Design and Analysis of Experiments
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Lecture - 03
Types of Experimental Design

Welcome to the 3rd lecture on Design and Analysis of Experiments. Today we will discuss the Types of Experimental Design.

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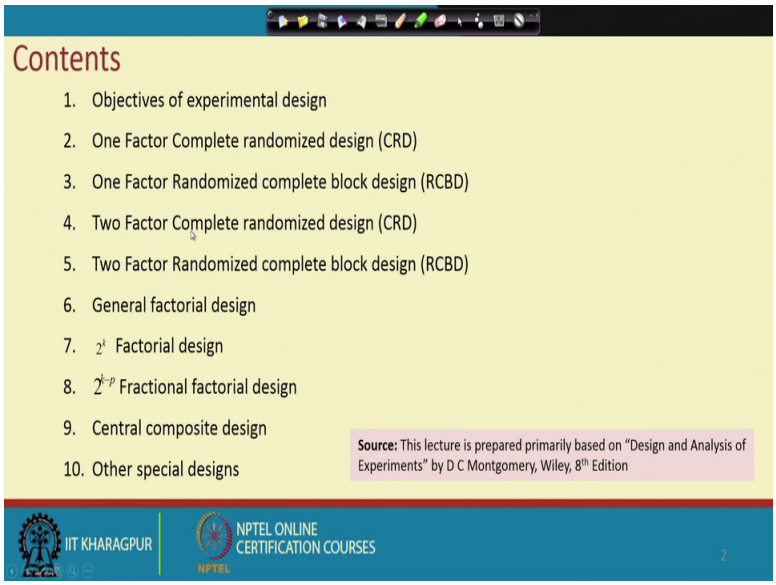

Contents of today's presentation or objective of experimental design, one factor complete randomized design, one factor randomized complete block design, 2 factor complete randomized design, 2 factor randomized complete block design, general factorial design, 2 the power k factorial design, 2 to the power k minus p fractional factorial design, central composite design and other special design.

So, we will discuss very brief what are those different types of designs and we will take around 1 hour into halfs of 30 minutes each to complete this into depth depart on types of designs. In fact, the subsequent lectures we will be detailing all those design and they and their analysis one after another.

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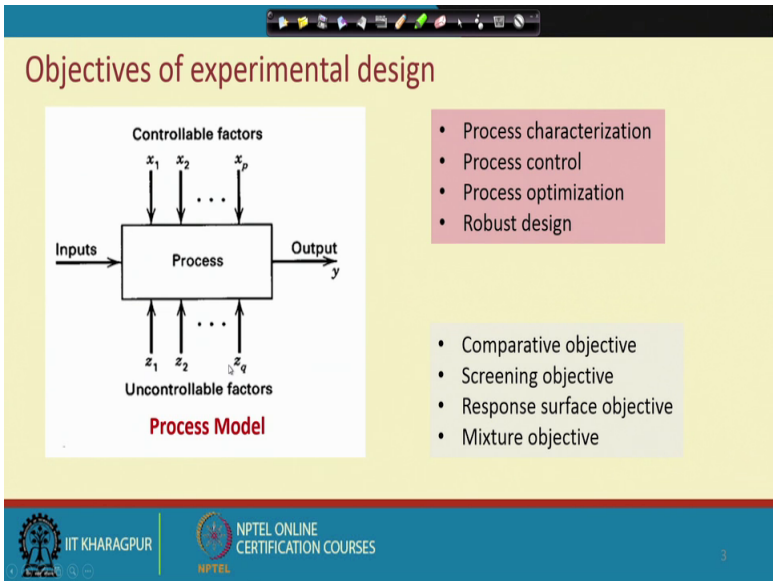

So, objectives of experimental design if you recall my first 2 lecture I explained you the process model this process model it is a very important one.

