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FM 방송서비스와 ILS localizer사이의 간섭분석에 관한 연구

(A Study on Interference Analysis between FM Broadcasting Service and ILS Localizer)

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요 약

무선통신 시스템간 간섭이 발생하면 시스템 성능이 열화된다. 따라서 시스템간 간섭이 발생하지 않도록 동작 주파수 및 송신 전력 등의 시스템 파라미터를 조절한다. 본 논문에서는 87.5 ~ 108 MHz 대역을 사용하는 음성방송 서비스로부터 108 ~ 112 MHz 대역을 사용하는 ILS localizer로 발생하는 간섭의 영향을 분석하였다. 간섭 분석 방법은 계산된 간섭량을 간섭 기준과 비교하여 간섭의 영향을 분석하였다. 그리고 항공 서비스의 주파수 대역 근처에서 서비스되고 있는 FM 음성 방성 서비스로부터 항공 서비스에 간섭이 일어나지 않도록 하게 위해 주파수와 송신 전력, 송신기 위치 등의 여러 파라미터를 결정하였다. 본 논문의 결과는 ILS localizer가 최적의 성능을 나타낼 수 있도록 시스템 파라미터를 설정하는데 적용될 수 있다. 또한 본 논문의 결과는 주파수 관리 정책을 결정하는데도 참고 될 수 있다.

Abstract

Radio systems decline in the system performances when one system is interfered from the other system. System parameters, which are operating frequency, transmit power, and so on, need to be determined in order that there is no interference between radio systems. We investigate the interference from the sound broadcasting service in the band 87.5-108 MHz to the ILS localizer, one of the aeronautical services, in the band of 108-112 MHz. The results are compared with the interference criteria. And then several system parameters, which are frequency, transmit power, and location, are determined in order to avoid the interference from the FM sound broadcasting service which occupies the frequency band near the band of the aeronautical services. The results of this paper can be applied to set up system parameters of the ILS localizer so that system performance can be maximized. Besides, the result of this paper can be applied for determining spectrum management policy.

Keywords : FM sound broadcasting service, ILS localizer, interference.

I. INTRODUCTION

Although frequency resources are limited, they are in great demand due to the rapid development of the wireless services[1~2] such as mobile communication, WLAN (Wireless Local Area Network), digital broadcasting service, satellite communication service, RFID/USN (Radio Frequency IDentification/ Ubiquitous Sensor Network), UWB (Ultra Wide-Band), WiBro (Wireless Broadband), and so forth. Then available frequency bands move to higher. This fact gives rise to the interference between services that use high frequencies. When some services, whose transmitting and receiving power are low, are interfered with other services, serious problems occur. Therefore many interference reduction and cancellation techniques have been investigated[1, 3~12].

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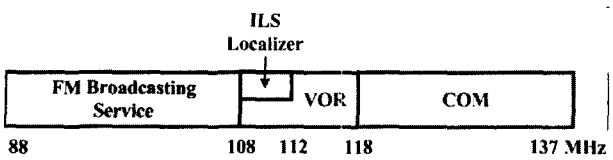


그림 1. FM 방송 서비스와 항공 서비스의 주파수 대역
Fig. 1. Frequency allocation of FM broadcasting service and aeronautical services.

Not only reducing the interference between the radio communication services but also managing the spectrum in order to effectively utilize wireless resources is important. So many countries and international organizations are interested in the problems of existing spectrum management and perform a lot of works including standardization activities, spectrum engineering technologies, and management policy overture[13~24]. In order to make use of the frequency resources efficiently, ITU (International Telecommunication Union) makes regulations for the utilization of frequency resources[25~32].

Frequency allocation of the FM (Frequency Modulation) broadcasting service and the aeronautical services is shown in Fig.1. The FM sound-broadcasting service in the band of about 87.5-108 MHz interferes the aeronautical services, ILS (instrument landing system) localizer, VHF omnidirectional radio range (VOR), and VHF communications (COM) equipment, in the band 108-137 MHz[33~34]. Among them, the interference to airborne ILS localizer is the more serious problem because an error during the critical approach and landing phase is not clear easily to the pilot.

In this paper, interference from the FM broadcasting service to the ILS localizer is analyzed. Based on the published interference assessment criteria, necessary parameters are extracted from the exemplary scenarios. This paper is organized as follows. Section Ⅱ describes the characteristics of ILS localizer and FM broadcasting service. And in Section Ⅲ, the interference assessment methods applied for this paper are presented according to the interference types. The interference from sound broadcasting service to ILS localizer is analyzed for the proposed scenarios in Section Ⅳ. And simulation results are shown in Section Ⅴ. Finally, some concluding remarks are given in Section Ⅵ.

Ⅱ. SYSTEM CHARACTERISTICS

1. ILS Localizer

A Typical DOC (designated operational coverage) is shown in Fig. 2. The minimum field strength to be protected throughout the ILS localizer front course DOC or provided in the ILS localizer back course coverage is 32 dB(μV/m). In the band 108-112 MHz, the ILS localizer frequencies lie and this band is divided into the 40 available channels. The center frequencies of each channel are as follows: 108.10, 108.15, 108.30, 108.35 MHz etc. to 111.70, 111.75, 111.90, and 111.95 MHz. The ILS localizer signal is horizontally polarized.

