Transducers For Instrumentation

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Lecture - 35

Smart Sensors: RF Sensing: Basics of EM Fields, Antennas and RFID Tags

Hello, welcome to the course Transducers for Instrumentation. Today we will discuss about the RF sensors or the RF sensing. These types of sensors are very much different than other conventional type of sensors because in these type of sensors we use RF waves or the radio frequency waves for the detection and the properties of RF waves are very much different than what we have seen in the entire course about thermal sensors or optical sensors. So now we use radio frequency waves for the detection and these type of sensors for example RF sensors or in particular RFID tags, the radio frequency identification tags. These are very much used to identify the objects or the people or any other object. These are used to identify, or we can track even the movement of the object using these RFID tags.

So, in, when we say we are discussing RF sensors we are particularly interested in RFID tags how they work and what is the principle behind those type of sensors. So today we are going to discuss RFID tags or RF sensors. So, RF sensing, here we are discussing mainly RFID tags. Which are used for identification.

So, RFID tag or nothing but the radio frequency identification tag. This describes the RFID tags. These are RFID tags or RFID tags. To automatically identify people or objects. So, these RFID tags are nothing but the technologies that use radio waves to automatically detect people or object.

Here the word automatically is a keyword here. These RFID tags we can use for detection automatically. However, there is another type of technology which is for example barcode kind of tags where we see a barcode on multiple products and those barcodes can also be used for identification but the problem with barcode is that process is slow and that is line of sight only. So, we have a receiver, we have to align with the barcode then only that barcode data will be read by the reader. However in RFID case the receiver can be a little bit non-aligned because this is not line of sight.

So anywhere RFID tag is in proximity of the receiver the data can be read by the receiver. So that is the main difference between RFID based tags or the barcode based tags where RFID tags use RF waves for data transfer or data reading by the receiver. This RFID system primarily has mainly three parts. The first one is the RFID tag where the data is stored the identification key is stored that RFID tag is one part then we have some sort of

antenna in this RFID tag as well as in the receiver. These antennas use RF waves for communication.

So, whatever is the data stored in the RFID tag that is transmitted using these antenna so that is the second part and the third part is a transceiver unit which actually read this data and connect to a central server or some data storage unit where all the identification keys are stored along with the object identification or the information. So, these are primarily three modules in a RFID system. So, we have three parts to a RFID system. The first one is the RFID tag which is actually programmed with the information. The second part is the transceiver unit.

This has a decoder to interpret the data. Then the third one is the antenna which is equally important for the system to work. So this antenna provides a mean of communication and energy to communicate RFID tags. The third part is the field of the antenna and detects the activation signal from the antenna causing the RFID tag to transmit the information. The third part is the transceiver unit.

So, here we have three parts in RFID system. The first one is the RFID tag which is the tag or the card which we carry or the object or the people carry with them. So, this RFID tags contains a certain information about that card maybe a unique number and all the different cards are given different numbers. So this is the information which is stored in the RFID tag. This particular number or we can say the information the specific object information this is buried in this RFID tag.

Then the second part is the transceiver. Transceiver is the base unit which reads this data. So, whenever this tag comes in the close proximity of the receiver then receiver is the unit or the transceiver is the unit which read this particular key which is stored in RFID tag and detects it communicates with a computer where this computer contains all the data of all these keys along with the information of the object. For example, this particular key belongs to this person. So, this data is stored in a particular computer and transceiver communicate with the computer and find out who is the object or which who is the person who is carrying this RFID tag.

So, this is second module. The third module which is very important is the antenna. So, antenna is the unit which transmits the energy in terms of RF waves. So, when there is a communication we use RF waves or the radio frequency waves for this communication and this antenna is a mean of communication and energy to communicate with RFID tag. So, this RFID tags there are two types of RFID tags we will discuss that.

These RFID tags may or may not contain a power source inside. So, this RFID tags to submit to transfer the data to receiver it needs certain energy. So, this antenna used for a communication as well as transfer of energy from the receiver to RFID tag and RFID tag will use this energy to transmit the data back to the receiver. So, this antenna is used for

communication as well as it provides energy to communicate with the RFID tags. So this is one function of antenna.

The second is when this RFID tag when they passes through the close proximity of an antenna, antenna has a certain area where it can radiate the energy. So as soon as the RFID tag passes through that area the energy will be given to RFID tags and RFID tag detects this energy using a inbuilt antenna which may be a smaller antenna and this energy is now used to communicate this information stored in the RFID tag to the receiver. So, this energy is sent back to receiver with a particular information which is stored in the RFID tag. So, this is how the receiver detects whether which kind of particular RFID tag is moving around in that radiation zone or close proximity to the antenna. So, these are the three main systems of RFID, main modules of RFID system.

