TECHNIAL DESCRIPTION

DUAL TRANSMITTER SECTION OF THE CONCENTRATOR

7. Dual Transmitter 910-924 MHz Board

7.1 PURPOSE OF TRANSMITTER

The Dual Transmitter is an integral part of the Concentrator Assembly. It provides the transmitted 902-928 MHz RF carrier(s) for repeating ERT transmitted signals. Depending on the field application these signals can be repeated ERT to Cell Control Unit (CCU), Handheld Computer to Mobile DataCommand Unit, ERT to Concentrator, or Concentrator to Concentrator messages.

7.2 GOVERNMENTAL APPROVALS

FCC	15.249

7.3 PHYSICAL DESCRIPTION

The Transmitter Printed Circuit Board (PCB) is 7.0" by 4.75" by 0.062", four layers, fabricated from FR-4 glass epoxy with 1.0-ounce copper. Essentially all fixed value capacitors and resistors are 0805 surface mount. Only the interface connectors and manufacturing alignment and calibration test points use through hole technology.

7.4 FUNCTIONAL DESCRIPTION

The Transmitter is comprised of two voltage controlled (tuned) oscillators (VCO). The VCO outputs are summed together then level controlled by two independent digitally controlled fixed attenuators. A high gain power amplifier amplifies the RF signal to the desired output level. This signal is applied to the antenna output connector via a RF PIN diode switch. The second input to the RF switch is from a coaxial connector that interfaces to the 900 MHz Transceiver. The transceiver is a modified CCU assembly and an integral part of the Concentrator Assembly.

The Transmitter is comprised of five major sub-systems

1. Two independently voltage tuned 900 MHz oscillators, VCO
2. One digitally controlled PIN diode RF attenuator
3. RF power amplifier
4. Single pole, two position PIN diode RF transfer switch
5. Control circuit for supplying bias to an external PIN diode antenna switch

7.5 INPUT AND OUTPUTS

In the text of this document to indicate a digital "NOT" function a "~" is placed in front of the term or word.

CONN.	TITLE	DESCRIPTION
P1-1	GND	Power and signal return
P1-2	GND	Power and signal return
P1-3	TUNE1G	Signal return for Osc. 1 tuning voltage
P1-4	TUNE2G	Signal return for Osc. 2 tuning voltage
P1-5	TUNE1	Analog tuning voltage for Osc. 1
P1-6	TUNE2	Analog tuning voltage for Osc. 2
P1-7	~OSC1	Digital enable/disable control for Osc. 1
P1-8	~OSC2	Digital enable/disable control for Osc. 2
P1-9	ANT SW	Digital control for external antenna switch polarity
P1-10	SPARE	
P1-11	CCU/Tx	Digital control for PIN diode transfer switch
P1-12	ATT1	Digital control for RF attenuator 1
P1-13	~MOD	Digital RF pulse modulation.
P1-14	RFLVL	Test port for RF level control
P1-15	+18V	Positive 18 Vdc power
P1-16	-18V	Negative 18 Vdc power
P1-17	GND	Power and signal return
P1-18	GND	Power and signal return
P1-19	+6V	Positive 6 Vdc power
P1-20	+6V	Positive 6 Vdc power
J1	ANT	RF input and output to an external antenna
J2	CCU	RF input and output to 900 MHz RF assembly

7.6 ENVIRONMENTAL SPECIFICATIONS

7.6.1 TEMPERATURE

Operating	-30° to +70° centigrade
Storage	80° centigrade

7.6.2 RELATIVE HUMIDITY

Operating	95 % non-condensing
Storage	95 % non-condensing

7.6.3 MECHANICAL

Vibration	TBD
Shock	TBD

7.7 MECHANICAL SPECIFICATIONS

7.7.1 WEIGHT

Assembled	8 ounces maximum
Size	7.0" X 4.75" X 0.062", four layer PCB

7.7.2 CONTROLS

Manufacturing Accessible Controls For Calibration

Reference	Adjustment	Function
LC1	Laser Trim	Set OSC1 to specified low frequency
LC2	Laser Trim	Set OSC2 to specified low frequency
R17	Potentiometer	Set OSC1 to specified high frequency
R48	Potentiometer	Set OSC2 to specified high frequency
R6	Potentiometer	Set RF power amp to specified current

7.8 ELECTRICAL SPECIFICATIONS

Unless noted otherwise, specifications are envelope conditions for input power and environment.

PS is used to indicate voltage at that Test Point (TP) or connector on the Unit Under Test (UUT). NC is used to indicate no connection at that TP or connector. GND is used to indicate 0.0 Vdc at that TP or connector.

Should there be a conflict between this specification, excluding figures, and any other document or specification this specification shall supersede.

7.8.1 TECHNICAL DESCRIPTION

Reference *Dual Transmitter Schematic* and *Dual Transmitter Block Diagram* (attached) for the following technical description.

The assembled transmitter PCB is designed to allow manufacture testing of all engineering required specifications. Test signals are monitored at specified TPs and or connector pins.

The transmitter has one RF output operating on two independent frequencies. It can operate using one or both frequencies simultaneously with On-Off-Key (OOK) modulation. However, special software algorithms are incorporated to eliminate the possibility of transmitting both oscillators on the same frequencies. A PIN diode switched attenuator sets the RF output level. The attenuator is used to set the RF output level to meet particular FCC part certification requirements. The transmitter control functions are generated by the Concentrator Logic Control Board Assembly and applied through a 20-pin connector between the two PCB's.

7.8.2 GENERAL

The transmitter is comprised of nine functional bl

1. DC supply regulator and filters
2. RF Voltage Controlled Oscillator (VCO) 1
3. RF VCO 2
4. RF combiner and filter
5. RF attenuator and control circuit
6. RF power amplifier and matching circuits
7. RF power amplifier modulation circuit
8. Antenna transfer switch and control circuit
9. DC bias control circuit for driving an external PIN diode antenna RF switch

DC Supply Regulator and Filters.

The transmitter operates from three external voltages. They are 6 Vdc, 18 Vdc and -18 Vdc and are supplied by the Logic Control Board. The 18 Vdc supplies are used for biasing the PIN diode, attenuators, CCU/Tx and External Antenna Transfer switches. The 6 Vdc supply powers the RF power amplifier U4 through FET switch Q4. A "lock off" circuit is provided which prevents Q4 from applying power to the RF power amplifier U4 should the -18Vdc fail. Resistor R59 samples the input +6V, P1-19 & 20 and R60 samples the -18Vdc. When no -18Vdc is present R59 biases Q1 into conduction. In turn it forward biases Q6 into conduction. The MMUN2112 transistor has two internal resistors. These internal 22K resistors limit current and provide a base-to-emitter return path. In this state the current from opamp U3-B through R25, which would normally turn "on" FET switch Q4, passes through Q6. When the -18Vdc is present Q1 is reversed biased by the voltage developed at the junction of R59 and R60. In this normal operating state FET switch Q4 is forward biased applying DC power to RF power amplifier U4 through current stabilization resistors R25, R54 and microstrip US6 and US8.

The 6 Vdc is also regulated to 5 Vdc by voltage regulator U2. The 5 Vdc (V+) output is used to supply power for operation of both VCO's and the RF power amplifier modulator low-pass filter operational amplifier (opamp). Operation of these circuits is described in the following paragraphs.

Voltage Controlled Oscillator

There are two common base Colpitts VCO circuits. Because they are identical only one oscillator circuit will be described, other than to note the different control pins when applicable.

Operating bias for both VCO's Q3 and Q6 is generated by the current through R14, R49 and Q2. The voltage across R14 and Q2 base-to-emitter set the VCO bias voltage. Transistor Q2 is the same type PNP transistor as the VCO's. This is done to achieve bias stability over a wide operating temperature range thereby reducing frequency drift. Resistors R20 and R45 provide DC and RF isolation between the two VCO circuits. A N750 negative temperature coefficient capacitor C15, is used to couple Q3 to FL1. This compensates for the positive coefficient of the overall VCO circuit.

The VCO is disabled by removing the "V5" power applied through microstrip US1 and current limiting resistor R18 to Q3 emitter. Transistor Q5, MMUN2112 function as a "switch" in this application. With a logic "1" or "open" signal applied via P1-7, OSC1 (P1-8, OSC2) Q5 is biased off disabling the VCO. A logic "0" will enable the VCO. This equals a "not" logic function, i.e. "on" is logic low "0". The MMUN2112 transistor has two internal resistors. These resistors provide input current limiting and a base-to-emitter return path. The control signal is generated by Logic Control Board. VCO transistor Q3 collector DC return is via L1 and microstrip US2. Both US1 and US2 are electrically 90° long at the 900 MHz operating frequency thereby presenting a high impedance "open" to the RF signal. The microstrips are 180° long at the VCO second harmonic frequency. To these frequencies they represent a low impedance "short" thereby attenuating the harmonic signal level.

The Colpitts "tank" circuit is formed by C16, CR3 and LC1. Varactor diode CR3 is a voltage variable capacitor and ceramic resonator LC1 functions as an inductor. The series capacitors C16 and CR3 in parallel with inductor LC1 resonate at the 900 MHz operating frequency. A N750 negative temperature coefficient capacitor C15 couples the tank circuit to the Colpitts oscillator. Capacitors C12 and C14 set the RF feed back ratio. Blocking capacitor C25 RF connects CR3 to the case of LC1 while DC isolating it from the board ground. Resistor R57 provides a DC return "ground" path for Varactor diode CR3 when the PCB is not connected to the Logic Control Board. This is done to prevent static buildup during test and general handling of the board. When in operation the diode DC return is via P1-3, TUNE1G, (P1-4, TUNE2G). This is done to prevent stray currents from modulating the tuning voltage generated on the Logic Control Board. Frequency tuning is accomplished by applying a reverse tuning bias voltage to CR3. As the voltage increases the capacitance decreases thereby increasing the VCO frequency. This tuning voltage is generated by a DAC on the Logic Control Board and applied to CR3 via P1-5, TUNE1, (P1-6, TUNE2).

