FCC Test and Evaluation Submission

For

Grace Industries, Inc.

Spread Spectrum Radio
Life Safety Transmitter

Prepared By:
Edward C. Nichols

Chief Engineer
Nichols RF Systems, Inc.

Descriptive Outline

Section I. General Description
- A. Specifications

Section II. Theory of Operation
- A. Power Supply and Support
- B. Microprocessor
- C. RF Section
- D. Transmitter Sequence of Events

Section III. Attatchments
- A. Block Diagram
- B. Electronic Schematic
- C. Component Parts Layout
- D. Bill of Component Material
- E. Sample of Pass PCB and Operational Description

The information contained within this document applies to FCC Compliance and Certification as necessary to operate in the United States. Documentation is specifically applied to rules designated for unlicensed operation using the FCC Parts 15.247 and other applicable chapters as needed.

I. General:

This spread spectrum transmitter, hereafter know as the SSTX-915, was developed to assist certain industrial and commercial industries with a true digital radio transmission source that could deliver critical command and status information in truly difficult communication conditions. Primarily it will see service in the remote control and life safety fields as a critical carrier of emergency messages intended to provide increased safety to personnel operating in hazardous conditions.

A. Specifications:

Transmitter type:	Spread Spectrum Frequency Hopping
Frequency:	902-928 MHz
Modulation:	Amplitude Shift Keyed, or On/Off Keyed
RF Power:	.3 Watt Typical (25dBm) into 50 Ohms
Antenna:	Single Matching Whip Style
Control Mechanism:	Microprocessor Based using compiled C or Machine Code
Temperature:	-30 Deg C. to +70 Deg C
Size:	1.25in X 2.10in X 3.25in
Government Regulations:	FCC Part 15.247 for Unlicensed operation

II. Theory of operation:

For ease of discussion the SSTX915 will be handled in three main sections, these are; power supply and support circuitry, microprocessor, and the RF section.

A. Power Supply and Support:

Two main voltage regulators are used to provide controlled accuracy of radio transmit power and voltage. The first is a low current 3.0 volt cmos type regulator that supplies power to the Atmel processor and also acts as the reference for maximum ramp voltage to the RF oscillator.

The second voltage control mechanism is derived by placing a varactor reference to the base of an NPN power transistor. This has the effect of smooth, low ripple voltage as well as isolation of the power source from transients that may be seen from heavy conduction conditions.
This supply is RFI and EMI protected from the Radio Transmit sectio by the use of ferrite beads that will effectively block any frequencies over several megahertz.

B. Microprocessor:

The microprocessor chosen for this application is the Atmel 90S2313 in a surface mount package. Several iterations of software have shown this processor superior in its software support, low current modes, and also its ease of programming via an accessable programming port.

A 3.0 Volt regulated source is used to power this device and it is normally left in a sleep state to conserve battery power. This device will be turned on into an active mode, or awoken, when certain critical states of it input connections are met. At that time a 4 Mhz ceramic resonator will act as its frequency control source to ensure accurate timing and control of the Radio Section.

C. RF Section:

Radio Frequency signal generation and transmission are developed in this section. The entire process in unique in its design and operation. In order to simplify explanation an overview will be given, and more details for operation will be noted in the Tranmitter sequence of events section.

The desired RF Signal frequency is generated by an UHF transistor and dielectric resonator Designed as a tuned oscillator, a varactor is setup in the circuit to tune the frequency via a control voltage from an RC network controlled by the processor using timed delay loops to charge and discharge the capacitor. (Ref. Schematic)

Once the initial signal is completely set to frequency the RF is sent along to an isolation transistor amplifier. The output of this circuit is sent to the RF Amplifier. This Amplifier is the RFMD 2104 High Gain RF ciciut. Power output is controlled by sourcing the RFMD 2104 with a power control voltage that is generated by a simple resistive divider network.

This carrier is modulated with an AM On-Off Keyed code that resembles pulse code modulation. Modulation is accomplished by controlling the Power control voltage to the RF oscillator and the RF Amplifier. This accomplishes very clean AM signature and allows a simple RF detector to reproduce the digital code.

Frequency hopping is completed by changing the refernce or frequency control voltage for each message that is sent. Using a random table of 255 stored values oscillator section is hopped to a new carrier frequency for every tranmission.

Also due the open loop nature of the oscillator desing, such changes as temperature, battery voltage and stray antenna effects all affect output freqeuncy. The design has been very carefully tested to ensure that even at extremes of temperature and voltage, it will still stay within the specified frequency range of 902-928 MHz.

D. Transmitter sequence of events for operation:

Radio Signal generation occurs after some event wakes up the on board processor. The processor in turn will operate the RF Section via the following scheme:

1. Processor senses change in status pin. Awakens and turns on it oscillator, checks for additional status command changes.

2. Power control voltage is keyed thru Q7, this turns on Zener D1. This reference will control the voltage supplied to the RF Oscillator and RF Amplifier.

3. Frequency Set point is determined by the processor, which in turn applies a charge then discharge cycle to capacitor C23. This is between 0 and 3 volts.

4. Pulse code data is fed into transistor Q4, this allows Q3 to source the RF oscillator and RF amplifier.

5. When data message is completed, all ports are turned off and transmitter goes back to sleep.

6. Depending on the urgency of the message to be sent, the tranmsmitter can send as many as 12 round of a complete message. In normal mode only a round of two message will be sent every thirty seconds.

III. Attatchments:

A. Block Diagram of Tranmitter
B. Schematic of Transmitter:
C. Parts Layout
D. Bill of Material
E Schematic of Pass PCB and Short Excerpt of its functions.

1.0 Introduction

This report has been prepared on behalf of Grace Industries, Inc., to support the attached Application for Certification of a Part 15 Spread Spectrum Transmitter. The Equipment Under Test was the **Model TPASS High Power Transmitter.**

Radio-Noise Emissions tests were performed according to ***FCC Public Notice 54797, titled "Guidance on Measurements for Direct Sequence SST".*** The measuring equipment conforms to ANSI C63.2 Specifications for Electromagnetic Noise and Field Strength Instrumentation.

Testing was performed at National Certification Laboratory in Ellicott City, MD. Site description and site attenuation data have been placed on file with the FCC's Sampling and Measurements Branch. FCC acceptance was granted on May 26, 1993.

1.1 Summary

The Grace Industries, Inc. **Model TPASS High Power Transmitter** complies with the FCC limits (15.247) for a Frequency Hopping SST.

2.0 Description of Equipment Under Test (EUT)

The EUT Features:

Unique Screw Antenna Connector per 15.203

+ 25 dBm RF Output Max.

902 - 928 MHz Freq. Range

130 kHz 20 dB Emission Bandwidth

Greater than 50 Hopping Channels

150 Khz Channel Separation

AM Modulated Hopping Channel

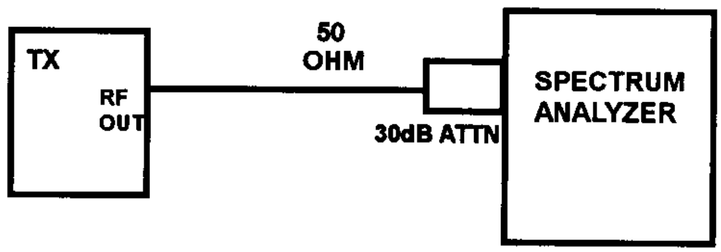
3.0 Test Program

This report contains measurement charts and data as evidence for the following tests performed:

1. (15.247 b) Peak RF output power.
2. (15.247 c) Field strength of harmonics and spurious out-of-band emissions.
3. (15.247 c) RF Antenna Conducted of harmonics and spurious out-of-band emissions.
4. (15.247 a) 20 dB Emission Bandwidth.
5. (15.207) Power Line Conducted Emissions.
6. (15.247 (a)1i) Average Time Occupancy.

4.0 Test Configuration

RF antenna conducted output tests such as Bandwidth, Spurious/Harmonics, and Power output, were taken with the transmitter antenna connector feeding directly into the spectrum analyzer via external 30 dB attenuator. The analyzer's internal attenuator was adusted to prevent overloading of the front end.



