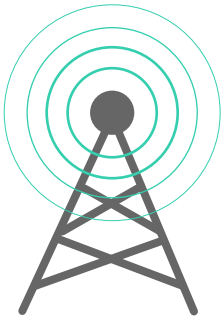
Specific Absorption Rate (SAR) and your product:

Everything you never wanted to need to know about radio waves and the human body



A radio transmitter does the same thing as a light bulb. When a radio transmits a signal, that transmitter is converting conducted electrical energy into electromagnetic radiation. For a light bulb, the radiation frequency is in hundreds of teraHertz (THz). Green light, for instance, is around 520 THz. For a cellular radio, the frequencies of operation normally run from around 650 MHz up to just under 3 GHz. The radiation is otherwise the same.

When most people hear the word radiation they immediately think “danger”. We’ve been conditioned to think that all radiation is bad and dangerous. This is because the word is often linked to radiation of ionizing subatomic particles released by radioactive decay. Radiation comes in two types: **non-ionizing radiation**, like a radio transmission or light from your TV or a light bulb, and **ionizing radiation**, like what is released when a radioactive element like uranium decays and a subatomic particle like a proton or neutron goes flying off.

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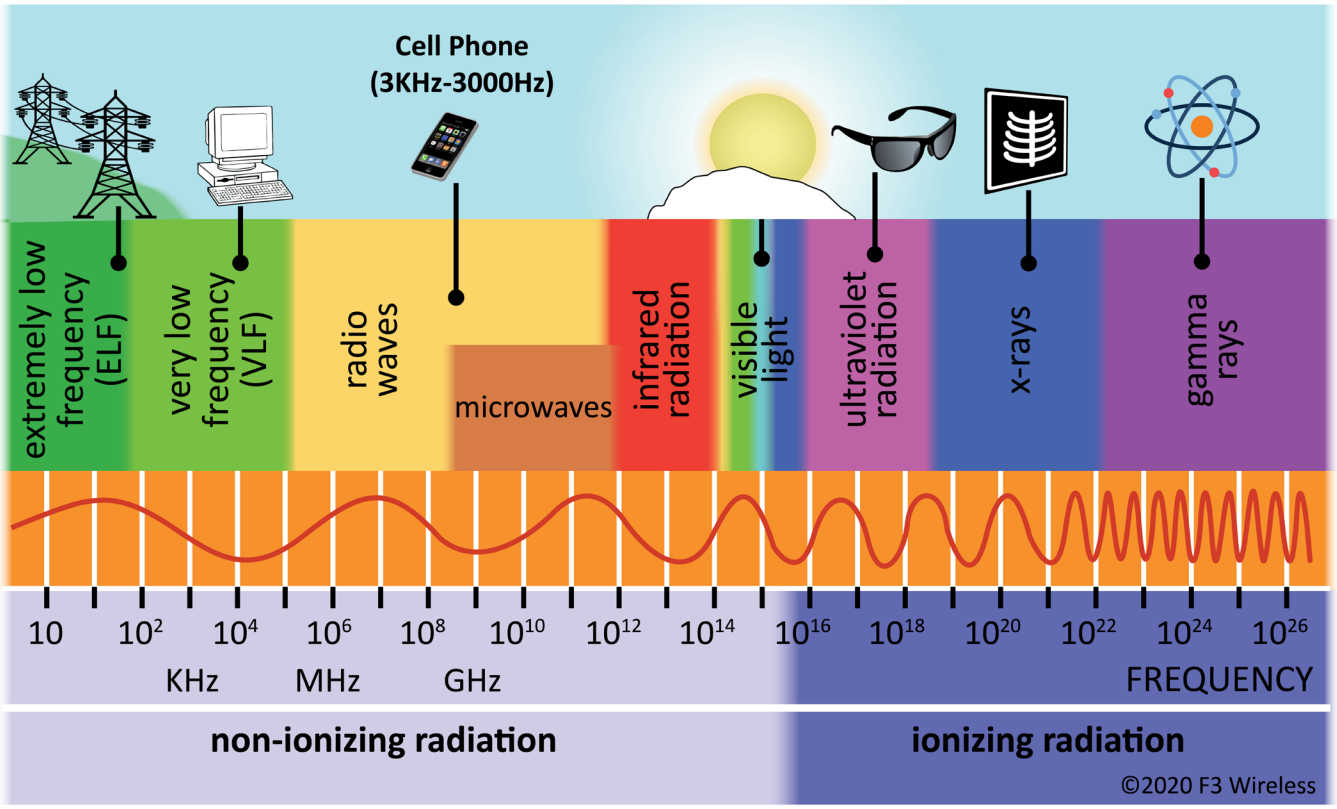
Types of Radiation



"...Radio waves generally have very poor depth penetration into body tissue. The higher the frequency, the lower the penetration."

