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Recent Contributions in Antennas and Propagation from Saudi Universities

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Abstract

Research contributions in the areas of antennas and propagation have experienced a noticeable increase from Saudi Universities in the past four years. Several research groups have become active in some new topics in the field, and their work and names started appearing in prestigious conferences and journals. In this article, we will give an overview of the research universities in the Kingdom of Saudi Arabia, and identify the groups and people in the areas of antennas and propagation, and what are their latest contributions and research areas.

1. Introduction

Wireless communications has experienced several major milestones, in evolving from military-based wireless terminals back in the 1940s, to extremely-small-form-factor mobile telephones nowadays. This noticeable reduction in the form factor of the wireless terminals has also resulted in the reduction of the sizes of the antennas within them. The antenna volume in current cellular phones does not exceed 2 cm^3 to 4 cm^3. In addition, the proliferation of portable devices in terms of tablets, smart phones, laptops, etc., has resulted in a large number of small-size (miniaturized) printed antenna solutions for such applications.

The research output from Saudi Universities in the areas of antennas and propagation has seen a dramatic increase within the past few years, due to the establishment of several key laboratories and the involvement of active young researchers. Out of a large number of Saudi higher-education institutions, only a few are actively engaged in research. Several research groups within these institutions are currently tackling various areas, such as computational electromagnetics, multiple-input multiple-output (MIMO) printed antennas, on-chip antennas, ultra-wideband (UWB) antennas, wave propagation, and scattering, among others. In this article, we will highlight these active areas of research and the research groups involved, in addition to their involvement and contributions to the Antennas and Propagation Society.

2. Historical Background

The first university that was established in Saudi Arabia was Umm Al-Qura University (UQU), in the holy city of Mecca, back in 1949, with a College of Islamic Studies. King Saud University (KSU) was established in 1957. The university started with one department (Arts), and then in the early 1960s, science colleges were established. KSU is the largest university in the central region in Saudi Arabia, and it is situated in the capital city of Riyadh. In 1963, the College of Petroleum and Minerals was established in the eastern region, next to the oil company Saudi Aramco. It was a technical college, intended to provide field engineers supporting the oil industry. The college was then declared as an official university in 1975, where it was called the University of Petroleum and Minerals. In 1986, the university was renamed to become King Fahd University of Petroleum and Minerals (KFUPM).

King Abdul Aziz University (KAU) was established in 1967 as a university supporting the western region of the country. The university started with a college of Business and Economics, and then other scientific departments were added. KAU is nowadays one of the largest universities in the western region. In 1975, King Faisal University (KFU) was established in the eastern region in the city of Al-Hasa. Afterwards, it wasn't until 1999 when the next public university was opened, in the city of Abha, in the southwestern part of Saudi Arabia. It was called King Khalid University (KKU). Since the late nineties, more than 15 new public universities have been established in all parts of the country to serve the growing population.

In 2009, King Abdullah University for Science and Technology (KAUST) was officially opened, with a focus on graduate education and research in science and technology.

Figure 1. The locations of the Saudi universities that are more than 10 years old, or are research oriented.

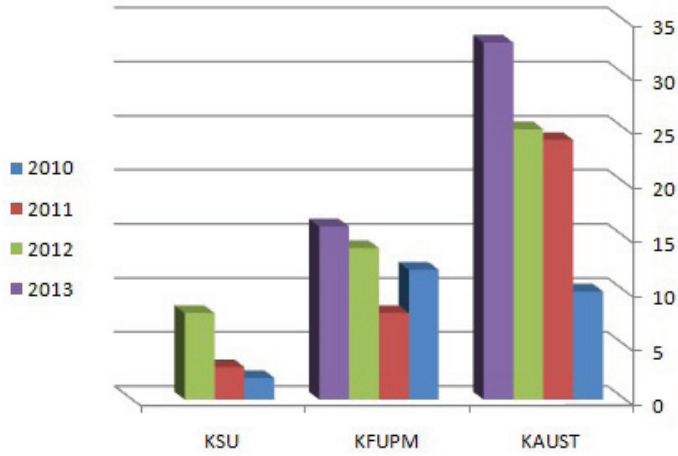

Figure 2. The number of antennas and propagation related publications from active Saudi universities during 2010-2013.

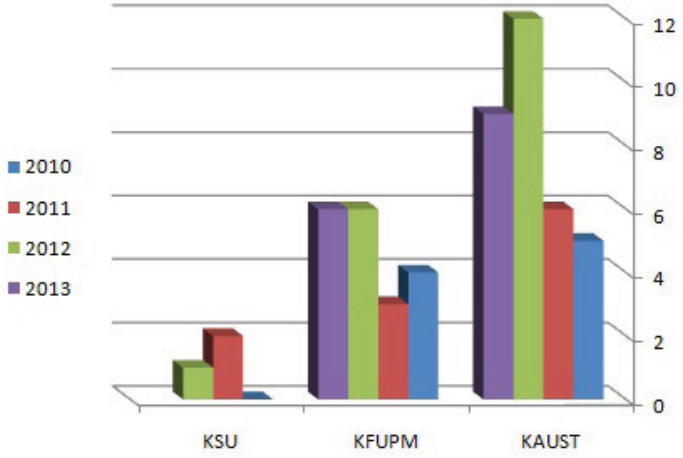

Figure 3. The number of antennas and propagation based published ISI journal papers from active Saudi universities during 2010-2013.

