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Performance Analysis for Throughput and BER in High Speed Train Broadband Wireless Mobile Communications System under Different Variable Cases

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Abstract: High Speed Trains (HST) is a wonderful way for transporting that raised more attention in wireless communication system within great speed environments. Numerous experiments of HST till 450 km/h are done around the world. The investigation of performance for standard structure design is concentrates on mobile system in the urban with respect of speediness. There are more factors that effect on the activity of this system but the most important effect is the Doppler shift frequency which becomes essential factor that corrupting the performance of the system which increases errors of received signal. The aim of this study is to demonstrate the robust of the system that is serve in HST by investigate the throughput with the Bit Error Rate (BER) for the signal that is transferred from the antenna and which error will be occurred with the same signal when it is received by the user outside or inside the train. The tests are done within different circumstances and variable cases in order to measures the powerful of this system. The results show that the system provides a high throughput with lower BER with variable parameters such as number of antennas, doppler shift frequency and reference channels.

Key words: HST, throughput, BER, reference channel, antenna, frequency

INTRODUCTION

Portable broadband communications have been widely industrialized for global transportation to reply the accumulative crowded of programs downloading. So, if the application still and never changed, these techniques will not appropriate for the requirements of HST travelers as the speed is much high and more stimulating for communication strategies (Luo *et al*., 2012). Every year, the contribution of automatic structure in numerous productions in the domain increases. The method computerization could decrease energy feeding and growth source productivity. In latest era, many hard works are done on adjusting the conservative GSM structure to High-Speed Train Communication (HSTC). It is not easy to support great-data-rate communication services, like "online video or gaming" within HST up to 450 km/h. So, within the fast growth of HST it is required to cumulative railway controlling data for security observing and conservation that is requests to be transmitted within HST (Zhang *et al*., 2014). Also, the passenger that use mobile phone request more capacity of the network and more dependable quality without depend on the position or speediness. It can be said that the current scheme "GSM-R" simply offers a supreme rate with fewer than 200 kbps. This is primarily works for railway control and cannot to occupy the necessities of upcoming great data rate transmission (Hiruta *et al*., 2009). So, an innovative wireless system is in request for HSR. Main think of design for any wideband mobile scheme is the propagation features for the channel. The dependable and accurate channel model works as the allowing basis for real-world scheme and challenging of the HSR scheme. In the real positioning of a wireless scheme, the genuine network arrangement optimization, ability and everything are applied conferring to the propagation atmosphere (Dong *et al*., 2010). The small scale fading topographies are critical in strategy which assist designer to made fading measures. This measure is variable like such as "Diversity of transmission/reception, error correction coding and interleaving and equalization procedures". So, the structures of HST channel model meaningfully vary as compare with other communication channel (Cichon *et al*., 1995). These differences originate from the following specific features of the HSR radio propagation.

Diverse scenarios. HST is regularly located on a viaduct overpass residential or rural zones. The transmitter and receiver meet altered channel surroundings. This variation contingent on topographical position, viaduct tallness, antenna location and other parameters and can be demonstrated in Fig. 1. Channel environments are categorized to more kinds such as: "Viaduct, hilly terrain and tunnel (Liu *et al*., 2012).

Line of Sight (LOS) ascendancy. The modern types of HST paths are illustrious from conservative outlines by milder curves, lower channels and broader channels. Joint

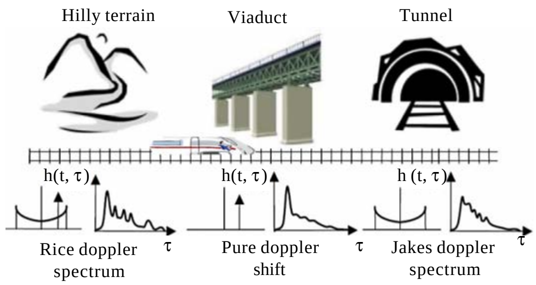

Fig. 1: Variable channel specification with different situation on HST

Fig. 2: The shape of the high speed train HST

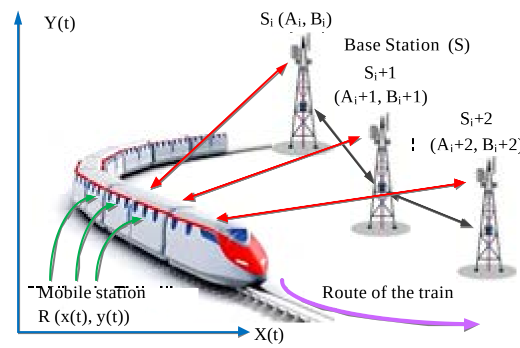

Fig. 3: The communication system between HST and base-stations

with tall antenna, these exterior situations produce a pure space to communicate. Dissimilar urban and interior situations with in these exterior situations, the specular LOS factor is robust and additional multipath reverberations happen fewer regularly among the mobile station and base-station.

Great Doppler shift and quick Doppler transition. The extreme speed of HST is currently 480 km/h. this speed lead to get "Doppler shift" of 946 Hz at 2.1 GHz. In case of the base station located remote from the train sideways. The chief aim is that the "Incident angle" among the train and the base station is about 90°. So, the base station is frequently fixed back thirty meter away from train. At once the train crosses the base station, the angle among the received signal and the movement route is altered quickly begun with 0° and end with 180°. This will lead to quick "Doppler transition" (Dimic and Sidiropoulos, 2005).