The VCO output impedance is matched to the 50Ω transmission line by inductor L1. A "π" attenuator (pad) formed by resistors R27, R31 and R32 is used to provide RF isolation between the oscillator output and load. The output signal is then filter by a 1,500 MHz, three section microstrip "π" low-pass filter. It is formed by two capacitors, microstrip US10 and US11 both 3 pF at 14° and one inductor, microstrip US5, 8 nHy at 28°. The values indicated on the schematic are the electrical lengths in degrees required to simulate the reactance value at the 900 MHz operating frequency.

VCO Frequency Alignment

During manufacturing test and alignment of the VCO, a specified bias voltage is applied at TP2 (TP6). Then inductor, ceramic resonator LC1, (LC2) is laser trimmed "tuned" for the specified low frequency of operation. Next the voltage is removed and a specified voltage is applied to P1-5, TUNE1 (P1-6, TUNE2). Then potentiometer R17 (R48) is adjusted "set" for the specified higher frequency of operation.

RF Combiner and Filter

The two VCO RF output signals are summed together using a RF Wilconsen combiner. It is formed by two 90° lengths of 75 ohm microstrip transmission line US16 and resistor R38. This circuit also provides 20dB reverse isolation between the two VCO outputs. Isolation is obtained by feeding a small amount of RF through R38 to the alternate input port. This is summed with the signal that passes through the both sections of microstrip US16. As this signal is delayed by 180° the signal through it and R38 are 180° out of phase. Therefore the signals subtract (cancel) each other to provide combiner input-to-input isolation. As used the 90°, 75 ohm transmission lines also provide impedance transformation "matching" such that the combiner input and output impedances are 50 ohms.

A shorted 180° microstrip US24 is used at the combiner output to attenuate "notch" the VCO second harmonic. Shorted transmission lines at 180° long present a low impedance "short" at the 180° frequency which in our application is 1,830 MHz frequency.

RF Attenuator and Control

Following the harmonic notch filters are two "Tee" attenuators. The first is fixed with the second being PIN diode switched. The fixed RF attenuator is formed by R33, R30 and the combined value of R21 and R30. The PIN diode controlled attenuator is used to switch the attenuators "in" or "out" of the through RF path. Resistors R35, R29 and R36 form the PIN diode attenuator.

The attenuator is switched "in" or "out" by PIN diodes CR2 and CR6 with opamp U1:A supplying the diode bias current. The negative "-" input of opamp U1:A is biased at 2.5 Vdc by the V1/2 power source, described elsewhere. The control signal is applied via P1-12, ATT2 to the positive "+" input of opamp U1:A. With a "1" logic level the attenuator is switched "in" thereby decreasing the transmitted RF output available at J1, ANT. In this state opamp U1:A output is at 5 Vdc forward biasing CR2 and reverse biasing CR6. The bias voltage is applied to the attenuator junction at R29, R35, R36 through R22. The voltage drop across R22 limits the bias current through CR2. As CR6 is reversed biased it represents a high impedance "open" circuit to the RF through path.

With a "0" logic level opamp U1:A output is at -5 Vdc. The negative voltage forward bias PIN diode CR6 and reverse biases CR2. When CR2 is reversed biased it disconnects (opens) the attenuator RF ground at R29. Then with CR6 forward biased it provides a low impedance RF path across R35 and R36 through CR6 and C51. The bias is still applied through R29 but now also flows through CR6 and R56. The bias current is now limited by the combined voltage drop across R29 and R56. These resistors present a relatively high impedance to RF and therefore do not present a significant load to the 50Ω through path.

Coupling capacitors C29, C30 and C31 are used to provide DC isolation for the attenuators while inserting essentially no RF attenuation.

RF Power Amplifier and Matching

The RF Power Amplifier U4 is comprised of two independent amplifiers within the single package. The 50 ohm transmission line impedance is matched to the first stage amplifier input by L2 and R39. Resistor R39, while part of the matching circuit, is used to increase amplifier stability by producing RF input degeneration. Microstrip U6, 4.7 nHy at 17° and U7, 6.8 nHy at 24° function as inductors as implemented. These are used to impedance match the first stage output to the second stage input impedance. RF bypass capacitors C22 and C23 RF ground the microstrip inductors at the proper phase length. The amplifier output is matched to the 50 ohm microstrip transmission line by microstrip inductor US8, 18.5 nHy at 19°, US14, 1.8 nHy at 11.8° and capacitor C34. Capacitor C24 RF grounds microstrip US8 at the proper phase length. Capacitor C32 RF couples U4 output to the 50 ohm transmission line while providing power supply isolation.

A Tchebycheff 1,500 MHz "π" low pass filter follows the RF amplifier output. Capacitor C34 as well forming part of the amplifier matching is used as the first element of the Tchebycheff filter. Microstrip inductor US3, 8nHy at 27° and C35 form the balance of the "π" filter.

Microstrip US12, US13 and US25 provide suppression to even harmonics. Microstrip US23 which is 90° long at the 3rd harmonic 2745 MHz of the 900 MHz operating frequency provides odd harmonic suppression.

RF Power Amplifier Modulation

The modulation method used is OOK and is applied to RF Power Amplifier U4. Modulation is accomplished by reverse biasing the gates of the two internal amplifier stages beyond DC cutoff. The 0 or 5 volt modulation signal from the Logic Control Board is applied via P1-13, ~MOD. The voltage level is shifted and scaled to -2.5 Volts to -3.75 Volts respectively. In turn this equals inverted modulation, i.e. ~MOD, logic level "0" for maximum RF " and "1" for minimum RF.

The input modulating signal via P1-13, ~MOD is applied to inverting-scaling opamp U5-A inverting "-" input through R9. The ratio of R9 to R4 set the voltage gain (loss for a gain of less than one) of the opamp. As scaled they set the gain to 0.25 for an output voltage change of 1.25 Volts. A second current from the V5 power source is summed into the inverting "-" input of opamp U5-A through R6, R11 and potentiometer R10. This current also flows through R4 creating a proportional output voltage shift in opamp U5-B.

An active three pole Butterworth low-pass filter follows the inverting-scaling opamp. This filter limits the digital modulation rise and fall time which in turn reduces the transmitted RF spectral bandwidth. The active filter is formed by C1, C2, C6, R1, R2, R3 and opamp U5-B. Resistor R5 is used to isolate the opamp output U5-B pin 7 from external capacitance thereby improving stability Vs load capacity. As R5 is within the opamp closed loop there is essentially no effect on filter performance. The opamp output is offset to a negative voltage for biasing RF amplifier U4 gates. Bias is applied through R37 for the first stage. It is applied through R24 and microstrip US8 for the second stage.

RF Power Amplifier Current Calibration

During manufacturing alignment and calibration a 0 Vdc (logic 0) test signal is applied to P1-13, ~MOD and P1-11, CCU/Tx. A 5 Vdc (logic "1") signal is applied to P1-12, ATT1. The voltage drop (current) is measured between TP3 and TP4 for the first stage of U4. It is measured between TP4 and TP7 for the second stage of U4.

Potentiometer R10 is adjusted "set" for the specified currents and RF signal level at J1, ANT.

Power Amplifier CCU Transfer Switch

The control signal CCU/Tx, P1-11 via opamp U3-B, previously described, also drives a single-pole-double-throw (SPDT) 50 ohm RF transfer switch. The RF portion of the switch is formed by PIN diodes CR4, CR7, microstrip US15 and US25. Diode bias is applied by opamp U3-B through microstrip US12 with C27 RF grounding US12 at 90°. Microstrip US12 presents a high impedance "open" to RF at the 900 MHz operating frequency. When the logic signal at P1-11, CCU/Tx is "1" opamp U3-B output is 18 Vdc. This voltage reverse biases CR7 thereby disconnecting the PIN diode from the microstrip transmission line between coaxial connectors J2, CCU and J1, ANT. The 18 Vdc also forward bias PIN diode CR4 to a current set by R41. This connects the 90° microstrip US15 to RF ground via CR4 and RF bypass C37. Microstrip US15 presents a high impedance "open" to the CCU transceiver RF signals. When the input logic level at P1-11, CCU/Tx is "0" the voltage at the output of U3-B is -18 Vdc. This voltage forward bias CR7 to a current set by resistor R44. This connects 90° microstrip US25 to RF ground via CR7 and RF bypass C40. Microstrip U25 presents a high impedance "open" to the RF signal from power amplifier U4. A secondary advantage of this design is that microstrip US15 and US25 are 180° long at the second harmonic of the 900 MHz operating frequency. This then presents a low impedance "short" to those frequencies thereby attenuating the undesired even harmonics.

Bias Control Circuit for External Antenna Switch.

The Concentrator assembly has the capability of controlling an external antenna PIN diode RF transfer switch. The circuit that biases this switch is opamp U3-A. The control signal is generated on the Logic Control Board and applied via P1-9, ANTSW. The Antenna switch is not part of the Concentrator Assembly but the design and operating principle is the same as the CCU/Tx transfer switch US15 and US25 previously described. In this application this approach has several advantages. First it does not require the high forward current needed to bias a series PIN diode like found in the traditional ¼ wave transmit-receive switch. Second as there is no series PIN diode the RF insertion loss can be less. Third it does not generate harmonics as sometimes associated within that switch. With this approach the diode in parallel to the RF path is reversed biased. This does add a requirement that the reverse bias voltage must be higher than the Peak RF Voltage. The CCU 900 MHz output power is 1 watt, +30 dBm. As the system uses 50 ohm transmission line the voltage equals 10 V-Peak. Other items such as load VSWR need to be considered; therefore the bias voltage used in this system is 18 Vdc.