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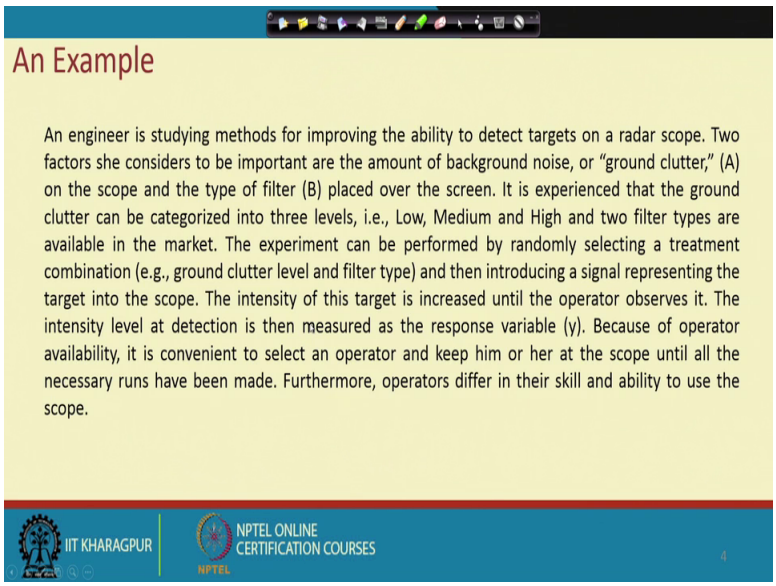

And you please understand that, whenever we talk about experiment we talk about experiment of a process on a process and which is controlled by several controllable factors, which is affected by under control uncontrollable factors and the effects are realized on the output response variable.

From that point in view then we have also discussed that process characterization, then process control, then your process optimization and robust design. These are the objectives what you want to achieve through design of experiments and analysis of experimental data. We can sees the objectives in some other ways like there may be comparative objectives by comparative objective we mean that there are several factors which are governing the output variable. So, which are the factors are having more effect which are having less effect that since you can do some comparison. The screening objectives there may be some factors which ultimately in insignificantly contributing towards the output or the behavior of the response variable, those will be screened out for subsequent analysis and decision making and that is why this is known as screening objective.

Then response surface objective the response surface is pertaining to the output variable or the response variable y. So, what it is objective we want to see the how the that behavior of y, will change when we go from the factor one level factors one level of a factor to another level or when we change several factors at a time from one level to another level. So, this can be seen through response surface which is basically a function of x. Now this response surface case it may we may be interested to know where the optimum optimum response lies at what does it mean it means that what are the settings for the control variables. So, that we can achieve the optimum desirable value of y and then the process operator will set the experiment set the process or tune the parameters of the process during in that range.

So, that why optima optimal optimum y will be achieved, another one is mixture objective in mixture objective what happened that there are certain situation where you require to mixing to mix several materials together in certain proportion and the total will be hundred percent. So, this require a different kind of design and that is known as mixture design and the objective is to find out the perfect blend the or the proportion of different in gradient that will be mixed. So, in order to achieve that the design, design is called mixture design and the objective is to get the perfect mixture. Now consider let us consider the factors. So, as you as you see from this model there can be several factors summer controllable summer uncontrollable and also the controllable factors can be one can be 2 can be many more.

Now, we when we will consider and sport primarily the controllable factors and we will try to find out how the design will experimental design will change if we see take one factor at a time 2 factors at a time and also include some of the uncontrol or noise variables in the experiment how the factor experimental design will change. We will see first one example. So, let me read out the example and engineer is studying methods for improving the ability to detect targets on a radar scope, what is the objective improving the ability to detect targets on a radar scope.

So, there have been this radar scope sub have is product produce certain through certain process and the radar scope will be such that it will be able to detect the operators while using the radar scope will detect the target quite easily. So, there are multiple factors controllable or uncontrollable factors which will govern the production process and as well as it should be considered that when the radar scope will be used what are the factors that will govern? Now the engineer finds that 2 important factors while designing the product that is the radar scope is amount of background noise which is known as ground clutter and second one is the type of filter placed over the screen so these 2 important factors.

There controllable factors because it assume that the ground clerk clutter can be controlled as well as type of field you have the opportunity to chose different kinds of filters so the dis controllable. So, it is experience that the ground clutter can be characterized into 3 levels like low clutter medium clutter and high clutter situation and 2 filter types are available in the market, the experiment can be performed by randomly selecting a treatment combination that many ground clutter level and filter time filter type and then introducing a signal representing the target into the scope, the intensity of this target is increased until the operator observes it, the intensity level at detection is then measured as the response variable y. So, the ability to detect targets this is measured through intensity level what is the intensity at which the operators is able to see the target.

