MEASUREMENT AND TECHNICAL REPORT

POWERWAVE TECHNOLOGIES
2026 McGaw Avenue
Irvine, CA 92614

DATE: 17 March 1999

This Report Concerns:	Original Grant: X	Class II Change:

Equipment Type:	Multicarrier PCS Amplifier System, Model MPA9600-25/MCR3303-3-1

Deferred grant requested per 47 CFR 0.457(d)(1)(ii)?	Yes: **Defer until:**	No: X

Company Name **agrees to notify the Commission by:** **of the intended date of announcement of the product so that the grant can be issued on that date.**	N/A

Transition Rules Request per 15.37?	Yes:	*No:

(*) FCC Part 2, Paragraphs 2.985, 2.989, 2.991, and 2993, Part 24, Paragraph 24.238(a)(b)(c)

Report Prepared by:

TÜV PRODUCT SERVICE
10040 Mesa Rim Road
San Diego, CA 92121-2912
Phone: 619 546 3999
Fax: 619 546 0364

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1 GENERAL INFORMATION

1.1 Product Description

CUSTOMER INFORMATION	
COMPANY NAME:	POWERWAVE TECHNOLOGIES
COMPANY ADDRESS:	2026 McGaw Avenue
	Irvine, CA 92614
PHONE NUMBER:	949 757 0530
FAX NUMBER/E-MAIL ADDRESS:	949 757 6674 / jdale@pwav.com
CUSTOMER CONTACT:	Jeffrey A. Dale
PRODUCT DESCRIPTION	
NAME, MODEL, SERIAL # OF EUT:	Multicarrier PCS Amplifier System, Model MPA9600-25/MCR3303-3-1

Electromagnetic Compatibility (EMC) Test Plan

1.0 EUT Documentation

This section provides the necessary documentation for detailing the Equipment Under Test (EUT). Descriptions of the equipment including software and documentation on installation and operations should be provided.

Additional documentation necessary for test plan completion should be attached to the back of the test plan. For additional instruction on how to complete your test plan contact your TÜV Product Service representative.

1.1 EUT Description: The MPA9600-25 amplifier is a linear, feed-forward power amplifier that operates in the 20 MHz frequency band from 1970MHz to 1990MHz. The amplifier can simultaneously transmit multiple frequencies, with better than -60 dBc third order intermodulation distortion (IMD). The amplifier system is modular in design, and is ideally suited for use in GSM base stations. The plug-in Model MPA9600-25 amplifier modules can each provide 25 watts of power and function completely independently of each other. The amplifier modules are designed for parallel operation to produce high peak power output and backup redundancy for remote applications. The system is housed in the MCR3303-3-1 subrack which holds up to three MPA9600-25 amplifiers to produce up to 75 watts output. All solid-state, the system is designed to provide trouble-free operation with minimum maintenance. The system's modular construction and unique and highly effective LED-based operational status and fault indicators help minimize down-time. The turn-on and turn-off sequences of voltages are fully automatic, as is overload protection and recycling. Inadvertent operator damage from front panel manipulation is virtually impossible.

The MCR3303-3-1 subrack contains an RF power splitter/combiner and a summary logic module that monitors the functional status of all plug-in amplifiers. The rear panel of the subrack has the system RF I/O connectors, an RF output sample connector, and DC power input terminals. The front panel of each amplifier module has unit level status/fault indicators and a power on/off circuit breaker. Primary power for the amplifier system is +27 Vdc. Cooling for each plug-in amplifier module is provided by two fans mounted on the front and one on the rear of the module. The fans draw outside air through the front of the module and exhaust hot air out through the rear of the module.

1.1.1 Components of EUT

(List each one separately. Add attachment if necessary. NOT TO INCLUDE PERIPHERALS.)

Description	Model Number	Serial Number	FCC ID Number
Multicarrier PCS Amplifier	MPA9600-25		E675JS0033
Multicarrier PCS Amplifier System Subrack	MCR3303-3-1		E675JS0033

1.2 Operating modes: (list and describe)

Electromagnetic Compatibility (EMC) Test Plan

The MPA9601-25 amplifier operates in the 1970-1990MHz frequency range at an average output power of 25W per module when installed in the MCR3303-3-1 subrack, for a total output of 75W (if three amplifier modules are installed). It is capable of amplifying multiple carriers of GSM modulated input signals. The amplifier does not provide any modulation of its own.

Electromagnetic Compatibility (EMC) Test Plan

1.3 EUT I/O Ports and Cables:

1.3.1 I/O Cables (Add attachment if necessary.)

CONNECTION:	RF Input
SHIELD:	Yes
CONNECTORS:	SMA
TERMINATION TYPE:	50 Ohm
LENGTH:	Not specified
REMOVABLE:	Yes

CONNECTION:	RF Output
SHIELD:	Yes
CONNECTORS:	Type N
TERMINATION TYPE:	50 Ohm
LENGTH:	Not specified
REMOVABLE:	Yes

CONNECTION:	DC Input (+27V, Gnd.)
SHIELD:	No
CONNECTORS:	Ring terminal
TERMINATION TYPE:	Bolt on
LENGTH:	Not specified
REMOVABLE:	Yes

CONNECTION:	
SHIELD:	
CONNECTORS:	
TERMINATION TYPE:	
LENGTH:	
REMOVABLE:	

Electromagnetic Compatibility (EMC) Test Plan

1.3.2 Power Cords (Add attachment if necessary.)

UNIT:	Not applicable
MANUFACTURER:	
SHIELDED:	
LENGTH:	

UNIT:	
MANUFACTURER:	
SHIELDED:	
LENGTH:	

UNIT:	
MANUFACTURER:	
SHIELDED:	
LENGTH:	

1.3.3 Power requirements:

***Note: European power is typically 230 VAC 50Hz or 400 VAC 50Hz, single and three phase, respectively. FCC requires testing to be performed at typical US power ratings at 60Hz.**

230 VAC 50Hz – single phase Amps

400 VAC 50Hz – three phase Amps per phase

120 VAC 60Hz – single phase Amps

+27 VDC 84 Amps

Battery: VDC Expected life: Hours

Other: (describe)

Electromagnetic Compatibility (EMC) Test Plan

1.4 Oscillator Frequencies

Frequency	EUT Location	Description of use
3.5795 MHz	Loop Ctrl. PCB	Freq. Ref.
8 MHz	Loop Ctrl. and Alarm PCB	Freq. Ref.
10.245 MHz	Loop Ctrl. PCB	Freq. Ref.

1.5 Power Supply

Description	Manufacturer	Model #	Serial #	Switching frequency or linear
DC power supply	HC Power	HC40-6	1014	Switching

1.6 Power Line Filters

Manufacturer	Model #	Qty	LOCATION ON EUT
Not applicable			

1.7 Critical EMI Components (Capacitors, ferrites, etc.)

Description	Manufacturer	Part # or value	Qty	LOCATION ON EUT
Not applicable				

1.8 Description of Enclosure: (Including Gasketing, Coatings, Bonding, etc.)

Aluminum alloy machined housing with chem-film and paint coatings.

Electromagnetic Compatibility (EMC) Test Plan

1.9 Interfacing and/or Simulators Peripheral Equipment

(Please provide a complete description of all peripherals to be used during testing, please note that all I/O ports must be appropriately loaded)

DESCRIPTION:	**Digital Signal Generator (Qty. 2)**
MANUFACTURER:	**Hewlett Packard**
MODEL NUMBER:	**E4432B, E4433B**
SERIAL NUMBER:	**US38330312, US38080117**
FCC ID:	**N/A**

DESCRIPTION:	**RF Power Meter**
MANUFACTURER:	**HP**
MODEL NUMBER:	**437B**
SERIAL NUMBER:	**3125U26022**
FCC ID:	**N/A**

DESCRIPTION:	**RF Power Sensor**
MANUFACTURER:	**HP**
MODEL NUMBER:	**8481A**
SERIAL NUMBER:	**3318A97928**
FCC ID:	**N/A**

DESCRIPTION:	**Dual Directional Coupler**
MANUFACTURER:	**Narda**
MODEL NUMBER:	**3022**
SERIAL NUMBER:	**74663**
FCC ID:	**N/A**

DESCRIPTION:	**50 Ohm Load**
MANUFACTURER:	**Weinschel**
MODEL NUMBER:	**45-40-34**
SERIAL NUMBER:	**KR025**
FCC ID:	**N/A**

1 GENERAL INFORMATION (continued)

1.2 Related Submittal/Grant

None

1.3 Tested System Details

The FCC IDs for all equipment, plus descriptions of all cables used in the tested system are:

None

1.4 Test Methodology

Purpose of Test: To demonstrate compliance with the ANSI C63.4 setup.

Test Performed:

- X 1. Conducted Emissions, FCC Part 2, Paragraphs 2.989, 2.991 and Part 24, Paragraph 24.238(a)(b)(c)
- 2. Radiated Emissions EN55022: 1992 Class B limit, 30 - 1,000 MHz, 10 meters
- X 3. Radiated Emission per FCC Part 2, Paragraph 2.993, & Part 24, Paragraph 24.238
- 4. Engineering evaluations
- 5. Frequency Stability, Part 2, Paragraph 2.995
- X RF Output Power, Part 2, Paragraph 2.985

Both Conducted and radiated testing were performed according to the procedures in FCC/ANSI C63.4 and CSA 108.8 - M1983. Radiated testing was performed at an antenna-to-EUT distance of 3 meters (1 - 20 GHz).

1.5 Test Facility

The open area test site and conducted measurement data were tested by:

TÜV PRODUCT SERVICE
10040 Mesa Rim Road
San Diego, CA 92121-2912
Phone: 619 546 3999
Fax: 619 546 0364

The Test Site Data and performance comply with ANSI 63.4 and are registered with the FCC, 7435 Oakland Mills Rd, Columbia Maryland 21046. All Measurement Data is acquired according to the content of FCC Measurement Procedure and ANSI C63.4, unless supplemented with additional requirements as noted in the test report.

1.6 Part 2 Requirements

Frequency range: 1970 - 1990 MHz;
Rated RF output power - 25W per amplifier, 75W maximum (3 amplifiers in subrack),
Frequency tolerance: N/A;
Emission Designators: GXW, Microprocessor Model Number: N/A

Quantity production: Greater than 30 units
Types of emission: GSM
Frequency range: 1970 - 1990 MHz
Range of operating power: 0 - 75 W
Maximum power rating: 75 W
Voltages and Currents applied: See Schematics and functional block diagrams (Block diagrams are in the manual, section 4, pages 4-2 and 4-3).

Functions of active circuit devices: See Schematics and functional block diagrams (Block diagrams are in the manual, section 4, pages 4-2 and 4-3).

Tune-up Procedure: Operator manual, Section 3, page 3-3.

Description of all circuitry and devices provided for determining and stabilizing frequency: Not applicable, EUT is a power amplifier.
Means for limiting spurious radiation: N/A;
Means for limiting modulation: N/A; EUT is a power amplifier;
Means for limiting power: the alarm logic controls the DC bias voltage which shuts down the amplifier on an input overpower condition.
Digital modulation tecnniques: N/A

2 PRODUCT LABELING

Figure 2.1 FCC ID Label

See following page.

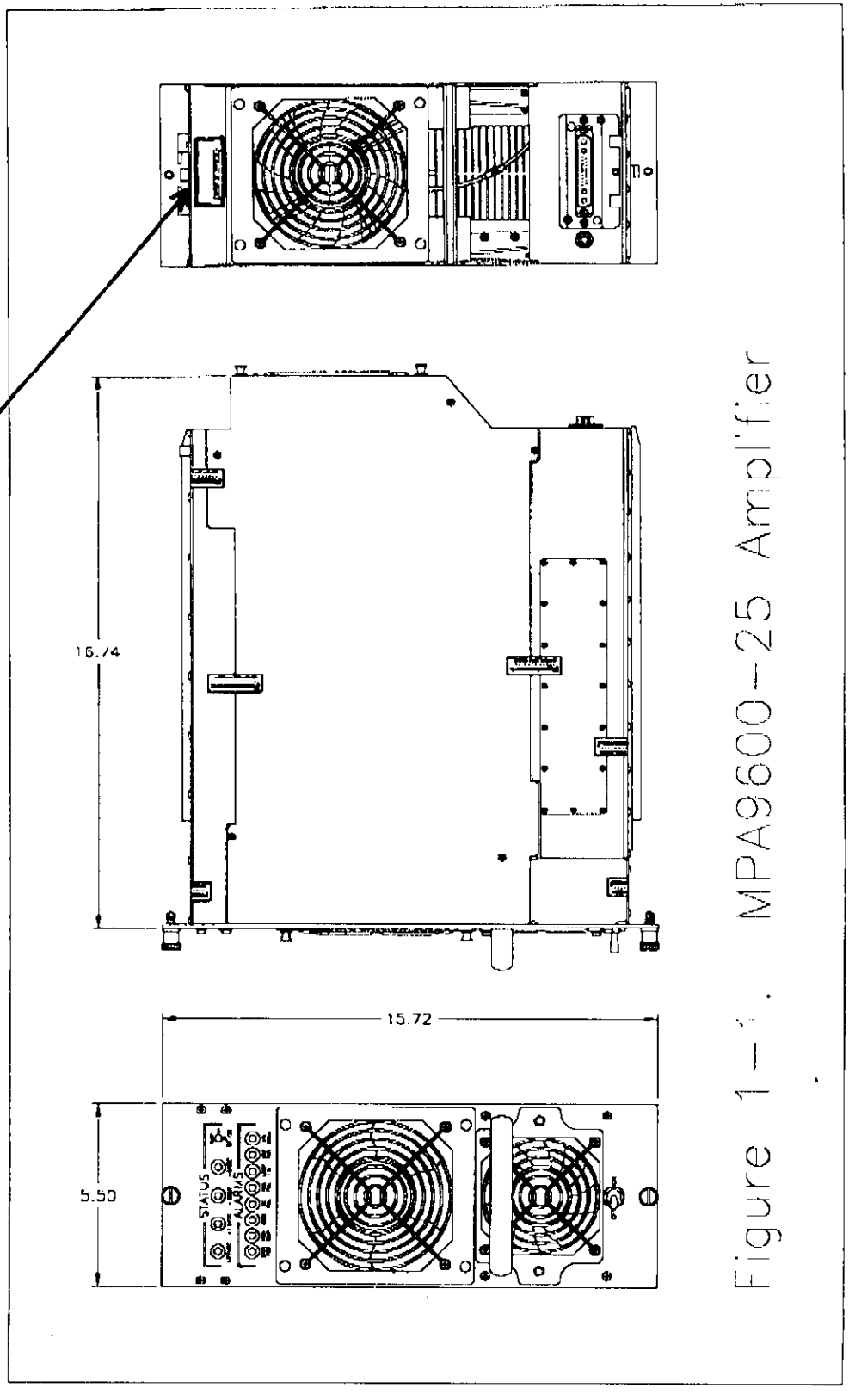

Figure 1-1. MPA9600-25 Amplifier

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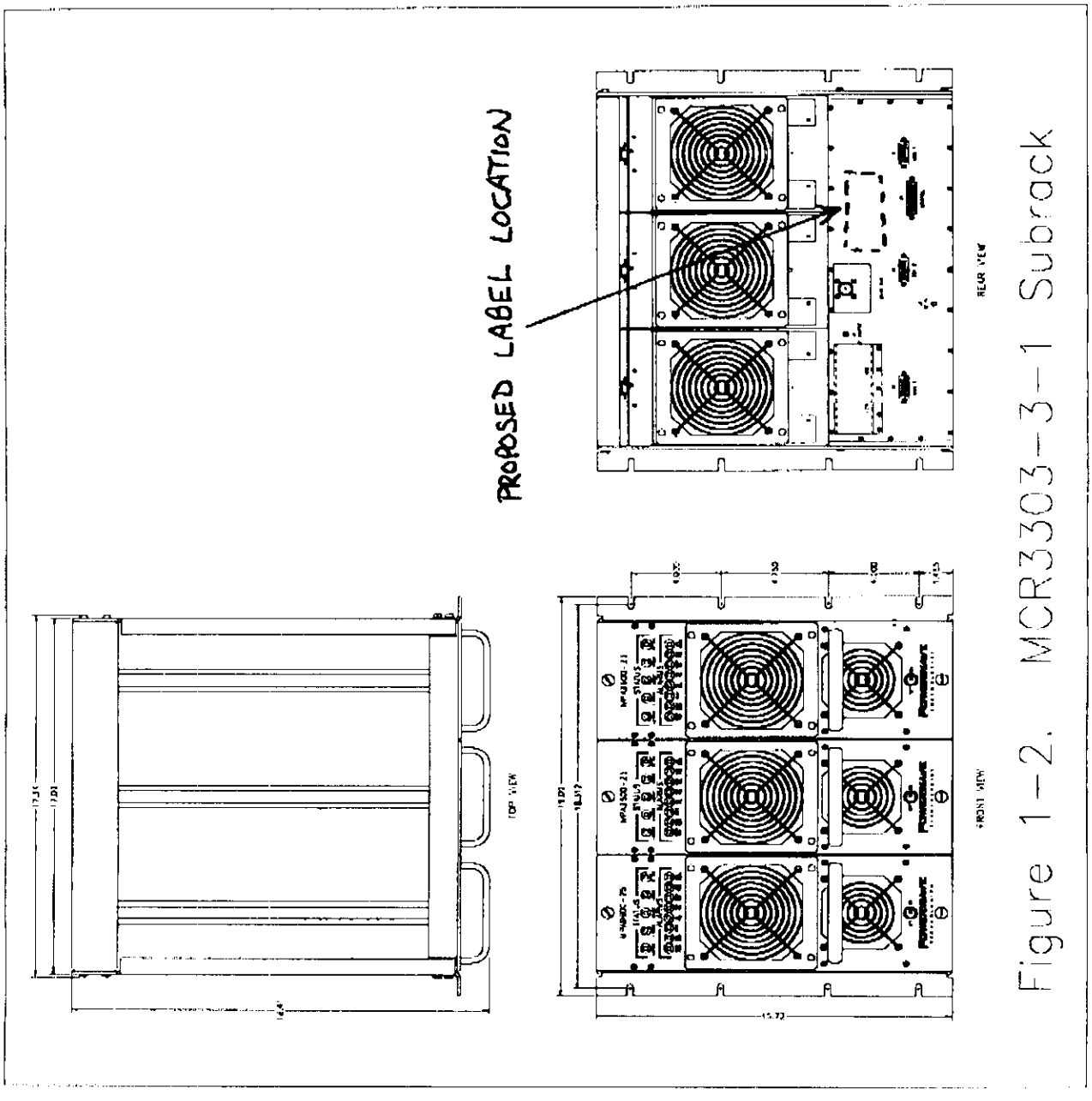

Figure 1-2. MCR3303-3-1 Subrack

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PROPOSED FCC ID LABELS:

POWERWAVE TECHNOLOGIES

FCC ID: E675JS0033

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Model MCA99600-25

POWERWAVE TECHNOLOGIES

FCC ID: E675JS0033

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Model MCR3303-3-1

3. SYSTEM TEST CONFIGURATION

3.1 Justification

The Multicarrier PCS Amplifier System, Model MPA9600-25/MCR3303-3-1 was initially tested for FCC emission in the following configuration:

See Block Diagram, paragraph 4.1.

