

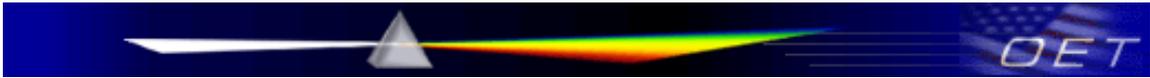
SAR Evaluation Considerations for Laptop Computers with Antennas Built-in on Display Screens



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Laboratory Division
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Laptop Computer SAR Procedures

Introduction

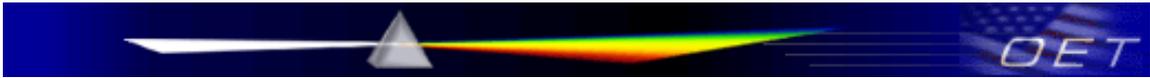
This document describes the procedures for determining the SAR evaluation requirements of multiple transmitting antennas built-in around the edges of laptop computer display screens. Manufacturers and test labs may apply these procedures to reduce the number of SAR tests necessary to demonstrate compliance for certain transmitter and antenna configurations in typical full-size laptop or notebook computers. The procedures mainly focus on 3G (WWAN), 802.11 a/b/g (WLAN) and Bluetooth transmitters where the higher output antennas are permanently integrated in the display screen. The output power, operating characteristics and antenna configurations are used to minimize redundant and unnecessary tests. The relative locations of antennas and their separation distances from users and nearby persons are also examined to determine the necessary SAR tests for both individual transmitters and simultaneously transmitting antennas to show compliance. It should be noted that these simple procedures are not SAR based. They are derived according to the specific operating configurations and exposure conditions of typical full-size laptop computers. It would be inappropriate to generalize these procedures to other product configurations without in-depth considerations of the complex relationships stipulated by frequency, power and separation distances between transmitters/antennas and nearby persons for the broader circumstances.

SAR Evaluation Considerations

Transmitters operating in laptop computers must be assessed independently according to applicable rules and policies to determine RF exposure compliance. The typical SAR tests required for wireless handsets are often excessive and inappropriate for testing antennas installed in laptop computer display screens. The number of tests for laptop computer transmitters to show compliance can usually be reduced by considering both output power and antenna-to-user separation distance.

Given that SAR is dependent on frequency, output power and separation distance; all of these operating parameters would require consideration according to the operating and exposure characteristics of the intended products to determine test requirements. A frequency dependent low power threshold of $60/f_{\text{(GHz)}} \text{ mW}$ has been used for TCB approval purposes since 2002. The derivation for this criterion is output power based. Since it is not SAR or exposure based, it does not address SAR changes associated with antenna-to-user distances and other external factors. The typical test results generally show that even similar transmitters with the same output power can often have substantially different SAR due to variations in transmitter operating characteristics and exposure conditions.

SAR is a measure of the rate of energy absorption inside tissues. Generally it does not have an exact or direct relationship to the power transmitted at the source or transmitting device. The resulting SAR is highly dependent on a multitude of exposure parameters and external factors between the source and tissues. While additional efforts are in progress to consider frequency, power and distance dependent criteria to establish SAR based thresholds for the broader and general circumstances, interim considerations may apply to specific products, such as laptop computers, to streamline test requirements until the more comprehensive SAR based thresholds are available.



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Individual Transmitters

For transmitters or antennas with maximum output $\leq 60/f_{(\text{GHz})}$ mW SAR evaluation is typically not required for TCB approval.¹ A simple distance-dependent power threshold may be considered based on multiples of $60/f$ to determine the number and types of tests required for laptop transmitters/antennas with output $> 60/f$ to show SAR compliance. These test reduction procedures can be applied to transmitter and antenna configurations that are clearly defined for the intended laptop applications with a minimum antenna-to-user separation distance of at least 5 cm. For antennas that are designed to provide $\geq (5 + \frac{1}{2} \cdot n)$ cm from users and nearby persons SAR may be evaluated on the highest output power channel only; where $n = P/(60/f) - 1$ is the number of times the antenna output power (P) is $> 60/f$.²

