Study on Interferences Between Future Railway Mobile Communication System (FRMCS) and Cellular GSM in Indonesia

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Abstract. The train signaling organization in the world is developing several technologies for high-speed train, one of which is the Future Railway Mobile Communication Systems (FRMCS) technology to be implemented in the world in 2022. This paper studies FRMCS for Indonesian high-speed train and possibility of being interfered by Global System for Mobile Communication (GSM) cellular because of the use of the same or adjacent frequency bands. This paper evaluates the performance of FRMCS in Indonesia with and without interference from GSM cellular networks. The effect of interference to the FRMCS is analyzed in term of Bit Error Rate (BER) against Signal-to-Noise Power Ratio (SNR) for several given speed and inzterference levels. The evaluation was performed using the Indonesian FRMCS channel model obtained from New York University Simulation (NYUSIM), where outage probability is functioning as the best performance (lower bound). The results of this paper are the performance of FRMCS Indonesia with and without interference from GSM cellular to FRMCS signals along railroads in Indonesia, in term of BER curve of FRMCS performance and GSM-R performances. The result of this paper shows that the performance of FRMCS is better than GSM-R in the aspect of resistance to interference. The results of this paper are expected to be a reference for the implementation of FRMCS in Indonesia.

Keyword: Interference, FRMCS, GSM-R, BER, and NYUSIM

1 Introduction

Technological developments are rapidly developing telecommunications technology in the current transportation system. This also contributes to the development of railway signaling systems throughout the world. The British railroad company the Great Western Railway (GWR) first used a communication system on trains in 1838. The telegraph technology, called the "indispensable companion of railways", was used by GWR in signaling between the train and the station [1]. Initially, the signaling system on railway communications used telegraphs, flags, position lights, and semaphores. This technology survived until technology continued to develop by using color positioning lights and wireless radio[2]. Both of these technologies make the railway communication system more optimal and more efficient.

At present communication systems for railway signaling are increasingly advanced with the existence of wired and wireless technology. This signaling system is also used in the development of fast trains throughout the world. Fast train transportation in Indonesia is also

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being developed with the making of the Jakarta-Bandung fast train. The signaling system planned to be used on the fast train is the Global System For Mobile Communication - Railway (GSM-R). GSM-R technology is expected to be applied in Indonesia as well as on trains in Germany that apply it to the Berlin line to Halle / Leipzig which is the first European Train Control System (ETCS) in Europe[3]. For the frequency spectrum used GSM-R is 876 to 880 Mhz for uplinks and 921 to 925 Mhz for downlink spectrum[4]–[6].

The problem when implementing this technology is that GSM-R technology is predicted to be obsolete and end in 2030 based on what is explained by the GSM-R Industry Group[7]and will be replaced with the technology of Future railway mobile communication systems (FRMCS). The frequency prepared for FRMCS is to replace the frequency of GSM-R with additional bandwidth[8]. However, the frequency allocation has been used by several existing cellular operators. This is feared to cause interference and will disrupt the fast train communication system that will be implemented.

This paper will conduct a study on the opportunities for interference that will occur by using Indonesian GSM channels obtained from New York University Simulation (NYUSIM) and will be simulated with conditions that represent the characteristics of GSM cellular and FRMCS that produce BER values so that the effects of interference that will occur.

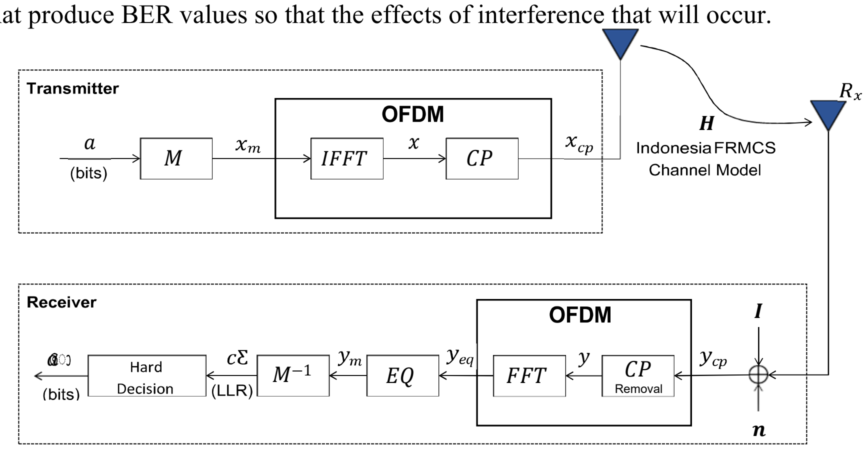


Figure 1. Block Diagram of a FRMCS simulation with interference.

