Engaging the Public: Using Microwave Wireless "Chargers" to Charge the Interest of Future Engineers

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It is widely recognized that introducing school-age students to Science, Technology, Engineering and Mathematic (STEM) subjects can directly translate to an increased interest in taking up STEM careers. From computers to virtual and augmented reality, there are many technologies which can attract future engineers, yet, can microwave engineering research spark an interest in becoming the next generation of STEM students? As a researcher focusing on microwave power transfer and harvesting, the quest of engaging the public using microwave engineering is an ongoing challenge which closely follows the research. Here, I present my answer to the how, where, and why questions of using microwave engineering research to engage, and inspire, the next generation of diverse scientists and engineers.

Creating an Engaging (Microwave) Research Presentations

Step one in STEM outreach is an engaging presentation; the presenter must be enthusiastic for the presentation to engage its, potentially difficult, audience [1]. The 3MT® initiative at the IEEE Microwave Week has resulted in a unique collection of straight-to-point presentations covering the breath of microwave engineering [2, 3]. Aspiring microwave ambassadors can draw inspiration from the three-minute-long introductions to research topics. The presentation's storyline should integrate all the tools available at the presentation. This includes slides, digital or printed, physical props, and any hands-on activities.

Physical props have been invaluable in attracting the attention of "future engineers" in my activities. In a world full of immersive animations and graphics, it is very unlikely that even a well-crafted slide deck by an engineer will be eye-catching for school students. However, prototypes, portable equipment, components, and "breadboard-y" demos often generate sufficient curiosity. In my opinion, raising the audience's curiosity and interest, particularly with young students in STEM outreach presentations, is the main objective as opposed to educating them.

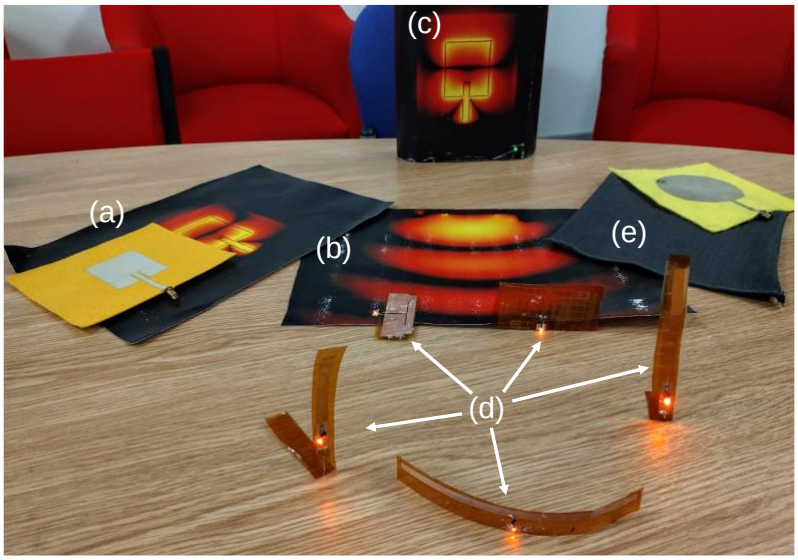

Fig. 1. The STEM outreach session toolkit: (a) printed antenna on textile, and a print of its surface *E*-fields; (b) the broadside E-fields of the patch; (c) a Powercast® transmitter; (d) a selection of state-of-the-art flexible rectennas [8]; (e) concealed rectenna in textile.

The two-way dialogue increases the positive impact of an outreach presentation. Where possible, structuring a session or a presentation to take an interactive format will grip the audience's attention. In an interactive "meet the Scientist" session with middle-school students, at the University of Southampton's Lifelab, a range of hands-on to presentation-style activities were incorporated in the 15 minutes session. This has led to the creation of my presentation toolkit, shown in Fig. 1, which is composed of:

- Flexible and printed antennas on textiles Fig. 1(a) and €.
- Electric field distributions: a printed *E*-field distribution plot, in Fig. 1(a) and (b), of the patch antenna on fabric.
- Flexible rectennas, based on different designs, loaded with LEDs.
- A far-field wireless power source (Powercast® 915 MHz 3 W transmitter).

Alternating between props, slides, and hands-on experiments gives the presentation a more natural feel. Starting by handing the wearable antenna samples, in Fig. 1 (a) and (e), over to the students and simply asking them to guess what their function raised the students' curiosity. It is crucial to note that, in some cases, STEM outreach presentations are an element of a structured school visit which the students did not voluntarily participate in. Therefore, the presenter has the job of exciting the audience early on during their presentation; finding a common ground that links the presentation's material to the students' interests is key.

Inviting students to volunteer to help running the demo engages both the volunteer and their peers. In the RF wireless power demo (using the kit in Fig. 1), the volunteer student explored how the positioning of a reflecting metal mesh around a rectenna influences the LED's intensity and working range. In an attempt to gamify the experience, one could ask the students to guess what caused the changes; in my presentation, the flexible reflector sheet was simply hidden in a paper folder.

The availability of very compact and extremely inexpensive hardware, such as the tinySA® Spectrum Analyzer [4], enables bringing a hands-on lab experience to the audience at very little cost or added complexity. Thus, observing how the human body interacts with wearable antennas can be easily visualized. Similarly, the influence of antenna's radiation patterns and directivity can also be explained by rotating a directional source and observing the effect in real-time. The same mechanism can be used to show a group of observers how the human body interacts with propagating electromagnetic waves.

