A–4–4 DIELECTRIC PLATE ANTENNA AND ITS IMPROVEMENT

M.Haneishi, S.Tanaka* and S.Yoshida
Dep.of Electronics, Saitama University
Urawa, Saitama, Japan
*Saitama Institute of Technology
Okabe-cho, Saitama, Japan

## 1. INTRODUCTION:

Recently MIC antennas have been developed rapidly. The strip-dipole (STD) made straightly of strip-line is one of the most available radiators for MIC.[1]
Starting from the development of the STD, the dielectric plate antenna(DPA) has been developed.
The DPA which is constructed by a combination of STD(launcher) and a dielectric thin slab(delay-line) is the most available surface wave antenna for MIC, since its configulation is suitable for printed circuits technology.[2]
The DPA presented here has small size, light weight and low profile.
Moreover it has excellent directivity having gain of about 17dB and low sidelobe level less than -20dB.
From the design purpose, the DPA is superior to the Yagi-type printed antenna[3] shown in Fig.(1a), as it is sufficiently characterized by a single parameter $\lambda_g$; the wavelength in direction of the propagation along the delay-line.
On the contrary, the Yagi-type printed antenna is not easy to design, since it has so many parameters such as the length, the width and the intervals of the directors.
In this paper, the general properties of the DPA and its improved type are described with the design procedure.

## 2. THE FUNDAMENTAL STRUCTURES OF THE DPA:

As well known, a surface wave antenna consists of a launching device and a surface wave delay-line.
The DPA proposed here is also constructed by a combination of STD(launcher) and dielectric thin slab (delay-line). As can be seen in Fig.(1b), the delay-line is mounted in front of and on the same plane of the STD.

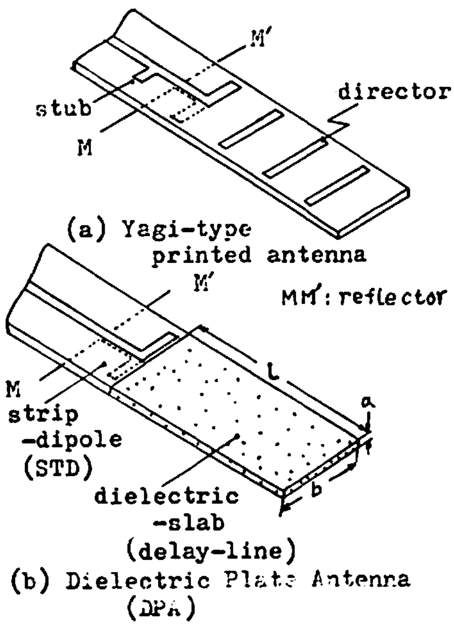


Fig.1-Yagi-type printed antenna and Dielectric Plate Antenna.

The STD is printed on a Teflon fiberglass slab( $\varepsilon_r$ =2.5) with dimention of 0.025" in thickness and ($\lambda_0/2$) in width , where $\lambda_0$ is the wavelength of free space. The VSWR of the STD is adjusted less than 1.1 when it is fed by a OSM-connector at X-band. The delay-line of DPA is made of a ceramic substrate. In order to obtain K of 1.1, where $K=\lambda_0/\lambda_g$ , the thickness of the ceramic substrate is adjusted 0.025" for $\varepsilon_r$ =18 and 0.05" for $\varepsilon_r$ =9.5 respectively. The wavelength $\lambda_g$ mentioned above is determined by measuring the node of the surface wave along the delay-line, and the results are shown in Fig.2.

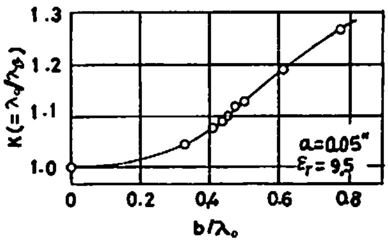


Fig.2-K vs b characteristics for the delay-line.

## 3. THE RADIATION PATTERNS OF THE DPA:

The experimental pattern of STD agrees well with the theoretical value of usual dipole antenna having reflector, as shown in Fig.3. The experimental pattern of the DPA is shown in Fig.4. The mechanism of the radiation from the DPA is understood as follows. A surface wave antenna couples a portion of a input power into the delay-line element, and the remainder of a input power radiates directly from the launching device[4] For this reason, in order to obtain the directivity of the DPA, the far-fields patterns of the launcher and delay-line are superposed in the ratio of $(1-\eta)$ to $\eta$, where $\eta$ is the launching efficiency, and the $\eta$ is defined as the amplitude of the surface wave to that of the total input field from the feeding system.