Let's discuss antenna in a little bit detail which is the key part of these RFID tags. So let's see how an antenna works. So for example we have a electrical system which is giving electrical signal which is time varying. So this is let's say transmitter. This system sends out electrical signal on a piece of metal which is our antenna.

So now this is our antenna and the signal comes like this. So let's say blue is the electrical signal and when this electrical signal comes to this piece of metal which is antenna this start radiating and let's say this radiation is shown by this red graph. So, these are the RF waves which are generated using the electrical signal. So, this is how the electromagnetic field is generated over the RFA. And this part is called the antenna which causes this conversion of electrical signal into RF signal or the electrical energy to an RF energy or astromagnetic energy.

This part is antenna and this is the transmitting antenna. There are certain rules which governs the radiation pattern of an antenna and there are certain rules for the length of the antenna which antenna is more efficient to converge this what kind of energy into a electromagnetic energy. So that is covered in the separate course antennas. So, for time being we just discussed that there is a piece of metal which is used to radiate electrical energy into the electromagnetic wave. On the receiving part so these waves can actually travel in the vacuum and when they reach the other side of the far end so these are the waves which are travelling in vacuum.

And when they come in contact with the receiving antenna these waves again converge back and generate electrical signal which is equivalent to the wave received. So this is the receiving part. These waves when they arrive on the antenna they lead to electrical signal which is shown here in blue and this wave can be detected the external electronic circuit. This is a similar antenna but now this antenna is acting as the receiver. So, this is how these two antennas work transmitting and receiving antenna can be of the same size and

shape because antenna same antenna can be received for the transmission as well as reception.

So in for example in the transmitting antenna we connect the antenna to a transmitter which is electrical transmitter which produces a time varying signal or the sinusoid wave for example. This sinusoidal wave electrical signal when this is applied to this antenna it produces a movement of charge along the length of the antenna for example from the middle to the towards the edge of this antenna. In this process when the charge is moving this produce a electromagnetic field which goes out of the structure in the vacuum and which creates this EM waves. So, this time varying electrical signal produces a time varying electromagnetic field which propagate further towards the right direction and this is how the electromagnetic waves are produced using this antenna. When these waves they travel in the vacuum they can travel in air or vacuum.

So, when they hits the similar kind of antenna it may be the same size as the transmitting antenna. So at the receiving end when these waves hits these receiving antenna they again produce the similar electromagnetic field or the same electrical signal in the antenna what was being used to generate them. This electrical signal is produced at the receiving antenna and now this electrical signal which flows out in terms of a electrical signal for example sinusoid wave. This sinusoid wave can be read by the receiver which may be a simple oscilloscope or may be some other measuring instrument. This signal will be electrical which can now be further processed using external electronic circuit or the computer.

So, this is how the antenna works the both antennas are same but one work as a transmitter and one work as a receiver in this unit. So, this is how an antenna works. Now we have two types of tags what we just discussed. A tag or RFID tag contains certain information within inside it may be a number may be a bar code may be a code or something. This RFID tag is of two types one is the passive tag which does not have a power source inside.

It just has that information buried into a layer and an antenna which is attached to this circuitry. This does not have any battery or the power source to transmit this information outside. This is called passive RFID tags. The other type of RFID tags are active RFID tags where we have a battery placed inside and this battery will provide enough power to the antenna so that this information can be sent outside without getting energy or without a requirement of energy from the outside one. So, these are two types of RFID tags passive and active RFID tags.

So, there are two types of RFID tags. The first one is passive RFID tags. So, these are the tags which does not have any internal power supply. And generally the power is supplied by the reader itself. And there are certain merits and demerits of these passive RFID tags.

The very first one is the cost. This is less expensive. The size is very small. The power is supplied by the reader itself. Distance is almost none. The read distance is typically a few feet.

Personal life typically up to 20 years. And the memory size is around 16 KB or so. So we have passive RFID tags which do not have any internal power supply and the power is supplied by the reader itself. Whoever is the device which is trying to read the RFID tag that has to supply the power to RFID tag. Certain advantage and disadvantage of passive RFID tag is the cost. The cost is of these RFID tag which is passive.

So, the cost is very less. These are very less expensive compared to the active RFID tags because we just need a small antenna which receives the RF waves and send it back. Size is also very small. We do not need any extra circuitry or electronic components and the battery. So, the size of these RFID tags are very small even in a few mm we can make these RFID tags.

The power is supplied by the reader itself. So there is no internal power supply available. Reader has to provide all the power and power is needed because these RFID tags need to send the information back. So, to sending this information this RFID tag needs certain power. So, this power is provided by the reader itself. Maintenance is almost none because there is no component or the circuitry which is decaying or which is degrading with time.

