Interference Evaluation between competiting Wideband CDMA systems

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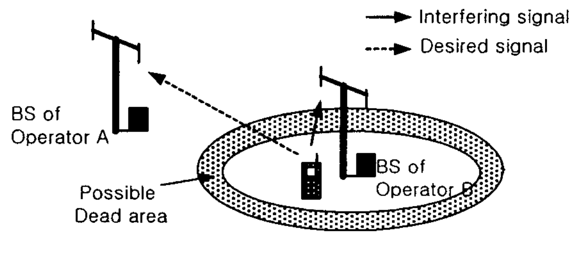
Abstract: In this paper, we evaluate the interference statistics between the competiting wideband CDMA systems, and optimize the frequency coordination between Wideband-CDMA systems by the Monte-Carlo methodology. We develop the simulator to analyze the radio interference between CDMA systems. It can calculate or estimate the probability of interference from adjacent frequency band, which is also power controlled. We simulate the interference effects between two Wideband CDMA systems. We present the required carrier distance and zone for two operators to meet the required coverage efficiency and outage probability of Signal to interference plus noise ration (SINR).

1. Introduction

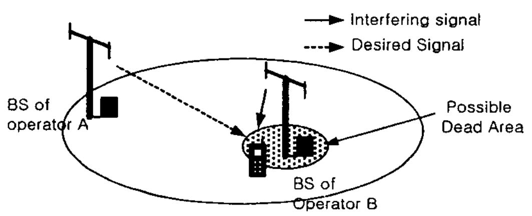
The rapid growth of wireless mobile communications is expected for mobile service providers to offer wide range of services. Wideband Code Division Multiple Access (W-CDMA) technology would be the most promising candidate for the future service [1][2] among the proposed radio interface specifications for IMT-2000. As CDMA system is the interference limited system, it is necessary for us to estimate or calculate the interference from other users in order to get the accurate real capacity. Even if there are investigation on the interference statistics of CDMA system under power control in [4] [5], it only deals with the power controlled interference phenomena for many users but limited environment.

There are two factors that affect the radio interference. One is the spurious requirement of the transmitter side and the other is the physical location of the each operator's cell. The former is well defined through the sincere investigation but the latter is renderd to operator's hamonization. We describe the latter case in figure 1 in detail. Even if we define the transmitter's spurious requirement tightly, there could be the strong signal from the adjacent frequency due to the different location of cell. It will increase the interference level in the desired user's receiver and finally make it nonlinear operation.

If both cells from different operators using the adjacent spectrum donot colocate, there must be near-far problem in both links between the transmitter from one operator and the receiver from other. In reverse link, mobile station with communicating with operator A come close to operator B, cell receiver of operator B receives the strong interference from adjacent band due to high power transmission of the mobile station, and eventually reduces the service area of operator B's cell. In forward link, mobile station with communicating with operator A come close to operator B, the mobile station's receiver receives the strong interference from adjacent band due to high power transmission from the operator B's cell, and eventually there will be the shadow region nearby in the operator B's cell.



(a) Reverse link



(b) Forward Link

Fig. 1. Interference modeling between different operatord using the adjacent frequency bands.

In this paper, We simulate the interference effects between two wideband CDMA systems. We present and propose the required carrier distance and zones for two systems to meet the required outage probability. It should be the percentage of the number of mobiles whose signal to interference plus noise ratio (SINR) don't meet the required SINR. It is mainly because the interferer from adjacent frequency band of the same or other operator increases the interference level. We present other effects in the radio environment such as out of band emissions and receiver blocking between two systems [6] [7].

2. Monte Carlo Simulation

The interference is the critical factor to system capacity and quality in the commercial radio communication system. Even if the interfering system and the interfered system donot use the same frequency, the out-of-band emmission of the interfering system, the receiver blocking of the interfered system or the intermodulation cause the interference between the systems. Therefore, we need a method to carefully define those charateristics to limit the interference. It is necessary to build the statistical model because the received signal and the interfering signal shows the random process.

Concretally, it is possible to solve the near-far problem in single operator system by using the power control, but it is nearly impossilbe in the multi-operator case. The worst scenario is the case that a cell of a operator is located on the cell boundary of another operator's cell. There are, in general, two solutions for the problem, guard band and guard zone.

2.1 Interference Modeling

When we consider the DS-CDMA systems using different frequecny, we can define SINR by equation (1)

$$SINR = \frac{S}{I_N + I_{SC} + I_{OC} + I_{OF}} \quad (1)$$

S and I_N is the desired user's received signal strength and thermal noise of the receiver, respectively. I_{SC}, I_{OC}, and I_{OF} is the interference from same cell, adjacent cell and adjacent band, respectively.