So, this intensity level can be measured and which is the response variable, because the operator because of operators availability it is convenient to select and operator and keep him or her at the scope until all the necessary runs have been made, further mores operators differ in their skill and ability to use the scope. So, you can convert this into the factorial representation like in the process model, but many a times what happened we

will be having the analogy with the product design sometimes it is not possible because when we may be interested to link with some kind of service some kind of other kind of observation also, but the process middle in general can be fitted to any example and with this example also. So, how your fitting this process model here, we are saying that what are the controllable factors controllable factors are ground clutter and type of filter ground clutter we are denoting by factor a types of level by factor b and there is another factor which is operator.

Now, depending on the situation operator can be a controllable factors or can be a noise also, but most of the time it will be uncontrollable one because the process the plant or the process where the operations will be taken place. The operators will come from that locality unless it is a very very specialized process. So, under the situation you have to rely on the local available people. So, it will be a uncontrollable one. So, another important one is the process output which is response variable in this case the intensity level at which the detection is possible so giving this information.

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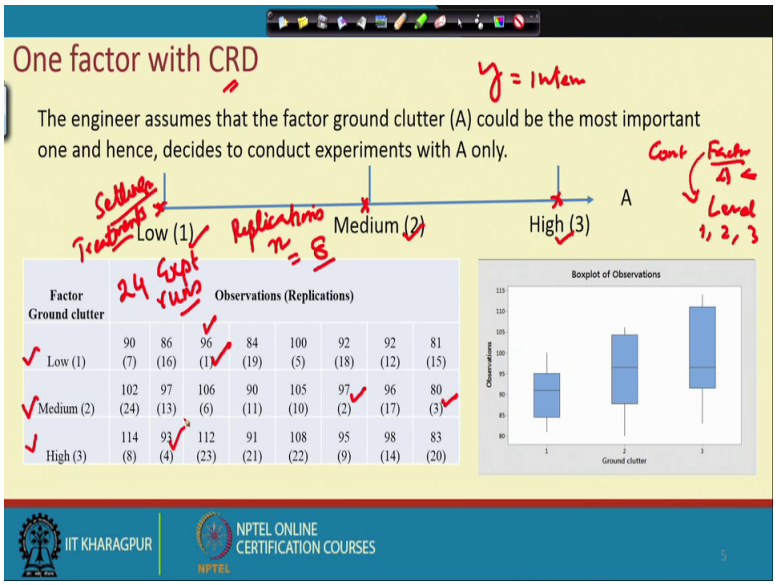

Let us see some of the designs first thing for one factor complete randomized design, here the engineer assume that the factor ground clutter could be the most important one and hence decides to conduct experiments with a only.

Please remember this is not the correct one, because first of all only 2 factors was we are consider and. Secondly, only one noise or uncontrol factor operators will also consider

and we have simplified this here further with one factor only it is just it is to show that it is to let you learn that, if you consider one factor when how you will do one factor complete randomized design. So, it may be a situation that one factor is important and you want to do one factor experiment.

So, in this factor case import another important consideration is the level here we are saying level, low level, medium level, high level, please keep in mind few things in the process model controllable factors. So, factor is very important in this case we are considering factor a. Second is it is not that all the values of the factors you will consider and accordingly you will do experiment it is it is not possible many a times factor can be categorical in nature, but even if continuous factor case you cannot consider all the all the values for a in this case ground clutter given 3 level. So, another important when you say factor another important 1 is level here we have 3 level 1 2 3. So, 1 is low 2 is medium 3 is high.

Then what you what doing here you want to you want to see that whether the y y is basically the intensity level at detection, what is y intensity level at detection? So, whether this y value changes if you if you do an experiment keeping ground clutter at low, keeping ground clutter at medium keeping clutter at high level or other way I can say factor with level 1, level 2, and level 3. So, then you have to conduct and experiment, there are 3 settings please keep in mind low, medium, and high. So, this 3 levels one factors. So, 3 independent or distinct experimental settings low, medium and high.

Suppose you thought that you will conduct experiment keeping at low a at medium and a at high and the number of experiment in each of the settings, these are experimental settings, which is also known as treatments. The process is treated at this level at this level or at this level. So, these are all treatments. So, factorial a when it is low this is one kind of treatment to the process when factor A is at medium level another kind of treatment at high level another kind of treatment. So, I can say that that that experimental setting or experimental treatments the material which is going through the process being treated all those different levels. So, maybe at is settings or treatment.