The negative input port to switch bias opamp U3-A is set at 2.5 Vdc by the V1/2 power source. When the input to P1-9, ANTSW is at logic level "0" the output of U3-A is -18 Vdc and for a logic "1" level it is 18 Vdc. Diode bias is applied through R52 and microstrip US13 to the 50 ohm transmission line connected to J1 ANT. At the 900 MHz operating frequency it presents a high impedance "open" to the 50 ohm output transmission line. At the second harmonic the microstrip is 180° long therefore it looks like a low impedance "short" attenuating these harmonic signals. Resistor R52 is rated at 1 watt to limit the power dissipation in opamp U3-A. It also limits current when output connector J1, ANT is DC shorted. This can be accidentally or when the external antenna transfer switch is not used and the antenna used has a DC path to the coaxial shield.

7.9 FUNCTIONAL SPECIFICATIONS

Unless noted otherwise:

In the text of this document to indicate a digital level "NOT" function a "~" is placed in front of the term/word.

When connecting "applying" DC power to the UUT the sequence of application shall be: -18Vdc then the 18Vdc and 6Vdc. Supply voltages may be applied concurrently if all circuits are functioning correctly.

All DC power inputs are with the return "ground" at P1-1 and 2, GND.

All control logic signals are with respect to P1-1 and 2, GND.

All signal specified are with the relative circuit activated.

7.9.1 Power Supply

Input Voltage and Current	
Voltage at P1-19 or 20, +6V	6.0 ± 0.25 Vdc
Current, transmitter enabled	350 mA maximum *1
P1-11, CCU/Tx = P1-13, ~MOD = 0 Vdc	calibrate to 150 ± 15 mA
	in output stage
Current, transmitter disabled	50 mA maximum *1
P1-11, CCU/Tx = 5 Vdc	
Current, modulation at minimum	50 mA maximum *1
P1-11, CCU/Tx = 0 Vdc, P1-13, ~MOD = 5 Vdc	
Voltage P1-18, +18V	18 ± 1.5 Vdc
Current	15 mA maximum
Current J1, ANT shorted to ground	40 mA maximum
Voltage P1-16, -18V	18 ± 1.5 Vdc
Current	15 mA maximum
Current, J1, ANT shorted to ground	40 mA maximum

7.9.2 RF Output, J1, ANT

Frequency at 25 ± 5° C	902 to 928 MHz
Tuning VCO's, P1-5, TUNE1 and P1-6, TUNE2	
250 mV	902 MHz
3700 mV	928 MHz
Rate (MHz/msec)	250 MHz/msec
Load Impedance	50 ohms
RF Power *1	≅-10dBm/50,000 mV/meter
Power into a 2:1 VSWR	reference ± 2 dBr
Harmonics	-55 dBc
Spurious Signals	-55 dBc
Load Without Spectral Breakup	

The transmitter shall operate into a short, open or any, not previously specified, antenna load between those points without spectral breakup or self-destruction. During these load conditions the output performance is not defined other than as stated.

7.9.3 Modulation

Occupied Bandwidth	450 KHz
Frequency (data rate)	16 KBS

7.9.4 Transfer Switch

Insertion Loss, 902-928 MHz and 952-962 MHz

J2, CCU to J1, ANT, P1-11, CCU/Tx = 0Vdc	0.6 ± 0.6 dB *1

7.9.5 Antenna Switch, DC

Bias Voltage with 4 mA load at J1, ANT

P1-9, ANT SW = 5 Vdc	-18 Vdc minimum
P1-9, ANT SW = 0 Vdc	+18 Vdc minimum

Bias Current, short circuit at J1, ANT

P1-9, ANT SW = 5 Vdc	-30 mA maximum
P1-9, ANT SW = 0 Vdc	30 mA maximum

7.9.6 Notes

* These paragraph items shall be tested by manufacturing before the assembled board is considered functional. The temperature at which calibration shall be performed is 23 ± 5° centigrade with a relative humidity of 50 ± 20 %

7.10 MANUFACTURING ELECTRICAL TEST REQUIREMENTS

Unless noted otherwise:

The following are the minimum acceptable tests that shall be performed by the supplier of the Concentrator Dual Transmitter PCB. Although testing of all specifications is not required at this level, the Dual Transmitter PCB shall be capable of meeting all specifications as set forth or referred to in this specification.

In the text of this document to indicate a digital level "NOT" function a "~" is placed in front of the term/word.

When connecting (applying) DC power to the UUT the sequence of application shall be: -18Vdc then the 18Vdc and 6Vdc. Supply voltages may be applied concurrently if all circuits are functioning correctly.

PS is used to indicate power voltage at the Unit Under Test (UUT) Test Point (TP) or connector pin. NC is used to indicate no connection at that TP or connector pin. GND is used to indicate 0.0 Vdc at that TP or connector pin.

All DC power inputs are with the return "ground" at P1-1 and 2, GND.

All control logic signals are with respect to P1-1 and 2, GND.

All signal specified are with the relative circuit activated.

7.10.1 TESTING ENVIRONMENT

Temperature	25° ± 5° C
Humidity	50 ± 20 %

ITRON

August 6, 1998

Federal Communications Commission
Authorization and Evaluation Branch
7435 Oakland Mills Road
Columbia MD 21046

Reference: Model: **CONCENTRATOR**

Gentlemen,

This is to advise you that Itron has not prepared the field service manual for our new product model identified as **CONCENTRATOR**.

We expect to have the preliminary manual completed in approximately 90 days. I will supply a copy to the Federal Communications Commission at that time.

If additional information is required, please call me at 509-891-3376

Sincerely,

Fred Phillips
Certification Engineer

c/c Klaus Bender Scott Cumeralto

2818 North Sullivan Road • Spokane, WA 99216 • 509.924.9900 • fax 509.891.3355

TEST: FIELD STRENGTH OF RADIATED EMISSIONS

Grantee: Itron, Inc.

FCC ID: EO9CONCENTRATOR Model: CONCENTRATOR

Setup:

The equipment under test (EUT) was configured and operated in accordance with the applicable provisions of ANSI C63.4-1992, Section 6, 13. Measurements were made in accordance with applicable paragraphs of Section 8.2.3, 8.2.4, Section 13.1.1, 13.1.4 Appendix D, and I.

The EUT was set up at a 1 meter height on a 1 by 1.5 meter table on the 2 meter diameter non-metallic turntable that sits above the 15 X 30 meter ground plane at Spectrum's Open Area Test Site. The bi-conical or log-periodic antenna was mounted on a tower spaced at a three meters distance, and arranged for adjustment in height (1-4 meters) and vertical/horizontal polarization to maximize the emissions levels when combined with turntable rotation of the EUT. The dual ridged guide antenna was mounted on a tripod at one meter height and adjusted for vertical or horizontal antenna orientation. An HP 8562A spectrum analyzer with an HP 8447F, Option H64 amplifier and an HP 83006A pre-amplifier were used for the measuring instrumentation.

Discussion:

No modifications were required prior to the final radiated emissions measurements reported herein.

The EUT portion subject to Certification under Part 15 is the Dual Transmitter section of the Concentrator which has a two transmitters operating in the 910 - 924 MHz portion of the 902 - 928 unlicensed band. The Concentrator is a device used to exchange data via RF from devices referred to as ERTs (Encoder, Receiver, Transmitter) which are connected to a utility customer meter. The ERTs and the Dual Transmitter are very similar in design and operate in the same band. The licensed transmitter section of the Concentrator subject to Part 101, for which Type Acceptance is simultaneously filed under the same FCC ID, transmits an AM wake up tone to utility customer ERTs in the MAS band 952 - 962 MHz band and receive data from the ERTs back to the Concentrator in the 910 - 924 MHz section of the band. The packetized data received is then conveyed to other Concentrators via the Dual Transmitters from one another until reaching a Concentrator connected via modem to the PSTN circuit. The data is then forwarded to the utility for billing and other functions as desired by the utility. Please refer to the enclosed detailed description for in depth information on the system.

The EUT was operated transmitting on four channels, however only two channels at a at a time. For the purpose of test the transmitter was operating under test software which allowed it to transmit continuously (one pair then the other) on the assigned pairs of frequencies which made it much easier to observe maximum emission levels when the turn table was rotated and antenna height and polarization adjusted for a maximum.

Measurements were made for the AM On Off Keyed intentional radiator operating at the four following fundamental frequencies 913.0, 914.5, 916.0, 917.5 MHz.

Preliminary measurements were made as described in Section 8.3.11 and 13.1.4.1 with the EUT operating as described. The configuration is detailed in the photographs of the test setup included within this report.

The final set of measurements as specified in Section 8.3.1.2 and 13.1.4.2 were made under the operating conditions specified in Section 13.1.1. The Concentrator transmitter was observed while positioned with the antenna vertically polarized as it would be installed by Itron in an actual installation. We rotated the turntable and varied antenna height and polarization as required endeavoring to maximize the signals being measured. RBW and VBW of 100 kHz was used for measurements below 1 GHz. Above 1 GHz peak measurements were made with a RBW and VBW of 1 MHz.

The low level harmonics were measurable with the aid of an HP amplifier at 3 meters during the final detailed radiated emissions measurements. The fourth harmonic was the highest level measuring 537 uV/m peak at 3652 MHz with a limit of 500 uV/m average limit. A band pass filter was used to attenuated the 900 MHz fundamental signal approximately 50 dB to insure no overloading of the front end of the spectrum analyzer would occur. None of the harmonics are in the restricted bands.

The EUT does not have a permanently attached antenna, however all of the Concentrator Systems are professionally installed by Itron, Inc.

Conclusion:

The Itron, Inc., FCC ID: EO9CONCENTRATOR when operated and measured as discussed above, meets the field strength limits for the fundamental and spurious emissions requirements under Title 47, CFR Part 15.249. This device has shown compliance with the current rules and is not subject to the transition provisions of Part 15.37.

SPECTRUM TECHNOLOGY, INC.

