Design for Internet of Things
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Lecture - 12
RFID Theory - 03

How do you understand hold thing on RFID in one small five-minute capture that is the real interest? So, let me just focus on five minutes you will get to know everything.

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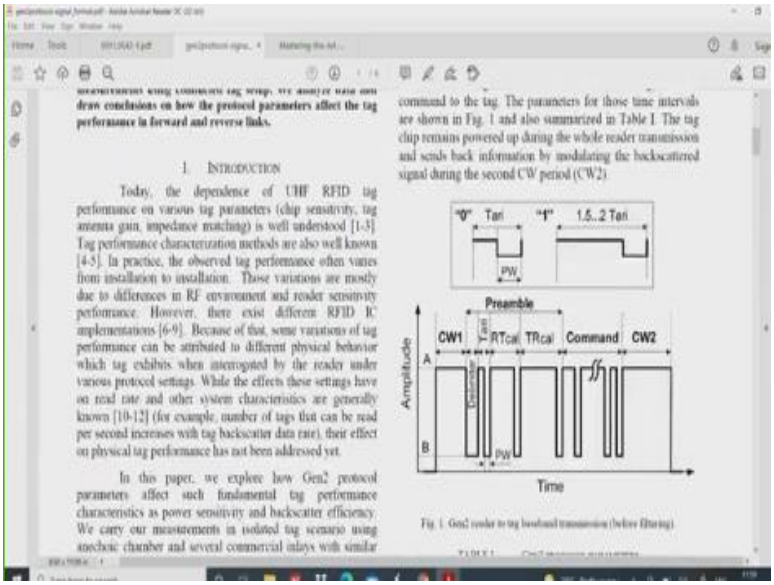

Let me turn your attention to this picture. This picture is very powerful very very big powerful. because if you know this picture you know everything about RFID. In the picture says the following. Look at the top picture, this picture says 0 is transmitted as with a term called Tari. Tari is nothing but some time interval there is some pulse width associated and 0 is nothing but up down and up back again.

This is your 0, bit 0, bit 1 is some thing related to this only. What is that? It can be 1.5 times Tari; it can be 2 times Tari that means it will be twice. So, you can see 0 is basic unit, which is called Tari, one is nothing but something times Tari, 1.5 times or 2 times Tari and so on. This is very very crucial. Now, you are the reader has to tell the tag, which is totally passive that I have powered you, but I have not told you at what data rate I am going to transmit to you.

That means it has to tell the tag what is my Tari 0 and how much is my 1 which is 1.5 times Tari or 2 times Tari and so on and so forth. This much information should be sent out before you do anything that is a starting point. That is soon after you power you should send all this data. You see this down picture is exactly saying the same thing. First is you power tag is up powered waiting for command, but before it can take a command all the parameters have to be pushed, this is the command.

Between the command and the powering of the tag you push all these parameters. What are those parameters? You tell what is a 0? The width of 0 is mentioned. You can see here it is clearly mentioned here. So, you put a continuous wave; differentiate the continuous wave from that of the parameters by putting a delimiter that is your delimiter here. Then this is Tari, once this is Tari that is fixed, it becomes very simple.

Because you're remaining 1 is also quite straightforward. It will tell you how easily you are 1 can be transmitted. Now the further good thing about this picture is it will tell you what is so, where is 1 here? Where is the 1 of which you are supposed to transmit? It is captured in this RT cal. This RTcal already tells you what is your 1, 0 is known and RTcal is known. You do not know 1, but RTcal also has 0 + 1 which is RTcal.

Therefore, it is easy for you to find out what is 1. You see it is indirectly known, 1 is indirectly known. You know RTcal, you know what is Tari therefore, you know what is 1 which is hidden here already there. That is what it is trying to say here. Similarly, if you know RTcal, you will also note TRcal because RTcal and TRcal are connected. How are they connected? What is this connection you are to know? So, you go down this paper, you will see all the connections.