Suppose you want to do the experiment several times if in a certain or treatment level if you repeat the experiment several times, basically you are interested to know more number of get more number of observations and which is known as replications. So, in

this case in general replication can be end. So, in this case suppose 8 number of experimental run in each application. So, what is happening here you have 8 into 3 total 24 experimental runs? So, it is complete because you have considered all the levels and what is randomization here. So, you required 24 experiments to be conducted keeping or at settings at low medium and high foreground clutter or at the treatment low medium and high and 8 on each of the treatment levels.

Now, what you required to do you cannot do the experiment supposed low keeping a factor at low and do 5 experiments get the data, then medium repeat then high repeat this is not randomization what you require has 24 experimental runs are required what you do you randomly choose the order of experimentation. So, using rand function income excel you can do this kind of randomization for example, using rand function you found that the first experiment is this one. So, the second experiment will be second experiment will be here. So, what does it mean first experimental run you are you are conducting first experimental run keeping ground clutter at low level and observing the response y which is 96 intensity levels, second experiment will be done at media medium level only and this is the case.

Third one third one where third one may be here fourth one fourth one here. So, like this this order of experimentation is random and using random number what happened you generate a different this things here actually that 24 observe observations what way we have we have done this this one we have we have thought that there will be 24 experiments and we give this 1 2 3 4 like this first and then using the n function we found out the which one will be, which still there are 24 still there are 20 of these data we put as for the there are 24 cells, this cells first this cell second this cell third this cell 4 like this so you to do randomization. So, once you do randomization and you take all the at the fact all factors all level then this is complete and we assume that this kind of data we will get.

Now, once you get this kind of data then what happened, what is your m here objective here you want to know that if you keep ground clutter at low level, medium level, high level well the weather there is change in change in mean value of the response y, A boxplot is one of the important boxplot is one of the important plot, which gives you some fair idea that whether there is difference in mean values of the responses or not. If you see there were somewhere mean value will be will be here somewhere mean value

will be here somewhere mean value will be there. So, there is a increasing trend. So, we and the difference may be significant. So, at first and we understand that yes if you change the factor from low to medium to high there is a possible change in response variable whether that change is significant or not that will be understood through analysis only.

So, now what is happening?

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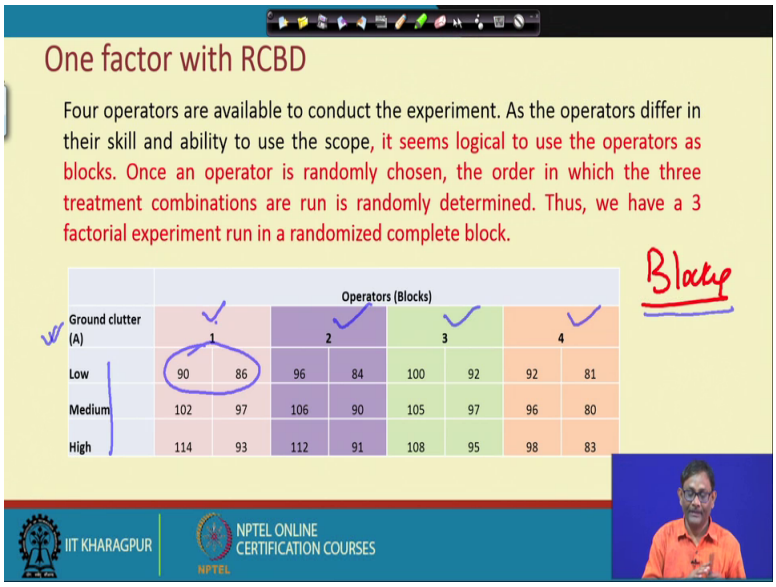

Now, we will discuss about one factor with random complete block design we are bringing one concept called block, if you have seen in first lecture I think in the second lecture that blocking is an important concept blocking. So, I said blocking is an important concept blocky. So, in this example so about there are 4 operators and as the operators differ in their skill and ability to use the scope it is logical to use the operators as blocks, because if I choose operator one operator 2 operator 3 and operator 4 and they vary in their expertise their knowledge their educational background that vary.

Then what will happen when operator one will see the SCO radar scope and the intensity level required to see the target it there maybe variability there will be variability induced in this process. So, in that case operators are contributing or contributing in the results. So, you can block these visions. So, if you do these this is known as blocking. So, in order to blocking what you required to do at least that all the levels for the factors this level all the level this will must be experiment must be conducted by each of the blocks.

So, cooperator one definitely will conduct experiment for all the 3 levels operator 2 also operator 3 also operator 4 also. So, that mean you have sufficient material or the time and other things available. So, that all the all the blocks here in this case operators can be effectively used.

