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Birth-death Dynamic Evolution of Multipath Signals Effect on WCDMA Receivers

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Abstract

This paper shows how to generate a birth-death dynamic channel in a laboratory, explain different parameters that are behind or generated by the birth-death behaviour, investigates the effect of the birth-death model on WCDMA receivers, shows how important to pay attention to the channel dynamics by comparing it with static channel behaviour, and shows the effect of different parameters related to the birth-death channel on WCDMA receivers.

Keywords: Birth-death, WCDMA, Synchronization errors, Hopping delay

Introduction

The investigations of channel dynamics, which are generated due to Mobile Station (MS) movement, on future generation receivers are crucial, as it influence both the spatial and temporal channel characteristics (Durrani 2006).

Since many years, extensive studies have been carried out in order to gain more profound knowledge about the propagation channel characteristics (Bultitude 1989, Zhao 2002). Some of them concentrated on the fading phenomenon where they classified it to small scale and large scale (Andrea 2005). The channel dynamics used to be referred to the fast change behaviour of the complex faded envelop within a period of time (Kim 1998). However; for some authors (Zwick 2000, Nielson 2001, Chiao 2003) channel dynamics are not referred to the fast behaviour of the faded envelope, they are referred to the dynamic change of the delay of each received reflected and scattered paths. The channel dynamics due to variable time delay path behaviour appears to be firstly studied by (Zwick 2000) through a ray tracing model and Nielsen (Nielsen 2001) through a temporal domain model.

Chiao (Chiao 2003) modelled this temporal variation of path delay by a 4 state markovian process, which describes birth death behaviour of paths noticed through an indoor measurement campaign held at University of Bristol (Tan 2002), where the proposed model fitted the measured data. However; it has to be mentioned that modelling the propagation channel dynamics through a birth-death process is referred to 3GPP organization, where one of its proposed channel models in 3GPP TS 25.104 (3GPP TS 25.104) is a birth death model. The contribution that Chiao made was by considering the case where there could be a birth state or a death state amongst the 4 suggested states. The 3GPP model only consider the birth and death state, which is the probability of having a death for a path equals the probability of having a birth for it, therefore there is no event of a death event only or a birth event only in the model, which could be one of the limits for the 3GPP birth-death model.

The 3GPP birth-death channel model is used by (Frigon 2005) in order to investigate its effect on a developed technique that mitigated the dynamic effect of paths named by WCDMA multipath searcher. The employed searcher enhanced the performance when it is compared to the typical receiver case without the addition of this multipath searcher.

Chen in (Chen 2006), developed an architecture for a multipath searcher technique and tested its performance against 3GPP birth-death channel, the technique showed an added improvement to the practical receiver structure.

Similarly (Kyung 2002) used the 3GPP birth-death model in order to perform conformance 3G mobile testing. The study showed that the receiver did not exceed the Block Error Limit specified in 3GPP 25.104 specifications under fading conditions.

It appears that birth-death channel dynamics are considered as a crucial matter for developer in order to test their developed receivers as shown in (Chen, Kyung); however they used the birth-death model as a study case only, without showing the impact of different parameters that are related to the birth-death dynamics on the receivers. Even the developed 4 state model by Chiao, is been only presented to model the behaviour of an indoor measurement campaign but its effect on the quality of received signals appears to not been studied.

This paper shows how to generate a birth-death dynamic channel in a laboratory, explain different parameters that are behind or generated by the birth-death behaviour, investigates the effect of the birth-death model on WCDMA receivers, shows how important to pay attention to the channel dynamics by comparing it with static channel behaviour, and shows the effect of different parameters related to the birth-death channel on WCDMA receivers.

The paper is organized as follows: in (1) it presents the Laboratory setup, in (2) it describes how to generate birth-death behaviour via PropSimC2, in (3) it shows testing scenarios, results and discussion and finally a conclusion is drawn in section (4).

1. Laboratory Setup and Measurements

The test is carried out through a connection between a wide band protocol emulator (CMU 200) [14], a Multipath Fading Channel Simulator (PropSimC2), a Radio Frequency (RF) Antenna Coupler and a Radio Frequency Shield which holds a Third Generation (3G) Mobile Station (MS) [15], this connection is shown in Figure (1a), where PropSimC2 is at the bottom, CMU 200 in the middle, Antenna coupler and RF Shield on the top.