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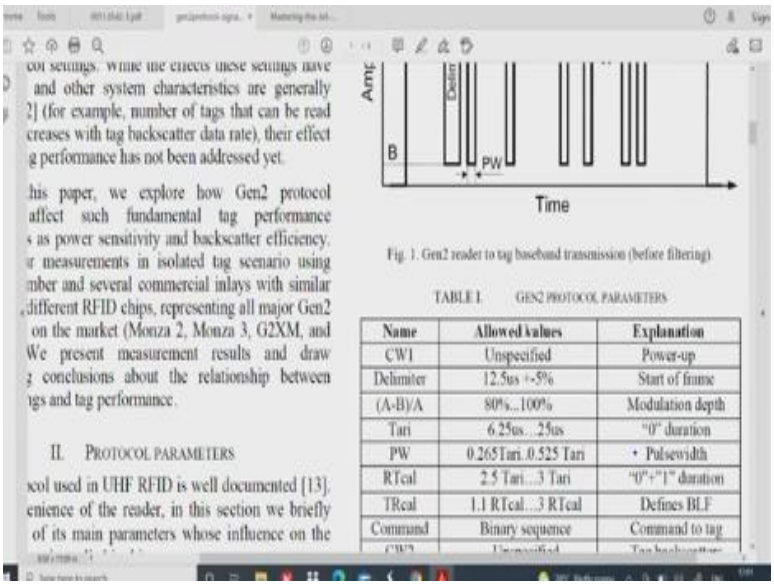

and other system characteristics are generally
2] (for example, number of tags that can be read
creases with tag backscatter data rate), their effect
g performance has not been addressed yet.

his paper, we explore how Gen2 protocol
affect such fundamental tag performance
s as power sensitivity and backscatter efficiency.
r measurements in isolated tag scenario using
mber and several commercial inlays with similar
different RFID chips, representing all major Gen2
on the market (Monza 2, Monza 3, G2XM, and
We present measurement results and draw
conclusions about the relationship between
gs and tag performance.

II. PROTOCOL PARAMETERS

col used in UHF RFID is well documented [13].
enience of the reader, in this section we briefly
of its main parameters whose influence on the

Amp
Delim
B
PW
Time

Fig. 1. Gen2 reader to tag baseband transmission (before filtering)

TABLE I. GEN2 PROTOCOL PARAMETERS

Name	Allowed values	Explanation
CW1	Unspecified	Power-up
Delimiter	12.5us +-5%	Start of frame
(A-B)/A	80%...100%	Modulation depth
Tari	6.25us...25us	"0" duration
PW	0.265Tari..0.525 Tari	= Pulsewidth
RTcal	2.5 Tari...3 Tari	"0"+"1" duration
TRcal	1.1 RTcal...3 RTcal	Defines BLF
Command	Binary sequence	Command to tag

Look here, you this table is crucial again. Tari, I can start with 6.25 I can go up to 25 microseconds. That means I know what is my bit 0 width, the bit 0 width the highest is 6.25 lowest is 25 microseconds, number is high but data rate will be low. If you are a bit width is high the data rate will be low. So that is you have to interpret so highest data rate you will get if it is at 6.25, lowest data rate you will get if you are a bit is at 25 microseconds because the duration of 0 is known now.

Then pulse width is also mentioned here it is 0.265 Tari 0.525 Tari and so on. From here you know RTcal, is you can see it is nothing but units of TRcal, Tari itself not TRcal. It is nothing but units of Tari itself, 2.5 times Tari, minimum up to a maximum of three times Tari that is also mentioned here. So, your 0 and 1 duration is mentioned here. You can see he is not even telling you about 0 and 1 he is telling you about RTcal directly.

Why is the question? Because TRcal is units off RTcal; because you know RTcal you can easily specify TRcal. What is RTcal? Reader to transponder calibration parameters. What is TRcal? Tag to reader calibration parameters. You can also say transponder to interrogator that is the right word. So, these things actually this table with this picture is the most powerful thing. Then you send out the command and then you wait for the reply from the response from the tag by putting out a unmodulated continuous way.

