A Study on Cross Slot Rectangular Patch Antenna

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Abstract
A single-feed, multiple-frequency rectangular patch antenna with a cross slot is studied. The number of operating frequencies of this antenna depends on the feed position and the shape of cross. The broadside null of the higher-order modes of an ordinary rectangular patch antenna is improved effectively by a cross slot on the patch.

Key Words
Multiple-frequency operation, microstrip antenna, cross slot

1. Introduction
Modern mobile phone handsets are required to operate at multiple frequency bands to provide various communication services. A number of novel antenna designs have been proposed so far [1]-[5]. It is well known that a rectangular patch antenna can be operated at dual frequencies using its dominant TM01 and TM10 modes, whereas its higher-order modes are generally not used due to the cancellation of the radiation fields in the broadside direction. When a cross slot is cut on the rectangular patch, the cancellation becomes imperfect and the broadside radiation occurs. Using this mechanism a simple multi-frequency band rectangular patch antenna is proposed and experimentally studied.

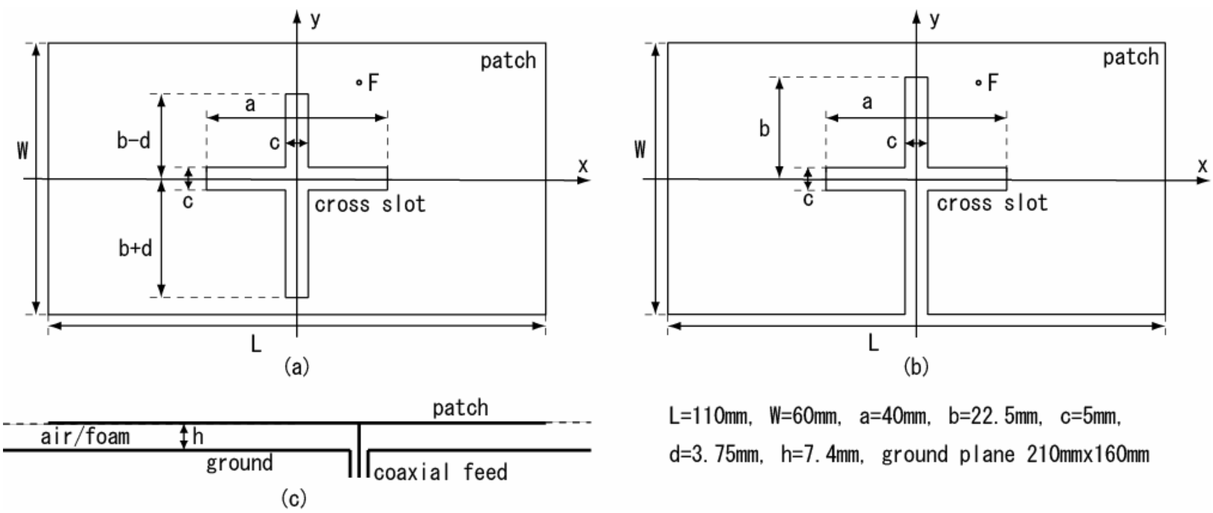
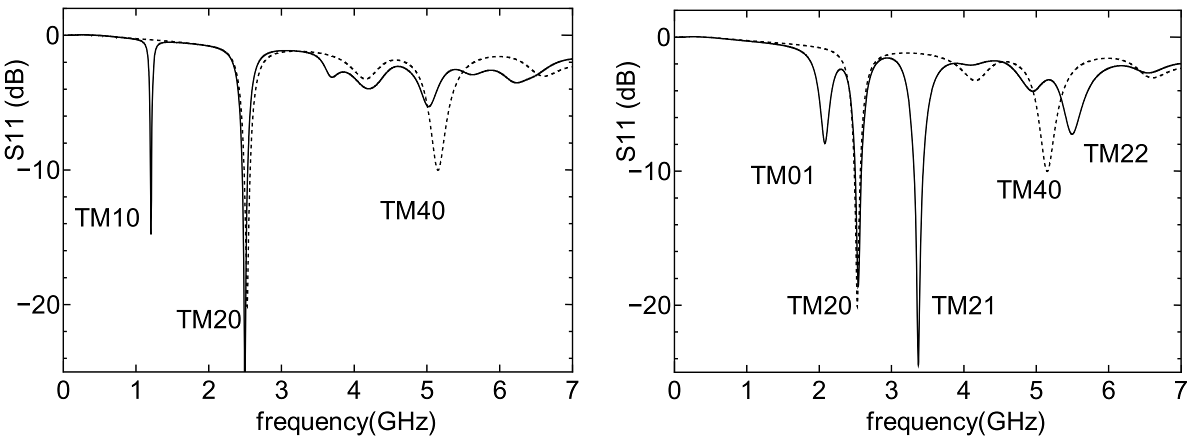


Fig.1 Geometry of microstrip antennas with cross slot. (a) Top view of antenna 1, (b) top view of antenna 2, and (c) side view. Point F is the feed position.

