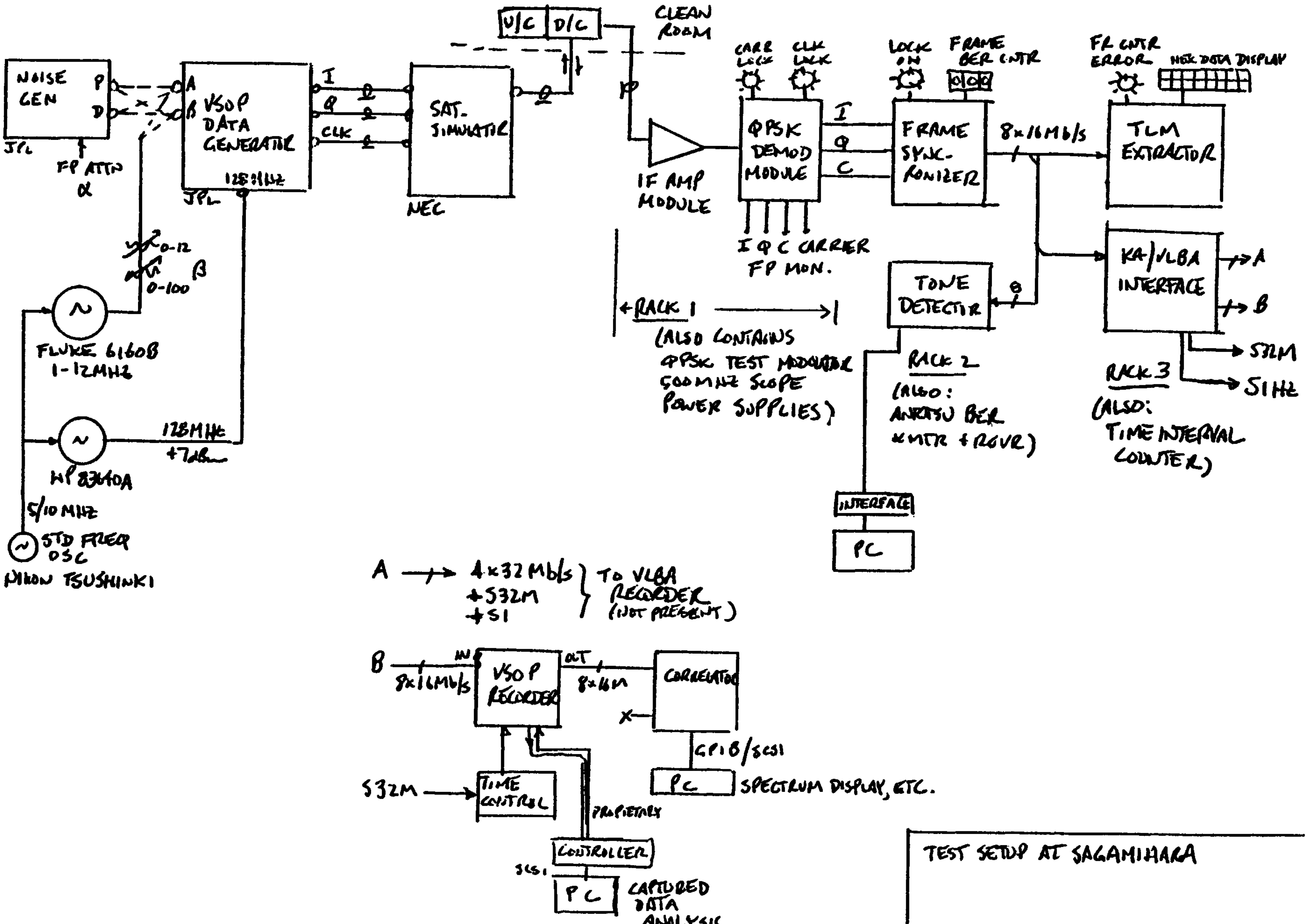


FIGURE 1

TEST SETUP AT SAGAMIHARA

961216-20.

Figure 2: Bit-level checks.