Field Strength of Radiated Fundamental and Spurious Emissions

47 CFR Part 15.249 - Final Data - Ref. --ITRON.R1

Grantee: Itron, Inc. 8/20/98

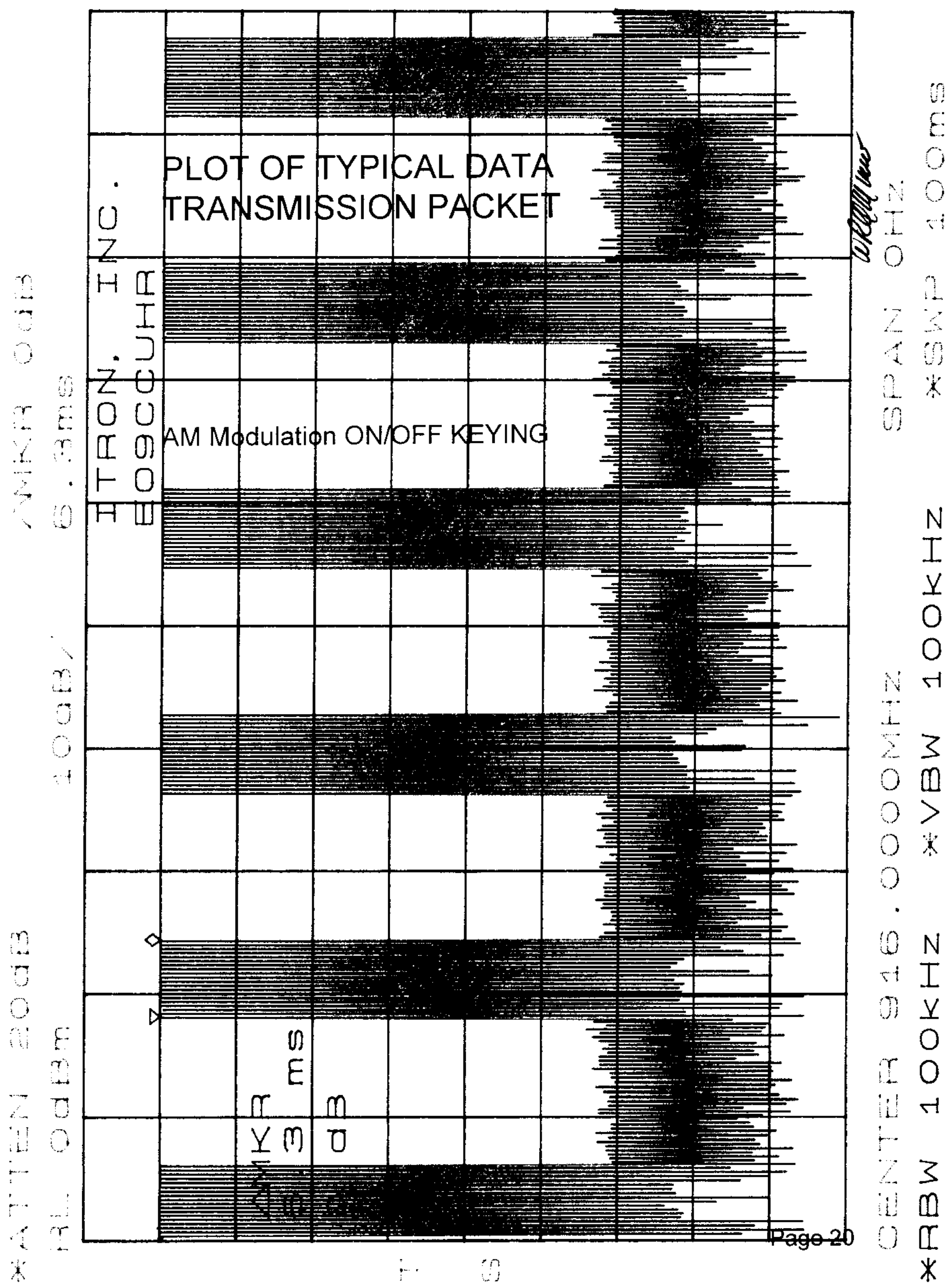
FCC ID: EO9CONCENTRATOR [signature]

Freq MHz	Max Rdg. Ver/Hor dBm	Ant-F & cable Loss	dBuV/m	Amp Gain	uV/m peak Rdg.	Limit uV/m Avg.
913.00	-43.5	29.7	93.20	0	45708.82	50,000
914.50	-43.83	29.7	92.87	0	44004.80	" "
916.00	-43.67	29.7	93.03	0	44822.91	" "
917.50	-43.67	29.7	93.03	0	44822.91	" "
1826	<-73.0					500
1829	-68.33	27.65	41.23	25.09	115.21	" "
1832	<-71.0					" "
1835	-68.5					" "
2739	<-73.0					500
27525	-70.5					" "
2748	<-73.0					" "
27525	-68.5	30.58	47.3	21.78	231.73	" "
3652	-63.67					500
3658	-63.33					" "
36664	-63.67	32.68	~~77.67~~ 54.61	21.4	**537.65 ***	" "
3673	-63.67					" "
4565	<-72.0	33.9	46.2	22.7	204.17	500
45725	<-72.0					" "
4583	<-72.0					" "
45875	<-72.0					" "

Only the highest level of the four harmonics measured at 2Fo, 3Fo, 4Fo, and 5Fo are calculated above.

* Under Section 15.249 the radiated emissions limits are expressed in terms of the average value of the emissions. The measurements reported above were made with a peak detector and according to 15.249(d) peak field strength can't exceed the maximum average limits specified by more than 20 dB.

Additionally ANSI C63.4-1992 Appendix I4 (10) also describes a method which could be used to correct for duty cycle when average detector function limits are specified for a pulse-modulated transmitter, the average level of emissions may be found by measuring the peak level of emissions and correcting them with duty cycle. With the harmonic limit exceed by only 37.65 uV/m this isn't really necessary to do.


PLOT OF TYPICAL DATA
TRANSMISSION PACKET
AM Modulation ON/OFF KEYING
ITRON, INC.
E09CCUHR
*ATTEN 20dB
RL 0dBm
10dB/
ΔMKR 0dB
6.3ms
CENTER 916.0000MHz
SPAN 0Hz
*RBW 100kHz
*VBW 100kHz
*SWP 100ms
MKR
3 ms
dB

