AT Technical Data
AT/39.2/053
September 22, 1993.

THE AUSTRALIA TELESCOPE NATIONAL FACILITY

VLBI TEST TONE UNIT

Russell Gough
Grahame Herbert

1. INTRODUCTION.

This note describes the test tone units used at Narrabri and Mopra during VLBI observations to check the phase coherence of the receiver system. The test tone is also used when the AT receivers are set up to receive circular polarization.

Sections 2 and 3 describe the installation and operation of the test tone units. The theory of operation of the test tone units is described in Section 4. Some manufacturer's data sheets are included in the Appendix.

2. INSTALLATION.

At both Narrabri and Mopra the test tone unit is installed in the equipment rack in the vertex room. The FLUKE synthesizers and the test tone units are phase-locked to a 5 MHz reference tone.

At Mopra, the 5 MHz reference comes from the control room. The FLUKE synthesizer is located in the control room for convenience.

At Narrabri, the 5 MHz reference comes from the crystal oscillator in the L41 (5MHz VCXO) module in the sampler rack. This oscillator is locked to the Rubidium oscillator in the correlator room via the 160 MHz phase transfer system. A splitter in the test tone unit provides the 5 MHz reference for the FLUKE synthesizer which is installed in the equipment rack, beneath the test tone unit.

3. OPERATION.

3.1. Test Tone Control.

Block diagrams of the Narrabri and Mopra test tone circuits are shown in Figs. 1 and 2 respectively. There are separate outputs on the test tone box for the L/S, C/X and METHANOL test tones. The test tone boxes at Mopra and Narrabri are basically similar, but there are differences in their operation.

At present (September, 1993.) there is no 12 GHz METHANOL receiver at Narrabri, so the 6.1 GHz filter and AVANTEK doubler have not been purchased for the Narrabi unit.

The output frequency and power of the test tone unit can be controlled by changing the output frequency and power of the FLUKE synthesizer. At Mopra the test tone is turned on and off via the RF output of the FLUKE synthesizer which is located in the control room. At Narrabri, , the test tone is turned on and off remotely as the FLUKE synthesizer is located in the antenna vertex room.

The output of the test tone unit at Narrabri is switched on and off via an RF switch in the line from the synthesizer. The RF switch can be controlled locally or remotely. On the front panel of the Narrabri unit there are two push-button switches and a toggle switch. For normal operation the toggle switch is in the up (REMOTE) position; for local operation the toggle switch is in the down (LOCAL) position. When the test tone unit is in LOCAL, the push-button switch on the left (with a red LED) turns the test tone on; the one on the right (with a green LED) turns the test tone off. For remote operation, the RF switch is controlled via a control point (CMD 09) on dataset 18. The LEDs show whether the test tone is on (red LED) or off (green LED). The state of the dataset control point is controlled by the observing program, CAOBS: the CAOBS commands SET TTON and SET TTOFF turn the test tone on and off respectively.

3.2. Test Tone Frequency.

The frequency of the test tone for the L/S receiver is 2× and 4× the FLUKE synthesizer frequency; for the C/X receiver it is 6500 MHz plus or minus 2× and 4× the FLUKE synthesizer frequency; for the METHANOL receiver it is 13000 MHz minus 4× the FLUKE synthesizer frequency.

The relationship between the FLUKE synthesizer frequency, F_{FLUKE} , and the test tone frequency, $F_{Test\ tone}$, is shown in Fig. 3. The synthesizer frequency is calculated using equations (1) to (7).

$$1200\text{MHz} < F_{Test\ tone} < 1800\text{MHz}: \qquad F_{FLUKE} = \frac{F_{Test\ tone}}{2} \tag{1}$$

$$2200\text{MHz} < F_{Test\ tone} < 2500\text{MHz}: \qquad F_{FLUKE} = \frac{F_{Test\ tone}}{4} \tag{2}$$

$$4400\text{MHz} < F_{Test\ tone} < 4500\text{MHz}: \qquad F_{FLUKE} = \frac{6500 - F_{Test\ tone}}{4} \tag{3}$$

$$4500\text{MHz} < F_{Test\ tone} < 6100\text{MHz}: \qquad F_{FLUKE} = \frac{6500 - F_{Test\ tone}}{2} \tag{4}$$

$$6600\text{MHz} < F_{Test\ tone} < 8500\text{MHz}: \qquad F_{FLUKE} = \frac{F_{Test\ tone} - 6500}{2} \tag{5}$$

$$8500\text{MHz} < F_{Test\ tone} < 9200\text{MHz}: \qquad F_{FLUKE} = \frac{F_{Test\ tone} - 6500}{4} \tag{6}$$

$$12000\text{MHz} < F_{Test\ tone} < 12400\text{MHz}: \qquad F_{FLUKE} = \frac{13000 - F_{Test\ tone}}{4} \tag{7}$$

where $F_{Test\ tone}$ and F_{FLUKE} are in Megahertz.

Commonly used test tone frequencies and the corresponding FLUKE synthesizer frequencies are given in Table 1.

$F_{Test\ tone}$ (MHz)	F_{FLUKE} (MHz)
1663.29	831.645
2290.3	572.575
4850.3	824.85
6668.3	84.15
8420.3	960.15
12180.3	204.925

Table 1. Commonly used test tone frequencies and the corresponding FLUKE synthesizer frequencies

3.3. Test Tone Output Power.

Although the test tone circuit was designed with a +13 dBm input from the FLUKE synthesizer, lower signal levels are used in practice The output power of the FLUKE synthesizer is used to control the output level from the test tone unit.

4. THEORY OF OPERATION.

4.1. Microwave Circuit.

The input from the FLUKE synthesizer drives a frequency doubler and then an AVANTEK amplifier. The output level of the FLUKE synthesizer is typically +13 dBm so the frequency doubler produces lots of second and fourth harmonic output, and drives the AVANTEK amplifier hard to enhance the fourth harmonic component. Some of this signal is coupled out as the L/S test tone. For L-Band, the second harmonic output is used; and for S-Band, the fourth harmonic output is used. Fig. 4 shows the spectrum of the test tone for the L/S receiver with a FLUKE output frequency of 572.5 MHz, and the envelope of the test tone as the synthesizer is swept from 500 MHz to 1000 MHz. This signal is used to modulate a 6500 MHz tone.

A MITEQ oscillator, phase-locked to the 5 MHz reference, provides the 6500 MHz tone which is modulated by the second and fourth harmonics of the FLUKE synthesizer frequency. The spectrum of the signal from the phase-locked oscillator is shown in Fig. 5.

Some of the modulated 6500 MHz signal is coupled out as the C/X test tone. The difference frequencies lie in C-Band and the sum frequencies lie in X-Band. Figs. 6 and 7 show the spectrum of the test tone for the C/X receiver with the FLUKE output at 960 MHz, and the envelope of the test tone as the synthesizer is swept from 200 MHz to 1000 MHz and from 500 MHz to 1000 MHz respectively.

With the FLUKE synthesizer set to 200 MHz, the output of the mixer has a component at 6100 MHz. This tone is filtered out, doubled to 12200 MHz, and used as the test tone for the METHANOL receiver. Fig 8. shows the spectrum of the output of K&L 3FV-6100/270 filter with the FLUKE synthesizer set to 200 MHz, and the envelope of the filter output as the synthesizer is swept from 75 MHz to 325 MHz. Fig. 9 shows the spectrum of the test tone for the METHANOL receiver with the FLUKE synthesizer set to 200 MHz.

The test tone is turned on and off by switching the RF output of the FLUKE synthesizer. Fig 10 shows the spectrum of the test tone for the C/X receiver, with the FLUKE synthesizer set to 200 MHz, with the RF output on and off. With the RF output on, the level of the 6500 MHz break through is -24 dBm, which is about 14 dB below that of the sum and difference tones at 6900 MHz and 6100 MHz. When the RF output is off, the level of the 6500 MHz break through drops to -31 dBm. The 6500 MHz break through should cause no interference as it is far from any VLBI observing band.

4.2. Test Tone Control Board (Narrabri Unit only).

The circuit diagram and component layout of the Narrabri test tone control board are shown in Figs. 11 and 12. S2/S4 is a ganged toggle switch which selects between LOCAL (connected to S1 and S3) and REMOTE operation.

For REMOTE operation, a rising (falling) edge on the opto-coupled dataset input, X2, will trigger a pulse from monostable U1:A (U1:B). This pulse activates the appropriate relay control line via U3:A (U3:B), TR1 (TR3) and TR2 (TR4). U2:A ensures that the pulse appears on the output of only one of U3:A and U3:B. The pulse from U3:A (U3:B) is inverted by U2:B (U2:C) and clears (sets) flip flop U5:A. LED2 (LED1) indicates that the test tone is on (off).

For LOCAL operation, push-button switches S1 and S3 replace the monostable outputs.

APPENDIX

Manufacturer's Data sheets

A-1 Avantek AFT-2032 amplifier.

A-2 K&L 3FV-6100/270 filter.

A-3 Miteq DPLM-5-6500-0-15P phase locked oscillator.

A-4 Miteq MAX2H080160 active doubler.

A-6 Western Microwave MJ37LV mixer.

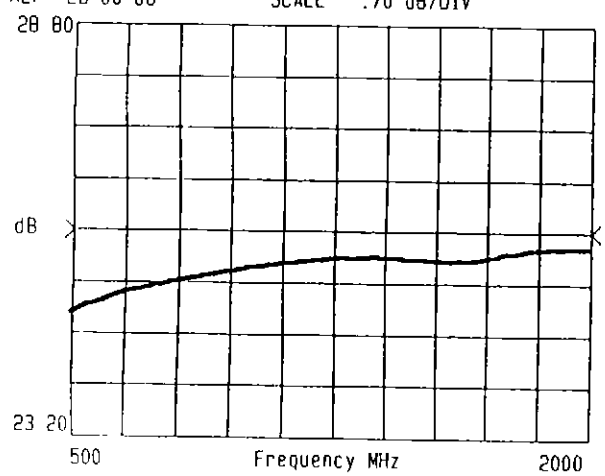
AVANTEK
104 Woodmere Road
Folsom, California 95630

ACCEPTANCE TEST DATA

CSO#: Model: **AFT-2032-10F** Ser.#: **367B** 2 Oct 1991

Bias Voltage: 15 VDC Bias Current: 106 mA Test Temp. 25 deg C

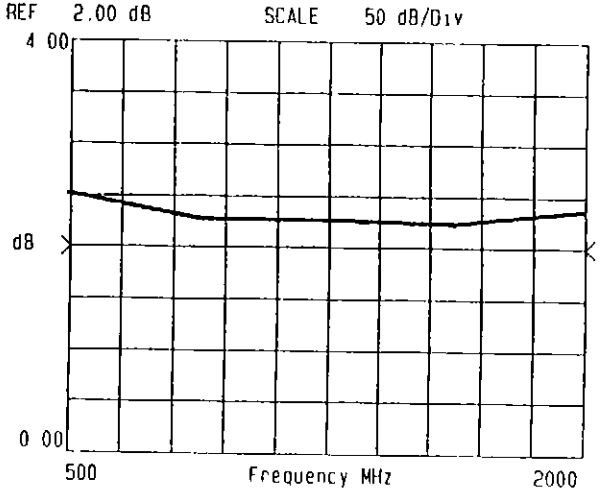
Gain



Freq MHz	Gain dB
500	24.91
875	25.42
1250	25 66
1625	25 64
2000	25 82
Min:	24.91
Max:	25.82

