FINITE PATCH ARRAY AS REFLECTOR FOR ANTENNA GAIN IMPROVEMENT AND SIZE REDUCTION

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ABATRACT

An array of rectangular patches is tested as antenna reflector. The reflection coefficient (amplitude and phase) for a plane wave is measured, the findings are explained by the functioning of a single patch. A $\lambda/2$ dipole and a 2-arm spiral antenna are fitted with the patch array as a reflector. The resulting return loss, the gain and the pattern are reported. The reflector array efficiently enhances the gain of the antenna in one direction with the complete structure remaining small.

INTRODUCTION

For the reflector several requirements exist. The most important requirement is that the reflector's reflection coefficient is high, at best, equal to 1 (total reflection). As second requirement, the electrical image current should be in-phase compared to the original current, in this case, the reflector can be placed as close as possible to the antenna. The third requirement is that an incident wave is reflected maintaining the same polarization as the original antenna, or, in other words, that the resulting cross polarization is as low as possible. A fourth requirement concerns the interaction of the antenna with the reflector if the reflector is placed very close to the antenna. If interaction occurs, questions arise on how large changes are introduced for the antenna current distribution, the radiation characteristics, and related hereto return loss, gain, and pattern.

In this paper, a $\lambda/2$ dipole and a 2-arm spiral antenna are utilized as antennas. Patch array acts as reflectors. The above mentioned criteria are addressed in an experimental way.

SINGLE PATCH ELEMENT RADIATIN PATTERN AND PLANE WAVE REFLECTOR

One patch is chosen to have a size of 9.5mm×9.5mm, the distance between the patches is d=0.5mm. The substrate is a h=1.57mm thick epoxy substrate with relative permittivity of ε=3.5. The patch array in this application is illuminated by a TEM wave with the electric field parallel to the plate. The reflection coefficient in amplitude and phase is measured and calibrated to a PEC reflector. From 4GHz to 20GHz, there are 2 resonance phenomena, at which the image current is in-phase compared to the original current. The first resonant frequency is 5.45GHz. The reflection coefficient is close to 0dB (Fig.1a), i.e., the complete power is reflected in specular direction. The second resonant frequency is about 3 times the first one, at 17.5GHz, the reflection coefficient is only -14dB (Fig.1b). No resonance at a frequency double of the first resonance is detected.

In order to explain the reflection coefficient's difference between the different resonant frequencies, the pattern of one single square patch antenna is taken. Since the single element in the reflector is a patch, in principle, it has in the far field the same functioning as in a patch antenna. The measured pattern of the single patch element shows the following characteristics. At the first resonant mode, the pattern of a patch antenna has one single and broad lobe, with the main radiation in normal direction (Fig.2a). The second resonant mode shows a pattern with two lobes, with a minimum radiation in normal direction as the current distribution is symmetric to the normal direction (Fig.2b). Therefore there is no resonance phenomenon in a reflection coefficient measurement since the second mode is not excited by the normal illumination. At the third resonant mode, the pattern has three lobes, with the center lobe is smaller than the other lobes. The radiation in normal direction in this case is about 15dB less than for the first mode (Fig.2c). These three modes agree well with the reflection coefficient measurement.

Therefore, the principle of the patch array reflector can be explained as follows: outside the resonant frequency range, it reflects the power like a PEC reflector; within the resonant frequency range, first it absorbs the energy from the incident wave, causes itself to resonance, then radiates the energy. The radiation pattern is according to the mode of the patch. Thus, by using a patch array reflector, even with a normally incident wave, the energy is not reflected in one direction as in a PEC, instead, it is radiated in many directions, and cross polarization can also be produced by the radiation.

ANTENNA REFLECTOR

A λ/2 (27.5mm) dipole is used as an antenna.. In order to compare the results, the dipole in free space without reflector, the dipole with the patch array reflector, with a PEC reflector, and with a corrugated plate as reflector are measured. The corrugation depth is λ/4 of the first resonant frequency, then as PMC[1]. The antenna and the reflectors are placed as close as possible. First, the return loss is measured. With the patch array and the corrugated plate as reflector, the return loss remains low; with the PEC reflector it becomes high, whereas the return loss of the dipole in free space is the lowest.