3.2 EUT Exercise Software

None

3.3 Special Accessories

None

3.4 Modification

None

3.5 Configuration of Tested System

See Block Diagram, paragraph 4.1.

4 BLOCK DIAGRAM OF Multicarrier PCS Amplifier System, Model MPA9600-25/MCR3303-3-1

4.1 Block Diagram Description

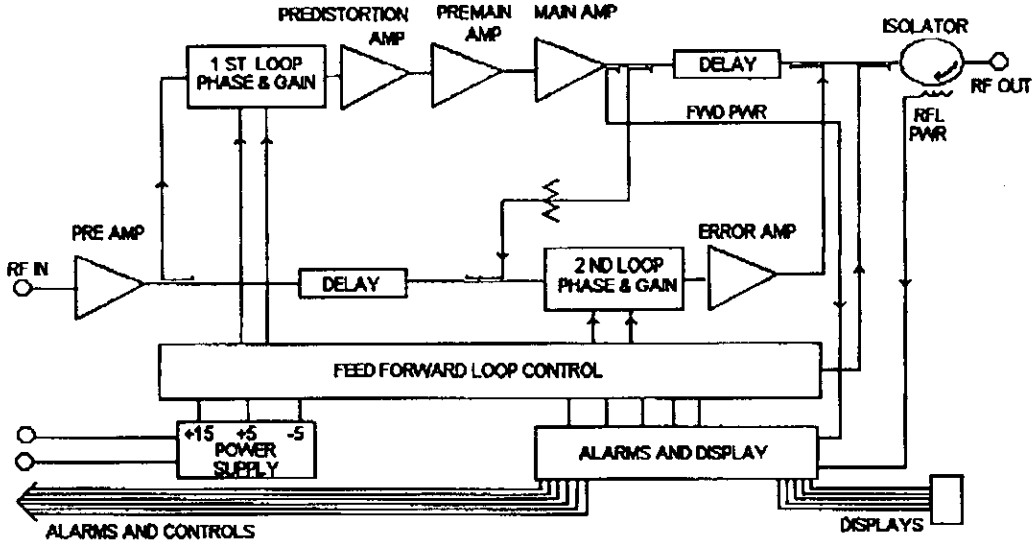
Multicarrier PCS Amplifier System, Model MPA9600-25/MCR3303-3-1 (See page 5 of this document.)

See following page for block diagram.

Electromagnetic Compatibility (EMC) Test Plan

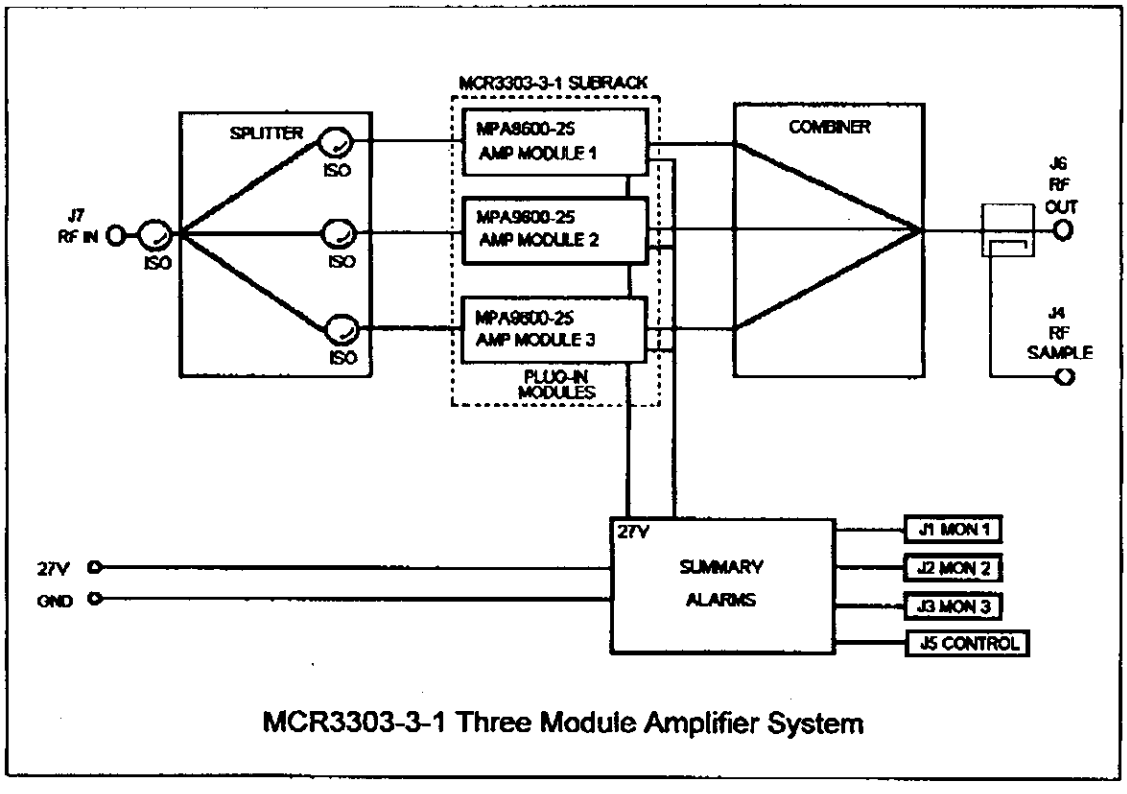
1.10 System Configuration Block Diagram

Use Word Draw or another draw program to draw the block diagram.



MPA9600-25 Power Amplifier Module Functional Block Diagram

Electromagnetic Compatibility (EMC) Test Plan



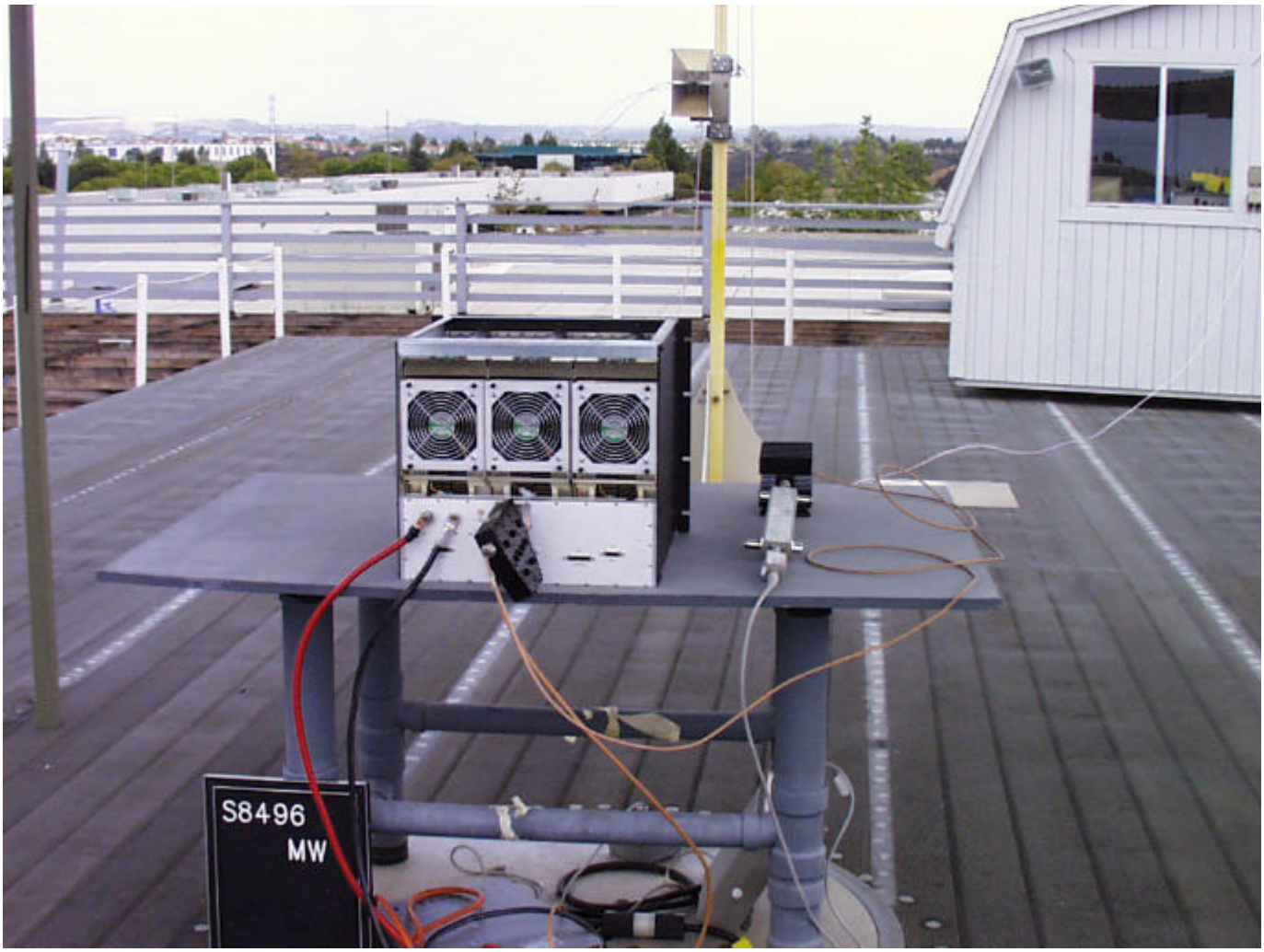
MCR3303-3-1 Three Module Amplifier System

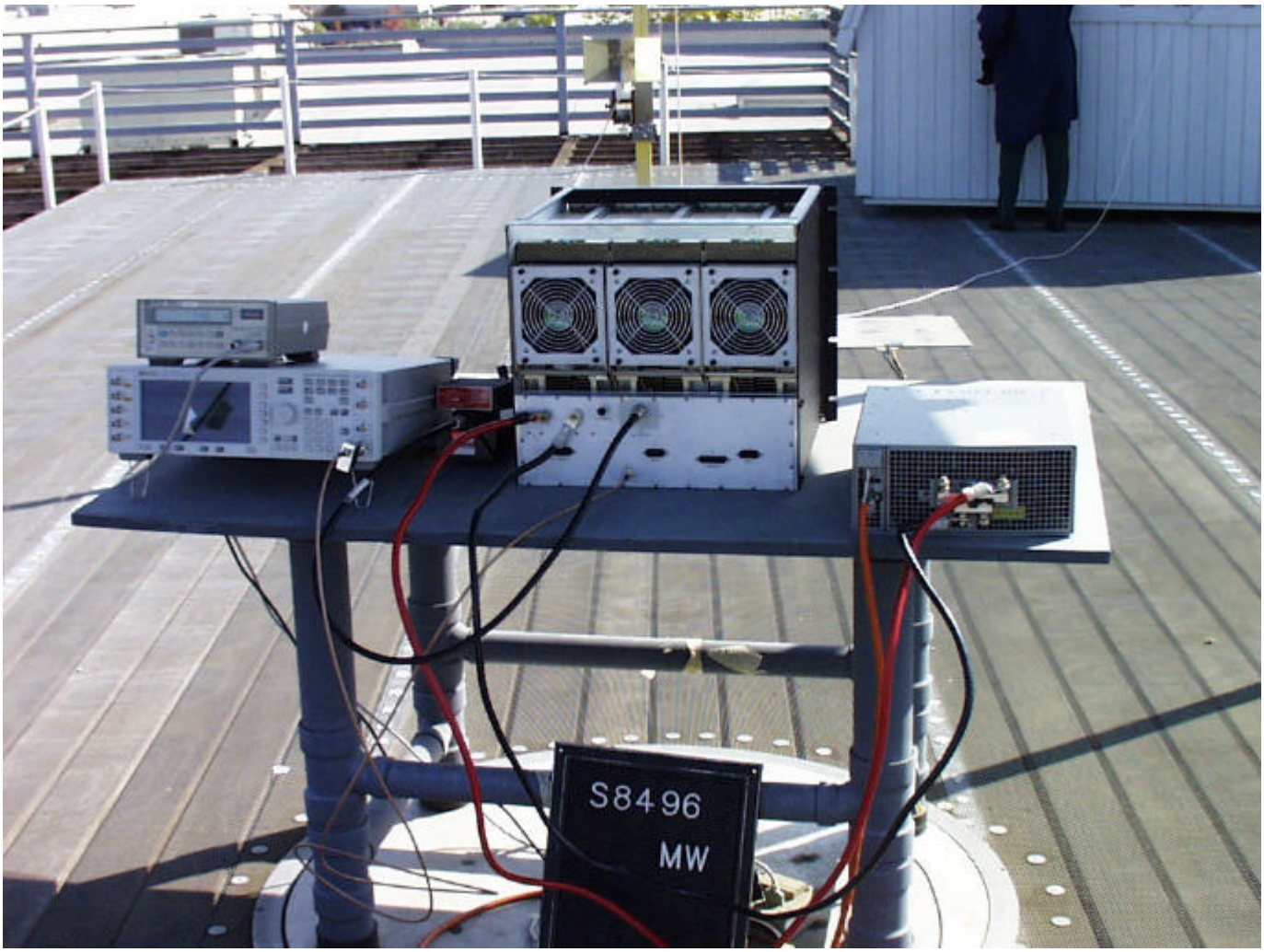
5 RADIATED EMISSION DATA

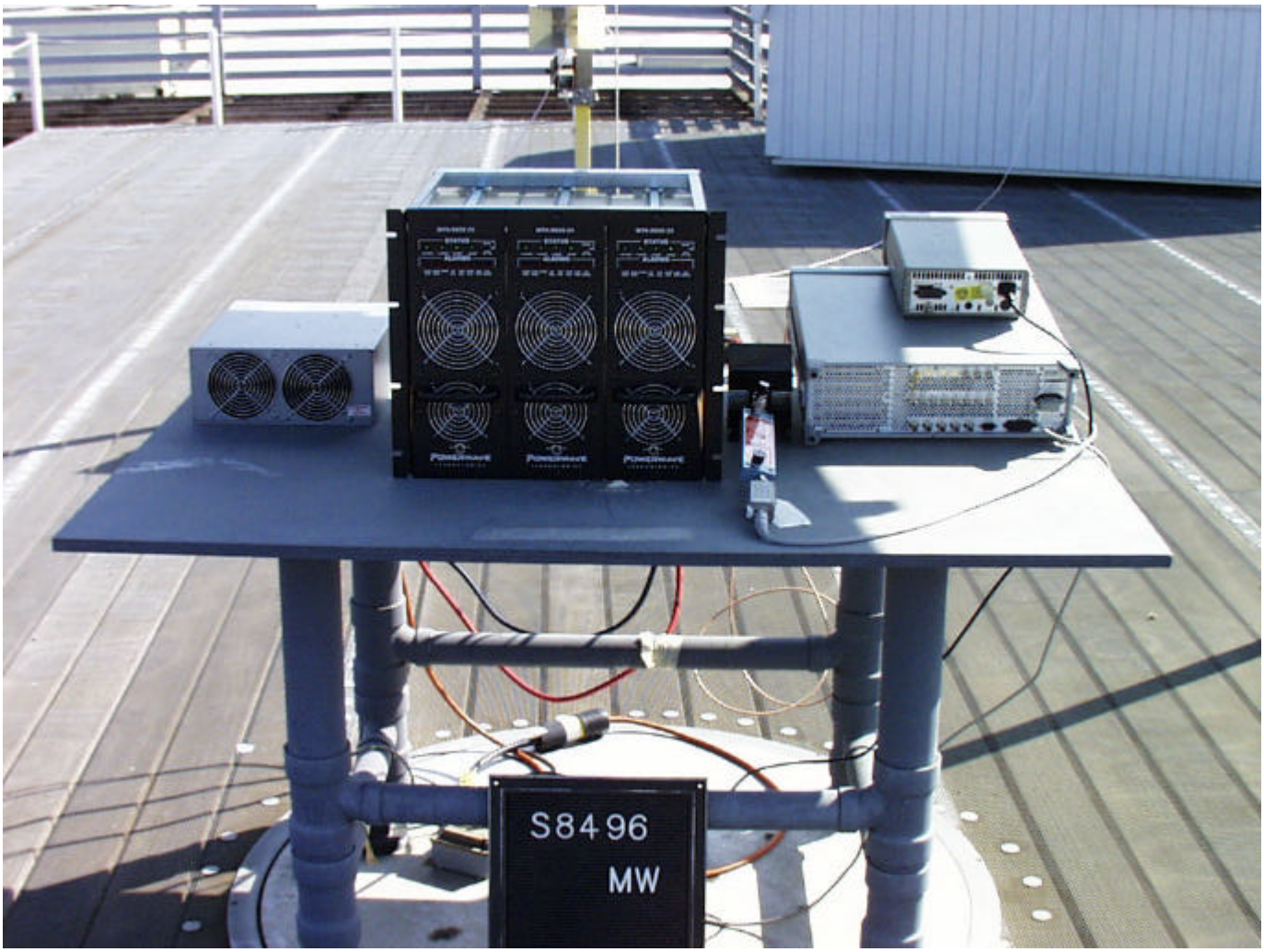
The following data lists the significant emission frequencies, measured levels, correction factor (which includes cable and antenna corrections), the corrected reading, and the limit.