2 Model System

This paper studies the wireless communication technology that will be applied to fast train signaling in Indonesia and the possibility of interference with existing commercial systems. The communication system is used to help train signaling to operate properly. At present there are two signaling systems used in the world, namely the China train control system (CTCS) and the European train control system (ETCS).

ETCS is basically an automatic train control developed by European countries by several parties that collaborate and involve industries, railway agencies, as well as command, control and signaling (CCS) experts. ETCS also functions as a fast train supervision system from trackside to transmission-based trains[9]. The ETCS system supports improved system performance and safety compared to previous systems.

CTCS is a surveillance system used for fast trains which is an adoption of the ETCS system. CTCS was proposed in 2002 which was used for the Chinese railroad by the Ministry of Railways and was developed for China's high-speed trains for technical reasons and the type of signaling applied in Europe could not be operated on the China fast train[10].

Both of these signaling support GSM-R technology which is planned to be applied to Indonesian fast trains. The GSM-R system is basically a GSM system with several special functions for the train, and different modulation techniques with GSM. In GSM-R use the Gaussian modulation technique minimum shift keying (GMSK)[11], GMSK is expressed by,

$$S(t) = \frac{1}{2}[erf\{R_a\} + erf\{R_b\}], \tag{1}$$

$$R_a = -\sqrt{\frac{2}{ln\ 2}}\pi B_{3\ dB}(t-a),$$

$$R_b = \sqrt{\frac{2}{ln\ 2}}\pi B_{3\ dB}(t+a),$$

where $S(t)$ is the result of modulation and B_{3dB} is bandwidth 3 dB[12]. GSM-R is implemented using a special base station (BS) built on the edge of the railroad tracks. However, the problem faced is the extinction of GSM-R infrastructure and technology and will end up worldwide in 2030[7]. Therefore a new technology called FRMCS was created.

To provide good communication, FRMCS is predicted to adopt 3GPP transportation technology. Using 5G[13] based technology, FRMCS will provide high data rates, lower data latency, multimedia communication, and improved communication reliability [14]. Block diagram of this simulation is generally shown in the Figure 1. In the simulation, the modulation technique used is Complex-Binary Phase Shift Keying (C-BPSK). The Binary Phase Shift Keying (BPSK) modulation in 5G NR is different from the old BPSK which only produces real value symbols, because BPSK in 5G NR produces complex value symbols (real and imaginary) so that it is called C-BPSK with the equation,

$$x = \frac{1}{\sqrt{2}}[(1-2b(i)) + j(1-2b(i))]. \tag{2}$$

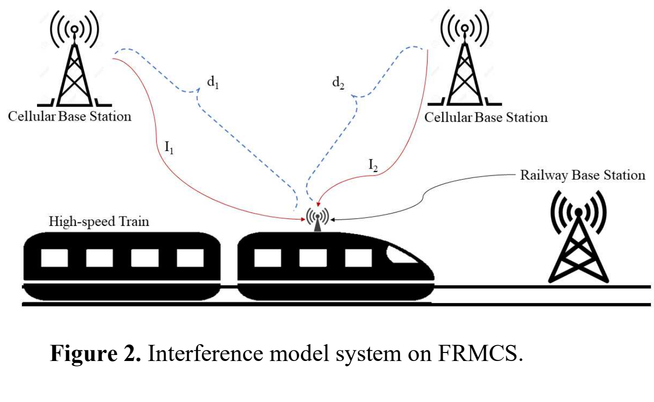


Figure 2. Interference model system on FRMCS.

The FRMCS system that will be used in fast train signaling is tested using computer simulations with certain scenarios. This paper analyzes the effects caused by interference experienced by the FRMCS system when the conditions of the train are stationary and when the train moves at high speed. This paper assumes the fast train base station is along the train line, and gets interference from cellular BTS such as Figure 2.