The meaning of High Speed Train (HST): The high-speed train which is shown in Fig. 2 is a flexible word. In order to know this survey, it involves schemes within the important features (Biguesh and Gershman, 2004):

- Trains aimed for continued works between 200 km/h to about 500 km/h
- Trains that deliver services among populace midpoints or urbanized zones. This service comes with some temporary end
- Trains that normally usage "Semi-permanently" coupled groups of energy engines and coaches of numerous structures
- Trains that ensure dedicate using "Rights-of-way", mainly external of stations
- Trains that utmost frequently using over-head, continually "Tensioned catenary" to take energy to trains and power engine
- Structures that using certain kind of "Automatic Train Control (ATC)" or "Positive Train Control (PTC)"

The communication system model: Dissimilar community wireless communication scheme, the system of communication that is design to works in railway is devoted to spreading control and transmitting information. The "Base Stations (Si)" are then positioned alongside the train to assurance high dependability. When making comparison to the weakening produced by "Distance and fading", the result of elevation difference on received sign is of "No account". In a actual easy method, the drawing of "Wireless communication system" for HST is shown in Fig. 3. So, the synchronize order of entirely base Stations (S) are fixed as a distinct order $\{(A_1, B_1), (A_2, B_2), \ldots, (A_i, B_i)\ldots, (A_m, B_m)\}$ in progress (Serbetli, 2008). Within real design, the tracks of the HST are never continuously straightforward. This is because certain difficulties in the route. These difficulties may be hills, rivers and woods. The situation of the "Mobile station (R)" rests on the track within train. This is signified as a "Continuous time function (x(t), y(t))". The ith base-stations are active within works in the case as (Hamdi and Pap, 2010):

$$\left(A_i, B_i\right) \min_{1<j<m} \sqrt{\left(A_j\text{-}y(t)\right)^2+\left(B_j\text{-}x(t)\right)^2} \qquad (1)$$

In calculation observation, “Discrete sequence” is a singular type of “Multi-partition function”. So, the function for the continuous time of the base station Si (A(t), B(t)) is (Suraweera *et al*., 2010):

$$\left(A(t), B(t)\right) = \left(A_j, B_j\right) \min_{1<i<m} \sqrt{\left(A_i\text{-}y(t)\right)^2 + \left(B_i\text{-}x(t)\right)^2} \quad (2)$$

To study the doppler influence as shown within Fig. 2, c(t) and e(t) are definite as” horizontal acceleration and vertical acceleration”, respectively. This are associated with topography and period between neighboring train stations. Within the physical side, the immediate velocity charted to x, y coordinate while the path angle is calculated as:

$$v_x(t) = \int_0^t e(\tau)d\tau \quad (3)$$

$$v_y(t) = \int_0^t c(\tau)d\tau \quad (4)$$

$$\theta_v = \arctan\left(\frac{v_y(t)}{v_x(t)}\right) \quad (5)$$

Therefore, the organization of R is moreover stated as a meaning of acceleration:

$$x(t) = \int_0^t v_x(\tau)d\tau = \int_0^t \int_0^\tau e(\theta)d\theta d\tau \quad (6)$$

$$y(t) = \int_0^t v_y(\tau)d\tau = \int_0^t \int_0^\tau c(\psi)d\psi d\tau \quad (7)$$

Now, the measure of angle among the received signal and the speed is:

$$\theta = \arctan\left(\frac{B(t)\text{-}y(t)}{A(t)\text{-}x(t)}\right)\text{-}\arctan\left(\frac{v_y(t)}{v_x(t)}\right) \quad (8)$$

So, Doppler shift of the straight line of site factor fs will be written as:

$$f_s(t) = \frac{\sqrt{v_y^2(t)+v_x^2(t)f}}{c} * \cos\theta \quad (9)$$

Also, the extreme Doppler spread f_{max} as:

$$f_{max}(t) = \frac{\sqrt{v_y^2(t)+v_x^2(t)f}}{c} \quad (10)$$

So, we can say that the HST situation for the check of the baseband act is “A non-fading propagation channel” with single tap. Then, Doppler shift is known by Ahmed and Arslan (2008):

$$f_s(t) = f_d \cos\theta(t) \quad (11)$$

f_d is represents the extreme Doppler frequency:

$$\cos\theta(t) = \frac{D_s /^{2\text{-}vt}}{\sqrt{D_{min}^2 + \left(D_s /^{2\text{-}vt}\right)^2}} \quad 0 \le t \le D_s /^{v} \quad (12)$$

$$\cos\theta(t) = \frac{\text{-}1.5D_s\text{+}vt}{\sqrt{D_{min}^2 + \left(\text{-}1.5D_s\text{+}vt\right)^2}} \quad D_s / v < t \le 2D_s /^{v} \quad (13)$$

$$\cos\theta(t) = \cos\theta\left(t \bmod \left(2D_s / v\right)\right) \quad t > 2D_s /^{v} \quad (14)$$

The $D_s/2$ is the original expanse of the train from base station. It is measures in meters. *v* is the speed of the train (Patzold and Nguyen, 2004).

MATERIALS AND METHODS

The hardware component of the system: The hardware components that are used for sending and receiving the information via the mobile wireless system in HST can be shown in Fig. 4. In this system, the signal will input as a block of modulation samples in which different types of modulation will be selected according to channel case (QPSK, 16QAM and 64QAM). the three types of modulation is shown in Fig. 5. That means when channel is in healthy condition the 64QAM will be apply with minimum bit error rate BER while when the channel in

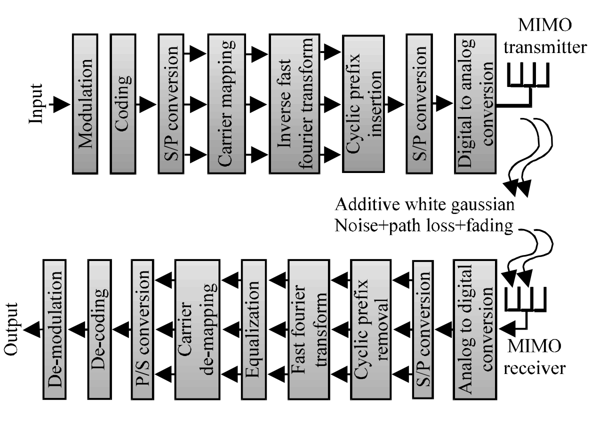

Fig. 4: The block diagram for the communication system in HST

bad condition the QPSK will be choose in order to reduce the BER. When the channel case is in the middle, the 16 QAM will be taken in order to minimize the Bit Error Rate (BER).

After that the modulated signal is moved to a next block which is the coding then the coded signal enters to serial to parallel block. Inside this block the signal is transferred to parallel form. The amount of parallel numbers corresponds to the amount of carriers in the system. Then the parallel signal pass through the new block which is subcarrier mapping in which the number of carrier will be increased. There are two types of mapping which are Localized Frequency Division Multiple Accesses (LFDMA) and Distributed Frequency Division Multiple Access (DFDMA). These two types of mapping are shown in Fig. 6.

