QSEC 800

SPECIFIC ABSORPTION RATE (SAR)

REPORT

Prepared By: ________________ ***Date:*** __________

John Forrester
Engineer

Approved By: ________________ ***Date:*** ___________

Paul Guckian
Director
Regulatory Group

CONTENTS

1 INTRODUCTION

This test report describes an environmental evaluation measurement of specific absorption rate (SAR) distribution in simulated human head tissues exposed to radio frequency (RF) radiation from a wireless portable device manufactured by QUALCOMM Inc. These measurements were performed for compliance with the rules and regulations of the U.S. Federal Communications Commission (FCC). The testing was performed on the 19th of May 2000 and the 23rd of June 2000 in the QUALCOMM SAR Test Facility. The wireless device is described as follows;

EUT Type:	*CDMA/Analog Cellular Phone*
Trade Name:	*QUALCOMM Inc.*
Model:	*QSEC 800*
FCC Identifier:	*J9CQSEC800*
Tx Frequency:	*824 - 849 MHz*
Rx Frequency:	*869 - 894 MHz*
Max. Output Power:	*29.2 dBm EIRP OR 27 dBm ERP*
Modulation:	*CDMA OR FM AMPS*
Antenna:	*Helical Stub antenna*
FCC Classification:	*Non-Broadcast Transmitter Held to Ear*
Application Type:	*Certification*
Serial Number:	*46*
Place of Test:	*Qualcomm Inc., San Diego, CA, USA*
Date of Test:	*June 26, 2000*
FCC Rule Part:	*1.1310, 2.1093; ET Docket 96.326*

2 SAR TEST FACILITY

SAR tests were performed in the Qualcomm SAR Test Facility located at the following address:

Qualcomm
Building AA.
10290 Campus Point Drive.
San Diego, CA 92121

3 APPLICABLE REGULATIONS

The QSEC 800 is designed to comply with the specific absorption rate SAR limits for distances within 20 cm of the transmitting elements of the MES, and with general public uncontrolled environment Maximum Permissible Exposure (MPE) limits at distances greater than 20 cm from the transmitting elements of the device, as required by Sections 1.1307 through 1.1310, 2.1091 and 2.1093 of the 47 C.F.R. (1997). These FCC RF safety limits, which are based on a hybrid combination of the SAR and MPE requirements from ANSI/IEEE C95.1-1992 and the National Council on Radiation Protection and Measurements (NCRP) report no. 86, are also consistent with the RF safety limits defined in the IRPA Guidelines on Protection Against Non-Ionizing Radiation which are reportedly in the process of being adopted in Europe, as codified in European Pre-Standard ENV 59166-2 approved by CENELEC (1994). This test report pertains specifically to the following limit from the Code of Federal Regulations 47:

> "Limits for General Population/Uncontrolled exposure: 0.08 W/kg as averaged over the whole-body and spatial peak SAR not exceeding 1.6 W/kg as averaged over any 1 gram of tissue (defined as a tissue volume in the shape of a cube). Exceptions are the hands, wrists, feet and ankles where the spatial peak SAR shall not exceed 4 W/kg, as averaged over any 10 grams of tissue (defined as a tissue volume in the shape of a cube)."

4 SAR TEST RESULTS SUMMARY

This device has been tested for localised specific absorption rate (SAR) for uncontrolled environment/general population exposure limits specified in ANSI/IEEE Std. C95.1 ~ 1992, and has been tested in accordance with the measurement procedures specified in ANSI/IEEE Std. C95.3 ~ 1992. Normal antenna operating positions were incorporated, with the device transmitting at frequencies consistent with normal usage of the device. The device has been shown to be capable of compliance for localised specific absorption rate (SAR) for uncontrolled environment/general population exposure limits specified in ANSI/IEEE std. C95.1-1992

5 TECHNICAL DESCRIPTION

The QSEC 800 is a dual mode CDMA/analog cellular mode. The CDMA mode is designed to transmit in the 824.04 – 848.97 MHz band at a maximum transmitter output power of 25 dBm conducted power with a peak antenna gain of 2.2 dBi, or a maximum EIRP of 27.2 dBm (25.0 dBm ERP). The cellular FM AMPS mode is designed to transmit in the 824.04 – 848.97 MHz band at a maximum output power of 27.0 dBm conducted power as measured at the antenna connector. With a peak antenna gain of 2.2 dBi, the maximum EIRP is 29.2 dBm (27.0 dBm ERP).

The QSEC 800 incorporates a stub helical antenna. The antenna cannot be extended or retracted, thus there is only one antenna position to be tested.

The QSEC 800 is also designed for “push-to-talk” (PTT) use. In this mode, the phone is held in front of the head and a button is pushed for continuous transmission. When the button is released, the phone operates in standard receive mode. The QSEC 800 was tested with a measured distance of 0.25 inches between the front of the phone and the flat phantom of the DASY3 test system. In order to ensure complete compliance with RF safety requirements, the user manual directs the user to hold the phone at least 1 inch from the face. This use of operation information is found in both the “Safety” and “Push-To-Talk” sections of the user manual.