Now, if you know this much, you want to do a simple calculation. Let me point you to this simple calculation here. Look at this thing that I right here on this tablet.

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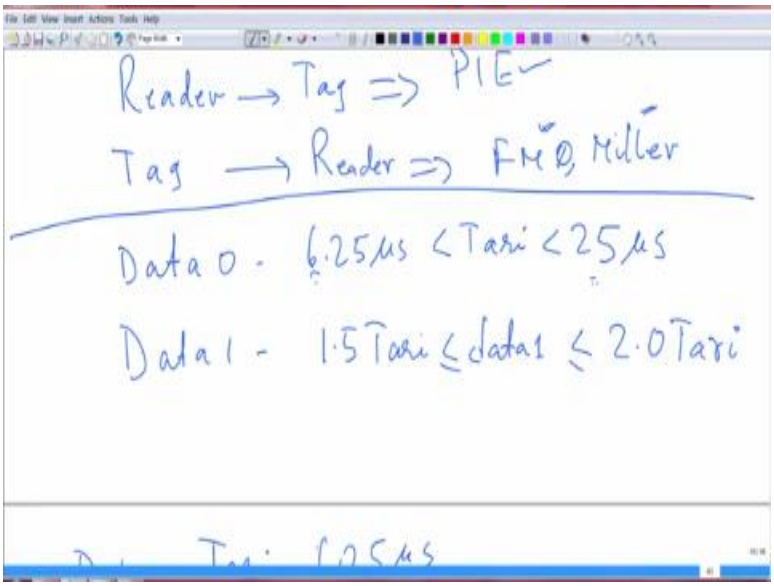

Reader to tag is PIE encoded, pulse interval encoding scheme that is called PIE encoding. Tag to reader uses another encoding scheme which is FM-0 or Miller. We discussed the merits of Miller and FM-0 in the class. So, I will not go into that detail of that. Just to give you some background on the encoding schemes. Now, let us say data 0 is mentioned as between 6.25 and 25 microseconds. Data one is 1.5 times Tari to 2 times Tari, easily you can see that. Now, let us put down some parameters.

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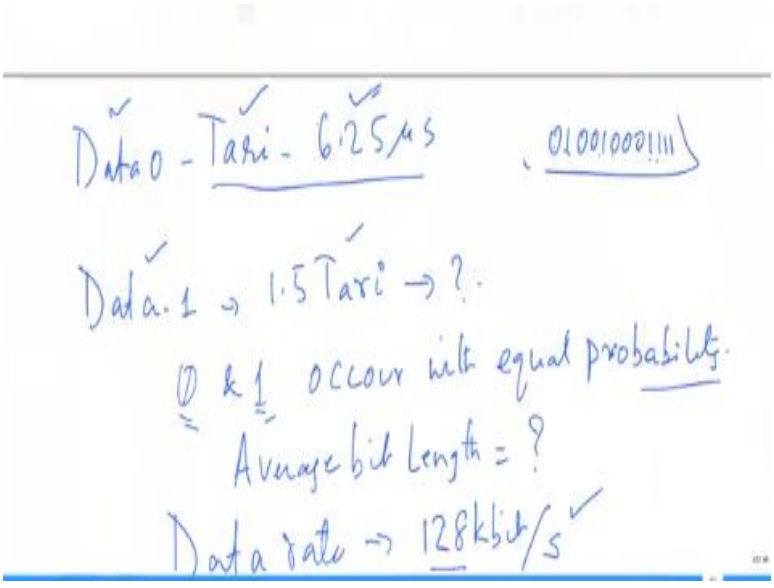

I will go down a little bit and I will show you what I have in mind. Put this here, I have not answered many questions, because I want you to answer them. Here is the problem. I give you Tari, if I have given you Tari, I have given you what is data 0. I have told you what the value of Tari is also, it is a minimum 6.25 microseconds. I have also told you what is data one it is 1.5 times Tari. Can you not multiply 6.25 into 1.5?

