ON DESIGN-IMPLEMENT PROJECTS IN ELECTRONIC ENGINEERING

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ABSTRACT

In engineering education, the link between the theory and the design and manufacturing of practical applications is very important. At our university, project-oriented courses providing design-build experience and following CDIO guidelines, are organized starting from the first bachelor year in electronic engineering. During the second bachelor year, a more advanced CDIO project is organized where students design, build and test a device in a team of five to seven people. In this course a new topic is chosen each new academic year and creativity is stimulated by allowing many degrees of freedom to define the final product. In their team, every student has a different task, determined by specific job profiles, such as project manager, analog design engineer, digital design engineer, software engineer, mechanical engineer and CAD engineer. However, it is also a requirement for every student to keep an overview over the complete project. Progress and milestones are discussed in regular project meetings. A project schedule is presented by means of Gantt charts and adjusted if necessary. Intermediate and final peer assessments are performed, of which the first one is only intended to provide tentative feedback. At the end of the project, the students make an oral presentation, give a lab demonstration and hand in a written report. Grading of the project is performed by relying on individual permanent assessment during the semester, general and specific project output, quality of the report and presentation as well as the final peer assessment. Communication skills are considered very important throughout the engineering program. Presentation as well as writing skills play an important role in the final grading of the project work. During the project, the importance of the CDIO cycle is stressed. Students learn that product development is an iterative process on many levels, where constant feedback allows the design strategy to be adapted in order to obtain a high-quality product as a final result. Students confirm this in the included course assessment.

KEYWORDS

Design-Implement Experiences, Engineering Workspaces, Integrated Learning Experiences, Active Learning, Learning Assessment.
(Standards: 5, 6, 8, 11).

INTRODUCTION

In engineering education, the importance of the link between the theory and the design and manufacturing of practical applications cannot be stressed enough. In the previous decade, our university underwent a significant program reform, providing more space for project-oriented courses. A similar program reorganization, including motivation, is presented in Shen, Y. (2015). A first design-implement experience at a basic level is included in the first bachelor year in electronic engineering at Ghent University. In this first year project, teams of students conceive, design, implement and operate an electric motor from basic mechanical and electrical components. A second, advanced level design-implement project course is organized in the second bachelor year, on which the focus is in this paper. This course presents an extreme challenge to the students for the first time in their academic career. Further CDIO initiatives are organized in the curriculum, with the ‘bachelor’s dissertation’ in the third bachelor year and the final ‘master’s dissertation’, resulting in four large projects of increasing complexity, as is also the case in Kjærgaard C. et al.(2012). This is completely in accordance with CDIO Standard 5.

The focus of this paper is presenting the design-implement projects of the second bachelor year in electronic engineering, as described in the Course Specifications (2015). Students design, build and test a device in a team of five to seven people. Each year another topic is chosen. Projects of the past ten years included a mechanically rotating LED display, the ‘snake’ (a device for measuring movements of the spine), an ultrasound scanner, an intelligent solar charger with rotating solar panel, a MIDI controlled analog music synthesizer as well as a bat detector. Another project example is displayed in Figure 1, where a complete digital clock radio was developed, including an OLED display. The microcontroller, at the heart of the circuit is programmed in the C language, which is also the case in all projects mentioned above. The complexity of the project is always large enough for an advanced-level design implement experience.