See following page(s).

See test setup photos for radiated emissions test setup.


S8496
MW


S8496
MW


S8496
MW

REPORT No: S8496 TESTED BY: MW&GW SPEC: FCC Part 2, Para. 2.993 & Part 24, Para. 24.238

CUSTOMER: POWERWAVE TECHNOLOGIES TEST DIST: 3 Meters

E U T: MPA9600-25/MCR3301-3-1 TEST SITE: 3

EUT MODE: Transmit Full Power, CW BICONICAL: N/A

DATE: 9/30&10/28/98 LOG PERIODIC: N/A

NOTES: RBW and VBW = 1 MHz. OTHER: 251

Downlink only. No emissions detectable after fourth harmonic.

FREQ (MHz)	VERTICAL (dBuv) pk	av	HORIZONTAL (dBuv) pk	av	CORRECTION FACTOR (dB/m)	MAX LEVEL (dBuV/m) pk	av	SPEC LIMIT (dBuV/m) pk	av	MARGIN (dB) pk	av	EUT Rotatio	Antenna Height	
1980	58.9		59.7		33.5	**93.2**						45	1.3	
3960	28		28.4		40.9	**69.3**		84.4		-15.1				
5940	20.9		22.1		44.1	**66.2**		84.4		-18.2				
7920	19.7		18		47.1	**66.8**		84.4		-17.6				
9900	23.4		22.8		48.9	**72.3**		84.4		-12.1				
11880	22		21.8		52.2	**74.2**		84.4		-10.2		120	1	
1970	58.2		56.7		33.4	**91.6**						129	1	
3940	26.8		28.4		40.8	**69.2**		84.4		-15.2				
5910	21.1		21.6		44.1	**65.7**		84.4		-18.7				
7880	21.8		20.7		47.0	**68.8**		84.4		-15.6				
9850	23.6		25.5		48.8	**74.3**		84.4		-10.1		349	1.3	
11820	23.1		23.3		52.0	**75.3**		84.4		-9.1		6	1.2	
1990	57.4		59.1		33.5	**92.6**						45	1	
3980	28		27.5		41.0	**69.0**		84.4		-15.4				
5970	22.4		24.9		44.2	**69.1**		84.4		-15.3				
7960	19.9		19.7		47.1	**67.0**		84.4		-17.4				
9950	22.5		25		48.9	**73.9**		84.4		-10.5		354	1.2	
11940	23.5		23.2		52.3	**75.8**		84.4		-8.6		150	1.2	

Emissions Test Conditions: RADIATED EMISSIONS, FCC Part 2, Paragraph 2.993 and Part 22, Paragraph 22.917

The *RADIATED EMISSIONS* measurements were performed at the following test location :

■ - Roof (Small Open Area Test Site)

Testing was performed at a test distance of:

■ - 3 meters

Test Equipment Used :

Model No.	Prop. No.	Description	Manufacturer	Serial No.	Cal Date
3115	251	Antenna, Double Ridge Guide	EMCO	2495	
8566B	720	Spectrum Analyzer	Hewlett Packard	211500842	02/18/99
8566B	721	Spectrum Analyzer Display	Hewlett Packard	2112A02185	02/18/99

Field Strength Calculation

If a preamplifier was used during the Radiated Emission Testing, it is required that the amplifier gain must be subtracted from the Spectrum Analyzer (Meter) Reading. In addition, a correction factor for the antenna , cable used and a distance factor, if any, must be applied to the Meter Reading before a true field strength reading can be obtained. In the automatic measurement, these considerations are automatically presented as a part of the print out. In the case of manual measurements and for greater efficiency and convenience, instead of using these correlation factors for each meter reading, the specification limit was modified to reflect these correlation factors at each frequency value so that the meter readings can be compared directly to the modified specification limit. This modified specification limit is referred to as the "Corrected Meter Reading Limit" or simply the CMRL, which is the actual field strength present at the antenna. The quantity can be derived in the following manner:

Corrected Meter Reading Limit (CMRL) = SAR + AF + CL - AG - DC

Where, SAR = Spectrum Analyzer Reading
AF = Antenna Factor
CL = Cable Loss
AG = Amplifier Gain (if any)
DC = Distance Correction (if any)

Assume the following situation: A meter reading of 29.4 dBuV was obtained from a Class A computing device measured at 83 MHz. Assume an antenna factor of 9.2 dB, a cable loss of 1.4 dB and amplifier gain of 20.0 dB at 83 MHz. The final field strength would be determined as follows:

CMRL = 29.4 dBuV + 9.2dB = 1.4 dB - 20 dB/M - 0.0 dB

CMRL = 20.0 dBuV/M

This result is well below the FCC and CSA Class A limit of 29.5 dbuV/m at 83 MHz.

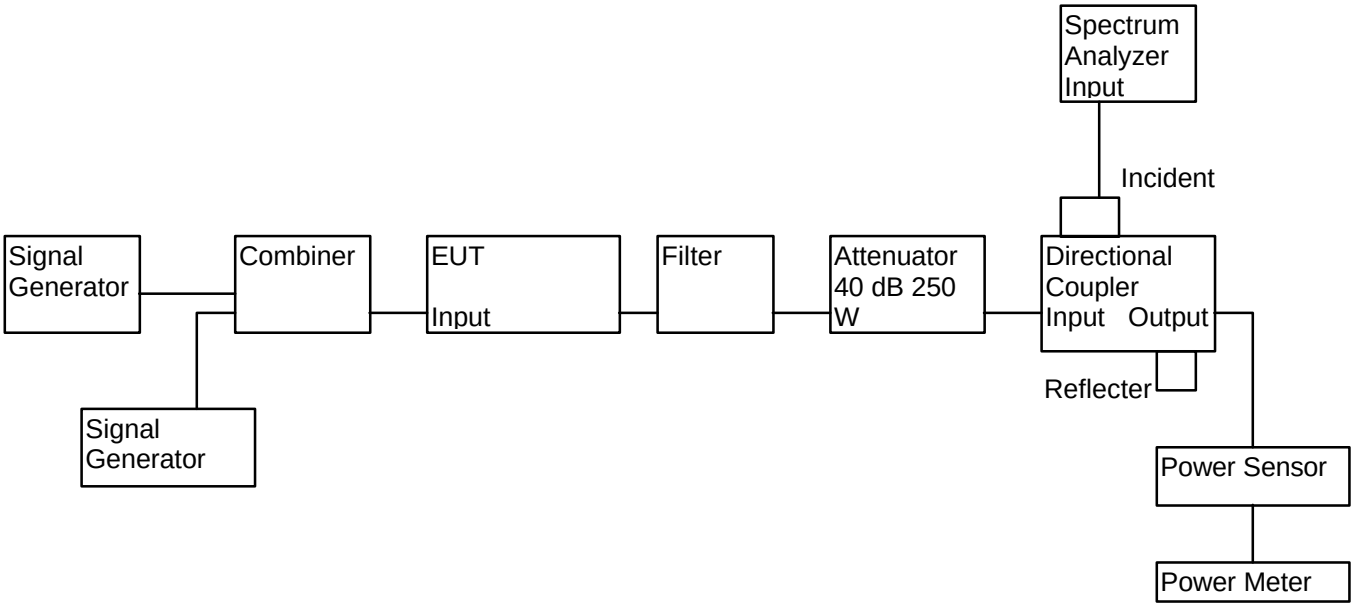
For the manual mode of measurement, a table of corrected meter reading limit was used to permit immediate comparison of the meter reading to determine if the measure emission amplitude exceeded the specification limit at that specific frequency.

6 CONDUCTED EMISSION DATA

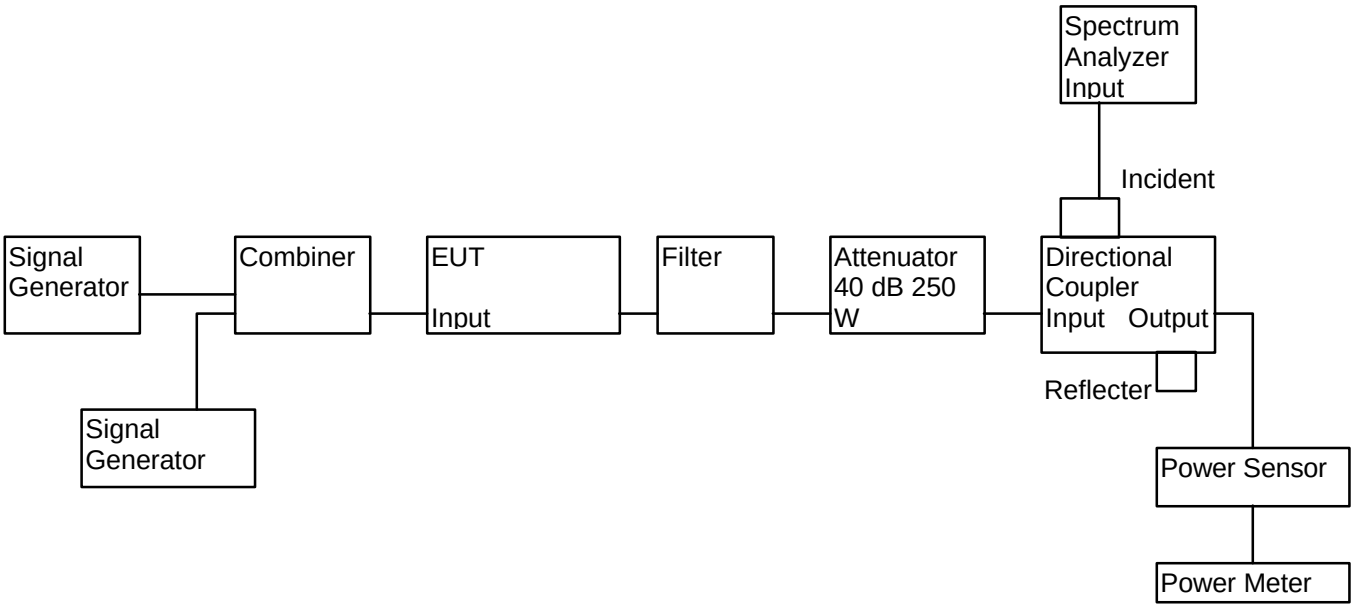
POWERWAVE TECHNOLOGIES
Multicarrier Cellular Amplifier and Subrack, Model MPA9600-25/MCR3303-3-1

See following page(s).

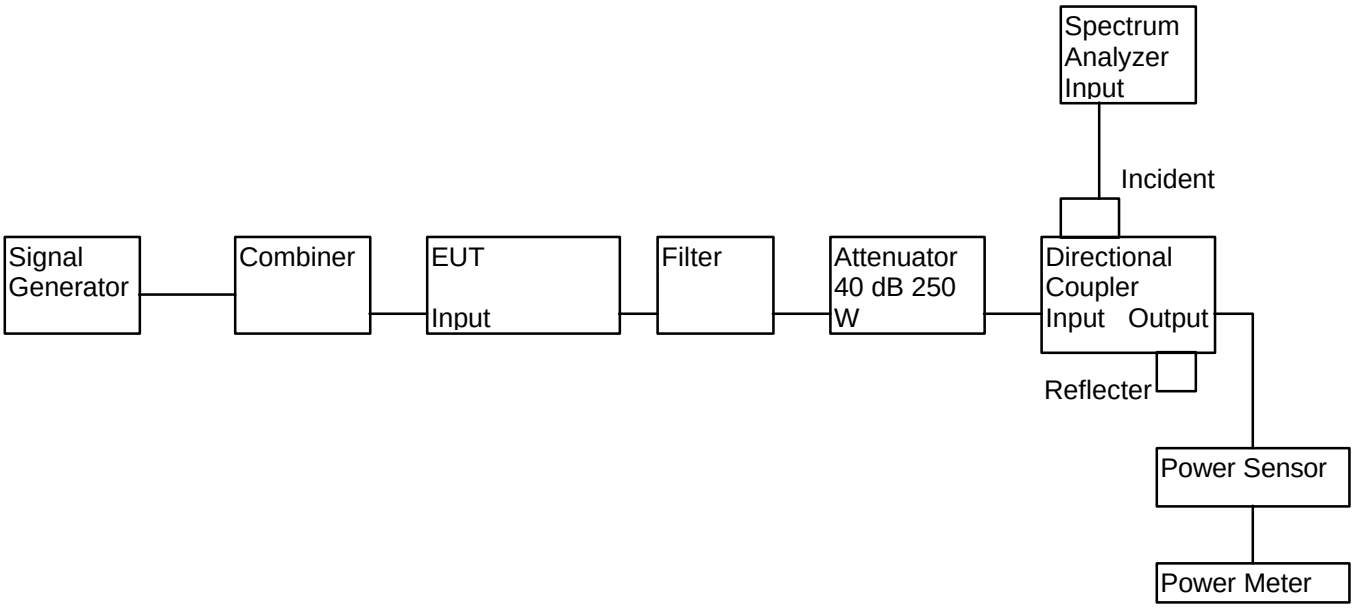
Part 2, Paragraph 2.985, 2.991 (two tones), Intermodulation (output plot)



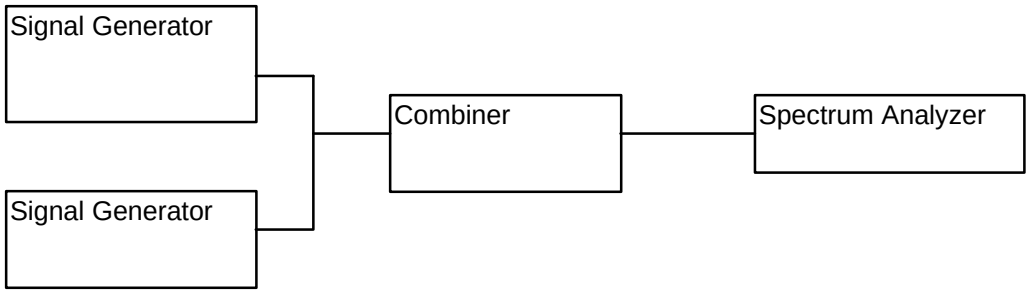
Part 2, Paragraph 2.991 (single tone), Part 24, Paragraph 24.238(a)



Part 2, Paragraph 2.989, Part 24, Paragraph 24.238(b)(c)



Input Plot Test Setup



Emissions Test Conditions: CONDUCTED EMISSIONS, FCC Part 2, Paragraphs 2.985, 2,989, 2.991 and Part 24, Paragraph 24.238(a)(b)(c)

The Conducted *EMISSIONS* measurements were performed at the following test location :

☐ - Test not applicable

■ - SR-3, Shielded Room, 12’ x 20’ x 8’, Metal Chamber

Test Equipment Used :

