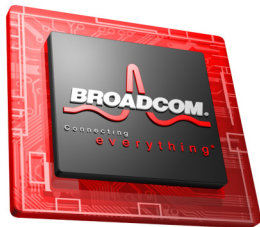


## Compliance with TIS and TRP Requirements

This document describes the issues related to meeting Total Isotropic Sensitivity and Total Radiated Power requirements for cellular products.

May 2006



## Overview

Broadcom offers cellular solutions that allow customers to meet or exceed requirements for Total Isotropic Sensitivity (TIS) and Total Radiated Power (TRP). Because several factors can affect both TIS and TRP, some of which are beyond Broadcom's control, it's important that these factors are understood and addressed during the design stage.

TIS and TRP metrics have become increasingly important for carriers, as they can quantify "over-the-air" performance with a single value. In addition, the measurement procedure is standardized in the following CTIA-controlled document:

- "Test Plan for Mobile Station Over the Air Performance: Method of Measurement for Radiated RF Power and Receiver Performance," © 2001 by the , available at <http://www.ctia.org/content/index.cfm/AID/10021>.

To understand how to design for TIS and TRP compliance, it's important to understand issues like the following:

- How are these metrics measured?
- What do they represent?
- Which part of a cellular phone design affects TIS and TRP?

In general, TRP is a measure for the spherical integrated radiated power of the device. Using this approach, lobes of high antenna gain and nulls in the antenna pattern are taken into account, and affect both the TRP and TIS values.

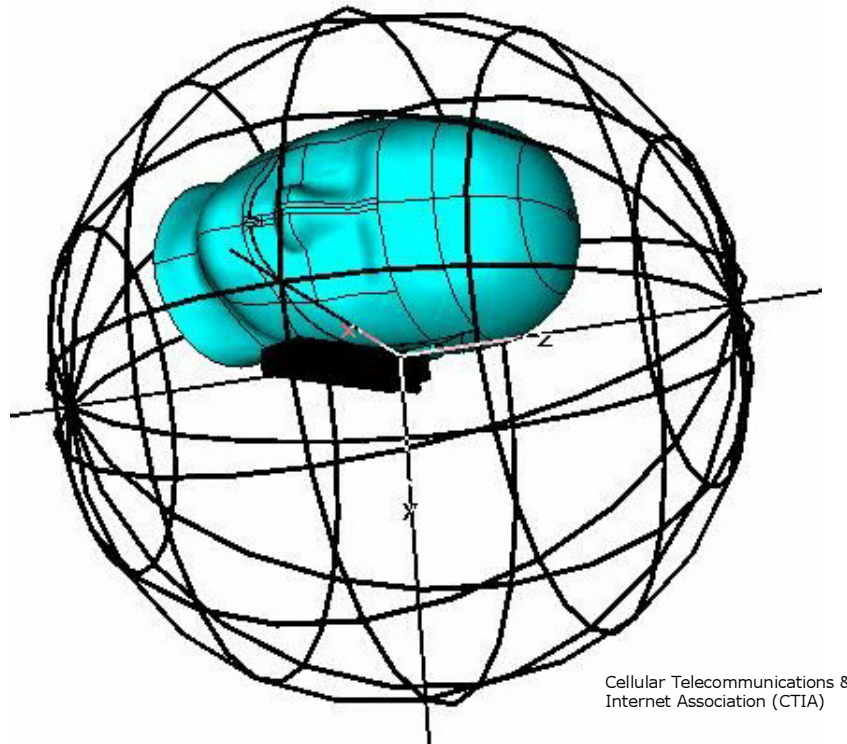
Since the method of measuring TIS and TRP resembles that of measuring 3D antenna efficiency, the 3D antenna efficiency is a key parameter to determine TIS and TRP, and vice versa. Knowing TRP and TIS requirements is fundamental to specifying antenna efficiency requirements.

## Antenna Efficiency

Efficiency is the ratio of input power to output power. This number is a measure for how well the antenna transforms incident (conducted) power to radiated power. Ideally, all incident power should be radiated, but there will typically be loss due to non-ideal matching and loss in matching components. A good, efficient antenna has efficiency in the range of 70-80%, but lower values are not uncommon.

