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Efficiency on the Fast Handover Technology in High Speed Environment

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ABSTRACT—*High speed rail has been developed rapidly in recentyears. Due to that, the increase of the number of passengers in fast train with increase demand of data usage, the communication technology must also be upgraded to meet user demand. Currently, a high speed environment poses a great challenge for mobile communication. A fast handover are the toughest problems to deal with and currently are the top of the list of problems that urgently cry for solution. The higher speed is, the worse the effects are in mobile communication. The presence of fast handover in fast environment will make mobile users to continue communicating while they are inside fast vehicle. When speaking of a fast handover, higher speed plainly means a short time allotment for this type of operation. The problem arises when the user equipment (UE) moves across the handover process especially with a speed of more than 500 km/h, which results in services interruption. In this paper we proposed Doppler shift with the help of stationary outdoor distributed antenna and movable onboard antenna for reducing power signal to the connected router before reaching UE. The results with MATLAB simulation shows that, by using MIMO-OFDM with the help of Doppler shift, a strong signal have been arrived at the receiver and make handover within 100milliseconds for the speed of 550km/h.*

Keywords*—Handover, Doppler shift, LTE-A, High Speed Environment (HSE), Outdoor Antenna, On-board Antenna, Router, Front haul, Backhaul, User Equipment (UE), MIMO - OFDM.*

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I. INTRODUCTION

Currently, the world experiencing huge growth of data and internet services in order to meet social and economic development. Due to this demand, people has a needs to be connected with internet at everywhere in their daily life. In order to meet user demand, a world now is going to be connected with smart devices which can provide multiple internet protocol (IP) with a support of wireless connection at everywhere. But wireless connection has a lot of challenges mostly in high speed environment. In high speed environment, the ability of users to be connected is little bit tough, because many wireless device has no capability to support signals while the vehicle are in high speed and cause interruption of signals. Because high speed train pass through different areas like urban, rural, tunnel, cutting and viaduct areas, this means that channel model will be different for propagation of scattering signal.

Advancement in high speed environment (HSE) transportation has resulted in more passengers transiting through railway networks [1]. HSE is currently growing more and more popular, and this mode of public transportation is preferred in several countries due to its advantages such as speed, safety, energy efficiency and larger passenger handling capacity [2][6].

The demand for high quality video, voice and data over broadband wireless communication in an HSE has thrown open various limitations of wireless technology. When a train moves in speed up to 270km/h or higher than that, only a few channel measurement data can be collected. The limited amount of samples is insufficient for constructing stochastic models.

As an alternative of active sounding, researchers to use a passive approach, i.e. Communication signals in an in-service wireless communication system deployed along the HSE railway are exploited for channel measurements. The advantages of this passive-sounding approach are that measurements can be HST railways are covered by the multiple generations of wireless communication network nowadays, and furthermore, with the signal recorder located in the HST carriage, the channel characteristics observed would be the same as those experienced by to user equipment (UE) on board exactly [9].

A. Differences Between Public And High Speed Environment Wireless Connection

There are features for HSE which must be known. Special propagation scenarios, high moving vehicles over 500km/h and interferences are the main differences between public and HSE connections.

We know that, wireless channel is the fundamental basis for the planning of wireless connection network and the design of transceiver. A wireless channel has a close relationship with physical conditions, topography and the surrounding environments. The typical railway environments are characterized by special scenarios such as viaducts, cuttings, tunnels, crossing bridge railway stations, marshalling stations and some combined scenarios such as the tunnels group and the combinations of viaducts and tunnels. Based on the actual test data collected from Zheng Xi HSR line, conclusions are drawn that these special scenarios sometimes cause deep fading of the signal [7][8].

II. CONTRIBUTION

A. Proposed System Structure and Model

i) At transmitting schematic:

MIMO – OFDM is a combination of Multiple Input Multiple Output (MIMO) with Orthogonal frequency division multiplexing (OFDM). It combines a technology which multiplies capacity by transmitting different signals over multiple antennas and orthogonal frequency-division multiplexing, which divides a radio channel into a larger number of closely spaced sub channels to provide more reliable communications at high speeds.