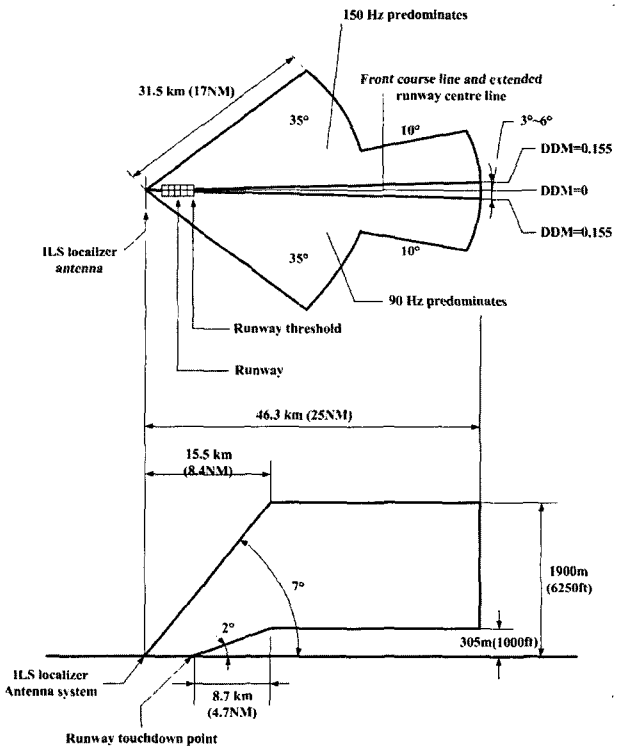


그림 2. 일반적인 ILS 로칼라이저 전방 DOC.
Fig. 2. Typical ILS localizer front course DOC.

2. FM broadcasting service

The free space field strength for broadcasting signals can be calculated as

표 1. 스퓨리어스 방사 억압값.
Table 1. Spurious emission suppression values.

Maximum e.r.p. (dBW)	Suppression (dB)
≥ 48	85
30	76
< 30	46 + maximum e.r.p (dBW)

$$E = 76.9 + P - 20\log d + H + V \quad (1)$$

where E is the field strength (dB(μV/m)) of the broadcasting signals, P is maximum e.r.p. (effective radiated power) (dBW) of the broadcasting station, d is the slant path distance (km), H is the h.r.p.(horizontal radiation pattern) correction (dB), and V is the v.r.p.(vertical radiation pattern) correction (dB).

In Region 1 and 3 defined in the Radio Regulations, the operation frequencies occupy channels spaced at 100 kHz intervals in the band 87.5-108 MHz and occur as follows: 87.6, 87.7 ···107.9 MHz. In Region 2, the band is 88-108 MHz, with channels every 200 kHz (88.1, 88.3 ··· 107.9 MHz). The polarization of an FM signal is horizontal, vertical or mixed. Spurious emission suppression values for the case of radiated intermodulation products from co-sited broadcasting transmitters in the aeronautical band 108-137 MHz are shown in Table 1.

Ⅲ. INTERFERENCE ASSESSMENT CRITERIA

According to the interference scenarios, there are four interference types, which are two A types (A1, A2) and two B types (B1, B2).

Type A1 interference is generated by spurious emission of a single transmitter or intermodulation components of several transmitters in the aeronautical frequency bands. Any product for which the frequency falls within 200 kHz of the aeronautical frequency is examined further to determine if its field strength is sufficient to cause Type A1 interference. For this interference type, the values of the protection ratio are given in Table 2. This type need not to be considered for frequency differences greater than 200 kHz.

Type A2 interference is created by non-negligible components of a broadcasting signal in the aeronautical bands. Each of the broadcasting stations is examined to determine if its frequency falls within 300 kHz of the aeronautical frequency and, if so, if its field strength is sufficient to cause Type A2 interference. The protection ratio values are shown in Table 3. This type need not to be considered for frequency differences greater than 300 kHz.

Type B1 interference is intermodulation component generated in an aeronautical receiver being driven into non-linearity by broadcasting signals outside the aeronautical band. Any product whose frequency falls within 200 kHz of the aeronautical frequency is examined further to determine if the sum of the powers at the input to the aeronautical receiver is sufficient to cause Type B1 interference. From (2) and (3), potential incompatibilities can be assessed when there are two and three interference signals, respectively.

$$2\{N_1 - 28\log\{\max(1.0; f_A - f_1)\}\}$$
$$N_2 - 28\log\{\max(1.0; f_A - f_2)\} + K - L_C > 0, \quad (2)$$

표 2. A1 형태의 간섭에 대한 보호비.
Table 2. Protection ratio for Type A1 interference.

Frequency difference between wanted signal and spurious emission (kHz)	Protection ratio (dB)
0	14
50	7
100	-4
150	-19
200	-385

표 3. A2 형태의 간섭에 대한 보호비.
Table 3. Protection ratio for Type A2 interference.