Pass GAIN Spec 20 0 dB Min Pass Flatness Spec +/- .7 dB Max

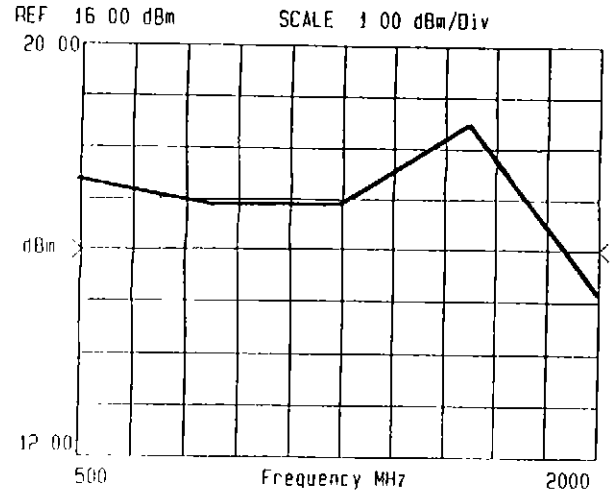
Noise Figure



Freq MHz	N F dB
500	2 53
875	2 30
1250	2 28
1625	2 25
2000	2 38
Min	2 25
Max	2 53

Pass Noise Figure Spec 3.7 dB Max

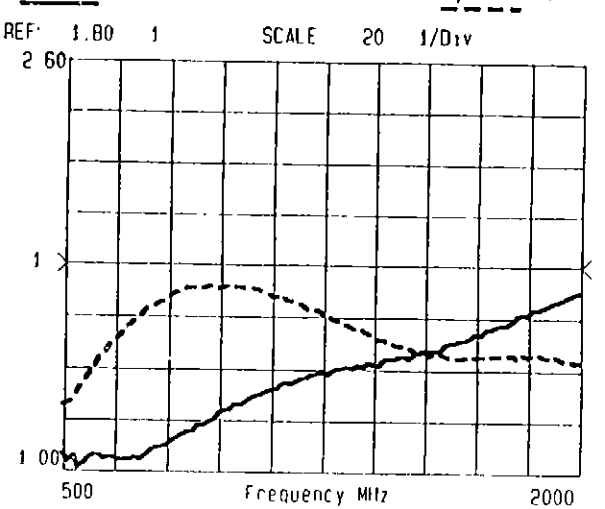
1 dB Comp



Freq MHz	P-1dB dBm
500	17 41
875	16 93
1250	16.94
1625	18 51
2000	15 20
Min	15 20
Max	18 51

Pass 1 dB Comp Spec 13 0 dBm Min

Input VSWR / Output VSWR



Freq MHz	I VSWR 1	O VSWR 1
500	1 08	1 26
875	1 17	1 72
1250	1 40	1 62
1625	1 51	1 45
2000	1 71	1 44
Max	1 71	1 73

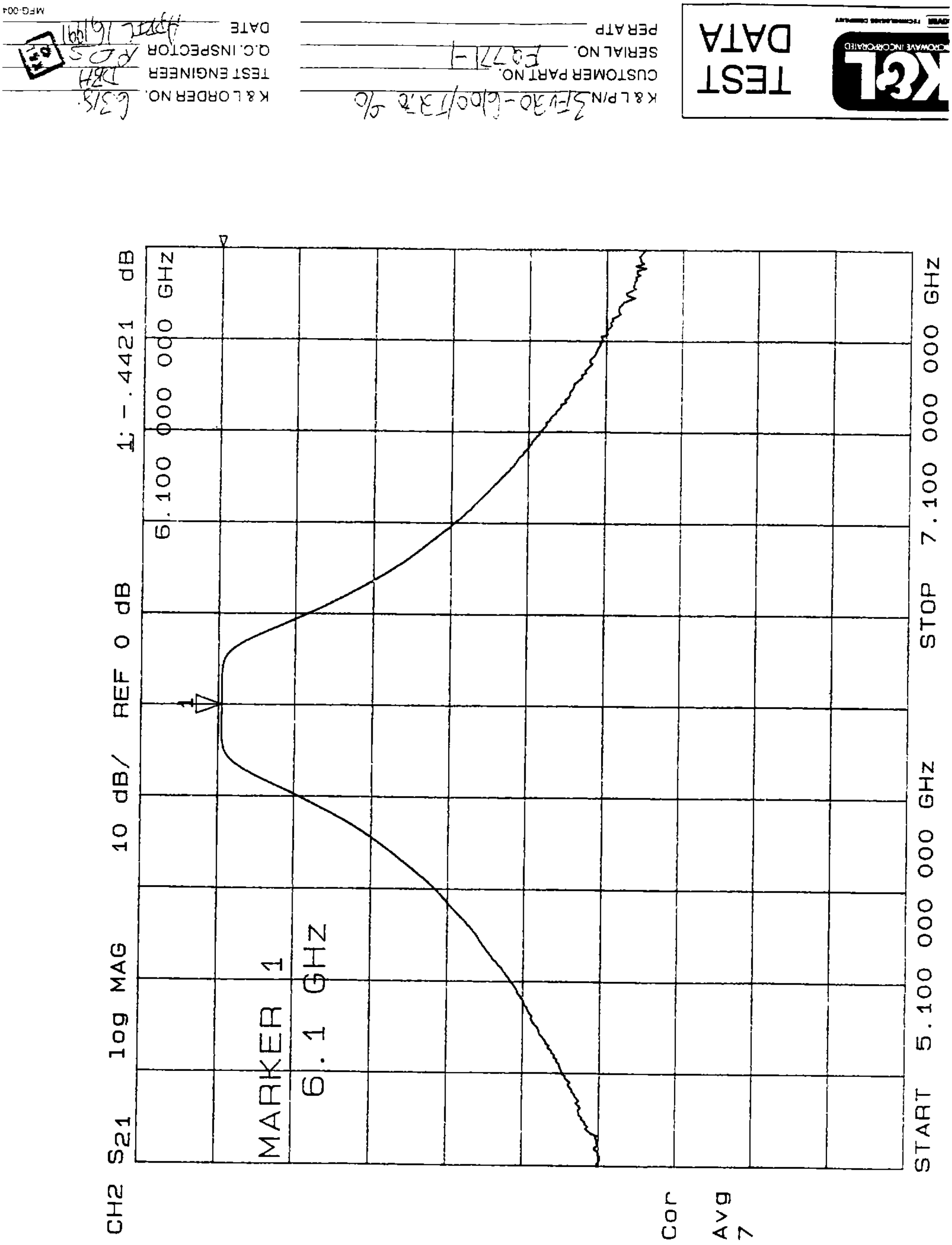
Pass In VSWR Spec 2 0 1 Max Pass Out VSWR Spec 2 0 1 Max

Additional Tests/Notes

10-2-91 AM

A-1

Avantek AFT-2032 amplifier.



A-2

K&L 3FV-6100/270 filter.

MITEQ
100 Davids Drive. Hauppauge N Y 1178
TEL (516)
TELEX
FAX 516-

PHASE LOCK OSCILLATOR TEST DATA

MITEQ Project#: P33745

MITEQ Model#: DPLM-5-6500-0-15P

MITEQ Serial#: 204651

FREQUENCY: 6500 MHz

A. Frequency - Power Characteristics

FREQUENCY (MHz)	POWER OUTPUT (+dBm)
6500	16.2
NA	NA

Minimum Power Output NA dBm at NA MHz

Maximum Power Output NA dBm at NA MHz

B. Phase Lock Test Point("TP") 10.3 volts

C. Spurious Rejection >-70 dB relative to carrier

D. DC Power 5/20 volts at 270/290 mA

E. Input Frequency 5 MHz

F. Input Power 0±3 dBm

Tested By: A.T. Date: 3/22/91

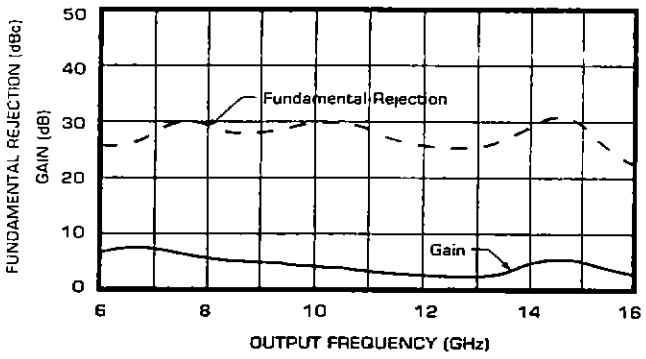
Miteq DPLM-5-6500-0-15P4
phase locked oscillator.

FREQUENCY MULTIPLIERS

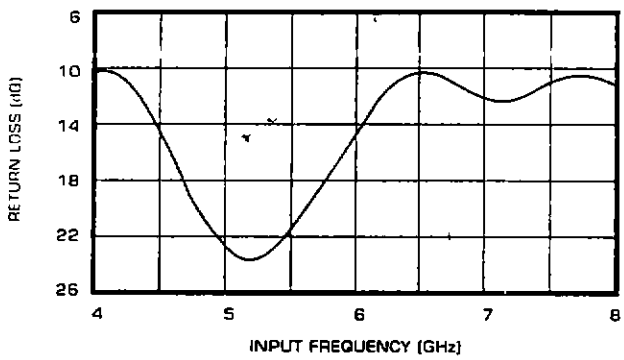
ACTIVE FREQUENCY DOUBLERS (Cont.)

Outline Number	Frequency Range (GHz) Input	Output	Doubling Gain (dB)	Input Drive (dBm)	Typical Rejection Relative to Doubled Output (dBc) Fundamental	Odd Harmonics
MAX2H080160	4-8	8-16	0	8-16	15	15
MAX2M008030	0 4-1.5	0.8-3.0	4	6-14	20	20

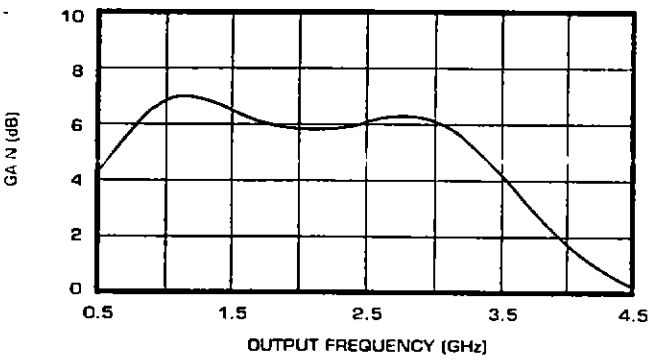
GAIN AND FUNDAMENTAL REJECTION
INPUT LEVEL = 15 dBm



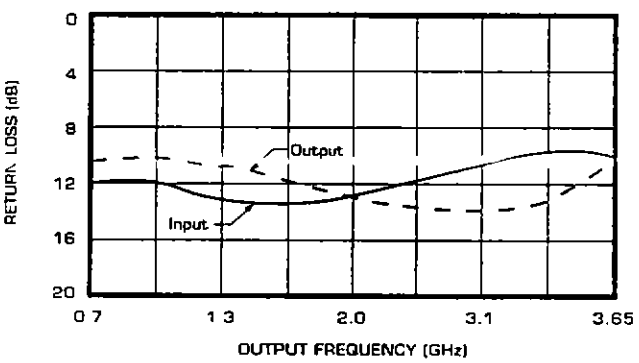
INPUT RETURN LOSS
AT +15 dBm INPUT LEVEL



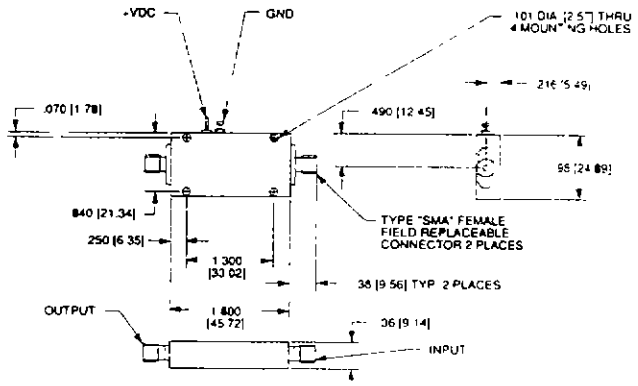
GAIN VS. FREQUENCY
INPUT LEVEL = 7 dBm



INPUT AND OUTPUT RETURN LOSS

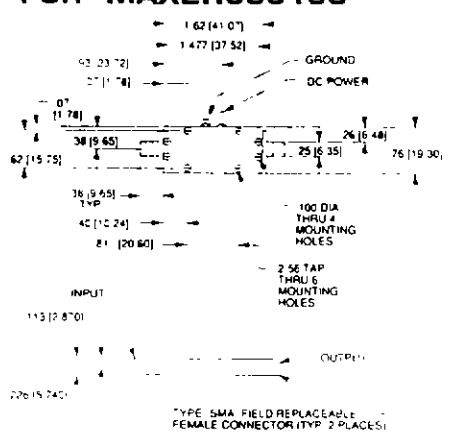


OUTLINE FOR MAX2M008030



NOTE: DIMENSIONS ARE IN INCHES AND [MILLIMETERS]