Case 1	2	3	4	5	6
Mode 3				Mode 2	Mode 1
M1 L1 M2 L2				M1 L1 M1 L1	M1 M2 M1 M2
0 1 0 1	0 1 0 1	0 1 0 1	0 1 0 1	0 0 0 0	1 1 1 0
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 0 0 1	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 1 0 1	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 1 0 1	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 1 1 0	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	1 0 1 0	1 0 0 0
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 1	1 0 1 0	1 1 0 0
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 1	1 1 1 1	1 1 0 0
1 0 0 1	1 0 0 1	1 0 0 1	0 1 1 0	1 1 1 1	0 0 0 0
1 0 0 1	1 1 0 1	1 0 0 1	0 1 1 0	1 1 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 0 1	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	0 1 0 1	0 0 0 0
1 0 0 1	1 1 0 1	1 0 0 1	0 1 1 0	0 1 0 1	0 0 0 0
1 0 0 1	1 1 0 1	1 0 0 1	0 1 1 0	0 0 0 0	0 0 0 0
0 1 0 1	0 1 0 1	0 1 0 1	0 1 0 1	0 0 0 0	1 0 1 0
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 0 0 1	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 1 0 1	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 1 0 1	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 1 1 0	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	1 0 1 0	1 0 1 0
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 1	1 0 1 0	0 0 1 0
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 1	1 1 1 1	1 0 1 0
1 0 0 1	1 0 0 1	1 0 0 1	0 1 1 0	1 1 1 1	1 0 0 1
1 0 0 1	1 1 0 1	1 0 0 1	0 1 1 0	1 1 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 0 1	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	0 1 0 1	0 0 0 0
1 0 0 1	1 1 0 1	1 0 0 1	0 1 1 0	0 1 0 1	0 0 0 0
1 0 0 1	1 1 0 1	1 0 0 1	0 1 1 0	0 0 0 0	0 0 0 0
0 1 0 1	0 1 0 1	0 1 0 1	0 1 0 1	0 0 0 0	1 0 1 0
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 0 0 1	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 1 0 1	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 1 0 1	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 1 1 0	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	1 0 1 0	1 0 1 0
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 1	1 0 1 0	1 0 0 0
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 1	1 1 1 1	1 0 1 0
1 0 0 1	1 0 0 1	1 0 0 1	0 1 1 0	1 1 1 1	0 0 0 0
1 0 0 1	1 1 0 1	1 0 0 1	0 1 1 0	1 1 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 0 1	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	0 1 0 1	0 0 0 0
1 0 0 1	1 1 0 1	1 0 0 1	0 1 1 0	0 1 0 1	0 0 0 0
1 0 0 1	1 1 0 1	1 0 0 1	0 1 1 0	0 0 0 0	0 0 0 0
0 1 0 1	0 1 0 1	0 1 0 1	0 1 0 1	0 0 0 0	1 0 1 0
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 0 0 1	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 1 0 1	1 0 1 0
0 0 1 0	0 0 0 1	0 1 0 1	0 1 0 0	0 1 0 1	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	0 1 1 0	1 0 1 0
0 0 0 1	0 0 0 1	0 1 0 1	0 1 0 0	1 0 1 0	0 0 1 1
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 1	1 0 1 0	0 0 1 1
0 1 0 1	0 0 0 1	0 1 0 1	0 1 0 1	1 1 1 1	0 0 1 0
1 0 0 1	1 0 0 1	1 0 0 1	0 1 1 0	1 1 1 1	0 0 0 0
1 0 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 1 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 1 0	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	1 0 0 1	0 0 0 0
1 1 0 1	1 1 0 1	1 0 0 1	0 1 1 1	0 1 0 1	0 0 0 0

FIGURE 3: STATISTICAL CHECK

a. 2b 2ch NORMAL LEVEL

1996年12月16日 16:56 (BITSTAT.07)

a-stream	total number	=	2000000	
	00	=	330790	0.165395
	01	=	684522	0.342261
	10	=	680864	0.340432
	11	=	303824	0.151912
b-strean	total number	=	2000000	
	00	=	258141	0.129071
	01	=	748112	0.374056
	10	=	752359	0.376179
	11	=	241388	0.120694

Mode 3 (2b 2ch) (16MHz)
NG attenuator α=4

A: -8.0 dBm
B: -9.2 dBm
} TO DIGITIZER

b. 2b 2ch +8dB

1996年12月16日 17:18 (BITSTAT.09)

a-stream	total number	=	2000000	
	00	=	699239	0.349620
	01	=	301822	0.150911
	10	=	309501	0.154750
	11	=	689438	0.344719
b-strean	total number	=	2000000	
	00	=	656329	0.328164
	01	=	341195	0.170597
	10	=	352030	0.176015
	11	=	650446	0.325223