In gain measurements with the patch array as reflector, the gain has a maximum slightly below the resonant frequency (Fig.3). This is due to the fact that the electrical length of dipole is longer than its physical length due to the fringing as the dipole is very close to the reflector (s<1mm). Therefore, the dipole works as λ/2 dipole at a slightly lower frequency. For the usual λ/2 dipole gain of 2.16dB, with the patch array reflector, the antenna shows a 3dB gain enhancement.

Then, the 2-arm spiral antenna with the same patch array as reflector is measured. The spiral antenna has diameter D=40mm, etched on a h=0.508mm thick Duroid5880 with relative permittivity of ε=2.2. The gain is measured when the separation s between the antenna and the reflector is changed. If s=λ/2, antenna has 3dB gain improvement compared to the simple antenna with no backing. If s=λ/4, the gain becomes very small. Both results are contrary to a PEC reflector. That is to say, the patch array works as a PMC. If the antenna and the reflector had no interaction, in theory, the gain of s=0 should be the same as the gain for s=λ/2. Finally the antenna and patch array are placed as close as possible, no gain enhancement is observed (Fig.4b), although the S11 remains relatively low in the resonant frequency range of the patch array (Fig.4a). Therefore, the interaction is large if antenna and reflector are close.

CONCLUSIONS

A patch array is tested as antenna reflector. Within a resonant frequency range, its reflection coefficient is measured to about +1, the image current is in-phase compared to the original current. Hence the patch array acts as an artificial perfect magnetic conductor. For a λ/2 dipole with the patch array, a 3dB gain improvement is observed compared to the simple antenna with no backing. For a 2-arm spiral antenna with the patch array reflector as close as possible, the interaction is observed.

REFERENCES

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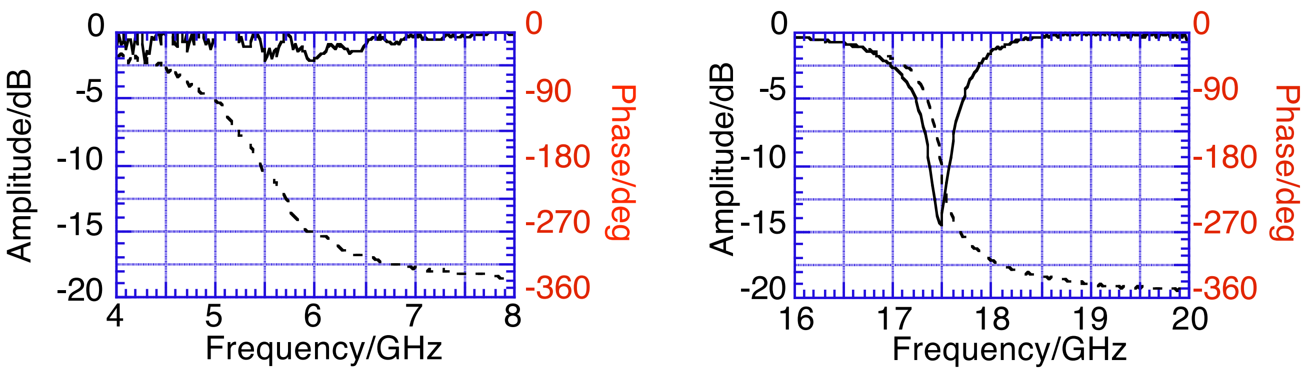
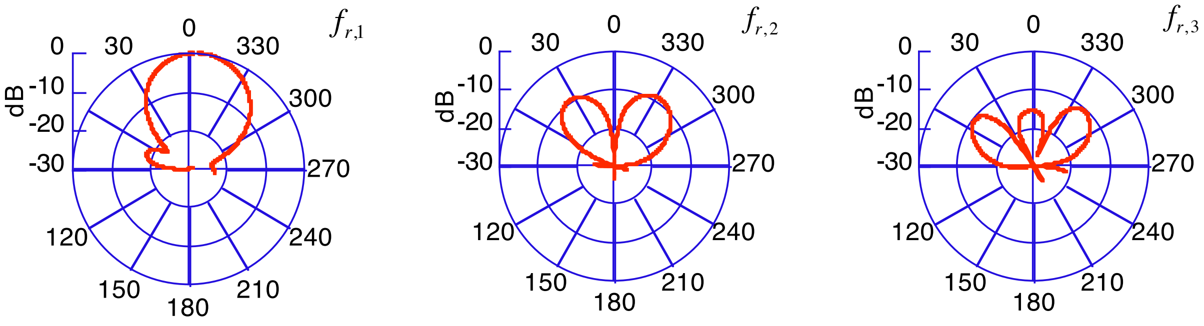