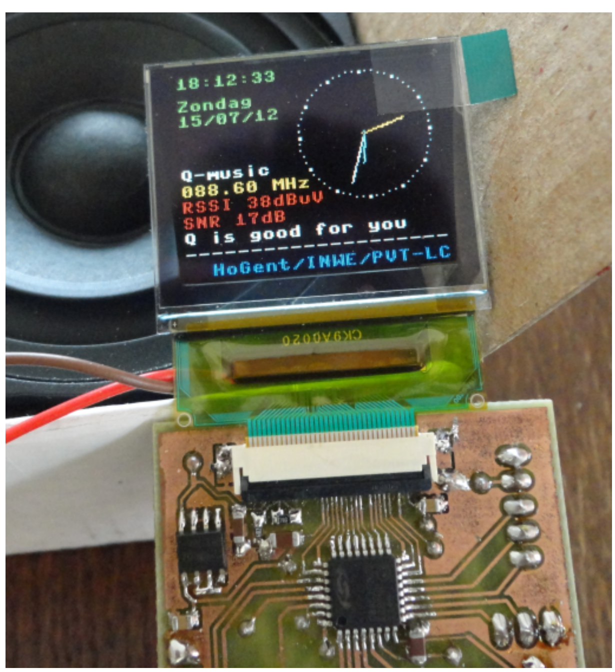

Figure 1. Clock radio with OLED display

The students are supposed to work on their projects one day per week during a full semester of 12 weeks. In their team, every student has different tasks to fulfill. We include the following job profiles: project manager, analog design engineer, digital design engineer, software engineer, mechanical engineer and CAD (computer aided design) engineer. However, it is important that every team member keeps an overview of the entire project.

The students meet regularly, where they discuss the progress and milestones of their project. Although the meetings are supervised, the students are always encouraged to take initiatives and be creative. At these meetings, a project schedule is discussed and adjusted where necessary. Gantt charts are employed to encourage better project management as well as to provide more overview.

Due to the limited technical background of second bachelor students, technical and scientific support is constantly provided by the two supervisors. Halfway the semester, an intermediate peer assessment is performed, which outcome does not count for the final grade. The supervisors clearly state to the students that this assessment is only intended to provide feedback on how the team members appreciate their work, and to inform the supervisors in time about potential problems in the team.

At the end of the semester, an oral presentation is performed with an active contribution of every team member. Additionally, a project report of about 30 pages is handed in. Furthermore, a final peer assessment is performed. The grading of the students is performed by the supervisors, relying on individual permanent assessment during the semester, general and specific project output, quality of the report and presentation as well as the final peer assessment. However, the final peer assessment is only employed as an additional instrument to support the permanent assessment.

The following sections of the paper describe the organization of the different projects, the project assessment, a SWOT analysis and the conclusions.

ORGANIZATION OF THE PROJECTS

Team Definition

From the first project session, teams of five to seven people are defined, including the following job profiles:

- Project leader (1, combined with another task in this list)
- Analog design engineer (1-2)
- Digital design engineer (1-2)
- Embedded software developer (1-2)
- CAD engineer (1)

Depending on the specific project content, two persons can have a similar job profile. The project leader combines his/her responsibility generally with a technical job shared with another student.

Job profiles are appointed to the students by letting them fill out their preferences on a list. They can rank the different job profiles by using numbers. Job profiles performed in other (earlier) projects are ranked at the bottom. The supervisors then search for team compositions in order to appoint the specific job positions to those students who have a high preference for it. Generally, students get a job which is their first or second choice.

Introductory Classes

A number of introductory classes are taught, on the following topics:

- Project history, methodology and assessment
- CDIO principles
- Technical details important for the current project
- Theoretical background of relevant technical issues
- CAD exercise, drawing a schematic and printed-circuit board
- Embedded software programming exercise

These introductory classes take two project sessions, after which the teams start planning and brainstorming about technical issues, a process illustrated very well in Khan R. et al. (2015).

Hands-on Project Work

Project work is performed in the lab at our university on a weekly basis. According to CDIO standards, the workspaces used are student-centered, user-friendly and always accessible.

The lab is available to the students most of the week, but extra hours are mostly spent in the last project weeks. For 2.5 hours per week, students are constantly supported by two supervisors, providing practical as well as theoretical advice, from design guidelines to ordering new components or providing them from the local stock.

According to CDIO standard 5, early success is an important motivating factor. Early success is stimulated by the constant support, helping the students to quickly achieve small goals in an early project stage. The project proposals are always written in order to include a large number of goals of increasing complexity.

All teams are encouraged to communicate their project experiences and design choices to the other teams, in order to make them learn from each other's design choices. Hands-on and social learning are included into CDIO standard 6. Iteration into a redesign, as a consequence of social learning, especially in an early project stage is a highly valuable experience.

Despite the interaction, the end result should be clearly different for each team because of their creative and independent design choices. Schematic and printed-circuit layouts as well as embedded software source code are compared and should be fundamentally different for each team.

PROJECT ASSESSMENT

Permanent Assessment

Permanent evaluation is the most important factor in grading the final project as well as in providing feedback. The supervisors are both continuously present during the project hours, inspecting the work of the students, and taking notes of the project status while providing feedback. The performance of individual students is constantly being observed. Figure 2 displays a student lab setup during project implementation in the first half of the semester. Such a measurement setup allows easy comparison of the project status between different teams.

