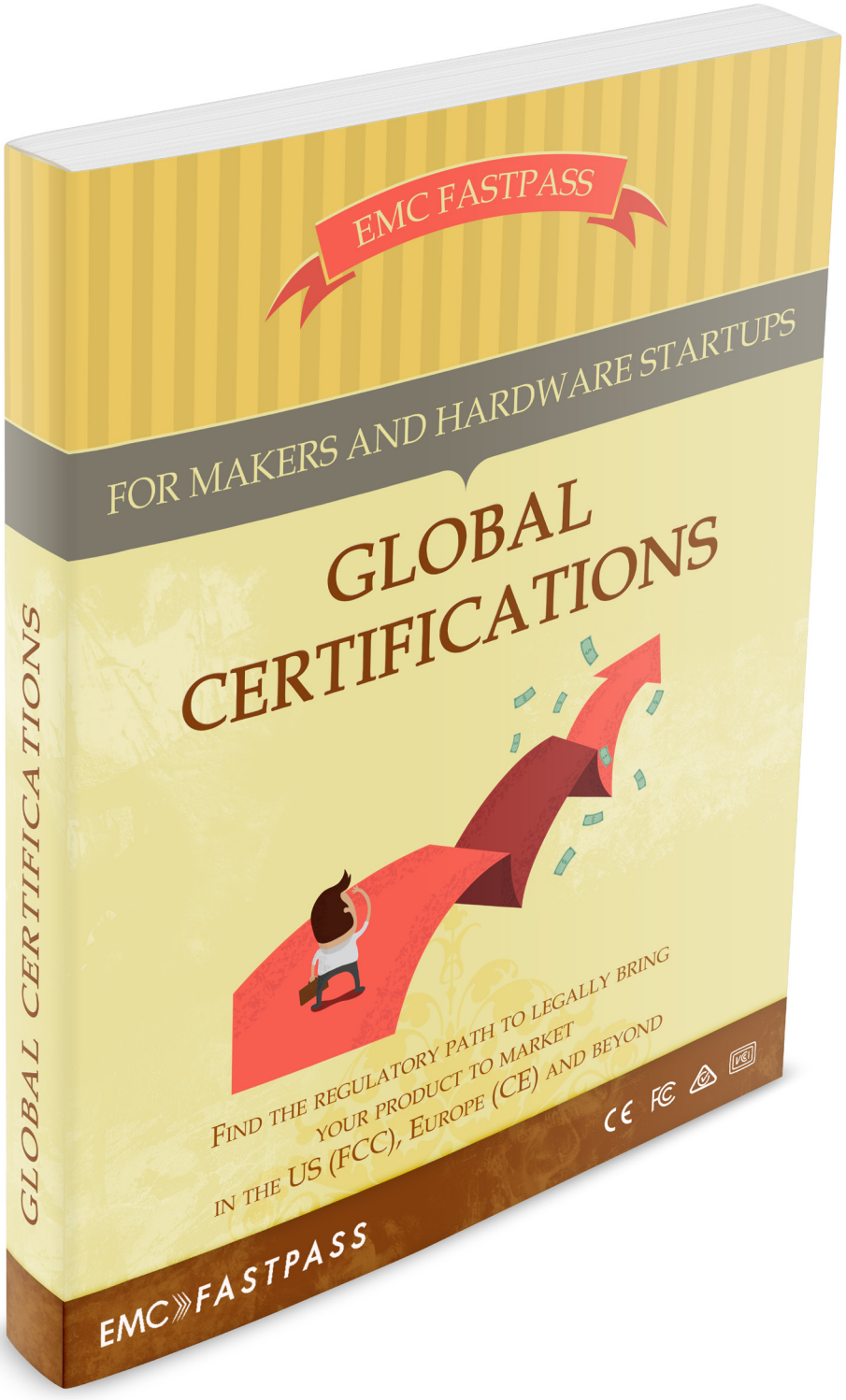

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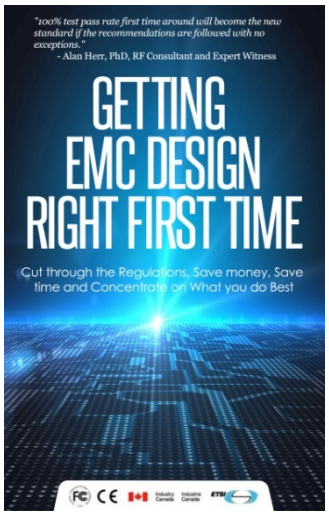
Essential Tools

Getting EMC Design Right First Time (Free Download)



If you want to get through regulatory testing as fast and cheaply as possible, you need to design your PCB with good EMC design techniques in mind.

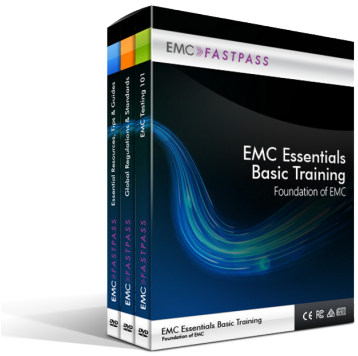
Downloaded and used by thousands of engineers and makers across the globe, this is the essential guide to EMC design.

This is also the best way to join the EMC FastPass mailing list. On the list, I send out blog updates and loads of information that can save you thousands of dollars on regulatory testing. No spam, obviously.

Go get it now!!

EMC FastPass Training Courses

If you want to train up your team on rules and regulations, EMC design strategy and pre-compliance testing tools, then your company needs EMC FastPass membership.



When you're a member, you get unlimited access to over 120 bite sized training modules on topics such as EMC testing, global rules & regulations, emissions, immunity and high speed design strategy as well as pre-compliance tools and techniques for emissions, immunity and RF (Wireless).

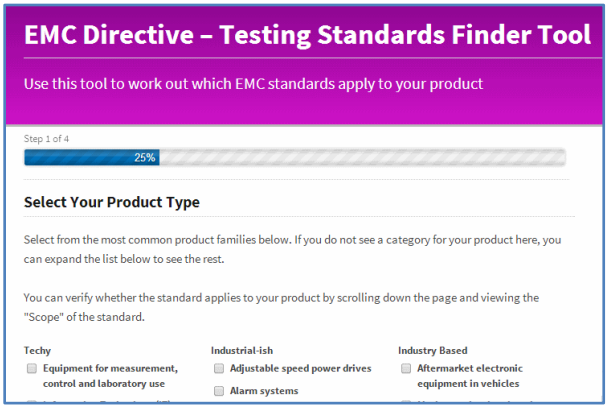
The library of modules is always expanding as regulations change and clients have different requests for further information.

EMC FastPass Design Review Software

With EMC FastPass Membership, you also get an annual license for the "EMC Design Review Pro" software. This is an online tool that guides you through a manual design review of your own product to check for good design practices for EMC emissions and immunity performance.

It provides a step by step process for evaluating your design's readiness for EMC compliance testing. Even engineers who are new to EMC compliance can pick up the concepts quickly. At every step there is a video training module so you can truly learn EMC "on the job".

Find out Which EMC Standards Apply to Your Product in Europe



Finding the right EMC standards that apply to your electronic product in Europe can be really difficult.

That's why we created a tool to help you find the standards quickly (and for free).

Just find your product family, check the scope of the standards and then view the name of the applicable standards. The tool generates a PDF report of the findings and automatically emails them to you.

Find your EMC standards now

Where to buy this eBook

Did you pay for this eBook? If you didn't, go and **buy a legal copy.** If you 'happened' across a copy of this eBook and need to purchase a 'legal' version, get your own copy **from here**.

Note: Duplicates are not legal. Receiving a copy as an email attachment from your friend 'Bob' or your work colleague 'Amanda' does not make it legal. It is only a legal version if you paid for it. Go **buy it now**.

Introduction

This eBook is intended to give you a top level overview of everything you need to know about approvals and certifications for taking your hardware design to market, legally.

About the Author and EMC FastPass

What would happen if the global EMC first time pass rate increased from 50% to 100%? That was the question on my mind when I started EMC FastPass. Here's how I arrived at this question and how I came to build a solution that addresses this important issue:

I began my engineering career back in 2001 with a degree from the University of Glasgow in Scotland. Although I took classes in electromagnetic engineering, I never suspected I would work in the industry. I spent the next 10 years working as a hardware design engineer for small start-ups as well as large corporations. I worked on projects in a diverse range of industries including consumer, military, medical and industrial.

In 2010 I saw the opportunity to branch out and start an EMC test lab where I live on Vancouver Island, West Coast Canada. I built the lab from the ground up and grew the business over 3 years to a point where I was getting clients from not just Vancouver and Vancouver Island, but from all across North America. I think the lab succeeded due to the proactive EMC design support I was able to offer my clients. They enjoyed talking with a skilled design engineer if they failed for any reason, for no extra cost. At many other labs, manufacturers are left to fend for themselves or pay over $150/h for a skilled EMC consultant.

In 2013 I chose to close down the test lab for a number of reasons. EMC labs are very capital intensive and also have several other downsides from a business perspective. I was geographically limited in the customer base, so the growth potential was very limited.

Also, my goal was to get hardware companies through EMC testing as efficiently as possible and I realized that I could only help a very small number of companies with a bricks and mortar business. Hence in 2014 I decided to close the lab and focus on helping hardware companies across the world using the power of the internet.

In my time running the EMC lab, I got a good feel for the hurdles hardware companies consistently ran into and over time I put together a robust design review process that clients could use before they even came for testing. The design review was hugely successful at increasing the odds of a client passing first time. I've since moved this design review online so that hardware companies around the world could take advantage of it. Additionally, I put together several training courses that companies can access online via EMC FastPass membership. As of time of writing (Oct 2014), the official launch of EMC FastPass is getting very close.

There is also a unique perspective that only an independent 3rd party advisor can provide. Test labs sometimes have an inherent financial interest to guide you one way or the other. They may 'gently

guide' you towards test requirements that aren't mandatory. In some cases a particular lab may not even be the best option for your needs, but they're probably not going to tell you that. Only an independent 3rd party such as EMC FastPass can offer advice on which lab would be the best selection and which certification route would be most efficient and cost effective.

With the rise of crowd-funding platforms like Kickstarter, where people from many regions across the world can now purchase hardware products from engineers and makers who are fresh to the certification process, the prospect of identifying and obtaining all of the correct certifications can be daunting. EMC FastPass can help companies like these to lower the risk of failure that regulatory testing poses and ultimately accelerate their time to market.

As for motivation, I get mine from helping clients to get through the red tape of regulations as quickly and efficiently as possible. The irony of being a free-market advocate working in the thick of global regulations is not lost on me. If I can offer advice that helps hardware companies navigate their way to market in a world of increasing bureaucracy, then my conscience is clear.

Legal Notices

The information contained within this eBook should be considered to be an opinion, not legal advice. Under no circumstances should you rely solely on the information in this eBook to determine which tests are mandatory or exempt. Testing and regulations are complex and vary significantly from product to product. Always contact a regulatory body or test lab authorized to give advice to get confirmation of the correct approvals route for your particular product.

Electronic Product Certifications - The Moon's Eye View

With the emergence of crowd funding platforms like Kickstarter coupled with the explosive growth of easy to use hardware development platforms like Arduino™, a new wave of electronic products is being unleashed around the world by creative enthusiasts who may otherwise be relegated to garage tinkering. For these makers and hardware startups alike, the road to launching a viable product is difficult enough without introducing the extra barrier to entry of product certifications. Most though, require at least some form of testing to show compliance with the rules that apply to their particular product. Information on the subject is often hard to find and is seldom concise. When I owned and managed an FCC listed test lab, I noticed that even well established hardware companies often struggled to work out which rules applied and how to interpret them.

Below, I dig into a top level overview of the many rules and regulations that can stand in the way of earning money from product sales.

Certifications for electronic products is such a huge subject because there are so many different types of electronic equipment and so many different regulations that can apply. Regulations can differ per geographical region, per product type and per industry. This section is an attempt to give not a bird's eye view, but a moon's eye view. Because birds can only see as far as the horizon, a bird's eye view would be too myopic. As a hardware company considering how to legally bring your product to market in many geographic regions around the world, you're going to need a better view than that.

What is Regulatory Testing?

Regulatory testing is mandated by various governmental and non-governmental organizations around the world to help provide order to the huge number of electronic products that enter the market every year. For most electronic hardware manufacturers, jumping over the regulatory testing hurdle is essential for legally marketing and selling their product.

There are many types of regulatory testing that can apply to electronic products. For creators of electronic hardware products, the big 3 regulations that you usually have to concern yourself with are EMC, safety and RF (Radio Frequency aka Wireless). Depending on the industry that you're designing your product for and which geographic regions you'll be selling into, other regulations may apply (these are discussed later in the eBook). But since EMC, safety and RF are the most widely applied regulations, that's what I'll focus on for the majority of the eBook. We'll dig into exactly what these regulations are in the following chapters.

Types of Certifications

Firstly, I should define what I mean by "certification". Typically, a product is tested by a 3rd party lab or in-house lab to make sure it complies with a specific set of tests or standards. If a product passes those tests or standards, it may be designated as "certified", "approved", "authorized", "listed", "verified" or "compliant" depending on which test was undertaken and what authority the organization performing the test holds. For now, I'm going to use the word "certification" to mean compliance with a test or standard, but understand that it may not be exactly the correct word to use in all cases. In the same way, I may use the words "regulations", "rules" and "laws" interchangeably. They should all be

understood to just be indicative of a set of instructions or guidelines set by a particular entity or agency that it is your job as manufacturer to comply with.

Next, I'm going to break down the types of certifications you may need into some large categories. The first two categories, "EMC" and "RF" are by far the most common test requirements for electronic devices. The subsequent test requirements "SAR", "Safety", "Environmental" and "Proprietary" are all dependent on what type of electronic device you're making, which geographic regions you're selling in to and what the application of your product actually is.

EMC - Electromagnetic Compatibility

This type of certification applies to almost every electronic product, regardless of product type, geography or function. There are a few exemptions, but for most of us who design electronic products, there is no escape! You can blame the laws of physics for that one, or the Scottish physicist James Maxwell for formulating the theory of electromagnetic radiation if you're looking for a culpable character.

EMC testing involves measuring the electric fields that your product unintentionally generates to ensure that the strength of the fields does not break the limits set by regulatory agencies around the world. This is called "emissions testing". If your product is powered from a public AC power supply, the noise that your device injects back on to the power grid may also be measured. This is primarily to ensure that your product does not interfere with nearby electronic products.

EMC testing also includes "immunity testing" in some geographic regions and for some specific product types. Immunity testing involves subjecting your device to several electromagnetic phenomena to ensure that it continues to perform as expected. Examples of the phenomena include ESD (Electrostatic Discharge) zaps (for example, when you get out of your car and get zapped when you touch the metal) as well as power supply surges. Immunity testing is mandatory for most electronic products sold into Europe (CE Mark).

Incredibly, approximately 50% of electronic products fail EMC testing first time. Failures usually mean product launch delays of several days to several weeks coupled with extra testing and production expenses. This is the problem that my company EMC FastPass was created to address.

RF (Wireless)

If your product includes a wireless transmitter that hasn't been previously certified, then you're most likely going to need to have your product tested for RF compliance. This type of testing/certification also applies regardless of geographic location or product type.

RF testing involves measuring and characterising the RF signal that your product intentionally generates. RF regulations are designed to provide order to the electromagnetic spectrum and ensure that wireless devices can live harmoniously together. They also provide limits for occupational exposure to RF fields.

SAR - Specific Absorption Rate

SAR testing is closely related to RF testing. This is used to measure the amount of RF energy absorbed by the human body when using or wearing a wireless device to ensure that it's safe. SAR testing is generally only necessary for wireless devices that are worn or used in close proximity to a human body (laptop, cell phone etc..). The applicability of SAR testing to your product depends on the frequency and power of the transmitter and its proximity to a human in normal usage. Most countries/regions have regulations for SAR test requirements. SAR testing labs will often also be EMC/RF testing labs. Contact a SAR lab to verify whether SAR testing applies to your product.

Safety

Safety testing assures consumers that a product is safe to use and complies with the relevant standards for a given geographic region and/or industry. Confusingly, safety testing only applies to some electronic products, in some geographic regions, in some circumstances.

For instance, in North America, safety testing of electronic devices is usually not mandatory (many caveats exist to this rule). Whereas in Europe, most electronic devices that are powered from >50V AC or >75V DC are subject to the "Low Voltage Directive" or GPSD (General Product Safety Directive) which are both safety related legal acts.

The applicability of safety testing is not only driven by geographical region, but also application and end customer. For example, safety testing of most medical devices is mandatory regardless of geography. This is the same for many other international product safety standards.

As an electronics manufacturer, your end customer often has the final say whether you need to have your product tested for safety. There may not be a legal mandate for your to do safety testing on your product, but your end customer may demand it.

Also in the US, the Department of Labour Occupational Safety and Health Administration (OSHA) mandates that many electrical products used in most public and private workplaces need to comply with safety rules and must be approved/certified by an NRTL (National Registered Testing Lab). So, if your product is destined for a workplace, you may well need to do safety testing. NRTL is discussed later in the eBook.

Environmental

Environmental test requirements can be split up into two sub categories. The first is environmental in the sense of "environmentally friendly". This type of testing relates to subjects such as energy efficiency (e.g. Energy Star), toxic substances and material composition (e.g. Lead Free RoHS) as well as recycling. Lead free compliance and recycling symbols are required for most electronic equipment in Europe. Energy efficiency testing tends to not be mandatory, but be driven by customer demand instead.
Sometimes subsidies are given by governments to consumers for purchasing energy efficient products, so it makes sense to cater to this market.

The second type of environmental testing deals with how a product performs in different ambient environments. Depending on the specific requirements for the product, this may include subjecting the device to extremes of temperature, moisture, vibration and even explosives. Wireless testing for Europe and the US often requires temperature testing to ensure that the transmission signal doesn't drift outside the allowable frequency band. Demand for these tests tends to be driven by the end customer requirements and specific product standards. If the environment that your product is designed to be used in could perceivably have a negative effect on your product's performance, and your end customer cares about that, then the chances are that some type of environmental testing applies. Additionally, if you make claims about the environmental operating conditions in your user manual, then you'll need to back those up with data obtained through testing.

Proprietary/ License

What do I mean by proprietary certifications/licenses? Here I'm talking about instances where you need to work with a 3rd party who are usually a private body or organization to make sure that your device/software/interface is compatible with their set of standards, protocols or other types of rules they may have.

Common examples of this include Apple, Android, Bluetooth and Zigbee. In many of these cases, it's usually not mandatory to get these certifications, but it does allow you to 'prove' that your device is compatible with their technology. In this case, they may allow you to use their trademark on your packaging which can help with sales and get you into distribution channels that would be otherwise unavailable.

EMC Certifications

What Is EMC?

EMC stands for "Electromagnetic Compatibility". One of the first EMC regulations were originally formed way back at the turn of the 20th century in Europe in response to specific problems that arose from usage of electrical devices. Defective electric lamps caused other lights in the neighbourhood to 'flicker'. This was back in the days when electric power grids were new to London, England and some other wealthy places. To curb this problem, probably the first EMC legislation was enacted, called "The Lighting Clauses Act" of 1899!

EMC regulations have grown in scope over the following decades, but their function essentially remains the same; to ensure that devices do not cause harmful interference and to ensure that the device can accept interference.

EMC testing is required for almost all hardware devices. Some say it is overly burdensome to small scale manufacturers and that it favours large corporations who can afford the testing. While others say that it's crucial for protecting the electromagnetic spectrum. I personally fall somewhere in between these two viewpoints. I think the EMC standards do present a huge hurdle for the small guys and it's in the best interests of test labs, regulatory bodies and large corporations to continue to increase the scope of regulations.