PEAK POWER TEST RESULTS

Limit: 1.0 watts (30 dBm)

Condition: Transmitter is set to a single AM modulated channel

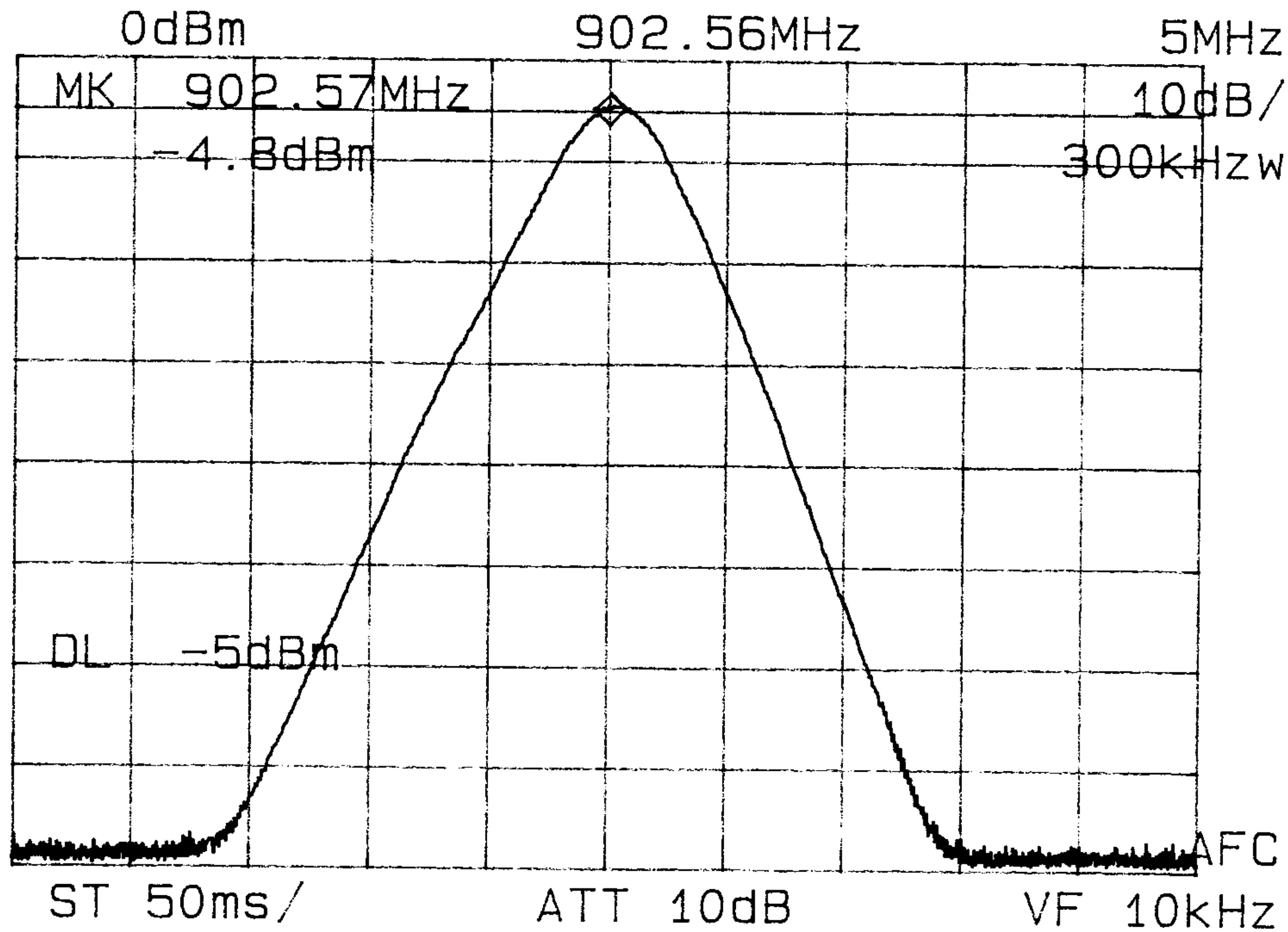
Readings from spectrum analyzer with 300 KHz Resolution BW setting:

Channel Low	**902.56 MHz**	**-**	**+25.2 dBm**
Channel Mid	**915.54 MHz**	**-**	**+25.4 dBm**
Channel High	**927.36 MHz**	**-**	**+24.8 dBm**

SEE FOLLOWING 3 PLOTS OF MODULATED CARRIER

PEAK RF POWER OUTPUT - LOW CHANNEL

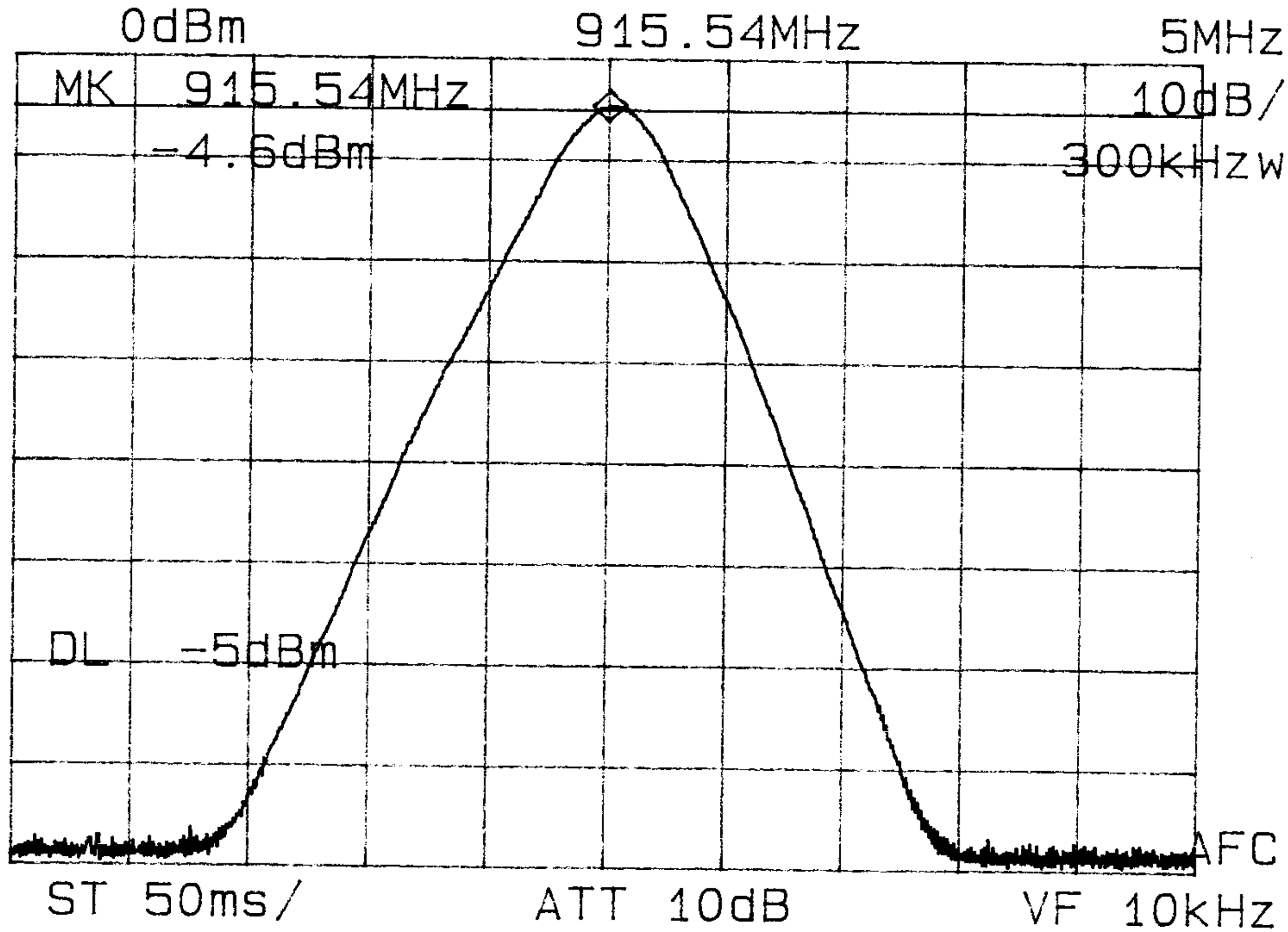
MODULATED **5.0 MHZ SPAN** **300 KHZ RES BW**



NOTE: 30 dB EXT. ATTN.