After a few weeks trends become visible: some students tend to present more creative ideas or take initiative; others tend to go with the flow. This phenomenon corresponds very well to typical engineering teams in realistic and industrial settings. Regular project meetings are held every week, where each team discusses the project status and future schedule in the presence of the supervisors. They provide feedback to improve the teamwork and also give technical input if necessary.

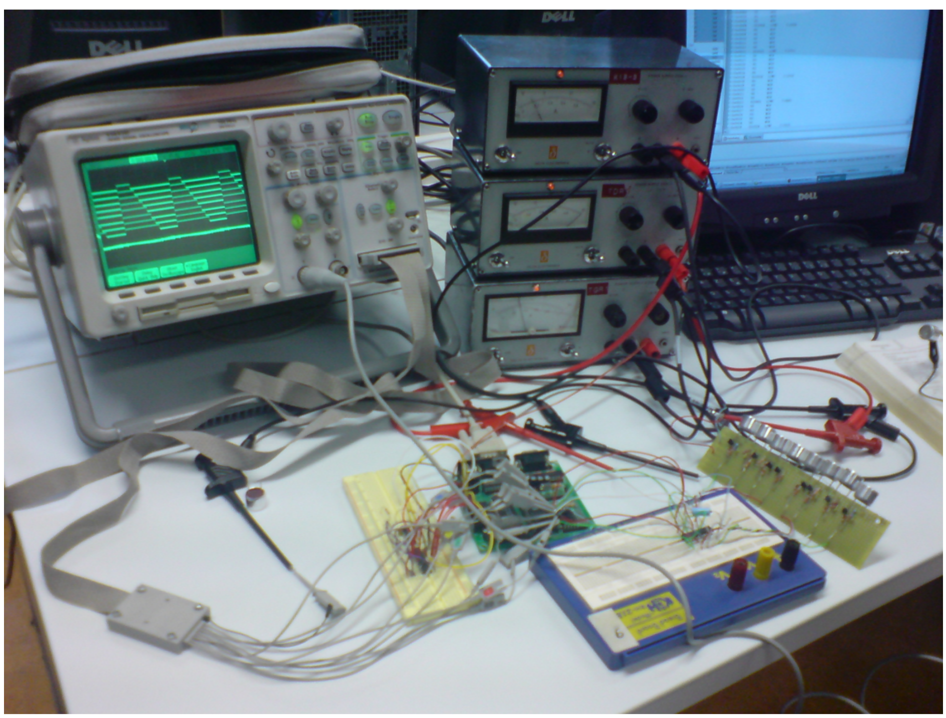

Figure 2. Project implementation during first half of semester

Intermediate Peer Assessment

In the first introductory class, the students are informed that peer assessment will be performed. They are already used to this system from their first year project course.

Halfway the semester, an intermediate peer assessment is performed, to allow the students to get feedback from their team members. It is stated explicitly that this intermediate peer assessment is not used for grading the project.

The intermediate peer assessment helps to spot large problems at an early stage, concerning individuals who do not fit well in the team. In case such a problem is apparent, extra meetings are held with the team as well as with the individual student and the supervisors. Practical experience learned that these problems are often caused by inefficient communication and can be solved most of the time.

Presentation

At the end of the semester, the students have to present their work in a written report of about 30 pages, a group presentation and a lab demonstration.

In this presentation, students will typically cover the topic, which they spent most of their time on. At the end of the presentation, questions are asked by the supervisors, concerning the jobs performed in the project as well as on project overview. Fellow students can also ask questions.

Demonstration

After the presentation, a demonstration is required in the lab. Here students generally show a working prototype as the end result of their project. Partially working or non-functional prototypes can also be presented.

In case a prototype does not work (partly or completely), a good grade can still be obtained if the project is clearly presented and documented and if the remaining problems are clearly identified.

Figures 3 and 4 display a working prototype of an ultrasound scanner, allowing visualization of objects in front of the scanner. This multidisciplinary project included all following skills:

- Project management
- Teamwork
- Analog circuit design
- Digital circuit design
- Mechanical design
- CAD
- Embedded software development
- MATLAB code development
- Test and measurement skills
- Writing and presentation skills

Therefore the project is also a valuable Integrated Learning Experience as explained in CDIO Standard 8, developing multidisciplinary knowledge simultaneously with personal and interpersonal skills.