After that the result signal enters to the important block which is the Inverse Fast Fourier Transform (IFFT). Now the signal passes through the very necessary block which is the cyclic prefix block. To explain the need for this block it can be said that When the OFDM data is serve to broadcast via. an extensive frequency, the inter signal interference is so large. This will destroy the orthogonally between subcarriers. This will produce demodulation mistakes and effect in BER. The designers supplement shield which is "Guard Interval (GI)". Though, in case of GI is unfilled, the orthogonality among sub-carriers is never longer obtainable, since of "Inter Carrier Interference (ICI)" produced by multipath. To remove the "ISI and ICI", Cyclic Prefix (CP) is put in OFDM transmission. The altered CP spans could be working in changed transmission situations (Fig. 7):

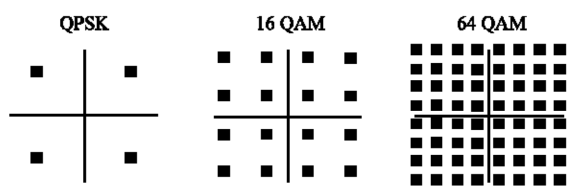

Fig. 5: The three types of modulation

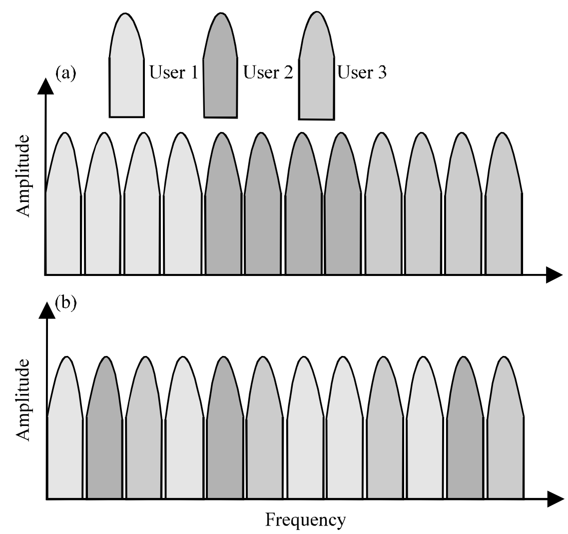

Fig. 6: The two types of subcarrier mapping: a) Localized mode and b) Distributed mode

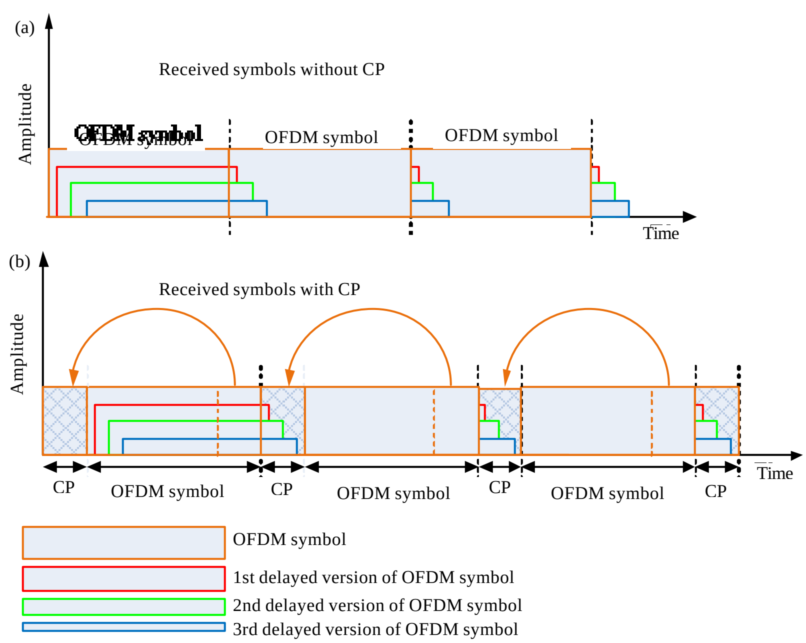

Fig. 7: The effect of adding or remove CP on the received signal

- Shorter cyclic prefix in normal-cell atmospheres to reduce the "Cyclic-prefix overhead"
- Longer cyclic prefix through risky time dispersion. In case of high speed train this type of CP is used

The process of CP is demonstrates in Fig. 7. In Fig. 7, we can understand the effect of adding CP to the symbol and how the signal loss part of the information in case of remove CP. Then the resulting signal after adding CP will be return to serial form using the parallel to serial block.

The signal now returns to analog form in order to transfer through channel to reach the receiving end. Now, the wireless channel suffering from three types of impairments which are frequency, distance and time which can be illustrated in Fig. 8. The distance impairments can be divided into three parts which are multipath fading, shadowing and path loss which is effected on power transmitted and cause the degradation as shown in Fig. 9. From Fig. 10, it can be shown that the data rate of the signal depends on the quality of the channel because when the channel is bad then error will be increased and retransmitted the signal is occurred and the data received with error will increased.

Doppler spread is additional chief test for understanding wireless broadband HST. Particularly for high speed train communication structure that depends on OFDM. The high channel differences inside one OFDM block terminate the orthogonally among subcarriers that lead to inter-carrier interference relative to the "Doppler frequency". The orthogonality means the peak point of one carrier equal to zero value of all other carriers. This rule of orthogonality between the carriers can be shown in Fig. 11.