OPEN-FIELD TEST SITE

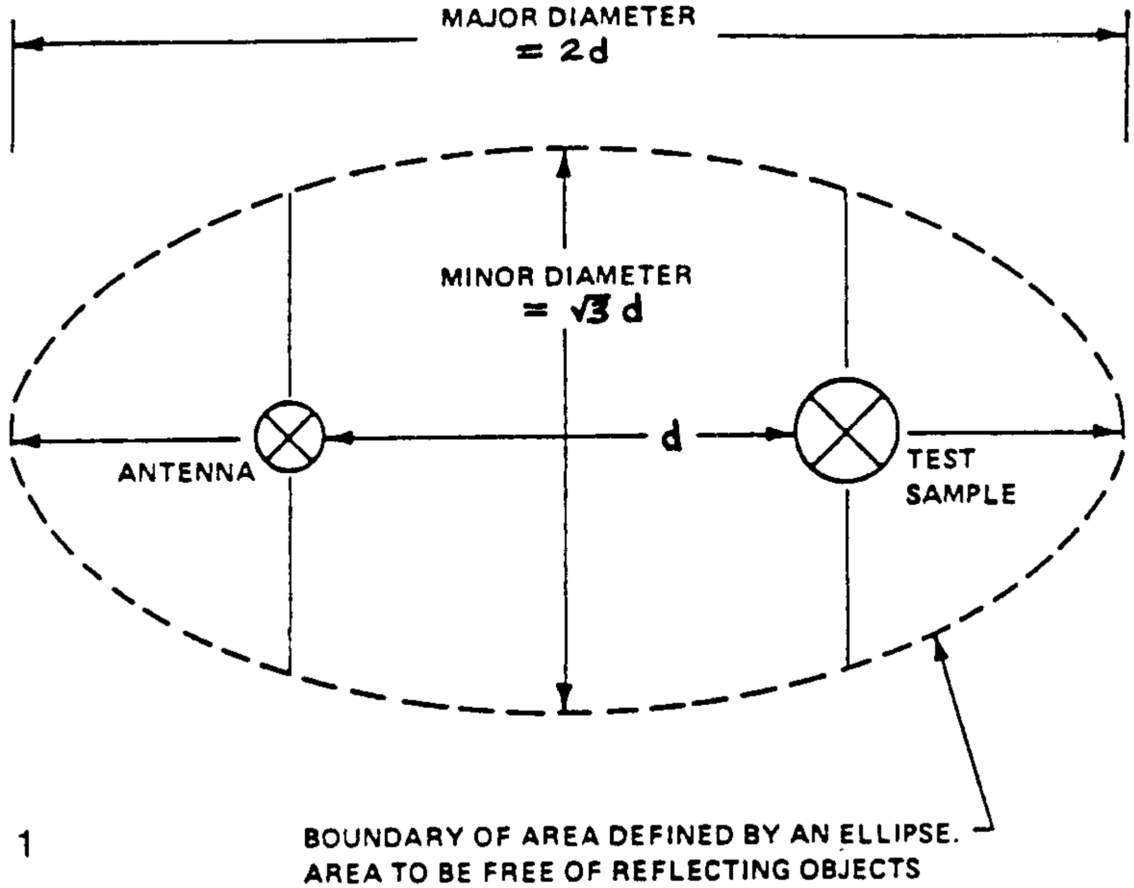


Figure 1

ANTENNA/EQUIPMENT ORIENTATION

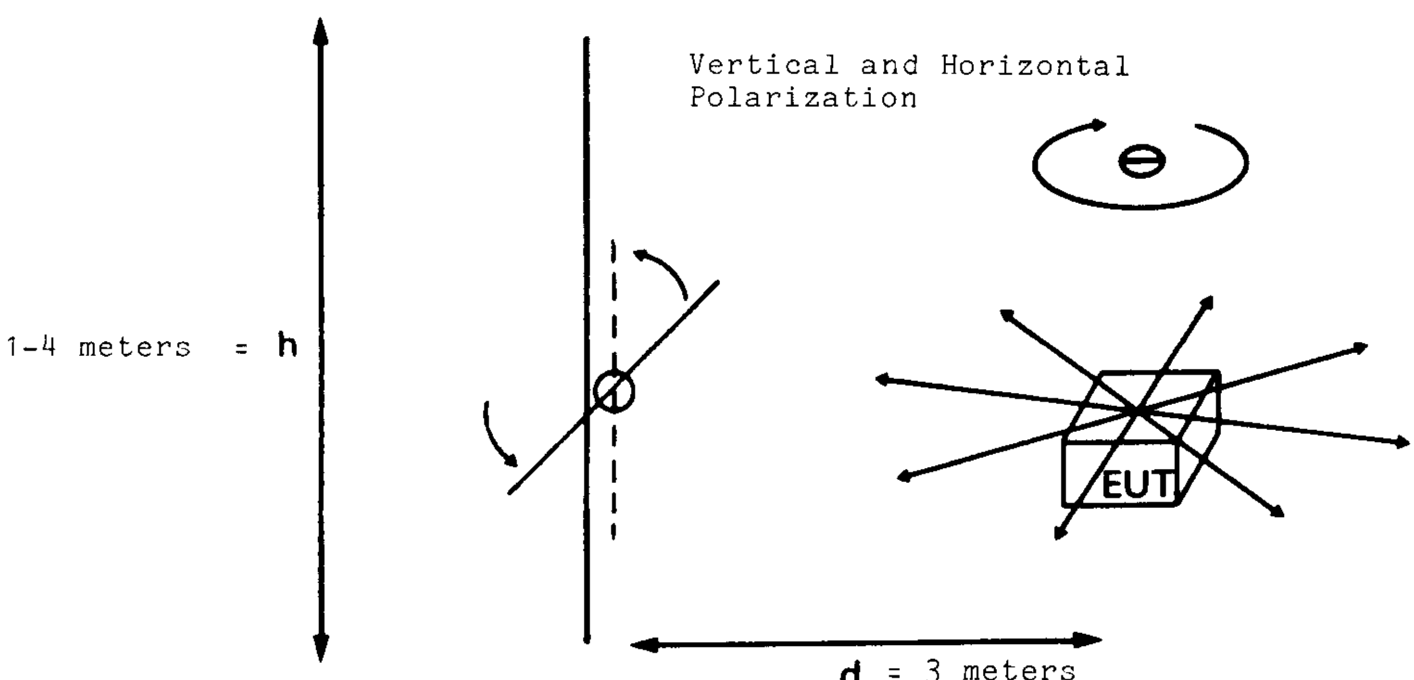


Figure 2

ANTENNA FACTORS FOR EMCO 3104 BICONICAL ANTENNA AND EMCO 3146 LOG PERIODIC ANTENNA INCLUDING CONVERSION TO OPEN CIRCUIT VOLTAGE.

Antenna Factor and Field Strength Formula

level as measured with Spectrum Analyzer

converts to dBuV @ 50 ohms

converts to dBuV/m

$$uV/m = \log^{-1} \frac{dBm + 107 + AF + 6}{20}$$

\+ 6 - converts to open circuit voltage

$\log^{-1}$ ... 20 — converts to uV/m

IF FREQ => 20	AND	FREQ =< 26.5	THEN ANTF = 12.5
IF FREQ => 26.6	AND	FREQ =< 28	THEN ANTF = 13.5
IF FREQ => 28.1	AND	FREQ =< 33	THEN ANTF = 14.5
IF FREQ => 33.1	AND	FREQ =< 35	THEN ANTF = 13.5
IF FREQ => 35.1	AND	FREQ =< 45	THEN ANTF = 13
IF FREQ => 45.	AND	FREQ =< 57	THEN ANTF = 12
IF FREQ => 57.1	AND	FREQ =< 63	THEN ANTF = 11
IF FREQ => 63.1	AND	FREQ =< 66	THEN ANTF = 10
IF FREQ => 66.1	AND	FREQ =< 75	THEN ANTF = 9
IF FREQ => 75.1	AND	FREQ =< 83	THEN ANTF = 8
IF FREQ => 83.1	AND	FREQ =< 86	THEN ANTF = 9
IF FREQ => 86.1	AND	FREQ =< 90	THEN ANTF = 10
IF FREQ => 90.1	AND	FREQ =< 95	THEN ANTF = 11
IF FREQ => 95.1	AND	FREQ =< 97.5	THEN ANTF = 12.5
IF FREQ => 97.6	AND	FREQ =< 101	THEN ANTF = 13.5
IF FREQ => 101.1	AND	FREQ =< 105	THEN ANTF = 14.5
IF FREQ => 105.1	AND	FREQ =< 108	THEN ANTF = 15.5
IF FREQ => 108.1	AND	FREQ =< 115	THEN ANTF = 16.5
IF FREQ => 115.1	AND	FREQ =< 123	THEN ANTF = 15.5
IF FREQ => 123.1	AND	FREQ =< 148	THEN ANTF = 14.5
IF FREQ => 148.1	AND	FREQ =< 151.5	THEN ANTF = 15.5
IF FREQ => 151.6	AND	FREQ =< 167.5	THEN ANTF = 17
IF FREQ => 167.6	AND	FREQ =< 182.5	THEN ANTF = 18
IF FREQ => 182.6	AND	FREQ =< 200	THEN ANTF = 19
IF FREQ => 200.1	AND	FREQ =< 202	THEN ANTF = 14.7
IF FREQ => 202	AND	FREQ =< 205	THEN ANTF = 14.5
IF FREQ => 205	AND	FREQ =< 215	THEN ANTF = 14.6
IF FREQ => 215	AND	FREQ =< 230	THEN ANTF = 14.55
IF FREQ => 230	AND	FREQ =< 235	THEN ANTF = 14.5
IF FREQ => 235	AND	FREQ =< 240	THEN ANTF = 14.8
IF FREQ => 240	AND	FREQ =< 242.5	THEN ANTF = 14.9

IF FREQ => 242.5	AND	FREQ =< 245	THEN ANTF = 15.1
IF FREQ => 245	AND	FREQ =< 247.5	THEN ANTF = 15.5
IF FREQ => 247.5	AND	FREQ =< 250	THEN ANTF = 15.7
IF FREQ => 250	AND	FREQ =< 252	THEN ANTF = 15.9
IF FREQ => 252	AND	FREQ =< 254	THEN ANTF = 16
IF FREQ => 254	AND	FREQ =< 256	THEN ANTF = 16.1
IF FREQ => 256	AND	FREQ =< 258	THEN ANTF = 16.2
IF FREQ => 258	AND	FREQ =< 260	THEN ANTF = 16.3
IF FREQ => 260	AND	FREQ =< 263.5	THEN ANTF = 16.4
IF FREQ => 263.5	AND	FREQ =< 265	THEN ANTF = 16.4
IF FREQ => 265	AND	FREQ =< 267.5	THEN ANTF = 16.6
IF FREQ => 267.5	AND	FREQ =< 271	THEN ANTF = 16.7
IF FREQ => 271	AND	FREQ =< 274	THEN ANTF = 16.8
IF FREQ => 274	AND	FREQ =< 276	THEN ANTF = 16.9
IF FREQ => 276	AND	FREQ =< 278	THEN ANTF = 17
IF FREQ => 278	AND	FREQ =< 280	THEN ANTF = 17.1
IF FREQ => 280	AND	FREQ =< 282	THEN ANTF = 17.3
IF FREQ => 282	AND	FREQ =< 284	THEN ANTF = 17.6
IF FREQ => 284	AND	FREQ =< 286	THEN ANTF = 18
IF FREQ => 286	AND	FREQ =< 288	THEN ANTF = 18.2
IF FREQ => 288	AND	FREQ =< 295	THEN ANTF = 18.4
IF FREQ => 290	AND	FREQ =< 295	THEN ANTF = 15.8
IF FREQ => 295	AND	FREQ =< 305	THEN ANTF = 18.6
IF FREQ => 305	AND	FREQ =< 310	THEN ANTF = 18.4
IF FREQ => 310	AND	FREQ =< 311	THEN ANTF = 18.3
IF FREQ => 311	AND	FREQ =< 312	THEN ANTF = 18.1
IF FREQ => 312	AND	FREQ =< 313	THEN ANTF = 18
IF FREQ => 313	AND	FREQ =< 340	THEN ANTF = 17.9
IF FREQ => 340	AND	FREQ =< 343	THEN ANTF = 18.1
IF FREQ => 343	AND	FREQ =< 350	THEN ANTF = 18.2
IF FREQ => 350	AND	FREQ =< 357	THEN ANTF = 18.3
IF FREQ => 357	AND	FREQ =< 360	THEN ANTF = 18.5
IF FREQ => 360	AND	FREQ =< 365	THEN ANTF = 18.6
IF FREQ => 365	AND	FREQ =< 375	THEN ANTF = 18.7
IF FREQ => 375	AND	FREQ =< 378	THEN ANTF = 19
IF FREQ => 378	AND	FREQ =< 381	THEN ANTF = 19.1
IF FREQ => 381	AND	FREQ =< 383	THEN ANTF = 19.2
IF FREQ => 383	AND	FREQ =< 385	THEN ANTF = 19.3
IF FREQ => 385	AND	FREQ =< 387.5	THEN ANTF = 19.4
IF FREQ => 387.5	AND	FREQ =< 390	THEN ANTF = 19.5
IF FREQ => 390	AND	FREQ =< 392	THEN ANTF = 19.7
IF FREQ => 392	AND	FREQ =< 394	THEN ANTF = 18.8
IF FREQ => 394	AND	FREQ =< 396	THEN ANTF = 19.9
IF FREQ => 396	AND	FREQ =< 398	THEN ANTF = 20
IF FREQ => 398	AND	FREQ =< 402	THEN ANTF = 20.1
IF FREQ => 402	AND	FREQ =< 405	THEN ANTF = 20.2
IF FREQ => 405	AND	FREQ =< 410	THEN ANTF = 20.3
IF FREQ => 410	AND	FREQ =< 415	THEN ANTF = 20.4
IF FREQ => 415	AND	FREQ =< 420	THEN ANTF = 20.6
IF FREQ => 420	AND	FREQ =< 425	THEN ANTF = 20.8
IF FREQ => 425	AND	FREQ =< 430	THEN ANTF = 21
IF FREQ => 430	AND	FREQ =< 435	THEN ANTF = 21.2
IF FREQ => 435	AND	FREQ =< 440	THEN ANTF = 21.3
IF FREQ => 440	AND	FREQ =< 445	THEN ANTF = 21.4
IF FREQ => 445	AND	FREQ =< 450	THEN ANTF = 21.5
IF FREQ => 450	AND	FREQ =< 455	THEN ANTF = 21.6
IF FREQ => 455	AND	FREQ =< 460	THEN ANTF = 21.8
IF FREQ => 460	AND	FREQ =< 465	THEN ANTF = 21.9
IF FREQ => 465	AND	FREQ =< 470	THEN ANTF = 22
IF FREQ => 470	AND	FREQ =< 472.5	THEN ANTF = 22.1
IF FREQ => 472.5	AND	FREQ =< 475	THEN ANTF = 22.2
IF FREQ => 475	AND	FREQ =< 477	THEN ANTF = 22.4
IF FREQ => 477	AND	FREQ =< 478	THEN ANTF = 22.5
IF FREQ => 478	AND	FREQ =< 481	THEN ANTF = 22.6