Simultaneous Transmission

Additional considerations are required to determine SAR compliance for multiple transmitters and antennas transmitting simultaneously at close proximity to each other. Depending on the frequency, output power and antenna locations, the SAR distributions are expected to overlap and vary substantially for different antenna and laptop computer configurations. Different test requirements are necessary to show compliance for simultaneous transmission conditions. When the antenna configurations and exposure conditions for simultaneous transmission are clearly defined, test reduction procedures may be considered according to the separation distances among the simultaneously transmitting antennas and their proximity to users and nearby persons. The similar criteria applied to individual transmitters and antennas may be adapted to establish minimum antenna-to-antenna and antenna-to-user separation distances to ensure both test integrity and compliance are not compromised.³

When the output power of an antenna is $\leq 60/f_{(\text{GHz})}$ mW and it is either ≥ 5 cm from all other transmitting antennas or it is deployed on the display screen with ≥ 5 cm separation from users and nearby persons, SAR evaluation for simultaneous transmission is not required for that antenna.⁴ When the output of a simultaneously transmitting antenna (x) is $> 60/f$, SAR evaluation for simultaneous transmission is required if it is $< (5 + \frac{1}{2} \cdot n_x + \frac{1}{2} \cdot n_y)$ cm from a simultaneous transmitting antenna (y) or if it is $< (5 + \frac{1}{2} \cdot n_x)$ cm from users and nearby persons; where $n_x = P_x/(60/f) - 1$ and $n_y = P_y/(60/f) - 1$ are the number of times the output power (P_x or P_y) of antenna x or y is $> 60/f$.⁵ A minimum antenna-to-antenna and antenna-to-user separation

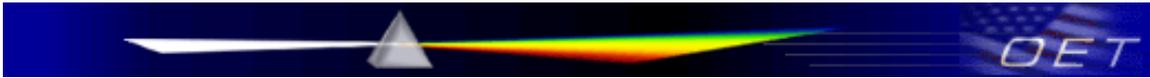
¹ See TCB Exclusion List for $60/f$ and low power threshold requirements.

² Evaluate SAR on the highest output channel for the operating modes and antenna positions that require testing. See 3G and 802.11 a/b/g SAR procedures to establish the required transmitter operating conditions. When the closest distance between an antenna and nearby persons is less than $(5 + \frac{1}{2} \cdot n)$ cm, normal test procedures for all channels and configurations apply. The value of n should be rounded to the nearest integer.

³ When SAR evaluation for simultaneous transmission is not required for all the antennas installed in a laptop computer, the conditions described in II-e and II-h-2 of the TCB Exclusion List do not apply.

⁴ When the closest distance from a target antenna to all other transmitting antennas is < 5 cm and it is also closer than 5 cm from users and nearby persons, SAR evaluation for simultaneous transmission is required for that antenna.

⁵ When an antenna is deployed on the display screen where the closest distance is at least $(5 + \frac{1}{2} \cdot n_x)$ cm from nearby persons and $(5 + \frac{1}{2} \cdot n_x + \frac{1}{2} \cdot n_y)$ cm from all other transmitting antennas, SAR evaluation for simultaneous transmission is not required for that antenna. The value of n should be rounded to the nearest integer.



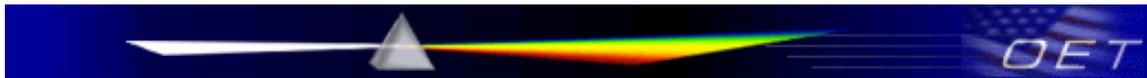
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distances of 5 cm are required for the test reduction procedures to apply. However, if the sum of the independently evaluated maximum 1-g SAR for all simultaneously transmitting antennas is less than the SAR limit and all the antennas are > 5 cm apart from each other and users and nearby persons, SAR for simultaneous transmission is not required. Table 1 illustrates the output power and separation distance considerations at several typical frequencies. A summary of the SAR evaluation requirements for both individual and simultaneous transmission are shown in Table 2. A hypothetical step by step example of a laptop computer with several transmitters and antennas is included at the end of this document to illustrate the procedures.