At this time the signal reach to the receiving end and all the blocks in the transmitting will be inversed and one

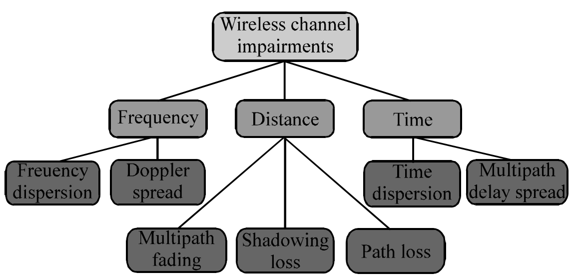

Fig. 8: The parts of wireless channel impairments

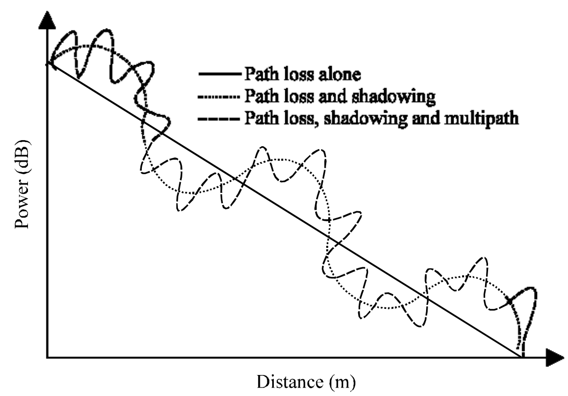

Fig. 9: The effect of distance impairments on power transmitted

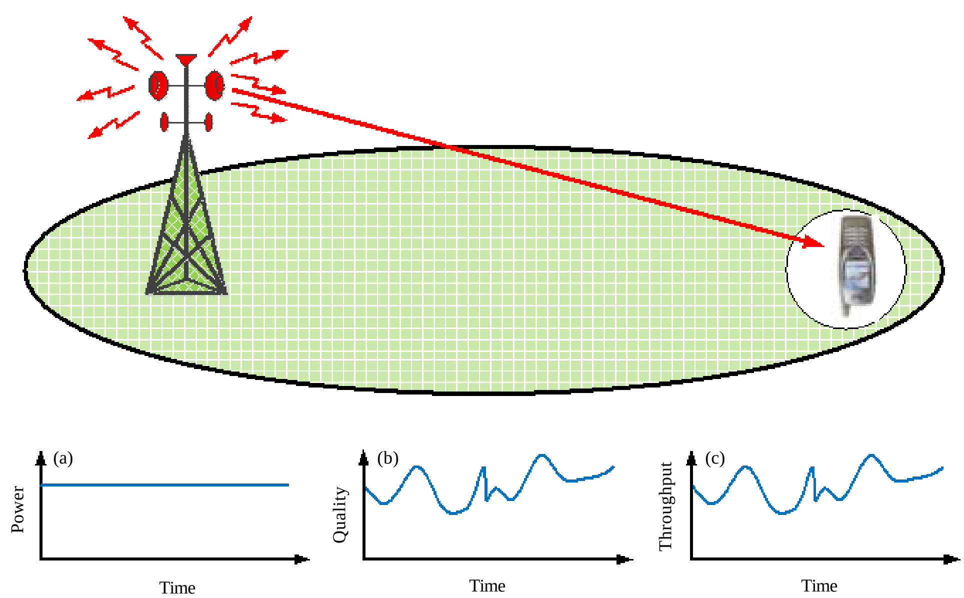

Fig. 10: The effects on channel quality on data rate of signal: a) Transmitted power; b) Channel quality and c) Date rate

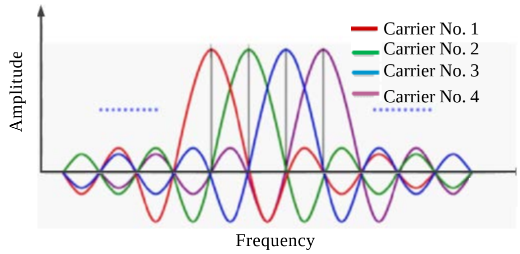

Fig. 11: The orthogonal carriers for communication system

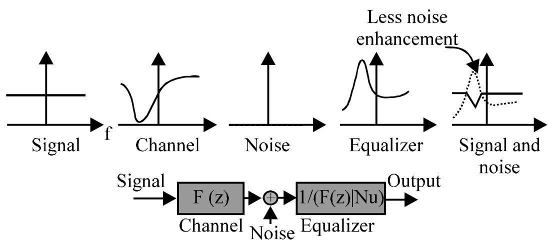

Fig. 12: The simple type of equalization used in communication system

block is adding to reduce the channel effect which is the equalization block. The purpose of equalization is to discover an opposite filter that recompenses the "ISI". So, the multipath signals turn out to be moved and allied in time. The simple type of equalization can be shown in Fig. 12.

It can be said that the design of the transceiver in the HST is robust against all types of degradation and errors that can be occurred due to the high speed and channel alteration within small period of time. So, the target of designer is to makes the BER be minimized and the throughput is maximized.

RESULTS AND DISCUSSION

In the HST, the route divided into two cases which are: the open space (case 1) which is the most case that is taken in HST while the other case is within tunnel (case 2) that is occurs within some times for small distance. The necessary values for simulation are found in Table 1. After apply the simulation the relations of Doppler shift with time for two cases are shown in Fig. 13 and 14.

In this study, the first situation which is open space (case 1) is taken in consideration. It can be said that a more amount of base station RRHs exist and dispersed in equal space or distance along the train-truck. The distance =Ds with the similar base station number as shown in Fig. 15

In the beginning, when running the simulation the trajectory of power in dB with respect to distance for

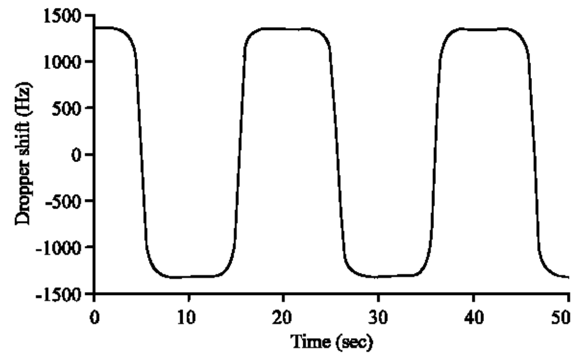

Fig. 13: The doppler shift trajectory for case 1 channel

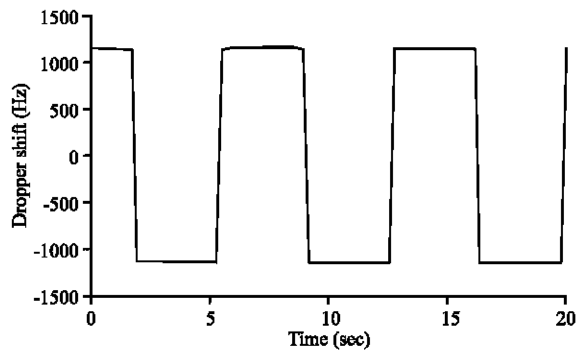

Fig. 14: The doppler shift trajectory for case 2 channel

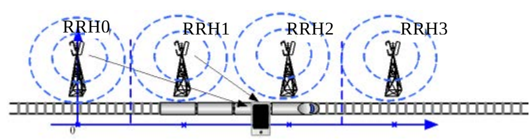

Fig. 15: The open cpace (case 1) configuration

Table 1: The value of necessary component in HST simulation with two cases of channels

