

**SPECIFIC ABSORPTION RATE (SAR) ANALYSIS
ON MICRO SYSTEMS, INC. RAPID SCORING SYSTEM**

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SAR99725
March 29, 2000
Rev -

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ACRONYM LIST

RSS	Rapid Scoring System
SAR	Specific Absorption Rate
SIM	Student Interactive Module

1.0 INTRODUCTION

1.1 Scope

This report documents conformance with the FCC Rules, Part 2, Subpart J, Radio Frequency Radiation Exposure as listed below, and details the results of testing and calculations performed on the Rapid Scoring System (RSS).

1.2 Product Description

The Rapid Scoring System (RSS) is a wireless system used to perform standardized testing in schools. The RSS includes 30 hand-held devices (remote units) (student interactive module, SIM) and a base unit connected to a personal computer via RS-232 interface. The base unit polls each remote unit periodically through an RF data link. When a remote unit is polled by the base unit it transfers any information that has been entered into it, also through an RF data link. The information that the base receives from the remote units is then passed on to the personal computer through the RS-232 interface for further processing.

1.3 Tested System Details

FCC Certification Testing was completed on the RSS at Wyle Laboratories on February 29, 2000. The test report that followed, documents the conformance of the RSS with FCC Rules, Part 15, Class A. The identifiers for the test specimen, support devices, and cables used in the tested system are:

TEST SPECIMEN

Item	Part Number	Serial Number	Quantity
Remote Unit	AY99735	P001	1
Base Unit	AY99745	P001	1

SUPPORT EQUIPMENT

There was no support equipment used during the FCC Part 15 testing.

1.4 Applicable Documents

- Report 43957-01 Wyle Laboratories: FCC Certification Testing on Micro Systems, Inc. Rapid Scoring System.
- FCC OET Bulletin 65 Evaluating Compliance with FCC Guidelines for Human Exposure to Radio Frequency Electromagnetic Fields.

- FCC OET Evaluating Compliance with FCC Guidelines for Human Exposure
 Bulletin 65 to Radio Frequency Electromagnetic Fields.
 Supplement C

2.0 SYSTEM INFORMATION AND CONFIGURATION

2.1 Device Category

The RSS is comprised of a base unit and 30 remote units. Under worst case operating conditions each of the transmitting devices will meet the conditions of a portable device. As a result, the base unit and each of the 30 remote units are evaluated under the portable device category in accordance with FCC Rules, Part 2, Subpart J, Paragraph 2.1093 – Radio Frequency Radiation Exposure Evaluation: Portable Devices. A portable device is defined as a transmitting device designed to be used so that the radiating structure of the device is within 20 centimeters of the body of the user.

2.2 RF Exposure Environment

The RF exposure environment will consist of a classroom with the RSS installed. Each desk will have a remote unit on it and the base unit will be at the front/back of the classroom where a personal computer may be located. Students will be seated at their desks, each with a remote unit (student interactive module, SIM) for individual use. The base unit and computer interface will be used by the test proctor during the RSS operation.

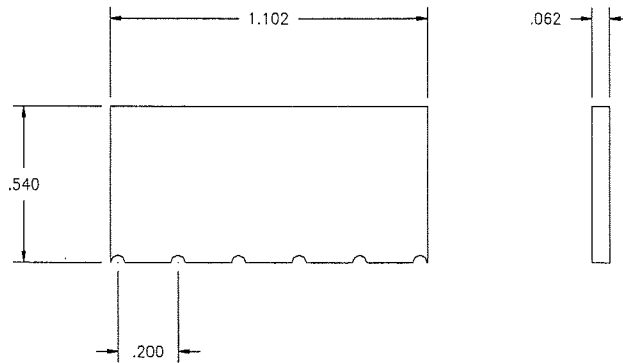
2.3 Test Method

The method used for conducting the specific absorption rate (SAR) analysis consists of extrapolating field strength data and computing SAR levels. The field strength data acquired in FCC Part 15 testing is used to calculate isotropic field strength at distances up to three meters. The field strength data from FCC Part 15 testing is measured per ANSI C63.4 – 1992, “Methods of Measurement of Radio Noise From Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz”. This document delineates the method of measuring transmitted field strengths and ensures that the maximum field strength of the transmitting device is evaluated.

