Analysis of ILS Localizer LPDA on Far and Operating Fields

Koichi Gyoda, Haruo Kawakami, Gentei Sato, Taneaki Chiba* and Yasuo Suzuki*
Faculty of Science and Technology, Sophia University *Toshiba Co.,Ltd.

Abstract—LPDA has been used for ILS Localizer antenna, but recently it is required to analyze radiation patterns of LPDA more minutely and precisely. So we calculated and measured farfield radiation patterns in free space. They show good agreement, and we found that we couldn't ignore the mutual coupling effect of LPDAs. Furthermore, we calculated patterns that take account of the earth to analyze effect of the real airport's condition.

1.Introduction

Instrument Landing System(ILS) was introduced as the international standards of landing system by International Civil Aircraft Organization(ICAO) in 1954 and worldwide in use today at most of important airports. ILS has pointed out essential disadvantage because it is a long-established system. So ICAO decided to introduce Microwave Landing System(MLS) as new-aged standards and advises to set it at airports of all over the world from 1990. MLS is enough to cover disadvantage of ILS, but it is also decided to use ILS provisionally at least until 1995.

Log-Periodic Dipole Antenna(LPDA) used for ILS-Localizer, has been studied a lot and used practically. So it seems to have finished developing it, but it is necessary to analyze LPDA more rigorously. Because essential disadvantage of ILS have never cleared completely and setting of MLS-Az antennas effects radiation pattern of LPDA and signal to the aircraft. Also current increase of air traffic requires ILS to be more stable and reliable.

In this paper, we have analyzed farfield radiation patterns in free space using moment method(1) and patterns that take account of reflection from the earth.

2.Analysis of LPDA

Analysis of LPDA was studied by Carrel(2), and how to apply moment method for it were studied by Stutzman and Thiele(3). We also use these techniques and calculate current distribution on each element of LPDA, and calculate farfield patterns. Geometry of our LPDA is shown in Fig.1 and details are described(4).

Number of element: 7
Distance between shortest and longest elements L:2.4669m
Scale factor τ:0.941
Spacing factor σ:0.173
Characteristic impedance of LPDA feeder W_0:55.6Ω
Terminating impedance of LPDA feeder Z_T:0Ω (shorted)
Designed frequency f_0:110MHz (λ_0:2.724m)

To analyze mutual effect of LPDA, we arranged those LPDA by spacing $d=0.6\lambda_0$ (shown in Fig.2). In this case, we feed only center of these LPDAs, and other two LPDAs were loaded 50Ω as a dummy. We call it 3LPDAs.

Furthermore, We synthesize sum and difference patterns of 24th LPDA array which is used for real ILS-Localizer by multiplying array factor as

$$E(\phi) = e(\phi)e_s(\phi)$$

where

$e(\phi)$: patterns of single LPDA or 3LPDAs

$$e_s(\phi) = \begin{cases} \frac{1}{12}\sum_{n=1}^{12} I_n \cos\{(n-\frac{1}{2})\frac{2\pi d}{\lambda}\cos\phi\} : \text{sum pattern} \\ \frac{1}{12}\sum_{n=1}^{12} I_n \sin\{(n-\frac{1}{2})\frac{2\pi d}{\lambda}\cos\phi\} : \text{difference pattern} \end{cases}$$

and I_n are shown in Table 1.

When we set antennas close to the earth, we have to take account of reflection from the earth. It effects only vertical pattern because LPDA is placed horizontally with the earth. There are two ways to analyze it. When the earth is regarded as a perfect conductor, we only place image antenna which is identical shape to real antenna on opposite direction with the ground and feed it opposite voltage. When we can regard the earth not as a perfect conductor, we can calculate the fvield of arbitrary point using the field in free space and reflection coefficient at the reflection points.