The university is located in the western region of Saudi Arabia, near the city of Jeddah. The university is fully dedicated to research, and is equipped with state-of-the-art laboratories. Figure 1 shows the map of Saudi Arabia, and the location of the public universities that are more than 10 years old or are research oriented.

Very few universities are ABET accredited, as well as teach antennas and propagation courses in their electrical engineering undergraduate as well as graduate curricula. While KSU and KAU have all kinds of disciplines, KFUPM and KAUST only provide programs related to science and engineering. KAUST only provides master's and doctoral degrees, while all other institutions offer a bachelors degree, as well. The major funding agency in the country is King Abdul Aziz City for Science and Technology (KACST). This is an equivalent to the National Science Foundation (NSF) in the USA. This agency identifies the tracks for future research based on the country's needs, and then provides funding for proposals that are within the national plan for science and technology.

The area of Antennas and Propagation has seen a noticeable increase in the number of publications in the past four years from Saudi Arabia due to some active research groups at KAUST, KFUPM and KSU. Figure 2 shows the published papers per year during the past few years from these active universities in this area. It includes conference and journal papers in international and ISI listed journals. Figure 3 shows the published ISI listed journal papers from the three institutions. The research areas cover a wide spectrum of topics starting from computational electromagnetics, to wave propagation, to printed antennas and antenna arrays, down to on-chip and on-package antennas. The contributions in each of the areas will be discussed in the sections to come, and the research groups involved will be identified.

3. Research Universities in Saudi Arabia

Although there are more than 25 public universities in Saudi Arabia, scattered all around the country and serving the population of 28 million, less than a handful are actively engaged in research. Several private universities exist in the western and eastern regions of the country, as well as in the capital, Riyadh, but they mostly serve as teaching universities. Only very few universities are actively engaged in research in general, not to mention the research area in antennas and propagation. Out of the 25 public universities, only three are identified as actively engaged in research in the antennas and propagation fields (based on the research work in the past four years). These are KAUST, KFUPM, and KSU. Table 1 shows the active universities, as well as the faculty and their research interests (according to the information provided on their Web pages, and personal correspondence). The contributions of the various universities and faculty members in the areas of antennas and propagation will be highlighted in the following section. The focus will be on the most-recent research tracks adopted.

4. Research Areas

The research areas from various faculty and universities within the kingdom have been grouped into five major areas within antennas and propagation. The following subsections summarize the research conducted within each category, and highlight the groups actively engaged in such activities.

4.1 Computational Electromagnetics and Wave Propagation

Computational electromagnetics is an extremely important field in antennas and propagation. It focuses on coming up with stable numerical methods to solve Maxwell's equations in various media and for structures of various sizes. The

Table 1. Major Saudi research universities active in the areas of antennas and propagation, their faculty, and their research areas of interest.

University	Faculty	Research Areas (Related to Antennas and Propagation)
King Abdullah University for Science and Technology (KAUST)	Hakan Bagci	Computational electromagnetics, and development of hybrid methods for analyzing wave interactions with complex and realistic structures.
	Atif Shamim	Printed and on-chip antennas, inkjet antenna printing
	Ying Wu	Effective medium theory for elastic metamaterials and wave propagation in strongly scattered random elastic media, electromagnetic waves in random media
King Fahd University for Petroleum and Minerals (KFUPM)	Essam Hassan	Electromagnetic wave propagation, phased antenna arrays, microstrip structure analysis
	Sharif S. Iqbal	Microstrip antennas
	Hassan Ragheb	Waveguide antennas, scattering and microstrip antennas
	Mohammad S. Sharawi	Applied electromagnetics, printed antennas and antenna arrays, MIMO antenna systems
	Mohammad A. Sunaidi	EM wave propagation, EBG structures and Metamaterials
King Saud University (KSU)	Khalid Jamil	Ultra-wide band printed antennas, radar systems, applied electromagnetics
	Majeed A. Al-Kanhal	Electromagnetic scattering, antenna design, computational electromagnetics
	Aabdul F. Sheta	Printed and microstrip antennas

advancements in this area have led to very stable analysis tools and packages that are heavily used for the design and analysis of antennas and of wave propagation in complex media. The research group at KAUST has focused on various aspects of applied and theoretical computational electromagnetics, with emphasis on time-domain integral equations, and developing fast hybrid methods for analyzing electromagnetic-wave interactions on complex platforms and in complex media [1]. In particular, Calderòn and hierarchical preconditioners have been developed to alleviate the ill-conditioning due to dense mesh and low-frequency breakdown of the frequency- and time-domain electric-field integral equations [2, 3]. In addition, FFT-accelerated exact boundary conditions have been formulated and implemented within time-domain discontinuous Galerkin finite-element (FEM) and finite-difference time-domain (FDTD) methods for accurate truncation of computational domains for open-region problems [4-6]. At KFUPM, some researchers are focusing on FDTD methods for computational electromagnetics. They have developed several fast algorithms for electromagnetic propagation in various media [7].