Frequency difference between wanted signal and broadcasting signal (kHz)	Protection ratio (dB)
150	-41
200	-50
250	-59
300	-68

표 4. 교정값.
Table 4. Correction term.

Frequency difference between wanted signal and intermodulation product (kHz)	Correction term (dB)
0	0
50	2
10	8
150	16
200	26

$$N_1 - 28\log\{\max(1.0; f_A - f_1)\} + N_2 - 28\log\{\max(1.0; f_A - f_2)\} + N_3 - 28\log\{\max(1.0; f_A - f_3)\} + K + 6 - L_C > 0 \quad (3)$$

where N_1, N_2, and N_3 are the broadcasting signal levels (dBm) at the input to the aeronautical receiver for the broadcasting frequencies f_1, f_2, and f_3, respectively. After applying a correction to each signal level from Table 4, (2) and (3) is applied. The broadcasting signal level correction is expressed as

$$N(corrected) = N - correction\,term \quad (4)$$

f_A is the aeronautical frequency (MHz), f_1, f_2, and f_3 are the broadcasting frequencies (MHz, $f_1 > f_2 > f_3$), K is set at 140, and L_C is the correction factor (dB) expressed in (5).

$$L_C = N_A - N_{ref}, \quad (5)$$

where N_A is the wanted signal level (dBm) at the input to the aeronautical receiver and N_{ref} is the reference level (dBm) of the wanted signal at the input to the aeronautical receiver, which is set at -89 dBm.

Type B2 interference occurs when the RF section of an aeronautical receiver is subjected to overload by one or more broadcasting transmissions. Each of the broadcasting stations is examined to determine if its power at the input to the aeronautical receiver is sufficient to cause Type B2 interference. In order to determine the maximum level of broadcasting signal at the input to the airborne ILS localizer for avoiding potential interference, (6) is used.

$$N_{\max} = -20 + 20\log\frac{\max(0.4; f_A - f)}{0.4}, \quad (6)$$

where $N_{\max}$ is the maximum level (dBm) of the broadcasting signal at the input to the aeronautical receiver, f is the broadcasting frequency (MHz), and f_A is the aeronautical frequency (MHz).

Ⅳ. INTERFERENCE ANALYSIS

The interference assessment procedure in[33] is applied.

At first a simulation scenario should be made. According to this scenario, system parameters, which are the e.r.p. and the centre frequency, are determined.

The next thing is to designate the test points related to the interfering transmitters in Fig. 5.

And based on the established parameters, the free space field strengths of the interfering systems and the victim systems should be calculated.

The free space field strength for a FM broadcasting signal is determined according to (1). For an ILS localizer signal, the field strength is calculated using two-ray geometry over a smooth spherical earth[33], which is shown in Fig. 3. In this model, Tx is an ILS localizer transmitting antenna, T is a test point, d is a slant path distance (km), and X is a curved earth height difference (m) given by

$$X = \left(\frac{D}{4.1}\right)^2 \quad (7)$$

The difference in path length, Δ (m), between the direct path and that involving a reflection is given as follows.

$$\Delta = \frac{2h_1[2h_2 - h_p - (D/4.1)^2]}{1000D} \quad (8)$$

where D is a horizontal distance (km) from the ILS

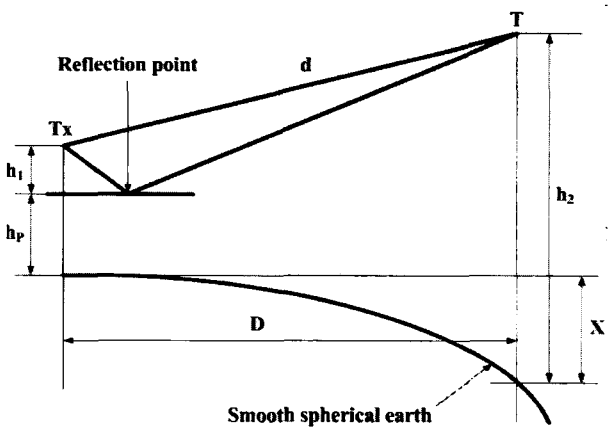


그림 3. 2-ray 지형.
Fig. 3. Two-ray geometry.

localizer site to the test point, h_1 is an ILS transmitting antenna height (m) above the reflecting place, h_2 is a test point height (m) a.m.s.l (above mean sea level), and h_P is a height of the reflection place (m) a.m.s.l, which is equal to the ILS localizer site height.

Because of the summation of the two signal components at the test point, the correction factor, C, is given by

$$C = 10\log\left(2 - 2\cos\left(\frac{2\pi\Delta}{\lambda}\right)\right), \tag{9}$$

where λ is the wavelength (m) of the ILS signal. And the field strength, E $(dB(\mu V/m))$, of the ILS localizer signal can be calculated as follow.

$$E = 76.9 + P - 20\log d + C + H, \tag{10}$$

where P is the e.r.p. (dBW) of the ILS localizer installation, d is the slat path distance (km), C is the correction (dB) given in (9), and H is the h.r.p. correction for the ILS localizer transmitting antenna in the direction of the test point. An allowance of 8 dB should be made in order to provide a safety margin. Then the final field strength $E_{ILS}(dB(\mu V/m))$ is

$$E_{ILS} = E - 8, \tag{11}$$

where E is given in (10).