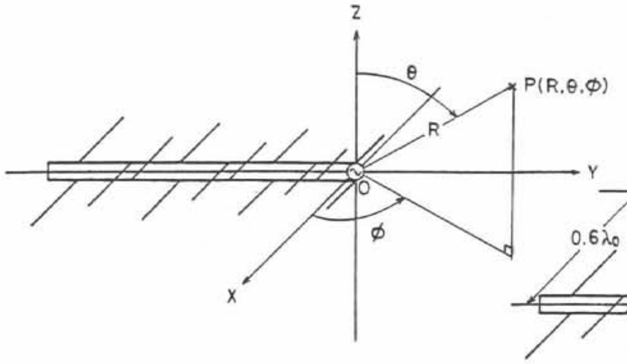


Fig.1 Geometry of LPDA

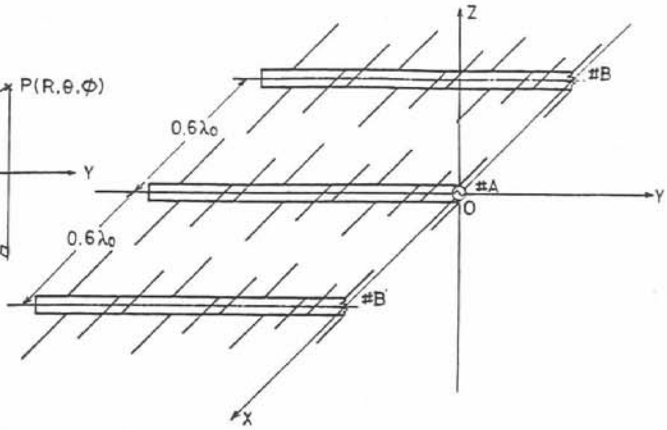


Fig.2 Geometry of 3LPDAs

n	1	2	3	4	5	6	7	8	9	10	11	12
sum pattern	1.000	0.076	0.362	0.152	0.264	0.143	0.191	0.111	0.128	0.075	0.076	0.013
diff. pattern	1.000	0.588	0.418	0.393	0.361	0.339	0.302	0.264	0.218	0.174	0.131	0.096

Table 1 I_n of LPDA array

3.Result of Computation and Measurements

A.*Farfield Analysis*

We first calculated current distribution on each element of LPDA and 3LPDA. It is shown in Fig.3. It doesn't contradict the behavior of radiation of usual LPDA. We can see that current distribution of center LPDA of 3LPDAs is similar to single LPDA, and there are a little current distribution on side LPDAs of 3LPDAs. Table 2 shows input impedance, gain, beam width and F/B ratio. Calculated and measured horizontal farfield radiation patterns of LPDA are shown in Fig.4(a). They are almost identical in front of antennas. The reason why they differs a little in backyard is the presence of feeder,etc. Patterns of 3LPDAs are shown in Fig.4(b). However calculated and measured pattern aren't quite the same, they agree well and they are considerably spread than that of single LPDA.

Fig.5 shows farfield radiation patterns of 24th LPDA array. In this figure, dashed pattern is obtained by multiplying array factor to the pattern of single LPDA, and solid pattern is obtained by multiplying array factor to that of 3LPDAs. the latter is closer to measured pattern of dotted line than the former.

B.*Fields Taking Account of Reflection from the Earth*

Fig.6 shows calculation result of vertical patterns of single LPDA which sets 2m high from the ground of perfect conductor. We can see sidelobes, which does not appear when LPDA is in free space. Fig.7 shows when the ground isn't capable to be regarded as a perfect conductor. Patterns changes slightly as condition of the ground changes.

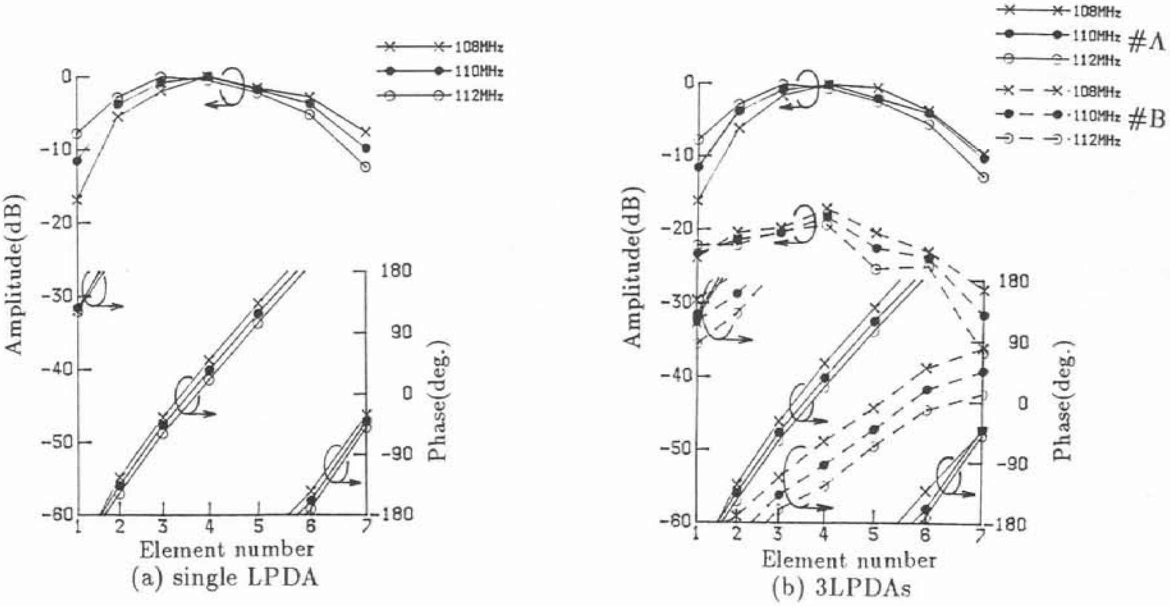


Fig.3 Current distribution of LPDA and 3LPDAs.
Current of #B' of 3LPDAs isn't shown because #B and #B' are symmetrically placed and regarded to have the same distribution.

