Design for Internet of Things
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Lecture - 40
Introduction to Low Power Wireless – 02

What is the vendors view on receiver sensitivity is important. We should know how the vendor is thinking and information is available. It is just that you need to consolidate and look up and understand the definitions correctly. So for that what I did, I never defined to you what exactly does receiver sensitivity mean is it not? So we should spend a little time trying to understand this.

See after all, you do not know which radio to pick, okay. You may have decided that I want to use ZigBee of your 802.15.4 or 15.4e variant which still uses the 15.4 radio price tag. So how to decide? So this is one important parameter and let us move on from here. The definition is the following, okay.

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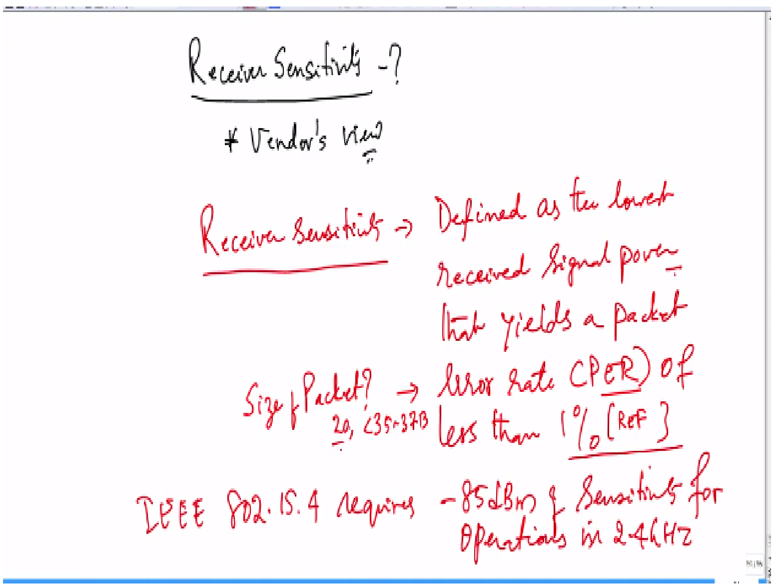

The distribution says it is defined, the receiver sensitivity is nothing but the lowest received signal power, lowest signal received power that yields a packet error rate of less than 1%. Some reference will be there here, okay. Some reference will be there. It has to be with respect to some known less than some number, okay. So this is less than 1% PER is what you are talking about.

But there is a catch here. When you say packet error rate, what is the size of the packet is the question, okay. What is the size is not known. But usually the vendor would have done it for small size packets. I would say 20 or 35 bytes, less than 35 bytes, or 37 bytes or something like that, 35 to 37 okay, bytes. So which is a small size. And that is very harsh actually.

Making a defining a PER for extremely small packet size is indeed a good step, right. That is one way of interpreting. The other way of looking at it is that if the air time of the packet if it is small, the air time of the packet is actually also small. And the link often perhaps, is idle.

So if there is indeed a problem about the link fading under some circumstance, then bigger size packets will actually see more PER as compared to smaller sized packets. But anyway that apart, the definition simply says that it is the lowest received signal.

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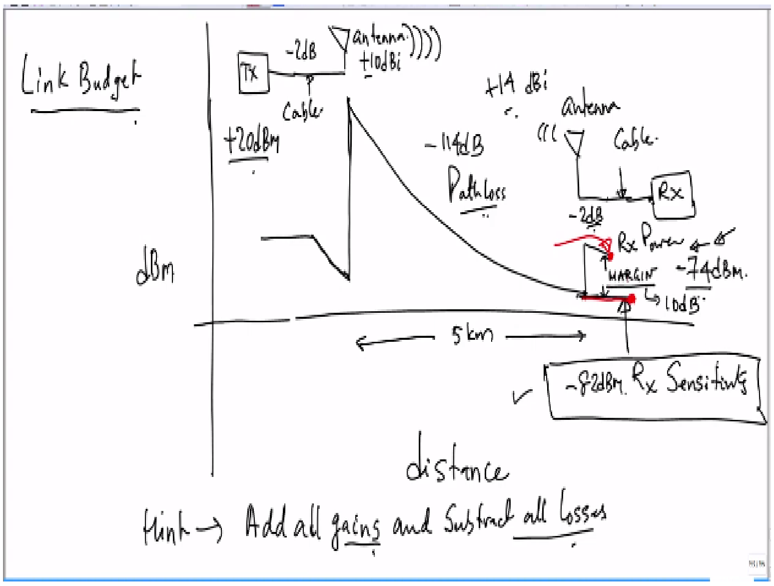

So you can go back and say this is the point of interest, is it not? This is the receiver sensitivity and this is what you received, right? This point, which is good right? You had a good margin here. So this is the lowest point and this is the actual sensitivity of the system. So up to this point is indeed when the transmissions are successfully received. Anything below this will not work. So essentially this, in this example the packet was received with this power.