The QSEC 800 can also be used with Qualcomm recommended accessories. A normal mode of operation for this phone would be with the use of the headset adapter (also called surveillance kit) and a belt clip. In this configuration, the phone would be connected to the user's belt, and the headset would be placed in the user's ear with the mouthpiece connected to the user's shirt. To verify compliance with RF safety guidelines, the unit was tested on the flat phantom with the belt clip and headset attached. The headset was connected to the ear and the cable routed along the flat phantom. In the "Safety" section of the user manual, there is also a statement warning to the user to keep the antenna at least 1 inch from the body whenever the phone is transmitting.

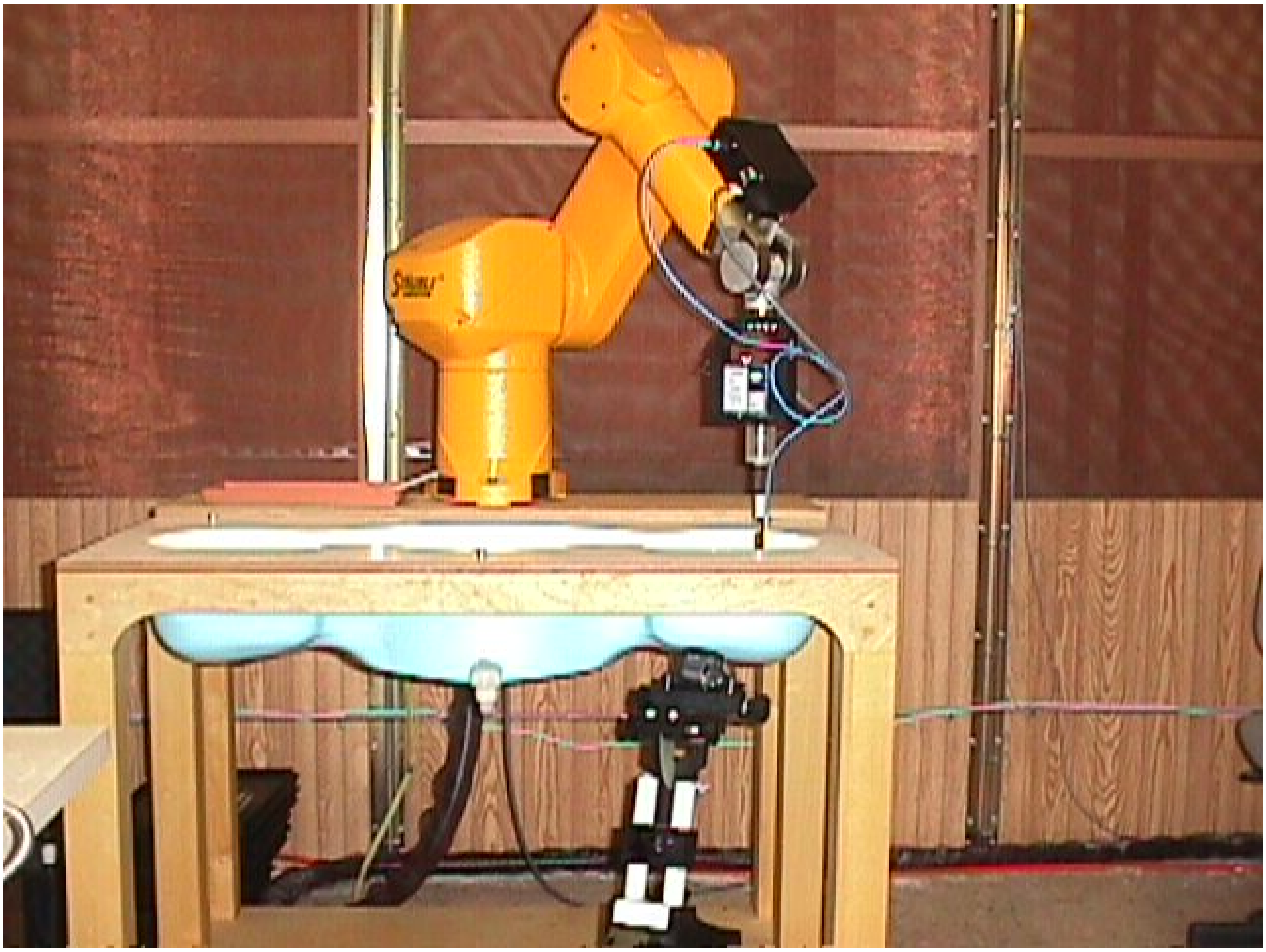
The QSEC 800 will also be marketed with an extended life external battery. The standard battery pack was established as the worst case SAR configuration due to the smaller size, so all SAR testing was done using a standard battery pack.