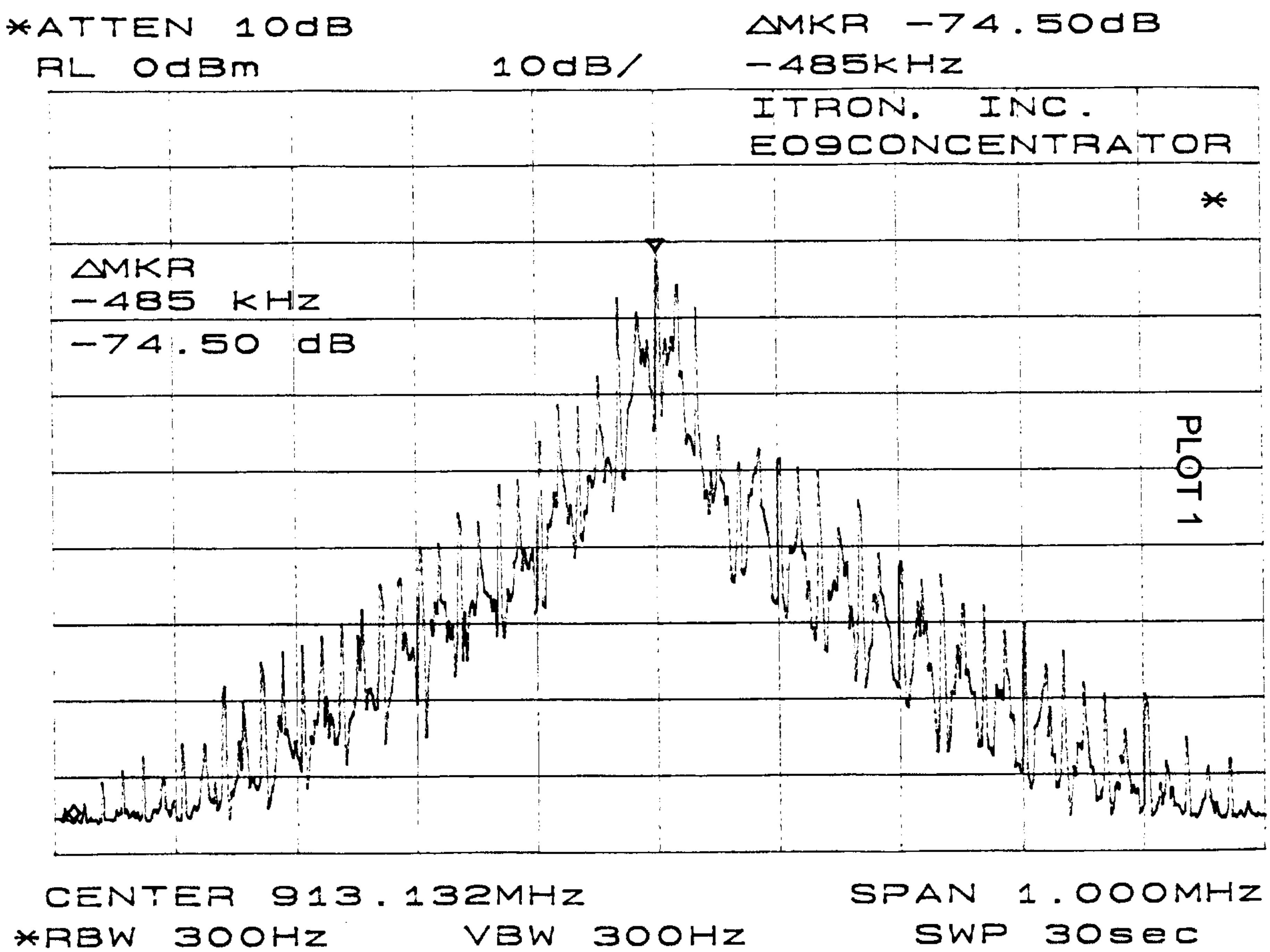
IF FREQ => 481	AND	FREQ =< 482.5	THEN ANTF = 22.7
IF FREQ => 482.5	AND	FREQ =< 485	THEN ANTF = 22.8
IF FREQ => 485	AND	FREQ =< 488	THEN ANTF = 22.9
IF FREQ => 488	AND	FREQ =< 515	THEN ANTF = 23.1
IF FREQ => 515	AND	FREQ =< 540	THEN ANTF = 23.3
IF FREQ => 540	AND	FREQ =< 560	THEN ANTF = 23.6
IF FREQ => 560	AND	FREQ =< 570	THEN ANTF = 23.7
IF FREQ => 570	AND	FREQ =< 580	THEN ANTF = 23.9
IF FREQ => 580	AND	FREQ =< 590	THEN ANTF = 24
IF FREQ => 590	AND	FREQ =< 610	THEN ANTF = 24.2
IF FREQ => 610	AND	FREQ =< 615	THEN ANTF = 24.4
IF FREQ => 615	AND	FREQ =< 620	THEN ANTF = 24.5
IF FREQ => 620	AND	FREQ =< 625	THEN ANTF = 24.6
IF FREQ => 625	AND	FREQ =< 630	THEN ANTF = 24.8
IF FREQ => 630	AND	FREQ =< 635	THEN ANTF = 24.9
IF FREQ => 635	AND	FREQ =< 640	THEN ANTF = 25
IF FREQ => 640	AND	FREQ =< 645	THEN ANTF = 25.1
IF FREQ => 645	AND	FREQ =< 647.5	THEN ANTF = 25.3
IF FREQ => 647.5	AND	FREQ =< 650	THEN ANTF = 25.4
IF FREQ => 650	AND	FREQ =< 652.5	THEN ANTF = 25.6
IF FREQ => 652.5	AND	FREQ =< 655	THEN ANTF = 25.7
IF FREQ => 655	AND	FREQ =< 660	THEN ANTF = 25.8
IF FREQ => 660	AND	FREQ =< 665	THEN ANTF = 26.1
IF FREQ => 665	AND	FREQ =< 670	THEN ANTF = 26.3
IF FREQ => 670	AND	FREQ =< 680	THEN ANTF = 26.6
IF FREQ => 680	AND	FREQ =< 690	THEN ANTF = 26.7
IF FREQ => 690	AND	FREQ =< 720	THEN ANTF = 26.9
IF FREQ => 720	AND	FREQ =< 760	THEN ANTF = 26.8
IF FREQ => 760	AND	FREQ =< 800	THEN ANTF = 27
IF FREQ => 800	AND	FREQ =< 802.5	THEN ANTF = 27.3
IF FREQ => 802.5	AND	FREQ =< 805	THEN ANTF = 27.5
IF FREQ => 805	AND	FREQ =< 807.5	THEN ANTF = 27.6
IF FREQ => 807.5	AND	FREQ =< 810	THEN ANTF = 27.7
IF FREQ => 810	AND	FREQ =< 815	THEN ANTF = 27.8
IF FREQ => 815	AND	FREQ =< 820	THEN ANTF = 27.9
IF FREQ => 820	AND	FREQ =< 840	THEN ANTF = 28.2
IF FREQ => 840	AND	FREQ =< 860	THEN ANTF = 28.4
IF FREQ => 860	AND	FREQ =< 870	THEN ANTF = 28.8
IF FREQ => 870	AND	FREQ =< 880	THEN ANTF = 29.3
IF FREQ => 880	AND	FREQ =< 890	THEN ANTF = 29.4
IF FREQ => 890	AND	FREQ =< 910	THEN ANTF = 29.6
IF FREQ => 910	AND	FREQ =< 920	THEN ANTF = 29.7
IF FREQ => 920	AND	FREQ =< 930	THEN ANTF = 29.9
IF FREQ => 930	AND	FREQ =< 940	THEN ANTF = 30
IF FREQ => 940	AND	FREQ =< 960	THEN ANTF = 30.2
IF FREQ => 960	AND	FREQ =< 970	THEN ANTF = 30.6
IF FREQ => 970	AND	FREQ =< 975	THEN ANTF = 30.8
IF FREQ => 975	AND	FREQ =< 980	THEN ANTF = 31
IF FREQ => 980	AND	FREQ =< 985	THEN ANTF = 31.1
IF FREQ => 985	AND	FREQ =< 990	THEN ANTF = 31.3
IF FREQ => 990	AND	FREQ =< 1000	THEN ANTF = 31.4