But in my time running an EMC test lab, I saw many devices that didn't comply with the rules, through design errors and incorrect firmware settings. These devices could perceivably affect the electromagnetic spectrum for other devices operating in the vicinity. As the number of transmitters and electronic devices increases, these rules are only going to become more important to the interoperability of devices. I've heard from businesses in countries where the regulations are much more lax who have many customer returns due to their wireless transmitters not operating in a high ambient noise environment for instance. Poor EMC of other products affects these companies in a financially quantifiable way.

What EMC standards apply to you?

There are a few different options for working out which EMC standards apply to your product. I'll outline some options below so that you can see what's available.

Option 1 - Ask a test lab

This is probably the easiest method. Just call up the sales department of a test lab that you're considering using for product approvals. They should be happy to provide a breakdown of the applicable tests and give a quote for testing services for your particular product. If they're not, choose a different test lab.

Bear in mind that sometimes test labs get it wrong. They do their best, but occasionally they will give you some incorrect information. I've seen several product datasheets where they claim compliance with the wrong standard. It's not the end of the world, but it's worth getting right.

If you need a legally correct interpretation of the standards that apply to your product, ask a TCB (Telecommunications Certification Body) in the case of the FCC, or an NB (Notified Body) in the case of CE Mark for Europe.

One thing to note is that test labs can spend a decent amount of time researching the standards that apply to a given product. If it's a simple job for FCC or CE testing, then they'll probably be able to tell you which standards apply to your product off the top of their head. However, if your product is a wireless device (RF testing) that will be fitted to a bus (automotive testing) in South America (complex regulations on a per country basis), then they're probably going to have to do a fair amount of legwork. My point is: don't go asking a lab if there's no possibility that you'll use their services. The exception to that is when it's a lab's responsibility to give advice - in Europe for instance, if you need a concise answer on exactly which tests apply to your product, you can hire an NB (Notified Body) to interpret the regulations for you.

At my lab, I was happy to give advice for existing customers or if I had a shot at securing a new client. I drew the line at providing advice to customers that were using labs in China but asked for free support here because of the language barrier.

Option 2 - Check your competitor's datasheet

If any of your competitors claim compliance for the same target markets as you're aiming for, they often cite the standards that they've tested to in their product datasheets. Search Google for identical products and look for the compliance and regulations section of their datasheet. Very often you'll find the answer you're looking for.

Option 3 - Find them yourself

Manually tracking down the EMC standards is no easy task. It varies between geographic region and product type and there's way too much information to cover in this eBook. I cover this in detail in the EMC FastPass online training program - both for intentional and unintentional radiators.

However, I did develop a tool to quickly track down the EMC standards that apply to electronic products in Europe (CE Mark). You can find the tool here.

How to select a 3rd Party Test Lab

Choosing a good 3rd party test lab is quite an important decision. Their competence not only affects their ability to undertake the test procedures correctly, but also will influence how much help they can offer if your product happens to run into issues at the lab.

Finding Labs

Finding a test lab near you can sometimes be tricky. Actually, I acquired a lot of testing business because it was tricky. Because my EMC lab ranked high on Google searches, I managed to pick up clients from all across Canada and the US. Often the client would have a lab in the city that they were in, but they weren't aware of it because it was hard to find on the internet.

Anyway, when you know where to look it isn't actually that hard. The FCC keeps a database of all FCC listed/accredited test labs around the globe. Here's the link:

https://apps.fcc.gov/oetcf/eas/reports/TestFirmSearch.cfm

List of TCBs (Telecommunication Certification Bodies):

https://apps.fcc.gov/tcb/TcbHome.do

Here are the lab registries for a few more countries:

Canada: Test site registry
Japan: Test site registry
Australia: EMC and safety test site registry
UK: "EMC Compliance and Testing Directory" by the EMC Journal.

Note: Some of the registered test sites are private companies that do not provide 3rd party testing services i.e. they only test their own products.

Attributes to Consider

When choosing a lab, it's worth keeping the following criteria in mind:

- Can the lab do all of the testing that you require or will you have to find another lab for some of the testing?
- How close is the lab? How much time and money is it going to cost you to travel to the lab if required?
- Is the lab accredited?
- Is the lab registered with all of the agencies required to certify/approve your product for every country that you need to sell into?
- Do they provide free design support if your product fails?
- What is their lead time (i.e. the delay from booking to an available test slot)?

There isn't enough space here to cover the implications of these decisions in detail, but I cover them thoroughly in the EMC Essentials training course.

Costs

Costs for EMC testing vary wildly. They vary depending on the product type and function as well as varying massively from lab to lab (for exactly the same test schedule). With that caveat in mind, here is a crude breakdown of some ballpark costs that you can expect for the US (FCC) and Europe (CE):

Unintentional Radiator		Intentional Radiator (Wireless)	
FCC	**FCC +CE**	**FCC**	**FCC+CE**
$1k-$2k	$5k-$10k	$7k-$15k	$10k-$20k

Note that this ballpark pricing is for EMC and RF testing only. If your product needs any other types of

testing, those costs will be on top of these. For FCC and CE EMC testing, the fees above are a one-time deal i.e. there are no follow up costs associated with FCC and CE EMC testing. For many other types of testing, especially safety and medical, you may need to pay an annual fee to have an inspection of your product and/or manufacturing facilities to ensure that there is ongoing compliance with the rules.

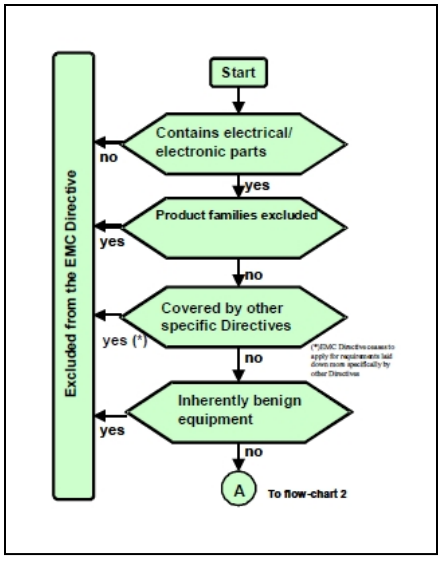
Exemptions

Unfortunately there aren't many EMC exemptions that you can take advantage of. If you're planning to design, manufacture, market and sell your product, then you're considered a manufacturer, even if you only sell 50 units a year. From the regulatory standpoint, you're no different than Samsung or Microsoft - you still need to ensure that your device complies with the rules.

If you're just starting out and have a limited budget, you're probably interested in ways to avoid the certification process. I have some bad news and good news for you now. The bad news is that in most cases, if you're making a product that you'll sell directly to consumers, there isn't really a way to avoid the test requirements. The good news is that there are a few exemptions to CE Mark and FCC rules that may or may not be relevant to your particular situation. Read on to see if you can take advantage of these scenarios.

CE Mark Exemptions

CE Mark testing under the EMC Directive, which is the main legislation in Europe governing the electromagnetic compatibility of electronic and electrical equipment, is usually quite a bit more expensive than FCC testing. That's because it involves emissions and immunity testing whereas FCC testing usually only involves emissions testing. Therefore, if you can avoid it you stand to save some serious time and money. The latest official guide for the EMC Directive outlines some products that are exempt. Firstly, take a look at this flow chart that gives you a general overview of the applicability of the EMC Directive. If you're reading this book, the chances are that you are involved with the design of some kind of electronic or electrical equipment, so it's safe to skip the exemption at the top of the tree.



Second, is the 'excluded product families' exemption. This refers to equipment covered by other standards such as radio equipment (covered by the R&TTE Directive instead). This doesn't necessarily mean that EMC testing won't be required for your product; it is usually just defined differently in another standard.

Thirdly, this is not shown on the chart, but it's important to mention that "*Components, subassemblies or other units which are intended for incorporation into apparatus, but which have no "direct function" for the end user*", are not considered to be products for the purposes of the EMC Directive. What this means is that if your company makes electrical products that will be integrated into other equipment,

this is a good exemption to take advantage of. Note that your end customer may still demand proof of compliance even if it isn't mandatory. Some examples of items that would fall under this exemption are:

- Components forming parts of electrical circuits, e.g. resistors, capacitors, coils, transformers, diodes, transistors.
- Cards or modules required for the minimum level of function of a system, e.g. central processing, minimum memory.
- Internal power supplies, including batteries- cathode ray tubes, light-emitting diodes (LED's), liquid crystal displays (LCDs).

The term "*Inherently benign*" is an exemption that covers a limited amount of electrical products. The definition of inherently benign is:

- Its inherent physical characteristics are such that it is incapable of generating or contributing to electromagnetic emissions which exceed a level allowing radio and telecommunications equipment and other equipment to operate as intended; and,
- It will operate without unacceptable degradation in the presence of the electromagnetic disturbance normally present in its intended environment.

Examples of inherently benign equipment include cables, passives, resistive loads, pocket lamps (without electronic circuits), quartz watches and loud speakers (without active amplification).

That covers all of the exemptions for the EMC Directive for Europe for electronic equipment. As you can see, there aren't too many.

FCC Exemptions

Most electronic devices destined for sale in the US fall under Part 15 (CFR 47) of the rules for limits to the unintentional (and sometimes intentional) emission of radiation. There are a number of exemptions that you may be able to take advantage of that you should keep in mind when designing your products.

You can find the bulk of this info in section 15.103 of the rules. The FCC recommends that even if your device is exempt, that you still aim to comply with the rules. They have the power to halt sales of your device if it has been found to cause harmful interference, so use the exemptions with caution!

Exemptions include:

1. A digital device utilized exclusively in any transportation vehicle including motor vehicles and aircraft. (Note: wireless devices are still subject to other FCC rules)

2. A digital device used exclusively as an electronic control or power system utilized by a public utility or in an industrial plant. The term public utility includes equipment only to the extent that it is in a dedicated building or large room owned or leased by the utility and does not extend to equipment installed in a subscriber's facility.

3. A digital device used exclusively as industrial, commercial, or medical test equipment.

4. A digital device utilized exclusively in an appliance, e.g., microwave oven, dishwasher, clothes dryer, air conditioner (central or window), etc. See KDB 772105 for more information on what this covers.

5. Specialized medical digital devices (generally used at the direction of or under the supervision of a licensed health care practitioner) whether used in a patient's home or a health care facility. Non-specialized medical devices, i.e., devices marketed through retail channels for use by the general public, are not exempted. This exemption also does not apply to digital devices used for record keeping or any purpose not directly connected with medical treatment. (Other EMC rules usually apply instead)

6. Digital devices that have a power consumption not exceeding 6 nW.

7. Joystick controllers or similar devices, such as a mouse, used with digital devices but which contain only non-digital circuitry or a simple circuit to convert the signal to the format required (e.g., an integrated circuit for analog to digital conversion) are viewed as passive add-on devices, not themselves directly subject to the technical standards or the equipment authorization requirements.

8. Digital devices in which both the highest frequency generated and the highest frequency used are less than 1.705 MHz and which do not operate from the AC power lines or contain provisions for operation while connected to the AC power lines. Digital devices that include, or make provision for the use of, battery eliminators, AC adaptors or battery chargers which permit operation while charging or that connect to the AC power lines indirectly, obtaining their power through another device which is connected to the AC power lines, do not fall under this exemption.

9. Home-built devices: Equipment authorization is not required for devices that are not marketed, are not constructed from a kit, and are built in quantities of five or less for personal use. It is recognized that the individual builder of home-built equipment may not possess the means to perform the measurements for determining compliance with the regulations. In this case, the builder is expected to employ good engineering practices to meet the specified technical standards to the greatest extent practicable.

Evaluation Kits

I'm often asked whether electronics 'kits', where the kit is a group of parts assembled by the end user can be exempted from the rules. This section explores that idea.

The FCC defines a kit as (FCC 15.3):

"Any number of electronic parts, usually provided with a schematic diagram or printed circuit board, which, when assembled in accordance with instructions, **results in a device subject to the regulations in this part, even if additional parts of any type are required to complete assembly**."

Based on the definition above, it looks clear that non-authorized kits that are intended to form a complete product when fully constructed are technically not legally permitted to be sold in the US. That is because if you are marketing and selling a kit to an end user, which the user will then build into a full product, there is no reason to suspect that the normal rules would not apply. Kits would have the same, if not more (because extra human error is introduced) chance of being non-compliant with the radiated

and conducted emissions limits. It just doesn't make logical sense that kits would be excluded from FCC emissions rules.

The same is true of intentional radiator kits (i.e. products with a transmitter that are subject to certification). In response to the question "*What are the FCC Rules for building and marketing of kits of products, which when completed are subject to the FCC Rules?*", the FCC replied quite clearly in KDB927445 that "*As described in Section 15.23, individuals are permitted to construct a device for personal use without seeking equipment authorization from the Commission, but it may not be marketed as a kit. All other devices subject to Certification (whether marketed as a Kit or not), must be certified under Subpart J of Part 2*."

I would point out that there is a distinction between a kit that when assembled will form a "subassembly" and a kit that will form a full device that will be subject to normal FCC authorization procedures. Kits that form subassemblies will be discussed separately below this section. Here I am only discussing kits that are intended to form a full product once the end user puts the pieces together.

You may be asking yourself how companies such as Sparkfun, a business based on selling electronics kits and wireless development kit companies continue to sell large numbers of non FCC authorized kits, with seeming impunity. For Sparkfun, the rules that apply in most cases relate to "subassemblies". This just means that Sparkfun's customers will most likely use the products to build larger products containing a number of subassemblies. For example, that may include an Arduino™ processor board along with several sensors or peripherals and an LCD. The user may even put all of these parts into an enclosure. If the user sells this product containing multiple subassembly parts in an enclosure, for all intents and purposes they are now a "manufacturer" and their equipment is subject to the normal FCC authorization procedures.

Where is the FCC's line in the sand for when home built equipment becomes subject to their rules? That is defined in Part 15.23.

"Equipment authorization is not required for devices that are not marketed, are not constructed from a kit and are built in quantities of five or less for personal use."

That's probably easier to understand if I say it in the opposite way; If you are marketing your product (are you putting out ads, or offering your product for sale?) or it is not intended for personal use (i.e. it's for someone else) or if you make more than 5 of them, then you need to have your device tested according to FCC rules. If you do any of these things, the FCC views you as a manufacturer.

Sub-Assemblies

Keeping your device within the scope of "subassembly" definition is one of the best chances you have of avoiding FCC (and CE) authorization requirements.

The exemption goes as follows (FCC 15.101):

"No authorization is required for a peripheral device or a subassembly that is sold to an equipment manufacturer for further fabrication; that manufacturer is responsible for obtaining the necessary authorization prior to further marketing to a vendor or to a user.

Subassemblies to digital devices are not subject to the technical standards in this part unless they are marketed as part of a system in which case the resulting system must comply with the applicable regulations. Subassemblies include:

(1) Devices that are enclosed solely within the enclosure housing the digital device, except for: power supplies used in personal computers; devices included under the definition of a peripheral device in §15.3(r); and personal computer CPU boards, as defined in §15.3(bb);

(2) CPU boards, as defined in §15.3(bb), other than those used in personal computers, that are marketed without an enclosure or power supply; and

(3) Switching power supplies that are separately marketed and are solely for use internal to a device other than a personal computer."

If you can keep your device within that definition, then you can probably get away without FCC testing. It would be up to the manufacturer that uses your "subassembly" in their own product to have their product tested.

FCC Caveat: "*Responsible parties should note that equipment containing more than one device are not exempt from the technical standards in this part unless all of the devices in the equipment meet the criteria for exemption. If only one of the included devices qualifies for exemption, the remainder of the equipment must comply with any applicable regulations. If a device performs more than one function and all of those functions do not meet the criteria for exemption, the device does not qualify for inclusion under the exemptions."*

For example, if you have a device with a wireless transmitter and some baseband circuitry that happens to be exempt, the wireless transmitter still has to be tested.

Labelling and Documentation

Correct labelling of your device is an important thing to get right. The FCC has a maximum penalty of $10,000 for not 'marking' your product correctly. Penalties are covered in section 1.80 of the rules. When I was running the test lab, the question of how to label devices properly as well as what information needed to go into the manual were some of the most frequently asked questions.

Rather than write a whole chapter on that here, I'll just point you to the FCC and CE guidelines that outline all of the information for different types of devices. I'm also working on an online question based tool to streamline this process, but it's not quite ready yet. Watch the EMC FastPass website for updates on that.

FCC

Part 15 and Part 18 labelling guidelines: KDB 784748 D01

E-labelling guide: KDB 784748 D02

Labelling quick guide: KDB 784748 D03

CE

CE Mark quick guide (page 2): General information of the EMC Directive

Labelling for intentional radiators (Sections 6.5.1 thru 6.5.6): Guide to the R&TTE Directive 1999/5/EC

Lead free: RoHS (Restriction of Hazardous Substances)
Recycling: WEEE (Waste Electrical and Electronic Equipment Directive)

Open Source

With the rise of platforms like Arduino™ and Raspberry Pi™, there's no doubt that there's a huge surge in new talent joining in on hardware development and sales. Even for established manufacturers, the routes to compliance are not obvious. For designers and makers who have never created or sold an electronic product before, the learning curve is even steeper.

This problem is compounded by the international sales aspect of funding sites like Kickstarter and Indigogo. Instant exposure to a global marketplace means that you may need multiple regional approvals in place before you can legally send your finished product to customers.

Hardware

From a product approvals aspect, there is no distinction between open source hardware and closed source (traditional) hardware. The FCC and similar regulatory bodies only consider whether a complete electronic product is marketed and offered for sale. If that is the case for a product you have designed, you are considered a manufacturer for all intents and purposes.

Platforms like Arduino™ and Raspberry Pi™ allow you to develop and create products quickly, but they usually only form a subassembly of the overall product that you're creating.

You may add several peripherals and sensors to your device or connect several boards together to create a product with more functionality. It is the complete product consisting of subassemblies and an enclosure (if you have one) that will be considered a complete product for the purposes of regulatory testing.

However, understand that working with open source hardware and software may have large implications in terms of copyright and trademark law. A good article on the subject gives you an overview. These are areas that you need to be aware of and comply with, but they don't have a bearing on the legality of your product for the purposes of import/export and product approvals, so they're outside the scope of this eBook.

Creative Commons Licenses

One of the aspects you need to be aware of when creating a product using open source hardware such as Arduino™ is that the designs are usually supplied with a license referred to as 'creative commons'. This allows you to modify their design and create derivative works based on their original design. As an example, Arduino™ allows you to do this, but they require you to credit Arduino™ and also release your design under the same creative commons license.

This agreement is between you, the manufacturer and a private entity such as Arduino™. This would fall under the "Proprietary" license category that I discussed in the first section of this eBook. There may be

other stipulations in the usage of open source hardware such as including trademark symbols and attribution of license information, but again, this is an agreement between you, the manufacturer and a private entity. Check the agreement with your open source hardware supplier to make sure that you are in compliance with all of their rules.

Software

For open source software, often provided under the GPL (General Public License) or LGPL (Lesser General Public License) framework, there are also no implications for regulatory product approvals or import/export rules.

There may be stipulations in the software licenses on how you use can utilize the base code and your responsibilities for keeping your own source code and extensions as open source (or not). But again, this is an agreement between you, the manufacturer and a private entity.

RF (Wireless) Certifications

What is RF Testing?

