Simulation of Quasi Periodic Fluctuation Caused by Aircraft Scattering Phenomenon

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1. Introduction

There is interference phenomenon of television that is caused by aircraft. It is called flutter. The flutter happen when direct signal is interfered by indirect signal which is scattered by aircraft. It is different from television reception interference by scattering of building. In flutter, scattering object is moving. Then difference of path length is changing at all time. Phase difference is also vary since difference of path length means phase difference of both signal. This interference make great fluctuation in receiving signal level. This phenomenon was observed in Thailand. In this paper simulation of this fluctuation is shown and from that we indicate potential of flight following by television signal.

2. Model considerations

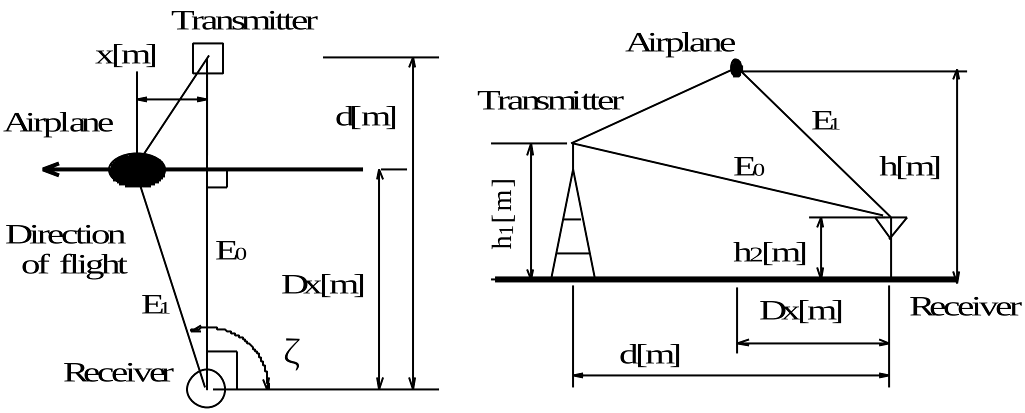

Fig.1 simulation area

We thought that QP(Quasi Periodic) fluctuation is caused by interfere by direct and indirect signal. So we regarded television signal as a sinsoidal wave of carrier frequency. Fig.1 shows cross section and bird's eye view of simulation area. Some constant in Table 1 was used as a calculation parameter for comparison with observed QP wave data taken in Bangkok, Thailand(1). We calculated received electric field strength by

$RL = 20 \log10|Er|/|E_0|$ [dB]

where $|Er| = |E_0+E_1| = |E_0|\{1+\alpha^2+2\alpha\cos(\Delta)\}^{1/2}$,

α:coefficient of indirect signal,

⊿:phase difference

Table 1 Calculation parameter

Transmitting antenna	h_1	230m
Receiving antenna	h_2	10m
Distance	D	45000m
	Dx	20000m
Frequency		55.25MHz

Interfered wave pattern

Fig.2 shows fluctuation caused by interference of indirect signal. Aircraft passed on route of flight which is 3000m height and 20000m from receiving point. Ratio of direct signal level strength and indirect signal level quantity was considered R% constant and α=R/100. In Fig.2, interval of peak amplitude is longest near x=0 where is on the line of receiver to transmitter. At far from x=0, waveform interval is smaller. Next we considered about directional pattern of receiving antenna and characteristics of airplane scattering.

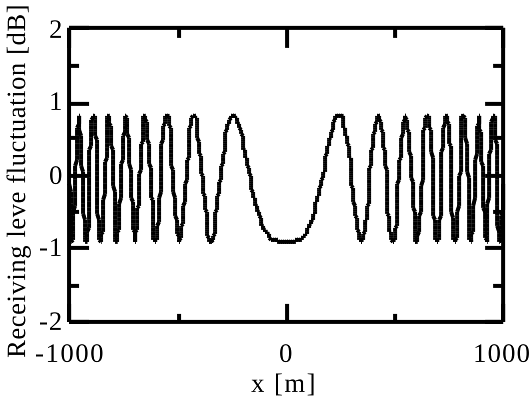

Fig.2 Interference pattern

Directional pattern of receiving antenna

Usually television receiving antenna is set up toward transmitter. So directional pattern is imported to model calculation. Characteristics of two type antenna -- 8-element Yagi and dipole -- is given below.

