GLOBALSTAR TRI-MODE

PORTABLE USER TERMINAL

GSP-1600

SPECIFIC ABSORPTION RATE (SAR)

TEST REPORT

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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 in the QUALCOMM SAR Test Facility. The wireless device is described as follows;

EUT Type:	Triple Mode, Satellite/CDMA Cellular/Analog Cellular Phone
Trade Name:	QUALCOMM Inc.
Model:	GSP1600
Tx Frequency :	1610 –1626.5 MHz (satellite mode), 824.04 – 848.97 MHz (terrestrial cellular mode)
Rx Frequency:	2483.5 - 2500 MHz (satellite mode), 869.01 – 893.97 MHz (terrestrial cellular mode)
Max. Output Power:	28.9 dBm ERP (satellite mode) 30.0 dBm ERP (analog cellular mode) 28.4 dBm ERP (CDMA cellular mode)
Modulation:	CDMA (satellite mode), CDMA and FMAMPS (terrestrial cellular mode)
Antenna:	Telescoping-revolving stacked quadrifilar helix for satellite mode. Retracting Whip and helix for cellular mode.
Trade Name / Model:	QUALCOMM GSP 1600
FCC Classification:	Non-Broadcast Transmitter Held to Ear
Application Type:	Certification
Serial Number :	
Place of Test:	QUALCOMM Inc., San Diego, CA, USA
Date of Test:	June 27, 1999
FCC Rule Part:	2.1093; ET Docket 96.326; part 25

2 SAR TEST FACILITY

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

Qualcomm Incorporated
Building AA.
10290 Campus Point Drive.
San Diego CA

3 APPLICABLE REGULATIONS

The Globalstar GSP 1600 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 test sample consisted of a pre-production Globalstar portable User Terminal (UT). This model will operate in Globalstar LEO satellite mode as well as CDMA and FMAMPS cellular mode. The satellite mode is designed to transmit in the 1610 – 1626.5 MHz band at a maximum transmitter output power of 28 dBm and a peak antenna gain of 3.0 dBi, or a maximum EIRP of 31 dBm or 28.9 dBm ERP. The transmitter is capable of variable rate transmission at 9600, 4800, and 2400 bps with associated changes in output power.

The GSP1600 is a Low Earth Orbiting (LEO) satellite earth station phone (photo 1 & 2). The LEO satellite mode employs a dual frequency stacked quadrifilar helix antenna that is deployed by the user by revolving out from the body of the phone and placing in one of the two clicking-retaining positions. One retaining click is felt when swinging the antenna to the left-ear position, another is felt when swinging the antenna to the right-ear position. Since either position is possible during use, both positions were tested, one position referred to as zenith because the antenna is aligned vertically, the other position referred to as horizontal because the antenna would be accidentally aligned with the horizon.

The Globalstar transmitter was controlled using an Anritsu satellite simulator. This device communicates with the GSP-1600 in the Globalstar mode and commands the GSP-1600 to transmit its maximum transmit power. For the terrestrial cellular mode a base station simulator, model CMD-80, was used. This piece of test equipment can establish a call with the cellular portion of the GSP-1600 and can send power control data to the phone commanding it to transmit maximum power, this is done using the voice MAC 0 command for analog, and the max power command for CDMA.

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 facilities shown in photo 3 .

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 DASY 3 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 DASY 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 probe, and validation kit.

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, so that combined with the 2mm fibre glass shell the 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 the test the permitivity and conductivity were measured with an automated Hewlett Packard 85070B dielectric probe in conjunction with an HP 8752C network analyser to monitor permitivity change due to evaporation. The electromagnetic parameters of the liquid were maintained as shown in table 1.

The conductivity of average brain tissue for 1620 MHz is 1.065728 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 . The conductivity measured with the HP85070M dielectric probe system at 1620 MHz is 1.44 S/m. Since the liquid for this frequency has no salt or any conductive additive (the chemical/physical properties of the water, preservative, and sugar molecules alone provide too much conductivity) it is impossible to lower the conductivity to 1.07 S/m without a new formula with different ingredients. In other words we would have to locate an ingredient to replace the sugar/water/preservative ingredients with materials providing similar density, permitivity, and optical properties (for the optical surface detection) but having lower conductivity at 1620 MHz.