A Base Band (BB) connection is made between CMU 200, through its IQ 15 bin channel which is shown in figure (1c), and the PropSimC2 Analogue Base band (ABB) Input/Output (I/O) as shown in figure (1d).

A RF connection is made between CMU 200 through its RF2 output port in the front panel, and the RF Shield Unit input port in the rear panel as shown in figure (1b). The Shield isolates the MS from external interference and noise, MS has to be placed in a reference zone provided by the manufacturer, in which a perfect RF match is met. This zone is highlighted by two concentric circles as shown in figure (1f).

In order to start the test, CMU 200, PropSimC2 and the MS are switched on, from CMU 200 start menu , Frequency Division Duplex (FDD) WCDMA modulation overview, which from it Frequency Band (I) , Reference Measurement Channel (RMC) (Tanner 2006) of a 12.5 kbps data rate is selected. From the connection menu, fading test is selected, which sends a WCDMA compatible signal to the CMU 200 IQ channel to be faded by the PropSimC2, and takes back the faded signal to be redirected through RF2 output towards the MS which is held in the RF Shield, the MS decode the received signal and sends a report to the CMU 200 in the form of Bit Error Rate (BER).

To display the BER report, receiver quality report is selected from the start menu; which the number of WCDMA blocks to be tested is modified. The number of required transmitted bits or blocks, to represent reliably a given error statistic (BER), can be obtained from (Tanner 2006, Jeruchim 1999):

$$N_{bits} = \frac{\varepsilon}{\sigma_e^2 \times BER}$$

Where ε denotes the number of counted errors, BER denotes the error level at which we want to operate, e.g. 0.001. The term σ_e^2 is the desired error variance of the result for which a value 0.1 has been suggested (Tanner 2006, Melis 2003).

From the receiver quality menu, Base station level I_{or} can be adjusted, according to our test; the sent signal to the mobile station has to be compatible with the 0dB power requirement to the transmitted signal.

The set of downlink physical channels (PhCH) for a connection setup with the MS are both synchronization channels P-SCH, S-CH, Primary Common Pilot Channel (P-CPICH), Primary Common Control Channel (P-CCPCH), Secondary Common Control Channel (S-CCPCH), Paging Indicator Channel (PICH), Acquisition Indicator Channel (AICH) and a DPCH. The relative power for each PhCH used in this test is tabulated in Table 1.

Orthogonal Channel Noise Simulator (OCNS) is set to compensate for the remaining power (Tanner 2006), which is not covered by the mentioned physical channels in Table 1.

After the signal is faded by PropSimC2, Additive White Gaussian Noise of -60 dB power (I_{or}) is spread over 3.48 Mbps is added to the faded signal.

2. Birth-Death Dynamic Channel generation via PropSimC2

A birth-death dynamic channel can be generated using PropSimC2 edit panel, when the PropSimC2 is turned ON it will displays three menus to select from, in order to generate a new scenario the "Create New Simulation" menu is selected, this will display a new window which shows a number of editing icons in its bottom.

Choosing add a new propagation path will display a window with 4 different options, the first one is time delay function the time delay function is the responsible of generating a birth-death event for a path, the function to be selected in order to do this is “Hopping”, from its name it will generate a hoping time delay, which hops from a position to another, this transition is altered with a period of time called Transition Time period and defined in the PropSimC2 as “Delay duration”, this transition time can be edited from the “delay properties” option, which from it, positions in time domain are defined, which from them a birth-death event will take place, can be edited too.

The third parameter is the path power, since the aim of this experiment to show the effect of channel dynamics which is caused by time delay variation, the path power will be set to 0dB which means no losses is introduced by the environment, therefore any error in the receive side will be caused by the dynamic behaviour of the paths. The third option is the “amplitude distribution”, as with the case of path power option this option is set to constant, which means no variation in the path will occur due to the environment.