Components	Case 1	Case 2
D_s	1000 m	300 m
D_{min}	50 m	2 m
v	350 km/h	300 km/h
f_d	1340 Hz	1150 Hz

different base stations RRHs which is began from the ID (-1) (RRH_{-1}) that means the train leave this base station and faraway from this base station therefore it can be seen that this power is low as compared with other base station as shown in Fig. 16. The trajectory of Doppler shift in (Hz) with distance in meter for all base station is shown in Fig. 17. Also the trajectory of absolute delay with relative delay for all base stations is shown in Fig. 18.

In this study, the behavior of the high speed train communication system is analyses within different cases with variable factors. The benefit of this study is to know the powerful and drawback points in this system,

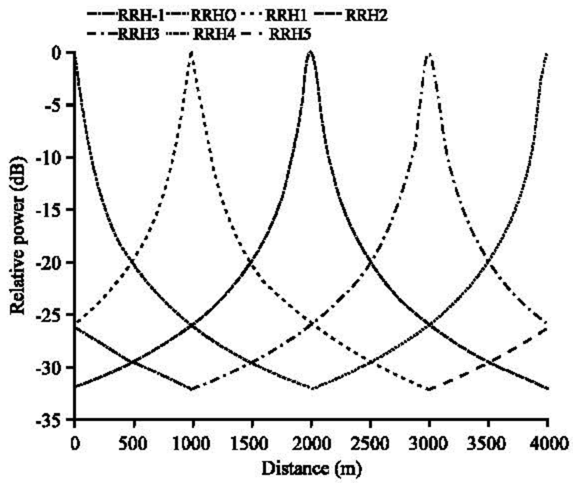

Fig. 16: The relation between relative power and distance

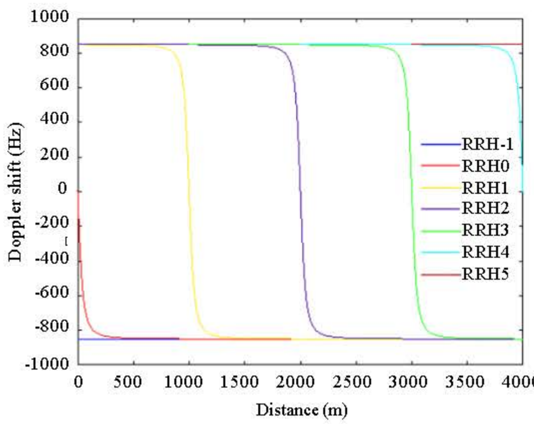

Fig. 17: The relation between doppler shift with distance

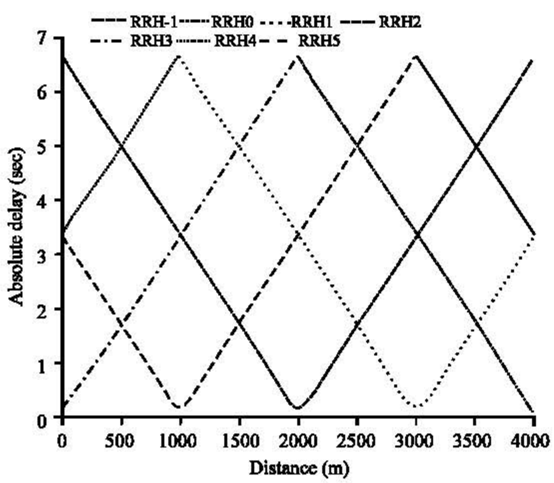

Fig. 18: The relation between bsolute delay and distance

especially, when the speed is very high and how can this system stay valid and can obtain the information with

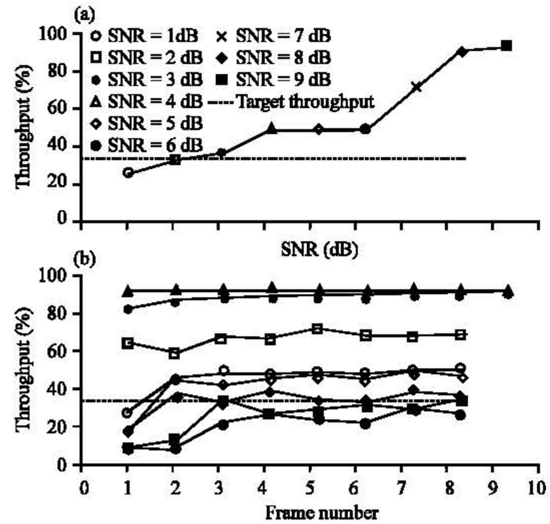

Fig. 19: The performance under the single antenna (SISO): a) Throughput vs. SNR and b) Running average throughput per frame for all SNR valuse

Table 2: The variables that is used in the simulation

Variables	Quantites			
No. of antenna	1	2	4	8
Doppler frequency (Hz)	5	70	300	750
Channel reference	R0	R1	R3	R5

minimum errors. The high speed train communication system is testes within three main variables which are: the amount of antennas used, Doppler frequency and the channel reference. All details of these factors are shown in Table 2. The main parameter that will take in comparison of performance for the system is the throughput which is the rate of successful message delivery over a communication channel. The data these messages belong to may be delivered over a physical or logical link or it can pass through a certain network node. Throughput is usually measured in bits per second (bit/s or bps) and sometimes in data packets per second (p/s or pps) or data packets per time slot. The system throughput or aggregate throughput is the sum of the data rates that are delivered to all terminals in a network. Throughput is essentially synonymous to digital bandwidth consumption; It can be analyzed mathematically by applying the queuing theory where the load in packets per time unit is denoted as the arrival rate (λ) and the throughput where the drop in packets per time unit is denoted as the departure rate (μ) (Fig. 19-30). In all figures which numbered from 19-30 it can be seen that the "Target throughput" is designed to 30% from the full amount of throughput and it can be noticed that the real throughput is increased from lower values to 100% when the amount of signal to noise ratio increased. The amount