Fortunately enough what happened we have for at each level against each against each operator 2 level of x 2 2 2 type 2 times experiments that is the sample size here for each combination is 2 show that mean we are doing replication also now this is known as complete random compliment complete block design RCBD. So, the experiment will be conducted based on that random certain random order any random sequence, it is that randomization using the random number table or using some program and that mean here again that 24-24 sales are there you required to do 24 experiment you randomize it. So, your randomization should not be in any sequence like these the order of experiment should not be like this that in first do low then medium level, that high level, here maybe you take first operator one then operator 2 operator 3 that should not be it should be completely randomized.

So, if you maintain this randomization and in a position to block the operator in this case the operators or the nation factors now you can add these nation factors into the design and then this design will be known as randomized block design. And again it is complete because all the settings that low medium high and also all the operators together we have done it, then I will go where is this one factor CBD then we will see that 2 factors.

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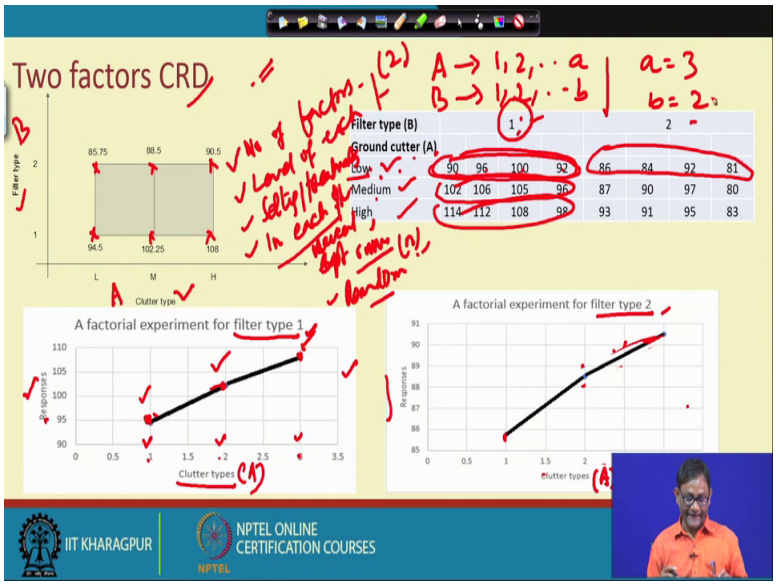

So, first I have so what I have explained I explained one factor complete randomized design then I have explained one factor with blocking now you are saying that another design 2 factors complete randomized design.

So, you have seen in this example that ground clutter and type of filter to controllable factor. So, if you consider clutter type and filter type that is the factor A and this is factor B, then as clutter type has C 3 levels and filter has 2 level. So, how many treatments combination you are getting 6 here 1 2 3 4 5 6, you see you are getting low medium high 1 2 3 into 2 to the 6 and how many observation under this case 1 2 3 4 you just see that low and type filter one in. So, replication 4 here also 4 so like this 4 replication 6 different treatment combinations or 6 different trainee settings and these settings with random with when this basis of complete randomization you have done it.

So, first one is one factor complete randomize design, second one is one factor randomization with blocking, third one is 2 factor complete randomized design we are not considering blocking here. Now if you see their response versus clutter types that is factor A and response versus that is filter type that is filter type then this is B. So, you see that clutter level 1 to level 2 to level 3. So, there is there is increase in response and similarly filter type also if you go from 1.

So, filter type this this is this is a wrong plot. So, filter type 1 to 2 this portion is not require this much. So, again it is increasing, but any how what do we required to do

because then you may be interested to know what is this value then what is this value because there are several values several observations are there.

So, what we are saying that when your filter clutter type level low then we found out the average of the all the Y responses I am sorry it is correct. I have just miss this one what we are doing here at this is clutter type a say it is A this is A. So, filter type 1, filter type 2. So, if I if you keep filter type 1 I mean this one and you change your clutter type from 1, level 1 to level 2 to level 3, how the changes in responses are taking place it is given here. So, filter type 1 low level what is the average value this, then second average value this third average value this. So, the average response average response for low medium high of factor A when factor B is at 1 that is type filter type 1, then this is the behaviour and same for filter type 2. So, this is known as 2 factor complete randomized design.