2.2 Interference modeling in forward link

Supposing that total received power from the desired cell at mobile station is $S_{O,R}$, and the received power from the first multipath componet is $S_{O,l}$, we can define β_l and α as equation (2).

$$\beta_l = \frac{S_{O,l}}{S_{O,R}}, \alpha = \frac{S}{S_{O,R}} \quad (2)$$

Where, β_l is the ratio of the received signal from the first multipath component to total received signal, α is the ratio of the desired received signal of a mobile station to total received signal. Therefore, the desired receiverd signal power from the first multipath component is $\alpha\ \beta_l\ S_{O,R}$. Also, the same cell interference power from the first multipath component is defined as equation (3).

$$I_{SC,l} = \sum_{k \neq l} S_{O,k} = S_{O,R} \sum_{k \neq l} \beta_k = S_{O,R}(1-\beta_l) \quad (3)$$

As the received power from the adjacent cell is not as orthogonal as the same cell case, the interference from adjacent cell is added as equation (4). Assuming that the transmit power of i' th cell is $S_{i,T}$, the adjacent cell's interference power at j-th mobile station's received power is defined as equation (4).

$$I_{OC,j} = \sum L_{j,i'} S_{i',T} \quad (4)$$

Where, $L_{j,i'}$ is the path loss between the j-th mobile station and the i-th cell .

The interference from adjacent spectrum is derived similar way as the derivation of adjacent cell's interference. If the transmit power of i-th cell using the different frequency is $S_{i',T}$, the received interference at j-th mobile station is defined as equation (5).

$$I_{OF,j} = \rho_F \sum L_{j,i'} S_{i',T} \quad (5)$$

Where, $L_{j,i'}$ is the path loss between the j-th mobile station and the i-th cell . ρ_F is the interference ratio of adjacent frequency band in forward link.

2.3 Interference modeling in Reverse link

Assuming that there is N users per a cell and a perfect power control is accomplished, we could describe the same cell interference in reverse link as equation (6).

$$I_{SC} = v(N-1)S \quad (6)$$

Where, v is voice activity factor, S is the cell received power from the mobile's transmit power.

Under the same condition, the other cell interference is expressed as equation (7).

$$I_{OC} = \left(\frac{1}{F_e} - 1\right) vNS \quad (7)$$

Where, F_e is frequency reuse efficiency.

The adjacent frequency interference could be expressed as equation (8) by using the equation (6) and (7).

$$I_{OF} = \rho_R \left(v'N'S' + \left(\frac{1}{F_e'} - 1\right) v'N'S' \right) = \rho_R \frac{v'N'S'}{F_e'} \quad (8)$$

Where, ν', N', S', and, F_e' is voice activity, number of users per cell, cell received power from the mobile's tranmsit power, and frequency reuse efficiency, respectively. ρ_R represents the interference ratio of adjacent frequency band in reverse link.

2.4 Simulation method

We show the block diagram of Monte-Carlo simulation in Figure 2.

First step of the simualtion is to set the necessary parameter values. Those are RF bandwidth, required SINR, orthogonality, Antenna height of cell and mobile, power control rule, Tx/Rx filtering characteristics, number of users per cell, Overhead channel power ratio, guard band and guard zone.

Second step is to determine each cell's location.

Third step is to distribute the mobiles in a cell. The loaction is randomly chosen every iterations.

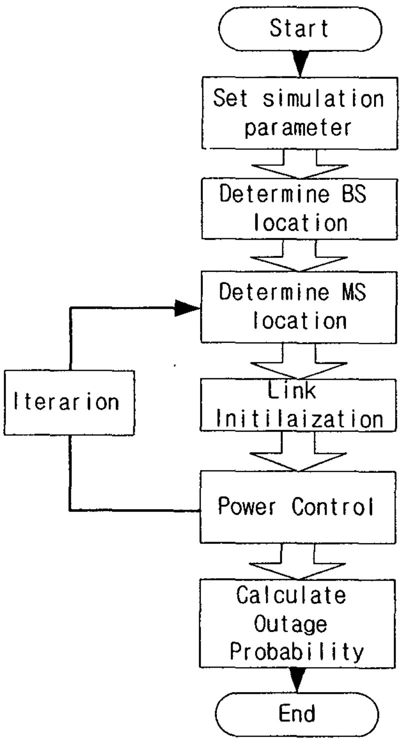


Figure 2. Simlation Flow chart

Fourth step is to store the calculated path loss between cell and mobile. Base on that, we could set up the strongest link between cell and mobile. The initial transmit power of each link is set based on the path loss.

Fifth step is the power control process based on the received signal strength to all kinds of interference to meet the required SINR. This step repeated until the power updates of all transmitter donot occur.

Sixth step is to calculate the outage probalility, the number of mobiles whose SINR is lower than the required SINR.

3. Interference evaluation example

Now, we are going to find out the proper guard band between two operators using the adjacent frequency when a cell of one operator is located on the cell boundary of another operator.

We have evaluated the interference effects between two IS-2000 systems at IMT-2000 sectrum. It is assumed that the same number of mobile stations is distributed over the 2 tier systems, respectively. Figure 3 shows the charateristics of the used transmit and receive filter.