PEAK RF POWER OUTPUT - MID CHANNEL

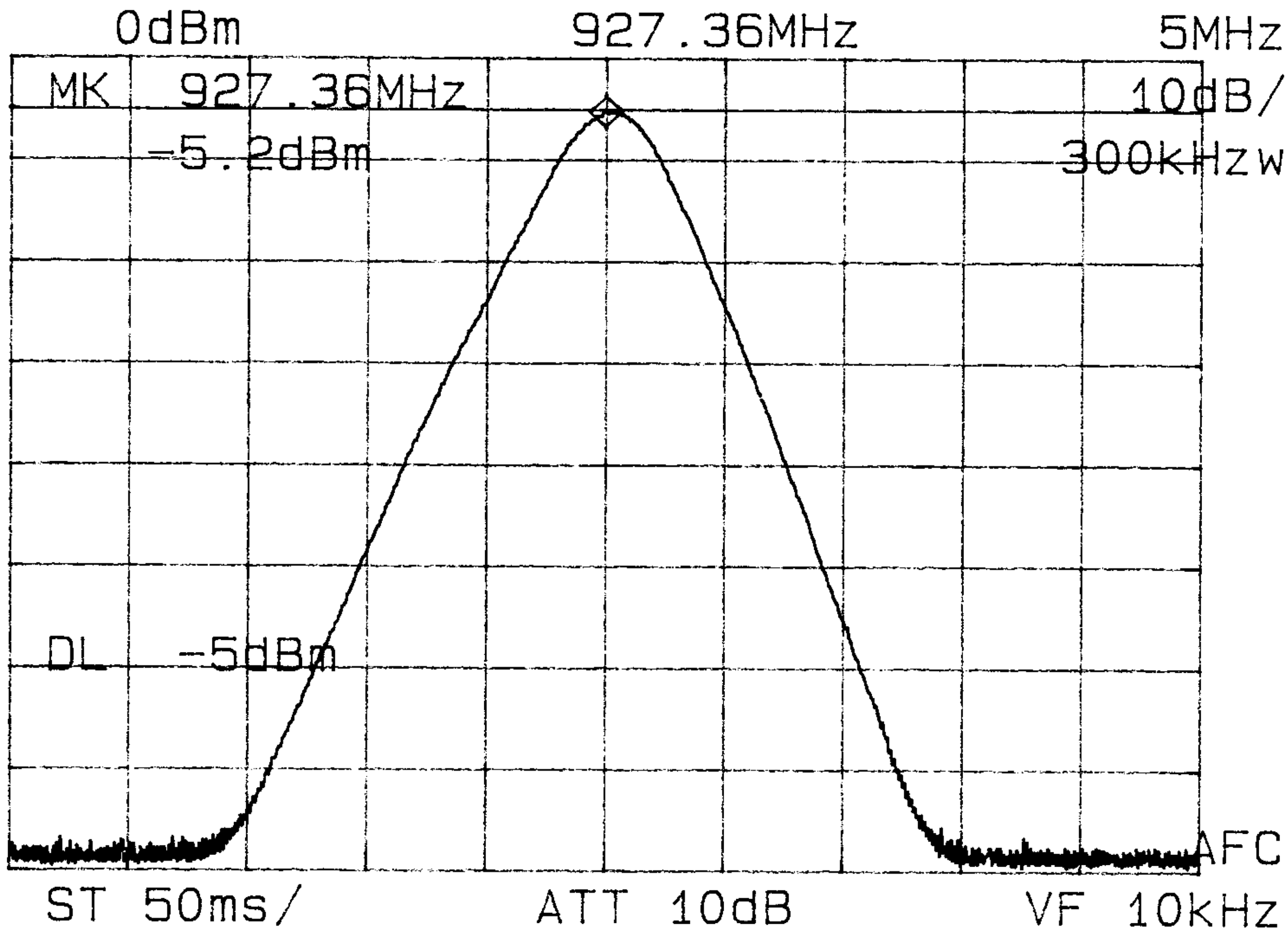
MODULATED **5.0 MHZ SPAN** **300 KHZ RES BW**



NOTE: 30 dB EXT. ATTN.

PEAK RF POWER OUTPUT - HIGH CHANNEL

MODULATED **5.0 MHZ SPAN** **300 KHZ RES BW**



NOTE: 30 dB EXT. ATTN.

20 dB EMISSION BANDWIDTH

Maximum 20 dB BW: 0.500 MHz
RBW Setting on S.A.: 3 kHz

Condition: Transmitter is set to a single AM modulated channel

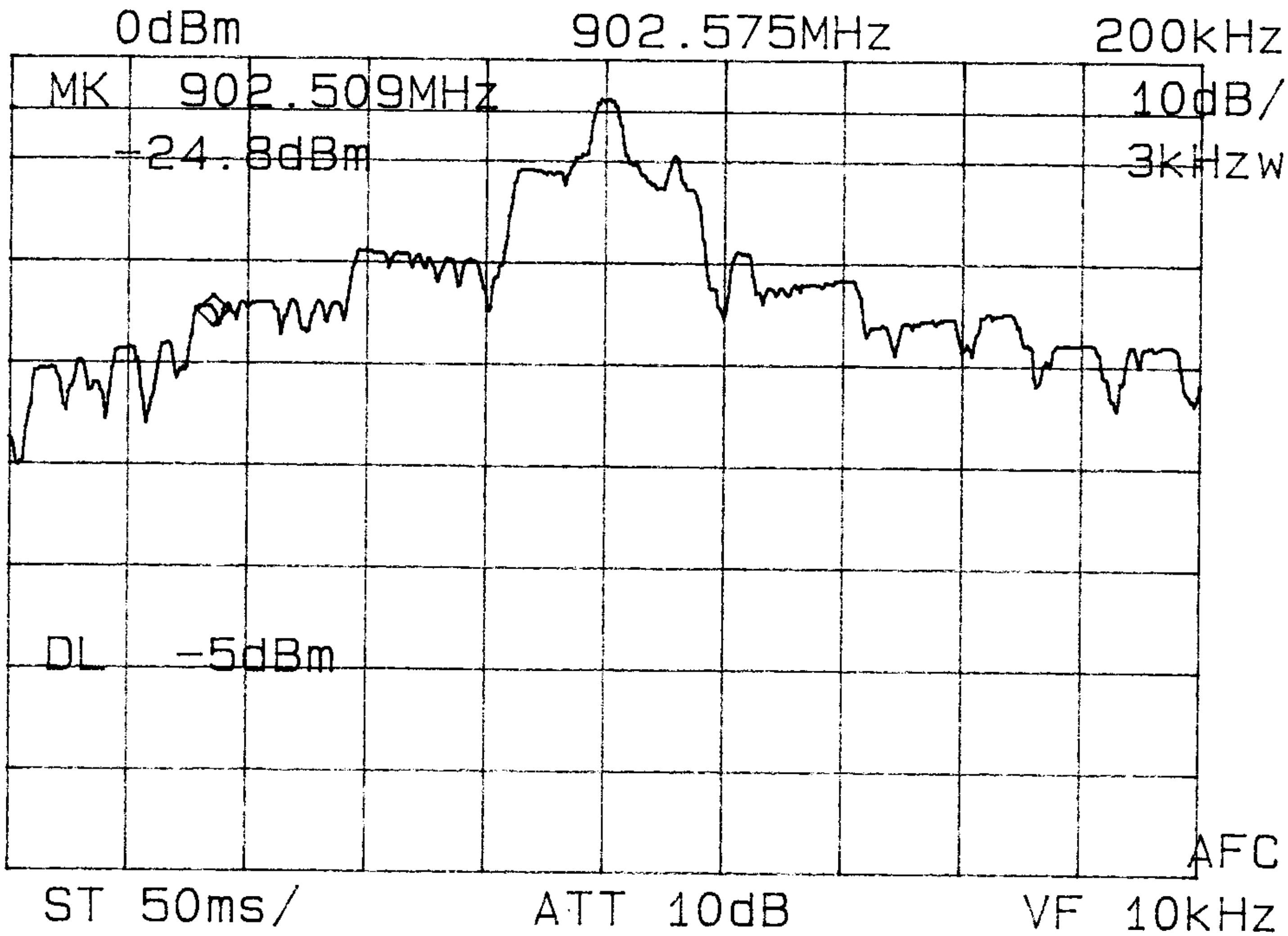
Readings from spectrum analyzer:

Channel Low	**902.57 MHz**	**-**	**132 kHz**
Channel Mid	**915.54 MHz**	**-**	**116 kHz**
Channel High	**927.37 MHz**	**-**	**136 kHz**

SEE FOLLOWING PLOT 3 PLOTS OF MODULATED CARRIER

20 dB BANDWIDTH MEASUREMENT - LOW CHANNEL

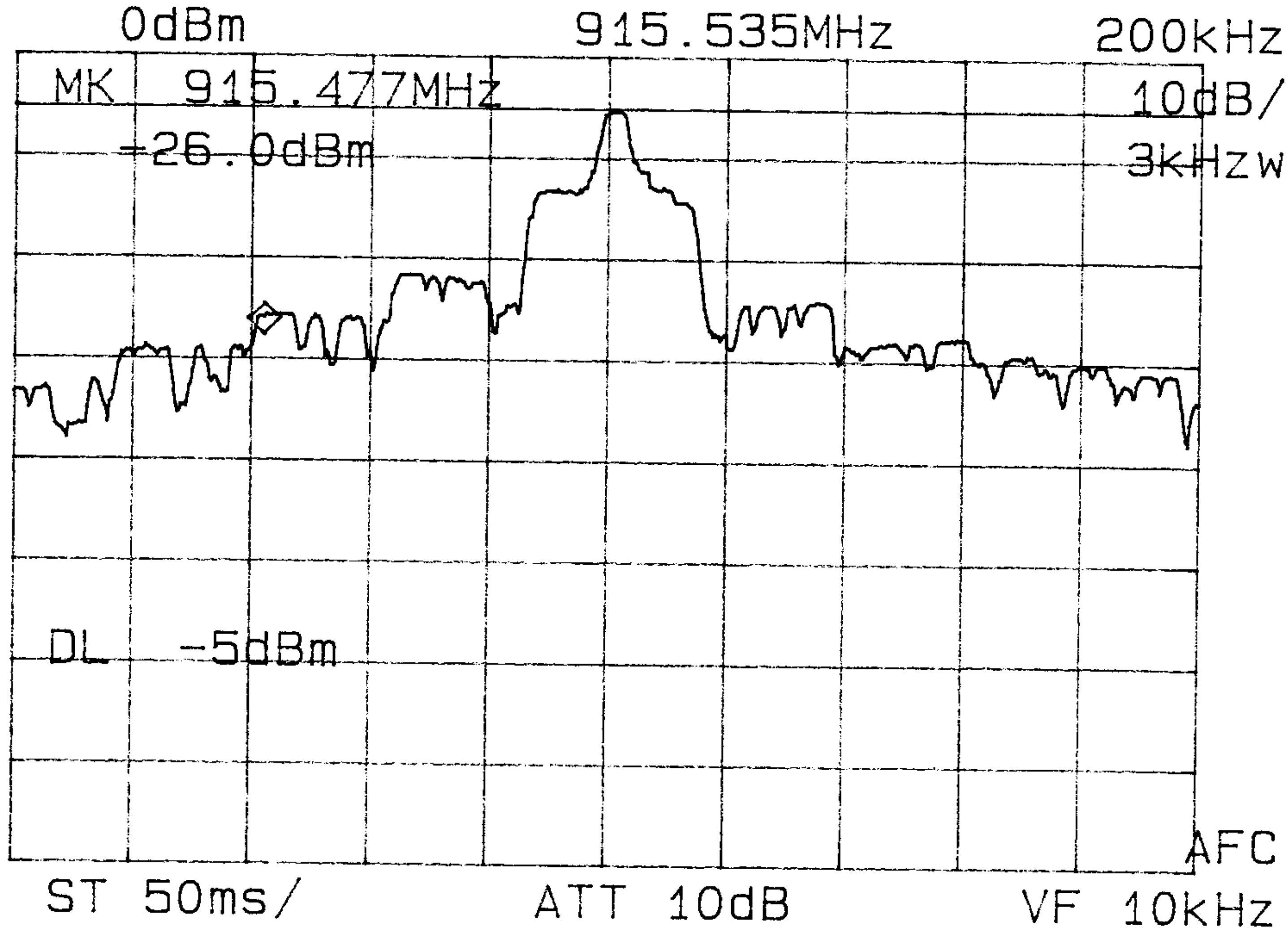
MODULATED **200 KHZ SPAN** **3 KHZ RES. BW**



NOTE: 30 dB EXT. ATTN.

20 dB BANDWIDTH MEASUREMENT - MID CHANNEL

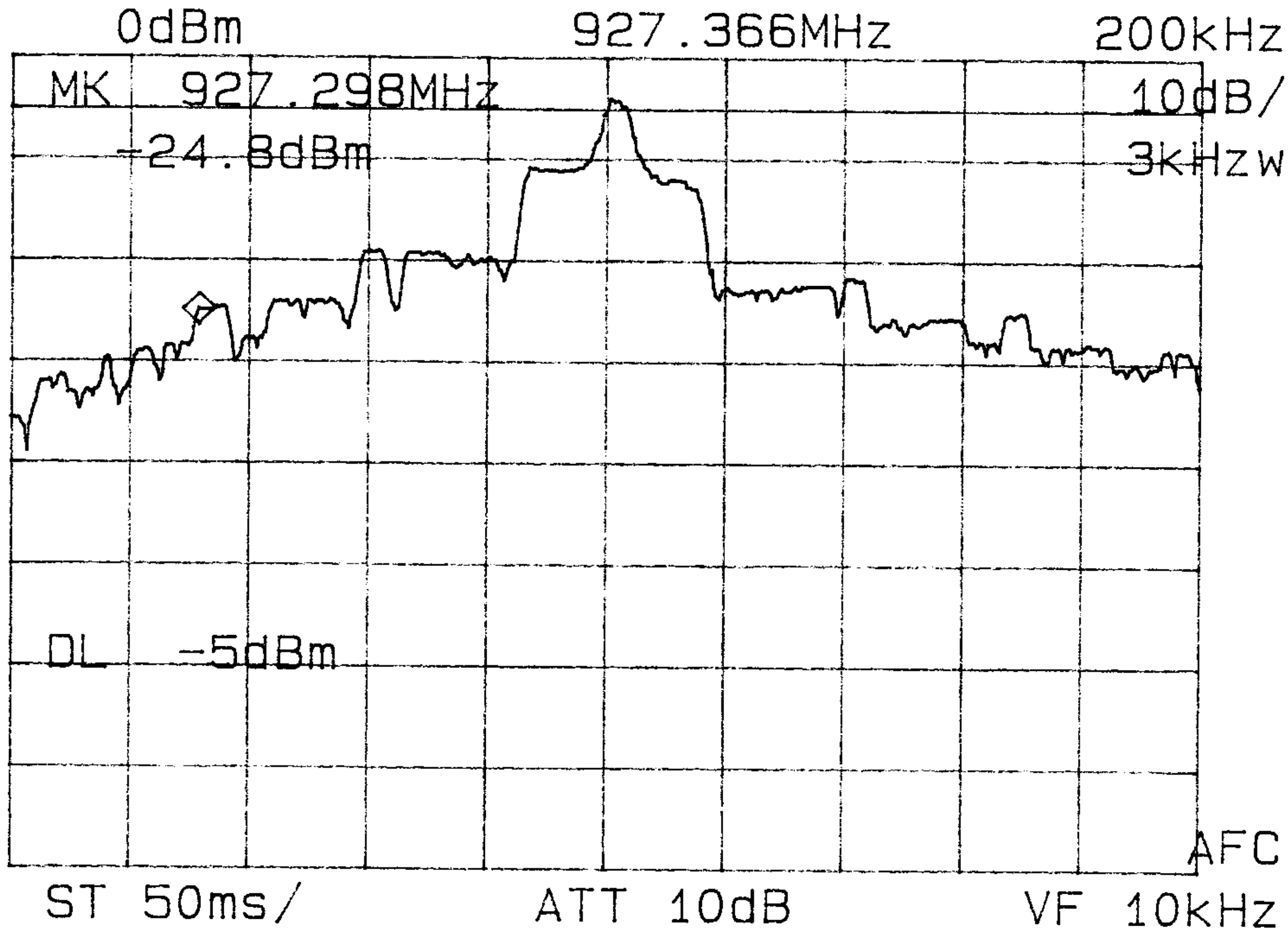
MODULATED **200 KHZ SPAN** **3 KHZ RES. BW**



NOTE: 30 dB
EXT. ATTN.