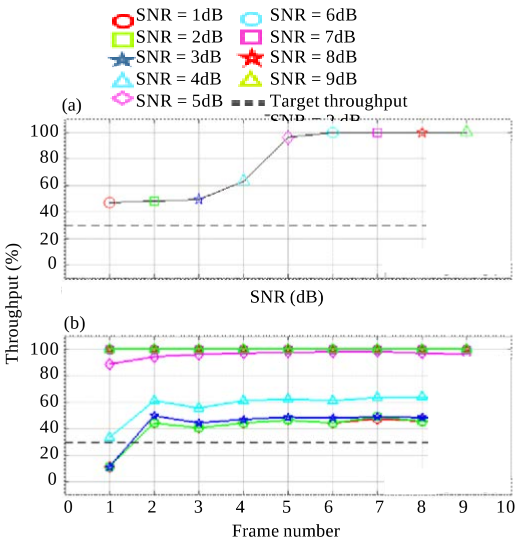

Fig. 20: The performance under the two antennas (MIMO): a) Throughput vs. SNR and b) Running average throughput per frame for all SNR value

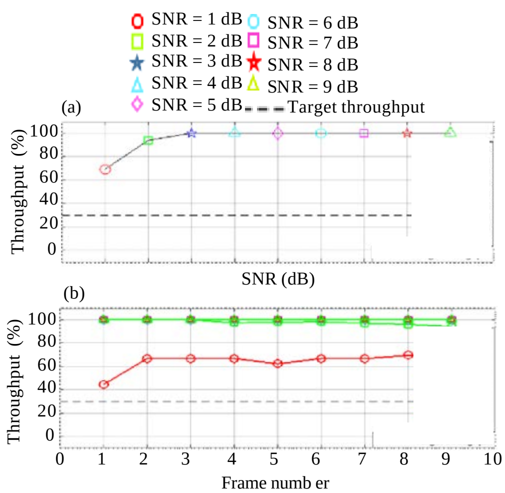

Fig. 21: The performance under the four antennas (MIMO): a) Throughput vs. SNR and b) Running average throughput per frame for all SNR value

of throughput is reach to maximum value at different amount of signal to noise ratio which differs from case to others that depends on the variables such that amount of antenna, Doppler frequency and reference channel. Within the first parameter which is the amount of antennas four values of the numbers of antennas are taken which began with single antenna until reach to eight. It can be shown that the throughput is with minimum value within the single antenna and begun with 20% from the maximum value of throughput with

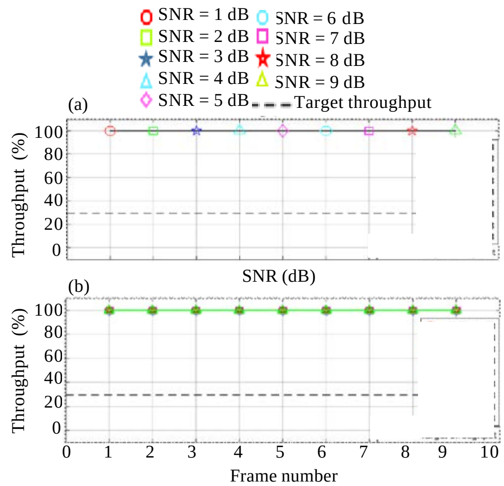

Fig. 22: The performance under the eight antennas (MIMO): a) Throughput vs. SNR and b) Running average throughput per frame for all SNR value

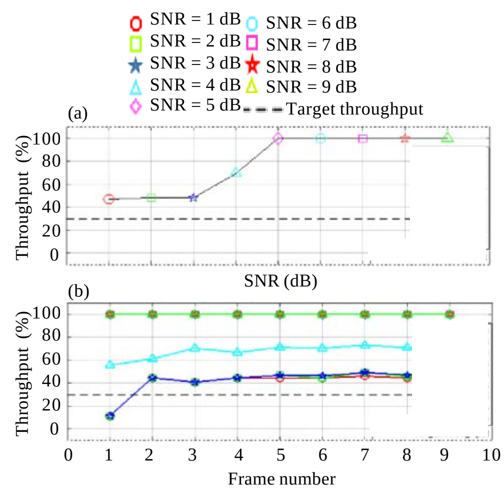

Fig. 23: The performance under doppler frequency equal to 5 (Hz): a) Throughput vs. SNR and b) Running average throughput per frame for all SNR value

SNR = 1 dB which is shown in Fig. 19 and raise until reach 100% at SNR = 8 dB. When the antenna become two antennas it can be show that the throughput begun with 47% from optimum at SNR = 1 dB as shown in Fig. 20 and reach to maximum value at SNR = 6 dB. But when the antenna increased and become four antennas the throughput will be increased and begun with 68% from optimum with SNR = 1dB as shown in Fig. 21 and become maximum value at SNR = 3 dB. The final value of changing

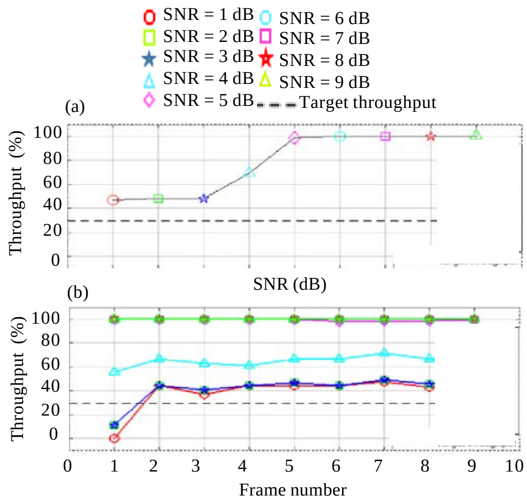

Fig. 24: The performance under doppler frequency equal to 70 (Hz): a) Throughput vs. SNR and b) Running average throughput per frame for all SNR valuse

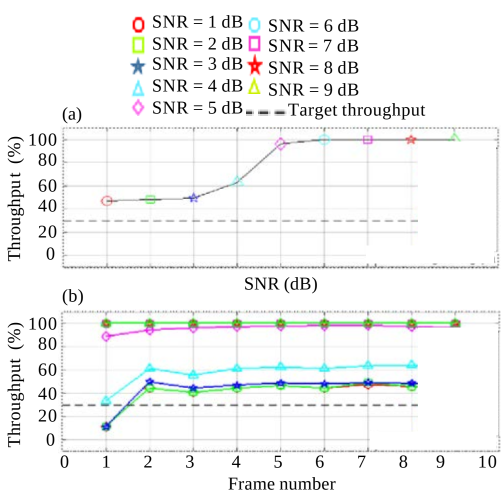

Fig. 25: The performance under doppler frequency equal to 300 (Hz): a) Throughput vs. SNR and b) Running average throughput per frame for all SNR valuse

the antenna amount is when the amounts of antenna increased and become equal to eight antennas. In this case which is the best one, it can be shown that the optimum will occurred from the beginning with SNR = 1 dB as shown in Fig. 22 and continued with optimum values for all signal to noise ratio.