So we had this much margin, but the receiver sensitivity definition goes back to this point. So essentially, everything falls in place here. There are some requirements that are laid out by the 802.15.4 standard itself. It says if you support -85 dBm of sensitivity for operations in the 2.4 gigahertz this is already good enough. That is what the standard says, okay. Now what does it mean?

It simply means that you are getting 12.6 microvolts from the antenna. This is the voltage that you are getting. This voltage is coming because you are getting 3.16 picowatt. You are getting this because you have defined the sensitivity as -85 dBm and we have assumed 50 ohm single-ended antenna. That will give you 12.6 microvolts, okay. -85 dBm will simply translate to 12.6 microvolts because -85 will give you 3.16 picowatts.

Signal voltage will be square root of P into R. R is 50 ohms. You know that the -85 dBm when translated to volts becomes, convert the power, it gives you 3.16 picowatts. 3.16 picowatts into 50 ohms will give you and the square root of that will give you 12.6 microvolts. And this measurement is done for octets of size 20 okay, and PER is about 1%.

Now is this making sense at all or is it something bookish or are we talking something completely different? Not really.

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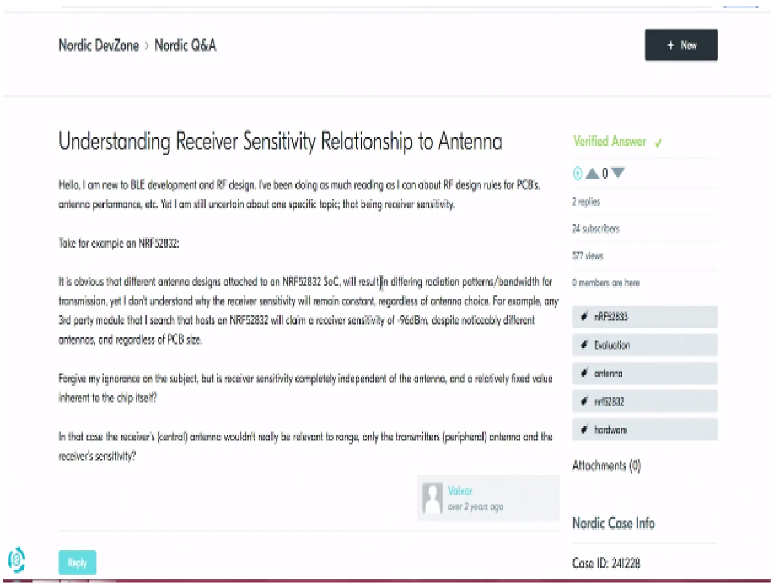

Look at what this Developer Zone mailing list is actually discussing about, okay. So there was a question from some user and he has taken NRF52832 as an example. And he is asking I do not understand this receiver sensitivity why will it remain constant regardless of the antenna choice. So he is confused, this gentleman, about why antenna has to do, why is receiver sensitivity is fixed irrespective of antenna, right?

So it goes back to our original question. Are you measuring receiver sensitivity with an antenna or you are only interested in the electronics measurement of sensitivity with respect to just the electronics or a combination of the antenna plus the electronics; that is the question. So now comes the reply, which is quite nice and useful for me to point this out to you. So let us go there. It says the following.