So, now let me repeat again you must first know number of factors, second you must know level of each factors, then you will know the settings or the treatments, then in each treatment or setting or treatment he will conduct several experiment several experimental runs this is known as replication and; obviously, your experiment will not be in a particular order it should be random order.

So, randomization with respect to that the order of that the factors that low medium y the combinations and also known also with it is not that if your replication you want to replicate 4 times. So, you choose randomly a particular setting or treatment and then experiment 4 times there in sequence that is also not permitted that also be random. So that means, you will choose one cell at a time and that selection will come through the randomization.

So, in the in 2 factor case your number of factor 2 here levels 3 and 2 levels well in general factor A level can be a levels, factor B level can be b levels in this particular example a equal to 3 and b equal to 2.

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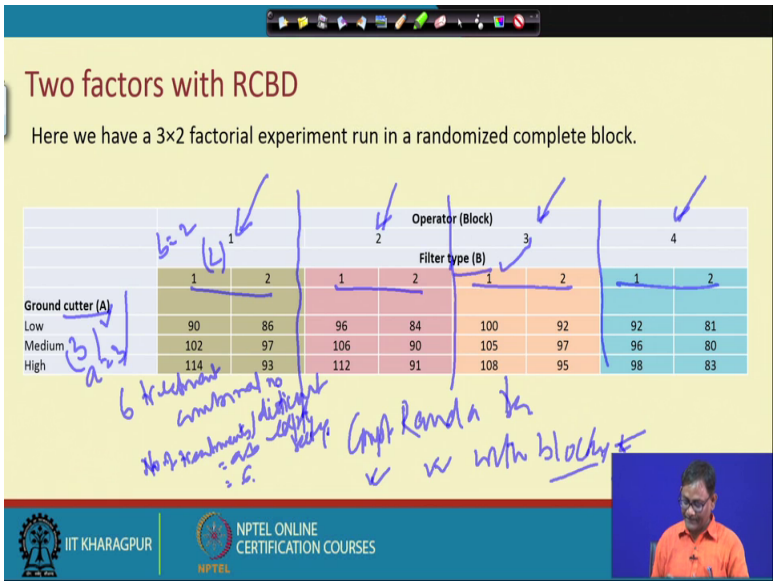

Then now you can do 2 factor factorial design with and with a blocking also, in the in the example if we keep operator as block and 2 different factors A and B A 3 level A 3 level and B B filter type 2 levels 2 levels each and we have first block operator, second block for operator 2, third block for operator 3, 4 block for operator 4. So, then what are you doing here in each block that all the 6 treatment combinations are treatment combinations 6 because here 3 here 2.

A equal to 3 b equal to 2 number of treatments will be number of treatments will be a b that is 6. I we also some the independence experimental setting distinct distinct experimental settings block operator 2 operator 3 operator 4. So, then I hope that you are now understood what is randomized block randomized design, complete randomized design and random complete randomized design randomization with blocking.

So, blocking for some noise variables or some variable whose inclusion inclusion ultimately affect the response, but you do not want to estimate what is it is effect rather you want to estimate the effect of the factors controllable factors like a and b in presence of the block in presence of the mention which is there.

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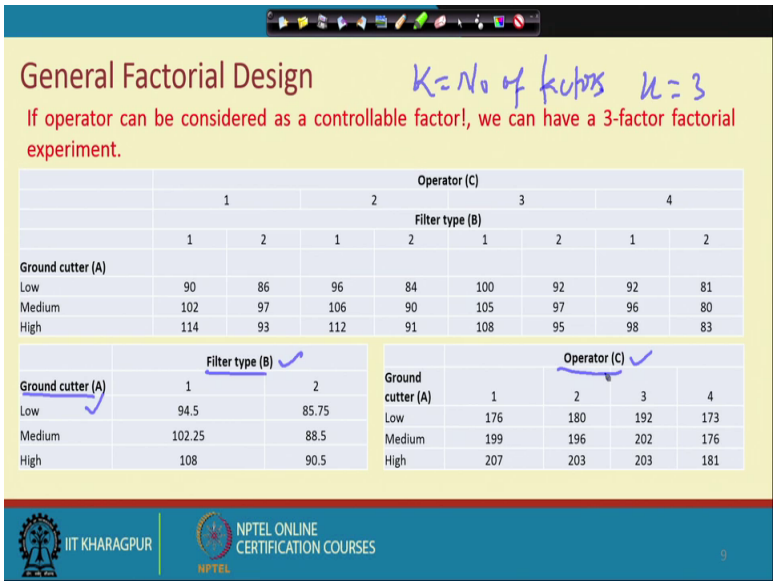

Then come to the general factorial design ; that means, suppose you think of that you have you have k number of factors K number of factors, if K equal to 3 then we can say ground clutter A 1 factor, filter type B another factor, maybe operator C another factors these are all controllable factors we are considering. So, here we assume that operator can also be controlled. So, in this case you will have a general factorial design. So, I say K numbers of factors are there.