5.1 DESCRIPTION OF QUALCOMM SAR TEST FACILITY

All tests were performed under the following environmental conditions:

Temperature Range:	15 - 35 Degrees C	(Actual 20 C)
Humidity Range:	25 - 75 %	(Actual 38 %)
Pressure:	860 - 1060 mbar	(Actual 1015 mB)

The SAR tests were performed using the following facilities:



All Qualcomm dosimetry equipment is operated within a shielded screen room manufactured by Lindgren RF Enclosures to provide isolation from external EM fields. The E-field probes of the DASY3 system are capable of detecting signals as low as 5μW/g in the liquid dielectric, and so external fields are minimised by the screen room, leaving the phone as the dominate radiation source. The floor of the screen room is reflective, so four two-foot square ferrite panels are placed beneath the phantom area of the DASY system to minimise reflected energy that would otherwise re-enter the phantom and combine constructively or destructively with the desired fields. These ferrite panels provide roughly 12 to 13 dB of attenuation in the frequency range of 900 MHz, and 7 to 8 dB of attenuation in the frequency range of 1.9 GHz. Space beneath the DASY3 system limits the absorber type to ferrite tiles, although this attenuation combined with scattering of the energy is sufficient to bring the system validation within the acceptable tolerance.

DOSIMETRY SYSTEM The dosimetry equipment consists of a complete dasy3 v1.0 dosimetry system manufactured and calibrated by Schmid & Partner engineering ag of Zurich, Switzerland, it is currently a state of the art system and from our research, it appears to be the best available at this time. The dasy3 system consists of a six axis robot, a robot controller, a teach pendant, automation software on a pentium 200 MHz computer, data acquisition system, isotropic e-field

E-FIELD PROBE This test was performed using an E-field probe with conversion factors determined by Schmid & Partner (s & p). The probe is the most important part of the system, so will be discussed in section 5.2.

Phantom The phantom was the so called “generic phantom” supplied by S & P, and consists of a left and right side head for simulating phone usage on both sides of the head. The phantom is constructed of fibreglass with 2 +/- 0.1 mm shell thickness. The shape of the shell is based on data from an anatomical study of a group of 33 men and 19 women to determine the maximum exposure in approximately 90% of all users. The Dasy system uses a homogeneous tissue phantom based on studies concerning energy absorption of the human head, and the different absorption rates between adults and children. These studies indicated that a homogeneous phantom should overestimate SAR by no more than 15% for 1 g averages and should not underestimate SAR. In similar studies, it was found that a typical ear thickness is approximately 4 mm, so a 2 mm rubber ring is attached to the phantom at the ear area. The combined total thickness is close to 4 mm.

LIQUID DIELECTRIC The tissue simulating liquid which fills the phantom is supplied by Schmid & partner. There are two separate formulas for the two frequencies 900 MHz and 1800 MHz. This is necessary because the water molecules raise the conductivity to approximately 1.65 +/- 10% at the 1800 MHz frequency, without the addition of salt, so no salt is needed. Before testing, the permittivity and conductivity were measured with an automated Hewlett Packard 85070b dielectric probe in conjunction with a HP 8752c network analyser to monitor permittivity change due to evaporation. The electromagnetic parameters of the liquid were maintained as shown in Table 1. The conductivity of average muscle tissue for 900 MHz is 0.969 S/m according to the data from the FCC web page for tissue dielectric properties with internet address www.fcc.gov/fcc-bin/dilec.sh.

Frequency	Permittivity	Conductivity	Density
900 MHz	41.5 +/- 5%	1.2 +/- 10% mho/m	1 g/cm^3
900 MHz Muscle	55.95 +/- 5%	0.969 +/- 10% mho/m	1 g/cm^3
1800 MHz	42.0 +/- 5%	1.65 +/- 10% mho/m	1 g/cm^3

Table 1

Schmid & partner have supplied us with data that can be used to show the error in SAR caused by using higher conductivity. In general higher conductivity, *over estimates* measured SAR values. This data is provided Table 2.

Distance of radiator from liquid surface	Frequency MHz	*Avg. Volume gram*	*% Increase of SAR per % increase in conductivity*	*Relative. Permittivity*	*Conductivity of liquid s/m*	*Density of liquid g/cm^3*
10 mm	900	1	+ 0 .62	41.5	0.85	1
10 mm	900	10	+ 0.39	41.5	0.85	1
15 mm	900	1	+ 0.63	41.5	0.85	1
15 mm	900	10	+ 0.39	41.5	0.85	1
30 mm	900	1	+0.63	41.5	0.85	1
30 mm	900	10	+0.39	41.5	0.85	1
10 mm	1500	1	+ 0.55	40.5	1.2	1
10 mm	1500	10	+ 0.27	40.5	1.2	1
15 mm	1500	1	+ 0.55	40.5	1.2	1
15 mm	1500	10	+ 0.27	40.5	1.2	1
30 mm	1500	1	+ 0.54	40.5	1.2	1
30 mm	1500	10	+ 0.26	40.5	1.2	1
10 mm	1800	1	+ 0.43	40.0	1.65	1
10 mm	1800	10	+ 0.13	40.0	1.65	1
15 mm	1800	1	+0. 42	40.0	1.65	1
15 mm	1800	10	+ 0.13	40.0	1.65	1
30 mm	1800	1	+ 0.41	40.0	1.65	1
30 mm	1800	10	+ 0.12	40.0	1.65	1