So, there is almost none maintenance of these RFID tags except normal wear and tear. So the read distance is typically a few feet because as we increase the distance the strength of RF signal goes down. So to receive a particular amount of energy for transmission this RFID tag need to be very close to the antenna or the receiver unit. So the read distance is limited to a few feet that is the drawback of passive RFID tags. The life is typically 15 to 20 years though there is no component which degrades with time.

But due to normal wear and tear the life is typically 15 to 20 years. And the memory is around 16 KB or less because we do not have complicated electronic circuitry in within the RFID tags. So the memory is also very limited. We cannot store much of information in the RFID tags. So generally the information which is stored in RFID is typically a number a sequence of numbers that is called key and this key is matched at the receiver side with the complete information of the object.

So, all the information is stored in the receiver unit and the RFID tag just contain a particular key or the sequence of numbers. So the memory of passive RFID tags are limited. This is also a limitation of passive tags. So these are some advantage and disadvantage.

Now let us see how the RFID works. So in RFID tags which is particularly passive type we have a RFID reader. This reader actually produces a electromagnetic field. Let us say these are the electromagnetic field generated by the receiving unit. As the distance goes high the field the strength of the field goes down. So this RFID reader is creating this electromagnetic field.

When we have a RFID tag which is placed close to this field this RFID tag contains a special structure which can pick up this RF energy from the electromagnetic field. In this region magnetic field is affected by the RFID tag data. This RFID tag has a particular digital number stored which can be in form of binary tag. So this tag ID is a unique number given to this RFID tag and when we place this RFID tag in the electromagnetic field this magnetic field is affected by this tag ID or the data stored on this RFID tag. This whole process is called near field sensing for RFID tags and this happens typically less than 100 megahertz frequency.

So, this is how this passive RFID tag works. So, in this system we have a RFID reader. This reader has a antenna or the system which produce this alternating EM field. So this RFID reader has a certain area where the strength of this electromagnetic field is sufficient enough. When we have a RFID tag this RFID tag is stored with a tag ID or the sequence of number which will be in the binary form let us say 011011 something like that. This tag ID is buried in the RFID tag and this RFID tag may contain some sort of spiral structure which can be some sort of a coil.

When we place this coil in a alternating electromagnetic field the flux RF flux will be linked to this coil and this coil will pick up the energy from the electromagnetic field. Now this energy will provide energy to RFID tag to send the data tag ID to the receiver unit or the RFID reader unit. So, this is how the data will be transmitted from RFID tag to the reader. Reader will then connect to the computer and figure out which RFID tag or which tag ID test based on that the identification will be done. This will be called the near field sensing for RFID tags because the distance from the receiver and the RFID tag is not very high it is limited to few feet only.

So, we use for near field sensing and the frequency of operation is typically less than 100 megahertz. We use high very low frequencies here because we need to transmit sufficient amount of energy from the reader to RFID tags and we use less than 100 megahertz or so kind of frequencies to excite the coils so that the energy is coupled efficiently to RFID tags. So, this is how the passive RFID tag works. Let us see the active RFID tags. So these active RFID tags they have their own internal power source.

And this source is typically in the form of a replaceable battery. One can have a replaceable battery and there are certain advantage and disadvantage of these active tags. The very first one is the cost. So, they are more expensive than passive RFID tags.

The size is larger. The power is provided by the battery. So this is battery replacement required. The read distance is up to hundreds of feet. The life is typically few years, one to three years depending upon the battery. And the memory can be high typically 512 kV or more. So, RFID tags are the tags where we have an internal power source right in the tags itself and this power source can be in terms of the replaceable battery with the button cell or the coin cell.

This battery provides the energy required for transmission on receiving of the data. Now the cost of RFID tags are higher because we need extra circuitry as well as the power source on the tag itself. So these are more expensive compared to the passive RFID tags. The size is also larger because these extra circuitry or the hardware need to be placed on the tag itself.

So, because of that the size goes up. The power is now provided by the battery only which is the advantage now in case of active RFID tags because in the passive RFID tags the energy received from electromagnetic field is very small. So this small energy only need to be used to transmit the data. However, in active RFID tag we have a dedicated battery to send the data. So we have a power source available within the tag itself.

So, this is advantage for RFID tags. Maintenance is required here because these batteries they run out of charge every now and then. So whenever the battery is discharged we need to replace the battery or charge the battery. So little maintenance is required in the active RFID tags. The read distance however is increased because we have a power source on the tag itself.

This power can be used to send the data. So the data can be sent over a longer distance. So, we have up to hundreds of feet we can send this data typically. The life of these RFID tags are limited by the battery because they use battery the power source to send the data. If the battery is drained, then these RFID tags will not work. So typically depending upon the life of battery 1 to 3 years we need a replacement battery.

