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Analysis on Relationship Between Signal Intensity and Antenna Height of Localizer Antenna Array by Digital Twin

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Abstract. To obtain optimized space radiation signal to satisfy the coverage requirement, it is essential to set the height of radiated antenna (h_a) effectively. Theoretical analysis with a series h_a (from 1m to 20 m) of mirror signal synthesis was studied. The three-dimensional mathematical model of localizer antenna array of 7216A was also established. Because of synthesis lobe effect, the variety of h_a can adjust the signal strength in vertical. The radio frequency (RF) level would increase obviously with ascending of h_a. This phenomenon presents extremely regularly in low altitude. Two curve surface models, conical surface and contour plane, with a series of height of antenna (h_a= 1 m, 2 m, 3m, 4m, 5m, 10 m, 15 m, 20 m) and three fly height (h_{fly}= 100 m, 600 m, 3000 m) were analyzed. With the excessively increasing of h_a, however, RF value would fluctuate in large elevation. At the same time, headspace blind area combines with circle effect become obvious. The study showed h_a rose to 4 meter presents a good quality. This result fits for any localizer antenna array of Instrument Landing System (ILS).

Keywords: mirror signal synthesis, horizontal polarization, signal strength, antenna height

1. Introduction

Localizer antenna array is horizontal polarization. After radiated signal reflected from ground, the synthesis signal combined with direct one and reflected one generates the lobe(s) oblique upward. This main synthetic lobe provides approach and landing guidance [1] for aeroplanes. The types of localizer beacon are the most abundant in Instrument Landing System (ILS) equipment. According to actual needs, they came out one after another. Such as series the early 3500-series: 3522[2], 3523B[3], 3524[4], 3525[5], 3526[6] and the later 7000-series: 7212A[7], 7212C[8], 7216A[9], 7216C[10], 7220A[11], 7220B[12] were produced by Normarc factory; and single frequency: 8-unit moderate-aperture, 12-unit medium-aperture, dual frequency: 13-unit wide-aperture, 21-unit ultrawide-aperture[13], and 420-series: 14-unit, 20-unit manufactured by Thales company; dual frequency:14-unit, 16-unit, 20-unit were designed one after another by Selex[14] company. The series above are mainly distinguished by horizontal radiated pattern. They almost play the same role in vertical pattern. However, the vertical pattern depends on the elevation (θ_v) changing of the main lobe. And the elevation is directly controlled by h_a. Correct setting of θ_v can improve intensity effectively of signal coverage. At the same time, optimized h_a would provide more energy-saving environment and longer lifecycle of localizer equipment in further operation. Otherwise, incorrect installation may cause insufficient coverage distance.

In this paper, h_a corresponding to the intensity of localizer was studied. This result fits to all the kind of localizer antenna array. The 3D mathematical model of 7216A localizer system was established. Two surface coverage models and radiated electromagnetic signal distribution of localizer array were simulated by software Matrix Laboratory (Matlab).

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2. Result and Discussion

2.1. Relationship Between H_a and Signal Distribution

2.1.1. Mirror Signal Synthesis

There are two components contributes to localizer signal in space. The direct radiated signal and its reflected signal. Two signals overlay in space. the amplitude of two signals is regarded as approximately the same. This signal superposition mode is called mirror signal synthesis.

In general, there are two kind of polarization modes, horizonal polarization and vertical polarization. They are widely used in radio field. The basic principle of polarization formation was introduced in figure 1, a charged metal rod AB and its reflected one marked c, they have the same distance (h) from the reflecting surface. When the rod positioned parallel to reflecting surface, it words as horizontal polarization. The phase of the reflected signal (A'B') is opposite to the direct signal (AB). When the rod positioned perpendicular to reflecting surface, rod AB works as vertical polarization. The phase of the reflected signal is same to direct one.

Localizer antenna array consists of a row of Log Periodic Dipole Antenna (LPDA). They are placed parallel to ground, so polarization mode is horizontal polarization. The reflected signal owns the opposite phase.

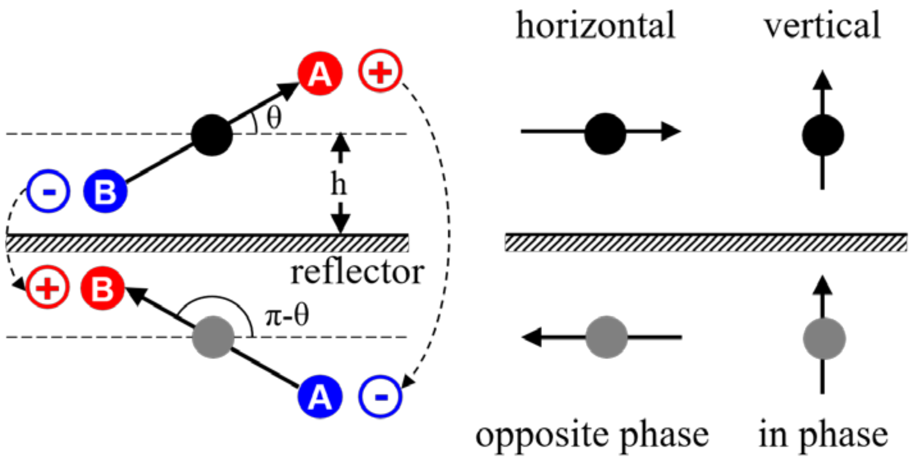

Fig.1: Electronic polarization formation.

