Analysis of annular ring based reflectarray elements

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Abstract

Annular patches have already shown to be good candidate for the realization of printed reflectarrays (PRA). Up to now however their use has been mainly limited to the realization of single-layer PRA in which the elements are single annular rings, and the phase compensation has been obtained essentially varying their inner radius. Here, we will investigate the possibility of using the annular ring to have more complex PRA elements, consisting in multiple annular patches, one inside the other, or printed on different dielectric layers, for which more than one geometrical parameter can be varied. These RA elements will show more degrees of freedom, and therefore it is possible to achieve a larger phase variation range.

1. Summary

Research activity in Printed Reflectarrays (PRAs) is still a theme of significant interest, as it is confirmed by the continuing recent scientific production on this subject (see e.g. [1], [2] and the references therein). The reason is well known: they have attracting characteristics in space and terrestrial telecommunication applications, because the reflectarray technology can lead to high directivity antennas with deployable lightweight flat structure (or made by flat panels), to reduce the losses with respect to an equivalent array and its feed system, combining in this way the advantages of reflectors and arrays; on the other hand, reflectarrays present also some limitations, as the poor bandwidth [3] or the difficulty to scan the beam.

The most common PRAs have square (or rectangular) patches, and the phasing characteristics are obtained with well know techniques (size variation, stubs, orientation, etc). Less investigation (although with some interesting results, as e.g. in [4]) has been carried out on PRAs consisting of non-square/rectangular shapes, as circular, annular, etc. In particular, the use of annular patches may be interesting because in the fundamental mode TM11 the resonant size is significantly lower than for the circular or rectangular patch, and also because of the additional degree of freedom of the aspect ratio (outer/inner radius ratio). Printed annular rings seem therefore to be good candidates for the realization of PRAs with enhanced features, mostly because they intrinsically possess more degrees of freedom for the control of the phase of the reflection coefficient.

In view of these potentials, we have recently studied the feasibility and the characteristics of a PRA with annular patches, in which the reflection coefficient phase is controlled by varying their inner radius. The preliminary results are reported in [5], [6]: in particular, a study of the sensitivity of the phase curves to the change of the patch parameters, as the substrate height and/or dielectric constant, the angle of incidence of the impinging field or the resonance frequency, has been carried out. Moreover, results on the design of a small prototype, manufactured and measured, have also been shown. The conclusions of these analyses are that the use of annular patches in reflectarrays is an interesting alternative to more conventional solutions, because it opens possibilities and options that are absent in rectangular patch shapes, as: the possibility of having a constant maximum size of the element by varying the inner radius only to control the phase; the wide range of variation of the reflection coefficient phase; the smaller size of the elements for the fundamental TM11 mode. The constant outer size allows a more regular and dense lattice, and the behavior independent on incident polarization allows the use of any polarization.

The literature on annular patches show that they are also suitable for the realization of more complex radiating elements, generally consisting in more annular rings, with enhanced features (see e.g. [8][9]). These elements possess more degrees of freedom and in principle this is an advantage also in the design of PRAs. In order to verify this hypothesis, we can consider elements consisting of several annular patches, printed on different substrate layers, or located one inside the other on the same dielectric layer, and compute the phase variations that are achievable by varying the geometrical parameters of such configurations. The results of this analysis will be shown at the conference.

2. References

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8. Appendix 1: Generating PDF Files

Adobe Portable Document Format (PDF) is a universal file format that preserves the formatting of a source document, regardless of the application and platform used to create it. PDF files are compact and can be shared, viewed, navigated, and printed by anyone using the free Adobe Acrobat Reader. Although there are third-party packages that will produce compatible PDF files, Adobe Acrobat software (Exchange, Distiller) is recommended for producing the PDF files. Information on Adobe software can be found at http://www.adobe.com. At the time this was written, a limited number of documents in Microsoft *Word* .doc format and other formats (including PostScript) can be converted to PDF for free using a tool on the Adobe Web site at http://createpdf.adobe.com/.

LaTeX and other TeX files must be converted by the author and submitted in PDF format only. There is a variety of third-party software that will produce PDF files from (La)TeX. Some comments on converting (La)TeX files to compliant PDF are given in Section 8.2. Another way to convert (La)TeX to PDF is to convert (e.g., print) the (La)TeX to a PostScript file, and to then submit that PostScript file to the Adobe Web-based PDF conversion utility mentioned above. If this is done, please be *sure* to use only Type 1, TrueType, or Open Type fonts, and to embed *all* fonts. PostScript drivers are available for download from the Adobe Web site.