MIMO-OFDM is the foundation for most advanced wireless local area network (wireless LAN) and mobile broadband network standards because it achieves the greatest spectral efficiency and, therefore, delivers the highest capacity and data throughput. MIMO-OFDM is a particularly powerful combination because MIMO does not attempt to mitigate multipath propagation and OFDM avoids the need for signal equalization. MIMO-OFDM can achieve very high spectral efficiency even when the transmitter does not possess channel state information (CSI).

It isknown that OFDM converts a frequency selective channel into a set of parallel flat fading channel. So, that MIMO-OFDM converts a MIMO frequencies selective channel into a set of parallel flat fading MIMO channels. In MIMO-OFDM we convert a frequency selective MIMO channel into multiple parallel flat fading MIMO channels, thus simplifying receiver processing. In the absence of a flat fading MIMO channel, one needs to eliminate MIMO inter-symbol interference (ISI), this essentially implies that we need a MIMO equalizer.

Hence, thereby MIMO-OFDM significantly simplifies baseband MIMO receiver processing by eliminating the need for a complex MIMO equalizer.

Hence in the presence of MIMO inter-symbol interference, one need equalizer thus, by removing the need for a MIMO equalizer this significantly simplifies based band receive processing that is, it is eliminates MIMO inter-symbol interference.

B. **Frequency Selective MIMO channel**

Frequency selective Single Input Single Output (SISO) channel is modelled as an FIR channel filter. In this fact, the output system model is given as and it show that each output symbol depends on both the current symbol and past symbol.

$y(k) = \sum_{l=0}^{l-1} h(l)x(k-l) + n(k)$……………..…… (1)

Where by $h(0)x(k)$ stands for a current symbol and$h(1)x(k-1)$ stands for a past symbol.

For aMIMO frequency selective channel is modelled as a MIMO FIR filter whereby each channel tap is MIMO channel matrix and it is known that MIMO system have multiple transmitter and receiver antennas. So, that transmit transmitted symbol is a vector comprising of the transmitted symbol, these receiver antennas and this receive symbol is also a vector corresponding to receive symbol at receive symbol at all the receive antennas.

The system model will be

$$\tilde{y}(k) = \sum_{l=0}^{l-1} H(l)\,\tilde{x}(k-l) + \tilde{n}(k) \quad \ldots\ldots\ldots\ldots(2)$$

From the above formula it shows that received signal depends on channel matrix $H(l)$ with transmitted signal $\tilde{x}(k-l)$at a time of $t\,\tilde{x}$ to a time $t-1$ up to a time $k-l+1$.

Remember, this is the model of inter-symbol interference between inter-vector symbol interference. Hence, this is the selective frequency MIMO channel.

For MIMO-OFDM system, we need to perform the IDFT or IFFT operation at each transmit antenna.

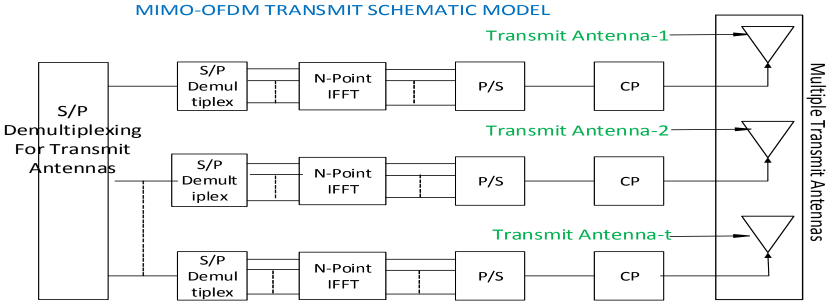


Figure 1: mimo-ofdm transmit schematic model

ii)At receiving schematic:

Similar to what we had in the OFDM receiver, we have to remove the cyclic prefix (CP), so that CP removals followed by serial to parallel DE multiplexing operation. Here we will perform N-point FFT, and we have to do detection similar to what we had in an OFDM receiver. This detection is called MIMO detection, because we are dealing with a MIMO frequency selective channel, which is converted into MIMO flat fading channel. MIMO detection must be done in all N sub-carriers from the 1^{st} receiver to r^{th} receiver antenna.