3 Channel Model

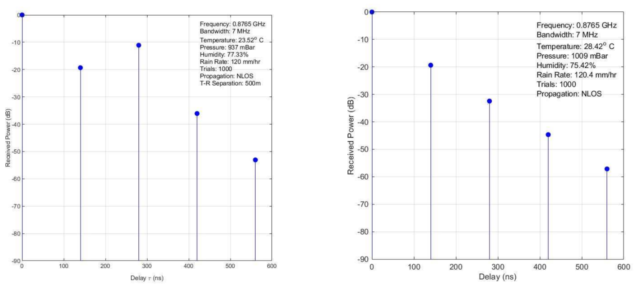
The frequency planned to be used by FRMCS is $873 - 880$ MHz for uplink and $918 - 925$ MHz for downlink[15]. Therefore, this paper uses narrowband on its channel model and uses the characteristics of Indonesian channels.

3.1 Broadband Channel

Communication systems use Broadband channels if the system uses frequency bandwidth that exceeds its coherent bandwidth. Broadband channels are used in communication systems that require high data rates[7]. The transmit power possessed by broadband is relatively small so that the resulting transmit power makes the coverage area narrow. In fast train signaling, broadband channels are used by FRMCS technology because it uses a bandwidth of 7 MHz in its working frequency.

3.2 Indonesian Channel Model

This paper uses the Indonesian channel model in the simulation. the channel used was obtained from New York University Simulation (NYUSIM) by inputting the parameters of Indonesia's environmental conditions especially the cities of Bandung and Jakarta. The environmental conditions of the cities of Jakarta and Bandung are taken from the data of the Badan Meteorologi, Klimatologi, dan Geofisika (BMKG) Indonesia in 2018. Figure 3 shows the FRMCS Indonesia channel model that has been simulated in the environmental conditions of Bandung City and Jakarta City.



(a) (b)

Figure 3. FRMCS Indonesian channel model in (a) Bandung; (b) Jakarta.

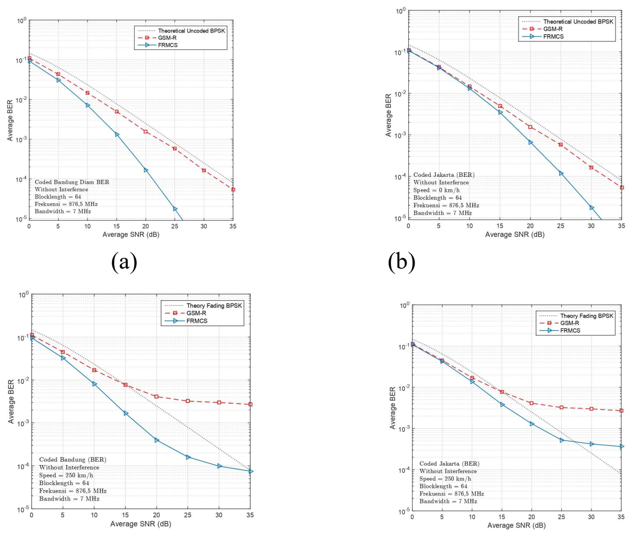
4 Performance Result

The development of fast train signaling technology in the world makes Indonesia have to adapt well. Plans for the construction of the Jakarta-Bandung fast train line are the first step in the development of fast train technology in Indonesia. In this simulation use two conditions, namely the effect of interference when the train is in a stationary state and when the train moves at high speed. This paper also evaluates GSM-R performance when it receives interference effects.

4.1 BER Performance Without Interference

The FRMCS BER performance without interference is shown in Figure 4. The result in Figure 4.a shows the performance results of FRMCS BER with the condition of Bandung when the train is stationary. The result in Figure 4.b shows the performance results of FRMCS BER with the condition of Jakarta when the train is stationary. Figure 4.a shows that BER value in Bandung of 1.75×10^{-5} for FRMCS and 5.75×10^{-4} for GSM-R obtained at $SNR 25$ dB. Figure 4.b shows that BER value in Jakarta of 1.00×10^{-4} for FRMCS and 5.75×10^{-4} for GSM-R obtained at $SNR 25$ dB.