Terminal A is positive of charged metal rod while another terminal B is negative. Through reflection the mirror rod, terminal A' becomes negative and terminal B' turns to positive. There are two polarization method, horizontal polarization and vertical polarization. The black dot is the center of the rod AB, the height from the reflector is h. The gray dot is the center of the mirror symmetry rod A'B'. If the angle (θ) is 0°, namely metal rod parallel with reflector, rod AB is horizontal polarization. The reflected signal owns the opposite phase to original one, If the angle (θ) is 90°, namely charged metal rod perpendicular to reflector, rod AB is vertical polarization. Both the original and reflected one own identical phase.

2.1.2. Relationship Between H_a and Lobe

Mirror signal synthesis generates directional lobes. Direct signal and reflected signal with identical amplitude but opposite phase overlay in space. Because of phase difference of two signal in space, synthetic signal is not omnidirectional distribution any more. It can be seen in figure 2, no matter how high h, there is little signal in horizontal plane ($\theta_v = 0°$). A series of lobes appear with the ascending of h_a. there is a rule that the number of lobes in every quadrant is proportional to h in electrical length. Quantitively speaking, every half of wavelength contributes a whole lobe in every quadrant. If h is less than half of wavelength, still one lobe is first quadrant existing, and mirror symmetry in each quadrant.

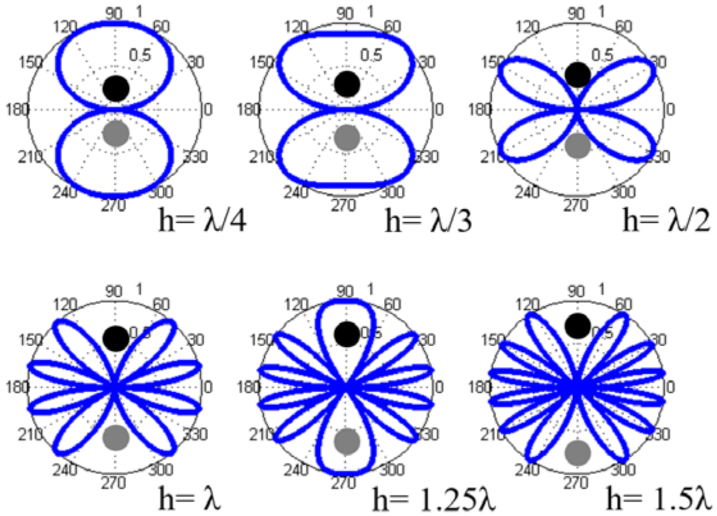

Fig.2: Opposite phase synthesis with different electrical length.

The gap (h) between original dot (black one) and reflector should be transferred to electrical length. Every half of lambda contributes a whole lobe in every quadrant. While h is 1.5 times of wavelength, there are three lobes generated in the first quadrant. It can be inferred that if h was 2 times of wavelength, there were four lobes generated. The number of synthesis lobe increasing with the extending of electrical length. The amplitude of synthesis lobe is always zero at the position θ_v =0°.

2.1.3. Vertical Signal of Log Periodic Dipole Antenna on Ground

The frequency (f) of localizer system is taken 110.1 MHz, then the corresponding wavelength (λ) is 2.72 m. Only the first quadrant should be considered in application. A series of h_a corresponding to vertical pattern was exhibited in figure 3. In the center of the figure, the vertical radiated pattern of LPDA was listed. It is just like the case of no actual height (h_a= 0 m). Once h_a exists, no matter how less, signal strength disappears immediately at θ_v =0°. The synthesis signal becomes upturned lobe. For the case of h_a= 1m, the wavelength is less than half of λ (λ/2= 1.36 m), only one lobe appears. When h_a arrives at 2m, the corresponding electronic length is about 0.73λ, which is more than 0.5λ, two lobes appear. The number of the lobes are increasing monotony with the ascending of h_a.

Different to the case in figure 2, the amplitude of every lobes listed in figure3 are not equal. This phenomenon attributes to the vertical pattern of LPDA, which is not omnidirectional, the maximum value (E_{max}) is located in the position of θ_v =0°. The amplitude attenuates with the increasing of θ_v. It can be found in the center of the figure, the vertical pattern of LPDA, the half power point is θ_v =33°. So, the first lobe owns the maximum amplitude always.

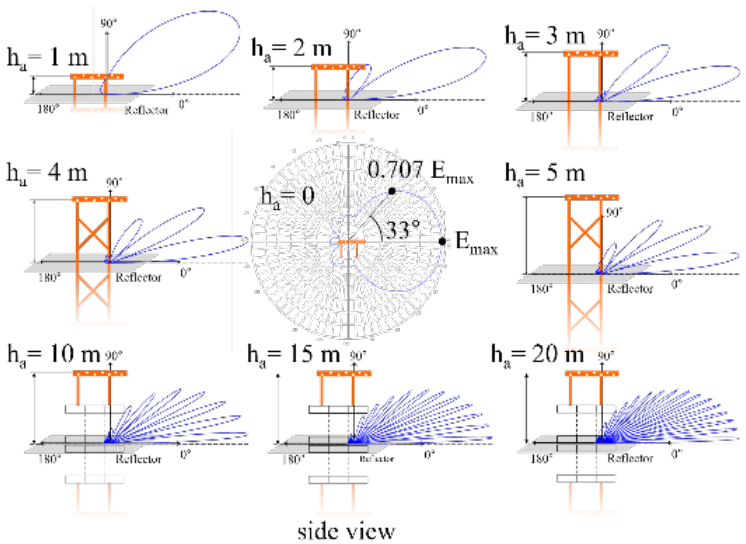

Fig.3: Vertical radiated pattern of LPDA corresponding to h_a.