α=0
Mode3 2b 2ch 16 MHz

c. 2b 2ch -8dB

1996年12月16日 17:20 (BITSTAT.12)

a-stream	total number	=	2000000	
	00	=	11973	0.005987
	01	=	1043401	0.521701
	10	=	938033	0.469016
	11	=	6593	0.003297
b-stream	total number	=	2000000	
	00	=	4010	0.002005
	01	=	1021175	0.510588
	10	=	972619	0.486309
	11	=	2196	0.001098

α=8
Mode 3

d. 2b 1ch NORMAL

1996年12月16日 17:03 (BITSTAT.08)

a-stream total number = 4000000, 656370, 0.164092 (00), 1358463, 0.339616 (10), 1376363, 0.3440
91, 608804, 0.152201 (11)

Mode 2 2b 1ch 32MHz
α=4

e. 2b 1ch +8dB

1996年12月16日 17:17 (BITSTAT.10)

a-stream total number = 4000000, 1387260, 0.346815 (00), 616577, 0.154144 (01), 614826, 0.15370 (10)
7, 1381337, 0.345334 (11)

α=0
Mode2 2b 1ch 32MHz

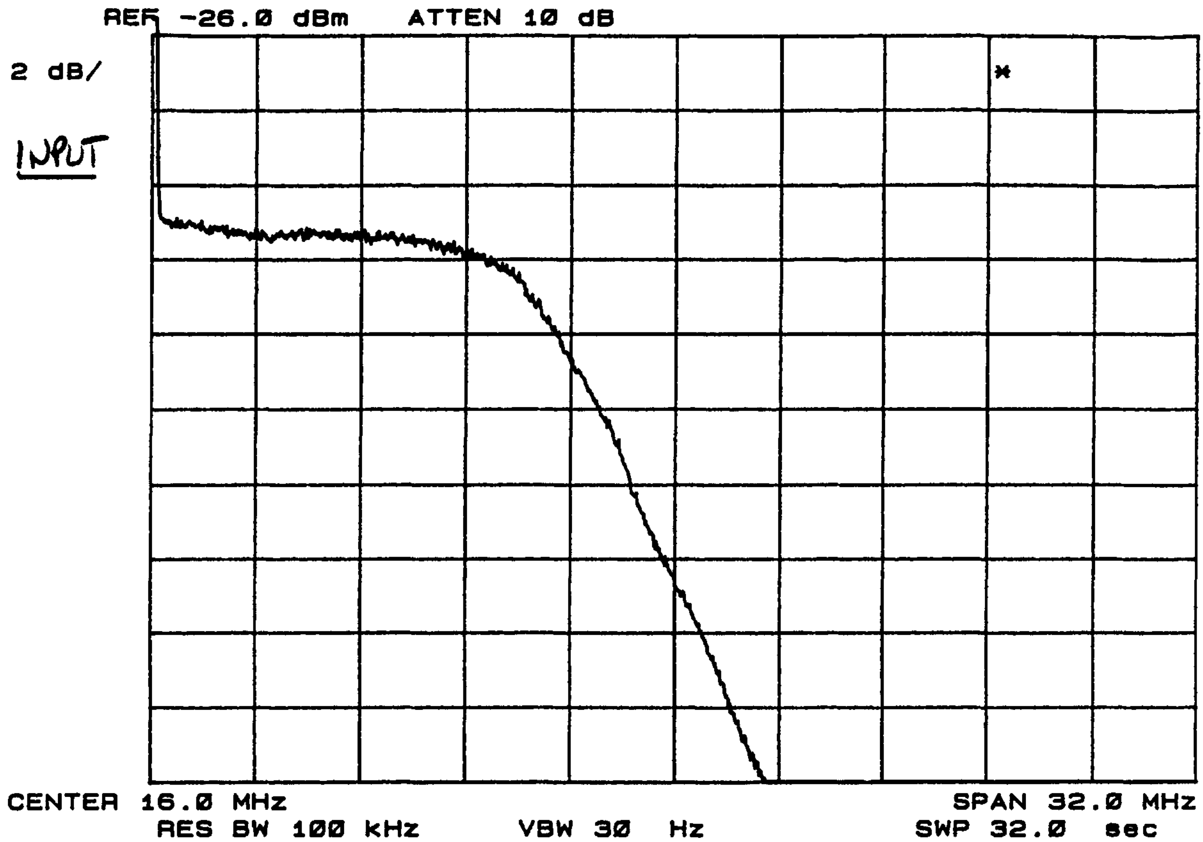
f. 2b 1ch -8dB

1996年12月16日 17:19 (BITSTAT.11)

a-stream total number = 4000000, 20638, 0.005160 (00), 2043285, 0.510821 (01), 1924863, 0.48121 (10)
6, 11214, 0.002804 (11)