The last option is the “Doppler Spectrum Shape”, this option works together with the amplitude distribution option, where a Rayleigh distribution for example will automatically set the Doppler spectrum to the U-shape (Elektrobit 2003), and since the amplitude is constant, which means no Doppler spectrum variation, and then the Doppler spectrum cannot be selected as an option for this experiment. This means that the mobile terminal velocity will not have a significant effect on any possible error at the receive side, hence, the isolation of amplitude, power and velocity effects, do really serve the purpose of this experiment in order to investigate the dynamic effect of path behaviour on the receive side of a WCDMA system.

The birth-death behaviour of a path, as stated above is generated by varying the time delay which is assigned to each path in a hopping fashion, in order to understand this process, the “Tap Delay Line” model for a propagation channel (Elektrobit 2003), will be a good example to simplify the concept of generating a birth or a death event for a path.

A tapped delay line model is shown in Figure 2, it shows one tap which is responsible for the delay, and two multipliers for fading effects, this model is just a simplification for the fading process, the model could be extended to include *N* number of multipliers and *N-1* delay taps if it has to model *N* number of paths.

The model generates a time delay effect by delaying it through a delay line, and then it directs it to a multiplier where the fading effect is applied to the input signal by multiplying it with a complex statistical value which encounters for the attenuation effects that is generated by the environment. The following equation is used to model the overall effect for delaying the input signal and attenuating it:

$$R(t) = \sum_{n=0}^{1} a_n \times S(t) \times \delta(\tau - \tau_n)$$

Since the effect of attenuation is not to be taken into account in this study, a_n is set to have a value of 1. The parameter that is to be studied is τ which from it the dynamic behaviour of the channel will be generated. In order to generate a birth-death abrupt event, the time delay of each path has to change abruptly too. PropSimC2 assigns a special variable function to τ and varies it in a hopping fashion as described in figure 3.

The abrupt change in the time delay of paths due to birth-death behaviour is shown in figure 3, it can be seen that each 191 millisecond (or any transition time) a birth and a death event occurs. It has to be mentioned that the PropSimC2 do not allow the event of a complete death for both paths at any instance to happen, therefore the birth-death process runs in an alternative way. For example path one dies after 191 ms at 1000 ns time delay position and born abruptly at 3000 ns, path 2 will stay at its position which is for example 4000 ns without any dynamic change. After 382 ms which twice the transition time, the second path is allowed to choose any position in time delay domain and occupy it, but this happens in the condition that path 2 is stand still at its occupied position.

This alternative process guarantees that there will be always some time relativity between the paths, which will maintain the time spread property of the propagation channel (Gombachika 1997).

The hopping behaviour of the time delay of path is illustrated in figure 3, where it shows how the time delay hope from a position to another for each path after a given transition time depending on the path number too.

3. Test Scenarios, Results and Discussion:

3.1 The effect of birth-death path dynamics behaviour compared to a static path.

The effect of birth-death path dynamic behaviour compared to a static one in a propagation channel, on a WCDMA receiver can be shown by the bit error rate analysis at the output of the receiver. The basic scenario is to set the PropSimC2 to generate a static channel by setting the path delay function to a fixed one at 0 seconds, this path is assumed to be perfectly received by the receiver where no delay is applied in the whole period of the laboratory experiment. The bit error rate is varied by changing the total output power (Ior) generated from the transmitter (CMU200), this change will produce a bit error rate curve which from it we can compare the effect of channel dynamics induced by birth death behaviour to the static behaviour, and it will show whether a power gain or loss incurred because of this dynamic change.

Figure (4), describes an example for a birth death possible scenario, where the experiment begins with setting two paths at any two positions between [0, 1, 2, 3, 4] (μs), when the simulation of this scenario starts, the first path changes its position after 191 (milliseconds), which is the birth-death transition time, the second path changes its position after 382 (milliseconds) which is twice the transition time of the first path, the two paths are free to take any position in a random fashion, however none of them is allowed to overlap the other, which means there will be always a relative delay between the two paths.

The randomly selected positions which again ranges from [0, 1, 2, 3, 4] (μs), represents different time delays that can be assigned to each born path at that particular time, the modification of these positions can easily be done through PropSimC2 editing screen, the five listed positions are considered as a standard choice for a birth death scenario.