You can show, you remove this by multiplying these two and putting it here. Then you know what is data once duration then you have a bit string which is 01001000111. So, let us count 1, 2, 3, 4, 5, 6, 6 zeros are there 1, 2, 3, 4, 5, 1 more input, just as an example. Now, let me count. How many zeros are there? 1, 2, 3, 4, 5, 6, 6 zeros, how many ones are there? 1, 2, 3, 4, 5, 6 so, six zeros.

This is in a probabilistic sense, you may have a bit string which is a little different, but in a probabilistic sense both are equal. So, I said 0 and one occur with equal probability. So, now you know what overall duration of 0, you know the overall duration of 1's you add both, you divide by two then you calculate the data rate. I am giving you the final answer, which is 128 kilobits per second.

Now you change Tari, make it now go put to the other side maximum, which is 25 microseconds, do the same calculation then you will realize that it will give you a different data rate. Will it be greater than this? I do not think so because if you increase the duration of Tari, your data rate will fall. Do that calculation yourself. You will understand how to use these parameters which are there in the standard document EPC Gen to standard document which I showed you.

You can easily download connected to these bullets. So, that is the one big takeaway and a little bit tough exercise, but I almost told you what to do. Next is coming to, how to use RTcal and TRcal that is the next part of the calculation.

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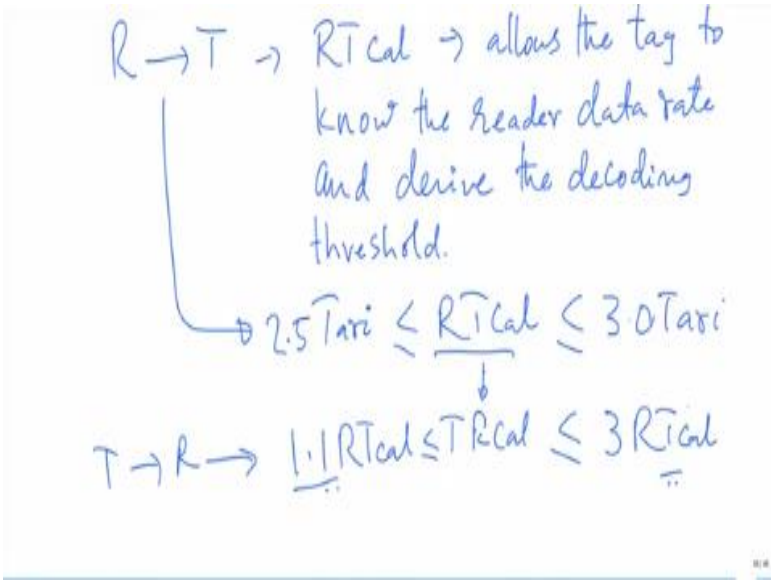

This calculation is just to tell you RT is allows what is it a reader to allows the tag to know the reader data rate and derive the decoding threshold which is called pivot and all that, do not worry about it. Here you are RTcal can lie between 2.5 times Tari including 2.5 times, because it is less than or equal to, it is including them. And 3.0 Tari including 3.0, this is a clear indicator there. Now what about TRcal? TRcal can be specified in terms of RTcal only. So, you see now.

TRcal is lying between RTcal and RTcal, 1.1 times RTcal and 3 times RT cal. With these two in the picture, you can easily calculate the backscatter link frequency BLF, you can easily calculate the backscatter link frequency which is called the divide ratio by TRcal.

