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ANALYSIS AND DESIGN ON A PROXIMITY FED MICROSTRIP ANTENNA

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1 Introduction

The microstrip antenna which is light weight and low profile has been studied widely as an antenna for mobile communication such as cellular phone. Practically, the co-planar antenna which has the feed line and the radiating element on the same plane can be easily fabricated on only one side of the substrate. One of co-planar feed structures is a Proximity fed Microstrip Antenna (PMA) in which the microstrip element is excited by a semi-infinite feed line via a gap as shown in Fig.1[1–3]. This configuration is known to have advantages such that the polarization plane can be switched. In the area of remote sensing, the antenna with changeable polarization is used when we watch the objects illuminated by the electromagnetic wave. For the use in this area, the accurate and quick polarization plane changing is extremely important. Hence, antennas with the polarization electronically controlled are required. The polarization of PMA can be switched electronically with only one set of PIN-diode and low pass filter[2]. The polarization plane can be switched by whether open or short condition of the end of the feed line.

In the past, we have analyzed the PMA using momentum method in spectral domain, and clarified the input and polarization characteristics of the PMA, for example, when that the gap g is relatively wide, the coupling between feed line and radiation patch is relatively small[4]. In this case, we must add matching circuit for practical use. As the gap is more narrow, it is more difficult to determine the current model in our conventional analysis since the current on the feed line includes high order mode.

In this paper, we use the electromagnetic simulator for analysis of the PMA. In the simulation, the currents on the feed line and radiation patch are expressed as the summation of the currents on the meshes. In this way the higher order mode is automatically considered. By using this simulation, we can analysis the PMA in the conditions where the coupling is very large, and can design the matched PMA with no matching network.

2 Operating Principle

The configuration of the PMA which is fed via the gap is shown in Fig.1. A semi-infinite microstrip line and the rectangular radiation patch with width w_p and length l_p are placed in parallel with gap of g on the substrate with a relative permittivity ε_r and the thickness h placed on a grounded plane. The coordinate system is a right-handed one with the y axis along the feed line direction and the z axis in the upward direction. The width w_f of the microstrip line is determined in such a way that the characteristic impedance of the infinite line is 50 Ω.

We can use a PIN–diode change between the open and short states of the end of the feed. In this paper, however, a stub with width w_f is extended from the end of the semi-infinite line and the length L of the stub is adjusted for open or short switching. When $L\sim 0$, the end can be considered as the open state. The current standing wave is generated on the feed line as the maximum of this exists at the center of the element, and the magnetic field vector is generated in the x direction as the antenna is wrapped. By the generated magnetic field, the current J_y is induced along the y direction (same the feed line direction) on the radiating patch. We call this coupling "inductive coupling".

When $L \sim \lambda_e/4$ (where λ_e is the effective wavelength), the end of the feed line can be considered as short–circuited. The voltage standing wave on the feed line becomes maximum at the center of the element so that the charges are induced on the edge of the rectangular patch adjacent to the line, on the other hand, the counter charges are generated on the opposite edge of the patch. Hence, the current J_x is induced in the x direction. We call this coupling "capacitive coupling".

3 Analysis

In the past, we considered the PMA with low permittivity substrate[4]. In this case, the inductive coupling is small even if the gap is very narrow (g=0.02mm $\sim$ 0.0003 λ_e). In this paper, we use the substrate with relatively high permittivity. Since the electrical length of dielectric thickness is larger, the inductive coupling via the magnetic field is more tight.

The parameters of substrate and rectangular patch used in the analysis are shown in Table 1. The resonant frequencies are about 2.885GHz for inductive coupling and 2.615GHz for capacitive coupling. The stub length L are about 2.0mm (open–end) and 15.0mm (short–end) respectively. We can obtain the matching condition at resonant frequencies both inductive coupling and capacitive coupling. The locus of input impedance at inductive and capacitive coupling resonant frequencies for the tuned L are shown in Fig.1. As the stub length L is increased from 2.0mm to 15.0mm, the capacitive coupling becomes gradually dominant. Then the stub length is over $\lambda_e/4$, the inductive coupling is more grater again.

In order to study the polarization characteristics, we calculate the axial ratio (AR) and orientation angle (τ) from the far-field patterns of the PMA. In this paper, the polarization chart is used to represent the polarization status, as shown in Fig.2[5].

