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# 각도 효과를 고려한 디지털 HD Radio 시스템에서의 간섭 분석

## Interference Analysis of Digital HD Radio System considering Angular Effect

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**요약** 무선통신 기술의 발전으로 인해 디지털 라디오 시스템은 아날로그 방송으로 대체되고 있다. In-band 디지털 라디오 시스템은 기존의 아날로그 라디오 주파수를 사용하기 때문에, 기존 방송과의 간섭이 발생할 수 있다. 따라서 디지털 방송을 위해 효과적인 간섭분석은 매우 중요하다. 이 논문에서는 디지털 라디오 시스템의 SINR과 BEP(bit error probability)를 분석하기 위해 각도 효과를 고려한 방법을 제안한다. 여기서 각도 효과는 송신기 주변에 다양한 방향에 수신기가 위치해 있을 때 간섭을 분석할 수 있는 방법을 의미한다. 분석 결과들은 디지털라디오 방송망을 배치하기 위한 기본 정보로 활용될 수 있다.

**Abstract** In the current wireless communication technology, the digital radio system replaces the analog radio broadcasting. Since the in-band digital radio systems are used in the existing analog radio frequency band, interference problems of digital radio are caused. It is important to effectively analyze the interference. In this paper, to analyze SINR and BEP (bit error probability) of digital radio system, we propose the analysis method considering angular effect. The angular effect means a method to analyze the interference when the receiver is located in different directions around the transmitter. These results are able to give basic information for the allocation of digital radio networks.

**Key Words :** Digital Radio, angular effect, SINR, BEP

### 1. Introduction

The digital radio system is a radio broadcast technology that spotlights in the world, because it has been proven many benefits. Therefore, the digital radio broadcasting has started in many countries including the U.S. and Europe<sup>[1]-[3]</sup>. However, digital radio

broadcasting must analyze and handle it effectively, because there is the interference with existing broadcast and comparable channels<sup>[4][5]</sup>. In existing papers, most of the researches tend to analyze only the performance about factor of distance between the receiver and the interferer<sup>[6]</sup>. In this paper, we analyze the various interference effects including the angle

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elements, as well as distance. This technique has an advantage to analyze the performance of the system, when a receiver accesses from multiple directions. Finally, the repeater stations can be effectively deployed to consider the density of the listener.

This paper is organized as follows: Section 2 presents the geometric model considering angular effect and proposes the analytic method of SINR and BEP. The simulations of proposed scheme are presented in section 3. Finally, our conclusions are given in section 4.

## II. Analytic Approach of the Proposed Model

The analytic modeling is composed of three parts; a geometric model, an interference effect analysis and a bit error probability (BEP) analysis.

### 1. Geometric Model

Fig. 1 shows the geometric model on a digital radio environment. The distance ( $r$ ) between repeater station 1 (RS1) and repeater station 2 (RS2) can be obtained easily because their positions are generally fixed. If the receiver to listen to the signal of RS1 exists, the RS2 serves as the source of interference.

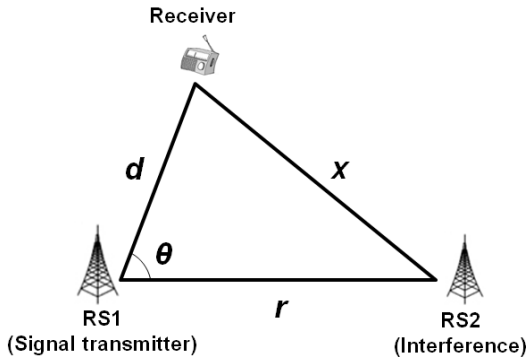


그림 1. 디지털라디오 시스템을 위한 geometric model  
Fig. 1. Geometric model for digital radio system

In this situation, the distance ( $x$ ) between the receiver and the source of interference can be given as

$$\begin{aligned} x &= (d^2 \sin^2 \theta + (r + d \cos \theta)^2)^{1/2} \\ &= (d^2 \sin^2 \theta + d^2 \cos^2 \theta + r^2 - 2rd \cos \theta)^{1/2} \\ &= (d^2 + r^2 - 2rd \cos \theta)^{1/2}. \end{aligned} \quad (1)$$

The distance ( $x$ ) is represented by following relationship: the distance ( $d$ ) between RS1 and the receiver; the distance ( $r$ ) between two repeater stations; and angle  $\theta$ .

