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A Pattern Synthesis for Optimum Beam Using Multipath Propagation Loss Formula

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Abstract —Antennas for radar and broadcasting usually use a cosecant beam shape, because it provides a lower change of desirable-to-undesirable signal ratio (DUR) within the receiving region. Some pattern synthesis methods for the cosecant beam shape have been already reported[1],[2].

This paper presents a computer-simulated optimum beam pattern which minimizes the change of DUR within the service zone by using multipath propagation loss formula for land mobile communications. This pattern is synthesized on the basis of the pattern synthesis method[1] for array antenna pattern with the well-known cosecant beam shape. This paper proposes a pattern synthesis method using simultaneously linear programming as well as Fourier transformation. In this proposed method, DUR is shown to be effectively improved compared to the method using only Fourier transformation.

1. OPTIMUM BEAM

We consider a model with a base station and an interfering station as shown in Fig. 1, where r_1 is the service zone radius, r_2 is the distance from the end of the service zone to the interfering station, h_b is the effective height of antenna on the base station, θ is the angle from a horizontal plane at the base station to the receiving point, and ϕ is the angle from a horizontal plane at the interfering station to the receiving point.

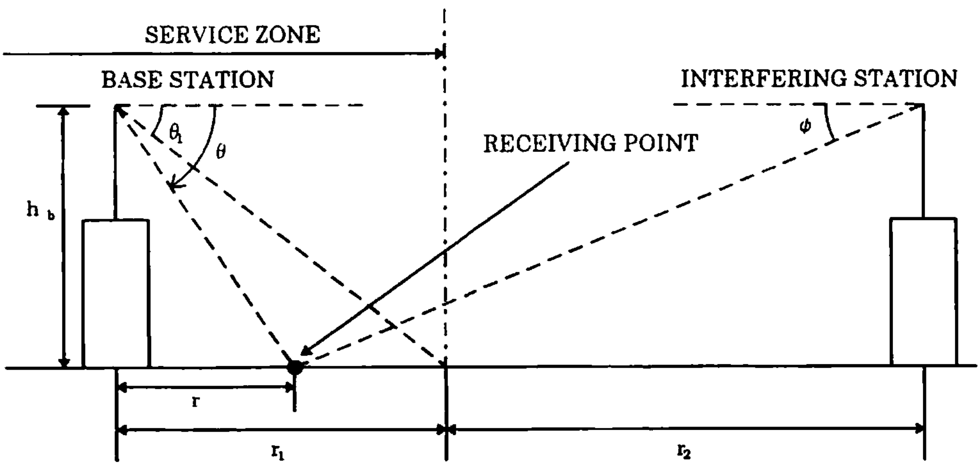

Fig. 1. The system model in land mobile service.

The optimum beam shape fulfills the following conditions.

(1) It minimizes the change of DUR within service zone.

(2) The side lobe level in the direction of the non-service zone is lower than one in the direction of the service zone.

Multipath propagation loss is calculated by Okumura-Hata propagation loss formula[3] for land mobile communications.

Therefore, optimum beam equations are defined as,

$$f(\theta) = \delta \qquad \left(\theta < \theta_t - \frac{\theta_w}{2}\right) \qquad (1),$$

$$f(\theta) = 1 \qquad \left(\theta_t - \frac{\theta_w}{2} \le \theta < \theta_t + \frac{\theta_w}{2}\right) \qquad (2),$$

$$f(\theta) = \left[\frac{\tan(\theta_t + \theta_w/2)}{\tan\theta}\right]^{\frac{p}{20}} \qquad \left(\theta \ge \theta_t + \frac{\theta_w}{2}\right) \qquad (3), \qquad p = 44.9 - 6.55\log_{10} h_b ,$$

where δ is the side lobe level, θ is the angle of radiation, and θ_w is the beam width. θ_t is the angle from a horizontal plane to the main lobe, and is defined as,

$$\theta_t = \tan^{-1}\left(\frac{h_b}{r_1}\right) - \frac{\theta_w}{2} \qquad (4).$$

Equation (3) shows that optimum beam pattern is equivalent to the cotangent curve in the direction of the service zone.

2. PATTERN SYNTHESIS

The pattern synthesis method consists of the following procedures.

(1) Excitation coefficients are calculated by Fourier transformation[2].

(2) Excitation amplitude is calculated by linear programming using the excitation phase obtained in Procedure 1.

(3) The array factor is transformed by Taylor expansion, namely is expanded to first degree. Linear programming is applied to this approximate equation. It is repeated until the sufficient approximate values of excitation coefficients are obtained. In addition, the excitation amplitude obtained in Proc. 2 and also the excitation phase in Proc. 1 are used as initial values.

3. COMPUTER SIMULATION RESULTS

This paper assumes the parameters in Table 1. The antenna on the base station is a 20-element equi-spaced linear array antenna, with half-wavelength spacing and non-directive elements.

Table 1. Assumed parameters.

Service zone radius	3.0 km
Effective height of antenna on the base station	200 m
Height of antenna on the mobile station	1.5 m
Carrier frequency	1.5 GHz
Beam width	8.0 deg
Side lobe level in the direct of non-service zone	-40 dB
Tolerance of gain deviation to optimum beam within	±1.5 dB
Distance from the end of service zone to interfering station	9.0 km

The directivity pattern obtained by Procs. 1, 2 and 3 is shown in Fig. 2. It is shown that the pattern after Proc. 3 has less error in the optimum beam than after Proc. 1 in the direction of service zone, and that the side lobe level of the pattern obtained Proc. 3 is under -40 dB at the set point.

Fig. 3 shows gain deviation, which is the difference between the optimum beam and the beam on the excitation coefficients calculated by Procs. 1, 2, and 3. The result after Proc. 2 and 3 is within ±1.5 dB at the set point.