OUTLINE FOR MAX2H080160



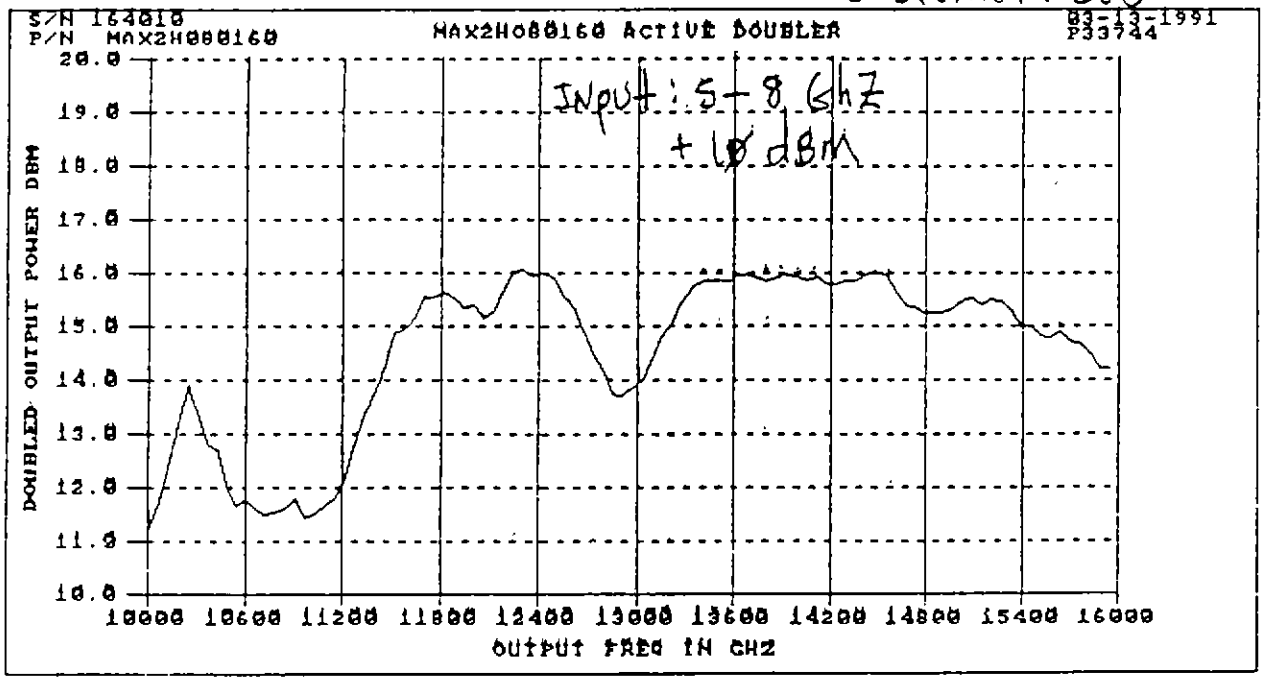
TYPE SMA FIELD REPLACEABLE FEMALE CONNECTOR (TYP. 2 PLACES)

Miteq MAX2H080160 active doubler.

MITEQ, INC.
PHONE (516) 436-7400 E
FAX 516-436-7430
100 DAVIDS DRIVE
HAUPPAUGE, NY 11788

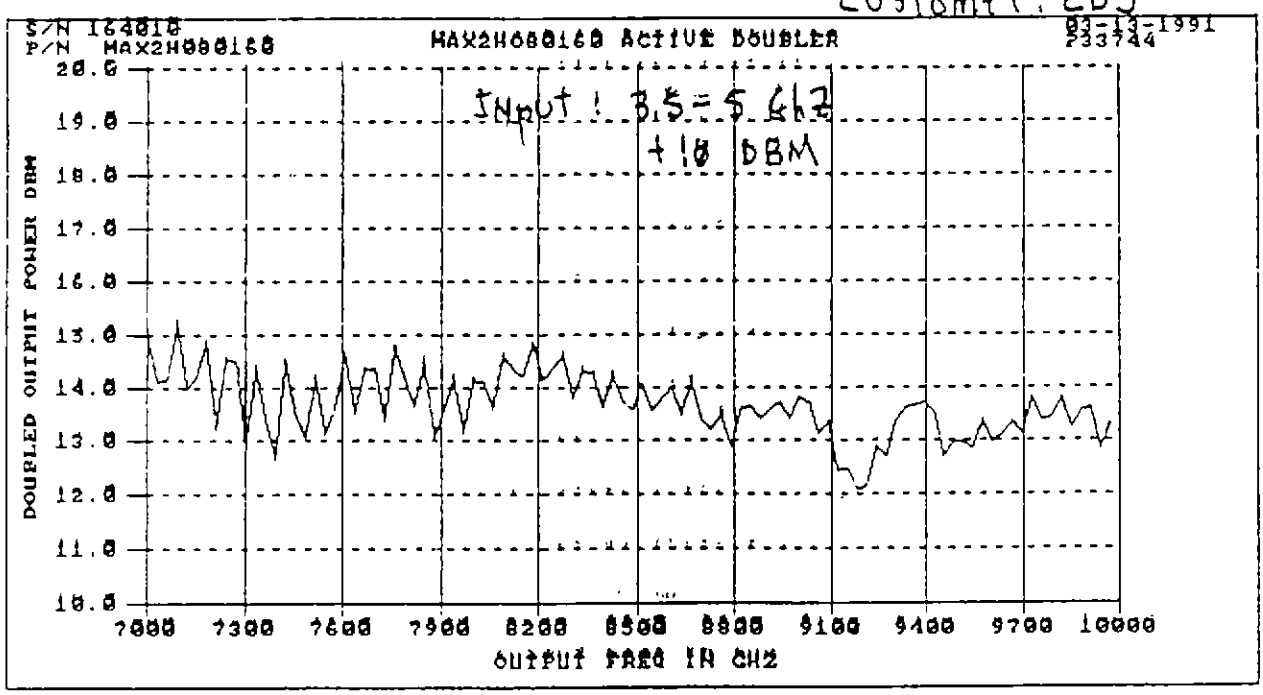
:18:36 Datapoint spacing = 60.6 MHz

CUSTOMER: EDS



:26:30 Datapoint spacing = 30.3 MHz

CUSTOMER: EDS



FUNDAMENTAL REJECTION WAS FOUND TO BE 15 dBc FOR THE ENTIRE OUTPUT RANGE OF 8-16 GHZ

HEAT SINK/SPACER IS SUPPLIED

POWER: +15VDC

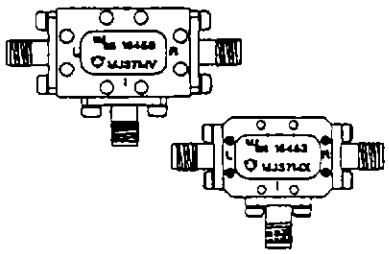
SMA CONNECTORS

ENGINEER: BAZ

2/12/91

MICROWAVE MIXERS

MJ37
4.0 to 18.0 GHz
DOUBLE BALANCED MICROWAVE MIXERS



- 4.0 TO 18.0 GHz RF and LO
- DC to 4.0 GHz IF Band
- Double Balanced
- Low Conversion Loss
- High Isolation
- Low VSWR
- High Intercept Point
- Hermetically Sealed
- Pin-Packages
- Field Replaceable Connectors

PERFORMANCE SPECIFICATIONS

PARAMETER	FREQUENCY RANGE	SPECIFICATION (2)
SSB Conversion Loss or SSB Noise Figure (1)	FR, FL 4.0 – 16.0 GHz FI DC – 1.0 GHz	6.0 dB typ 7.5 dB max
	FR, FL 4.0 – 16.0 GHz FI DC – 4.0 GHz	6.5 dB typ 8.5 dB max
	FR, FL 4.0 – 18.0 GHz FI DC – 4.0 GHz	7.0 dB typ 9.0 dB max
Isolations L–R, R–L, R–I	FL, FR 4.0 – 18.0 GHz	30 dB typ 18 dB min
L–I	FL 4.0 – 6.0 GHz	10 dB typ 8 dB min
	FL 6.0 – 8.0 GHz	15 dB typ 10 dB min
	FL 8.0 – 10.0 GHz	22 dB typ 15 dB min
	FL 10.0 – 18.0 GHz	25 dB typ 18 dB min
Conversion Compression 1.0 dB max	FR, FL 4.0 – 12.0 GHz FI DC – 4.0 GHz	+1 dBm min. L Version +4 dBm min. M Version +7 dBm min. I Version +10 dBm min. T Version +12 dBm min. H Version
Third Order Two-Tone Intercept Point	FR, FL 4.0 – 18.0 GHz FI DC – 4.0 GHz	+11 dBm typ. L Version +14 dBm typ. M Version +17 dBm typ. I Version +19 dBm typ. T Version +20 dBm typ. H Version

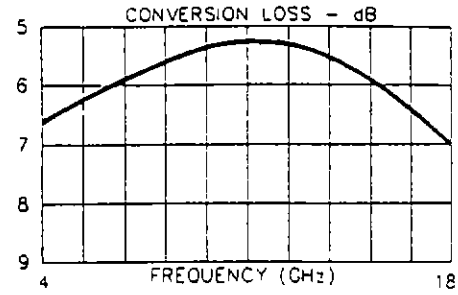
1. Noise Figure specified for FI above 30 MHz.
2. All specifications guaranteed for an LO drive of +7 dBm minimum for the "L" version, +10 dBm for the "M" version, +13 dBm for the "I" version, +16 dBm for the "T" version, and +19 dBm for the "H" version
3. See outline drawings for the "M", "R", "V", "X", "XA", "XJ", "XC1", "XC2", and "Z" type packages

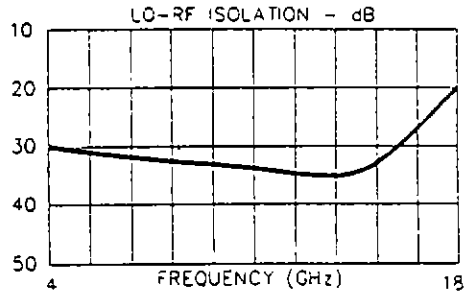
MODEL NUMBERING SYSTEM

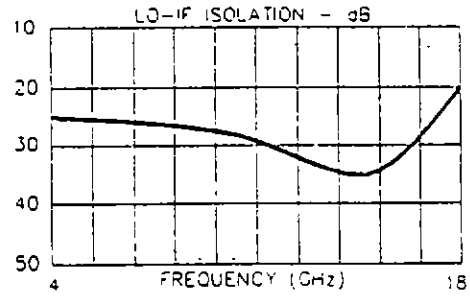
MJ37LX
- L — PACKAGE STYLE
- X — LOCAL OSCILLATOR DRIVE

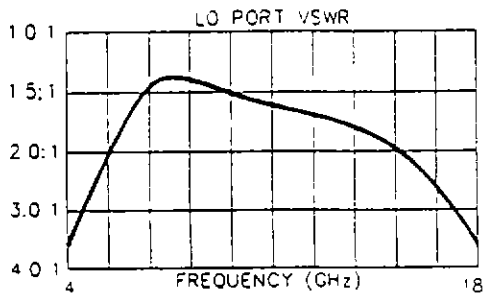
495 Mercury Drive, Sunnyvale, CA 94086
Tel (408)738-2800 FAX (408)738-2846

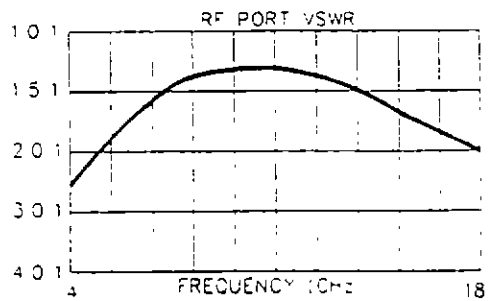
TYPICAL PERFORMANCE AT 25°C,
IN A 50 OHM TEST ENVIRONMENT











Western Microwave MJ37LV mixer.