20 dB BANDWIDTH MEASUREMENT - HIGH CHANNEL

MODULATED **200 KHZ SPAN** **3 KHZ RES. BW**



NOTE: 30 dB EXT. ATTN.

RF ANTENNA CONDUCTED SPURIOUS/HARMONICS EMISSIONS

Limit: 20 dB below Carrier Level Measured with 100 kHz RBW
RBW Setting on S.A.: 100 kHz

Condition: Transmitter is set to a single AM modulated channel.
RF power = 25 dBm

Three separate Measurements are performed to show harmonic and spurious emissions generated with the transmitter tuned to low, middle, and high parts of the spectral range.

SEE FOLLOWING 3 PLOTS & DATA TABLES

FCC PART 15.247(c) - CONDUCTED SPURIOUS EMISSIONS

Frequency of Carrier = 902.5 MHz
Limit = 20 dBc

Condition: Transmitter is set to a single AM modulated channel.

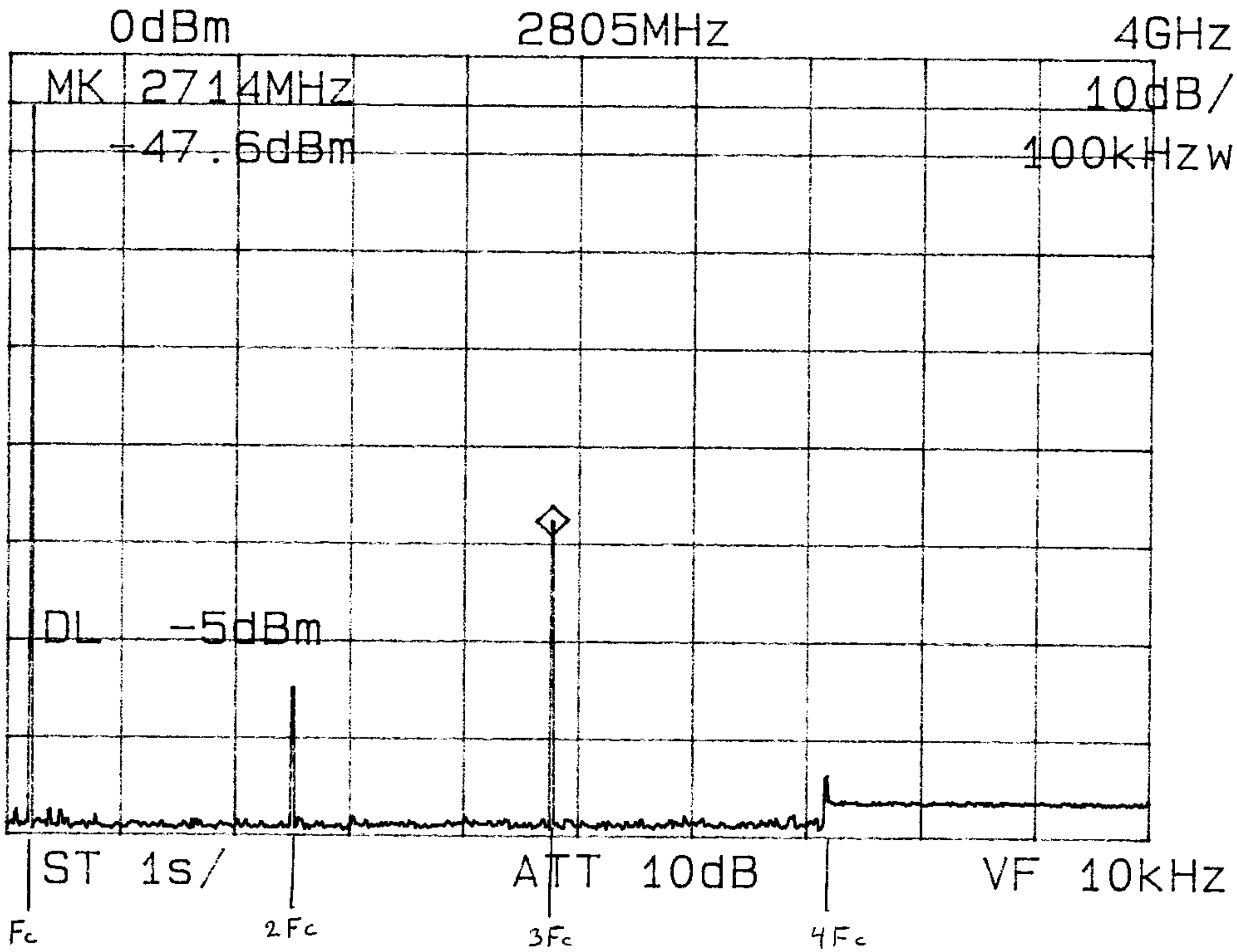
TEST RESULTS

LIMIT: -20 dB FROM PEAK CARRIER

COMPONENT	FREQUENCY (MHZ)	RESULT (dB FROM PEAK)
HARMONIC	1805.00	- 60.0
HARMONIC	2707.50	- 43.0
HARMONIC	3610.00	- 69.0
HARMONIC	4512.50	- 73.0
HARMONIC	5415.00	- 74.0
HARMONIC	6317.50	- 74.0
HARMONIC	7220.00	- 72.0
HARMONIC	8122.50	- 73.0
HARMONIC	9025.00	- 74.0

ANTENNA TERMINAL CONDUCTED SPURIOUS/HARMONICS EMISSIONS - LOW CHANNEL

MODULATED **4.0 GHZ SPAN** **100 KHZ RES. BW**



NOTE: 30 dB EXT. ATTN.

FCC PART 15.247(c) - CONDUCTED SPURIOUS EMISSIONS

Frequency of Carrier = 915.5 MHz
Limit = 20 dBc

Condition: Transmitter is set to a single AM modulated channel.