RF testing involves measuring and characterising the intentionally generated RF signal coming from your transmitter. This is done to ensure that your RF transmitter complies with the rules for the region or regions that you're selling your product into. Characteristics such as power output, emissions bandwidth and channel allocation are some of the things that a test lab will check. RF frequency allocations differ quite a bit depending on geographical location, so a transmitter certified for one country may not be compliant in another country. A good test lab will give you guidance on picking transmission frequencies for your application.

Pre-Certified vs. Certification Overview

If you need to design an RF transmitter into your product, the choice between using a pre-certified RF module, non-certified RF module or designing your own transmitter from scratch is not easy. In the section below, I outline some options for wireless certification routes. In particular, I want to point out that if you design multiple products containing similar RF transmitters, designing and certifying your own RF module is one of the best ways to save over $10,000 and 1 month time to market per product. Read on to discover the ins and outs of RF modules and what you need to know to avoid some common pitfalls…

RF Implementation Comparison

Here's a top level overview of the routes you can take to implementing a wireless solution into your product. The ballpark pricing here is for Wi-Fi modules, just to pick an example. The certification costs brackets are wide because they account for variations in regional test requirements and configurations of equipment.

Type	Cost PU	Certification Cost	Certification Delay	Design Effort	Certification Cost (next product)	Design Effort (next product)
Pre-Certified Module	$25-$50	$1k-$2k	<5 days	Low	$1k-$2k	Low
Non-Certified Module	$15-$20	$7k-$20k	4-6 weeks	Med	$7k-$20k	Med
Your own module	**$3-$10**	**$7k-$20k**	**4-6 weeks**	**High**	**$1k-$2k**	**Low**
Standard transmitter on your PCB	$3-$10	$7k-$20k	4-6 weeks	High	$7k-$20k	High

Figure 1 - Wireless Implementation Comparison

Note that designing your own module really makes a difference to the certification cost and design effort for your next product…. and the one after that…. and the one after that. You get the idea.

What Is An RF Module?

An RF module is a separate circuit board (subassembly) that contains all of the circuitry needed to transmit (and usually receive) RF energy. It may include an integrated antenna or a connector for an

external antenna. It's typically shielded to limit unintended emissions and increase EMC immunity. RF modules are typically integrated into a larger embedded system to add wireless communication functionality. There are "receive only" RF modules and "transmit only" RF modules, but because most implementations include transmit and receive, that's what we'll be covering below.

Two of the most widely used RF modules are Bluetooth modules and Wi-Fi modules. But, almost any transmitter can be a wireless module. It's important to note that even 'licensed transmitters' (transmitters that require the operator to get a license to legally use the device) can get modular certification. However, in this section I'm going to focus on the most common implementation, which is 'unlicensed low power transmitters' where the operator can just buy the equipment and start using it immediately. In FCC terms, that means a transmitter that falls under part 15 of the FCC's rules and frequently subpart C.

As I mentioned, some examples of RF modules are Bluetooth modules and Wi-Fi modules. You can easily add in this functionality into your system by dropping in a module.

Pre-Certified vs. Non Certified RF Modules

When you're shopping around for a solution, you'll notice that manufacturers of RF modules offer both pre-certified and non-certified options. Read on below to find out the pros and cons of each option.

Pre-Certified RF Modules

A pre-certified RF module means that the manufacturer has gone to the effort and cost of certifying that particular module. It's very important to note that the manufacturer must have certified the module in all of the countries or regions that you intend to sell your product, otherwise you're going to have to get a lab to do a full RF certification anyway to cover the new region.

Pre-Certified RF Modules Upsides

- Fastest time to market
- Reduces risk of RF certification to zero
- Fast integration time into your product

Pre-Certified RF Module Downsides

- High cost per unit
- Restricted to antenna type(s) used in original certification
- Restricted to modulation schemes used in original certification
- Risk of OEM (Original Equipment Manufacturer) product shortages

When you use a pre-certified RF module, you're restricted in your choice of antenna(s). The original manufacturer (OEM) would have provided the EMC testing laboratory doing the RF testing with one or more antennas to certify the transmitter with. Because the antenna type has such a large effect on transmitter behaviour and performance, the end customer (you) have to choose an antenna type that is electrically identical to those used during the original tests. The RF module OEM will/should provide you with an 'integration manual' that details exactly how the module should be integrated into your device, including the choice of antennas.

In the same way, you're also restricted to the modulation types that the OEM used during the original certification.

FCC ID Search Tool >>

You can search for this information by typing the FCC ID number in the FCC's search tool. The manual and implementation manual will be visible because it's publicly available information.

The obvious downside for using a pre-certified RF module is the per-unit cost. The OEM charges you a premium (quite rightly) for having gone through the headache of RF certification testing. It can take 4-6 weeks to fully certify a transmitter, and that's assuming all goes well! And costs can run anywhere from $7k to $20k per transmitter depending on which regions you want to certify for and how many antennas/modes of operation the transmitter has. If your goal is fastest time to market, using a pre-certified RF module reduces the risk introduced by wireless certifications to practically zero. Similarly, if your product is low volume and high margin, it may not be worthwhile to fork out for your own transmitter design.

Pre-Certified RF Module Examples

Upverter have compiled a good list of Wi-Fi and Bluetooth modules including average pricing, certification regions and a bunch of other useful criteria. Here are the links:

Picking the right Wi-Fi module >>
Picking the right Bluetooth module >>

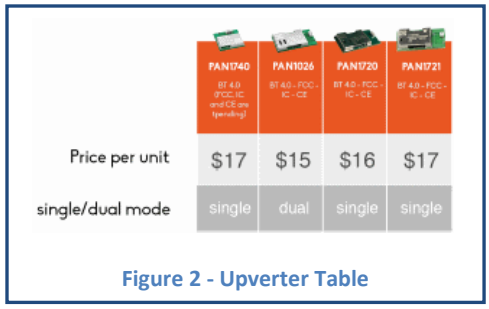


Figure 2 - Upverter Table

Non-Certified RF Modules

Non-certified RF modules are exactly the same as pre-certified modules, only the OEM hasn't put the module through official certification testing. They may well have undertaken their own testing on the device to prove that it is compliant, but you will also need to go through certification. I've unfortunately spoken to several companies who already designed in a non-certified module and weren't aware of this difference. It cost them around $10k and 4 weeks time to market that they didn't account for.

Non-Certified RF Modules Upsides

- Lower cost than pre-certified module
- Reduces risk of RF certification compared to designing your own module
- Fast integration time into your product
- Choose your own antenna(s) and modulation

Non-Certified RF Module Downsides

- Still higher cost than designing your own
- Reliant on OEM for parts (may go obsolete or have long lead time)

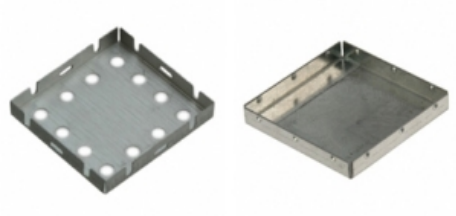
How to Design Your Own RF Module

The FCC has pretty good guidance on how to design your own RF module. The key is to make sure that you've ticked all of their boxes.

Probably the first thing to note is that there are 4 different levels of modular certification: single-modular transmitter, limited single-modular transmitter, split-modular transmitter and limited split-modular transmitter. The 'limited' options allow for relaxation of the rules at the cost of being constrained to your own host(s) i.e. you can't sell the module to other people or radically change the enclosure of your design. In this section, I'm going to focus on the Cadillac of modular certifications, the "Single-modular transmitter", because that's what you'll need if you intend to use in different styles of products.

Below I'm going to outline the requirements for FCC modular certification:

RF Module Shielding



The radio elements of the transmitter must be shielded. There are a few parts that are permitted to be external to the shield such as PCB antenna (if that's the type you're using) and tuning capacitors. But for the most part, all components associated with your transmitter should be housed beneath a shield. This is to limit any emissions from the design. I've seen FCC submissions where the OEM has claimed that a ground plane is sufficient for a 'shield', and they got away with it. But they must have caught the TCB (Telecommunications Certification Body - the body that issues the certification) on a good day. In my experience I would say not many TCBs would let you away with that.

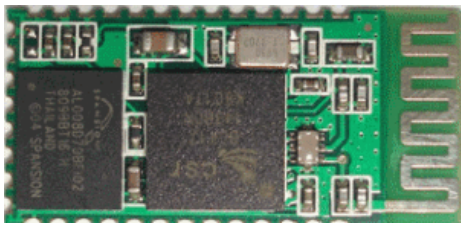
RF Module Buffered Data Inputs

The module must have buffered modulation/data inputs. Again this is an attempt to limit emissions for any type of host that the module will be integrated into. I've seen many modular certifications that use the justification that the inputs to the RF chip are buffered so therefore external buffers are not required. If you want to avoid any doubt, drop in some cheap data buffers.

RF Module Power Supply Regulation

The module must contain power supply regulation. Again, this is an attempt to ensure that emissions are contained when integrated into all hosts. Many RF solutions provide an on-chip regulator for powering a part of the transmitter circuitry. Depending on your solution, you may or may not need to include a separate external regulator for the RF module.

RF Module Antenna



The module must contain a permanently attached antenna, or contain a unique antenna connector, and be marketed and operated only with specific antennas. If you're not including a permanently attached antenna, you can see that the FCC wants you to use a 'unique' antenna connector. This is an attempt to make it difficult for the end user to use their own type of antenna. Ironically, antennas that fit the 'unique' connectors are now easily available from companies like Digikey. Connectors such as "SMA-RP" are considered unique, but not "SMA".

The RF module must demonstrate compliance in a stand-alone configuration

This just means that the EMC lab will need to test the module on its own. You can provide support hardware such as a carrier board or auxiliary debugging equipment, but the module should not be within a host device for testing purposes.

The RF module must be labelled correctly

With your certification application, you need to include a diagram or photograph of the FCC ID number affixed to your module. It can also be displayed electronically if you like.

The RF module must comply with all specific rules applicable to the transmitter

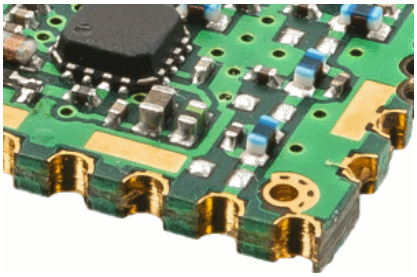
If for instance you have a 2.4 GHz transmitter that falls under 15.247 of the rules, then you need to test the module to 15.247. This is no different to the requirement for a non-modular certification. With your application, you need to provide the test report that shows compliance with the rules.

The module must comply with RF exposure requirements

This is also a requirement for a non-modular certification. It means that the maximum field strength of the product will be evaluated and compared to government RF exposure limits. The EMC test lab will do this. For most wireless products, this is just a calculation in a spreadsheet and isn't a problem for most low power transmitters. But, if you expect your transmitter module to be warn in close proximity to the human body, you may also need to undertake SAR (specific absorption rate) which can easily run you $5k+. SAR testing is usually required for things like cell phones and laptops. There are exemptions depending on how powerful the transmitter is and how close to the body your device will be placed. Contact a SAR testing lab for more info.

For more guidance on designing an FCC compliant RF module, see KDB996369 and this FCC presentation.

Connectors



You needn't even use connectors on your module. You can use half holes and solder it directly to your circuit board, so the increase in cost of an extra PCB is minimal. Make sure to clear the board of tracks and vias below the RF module to avoid potential shorts.

RF Module Documentation Requirements

When you design your own RF module, there are some differences in the documentation requirements you need to take care of. This example is for the FCC, but similar rules apply to different regions around the world.

Extra documents you need to produce include:

1. An integration manual

This is required to show your customer or your own engineers how the module should be implemented. It includes information such as antenna choices and labelling requirements that they should use on the host product.

2. Labelling

The FCC's labelling requirements are slightly different for product that contain wireless modules. The module itself needs to be labelled with the FCC ID number and on the outside of the host product, the label need to include text such as: "Contains Transmitter Module FCC ID: ABC12345" or "Contains FCC ID: ABC12345." The rules for this can be found in part 15.212.

When NOT to design your own RF Module

There will be some cost trade off involved with this choice. If your predicted sales volume is low and your margins are high, then designing your own module may not be the way to go. Also, if your product is a one off design and you don't think you'll ever need an identical transmitter again, there's less reason creating your own module.

If you want to dig more into the cost analysis of pre-certified modules, I highly recommend Texas Instrument's app note on the subject. They suggest that the tipping point for **the financial decision to use a pre-certified module or not is approximately 10k units per year** (evaluated on a 2 year ROI).

There is negligible cost difference in certifying a module vs. certifying a transmitter within your product, so if there's even a small chance that you'll need the same radio for future products, I'd recommend going with the module.

RF Modules FAQ

Can I Copy a Pre-Certified RF Module to Avoid Certification?

Unfortunately not. The reason is that the certification is granted only to the manufacturer of the module. They are responsible for ongoing compliance of the modules so therefore, if you copy their module design (even if they give you the schematic and layout), they no longer have the power to verify that the modules continue to be in compliance. On the face of it, this seems like an unnecessary and costly extra step that the regulatory bodies put in place. I'm normally against unnecessary regulations and testing requirements that seem too stringent, but this time there's actually some logic to it. Say you copy the schematic and layout of an RF module. If you change something crucial by accident, such as the PCB stack, that can totally change the characteristics of the RF transmitter. There are many places you can go wrong with copying a module: maximum gain, frequency settings and antenna selection to name a few common culprits. I saw this scenario countless times at my lab; a manufacturer copied a module design, but made a mistake in hardware or firmware that caused the transmission characteristics to become non-compliant. This is why copying a pre-certified module design doesn't mean you are guaranteed to have a compliant device.

What if I ship around the world?

If you are designing a pre-certified RF module into your product, make sure that it has all of the global certifications that you need. Wireless regulations are different around the world, so if your module only has FCC certification, that doesn't mean you can ship your product to Europe or Japan. To ship to different regulatory zones, the module would need to be pre-approved for those particular zones.

With a pre-certified RF module, do I need to still do other emissions testing?

Yes. You still need to have your product tested for unintentional emissions associated with the non-transmitter circuitry in your design. This process is much less painful – only 1 or 2 days if all goes well, and $1k-$2k costs. If you need immunity testing, that would be extra, but your product is essentially treated as a product without a wireless transmitter in it.

What about wireless module usage in Europe?

Europe's rules for wireless modules are different than those for the US. Wireless devices are regulated under the R&TTE (Radio & Telecommunications Terminal Equipment) directive and the definitions of a wireless module aren't quite as clear as they are in the US. It is the responsibility of the manufacturer to declare if a product is a module or not.

If you're using a wireless module that has already been assessed for compliance with the R&TTE directive, that compliance may or may not be transferred to your product depending on the way you purchased it and the way you use it. This guidance document outlines your responsibilities as a manufacturer for integration of module into your product. Adhering strictly to the rules, it is likely that even if the module is 'pre-approved' for use in Europe, you will also need to have your final product tested to wireless, safety and EMC standards. See ETSI TR102 070-1 for more details.

Legalities of Testing Prototypes Before Certification

Using and marketing of wireless devices prior to testing is covered under section 2.803 of the rules. With some caveats, this section allows you to use an uncertified wireless transmitter (e.g. Bluetooth or Wi-Fi) as long as it's for one of the following purposes:

- Compliance testing (i.e. you're getting the device certified)
- Demonstration at a trade show or exhibition (proper labelling required)
- Evaluation and development purposes at the manufacturer's facilities

If you want to test your device out in the field, for example at a customer site or anywhere other than your own 'facilities', then Page 32 of OET Bulletin 63 probably applies to you. It states that you should get what's called an 'experimental license' to legally evaluate your transmitter in the field before certification testing has taken place. In practice, I don't think many companies actually do this, but legally, they are breaking the law and technically should get an experimental license. If they were caught, there are large fines that could technically be applied.

Other Certifications

Safety

If your electronic product is subject to safety testing, then you have many different private test labs that you can choose from for 3rd party testing.

Companies such as UL, CSA, TUV and MET will all gladly take your safety testing business. These companies all offer similar services. There are a great number of safety testing standards that depend on your product type, export market and application. Given the huge variety of testing standards and methods, not every lab will have the equipment and expertise to test every product. Often you may have to send your product to a different test facility to have a particular safety test undertaken. Another point to watch out for is the scope of accreditations that your chosen lab has. Occasionally, a lab's scope of accreditation may not cover the complete suite of tests that you need. Given the risks of liability, it's wise to choose a lab that is accredited for every safety test that your product requires.

A good point to note is that most safety testing labs are private companies and tend to test to the same group of standards. They compete with each other to have the most widely accepted 'brand' if you like. Where one is accepted, you can likely substitute for another. As long as your end customer (which may be another company, a major retailer, state, city or country, or private consumer etc..) accepts the 'mark' then you can take your pick from the available labs.

Safety testing has large implications for the liability your company may face. If someone sues your company due to allegations of unsafe equipment, then you'll likely be in a better position if you have a test report showing compliance with the applicable rules. It is best to contact a safety testing lab directly and talk with them about the mandatory and 'nice to have' safety testing requirements for your particular product and weigh that against liability concerns. However, do remember that these are companies and they would very much like to obtain your business. I would recommend contacting 3 safety testing labs to ensure that their advice matches up.

NRTL

One other aspect you may want to consider is the "NRTL" (National Registered Testing Lab) program in the US which was created by the OHSA (Occupational Health and Safety Administration) to "assure as far as possible every working man and woman in the nation safe and healthful working conditions." It generally applies to the majority of private and federal workplaces in the US. Even if the employer is not mandated to adhere to OHSA rules, they may still choose to purchase only NRTL approved products.

OHSA authority is limited to **employers**, not **manufacturers**. There is usually no legal requirement for the manufacturer or distributor of the product to seek NRTL approval (ask an NRTL for confirmation of the requirements for your specific product). However, if the employer (be it a private company workplace, or government facility) requires NRTL approved equipment, then you will limit your sales if the product doesn't have it.

Any product that "utilizes electric energy for electronic, electromechanical, chemical heating, lighting or similar purposes" is classified as "Electric Utilization Equipment" and is subject to the requirements

of Subpart S of the Occupational Safety and Health Act (i.e. is destined for a workplace) which requires equipment to be "acceptable" to the Assistant Secretary of Labour. The term "acceptable" is defined in 29 CFR 1910.399, and for most electrical products, that means certification by an NRTL. There are exceptions for custom made equipment, or products which no NRTL will test. The regulations do not specify a low voltage exception, since low voltage products can still pose a safety risk.

A list of product categories requiring NRTL approval can be found here and here. Examples of electrical products that need NRTL approval for use in the workplace are: printers, copiers, desktop computers, telephones, employee alarms, water coolers, Christmas lights, electric heaters, air conditioners, electric generators, surveillance cameras, electrical conduits, conductors and electric motors.

You can find a list of NTRLs here.

Intrinsically Safe

Intrinsic safety (IS) is a protection technique for safe operation of electrical equipment in hazardous areas. Often mandated for products operating in environments that come into contact with flammable gases or dust such as petrochemical refineries and mines.

Many test labs can also test and evaluate electrical products to IS compliance standards. In Europe, the overarching guidance covering the same products usually fall under the "ATEX Directive".

Medical

In almost all jurisdictions around the world, the development and sale of medical devices is controlled by some combination of laws, regulations and standards. All of these national and regional regulatory processes are based on the need to prove the device is safe, effective and properly labeled before allowing the sale and distribution of the device.