The calculated data is used to compute SAR levels that are consistent with the operating characteristics of the system. Worst case scenarios concerning the operating characteristics of the system are used when modeling the transmitting devices. This method is used to ensure that a more than adequate analysis of the human exposure to RF electromagnetic fields by the RSS is performed as well as to simplify the calculations made in the analysis. Equations used for SAR analysis on the RSS are shown in paragraph 3 (Equations).

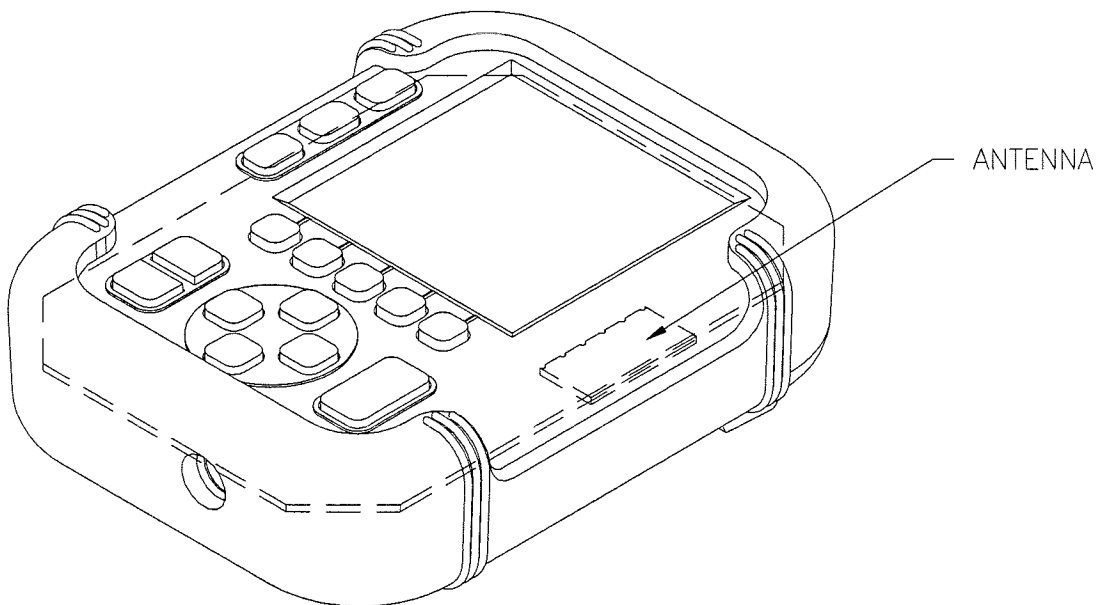
2.4 Antenna Description

The antenna used on the transmitting devices is a planar patch antenna with an isotropic beam pattern. The physical dimensions of the antenna are shown in Figure 1. The antenna is located inside the device (base and remote unit) in a fixed position on the right hand side of the unit as shown in Figure 2. The gain of the antenna is specified at -1 dBi.



CAD DWG FIG-0548

Figure 1. Planar Patch Antenna



CAD DWG FIG-0548

Figure 2. Planar Patch Antenna Location

2.5 RF Signal Characteristics

The operating frequency of the system is 916.5 MHz. The transmitted RF signal is amplitude shift key modulated at a data rate of 115.2 kbps. The system is time division multiplexed providing each remote unit with an opportunity to transfer information with the base unit. The output power of each transmitting device is less than 0 dBm (1 milliwatt).

A tentative network protocol dictates that each remote will transmit an 8 msec message every 500 msec. The duty cycle for each remote is then calculated at 1.6 percent. The base unit will transmit an 8 msec message for each remote which totals to 240 msec every 500 msec. The duty cycle for the base unit is then calculated at 48 percent. The FCC Part 15 testing was performed with the device transmitting constant ones and zeros. This constitutes an operating duty cycle of 100 percent for amplitude shift key modulation with a DC balanced data code. This test method was employed for FCC Part 15 testing in order to evaluate absolute worst possible operating conditions for the RSS.

2.6. Device Position

The remote unit will be placed on a desk located in a classroom. The user is an individual seated at the desk with the remote unit placed in front of them. During system operation, the remote unit may remain on the desk or be picked up and handled while the user enters in commands on the keypad.