	Input imp. (Ω)	Gain (dB)	Horizontal Beamwidth(deg.)	Vertical Beamwidth(deg.)	F/B ratio (dB)
single LPDA	49.83-j2.78	10.40	54.3	71.1	-31.27
3LPDAs	49.42-j1.49	8.34	94.6	57.1	-27.14

Table 2 Calculation result of LPDA and 3LPDAs

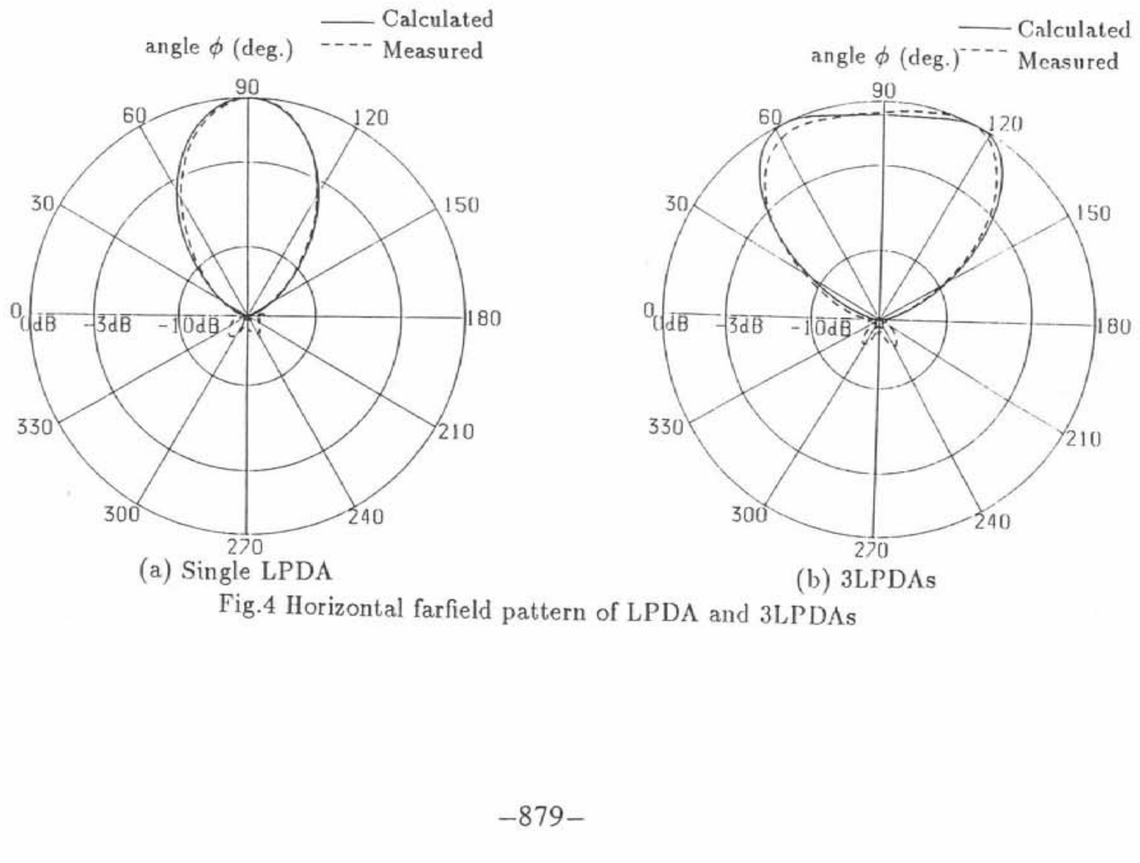
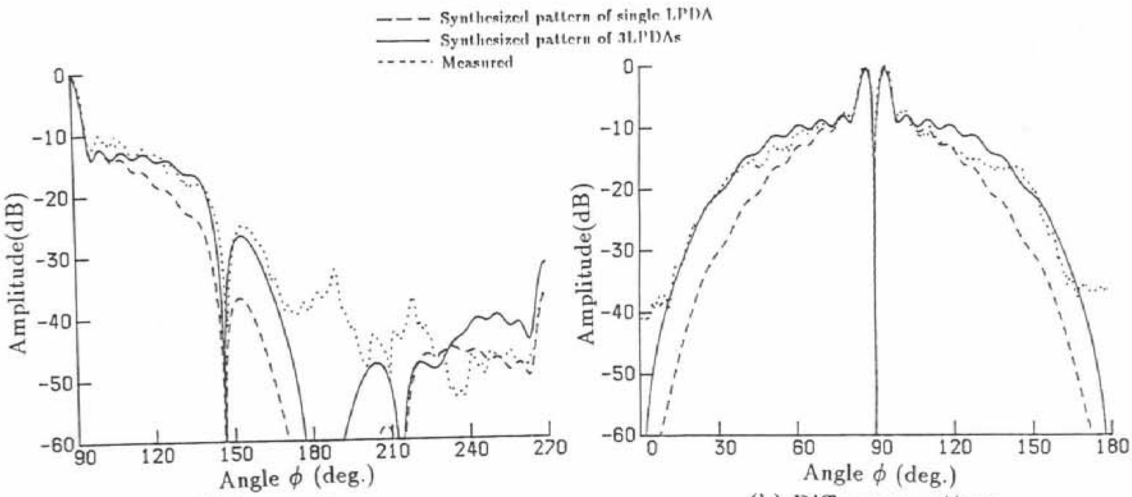