$DA_{yagi}=\cos(\pi/2*\cos\xi)*\sin(4\pi\sin\xi\cos\zeta)/\ 8\sin\xi\sin(\pi/2*\sin\xi\cos\zeta)$

$DA_{dipole}=\cos(\pi/2*\cos\zeta)/\sin\zeta$ where ξ=90-elevation angle [degree]

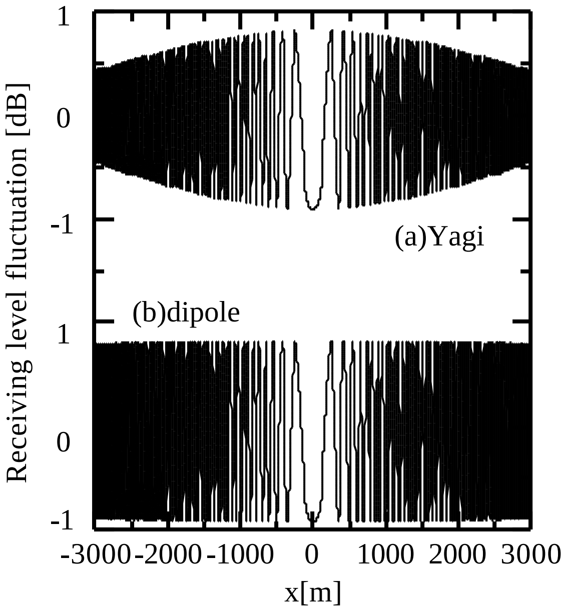

Fig.3 Difference in interfered signal by antenna pattern

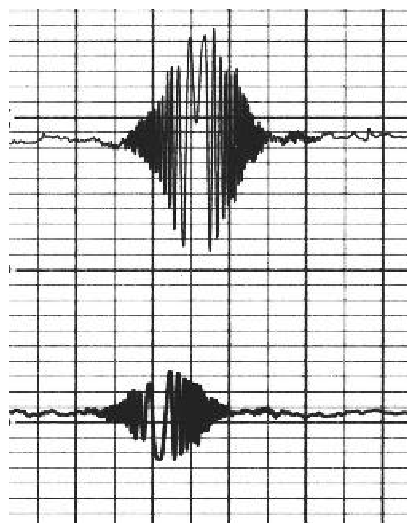
Fig.4 Example of level fluctuation (Bangkok,Thailand)

Ratio of direct signal and indirect signal is R% constant at receiving point. From this, receiving level of indirect signal at receiver is given

direct signal level * R/100 * DA

(We didn't consider antenna pattern effect of direct signal since it is constant.)

Fig.3 shows this calculation result(R=10%,h=3000m). There is big difference in envelope of QP fluctuation because of antenna pattern. Fig.4 is observed QP fluctuation. Upper line is recorded reception level using Yagi antenna, lower one is using dipole antenna. In observed data, each duration is similar and periods of fluctuation is relatively more long than Fig.3. From this result, antenna pattern is not considered main factor of to decide wave form.

Airplane scattering

Recently numerical analysis of airplane scattering has studied. In this paper, radar cross section is applied to scattering pattern. Generally radar cross section (RCS) is a power density ratio of the scattered radar wave to incident wave in the direction of the receiver. In this calculation bistatic RCS is used. Bistatic RCS is a power density ratio of the scattered radar wave in the total direction. The angle between incident direction and scattering direction is defined bistatic angle. Especially when bistatic angle is near 180 degrees, one can calculate approximately bistatic RCS of aircraft by below(2).

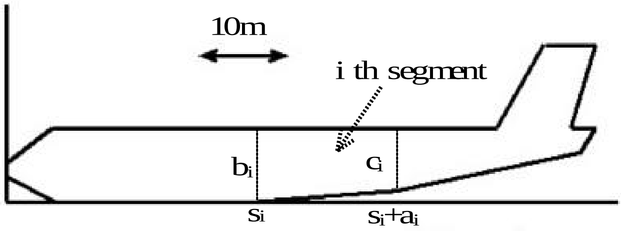

Fig.5 Simplified side view of aircraft

Consider incident direction is side of aircraft. Bistatic RCS of horizontal direction is calculated by

1. to approximate side view of aircraft by straight line.(Fig.5)
2. to divide it N segments each of which is surrounded by vertical straight line and horizontal or slant straight line.
3. to calculate A_i for each segment by

$$A_i = \exp(jus_i)\left\{\frac{a_i b_i[\exp(jua_i)-1]}{jua_i} + \frac{a_i(c_i-b_i)[\exp(jua_i)(jua_i-1)+1]}{(jua_i)^2}\right\}$$

