# Taoglas Guidelines for achieving highest RF performance and passing select regulatory approvals for cellular devices with internal antennas

## 1. Just Ask –

Please consult with Taoglas **BEFORE** you begin your product design to;

- **Define RF Performance Targets**
- **Antenna options**
- **Layout guidelines**

Why? We have found people who try to do these themselves **FAIL**

Before selecting the antenna or antenna design and defining the mechanical specifications for a wireless product the product designer must understand clearly the **RF performance targets** the product must reach in order to;

- achieve good RF performance in the field to ensure market success and
- pass all regulatory and operator approvals

## 2. Performance

The Basic concepts – **TRP, TIS** and **RSE**

For cellular applications such as GSM or CDMA basic RF performance is measured in terms of the product being able to transmit and receive reliably on a network. The scientific way to measure performance is in an anechoic chamber.

The measurements numbers used are outlined here;

- **TRP – Total Radiated Power**
  This defines how much power is being radiated from the device and is measured in dBm. The higher this number, the better the device is able to transmit.

- **TIS – Total Isotropic Sensitivity**
  This defines how low a signal the device can receive and demodulate. The lower this number (with a minus figure) the better the device can operate in weak signal environments.

- **RSE – Radiated Spurious emissions.**
  In practice this is the most difficult test for cellular products to pass from Taoglas' experience. These are radio waves output by the device which are above the power limit set by regulatory authorities to avoid interference. When a test confirms a radiated spurious emission over the limit either the device or the antenna must be modified to get it below the limit and thus pass certification. Otherwise the device cannot be sold in that country.

Different operators, especially in the USA (such as AT&T, Sprint etc) have specific numbers for TRP and TIS that the device must reach to be accepted on their networks. Other operators do not specifically set any requirements. No matter if it is mandatory or not, it is our experience that the wireless products with the best TRP and TIS values succeed in the market. Passing RSE is mandatory for any operator whom requires PTCRB or type approvals. A design that has optimized TRP/TIS will usually pass RSE on the first attempt.

Wireless products are regulated in each country by slightly different standards. Taoglas in co-operation with certified test labs can advise on the exact regulations a product must conform to and provide a test plan.

Below are targets to reach for passing most but not all operator TRP/TIS approvals. Some operators have specific targets for certain products or applications so you need to confirm individually. In any case these are the numbers any designer should target for their device.

| | Maximum Conducted Power | TRP | Maximum Conducted Sensitivity | TIS |
|---|---|---|---|---|
| GSM 850 | 33 | 22 | -109 | -99 |
| GSM 900 | 33 | 23 | -109 | -100 |
| GSM 1800 | 30 | 24 | -109 | -101 |
| GSM 1900 | 30 | 24.5 | -109 | -101 |
| UMTS/HSPA/ HSPA+/WCDMA 850 | 23 | 13 | -109 | -97 |
| UMTS/HSPA/ HSPA+/WCDMA 1700 | 23 | 18.5 | -109 | -101 |
| UMTS/HSPA/ HSPA+/WCDMA 1900 | 23 | 18.5 | -109 | -101 |
| UMTS/HSPA/ HSPA+/WCDMA 2100 | 23 | 18.5 | -109 | -101 |

Note: all figures in dBm

If your operator does not have a stated standard, or their standard is not mandatory it is advisable to aim for these, or higher, numbers in order to accomplish the best industry standard.

Your product can in many cases still function normally below these values, there is no industry set cut-off for operation. It will depend on the actual application environment and your own conditions for what is acceptable in terms of reliability and the outcome of your own product field tests.

How are these **TRP** and **TIS** numbers calculated?

**TRP**

For TRP we have to work backwards from the maximum power allowed from a RF module. For most cellular modules this is capped by the FCC at 33dBm for GSM 850 and 30dBm for GSM 1900.

Let's take a specific example. Usually the module will be set at a slightly lower power rating than maximum allowed. This would mean at GSM 850 with a power level of 32dBm this leaves us 10dB of loss in the device to still pass the 22dBm target. This sounds like plenty of margin but there are a lot of losses in the system.

As the RF signal passes down a cable or a transmission line on the device board it easily loses 4dB or more. 4dB loss is **more than half the loss** of the original power coming from the module.

- When the signal reaches the antenna and is radiated out into the air it will also inevitably lose more
- So 32dBm - 4dB = 28dBm, meaning we need to reduce the loss from the antenna side to -6dB or less
- This -6dB loss is equivalent to saying the antenna has an average gain of -6dB
- Therefore we need to design an antenna that has better than average gain of -6dB for the device to reach the TRP performance required

**TIS**

For TIS a similar calculation can be done. For example knowing that a network operator for GSM 850 has set a signal strength of greater than -99dBm, we can work backwards to what losses are allowed in the device for the device to still operate on the network.