It was determined that using the 1800 MHz fluid from Schmid & Partner would overestimate the SAR by a small margin, and maintain maximum confidence. Although there are formulas readily available for both 900 MHz and 1800 MHz, there are none for 1620 MHz. A formula could be developed for this band but it was decided the error in permitivity and conductivity would be minimal if the 1800 MHz formula was used. Note that it was measured at 1620 MHz and the conductivity was approximately 35% higher than the value listed at the FCC web page for 1620 MHz average brain tissue.

FREQUENCY	PERMITIVITY	CONDUCTIVITY	DENSITY
900 MHz	41.5 +/- 5%	1.2 +/- 10% mho/m	1 g/cm^3
1620 MHz	43.2 +/- 5%	1.44 +/- 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 has supplied us with the data in Table 2, below, which shows the error in SAR caused by using higher conductivity. In general, higher conductivity, ***over estimates*** measured SAR values. So by using a higher conductivity in the 1620 MHz band we were measuring SAR values higher than would exist in the human brain.

Distance of radiator from liquid surface	*Frequency MHz*	***Avg. volume gram***	***Increase of SAR per Increase in conductivity***	***Relative. permitivity***	***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

These derivatives do not include 1620 MHz but the change in SAR with respect to conductivity appears to vary slowly with frequency. Using the value for 1500 MHz at a 10 mm seperation we have as an approximation :

$$\% \text{ change in SAR} = \%\text{change in } \sigma \times 0.55 = \left\{ [1.44 - 1.06573] / 1.06573 \right\} \times 0.55 \times 100\%$$

% change in SAR = **+** 19.3%

Errors in this approximation include the frequency, distance of the currents to the surface of the phantom, and the slight difference in permitivity and conductivity of the liquid used in the S & P calculation. Actual overestimation is likely to be smaller since the factor 0.55 appears to decrease with increasing frequency, and 0.55 is the value for 1500 MHz, not 1620 MHz. 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 +/- 0.2 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 that 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

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

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

$$P_g = \frac{1}{2} \, \sigma/\rho \, |E|^2 \qquad \text{W/kg}$$

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 permitivity;

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

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

$$\textbf{Loss Tangent} \equiv \tan\delta = \varepsilon'' / \varepsilon'$$

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 permitivity of the substrate. In other words, since the substrate and the liquid dielectric have differing permitivities, the E-field will diffract as it passes through the interface, and so 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

The wireless device was made to transmit maximum power that is allowed by the software in the device. The SAR test transmit power level (which is the maximum level the software is set to allow) is determined by measuring the conducted power, and adding a safety factor for manufacturing tolerances. During the test the base station simulator was put in the "max output" mode or "voice mac 0" depending on whether the modulation was digital or analog. The Anritsu test equipment has a similar function that causes the phone to transmit maximum power. Both of these modes ensure maximum RF power is transmitted during the SAR scans by sending a digital signal telling the phone to raise the TX power level to its highest level.

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 dates for each measurement instrument is shown in the following table.

EQUIPMENT MANUFACTURER & TYPE	SERIAL NO.	LAST CAL.	NEXT CAL.
Schmid & Partner Engineering AG Dosimetric E-field Probe:ET3DV5	1348	AUG 14, 1998	AUG 14 1999
Schmid & Partner Engineering AG dipole validation kit : type D1800V2	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
Anritsu MT 8803G Globalstar User Terminal Tester	K73709	Dec 7, 1998	Dec 7, 1999
Tektronix / Rhode & Schwartz Digital Radiocommunication Tester CMD-80	826934 / 045	Sep 10, 1998	Sep 10, 1999
HP ESG-D3000A Digital Sig Gen	US37231039	Aug 3, 1999	Aug 3 2000
HP 437B RF Power Meter	3125U24489	April 17, 1999	April 17, 2000
HP Vector Network Analyzer	341OAO3621	Oct 10, 1999	Oct 10, 2000
HP 85070M Dielectric Probe System	US33020336	Not Required	
Amplifier Research High Pwr Amp		May 12, 1999	May 12, 2000
Liquid Dielectric for 900 MHz		Replaced every 3 months	Measured daily
Liquid Dielectric for 1620 MHz		Replaced every 3 months	Measured daily

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. 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 permitivity and conductivity was entered into the DASY settings window (there are slight variations in the permitivity 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 1800 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.