As how we also subsequently later modified the OFDM system to include a MIMO-OFDM system. We modified this OFDM to MIMO-OFDM to basic extend its frequency selective MIMO communication system, that is to handle the problem of selective MIMO communication system.

We said, OFDM converts the frequency selective MIMO channel into a set of parallel flat fading MIMO channels. Similarly, MIMO-OFDM converts a frequency selective MIMO channel into multiple parallel flat fading MIMO channels.

At the output, after employing MIMO-OFDM, the MIMO frequency selective channel can be converted into a set of parallel flat fading MIMO channels. Look at the output across each sub-carrier which called N-Parallel flat-fading MIMO channels.

$$\bar{y}\,(k) = \hat{H}\,(k)\,\bar{x}\,(k) \qquad (3)$$

By this way, it means a received signalmust be in a vector to
form flat channel matrix with its carrier frequency which will make a transmitted to be in vector form also

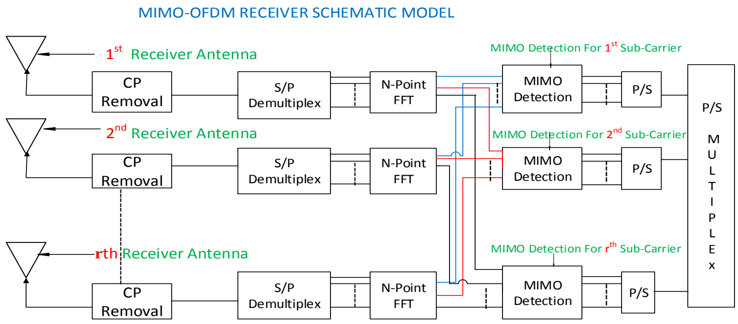


Figure 2: mimo-ofdm receiver schematic model

C. Model of Communication in High Speed Environment (HSE)

In this paper we consider outdoor distributed antenna and indoor distributed antenna which forms multiple input – multiple output for transmission and receiving of signal with a support of router inside the train as shown in a figure 1. Those routers are connected from indoor antennas with Ethernet cable, one from front haul and another from backhaul.

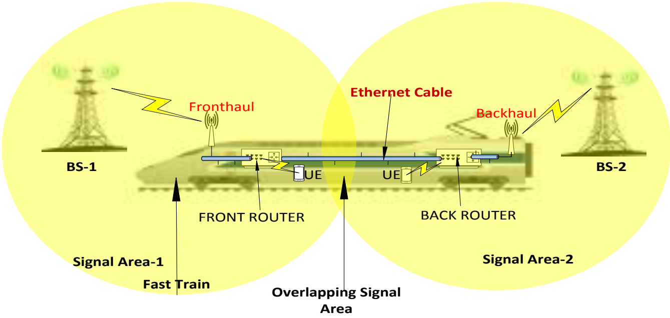


Figure 3. Distributed outdoor and indoor antenna with routers

D. Channel model with Doppler effects mathematics.

Assume a high speed train is moving from one point to another point with a velocity v (km/h), phase change $(\Delta\emptyset)$, Carrie frequency (F_C) , radio wave length (λ), change in time (Δt) and angle of arrival of signal (θ) at the receiver it induces a Doppler frequency as shown in the equation and figure below.