Most jurisdictions classify devices according to the risk posed to the patient. The regulatory requirements range from minimal for the lowest risk devices to comprehensive in the case of implantable and life support devices. While most jurisdictions do not mandate a process for proving safety, the most common approach involves testing a sample device against accepted standards or guidelines for electrical and mechanical safety (IEC-60601-1), electromagnetic compliance (IEC-60601-1-2) and biocompatibility (ISO-10993-1).

A clear statement of the intended use, i.e. the disease, condition or abnormality the device is intended to detect, diagnose or treat is required to allow a determination of the effectiveness. To prove effectiveness some combination of bench testing to prove performance equivalent with existing proven devices, animal testing and clinical testing is required.

Labeling requirements differ depending on the jurisdiction, but all require the labeling, which includes instructions for use and training materials, be adequate to allow the safe and effective use of the device.

There is a requirement for a 'quality system' to ensure all subsequent devices meet these same standards is also common to all jurisdictions. In the case of medium to high risk devices the quality system is also required to provide evidence that the design and development process addressed both risk management (ISO-14971) and usability (IEC-62366).

As an example consider the requirements for a medium risk device in Canada, the EU and the USA.

Health Canada controls the distribution of medical devices by the granting of a device license once all of the requirements for safety and effectiveness have been met. In the case of a medium risk device this involves testing to accepted standards and some form of effectiveness testing. As well evidence of a quality system certified to ISO 13485 and the requirements of the Canadian Medical Device Regulations is required as part of the submission.

Similar to a consumer device, application of the CE mark is required to distribute a medical device in the EU. For a medium risk device this differs from consumer products in that a 3rd party is required to certify that all the requirements of the Medical Device Directive have been met before the CE mark is applied. This involves preparation of a technical file, including testing to applicable standards, and evidence a quality system meeting the requirements of the Medical Device Directive is in place.

The FDA grants clearance to distribute a device once safety and effectiveness is proven. In the case of a medium risk device this involves proving equivalent performance to a previously cleared device. The proof of safety generally involves testing to accepted standards.

A quality system meeting the requirements of CFR Part 820 is required before distribution can begin.

In all cases testing the device to accepted standards is part of the regulatory process. In most cases the trend towards globalization has resulted in standards that are accepted around the world with only minimal differences to account for local conditions such as supply voltages.

If in doubt, it's well worth your time consulting with a medical device development consultancy such as Starfish Medical to map the correct path to market. I've worked with Starfish in the past and can highly recommend their organization.

Military

Military emissions and immunity requirements tend to be much more stringent than equivalent commercial requirements. In addition to EMC testing, there is also power environment testing which is required as military equipment usually operates from generator or vehicle power sources. It is necessary to ensure that equipment doesn't affect the power source, or be adversely affected by the power source.

The most common equipment level military EMC standard in use around the world is MIL-STD-461. The similar British standard DEF STAN 59/411 is also fairly common in NATO. There is also a platform level (as opposed to equipment level) EMC requirement covered by MIL-STD-464, as it is also required by the military that the equipment when interconnected on a vehicle also yields acceptable performance. The

Power Environment standards are MIL-STD-704 for aircraft, and MIL-STD-1275 for land vehicles, and MIL-STD-1399 for ships.

EMC requirements for equipment used in secure applications often have TEMPEST specifications applied to them. The TEMPEST specifications are classified, and TEMPEST testing is performed by specially qualified personnel in selected laboratories meeting the requirements of the Industrial TEMPEST program.

Only a subset of EMC testing labs have the capabilities to test to military standards. This is likely due to the large extra expenses for high performance test equipment that can meet the MIL spec standards.

Automotive

If you're designing a product that will be used in an automotive environment, you're facing some tough regulatory hurdles. Note that there is often a distinction between automotive products that are fitted 'aftermarket' and those that are not. It's worth talking with a lab about this distinction to verify which standards apply to your product.

Many different automotive EMC standards exist. It's really up to the automotive manufacturer to dictate which standards their component suppliers must adhere to. That can make it very difficult for a manufacturer to test to one particular set of standards and pitch their product to several vehicle manufacturers. One manufacturer may require their suppliers to follow a given set of test standards and methods, while another manufacturer may not accept the same standards.

Given that there are such a large number of automotive standards, I would just point the interested reader to some of the most widely used standards such as SAE, ISO7637, IEC CISPR-25 and the Automotive Directive ("E-mark" for Europe).

To move forward with determining the EMC, safety and any other testing requirements for your automotive product, I would suggest getting clarification from the vehicle manufacturer (end customer) if that applies, and/or an accredited test lab familiar with automotive requirements.

Telecoms

Relating to the FCC, any equipment that connects to the public switched telephone network, such as a cordless telephone, is also subject to regulations in Part 68 of the FCC Rules and must be registered by the FCC prior to marketing. The rules in Part 68 are designed to protect against harm to the telephone network.

Additionally, Europe and many other international product standards provide a limit to the amount of noise electronic products can inject back on to Ethernet cabling. This is measured by a test lab in much the same way as conducted emissions from a power port. A test lab will be able to tell you whether this test applies to your product.

EMC/RF Certifications - The Global Landscape

Overview

EMC and RF Regulations vary significantly from region to region, so you need to be aware of the regulations that apply in each of the areas that you intend to export to. Most of the EMC regulations relating to electronic products overlap between countries, but there are more often than not, subtle differences that can significantly affect your route to market.

The Major Markets

North America - FCC and Industry Canada

To sell a standard electronic widget into North America, the big players that regulate the legalities of electronic products are FCC and Industry Canada.

From an electronic design company's perspective, the important things to know about FCC testing is that there are 3 different 'authorization routes' for both intentional and unintentional radiators. The routes are called "verification", "declaration of conformity" and "certification". The routes available for your product depend on what your product is and whether it has a wireless transmitter.

First we'll deal with the products that do not include wireless transmitters. These are called "unintentional radiators" because the radiation that they emit is unintentionally generated. The radiation is an unavoidable by-product of the switching voltages and currents in all electronics designs.

For unintentional radiators, the place to check which routes are available to you is part the table in part 15.101 of the FCC's rules.

Here is the table:

Type of device	Equipment authorization required
TV broadcast receiver	Verification.
FM broadcast receiver	Verification.
CB receiver	Declaration of Conformity or Certification.
Superregenerative receiver	Declaration of Conformity or Certification.
Scanning receiver	Certification.
Radar detector	Certification.
All other receivers subject to part 15	Declaration of Conformity or Certification.
TV interface device	Declaration of Conformity or Certification.
Cable system terminal device	Declaration of Conformity.
Stand-alone cable input selector switch	Verification.
Class B personal computers and peripherals	Declaration of Conformity or Certification. [1]
CPU boards and internal power supplies used with Class B personal computers.	Declaration of Conformity or Certification. [1]
Class B personal computers assembled using authorized CPU boards or power supplies.	Declaration of Conformity.
Class B external switching power supplies	Verification.
Other Class B digital devices & peripherals	Verification.
Class A digital devices, peripherals & external switching power supplies.	Verification.
Access Broadband over Power Line (Access BPL)	Certification.
All other devices	Verification.

Figure 3 - FCC Equipment Authorization Routes

Scan the list on the left of this table and find your device type. If you're unsure, you can check the definitions of these terms in FCC 15.3. Then look at the right hand column to see which authorization routes are available for your product.

Unintentional Radiators

The FCC rules that deal specifically with unintentional radiators are called CFR Title 47 Part 15 Subpart B (usually just referred to as FCC Part 15B). For unintentional radiators, all three "authorization routes" are possible. Below I'll discuss the implications you need to be aware of for each. The FCC has defined these routes presumably on the potential risks involved to the electromagnetic spectrum that different types of equipment pose. I'll discuss them in ascending order of difficulty (or robustness if you like).

Verification

Verification is the easiest and quickest authorization route. Verification just involves you sending your product and any required auxiliary equipment and cables to a test lab. The lab spends approximately 1-2 days measuring the radiated and conducted (if required) emissions coming from your product. If all is well, they generate a test report and send it to you. That's all there is to it. You're now at liberty to label, market and sell your product.

Of the 1000 or so FCC test labs around the world, you can select any of them to do this job. From the FCC's perspective, there are "2.948 listed" test labs and "accredited and FCC recognized" test labs. The difference is that trusted independent 3rd party companies are used to inspect accredited labs to verify a certain level of competence and that procedures are implemented and being followed properly. For non-accredited, registered test labs, no such 3rd party inspection take place. Approximately 75% of FCC test labs around the world are not accredited.

Declaration of Conformity (DoC)

Not to be confused with the Declaration of Conformity for Europe, which is completely non-related, the DoC method for the FCC covers certain types of electronic equipment.

If your device is in a category that allows the DoC authorization route, the key here is that you need to select an FCC accredited test lab. Test labs that are only '2.948 listed' with the FCC and are not accredited, are not allowed to test devices using the declaration of conformity authorization route.

"Listed" test labs can get around this requirement by instead undertaking a certification on your device. But that will take at least a few days longer than the DoC route because you have to submit an application to a TCB (discussed below).

If you pick an accredited lab for this task, then the procedure is exactly the same as that for verification. I.e. The lab spends approximately 1-2 days measuring the radiated and conducted (if required) emissions coming from your product. If all is well, they generate a test report and send it to you.

Certification

Certification is a little more complicated than the other two authorization routes. That is because the FCC stores information on all certified products. The information on all certified devices is searchable on their website. If you go the certification route, your company will need to be registered with the FCC with an "FCC Registration Number" (FRN). You can get one of those here.

Certifications require an application package to be submitted to a particular type of test lab called a Telecommunications Certification Body (TCB). Your product will also need an FCC ID number which you can choose within your application package.

You can see a sample application package in the appendix of this eBook. Your test lab will likely offer a service to help you prepare this package. There is normally a fee associated with this, but it's usually money well spent because the process can be very time consuming.

TCBs are essentially test labs that have extra responsibilities over listed or accredited test labs. Back in 1998, the FCC delegated some of its' responsibilities to private test labs in an effort to make the certification process faster and more efficient. Some of the more experienced test labs stepped up and jumped through the extra regulatory hoops to become TCBs. Now they have the authority to issue certifications for most types of products (some caveats apply where the FCC retains the sole power to issue authorization).

Note that the test lab that you have your product tested at does not need to have TCB designation. If you choose a non-TCB test lab to do the testing, the full application package can be sent to a TCB for review after testing is completed. We'll dig into this process further in the "Testing Process" section below.

Intentional Radiators

Intentional radiators are split up into two categories - unlicensed and licensed.

In this eBook, I'll focus on the unlicensed bands since that is the spectrum that the vast majority of makers and hardware startups utilize. For example, Bluetooth, Zigbee and Wi-Fi all utilize unlicensed bands.

If you'd like more information on licensed vs. unlicensed bands, see the following link for more information:

http://www2.ntia.doc.gov/documents/LicensedLicenseExempt_BBWorkshop0805.pdf

FCC Rule Parts for Transmitters

The FCC has many rule parts that apply to different types of wireless transmitters under Title 47. Part 2.106 gives a complete table of frequency allocations from 9 kHz all the way up to 275 GHz! In the right most column of the table, you can see the FCC rule parts that are applicable for each of the frequency bands.

For the purposes of this eBook, we'll focus on Part 15 Subpart C since this contains the rules for the low power transmitters that most makers and hardware startups will be utilizing.

Authorization Routes

Two of the three authorization routes discussed in the previous section are available for low power wireless transmitters, depending on the type of transmitter. The routes available are verification and certification.

Authorization Procedures for Part 15 Transmitters

Low Power Transmitter	Authorization Procedure
AM-band transmission systems on the campuses of educational institutions	Verification
Cable locating equipment at or below 490 kHz	Verification
Carrier current systems	Verification
Devices, such as a perimeter protection systems, that must be measured at the installation site	Verification of first three installations with resulting data immediately used to obtain certification
Leaky coaxial cable systems	If designed for operation exclusively in the AM broadcast band: verification; otherwise: certification
Tunnel radio systems	Verification
All other Part 15 transmitters	Certification

Since the vast majority of wireless devices are authorized under the 'certification' procedure, for the purposes of the rest of this eBook, I'll focus on the certification authorization route when referring to wireless devices.

That was a quick overview of the FCC's rules for unintentional and intentional radiators. Next, I will highlight the equivalent rules for Europe.

Europe - The CE Mark

The European Union has for the most part standardized the regulations across the whole region. The umbrella mark that is applied to products to show that they are compliant with the regulations is the well known "CE Mark".

It's important to know that the CE Mark is not a certification given by any test lab or regulatory body. The CE Mark is applied by the manufacturer to show that they believe their product is compliant with the rules. The manufacturer holds all of the responsibility for compliance - it is what's called a 'self-declaration'.

There are many overarching directives that apply under the CE Mark for various types of products. These are the top level documents that define particular 'results' or 'goals' that must be achieved by the member countries within Europe. Importantly, the directives do not define the how the results are achieved; that is the job of the "harmonized standards" that sit below the directives.

For hardware startups and makers, the directives of most interest will likely be the EMC directive, the LVD (Low Voltage Directive) and the R&TTE (Radio and Telecommunications Terminal Equipment) Directive. Manufacturers generally show compliance with the applicable directives by testing to harmonized standards that fall under each directive.

The standard route that electronics manufacturers use to satisfy themselves that they are in compliance with the regulations is by submitting their product to a 3rd party test lab. The test lab tests the product against the relevant harmonized standards and produces test reports with the data collected. The manufacturer then holds these test reports on file and creates a document called a 'Declaration of Conformity" (DoC for short). The DoC references the standards and is signed by a responsible party at the manufacturing company. The manufacturer affixes the "CE" logo and is now free to import the products. Note that the path I've described here is just one of a number of "conformity assessment procedures" outlined by the EU. It is that path that is most familiar to electronics design companies. However, for some higher risk products, you may need the assistance of what's called an NB (notified body). You can check the need for an NB here.

The EMC directive applies to almost all electronic equipment as discussed in the exemptions section. It covers the radiated and conducted emissions of electronic products as well as the radiated and conducted immunity. You'll notice that Europe has the additional criteria of 'immunity' testing compared to FCC requirements which only specify emissions limits. This can be a cumbersome (and expensive) extra requirement for manufacturers, but the rules are intended to provide the consumer with a minimum level of quality for electronic products. However, a report on market surveillance of electronic products in Europe conducted in 2012 (based on a sample size of approximately 10,000 products) showed that approximately 2/3 of equipment was non-compliant with the rules in some way. They point out that this sample may not be representative of the region as a whole due to focussing on areas suspected of high non-compliance rates. But even if the number was halved, it would still be a staggeringly high rate of non-compliance.

The LVD which is a safety directive applies to all electrical equipment designed for use with a voltage rating of between 50 and 1000 V AC and between 75 and 1500 V DC. The lower voltage limits are removed for wireless devices, which essentially means every wireless device sold into Europe, even if it's a tiny 5V DC, 1 mW Bluetooth transmitter, needs to be tested for safety. I wonder how much lobbying that requirement took to implement? However, even if the LVD is not applicable to your product, the EU rules clearly state that a product must be still be 'safe'. Other directives such as the GPSD (General Product Safety Directive) may still apply.

The R&TTE Directive applies to all radio equipment and to telecommunications terminal equipment intended to be connected to public telecommunications networks. It covers the radio characteristics and frequency allocation of wireless transmitters in Europe. A point to note is that if your equipment falls under the R&TTE directive, then different EMC standards are usually called out instead of those used for unintentional radiating devices which fall under the EMC directive. This is because the standards for wireless transmitters in Europe also cover emissions and immunity performance specifically for transmitters.

RoHS

An often overlooked aspect of CE compliance is the RoHS directive. This governs the maximum concentrations of hazardous substances contained within products. A new version of this directive came out in 2013 which now requires most electronic equipment to be compliant with the rules. Some examples of the concentration level limits, bases on weight within homogeneous materials are:

Lead: 0.1 %
Mercury: 0.1%
Cadmium: 0.01%

This has a real effect on electronics manufacturers for the components and technology you choose to use. Lead free solder is now widely available, but it can be harder to work with. If you want to be in compliance with the rules, make sure that your components and manufacturing processes comply with the RoHS requirements. Guidance on a new version of the RoHS directive, which was released in 2013 can be found here.

Recycling

The WEEE Directive (Waste from Electrical and Electronic Equipment Directive) is now applicable to most electronic and electrical equipment in Europe. It's aimed at redirecting waste electronic and electrical equipment from the landfill to a recycle depot instead.

As a manufacturer (referred to as a 'producer' for the purposes of this directive), you have some obligations under this directive. Those obligations may include:

- Marking your equipment with the WEEE logo
- Joining a PCS (producer compliance scheme) - this is to finance the collection and recycling scheme.
- Providing information to a PCS on items such as product sales

Although currently in full force, there is still a transition period, with a target implementation date of 2018. According to this guidance document, even manufacturers who are based outside of the EU are required to join a PCS **in every member state** (country) that their product is sold into! Whether that is actually happening or not, is up for debate. Further information on the WEEE can be found here.

Useful Resources for CE

GENERAL INFORMATION OF THE EMC DIRECTIVE 2004/108/EC
A quick top level overview of administrative requirements for compliance with the EMC directive. Includes labelling information and a blank declaration of conformity template

Guide for the EMC Directive 2004/108/EC
A complete guide to the EMC directive including essential requirements, conformity assessment procedures and documentation.

Blue Book Guide
A top level overview of the CE Mark scheme.

Other Markets

Many other distinct regulatory areas exist around the globe. Some of the other popular export areas include Japan (VCCI), China (CCC), Australia & New Zealand (ACMA). The routes to approval differ for each regulatory region. Sometimes it may be as simple as asking your existing test provider to test for the additional region at the same time. But other times it may be much more complex.

You may need to have a local representative in the country you're exporting to that can take responsibility for ongoing compliance. You may even need to have your product tested within the country itself. Some countries also mandate an annual inspection of your manufacturing facility to ensure ongoing compliance of your products.

As you can see, the worldwide EMC and RF compliance requirements are not easy to navigate. It's also worth noting that they are in a constant state of flux. There is a move towards international standardization, so in theory at least, the barrier to international approvals should diminish over time. Bureaucracy moves very slowly though and we're a long way off having a standardized test and regulatory framework that will allow access to global markets. With EMC FastPass membership, you get access to an ever expanding library of training videos on routes to EMC/RF compliance for various markets. As client requests come in for different regions, I expand our library of training videos so that all members can benefit. I also update the training as regulations change over time so you know that you're getting the latest information.

Test labs often have an inherent financial incentive to guide you down the compliance route that serves their company's goals. That may well not align with your company's goals. For example, a test lab may not be registered/accredited for a particular region that you may want to expand into in the future. They don't have an incentive to volunteer this information, so you may end up choosing a lab that doesn't suit your long term needs.

Only with independent 3rd party advice like given by EMC FastPass can you get an un-biased vantage point of the best lab to choose and the best route to market.

Unintentional Radiator Testing Process (FCC)

I'm going to describe the full testing process to you as if you've never been through it before. This includes products subject to the verification and DoC authorization procedures that I discussed in the section above. Usually this applies to devices which either don't incorporate a wireless transmitter OR devices that incorporate a pre-certified wireless module (and you adhere to all of the guidelines within the existing modular certification grant so that you don't invalidate the certification).

Step by Step

1. Contact 3 labs and discuss the project

It's important to get a dialogue going with a lab so that they can get a feel for your project. They may give you advice on the required software/hardware configuration, auxiliary equipment, cabling and a host of other information.

2. Get quotes from 3 labs

The labs will also need to discuss the function of your product, the target geographic markets and the ports that your product has (e.g. power port, USB port etc...). Using this information, they will determine which tests are necessary and will create a quote.

