Capacity Degradation due to External Interference in Mobile Communication Systems

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***Abstract**: Mobile communication systems recently use adjacent frequency bands with each other or with other services, due to the lack of frequency bands. In such situation, the capacity of mobile communication system will be reduced by the external interference from the system using adjacent frequency band. In this paper, relations between the external interference level and the up link capacity degradation are estimated for mobile communication systems. In the investigation, other mobile communication systems, satellite and terrestrial TV broadcasting systems are considered as the external interference sources.*

***Keywords**: external interference, adjacent frequency, system capacity, radio link design.*

I. INTRODUCTION

In line with the introduction of digital TV broadcasting service, the band expansion plan for mobile communication services in the UHF band is recently announced in Japan [1]. The lack of frequency bands caused by the increase of users and demands for high data rates becomes the actual problem in the mobile communication services. Reallocation of frequency bands for the second and the third generation mobile communication systems is also foreseeable issue with the same reason.

The integration of mobile communication and terrestrial TV broadcasting systems in the UHF band has been proposed recently to realize efficient spectrum utilization and new attractive services [2]. Since current mobile communications systems have already use adjacent frequency bands with each other or with other services, these points suggest that the consideration of mutual interference problem in the systems using adjacent frequency bands becomes more important issue from the viewpoint of radio resource management.

In this paper, we consider the allowable external interference level for mobile communication systems and evaluate the system capacity degradation comparing with and without external interference. The outline of this paper is as follows. Section II shows external interference models and discusses the allowable external interference level in the frequency reuse system and CDMA system. The up link capacity is considered to simplify the discussion. In Section III, examples of system capacity degradation in PDC second generation digital cellular system [3] and W-CDMA third generation cellular system [4] are investigated for the actual external interference sources such as BSS(Sound) digital audio broadcasting satellite service [5], PHS digital cordless telephone system [6], and terrestrial TV broadcasting systems. Finally, Section IV presents the conclusions.

II. EXTERNAL INTERFERENCE LEVEL

Since the dominant system capacity is the up link capacity and interferences from mobile stations depend on the locations of mobile stations and the probability of call attempts, we consider the interference between base stations to simplify the discussion. As shown in Fig.1, let assume System B is a mobile communication system subject to the capacity consideration, and System A and System C are external interference systems using adjacent or same frequency band. System A is, for example, a different mobile communication system and System C is other communication service like as BSS(Sound).

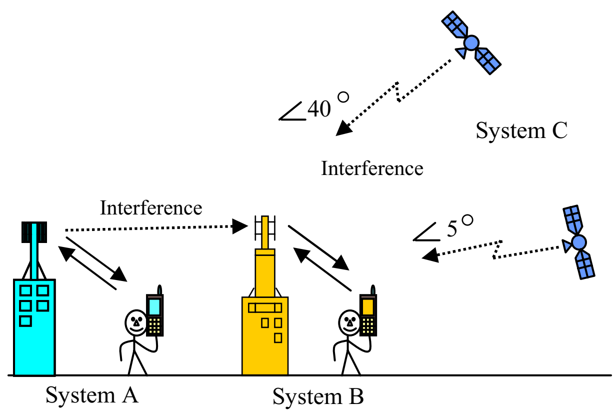

Figure 1. External interference in mobile communication systems

A. Frequency Reuse System

The allowable external interference level of the frequency reuse system, for example, PDC system, can be estimated using radio link parameters [3]. The summary of result is shown in Table 1. Following the CCIR Report [7], 10% of the total interference budget to the external sources is assumed in the consideration. The result shows that the allowable external interference becomes -134.5dBm, which corresponds to -171.7dB(W/4kHz) or -117.7dBm/MHz.