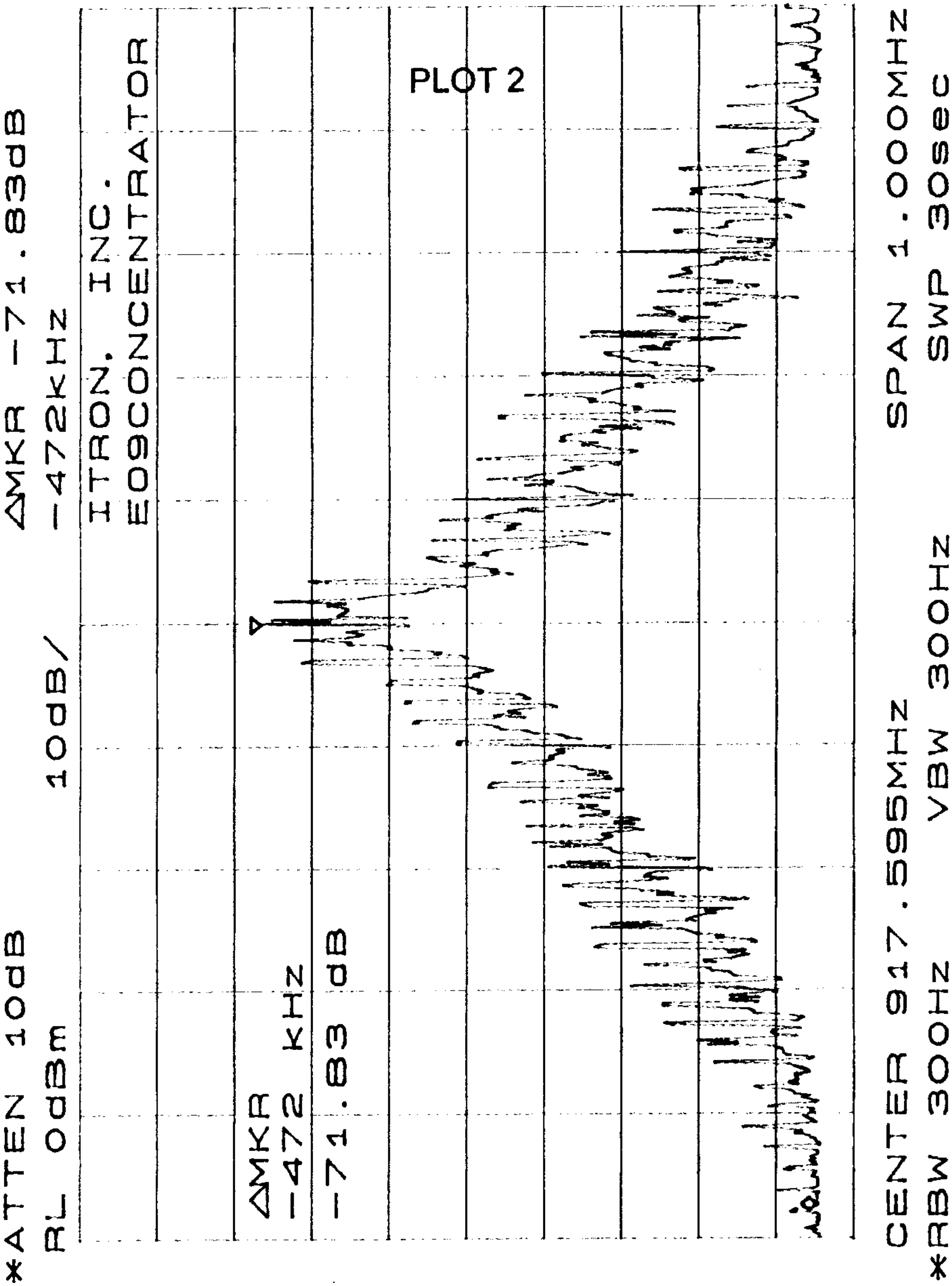
Serial Number 6225	ELECTO-METRICS GAIN AND ANTENNA FACTORS MODEL RGA-60	1 METER CALIBRATION

FREQUENCY MHz	14 FOOT CABLE LOSS FSJI-50A	ANTENNA FACTOR
1000	.84	23.21
1500	1.05	25.70
2000	1.22	27.15
2500	1.38	28.37
3000	1.53	29.93
3500	1.67	31.01
4000	1.80	32.45
4500	1.92	31.98
5000	2.04	33.33
5500	2.15	34.24
6000	2.27	34.48
6500	2.37	35.19
7000	2.48	36.05
7500	2.58	36.77
8000	2.68	37.33
8500	2.78	37.38
9000	2.87	37.14
9500	2.96	37.55
10000	3.06	38.33

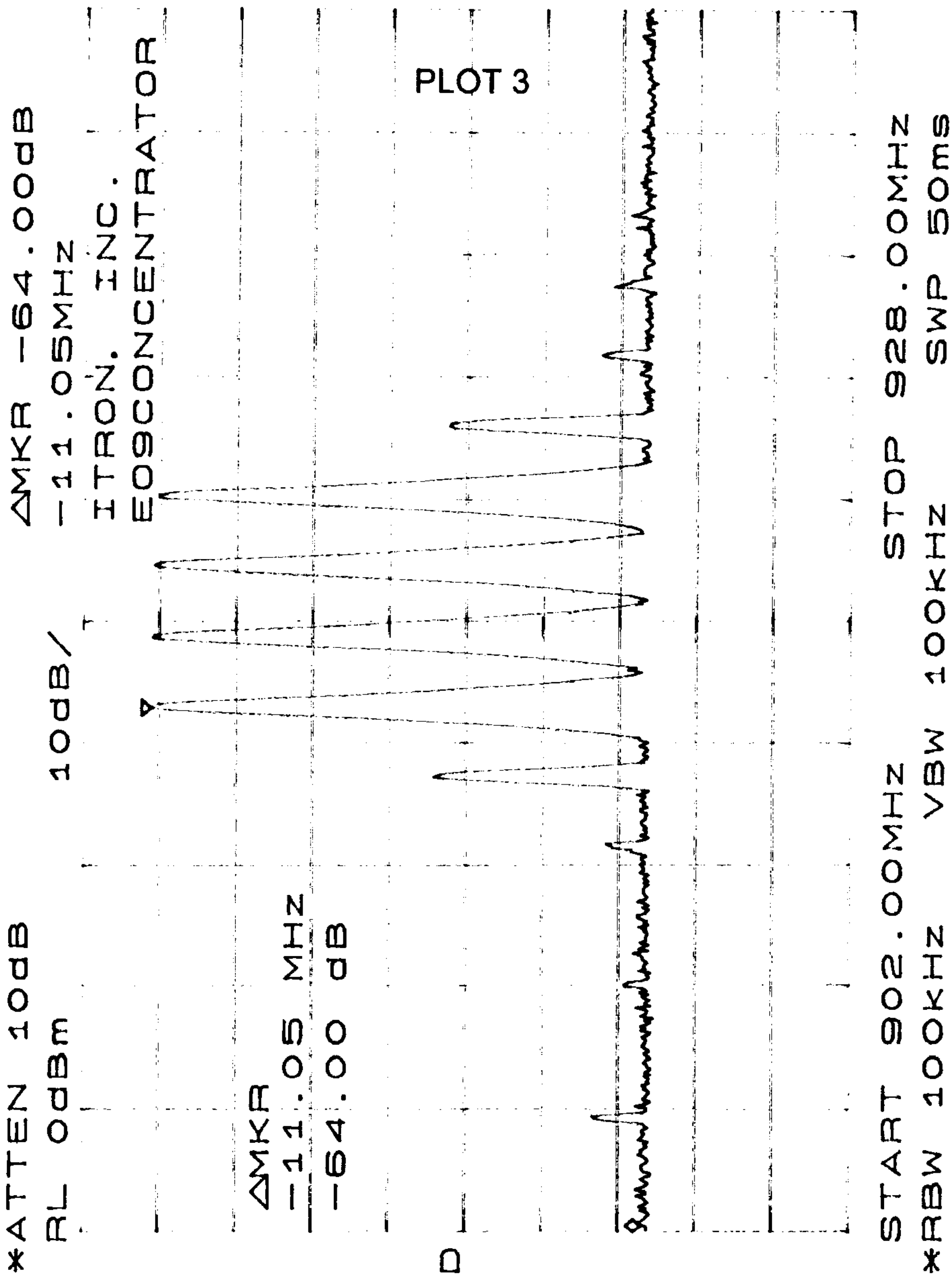
TEST EQUIPMENT LIST A
SPECTRUM TECHNOLOGY, INC.