Fig. 4 shows DUR deviation (absolute value), which is the difference between the optimum beam and the beam on the excitation coefficients calculated by Procs. 1, 2, and 3. The result after Proc. 3 is wider in area and lower for DUR deviation than after Procs. 1 and 2.

This demonstrates that the beam shape obtained by the proposed method can be synthesized close to the optimum beam shape.

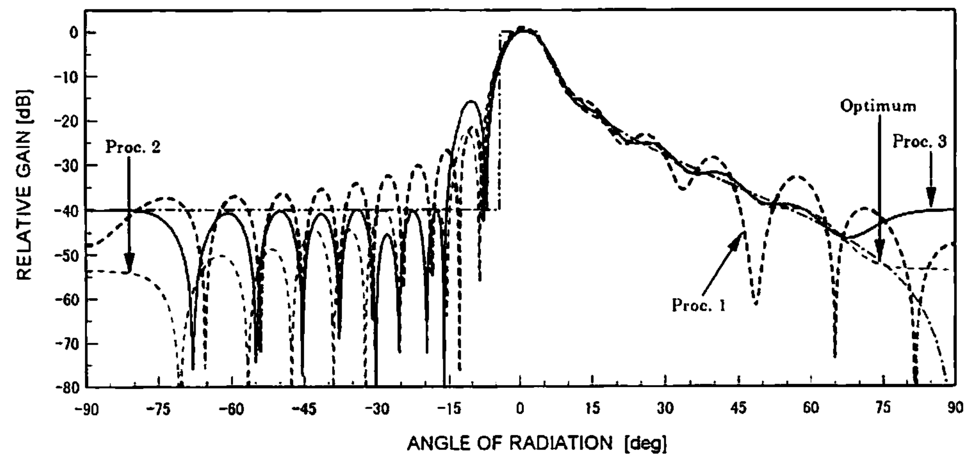

Fig. 2. Directivity pattern by Proc. 1, Proc. 2, Proc. 3, and optimum beam.

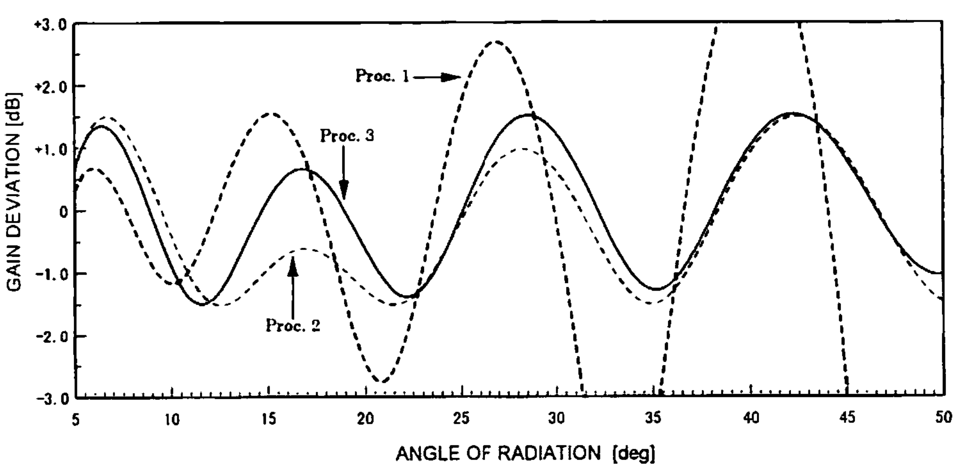

Fig. 3. Gain deviation.

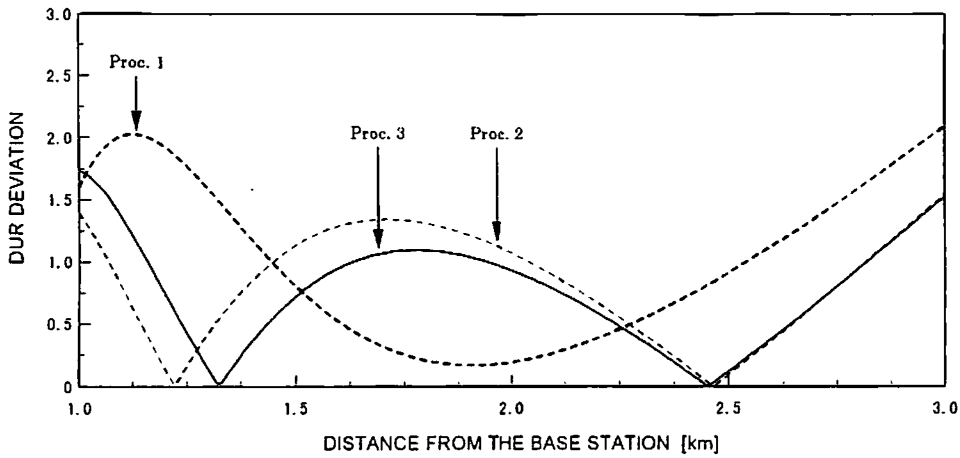

Fig. 4. DUR deviation (absolute value).

4. CONCLUSION

It has been shown that the optimum beam pattern, which minimizes the change of DUR within the service zone, using the Okumura-Hata propagation loss formula for land mobile communications, is a cotangent curve in the direction of the service zone.

Moreover it has been shown that the proposed method, which uses not only Fourier transformation but also linear programming, can synthesize close to an optimum beam shape on the linear array antenna, with DUR more effectively improved by the proposed method than with Fourier transformation alone.

REFERENCE

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[2] T. Chiba : "On a Pattern Synthesis Method for a Linear Array", IEEE International Convention Record, Pt. 5, pp.172-179 (1966).

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