Do not submit scanned PDF files.

8.1 PDF Settings

The use of the following PDF settings in Acrobat Distiller or in the PDF Maker "applet" installed in Microsoft *Word* is recommended. To change settings in PDF Maker, use Adobe PDF...Change Conversion Settings...Advanced Settings and then click on each folder to access the various settings. To change settings in Distiller, use Settings...Edit Adobe PDF Settings... and then click on each folder. The following are the recommended settings:

PDF Version: PDF 1.4 (Acrobat 5) or later
Use passwords or security?: No
Use bookmarks or links: No
Allow crop marks, registration marks, or other marks?: No
PostScript code overrides setting file?: No
Embed all fonts: Yes
Embedded subset fonts: May be OK, but not recommended (i.e., set subsetting 100%)
Contains merged files or packaged files: No
Contains attachments: No
Latest version of fonts: Yes
Fast Web view (linearized): Yes
Open Type fonts: OK
Color images: 300 dpi resolution, bicubic downsampling, JPEG/medium compression
Grayscale images: 300 dpi resolution, bicubic downsampling, JPEG/medium compression
Monochrome images: 600 dpi resolution, bicubic downsampling, CCITT Group 4 compression, anti-alias off
Thumbnail of image in PDF: Yes

8.2 Comments Related to LaTeX and TeX File Conversion

Documents converted from the (La)TeX typesetting language into the Adobe PostScript language or Acrobat Portable Document format (PDF) files usually contain fixed-resolution (Type 3) bitmap fonts. These do not print or display well with a variety of printer and display environments. Only Type 1, TrueType, or Open Type versions of the fonts are acceptable.

As an example, the default behavior of Rakicki's DVIPS is to embed Type 3 bitmapped fonts. You need access to the Type 1 versions of the fonts you use in your documents in order to embed the fonts. Type 1 versions of the Computer Modern fonts are available in the BaKoMa collection (http://ctan.tug.org/tex-archive/fonts/cm/ps-type1/bakoma/) and from commercial type vendors. Before distributing files with embedded fonts, consult the license agreement for your font package. Some typeface vendors do not allow you to embed complete fonts into a PDF file for public distribution. You may embed all fonts included in the Adobe Type library.

When using LaTeX, only embedded fonts should be used to ensure a decent conversion to PDF. Use of Times fonts are recommended. With LaTeX2e use the command \usepackage{times} and with LaTeX 2.09 use the command \documentstyle[times]{…}. You will need the following packages: times.sty, rawfonts.sty.

8.3 The Most Common Reasons PDF Files are Reported as Non-Compliant

1. Other than a single-column format has been used.

2. Encryption or other security settings have not been turned off (do *not* use a password on your PDF file).

3. Bitmap (e.g., Type 3) fonts have been used (use Type 1, TrueType, or Open Type fonts).

4. All fonts have not been embedded (it is also a good idea to set "Subset fonts" at 100%).

5. A scanned PDF file is submitted.

6. A link or bookmark has been included (e.g., by using PDF Maker in *Word* with its default setting to create a PDF from a *Word* document containing a Web or e-mail address that is a link).

7. Fonts in EPS graphics are either not embedded, or are bitmap fonts.

9. Appendix 2: Some Tips for Graphics

In general, the use of vector graphics, such as those produced by many presentation and drawing packages, can be used without concern and is encouraged. The use of bitmap images, such as those produced when a photograph is scanned, can require significant storage space and therefore must be used with care. Bitmap graphics store an image as a series of numbers that represent the color of each dot in the image. Increasing the size, resolution (dots per inch), or number of colors in an image will dramatically increase the size of the image.

If your paper contains many images and/or large images, they will be down-sampled to reduce their size during the process of converting to PDF format. However, the automated process used will not always produce the best image, and you are encouraged to perform down-sampling yourself on an image by image basis, using an image-manipulation program such as *PhotoShop*.

It is strongly recommended that you both look at the PDF you create on a computer display and print it out, paying particular care to the quality of the images, before you submit the PDF.

Where possible, bitmap images should be limited to 256 (8-bit) colors or gray scale. A resolution of 150 dpi is often adequate, particularly for screen shots. You can often reduce the number of display colors before making screen shots. The majority of computer applications use less than 16 colors for their menus, dialog boxes, etc.