Since it is physically impossible for a radio transmitter to create ionizing radiation, they can't cause cancer. They can cook things, of course, as they do in a microwave oven. Actual microwave ovens use very specific frequencies to efficiently heat up your food. In general, however, most radio transmitters aren't as efficient at it. Radio waves generally have very poor depth penetration into body tissue. The higher the frequency, the lower the penetration. The human body also has a lot of thermal mass because it's mostly water, so it takes a lot of RF energy to make much of a difference in tissue temperature. Where things get complicated is when a radio signal is focused in a given direction or when the transmitting antenna is very close to the body.

Maximum Permissible Exposure (MPE) and SAR Testing

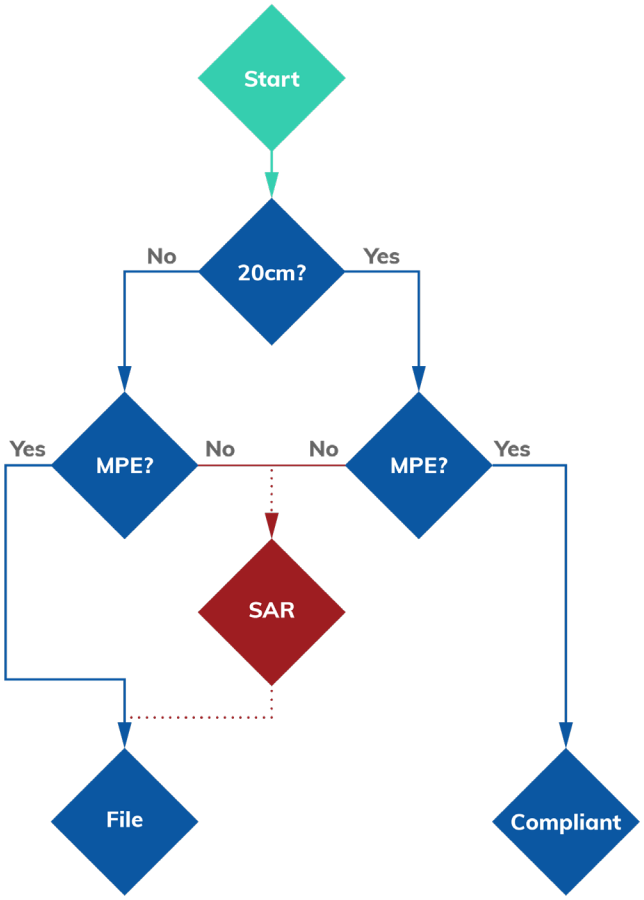
The Federal Communications Commission (FCC) regulates radio transmitters in the US and defines in the Code of Federal Regulations (CFR) limits on human body exposure to RF energy. For communications transmitters, this takes the form of two concepts that your radio device must comply with in order to be offered for sale. These are generally referred to as **Maximum Permissible Exposure** (MPE) and **Specific Absorption Rate** (SAR). CFR title 47 covers telecommunications and includes sections that cover fixed antennas on a structure (1.1307), mobile devices such as a cellular data router mounted in a vehicle (2.1091) and portable devices carried by or worn on a person (2.1093). To find out more about these specific requirements, head to those sections of the Code of Federal Regulations, title 47. You can find them online at **https://www.ecfr.gov/** Another great resource is the FCC's *OET Bulletin 65 Evaluating Compliance with FCC Guidelines for Human Exposure to Radio frequency Electromagnetic Fields.*

$$P_{th}(mW) = ERP_{20cm}\ (mW) = \begin{cases} 2040f & 0.3\ GHz \le f < 1.5\ GHz \\ 3060 & 1.5\ GHz \le f \le 6\ GHz \end{cases}$$

This is the formula that tells if you've passed or not, and we can help you figure that out.

MPE is a mathematical exercise where you enter details of your transmitter and antenna into a formula to calculate the resulting RF energy field strength at a specific distance from the antenna. If your device complies with the appropriate limit for your product (occupational or general), you're done. The details regarding the calculation of MPE can be found in section 2.1091 of title 47 of the CFRs.

"If your product is over the limit, then you need to do SAR testing."



20cm? Antenna 20cm or more away from a person under normal operating conditions

MPE? Calculated MPE below limit

SAR Need to do SAR testing

Compliant Your device complies to the modular cert grant requirement so while you may have to do a new FCC ID still for other reasons, RF exposure is not one of them

File Need to file for a new device level FCC ID

If your product contains an FCC approved radio transmitter, and you meet all other requirements to use that transmitter, you don't need to do anything more. You don't have to file anything with the FCC, you can just go sell your product. If your product is over the limit, then you need to do SAR testing.