Table 2

The e-field probe is calibrated by the manufacturer in brain simulating tissue at frequencies of 900 MHz, and 1.8 GHz, accurate to +/- 8%. Linearity is said by the manufacturer to be +/- .2 dB from 30 MHz to 3 GHz. Dynamic range is said by the manufacturer to be 5 µw/gm to > 100 mw/g. The probe contains 3 small dipoles positioned symmetrically on a triangular core to provide for isotropic detection of the field. Each dipole contains a diode at the feed point that converts the RF signal to dc, which is conducted down a high impedance line to the data acquisition system.

The data acquisition system amplifies the signals, and converts them to digital values so they may be sent to the computer. The inputs to the signal amplifiers are auto zeroed after every measurement to prevent charge build up on the lines, which could lead to errors.

5.2 SAR SYSTEM THEORY

The human body absorbs energy from a radiating cell phone by ionic motion and oscillation of polar molecules. The human head is in the near field of the device where polarisation and field intensity are very complex. Also the human head can cause large reflections and scattering, so it is more practical to measure the field absorbed inside the head, than to measure incident power before it enters the head. Inside the lossy brain tissue, the power per unit volume is given by

$$P_v = \tfrac{1}{2}\ j \bullet e^* = \tfrac{1}{2}\ \sigma\ |E|^2 \quad \text{W/m}^3$$

Where j is current density

σ is conductivity of human tissue due to conductive and lossy displacement currents.

E is the electric field

But since SAR is the absorption of RF power per unit mass

$$P_g = \tfrac{1}{2}\ \sigma/p\ |E|^2\ \text{w/kg}$$

Where p is density of the tissue in kilograms per cubic meter.

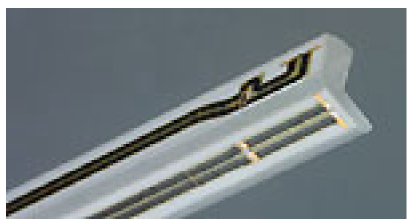
In this equation, σ is a function of frequency, and so it must be measured at the frequency of the test. It is measured in terms of the real and imaginary components of the complex permittivity;

$$\varepsilon = \varepsilon_0\ (\varepsilon' - j\varepsilon'')$$

$$\sigma = 2\pi f \times (8.854 \times 10^{-12}) \times \varepsilon''$$

Loss tangent $\equiv \tan\delta = \varepsilon''/\varepsilon'$

In order to measure the e field strength without distorting the field, the e field probe (shown here) is made as described by Schmid, Egger, and Kuster in [3].



E-field probe

A major concern is that secondary coupling of the EUT radiated fields to the feed lines of the probe are minimised. This is done by making the feed lines of high impedance “twin-line” transmission line, printed very close together. In the probe tip there are three orthogonal dipoles, electrically small to minimise field distortion from coupling. The electrically small dipoles have source impedance’s of 5 to 8 mΩ due to their small size, the high resistive feed lines, and the distributed filters on the lines. This high impedance makes them less sensitive so a sophisticated data acquisition electronics (DAE) box is needed to amplify, multiplex, and digitize the signals. The dae is installed on top of the robot arm. It also detects the proximity of the phantom surface with a fiber-optic cable. It provides for multiplexing between the three dipoles, and between 1x gain and 100x amplification, and it provides some filtering that will remove unwanted signals picked up by the probe. The DAE also provides a fast digital link to the robot for stopping in the event of a touch detection. It samples the probe output for 2600 complete e field measurements per dipole, per second. These samples are used to determine the amplification needed, 1x or 100x, and the magnitude determines what diode compression correction factor should be used. These factors as well as sensitivity factors of the specific probe, which are stored in the program, are used to determine the actual field strength for the test point.

The substrate on which the dipoles are printed, has been shaped to align each dipole with the e-field *after* the field lines are distorted by the permittivity of the substrate. In other words, since the substrate and the liquid dielectric have different permitivities, the e-field will diffract as it passes through the interface. To account for this, the dipoles have been positioned to align with the fields *after* this distortion is accounted for.

The dipole elements in the probe are offset from the tip of the probe approximately 2.7 mm so unfortunately the field strength cannot be measured at the surface of the phantom, where it is likely to be maximum. The magnitude of the field at the surface must therefore be calculated with interpolation by using the data points stepped away from the surface and curve fitting. This is done automatically by the software.

6 TEST SAMPLE OPERATION AND CALIBRATION

The wireless device was made to transmit maximum power that is allowed by the software in the device. A Tektronics CMD-80 was used to force the device to transmit maximum power for the duration of the SAR tests. The DASY 3 system checks E field strength at a fixed location before and after each scan, and checks for drift due to draining of the battery or some other effect. This shows up as “drift” on the report and if it is too high the test is repeated.