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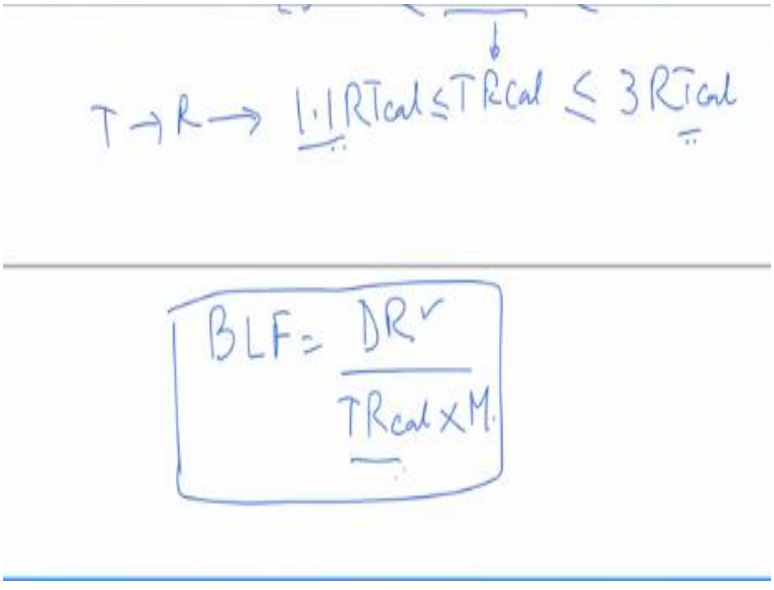

See it has an M, M is the Miller encoding term. If you are not using Miller encoding this will not this term will not be there, but M is therefore Miller encoding. It will be 248 or one of them, you read the standard you will know about this M. Please read the standard otherwise you cannot find out how to substitute these things. Alright, so now BLF backscatter link frequency is divide ratio divided by TR into M.

So, the big takeaway from this expression is you will know the data rate from the tag to the reader through this expression. You will know the reader to the tag by the previous calculation I showed you. Therefore, you know the data rates for the up and the downside. Use these expressions which you have seen in great detail. Look at the standard you do not need any further papers to read; easily you can calculate the data rates.

This is the important takeaway I wanted to tell you. After this calculation part is done, you may want to know how to use readers. What are those practical scenarios under which readers can be applied? Remember, I mentioned to you about RFID sessions, session 0, session 1, session 2, session 3 and so on. How to use these sessions in an interesting way? So, that it can answer several practical scenarios.

For that, I thought it is best to show you a document which I downloaded. And you can also download that and read that a little more carefully to see how to connect the missing dots.
(Video Starts: 13:34)

I direct you to this document which says mastering the art of inventory control with rain RFID sessions, this is from NXP. But what is important is I read this myself to give you some idea. Rain is a name of some type of readers that is not important for you. But the document itself is very valuable. Tags are inexpensive they are produced in large batches up to 1000 tags per second.

You can read them, and it gives you a fantastic performance way beyond what one can expect in terms of technology intervention for retail outlet, monitoring medications in healthcare facility, keeping track of tools on the factory floor or receiving goods at a warehouse. All these things are

out there. Now we should sort of focus on the most important things that I thought were important for you.

So, I will direct you right there. This first paragraph is actually telling you that not all is hunky dory. It says orientation of the tag to the reader's antenna and or the material next to the surrounding can be a big problem. Operating environment has an issue with respect to reading of the tags. Thick stacks of folded denim are piles of heavy tires. In general, the denser the material the more signal from the RFID reader changes as it passes through and harder it is for a given tag to harvest the power, it needs to be read.

So, if you have very thick material it has to penetrate, RF signal has to penetrate, power the tag and take the commands, get hold of the preamble first. Because it has to know all the parameters of interest, then it has to get the query command and then it has to inventory, it has respond back to the reader is going to be a hard problem. So, think about this paragraph as how hard that problem can be.

And then it goes on to talk about I expect you to read folks. So, I am just giving you an overview, it goes back to explaining a few things about sessions to control crowds, he says. This section is called sessions to control crowds. So, he talks about using sessions to trigger a short period of dormancy after the EPC number has been read, use weaker less sensitive tags, a chance to speak are heard.

Once a tag is read, you should not let the tag be read again and again and again folks. You are not giving a chance for other tags to be read. In an inventory system where there are 1000s of tags, if one tag always hogs the bandwidth, it is not going to work, you are not completely inventorying. So, you must use sessions as effectively as possible. You must use the states also that is mentioned here.