α=8
Mode2

JPL DATA GEN, CH 1 FILTER OUT W/ NOISE GEN PROMPT IN, MODE 3, α=4dB 961216.3



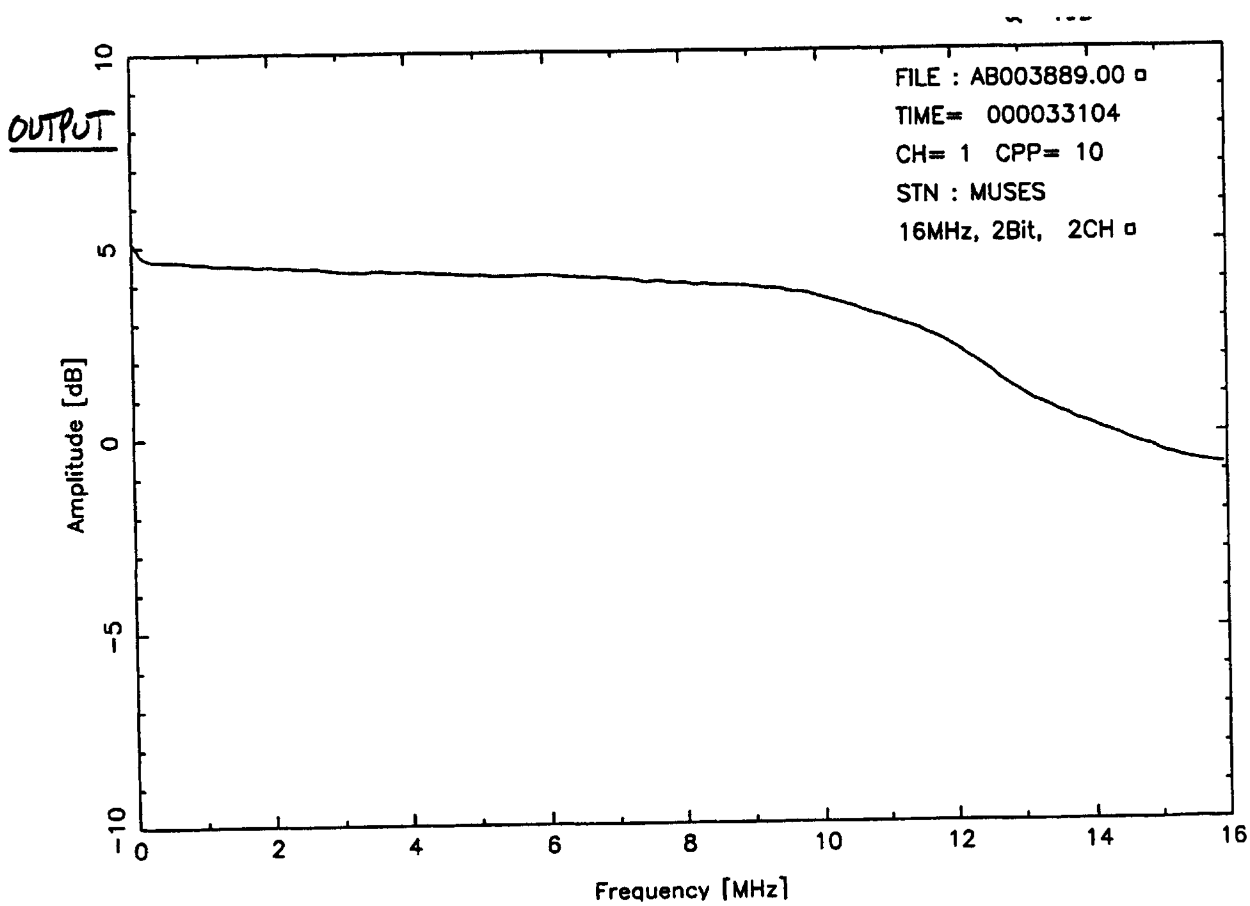
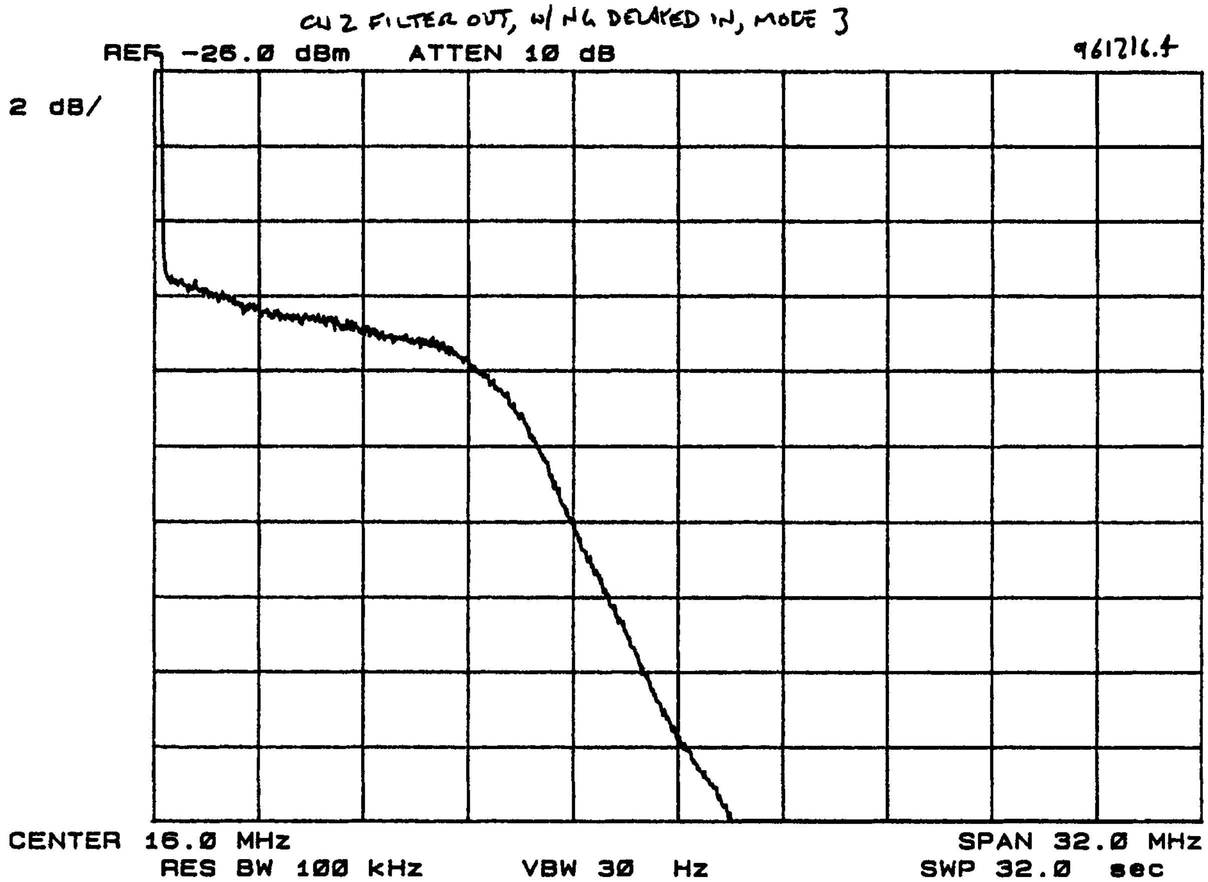