Moreover, the supervisors use concepts from the students' theory courses to provoke a deeper understanding of practical issues encountered during this project, hence promoting active learning (CDIO Standard 8), comparable to Liqiao W. et al. (2015). Realizing the project requires background from multiple theory courses, such as analog electronics, digital electronics, embedded systems, physics and mathematics.

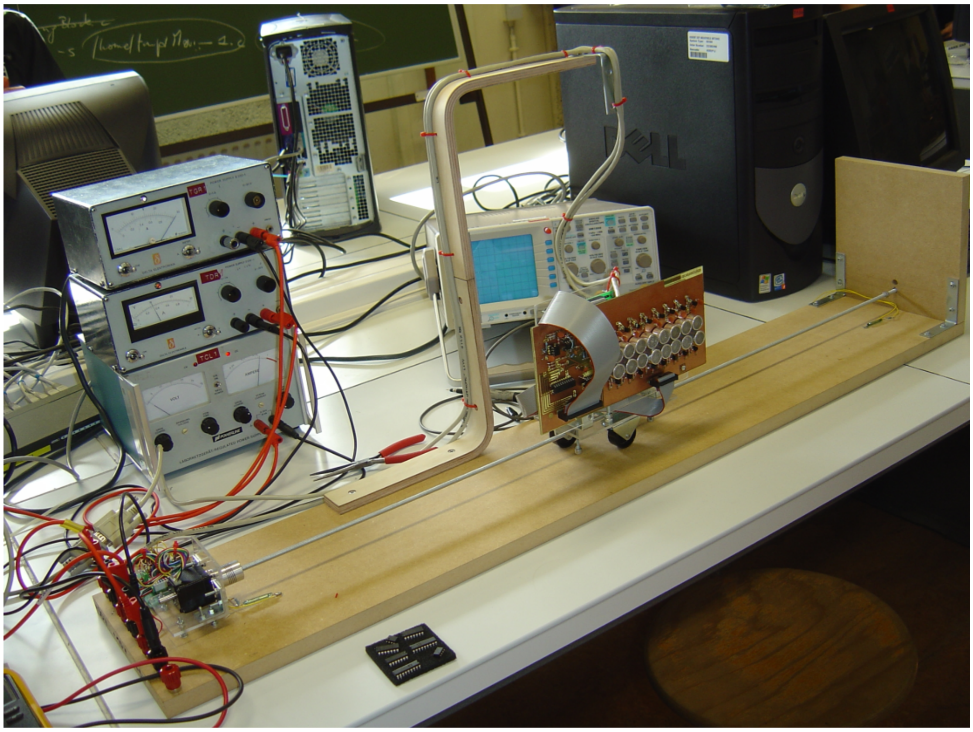

Figure 3. An ultrasound scanner as implemented by the end of the semester

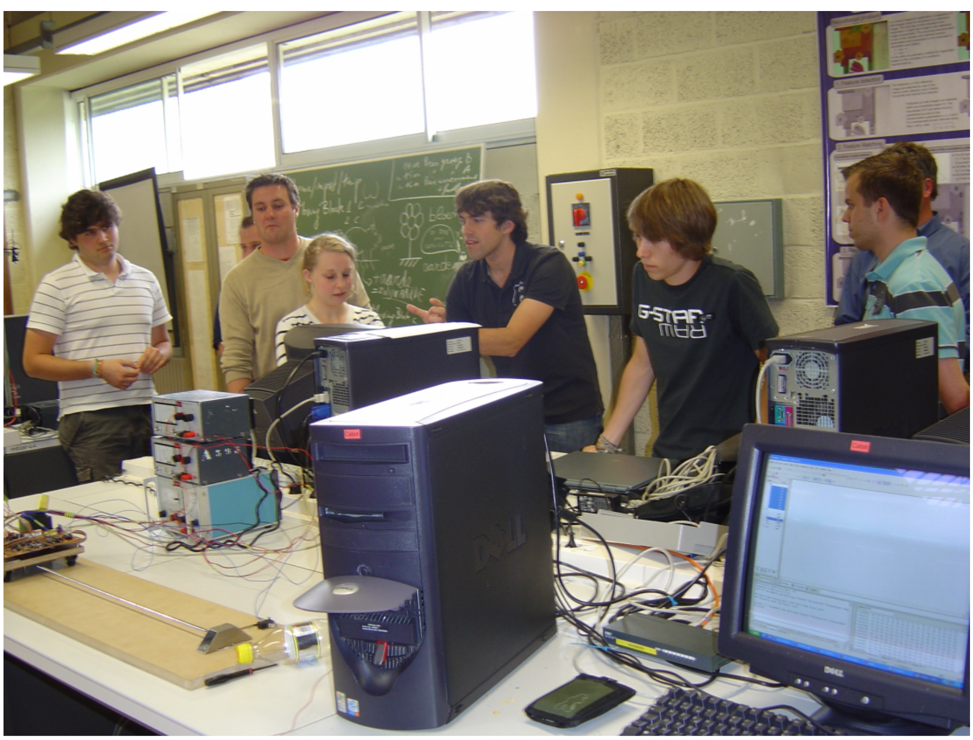

Figure 4. A team demonstrating their ultrasound scanner

Final Peer Assessment

The final peer assessment is performed after the presentations, right at the end of the project. It is mandatory for each student to fill out the peer assessment in order to obtain an individual project score.

The students are informed that the peer assessment will only be used as a guideline in grading the students. Permanent assessment by the coaches is much more important, but the peer assessment shows if the opinion of the supervisors is supported by their team.

Well-known methods, such as calculating a peer assessment factor and multiplying global project marks by this factor to obtain individual results are not employed, as we have the experience that this system allows the students to have too much impact on the grading. Care should be taken at all times that some students do not fail the course solely because of group dynamics.

Grading

After the presentation, demonstration and final peer assessment, both supervisors exchange views to determine the results. Generally this happens within two weeks after the end of the course, when all project reports have been.

A meeting is then held where first, for each team, the performance of different students is compared. Then the overall performance of different teams is compared, as well as the individual performance of students in similar jobs in different teams.

The following factors are taken into consideration:

- Motivation
- Attitude
- Creativity