And the next step is to convert the field strength of the broadcasting signal and of the aeronautical signal to power at the input to an aeronautical receiver. For a broadcasting signal in the band 87.5-108.8 MHz,

$$N = E - 118 - L_s - L(f) - L_a, \tag{12}$$

where N is the broadcasting signal level (dBm) at the input to the aeronautical receiver, E is the field strength (dB(μV/m)) of the broadcasting signal, L_S is the signal splitter loss of 3.5 dB, $L(f)$ is the antenna system frequency-dependent loss at broadcasting frequency f (MHz) of 1.2 dB per MHz below 108 MHz, and L_a is the antenna system fixed loss of 9 dB. For an aeronautical signal and a Type A1 interference signal in the band 108-118 MHz,

$$N_a = E_a - 118 - L_s - L_a, \tag{13}$$

where N_a is the signal level (dBm) at the input to the aeronautical receiver and E_a is the field strength $(dB(\mu V/m))$ of the aeronautical or Type A1 signal. Based on the information obtained from the previous steps and the interference assessment criteria in Section III, the interference level can be assessed for each type of interference.

V. SIMULATION RESULTS

In the simulation, Fig. 4 represents an interference link and a victim link.

In fig. 4, wt is a wanted transmitter, vr is a victim receiver, it is an interfering transmitter, and wr is a wanted receiver. A victim link is composed of a wanted transmitter and a victim receiver. An

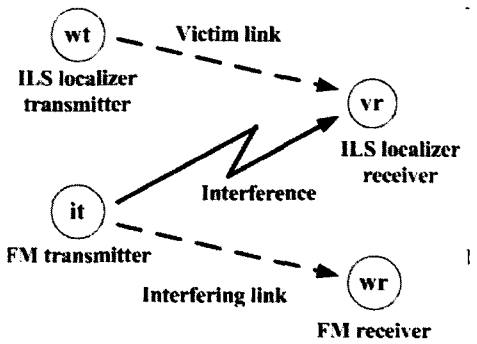
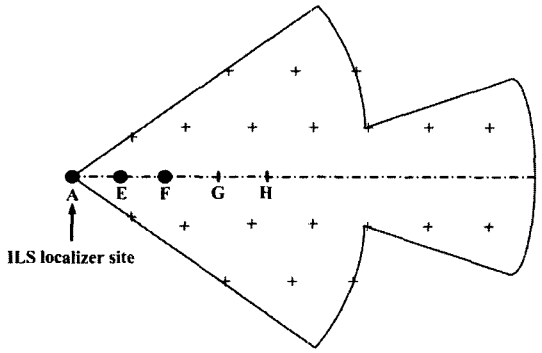
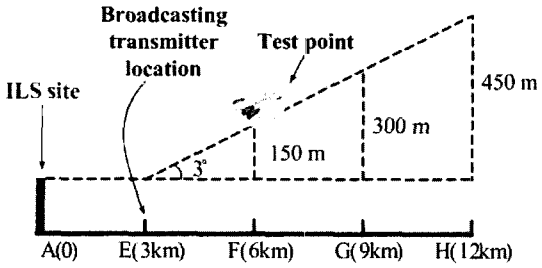


그림 4. 간섭 링크와 피간섭 링크
Fig. 4. interference link and victim link.



(a)



(b)

그림 5. 고정된 테스트 위치
(a) 위에서 본 그림, (b) 옆에서 본 그림.
Fig. 5. Fixed test point location.
(a) top view, (b) side view.

interfering link is made up of an interfering transmitter and a wanted receiver. An interfering transmitter is a transmitter of the FM broadcasting service and a victim receiver is a receiver of the ILS localizer. A victim receiver wants to receive the signals of the ILS localizer transmitter. But the received signals are not only the signal of the wanted transmitter, ILS localizer transmitter, but also that of the interfering transmitter, FM sound broadcasting service transmitter. Therefore, the victim receiver, ILS localizer receiver, receives the unwanted signals so that the performance of the receiver is debased. Then the victim system may operate incorrectly.

Fig 5 represents the fixed test point location within ILS DOC. It is assumed that a test point is F in Fig 4 and interference is Type A1 interference. The broadcasting frequency is set at 107.9 MHz and the e.r.p. of the FM transmitter is assumed to be 30 dBW. The centre frequency of the ILS localizer is assumed to be 108.35 MHz. Fig. 6 represents this interference scenario.