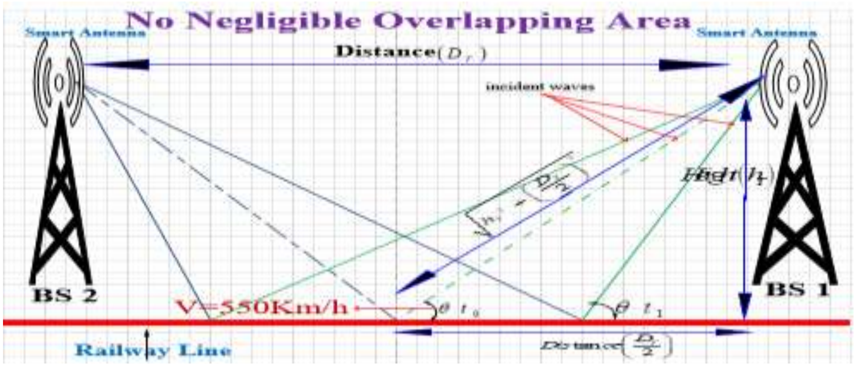


Figure 4. Overview on how multiple signals is received by train with different angles.

During moving of indoor antenna, there is a different incidence angle which is caused by reflections and scattering of propagation paths in the radio channel, and these phenomenon's cause that and identical signal arrives at different times at its destination point (receiver) from the source (transmitter). And this scenario will be observed when a train is moving toward the Base Station (BS) and also when a train is moving away from the Base Station (BS).

$$(\Delta\emptyset) = \frac{2\pi V \Delta T}{\lambda}\cos\theta \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where by wavelength (λ)is a ratio between speed of light (C) and carrier frequency (F_C)

From the reference of figure no. 4

$$f_D = \frac{1}{2\pi}\cdot\frac{\Delta\emptyset}{\Delta t} = \frac{Vf_C}{C}\cos\theta$$

$$\cos\theta = \frac{D_T/2}{\sqrt{h_A{}^2 + \left(D_T/2\right)^2}}$$

$$f_D = \frac{Vf_C}{C}\frac{D_T/2}{\sqrt{h_A{}^2 + \left(D_T/2\right)^2}}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

c = speed of light($3.0\text{x}10^8$ m/s^2)

h_A = Height of Antenna

D_T = Distance between two adjacent Antennas.

The Maximum Doppler shift(F_D) is achieved when $\theta = 0$, i. e$\mathbf{F_D} = \frac{V}{C}f_0$ ……………………………………(6)

For received Frequency (F_R)

$$F_R = F_C + F_D$$

$$F_R = \mathbf{F_c} + \frac{VF_C}{C}\cos\theta$$

$F_R = F_c\left(1+\frac{V}{C}\cos\theta\right)$……………........………..………………...…. (7)

The Maximum Received Frequency(F_R) is achieved when $\theta = 0$, i.e

$(F_R) = F_C\left(1+\frac{V}{C}\right)$……………..………………………………. (8)

During to the movement of fast train, there's two scenario happens which makes angles of incident to vary.

(a) Train moving towards the base station.

$F'_D = 1+\frac{V}{C}f_0\ \cos\theta$…………………...………………. (9)

(b) Train moving away from base station.

$F'_D = 1-\frac{V}{C}f_0\cos\theta$………....………………………..….(10)

III. MULTIPATH PROPAGATION EXPRESSION

Multipath in wireless communication is the propagation event that results after a radio signals reaching the receiving antenna by more than one paths. The causes of multipath includes atmospheric ducting, ionospheric reflection and refraction, and reflection from water bodies and terrestrial objects like mountains and buildings.

Multipath causes multipath interference including constructive and destructive interference and phase shifting of the signal. Destructive interference causes fading. Where the magnitudes of the signals arriving by the various paths have a distribution known as the Rayleigh distribution, this is known as Rayleigh fading (Non-line of sight). Where one component (often, but not necessarily, a line of sight component) dominates, a Rician distribution provides a more accurate model, and this is known as Ricin fading (Line of sight). In addition, Doppler frequency shift can be incurred by the relative motion between the transmitter and receiver. In order to get fast handover, in this paper, we based only on Rician fading (Line of sight) for the high speed train.