The frequency (f) of localizer signal is taken 110.1 MHz, then the corresponding wavelength (λ) is 2.72 m. When the height of antenna is 1m, there are 0.36 times of λ, there is only one lobe appears. When the height of antenna is 2m, there are 0.73 times of λ, namely more than 0.5 times of λ, there are more than one lobe generated. The lobes appear in positive proportion to h_a. While h_a=0, the synthesis formation is the vertical pattern of LPDA, listed in the center of the figure.

2.2. Relationship Between H_a and Receive Position

In this section, according to the distribution of 7216A antenna array, signal strength radiated at specific receive point in space would be discussed.

2.2.1 Signal Characteristic at Different Azimuth

The 7216A antenna array consists of sixteen elements, the mirror symmetry from center generates eight pairs [9]. The width of the antenna array is 38.5 m. The total horizontal pattern of sixteen LPDAs can be found figure 4, there is a sharp lobe right ahead. This sharp lobe is divided equally by the runway centerline. The azimuth located in centerline is defined as θ_h = 0°.

The horizonal pattern of one single LPDA is marked at the right top of the figure. The specific step to establish the field signal can refer to reference 15. According to horizontal pattern, five points with radius of 1 km are chosen to be analyzed. Namely θ_h = -35°, -10°, 0°, +10°, +35°. All the height of these points is 10 m. The position in front of the center of antenna with a distance of r_2= 5 km is also calculated in the discussion below.

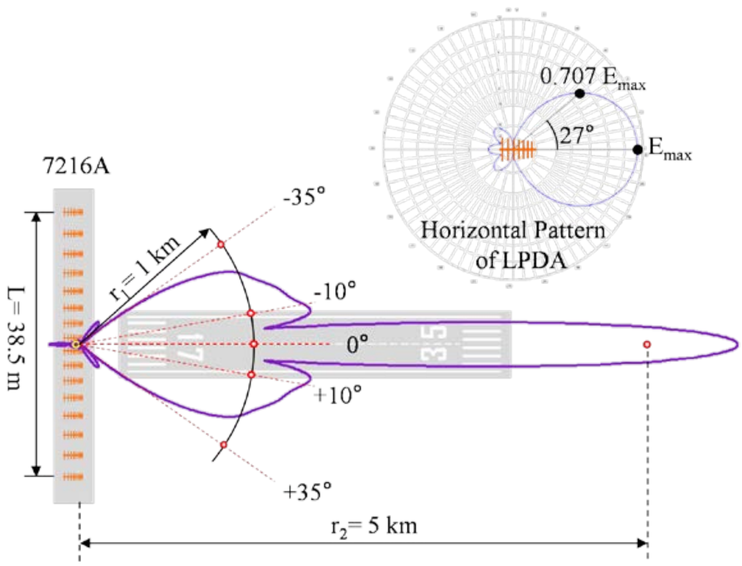

Fig.4: Horizontal radiated pattern of LPDA and 7216A localizer antenna array.

Inset shows the horizontal pattern of single LPDA. 7216A localizer antenna array consists of sixteen LPDAs, the total width of the array is 38.5 m. Both LPDA and antenna array compose the whole horizontal pattern. There are two radiuses taken into consider, r_1= 1km and r_2= 5km. There are five point chosen for r_1= 1km, azimuth (θ_h) from -35° to +35°, namely θ_h= -35°, -10°, 0°, +10°, +35°.

From five points with radius of r_1= 1 km and 10 m high, the RF corresponding to h_a has been calculated, exhibited in figure 5. RF level of each point increases monotonically with the increasing of h_a. The value of θ_h = 0° is maximum, second for θ_h = ±10° and minimum for θ_h = ±35°. Although RF is rising with ascending of h_a, it is not increasing linearly. The increment (ΔRF) is getting smaller and smaller in high region of h_a. It is not advisable to increase h_a blindly. The fitting curve indicates the critical point (h_c) of h_a corresponding curve. When h_a below h_c, the increment is obvious, but once h_a above this value, the increment of RF would not be effective any more.

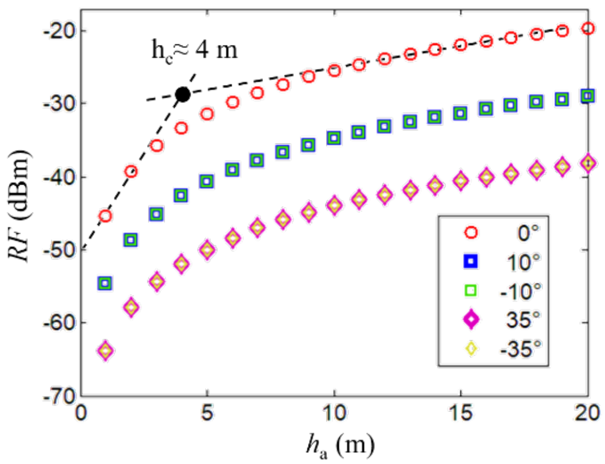

Fig.5: RF level corresponding to h_a in different azimuth.