TABLE I. EXTERNAL INTERFERENCE LEVEL OF PDC SYSTEM

Minimum receiving level: S	-109dBm (-146.2dB(W/4kHz))
Signal to noise ratio: $S/(N_0+I)$	13dB
Thermal noise level: N_0	-125.6dBm B: 32kHz, N_f: 3.4dB
Internal interference level: I	-124.5dBm
10% allowable external interference level: I_x	-134.5dBm (-171.7dB(W/4kHz))

B. CDMA System

The allowable external interference level of CDMA system can be also estimated using the radio link budget. According to the uplink budget shown in the reference [8], for example, the allowable external interference level of W-CDMA system becomes -120dBm/MHz, including 10% allocation of the total interference budget to external interference sources. The value is near the PDC system's value -117.7dBm/MHz.

III. SYSTEM CAPACITY DEGRADATION

A. Frequency Reuse System

At first, we evaluate the effect of external interference from BSS(Sound). This case corresponds to System B and System C in Fig.1. Considering the typical antenna patterns of PDC system shown in Fig.2 [9], the aperture area of the antenna becomes -31.5dB(m^2) at the elevation angle of 40 degrees and -28.5dB(m^2) at 5 degrees in base station and

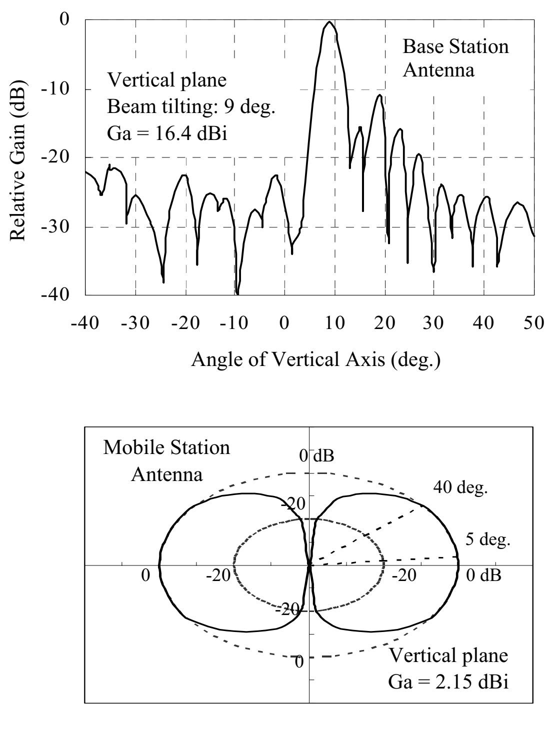

Figure 2. Typical antenna patterns of PDC system

-22.8dB(m^2) for both 40 and 5 degrees in mobile station. Let the interference power flux density from BSS(Sound) at 40 and 5 degrees elevation angle be x and y, respectively. Since the allowable external interference level of PDC system is -117.7dBm/MHz or -171.7 dB(W/4kHz)), then x and y have to satisfy the following conditions.

for base station:

$$x + (-31.5) < -171.7,\ y + (-28.5) < -171.5 \quad (1)$$

for mobile station:

$$(x, y) + (-22.8) < -171.5 \quad (2)$$

Therefore, the minimum value of the allowable external interference level becomes -148.9dB(W/m^2/4kHz) power flux density. If the interference from BSS(Sound) exceeds this level, PDC system capacity will be degraded.

In the frequency reuse system, cluster size N is in inverse proportion to the system capacity and given by $(1+\Lambda^{1/\alpha})^2/3$, where α is the propagation attenuation constant. According to Table 1, the required signal to internal interference ratio Λ becomes 15.5dB, and then $N = 7$ for $\alpha = 3.5$. When external interference is added to the internal interference, N becomes more lager value and then the system capacity is degraded.

Let the system capacity with and without external interference is C and C_0, the relative system capacity C/C_0 becomes as shown in Fig.3. The result shows that even the external interference level is -117.7dBm/MHz corresponding to -148.9dB(W/m^2/4kHz), approximately 4% system capacity has been degraded. If the power flux density from BSS(Sound) is 10dB higher than this level [10], the system capacity of PDC is reduced to 75%. This means that the operation in the same frequency band is difficult for those systems.