The SAR test transmit power is determined as follows; The device is placed in an anechoic chamber and the effective isotropic radiated power is measured when the device is transmitting its highest possible output power available from the power amplifier. The peak ERP is measured, at the angle of peak gain of the antenna. The conducted output power of the device is measured with an RF power meter using the RF connector on the device. The phone software is then programmed to adjust the power so that the maximum output power does not exceed 29.2 dBm EIRP.

When testing the push-to-talk feature and waist SAR, the phone was configured to transmit maximum power in the same way as head use.

7 CALIBRATION DATES OF TEST EQUIPMENT

All measurements were made with instruments whose operation and accuracy has been verified by a Calibration Laboratory with traceability to National standards. The calibration date for each measurement instrument is shown in Table 3.

EQUIPMENT MANUFACTURER & TYPE	SERIAL NO.	LAST CAL.	NEXT CAL.
Schmid & Partner Engineering AG Dosimetric E-field Probe:ET3DV5	1348	AUG 16, 1998	AUG, 1999
Schmid & Partner Engineering AG dipole	220	Jan, 1998	Jan, 2000
Schmid & Partner Engineering AG dipole validation kit : type D900V2	024	Jan, 1998	Jan, 2000
Schmid & Partner Engineering AG Data Acquisition Electronics : Model DAE3 V1	335	June 6, 1998	June 6, 2000
HP ESG-D3000A Digital Signal Generator		Aug 3, 1999	Aug 3 2000
HP 437B RF Power Meter	K59325	May 6, 2000	May 6, 2001
HP Vector Network Analyzer		Oct 10, 1999	Oct 10, 2000
HP 85070M Dielectric Probe System		Not Required	
Liquid Dielectric for 900 MHz		Replaced every 3 months	
validation kit : type D1800V2		Not Required	

Table 3

8 SAR TEST SYSTEM VALIDATION

Before the test, the system was validated using a symmetric dipole designed to be impedance matched when pressed against a machined dielectric spacer, touching the phantom filled with the brain simulating fluid (photo 5). The separation distance between the validation dipole and the flat phantom is maintained at 10 mm from dipole centre to solution surface with a machined plastic spacer, manufactured for the validation kit. The measured permittivity and conductivity was entered into the DASY settings window (there are slight variations in the permittivity from day to day due to evaporation, although water is added to minimise the variation) A signal generator and a high power amplifier were used to generate a very stable one Watt continuous wave signal, which was checked with an HP RF power meter (calibrated to 900 MHz) several times over a 30 minute period (to eliminate drift by reaching stable temperature), then input to the validation dipole. Then the DASY3 system was put through an automated validation cycle to determine if the correct SAR is measured. The correct SAR was determined by Schmid & Partner to be 39.9 mW/gm for the type D1800V2 dipole, and 9.44 mW/gm for the D900V2 dipole. These values measured indicate that the system is measuring correctly at these frequencies.

If the validation result were to give a value high or low by more than 4%, the liquid is re-measured to check for evaporation, and other parameters are checked until this validation produces the correct SAR value. Parameters frequently checked if the validation gives erroneous SAR include diode compression factors, probe conversion factors, frequency settings for the probe, frequency, permittivity, and conductivity settings for the liquid. Placement of ferrite panels beneath phantom, drift in the signal generator, power meter calibration settings, stirring of the liquid dielectric, or the teaching of the robot the exact location of the phantom. This is the main validation test for the system configuration.

Over a period of several days, the robot loses the exact position of the phantom, this information is stored in memory and must be “re-taught” to the system. Before each day of measuring begins, the robot is sent to three test points on the phantom to determine if the exact position information has been lost. If so, the robot is manually sent to these three points and the computer is told to record the information from position sensors in the robot joints. This insures that the system can place the probe as close as possible to the phantom surface.

SAR SYSTEM SPECIFICATIONS

Data Acquisition

Processor:	Pentium 200 MHz
Operating Sys:	Windows 995
Software:	DASY3 V1.0b Dec 97 edition, Schmid & Partners Eng. AG, Switzerland
Amplifier Gain:	10X or 100X depending on signal level
Surface Detection:	Optical and Mechanical
Sample Rate:	7800 data sets per second
Isolation:	Fiber Optics to computer, 100KΩ/m to probe tip

E-Field Probe

Offset tip to sensor center:	2.7 mm
Offset surface to probe tip:	1.8 +/- 0.2
Frequency:	30 MHz to 3.0 GHz
Dynamic Range:	5μW/g to 100 mW/g
Isotropy:	+/- .15 dB (in brain liquid)

Phantom

Dielectric:	Homogeneous sugar/salt/cellulose liquid
Shell	2 mm +/- 0.2 mm polyester fiber glass
Ear:	2 mm rubber ring

Liquid Dielectric

Permittivity:	42.5 @ 900 MHz for brain tissue, 56.1 @ 900 for muscle tissue
Conductivity:	0.85 S/m @ 900 MHz brain tissue, 0.95 S/m @ 900 for muscle tissue

9 SAR MEASUREMENT PROCEDURE

POWER LEVELS After calibration/validation of the SAR system, the test of the QSEC 800 proceeds as follows.