A. Slow and Fast Fading Channel:

Wireless fading channel is normally modelled as a linear time-variant (LTV) system. The speed of varying with regard to time refers to how fast the magnitude and phase of signals are changing in propagation, which is measured by the coherence time of the channel denoted by $(\Delta t)_c$ and the delay requirement that usually choose the symbols duration T_S. When $(\Delta t)_c \gg T_S$, the amplitude and phase change caused by the channel can be considered constant over a certain time period, the channel is relatively slowly fading compared with signals, which is so called slow fading. On the contrary, fast fading occurs when the coherence time of the channel is relatively smaller or comparable to that of the symbol duration. Moreover, the coherence time has been proved to be inverse proportional to the Doppler spread denoted by B_d, i.e..

$\frac{1}{(\Delta t)_c} \approx \frac{1}{B_d}$……………………………………..……………………… (11)

B. Mathematical modelling of multipath

A method which can be useful to present multipath in wireless communication is impulse response used for studying linear systems.During transmission of a single or ideal Dirac pulse of electromagnetic power at time t, a small time will be considered as $\delta(t)$ is equivalent to $x(t)$

Due to the presence of multiple electromagnetic paths at the receiver, means that more than one pulse will be received, and each one of them will arrive with its own time.

It is known that, electromagnetic signals travel with a speed of light, and since every path generate its own geometrical length possibly different from that of the other ones. Due to different air travelling times, let's as consider in free space a light will consumeonly $3x10^8\ m/s$. Thus, the received signal will be expressed by

$y(t) = h(t) = \sum_{i=0}^{L-1}\rho_n e^{j\emptyset_n}\delta(t-\tau_n)$……....... (12)

Where L is the number of received impulses, τ_n is the time delay of the generic n^{th} impulse, and $\rho_n e^{j\emptyset_n}$ represent the complex amplitude which has magnitude and phase of the generic received pulse. As a consequence, $y(t)$ also represents the impulse response function $h(t)$ of the equivalent multipath model.

Generally, in presence of time variation of the geometrical reflection conditions, this impulse response is time varying, and as such we haveτ_n as a function of time it will be $\tau_n(t)$, ρ_n as a function of time it will be $\rho_n(t)$ and $\emptyset_n$ as a function of time it be $\emptyset_n(t)$.

We assume one parameter is used to denote the severity of multipath conditions, and it is called the multipath time, T_M, and it is defined as the time delay existing between the first and the last received impulses

$T_M = \tau_{L-1} - \tau_0$……..…………………….……..… (13)

Practically, the multipath time we computed it by considering as last impulse as the first one which allows receiving a determined amount of the total transmitted power. Keeping our aim at linear, time invariant systems, we also characterize the multipath phenomenon by the channel transfer function $H(F)$, which is defined as the continuous time Fourier transform of the impulse response $h(t)$.

$$H(F) = \delta\big(h(t)\big) = \int_{-\infty}^{+\infty} h(t)e^{-j2\pi ft}\, dt$$

$$\mathrm{H}(F) = \sum_{i-0}^{L-1} \rho_n e^{j\emptyset_n} e^{-j2\pi f\tau_n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (14)$$

IV. COVERAGE AREA ANALYSIS

A. PATH LOSS

Each of the signal travelling form transmitting antenna undergoes several radio channel uncertainties like path loss, shadowing coefficient and multipath fading coefficient [17].

When the signal propagates from transmitter to receiver without any delay and multipath effects is referred as line of sight (LOS) propagation. When electromagnetic wave propagates it is distorted by number of phenomena such as absorption, reflection, refraction, diffraction, scattering this occurs a non-line-of-sight propagation (NLOS) [21].

Path loss will be added to the model of the channel to make possibility of determining the maximum range of power transmission in the wireless system. Simple propagation output model [18]. In path loss or power loss we considering large scale propagation and small scale propagation.