Fig.4 Horizontal farfield pattern of LPDA and 3LPDAs



(a) Sum pattern

(b) Difference pattern

Fig.5 Horizontal farfield pattern of 24th LPDA array

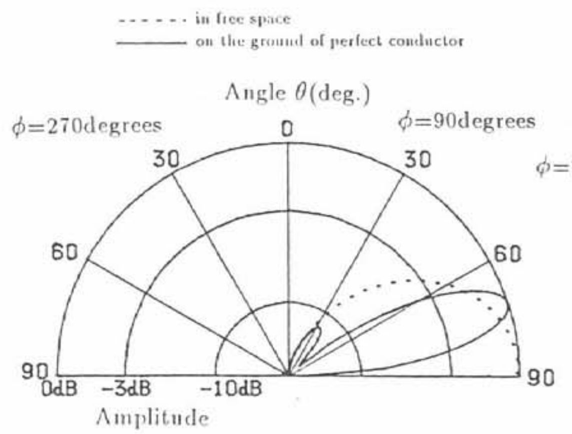


Fig.6 Vertical pattern of LPDA in free space and that on the ground of a perfect conductor

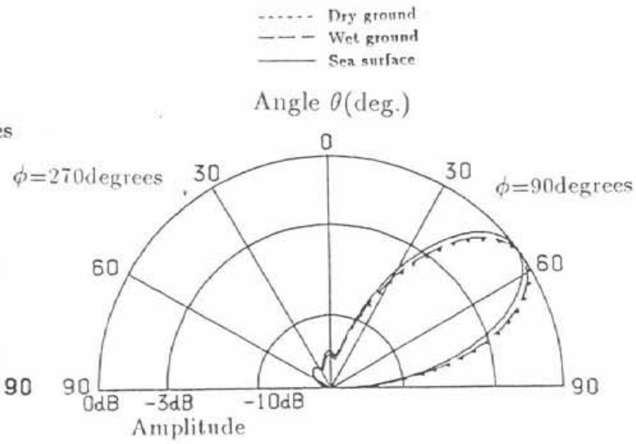


Fig.7 Vertical pattern of LPDA when the ground isn't capable to be regard as a perfect conductor

4.Conclusion

We analyzed LPDA for ILS Localizer using moment method. Both calculated and measured farfield radiation pattern in free space showed a good agreement. It has been known that LPDA has little mutual coupling effects, but it is shown that the effect of not-fed LPDAs nearby to the radiation pattern is not negligible. So it is obvious that the way of multiplying array factor to the pattern of 3LPDAs is better than the usual way of multiplying it to the pattern of single LPDA to get synthesized pattern of arrayed LPDA. And we analyzed vertical pattern taking account of reflection from the earth. It is important for designing buildings and sites of airports.

References

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(3) W.L.Stutzman and G.A.Thiele:"Antenna theory and design", John Wiley&Sons,New York (1981).
(4) K.Inoue *et al.*"New Type LPDA ILS Localizer Antenna", IECE Technical Report, AP81-35, p31–36 (Jun.1981). (in Japanese)