You have session 0, you have state A and state B, you have reading of tags can happen in single target or in dual target and so on. So, this picture is again telling you that. Now he tells you in pictorial form, what is single target and what is dual target? This picture is actually speaking

quite some has quite some information about single target and dual target. Look at this picture what a beautiful sketch of the picture that he has shown here which will chart of capture the imagination of the reader. Now he also makes one nice comment here you should read this.

When should you use single target? When should you use dual target? He says in dual target mode, you do all this, and this is useful when static configurations, when it is important to know if a tag is no longer present. If you are interested, your main target of application is to know when a tag, when an item has been removed, do dual target mode on a busy shelf where you have go to a departmental store and the shopkeeper or the store keeper is interested in knowing if an item has been removed.

And customer asked him is this item available or not? He said inventory says it is available. But on the shelf, it is not that, he wants to know whether it is there on the shelf or not. So, the storekeeper goes with a handheld reader and then uses dual target mode because you are interested in knowing if a target tag has been removed from them. So that is essentially what he talks about.

Reading using in dual target mode very rarely it is used. But it is a very useful thing in a departmental store. Now, we will talk about single target mode tags in when they are in only their read in when they are in state A and read once then move on. That is you read it once, you go to the next tag and the next tag and next tag. Because when it goes to state B, you are the tag remains dormant and sets that flag there. So, that is what he tells here.

Then this document goes on to say about the four session types. I will not go into the detail, but I will tell you how this document can be used. So, to that I will go and show you the final answer. This you read this document, this sentence I found to be useful. What does it say? Let us read it together. He says you use session 0 is a good choice for smaller populations where the tags need to be identified multiple times.

This can however lead to large volumes of data and can reduce the number of unique tags recorded. That is the compromise. It becomes a compromise if you have very large populations

If it is a smaller population session 0 is good enough. That is his conclusion. Similarly, he concludes about session one also in a way. It is just a high-level view of his conclusion. Session 1 is well suited for use with larger population, tag populations where the tag needs to be read repeatedly, but with that delay between reads.

This makes it a good choice for smart cabinets and potentially retail stock inventory. Now you see continuous slow reading session one and single target search mode. Just look at this picture, it will read volumes of information about the way by which you can configure readers. Similarly, session 2 and session 3 support read once functionality which is great for large populations where the tags do not need to be read again immediately after leaving the antenna energy.

So, this is also very important. You may want to use this in scenarios where there are two requirements to be have a tag being read twice by two different readers. Remember, a tag can be read only once by one reader, the second reader has to be read time interleaved. So, he will give you options in session two and three for you to configure it. So, you are deeper understanding of RFID actually depends on how well you have understood session 0, session 1, session 2 and session 3.

So, put maximum energy in trying to understand these four sessions. So, now session 2 have an extended persistence period and remain asleep. The next time they need to be read the inventory count will be missing some items. Anyway, so if you read it, you will very quickly realize those issues as well. Then how to combine everything into one is the question. He takes fantastic four example, two or three good, very good examples.

One example he is talking about is retail outlet. And he will tell you the nice things about this application. Session 2, for example, might be used for handheld terminals and session 3 for gate readers. So, you see already is talking about a scenario where two readers are there, you have handheld terminal by a human and session 3 you can put for the gate readers. Sessions 2 and 3 are good options in these cases, because they let multiple devices, read the same tags at roughly the same time, to generate independent inventories.

So, he gives you an example. He will go on with this and tell you that you have to be a little more, clever enough to manage this session 2 and session 3. So, please I would strongly suggest that you read this article. Then he talks about another application, which is the smart supply cabinet. And there he talks about the paper goes on to document talks about when tools are in their designated positions, the cabinets onboard reader will identify the tool as present.

In this case continuous reading in session 0, or session 1 is called for. That means you put the tools into put this for this application; put it to session 0 or session 1. So, the point really is that this document and few more, which I pointed during the class might help you to understand the way by which sessions can be exploited for multiple applications. And this document I pointed you is extremely useful. Thank you very much folks.

(Video Ends: 23:42)