Figure 5, shows the effect of changing the channel behaviour from a static scenario to a dynamic birth death scenario. It is clearly noticed that the receiver performance under dynamic change of the channel is worse than the static case, there is approximately 2.8 dB power loss between the static and dynamic channel.

This loss can be best explained by the power loss that happens due to synchronization errors between the locally generated PN code at the receiver and the incoming delayed wave, where a ¼**Tc* (WCDMA chip rate) misalignment could generate 1 dB power loss, assuming that no losses incurred by the receiver and transmitter pulse shaping filters, and a 3 dB loss if a misalignment of ½**Tc* with the incoming wave (Chen 2006).

The bit error rate curve in figure 5, shows that the receiver is really able to work under low signal to noise ratio conditions at the static channel assumption, where at *Ior/Ioc* = -8.6 dB the receiver is able to reach the minimum BER voice communication requirement which is 1×10^{-3}, however for the same power level, the receiver just reaches a 1×10^{-1} when the channel dynamics is considered.

3.2 The effect of birth-death transition time.

The birth or death transition time of a path is defined by the time needed for a birth or a death event to happen, this time is set to 191 (ms) in the 3GPP TS25.104 specifications. Authors in (Chen 2006) showed that the transition time of a propagation dynamic birth death channel can be exponentially distributed; this conclusion is based on an indoor measurement campaign. PropSimC2 allows the user to modify this parameter from the editing screen.

In order to see the effect of different transition times on the performance of WCDMA receivers, the transmitter power is to be changed through a range of values, which from it, a bit error rate curve will be generated, and from it a comparison with the static channel condition is carried out.

The PropSimC2 is modified through its edit screen to change the value of the transition time for a birth-death event, the minimum allowed value is 25.7 milliseconds and the maximum value for a transition time is 1000 seconds.

Figure 6, shows the effect of transition time on WCDMA receivers, when the transition time changes from 191 millisecond to 90 millisecond, a 0.2 dB power loss is noticed, and a 3dB loss compared to the static channel.

When the transition time changes to 30 millisecond, a 2.2 dB power loss is noticed, this means that’s as long as the path stays at a specific position before it transit to another one, will give the receiver the opportunity to synchronize with the delayed wave without introducing significant power loss.

Therefore; when the transition time increases, it means that less opportunity for the locally generated PN code to lock perfectly with the delayed incoming wave, assuming that, the delay shifted the incoming wave from a perfect synchronization position, this misalignment will introduce some power losses.

From the above discussion it can be seen that, an increasing transition time has a positive effect on WCDMA receivers, however this positive effect has a limit, and where increasing the transition time after a certain limit will not affect the receiver performance.

This can be shown in figure 7, where it shows that the bit error rate decreased steeply from 1×10^{-3} to 1×10^{-5} when the transition time increased from 30 millisecond to 191 millisecond, however increasing the transition time more than 191 milliseconds do not have any significant change, this means that 3GPP TS25.104 standard uses the maximum limit for an effective transition time in order to be applied for a birth death propagation channel scenario.

3.3 The effect of birth-death time position.

The birth-death time position as defined above, is the position in time where a birth-death event take place, or in other meanings it is the position where a path dies or born at. Figure 8, describes a scenario which shows five different positions that each path can occupy, without overlapping the other.

The scenarios described in figure 8 is used to investigate the effect of time position on WCDMA receivers, the 5 positions scenario described in figure 2, is used as reference, which from it a comparison with a 7 and 9 positions scenario is performed.

Figure (8A), shows a 9 positions possible scenario, where each path is free to move to any position selected from [0, 1, 2, 3, 4, 5, 6, 7, 8] (ìs) time position set, the change of position is always after a specified transition time, a 191 milliseconds is selected as a standard transition time for this experiment. Figure (8B), shows a 7 positions possible scenario, the two paths can occupy any position from [0, 1, 2, 3, 4, 5, 6] (ìs) time position set.