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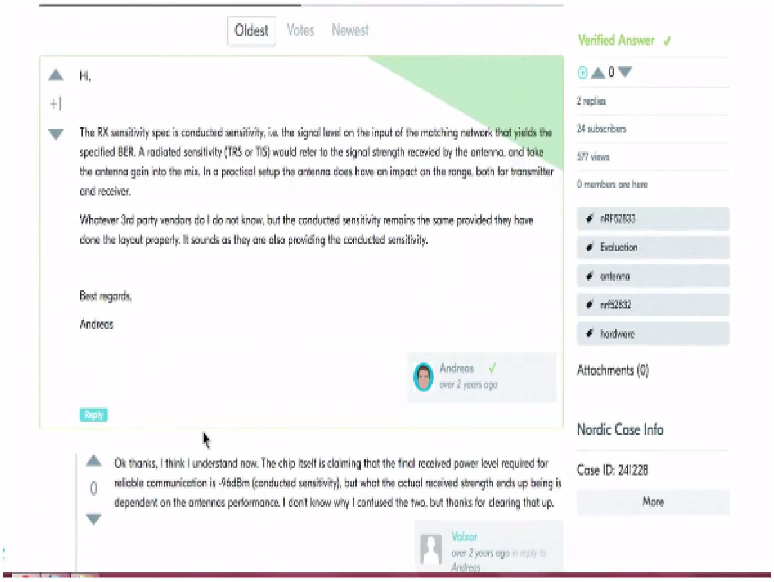

Look at this nice answer. So if you read this it says the RX sensitivity spec is conducted sensitivity, says it is all about conducted sensitivity. That is the signal level on the input of the matching network that yields the specified BER. The radiated sensitivity would refer to the signal strength received by the antenna and take the antenna gain into the mixture.

In a practical setup, the antenna does have an impact on the range, both for transmitter and receiver. Whatever third party vendors do, he is saying that I do not know. But specification is for conducted sensitivity and that remains the same provided they have done the layout properly. And that is what the vendor is claiming. Do not go by the antenna tricks that you can attach to the power amplifier.

Go by just the conductor sensitivity, receiver sensitivity, okay. And that is what, then if you just go by conducted sensitivity, it does not account for the type of antenna that you are connecting to. That is essentially what the reply comes for the vendor. And of course, the person thanks and says I understand it now and so on.

So this is a very important point which you should make a note of and its impact on the overall you know purchase of, choice of your particular radio for your application. So this is one aspect of it. There are other aspects and other facets of poor receiver sensitivity. And you should also note that those are also important parameters.

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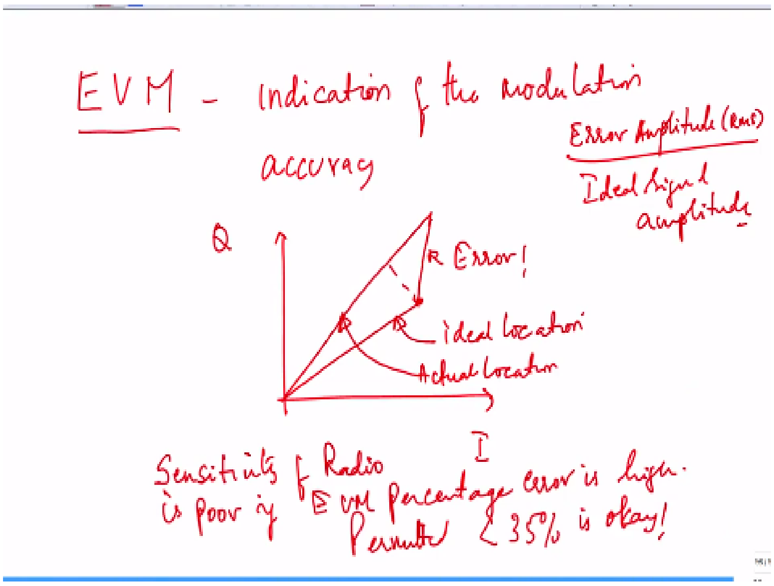

For example, there is something called error vector magnitude, okay. It is called EVM, okay. So the EVM indeed is a very important indication. It is a very important indication. What is it indication of, the modulation accuracy, okay. So essentially if you take the I component and the Q component, fine. It should go like this. Ideally it should go here.

But what would happen is it would have shifted here, okay? It would have shifted here. Maybe not so bad, maybe it will go like this. This is ideal and this is the actual. Now this is your vector error, okay. In fact, it can also be like this. This is how it is. Of course, this is the error and this is an indication of your modulation accuracy. Now if the EVM is destroyed your sensitivity will get poorer and poorer.