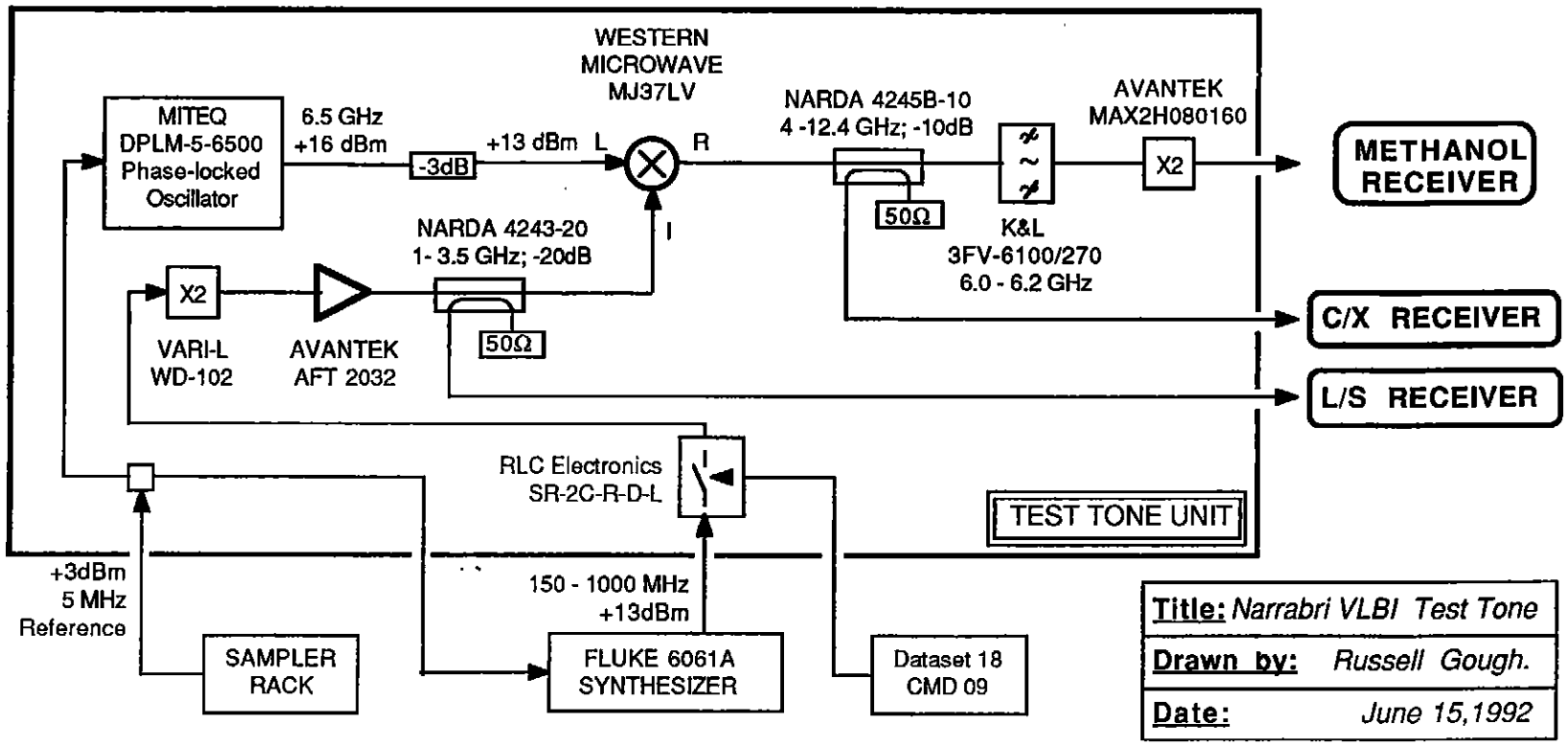


Fig. 1. Block diagram of the Narrabri test tone circuit.

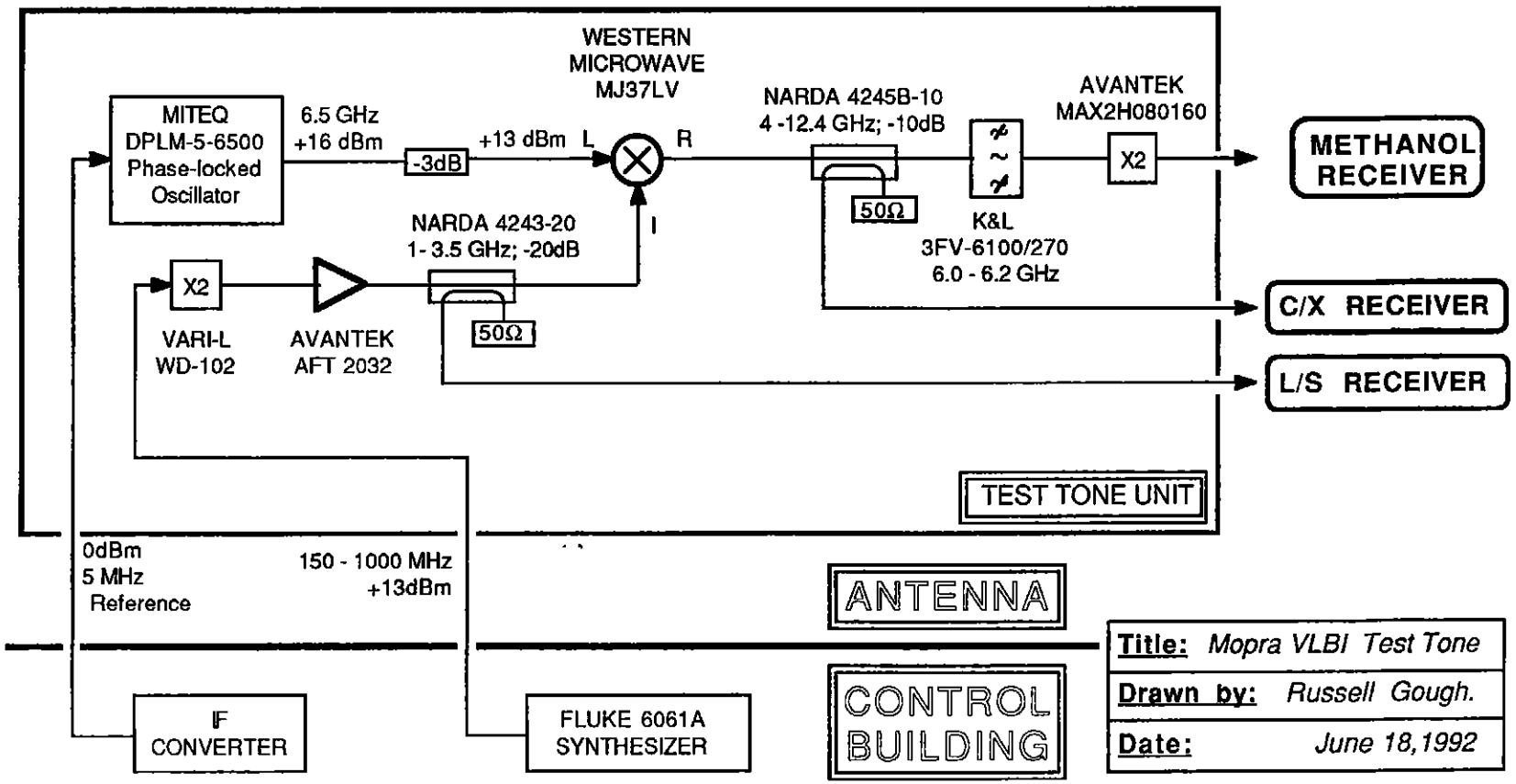


Fig. 2. Block diagram of the Mopra test tone circuit.