The QSEC 800 cellular phone transmits at a peak Effective Isotropic Radiated Power of 29.2 dBm EIRP (27 dBm ERP). The antenna was measured in an anechoic chamber and was found to have a directive gain of 2.2 dBi. The power setting was verified by measuring the conducted power at the antenna port coaxial connector and by measuring the effective isotropic radiated power.

PEAK EFFECTIVE ISOTROPIC RADIATED POWER =	**29.2 dBm EIRP**
ANTENNA GAIN (dBi) =	**2.2 dBi**
POWER REQUIRED =	**27.0 dBm (conducted)**
POWER SETTINGS USED FOR SAR MEASUREMENT =	**27.2 dBm @ 824 MHz** **27.0 dBm @ 836 MHz** **27.3 dBm @ 848 MHz**

POWER VERIFICATION The QSEC 800 radiates through a stub helical antenna. A flexible coaxial cable connects the antenna to the RF circuitry board. A directional coupler is connected to a CMD80, and then to the RF coaxial port of the board via a calibrated coaxial cable. An HP 437B RF power meter is then connected to the –10dB coupling port of the directional coupler. The CMD80 is used to initiated an FM call and set the phone to transmit at maximum output power. The power is then measured through a directional coupler. The power level is entered in the comment section of the DASY system test file, so that it is printed on the SAR graphic plot included in this report.

COARSE GRID The 5 x 5 x 7 point fine scan that the DASY system measures over the “hot spot” generally follows the position of the antenna from the top of the head to the back of the head as it is rotated. Because of this, the coarse grid setting is adjusted to cover the entire head (left or right) so that there is no chance of the “hot spot” falling outside of the coarse scan. The resolution of the course scan was Dx = 20 mm, Dy = 20 mm, and Dz = 10 mm.

DEVICE POSITIONING The phone was tested in several positions, but the primary test position was that described by Supplement C of OET Bulletin 65 from the Office of Engineering & Technology, of the FCC.

CREST FACTOR To compensate for probe diode compression with strong signals, the DASY3 system software utilises the crest factor (the ratio of peak to RMS signal level) of the measured waveform to scale a second order correction term in the output voltage from the probes. The correction factor is applied using the following built-in equation to each (x, y, z) probe channel:

Channel signal voltage = input signal + [(input signal)^2 * crest factor / diode compression point]

Both the crest factor and the diode compression point are DASY3 system input parameters; the latter probe specific, the former waveform specific. For small measured signals, the crest factor selected is immaterial, but the system requires that one be specified. For a TDMA waveform, the crest factor is simply the inverse of the duty cycle (a factor of 8 for GSM signals). For CDMA waveforms, the crest factor is difficult to predict and must be measured; the CDMA waveform crest factor is 1. This Crest factor was measured using a Gigatronics 8542 C Power meter with a power sensor model 80601 A.

CUBE EVALUATION The explanation of the fine scan, or cube evaluation is given in the manual for the DASY system by Schmid & Partners, and is repeated here.

> The spatial peak SAR value for 1 and 10 g is evaluated after the cube measurements have been done. The algorithm that finds the maximal averaged volume is divided into three different stages.
>
> (1)The data between the dipole center of the probe and the surface of the phantom is extrapolated. This data cannot be measured because the dipoles are 2.7 mm away from the actual tip of the E-field dosimetry probe. The distance between the surface and the lowest measuring point is approximately 1 mm, so they can never be placed in the field at the surface of the phantom. The extrapolation is based on a least square algorithm [W. Gander, Computerm athematik, p. 168 – 180]. Through the points in all z-axis polynomials of order four are calculated. This polynomial is then used to

evaluate the points between the surface and the probe tip. The points calculated from the surface, have a distance of 1 mm from one another.

(2)The maximal interpolated value is searched with a 3d-spline. The 3d-spline is composed of three one-dimensional splines with the “Not a knot” condition [W.Gander, Computermathematik, p.141 – 150] (x, y, and z direction) [Numerical Recipes in C, Second Edition, p.123ff]. Around this maximum, the SAR values averaged over the spatial volumes (1g or 10g) are computed using the 3d spline interpolation algorithm. If the volume cannot be evaluated (i.e., if part of the grid was cut off by the boundary of the measurement area) the evaluation will be started on the corners of the bottom plane of the cube.

(3) All neighboring volumes are evaluated until no neighboring volume with a higher average value is found. For the volume, averaging the size of the cube is first calculated. The volume is then integrated with the trapezoidal logarithm. 1000 points (10 x 10 x 10) are interpolated to calculate the average.

Typically, the maximum SAR values occur on the outer boundary of the liquid nearest the radiation source, at the fluid-phantom shell interface. The extrapolation of this maximum will indicate that the maximum is outside of the measurable area. When this occurs the DASY system writes the comment “maximum outside” on the SAR plots. This is not an indication of a bad measurement, but indicates that the maximum was extrapolated since it was physically impossible to measure.