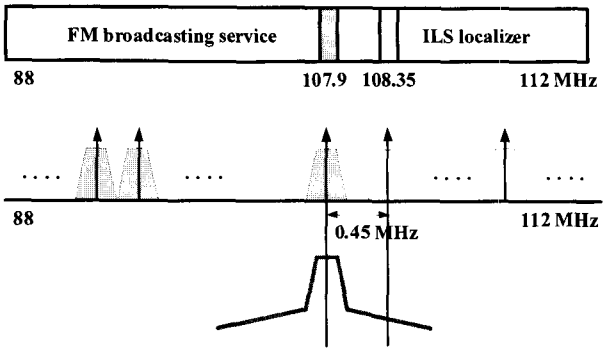


그림 6. 간섭 시나리오 1
Fig. 6. Interference scenario 1.

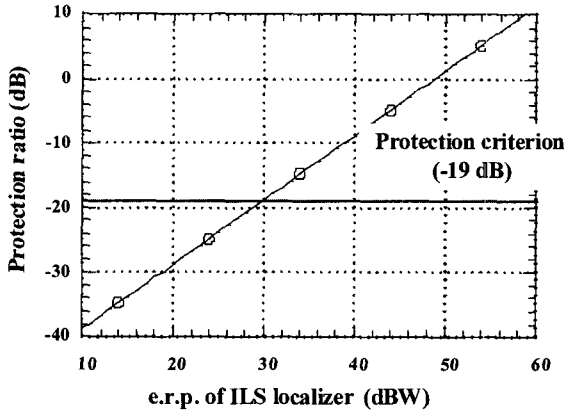


그림 7. ILS 로칼라이저의 등가복사전력에 따른 보호비
Fig. 7. Protection ratio versus e.r.p. of ILS localizer.

After calculating the field strength and receiver input power of each system, the interference can be assessed by using Table 2. Fig. 7 shows the protection ratio versus the e.r.p. of the ILS localizer performance.

It is clear from Fig. 7 that when the e.r.p. of the ILS localizer is over 30 dBW, the protection ratio is over the criterion -19 dB. Hence in this interference scenario, the minimum e.r.p. of ILS localizer is 30 dBW in order to avoid the effect of interference.

When the broadcasting frequency is set at 107.9 MHz, the centre frequency of the ILS localizer is 108.35 MHz, and the e.r.p. of the ILS localizer is 32 dBW, the protection ratio versus the e.r.p. of the FM broadcasting service performance is shown in Fig 8. Interference scenario is the same shown in Fig. 6.

From this simulation result, it can be known that the ILS localizer is not affected by the FM broadcasting signal when the e.r.p. of FM signal is

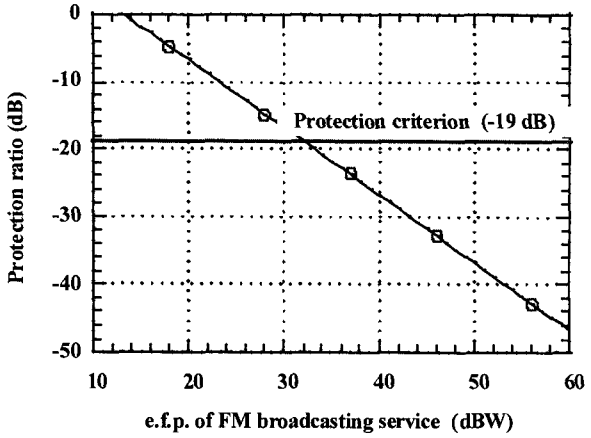


그림 8. FM 방송 서비스의 등가복사전력에 따른 보호비.

Fig. 8. Protection ratio versus e.r.p. of FM broadcasting service

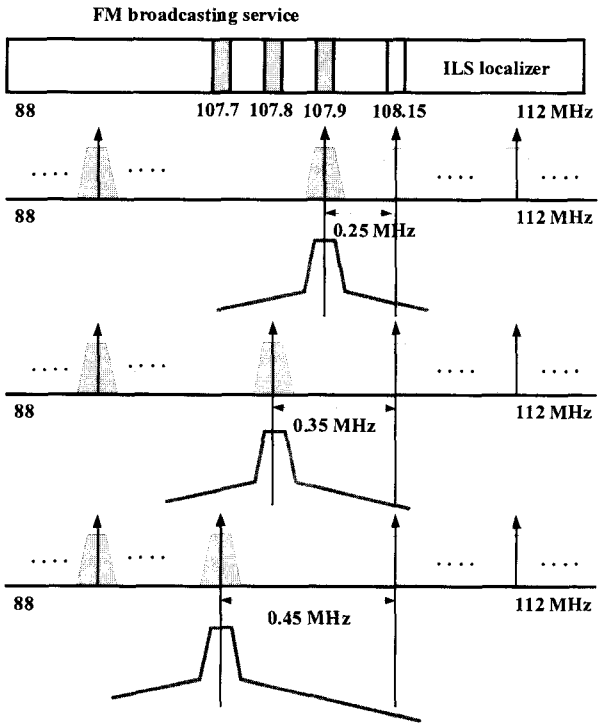


그림 9. 간섭 시나리오 2

Fig. 9. Interference scenario 2.

less than 32 dBW.