FIGURE 4: SPECTRA, CHAN 1, PROMPT NOISE.



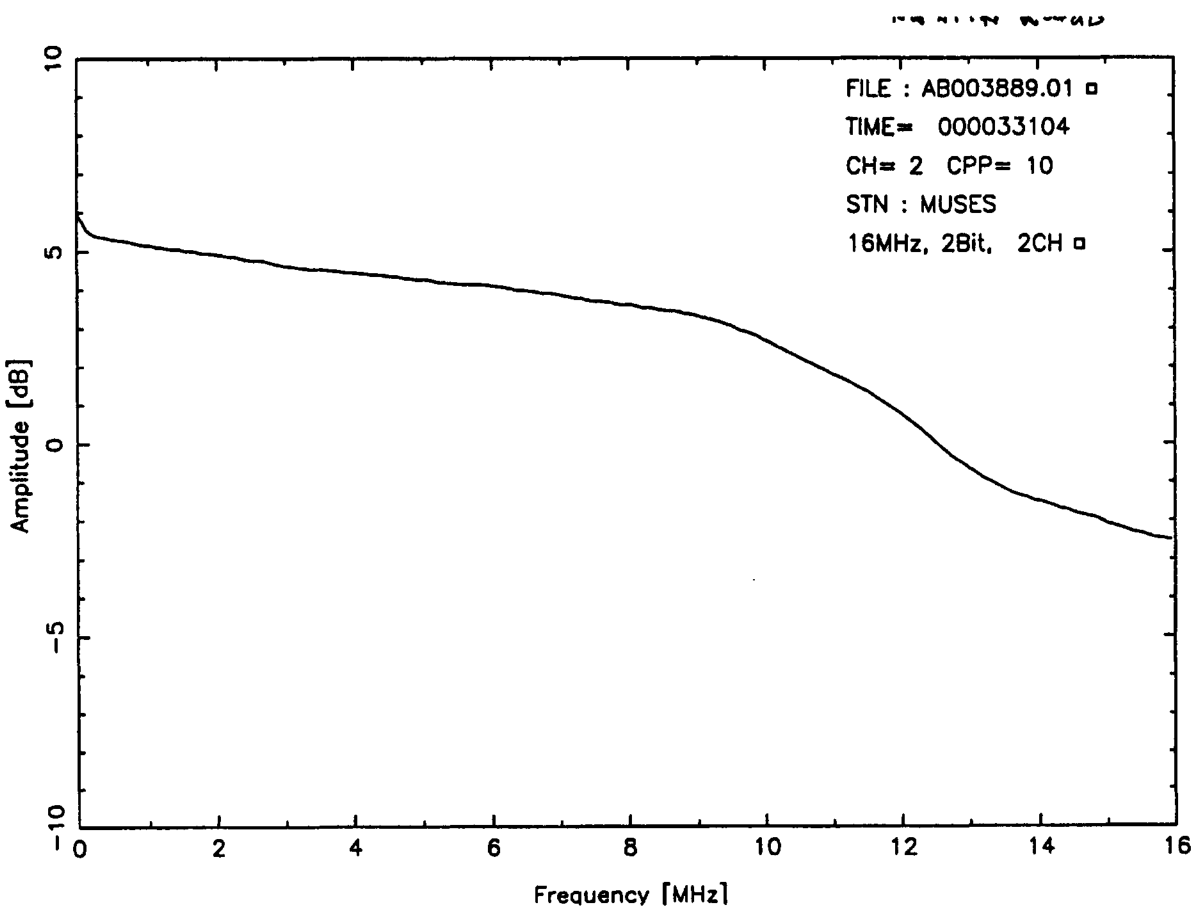


FIGURE 5: SPECTRA, CHAN 2, DELAYED NOISE.

