# SAR UPPER BOUNDS FOR LINEAR ANTENNAS IN THE FREQUENCY RANGE OF 300 MHZ TO 6000 MHZ

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**ABSRTACT**

The specific absorption rate (SAR) of a number of linear antennas (straight-conductor dipoles, meander dipoles, loops, and inverted-F antennas) was investigated using the Finite Difference Time Domain (FDTD) method. Since many commercial wireless devices use self-resonant or inherently non-resonant electrically small antennas, the SAR is a function of the antenna size and type. However, antenna sizes can be correlated to antenna operating bandwidths defined within a specific return loss. SAR characterization as a function of antenna bandwidth instead of antenna size is significant because for a particular application selecting or designing a specific antenna is primarily based on that specific design satisfying the bandwidth requirement first. In this paper the SAR of a number of wireless antenna types were computed as functions of the antenna bandwidths. To compute the bandwidths and SAR of non-resonant antennas, a perfect match condition at the operating frequency was assumed. Bandwidths and SAR of self-resonant antennas were computed without any additional matching.

First, the bandwidth and efficiency of cylindrical straight conductor printed dipole antennas of different lengths and wire radii were computed in free-space and against a flat phantom using HFSS (High Frequency Structure Simulator from Ansoft Corporation). The tissue and phantom shell material have the dielectric constant and conductivity described in [IEEE Recommended Practice for Determining the Peak Spatial-Average Specific Absorption Rate (SAR) in the Human Head from Wireless Communications Devices: Measurement Techniques, IEEE Standard 1528, 2003]. For example, the 3 dB return loss bandwidths of a 3.6 mm diameter cylindrical dipole antenna at a distance of 10 mm from the tissue-shell interface are 0.9%, 4.6%, and 11.5% when the lengths are approximately $\lambda/16$, $\lambda/8$, and $\lambda/6$, respectively.

Second, the SAR values of these antennas against a flat phantom at distances of 5, 10, and 20 mm were computed. These results when compared with the FCC limit of 1.6 W/kg for 1g averaging of tissue result in an upper limit of antenna radiated power for each case. For example, at 900 MHz and antenna separation distance of 5 mm, the power thresholds for dipole lengths of $\lambda/2$, $\lambda/4$ and $\lambda/8$ are 95 mW, 50 mW and 32 mW, respectively.

Finally, this paper also presents a comparative study of the SAR behavior of several self-resonant antennas at various distances from the phantom, such as a half-wave cylindrical dipole, a full-wave circumference loop, a resonant meander dipole, and a resonant integrated inverted-F antenna which is an embedded antenna on a printed circuit board.