Since these validation dipoles are designed to validate at a specific frequency, we cannot validate the system at 1620 MHz. What is done is to validate at 1800 MHz and change the parameters of the liquid, probe, and device in the DASY software to compensate for the change in frequency. To change the conversion factors for the probe for the 1600 MHz Globalstar transmit frequency, the conversion factors for the probe are based on a linear interpolation from the conversion factors supplied for the probe at 1500 MHz and 1800MHz, which are 5.3 and 5.0 respectively. Interpolating these values gives 5.2 , the frequency response for the electric field in a TEM cell is quite flat with changing frequency. Although calibration of the probe was done at 1800 MHz and 900 MHz, the probe data indicate that the probe can be used safely at 1600 MHz with interpolated conversion factors.

If the validation result yields 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, permitivity, 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 3 test points on the phantom to determine if the exact position information has been lost. If so, the robot is sent to these three points manually 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
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/☐ 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

Permitivity	42.8 @ 900 MHz, 43.2 @ 1620 MHz
Conductivity	.82 S/m @ 900 MHz, 1.44 S/m @ 1620 MHz

9 SAR MEASUREMENT PROCEDURE

POWER LEVELS After calibration/validation of the SAR system, the test of the phone proceeds as follows. Two of 3 modes were completely tested: Globalstar LEO satellite mode (which is CDMA) and FMAMPS. The other terrestrial mode, CDMA, was tested only in the worst case antenna position at the worst case frequency, since this mode requires lower conducted power transmission at the same respective frequencies as AMPS mode.

COARSE GRID The possible locations for the Globalstar LEO satellite mode transmit antenna form a circle centred on the users ear. 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 the 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 = 15 mm, Dy = 15 mm, and Dz = 10 mm.

DEVICE POSITIONING The phone was tested with several antenna combination positions (see photo's 4 and 5) involving the whip and the Globalstar antenna either retracted or extended. The primary test position was that described by Supplement C of OET Bulletin 65 from the Office of Engineering & Technology, of the FCC. The procedure places the surface of the phone in contact with the phantom, but also places the Globalstar transmit antenna 1.85 inches or more above the head of the user (see figure 1). The distance to the radiating portion of the antenna greatly reduces the SAR levels, which is why the levels measured in Globalstar mode are unusually low. It can be seen that the radiating section of the Globalstar antenna is 1.85 inches or more from the users head when the ear-speaker is near the users ear. This is because the radiating portion of the antenna is, by design, in the top portion of the telescoping tube, putting it as far as possible from the users head (see figure 1). Additionally the radiation pattern of the transmitting antenna was designed to be pseudo Omni-directional above the horizon, with minimum radiation below the horizon, since it must link with a satellite. This also has a great reducing effect on the SAR. As such, in the normal position the SAR values measured are extremely low.

CREST FACTOR To compensate for probe diode compression with strong signals, the DASY3 system software utilizes 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 Globalstar CDMA waveform crest factor is 3. 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, and 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, Computermathematik, 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 algorithm. 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.

7 SAR MEASUREMENT UNCERTAINTY

The possible errors included in this measurement arise from device positioning uncertainty, device manufacturing uncertainty, liquid dielectric permitivity 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 tooth pick 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, for most positions. 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.