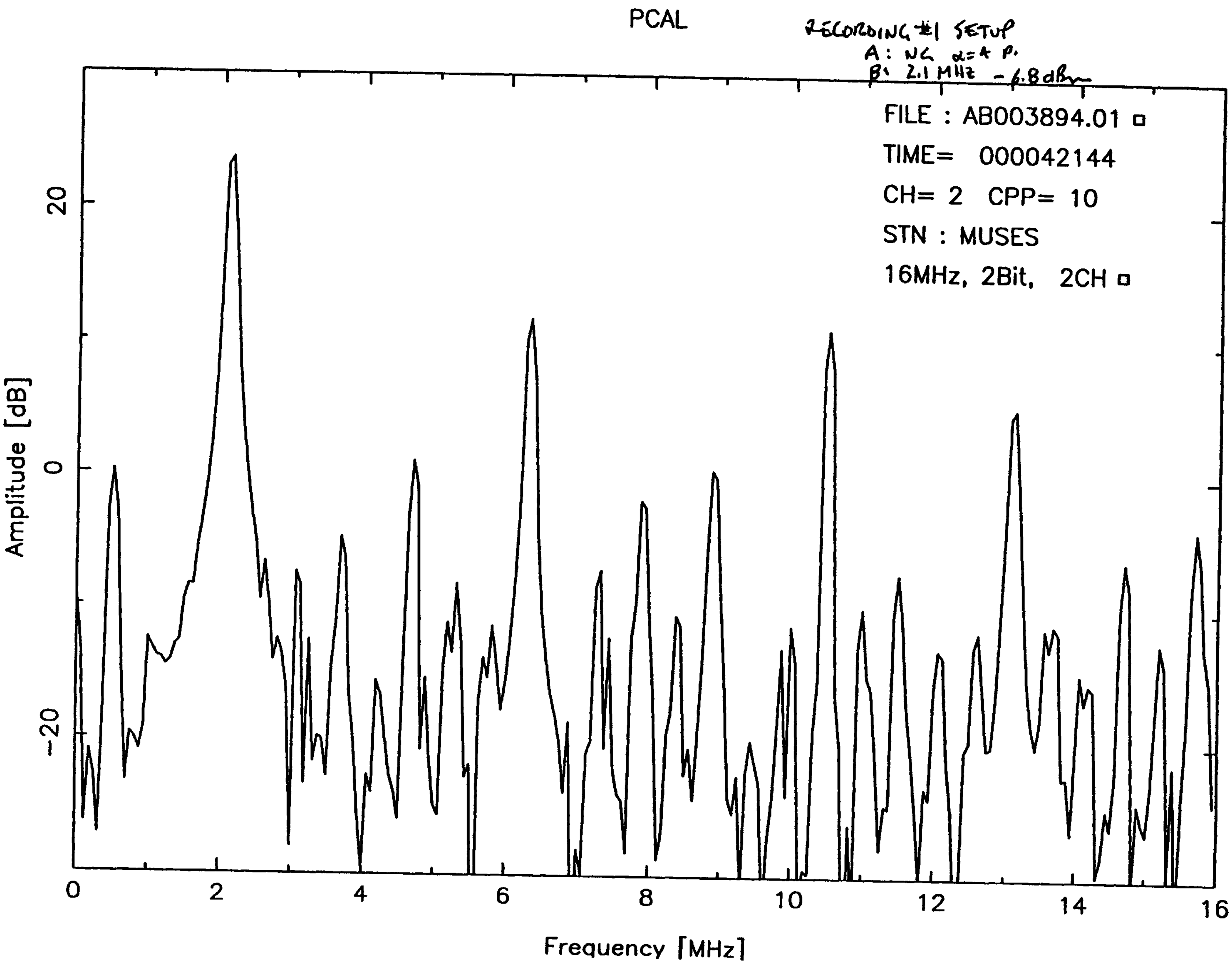


FIGURE 6: OUTPUT SPECTRUM, CHAN 2, 2.1 MHz SINUSOID AT -6.8dBm.

FIGURE 7: RECORDING LOG.

JPL コンパチ　VSOP-7125-OB　シートNo.

試験名	MUSES-B(FM) ~~衛星総合試験 (最終組立後詳細動作チェック)~~					試験成果 合否判定	合・否
品名	MUSESB-(FM)観測信号系サブシステム	P/N	183-508416-001	S/N	001	データレビュー	
日付・検査者	'96. 12. 17 /	温度	常温、(　°C)			データ取得時 手順書版数	
項目名	観測信号系　分光計データ						

測定時刻　　:　　:　　　NOTE: VSOP Tape Recording

~~UP LINK LEVEL : 95dBm　KRX AGC TLM:　dBm　DOWN LINK PWR:　dBm　KTX PWR TLM:　dBm~~

データ　ログ表　注；各測定モードでの OBS_QL画面のコピーを取得すること。
データ　ログ表　　　　16-2-2

実施日	試験項目		レコダー情報				QL情報		
	項目	詳細パラメータ	テープID	スタート	ストップ	レコード時間	ファイルNo.	PP_No.	
Ku TLM ON →									
	REC 1	mode3 (A) JPL N4 (B) 2.1MHz	NRO95098	45,164	96,474	7 min	AB003905	20	
	REC 2	mode3 (A) Noise (delay) (B) ~~delayed~~ Noise		96,474	144,588	7 min	AB003907	20	
	REC 3	(A) 2.1MHz p=13 (B) Noise (delay)		144,588	203,434	7 min	AB003912	20	
Ku TLM OFF →									
	REC 4	(A) Noise (B) delay Noise		203,434	260,796	>7 min	AB003913		11/2
	REC 5	(A) Noise (B) 11.0MHz (13dB)		260,796	338,702	>7 min	AB003914		11/4
	REC 6	(A) Weak 11MHz + Noise (B) Noise (delay)		338,702	388,628	>7 min	AB003916		