It's important to note that you may get differences in test schedules between labs that lead to wildly different quotes. One lab may have incorrectly stated that a particular test is mandatory, while another lab may have inadvertently missed including a mandatory test on the list. If you see a discrepancy between quotes, talk with the labs about why they included/left off a particular test and determine who was correct. This is why it's important to get 3 quotes.

3. Select lab based on criteria talking about in 'selecting a test lab' section

Consider not only the quotes, but also the criteria I outlined in the 'selecting a test lab' section. If your product fails a test, the upfront cost of a test schedule may pale into comparison compared to hiring a consultant and re-test fees. It's worth thinking about this eventuality carefully and consider what a test lab can bring to the table.

4. Send in a prototype or pre-production unit for pre-scan (optional)

Many hardware manufacturers choose to have what's called a 'pre-scan' of their product by the 3rd party test lab. They do this with a prototype version of their product rather than pre-production unit so they can get a grasp of the potential scope of issues that the product may face at the lab. It's essentially an exercise in risk reduction. That way, if they run in to issues during a pre-scan, any required changes can be rolled in to a later version of hardware that was already scheduled.

Many companies just pre-scan radiated and conducted emissions, but you can also request a pre-scan of any other aspects of your device that you suspect may be an issue during final certification testing. For example, if your device is destined for Europe where immunity testing is needed, and you're concerned

that ESD testing may affect the operation of your product, you could request an ESD pre-scan. The lab may be able to advise you on the potential risk areas for your product.

Labs generally do pre-scans in 4 hour blocks, so it's up to you what you have done in that time.

5. When product is fully functional + mechanically sound, send unit in for finals testing.

For what's normally referred to as "finals" testing, you should have your product fully functional and in the correct enclosure. The enclosure can have an effect on the emissions from your device, so it's important that you provide the lab with an enclosure of the same material type that you're going to be selling. Small variations to non-conductive enclosures are probably ok, but a change from conductive to non-conductive or vice versa would be very risky and would likely invalidate any testing that is undertaken on your product.

Additionally, your product should always be operating in 'worst case' mode, which means all functions of your product are operational and running at 100%. This may mean that your motors are running, LCD display is being updated constantly and DDR memory is running continuously. Manufacturers often create a special purpose test software/firmware version to exercise the full functionality of their product during testing. The risk of not doing this is that the test lab may not measure worst case emissions and your product could be found to be non-compliant in the field.

6. If your product fails, troubleshoot and fix issues

Approximately 50% of products fail EMC first time according to Intertek Labs, one of the larger lab groups in the world. If your product fails, you can either try to fix it during the test schedule or take it back to your office. Depending on the nature of the failure, you may get (extremely) lucky and manage to fix it within the allotted time, or more likely, you'll need to investigate the failure back at your office. It's beyond the scope of this eBook to get into EMC troubleshooting techniques; there are plenty of textbooks on that subject.

Let's assume that you've fixed the issue. Depending on which test your product failed and the scope of the modifications to the product, you may have to:

(a) Re-test only the test(s) that failed
(b) Re-test all of the tests

The deciding factor is usually whether you perceive that the changes you made could negatively affect the results of the previously successful tests. There is a discussion on this topic on the section below.

7. Once you've passed, test lab will generate test reports.

The test lab generally takes 5-10 days to generate a test report. For "verification" and "DoC" authorization routes, no further action is required other than marking your products and packaging correctly. You can go ahead and start marketing and selling your product. For "certification" authorization routes, your test report must be submitted along with a full application (see appendix A for typical documents required) to a special test lab called a "TCB" (Telecommunications Certification Body). The TCB then reviews the test report and application package. Assuming all is in order, they will issue the certification within 2-5 days. I cover the certification route in detail in the next section.

8. Assuming there are no other approvals required, now you're at liberty to affix FCC/CE labels and sell/import your product.

9. FCC Form 740

If your product is being manufactured outside of the US, you may need to fill out Form 740 for the FCC. This will be checked at customs and your shipment may bounce back or be held if the document is not present.

What Hardware and Software Configuration do you Need to Provide?

One of the most common delays to certification is when a manufacturer doesn't provide all of the required hardware, software, firmware, auxiliary equipment or cabling to the 3rd party lab. If you want things to go smoothly and avoid delays to the start of testing, you should make sure that you have everything in order.

Here's a non exhaustive list of items you will need to provide:

Hardware

1. At least 1 device for testing purposes. 2 or 3 devices would be better in case one malfunctions or is damaged during susceptibility testing.

2. Any auxiliary equipment required to exercise the full functionality of your product. This may include a laptop or power supply etc. Note that if all ports (e.g. USB, Ethernet etc.) can be fully functional in normal usage, then they should also all be enabled and functional during testing.

3. Real or dummy loads. If your equipment provides drive signals to other equipment, provide either a typical real load or a dummy load to simulate a real load.

Software

1. Test mode software/firmware that exercises all of the internal and external interfaces to the maximum extent that would be possible in normal usage.

2. For immunity testing, (for Europe and other international product standards) a method to monitor the performance of your product. This may be an on screen display of measurements or a program running on a separate machine that verifies your equipment is operating as it should.

3. To make the test schedule go smoothly, it's advised that your equipment boots up as quickly as possible. It's often the case that the lab will want to switch your equipment off and on to check whether an emissions is being generated by your product (especially when being tested at an OATS). If the equipment boot up time is in the order of minutes or requires lots of human input to get it into the correct mode, the testing can take much longer.

Cabling

1. For emissions testing, all I/O ports should be loaded with a cable. For FCC testing, the minimum cable length is 1 meter. For other standards, the rules can vary. Contact your test lab for confirmation of required cable lengths for your product.

2. Shielded/suppressed cabling. As a precaution, I would also recommend giving the lab shielded versions of your cables and/or cables with ferrite noise suppressors. If your product fails testing with unshielded cables, but passes with shielded/suppress cables, then you can most likely still be able to sell your product if you ship it with shielded cables.

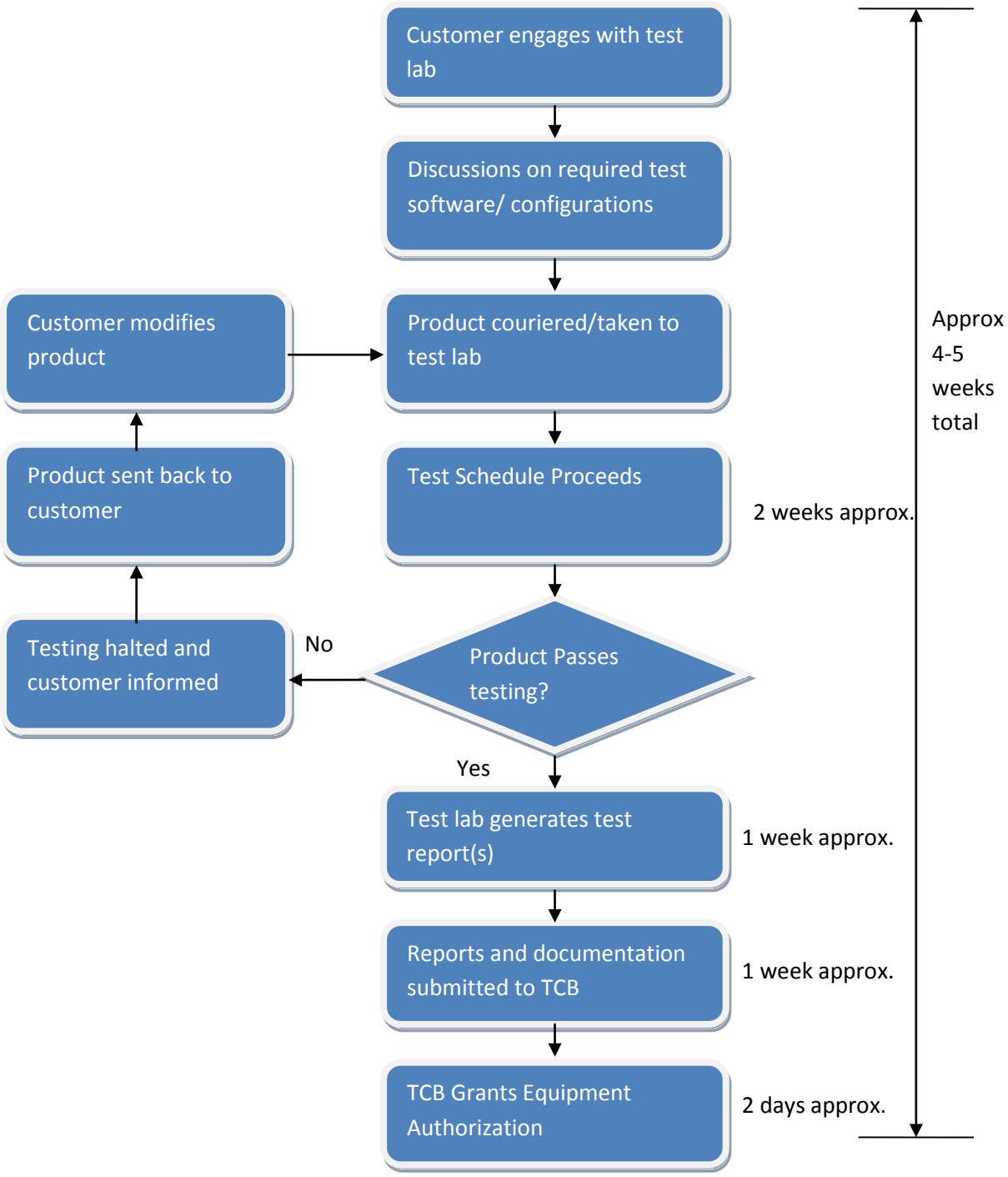
Timescales

Testing for a simple verification or DoC authorizations can take as little as one day. Once the test lab informs you that the device passed, then you can go ahead immediately and start marketing and selling it. The test lab will follow up in a few days with your completed test report which you must archive in case authorities request to see it.

Intentional Radiator (Wireless) Certification Process (FCC)

Overview

Here we'll concentrate on the certification authorization route. Note that transmitters subject only to verification, follow the same procedure as defined in the unintentional radiator process described above instead.



Step by Step

The procedure is almost exactly the same as the procedure described for unintentional radiators above. The main difference is that the test reports need to be submitted along with supporting documentation to a TCB. The documentation is described in Appendix A of this eBook. You also need an FRN number from the FCC so that they have you in their system.

What Hardware and Software Configuration do you Need to Provide?

You can add several days delay if your product is not properly configured for testing. It's crucial to get your hardware and software/firmware package correct, especially for wireless devices.

Hardware

1. A fully functional production or near-production unit with all necessary ancillary hardware to operate the unit to the full extent of its capabilities.

2. Testing or modifying units for testing purposes can occasionally be destructive to the equipment under test, so two units are recommended.

3. If possible, one unit should be modified with an SMA connector so that conducted RF measurements can be made.

Software/Firmware

1. Software control, or means to program the transmitter frequencies among all available channels. At a minimum, the test lab will need the ability to individually select the highest, middle and lowest channels within the band.

2. A unit that is capable of selecting between all modulation modes and data rates.

3. If the unit is only intermittently transmitting, provide a means to enable transmission 100% of the time.

4. If the unit transmits several different packet sizes, provide a means to select between the smallest, medium and largest packet sizes.

5. If your transmitter is also subjected to immunity test requirements (Europe and other international wireless standards) then provide a means to detect whether the wireless link remains operational. In some cases you may also need to provide a means to monitor the BER (bit error rate) of your communications link.

Timescales

A typical test schedule for a wireless transmitter should only take between 3 and 7 working days. As you can see from the overview diagram though, the additional time for other items can easily add up. Budgeting 4-6 weeks for a wireless certification would be about average. However, the main threats to schedule come from a few sources:

1. **Test Failure**

If your device fails testing, the time it takes to debug, re-manufacture (in some cases) and to re-test the product can easily be in the order of weeks. You really want to make sure that your equipment passes first time. EMC FastPass provides online training for wireless pre-compliance testing so that you can make sure you've nailed the design before sending it for certification.

2. **Submission Package**

If your submission package isn't perfect, it will be bounced back from the TCB. By perfect I mean you need to make sure that absolutely every document you provide is consistent and the forms are filled out correctly. Very common errors include model numbers and FCC ID numbers being inconsistent between labelling and other documentation. Other common issues include missing documentation and blurry photographs of the circuit board(s). I can't stress enough that you cannot half ass this submission package. The more care you take to create the package, the smoother the certification will go.

It isn't uncommon for submission packages to be bounced back from the TCB two or three times before it is accepted. This can easily add a couple of weeks to the total certification time. You should also be aware that TCBs often have a maximum number of submission package reviews before they start charging for extra reviews.

3. **Test Lab Lead Time**

Busy test labs can have a lead time of 4 weeks or more. If you need to use a particular test lab, it's best to book as far in advance as you can.

EMC/RF Certification Process for Other Regions

Canada

The procedures for entering the Canadian market are almost identical to the US. There are a few subtle differences that your test lab will inform you about, but for most companies, the guidance given above will also gain you entry into the Canadian market.

One key thing to ensure is that the test lab you select is registered with Industry Canada as well as the FCC. Otherwise your test reports may not be acceptable for importing products into Canada.

Europe

Many test labs will be able to undertake EMC, RF and safety testing for Europe at the same time as your FCC test schedule. Confirm this beforehand though, as some test labs do not have the test equipment available to undertake some aspects of European testing such as immunity testing.

Overview

For the purposes of showing you a step by step procedure on how to show compliance with the European rules, I'm going to focus on the conformity assessment procedure that uses EMC harmonized standards. For the EMC directive, this is only one of 3 potential assessment procedures as you can see from the diagram below. The harmonized standards method is the one that is most widely used, so I'll focus on that. If you are interested in the other methods, see section 3.2 of the general guide for the EMC directive for further information.

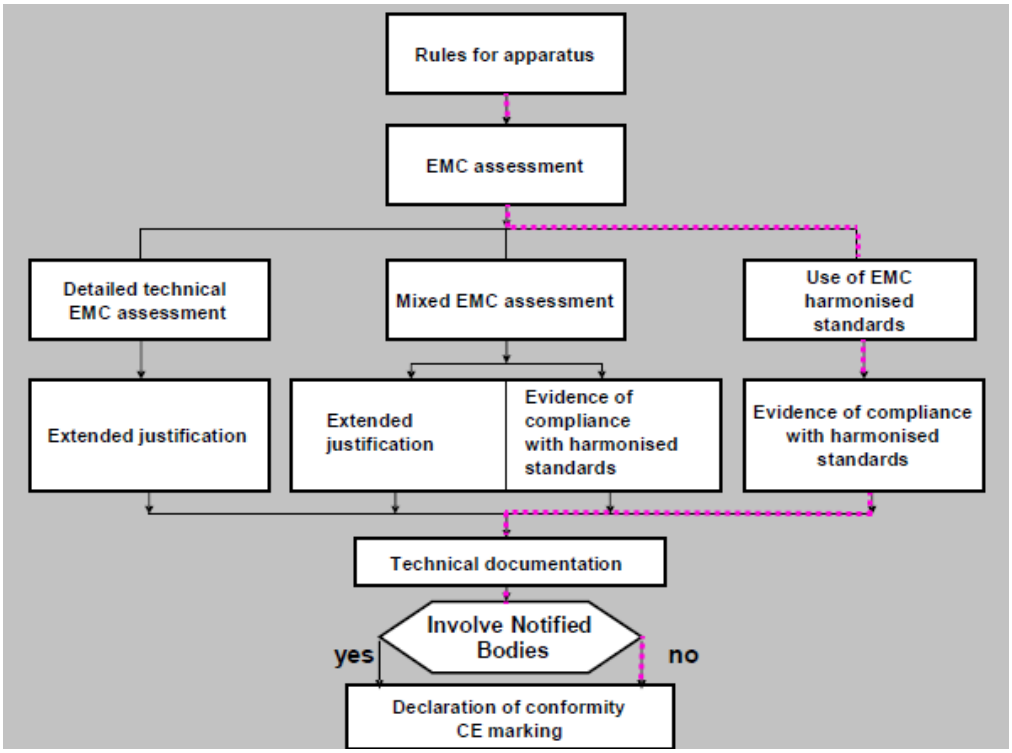


Figure 4 - CE Mark Conformity Assessment Routes

Step by Step

1. Identify the harmonized standards that apply to your product

Harmonized standards sit below the directives to allow manufacturers to claim compliance with the directives. The standards are the documents that contain definitions of test requirements that will be applied to your product. You can follow the section on how to work out standards that apply to you or go find out at the EMC standards finder tool from EMC FastPass. Usually, several standards are required to cover all of the requirements of the EMC directive. These may include: high frequency emissions, low frequency emissions and immunity to EMC phenomena.

The correct application of the relevant harmonized standards is equivalent to the carrying out of a detailed technical EMC assessment.

3. Evidence of compliance with harmonised standards

The evidence of compliance with the harmonized standards usually takes the form of test reports from a 3rd party test lab. If you have your own in house lab, then the evidence may come from that. You can even do some tests yourself and outsource some to a 3rd party lab.

Your product needs to be tested in a worst case scenario. This usually means that the highest level of functionality is tested (applies if you have a family of derivate products with lower functionality).

4. Technical documentation

It is your responsibility as manufacturer to collate the technical documentation and keep it in a file for at least 10 years. The documentation should contain:

- An identification of the product
- A general description of the product (e.g. a manual)
- Evidence of compliance (e.g. a dated list of the harmonized standards applied and the results obtained)

6. DoC and CE Marking

Now you need to declare that your product complies with all of the requirements of the relevant directives. You do this by creating a DoC (Declaration of Conformity). It is issued by you, the manufacturer, and nobody else. You can find a template of a DoC here (page 3). You also need to physically apply the CE Mark to your product and packaging. The WEEE logo may also be required (see earlier section).

The DoC needs to travel with your product when you import it. The package may be blocked at customs without one.

That's it!

Note that the process above covers only the EMC directive. For other applicable directives such as for wireless devices (R&TTE directive) and safety (Low Voltage Directive), the process is usually much the same. Get confirmation from an accredited lab on the exact process for your particular product.

For further detailed instructions, refer to the general guide.

Other Regions

For other regions I haven't mentioned, sometimes it can be as simple as asking your test lab to perform any additional testing at the same time. There may be slightly different limits to emissions or immunity requirements, but these can usually be rolled in to your existing test schedule as long as the requirements are discussed up front.

RF (wireless) requirements and certifications tend to vary more than EMC between regions because frequency band allocation can differ significantly between regions. If your wireless device will be sold around the world, it's definitely worth your time to contact a test lab early in your development cycle to ensure that your chosen wireless solution is capable of meeting the requirements of every region that you intend to sell into. They may give you advice on the available unlicensed frequency bands, and maximum radiated and conducted output power that you can legally use.

Some regions are tougher to access than North America and Europe. For example, in some regions, you may need to hire a local representative to import and take responsibility for the compliance of your product. In others, such as China (in some instances), you may need to use an approved test lab within their borders. They may also mandate an annual inspection of your production facilities to ensure ongoing compliance.

When you enter multiple markets, it is really best to approach a test lab familiar with many international approvals. Another potential source of assistance for entering specific markets is a "type approval specialist". Just search Google for that term along with the name of the region in question and some help should pop up.

Preparation: Training, Design Reviews & Pre-compliance Testing

By now you should have a pretty good overview of the regulatory requirements that may apply to your product. It's one thing to know what regulatory requirements apply, but it's a completely different thing to know how to design your product to pass those requirements and how to verify that your product is probably compliant before you actually submit it to a 3rd party lab for testing.