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 liquid prepared at QUALCOMM measures approximately 42 at 1900 MHz and 43.2 at 1620 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 which uses sugar to raise the permittivity, salt to raise the conductivity, and cellulose to hold the two in suspension. The QUALCOMM lab prepares the liquid following the recipe provided by Schmid & Partner and used by much of the industry. After preparing 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 permitivity and conductivity must be checked after the liquid is cool, as different readings will be obtained due to expansion. 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 polarisation of the fields are unknown, the near field probe must measure all polarisation's 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/gm. 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 setup 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 location of the antenna feedpoint for the Globalstar UT is above the users head for the intended mode of operation. This causes a very low level peak in the SAR to be found at the top of the users head. This area of the phantom as situated in the DASY3 system is a vertical surface, and as a result the dosimetry probe during measurement is parallel to this surface. As a result of this the optical detection which is designed for surfaces perpendicular to the dosimetry probe, does not function. The immediate surface of the liquid dielectric cannot be measured due to limitations of the systems optical and mechanical surface detection. The border of the phantom was moved approximately 10 mm further from the surface to prevent the system from shutting down. Because the SAR values are extremely far from the limit of 1.6 mW/g (the highest measured being .0161 mW/g) the error caused by this limitation of the system is acceptable. In other words it is likely the SAR increases closer to the edge of the liquid, but it is impossible for it to increase by a factor of 99 in 10 mm, and even if this could occur, that data point would be averaged with low levels that surround the peak, which were the measured levels, and the averaging process would bring the SAR below the 1.6 mW/g limit.

11 TEST DATA SUMMARY

The device which was tested is the final production. No more design changes are to be made which will effect SAR. The device represents the frozen design of the GSP1600.

The SAR values measured for the Globalstar UT in Globalstar mode are extremely low due to the design of the Globalstar antenna. The antenna is positioned several inches from the users head unlike many cellular phone antennas, and the antenna radiates directionally away from the users head. In some cases the levels measured are near the bottom of the dynamic range of the DASY systems measurement capability. Some of the values when examined with respect to neighboring frequencies values appear to be inconsistent. This occurs because at levels this low more accuracy is needed, and the system is more greatly effected by the many causes of error, such as static, slight settling of the liquid during measurement, device positioning, and other smaller sources of error. This does not indicate faults with the measurements, it is a result of the difficulty of measuring extremely small SAR levels. Since the levels are far below the limits (approximately one or two percent of the limit), these variations are of lesser concern.

The following is the Globalstar mode SAR, and the terrestrial mode digital and analog SAR:

Ambient TEMPERATURE (°C) __20 C___

Relative HUMIDITY _ _38%____

Atmospheric PRESSURE _1015 mB_

Mixture Type: _Water/Sugar/cellulose/Salt
Dielectric Constant: __43.2_@ 1620 MHz_________
Conductivity: __1.44 +/- 10% mho/m___
Closest Distance between E-Probe & Globalstar 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)

GLOBALSTAR MODE

Freq. MHz (ch #)	POWER ERP	HEAD SIDE	GLOBALSTAR ANT POSITION	1 GRAM AVG. SAR (MW/G)	10 GM AVG. SAR (MW/G)
1611 (ch 4)	28.9	L	Zenith	.0036	.0014
1611 (ch 4)	28.9	L	Horizontal	.0024	.0005
1618 (ch 250)	28.9	L	Zenith	.0003	.000
1618 (ch 250)	28.9	L	Horizontal	.0006	.000
1625.5 (ch 506)	28.9	L	Zenith	.0017	.000
1626 (ch 496)	28.9	L	Horizontal	.0014	.0000
1611 (ch 4)	28.9	R	Zenith	.0161	.0086
1611 (ch 4)	28.9	R	Horizontal	.0031	.0010
1618 (ch 250)	28.9	R	Zenith	.0158	.0085
1618 (ch 250)	28.9	R	Horizontal	.0018	.0002
1626 (ch 496)	28.9	R	Zenith	.0034	.0001
1626 (ch 496)	28.9	R	Horizontal	.0016	.0000

TERRESTRIAL CELLULAR MODE / FMAMPS

Mixture Type: __Water/Sugar/cellulose/Salt
Dielectric Constant: __42.8_@ 900 MHz_________
Conductivity: __.82 +/- 10% mho/m___