### 2. Interference effect analysis

SINR is calculated to analyze interference from a receiver in the geometric model of Fig. 1.

$$SINR = \frac{P_S}{kTB P_I}. \quad (2)$$

In (2),  $k$  is the Boltzmann constant ( $1.38 \times 10^{-20} mW/K$ ),  $T$  is noise temperature of a receiver and  $B$  is the bandwidth.  $P_S$  is the received power from the RS1 signal and given as

$$P_S = P_{RS1} + G_{RS1} + G_r - L_S(d, f) \text{ dBm} \quad (3)$$

where  $P_{RS1}$  is the transmission power of RS1,  $G_{RS1}$  is the antenna gain of RS1 and  $G_r$  is the antenna gain of the receiver. If the radio channel is applied to the free-space pathloss, the propagation loss ( $L$ ) is given as

$$L_S = 20 \log_{10}(d_{km}) + 20 \log_{10}(f_{MHz}) + 32.45 \text{ dB}. \quad (4)$$

The free-space path loss is expressed as the relationship between a distance and frequency.

The interference power ( $P_I$ ) is the received power from RS2 signal and given as

$$P_I = P_{RS2} + G_{RS2} + G_r - L_I(x, f) \text{ dBm} \quad (5)$$

where  $P_{RS2}$  is the transmission power of RS2 and  $G_{RS2}$  is the antenna gain of RS2.  $L_I$  is the propagation loss between the RS2 and the receiver. It is applied to equation (4) equally.

In (2),  $kT$  is as follows at room temperature.

$$\begin{aligned} kT &= 1.38 \times 10^{-20} \times 290 [K] \\ &= 4.002 \times 10^{-18} \cong -174 [dBm/Hz] \end{aligned} \quad (6)$$

Thus, SINR is obtained by the following as

$$\begin{aligned} \left( \frac{S}{N+I} \right)_{dB} &= P_S - k - T - B - P_I \\ &= P_{RS1} + G_{RS1} + G_r - \\ &\quad L_S(d, f) - 174 - B - P_{RS2} \\ &\quad - G_{RS2} - G_r + L_I(x, f) \quad dB. \end{aligned} \quad (7)$$

If all of the antenna gains are 0dBi and  $x$  is substituted with the equation (1), the equation (7) can be written by

$$\begin{aligned} \left( \frac{S}{N+I} \right)_{dB} &= P_{RS1} - L_S - 174 - B - P_{RS2} \\ &\quad + L_I((d^2 + r^2 - 2rd \cos \theta)^{1/2}, f) \quad dB. \end{aligned} \quad (8)$$

Finally, if there is no distance information between a receiver and a source of interference, we can get SINR using the equation (8). In addition, we can draw results according to the change of angle  $\theta$ .

### 3. Bit Error Probability (BEP) analysis

We analyze bit error that is the main cause of degradation in the quality of digital communications and evaluate the BEP performance according to the change of angle  $\theta$ . If the modulation is DPSK, BEP is suggested by

$$P_b = P_b(\gamma) = \frac{1}{2} e^{-\gamma}, \quad (9)$$

where  $\gamma$  is energy per bit ( $E_b$ ) to noise power spectral density ratio. The noise power divides the interference effect and AWGN component. Therefore,  $\gamma$  is as follows.

$$\gamma = \frac{E_b}{N_I + N_0} = \frac{E_b}{\frac{P_I}{B} + N_0}, \quad (10)$$

where  $N_I$  is the interference power ( $P_I$ ) normalized to a bandwidth of 1Hz. Thus,  $N_I = P_I/B$ .