It is assumed here that the surface wave propagated along the delay-line is excited by the static field of the STD (the term of $1/r^3$ of the radiated field, where "r" is the distance from the STD).

The theoretical expression for the pattern, according to this analysis, is given as follows.

$$D(\theta) = \sqrt{M_1^2(\theta) + M_2^2(\theta)} \quad \cdots\cdots(1)$$

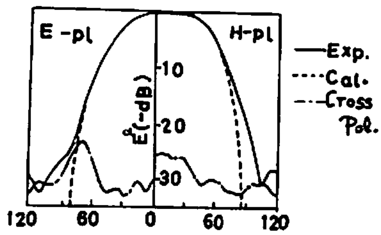


Fig.3-Typical patterns for launching element (STD).

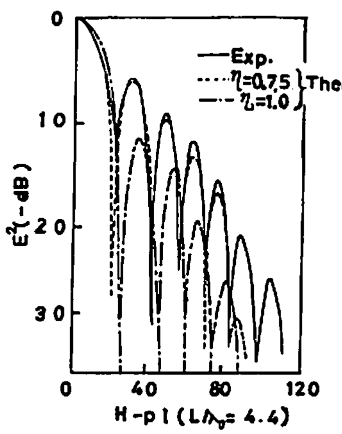


Fig.4-Typical pattern for non-tapered DPA.

$$\begin{cases} M_1(\theta) = \{\eta(\sin X)^2/X - (1-\eta)\sin(2P)/2\} \\ M_2(\theta) = \{(1-\eta)\sin^2(P) + \eta\sin(2X)/(2X)\} \\ X = \pi(L/\lambda_0)(K - \cos\theta) \\ P = \pi\cos\theta/2 \end{cases}$$

The experimental pattern is shown in Fig.4 as solid-line. The theoretical pattern calculated with the assumption of $\eta$ =0.75 in equation(1) agrees also well with the experimental pattern as can be seen in Fig.4.

The assumption of $\eta$=0.75 in this analysis agrees well with the experimental value obtained by means of Deschamps method, as can be seen in Fig.5. The calculated pattern neglecting the effect of the radiation from the launcher, that corresponds to $\eta$=1.0 , does not agree with the experimental pattern as shown in Fig.4.

It is shown that the present analysis taking account of the influence of the direct radiation from the launcher is the most useful analysis for the DPA.

## 4. THE SIDE-LOBE SUPPRESSION AND GAIN CHARACTERISTICS OF DPA:

It is well known that a surface wave antenna with an appropriate directivity can be achieved by a suitable tapering of the delay-line.

The typical profile of the tapered DPA is shown in Fig.6. As expected, the side-lobe levels of the directivity pattern are extremely suppressed to -20dB, as can be seen in Fig.7.

The optimum length of the DPA calculated by means of Hansen-Woodyard condition is $5.1\lambda_0$ long for K=1.1.

The value of the optimum length agrees well with the value obtained in experiment, as can be seen in Fig.8.

The maximum gain of the DPA is about 14dB for K=1.1. The tapered DPA with long delay-line more than $5\lambda_0$ in length has a higher directivity than the non-tapered one, and the measured gain of tapered DPA with the length of $10\lambda_0$ is about 17dB over isotropic radiator.

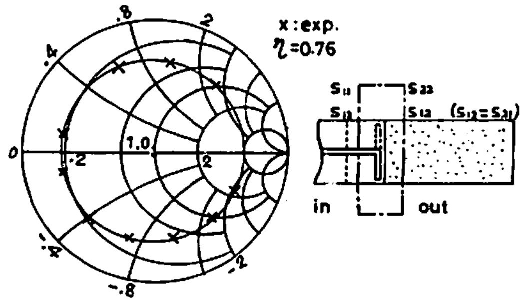


Fig.5-Measurement of $\eta$ by means of Deschamps method.

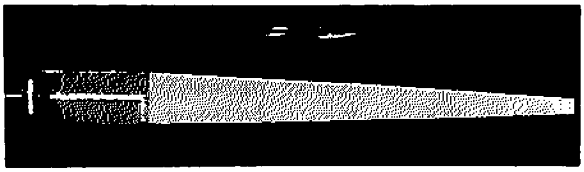

Fig.6-Tapered DPA.

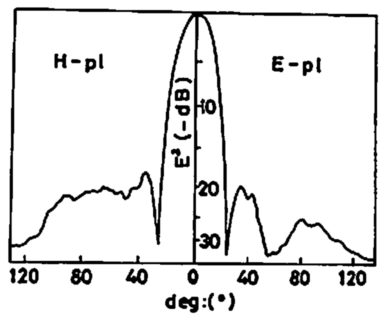


Fig.7-Typical pattern for tapered DPA($L/\lambda_0$ =10).