The next parameter that will changes in this simulation is the Doppler frequency which relative to speed of the train and carrier frequency that is used in the

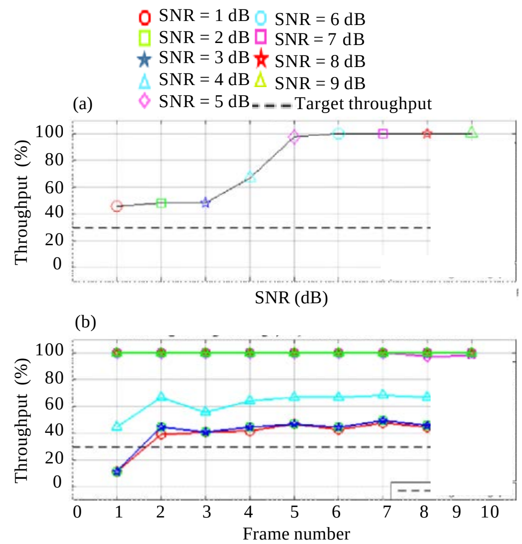

Fig. 26: The performance under doppler frequency equal to 750 (Hz): a) Throughput vs. SNR and b) Running average throughput per frame for all SNR valuse

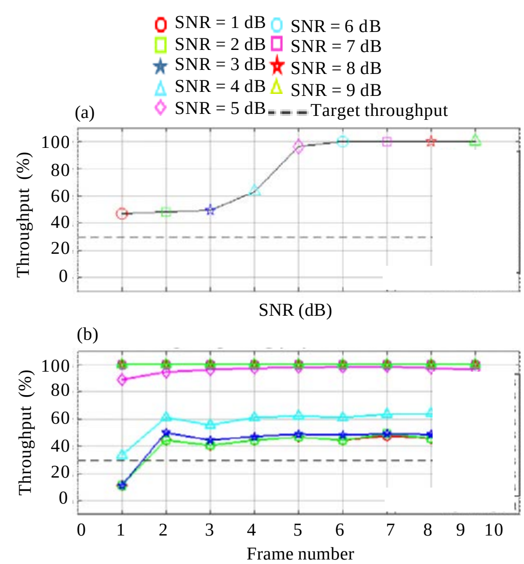

Fig. 27: The performance under the reference channel equal to R_0: a) Throughput vs. SNR and b) Running average throughput per frame for all SNR valuse

process of transmission. This parameter will take in the beginning the value of 5 Hz. In this value, it can be seen that the amount of throughput is begun with about 46% from optimum value at SNR = 1 dB as shown in Fig. 23 and increased until reach the optimum value with SNR = 5 dB. After that the Doppler frequency become

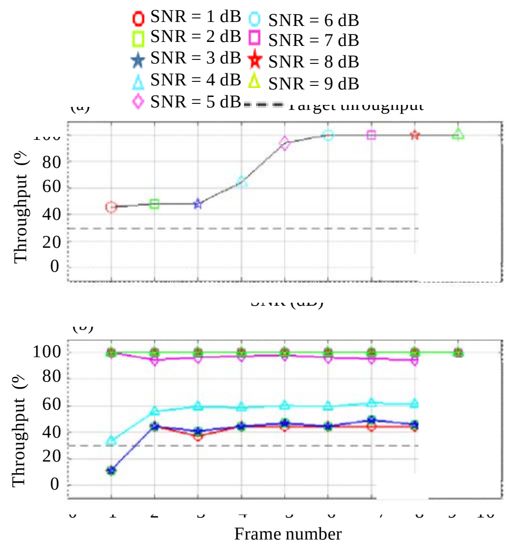

Fig. 28: The performance under the reference channel equal to R_1: a) Throughput vs. SNR and b) Running average throughput per frame for all SNR valuse

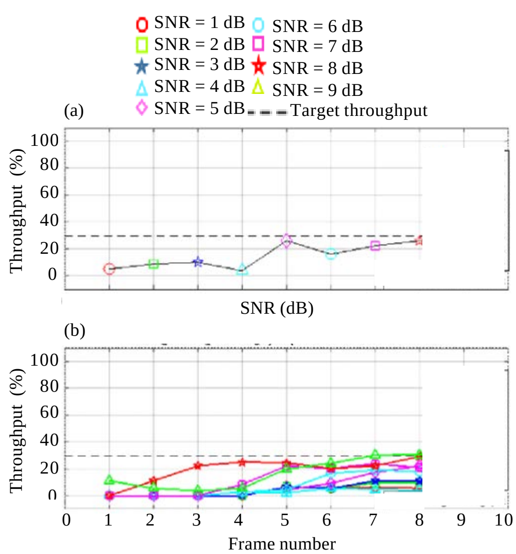

Fig. 29: The performance under the reference channel equal to R_3: a) Throughput vs. SNR and b) Running average throughput per frame for all SNR valuse

70 Hz and the throughput begun with 45% from optimum value as shown in Fig. 24 but reach the maximum value in SNR = 5.7 dB. Now, the value of Doppler frequency becomes 300 Hz and the throughput begun with value of 44% from maximum value as shown in Fig. 25 and the optimum value reach at SNR = 5.9 dB. The final value of Doppler frequency is 750 Hz. In this value the