Equipment List,

Signal Generator, HP E4432B, S/N US38330312 Cal Date: 08/24/99
Signal Generator, HP E4433B, S/N US38080117 Cal Date: 09/01/00
Power Meter, HP 437B, S/N 3125U26022 Cal Date: 09/16/99
Directional Coupler, Narda, Model 3022, S/N 74663, Cal Date: NCR
Power Sensor, HP 8481A, S/N US37290513 Cal Date: 09/17/99
Attenuator, Weinschel, Model 45-40-43, 40 dB, 250W, S/N KTZZZ, Cal Date: NCR
Combiner, Anaren, S/N 42010

Remarks: _____

REPORT NO: S8496 **DATE**: 13 January 1999

TEST: RF Output Power

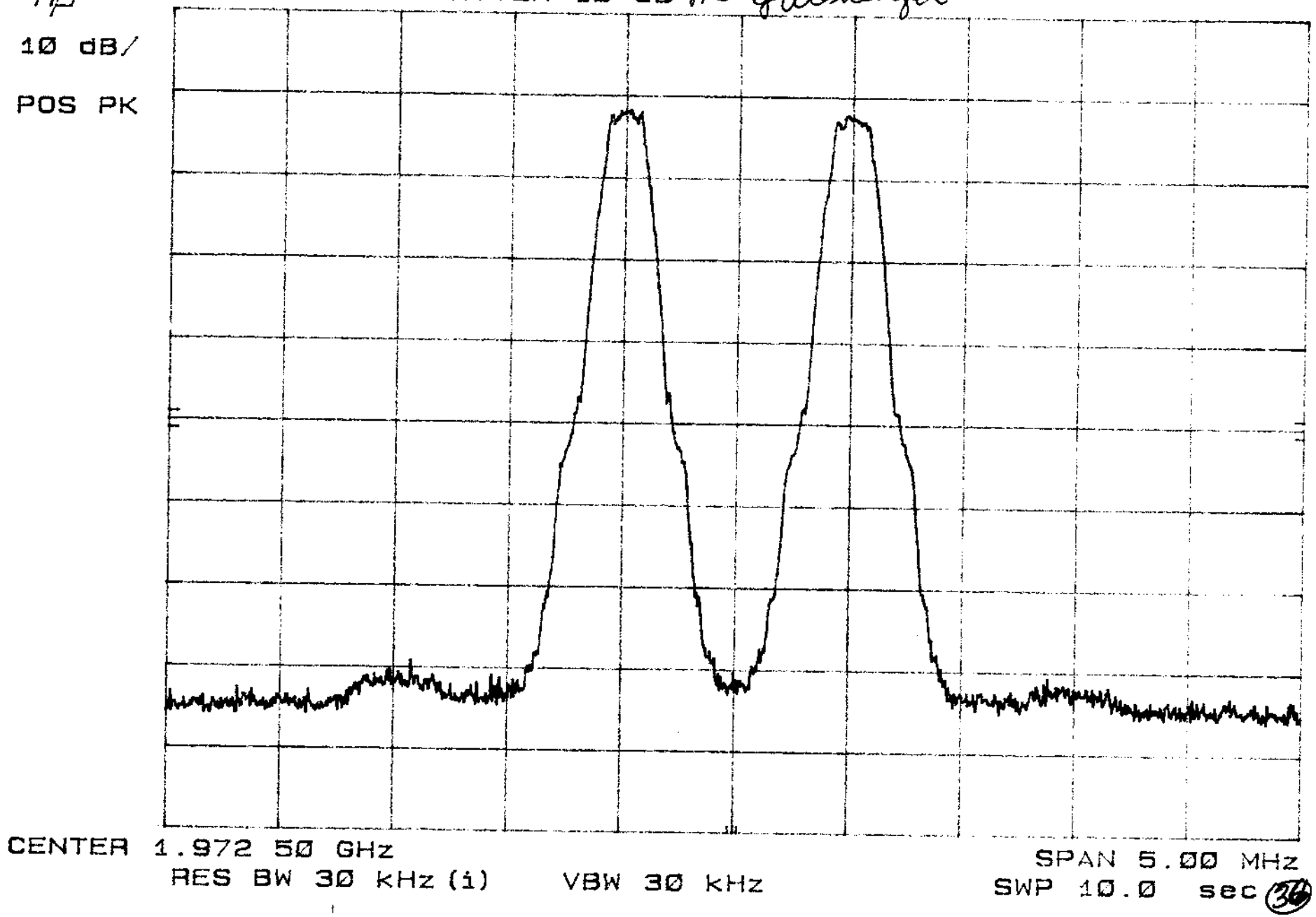
CUSTOMER: POWERWAVE TECHNOLOGIES, INC.

EUT: Multicarrier PCS Ampliifer System, Model MPA9600-25/MCR3303-3-1

SPECIFICATION: FCC Part 2, Paragraph 2.985

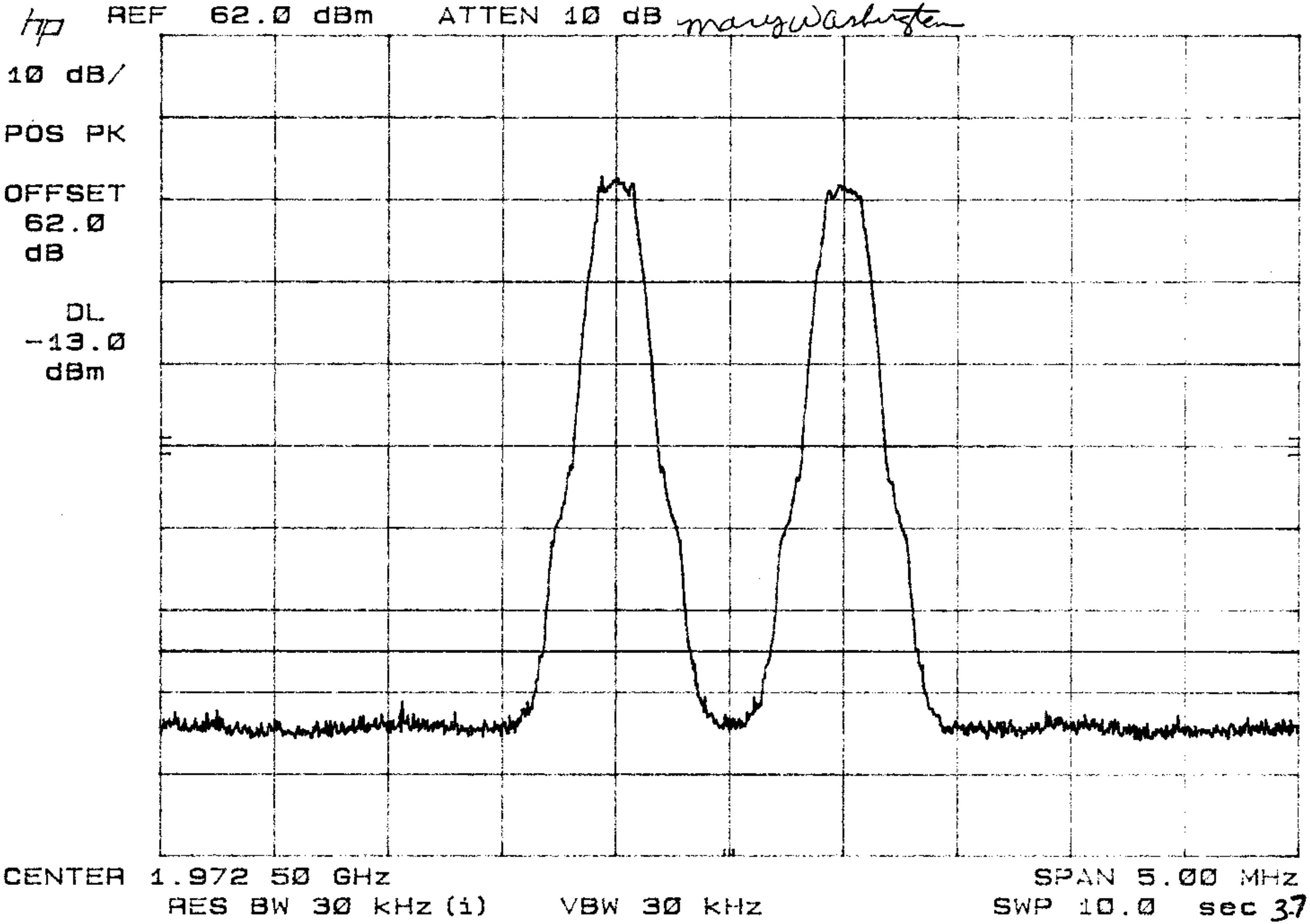
Modulation	Output Power	Two Tones:
GSM	75 W	1980 and 1981 & 1972 and 1973 MHz

1/13/99 Powerwave Intermodulation (Input to Amplifier - EUT)
S8496 GSM Two tones: 1972.4 1973 MHz Block F

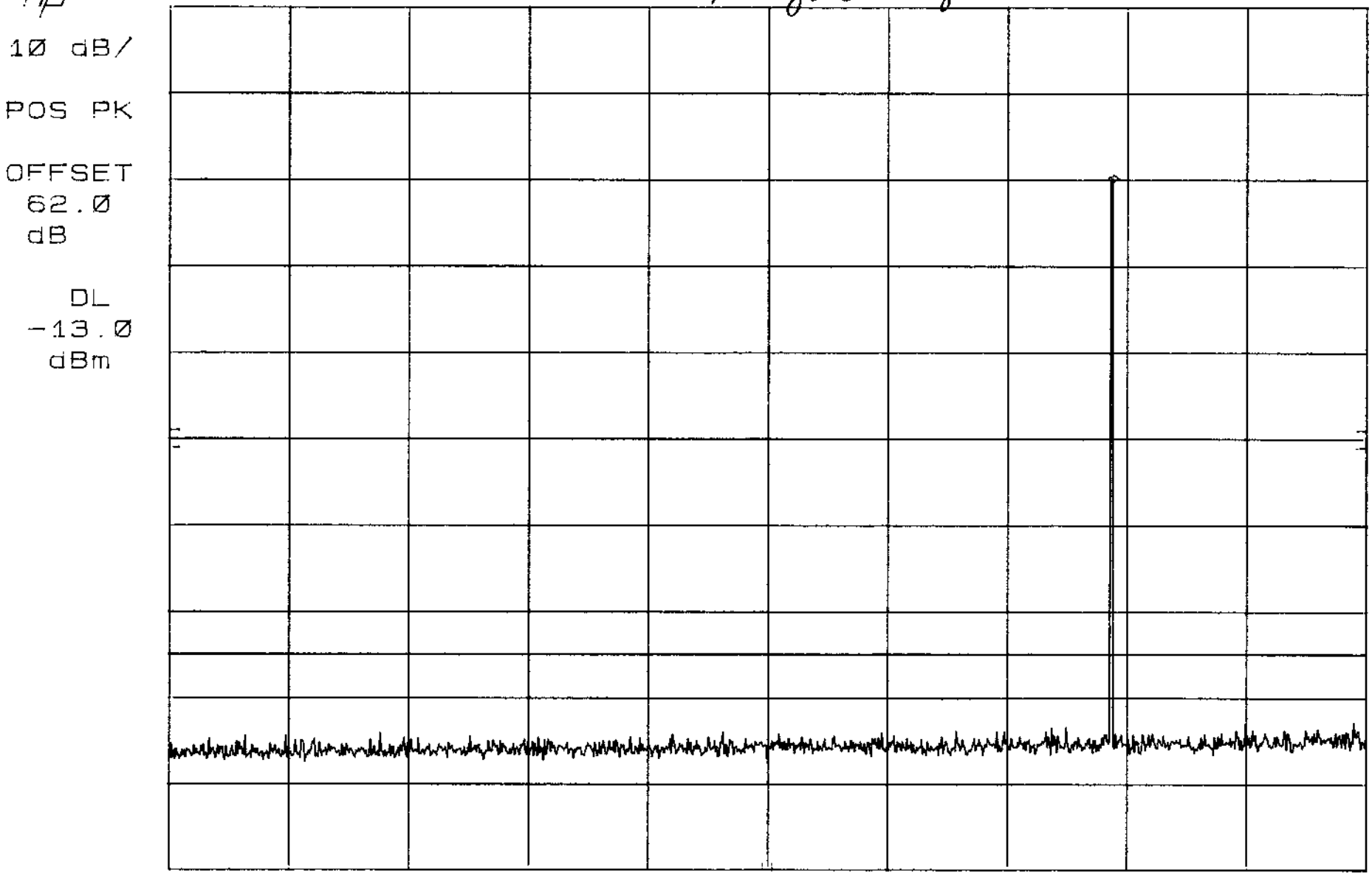


many Washington

1/13/99 Powerwave Intermodulation (output of Amplifier (OUT))
S8496 GSM Two tones: 1972 & 1973 MHZ Block F



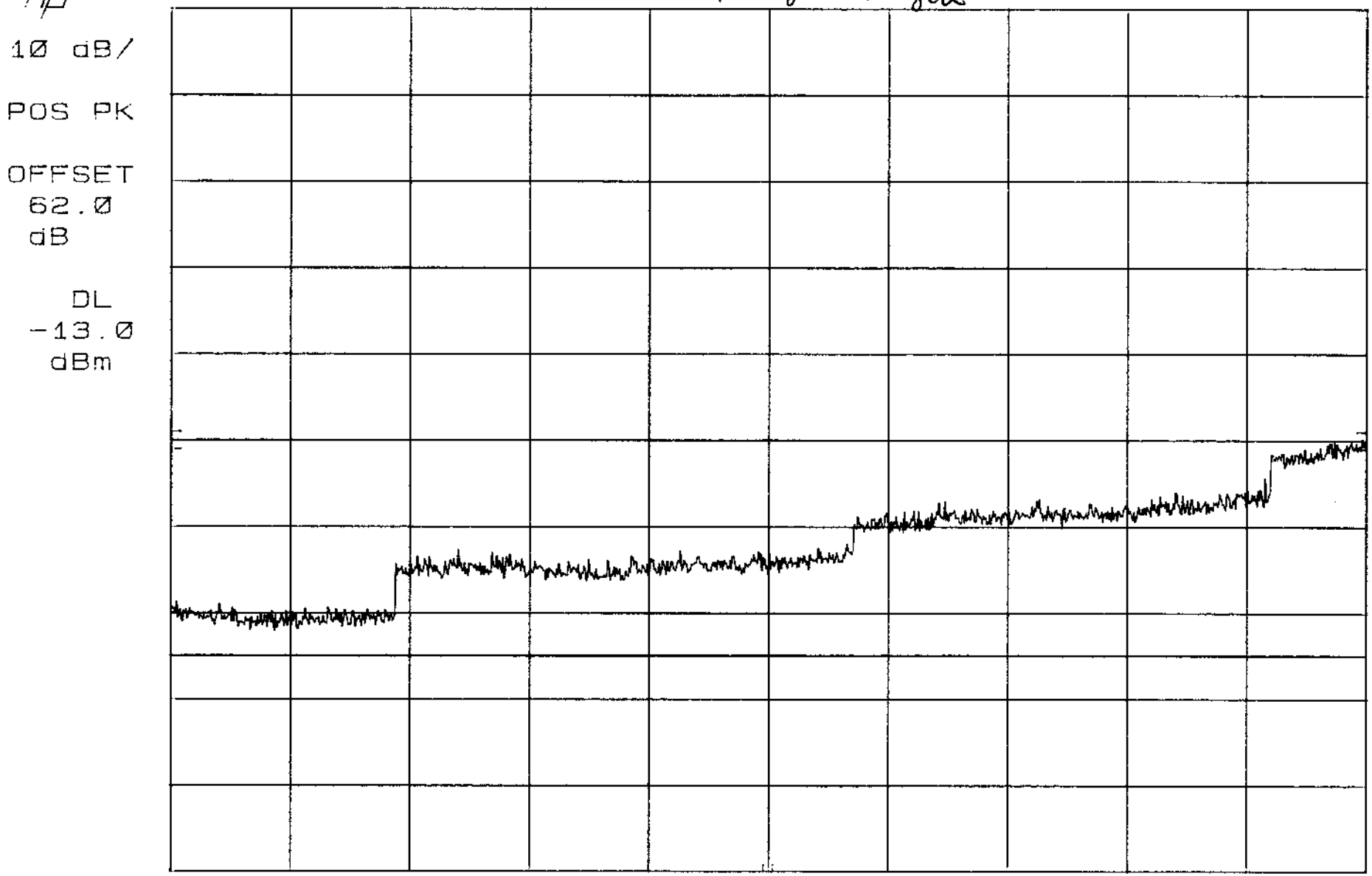
1/13/99 Powerwave 2.991 & 24.238(a) Spurious & Harmonics and Block F
5849b GSM Two tones: 1972 & 1973 MHz out-of-Band Emissions
MKR 1.976 GHz
HP REF 62.0 dBm ATTEN 10 dB Mary Washington 42.20 dBm