The base unit will be placed on a desk or podium in the front/back of the classroom where a personal computer may be located. The user is a test proctor that may be required to occasionally enter/monitor data on the base unit. During system operation, the base unit will be physically connected to the personal computer through an RS-232 interface. Human interaction with the base unit during system operation will be extremely limited, occurring primarily for periodic system monitoring.

3.0 SAR INFORMATION AND COMPUTATION

3.1 Average Tissue Properties

The tissue properties used for SAR analysis are listed in the FCC OET Bulletin 65 Supplement C, Appendix C (Tissue Dielectric Property Data). The average tissue properties for brain, skull and muscle are shown in Table I.

TABLE I			
Tissue Dielectric Property Data for 915 MHz			
	ϵ_r	σ [S/m]	ρ [kg/m ³]
Brain	45.7	0.77	1030
Skull	16.6	0.24	1850
Muscle	55.9	.98	1040

3.2 Specific Absorption Rate (SAR) Limits

The FCC limits for specific absorption rate (SAR) are listed in the FCC OET Bulletin 65 Supplement C, Appendix A (FCC Exposure Criteria). The limit category used for the RSS is for General Population/Uncontrolled Exposure. Although the wireless nature of the system is understood by the users, the uncontrolled exposure limit is used because exposure control may be limited in this application. The FCC SAR limits fall under three categories. These categories include Whole-Body, Partial-Body, Hands, Wrists, Feet, and Ankle exposure. These limits are shown in Table II.

TABLE II		
FCC Limits for Specific Absorption Rate (SAR)		
General Population/Uncontrolled Exposure [W/kg]		
Whole-Body	Partial-Body	Hands, Wrists, Feet and Ankles
0.08	1.6	4.0

3.3 Computation Uncertainty

Computational uncertainty exists in various forms for each of the three categories of General Population/Uncontrolled Exposure. Human interaction with the transmitting device occurs by hand operated key entry. The nearest key entry is 0.868 inches from the transmitting device (antenna). The antenna is a surface mount planar patch located inside the unit. As a result, the closest point a hand can physically get to the antenna is 0.342 inches. The field strength at this distance is the value used to calculate the SAR level for hands, wrists, feet, and ankles.

Considering that the unit may be picked up and placed on any part of the body, the same distance value used for hands, wrists, feet, and ankles is used to calculate the SAR level for partial-body exposure.

Whole-body exposure analysis involves the field strength applied throughout the entire body. These field strength levels are used to calculate the specific absorption rate level which is averaged over the entire body. The closest point between an average person sitting in a desk and the remote unit sitting on the desk is the distance used to calculate the SAR level for whole-body exposure. The calculations made to analyze the specific absorption rate are simplified by taking the point of maximum exposure and using the results as the overall average for whole-body exposure. This method of analyzing the whole-body exposure level for the RSS clearly yields computed SAR levels that exceed the actual conditions.

Consideration for worst case scenarios in system configuration are used wherever computational uncertainty exists. In every calculation made involving the specific absorption rate analysis where unknown conditions or variables exist a worst case scenario is used to derive SAR levels.

3.4 Equations

- $L[dB] = 10 \log \left[\left(\frac{\lambda}{4\pi d} \right)^2 \right],$ Free Space Loss,
where λ is the operating wavelength,
and d is the distance from the power source.
- $P_s[dBm] = S_A[dB\mu V] - 77,$ Source Power,
where S_A is the signal amplitude from FCC testing.
- $E \left[\frac{V}{m} \right] = \frac{\sqrt{30P_s}}{d},$ RMS Electric Field Strength,
where P_s is the linear source power in watts,
and d is the distance from the source.
- $SAR \left[\frac{W}{kg} \right] = \frac{|E|^2 \sigma}{\rho},$ Specific Absorption Rate,
where E is the computed RMS electric field strength,
 σ is the tissue conductivity,
and ρ is the tissue mass density.

The source power (P_s) is calculated by using the highest dB μ V value measured during FCC Part 15 testing. The test is performed at a distance of three meters. However, the recorded data is an extrapolation of the point source power from the measured field strength at three meters.