- Taking initiative
- Problem solving
- Communication skills
- Teamwork
- Perseverance
- Presentation skills
- Writing skills
- Peer assessment

After the final marks are calculated, a ranking of the students is performed. The list is checked for anomalies and slight corrections are possible according to comparison based on the constant monitoring of the students during the entire semester.

Feedback

Students receive via the electronic learning environment Minerva. They are allowed to ask feedback on these results, but they rarely make use of that. Generally, students accept their grade without discussion as they trust the supervisors in judging in an objective and honest way. By filling out the peer assessment, each student has already reflected about his/her own results and his/her place in the team. Additionally some feedback had already been provided after the presentation, hence students know what to expect approximately.

Learning assessment

According to CDIO Standard 11, it is highly important to have an effective assessment process for measuring the different learning outcomes. Fixed weights are employed to calculate the average grade based on specific assessment types for the different learning objectives that need to be achieved. Writing and presentation skills are even assessed by a language professor. Determination of students' achievements is hence performed accurately for each specific learning objective.

ASSESSMENT AND SWOT ANALYSIS OF THE COURSE

Assessment

At Ghent University, all courses are assessed by the students on a regular basis. Students fill out a number of questions, assigning scores from one to five to different course aspects. Figure 5 displays the results of such a student assessment for this second bachelor year CDIO project. Although the number of students who responded was rather limited (i.e. 17 %), the course is clearly appreciated, as the score is higher than the faculty reference (the average for all courses) in all aspects, with 'Learning effect' and 'Project coaching' even very near the maximum score (5/5).