So, the typical life depends on the battery. We can replace the battery every 3 years so they can continue for a longer time. Memory now we can have even larger memories compared to passive RFID tags because we have now power source and we have a dedicated electronics placed on the tag itself. This extra electronics can have certain amount of memory placed inside the tag itself. We can use complex ID types or we can even put certain amount of information also about the particular object in the RFID tag itself. However, in the passive RFID tags we were just allowed to store a sequence of numbers which is a unique number and this unique number was matched at the receiver side to find out the details.

However, in active RFID tags we can put little bit of information in the RFID tag itself and we need not to do the processing at the later stage. So these are some advantages of active RFID tags. Let us see how these active RFID tags works.

So let us see how it works. The active RFID tags. This is also called the far field sensing. Which is typically more than 100 MHz frequency. So in far field sensing or active RFID tags we have again an RFID reader. This reader has a certain antenna attached to it.

This is a simple dipole antenna. This dipole antenna converts the electrical signal into electromagnetic field and this electromagnetic field goes out in terms of RF waves. Now we have a RFID tag which is placed up to few hundreds of feet. Now this RFID tag use internal power to send the information which is stored in this RFID tag for example this information. Now this information will be modulated with high frequencies so that it can be transmitted through this antenna.

This is modulated signal comes out of antenna which can be typically like this. So this RF signal will come out from this transmitting antenna and this signal will be sent towards the reader which will be going to detect this signal. So now we have a RFID reader which is sending and receiving a RF signal through these antennas and the working of antenna we just saw in the few slides back. Then we have a RFID tag which is in proximity of this RFID reader and the proximity we say it is hundreds of feet which is quite a long distance. This RFID tag is using a battery inside along with certain hardware electronics and antenna is attached to it.

So, this RFID tag has certain information this RFID or the key or the tag ID. This information is now mixed with high frequencies so that this frequency can be easily transmitted using this antenna placed on RFID tag. We need to mix it with high frequencies so that the size of antenna comes down because we know that the length of antenna is proportional to the wavelength of the signal. So the longer is the wavelength the longer we need the antenna. So to keep a small size of RFID tag we need to have a very high frequency so that the wavelength of RF signal is smaller. So this RFID key is mixed with high frequencies and applied to the antenna that antenna will transmit this electrical signal in terms of RF wave and this RF wave will reach the reader it can travel a certain distance because it is powerful enough using the internal battery source.

This wave will be received by the RFID reader and will be converted into electrical signal back and goes to the computer and the computer does all the processing. So this is how the active RFID tags works or we call it the far field sensing and the frequency we generally use is typically high frequencies because the size of antenna need to be small enough so that we can efficiently transmit the RF signal without increasing the length of antenna. So typically more than 100 megahertz. This is far field sensing operating at greater than 100 megahertz.

Now let's discuss some of the frequencies what we used with RFID tags. The first one is the low frequency or LF. These are typically 125 kilohertz. These have shorter read length and rate but these are less sensitive to interference.

The next is the high frequency or HF. These are typically 13.5 megahertz. The third is the ultra high frequency or UHF we call it. These are typically 860 to 930 megahertz. They have faster data rate and the fourth is the microwave where we have the frequency range is 2.45 gigahertz.

These have highest data read among these but the range is limited of typically Q feet. So, in these RFID tags we typically use certain frequencies. For example the low frequencies or LF we call it. The frequency used is 125 kilohertz. The benefit of using low frequencies these are very less sensitive to interference if there is a another signal nearby.

These low frequencies are not very much distorted. The problem is the short read length and the rate we cannot read the data very fast using these low frequencies. Then we go to little higher frequency which is called HF or the high frequencies. The frequency is typically 13.5 megahertz. Here we have a higher data rate than the LF the low frequencies. Above this we have UHF or ultra high frequencies where the frequency range is typically 860 to 930 megahertz and we have a faster data rate in UHF and the fastest is the microwave. These are the fastest RFID tags where we use microwave frequencies of 2.45 gigahertz frequency. We have highest data rate in this kind of RFID tags, but the range of these RFID tags are typically limited.

So, up to a few feet only we can detect the RFID tags if we are using the microwave signals. So, these are some of the frequencies we used for RFID tags in the system RFID systems and this is how the RFID tags works for identification. These RFID tags are very much used in industry for example for identification of objects for identification of animals and these are also used in commercial places like malls and shops for identification of a particular object and this RFID tag can be conveniently placed on the object which because these RFID tags are very small in size they can be very comfortably placed on the object and we can track all the objects in the complete warehouse or industry.

So, these are this is the RFID tags and this is all for today.

Thank you.