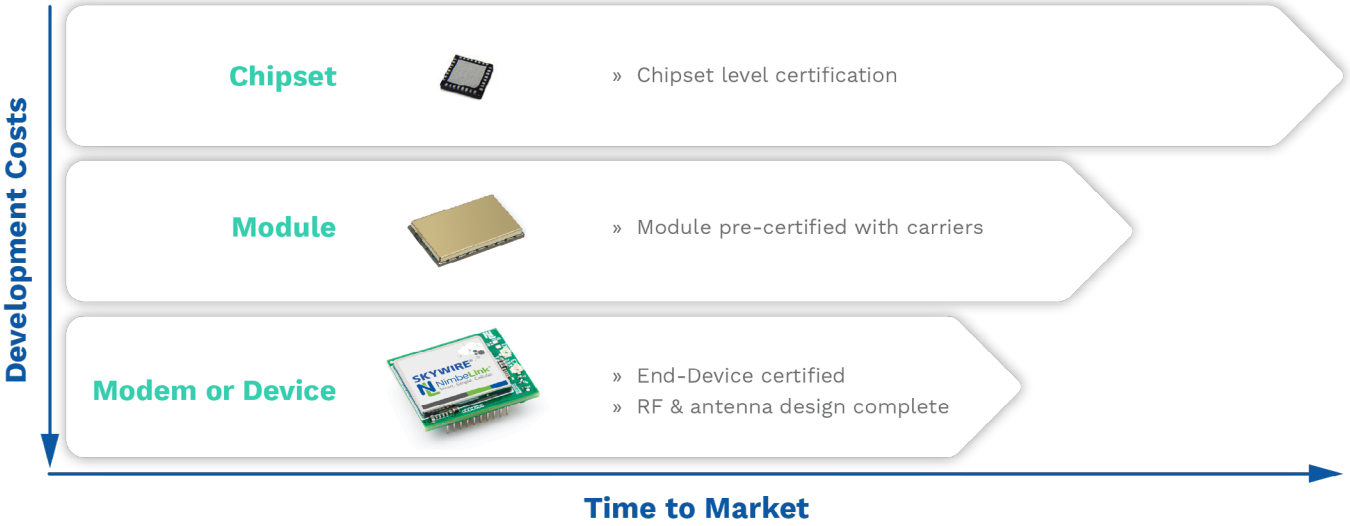
SAR is the rate at which human body tissue heats up when exposed to a specific radio transmission. SAR is literally a measure of **"Will this transmitter cook you?"**. While MPE is a math problem that you pass or fail, SAR testing is a lab test performed with a specialized test system using real samples of your product placed on a simulated human body. There are additional things to consider for SAR testing, such as how to make your device sit in continuous transmit mode for long periods of time. This includes dealing with overheating, battery depletion, device communication and other factors. The more prepared you are for the testing, the faster it will go and the greater the likelihood you'll pass the first time. This can be a high-value situation to pull in an experienced consultant.

In general, if you develop a product with a transmitter in it, the first thing you do is evaluate the use cases. If your antenna is mounted in a place where it's more than 20cm from people under normal operating conditions and your transmitter power isn't huge (i.e. TV station kilowatt huge) then you're good to go. If the antenna is closer than 20cm but your transmit power is small, like

most common cellular, Wi-Fi and Bluetooth transmitters, use the MPE calculation to determine your field strength. If you're over the MPE limit, then you do SAR testing. If the SAR testing shows you're over the SAR limit, you'll need to address that issue under the specified normal operating conditions. This is where an experienced consultant can save you a lot of time and money as there are tricks to achieving compliance without detrimental changes to the radio's performance.

Device and Modular FCC Certifications

If your product has a radio transmitter in it, that radio transmitter requires some sort of license grant from the FCC for it to be legally offered for sale in the US. The fine for selling products without a proper license grant is triple whatever revenue you made selling it. Let's say you implement a Bluetooth radio chip from one of the silicon suppliers who sell such things. Because it's a chip, it generally hasn't had any FCC testing done to it so you will need to perform that testing, typically at an accredited test lab, and file an FCC submission to get a grant to sell that product. That grant is a **Device-level certification**. It holds for that device in that configuration. Different rules apply for different radio types and sometimes include the configuration of the antenna.



