SAR and Current Density Estimates for the Forward Telemetry Link of the Argus II Retinal Prostheses System

The Argus II Retinal Prosthesis System was measured for worst case primary excitation coil current levels in six configurations evaluated in [1]. The following table shows the worst case current levels for the configurations:

Configuration	Peak Primary Coil Current
A	980 mA
B	980 mA
C	980 mA
A’	560 mA
B’	660 mA
C’	800 mA

The safety limits to be considered are given in the table below.

Quantity	Forward Telemetry Limit (3.156 MHz)
Current Density	6312 mA/m^2
Whole Body Average SAR	0.08 W/kg
Localized SAR (head and trunk)	1.6 W/kg
Localized SAR (limbs)	4 W/kg
Contact and Limb Current	20 mA

<u>SAR</u>

According to [1] the peak 1 gram SAR scales linearly with frequency. The values of peak 1 gram SAR is reported at 2, 5, 10, 15 and 20 MHz for a peak current of 620 mA. The reported values at 2 and 5 MHz are shown in the table below.

Frequency	SAR (W/Kg)
2 MHz	0.005
5 MHz	0.078

Since the SAR scales linearly we obtain the slope of the line as $(\frac{0.078 - 0.005}{3MHz}) = 0.0243$

It was also reported that determining the peak 1 gram SAR from the nearest available frequency will result in a more accurate estimate. So we use the SAR value at 2 MHz for scaling purposes.

$$\therefore \frac{SAR_{3.156MHz} - 0.005}{3.156MHz - 2MHz} = 0.0243$$

which gives $SAR_{3.156MHz}$ = 0.033 W/Kg . This is for a current of 620 mA. Since SAR is also directly proportional to the square of the current in the coil, taking into account the peak current of 980 mA, the estimated peak 1 gram SAR at 3.156 MHz for a current of 980 mA is 0.033 x $\left(980/620\right)^2$ = 0.082 W/Kg. This value is well within the safety limit of 1.6 W/Kg (2.1093(d)(2)).

Current Density

The maximum current density ($J_{\max,620mA}$) at 10 MHz with 620 mA peak coil current for each configuration defined in [1] is given below.

Configuration	$J_{\max,620mA}(\mathrm{A}/m^2)$
A	6.4
B	5.2
C	5.2
A’	16.05
B’	7.7
C’	7.7

In [1], the variation of $J_{\max}$ with coil current is given at 10 MHz. The values reported are given below.

Current	$J_{\max}(\mathrm{A}/m^2)$
620 mA	16.05
780 mA	20

Using linear scaling the slope obtained is $(\frac{20-16.05}{160}) = 0.025$.

Using this value, the current density for the each configuration can be calculated at the various peak currents using the value at 620 mA at 10 MHz.

$$\therefore \frac{J_{\max,peak} - J_{\max,620mA}}{PeakCurrent - 620} = 0.025$$

which gives

Configuration	$J_{\max,peak}(\mathrm{A}/m^2)$
A	15.4

B	14.2
C	14.2
A’	14.55
B’	8.7
C’	12.2

From [1], the maximum current density ($J_{\max,620mA}$) at 2 MHz and 10 MHz for a current of 620 mA is given below.

Frequency	$J_{\max,620mA}\ (\mathrm{A}/m^2)$
2 MHz	3.87
10 MHz	16.05

Since the current density is linear from 2 – 20 MHz as reported in [1], we obtain the slope of the line as $(\frac{16.05-3.87}{8MHz}) \approx 1.52$

Extrapolating the maximum current density values for the peak currents of the Argus II System at 10 Mhz to 3.156 MHz, we get

$$\frac{J_{\max,peak} - J_{\max,3.156MHz}}{10MHz - 3.156MHz} = 1.52$$

which gives

Configuration	$J_{\max,3.156MHz}(\mathrm{A}/m^2)$
A	5
B	3.8
C	3.8
A’	4.15
B’	-
C’	1.8

The worst case induced current densities fall within the safety limit of 6.312 $J_{\max,3.156MHz}(\mathrm{A}/m^2)$

References:

1. V.Singh et.al, “Specific Absorption Rate and Current Densities in the Human Eye and Head Induced by the Telemetry Link of an Epiretinal Prosthesis”, IEEE Transactions on Antennas and Propagation, vol.57, No.10, October 2009, pp 3110 – 3117.