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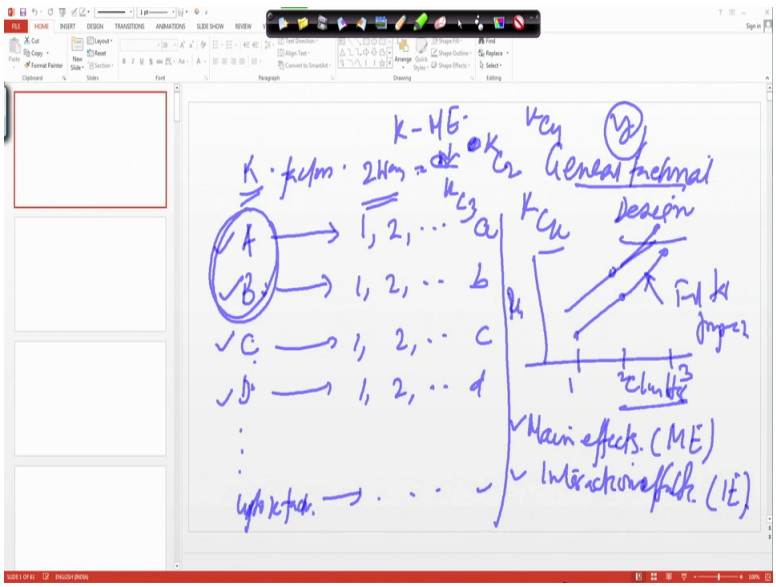

So, in this case suppose you have k number of factors K factors. So, I can say ABCD like this up to K.

So, then each factor here in case of ground clutter low medium high for similarly there may be different A levels. So, for B it maybe at b levels, C it may be c levels, D it may be with d levels, like up to k that maybe your some m level the k th level. So, all those factors if you consider and then do the complete randomized design and then you generate and this is this will be known as general factorial design general factorial design.

So, in general in factorial design there are any few interesting fact things are there suppose you have seen a already seen that in the example that clutter versus your response why, when your clutter ground clutter low level medium level and high level and then how this change is taking place.

Suppose this is filter type one now it may. So, happened and also you have seen for filter type 2 maybe something like this, but I have to check. So, in that case what actually what is happening that what effect you are you may be interested to know the effect of A. Similarly you may be interested to know the effect of B, similarly you will be effect to know the effect of C effect of d like this when you are interested to know effect of ABC all these are all those things they are known as main effects, but it may be you may be interested to know if both the factors present how they may they ultimately influence the y. So, there mean there interaction effects you may be interested to know interaction effects.

So, in factorial design main effects and interaction effects are very very important, if there are K number of factors. So, you will be having K main effects and how many interaction effects will be there will be many interaction effects because there will be 2 way interaction when A in between A and B or b and C or a and d like this. So, 2 way that will be N, if there are how many factors k number of factors are there k c 2, similarly 3 way interaction k c 3, 4 way interaction k c 4, finally, k-th way interaction k c k. So, many inter interactions will be there.

So, the these are all important things to know in factorial design we want we want to know what are the effect of each of the factors and whether they are significant on not what are the interaction effects maybe 2 way interaction 3 way interaction 4 way

interaction depending on the number of factors present, but it is interesting to note that the main effects and the lower order interaction effects are usually significant and higher order or more higher order integration effects are usually become in significant this is known as the those per city of the effects principle. So, we will discuss this when will detail the general factorial design.

So, thank you very much in next class some of the other designer splits will be discussed and today in this lecture today in this lecture. So, we have discussed that there will be a complete randomized design with one factor complete randomized design with 2 factor, complete randomized design with more than 2 factors multiple factors which is general factorial deign there is another important concept called blocking. So, what you require to do you require to block the notations variables during design then it with one factor to be one factor blocking with blocking 2 factors with blocking or multiple factor factors with blocking.

Thank you.