Finally, BEP is given as

$$P_b(\gamma) = P_b \left( \frac{E_b}{\frac{P_{RS2} G_{RS2} G_r}{B \cdot L_I((d^2 + r^2 - 2rd \cos \theta)^{1/2}, f; dB)} + N_0} \right). \quad (11)$$

## III. Simulation Results

The major parameters for a simulation are the following: a center frequency of 103.5 MHz; the transmission power of RS1 and RS2 is 100W; an antenna gain ( $G_{RS1}$ ,  $G_{RS2}$ ,  $G_r$ ) is assumed to be 0dBi; the path loss model is a free space model.

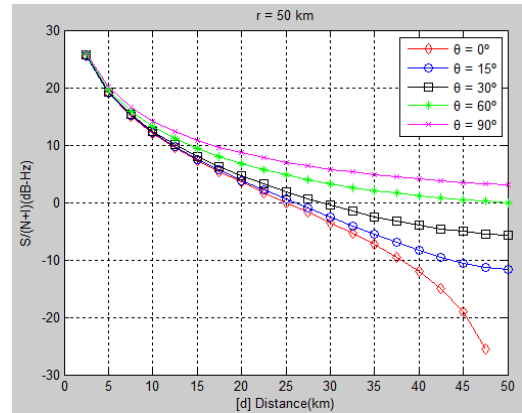


그림 2. 다양한 각도( $\theta$ )에서 거리( $d$ )에 따른 SINR 결과. 거리( $r$ ) = 50km

Fig. 2. Results on SINR versus distance ( $d$ ) from various angles ( $\theta$ ). The distance ( $r$ ) is 50km.

Fig. 2 is SINR drew by the alteration of the distance ( $d$ ) between the RS1 and the receiver. The distance ( $r$ ) between the RS1 and the RS2 is fixed at 50km. If the angle  $\theta$  is  $0^\circ$ , RS1, receiver and RS2(interference) are placed on the line. According to the result, the

interference effect is the least when the angle is  $90^\circ$

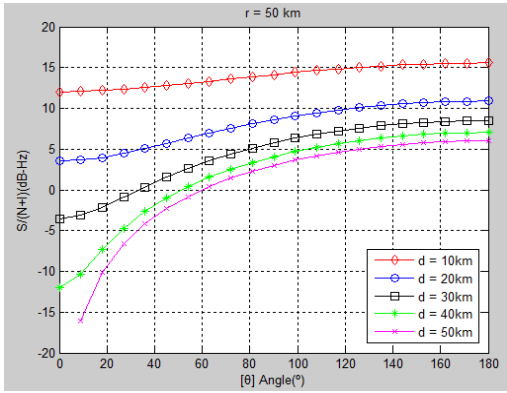


그림 3. 다양한 거리(d)에서 각도( $\theta$ )에 따른 SINR 결과. 거리( $r$ ) = 50km  
 Fig. 3. Results on SINR versus angles ( $\theta$ ) from various distance ( $d$ ). The distance ( $r$ ) is 50km.

Fig. 3 is SINR drew by the alteration of the angle. The distance ( $r$ ) between two RSs is also fixed at 50km. The degradation of SINR is the least when the distance ( $d$ ) between the RS1 and the receiver is 10km. The interference effect by the angle changes is less because distance of the RS1 and receiver is relatively close. On the other hand, SINR loss is greatest when both distance ( $d$ ) and distance ( $r$ ) is 50km.

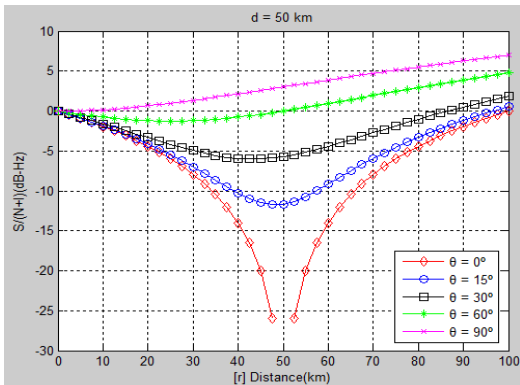


그림 4. 다양한 각도( $\theta$ )에서 거리( $r$ )에 따른 SINR 결과. 거리( $d$ ) = 50km  
 Fig. 4. Results on SINR versus distance ( $r$ ) from various angles ( $\theta$ ). The distance ( $d$ ) is 50km.