Efficiency can be measured in one direction, but since power typically isn't radiated equally in all directions, this parameter does not provide a lot of information. Efficiency measured as the spherical integrated power vs. incident power is a better way to characterize the quality of the antenna and the overall system, and this value is typically used in establishing requirements for the antenna.

Efficiency is greatly dependent on material that absorbs radiated power, and since the typical usage scenario of mobile phones requires the device to be held close to a human head, the efficiency number for antenna will be different in a position close to human tissue. This means that characterizing an antenna using efficiency typically requires a free-space efficiency and an efficiency measured next to a head. (The latter is often referred to as a Specific Anthropomorphic Mannequin, or SAM, shown in Figure 1.)



**Figure 1. SAM Head with Great Circle Cuts and Measurement Points**

## **TRP and TIS Examples**

The total radiated power from a cellular phone depends on how much power is conducted from power input to the antenna, and how good the antenna is at transforming that to radiated power—in other words, the antenna’s efficiency.

### **TRP Example**

Let’s assume that a GSM carrier requires a handset to meet a TRP requirement of +22 dBm in the GSM850 band when the device is held next to a head.

Since the nominal conducted power in GSM850 is +33 dBm, the antenna efficiency and the changes caused by the head are allowed to cause a degradation of 11 dB and still be able to meet the TRP number.

The required efficiency can be calculated as:

$$eff = 10^{(-x/10)}, \text{ with } x \text{ being the degradation, and } eff \text{ the efficiency.}$$

With an allowable degradation of 11 dB, the efficiency becomes  $\sim 8\%$ .

**Note:** In this example, nominal output power is used. If the product is designed and calibrated to operate with a maximum transmission power of +32 dBm (which is still within the requirement), the degradation caused by antenna efficiency will be only 10 dB, and thus the efficiency requirement will change as well.

### TIS Example

A TIS requirement of -99 dBm next to a phantom head is required in GSM850 by at least one carrier. If the "8%-efficient antenna" from the previous TRP calculation is used, the conductive sensitivity would need to be -110 dBm. Although this is not impossible today, it would be a major design challenge. Assuming a conductive sensitivity of -108 dBm, the degradation caused by antenna efficiency can only be 9 dB.

In general, the antenna should be placed in such a way that the radiating element has optimum condition. For an external antenna, this usually means a ground plane beneath it and nothing conductive and nothing that shields the signal around it.

Figure 2 shows the SAM head phantom orientation for the Great Circle Cut setup, and Figure 3 shows the SAM head phantom orientation for the conic cut setup.