Fig. 10 shows the protection ratio versus the centre frequency of the FM broadcasting service when the e.r.p. of the ILS localizer and of the FM service are 32 dBW and 20 dBW, respectively, and the centre frequency of the ILS localizer is 108.15 MHz. The centre frequency of the FM service varies from 107.7 MHz to 107.9 MHz spaced at 100 kHz

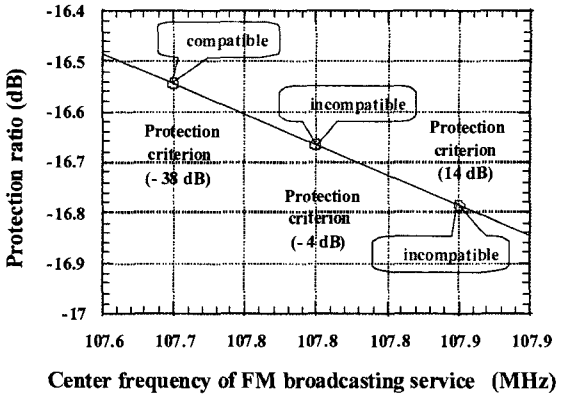


그림 10. FM 방송 서비스의 중심 주파수에 따른 보호비

Fig. 10. Protection ratio versus center frequency of FM broadcasting service.

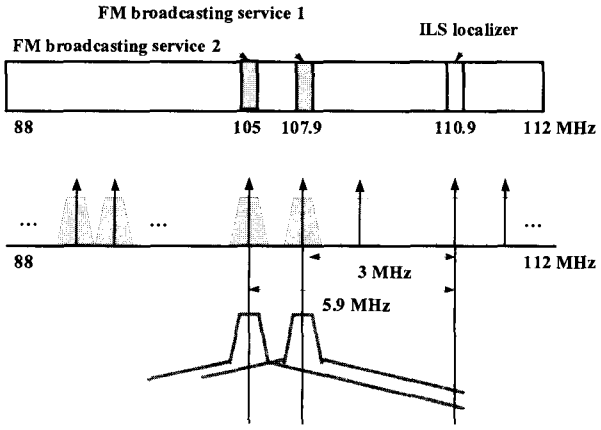


그림 11. 간섭 시나리오 3.

Fig. 11. Interference scenario 3.

interval. An interference scenario is shown in Fig. 9. Only when the centre frequency of the FM service is 107.7 MHz, the protection criterion is satisfied. Then the FM service does not affect to the ILS localizer only in this case.

Fig. 12 represents the potential incompatibility versus the e.r.p. of the FM broadcasting service 1 performance. In the simulation, the followings are assumed. Interference is Type B1 interference. The center frequency of the ILS localizer is set at 110.9 MHz, that of the FM broadcasting service 1 is 107.9 MHz, and that of the FM broadcasting service 2 is 105 MHz. The e.r.p. of the ILS localizer is set at 32 dBW and that of the FM broadcasting service 2 is 50 dBW. An interference scenario is shown in Fig. 11.

From this result, we can see that when the e.r.p.

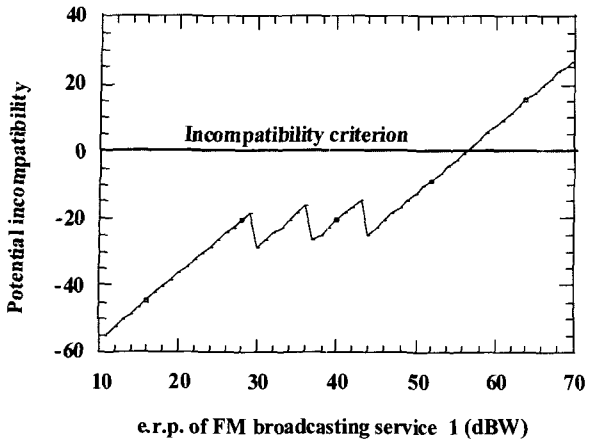


그림 12. FM 방송 서비스 1의 등가복사전력에 따른 비양립 가능성

Fig. 12. Potential incompatibility versus e.r.p. of FM broadcasting service 1.

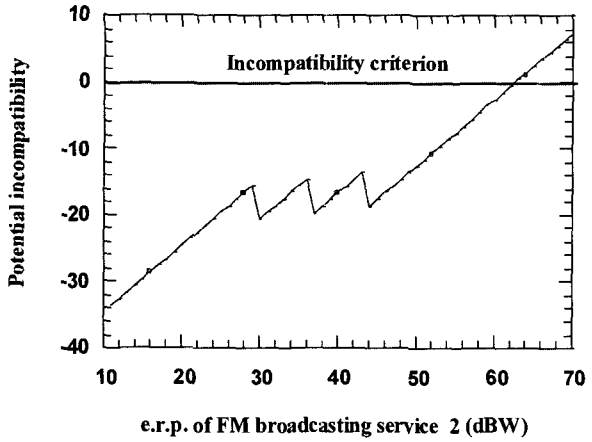


그림 13. FM 방송 서비스 2의 등가복사전력에 따른 비양립 가능성

Fig. 13. Potential incompatibility versus e.r.p. of FM broadcasting service 2.

of the FM broadcasting service 1 is less than 56 dBW, the potential incompatibility value is less than the incompatibility criterion. Then the ILS localizer can avoid the interference from the FM services in scenario shown Fig. 11.