All the data tested 10-meter-high (h_{fly}=10 m). Fitted curve shows the critical point at h_c= 4 m. RF level increases with the ascending of h_a, it grows quickly in low h_a zone, when h_a is higher than 4m, the growth becomes much slower.

The increment of RF (ΔRF) is calculated quantitatively for two ways. Table 1 lists the ΔRF by ascending one meter of h_a. For example, when h_a= 1 m is elevated to h_a= 2 m, the corresponding increment of RF is 6 dBm. When h_a is elevated from 2 m to 3m, ΔRF turns to 3.5 dBm for θ_h = 0° and 3.6 dBm for θ_h = ±10° and θ_h = ±35°. When h_a is below 4 m, the increment of RF is more than 2 dBm. When h_a is higher than 8 m, corresponding ΔRF is less than 1 dBm. So, if you want to improve RF level by ascending h_a linearly, h_c = 4m is critical transition height.

Table 1: Increment of RF (ΔRF) for ascending Δh_a= 1 m

h_a(m)	0° (dBm)	10°(dBm)	35°(dBm)
1→2	6.0	6.0	6.0
2→3	3.5	3.6	3.6
3→4	2.5	2.5	2.4
4→5	2.0	1.9	2.0
5→6	1.5	1.6	1.6
6→7	1.4	1.3	1.3
7→8	1.1	1.1	1.1
8→9	1.0	1.0	1.0
9→10	1.0	0.9	0.9
10→11	0.7	0.8	0.9

The other way to improve RF level is ascending h_a by doubling, seen the calculation result in table 2. When h_a is doubled, the increment is almost approximately 6.0 dBm. When h_a has been reached a high value, the increment of RF needs significant improvement of h_a. In other words, if the RF level need be enhanced by certain decibels, the h_a should be doubled.

Table 2: Increment of RF (ΔRF) for double h_a

h_a(m)	0°(dBm)	10°(dBm)	35°(dBm)
1→2	6.0	6.0	6.0
2→4	6.0	6.1	6.0
3→6	6.0	6.0	6.0
4→8	6.0	5.9	6.0
5→10	6.0	5.9	5.9
6→12	6.0	5.9	5.9
7→14	6.0	5.9	5.9
8→16	5.9	5.9	5.9
9→18	5.9	5.9	5.9
10→20	5.9	5.8	5.8

There is a little difference of ΔRF of three azimuths in both tables. This is contributed to near field characteristic. The signal in far field would trend to the same of different azimuths. The variation of RF by changing h_a of far field model could be described as formula 1:

$$\Delta RF = 20\log\frac{\sin(\frac{2\pi}{\lambda}h_a^{'}\sin\theta_v)}{\sin(\frac{2\pi}{\lambda}h_a\sin\theta_v)} \tag{1}$$

When the height is far less than horizontal distance, θ_v is negligible, $\sin(\theta_v)$ is approximate equal to θ_v.

$$\sin\theta \approx \theta \tag{2}$$

$$\sin(\frac{2\pi}{\lambda}h_a\sin\theta_v) \approx \frac{2\pi}{\lambda}h_a\sin\theta_v \tag{3}$$

From formula 2 and formula 3, The variation of RF could be described as formula 4:

$$\Delta RF = 20\log\frac{\sin(\frac{2\pi}{\lambda}h_a^{'}\sin\theta_v)}{\sin(\frac{2\pi}{\lambda}h_a\sin\theta_v)} \approx 20\log\frac{h_a^{'}}{h_a} \tag{4}$$

At last, the variation of RF in far field could be described as formula 5:

$$\Delta RF \approx 20\log\frac{h_a^{'}}{h_a} \tag{5}$$

When h_a is doubled, ΔRF is about 6 dB, seen the result in formula 6:

$$\Delta RF \approx 20\log\frac{2h_a}{h_a} = 20\log 2 \approx 6 \tag{6}$$

2.2.2. Signal Characteristic at Different Altitude

There are two horizontal distances have been defined to calculation in figure 4, r_1= 1 km and r_2= 5 km. But in figure 6, it is not just one altitude for h= 10 m only, a series of altitude are added to compare, namely h= 10 m, 50 m, 100 m, 300m, 600 m, 1200m.

Six heights are divided into three groups. group a, b, c for the case of r_1= 1 km and group e, f, g for the case of r_2= 5 km, respectively. In group a, RF is almost monotonic increasing with the ascending of h_a. In group b, monotonicity vanished, and the corresponding curve starts to fluctuate, like a "M" shape. In group c, the relationship between RF and h_a seems to be changeable, distribution curve produces violent vibration. The similar phenomenon also appears in case of r_2= 5 km. The difference is vibration only appears at the altitude of 1200 m. More regular distribution curves are presented in low altitude.