START 30 MHz STOP 2.50 GHz
RES BW 30 kHz (i) VBW 30 kHz SWP 20.0 sec

1/13/99 Powerwave 5849b 2.99(d) 24.238(a) Input to spectrum Analyzer

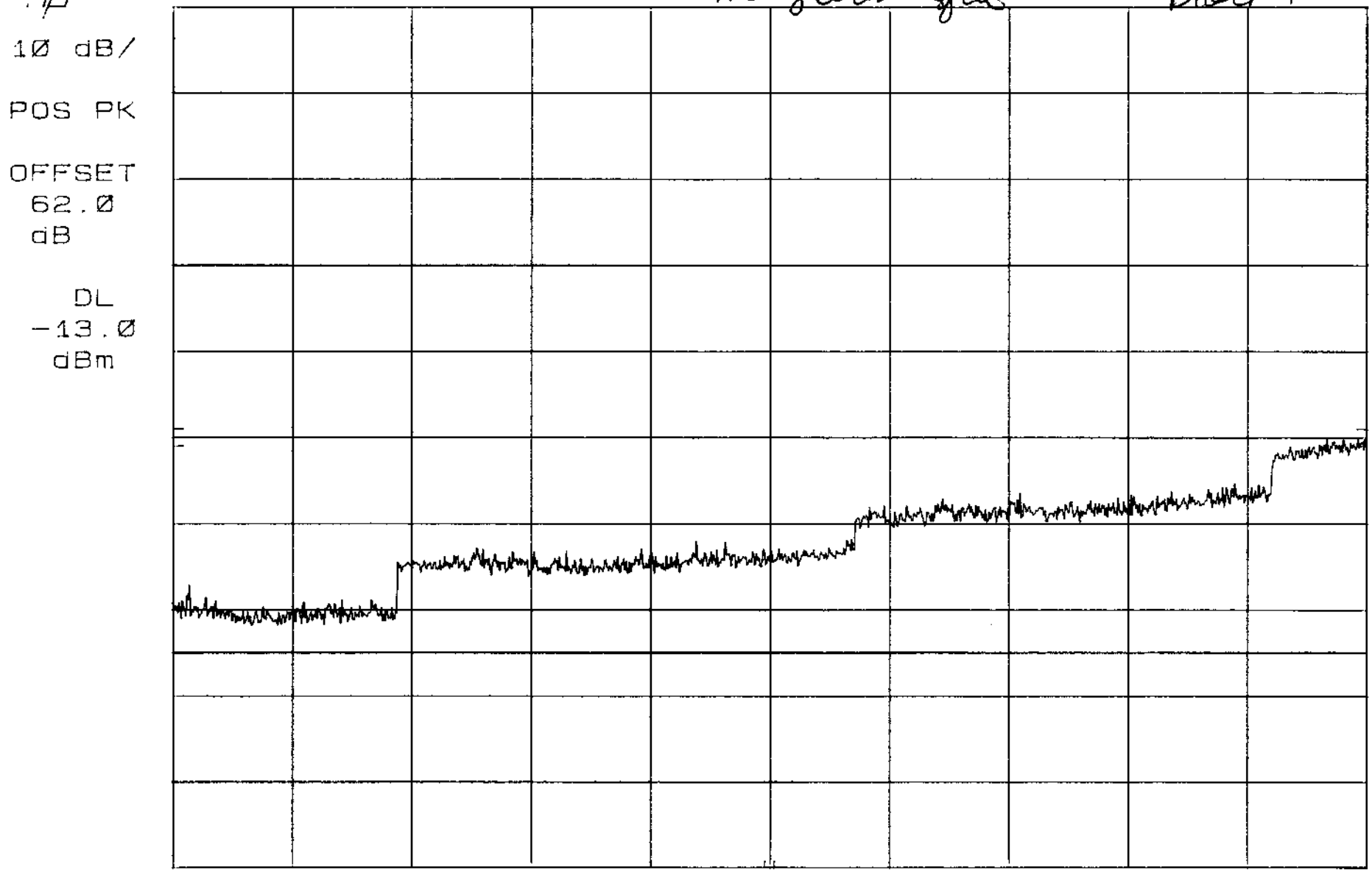
Gsm Two tones: 1972+1973 MHz Block F



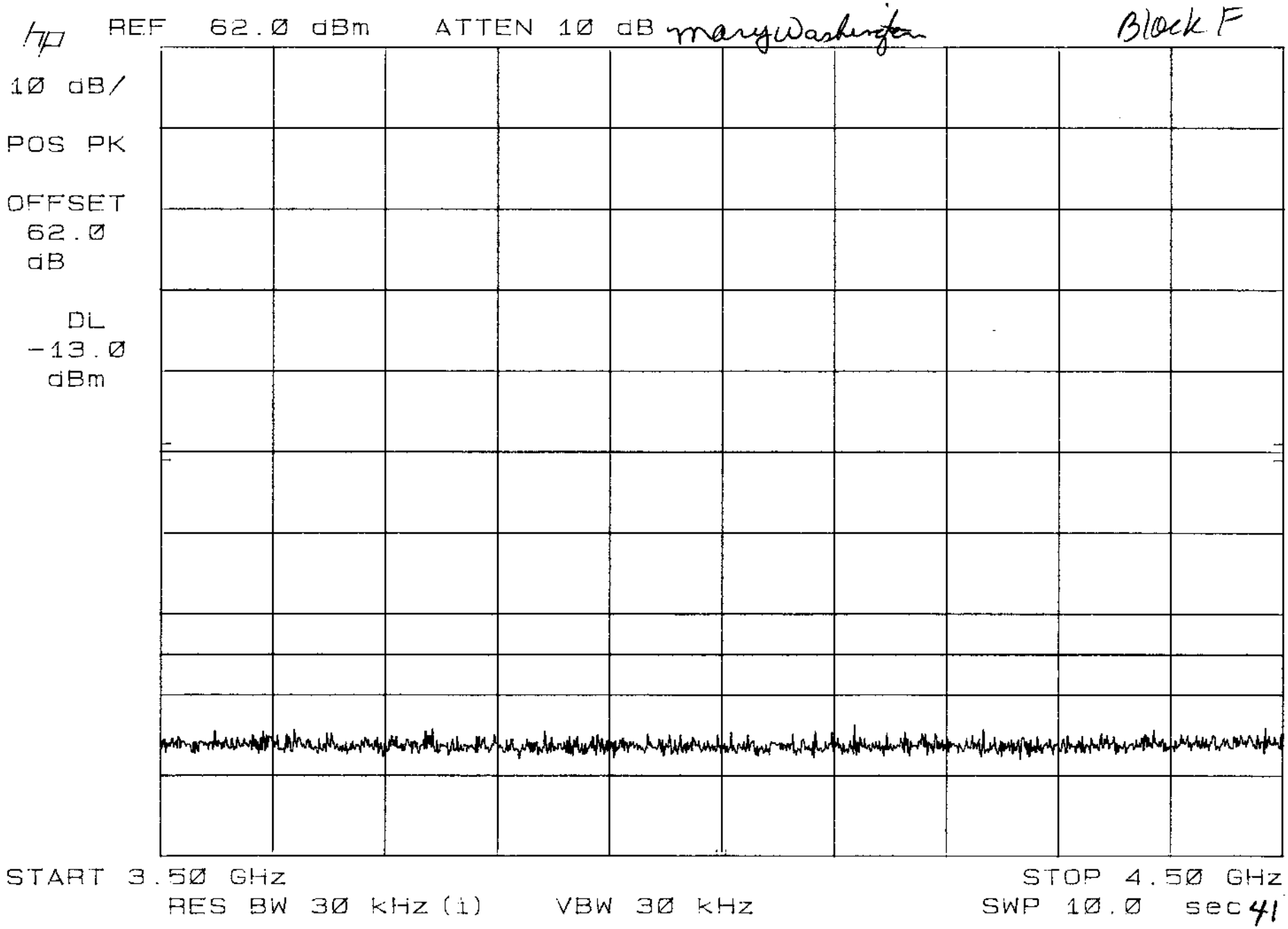
1/13/99 Powerwave 2991 ±24.238(a) no input to spectrum analyzer

5849b GSM Two tones; 1972+1973 MHz

Block F

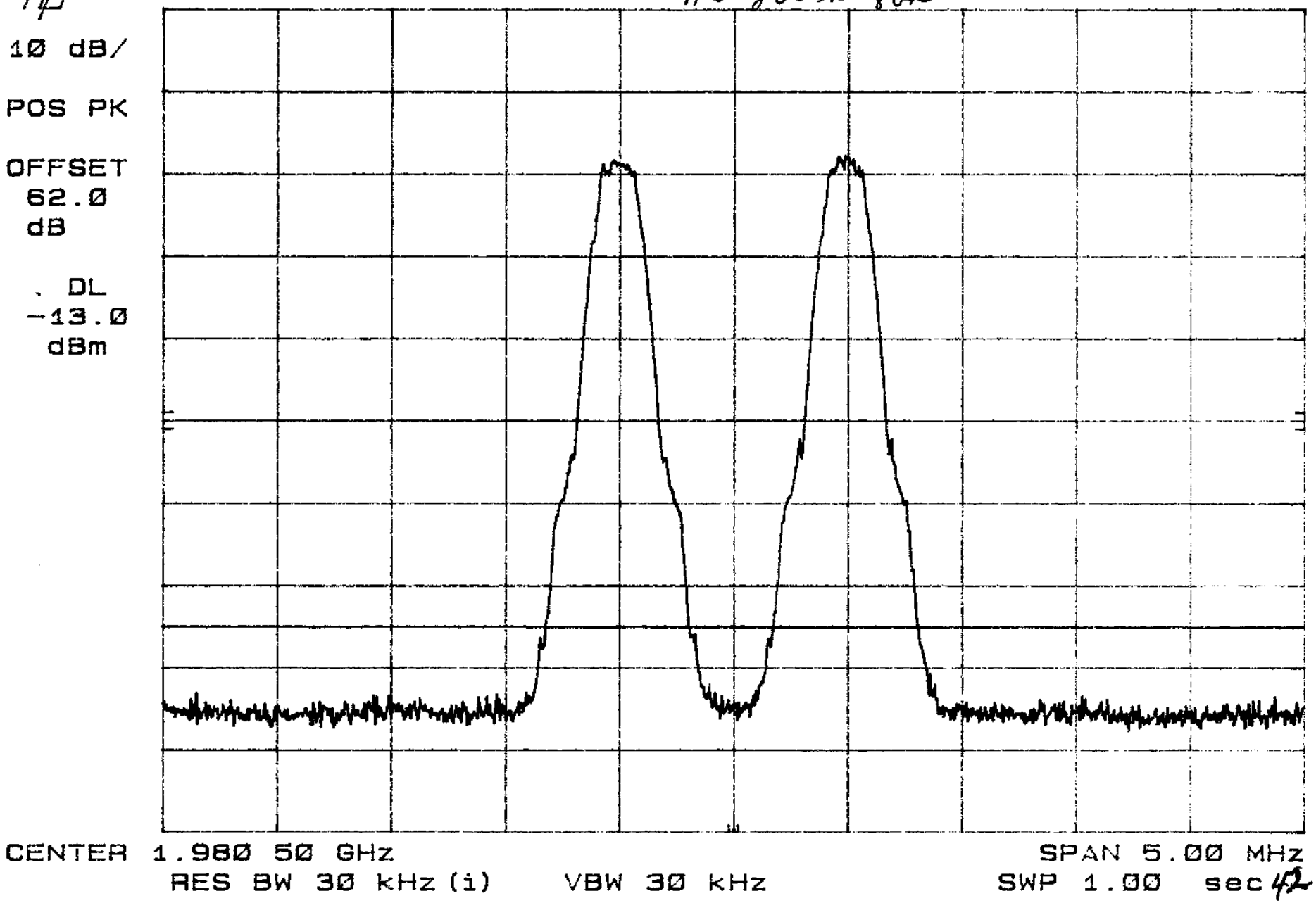


1/13/99 Powerwave 2991 & 24.238(a) Spurious Harmonics and Out-of-Band Emissions Two tones: 1972 & 1973 mHz
S8496 GSM



41

1/13/99 Powerwave 58496 Intermodulation (output of Amplifier - ENT)
Gsm Two tones: 1980 & 1981 MHz. Block C