Many, if not most electronic manufacturers that visited my EMC lab, I would say were just keeping their fingers crossed that they would pass. Most had not done any pre-compliance testing at all and most did not know how to review their design for good emissions, immunity or RF performance before submitting their device for testing. Heck, most had no clue what it was I was doing with their product. Is it any wonder then that the global first time pass rate is only 50%? - (According to Intertek Labs - one of the largest testing providers in the world).

Design for Compliance

Huge books have been written on the subject of design for EMC compliance. One of the most popular books is over 800 pages long. It's like information in this industry is sold by weight! Assuming you're like most engineers who don't have time to wade through mountains of textbooks, I created a concise video training course covering the key design techniques for emissions, immunity and high speed performance. The course is split up into bite sized videos so that you can focus in on a particular area if you need to, or take the full course from start to finish.

EMC design techniques are way beyond the scope of this eBook. However, the "Getting EMC Design Right First Time" eBook from EMC FastPass gives you a concise introduction to EMC design techniques for emission and immunity performance. If you want a much more in-depth training for your entire company or team, EMC FastPass membership is the way to go.

Design Reviews

To simplify the process even further, I've created EMC design review software that guides you through manually checking your own design for good emissions and immunity design techniques. Once you've finished each review, you get a report of action items that you should address before you submit your device for 3rd party testing.

Below, I'll give a brief overview on some pre-compliance testing options. Pre-compliance testing helps to improve your chances of passing EMC testing and lowers the risk of failure. There are a many pre-compliance options, but in the section below, I'll focus purely on emissions testing.

What is Pre-Compliance Testing?

Pre-compliance testing can take many forms. In most cases, pre-compliance testing involves an attempt to simulate the methods (or a close approximation to it) that a full compliance lab would undertake on your product. For EMC, that means quantifying the emissions coming from the product – both radiated and conducted, and for the products that will be subjected to immunity tests (for example CE testing and some product standards), some other electromagnetic phenomena will be applied to the product as

well. For wireless products, you can also do RF pre-compliance tests, but that's outside the scope of this eBook.

Long story short, pre-compliance testing is any way that you can mimic what a test lab is going to do to your product to increase the chances of passing at a test lab.

When you're an EMC FastPass member, you also get access to all of my video training on selecting low cost test equipment to purchase to do emissions, immunity and wireless pre-compliance testing as well as exactly how to use the equipment to test your product. It's far too much information to include in an eBook and you really need to see how I use the equipment on video to learn how to do it.

Why Do Pre-Compliance Testing?

Many companies don't do any pre-compliance testing before they send their product off to a test lab. And honestly, some get away with it – they pass first time and they're off to the races. But for most companies, the prospect of failing EMC testing poses a substantial enough risk to project timelines and budgets that pre-compliance testing is a necessity.

*Hitting EMC problems at an EMC lab can literally cost your company **tens of thousands of dollars** in debugging time, re-design costs, re-testing costs, re-manufacturing costs and delays to your critical time to market schedule.*

Pre-compliance testing is essentially an exercise in de-risking the approvals process. It attempts to transform a relatively unknown risk into a known risk and seeks to give a higher level of confidence that a product will sail through finals testing first time around.

One of the most important factors in pre-compliance testing is the concept that EMC problems are **much, much** cheaper and easier to fix the earlier they are caught in the design cycle. A few reasons for this are:

- Any problems you find can be fixed in a PCB or product revision that you were going to do anyway for other reasons. For example, if you do pre-compliance testing on a pre-production batch run and find an EMC problem. Any changes and fixes can be rolled into the final production run.
- In-house pre-compliance testing is generally much cheaper to do than full compliance testing at an accredited EMC test lab. Typical lab rates are anywhere between $180/h USD and $250/h USD. If you catch any potential issues before you get to a test lab, then you're going to save a lot of expensive lab time.
- If you've already pressed the 'Go' button on a production run of product which you've sold to your customers and you subsequently fail testing, then you've just made some expensive beer coasters. It's sometimes possible to re-work existing product to implement EMC fixes, but this is usually labour intensive and high cost in terms of EMC suppression products. This happens way more often than you might think. It proves that lack of awareness of the importance of regulatory compliance can lead to huge financial losses.

- Related to the last point, it's much cheaper to implement an EMC fix on a circuit board than it is to add a remedial fix once the design is finalized. For example, a simple resistor/capacitor low pass filter on data signals just before they traverse a radiating cable may cost you $0.002 per PCB, but if the PCB is finalized and you need to find a solution to radiating cables without altering the PCB, a cable choke may cost you $1+ per cable plus debug time. Another example is solving power supply noise on a PCB rather than having to buy a much more expensive low noise power supply adapter or brick. Careful design of the PDN (power distribution network) could save you several dollars per unit if you're relying on a low noise power supply to suppress noise.

There are a ton of reasons to do pre-compliance testing. If you're not doing it, you're leaving the door open to an unknown cost and project delay liability.

What Are The Pre-Compliance Trade-Offs?

Of the many solutions available for pre-compliance testing, each of them have their own pros and cons. Here are a few things to consider when choosing a pre-compliance option:

- **Budget -** How much will it cost to buy or rent the solution?
- **Time -** How long will it take to undertake the pre-compliance test?
- **Expertise -** What training will you need to get up to speed on the technology?
- **Likelihood of failure -** What are the most likely failure modes for my product?
- **ROI** – What kind of ROI will you see in terms of time and money for an investment in a pre-compliance solution?

Keep these thing in mind when viewing the various option below.

Overview of Pre-Compliance Options

I'll quickly give a top level overview of some pre-compliance options, then in the next section we'll dig into some actual solutions.

At A Lab

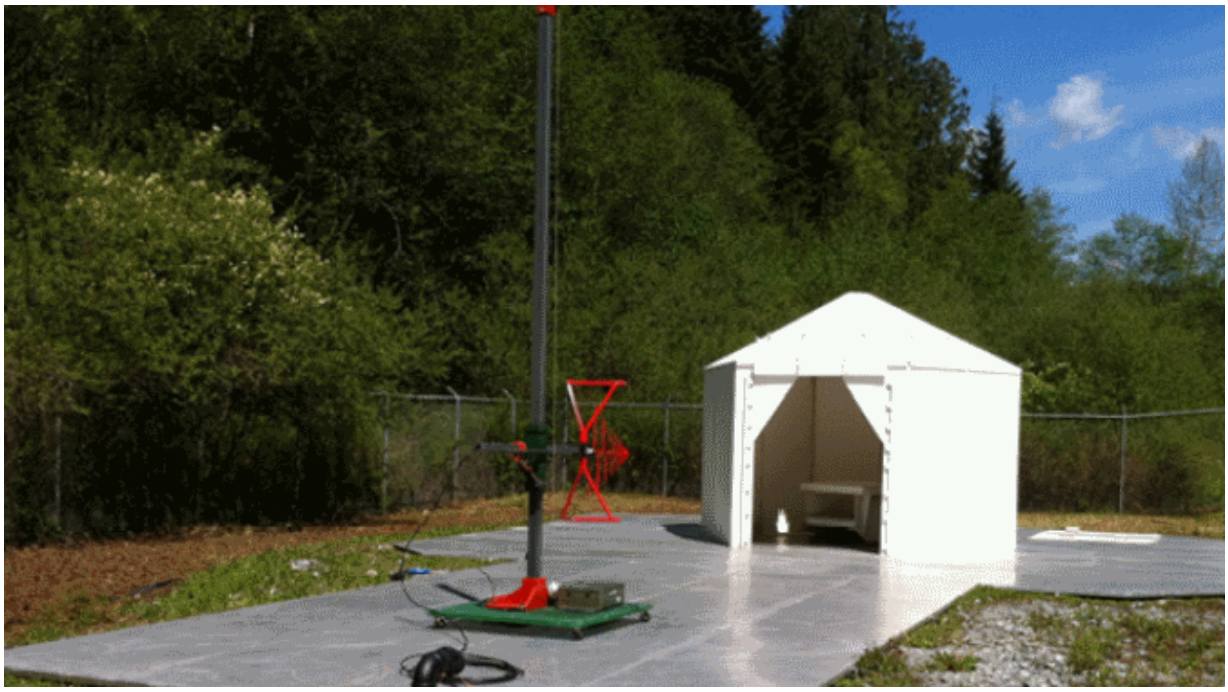


Figure 5 - OATS at QAI, Vancouver

A test lab will gladly rent their services hourly for some pre-compliance testing. They have all of the full compliance test gear, so this would give you some great confidence that your product will be ready for finals testing. A good lab should be able to look at your product and give you recommendations for what likely issues may be so that you can focus your pre-compliance efforts on that. Some labs may even give you a deal on a half day of pre-compliance testing if you go ahead and book a full compliance test schedule with them. Some advantages and disadvantages with this route are:

Pros

- Same calibrated test gear as finals testing, so high degree of accuracy
- For emissions testing, you get absolute measurements rather than relative (discussed further later)
- No capital expenditure (i.e. you don't have to buy test equipment)

Cons

- High hourly cost,
- Potential lead time to book lab space,
- You have to continue paying for lab time while you're modifying your product,
- You need to go with your product to a lab (ideally)
- The money you spend is not being invested in a long term asset such as test gear or training.

In Your Office

A great way to do pre-compliance testing is at your own office. It's convenient, but comes with a few downsides too.

Pros

- Easy accessibility any time
- You can easily disappear for a few hours to modify your product then re-test without incurring charges
- Better set-up to try out your product early in the design cycle. You can re-verify often to make sure any developments don't impact the EMC performance.
- You can re-use your test equipment on many different projects.
- The ROI of purchasing pre-compliance equipment can usually be justified within months, depending on how many products you design per year and what tests are necessary.

Cons

- You may not get the same results as a test lab. (I'll talk more about this below).
- Some methods are only good for relative measurements, not absolute measurements.
- You need to learn how to do the tests and what you're looking for (training required).

Equipment Co-Op

You might be one of the lucky few that live near to an EMC equipment co-op. I've heard of a couple available in the UK and the US. Essentially it's a store of test equipment that you can go and use yourself for a fee much cheaper than a full test lab.

Alternatively, there may be some other electronics companies in your area that have some test equipment that you could borrow or rent. EMC testing tends to happen in short bursts during a design cycle, so test gear often lays dormant for months. Ask around in your community – you might be surprised who has an ESD simulator or spectrum analyzer lying around.

Top 5 Radiated Emissions Pre-Compliance Options

Let's start with the most common EMC tests. Radiated emissions. These tests are required for most electronic and electrical equipment that will be sold into any major market in the world. FCC testing for instance mandates radiated and conducted emissions testing, as does CE Mark (Europe), VCCI (Japan), RCM (Australia), CCC (China) etc.

1. Design Review

Cost: Low ($1200 or cheaper if you do it yourself)
Learning curve: Low for outsourcing, high for DIY
Usefulness: Very High
Equipment Required: None

One of the most overlooked pre-compliance methods is a very robust and systematic schematic and layout design review. It isn't strictly pre-compliance 'testing', but it does exactly the same thing. i.e. it substantially reduces the risk of your product failing at an EMC test lab.

This is really my favourite method to increase chances of passing testing first time around because you can catch so many potential **emissions** and **immunity** problems in one design review.

Rather than doing pre-compliance testing for radiated emissions, ESD, surge etc.. a solid design review will catch many of the root causes of these issues even before your first PCB is manufactured.

At my EMC lab and at EMC FastPass we've had great success increasing the first time pass rate of our clients up to 90% using a design review alone. Compare this to an average first time pass rate of 50% and you'll see that it's a worthwhile investment of time. Over that time, the design review grew and evolved. I wanted to make the review available to engineers around the globe so that they could take advantage of it too, but I realized that it needed to be backed up with training so that the key concepts were passed along. Hence the "Design Review Pro" software from EMC FastPass includes video training at every step - so that you know exactly what you're looking for during a design review.

2. In-house Semi-Anechoic Chamber (SAC)

Cost: High ($100k +)
Learning curve: High
Usefulness: High
Main equipment required: Chamber, spectrum analyzer/receiver, antennas, turntable

This option is for the high rollers. Typically reserved for companies with deep pockets and those that design several products per year. A second hand 3 meter chamber may cost $100k+. You can typically get results quite close to those that a test lab would measure for final testing. Factor in a few dB margin of error and you basically have yourself a fully functioning emissions measurement facility.

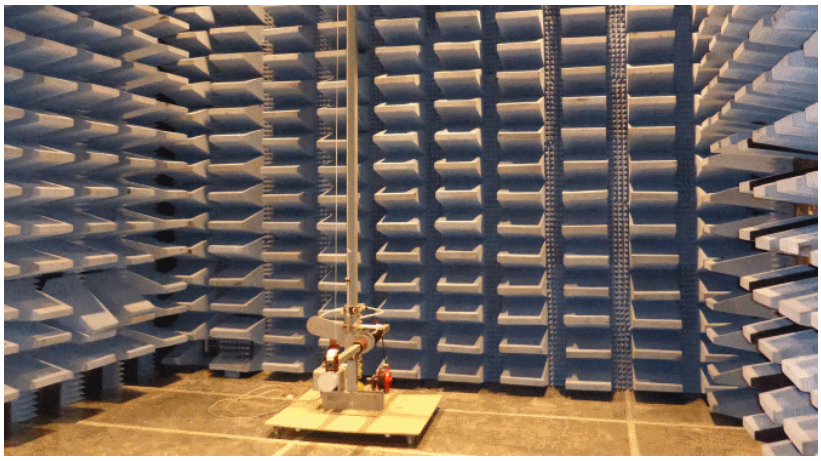


Figure 6 - Semi Anechoic Chamber - QAI, Vancouver

In this case, you'll also need a decent spectrum analyzer or EMI receiver, and antennas covering the frequency range of interest for your product.

It is possible to find used chambers, but beware that the effectiveness of the material lining the chamber, used for absorbing the RF energy and prevent it from bouncing off the metal walls, degrades over time. As the material degrades, reflections increase and measurements become less reliable.

When you have a chamber installed, you need to do an NSA (normalized site attenuation) survey which will tell you how close your setup is to an idealized site.

3. In-house OATS (Open area test site)

Cost: Medium ($5k-$50k)
Learning curve: High
Usefulness: Medium
Main equipment required: Spectrum analyzer/receiver, antenna(s)

An open area test site (OATS) is what many accredited test labs use to perform the final measurements when testing products. An ideal OATS is constructed according to the standards ANSI C63.7 and C63.4 and/or CISPR 16-1-4 for Europe. As there are no walls, the signal received at the antenna is just a combination of the signal received directly from the equipment under test (EUT) and the signal that has bounced off the metallic ground plane.

This is a good second best option to having a chamber. The downside is that it's more difficult to see what emissions are coming off the product because you're not shielded from ambient radiation. Wherever you set up your OATS, whether it's outside in a field or inside a large room in your office, you're going to see extra signals such as those from FM stations, cell phone band and a bunch more. If you're within city limits, the spectrum can be pretty full up across the band of interest.

Listed below, you'll find 3 different types of open area test sites in descending order of cost and accuracy.

- (i) Outdoor OATS

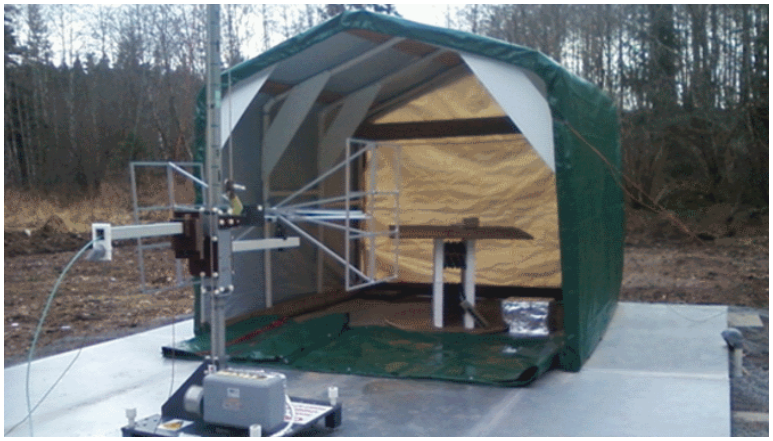


Figure 7 - Basic 3m OATS

If you have the luxury of setting up a 3 meter or 10 meter OATS in a field or outdoor location, it's a good way to go. Construction of an OATS is no small project. Depending on what quality of equipment you go for, you could probably put one together for $20k. If you choose high end gear, you could easily spend $50k – $100k.

- (ii) Indoor

Many companies just re-create an outdoor OATS in a big room such as a board room or loading bay. Typical separation distance between the EUT and the measurement antenna is 3 meters or 10 meters, but you can get away with closer at the cost of measurement accuracy. Typically the lowest measurement frequency is 30 MHz which has a wavelength of 10 meters, and as you approach the near field, the measurement can be influenced much more by positioning of the antenna.

While this isn't strictly an 'OATS' this setup can still be useful for absolute measurements because you can achieve a close approximation to the test lab's results, but you'll likely have some issues with reflections and ambient noise. Your time will be spent working out what is coming off your product and what is just background noise. For this reason, many companies choose to get an emissions pre-scan done at an EMC lab, then if they run into problems, they have a record of which frequencies to focus on at their indoor OATS back at the office. You'll also need a decent spectrum analyzer with low noise floor (probably a pre-amp required) and a proper measurement antenna.

- (iii) Cheaper Indoor Setup

It's possible to implement an even cheaper indoor version of an OATS with just a low end spectrum analyzer and a hacked together antenna (piece of wire or coat-hanger). This can be good for debugging a product that has failed at an EMC lab, but won't be much good for absolute measurements. That means you'll be able to do relative measurements to check whether any fixes you've implemented have an impact on the amplitude of frequencies of interest. This type of setup is more suitable for debugging rather than pre-compliance testing, but as you get more confidence in the results, you may begin to get a feel for a correlation between near and far field measurements.

For this type of setup, it's even more critical to keep the EUT, cabling and 'antenna' in exactly the same positions because you may be operating in the near field. Even the smallest positional changes can impact your readings by several dB. To be sure that you're measuring the change from your fix, everything else in the test setup has to remain the same.

4. GTEM Cell

Cost: Medium ($5k-$50k)
Learning curve: High
Usefulness: Medium
Main equipment required: GTEM, Spectrum analyzer/receiver

These things are pretty cool. They're like semi-anechoic chambers but much smaller. They're shaped like a wedge and integrate a stripline antenna that can act as a receiving or transmitting antenna. The EUT is placed inside the GTEM, between the antenna and a resistive load. The size of the EUT is restricted to a cubic area within the GTEM, but GTEMs do vary in size from small (50 cm) to a few meters. GTEMs are useful for both emissions testing and radiated immunity testing. Given the small dimensions, it's much

easier to generate a large electric field of 30 V/m or higher using much smaller power-amps than you would need in a SAC.

The FCC have issued a couple of KDBs (Knowledge database articles) about the usage and acceptability of measurement results obtained from GTEMs. Under certain circumstances, the FCC will accept measurement data from GTEMs as proof of compliance.

I chatted with a technical assessor at an accreditation body about GTEMs and they strongly advised against their usage as they can yield much different results both for emissions testing and radiated immunity testing. They warned that even for pre-compliance testing their results should be taken with care because they can vary so much from an OATS or chamber. However, many reputable companies still choose to use them and if you're interested in exploring their usefulness further, Nokia released a good technical note on the correlation between their GTEM, OATS and chamber which makes for some interesting reading.