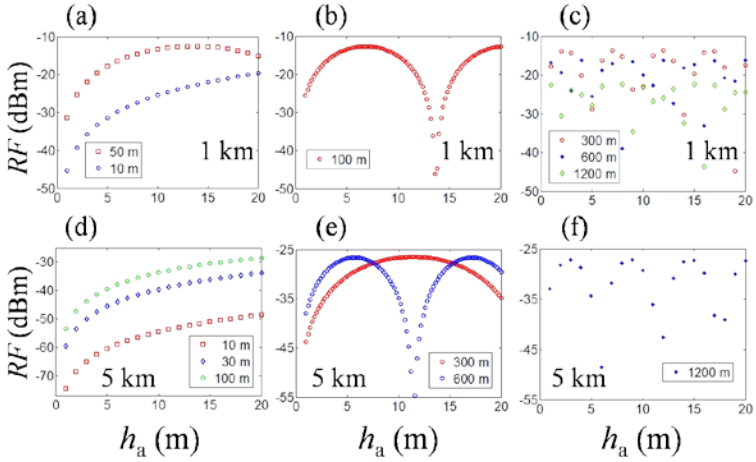

Fig.6: RF corresponding to h_a with different altitude in front of the centre of antenna array with 1 km and 5 km.

For the case of r= 1km, RF is increasing obviously with the ascending of h_a at the altitude of 10 m, while RF is increasing slowly at the altitude of 50 m. At the altitude of 100 m, RF is reversed when h_a surpasses 10 m. When the altitude higher than 300 m, the RF is vibrated, almost no regular presentation. For the case of r= 5km, RF is increasing obviously with the ascending of h_a at the altitude of 10 m, 30 m, and 100 m. The phenomenon of RF reversed appears at the altitude of 300 m, when the altitude arrives at 1200 m, almost no regular presentation.

2.3. Relationship Between H_a and Surface

There are two surface modes established in this section, conical surface model and contour plane model. The range of receive position is not just a single point, or a series of points within a line segment. The scope of the study was expanded to a whole area. And this is not plane, but curve surface.

Coverage zone of localizer 7216A system in two kind of surface would be introduced one by one. The transmitter power of 7216A system is set to 20 watts. The minimum acceptable RF level in space is set to -93 dBm.

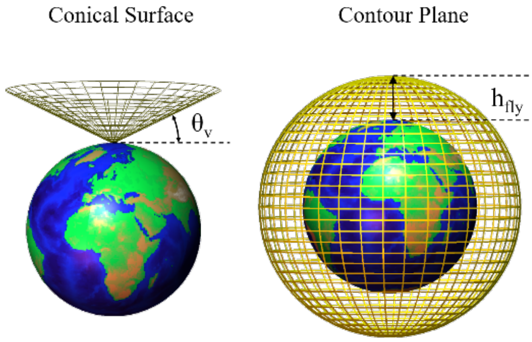

Fig.7: Two kind of cross section models.

In conical surface model, angle of altitude (θ_v) between the horizon and inclined plane is main parameter. In contour plane, fly altitude (h_{fly}) is main focus. Because of Earth curvature, contour plane is not a flatten plane, it looks like a sphere. Earth curvature error correction was considered in the follow passage.

2.3.1. Conical Surface Coverage Responding

The design of mirror synthesis follows conical surface rule. the conical tip is the ground under the center of the localizer antenna array. The coning angle is corresponding to the elevation (θ_v). In conical surface, the coverage zone is more regular than that of contour plane. It just changes with elevation and h_a.

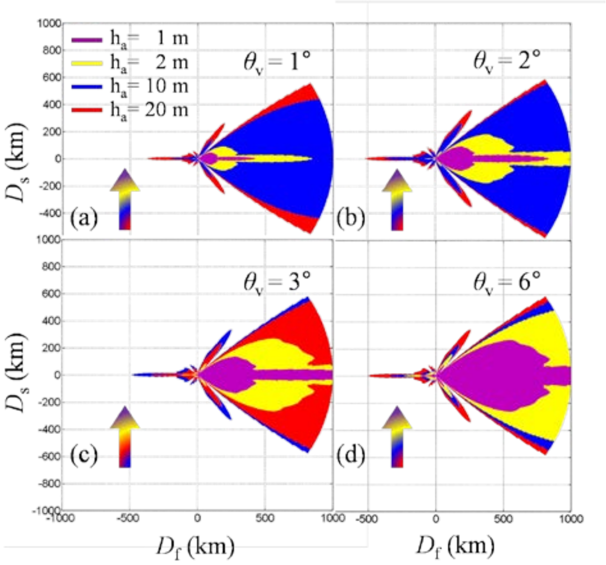

Fig.8: Conical plane corresponding to h_a with a series of θ_v.

Fig.(a) shows coverage zone in θ_v = 1° with different h_a. Horizontal coordinate (abscissa x-axis) indicates the front of the antenna array and longitudinal coordinates represents the side direction of the antenna array. The maximum zone with h_a= 20 m (red area) placed at the bottom layer, the second one with h_a= 10 m (blue area) was placed on the bottom one, the next one with h_a= 2 m (yellow area) was placed on the blue layer, the minimum coverage zone with h_a= 1 m (cyan area) was placed on the top of the other three layers. The colorful arrow indicates the stacking order. Identical description method is applied to the other three figures, fig.(b), fig.(c) and fig.(d). It can be note that in fig.(c), coverage range of h_a= 10 m (blue one) is larger than that of h_a= 20 m (red one). This order is different to the other three figures.