Figure 9, shows that effect of increasing the number of time positions on WCDMA receiver. A small amount of power loss of 0.2 dB is noticed when the number positions is increased to 7 positions and a 0.3 dB loss when the position are further increased to 9 positions. This indicates that the time relativity between the two paths which is defined in section above is the reason to not impose a noticeable amount of power loss (Rohde & Schwarz 2006).

4. Conclusion

This paper showed how to generate a birth-death dynamic evolution of a multipath in a laboratory, it studied the effect of this dynamic evolution and compared it with static behaviour of paths, and the study showed that there is a 2.8 dB power loss when the transmitted signal is affected by dynamic path behaviour compared to the static one. It showed that increasing the transition time of each path has a positive effect in improving the performance of the receiver, however it has a limit at 191 ms where there is no added improvement after this limit, it showed that the position of evolution of each path in time delay does not have a great effect on the receiver as long there is a relativity in time delay between the generated paths.

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Table 1. Power allocation values for different physical channels

Ratio	Relative Power
*P-CPICH_* E_c / I_{or}	-10 dB
*S-CPICH_* E_c / I_{or}	-10 dB
*P-CCPCH_* E_c / I_{or}	-10 dB
*P-SC_* E_c / I_{or}	-15 dB
*S-SCH_* E_c / I_{or}	-15 dB
*PICH_* E_c / I_{or}	-10 dB
*DPCH_* E_c / I_{or}	-10 dB
OCNS	Remaining power

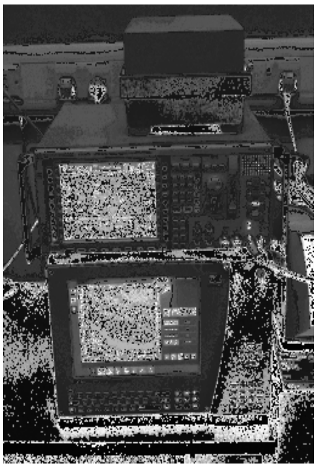

Figure 1 (a). displays PropSimC2 in the bottom, CMU 200 in the middle and the RF shield on top