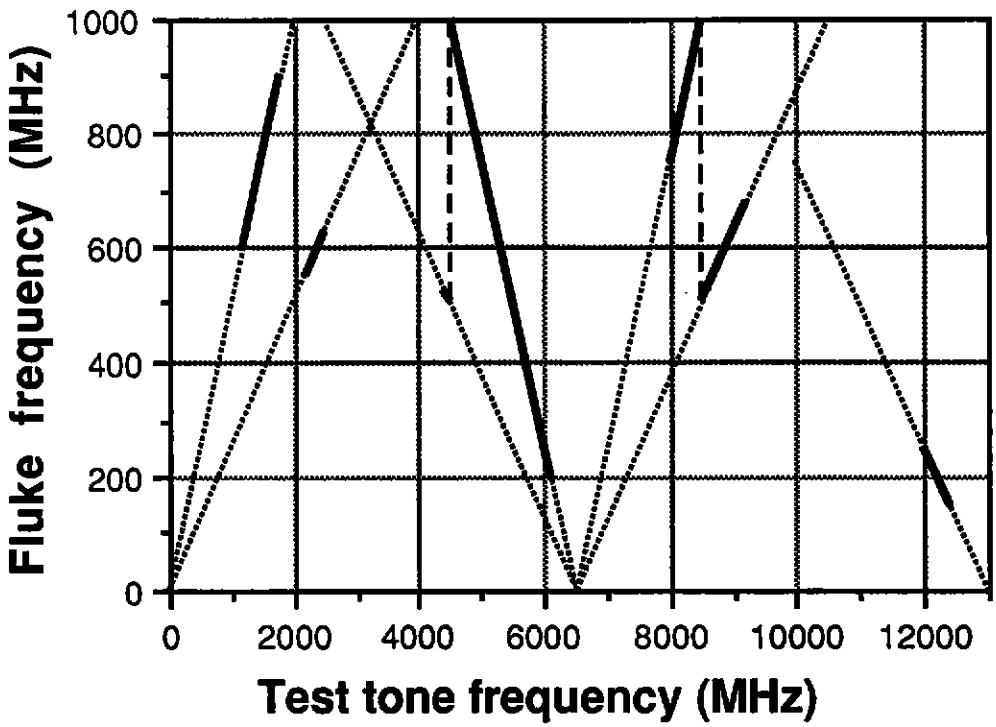
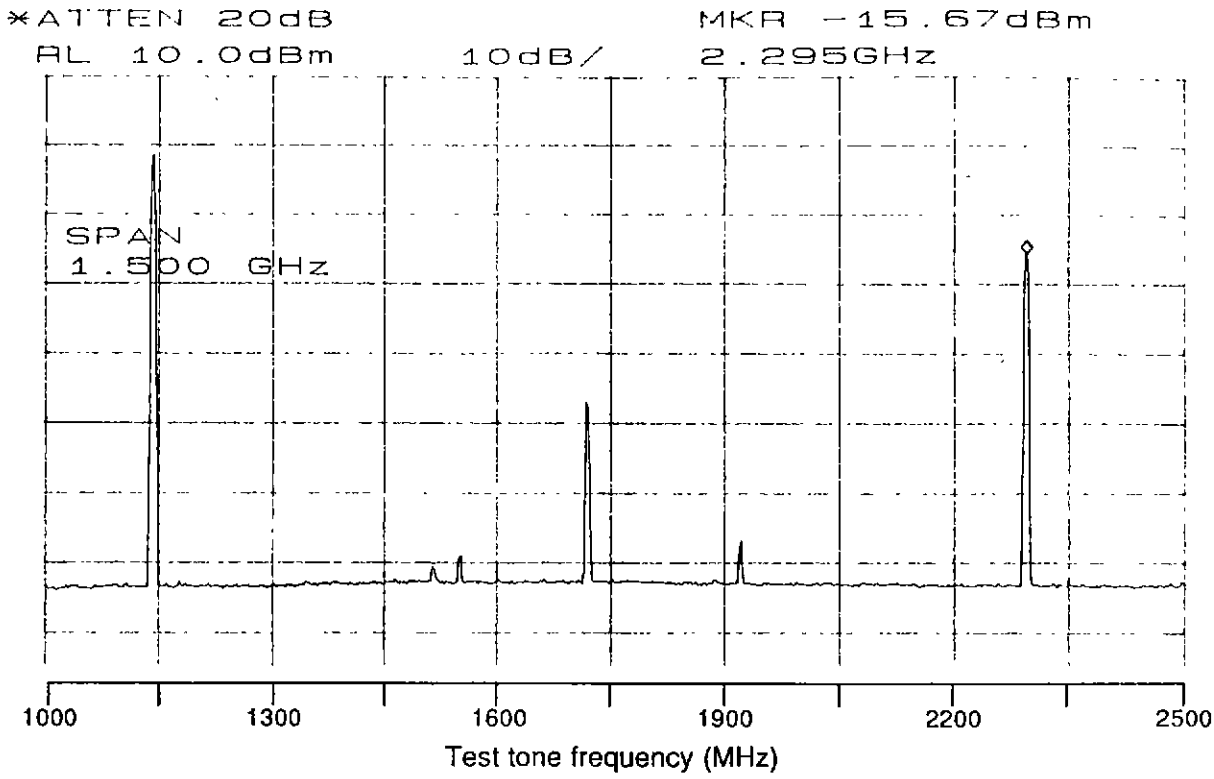
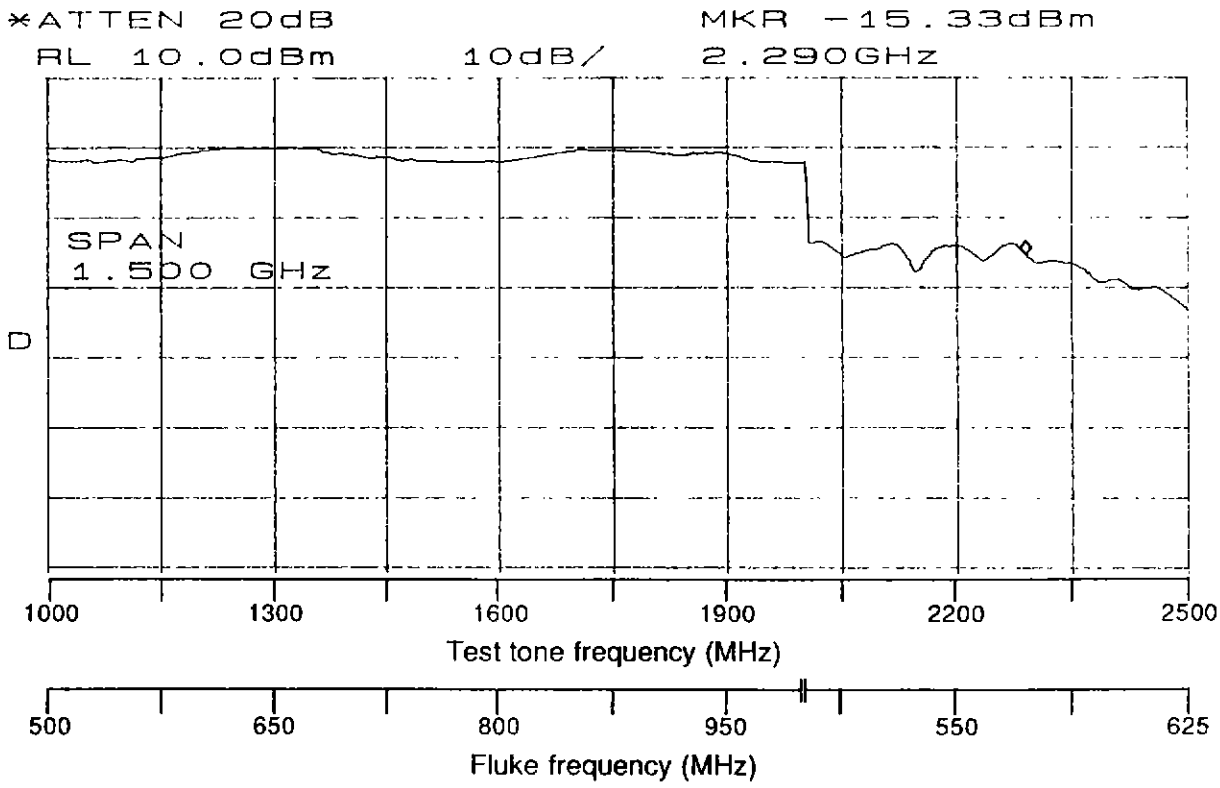


Fig. 3. FLUKE synthesizer frequency required to generate a test tone at a given frequency.



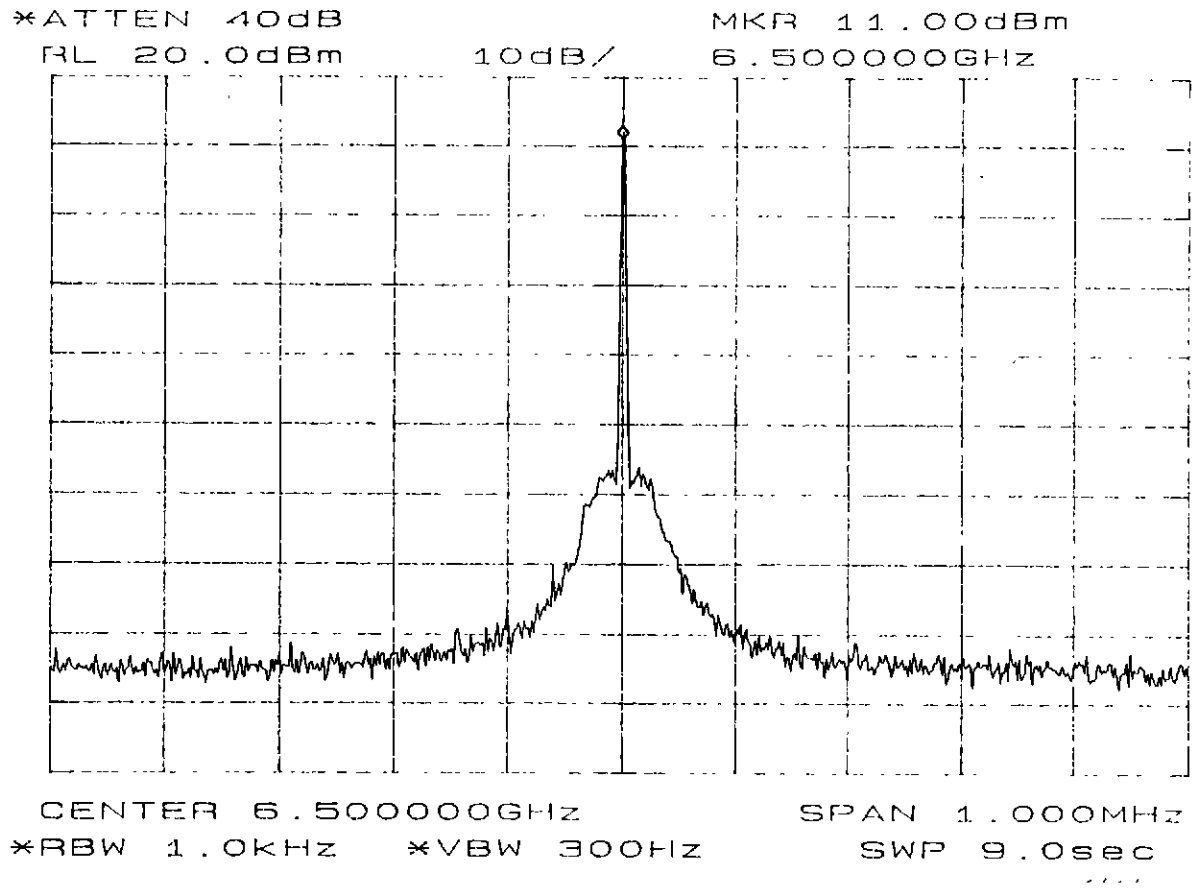
(a)

9/7/91

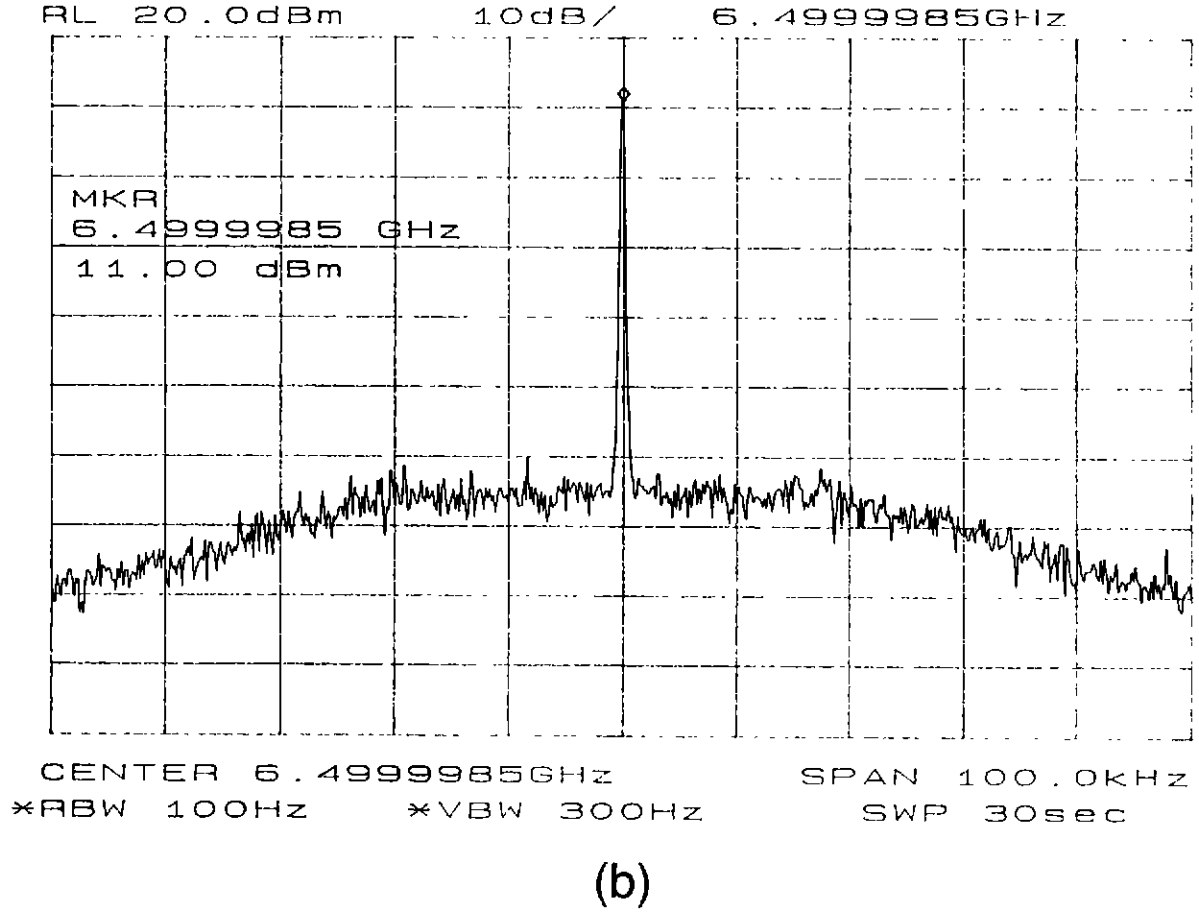


(b)

Fig. 4. Test tone for the L/S receiver.
(a) Spectrum with FLUKE output frequency of 572.5 MHz. The test tone is -2 dBm at 1145 MHz and -16 dBm at 2290 MHz.
(b) Envelope as FLUKE output frequency is swept from 500 MHz to 1000 MHz.