Hands-on activities can also apply in more mobile exhibitions. For example, "Microwaves in Everyday Life" were present at the Glasgow Doors Open Weekend Festival, organized by the University of Glasgow's ARCadia festival, seen in Fig. 2. The audience of such outreach fairs is wider than that of organised school groups and can range from pre-school-age children to experienced senior scientists from other backgrounds. One also needs to consider the venue when planning the material to be delivered. In a fair-type exhibition stall, the reflectivity of the human body can be easily demonstrated to a small group simply by observing how the subtle movements of the presenters and the audience influence the received power levels.

The appeal of involving the audience however comes at a risk of derailing the presentation. This can only be manged by rehearsing the "show"; inviting a colleague or friend from who is not familiar with the work to test-drive the setup is a good approach to gain feedback and explore potential pitfalls. Overall, I recommend that the presenter budgets more time than expected when a two-way interaction is planned, but also keeps a number of back-up activities under their sleeve in case the audience goes through an activity rather quickly.

Connecting with the audience's interests, and potentially concerns, is key to an engaging and useful presentation. For instance, the safety of pervasive microwave technologies is a key frequency asked question. Most students are active users of microwave-enabled technologies such as smartphones; explicitly explaining the similarity between a microwave oven and Wi-Fi, both operating in the 2.4 GHz band, helps the audience appreciate the difference power levels and

the operation environment could make. Likening emerging microwave applications, such as wireless power and RF (radar and RFID)-based sensing to the power emissions of Wi-Fi gives a tangible feel of safe radiated power levels. One could acknowledge the ongoing work to evaluate the safety of new mmWave frequency bands [5]. In my opinion, the approach of acknowledging ongoing work on evaluating the safety of microwave technologies, with the aid of clear diagrams of parameters such as the specific absorption rate (SAR), both informs the audience and sparks curiosity.

Fig. 2. A photograph of the author explaining microwave wireless charging technologies at the Glasgow Doors Open Festival in an exhibition stand; the inset shows a recently developed flexible rectenna array [9] likened to a battery.

How to Get the Most Out?

In many cases, especially for researchers in academic institutions, dedicated public engagement and outreach teams, and STEM ambassadors/networks have relevant events and venues where engineers can interact with schools, families, and the public. Particularly for young professionals, leading STEM activities and communicating research to non-technical audiences can be a rewarding experience [6]. A young professionals-led STEM workshop benefits the organisers, assisting university (engineering) student volunteers, and the ultimately the audience [7]. The ability to convey technical information effectively to a non-specialist, but interested, audience is transferable to all engineering communication domains [1-3].

Feedback is invaluable and could translate to technical presentations, tradeshows, interviews, and public lectures. The questions received from (an excited group of) middle or high-school students were broadly akin to those received at exhibitions aimed at researchers and engineers from other disciplines. Collecting feedback from nearly 30 students following multiple interactive sessions was highly valuable in getting an insight in what worked well, and, crucially, where to improve the presentation. From commending the practical hands-on elements of the event, stating that the presentation “inspired [them] to help the planet”, to asking the presenter to “be a bit more confident with your words”, a number of post-it notes, shown in Fig. 3, collected from the students acted both as a reward and a guide to enhance future public engagement activities.

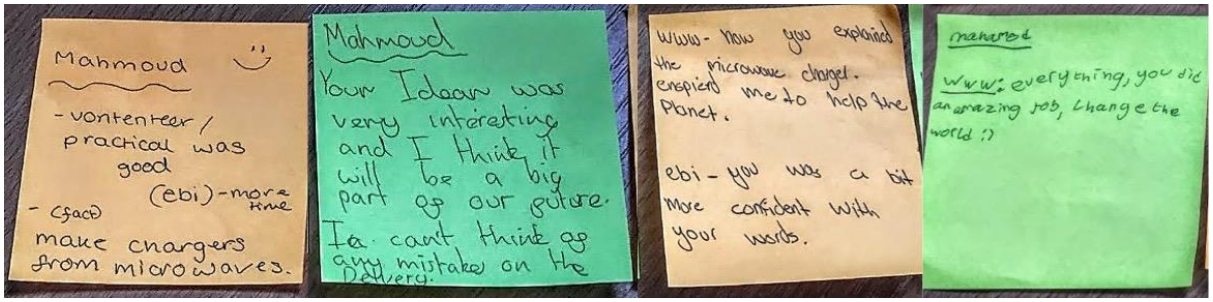

Fig. 3. Extracts from feedback notes from school students following a 15-minute interactive “Meet the Scientist” session on wireless power transfer using microwaves.

One must remember that STEM outreach and public engagement activities have a key benefit in making our profession more diverse and inclusive. From increasing the presence of women in (microwave) engineering to approaching students from under-represented minorities [10], taking part in STEM outreach events has more than one benefit. Engaging a broad range of students at a young age, showing them an area of engineering and its applications that is usually transparent, will help diversify the pool of future engineers. The additional and often missed benefit is that by preparing and taking part in public engagement events, one can develop presentation skills which are particularly useful when engaging audiences from diverse and often under-represented backgrounds, contrary to the conventional research presentations to “like-minded” audiences at conferences and technical events.

In summary, my experience has shown that the best way to approach STEM outreach activities is to closely link it to ongoing research activities. Rather than thinking about public engagement at the end of a project, taking research prototypes straight of the lab to the public, see Fig. 2 [9], makes the process more rewarding and seamless to implement. Asking ourselves which element of my research would interest the public could help us identify new research and engineering challenges. Finally, I would encourage microwave engineers to think more about which element of their everyday tasks would appeal to the public, and to start a conversation with a local STEM outreach-focused network on how to get started.

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