10 SAR MEASUREMENT UNCERTAINTY

The possible errors included in this measurement arise from device positioning uncertainty, device manufacturing uncertainty, liquid dielectric permittivity uncertainty, liquid dielectric conductivity uncertainty, uncertainty due to disturbance of the fields by the probe.
These will be discussed as they are of much importance to the final dosimetric assessment. Every attempt is made to reduce uncertainty, as well as to test for worst case SAR. These uncertainties are likely to be pessimistic, but they should be considered when comparing data taken from one lab to another. Thomas Schmid of Schmid and Partners has performed a study of SAR repeatability due to many different uncertainties, this is likely the most complete study of the topic so it is referred to here.

Device positioning; this uncertainty is due to different operators positioning the device on the phantom differently, it depends on the operators, the device design, the phantom, and the device holder. Repeatability for some devices in Schmid’s study was as poor as +/- 30% for the “touch” position. For the “intended use” position the repeatability was approximately

+/- 5%, depending on the device tested, overall a figure of +/- 6% was taken as typical device positioning uncertainty. One operator is used at the QUALCOMM lab, trained to place the phone as close as possible to phantom, and the test is performed after the position of maximum SAR is determined. This minimises device positioning error. Typically, the phone is clamped in the holder in the horizontal position, and a short wooden dowel is placed in a small hole where the center of the ear speaker resides. This wooden dowel allows the operator to line up the speaker with the ear canal. Once aligned, the toothpick is removed, and the phone is raised up until it touches the phantom on the ear. Then the cradle is rocked so the phone rocks toward the chin of the phantom, touching as closely as possible without depressing the keypad. This puts the phone as close as possible to the phantom, allowing maximum SAR to be measured. In the event that this may not produce maximum SAR, the phone is placed in several other positions and a coarse scan is run for each position. The DASY system has a command called “move to max” which allows the probe to be sent to the point of max field intensity found with the coarse scan. This gives a visual indication of where the maximum surface currents may be, and allows the operator to position this point of the phone as close as possible to the phantom.

To simulate hip SAR when the phone is used with a belt clip adapter, DASY3’s flat phantom is used. The belt clip is installed on the phone as per the belt clip instructions. The phone is placed face down and clamped into the test fixture. The phone is then raised until the belt clip makes contact with the phantom. The fixture is then rotated until the bottom of the phone makes contact with the phantom. Since normal use with a belt clip includes the use of a headset, the headset is connected to the phone. The headset earpiece is taped to the phantom ear, and the microphone is attached to an area of the phantom indicative of the chest. The extra headset cable is then taped along the phantom to represent the cable hanging on an upright user.

To simulate the push-to-talk mode of operation, DASY3’s flat phantom is used. The phone is clamped face-up into the test fixture. A distance of 0.25 inches distance is measured between the face of the phone and the phantom. This distance is measured at two locations: the very top of the phone and at the very bottom of the phone.

Liquid dielectric permittivity and conductivity; The average permittivity of a typical human head was determined by Dr. Gabriel and has been listed by the FCC (OET bulletin 65 supplement C) as 46.1 at 835 MHz and 43.4 at 1800 MHz. The lower permittivity generally gives a slightly higher SAR value, so these values were used for the test. Since SAR is defined as the time rate of absorption per unit of weight, only the macroscopic simulation of the tissue’s permittivity, permeability, and conductivity are required. These electrical properties are obtained with a liquid that uses sugar to raise the permittivity, salt to raise the conductivity, and cellulose to hold the two in suspension. The QUALCOMM lab purchases the dielectric from Schmid and Partners so that maximum accuracy of permittivity and conductivity is insured, by eliminating any possibility of liquid preparation errors, i.e. lumps in cellulose, excess viscosity causing excess bubbles, etc After receiving the liquid it is measured with an HP 85070A dielectric probe kit. The achievable accuracy of this device is +/- 5% for the permittivity and +/- 10% for the conductivity. The permittivity and conductivity match with those claimed by Schmid & Partners. The liquid is also measured at the beginning of each SAR measurement day, to check for evaporation.

FIELD DISTURBANCES Errors due to disturbance of the fields by the probe; because the polarizations of the fields are unknown, the near field probe must measure all polarizations without disturbing them by being present.   Three orthogonal dipoles are located at the tip of a special dielectric support, with diodes at the feed points sensitive to fields as small as 5 microWatt/gram. To prevent secondary coupling of the fields to the feed lines, the lines are high resistance printed lines with distributed filters integrated in the lines, after the diode. Much research has been put into these probe designs, so their uncertainty is considered minimized. There are other uncertainties, such as laboratory set-up uncertainty, the reader should refer to attachment 10 of the March 1998 minutes of the IEEE standards coordinating committee, by Thomas Schmid. Mr. Schmid's preliminary uncertainty figure is –12% to +52% for the SAR measurement. As stated before this is possible, but believed to be pessimistic because many of the sources of uncertainty have been reduced or eliminated, at considerable expense. All practical precautionary measures are taken to reduce these errors in the QUALCOMM Inc. SAR lab.