Small scale effects:Because the outdoor antenna for transmission of signal will be along the truck of maximum height of 30 meter, then the power loss will be caused by rapid fluctuations of the amplitudes, phases and delays of a transmittedsignal over a short period of time or a short distance [15]. Two significant effects of small-scale fading are time dispersion caused by multipath propagation and frequency dispersion caused by Doppler spread [16].

A general path loss is defined as the ratio of effective power and receiving power.

$$Power\ Loss\ (\overline{PL}) = \frac{Power\ Transmiter\ \ (P_T)}{Power\ \ Receiver\ (P_R)} \ldots\ldots\ldots\ (15)$$

For any distance, average large scale path loss is denoted as.

$$\overline{PL}(\Delta d) = \overline{PL}(d_O)(\frac{d}{d_o})^n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(16)$$

Where by d denotes the distance between transmitter and receiver; n denotes path loss exponent; d_O denotes the ground proximity reference distance; $\overline{PL}(d_O)$denotes the average path loss from transmitter to ground proximity reference point.

In this paper we take a reference distance is normally from 0km to 1km [10] under outdoor environment.

A simplified calculationof a path loss is used to predict received signal strength when the transmitter and receiver have a clear unobstructed line of sight path between them [19].

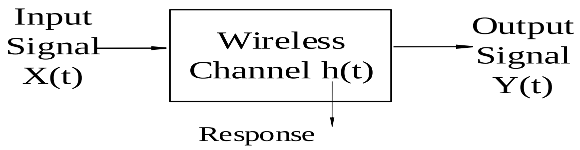
Path loss for free space is calculated by [17]: PL=32.4+20log (Fc)+20log(d)…………………(18).In overlapping area, a signal with low power loss will be connected from outdoor antenna to onboard antenna which is connected withrouter for distribution of Wi-Fi inside the fast train, and Passenger will be connected through Wi-Fi to access a data.

B. Rician channel model

As we know wireless communication system consists of transmitter and receiver. The path from transmitter to the receiver is not smooth and the transmitted signal undergo through various kinds of attenuations including path loss, multipath attenuation etc. The signal attenuations including the path depends on various factors which are time, frequency and path or position of transmitter or receiver. Due to that, a fast mobile handover system will be easier to accomplish once a signal is considered to be in a line of sight in order to enhance connection from transmitting antenna which is in stationary form to onboard antenna which is in motion form.

With rician channel model line of sight (LOS) components are simulated between transmitter and receiver. This channel model is used to implement real time fading observed in wireless communication system.

By considering figure 1,2,3 & 4, the model for multipath propagation will be as follows below



i^{th} Path of wireless environment in characterized by

$\rightarrow Delay\ Z_i$

$\rightarrow Attenuation\ a_i$

$a\,\partial(t - Z_i)$ Impulse shifted by Z_i

$0^{th\ path} \rightarrow a_{0,Z_0} \rightarrow a_0\partial(t - Z_0)$

$1^{st\ path} \to a_{1,Z_1} \to a_1\partial(t - Z_1)$
.
.
.
$(L-1)^{th\ path} \to a_{L-1}Z_{L-1} \to a_{L-1}\partial(t - Z_{L-1})$
$0, 1, \ldots\ldots L-1$ = Multipath Response = $h(t)$. So that, sum of individual response will be $h(t)$.
$h(t) = \sum_{i=0}^{L-1} a_i\ \partial(t - Z_i)$……………….……….(19)
Due to So that; Transmitted Signal
$S_p(t) = R_e\{S(t)e^{j2\pi F_c t}\}$……….……………….....(20)