The ease of use, cost and time saving (you can do 8 hours work of emissions testing in less than 1 hour in an automated GTEM) draw many manufacturers in. If you include a healthy margin (say 10dB) and make sure the GTEM has an automated turntable so that the automation software can resolve the emissions profile from 3 dimensions, you can still get meaningful data.

I know several companies that legally use a GTEM to show compliance to radiated emissions and immunity standards in Europe (for CE Mark compliance) as well as use it for pre-compliance testing.

5. Cable current clamps

Cost: Low ($1k-$10k)
Learning curve: Medium
Usefulness: Medium
Main equipment required: Spectrum analyzer/receiver, current probes

Kenneth Wyatt describes a measurement technique that can be very useful in determining the radiated noise contribution of external cabling. By measuring the RF common mode currents present on each of the cables connected to your product, you can easily extrapolate an approximation to the far field electric field strength that would be measured at an EMC test lab due to these cables.
This can be a really good and inexpensive method to sanity check whether your cabling is likely to meet the radiated emissions requirements at a test lab. In the article, Kenneth describes how to make your own probes (cheapest route) as well as suggesting a commercial alternative which would be in the $1k to $2k price bracket.

Conducted Emissions Pre-Compliance

For most electronic equipment that connects to a public AC power source, either directly or via a power adapter, regulatory bodies prescribe limits to the amount of noise that the equipment can inject back onto the power grid.

At an EMC test lab, the equipment they use to test these emissions is just a LISN (Line Impedance Stabilization Network) and a spectrum analyzer. You may need other equipment such as CDNs (Coupling/Decoupling Networks), depending on your set-up, but for the purposes of this section, we'll

just focus on LISNs. A LISN is a low-pass filter typically placed between an AC or DC power source and the EUT (Equipment Under Test) to create a known impedance and to provide an RF noise measurement port which connects to a spectrum analyzer or oscilloscope. It also isolates the unwanted RF signals from the power source.

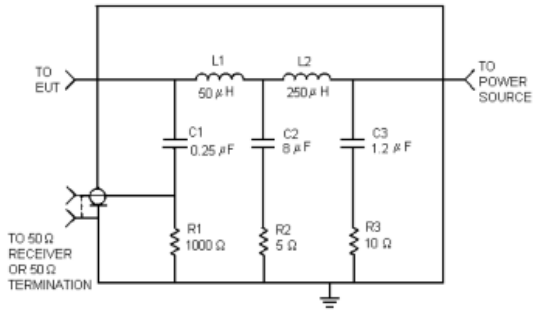


Figure 8 - Sample LISN Circuit Diagram

Commercial LISNs are fairly inexpensive ($1k-$5k). Couple that with a low end spectrum analyzer ($5k to $10k) or 'scope with an FFT function and you could re-create your own pre-compliance set up quite easily.

If you don't want to fork out for a commercial LISN, you could create your own. Annex A of CISPR 16-1-2 or section 4.8 of C63.4 give circuit diagrams for several different types of LISNs (or Artificial Mains Networks).

You'll be dealing with mains voltages and a large amount of energy stored in capacitors, so this route can be really dangerous.

C63.4 also details usage of a voltage probe instead of a LISN, but the difficulty here is that the impedance presented to the spectrum analyzer isn't uniform. Given the low cost of a LISN and inferior quality of measurement results using a voltage probe, I wouldn't recommend this route.

What happens if you change your product after testing?

The frustrating question often came up when I was designing electronic products whether a minor hardware change to an already tested product would mean we'd have to go through EMC testing all over again. I could never find a concise answer on the net, and the test lab never seemed to give us the full story. We didn't know who had been fined in the past and what for. Ultimately we weren't sure how big the risk was if we didn't re-test. If you want to know in what situations fines are issued, how much they were and also the responsibilities and risks of re-testing, read on..

What type of equipment do you have?

Firstly, I'll break the guidelines down a bit because the answer is different depending on the type of product you make. From the FCC's perspective, let's just break it down to wireless and non-wireless devices.

Non-Wireless Devices (FCC)

Products that don't incorporate a wireless transmitter are typically subject to the 'verification' or 'declaration of conformity' authorization procedures (as discussed previously). This is a fancy way of saying an EMC test lab needs to measure the radiated and conducted emissions coming from the product and your test reports most likely don't need to be filed with a TCB. You can determine if your product is subject to these authorization procedures by checking out the table in Part 15.101 of the rules.

If your product is subject only to 'verification', then the paragraph you need to know is:

Guidance for devices subject to 'Verification'

"In verifying compliance, the responsible party … warrants that each unit of equipment marketed under the verification procedure will be identical to the unit tested and found acceptable with the standards and that the records maintained by the responsible party continue to reflect the equipment being produced under such verification within the variation that can be expected due to quantity production and testing on a statistical basis.

Verified equipment shall be re-verified ***if any modification or change adversely affects the emanation characteristics of the modified equipment****. The party designated in §2.909 bears responsibility for continued compliance of subsequently produced equipment."* (FCC CFR47 Part 2.953)

As you can see from the text in bold, it's a bit of a chicken and egg scenario. Of course, to know 100% whether the change you made adversely affected the 'emanation characteristics', you would need to re-verify the test results.

Guidance for devices subject to 'Declaration of Conformity'

The FCC is a bit clearer with the guidance for DoC authorized devices:

"Equipment shall be retested to demonstrate continued compliance with the applicable technical standards if any modifications or changes that could adversely affect the emanation characteristics of

the equipment are made by the responsible party. The responsible party bears responsibility for the continued compliance of subsequently produced equipment." (FCC CFR47 Part 2.1073(d))

So this leaves it up to the manufacturer to determine whether they believe the changes they made could negatively affect the emissions profile.

The ultimate answer would be to re-test (or at least do a short pre-scan), but in reality there is probably some wiggle room.

How Much Wiggle Room Do You have?

Let's keep in mind that the measurement uncertainty of radiated emissions at an EMC lab are mandated to be within +/- 4dB from an 'ideal' site. This means that an emission measured at one lab may be as much as +8 dB higher than the same emission measured at another lab. That's pretty big. If the FCC is investigating a complaint of a non-compliant device, they're likely going to give you a bit of the benefit of the doubt since an emission that they measure could perceivably be 8 dB higher than when you had your device measured at another lab. Not to mention the natural device to device variance. Ultimately they will review the measurements compared to the actual limits, but from a risk analysis perspective it means that you essentially have some wiggle room for making minor changes if you started with a lot of margin.

Practically speaking, a test lab re-measuring the emissions from your product would not be able to tell whether an increase in a particular emission amplitude came from:

(a) Test set-up (did they recreate an identical test set-up?)

(b) Product to product variance

(c) Lab to lab measurement variance (potentially +/- 8 dB)

(d) A design modification

If I was wondering how much wiggle room I had, I would consider what the perceivable impacts were of the change I made and also how far below the limits the product was to begin with. If I changed the value of a pull up resistor for instance on a static GPIO net, I'd think the risk of adversely affecting emissions would be pretty damn low. On the other hand, if I changed a processor out for a completely different model, then I would have no idea what the new emissions profile would look like, so I would get the product re-tested. Or if I changed the termination resistors on bus signals that I knew were oscillating at a frequency listed on a previous test report as 2 dB below the limit line, I would call that risky.

Here is a non-exhaustive list of changes that I would perceive to be **high risk:**

- Changing any active components to components with completely different switching/power characteristics
- Changing the enclosure material

- Any components around the power supply that could affect conducted emissions (switching supplies, smoothing circuits, rectifiers etc).
- Changing LCDs
- Increasing the port count (always test with all ports enabled)
- PCB stack-up changes

And low risk:

- Pull up resistors
- Protection circuitry
- Low speed GPIO routing
- Identical part substitution
- Adjusting connector placement slightly

The point is that common sense should prevail. If you seriously don't know what impact your change might have on emissions, then get it re-tested.

What's the Risk of Being Fined by the FCC?

The FCC's schedule of maximum fines shows that the penalties can be big. They are worth keeping in mind as you evaluate the risks.

So, if you decided to go ahead and make a change to your product without having it retested and now you're worried that you could be fined, read on below for a history of the fines issued by the FCC for non-compliant devices (it's not as bad as you think)…

Take a look at this history of legal actions by the FCC on product manufacturers from 2006-2012 compiled by Fish and Richardson legal firm. You'll see that the vast majority of the penalties were for wilfully marketing and/or selling electronic products that were not tested at all. Very few (under 10, in 6 years!) were violations where previously tested equipment was later found to be non-compliant. Now, I can't vouch that this is a complete list of violations, and it certainly doesn't list any lawsuits brought by private companies or individuals for any resulting liabilities due to non-compliant devices. But it would be easy to see how a manufacturer could read this enforcement list and perceive that the risk of being fined by the FCC for modifying a previously tested device is low, especially for non-radiating devices.

Ultimately the risk lies with the manufacturer, so use your judgement wisely and consult a lab or legal team if in doubt.

If you want to know more about the potential legal liabilities of non-conforming equipment, I highly recommend scanning this "The Legal Aspects of Regulatory Compliance" or contacting Fish and Richardson directly. This presentation delves a bit deeper into the legal aspects of compliance and the theories of liability.

Intentional Radiators (FCC)

If your product has a transmitter in it, the rules are much clearer. As discussed in previous sections, these devices are generally subject to the 'certification' authorization procedure, which means your product will need to be tested at an EMC test lab, then you'll file an application with a TCB. You will probably have to include your schematics and bill of materials, so it's much easier for the FCC to track modifications made to your device after certification.

They also undertake market surveillance to ensure that (a) the original test lab performed the testing adequately and (b) to ensure ongoing compliance. The FCC currently mandates all TCBs to perform follow up market surveillance on 5% of all transmitter certifications.

The FCC have issued a full PDF (178919 Permissive Change Policy) outlining the different types of changes you can make to a certified transmitter. Note that any modifications to the baseband circuitry not associated with the transmitter are subject to the DoC or Verification guidance above. i.e. the information in the PDF only apply to changes specifically to aspects of the RF transmission portion of your circuit.

There is too much information within the Permissive Change Policy to cover in this eBook, but essentially it covers the following types of changes to your device:

- Antenna changes
- Printed Circuit Board (PCB) and Hardware changes
- Enclosure changes
- Software changes
- Miscellaneous changes

Depending on the seriousness of the change you've made, you may have to do one of the following things:

- File a completely new certification application (the device will be treated as a different transmitter)

- File a modification to your existing certification

- Just re-verify a subset of the RF tests and keep the measurement data on file (don't need to file anything with a TCB)

Bonus: How to Find Test Equipment Bargains

When I set up a small independent EMC test lab from the ground up, I didn't have a big budget. Actually it was minuscule by most test lab standards. I really didn't know whether I could buy all of the test equipment that I needed to run a test lab on such a tight budget but I had a lot on the line, so it was an absolute necessity to find the best deals. Meters, power supplies, oscilloscopes, signal generators, ESD simulator, analyzers, amplifiers, probes.. it was all essential for the success of my business.

Over several months, I discovered some great ways to secure the bargains that brought the project in on time and on budget. On at least 2 occasions I was able to pick up a piece of used test equipment worth over $5000 for less than $500. If you ever need to buy test equipment for yourself or your company, follow the guidelines below to secure the best possible prices.

Buy Used Wherever Possible

This almost goes without saying, but if you're not designing products on the bleeding edge of technology, there is rarely a good reason for buying new test equipment. The used test equipment market is massive so it's almost guaranteed that you'll be able to find used equipment with the technical specifications that meet your needs. I would say I found 90% of the gear that I needed on the used market, with a few exceptions for very niche, rare equipment.

Most good used dealers will give you a warranty and calibration service, so you know that you're not buying a lemon. For extra piece of mind, look for dealers with an in-house ISO 17025 accredited calibration lab.

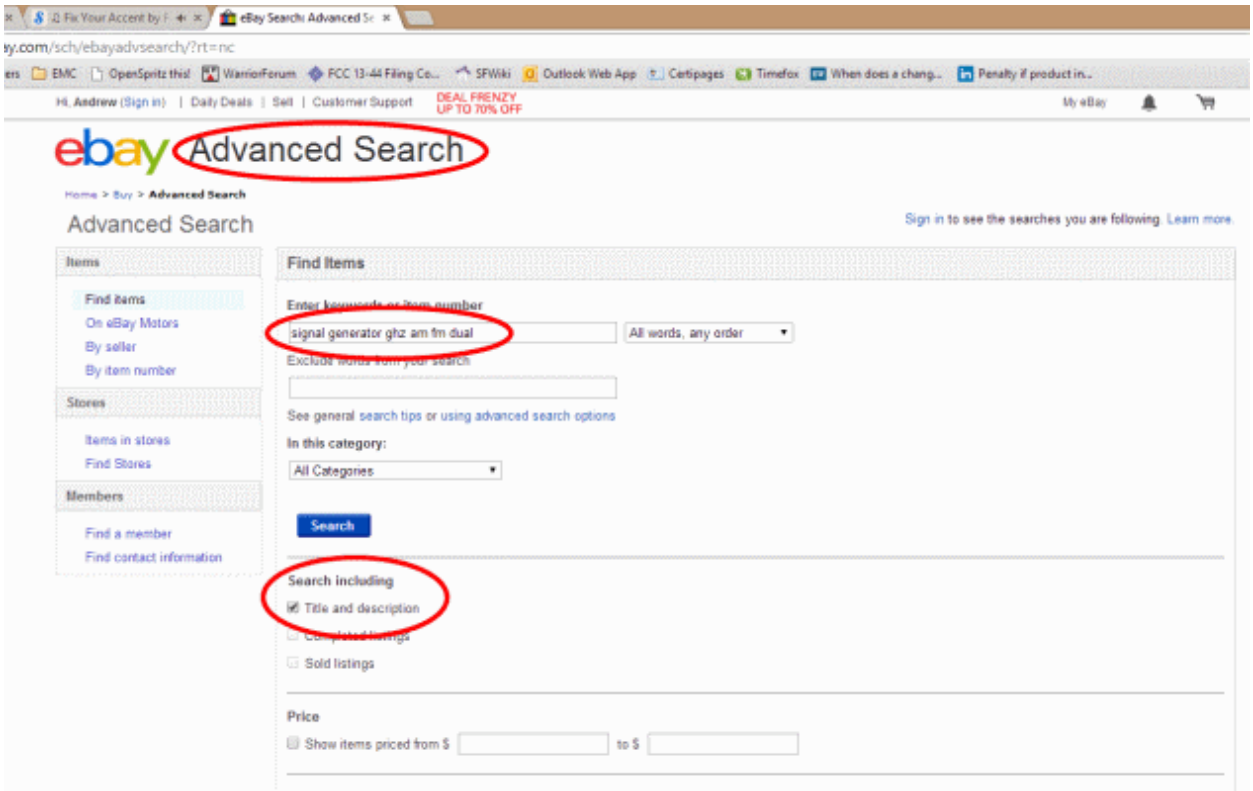
Narrow Down Your Options

First you need to narrow down exactly which make and model of equipment that you're interested in. Let's say you want a signal generator. Outline a few criteria that are must haves. E.g.

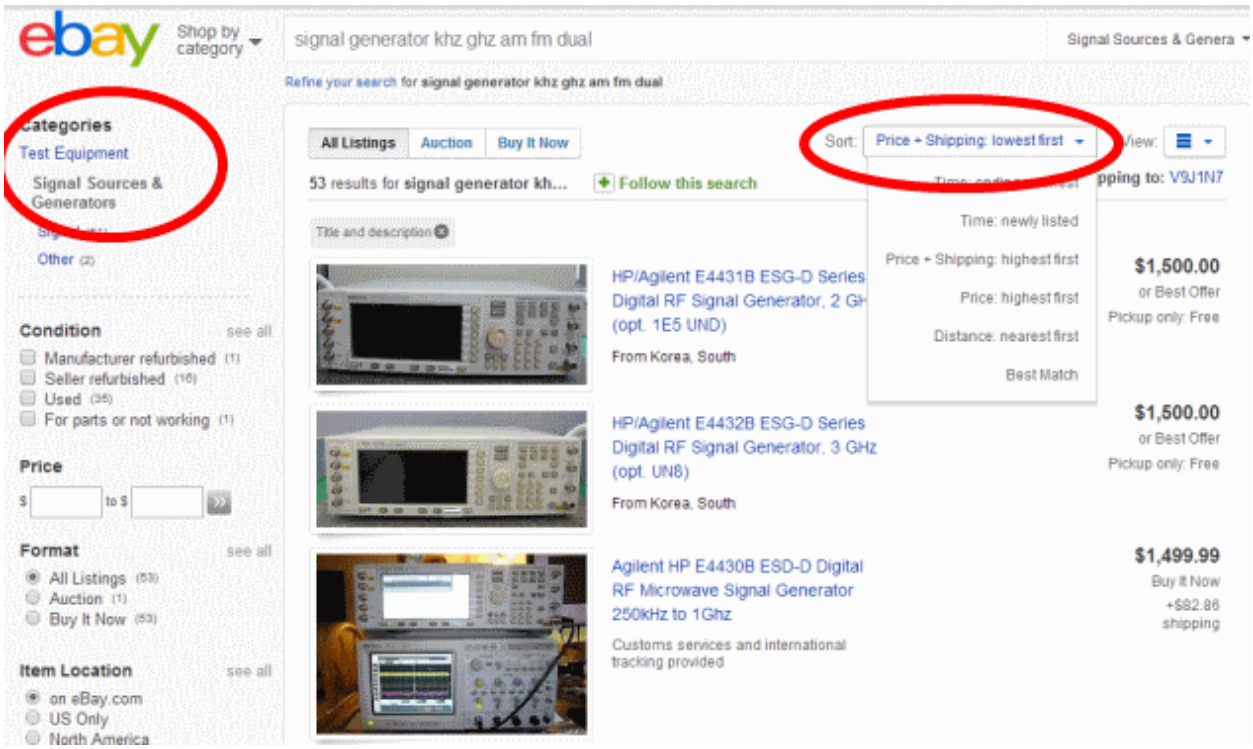
- Minimum and maximum frequency (Let's pick 100 kHz and 2 GHz)
- Modulation modes (AM, FM)
- Number of outputs (2)

The main way I use to select possible equipment candidates is to the 'Advanced Search' feature on EBay.com.

In the example above, I would search for, "Signal generator GHz KHz AM FM dual". Make sure to also select the "Search title and description" box as well!!



The search results will include results from many categories. Just use the category selection tool in the top left hand corner of the browser to narrow down the search. In this example I selected “Signal sources and generators”. Then I used the ‘sort by’ tool to sort by “Price + shipping, lowest first”. See below:



From this search, I can see that the Agilent E4431 and E4432B are possible candidates. I would then go and read the datasheets for these pieces of equipment (and any other pieces that came up during the search) to see if they met my performance criteria.

What's a Good Price?

So let's assume you've now found one or two models that match your criteria. Before you go bargain hunting, you'll really need to work out what a bargain price actually is. Firstly I'd go to Used-Line.com and ebay.com to search for the exact make and model number I was looking for. Same as in the example above, I would sort by "Price + shipping, lowest first". There would usually be some accessories or spare parts (broken) units noted in the list as well, so I'd scan down the list to see what the cheapest actual in stock working unit was. This price is a good starting point for what would be considered the 'highest' target price that I would expect to pay.