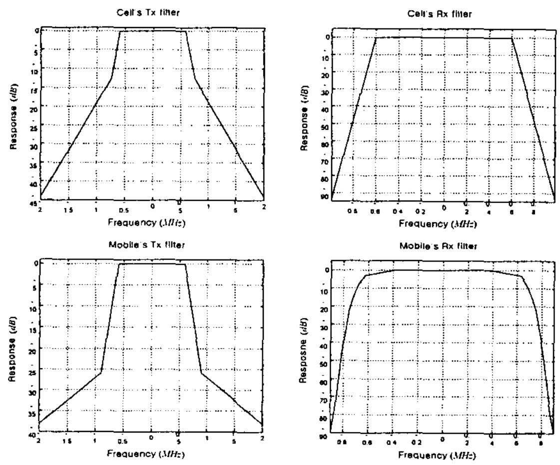


Fig. 3 The frequency response of Tx/Rx filer

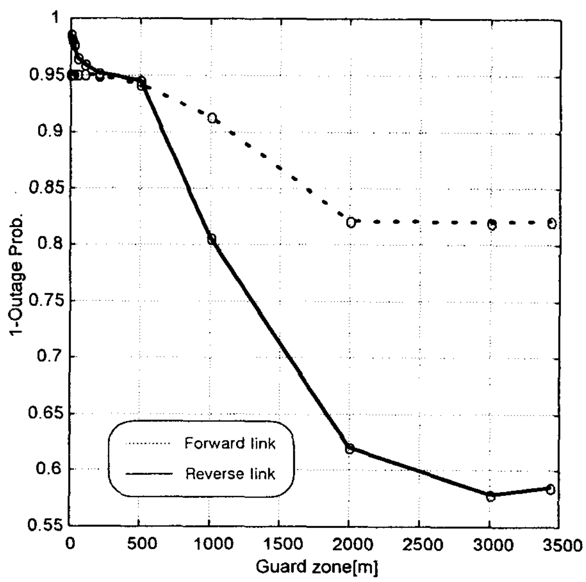


Fig. 4. The outage probability with 0MHz guard band

Figure 4 shows the results of 1-outage probability as the functions of guard zone in both links when the guard band is 0 MHz. Until the guard zone is 500m, the outage probbility is 5 %. When the location difference between two operator's cell is larger than 500m, both link shows the drastic increase of outage probability. It is due the increased interference from competiting operator's strong signal. We could easily find that the reason for the lower decrease of outage probability in the forward link is that the shadow area in forward link is much smaller than the reduced coverage in the outer circular area.

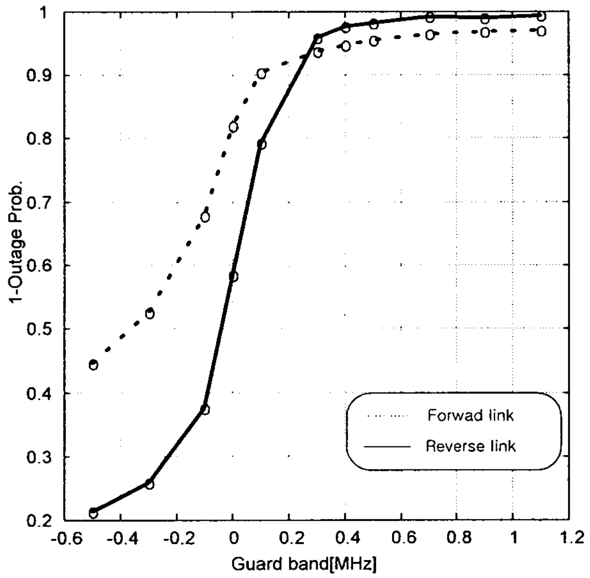


Fig. 5. The 1-outage probability with 3400m guard zone

Figure 5 shows the results of 1-outage probability as the functions of guard band in both links when the guard zone is 3400m. This could be the worst case scenario. We found that the required guard band to meet the 955 outage probability is 0.5MHz for forward link and 0.3MHz for reverse link in the worst case deployment. However, even if we increase the guard band more than the above values, the outage probability increase very small.

It could be concluded from the silmulation results that the interference from competiting operator is increased as the separation between the center of two competiting cells is increased, and the interference would be decreased with the proper guard band between the opertators.

4. Concluation

In this paper, we evaluate the interference statistics between two different Wideband CDMA systems by the Monte-Carlo methodology. In this simulator, we introduce the statistical approach to analyze the radio interference between two CDMA systems. We present and propose the required carrier distance and zones for two systems to meet the required outage probability.

We investigate the relationship between the required guard band and guard zone. When the worst case scenario case, we need at least 0.5MHz guard band for two IS-2000 1X systems of different operators to meet the 5% outage probability of the service areas.

Even if this simulator mainly focused the interference related issues concerning the deployment of radio station, this basic platform coud have the divers application: developing the spectral mask of transceiver, interference analysis of a transmission technology, the more relaistic system level simulation of modem, and handoff issues etc.

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