At $0^{th} Path - a_{0,}z_0$
$R_e\{a_0\partial(t - z_0)e^{j2\pi F_c(t - z_0)}\}$
At $1^{th} path - a_1, z_1$
$R_e\{a_1\partial(t - z_1)e^{j2\pi F_c(t - z_1)}\}$
.
.
.
.
At $(L-1)^{th}\ path - a_{L-1,}Z_{L-1}$

$$R_e\{a_{L-1}\partial(t - L - 1)e^{j2\pi F_c(t - z_{L-1})}\}$$

With relationship of Doppler shift in MIMO-OFDM
Recall that; The fading Coefficient is
$h = \sum_{i-0}^{L-1} a_i e^{-j2\pi F_c Z_i}$..(21)
By considering fig 4 and with $i^{th}\ Path$

$\left(\sqrt{h_A{}^2 + \left({}^{D_T}/_2\right)^2}\right) \to$ It is a distance between transmitter and receiver which decreasing or increase as a train moving towards or away from base station due to the changes of angleθ. We took this reference of distance at a point where incidence ray or signal from two adjacent base stations.
Therefore:

$$Z_i(t) = Z_i - \frac{V\cos\theta}{C}t$$

$$h = \sum_{i-0}^{L-1} a_0 e^{-j2\pi F_c\left(Z_i - \frac{V\cos\theta}{C}t\right)}$$

$h = \sum_{i-0}^{L-1} a_i e^{-j2\pi F_C Z_i}\ e^{j2\pi F_C \frac{V\cos\theta}{C}t}$……………..(22)
But recall formula number (5) which state that,

$$F_C\frac{V\cos\theta}{C} = F_d = Doppler\ Frequency$$

So that,
$h = \sum_{i-0}^{L-1} a_i e^{-j2\pi F_C Z_i}\ e^{j2\pi F_d t}$………...……….(23)
The presence of time in the above formula, means that, changing with respect to time. So that, the channel coefficient h is time varying.
Such a time varying channel is also known as a time selective channel
$Mobility \to Doppler$
$Doppler \to Time\ varying\ channel \to Time\ Selective$

From Phase factor : $e^{j2\pi F_d t}$
$t \approx 0$,

$$\text{Phase} = 0$$

$t \approx \frac{1}{4F_d}$,
$\text{Phase} = 2\pi F_d . \frac{1}{4F_d} = \frac{\pi}{2}$………………………..(24)
This means that, Channel changed significantly from $t = 0$ to $t = \frac{1}{4F_d}$ = Coherence time of Channel.
Coherence time of Channel $= T_C$

V. SIMULATION RESULTS AND DISCUSSIONS

A. Fast Time-Varying Fading

It is obvious that in order to implement the proposed Doppler method for fast train environment, two onboardantennas are necessary, because an incident signal have a different strong power and a signal which has low power loss will be connected either at front haul or back haul.One of the main distinguishing factors of high mobility communications is the fast time-variation of the fading channel caused by the large Doppler Spread. For a wireless terminal operating at a speed of more than 500 km/h with a carrier frequency of 5 GHz, the maximum Doppler frequency is $F_D = 2314\ \text{Hz}$, which corresponds to a channel coherence time of approximately 108 microsecond. It should be noted that most wireless communication systems are designed to operate for F_D on the order of hundreds of Hz. In addition, the movement speed of the wireless terminals will change with respect to time, and this results in time-varying Doppler spreads and non-stationary fading coefficients. The non-stationary properties of the fading channel, along with the fast changing scattering environment, make it a challenging fast for the accurate modelling and analyzing of high mobility channels [22].