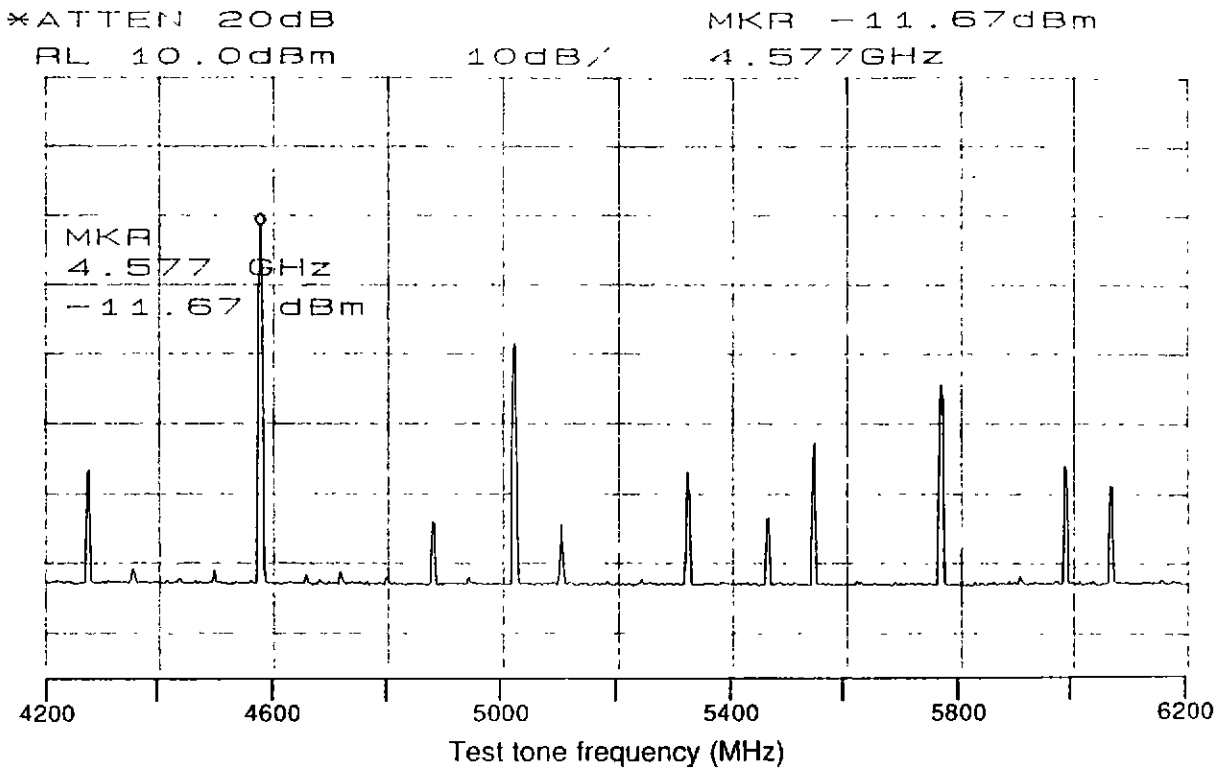


(a)

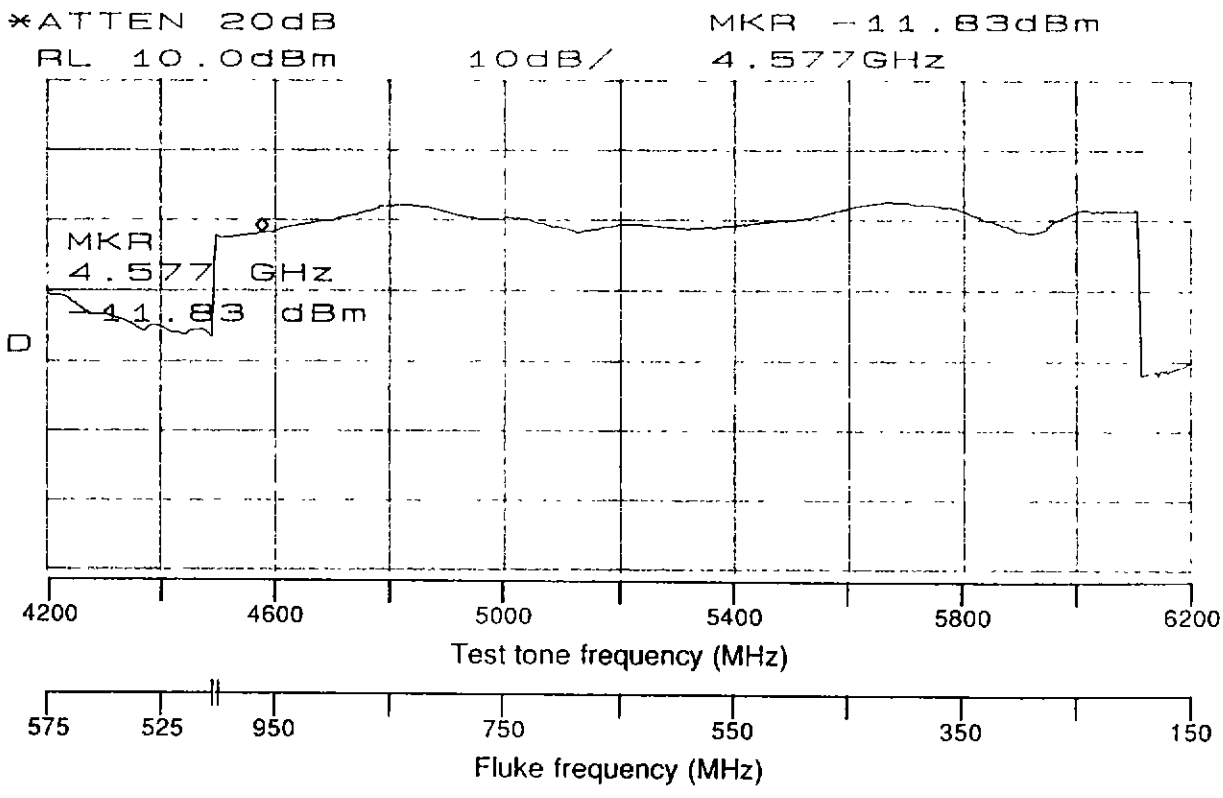


(b)

Fig. 5. Spectrum of the 6500 MHz signal from the phase-locked oscillator.
(a) Span 1.0 MHz
(b) Span 0.1 MHz

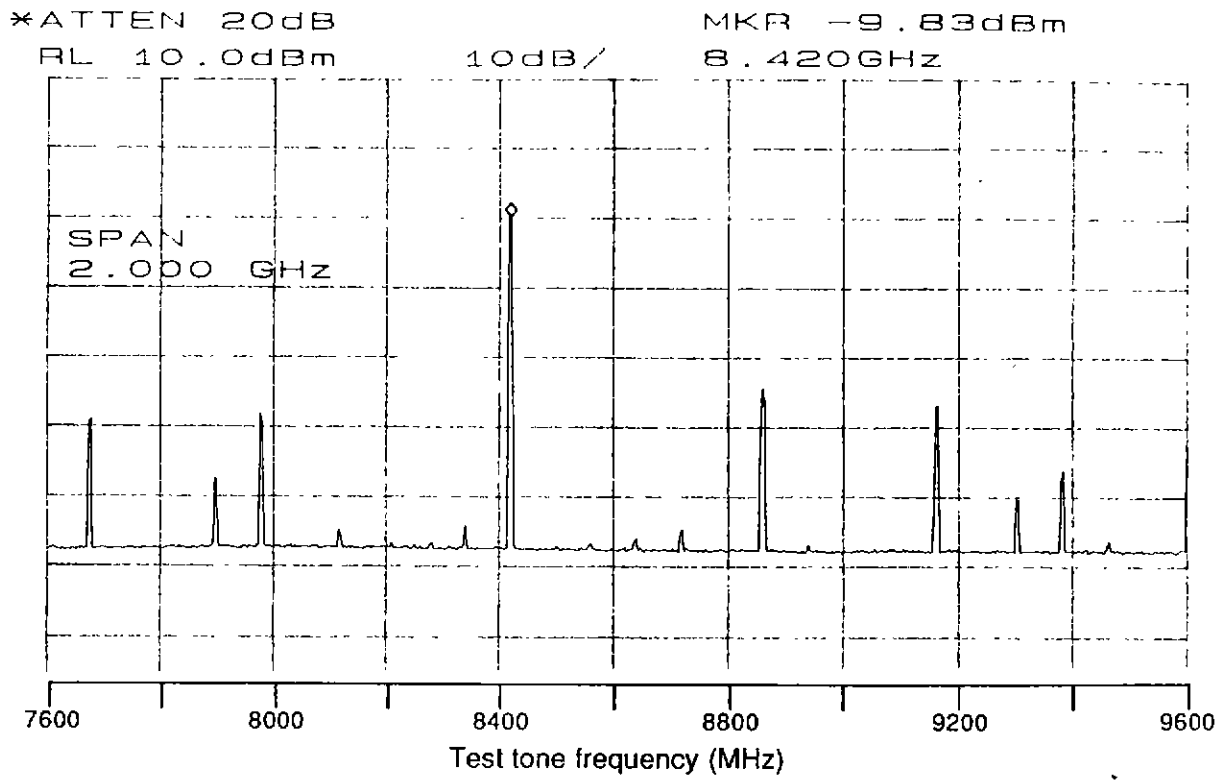


(a)

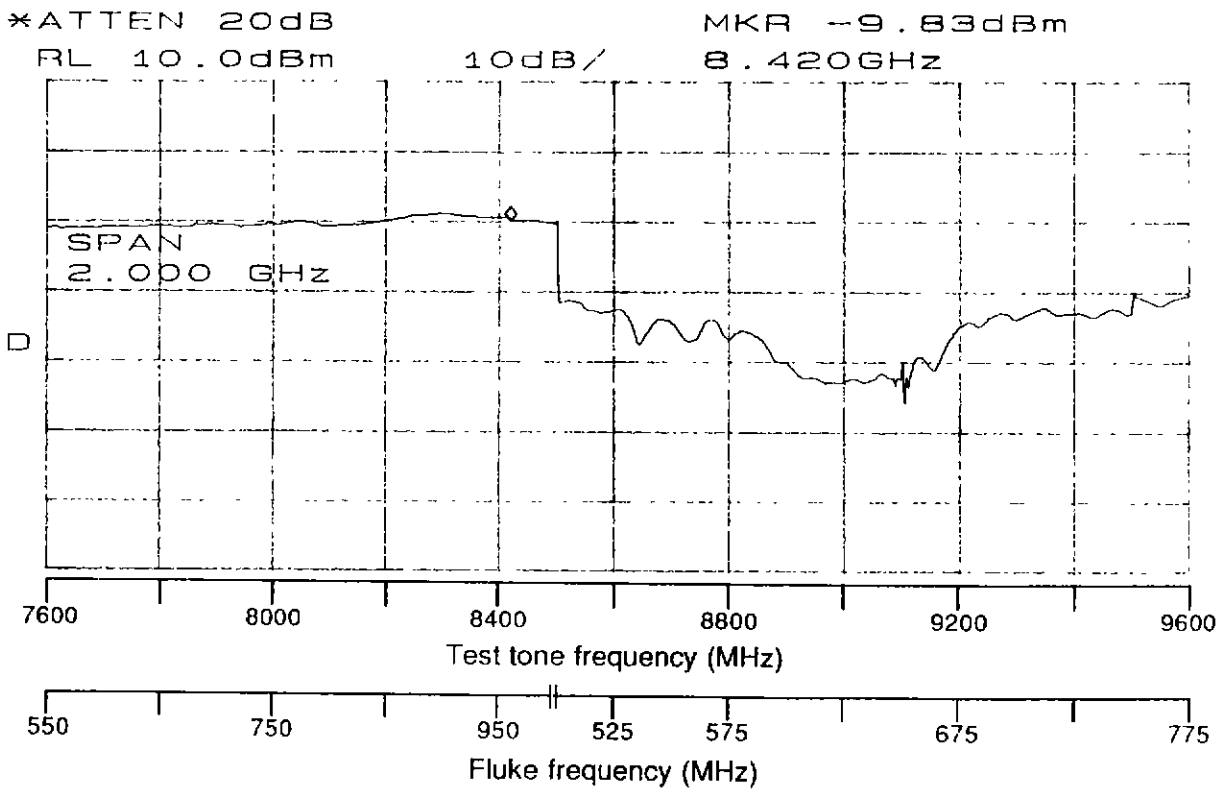


(b)

Fig. 6. Test tone for the C/X receiver (4200 – 6200 MHz).
(a) Spectrum with FLUKE output frequency of 960 MHz. The test tone is -12 dBm at 4580 MHz.
(b) Envelope as FLUKE output frequency is swept from 200 MHz to 1000 MHz.