(a) (b)

Fig.1: Reflection coefficient of patch array (amplitude:—— ; phase: ------)



(a) (b) (c)

Fig.2: Patterns of the patch antenna

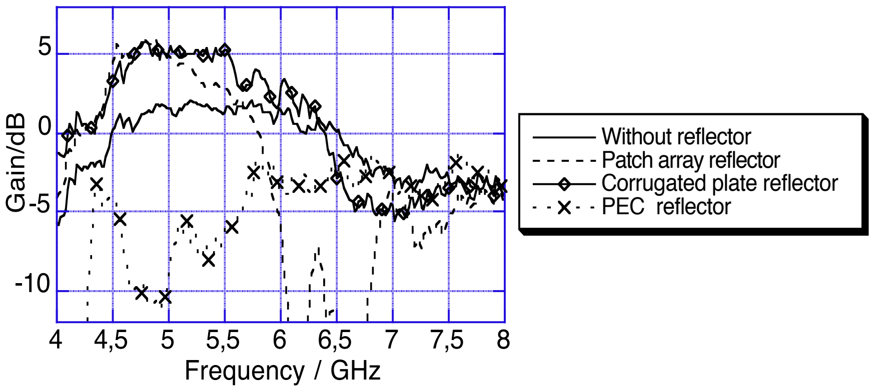
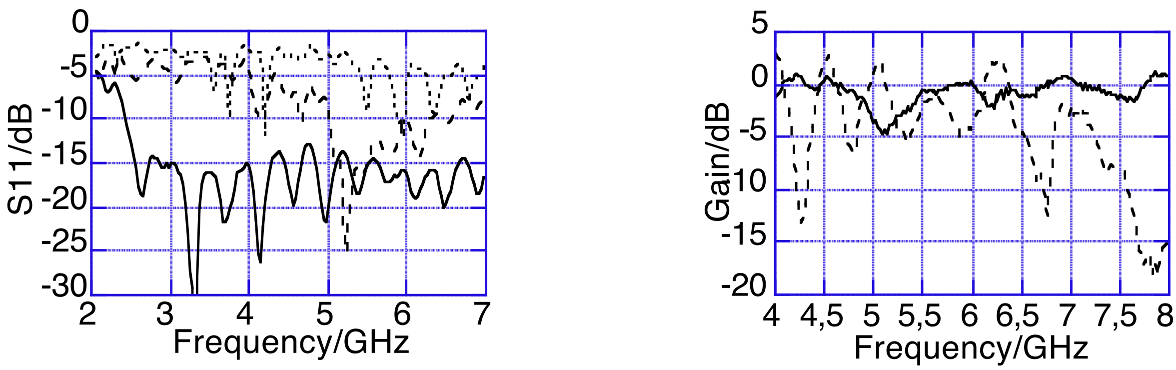


Fig.3: Gain of the dipole with different backings as close as possible



(a) (b)

Fig.4: S11 and gain of a 2-arm spiral antenna (without reflector: □ □, with patch array reflector:---; with PEC reflector:□)