The Simulation was done on MAT LAB, as shown below

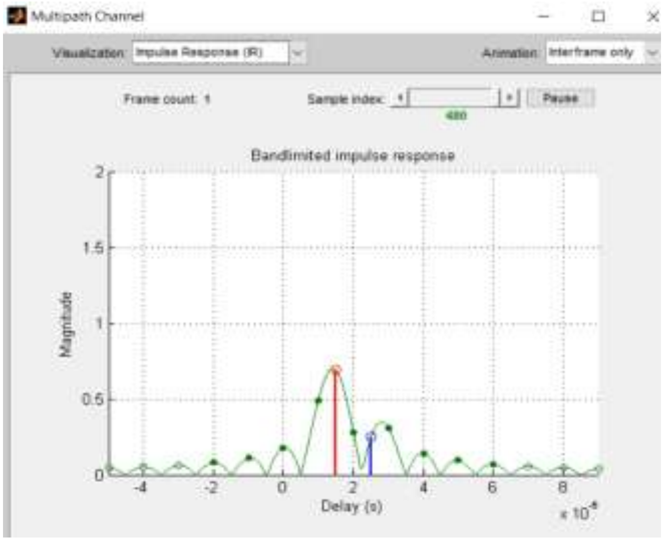


Figure 5. MATLAB results of the Magnitude of handover against transmitting time delay.

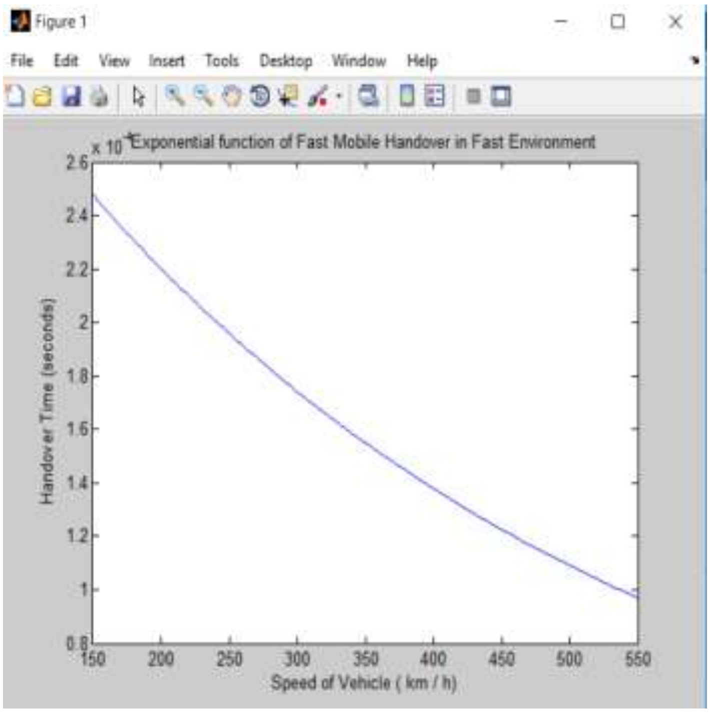


Figure 6. MATLAB results of handover time against speed.

Simulation Parameters:

Table 1.

Carrier Frequency	5 GHz
Channel Model	Rician Channel model
Speed of Train	550 km/h
Maximum Doppler Frequency	2314Hz
Height of Transmitter	30 m
Height of Receiver	10 m
Angle range from Transmitter to point of Overlapping Area	90° – 2.3°
Ground Distance From Transmitter to Receiver	Varying from 0 – 1 km
Free space path loss exponent	2

VI. CONCLUSION

The future wireless communication in high speed environment, multiple input multiple output (MIMO) Orthogonal frequency division multiplexing (OFDM) antennas must be appliedwith a carrier frequency of 5GHz and coherence time in transmitting signal. In this paper we based in rician channel model with Doppler shiftby choosing direct path or line of sight in order to reduce power loss. Since the magnitude of the impulse response shows that, time delay is in a range of free space exponent which is 2 for line of sight (rician fading). Due to that results, signal will to be connected easier in mobility connections and make handover to be completed within a short time in overlapping area as it shown in figure 6 that, with a speed of vehicle of not more than 550km/h, a handover can be completed with 108 microseconds, which means that in overlapping area when incidence ray is interchanging from the first base station to next base station as the angle changes, it will be completed because signal is transmitting with a speed of light which is 3microsecond per 1 km. But the smallest changes in time during fast handover need more researches in order to maintain stability of signal connectivity under overlapping area to escape the delay with strong signal at the receiver side.

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