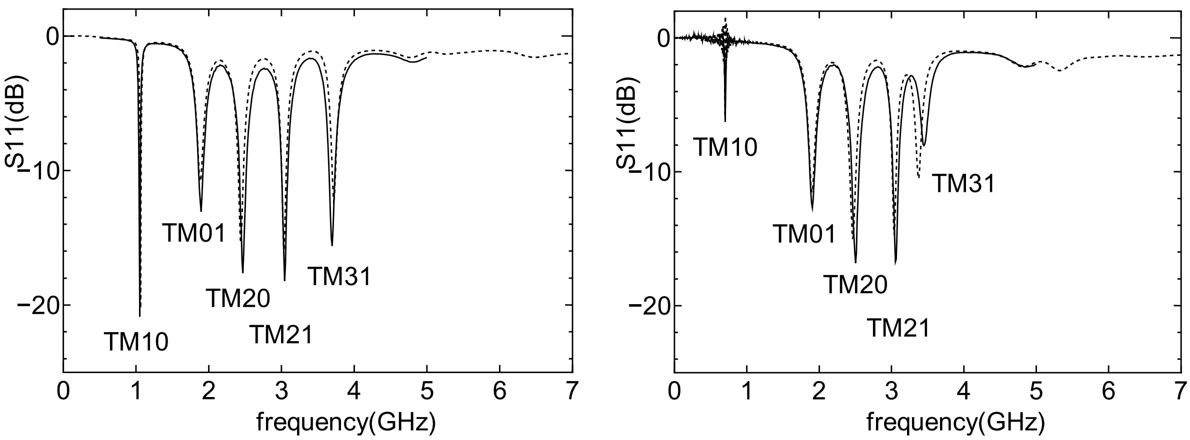
2. Antenna configuration and simulation results

The configurations of the patch antennas with a different cross slot are shown in Fig.1. These antennas resonate at frequencies closed to the resonant frequencies of the rectangular patch antenna of the same dimension without a cross slot. The calculated results of return loss of the rectangular patch antenna without a cross slot are shown in Fig.2 for different feed positions. Fig.3 shows the return losses of antenna 1 and antenna 2, respectively. The finite-difference time-domain (FDTD) code was used to simulate these antennas. It is found that there exist four resonant frequencies in a band from 2.5GHz to 4GHz. The feed positions were chosen so that the return losses became small as possible.



(a) (b)

Fig.2 Calculated return losses of a rectangular patch antenna without a cross slot, L=110mm, W=60mm, h=7mm, $\varepsilon_r = 1.0$. (a) solid line: feed position (x,y)=(10mm, 0), dotted line: (x,y)=(0,0), (b) solid line: feed position (x,y)=(0, 25mm), dotted line: (x,y)=(0,0),



(a) antenna 1 (b) antenna 2

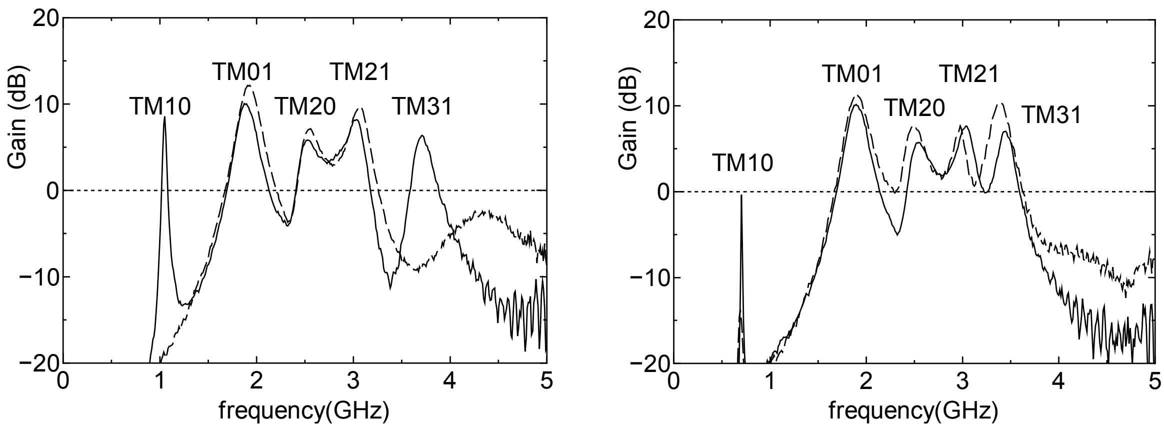
Fig.3 Return losses of rectangular patch antennas with cross slot.

(a) antenna 1 fed at (x, y)=(8.75mm, 18.75mm), (b) antenna 2 fed at (x, y)=(5mm, 21.25mm).