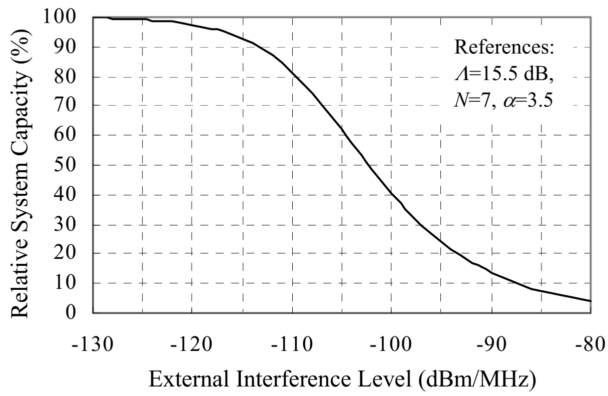

Figure 3. Capacity degradation of a frequency reuse system

B. CDMA System

Assuming that System B is W-CDMA and System A is PHS system in Fig.1. If the characteristic of PHS transmission spectrum is $T(f)$ and W-CDMA reception filter is $R(f)$, the external interference power I_x within W-CDMA receiving bandwidth can be calculated by the following equation.

$$Ix = \int T(f)R(f)df \tag{3}$$

Fig.4 shows typical characteristics of PHS transmission and W-CDMA reception filters with 5MHz carrier spacing [11]. Let assume the worst interference case, i.e. antenna height of both base stations are same and the path loss characteristic follows the free space loss. The peak transmission power of the 500mW-PHS base (cell) station is 36dBm within 288kHz bandwidth [6], and also assuming the antenna patterns of PHS and W-CDMA systems are as shown in Fig.5 [11]. By using (3) and the data of these figures, the relation between the external interference level from the 500mW-PHS base station and the coordination distance of base stations can be obtained as shown in Fig.6. The result shows that the required coordination distance to keep the allowable external interference level -120dBm/MHz becomes roughly 200m for 5MHz carrier spacing. In actual case, the base station antennas are not facing each other and the height of PHS base station antenna is lower than that of W-CDMA system. Therefore, the base stations of each system can be set within more short distance. If PHS base station is located near than the required distance, W-CDMA system capacity will be degraded. The required average signal to noise and interference ratio, *Eb/Ireq*, in the CDMA system is given by

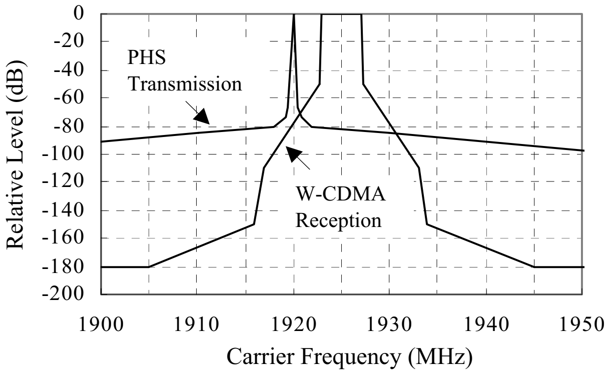

Figure 4. Typical filtering characteristics of PHS transmission and W-CDMA reception filers