In figure 8, there are four h_a (1m, 2m, 10m, 20 m) as well as four θ_v (1°, 2°, 3°, 6°) in research. In figure a, the coverage zone of h_a= 1m (marked in cyan) is less than that of h_a= 2m (marked in yellow), the max coverage distance (d_{max}) is about 400 km for h_a= 1m and 800 km for h_a= 2m. So, the d_{max} of h_a= 1m is half of h_a= 2m. Therefore, the coverage area is quarter of the case of h_a= 2m. The interesting thing is their coverage shapes are almost the same. And follow the rule of equal proportion distribution. When h_a arrives at 10 m (marked in blue), the coverage area has been greatly expanded. It is beyond a radius of 1000 km. when h_a doubled again, ascending to 20 m (marked in red), the corresponding coverage area in front could not be compared directly. It is only observed by back lobe. Also, the coverage distance is approximately two times of h_a= 10 m, about 380 km for h_a= 20 m and 200 km for h_a= 10 m. In figure b, the proportion with h_a= 1 m and h_a= 2 m is still 1:2, but it can be observed from back lobe of h_a= 10 m and h_a= 20 m, about 400 km for h_a= 10 m and 500 km for h_a= 20 m. Obviously, the ratio is no longer follows 1:2. In figure c, for θ_v= 3°, d_{max} of h_a= 10 m is dramatically more than that of h_a= 20 m. However, d_{max} of h_a= 1 m and h_a= 2 m is still follows the rule of 1:2. In figure d, the coverage area of h_a= 20 m is larger than h_a= 10 once again.

To explain the abnormal phenomenon scientifically, the relative amplitude of mirror synthesis signal corresponding to θ_v of each h_a has been drawn in figure 9. For lower h_a, the corresponding curves are almost straight line, but for higher h_a, their curves begin to bend. For h_a= 20 m, the maximum value appears at θ_v = 2°, and then sharply drops. At θ_v = 3°, the value of h_a= 20 m is less than that of h_a= 10 m. this is the reason in figure 8(c), the coverage area is smaller for h_a= 20 m. Because of the linear behavior in low h_a, shape of coverage area keeps good proportion, despite of θ_v up to 6°.

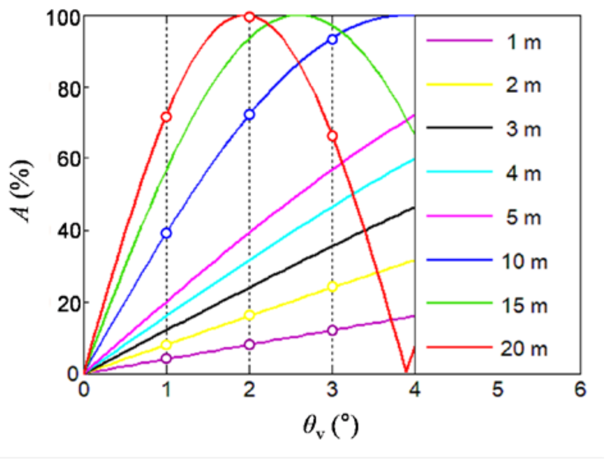

Fig.9: Relative amplitude corresponding to θ_v with different h_a.

A= 100% represents the maximum value of each h_a. When θ_v greater than 2°, A (h_a= 20 m) starts to decline, but A (h_a= 10 m) is still ascending. This is the reason coverage range of h_a= 10 m is larger than h_a= 20 m at θ_v= 3°. When θ_v arrives at 4°, relative amplitude of h_a= 20 m is negligible. A (h_a= 20 m) is the minimum value in all height of h_a at 4°.

2.3.2. Contour Plane Coverage Responding

When the aircraft flies in sky with a certain altitude, the orbit in space is a contour plane. The contour plane is just like the surface of a sphere instead of a flat surface in fact. So, the precise position on the contour plane should be revised for Cartesian coordinates of antenna system [16]. The calculation discussed below is based on the hypothesis that the Earth is a spheroidal ball with smooth surface.

In table 3, both of the coverage of plane and contour plane are calculated, and the ratio of d_{max} by two circumstances is also listed. It can be found clearly that unrevised model, d_{max} of flat surface owns longer distance. For conventional coverage requirement (minimum RF= -93 dBm), d_{max} is 147 km for h_{fly}= 300. While the value of revised model is just 64 km. So, it is necessary to revise Earth curvature error. Otherwise, the error is pretty unbelievable.

The ratio of d_{max} of different h_{fly} is stable, which is always 2.3 for minimum RF= -93 dBm. In further, the stricter coverage requirements (minimum RF= -88 dBm, -83 dBm, -78 dBm, -73 dBm) were also analyzed. The ratio descents a bit. The higher requirement corresponds the smaller ratio. The error is just 20% for minimum RF= -73 dBm. Otherwise, if the coverage requirement was lower standards, the error would not be negligible, the error correction is necessary. The discussion below, the common coverage requirements (minimum RF= -93Bm) is always used.