4.2 Printed Antenna Systems

Printed antennas are widely used in current mobile and consumer electronics devices, due to their low cost, and ease of integration and design. For 4G terminals and devices, MIMO technology is used. Several groups around the world have thus started developing printed MIMO antenna systems that provide good system performance and that are miniaturized in size. Another challenge in this area is the fact that lower-frequency bands have opened in the 600-800 MHz range around the world, which led to the need for highly integrated antenna solutions.

The group at KFUPM has been very active in this area. They have come up with novel antenna structures that are dual-band (covering the 700 MHz and 2500 MHz bands) for MIMO antenna systems [8-11]. In addition, two to eight antenna elements were integrated on a regular 100 mm × 50 mm × 1.56 mm FR-4 substrate, as was presented in [12, 13], for the latest 802.11ac standard. The group is also involved in developing isolation-enhancement structures for closely packed printed MIMO antenna systems. These have included defected ground structures, metamaterial- (MTM) based isolation enhancement, and neutralization lines, as well as other methods that are being investigated [14, 15].

Printed antenna systems, based on microstrip, wideband, slot, and tapered antipodal antennas for UWB applications have been the focus of the group at KSU. They have worked on novel structures for printed UWB antennas [16-18]. KAUST has an active microwave and antennas group, working on novel antenna structures using inkjet printing for various wireless applications. The first tri-band U-slot monopole antenna printed on paper using metallic nanoparticle inkjet printing was demonstrated by the group in [19]. The antenna covered GPS, WLAN, and WiMA bands. Several other paper-based inkjet-printed antennas were presented by the group for UWB and sensory applications, such as those in [20-22].

4.3 Antenna Arrays

Antenna arrays are used for increased gain and focused-beam transmissions. Embedding antenna arrays within the structure of unmanned aerial vehicles (UAVs) is the focus of the KFUPM research group. They have demonstrated and evaluated the performance of embedded printed antenna arrays in linear and planar geometries, and tested their performance outdoors, as shown in [23, 24]. In addition to UAVs, the group also worked on some automotive applications for direction finding, where they came up with printed antenna structures with small sizes for vehicular direction-finding systems [25, 26]. Algorithms for sidelobe suppression and antenna-pattern shaping have also been investigated and proposed by the group at KFUPM [27, 28]. The group at KSU has focused on beamforming and digital beamforming algorithms for UWB applications in radars and remote sensing [29].

4.4 On-Chip Antennas

On-chip antennas have just recently become a reality, making the dream of having a complete radio system on a chip (SoC) – comprising the baseband, RF electronics, and the antenna – on a single die come true. The applications in the 24 GHz, 60 GHz, 77 GHz, 94 GHz, and 140 GHz bands have made on-chip antenna integration possible. The group at KAUST has contributed to the field of on-chip antennas. Their work has been presented in recent conferences and journal papers, such as those in [30-33]. Such integrated systems have very interesting uses in biomedical and RF energy-harvesting applications. The group continues to work in this area with the new paradigm of system-in-package (SiP), where the antenna is placed on the package rather integrated on the silicon die. This will reduce the losses and provides better radiation characteristics.

4.5 Scattering Problems

Scattering is a very important area in electromagnetic wave propagation. Some of the researchers at KFUPM have been looking at scattering problems. In particular, a semi-analytical solution for the scattering of an electromagnetic plane wave by multiple coated conducting strips was developed, which ended up with a system of linear equations in N unknowns. Numerical calculations using computer programs were also performed. A new technique for a plane electromagnetic wave scattered by an arbitrary-cross-section conducting cylinder was also introduced. This technique is based on simulating the arbitrary cylindrical cross section by N narrow strips, for which a semi-analytical solution was carried out [34, 35].

5. Future Directions

The research groups at the research-active Saudi universities will continue to contribute to the Antennas and

Propagation Society by getting involved in new research areas. These include RF energy harvesting, new hybrid methods in computational electromagnetics that are stable and fast, novel integrated systems and antennas on chips, and micro-devices. In addition, novel electrically small antennas for the fourth and fifth generations of mobile wireless devices will be worked on.

The creation of a new Antennas and Propagation Society Chapter in Saudi Arabia is being discussed. Hopefully, in the near future it will become a reality, where Distinguished Lecturers from the Society can visit and interact with the active faculty and students, and raise the awareness in this area at various institutions around the country.

6. Conclusions

The areas of antennas and propagation are gaining momentum in Saudi Arabian universities. Several groups in major research-oriented universities are actively involved in the most recent areas in this field. This article highlighted the most recent work and contributions of these universities and groups, and showed their areas of research interest.

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