A NEW FEEDING METHOD FOR A DUAL-POLARIZED PATCH ANTENNA WITH LOW CROSS-POLARIZATION RATIO

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Abstract

A new feeding method—combining conventional slot-coupled feed and pin feed—that can reduce cross polarization of an orthogonal dual-polarized patch antenna with a simple composition was developed. Theoretical calculation of its feeding method was made using electromagnetic simulator and its value is confirmed by the experimental data. Planar near field measurement used to show the low cross polarization level of proposed antenna. It can be applicable to commonly used orthogonal polarization communication systems.

1. Introduction

An orthogonal dual-polarized circular-patch antenna, which has a high cross-polarization discrimination ratio, can be applied as a rectenna for transmitting microwave power [1], an antenna element for a Van-Atta-Array [2], and commonly used orthogonal polarization communication systems such as Ku-band satellite communication.

Conventionally, a dual polarized circular patch antenna uses two points pin feed [3] or dual slot coupled feed [4, 5]. Two points pin feed generates cross polarization due to a mutual coupling between two orthogonal feed pins. Moreover, in the case of the double slots feed technique [5], the slots must be separated from the center of the patch, since both slots must not overlap. However, in the case of this configuration slots are offset from the center of the patch, hence, a higher mode current is excited. So, this becomes a reason of generating the cross polarization. We have developed a new feeding technique that can reduce the cross polarization by combining the pin feed with the slot-coupled feed.

2. Low cross polarization feeding method

Figure 1 shows a schematic of the proposed feeding method. By combining a slot-coupled feed with a pin feed in the circular patch antenna, a dual polarized feed is possible. (This feeding technique is referred to as "slot-pin feed" hereafter.) Linear polarization in the y direction is generated by using a slot coupled feed at feed point 1; the linear polarization in the x direction is generated by using a pin feed at feed point 2. In the case of this feeding method, the antenna structure is always symmetrical with feeding point 2 (the pin-feed side). Hence, the cross-polarization radiation characteristic produced by this feeding method will be equivalent to that produced by the pin feed of single linear polarization circular patch antenna. In addition, in the case of slot-coupled feed, since the slot is installed at the center of the antenna, a small amount of higher mode is excited at feed point 1, and cross polarization radiation becomes low [6]. By combining both feeding techniques for a dual-polarized antenna, the cross-polarization characteristic will be improved, compared to that produced by only the two-point pin feed.

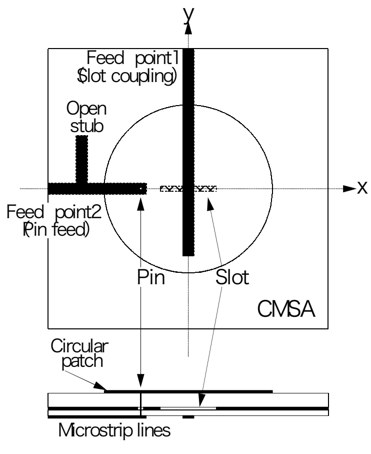


Figure 1 Slot-pin feed patch antenna

Normally, the position of the feed pin is offset from the center of the patch, but if the pin is offset by the normal amount, it will overlap with the slot. Therefore, the pin position is moved outside of the slot on the x-axis. For impedance matching of the antenna to the feed line, a matching circuit is made from an open stub on a microstripline. In the case of the circular microstrip patch antenna(CMSA), a honeycomb substrate was used in order to obtain a low dielectric constant. The antenna was made by bonding a 0.1-mm-thick BT resin substrate with a 5-mm-thick aramid honeycomb. A 0.5-mm-thick glass-cloth Teflon substrate provided the feed line.

The performance of the slot-pin feed dual polarized circular patch antenna was theoretically evaluated by an electromagnetic field simulator of the moment method (IE3D) and compared with the case of a conventional two points pin feed antenna.

The simulated geometrical parameters of a slot-pin feed circular patch antenna and a two points pin feed antenna are listed in Table 1.