The result in Figure 4.c shows the performance results of FRMCS BER with the condition of Bandung when the train is moves at high-speed $v = 250$ dB. The result in Figure 4.d shows the performance results of FRMCS BER with the condition of Jakarta when the train is moves at high-speed $v = 250$ dB. Figure 4.c shows that BER value in Bandung of 0.85×10^{-4} for FRMCS and 2.2×10^{-3} for GSM-R obtained at $SNR 25$ dB. Figure 4.d shows that BER value in Jakarta of 5.95×10^{-4} for FRMCS and 2.2×10^{-3} for GSM-R obtained at $SNR 25$ dB.



(a) (b)

(c) (d)

Figure 4. BER performance with channel coding (repetition codes) and without interference when the train is stationary $v = 0$ km/h in (a) Bandung, (b) Jakarta, and when train is moves at hig-speed $v = 250$ km/h in (c) Bandung, (d) Jakarta.

4.2 BER Performance With Interference Power $I = -20$ dB

The FRMCS BER performance with interference power $I = -20$ dB is shown in Figure 5. The result in Figure 5.a shows the performance results of FRMCS BER with the condition of Bandung when the train is stationary. The result in Figure 5.b shows the performance results of FRMCS BER with the condition of Jakarta when the train is stationary. Figure 5.a shows that BER value in Bandung of 4.5×10^{-4} for FRMCS and 2.1×10^{-3} for GSM-R obtained at $SNR25$ dB. Figure 5.b shows that BER value in Jakarta of 1.85×10^{-3} for FRMCS and 2.1×10^{-3} for GSM-R obtained at $SNR25$ dB.

The result in Figure 5.c shows the performance results of FRMCS BER with the condition of Bandung when the train is moves at high-speed $v = 250$ dB. The result in Figure 5.d shows the performance results of FRMCS BER with the condition of Jakarta when the train is moves at high-speed $v = 250$ dB. Figure 5.c shows that BER value in Bandung of 8.2×10^{-4} for FRMCS and 5.00×10^{-3} for GSM-R obtained at $SNR25$ dB. Figure 5.d shows that BER value in Jakarta of 2.43×10^{-3} for FRMCS and 5.00×10^{-3} for GSM-R obtained at $SNR25$ dB.

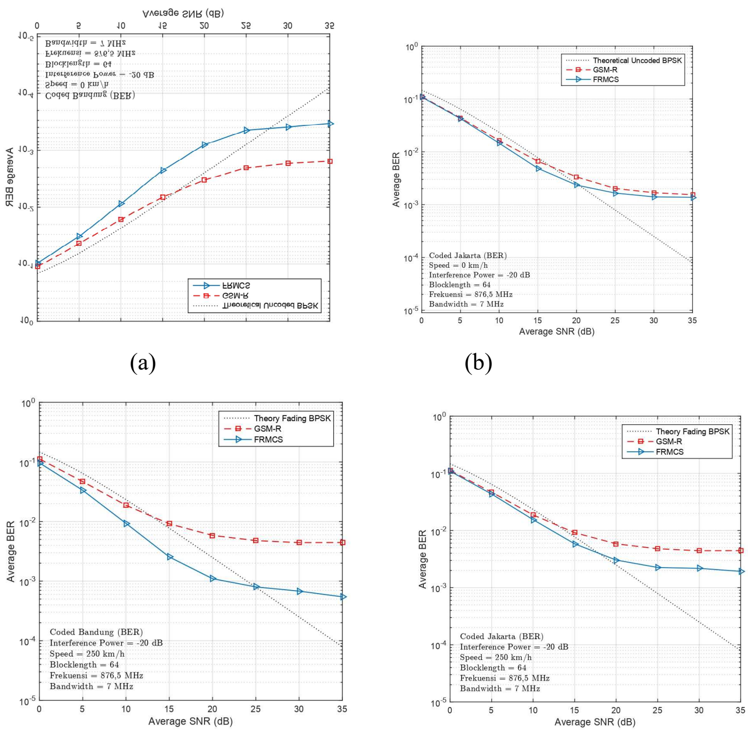


Figure 5. BER performance with channel coding (repetition codes) and with $I = -20$ dB when the train is stationary $v = 0$ km/h in (a) Bandung, (b) Jakarta, and when train is moves at hig-speed $v = 250$ km/h in (c) Bandung, (d) Jakarta.