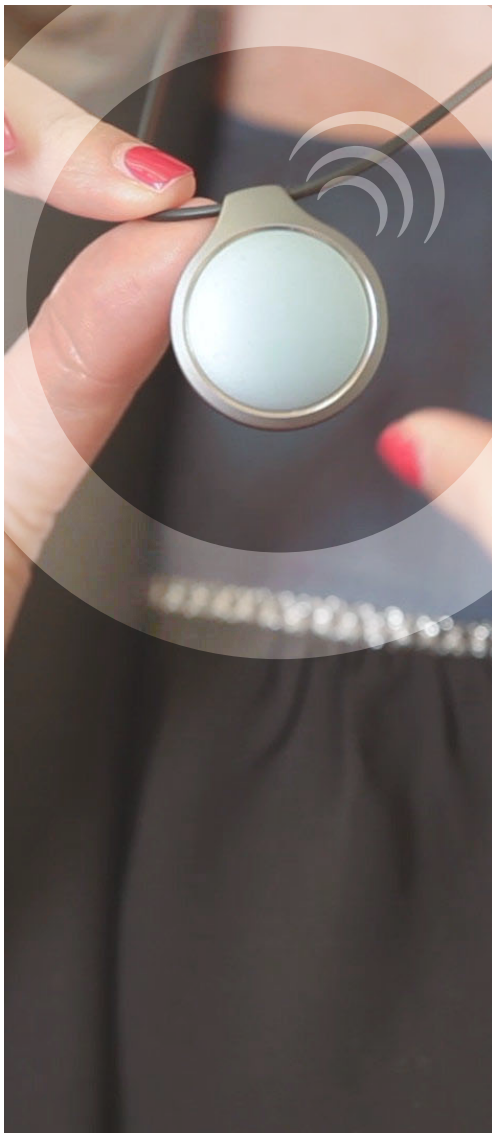
Another way to accomplish this is to use a radio module or embedded modem that includes the above radio chip, that has already had FCC testing done. This type of license grant is called a **Modular certification**. A modular certification allows that radio module to be included inside many different end products and as long as the end product uses the transmitter in compliance with the grant from the FCC, the end product doesn't need any additional transmitter testing. Note that it may need other sorts of testing that FCC would care about, depending on the nature of the device.

"...if your device doesn't meet that requirement, you can't sell your product using just the modular certification, you have to file your own FCC submission for your product and get your own device-level certification."

Now here is where things get more complicated. ALL FCC modular certifications include the following two restrictions on the use of the radio module:

1. The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20cm from all persons.
2. It must not transmit simultaneously with any other antenna or transmitter, except as evaluated in this filing or in accordance with FCC multi-transmitter product procedures.

The first part about antennas being 20cm from all persons is the FCC saying that your end device must automatically comply with the MPE rules. That second part is saying that this module can't be combined with other transmitters in your product. In both cases, if your device doesn't meet that requirement, you can't sell your product using just the modular certification, you have to file your own FCC submission for your product and get your own device-level certification. These two restrictions are on ALL modular certifications. Most modular certifications also have additional restrictions, sometimes on attached antenna type/model/gain, sometimes regarding documentation and implementation.



Let's say your product is a pendant with a cellular radio in it that hangs on a chain around a person's neck. It lays right up against the chest under normal conditions. You chose to use an off-the-shelf radio module, and create your product and do the MPE calculation, and it fails the MPE limit. ***Note:*** *An experienced radio designer can tell you what will likely pass or fail just by looking at the planned details of your product, in which case you may well have known this at the start of the project and prepared for it.* At this point you need to do SAR testing, and file for a new FCC ID for your product. The good news is that this happens all the time. It's not a big deal and you should absolutely not let it dictate other aspects of your product development. Most companies that sell radio modules with a modular certification are used to customers needing to file for an ID change. As part of the ID change, you're getting a device certification so you will need to do testing that is affected by your implementation of the radio module. In the context of SAR testing this can be as little as doing the SAR testing and other radiated transmitter related and submitting those results along with referencing the original FCC filing from the supplier.

SAR testing will often be needed if you're building a body-worn product with a radio transmitter. SAR testing for a cellular radio (single technology like M1, 5 bands, US only) runs around $7k and takes about 5 lab working days. European regulators care about SAR as well, and have different rules and bands. So doing US and EU for a global product runs around $11k and is closer to 7 working days at the lab. The actual FCC filing typically costs about $1,200 and approval times are usually around 2 weeks. The costs and durations will vary from lab to lab, so you'll always want to get a quote specific to your product from whatever lab you select.

Region	Cost	Lab Time
US only	~$7K	~5 Days
US and EU	~$11K	~7 Days

Approximate Cost & Time involved with SAR Testing and FCC Testing

Avoiding SAR testing is obviously desirable, but every cellular handset, WiFi enabled tablet and many other products include SAR testing as a standard part of the development process. It doesn't have to be a major development risk as long as you understand what you're getting into.

If you have questions about SAR testing, or would like guidance on how to accomplish this process, reach out to F3 Wireless or NimbeLink. We have the experience and know-how to guide you through while avoiding potential pitfalls.

www.F3Wireless.com

Sales@F3Wireless.com

www.NimbeLink.com

Sales@NimbeLink.com