Antennas transmitting simultaneously within the same frequency band should be evaluated in the same SAR measurement. Antennas transmitting simultaneously at different frequency bands require different tissue simulating liquids and SAR probe calibrations; therefore, these must be evaluated separately. SAR for simultaneous transmission should be measured using the configuration (RF channel, operating mode, antenna position etc.) corresponding to the highest SAR determined during individual transmitter (antenna) evaluation. The laptop computer and all relevant antennas requiring simultaneous transmission evaluation must remain at the same test position with respect to the phantom for all simultaneous transmission SAR measurements. Even though separate SAR measurements are necessary for some simultaneous transmitting antennas, the same measurement volume must be used to encompass all the simultaneously transmitting antennas for each SAR measurement. The same spatial resolution and grid spacing must also be used in all measurements to enable the measured points to be summed on identically registered spatial grids to ensure the overlapping SAR distributions are post-processed correctly for the antennas at all measurement locations in order to compute the 1-g SAR for the group of simultaneously transmitting antennas.

Other Considerations

Identical transmitter and antenna configurations deployed in laptop computers using the same display screen can be covered under the same equipment certification. Class II permissive change filings with new test data are required when changes in material or construction occur within 5 cm from any part of an antenna; for example, changing laptop cover or LCD materials. When one or more antennas are shifted by up to ± 1 cm from their originally approved locations but the same or larger antenna and user separation distances are maintained, permissive change filings are required only if the previously measured SAR for independent or simultaneous transmission is $> 75\%$ of the SAR limit. Other test requirements and approval policies should be applied in conjunction with these laptop computer SAR procedures; for example, certain modular approval and unique antenna considerations relating to unlicensed transmitters.



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Table 1 – Example Output Power and Separation Distance Considerations

Output Power, P (mW)	835	1900	2450	5200	5800
$\frac{1}{2} \cdot n$	(MHz)				
0	≤ 143	≤ 63	≤ 48	≤ 23	≤ 20
1	144	64	49	24	21
2	288	127	98	47	42
3	432	190	147	70	63
4	575	253	196	93	83
5	719	316	245	116	104
$n = P/(60/f)-1$; P is rounded to the nearest mW and $(\frac{1}{2} \cdot n)$ is rounded to the nearest cm Antenna-to-antenna distance = $(5 + \frac{1}{2} \cdot n_x + \frac{1}{2} \cdot n_y)$ cm. Antenna-to-user distance = $(5 + \frac{1}{2} \cdot n)$ cm					

Table 2 – Summary of SAR Evaluation Requirements

Antenna Output Power (mW)	$\leq 60/f_{(GHz)}$	$> 60/f_{(GHz)}$
Individual Transmitter or Antenna	SAR not required	Antenna-to-user distance – $\geq (5 + \frac{1}{2} \cdot n)$ cm: test SAR on highest output channel only $< (5 + \frac{1}{2} \cdot n)$ cm: test SAR according to normal procedures
Simultaneously Transmitting Antennas	SAR not required: antenna-to-antenna or antenna-to-person distance ≥ 5 cm SAR not required: $\sum (SAR_{1g}) < SAR$ limit otherwise, test antenna(s) using highest SAR configuration for the individual transmitter/antenna	SAR not required: antenna-to-antenna $\geq (5 + \frac{1}{2} \cdot n_x + \frac{1}{2} \cdot n_y)$ and antenna-to-person $\geq (5 + \frac{1}{2} \cdot n_x)$ cm

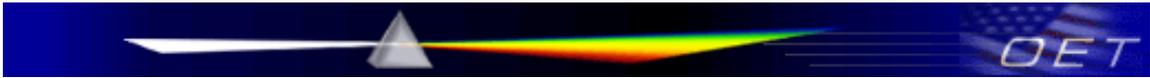
Example

The following is an example illustrating how the test reduction procedures are applied to a group of transmitters and antennas configured in a hypothetical laptop computer:

Assumed hypothetical configurations:

Transmitters and antennas

- 1900 MHz, 255 mW 3G transmitter with antenna located on the left edge of the display screen, at 10 cm from the bottom of the laptop base (with display open at 90° to keyboard)
- 802.11 a/b/g transmitter with 50 mW output at 2.45 GHz and 25 mW at 5.8 GHz, using a single antenna for both frequency bands; located along the middle, top edge of the display screen
- 3 mW Bluetooth with an integral antenna built-in on the transmitter module, located on the keyboard section next to the left display screen hinge at 0.5 cm from the back of the computer