Surface Detection The surface detection on the DASY system is mechanical and optical, it is checked and compared automatically to ensure correct operation. This can indicate that the optical surface detection is not in agreement with the mechanical, which might mean the liquid needs to be stirred. This process insures minimum distance from the surface of the phantom for measurements.

11 TEST DATA SUMMARY

The SAR values measured indicate that the device produces SAR levels below the limit of 1.6 mW/g averaged over 1 gram. The data represents the phone tested in the normal head position, in the push-to-talk position, in the waist position with brain dielectric, and in the waist position with muscle tissue dielectric.

Measured 900 MHz Brain Dielectric 5/19/00

TEMPERATURE (°C)	20 C
RELATIVE HUMIDITY	38%
Atmospheric PRESSURE	1015 mB

Mixture Type:	Water/Sugar/cellulose
Dielectric Constant:	43.4
Conductivity:	0.85 +/- 10% mho/m
Closest Distance between E-Probe & Phone Antenna:	1.85 Inch (intended use position)

Measured 900 MHz Brain Dielectric 6/19/00

TEMPERATURE (°C)	20 C
RELATIVE HUMIDITY	38%
Atmospheric PRESSURE	1015 mB

Mixture Type:	Water/Sugar/cellulose
Dielectric Constant:	41.6
Conductivity:	0.85 +/- 10% mho/m
Closest Distance between E-Probe & Phone Antenna:	1.85 Inch (intended use position)

Measured 900 MHz Muscle Dielectric 6/19/00

TEMPERATURE (°C)	20 C
RELATIVE HUMIDITY	38%
Atmospheric PRESSURE	1015 mB

Mixture Type:	Water/Sugar/cellulose
Dielectric Constant:	55.1
Conductivity:	0.93 +/- 10% mho/m
Closest Distance between E-Probe & Phone Antenna:	1.85 Inch (intended use position)

ANSI/IEEE C95.1 1992 – SAFETY LIMIT Spatial Peak (Brain) Uncontrolled Exposure/General Population	1.6 W/kg (mW/g)

Frequency (MHz)	Channel	Conducted Power (dBm)	Position	Dielectric	1 Gram Avg. SAR (mW/g)
824.04	991	27.2	Left Head	900 MHz Brain	1.43
836.49	383	27	Left Head	900 MHz Brain	1.03
848.97	799	27.3	Left Head	900 MHz Brain	1.04
824.04	991	27.2	Right Head	900 MHz Brain	1.43
836.49	383	27	Right Head	900 MHz Brain	0.935
848.97	799	27.3	Right Head	900 MHz Brain	0.907
824.04	991	27.2	Waist	900 MHz Brain	0.530
836.49	383	27	Waist	900 MHz Brain	0.461
848.97	799	27.3	Waist	900 MHz Brain	0.561
824.04	991	27.2	Push To Talk	900 MHz Brain	1.33
836.49	383	27	Push To Talk	900 MHz Brain	0.944
848.97	799	27.3	Push To Talk	900 MHz Brain	1.08

824.04	991	27.2	Waist	900 MHz muscle	0.230
836.49	383	27	Waist	900 MHz muscle	0.21
848.97	799	27.3	Waist	900 MHz muscle	0.293

12 REFERENCES

[1] Klaus Meier, Voker Hombach, Ralf Kastle, Roger Yew-Siow Tay, and Neils Kuster "The dependence of Electromagnetic Energy Absorption upon Human-Head Modeling at 1800 MHz" IEEE Transactions on Microwave Theory and Techniques, Vol. 45 No 11, November 1997

[2] Volker Hombach, Klaus Meier, Michael Burkhardt, Eberhard Kuhn, and Neils Kuster "The Dependence of EM Energy Absorption Upon Human Head Modeling at 900 MHz" " IEEE Transactions on Microwave Theory and Techniques, Vol. 44 No 10, October 1996

[3] Thomas Schmid, Oliver Egger, Niels Kuster "Automated E-Field Scanning System for Dosimetric Assessments" IEEE Transactions on Microwave Theory and Techniques, Vol 44, No 1, January 1996

[4] Niels Kuster, Q. Balzano, and J.C. Lin "Mobile Communications Safety" Chapman & Hall, First edition 1997

13 SAR DATA

See exhibit 11b: data-calibration info.pdf

14 VALIDATION DATA

See exhibit 11b: data-calibration info.pdf

15 DIELECTRIC MEASUREMENT DATA

See exhibit 11b: data-calibration info.pdf

16 PROBE INFORMATION

See exhibit 11b: data-calibration info.pdf

17 PHOTOGRAPHS

See exhibit 11c: sar system photos.pdf
See exhibit 11d: sar head photos.pdf
See exhibit 11e: sar waist photos.pdf
See exhibit 11f: sar ptt photos.pdf