RECORDING #6

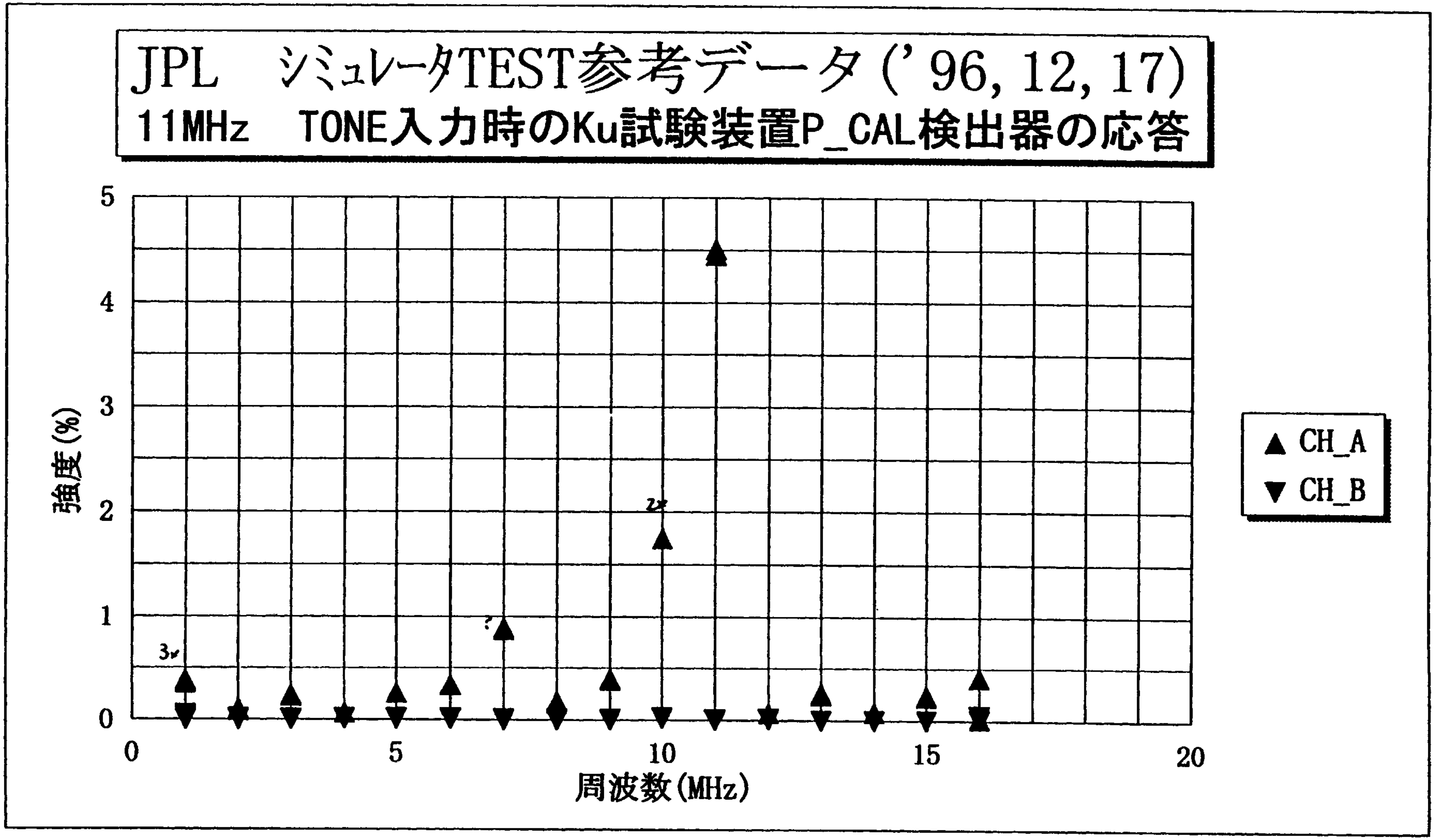


FIGURE 8: TONE EXTRACTOR RESULTS.

CH A: NOISE, NORMAL LEVEL + 11.0MHz TONE AT -20dB.

CH B: DELAYED NOISE, NORMAL LEVEL (NO TONE).