Solid line: measured result, dotted line: calculated result.

3. Experimental results

In the experiment a Styrofoam board covered with paper whose permittivity $\varepsilon_r = 1.1$ has been used. For the patch and the ground plane, copper foil with adhesive was utilized. Fig. 4 shows the total gain including the reflection loss in the z direction. The radiation fields in the broadside direction were not cancelled. The gain for the TM31 mode of antenna 2 is larger than that of antenna 1. By moving the feed position to (x,y)=(13.75mm, 21.25mm), the gain of antenna 2 was improved and it became larger than 0dB in the frequency range from 1.67GHz to 3.62GHz due to the increase of the radiation of TM20 and TM31 modes. In contrast antenna 1 has a large fluctuation in the gain. Fig. 5 shows the radiation patterns of antenna 2 fed at (x,y)=(13.75mm, 21.25mm).



(a) antenna 1 (b) antenna 2

Fig.4 Gain including reflection loss. (a) solid line: feed position (x,y)=(8.75mm, 18.75mm) , dash line (x,y)=(13.75mm, 21.25mm), (b) solid line: feed position (x,y)=(5mm, 21.25mm). dash line (x,y)=(13.75mm, 21.25mm).

4. Conclusions

Multi-band characteristics of rectangular patch antennas with a cross slot have been studied. It was demonstrated that the broadside null of the higher-order modes of rectangular patch antennas can be effectively improved by a cross slot, and that the cross slot helps the rectangular patch antenna to operate in a wide frequency band.

Acknowledgements

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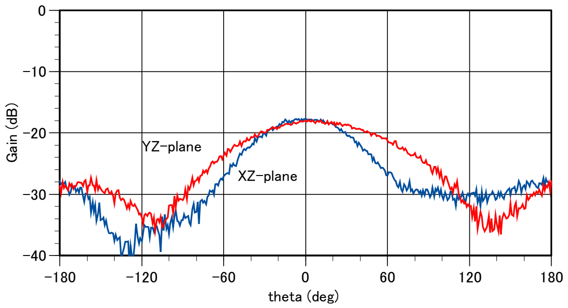
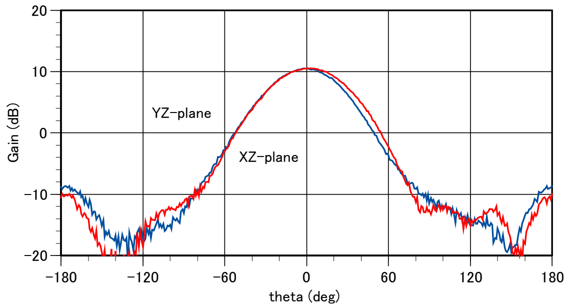
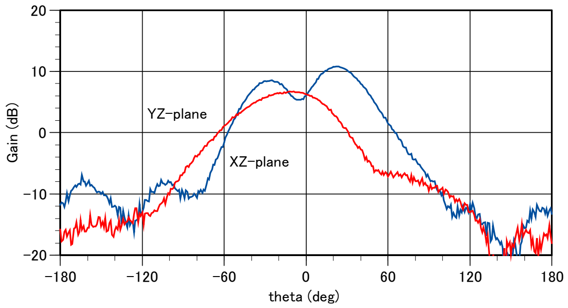


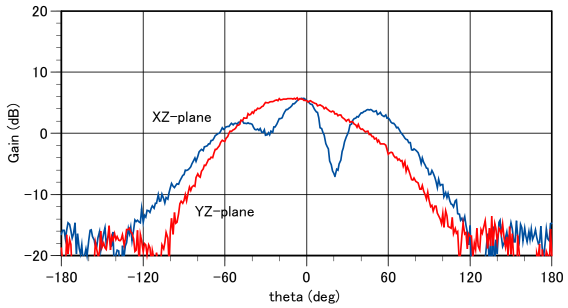
(a) TM10, f=0.7GHz



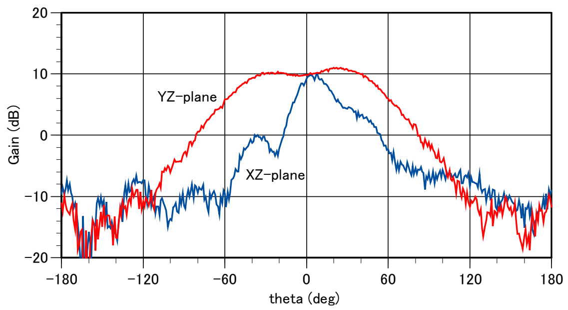
(b) TM01, f=1.91GHz



(c) TM20, f=2.48GHz



(d) TM21, f=2.99GHz



(e) TM31, f=3.39GHz

Fig. 5 Measured radiation field patterns of antenna 2. The gain includes the reflection loss. Feed position (x,y)=(13.75mm, 21.25mm).

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