Sensitivity of radio is poor if EVM, sometimes EVM is expressed in percentage; EVM percentage error is high. What is permitted is from what we know, less than 35% is okay. Anything greater than that is an issue because receiver sensitivity will come down drastically. So these points also have to be noted, okay.

You basically talk about EVM, which is the error vector magnitude, which is nothing but the ratio of error amplitude in RMS. This is the RMS error amplitude divided by the ideal signal amplitude, fine. This is one issue. The other issue which also can hamper your sensitivity is related to the drift, okay.

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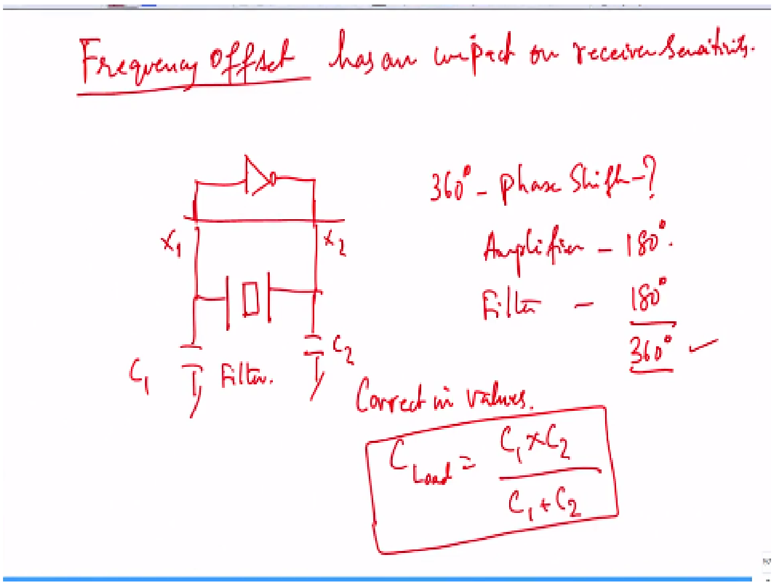

Frequency offset as it is called, not actually drift, it is actually called the frequency offset, okay. This is you can correct it, but then you have to make a note that frequency offset has an impact on receiver sensitivity. And you must ensure that this is under control, and how do you do that? You do that because you essentially use a crystal, right? You use a crystal oscillator.

You apply an external crystal and the crystal will associate itself when you buy a crystal different ppm levels, parts per million level change. If this crystal that you buy is poor and has a large ppm, then you will have a frequency offset. If the frequency offset changes again you will have a change in the receiver sensitivity. And for that there are remedies. Let me show you a picture of how the crystal is coupled.

So you will have a crystal like this, which is interfaced to the electronics, your SOC system here. x 1 and x 2 will be the two pins. That will be given by your SOC. And they will suggest that you should put two capacitances, okay. This will be C 1 and C 2. Essentially this is a filter. Because you need 360 degree rotation, this you may not get a full 360 if you do not put these two filters.

Filter will do actually do a correction, okay. The filter stage will actually provide you, so I will put it this way. Amplifier which essentially works like an inverter here. So I did not put the inverter gate. So let me just show you that. Here to essentially take care of the 360 degree phase shift, I will write it like this. How is this possible? Amplifier okay, the amplifier gives you 180 degree phase shift.

Filter gives you 180 degree phase shift. If this comes, then the total phase shift of the loop will be equal to 360 degree and that is what you need to get to, is it not? Now this is possible only if your filters C 1 and C 2 are correct in values, okay. So the basically you have C load which is nothing but C 1 times C 2, C 1 plus C 2. This is the load capacity.

This is C L is the load capacitances of C 1 and C 2 that you should include in the PCB and ensure that you get exact filter match so that 360 degree filter, the crystal, is working satisfactorily. There are discussions related to the TX carrier offset also by the vendor, okay.