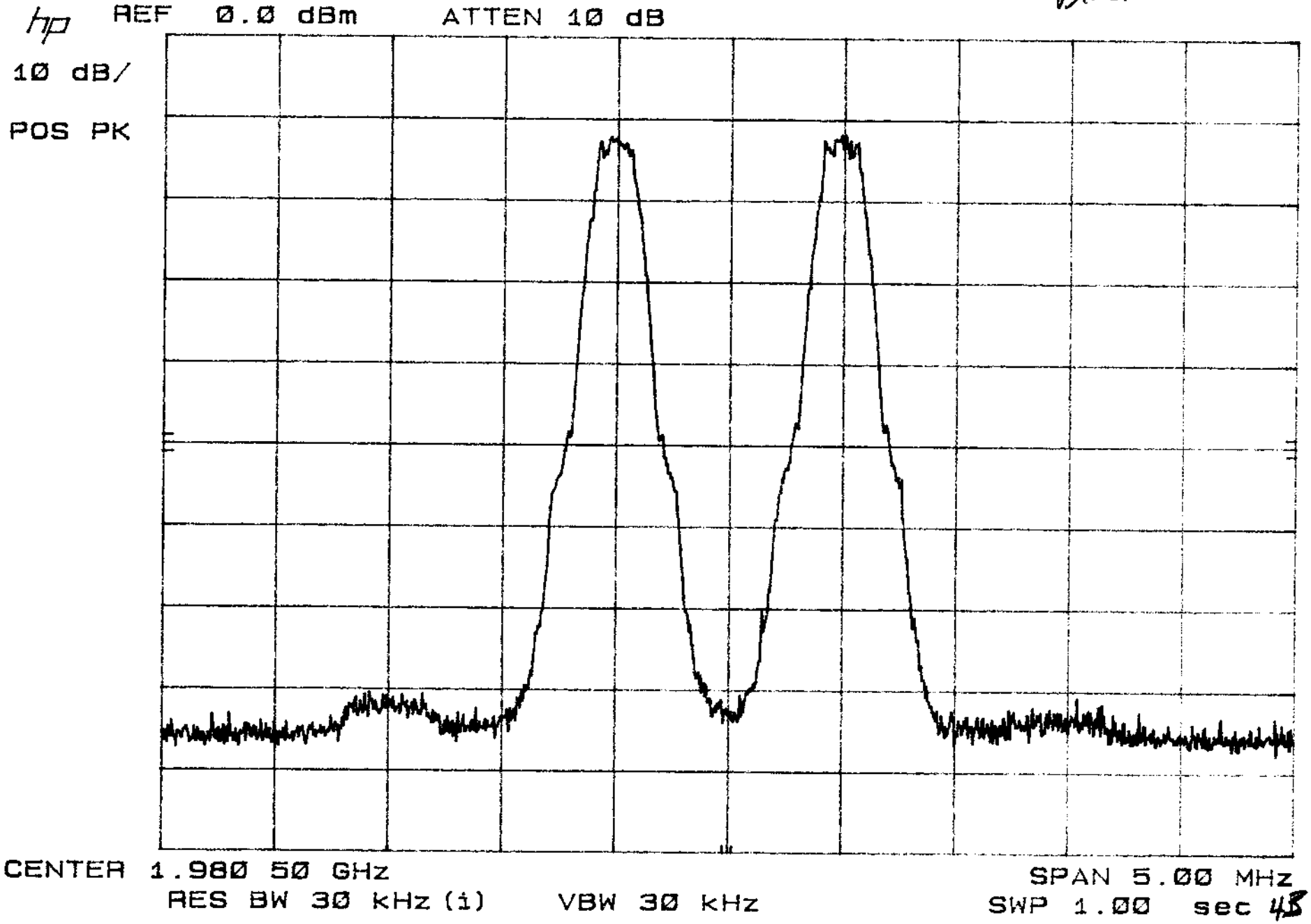


42

1/13/99 Powerwave S8496

Intermodulation (Input to Amplifier-EUT)
Two tones: 1980 & 1981 MHZ

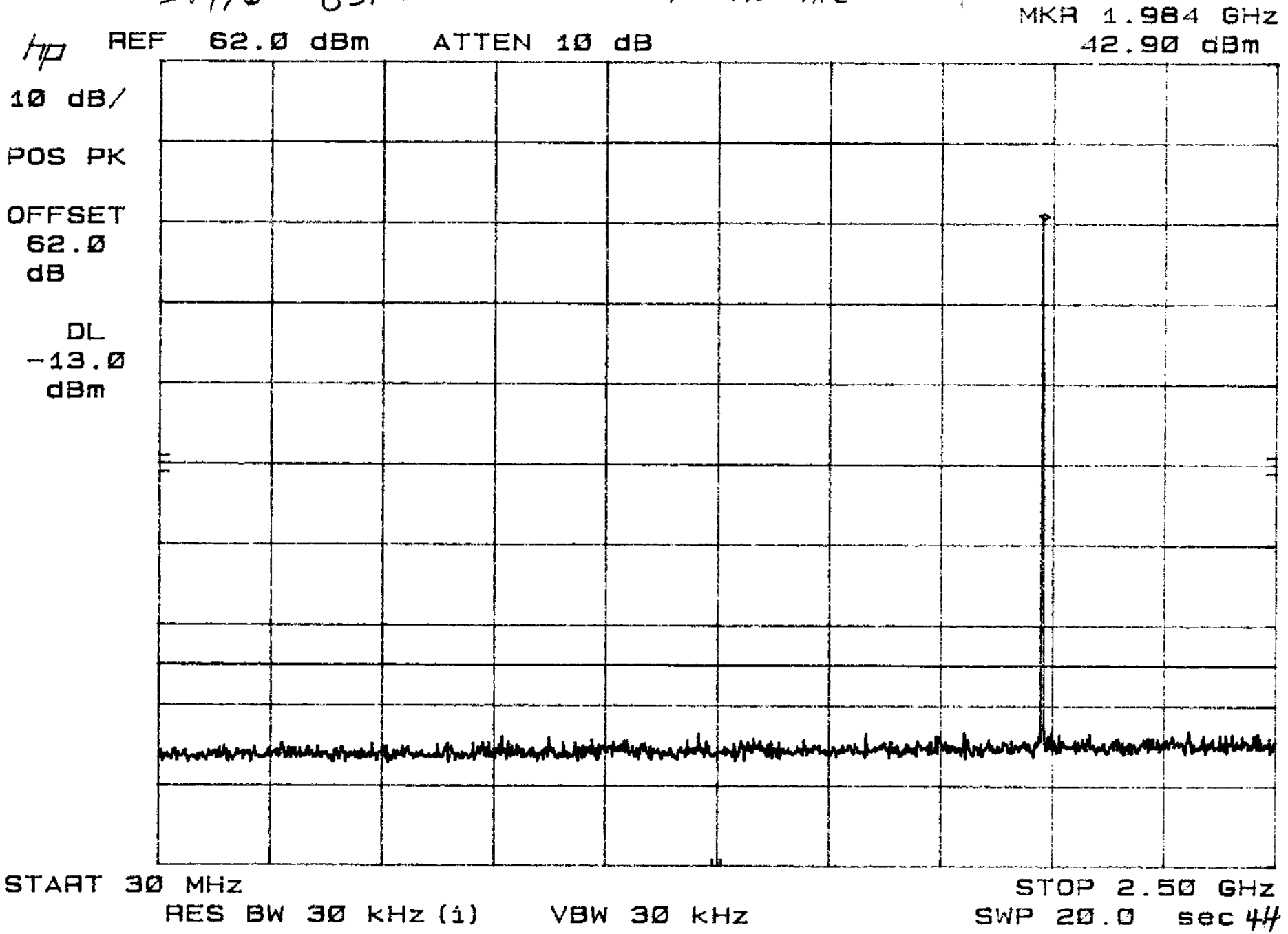
Block C



45

1/13/99 Powerwave 2.991 & 24.238(a) Spurious & Harmonics and Out-of-Band Emissions

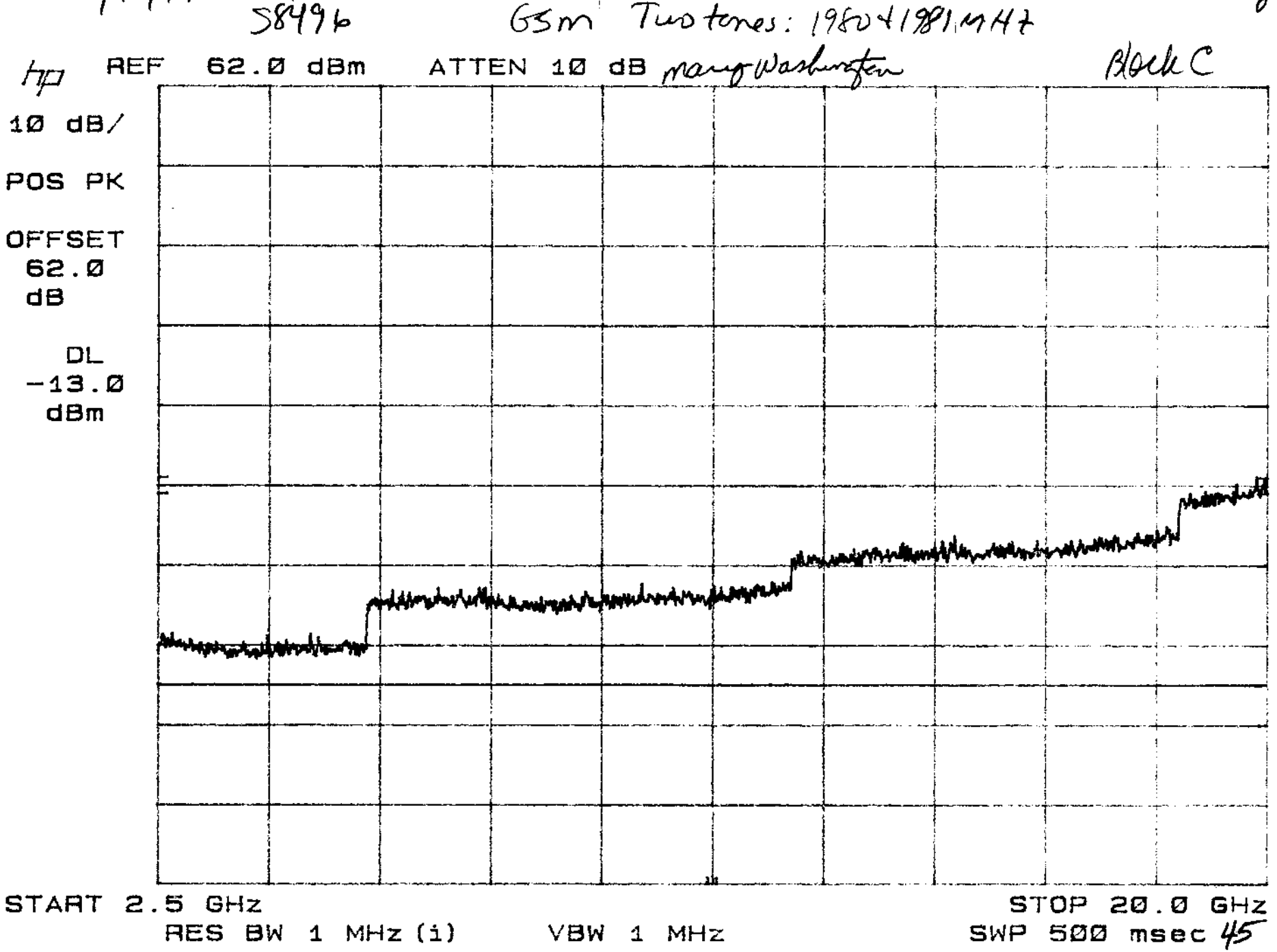
58496 Gsm Two tones = 1980 & 1981 MHz Block C



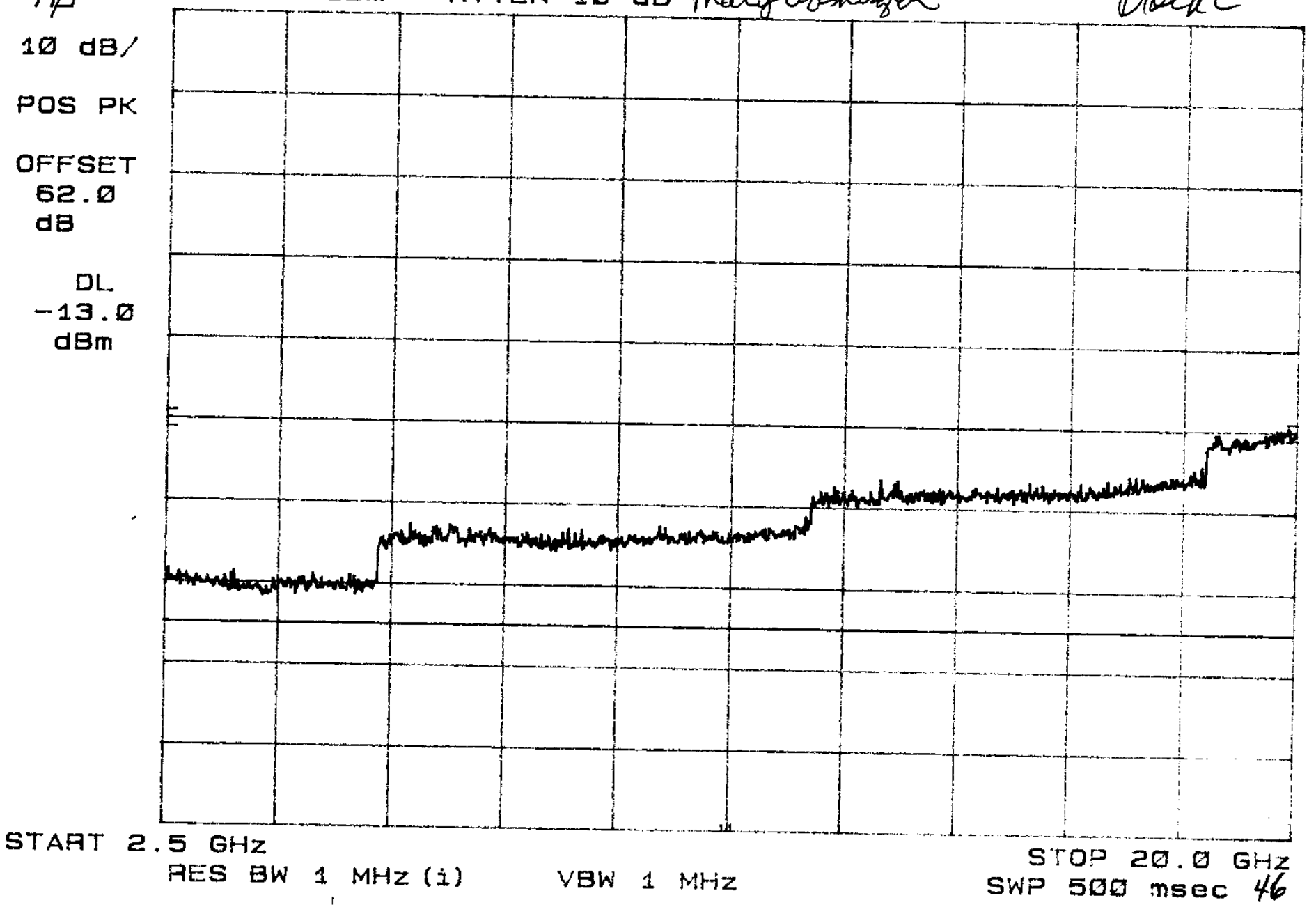
44

1/13/99 Powerwave 2.991 & 24.238(a) Input to Spectrum Analyzer

58496 GSM Two tones: 1980 & 1981 MHz



1/13/99 Powerwave 2.991 & 24.238(a) No input to spectrum
S8496 GSM Two tones @ 1980 & 1982 MHz Analyzer
Mary Washington Block C



1/13/99 Powerwave 2.991 & 24.238(a)

58496 GSm Two tones: 1980 & 1981 MHz

Block C

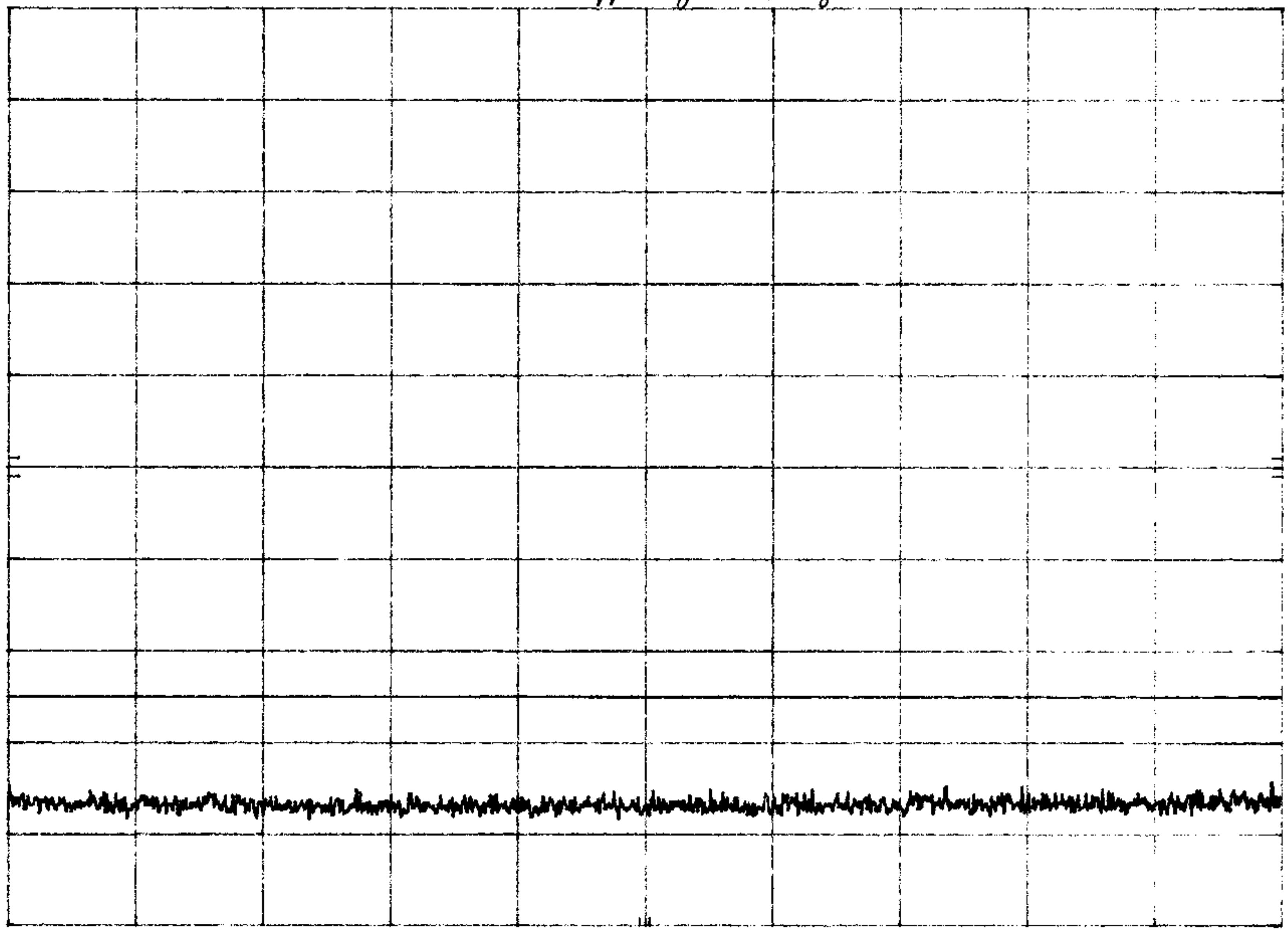
hp REF 62.0 dBm ATTEN 10 dB mary washington