Fig. 13 represents the potential incompatibility versus the e.r.p. of the FM broadcasting service 2 performance. In the simulation, the followings are assumed. Interference is Type B1 interference. The center frequency of the ILS localizer is set at 110.9 MHz, that of the FM broadcasting service 1 is107.9 MHz, and that of the FM broadcasting service 2 is 105 MHz. The e.r.p. of the ILS localizer is set at 32

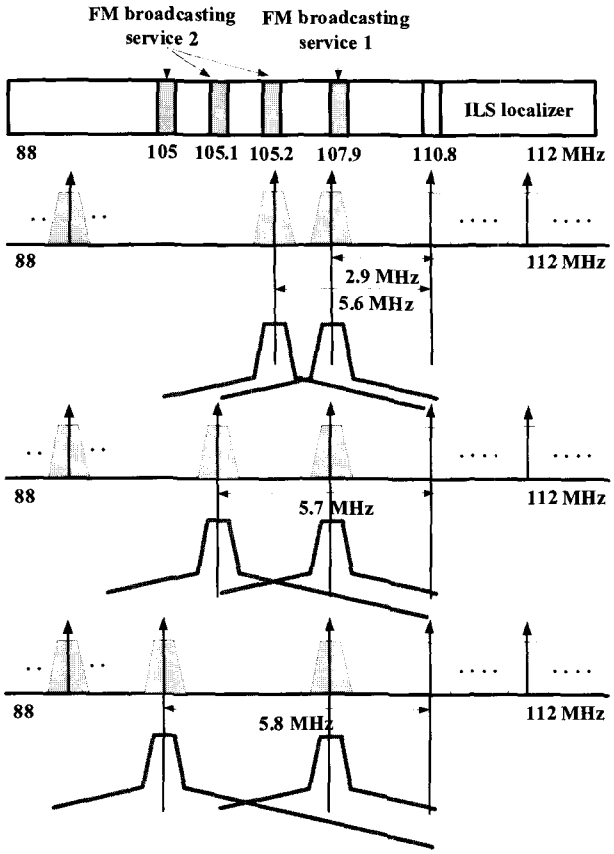


그림 14. 간섭 시나리오 4

Fig. 14. interference scenario 4.

dBW and that of the FM broadcasting service 1 is 50 dBW. An interference scenario is shown in Fig. 11.

It can be known that when the e.r.p. of the FM broadcasting service 2 is less than 62 dBW, the potential incompatibility value is less than the incompatibility criterion. Then the ILS localizer can avoid the interference from the FM services.

Fig. 15 shows the potential incompatibility versus the centre frequency of the FM broadcasting service 2 performance. It is assumed that the e.r.p. of the ILS localizer is 32 dBW, that of the FM service 1 is 50 dBW, and that of the FM service 2 is 62.5 dBW. The centre frequencies of the ILS localizer and of the FM service 1 are set at 110.8 MHz and 107.9 MHz, respectively. The centre frequency of the FM service 2 varies from 105 MHz to 105.2 MHz spaced at 100 kHz interval. An interference scenario is shown in Fig. 14. Only when the centre frequency of the FM service 2 is 105 MHz, the potential incompatibility value is satisfied with the criterion. Then the FM

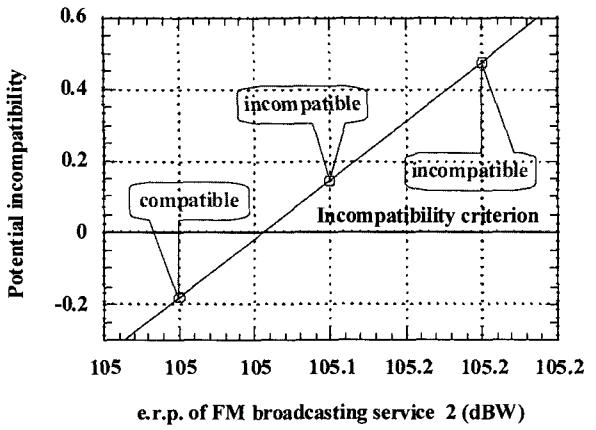


그림 15. FM 방송 서비스 2의 중심 주파수에 따른 비양립 가능성

Fig. 15. Potential incompatibility versus center frequency of FM broadcasting service 2.

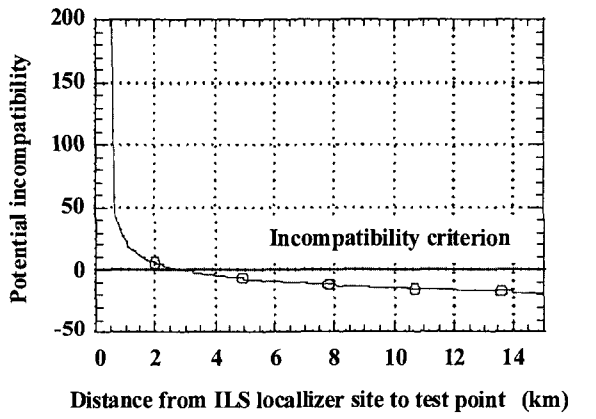


그림 16. ILS 로칼라이저 위치로부터 테스트 지점까지의 거리에 따른 비양립 가능성

Fig. 16. Potential incompatibility versus distance from an ILS localizer site to a test point.