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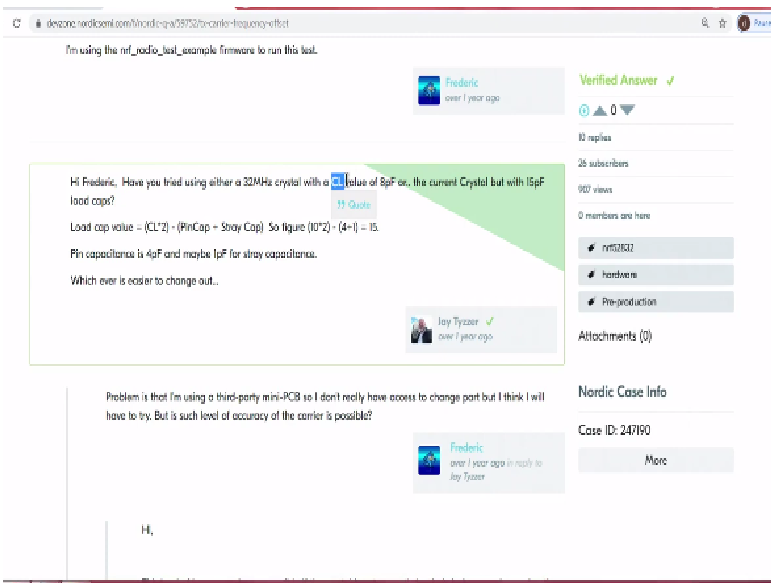

Again I want to point you to TX carrier offset calculations. You can see that there is discussion on, leave the discussion, you can of course see it at any time. The big takeaway is the question here. He says have you tried 32 megahertz crystal with a C L which is the load capacitance of 8 puff or 8pF, okay. For that there is a discussion, okay.

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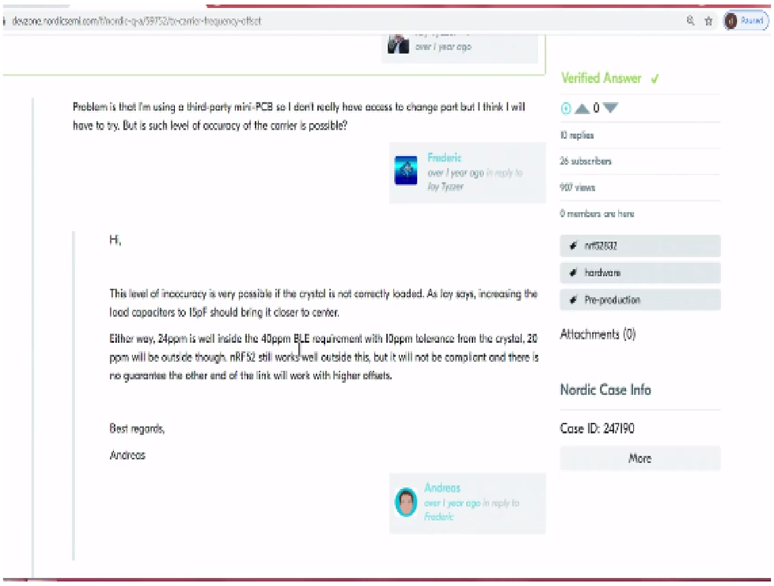

Now the level of inaccuracy is very possible if the crystal is not correctly loaded, okay. And increasing the load capacitance to 15 pF should bring it closer to center. So essentially you do not want the center frequency of a particular channel to move away right and that happens if you have a poor crystal. Therefore, choose a good crystal 24 ppm crystal if you choose is well within the 40 ppm suggested by a technology like BLE.

Okay, so look at the BOM, bill of materials carefully. Look at what is allowed and what is not allowed and choose something which is well within the required levels. For example 40 ppm was proposed for BLE okay, and you have 24 ppm which is well inside that and you have 10 ppm tolerance from the crystal. So if you choose 20 ppm, will be outside though, okay.

If you choose 20 ppm that will be an issue. Either way 24 ppm is well inside the 40 ppm BLE requirement. With 10 ppm tolerance from the crystal 20 ppm will be outside though. So NRF still works well outside this, but it will not be compliant and there is no guarantee the other end of the link will work with higher offsets.

So choice of your crystal oscillator, radio crystal oscillator is also critical because you do not want to see frequency offsets happening to during transmission. And so take care of that point also. Look at the degradation in the receiver sensitivity because of frequency offsets. So folks, this is overview of what I wanted to tell you about receiver sensitivity, the impact of receiver sensitivity on reception of data, its definition.

And so many parameters which are so deeply embedded when you want to make a choice of a radio. Let us now concentrate a little bit on the standards themselves. So this is how you would introduce yourself to the two good standards that we want to cover. One is on ZigBee and the other is related to BLE, okay. And then we will close this section with some interesting insights into low power and energy impact on BLE with some simple calculations. Thank you very much.