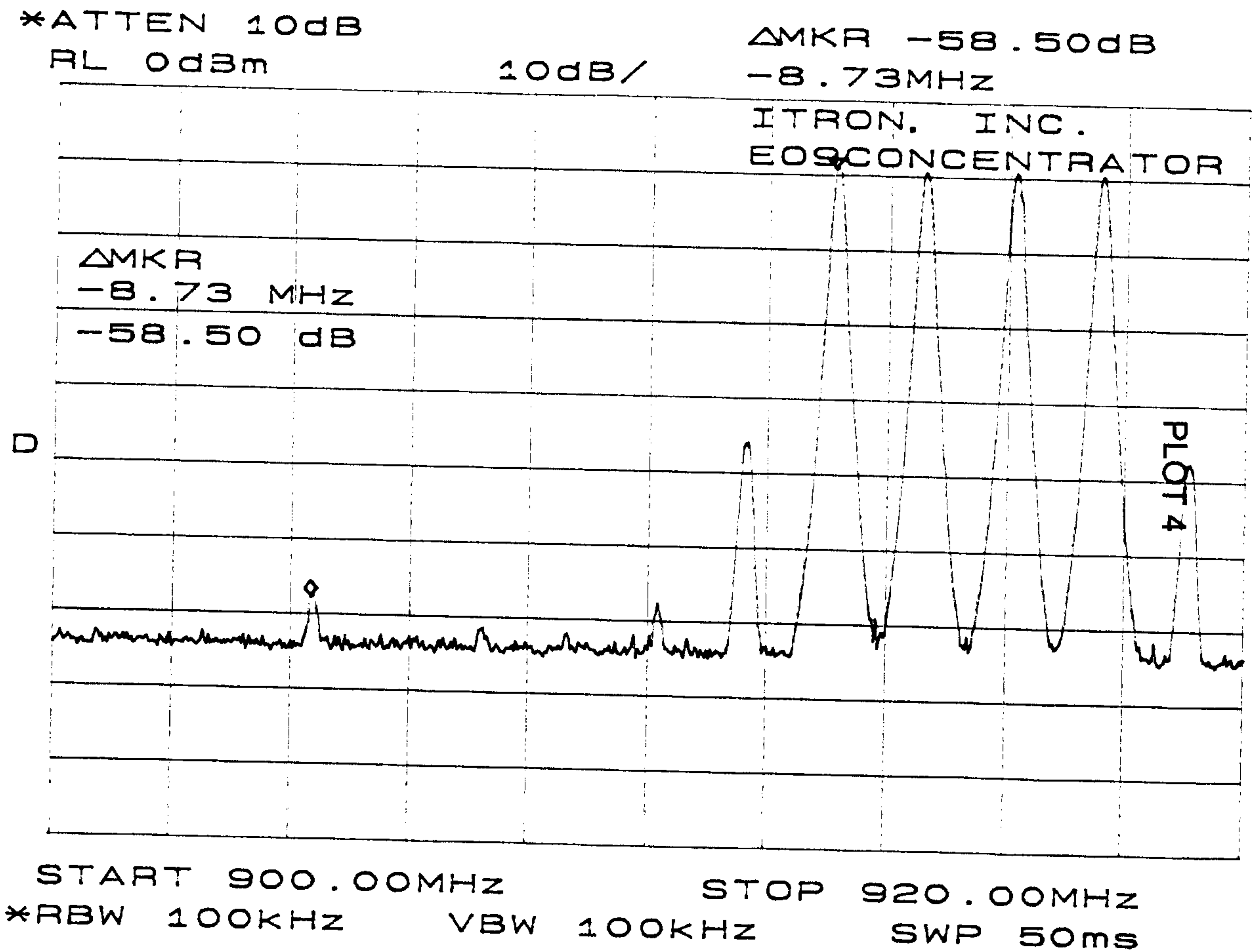
Equipment	Manufacturer	Serial Number	Cal Date/Due Date	
Spectrum Analyzer	Hewlett-Packard 8562A	08562-60062	9/15/97	9/15/98
Amplifier 9 kHz-1300 MHz	Hewlett-Packard 8447F OPT H64	2727A02208	9/15/97	9/15/98
RF Signal Gen.	Fluke 6071A	2915016	8/11/97	5/11/98
Service Monitor	IFR FM/AM 500A	4103	---	
Oscilloscope	Kikusui C055060	6132295	---	
Power Supply	Astron VS35	8601266	---	
Voltmeter	Fluke 8020A	N2420658	---	
Multimeter	Fluke 25	3710310	---	
Wattmeter	Bird 43	56227	---	
RF Termination	Bird 8135	10004	---	
Dual Phase LISN 50 ohm/50 uH	STI per MP-4	02	1/9/98	1/9/99
Dual Phase LISN 50 ohm/50 uH	Compliance Design	8012-50R-24-BNC	1/9/98	1/9/99
Audio Generator	Hewlett-Packard 205-AG	8689	---	
Attenuators:	Texscan FP45-20 Texscan FP45-10 Weinshel 40-10-33 Mini-Circuits CAT30 Pomona 4108-10	 CZ682 8419 01		
Thermometer	Fluke 52	3965185	---	
Test Line Simulator	Teltone TLS-2	none	---	
Turn Table, RC	EMCO 1060-2M	8912-1415	---	
Antenna Mast, RC	Compliance Design, Inc.	M100	---	
Antennas:				
DiPole Set	EMCO Model: 3121C	1335	9/18/97	
Diploe Set	EMCO Model: 3121C	1336	9/18/97	
Bi-Conical	EMCO 3104	3763	reference only	
Bi-Conical	EMCO 3104C	9401-4635	6/20/97	1/20/99
Log-Periodic	EMCO 3146	1754	9/15/98	9/15/99
Active Loop	EMCO 6502	9107-2645	reference only	

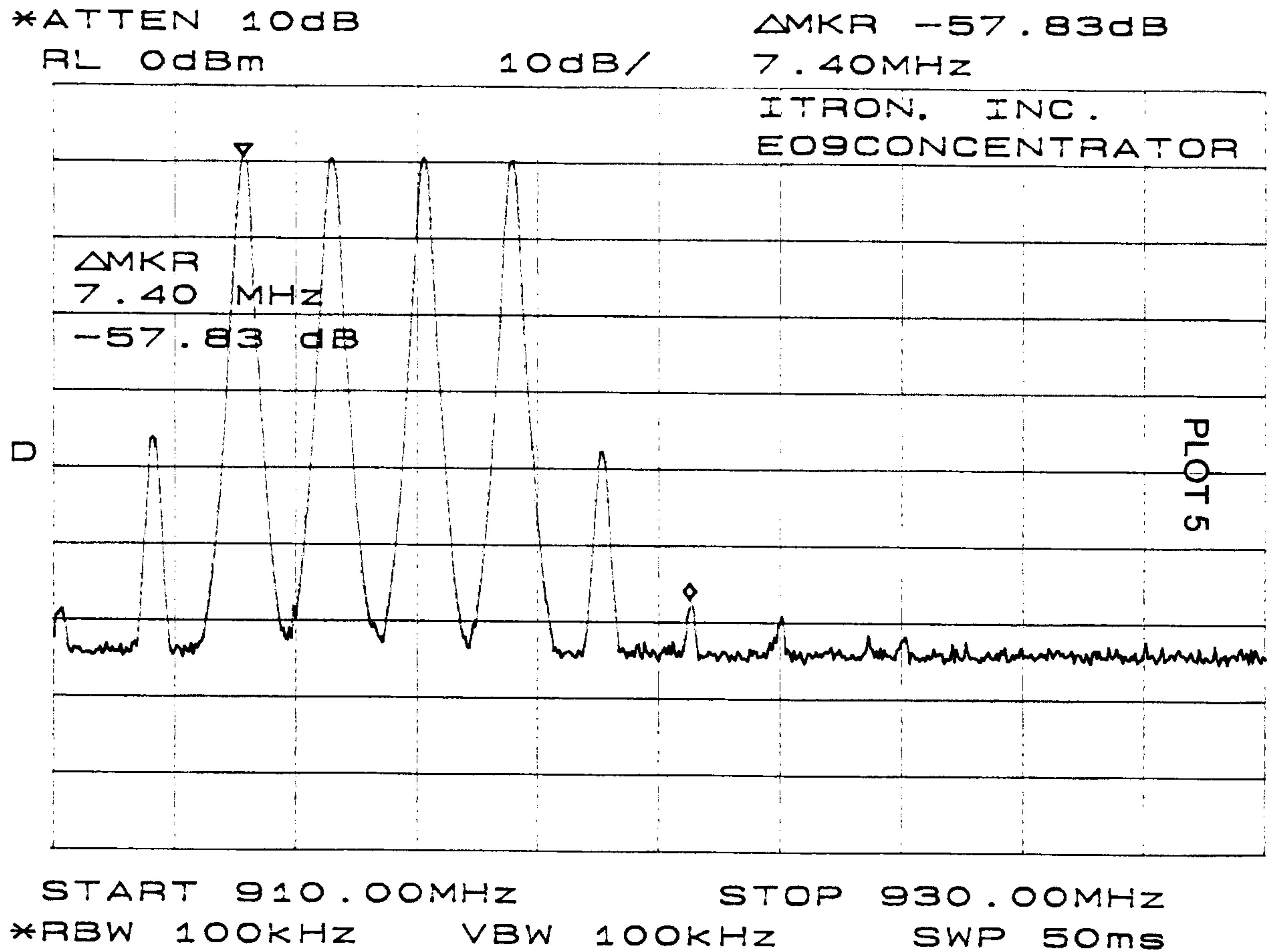

*ATTEN 10dB
RL 0dBm
10dB/
ΔMKR -74.50dB
-485kHz
ITRON, INC.
E09CONCENTRATOR
*
PLOT 1
ΔMKR
-485 kHz
-74.50 dB
CENTER 913.132MHz
SPAN 1.000MHz
*RBW 300Hz
VBW 300Hz
SWP 30sec


*ATTEN 10dB
RL 0dBm
10dB/
ΔMKR -71.83dB
-472kHz
ITRON. INC.
E09CONCENTRATOR
PLOT 2
ΔMKR
-472 kHz
-71.83 dB
CENTER 917.595MHz
SPAN 1.000MHz
*RBW 300Hz
VBW 300Hz
SWP 30sec

PLOT 3


*ATTEN 10dB
RL 0dBm
10dB/
ΔMKR -64.00dB
-11.05MHz
ITRON, INC.
E09CONCENTRATOR
ΔMKR
-11.05 MHz
-64.00 dB
D
START 902.00MHz
STOP 928.00MHz
*RBW 100kHz
VBW 100kHz
SWP 50ms


*ATTEN 10dB
RL 0dBm
10dB/
ΔMKR -58.50dB
-8.73MHz
ITRON, INC.
E09CONCENTRATOR
ΔMKR
-8.73 MHz
-58.50 dB
D
PLOT 4
START 900.00MHz
STOP 920.00MHz
*RBW 100kHz
VBW 100kHz
SWP 50ms


*ATTEN 10dB
RL 0dBm
10dB/
ΔMKR -57.83dB
7.40MHz
ITRON, INC.
E09CONCENTRATOR
ΔMKR
7.40 MHz
-57.83 dB
D
PLOT 5
START 910.00MHz
STOP 930.00MHz
*RBW 100kHz
VBW 100kHz
SWP 50ms