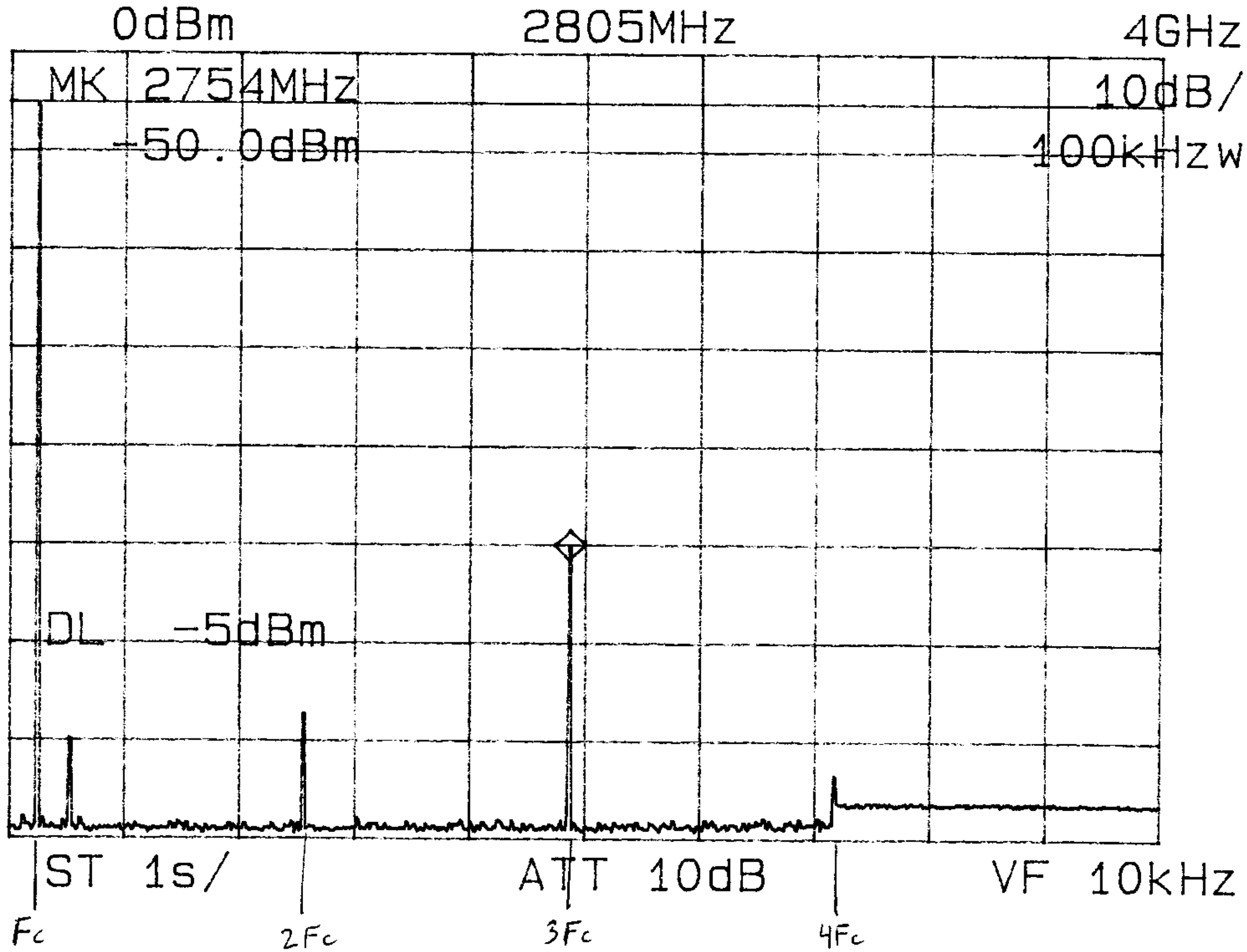
TEST RESULTS

LIMIT: -20 dB FROM PEAK CARRIER

COMPONENT	FREQUENCY (MHZ)	RESULT (dB FROM PEAK)
HARMONIC	1831.00	- 62.0
HARMONIC	2746.50	- 45.0
HARMONIC	3662.00	- 69.0
HARMONIC	4577.50	- 71.0
HARMONIC	5493.00	- 72.0
HARMONIC	6408.50	- 74.0
HARMONIC	7324.00	- 71.0
HARMONIC	8239.50	- 73.0
HARMONIC	9155.00	- 74.0

ANTENNA TERMINAL CONDUCTED SPURIOUS/HARMONICS EMISSIONS - MID CHANNEL

MODULATED **4.0 GHZ SPAN** **100 KHZ RES. BW**



NOTE: 30 dB EXT. ATTN.

FCC PART 15.247(c) - CONDUCTED SPURIOUS EMISSIONS

Frequency of Carrier = 927.4 MHz
Limit = 20 dBc

Condition: Transmitter is set to a single AM modulated channel.

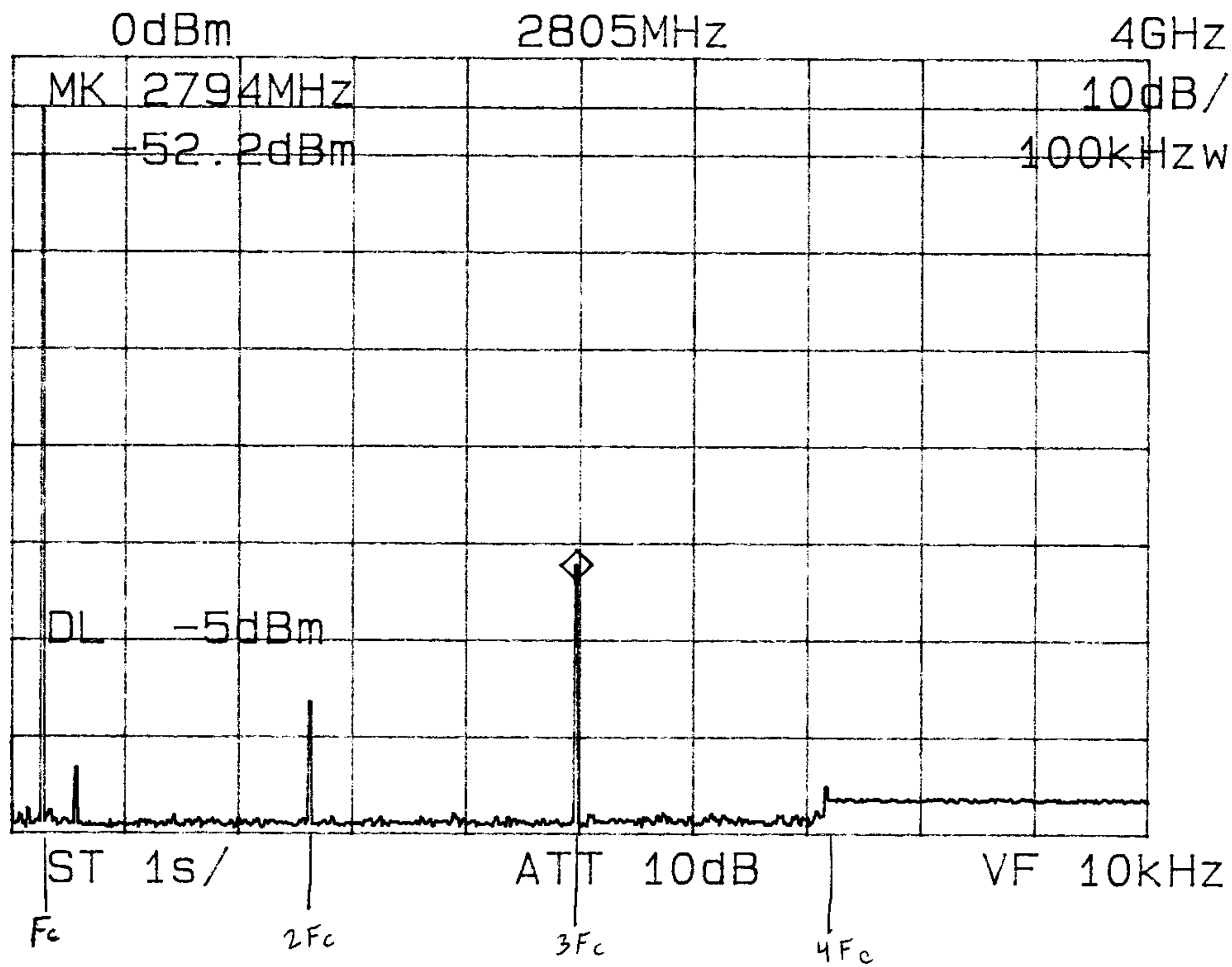
TEST RESULTS

LIMIT: -20 dB FROM PEAK CARRIER

COMPONENT	FREQUENCY (MHZ)	RESULT (dB FROM PEAK)
HARMONIC	1854.80	- 61.0
HARMONIC	2782.20	- 47.0
HARMONIC	3709.60	- 70.0
HARMONIC	4637.00	- 73.0
HARMONIC	5564.40	- 71.0
HARMONIC	6491.80	- 74.0
HARMONIC	7419.20	- 74.0
HARMONIC	8346.60	- 71.0
HARMONIC	9274.00	- 73.0

ANTENNA TERMINAL CONDUCTED SPURIOUS/HARMONICS EMISSIONS - HIGH CHANNEL

MODULATED **4.0 GHZ SPAN** **100 KHZ RES. BW**



NOTE: 30 dB EXT. ATTN.