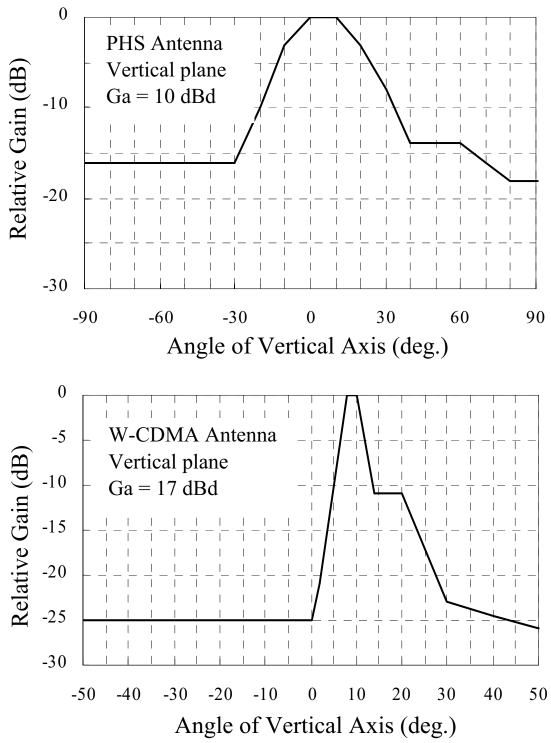

Figure 5. Typical antenna patterns of PHS and W-CDMA systems

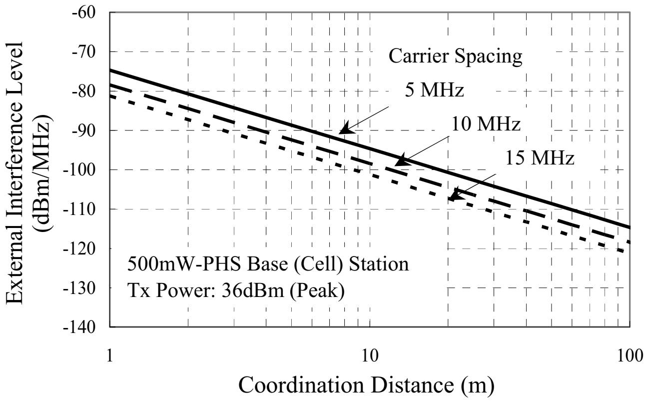

Figure 6. External interference level and coordination distance I

$$\frac{Eb}{Ireq} = \frac{Eb}{\frac{C_0 - 1}{pg} \cdot Eb + \frac{C_0}{pg} \cdot Eb \cdot fx + N_0} \tag{4}$$

where *pg* is the process gain, *fx* is the ratio of total other-cell interference to same-cell interference, N_0 is the thermal noise level, and C_0 is the number of users per cell without external interference. If the external interference *Ix* is added in (4), and the number of users per cell becomes *C*, the relative system capacity C/C_0 can be estimated by the following equation.

$$\frac{C}{C_0} = \frac{1 - (Ireq/(N_0 + Ix))^{-1}}{1 - (Ireq/N_0)^{-1}} \tag{5}$$

The calculation result using radio link parameters [8], [12] is shown in Fig.7.

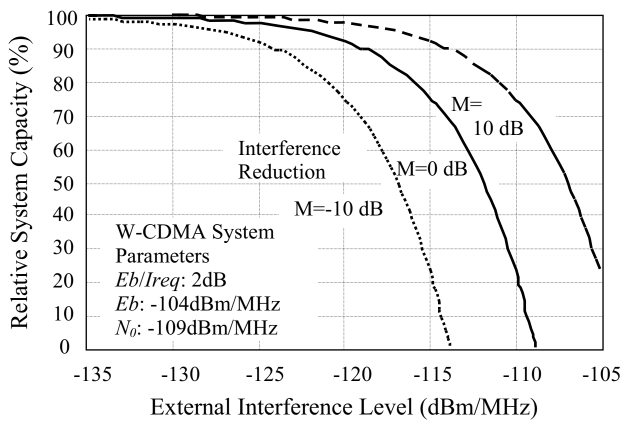

Figure 7. Capacity degradation of W-CDMA system

The result shows that system capacity degradation is sensitive to the external interference level. Even though the level is -120dBm/MHz, approximately 8% capacity reduction has been occurred without interference reduction condition. However, we can keep the capacity reduction within a few % by adopting interference improvement techniques and setting the location and antenna direction of base stations in the lower interference position.

According to the future frequency allocation plan in the UHF band [1], TV broadcasting and mobile communications services will use adjacent frequencies in the upper part of the UHF band. Therefore, let us consider the case that the TV broadcasting station (TVS) is the other external interference source to the CDMA system.

Figure 8 shows the typical situation in a local city. The simple estimation of external interference level without the data of transmission and reception filters and antenna pattern characteristics can be done by depicting the basic relation between TVS transmission and MBS reception filters as shown in Fig.9.