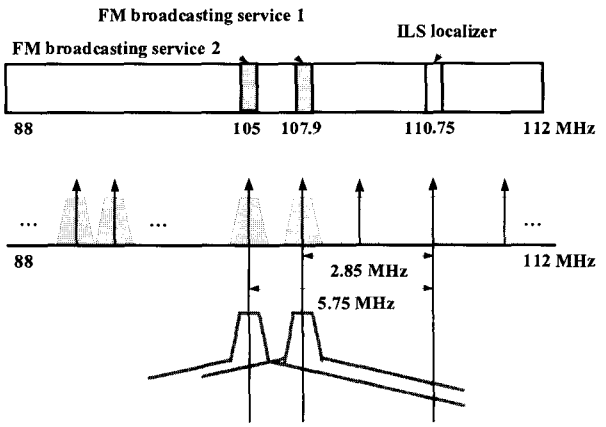


그림 17. 간섭 시나리오 5

Fig. 17. Interference scenario 5.

service does not affect to the ILS localizer only in this case.

Fig. 16 shows the potential incompatibility when the distance from an ILS localizer site to a test point varies. Type B1 interference is assumed. The center frequency of the ILS localizer is set at 110.95 MHz, that of the FM broadcasting service 1 is 107.9 MHz, and that of the FM broadcasting service 2 is 105 MHz. The e.r.p. of the ILS localizer is set at 32 dBW, that of the FM broadcasting service 1 is 60 dBW, and that of the FM broadcasting service 2 is 50 dBW. An interference scenario is shown in Fig. 17.

From Fig. 16, we can see that the further the distance is from an ILS localizer site to a test point, the more the potential incompatibility decreases. And when the distance from an ILS localizer site to a test point is over 3 km, the incompatibility criterion is satisfied.

VI. CONCLUSIONS

A frequency band of the FM sound broadcasting service in the band 87.5-108 MHz is allocated near a band of the aeronautical services, which is composed of ILS localizer, VOR, and COM, in the band of 108-137 MHz. Hence the unwanted emission of the FM broadcasting service works as interference to the aeronautical services and has a bad influence on them. When the unwanted emission occurs in the aeronautical band, the ILS localizer is much affected by interference especially.

In this paper, the interference from the sound broadcasting service in the band 87-108 to the ILS localizer, one of the aeronautical services, in the band of 108-112 MHz is analyzed. The effects of interference are analyzed according to the e.r.p of ILS localizer, the center frequency of FM broadcasting service, and the distance from an ILS localizer site to a test point. And the values that satisfy the incompatibility criterion for each case are deduced from the simulation results.

When the e.r.p. of the FM broadcasting service is set at 30 dBW, that of the ILS localizer should be over 30 dBW to operating without the interference

problems. When the e.r.p. of the ILS localizer is 32 dBW, that of the FM broadcasting service is less than 32 dBW. When the e.r.p. and the centre frequency of the ILS localizer are 32 dBW and 108.15 MHz, respectively, the centre frequency of the FM broadcasting service should be less than 107.7 MHz. In the case that the e.r.p. and the centre frequency of the ILS localizer are 32 dBW and 110.9 MHz, respectively, the center frequencies of the broadcasting services are 107.9 MHz and 105 MHz, and the e.r.p. of the FM broadcasting service 2 is 50 dBW, the e.r.p. of the FM broadcasting service 1 should be less than 56 dBW in order to be compatible with the ILS localizer service. If the same conditions are assumed except that the e.r.p. of the FM broadcasting service 1 is 50 dBW, the e.r.p. of the FM broadcasting service 1 should be less than 62 dBW. In the case that the e.r.p. and the centre frequency of the ILS localizer are 32 dBW and 110.8 MHz, respectively, the e.r.p.s of the broadcasting services are 50 dBW and 62.5 dBW, and the centre frequency of the FM broadcasting service 1 is 107.9 MHz, the centre frequency of the FM broadcasting service 2 should be less than 105 MHz to protect the ILS localizer from interference of the FM broadcasting services. And in the case that the e.r.p. and the centre frequency of the ILS localizer are 32 dBW and 110.95 MHz, respectively, those of the broadcasting service 1 are 60 dBW and 107.9 MHz, respectively, and those of the FM broadcasting service 2 is 50 dBW and 105 MHz, respectively, the distance form the ILS localizer site to the test point should be over 3 Km to satisfy the incompatibility criterion.

By using the methods of analyzing the interference, which are applied in this paper, it is greatly expected that the performance of the aeronautical service can be optimized. Besides, the result of this paper can be applied for determining spectrum management policy as well as establishing the foundation of the frequency resource management systems.

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