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Closest antenna-to-antenna distances (according to configurations assumed above)

- 3G WWAN & 802.11 a/b/g: 23 cm (d_1)
- 3G WWAN & Bluetooth: 10 cm (d_2)
- 802.11 a/b/g & Bluetooth: 26 cm (d_3)

Antenna-to-user distances (according to configurations assumed above)

- 3G WWAN: 10 cm (r_1)
- 802.11 a/b/g: > 20 cm (r_2); SAR does not apply to mobile exposure conditions
- Bluetooth: 1.5 cm (r_3)

Antenna-to-user separation distance calculations for independent SAR requirements:

Output > 60/f: SAR evaluation is required when antenna-to-user distance is < $(5 + \frac{1}{2} \cdot n)$ cm

- 3G WWAN: $(5 + \frac{1}{2} \cdot n) = 5 + \frac{1}{2} \cdot [255 / (60 / 1.9) - 1] = 5 + 4 = 9$ cm (R_1)
- 802.11 at 2.45 GHz: $(5 + \frac{1}{2} \cdot n) = 5 + \frac{1}{2} \cdot [50 / (60 / 2.45) - 1] = 5 + 1 = 6$ cm (R_2)
- 802.11 at 5.8 GHz: $(5 + \frac{1}{2} \cdot n) = 5 + \frac{1}{2} \cdot [25 / (60 / 5.8) - 1] = 5 + 1 = 6$ cm (R_3)
- r_1 (10 cm) > R_1 (9 cm); test reduction applies, SAR evaluation is required on the highest output channel only for the WWAN
- SAR does not apply to the 802.11 a/b/g antenna due to mobile exposure conditions; therefore, R_2 and R_3 do not apply

Output \leq 60/f: user distance restriction does not apply; therefore, r_3 (1.5 cm) also does not apply and SAR evaluation is not required for the Bluetooth for independent transmission

Antenna-to-antenna separation distance calculations for simultaneous SAR requirements:

Output > 60/f: SAR evaluation is required when antenna-to-antenna distance is < $(5 + \frac{1}{2} \cdot n_x + \frac{1}{2} \cdot n_y)$ cm

- 3G WWAN & 802.11 (2.45 GHz): $(5 + \frac{1}{2} \cdot n_x + \frac{1}{2} \cdot n_y) = (5 + 4 + 1)$ cm = 10 cm (D_1)
- 3G WWAN & 802.11 (5.8 GHz): $(5 + \frac{1}{2} \cdot n_x + \frac{1}{2} \cdot n_y) = (5 + 4 + 1)$ cm = 10 cm (D_1)
- 3G WWAN & Bluetooth: $(5 + \frac{1}{2} \cdot n_x + \frac{1}{2} \cdot n_y) = (5 + 4 + 0) = 9$ cm (D_2)
- 802.11 (2.45 GHz) & Bluetooth = $(5 + \frac{1}{2} \cdot n_x + \frac{1}{2} \cdot n_y) = (5 + 1 + 0) = 6$ cm (D_3)
- 802.11 (5.8 GHz) & Bluetooth = $(5 + \frac{1}{2} \cdot n_x + \frac{1}{2} \cdot n_y) = (5 + 1 + 0) = 6$ cm (D_3)
 - note: 802.11 is mobile and Bluetooth is < 60/f, calculation for D_3 is unnecessary
- d_1 (23 cm) > D_1 (10 cm) and d_2 (10 cm) > D_2 (9 cm), SAR evaluation for simultaneous transmission is not required for the WWAN antenna; it is also not required for the 802.11 and Bluetooth antennas

Output \leq 60/f: SAR is not required when the antenna is \geq 5 cm from other antennas or users and nearby persons

- Bluetooth: evaluation is required only if both antenna-to-antenna and antenna-to-user separation distances are < 5 cm
 - both d_2 (10 cm) and d_3 (26 cm) are > 5 cm, SAR for simultaneous transmission is not required; therefore, user separation distance ($r_3 = 1.5$ cm) does not apply