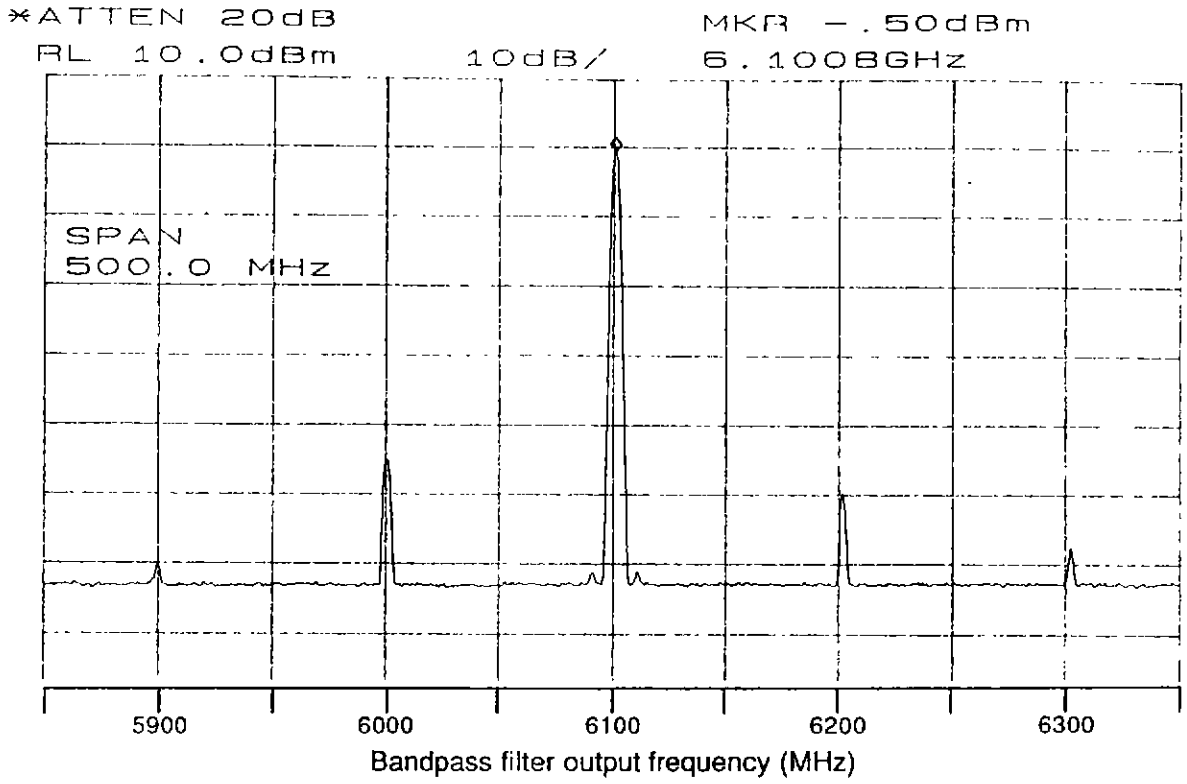


(a)

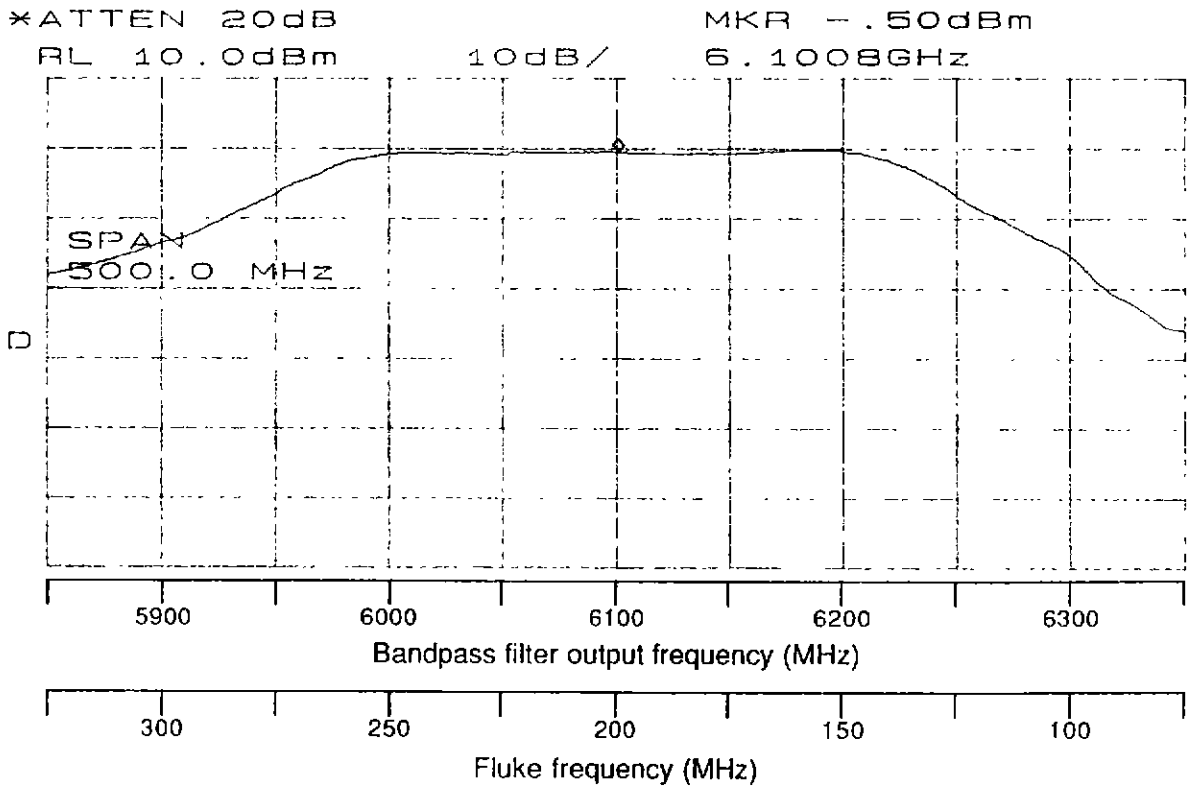


(b)

Fig. 7. Test tone for the C/X receiver (7600 – 9600 MHz).
(a) Spectrum with FLUKE output frequency at 960 MHz. The test tone is -10 dBm at 8420 MHz.
(b) Envelope as FLUKE output frequency is swept from 500 MHz to 1000 MHz.



(a)



(b)

Fig. 8. Output of K&L 3FV-6100/270 filter.
(a) Spectrum with FLUKE output frequency of 200 MHz. The test tone is 0 dBm at 6100 MHz.
(b) Envelope as FLUKE output frequency is swept from 75 MHz to 325 MHz.