AVERAGE CHANNEL TIME OCCUPANCY

Limit: 0.4 Seconds/20 Seconds Period
RBW Setting on S.A.: 10 kHz

Condition: Transmitter is in frequency hopping mode.

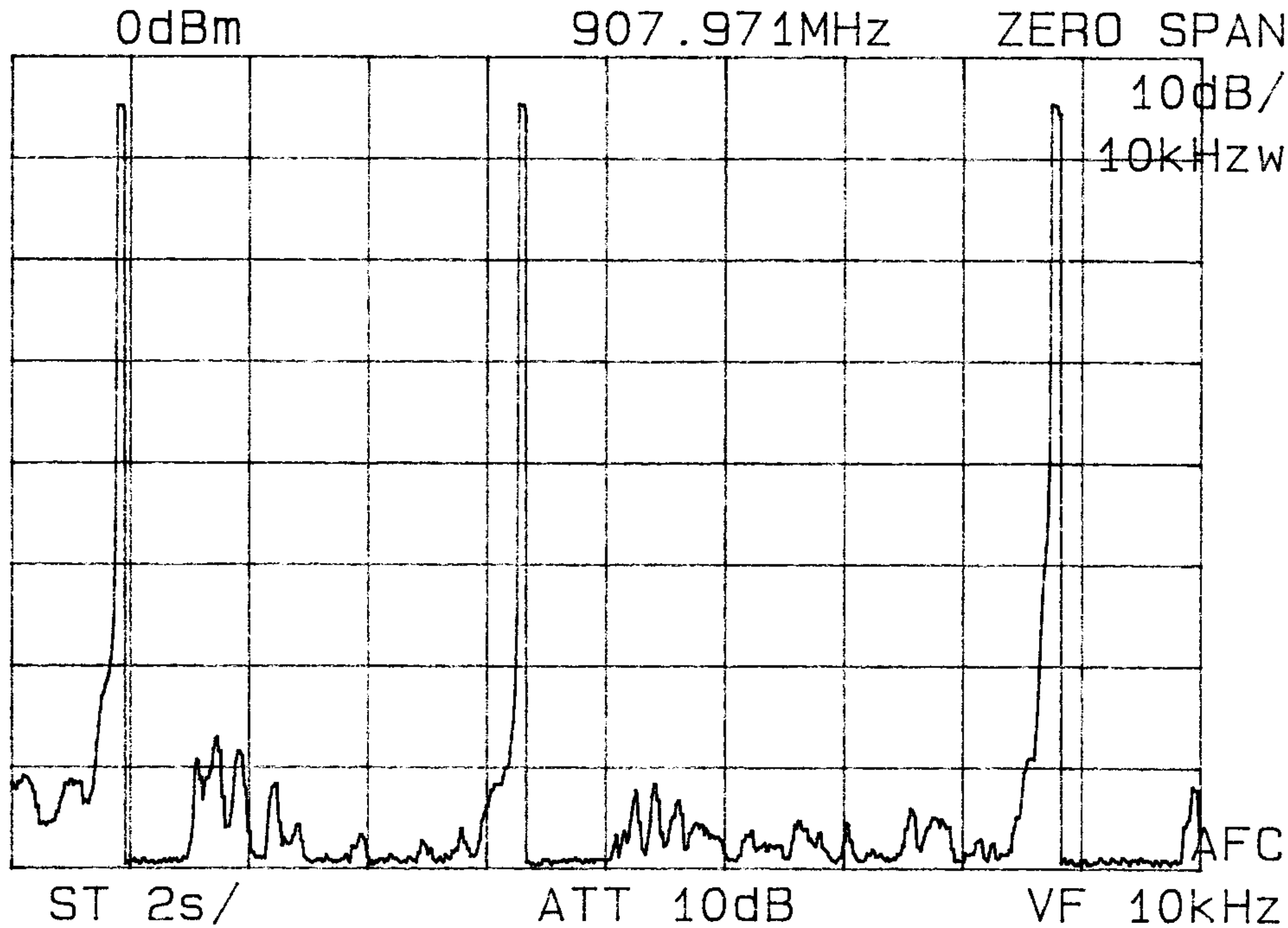
Spectrum Analyzer is set to Zero Span and tuned to a random channel at 907.97 MHz. A 20 second scan is stored which shows the total occupation time of this channel over a 20 second transmission period.

Readings from Spectrum Analyzer:

Three transmissions recorded over 20 sec. Each emission occupies 65 msec. Total channel occupancy = .195 seconds

AVERAGE TIME OCCUPANCY PER CHANNEL

MODULATED **ZERO SPAN** **10 KHZ RES. BW**



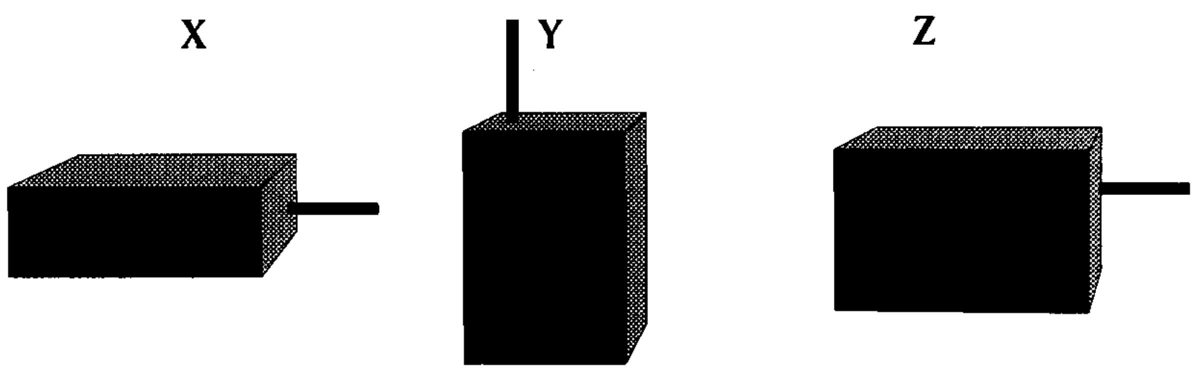
NOTE: 30 dB EXT. ATTN.

4.0 Test Configuration

RADIATED EMISSIONS

The EUT was setup on the test table in a manner which follows the general guidelines of ANSI C63.4, Section 6 **"General Operating Conditions and Configurations"**. One of the keying buttons was bound to the "on" position during testing.

The EUT was configured in 3 orthogonal positions to determine the maximum RF level at each emission frequency. The data tables give the EUT postion designation that produces worst-case field strength, in an X, Y, Z system. This is described below:



5.0 Conducted Emissions Scheme

The EUT is placed on an 80 cm high 1 X 1.5 m non-conductive table. Power to the RF modem is provided through a Solar Corporation 50 Ω/50 μH Line Impedance Stabilization Network bonded to a 2.2 X 2 meter horizontal ground plane, and a 2.2 X 2 meter vertical ground plane. The LISN has its AC input supplied from a filtered AC power source. A separate LISN provides AC power to the peripheral equipment. I/O cables are moved about to obtain maximum emissions.

The 50 Ω output of the LISN is connected to the input of the spectrum analyzer and emissions in the frequency range of 450 kHz to 30 MHz are searched. The detector function is set to quasi- peak and the resolution bandwidth is set at 9 kHz, with all post-detector filtering no less than 10 times the resolution bandwidth for final measurements. All emissions within 20 dB of the limit are recorded in the data tables.

6.0 Radiated Emissions Scheme

The EUT is placed on an 80 cm high 1 X 1.5 meter non-conductive motorized turntable for radiated testing on the 3-meter open area test site. The emissions from the EUT are measured continuously at every azimuth by rotating the turntable. Guided horn and log periodic broadband antennas are mounted on an antenna mast to determine the height of maximum emissions. The height of the antenna is varied between 1 and 4 meters. Both the horizontal and vertical field components are measured.