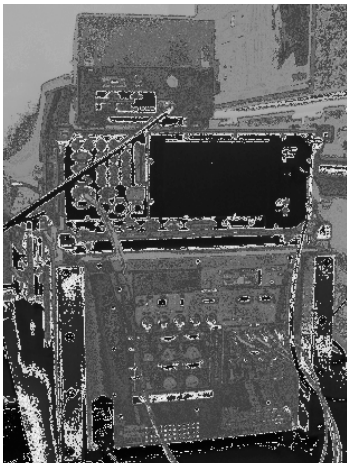

Figure 1 (b). Back panel of the test bed

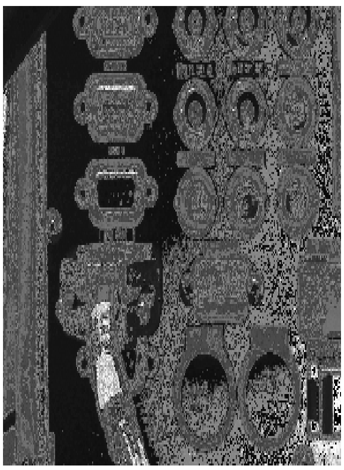

Figure 1 (c). back panel of CMU 200 showing the IQ channel connector

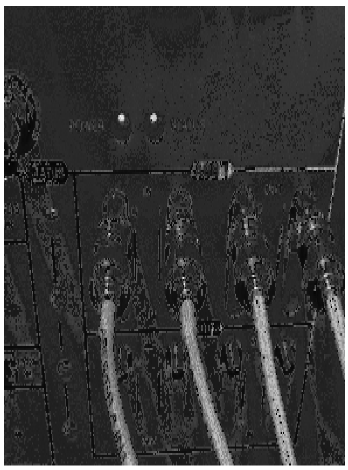

Figure 1 (d). PropSimC2 ABB interface

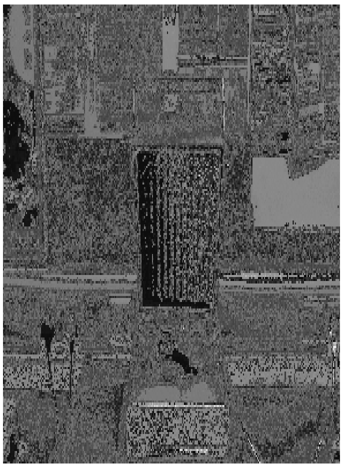

Figure 1 (e). RF shield holding a MS

Figure 1 (f). Circles showing the perfect matching RF zone

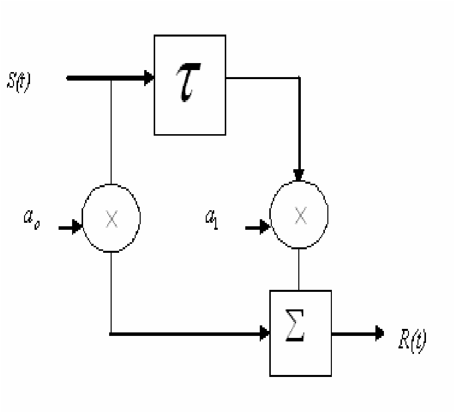

Figure 2. A Tap Delay Line model

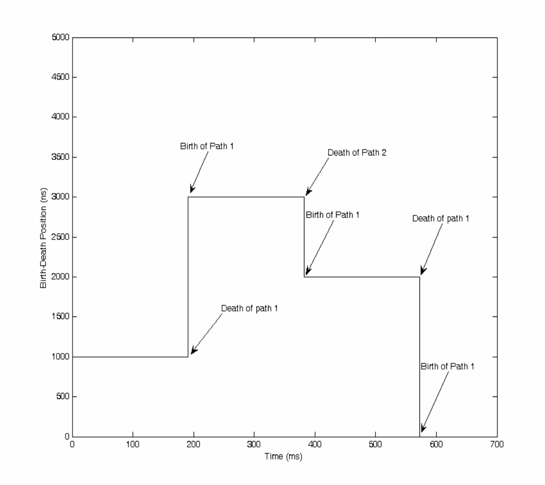

Figure 3. Time delay Vs. Time domain

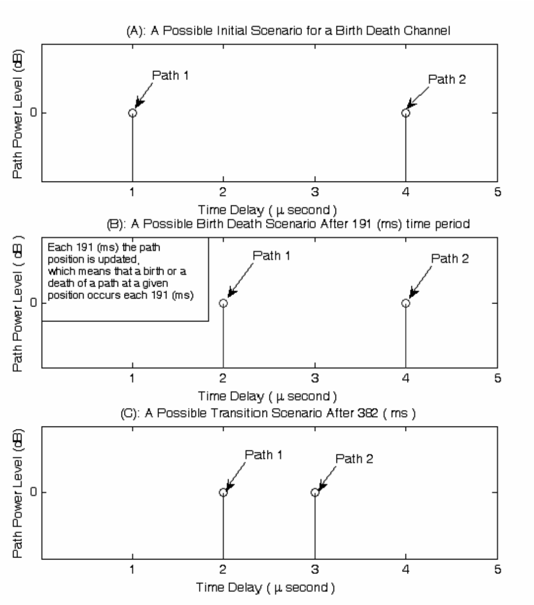

Figure 4. Path Power vs. Time Delay for three different scenarios that generates a birth death behaviour

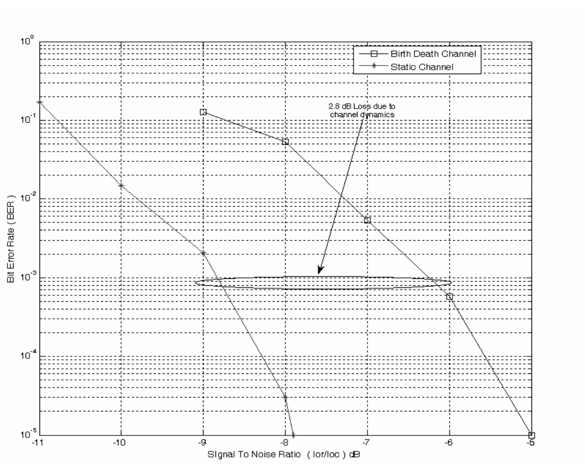

Figure 5. BER vs. Signal to Noise Ratio (*Ior/Ioc*) for a static and a dynamic birth death channel