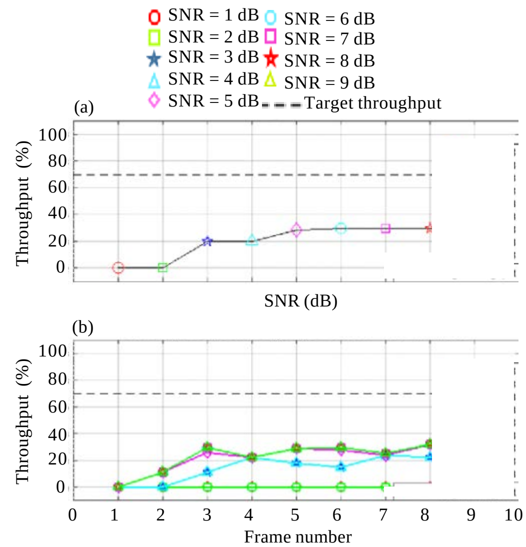

Fig. 30: The performance under the reference channel equal to R_5: a) Throughput vs. SNR and b) Running average throughput per frame for all SNR valuse

throughput begun with value of 43% from optimum value as shown in Fig. 26 and raised until reach maximum at SNR = 6 dB.

The third parameter that is taken in simulation is the reference channel. In this case four types of reference channel are taken which are R_0, R_1, R_3 and R_5. In the first reference channel which is R_0 the value of throughput is 46% from the maximum value at SNR = 1 dB as shown in Fig. 27 and reach the maximum value at 5.8 dB. In the second case when the reference channel is R_1 the throughput will began from 44% from the optimum value at 1 dB as shown in Fig. 28 and reach the maximum value at 6.1 dB. The third case when change the reference channel to R_3. In this case, the throughput start with 6% from the optimum value at SNR = 1 dB as shown in Fig. 29 and reach the 36% from the maximum value at 9 dB. The last value of reference channel is R5 in which the throughput began with 0% from maximum value at 1 dB and reach 32% from maximum value at 9 dB as shown in Fig. 30.

CONCLUSION

The high speed property for this type of train which is called (high speed train "HST") makes it more complex to deal with the circumstances that will drop the efficiency of this system. So, more than one factor will effects on the working of communication system that exist in this train. In this study, three selected factors that is govern the activity of the communication system are selected to test and show how can the throughput changes with these factors. In the first factor that is the amount of antennas used in simulation when increase the number of antennas the throughput will improved and the error will be decreased but this need robust control system on the information that will splits between the antennas in order not to mix the information and loss the data so make the tradeoff between the number of antennas and the throughput that will be gained. Within the second parameter which is the Doppler frequency when increase the Doppler frequency the throughput will be decrease and the error is increased in the signal that is transferred though the channel. It can be noticed from third parameter which is the reference channel when increase the reference channel from R_0-R_5 lead to decrease the performance of the system to lowest value within the simulation.

REFERENCES

Ahmed, S. and H. Arslan, 2008. Evaluation of frequency offset and Doppler effect in terrestrial RF and in underwater acoustic OFDM systems. Proceedings of the IEEE Conference on Military Communications (MILCOM'08), November 16-19, 2008, IEEE, San Diego, California, USA., ISBN:978-1-4244-2676-8, pp: 1-7.

Biguesh, M. and A.B. Gershman, 2004. Downlink channel estimation in cellular systems with antenna arrays at base stations using channel probing with feedback. EURASIP. J. Appl. Signal Process., 2004: 1330-1339.

Cichon, D.J., T. Zwick and W. Wiesbeck, 1995. Radio link simulations in high-speed railway tunnels. Proceedings of the 9th International Conference on Antennas and Propagation Vol. 2, April 4-7, 1995, IET, Eindhoven, Netherlands, pp: 216-219.

Dimic, G. and N.D. Sidiropoulos, 2005. On downlink beamforming with greedy user selection: Performance analysis and a simple new algorithm. IEEE. Trans. Signal Process., 53: 3857-3868.

Dong, W., G. Liu, L. Yu, H. Ding and J. Zhang, 2010. Channel properties of indoor part for high-speed train based on wideband channel measurement. Proceedings of the 5th International ICST Conference on Communications and Networking in China (CHINACOM'15), August 25-27, 2010, IEEE, Beijing, China, ISBN:978-0-9845893-3-3, pp: 1-4.

Hamdi, K.A. and L. Pap, 2010. A unified framework for interference analysis of noncoherent MFSK wireless communications. IEEE. Trans. Commun., 58: 2333-2344.

Hiruta, M., M. Nakagawa, S. Haruyama and S. Ishikawa, 2009. A study on optical wireless train communication system using mobile object tracking technique. Proceedings of the IEEE 11th International Conference on Advanced Communication Technology Vol. 1 (ICACT'09), February 15-18, 2009, IEEE, Phoenix Park, South Korea, ISBN:978-89-5519-138-7, pp: 35-40.

Liu, L., C. Tao, T. Zhou, Y. Zhao and X. Yin *et al*., 2012. A highly efficient channel sounding method based on cellular communications for high-speed railway scenarios. EURASIP. J. Wirel. Commun. Networking, 2012: 1-16.

Luo, Q., W. Fang, J. Wu and Q. Chen, 2012. Reliable broadband wireless communication for high speed trains using baseband cloud. EURASIP J. Wireless Commun. Network., 10.1186/1687-1499- 2012-285

Patzold, M. and V.D. Nguyen, 2004. A spatial simulation model for shadow fading processes in mobile radio channels. Proceedings of the 15th IEEE International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC'04) Vol. 3, September 5-8, 2004, IEEE, Barcelona, Spain, pp: 1832-1838.

Serbetli, S., 2008. A simple antenna combining framework for Doppler compensation in mobile OFDM systems. Proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing, (ICASSP'08), March 31-April 4, 2008, IEEE, Las Vegas, Nevada, USA., ISBN:978-1-4244-1483-3, pp: 3037-3040.

Suraweera, H.A., H.K. Garg and A. Nallanathan, 2010. Performance analysis of two hop amplify-and-forward systems with interference at the relay. IEEE. Commun. Lett., 14: 692-694.

Zhang, J., F. Jin, Z. Tan, H. Wang and Q. Huang *et al*., 2014. Performance analysis of high-speed railway communication systems subjected to co-channel interference and channel estimation errors. IET. Commun., 8: 1151-1157.