Table 1 Geometrical parameters of the circular-patch antenna

Feeding method	slot-pin feed	two points pin feed
Material	Honeycomb substrate	
relative permiability	1.25	
Patch radius [mm]	26.16	30.1
thickness [mm]	5	5
slot length [mm]	23	-
slot width [mm]	1	-
stub length of the slot [mm]	10.5	-
Pin position [mm]	x=-17.0	x=-15.0
stub length of the pin feed [mm]	14.8	-
stub position of the pin feed [mm]	28.2	-

3. Evaluation of cross-polarization level

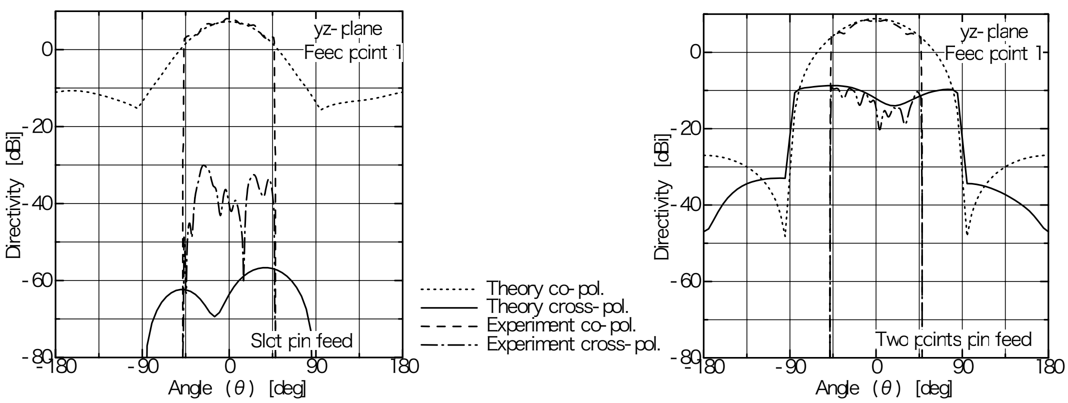
Table 2 lists the theoretical and experimental values of resonant frequency and mutual coupling between two ports in the case of each feeding method. It is clear that the experimental value of resonant frequency is lower than the theoretical values in the case of both feeding methods. It is considered that this error originates from the incompleteness of the mesh used in the moment method. In the case of the two-point pin feed, the mutual coupling between ports is about -21 dB for both theoretical and experimental values. The mutual coupling produced by the proposed feeding technique was –66 dB in the case of the theoretical value and –42 dB in the case of the experimental value. These values are 20 dB lower than those in the case of the two-point pin feed, so it can be concluded that the mutual coupling produced by the new feeding method is very small.

Table 2 Resonant frequency and mutual coupling level

feeding method	slot-pin feed		two points pin feed	
value	theory	experiment	theory	experiment
resonant frequency (pin feed)	2.585GHz	2.54GHz	2.485GHz	2.45GHz
resonant frequency (slot coupled feed)	2.575GHz	2.54GHz	-	-
mutual coupling between ports	-66.08dB	-42dB	-20.61dB	-21.1dB

Next, directivity of the new antenna is examined. The operating frequency of the slot-pin feed CMSA is 2.54 GHz, and that of the two points pin feed CMSA is 2.45 GHz, which are equal to the experimentally measured resonant frequency. An infinite ground plane was assumed at the theoretical value and a square ground plane about five wavelengths (60 cm) was used in the experiment.

To accurately measure the two-dimensional radiation pattern of the cross polarization, the experimental value was obtained by the planar near field measurement which is not used in the measurement of the low gain antenna. Therefore, angular range in the measurements was limited to



(a) Slot-pin feed (b) Two points pin feed

Figure 2 Theoretical and experimental value of the directivity on CMSA within yz-plane excited at feed point 1.