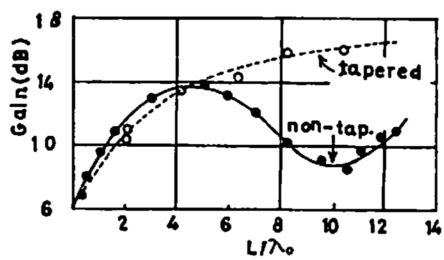


Fig.8-Gain characteristics for DPA.

## 5. THE DPA LAUNCHED BY STRIP-HORN:

In order to obtain the higher launching-efficiency, another type of DPA is constructed by a combination of strip-horn(STH) and dielectric thin delay-line with ground-plane, as can be seen in Fig.9.

The DPA proposed here is also very thin and moreover rugged and easy to fabricate. The main radiating element is the delay-line, and the launching element is the strip-horn section(STH). The width W of the STH is designed below $\lambda_g'/2$ at its feeding end, to prevent the excitation of the higher-mode, where $\lambda_g'$ is the wavelength in the feeding system.

The stub of STH is necessary to match the impedance between the launcher and the strip-line.

Fig.10 shows the experimental pattern of this DPA tapered in thickness.

The main-beam of E-plane directivity tilts about 15° from the boresight, since the ground-plane of this DPA has a finite dimention.

The launching-efficiency $\eta_L$ by means of the Deschamps method becomes about 0.8 in this improved DPA.

The frequency-dependence of the DPA has also excellent properties as can be seen in Fig.11.

## 6. CONCLUSION:

Starting from the development of the STD, authors have developed the DPA, the most useful surface wave antenna for MIC. The DPA has small size, light weight and low profile, and it has excellent directivity having gain of about 17dB and low sidelobe level less than -20dB.

Moreover, from the design purpose, the present DPA is superior to the Yagi-type printed antenna, as it is sufficiently characterized by a single parameter $\lambda_g$.

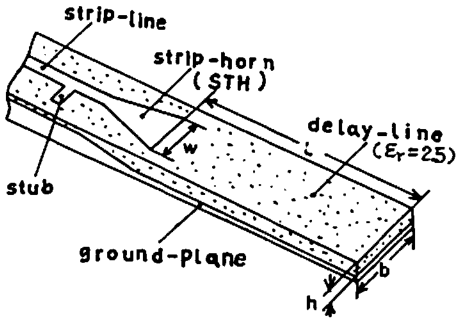


Fig.9-DPA launched by strip-horn.

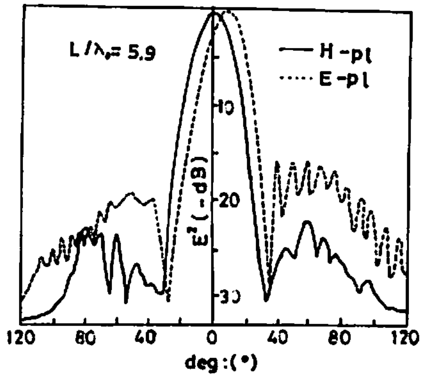


Fig.10-Typical patterns for tapered DPA launched by STH.

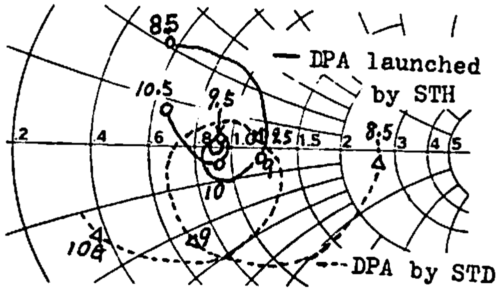


Fig.11-Impedance-characteristics.

### —— REFERENCES ——


(1)M.E.Davis,"Integrated diode phase-shifter elements for an X-band phased arrays antenna", IEEE Trans. MTT-23,pp.1080-1084,Dec.1975.

(2)M.Haneishi and S.Tanaka, "Dielectric Plate Antenna",Trans.of IECE of Japan,Vol.60-B,No.7,p484,July, 1977.

(3)H.Groll,"Investigation on strip-line end-fire antennas printed on ceramic substrate for the range of 10GHz",1971 ISAP,JAPAN,1-IIC4.

(4)R.E.Collin and F.J.Zucker, " ANTENNA THEORY ", McGraw-Hill Book Co. chap.21, (1969).