4. to calculate σ by

$$s = \frac{4p}{l^2}\left|\sum_{i=1}^{N} A_i\right|^2$$

This σ was regarded as a parameter which shows scattering characteristics when incident direction was just side. Fig.6 indicate angular characteristics of σ where frequency is 55.75MHz. σ was converted to coefficient of indirect signal level by divided by maximum sigma. Namely, coefficient of arbitrary angle (θ') is

coefficient $=\sigma|_{\theta'} / \sigma|_{\theta=180}$

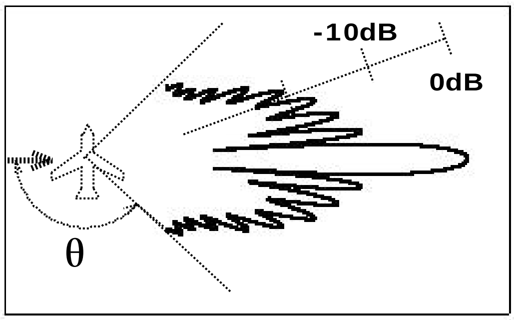

Fig.6 Bistatic RCS characteristics

then receiving level of indirect signal at receiver is

direct signal level * R/100 * coefficient * DA

For this approximation, some conditions were used. Bistatic angle was regarded as the angle between aircraft-receiving point and a line perpendicular to flight course on the plane which include receiving point and flight course.

There was another condition that same angular characteristics of σ was used at any point of aircraft though elevation angle to airplane is change by flight transfer.

Fig.7 shows calculation result by applying this characteristics of scattering (R=10%,h=3011m). Upper waveform is using Yagi antenna function, lower waveform is using dipole antenna function. From this figure, it is clear that envelope of QP fluctuation is independence of antenna directivity pattern.

Comparison to observed data

Last of this section, we show observed data in Bangkok and simulation result. In Fig 7, the abscissa is position of airplane ,but in Fig8 the abscissa is time. If aircraft flys in 360 km/h during 10sec ,it moves about 1000m. This flight speed is relatively slow for B747 aircraft. Calculation values agree well with observed wave result.

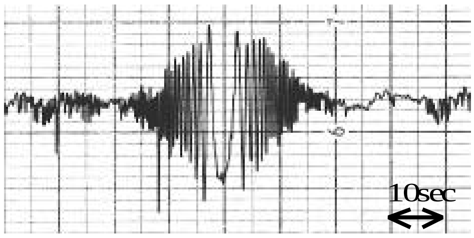

Fig.8 Example of level fluctuation (Bangkok,Thailand)

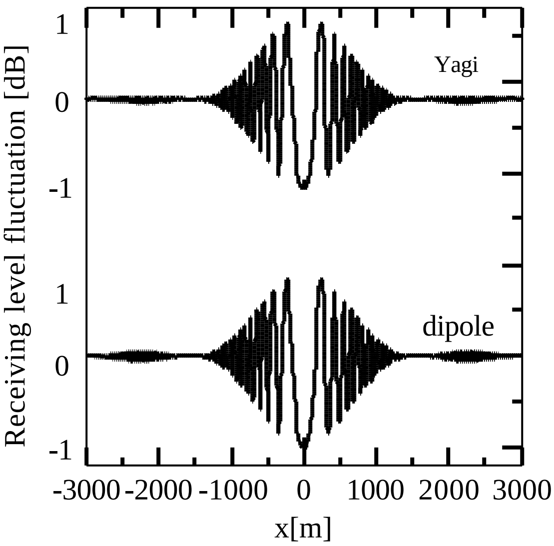

Fig.7 Simulation result

3. Conclusion

We have simulated QP fluctuation of TV signal. QP fluctuation is happened by interference between direct signal and indirect signal scattered by aircraft. Interval of amplitude peak of it has the maximum when aircraft crosses on the transmitter-receiver line. Envelope of QP fluctuation is defined by scattering characteristics of aircraft and is not so effected by antenna pattern. QP fluctuation converge quickly when distance from receiving antenna to flight path is short. From these result we concluded that you can watch distance and course of airplane which pass on the transmitter-receiver line by observation of QP fluctuation wave form.

4. Discussion

The variable R used in simulation was coefficient of quantity ratio between direct and indirect signal. We used R given value but it is to be desire that R is obtained by calculation. For that purpose it is necessary to obtain the knowledge of attenuation characteristics propagating in the upper air and antenna pattern of transmission antenna.

It is also to be desire that detailed scattering characteristics of aircraft is given. The characteristics we used in this paper is symmetry with θ=180.It is expected that real scattering characteristics is asymmetric because side view of aircraft is asymmetric. If we get detailed scattering characteristic, we could define direction of flight by QP fluctuation wave form.

References

1.Nagahora, Takahashi, Moriya, and Sakurada "Receiving Field Strength by Aircraft Scattering" ITE Technical Report Vol.22 No.11 PP43-68 1998

2.Jerome I. Glaser "Bistatic RCS of Complex Objects Near Forward Scatter" IEEE Transactions on Aerospace and Electronic System AES-21 No.1 PP70-78 1985