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Project 2: Design and Implementation of a Patch Array with Sum/Difference Patterns at the ISM 5.8GHZ band.

Objective

Apply the theory of printed transmission lines and antennas in the design and implementation of a practical antenna array system.

Learning outcomes

Successful completion of this activity will provide the students with:

1. Experience in the design, fabrication, application and performance of microwave printed systems: rectangular patch antennas, printed arrays and microstrip-based beam forming networks.
2. Basic knowledge on the operation and applications of microwave measurement equipment.
3. Working knowledge on full-wave simulation tools and its application in the design/optimization process of microwave systems.

Problem statement and specifications

It is required to implement a 4-element array of rectangular patch antennas with the following specifications:

1. Array must be uniform both in spacing and excitation amplitude.
2. Field polarization orthogonal to the array axis.
3. Overall antenna must have two ports which provide sum/difference patterns.
4. Frequency of operation: 5.8GHz with the following specifications to be satisfied in a bandwidth of at least ±1% around the center frequency:
   (a) The scattering matrix of the resulting two-port system must obey:
   $$|S_{a,b}| \leq -15\text{dB} \quad \forall\ a, b \tag{1}$$
   These constraints are required in order to have good input matching (a=b case) and good isolation between ports (a≠b case).
   (b) $G_{max} \geq 10$dBi for the sum pattern.
   (c) SLL < -13dB.
   (d) The difference pattern must have a maximum null width of 15° measured between the points 6dB below the maximum of the side lobes.

Grading

Examination will consider the following items:

1. (50%) Final report (see below for details on format and contents).
2. (15%) Array prototype.
3. (15%) Measurement results, satisfaction of requirements.
4. (20%) Individual (oral/written) evaluation on the theory and practical aspects of the project.

Final Report

Final report must have the official format of the IEEE Transactions, there are templates available in LaTeX and MS-Word in this link (select "template for all Transactions"):

`http://www.ieee.org/publications_standards/publications/authors/authors_journals.html`

The final report must include these sections:

- Abstract
- Background: describes the relevant theory and equations citing the original sources. This section includes also a discussion on the application of the system to be built.
- Design: describes in detail the design criteria and all the calculations required to ensure satisfaction of the system requirements. This section must conclude with a full schematic of the system including all relevant dimensions/parameters.
- Design validation using simulation: description of the procedure followed to simulate the system at two abstraction levels: transmission line (e.g. using QUCS) and full-wave simulation (e.g. using FEKO) and confirmation of the satisfaction of *all* the system specifications.
- Discussion of results: Summary of the results achieved, how these compare to specifications, what is expected from measurements considering tolerances, and mention of any open/solved problems found during design/validation proposing ways out of them if applicable.
- References.

Notes

- The report is limited to an extent of four pages: additional pages will not be considered.
- The report will not include measurement results; however it must include a photograph of the final prototype with a suitable metric reference (e.g. a ruler).

Schedule and products

- Final report is due by Tuesday December 4 at 23:59. This is to be sent in PDF format to jlaraqueq@unal.edu.co.
- Prototypes will be measured on Thursday December 6 in turns to be defined between 7am and 12am. Measurements will be allowed only to groups having their system ready by the start of the assigned time.

Suggested reading

The basic theory of rectangular patch antennas and antenna arrays will be provided in class, as will be the relevant design techniques. Additional readings required are:

1. Discussion on sum/difference arrays, characteristics and applications are found in [1, pag. 125].
2. A basic microwave building block that may be useful for this design is the quadrature hybrid coupler. Its description, analysis and design can be found in [2, p.344].

References

[1] R. S. Elliot, *Antenna Theory and Design*. IEEE press, 2003.

[2] D. M. Pozar, *Microwave Engineering*, 4th ed. John Wiley & sons, 2012.

[3] T. A. Milligan, *Modern Antenna Design*. IEEE Press, 2005.

[4] B. C. Wadell, *Transmission Line Design Handbook*. Artech House, 1991.