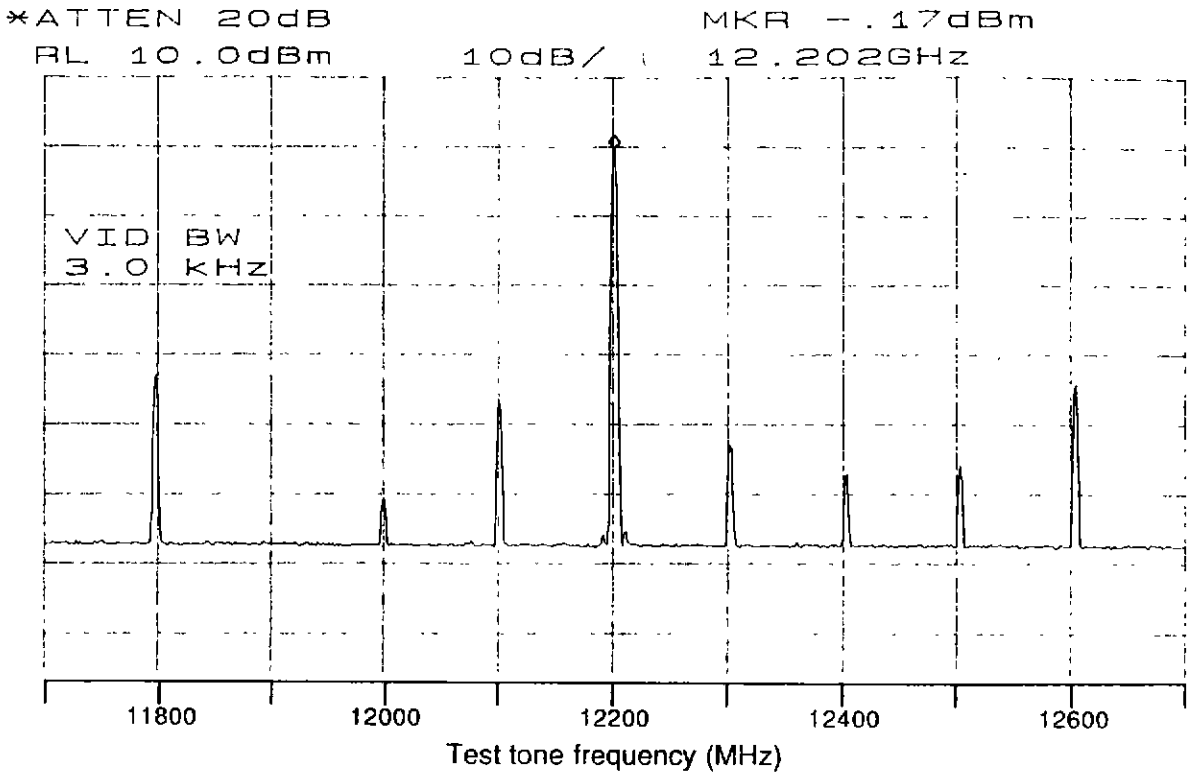
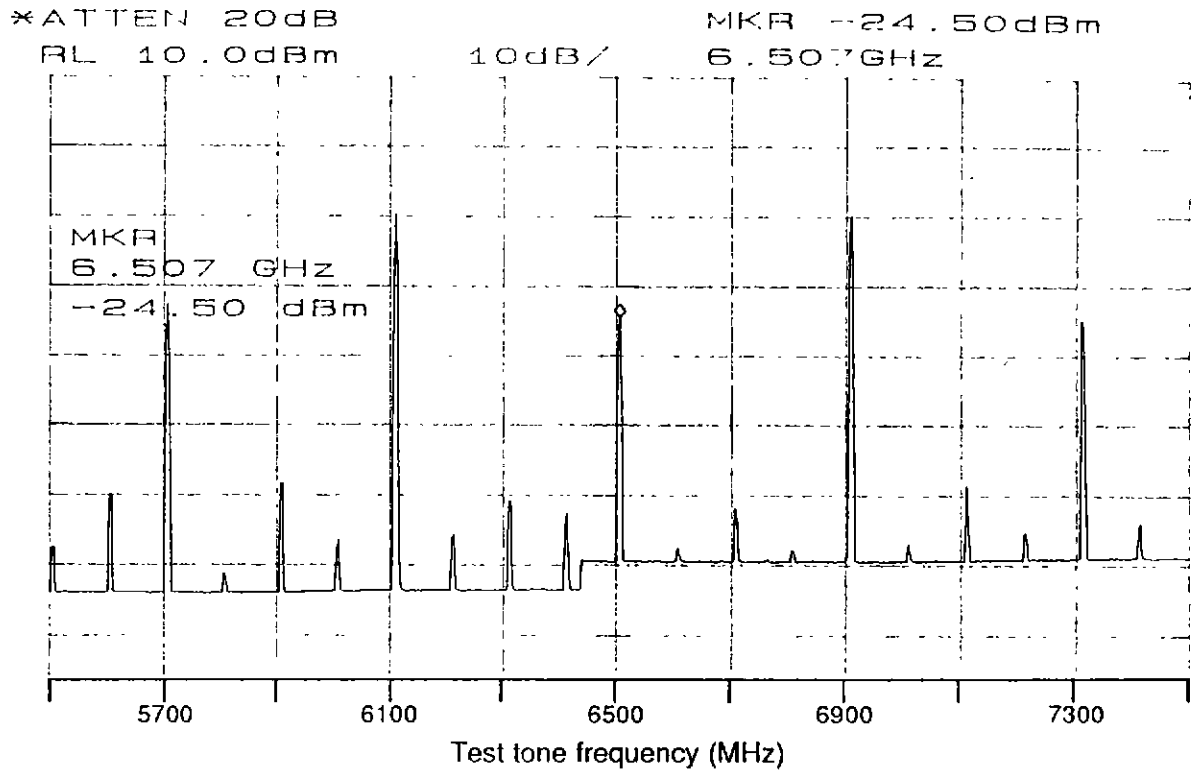
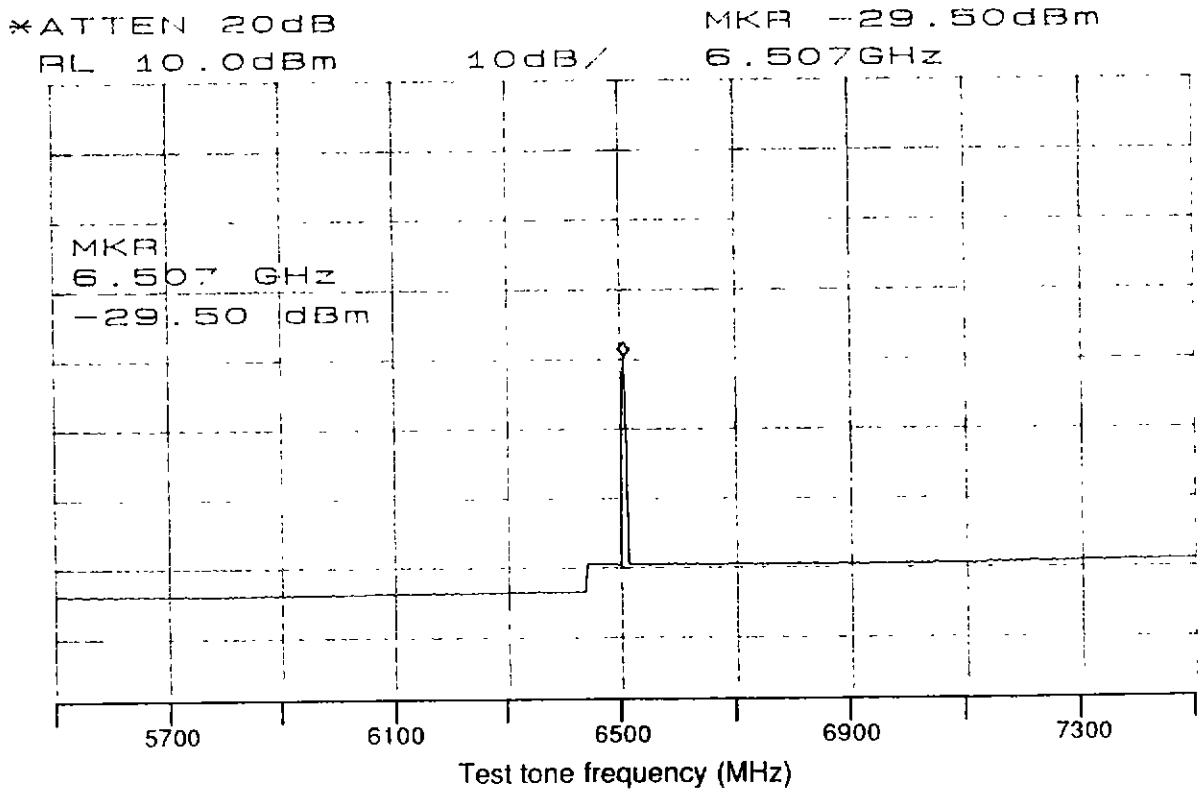


Fig. 9. Spectrum of the test tone for the METHANOL receiver. FLUKE output frequency is 200 MHz; the test tone is 0 dBm at 1220 MHz.



(a)



(b)

Fig. 10. Test tone for the C/X receiver (5500 – 7500 MHz).
(a) Spectrum with FLUKE output frequency of 200 MHz. The level of the 6500 MHz break through is -24 dBm.
(b) Spectrum with FLUKE output off. The level of the 6500 MHz break through is -29 dBm.

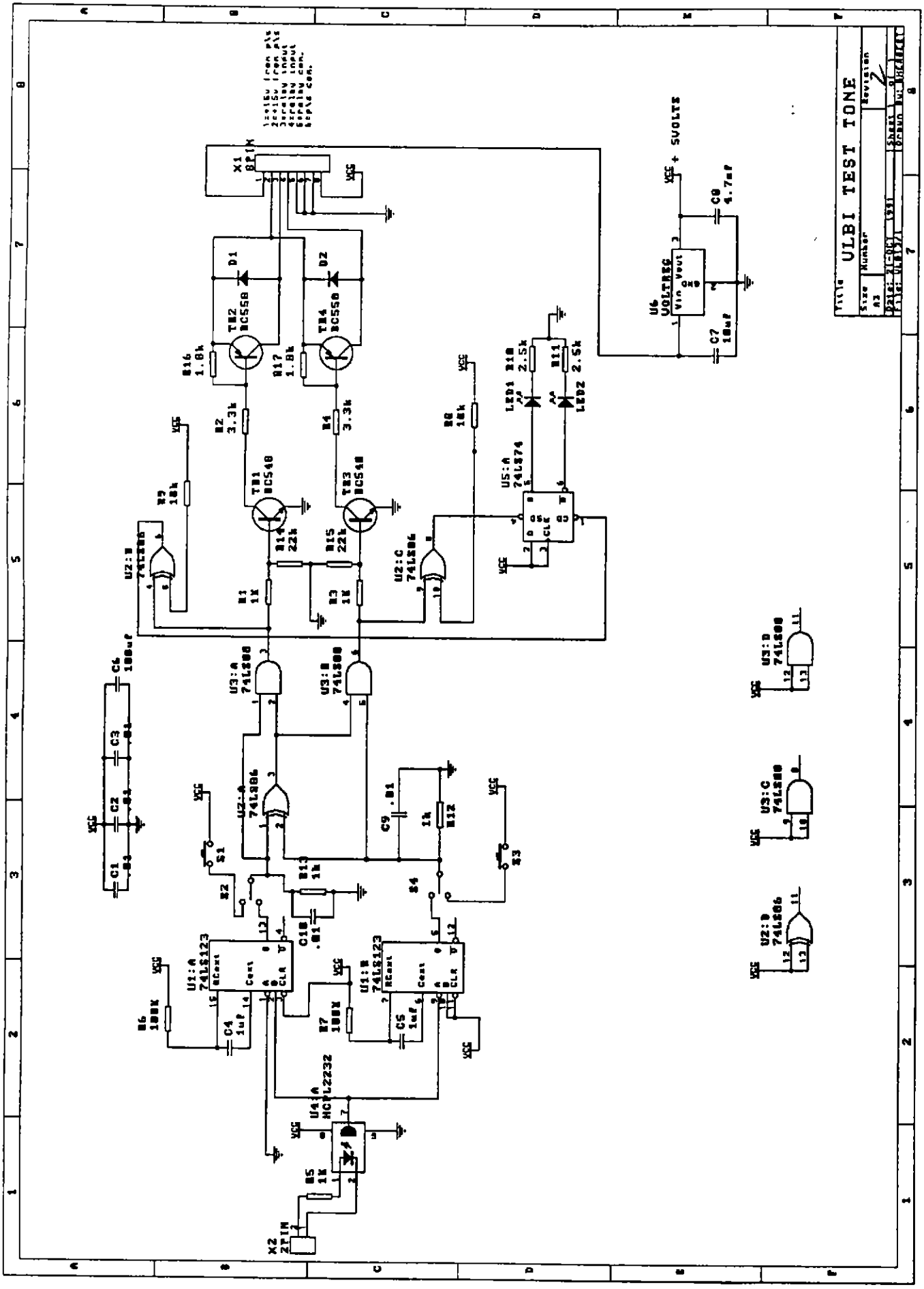


Fig. 11. Circuit diagram of the Narrabri test tone control circuit.

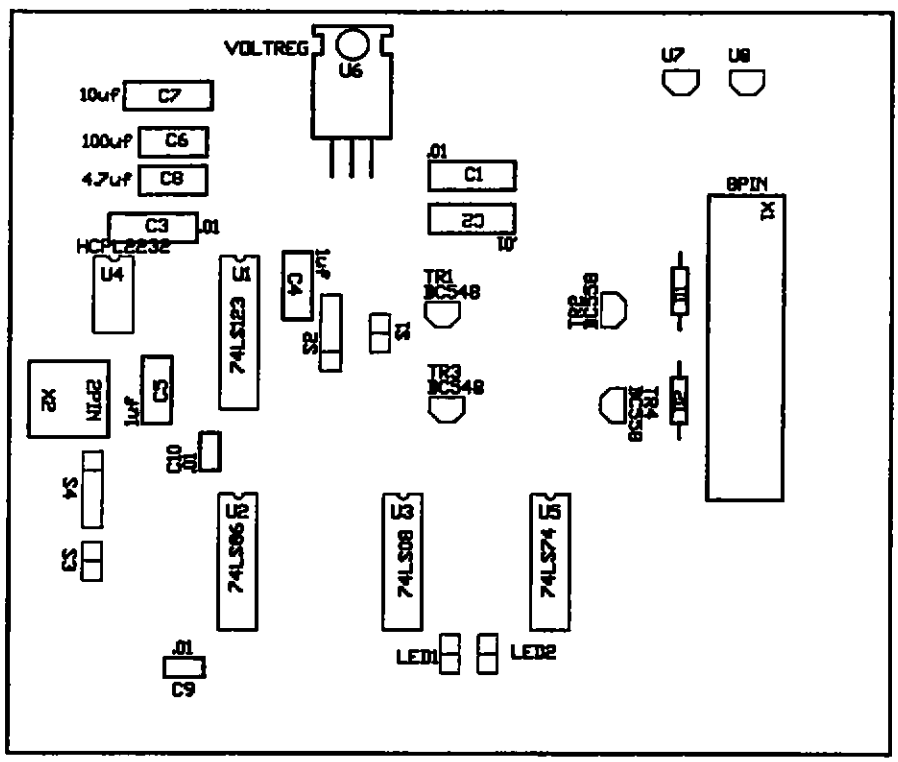


Fig. 12. Component layout of the Narrabri test tone control board.