10 dB/

POS PK

OFFSET
62.0
dB

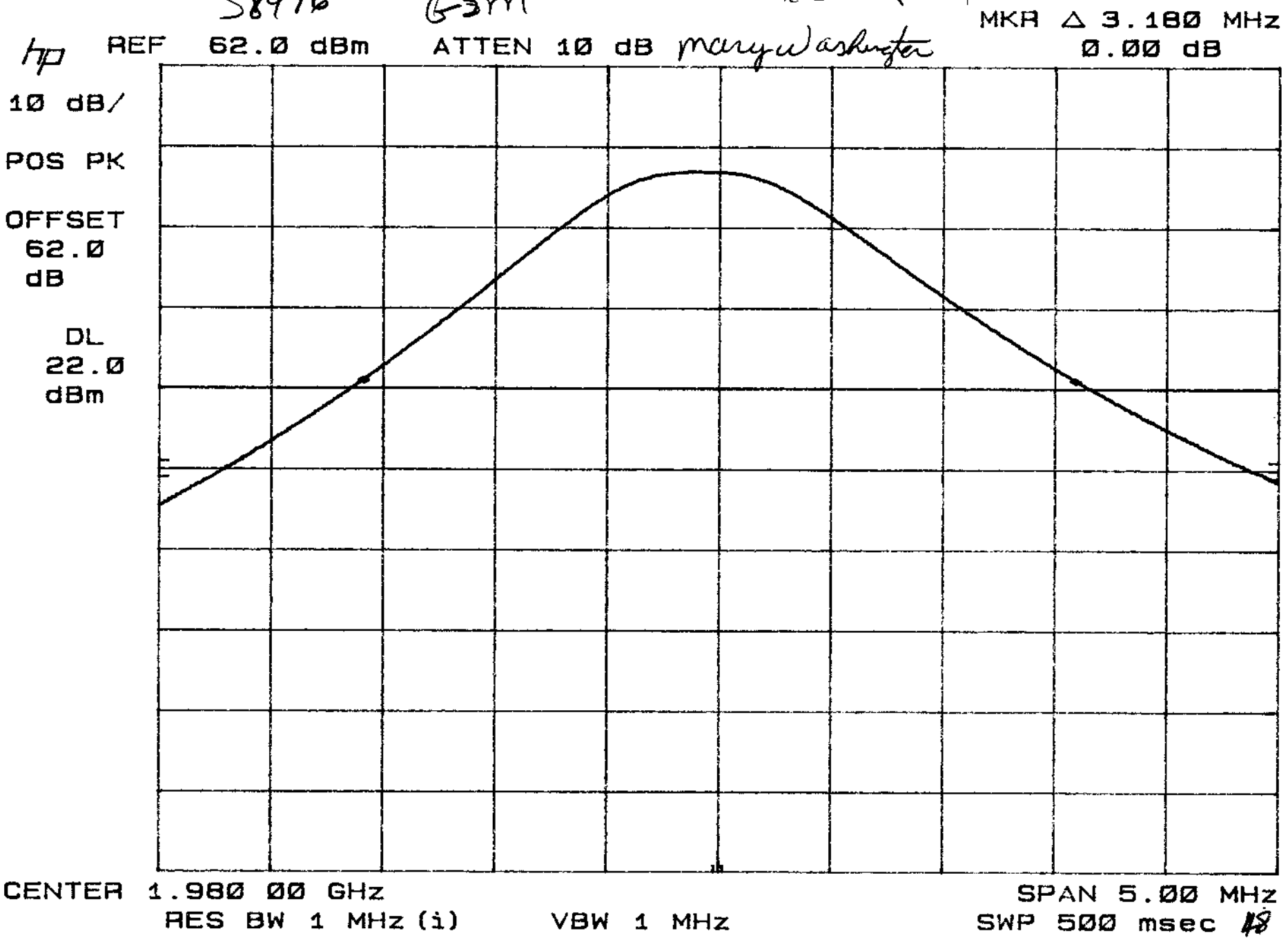
DL
-13.0
dBm



START 3.50 GHz STOP 4.50 GHz

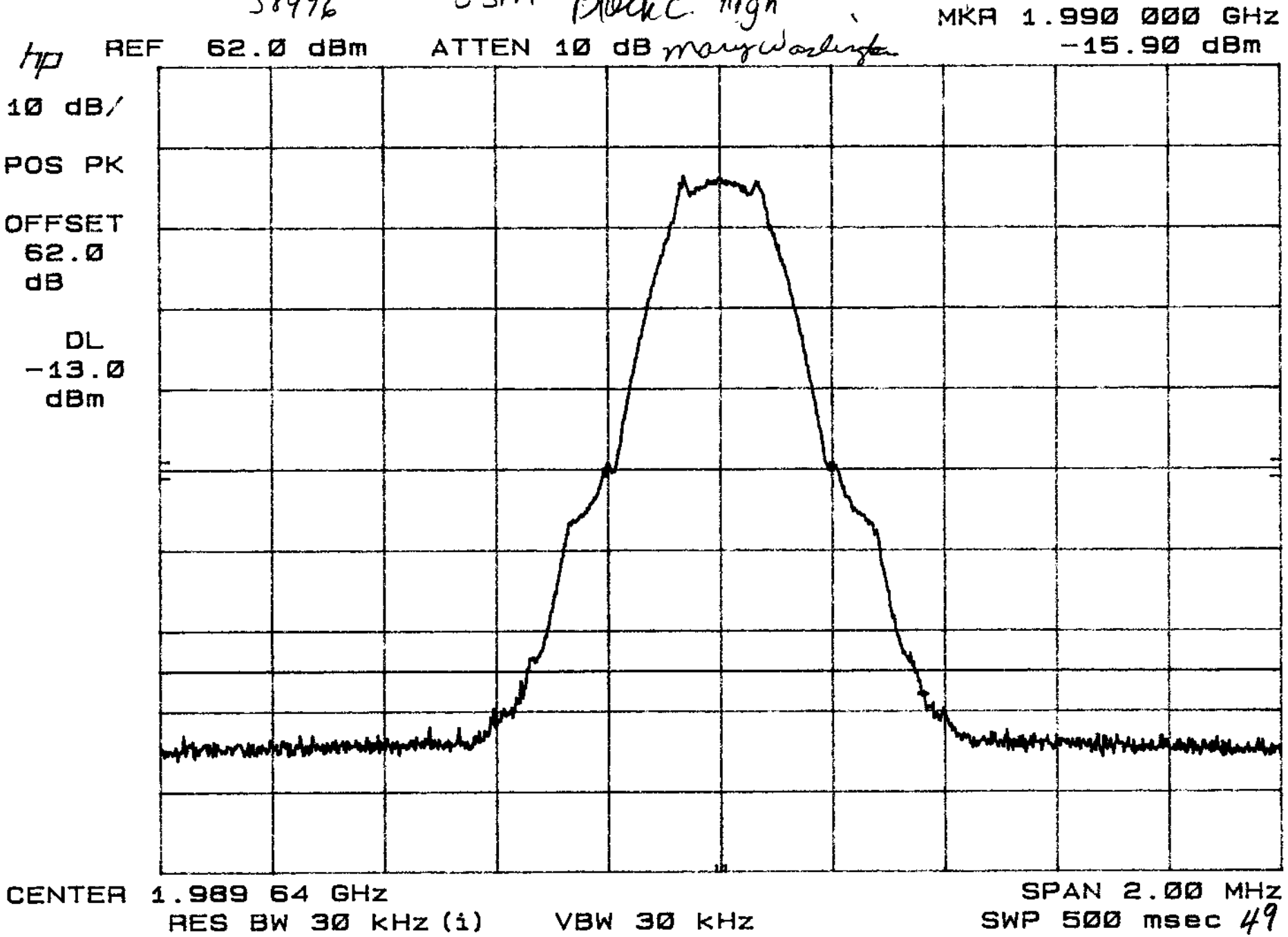
RES BW 30 kHz (i) VBW 30 kHz SWP 10.0 sec

1/13/99 Powerwave 24.238(b) Emission Bandwidth ±2.989 Occupied Bandwidth
S8496 GSM Block C