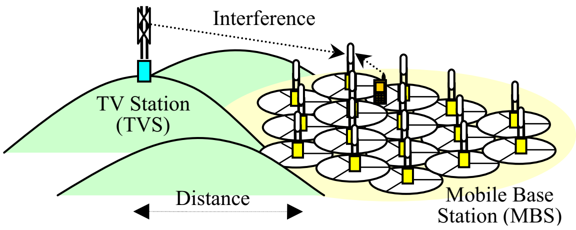

Figure 8. Interference from TV broadcasting system

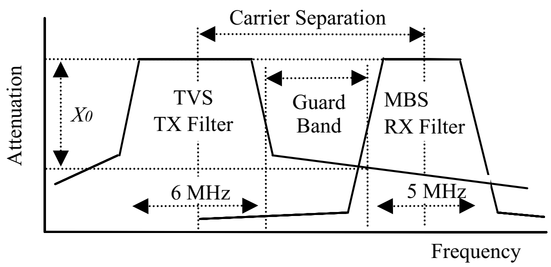

Figure 9. Relation between TX and TR filters

Let the interference attenuation is X_0(dB), the free space loss corresponding to the coordination distance is L(dB), the interference reduction is M(dB), and the radiation power of TVS is T(dBm/MHz), then, the external interference level Ix (dBm/MHz) is given by

$$Ix = (T - (X_0 + L - M)). \quad (6)$$

The results are shown in Fig.10 as the relation between the external interference level from the TVS and the coordination distance between TVS and MBS.

If T is 75dBm/MHz which equals to 190kW in 6MHz bandwidth, L is 95dB corresponding to about 1.9km distance at 710MHz, and M is 0dB, X_0 should be more than 100dB to satisfy the allowable external interference level -120dBm/MHz. Counting the interference reduction M=30dB by using beam tilting at mobile base station antennas and other improvement technologies, the TVS transmission filter has to have at least 70dB down floor characteristic in the out of occupied frequency band and 12.5dB/MHz down slope characteristic for the 6MHz guard band. These requirements for the filter are considered to be feasible one by using current manufacturing technologies.

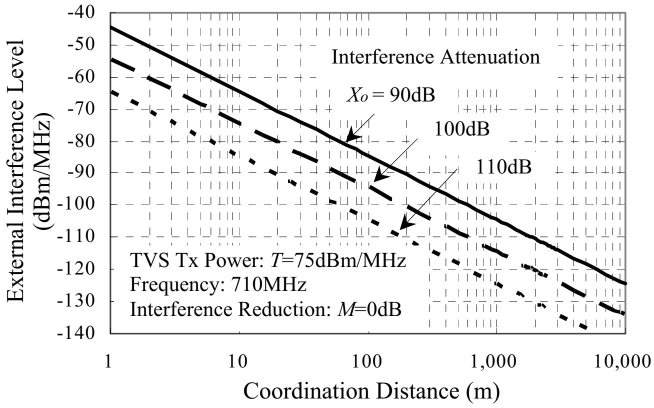

Figure 10. External interference level and coordination distance II

IV. Conclusions

The up link capacity degradation due to the external interference from other systems has been evaluated for mobile communication systems. The result shows that a few percent of system capacity will be reduced even at the allowable external interference level. Considering the result of PDC system capacity degradation due to BSS(Sound) system and the allowable external interference level is almost same in W-CDMA system, the sharing with the satellite broadcasting system in the same frequency band will be difficult for mobile communication systems. The results of the external interference to W-CDMA system shows that the adjacent frequency band use by other mobile communication system is feasible adjusting location, height and beam direction of other system's base station antennas. The result of the external interference from terrestrial TV broadcasting system also shows that interference improvement techniques including filtering make it possible to use the adjacent frequency band with each other. However, system capacity degradation is sensitive at around the allowable external interference level, the radio resource management for the systems operating in adjacent frequency bands should be done with care of this point.

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