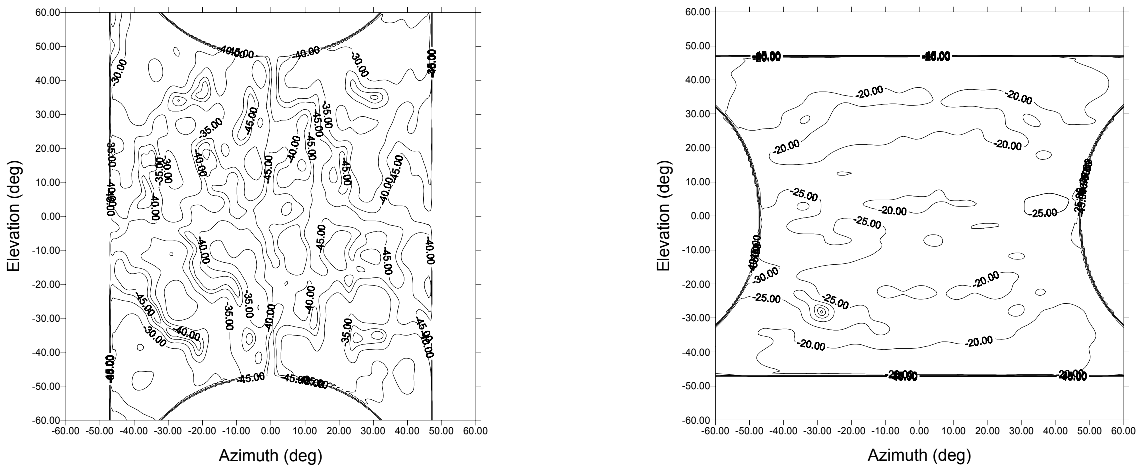
about ±45 degrees from the boresight. Figure 2 shows the theoretical and experimental values of the directivity for the slot-pin feed CMSA and two points pin feed CMSA for each polarization within the yz-plane at feed point 1. These theoretical and experimental values agree well with each other.

The theoretical and experimental cross-polarization levels in the boresight direction are listed in Table 3. Regarding the two-point pin feed, the theoretical and experimental values of the cross polarization level are 21 dB and 23 dB, respectively. In the case of slot-pin feed, they are 56 dB and 38 dB, respectively. This result means that the slot-pin feed improves cross-polarization level by at least 15 dB.

Table 3 Cross-polarization level in the boresight direction

feeding method	slot-pin feed		two points pin feed	
value	theory	experimen	theory	experimen
XPD value (pin feed)	56.14dB	48.04dB	20.94dB	23.07dB
XPD value (slot coupled feed)	70.84dB	37.77dB	-	-

Figure 3 shows a two-dimensional pattern produced by the new slot-pin feed CMSA and that of the conventional two points pin feed CMSA. In these figures, the x-axis is defined as an elevation axis, and the y-axis is defined as an azimuth axis. In the case of the slot-pin feed, the cross-polarization level at almost all angles is over 30 dB in Fig. 3(a). However, in the case of the two point pin feed, as shown in Fig. 3(b), it is around 20 dB. This result confirms the low cross-polarization characteristic produced by the slot-pin feed.



(a) Slot-pin feed (b) Two-point pin feed

Figure 3 Two-dimensional cross-polarization pattern by using near-field measurement (Feed point 1).

Mutual coupling and gain in slot-pin feed CMSA as a function of the feed-pin position along the x-axis were calculated by using IE3D (Fig. 4). It is clear that mutual coupling decreases as the pin becomes further from the center of the patch. It became –60 dB or less, except when the pin position (x) was -13 mm (i.e., 1 mm from the slot edge). Moreover, the front gain decreases as the pin becomes further from the patch center. The cross polarization stayed around 60 dB regardless of the pin position. It can thus be concluded from the graph shows that the optimum pin position is from 17 to 18 mm.

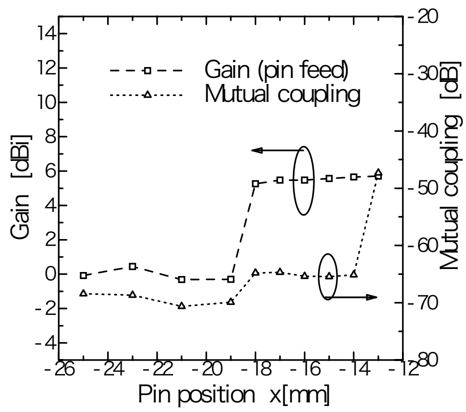


Figure 4 Mutual coupling and gain as functions of feed pin position

4. Summary

A slot-pin feed dual polarized circular patch antenna, which combines the conventional slot-coupled feed and pin feed, was developed and confirmed by a theoretical calculation using an electromagnetic field simulator to generate 15 dB lower cross polarization than the conventional two points pin feed alone. The validity of this calculation was confirmed by planar near-field measurement. This new feed technique can change the resonant frequency by adjusting the antenna parameters on the pin and slot sides. It is thus applicable to commonly used orthogonal polarization communication systems.

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