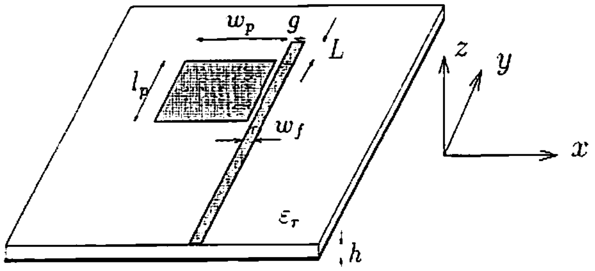

Fig.1: Geometry of a proximity fed microstrip antenna (PMA).

Table 1: Specification of the dielectric substrate and radiation element.

ε_r	h(mm)	$\tan\delta$	g(mm)	w_f(mm)	w_p(mm)	l_p(mm)
2.1	0.77	0.005	0.8	2.14	24.5	22.6

Table 2: Analyzed input and polarization characteristics.

L(mm)	Inductive or Capacitive	f_r(GHz)	return loss(dB)	AR(dB)	τ(degree)
2.0	Inductive	2.61538	−21.5	24.3	2.87
15.0	Capacitive	2.88462	−19.8	10.15	89.3

For $L \sim$ 2mm. The inductive coupling becomes dominant at f=2.885GHz. Hence, the polarization is almost linear in the y direction, so the locus of polarization is right side on this chart. The axial ratio is 24.3dB. At this stub length, the polarization rotation changes from counter-clockwise to clockwise.

On the other hand, $L \sim$ 15.0mm, the capacitive coupling becomes dominant. However, the axial ratio at 2.615GHz is 10.15dB. E_x in the front direction is generated by only x directed current caused by capacitive coupling. E_y is generated by the y directed current on the patch and feed line. It seems that the illumination of the feed line radiation makes worse the axial ratio at short-end condition. Because of this illumination, the polarization rotate doesn't change at L=15.0mm and it changes at $L \sim$ 27.5mm.

The results above are summarized in Table 2.

4 Conclusion

In this paper, we introduce the substrate with high permittivity to the PMA, so that the coupling (especially inductive coupling) becomes large. To use this substrate, no matching network is need. Further, we clarify the input and polarization characteristics of the PMA which has large coupling, that it is possible to switch the polarization plane while the matching condition is held.

Acknowledgement

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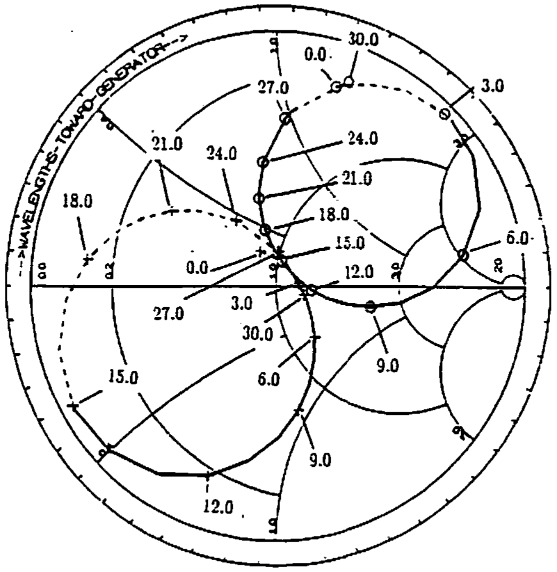

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Fig.2: Smith chart plot of the input impedance locus as a function of the stub length L at f=2.88462GHz (×) and 2.61538GHz (O).

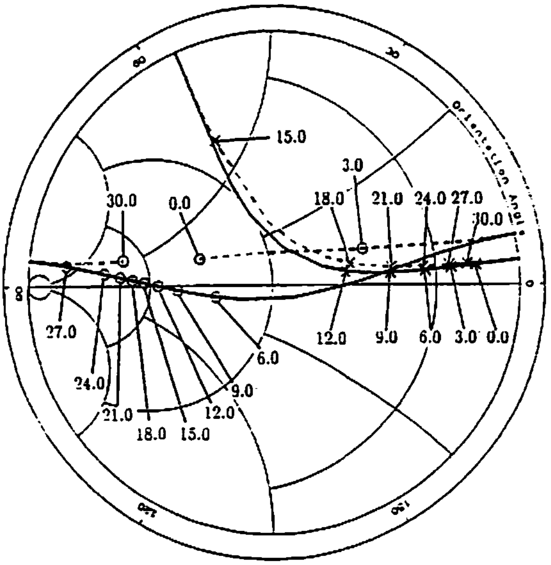

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Fig.3: Polarization chart plot of the polarization in the frontal direction of PMA as a function of stub length L at f=2.88462GHz (×) and 2.61538GHz (O).