The RF spectrum is searched from 30 MHz - 9.280 GHz.

The output from the antenna is connected to the input of the preamplifier. The preamp out is connected to the spectrum analyzer. The detector function is set to **Peak**. The resolution bandwidth of the spectrum analyzer is set at 120 kHz, for the frequency range of 30-1000 MHZ, and 1 MHz for the range of 1 GHz-9 GHz. A 10 Hz video BW setting is used to average readings above 1 GHz. All emissions within 20 dB of the limit are recorded in the data tables.

To convert the spectrum analyzer reading into a quantified E-field level to allow comparison with the FCC limits, it is necessary to account for various calibration factors. These factors include cable loss (CL) and antenna factors (AF). The AF/CL in dB/m is algebraically added to the Spectrum Analyzer Voltage in dbμV to obtain the Radiated Electric Field in dBμV/m. This level is then compared with the FCC limit.

Example:

Spectrum Analyzer Volt: VdBuV

Composite Factor: AF/CLdB/m

Electric Field: EdBμV/m = VdBμV + AF/CLdB/m
Linear Conversion: EuV/m = Antilog (EdBμV/m/20)

FCC 15.209 RADIATED EMISSIONS DATA

FCC ID: J5XTPASSTX

CLIENT: GRACE
EUT: TPASS SST

CARRIER: 902.5 MHZ

FREQ MHz	POL H/V	AVRG SPEC A dBuV	AF/C dB/m	PREAMP GAIN	E-FIELD dBuV/m	AVRG E-FIELD uV/m	AVRG LIMIT uV/m	MRG dB
2707.50	V	39.0	35.0	-25	49.0	281.8	500.0	-5.0
3610.00	H	34.0	36.0	-25	45.0	177.8	500.0	-9.0
4512.50	H	30.0	39.0	-25	44.0	158.5	500.0	-10.0
5415.00	H	30.0	37.0	-25	42.0	125.9	500.0	-12.0
8122.50	V	25.0	38.0	-25	38.0	79.4	500.0	-16.0
9025.00	H	24.0	39.0	-25	38.0	79.4	500.0	-16.0

TEST ENGINEER

S.D DATE 12/2/95

STEVE DAYHOFF

FCC 15.209 RADIATED EMISSIONS DATA

FCC ID: J5XTPASSTX

CLIENT: GRACE
EUT: TPASS SST

CARRIER: 902.5 MHZ

FREQ MHz	POL H/V	PEAK SPEC A dBuV	AF/C dB/m	PREAMP GAIN	E-FIELD dBuV/m	PEAK E-FIELD uV/m	AVRG LIMIT uV/m	MRG dB
2707.50	V	41.0	35.0	-25	51.0	354.8	500.0	-3.0
3610.00	H	36.0	36.0	-25	47.0	223.9	500.0	-7.0
4512.50	H	32.0	39.0	-25	46.0	199.5	500.0	-8.0
5415.00	H	32.0	37.0	-25	44.0	158.5	500.0	-10.0
8122.50	V	27.0	38.0	-25	40.0	100.0	500.0	-14.0
9025.00	H	26.0	39.0	-25	40.0	100.0	500.0	-14.0

TEST ENGINEER

________________ DATE 12/2/95
STEVE DAYHOFF

FCC 15.209 RADIATED EMISSIONS DATA

FCC ID: J5XTPASSTX

CLIENT: GRACE
EUT: TPASS SST

CARRIER: 915.5 MHZ

FREQ MHz	POL H/V	AVRG SPEC A dBuV	AF/C dB/m	PREAMP GAIN	E-FIELD dBuV/m	AVRG E-FIELD uV/m	AVRG LIMIT uV/m	MRG dB
2746.50	V	39.0	35.0	-25	49.0	281.8	500.0	-5.0
3662.00	H	34.0	36.0	-25	45.0	177.8	500.0	-9.0
4577.50	H	32.0	39.0	-25	46.0	199.5	500.0	-8.0
7324.00	H	30.0	37.0	-25	42.0	125.9	500.0	-12.0
8239.50	V	30.0	38.0	-25	43.0	141.3	500.0	-11.0
9155.00	H	27.0	39.0	-25	41.0	112.2	500.0	-13.0

TEST ENGINEER

SD DATE 12/2/95

STEVE DAYHOFF

FCC 15.209 RADIATED EMISSIONS DATA

FCC ID: J5XTPASSTX

CLIENT: GRACE
EUT: TPASS SST

CARRIER: 915.5 MHZ

		PEAK				PEAK	AVRG	
FREQ MHz	POL H/V	SPEC A dBuV	AF/C dB/m	PREAMP GAIN	E-FIELD dBuV/m	E-FIELD uV/m	LIMIT uV/m	MRG dB
2746.50	V	40.0	35.0	-25	50.0	316.2	500.0	-4.0
3662.00	H	36.0	36.0	-25	47.0	223.9	500.0	-7.0
4577.50	H	33.0	39.0	-25	47.0	223.9	500.0	-7.0
7324.00	H	32.0	37.0	-25	44.0	158.5	500.0	-10.0
8239.50	V	32.0	38.0	-25	45.0	177.8	500.0	-9.0
9155.00	H	29.0	39.0	-25	43.0	141.3	500.0	-11.0

TEST ENGINEER

SD DATE 12/2/95
STEVE DAYHOFF

FCC 15.209 RADIATED EMISSIONS DATA

FCC ID: J5XTPASSTX

CLIENT: GRACE
EUT: TPASS SST

CARRIER: 927.4 MHZ

FREQ MHz	POL H/V	AVRG SPEC A dBuV	AF/C dB/m	PREAM GAIN	E-FIELD dBuV/m	AVRG E-FIELD uV/m	AVRG LIMIT uV/m	MRG dB
2782.20	V	40.0	35.0	-25	50.0	316.2	500.0	-4.0
3709.60	H	35.0	36.0	-25	46.0	199.5	500.0	-8.0
4637.00	H	28.0	39.0	-25	42.0	125.9	500.0	-12.0
7419.20	H	33.0	37.0	-25	45.0	177.8	500.0	-9.0
8346.60	V	27.0	38.0	-25	40.0	100.0	500.0	-14.0

TEST ENGINEER

SD DATE 11/2/92
STEVE DAYHOFF

FCC 15.209 RADIATED EMISSIONS DATA

FCC ID: J5XTPASSTX

CLIENT: GRACE
EUT: TPASS SST

CARRIER: 927.4 MHZ

FREQ MHz	POL H/V	PEAK SPEC A dBuV	AF/C dB/m	PREAM GAIN	E-FIELD dBuV/m	PEAK E-FIELD uV/m	AVRG LIMIT uV/m	MRG dB
2782.20	V	41.0	35.0	-25	51.0	354.8	500.0	-3.0
3709.60	H	37.0	36.0	-25	48.0	251.2	500.0	-6.0
4637.00	H	30.0	39.0	-25	44.0	158.5	500.0	-10.0
7419.20	H	35.0	37.0	-25	47.0	223.9	500.0	-7.0
8346.60	V	28.0	38.0	-25	41.0	112.2	500.0	-13.0

TEST ENGINEER

S.D. DATE 12/2/95

STEVE DAYHOFF

Table 1

Measurement Equipment Used

The following equipment is used to perform measurements:

HP 435A RF Peak Power Meter	- Serial No. 1362016
EMCO Model 3110 Biconical Antenna	- Serial No. 1619
Antenna Research MWH-1825B Horn Antenna	- Serial No. 1005
EMCO Model 3115 Ridged Horn Antenna	- Serial No. 3007
HP 8348A Preamplifier	- Serial No. 197-2564A
Solar 8012-50-R-24-BNC LISN	- Serial No. 924867
Bird 8306-300-N 30dB Attenuator	- S/N: 29198391515
Tektronix R3272 Spectrum Analyzer	- Serial No. 6-95-1124
4 Meter Antenna Mast	
Motorized Turntable	
Heliax FSJ1-50A 1/4" Superflex Coax Cable (12 Ft.)	