Fig. 4 is SINR drew by the changes of the distance ( $r$ ) between two RSs. The distance ( $d$ ) is fixed at 50km. SINR is the highest when the angle is the largest ( $\theta = 90^\circ$ ). However, the fluctuation of SINR is heavy when the angle is  $0^\circ$ . If the angle is  $0^\circ$  and the distance ( $r$ ) is 50km, the position of the receiver and RS2(interference) are the same. Therefore, the SINR performance decreases extremely.

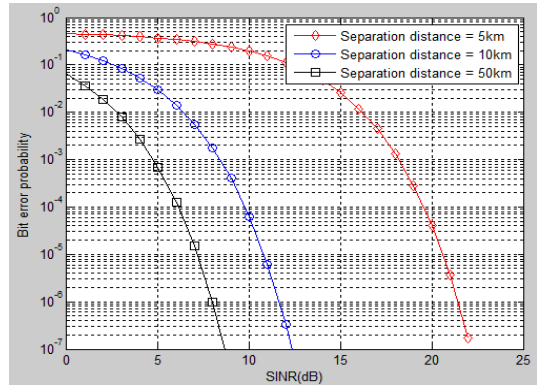


그림 5. 이격 거리와 SINR 변화에 따른 BEP 결과  
 Fig. 5. Results on BEP versus SINR and separation distance

Fig. 5 is the bit error probability by the changes of SINR. The separation distance means the interval between the receiver and RS1. In this situation, SINR is changed by movement of RS2. The results show that, as the separation distance decreases, the BEP performance is increased.

In summary the results, if angle  $\theta$  is  $90^\circ$ , the performance is the best. It implies that the separation distance between the receiver and the interference source keeps always, because the receiver and RS2 are placed vertically with RS1 as the center. Consequently, if the repeater station is placed considering the density of the receiver, the system performance can be improved by setting the angle above  $90^\circ$ .

## V. Conclusion

Since the in-band digital radio systems are used in

the existing analog radio frequency band, interference problems of digital radio are caused. In this paper, we investigated the interference analysis of digital radio system. In the simulation result, we get various results as SINR and BEP considering the angular effect. This analytic method can overcome the monotony in existing analytic method. In addition, the presented result offers information for placement of radio station considering receiver accesses from multiple directions. Finally, the repeater stations can be more effectively deployed to use this method and to consider the density of the listener.

### References

- [1] ETSI EN 300 401, "Radio broadcasting systems: digital audio broadcasting(DAB) to mobile, portable and fixed receivers," ETSI, Tech. Rep., June 2006.
- [2] Y.J. Lee, J. Seo, S. Beack, D. Jang, K. Kang, J. Kim, and J. W. Hong, "Design and Development of T-DMB Multichannel Audio Service System Based on Spatial Audio Coding," ETRI Journal, vol. 31, no. 6, pp. 795-802, December 2009.
- [3] iBiquity Digital, "HD Radio TM air interface design description series," August 2007.
- [4] ETSI ES 201 980 V2.2.1, "Digital radio mondiale (DRM) system specification," ETSI, August 2009.
- [5] Y.-T. Lee et al, "Laboratory test results of digital radio technologies: DAB, DAB+, T-DMB audio and HD Radio," Proc. 2010 NAB BEC, April 2010.
- [6] Lourens, J.G and Weber, D.M., "Measuring audio SNR on digital broadcast systems," Broadcasting, IEEE Transactions on, vol.40, no.2, pp.98-101, Jun 1994.

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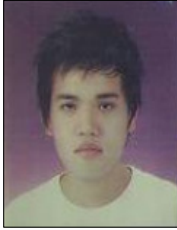
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