Table 3: Maximum coverage distance (d_{max}) before and after Earth curvature error correction

cut off RF (dBm) h_{fly}(m)	-93	-88	-83	-78	-73
d_{max} (km)-unrevised (Before)					
300	147	110	81	62	46
600	208	155	117	88	65
1200	294	221	166	124	93
2400	417	312	234	175	131
d_{max} (km)-revised (After)					
300	64	59	53	46	39
600	90	84	76	66	55
1200	128	119	107	92	78
2400	181	169	152	132	110
ratio of d_{max} (Before/After)					
300	2.3	1.9	1.5	1.3	1.2
600	2.3	1.8	1.5	1.3	1.2
1200	2.3	1.9	1.6	1.3	1.2
2400	2.3	1.8	1.5	1.3	1.2

In general, the minimum RF of signal coverage is -93 dBm, to study more systemically, the coverage requirement was raised. From five kind of coverage requirements (cut off RF= -93 dBm, -88 dBm, -83 dBm, -78 dBm, -73 dBm), the ratio of d_{max} (the value of d_{max} unrevised divided by the revised one) can be apparently understanding. If Earth curvature unrevised, the contour plane was regarded as flattened, the lower coverage requirement would cause greater error.

In figure 10, there are three h_{fly} (100 m, 600 m, 3000 m) as well as four h_a (1m, 2m, 10m, 20m) in research. In figure a, scanned with a radius of 50 km, as expected, the higher h_a owns the larger coverage area. But the lower h_a owns a sharp lobe in front. in figure b, almost shows a same rule. the higher h_{fly} corresponding larger coverage area. However, in figure c, although d_{max} of h_a= 20 m (red one) is more than h_a= 10 (blue one), there are some gaps in the center.

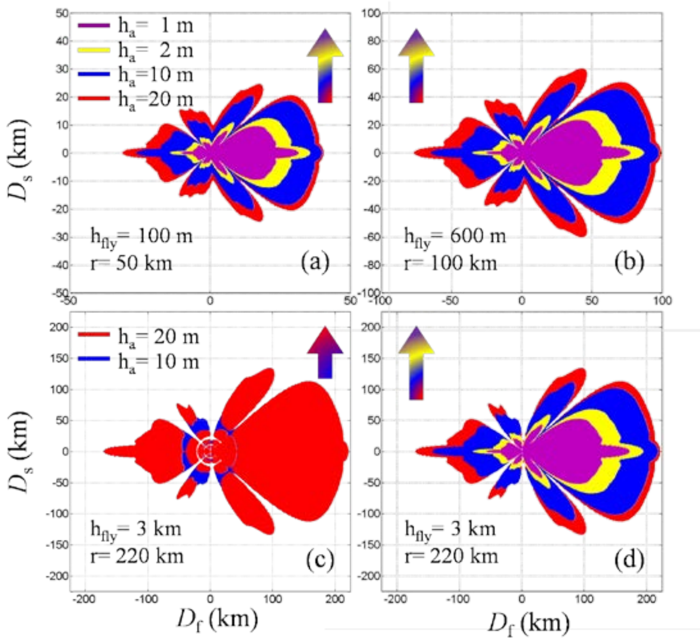

Fig.10: Contour plane corresponding to h_a in different h_{fly}.

Fig.(a) shows coverage zone in the altitude of h_{fly}= 100 m with different h_a. The maximum zone with h_a= 20 m (red area) placed at the bottom layer, the second one with h_a= 10 m (blue area) was placed on the bottom one, the next one with

h_a= 2 m (yellow area) was placed on the blue layer, the minimum coverage zone with h_a= 1 m (cyan area) was placed on the top of the other three layers. The colorful arrow indicates the stacking order. Identical expression is applied to the other three figures, fig.(b), fig.(c) and fig.(d). It can be note that in fig.(d), the coverage range of h_a= 20 m (red one) is larger than that of h_a= 10 m (blue one). But in fig.(c), red one covered less than blue one within the of radius 50 km.

To find the details more clearly, the case of h_{fly}= 3000 m has been specifically listed in figure 11. For lower h_a, there is no obvious evidence, seen in the enlarged zone of figure a and figure b. For higher h_a, both figure c and figure d appear some circles. Because of overlap in figure 10, this coverage insufficient was not discovery systemically. The abnormal zone should be enlarged more detailly.

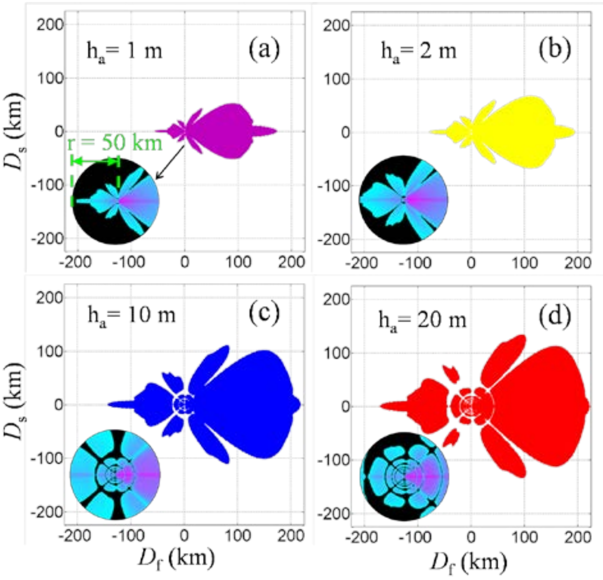

Fig.11: Contour plane in the altitude of h_{fly}= 3 km with various h_a.

The main graph owns the radius with 220 km. Their insets show the enlarged zone of the center. Each coverage zone of inset covers the area with the radius of 50 km. Circle appears more frequently with the higher h_a.