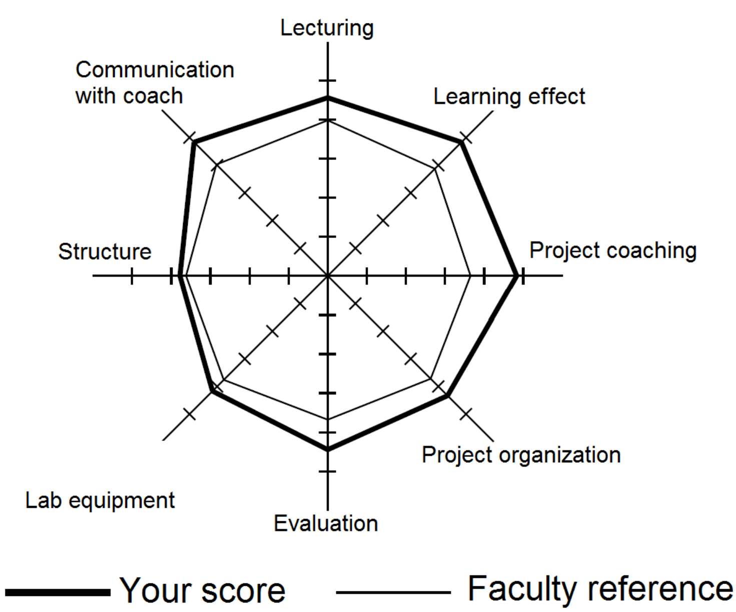

Figure 5. Graphical presentation of course assessment

Strengths

The project sessions are extremely motivating. Students regularly cite this as the course where they learned the most at this point in their education. They regularly work more hours than requested, stay in the lab much longer, or perform work outside the scheduled project hours, especially during the final phase of the project.

The project provides a unique hands-on experience and the degrees of freedom given for the design help to boost creativity. Students experience the whole design cycle, starting with only some vague ideas and finishing with a documented and functional prototype.

Weaknesses

Replacing classic courses with project-oriented lab sessions of this type causes people to acquire specific knowledge around their function in the group, leaving voids in their knowledge with respect to other fields. Year after year students could for example avoid drawing a printed-circuit board, finally graduating as an electronic engineer without having obtained this skill. Care has to be taken when composing the educational program in order to avoid such knowledge gaps.

Opportunities

CDIO projects can also be performed as a proof of concept for third parties, who have an idea that needs to be tested, as a way of community service learning. This has been done once in the past for a Belgian health insurance organization, requesting the development of a system for measuring movements of the spine. Such a project needs to be at a suitable level of difficulty and allow enough creativity for the students to realize their own ideas. A careful selection of such requests is very important, as illustrated in Törnqvist E. (2015).

Threats

Manipulation of the peer assessment system by the students is a risk. Popular students are sometimes protected by their peers, whereas other students can be severely discriminated. This is the main reason why peer assessment is only used as a guideline.

CONCLUSIONS

This paper described ten years of experience with advanced CDIO project courses in the second bachelor year of a curriculum in electronic engineering at Ghent University. Organization, topic selection and grading were discussed.

The main features of the course were the variety of project topics, with a completely new topic presented each year, combined with selected job profiles for the students and allowing ample creativity in design choices. A SWOT analysis of the course provided more insight into some specific issues encountered over all those years.

The experience of the past decade of project courses is very valuable. Students are always highly motivated for the projects and obtain good results as a team in nearly all cases. At course assessments, students regularly state this project is the course where they have learned the most in their educational career so far. The hands-on approach as well as the concentric learning and teamwork experience are highly appreciated. It is impressive how result-driven the students are, with near the end of the semester more and more people choosing to work overtime to get things working as the deadline approaches, like professional engineers. The student assessment results confirm their appreciation of the course.

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BIOGRAPHICAL INFORMATION

Jo Verhaevert, Ph.D. received the engineering degree and doctoral degree in electronic engineering from the Katholieke Universiteit Leuven, Belgium, in 1999 and 2005, respectively. He currently teaches courses on telecommunication at the Department of Information Technology at Ghent University, Ghent, Belgium, where he also performs research. His research interests include indoor wireless applications (such as Wireless Sensor Networks), indoor propagation mechanisms, and smart antenna systems for wireless systems. He is currently also program leader of the electronic engineering curriculum at Ghent University.

Patrick Van Torre, Ph.D. received the Electrical Engineering degree in 1995 and the doctoral degree at Ghent University, Belgium in 2012. He has been employed by Ghent University, at the Faculty of Engineering and Architecture since 1999, where he teaches theory courses in Electronics and ICT, organizes project-oriented lab sessions and is involved in public relations activities as well as hardware development projects for third parties. He is active as a researcher, in the field of wireless communication, focusing on body-centric multiple-input multiple-output (MIMO) and beam-forming systems.

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