Measured signal amplitude: $S_A = 68.77$ dB μ V

Source power: $P_s = -8.23$ dBm (0.1503 mW)

4.0 SPECIFIC ABSORPTION RATE (SAR) CALCULATED RESULTS

4.1 Whole-Body Exposure

The “Whole-Body” exposure variables are as follows:

$d = 7$ [in] (0.1778 m), nearest distance to body.

$E = 0.378$ [V/m], electric field strength at distance evaluated.

$\sigma = 0.98$ [S/m], muscle tissue conductivity.

$\rho = 1040$ [kg/m³], muscle tissue mass density.

Muscle makes up the majority of the tissue represented in the whole-body exposure analysis. Additionally, muscle tissue properties represent the maximum specific absorption rate calculated for the human body (see Table I and Paragraph 3.3 Equations). As a result, muscle tissue properties are used exclusively in the SAR Whole-Body Analysis. Using these values, the specific absorption rate can be calculated at the point designated by the distance as:

$$\text{SAR} = 0.000134 \text{ [W/kg]}$$

The specific absorption rate (SAR) limit set by the FCC is 0.08 [W/kg] for whole-body exposure as indicated in Table II. The SAR level calculated is significantly lower than the limit set by the FCC. Considering a worst case scenario - if all 31 transmitting devices were placed on the desk of a single user while the RSS was in operation, the calculated whole-body SAR level would be 0.00417 [W/kg]. Again, this calculated level is significantly lower than the limit set by the FCC for whole-body exposure.

This analysis shows that the RSS operating under the worst possible conditions for RF exposure to the human body as categorized for "General Population/Uncontrolled Whole-Body Exposure" is within specific absorption rate limits set by the FCC.

4.2 Partial-Body Exposure

The "Partial-Body" exposure variables are as follows:

$d = 0.342 \text{ [in]} (0.00867 \text{ m})$, nearest distance to body.

$E = 7.745 \text{ [V/m]}$, electric field strength at distance evaluated.

$\sigma = 0.98 \text{ [S/m]}$, muscle tissue conductivity.

$\rho = 1040 \text{ [kg/m}^3\text{]}$, muscle tissue mass density.

Various tissue types may be used in the partial-body analysis. As a result, muscle tissue properties are used in the SAR Partial-Body Analysis because they represent the maximum specific absorption rate calculated for the human body (see Table I and Paragraph 3.3 Equations). Using these values, the specific absorption rate can be calculated at the point designated by the distance as:

$$\text{SAR} = 0.05653 \text{ [W/kg]}$$

The specific absorption rate (SAR) limit set by the FCC is 1.6 [W/kg] for partial-body exposure as indicated in Table II. The SAR level calculated is significantly lower than the limit set by the FCC.

This analysis shows that the RSS operating under the worst possible conditions for RF exposure to the human body as categorized for “General Population/Uncontrolled Partial-Body Exposure” is within specific absorption rate limits set by the FCC.

4.3 Hands, Wrists, Feet and Ankles

The “Hands, Wrists, Feet and Ankles” exposure variables are as follows:

$d = 0.342$ [in] (0.00867 m), nearest distance to body.

$E = 7.745$ [V/m], electric field strength at distance evaluated.

$\sigma = 0.98$ [S/m], muscle tissue conductivity.

$\rho = 1040$ [kg/m³], muscle tissue mass density.

Human interaction with the transmitting device occurs by hand operated key entry. The unit may also be operated as a handheld device. As a result, muscle tissue properties are used in the SAR Hands, Wrists, Feet and Ankles Analysis. Additionally, muscle tissue properties represent the maximum specific absorption rate calculated for the human body (see Table I and Paragraph 3.3 Equations). Using these values, the specific absorption rate can be calculated at the point designated by the distance as:

$$SAR = 0.05653 \text{ [W/kg]}$$

The specific absorption rate (SAR) limit set by the FCC is 4 [W/kg] for hand exposure as indicated in Table II. The SAR level calculated is significantly lower than the limit set by the FCC. The distance used in the calculation for SAR level is indicative to the worst case conditions while the RSS is in operation.

This analysis shows that the RSS operating under the worst possible conditions for RF exposure to the human body as categorized for “General Population/Uncontrolled Hands, Wrists, Feet and Ankles Exposure” is within specific absorption rate limits set by the FCC.