The majority of cellular module sensitivity is around -109dBM, therefore the device can sustain another 10dB in loss on the antenna and transmission lines/cable and still reach the operator requirements.

- This means in theory again we can budget for -4dB loss for example in the transmission line (could be less or more).
- It leaves us -6dB in loss for the antenna.
- This is equivalent to the antenna average gain of -6dB which is usually possible for the antenna designer to do.

However, **in real life** TIS is most affected by noise on the board. In many cases this noise will totally overpower the underlying GSM signal. This noise must either be removed from the system, or the antenna placed far enough away from it not to pick it up. Of course either way is very difficult to achieve when the design is complete.

## What can Taoglas do to help?

Designing an optimized RF device depends on many parameters, both electrical and mechanical. Fortunately Taoglas can utilize our experienced engineers, unparalleled range of antennas and real industry experience to come out with a solid reliable process to enable a customer's product to succeed.

## 3. Antenna type (including mechanical design and layout)

Below are some simple rules to follow for the mechanical dimensions of a product which can pass the strictest operator TRP/TIS requirements. I am sure you are asking yourself - how come I used mobile phones that clearly violate these guidelines? Firstly they may not have targeted the above figures for device efficiency but if you look closely, most mobile phones do adhere to the guidelines below. Certain operators negotiate directly with mobile phone companies on lower TRP/TIS standards on their device on a case by case basis. These options are unlikely to be available to M2M devices.

**(A)** Ground planes < 60mm long

For a ground plane with a length of less than 60mm (and 40mm wide) we have only one proven antenna solution. This is a completely custom printed trace antenna which exists on one of the short edges taking up 12mm x 40mm in space. (This leaves the remainder of the ground plane at 48x40mm). It uses a direct CoPlanar Waveguide (CPW) connection to module. The antenna requires 15mm clearance from metal on the module side. Other sides around the antenna must be completely free of metal with no ground-plane or components under or above the antenna.

**(B)** Ground planes > 60mm long

**(i)** On-board Antenna Solutions - Minimum width needs to be 40mm

PA-25a Ceramic Antenna –


- cleared area needs to be all the way across the short side of the board – see the application note
- From module side to antenna it requires 10mm clearance to metal.
- Other sides must be completely free of metal.

Custom Metal PIFA Antenna –

- can work directly on ground plane on centre edge of PCB minimum height of elements 10mm, length 60mm, width 25mm
- Clearance to other metal components ideally 20mm or greater in all directions

Custom printed trace antenna –

- need to use up one whole edge (shorter) of the board
- minimum length of PCB will need to be 57mm, width 20mm
- From module side of antenna 10mm clearance to metal
- Other sides of antenna must be completely free of metal
- No ground-plane under antenna on top or bottom side.

Trace Antenna example

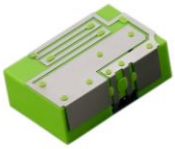
**(ii)** Off-board Antenna Solutions – Ground plane width of the device needs to be greater than 20mm.

Proven example is 80x40mm of ground plane and 20 mm of clearance from antenna to metal, but in theory the ground plane of the device can be smaller

Flexible circuit antennas – FXP14

- Can be mounted to the inner plastic housing of the device
- Minimum clearance of 20mm from metal in all directions
- Mount at right angles (perpendicular) to any main-board
- Cable should be shorter than 150mm but not less than 80mm.
- Place antenna away from noise / activity sources

PIFA on housing



- Dimensions approximately 60 x 20mm x 10mm
- 20mm clearance to metal
- Spring contact can be used for connection

Rigid PCB FR4 Antennas – PC.30

- Can be mounted to the inner plastic housing of the device
- Minimum clearance of 20mm from metal in all directions
- Mount at right angles (perpendicular) to any main-board
- Cable should be shorter than 150mm but not less than 80mm.
- Place antenna away from noise / activity sources

## 4. PTCRB

For cellular wireless products sold in USA and Canada and other regions it is necessary to apply for PTCRB approval from the CTIA wireless association.

A designated lab will test your product to establish if it meets the requirements.

PTCRB itself does not set minimum pass/fail standards for TRP/TIS, but there is a strict RSE standard - higher than the traditional FCC test standard. So you can actually pass RSE and get PTCRB even with compromised device performance (if TRP and TIS are not considered)

Individual operators may specify their own TRP/TIS test standards and even more tests before they will accept your device on their network. Taoglas can assist wireless device designers in meeting these approvals first time around

**Disclaimer :** RF design is inherently difficult. Taoglas provides this document as a reference only and cannot be held responsible for errors or omissions in this information or for the performance of devices that use this above information. Users are advised to discuss with a Taoglas representative for a formal solution proposal before proceeding on any design.