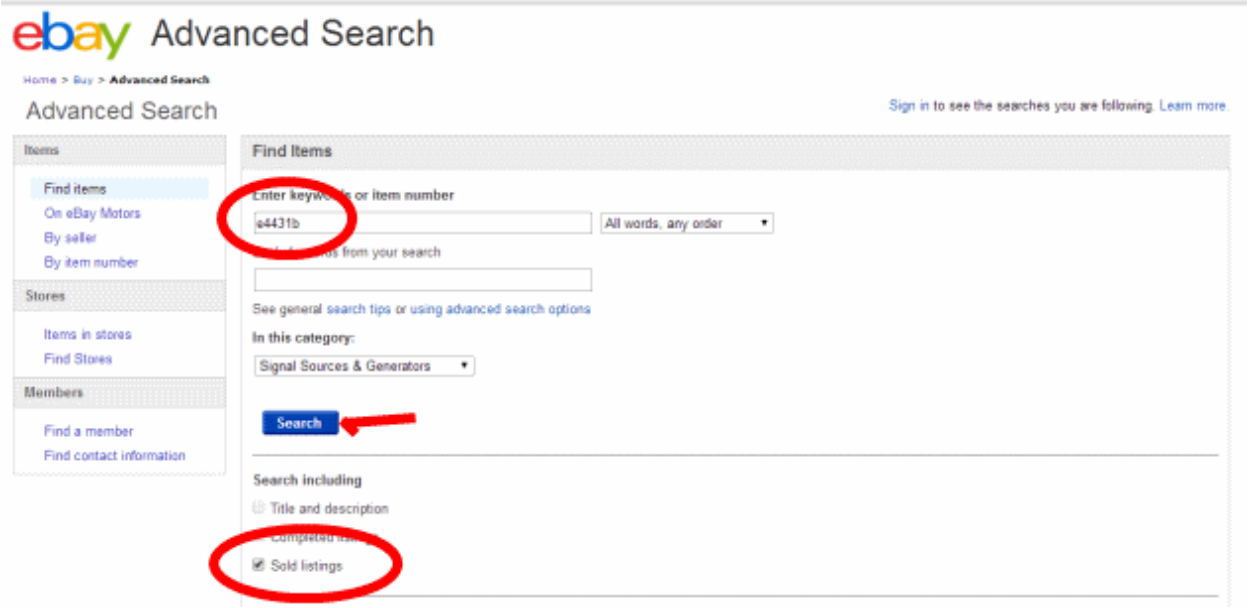
You should always keep in mind that most used test equipment sits dormant in a warehouse for months or even years before a sale actually happens, so the prices listed on websites should always be considered highly negotiable.

Use EBay's "Sold Listings" Feature to Find Out how Much Products Actually Sold For

A better way to gauge *actual* sale prices is to use an advanced search feature on eBay called 'Sold Listings'. This will tell you the history of exactly how much specific models of test gear sold for on eBay. It's very common to see here that the accepted bid/offer price is much, much less than the 'buy it now' price.

1. Go to advanced search
2. Click 'Sold Listings'
3. Type in the model number that you're interested in

View actual sale prices.



In this example, I can see that while E4431B's are listed for sale at $1500+, only one has sold in the archive period and the sale price was $545! In general, asking prices for electronic test equipment seems to be much higher than people are willing to pay for them.

Note: EBay recently changed their rules by hiding the winning 'Best Offer' price. To get around this, you just need to copy and paste the item URL into www.watchcount.com and it will show you the actual 'Best Offer' accepted price!

You'll typically find that the accepted best offer prices are significantly lower than the lowest prices listed on Used-Line.com or ebay.com. You can use this information as your new low target price and a very effective bargaining tool.

Knowing When to Jump on a Good Deal

The best deals I got (I'm talking $500 for a $7000 piece of test gear) were always from people who didn't know what they were selling. One example was a fellow who was given the task of listing the contents of his neighbour's garage on eBay because he was more 'tech savvy'. He had no idea what the equipment was, so he listed the items on eBay as an auction with a low starting price and no reserve. There are hundreds of used test equipment dealers that keep a watchful eye on new items like this appearing on Ebay every day. They will either snap up good deals on eBay very quickly or they will bid up the equipment significantly so it is much more expensive. It is never a good idea to get in to a bidding war. If possible, always try to snap up the equipment before other people notice it. In this case, I emailed the seller and told them I would like to buy the equipment right now because I had an urgent job (which was true) and asked him to change the listing to 'buy it now' and let me know the price he would be happy to accept. He took some convincing, but eventually we settled on $500 for a $7000 piece of test gear!

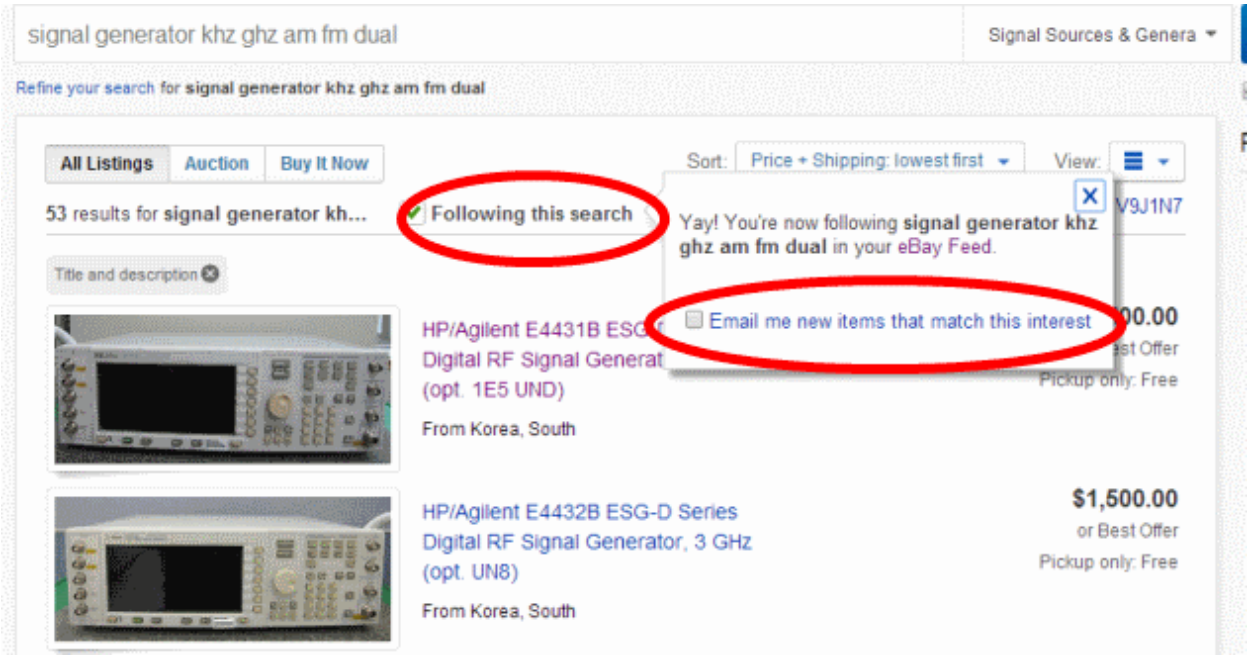
Another example of why some people may not know what they're selling is a when a company picks up a batch of equipment from an electronic company foreclosure. They may not have a clue what any of the equipment does or what it's worth. They go ahead and list the equipment on craigslist or eBay.

Speed is of the Essence

The key to securing a bargain in both of these scenarios is speed. You must find out about the listing before the equipment dealers find out about it. There are a couple of pro-secrets to accomplish this:

eBay 'follow' search

If you know exactly what you want, just click 'follow search' at the top of the search listings. Make sure you check the box that says, "Email me new items that match this interest". This means eBay will email you the instant anything matching your search is posted to eBay.



An Extra A+ pro-tip to this method, is to set up email forwarding with your email service provider to forward email from EBay to the email address associated with your cell phone [10 digit number@your cell phone provider.com]. Any email sent to this address will be sent to your cell phone as a text message!

Craigslist RSS feed

In a similar fashion, craigslist lets you feed any new listings matching your search criteria to your email address. Follow their instructions here to receive an email alert whenever an item matching your search term is added to Craigslist.

Finding Test Equipment In Your City

Let's keep in mind that there is a real world as well as the internet. Occasionally, it's possible you'll come across a bankruptcy, closure or clear-out of a large electronics company in your city. It's a lot harder to find out about these events, but I found that used furniture dealers always had their fingers on the

pulse. They would typically be the first to hear about a company that was closing in the city. Because the sale market is smaller (i.e. your city vs. the internet), you'll usually find that the prices are much lower than you'd find on the internet.

Another good place to watch out for this is on government websites. For example, here in Canada, there is the GC Surplus website, where the government lists repossessed equipment. You probably have similar government auction websites in your country.

Driving a Hard Bargain

Let's say that you now know exactly what piece of test gear you want and what's considered a great price. Now you need to go and find several people/companies who are currently selling that equipment and start playing them off against each other. See the 'essential websites' section below for several sources on the internet for finding the piece of test equipment that you're looking for.

My method of negotiating involves a combination of:

- Showing them the previously sold prices (obtained using the methods described above)
- Asking one dealer if they can beat the other dealer's price
- Asking for the best price if I buy today
- Asking whether they can include a fresh calibration with the price
- Asking them if they will pay for shipping and import taxes

If you need the equipment quickly and there are very few dealers with stock, then it will be much harder to drive a hard bargain. You usually get the best deals if you can find several sources for the equipment and if you're really prepared to walk away from a deal.

Be Careful of Fraud

Fraud is a real concern when buying high value test equipment on the internet. There are several things to watch out for:

Untrustworthy Calibration Labs

Sometimes a used dealer will say they have an in-house calibration lab, but they actually just place a sticker on the test gear without testing it. It's best to always ask for a report "with data" which gives you more confidence that they actually verified your equipment properly. Also look for calibration labs with ISO 17025 accreditation. This gives a much higher probability that the test lab is trustworthy, although it is not a guarantee.

Ebay ratings

Verify the Ebay ratings of any sellers. I make a rule of avoiding any Ebay sellers with a rating of less than 95%. Also you should be very weary of sellers with brand new accounts or those that have not sold high value items in the past (check the seller history).

Craigslist fraud

Craigslist has a very high incidence of fraud. I personally have encountered 2 instances of attempted fraud when attempting to buy test equipment off Craigslist. If the seller requests money before you

have received the product, most of the time this means that you should walk away. Always try to view the product in person before buying items off eBay, or if the equipment is far away, try to do as much background checking of the person/company who is selling, before transferring any money. I have actually found a few bargains on Craigslist and sent money before receiving equipment, but that was after talking to the seller on the phone and satisfying myself that they were trustworthy.

Does the dealer actually possess the equipment?

A common occurrence is for a used equipment dealer to list a product on the internet that they don't actually have in stock. When you call them, they tell you that they have it in stock and they will check it for 'availability'. What they're actually doing is checking a database of stock that is shared between many equipment dealers. This means they don't really know what condition the item is in and what the calibration status is. If I'm talking with an equipment dealer, I always make sure they have it in stock themselves or I walk away.

Foreign supplier fraud

When you're buying test equipment from a foreign country, you need to be hyper-vigilant for fraud. If there are no ratings available for the seller and no easy way to verify whether they are legitimate, always insist on using an escrow service such as www.escrow.com. Services like this will act as a middle man and will only release your money to the seller when you have confirmed that the test equipment has arrived.

Essential Websites

Here's a few go-to websites that I visit whenever I need a new piece of test equipment.

www.Ebay.com

This is my main go-to source for test equipment. Occasionally, a particular test equipment sale item may not be visible in your country's Ebay listings (e.g. Ebay.co.uk) because the seller has not listed your country as a shipping destination. If you can't find your item on Ebay, it's worth trying some other country's Ebay sites too.

www.used-line.com

Good source of used equipment dealer stock. It's the largest database that I've come across that contains the used equipment stock of lots of equipment dealers. They also have a 'wanted' function, but I've never found this very effective (the response rate is low).

www.go-dove.com

These guys are tasked with disposing of large amounts of test equipment from big electronic company clear-outs or closures. It's like eBay, but with low reserves and no repeat listing. The equipment that goes on sale here is very dependent on which companies have recently closed. The downside to this source is that many used test equipment dealers watch it for bargains, so the competition is high. The upside is that you'll often see 20+ units of a particular piece of test equipment and even used equipment dealers are weary about sucking up that much inventory. It's very possible that you'll pick up test gear for the reserve price, which is typically low.

www.craigslist.org

It's quite possible to find test equipment gems on Craigslist. If you don't find what you're looking for in your city, just use Google to search for your item and add the term 'craigslist' to search all of the craigslist sites.

Appendix A - FCC Certification Application Package

The following information is required as part of the TCB application for certification of your product. You can print out the checklists and tick off all relevant exhibits as you have completed them.

1. **Applicant Information** (Who the certification will be issued to)

Product Model Number:

FCC FRN Number:

(Click here if you do not have one)

FCC Product ID number (XXX = Grantee Code (3 characters); YYYY = Product Identifier (maximum of 14 characters)**:**

2. **Equipment Exhibits Required for FCC Certification**

Provide the following exhibits in PDF format:

1. FCC ID – XXXYYYYY (XXX = Grantee Code (3 characters); YYYY = Product Identifier (maximum of 14 characters)

2. Theory of Operation/Technical Description

3. Tune-Up Procedure (If applicable)

4. FCC ID Label Artwork

5. Label Location

6. User's Manual

7. Block Diagram

8. Complete Schematics in one PDF document

9. Complete Parts List in one PDF document

10. Confidentiality Request Letter

11. External Photos

12. Internal Photos

13. SAR (specific absorption rate) and/or MPE (maximum permissible emissions) data (if applicable)

14. Scanning Receivers – If applicable, a statement describing methods used to comply with design requirements of all parts of Section 15.121.

Guidance for preparation of exhibits

FCC Exhibits:

Item 1: FCC ID – XXXYYYYY (XXX = Grantee Code (3 characters); YYYY = Product Identifier (maximum of 14 characters) – The grantee code must be obtained from the FCC, and it is company and address specific (this code identifies you and you only). The product identifier is chosen by the grantee. It may be a maximum of 14 characters, and may include the dash (-) but no other symbols; just alphanumeric characters.

Item 2: Theory of Operation/Technical Description - A brief description of the circuit functions of the device along with a statement describing how the device operates; to include a description of the ground system and antenna, if any, used with the device. (Catalogue sheet may contain most information. It is necessary that this be in a separate document - PDF preferably). May be held confidential if included in Confidentiality Request.

Item 3: Tune-Up Procedure – Procedure for ensuring the device is tuned to the correct frequency/frequency range and that it is operating at proper level. May be held confidential if included in Confidentiality Request.

Items 4 and 5: FCC ID Label and Location - A photo or drawing showing the identification label clearly (you must be able to see the FCC ID number), and the location on the device. These may be submitted as one document demonstrating both, or two separate documents (again *preferably PDF*).

Information to be included on the label:

The term "FCC ID:" must be included prior to the XXXYYY and all must be contained on one line and legible (it is recommended that the type be 6-point or larger).

If product is larger than "palm-sized" (or 8x10cm), the statement according to Section 15.19 (a) must be included on label (15.19 (a) (1) or (2) or 3) depending on device).

If product is smaller than "palm-sized" (or 8x10cm), the required statement may be included in the User's Guide/Owner's Manual.

In addition, pursuant to Section FCC 15.19(b)(5) information regarding the label material and method of permanent attachment to the product should be supplied, i.e. the label must not be paper, and the ink and label material must be a quality and type that must last the life of the device.

Label Location:

In addition to being visible to the consumer, the label cannot be located on a removable part, such as a battery cover.

Item 6: User's Manual/Installation Instructions - A draft copy of the instructions may be submitted if the actual documentation is not available. Modules require specific verbiage – please enquire further if this applies to your device.

Information to User (From the FCC Rules) - to be included in the user's manual:

a. Section 15.19 statement – If device is smaller than the palm, this may be included in manual.

b. Section 15.21 statement (for all intentional and unintentional radiators)– "Changes or modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment".

c. Section 15.25 Info (if applicable)

d. Section 15.27 Info (if applicable)

e. Section 15.105 statement (for digital devices)

f. Modules (Instructions for installation by the "assemblers" as to method of ensuring proper separation distance between module and antenna and user.

g. RF Exposure info (if applicable) - See 2.1093 of the FCC Rules

FCC Part 18 devices - To be included in the user's manual or on packaging if manual is not provided (ex. Some ISM equipment): Section 18.213 Information.

Item 7: Block Diagram – See Section 2.1033(b)(5) – Exhibit must show "…frequency of all oscillators in the transmitter portion of the device . The signal path and frequency shall be indicated at each block. The tuning range(s) and intermediate frequency(ies) shall be indicated at each block." Document must be separate from manual, and preferably a PDF document.

Item 8: Schematics – Please submit **only** the Schematics for the transmitter portion of the device or transmitter module. We do not need the Schematics for the entire host, which may include digital devices or other modules that are subject to separate requirements or requirements other than certification. **NOTE:** Please ensure that the components and component values are legible on the schematics. This exhibit may be held confidential if included on the Confidentiality request letter.

Item 9: Parts List – Parts list for the radio device, listing all components and/or identifying the source of OEM modules. This exhibit may be held confidential if included on the confidentiality request letter.

Item 10: Confidentiality Request Letter – The exhibits provided to the FCC are accessible by the public on their site. A special request letter must be submitted to FCC for confidentiality to be granted to certain exhibits. Both permanent confidentiality (only specific documents allowed – schematics, block diagrams, parts lists, tune-up procedure, operational/technical description) and short-term confidentiality (certain documents are allowed to be held confidential for a **maximum of 180 days** as

long as device is not being marketed) The documents allowed to be held short-term confidential are external and internal photos, test photos, block diagrams, schematics, user's manual, parts list, tune-up procedure and operational description. Under short-term confidentiality, you must request an extension before the end of the initially requested time frame if you still require this service, for a total of 180 days.

Also, if you market before the requested STC timeframe is over, you must notify the FCC to lift the short-term confidentiality.

Item 11 and 12: External Photos and Internal Photos - EUT photos, internal and external, showing all faces of the device and all circuitry, and one shot per page. Photos shall show top and bottom of each circuit board, also with any metal shields removed. Internal photos shall show the component placement on the chassis and the chassis assembly. If components are covered by an insulator, provide a photo with the cover on, and one with the cover removed. External photos shall show the overall appearance, the antenna used with the device (if any), and the controls available to the user. Please provide as **ONE** legible PDF document for **internal** photos and **ONE** for **external** photos.

Item 13: When SAR requirements apply to your product, a SAR test report is required for submission. Contact the lab for applicability or SAR testing to your product.

Special Thanks and Acknowledgments

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Starfish Medical kindly contributed the section on medical regulations. They are a medical device design consultancy with a full complement of design, development, and manufacturing services based in Victoria, BC, Canada.

Bill Crunkhorn kindly contributed the section on military regulations. Bill has an in-depth background in design and testing for military specification products.

Also, thanks to my partner Chelsea Gogal for helping to proof read this text and also for putting up with my very extended workdays.

I would like to also acknowledge the Arduino™ and Raspberry Pi™ licenses that may apply due to the use of their trademarks within this publication.

Contact

I realize that this eBook may not answer every question about the rules and regulations that you may have. I tried to make it as inclusive as possible while still keeping it concise, but there are always going to be more questions due to the intricacies involved. However, it's possible that there will be updated versions of this eBook. If you have any feedback, questions or suggestions, I'd love to hear from you.

Email me at: ebook@emcfastpass.com

I get tons of email every day, so I can't guarantee I'll reply to everyone. But your email will be read and considered for any future updates of this eBook.