2.3.2.1. Coverage Insufficient----Headspace Blind Area

To more carefully and intensively, the coverage area of figure 11 is enlarged 100 time. A series of h_a with a radius of 5 km can be found clearly in figure 12. All the cases, no matter how high or how low of h_a. exist coverage insufficient, this position is located in the headspace of antenna array. So, it can be called "headspace blind area". In detail, the blind area is comparatively fixed. They are distributed on both sides of the center point. The double holes are related to the vertical pattern of LPDA. The hyperbolic shape originates from twenty antennas array effect.

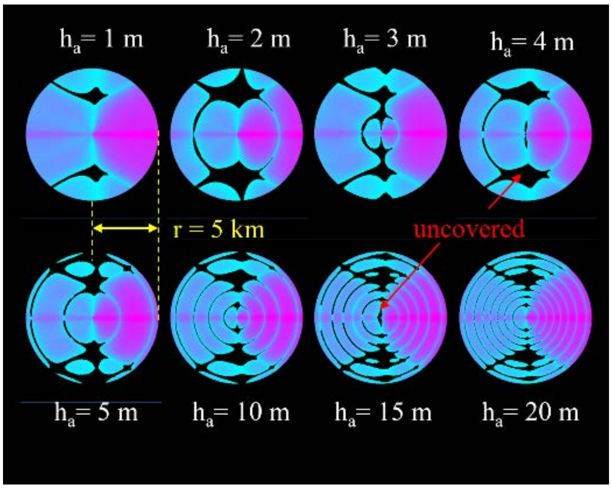

Fig.12: Contour plane in the altitude of h_{fly}= 3 km with various h_a.

Besides the circle effect, there are some certain zone uncovered. They are located in the position above the headspace of antenna array for all height of h_a.

2.3.2.2. Near Field Situation----Circle Effect

There is not remarkable circle for the cases of h_a lower than 5 m. But there are more than two circles for the case of h_a higher than 5 m. A lot of circles appear in near field for h_a = 20 m. Back to figure 3, these circles are corresponding to the gap of lobes. For lower h_a, circle in near field would not impact approaching. There are several kilometer distances between localizer antenna array and the threshold of runway. But it is hard to say for higher h_a.

3. Summary

The mirror signal synthesis of localizer antenna array was investigated in series. The heights of localizer antenna (h_a= 1 m, 2 m, 3m, 4m, 5m, 10 m, 15 m, 20 m) corresponding to radiated space signal were study for both vertical section and 3D surface. From vertical section, the space RF level increase obviously with the ascending of h_a below altitude of 50 m. But it is not fitted to high altitude, the signal strength shakes up and down with the ascending of h_a above altitude of 600 m. The optimized height of h_a is about 4 m obtained from curve fitting. From 3D surface, there were four elevate angle (θ_v= 1°, 2°, 3°, 6°) in conical surface and three height (h_{fly}= 100 m, 600 m, 3000 m) in contour plane have been studied. For conical model, the shape of coverage area of lower h_a became equally amplify with the increasing of θ_v. However, it was not monotonically increasing for higher h_a (h_a= 20 m). For contour plane model, the higher for h_{fly}, the more area could be covered, especially for higher h_a, but coverage insufficient also generated, such as headspace blind area and circle effect. Similarly, the 3D model also indicated the h_a is not the higher the better. This study can be widely applied to on-site installation of equipment about antenna height demand.

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5. References

[1] Normarc. Normarc 7000B ILS Training manual [M], Park Air Systems, 2013

[2] Normarc. Normarc 3522 Instruction manual [M], Park Air Systems, 2011

[3] Normarc. Normarc 3523B Instruction manual [M], 21450-39, *Park Air Systems*, 2011

[4] Normarc. Normarc 3524 Instruction manual [M], 21451-75, *Park Air Systems*, 2005

[5] Normarc. Normarc 3525 Instruction manual [M], 21452-0610, *Park Air Systems*, 2011

[6] Normarc. Normarc 3526 Instruction manual [M], 21453-32, *Park Air Systems*, 2011

[7] Normarc. Normarc 7212A Instruction manual [M], 23746-018, *Park Air Systems*, 2012

[8] Normarc. Normarc 7212C Instruction manual [M], 70375-012, *Park Air Systems*, 2012

[9] Normarc. Normarc 7216A Instruction manual [M], 24797-013, *Park Air Systems*, 2012

[10] Normarc. Normarc 7216C Instruction manual [M], 71507-01, *Park Air Systems*, 2012

[11] Normarc. Normarc 7220A Instruction manual [M], 24136-015, *Park Air Systems*, 2012

[12] Normarc. Normarc 7220B Instruction manual [M], 24137-015, *Park Air Systems*, 2012

[13] Thales. Thales ILS-LOC 411-Technical Manual [M], *Thales Antenna Systems,* 2000, **1**(B)

[14] SELEX. SELEX Operations and Maintenance Manual [M], *Overland Park, KS, U.S.A.,* 2005

[15] C.Q.Qu. Research on signal of field monitor of 7220A localizer beacon subsystem of ILS [J]. *Open Journal of Antennas and Propagation*, 2015, **3**(4):37-50.

[16] C.Q.Qu. Research on Contour Plane Coverage of 20-unit Localizer Antenna Array [J], *Proceedings of 2020 the 10th International Workshop on Computer Science and Engineering (WCSE 2020)*, 2020, Chapter **7**- Electronics and Communication Engineering:425-434.