FREQ. MHZ	POWER ERP	HEAD SIDE	ANTENNA POSITION	1 GRAM AVG. SAR (MW/G)	10 GM AVG. SAR (MW/G)
824.04 MHz (ch. 991)	30.0	L	G* stowed Whip ext.	1.47	1.12
824.04 MHz (ch. 991)	30.0	L	G* stowed Whip ret.	.784	.583
836.49 MHz (ch. 383)	30.4	L	G* stowed Whip ext.	1.31	.985
836.49MHz (ch. 383)	30.4	L	G* stowed Whip ret.	.981	.737
848.97 MHz (ch. 799)	30.3	L	G* stowed Whip ext.	1.10	.831
848.97 MHz (ch. 799)	30.3	L	G* stowed Whip ret.	.915	.683
824.04 MHz (ch. 991)	30.0	L	G* zenith Whip ext.	1.01	.754
824.04 MHz (ch. 991)	30.0	L	G* zenith Whip ret.	.754	.553
836.49 MHz (ch. 383)	30.4	L	G* zenith Whip ext.	.925	.683
836.49MHz (ch. 383)	30.4	L	G* zenith Whip ret.	.737	.546
848.97 MHz (ch. 799)	30.3	L	G* zenith Whip ext.	.810	.602
848.97 MHz. (Ch 799)	30.3	L	G* zenith Whip ret.	.988	.733

824.04 MHz (ch. 991)	30.0	R	G* stowed Whip ext.	1.26	.941
824.04 MHz (ch. 991)	30.0	R	G* stowed Whip ret.	.592	.442
836.49 MHz (ch. 383)	30.4	R	G* stowed Whip ext.	1.34	1.01
836.49MHz (ch. 383)	30.4	R	G* stowed Whip ret.	.849	.635
848.97 MHz (ch. 799)	30.3	R	G* stowed Whip ext.	1.05	.787
848.97 MHz (ch. 799)	30.3	R	G* stowed Whip ret.	.923	.678
824.04 MHz (ch. 991)	30.0	R	G* in Horizon Whip ext.	1.24	.932
824.04 MHz (ch. 991)	30.0	R	G* in Horizon Whip ret.	.528	.398
836.49 MHz (ch. 383)	30.4	R	G* in Horizon Whip ext.	.692	.519
836.49MHz (ch. 383)	30.4	R	G* in Horizon Whip ret.	.645	.485
848.97 MHz (ch. 799)	30.3	R	G* in Horizon Whip ext.	.812	.606
848.97 MHz (ch. 799)	30.3	R	G* in Horizon Whip ret.	.583	.433

TERRESTRIAL CELLULAR MODE / CDMA
Worst case channel and antenna positions

Only the frequencies and positions corresponding to worst case SAR are shown here. The CDMA cellular mode uses the same transmit hardware as the analog cellular mode, i.e. the same antenna and same high power amplifier. The two modes differ slightly in band width, but the band width of the E field probe exceeds both signal types, so that only the power content is relevant. As a result, radiation in the digital mode produces the same current distributions on the phone as the analog mode (for a given channel), and thus the same specific absorption rate as the analog mode for a given channel. The CDMA mode is allowed to radiate at a lower power level due to the processing gain (28.4 dBm ERP), which results in proportionally lower SAR. The E field probe is a broad band sensor, which converts all RF signals to DC. Thus the Probe only measures the power signal, and the modulation used will be integrated out, leaving only the power magnitude. The worst case frequencies for this device were similar to most phones tested in the past, the lowest frequencies where the phone is electrically smallest. The worst case positions occurred on the right head phantom, with the positions listed in the table.

FREQ. MHZ	POWER ERP	HEAD SIDE	ANTENNA POSITION	1 GRAM AVG. SAR (MW/G)	10 GM AVG. SAR (MW/G)
824.04 MHz (ch. 991)	28.4	R	G* stowed Whip ext.	.937	.715
824.04 MHz (ch. 991)	28.4	R	G* stowed Whip ret.	.534	.398
824.04 MHz (ch. 991)	28.4	R	G* in Horizon Whip ext.	.797	.594
824.04 MHz (ch. 991)	28.4	R	G* in Horizon Whip ret.	.624	.468
824.04 MHz (ch. 991)	28.4	L	G* vertical Whip ext.	.900	.665

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