4.3 BER Performance With Interference Power $I = -10$ dB

The FRMCS BER performance with interference power $I = -10$ dB is shown in Figure 6. The result in Figure 6.a shows the performance results of FRMCS BER with the condition of Bandung when the train is stationary. The result in Figure 6.b shows the performance results of FRMCS BER with the condition of Jakarta when the train is stationary. Figure 6.a shows that BER value in Bandung of 1.45×10^{-2} for FRMCS and 1.65×10^{-2} for GSM-R obtained at $SNR 25$ dB. Figure 6.b shows that BER value in Jakarta of 1.55×10^{-2} for FRMCS and 1.65×10^{-2} for GSM-R obtained at $SNR 25$ dB.

The result in Figure 6.c shows the performance results of FRMCS BER with the condition of Bandung when the train is moves at high-speed $v = 250$ dB. The result in Figure 6.d shows the performance results of FRMCS BER with the condition of Jakarta when the train is moves at high-speed $v = 250$ dB. Figure 6.c shows that BER value in Bandung of 1.65×10^{-2} for FRMCS and 1.95×10^{-2} for GSM-R obtained at $SNR 25$ dB. Figure 6.d shows that BER value in Jakarta of 1.85×10^{-2} for FRMCS and 1.95×10^{-2} for GSM-R obtained at $SNR 25$ dB.

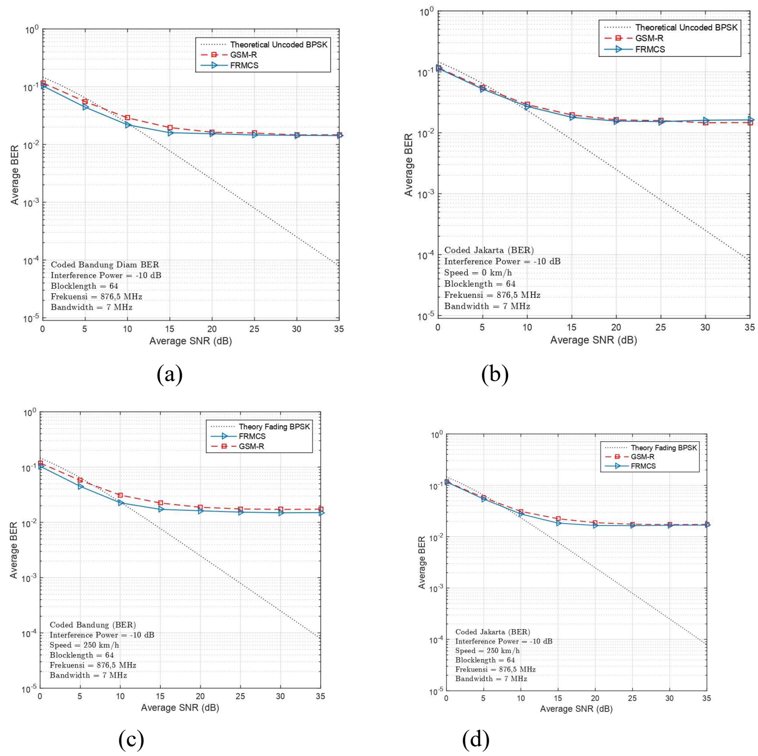


Figure 6. BER performance with channel coding (repetition codes) and with $I = -10$ dB when the train is stationary $v = 0$ km/h in (a) Bandung, (b) Jakarta, and when train is moves at hig-speed $v = 250$ km/h in (c) Bandung, (d) Jakarta.

5 Conclusion

This paper has studied high speed train signaling systems using FRMCS technology. The technology is analyzed numerically using a series of computer simulations with environmental conditions of Indonesia, especially the cities of Jakarta and Bandung. The simulation results in this paper show that the system uses channel coding (repetition codes), FRMCS performance is better than GSM-R. This shows that the performance of FRMCS is more reliable to interference compared to GSM-R. This paper also found that the interference effect has a greater effect than the speed effect.

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