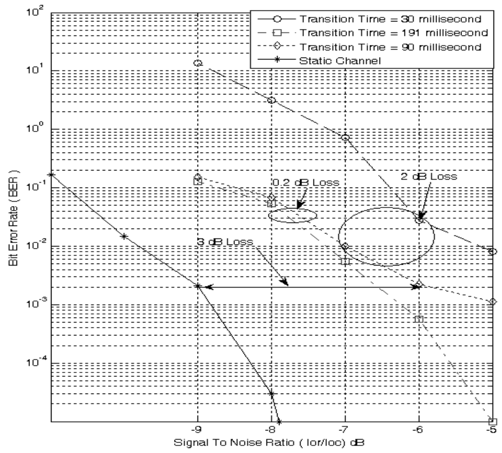

Figure 6. BER vs. Signal to Noise Ratio (*Ior/Ioc*) considering the case of different transition times

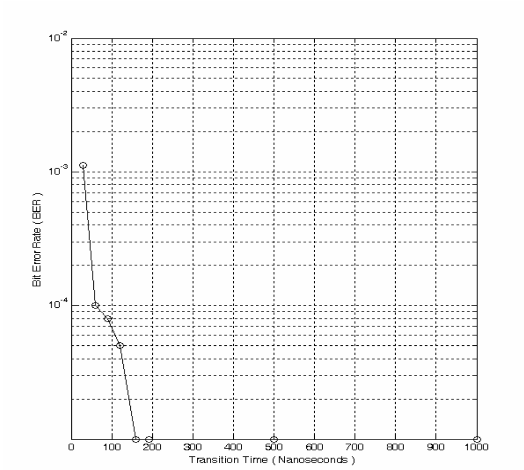

Figure 7. BER vs. Transition Time of a birth death channel

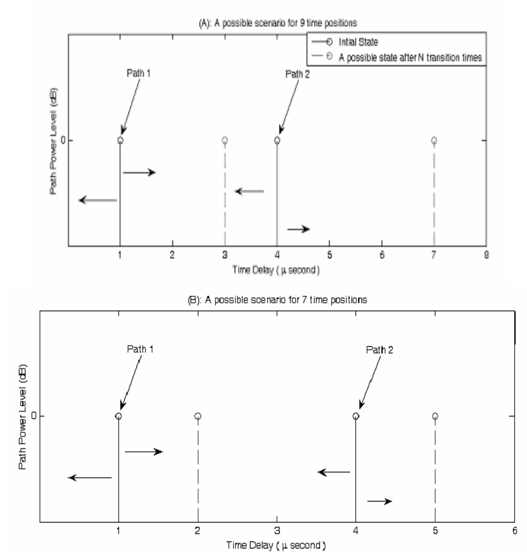

Figure 8. Path Power vs. Time Delay for 2 different scenarios that shows a change in their position in time delay

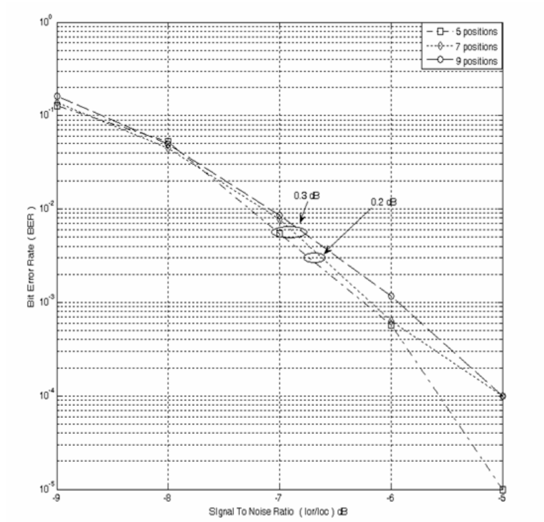

Figure 9. BER vs. Signal to Noise Ratio (*Ior/Ioc*)