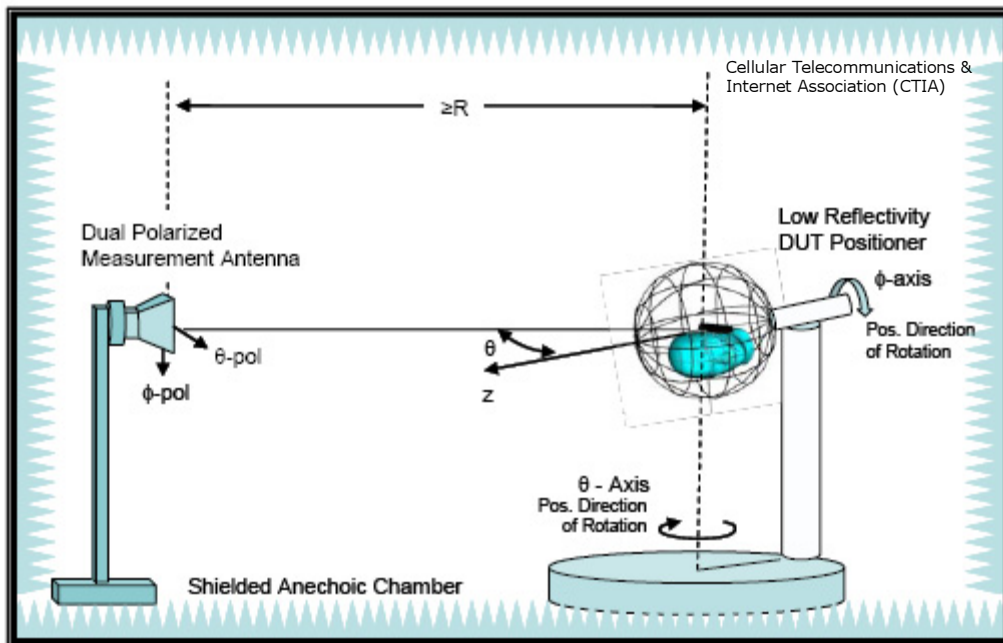
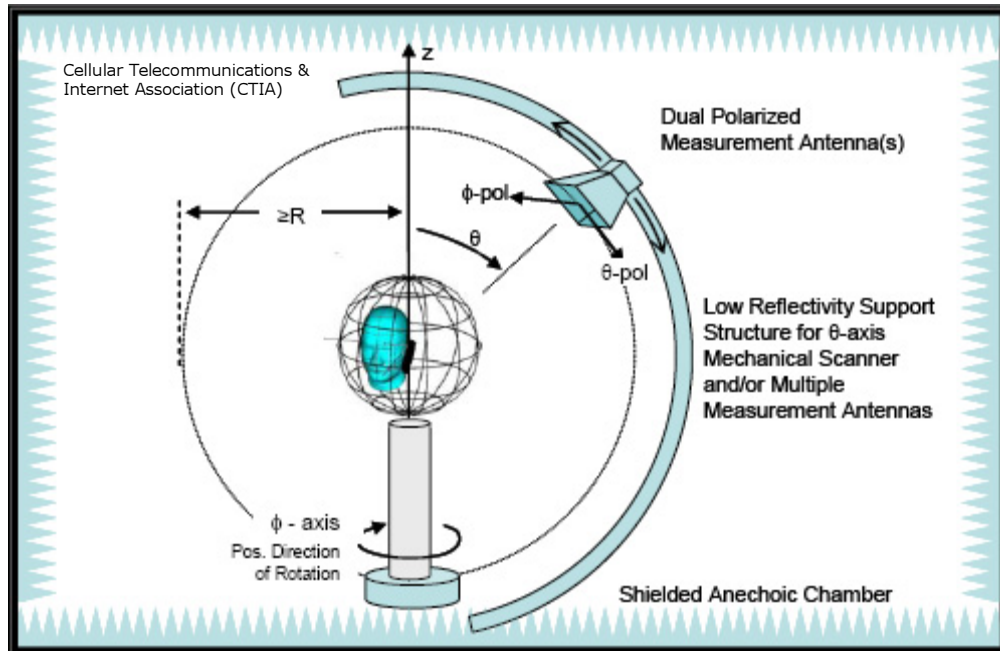


Figure 2. Typical Test Setup: Great Circle Cut with SAM Head Phantom



**Figure 3. Typical Test Setup: Conic Cut with SAM Head Phantom**

For an internal antenna, the optimum placement typically would be elevated above a large ground plane, with the antenna radiating away from the user's head. Other considerations in placing the antenna would be how it is held during conversation and when it is being carried. It's obviously difficult to determine how people hold their phones, but with proper industrial design, it is possible to motivate the user to hold the phone in a way that the hand does not cover the antenna. Similarly, beltclip or carrying cases should be designed to promote optimal conditions for the antenna (for example, a belt clip designed with the antenna's radiation pattern pointing away from the user's body when the phone is attached to the belt).

## Noise

As described above, conducted performance and antenna characteristics in terms of efficiency are important to meet TRP and TIS. It is equally important, however, to understand that system-radiated noise that falls into the receive band will affect TIS performance.

In this context, "noise" would typically be digital signals radiating from traces that carry high-speed digital signals. Since digital signals in nature are square waves, they will contain several harmonics, of which some are likely to fall within the frequency band of reception.

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If and when these signals are radiated, they will be picked up by the antenna and will be seen as co-channel interference. This obviously degrades receiver sensitivity as well and will affect TIS performance. In a situation like this, improving antenna efficiency will very likely *not* improve performance because, even though more of the desired signal is picked up with a more efficient antenna, the noise signals will be equally higher, keeping the C/I ratio constant.

This means that designing for TIS compliance also implies that radiated system noise is kept at a minimum. Ways of accomplishing this would include shielding high speed signals, under metal cans, routing entire signals in an inner layer or, even better, applying both techniques. Other things to consider are keeping noisy signals and connectors (such as LCD connectors) as far away from the antenna as possible. Finally, consider the use of EMI filters on all critical (noisy) traces.



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05/25/06