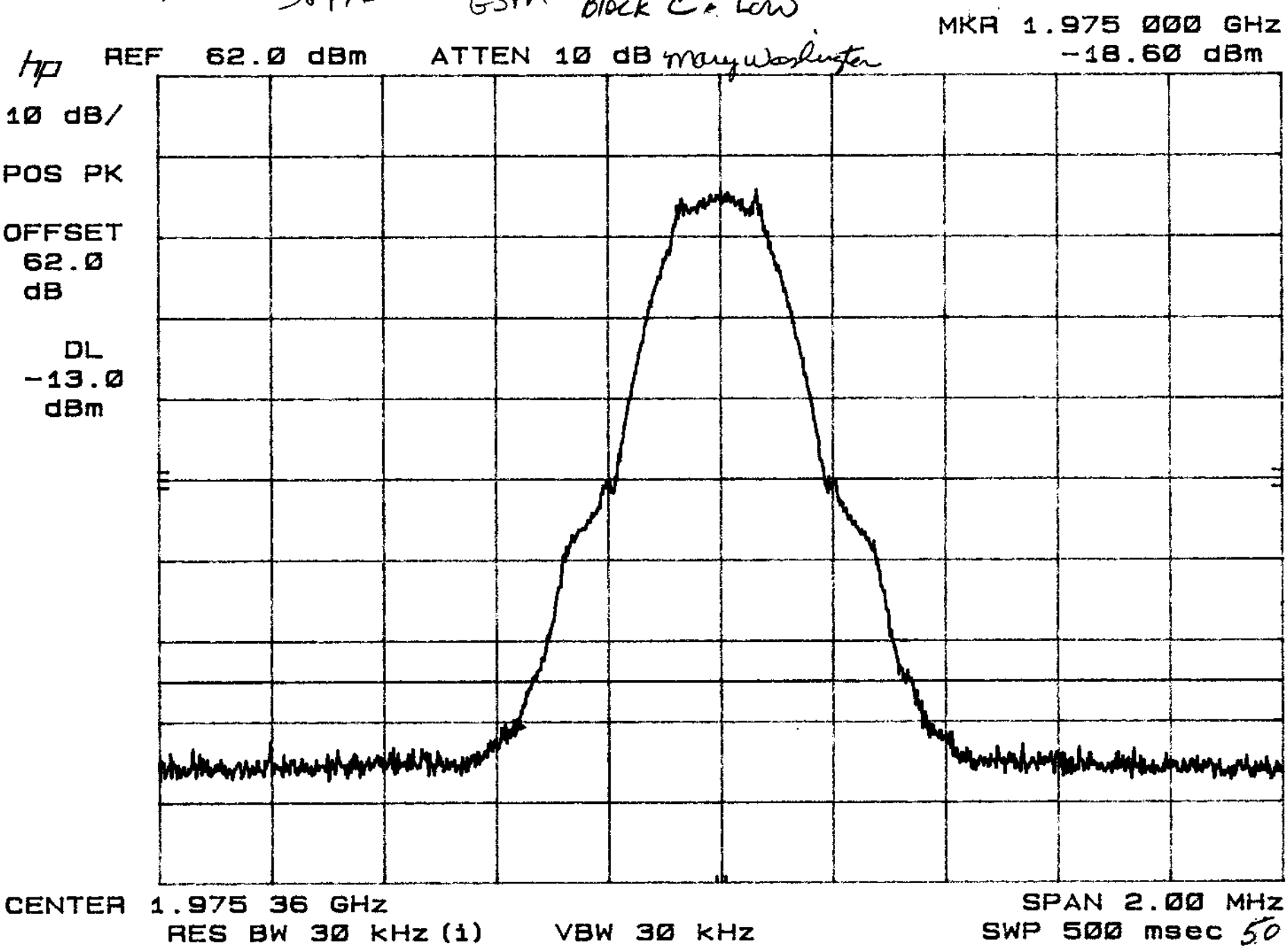
mary washington

1/13/99 Powerwave 24.238(c) Block Edge
5849b GSM Block C High



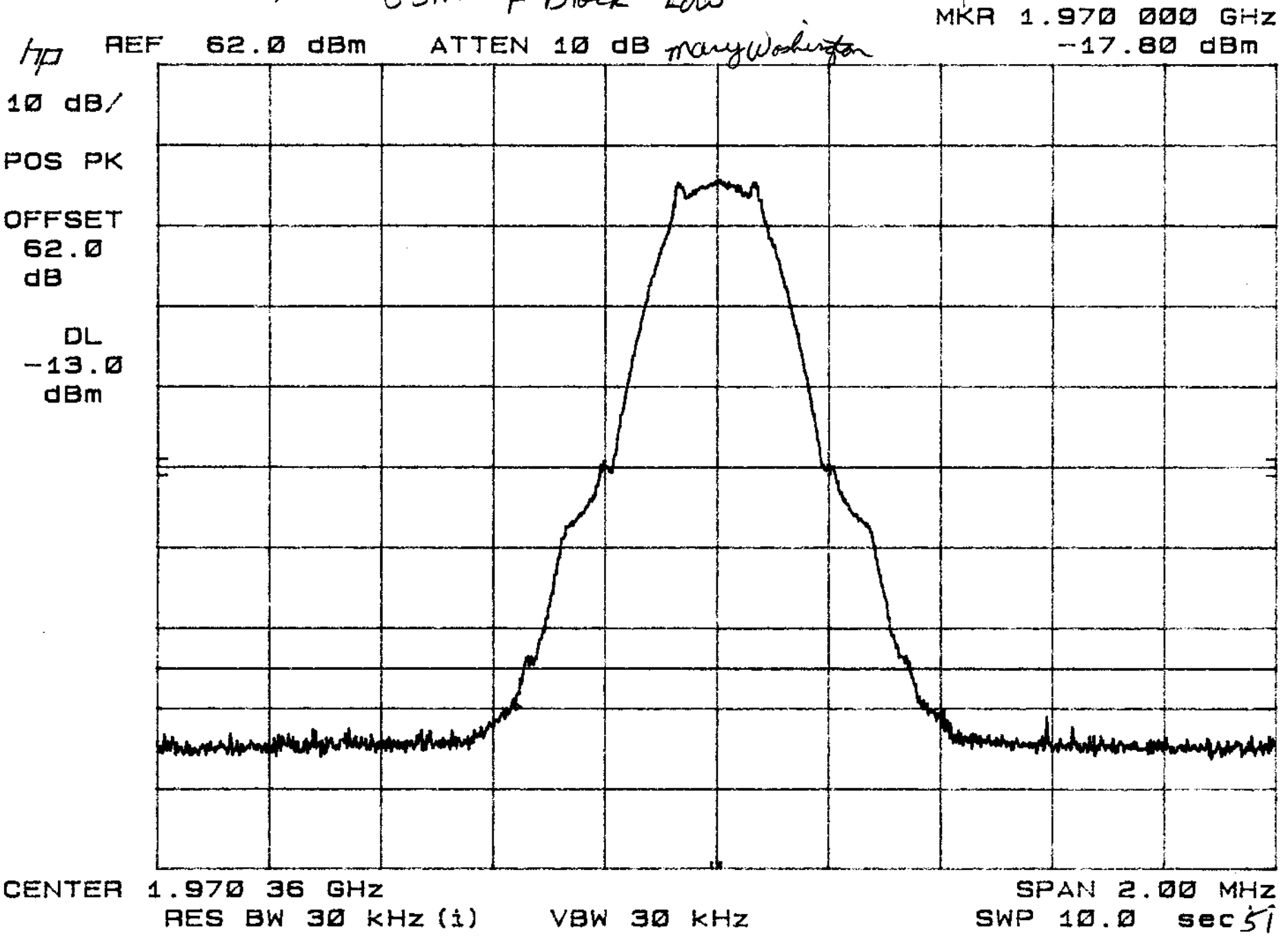
49

1/13/99 Powerwave 24.238(c) Block Edge
S8496 Gsm Block C Low

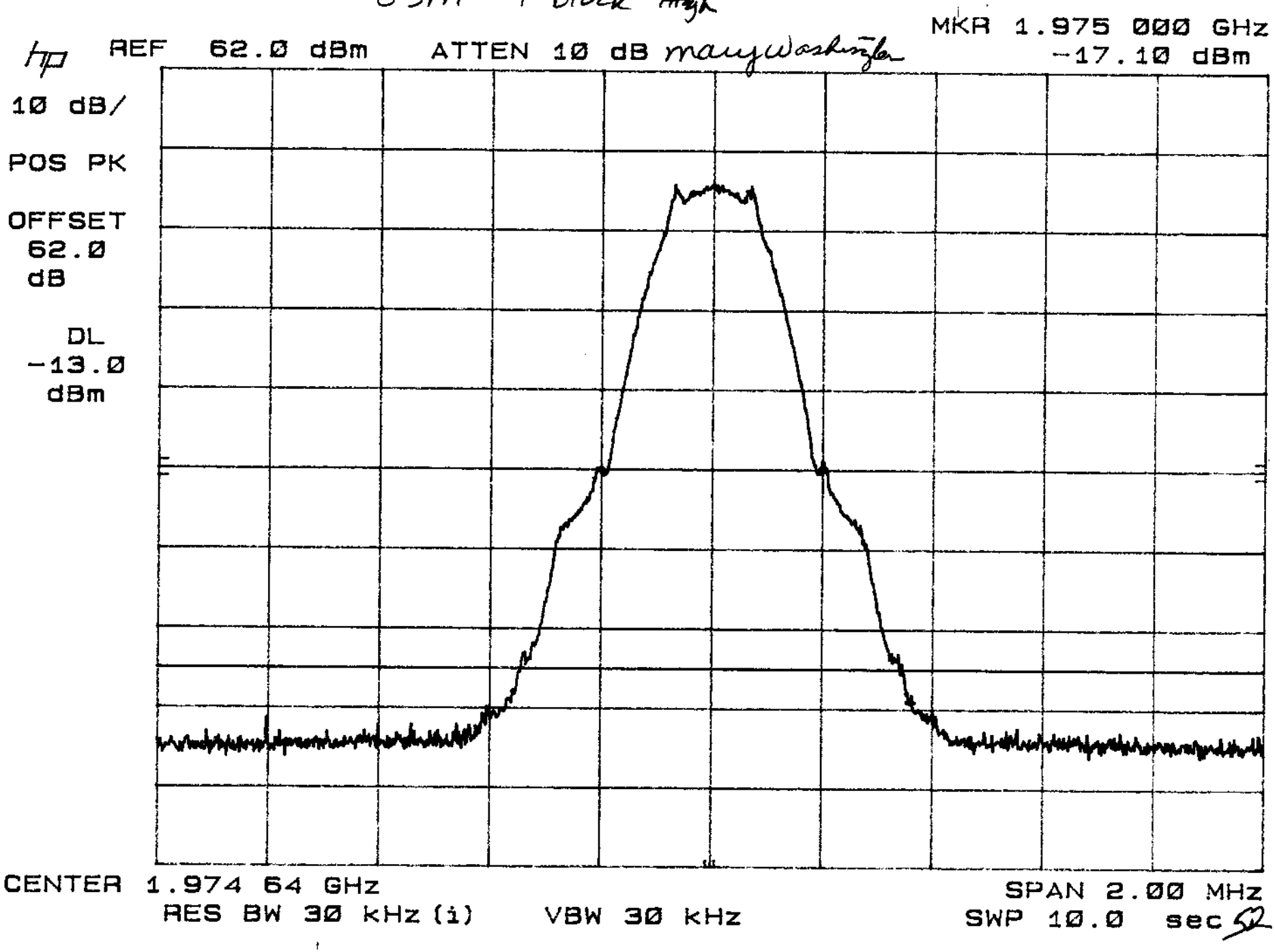


50

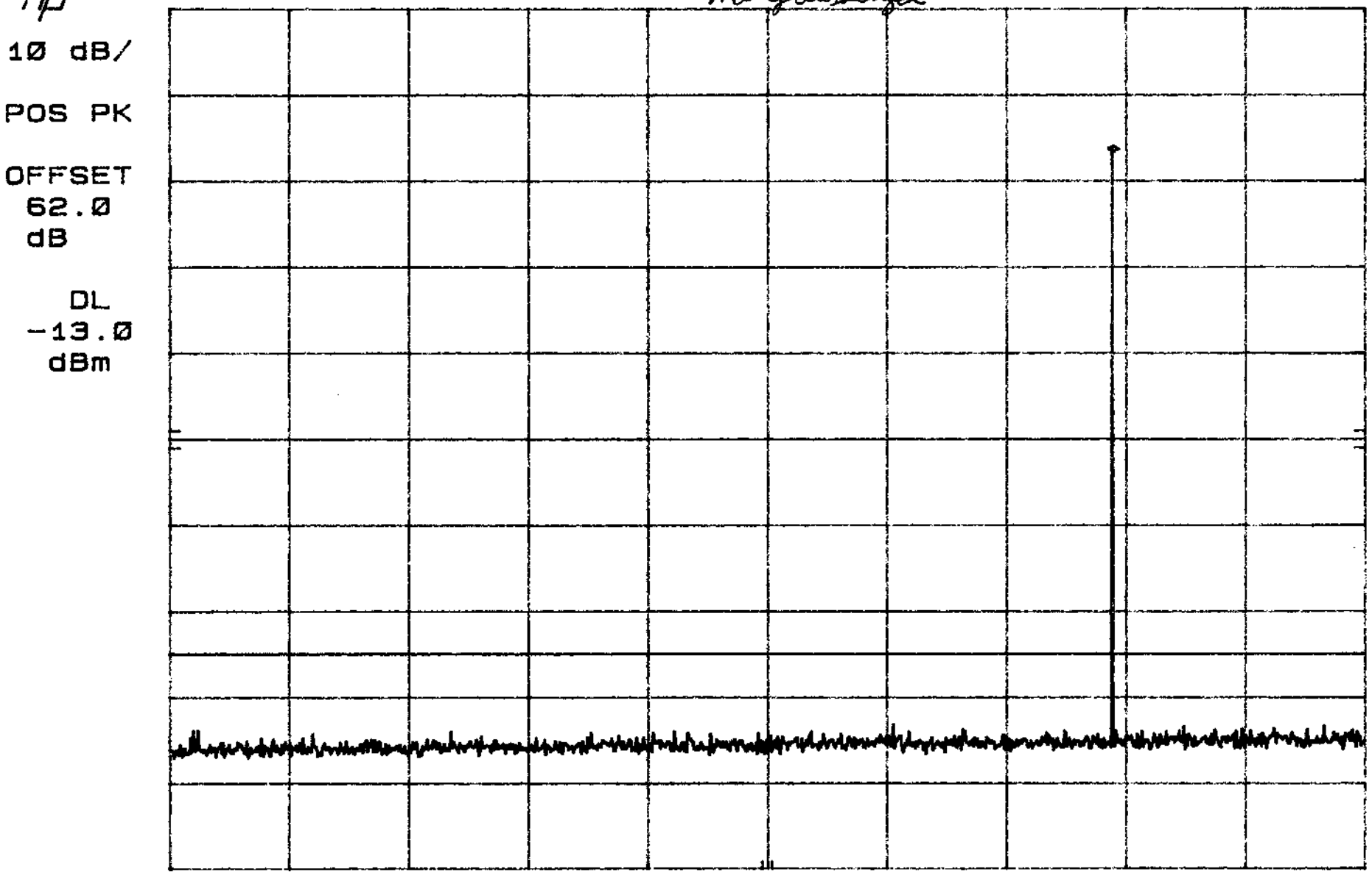
1/13/99 Powerwave 24.238(c) Block Edge
58496 GSM F Block Low



1/13/99 Revenue 24.238(c) Block Edge
SP496 GSM F Block High

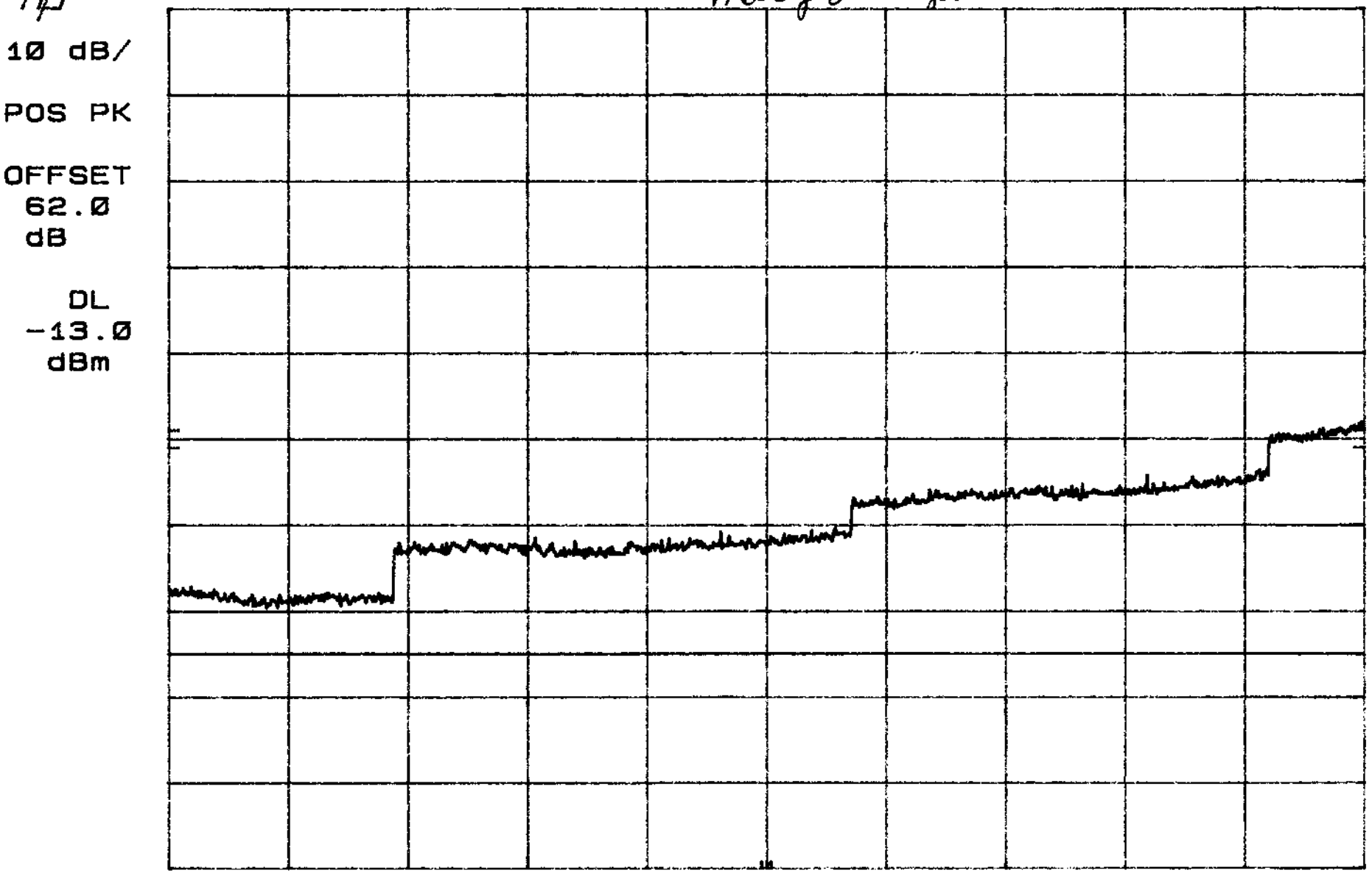


Powerwave
1/13/99 58496 GSM 24.238 & 2.991 Single tone
Block C out-of-Band and Spurious and Harmonics Emissions
mary washington



1/13/99 Powerwave 58496 GSM 24.238 & 2.991 Block C out-of-Band Emissions Spurious and Harmonics Emissions Input to spectrum analyzer Single tone

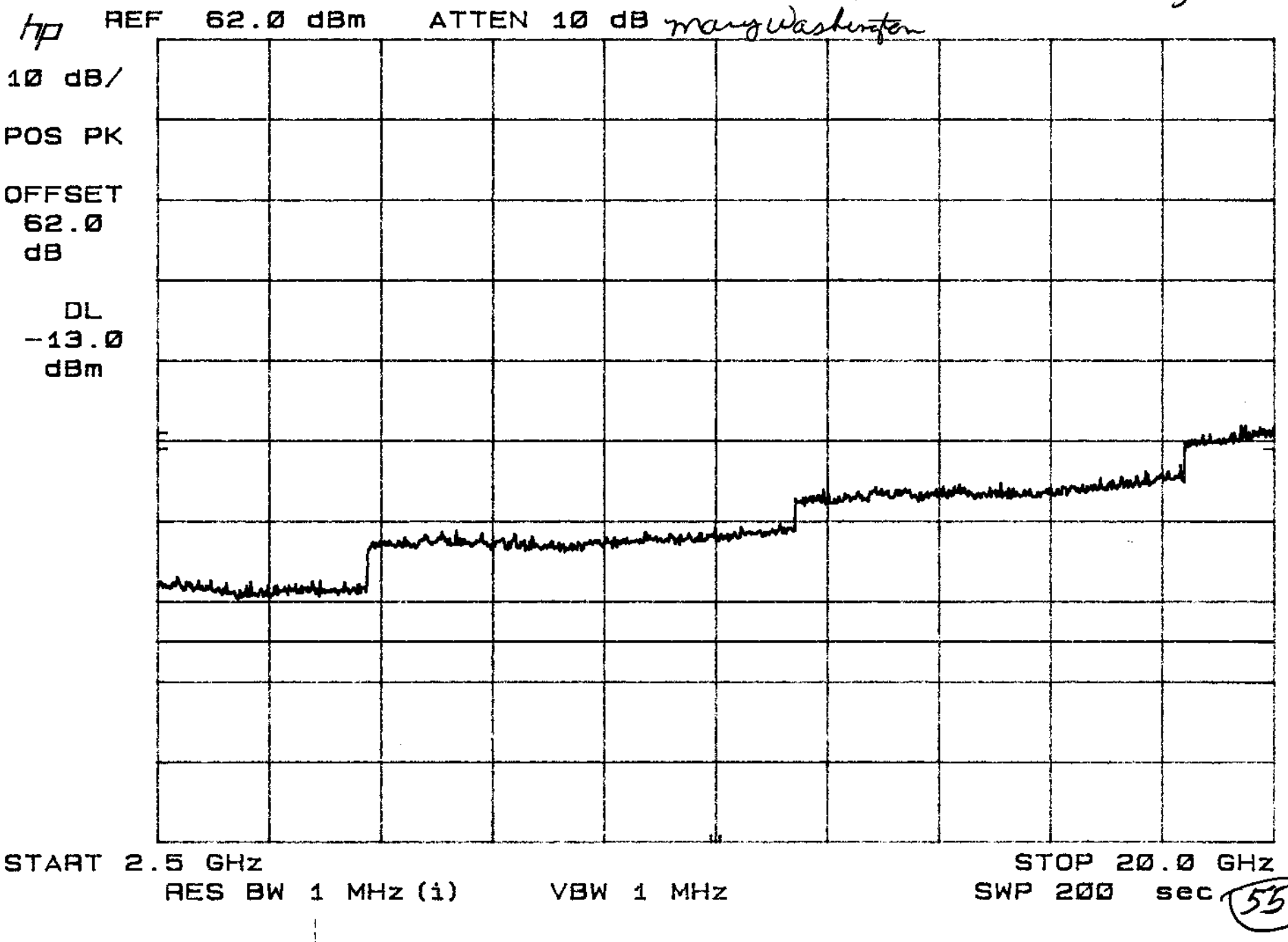
Mary Washington



54

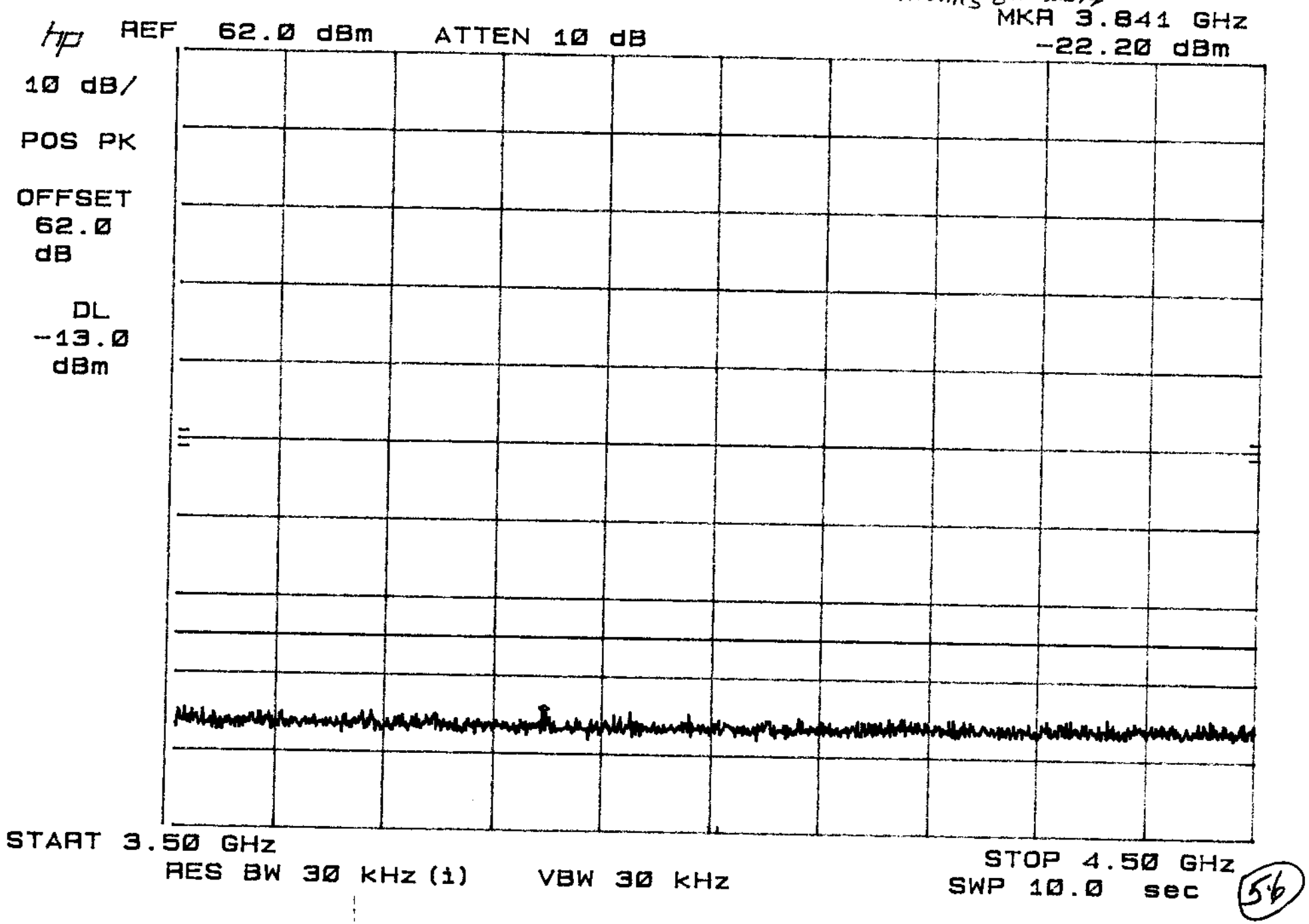
1/13/99 Powerwave S8496 24.238 & 2.991 GSM Block C Out-of-Band Emissions Spurious and Harmonics Emissions

No input to spectrum analyzer Single tone



55

1/13/99 Powerwave 24.238 & 2.991 out-of-Band Emissions Single tone
5849b GSM Block C Spurious and Harmonics Emissions



7 SIGNATURE PAGE

GENERAL REMARKS:

SUMMARY:

All tests according to the standards sited on page 1 of this report.

■ - Performed

☐ - **Not** Performed

The Equipment Under Test

■ - **Fulfills** the general approval requirements cited on page 1.

☐ - **Does not** fulfill the general approval requirements cited on page 1.

- TÜV PRODUCT SERVICE, INC. -

Responsible Engineer:

Mary Washington
(EMC Engineer)