Use of In-Class Wireless Circuits Demonstration to Explain Antenna Concepts to Undergraduate Electrical Engineering Students

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Abstract

Electromagnetics concepts are traditionally considered among the most difficult to understand and least popular by undergraduate students in electrical engineering. Learning of such concepts often requires the understanding of phenomena that are not visible. Therefore, they highly rely on the student's ability to perform abstract reasoning. In this paper, a demonstration to explain concepts related to antenna electromagnetic radiation, and field polarization, is designed and implemented. An audio signal is transmitted from one side of the classroom to the other, using a simple experimental setup, providing a direct way to sense (hear) the changes in signal intensity to the students. The percentage of students that stated that they had a very clear understanding of antenna radiation and polarization concepts changed increased by 72.5% thanks to the activity. Furthermore, all the students either agreed or strongly agreed that the activity should be implemented in future semesters.

Keywords

Electromagnetics, in-class demonstration, radiation pattern, polarization, antenna.

I. Introduction

Traditionally, in electrical engineering programs, the courses related to electromagnetic theory are often considered among the most challenging and least popular by the students[1,2]. Many factors contribute to this situation, including the fact that the concepts in these courses are related to phenomena that are not visible (i.e., electric and magnetic fields), nor can they be sensed by the students, as in the case of temperature and wind. Therefore, the understanding of such concepts is conditioned to having a good abstract reasoning ability, as well as good vector math background.

The described situation can diminish the motivation of the students, as well as generate frustration for the students that cannot understand the content that is being discussed in the class. The traditional resources, such as textbooks, show 2D representations of 3D fields and focus mainly on written discussions. Hence, the use of non-traditional techniques, such as in-class live demonstrations, are instrumental in ensuring the success of the class in this particular field.

Among the different strategies to improve learning in the electromagnetic courses are the use of active learning and applications focus teaching[3] , a hands-on approach using experimental setups[2,4], CAD simulation tools[5], experiments using student-owned laboratories[6], and course content re-structuring[3,7]. In general, these strategies lead to favorable results. However, the challenge for the instructor is to select the most efficient combination, which provides the best results with a correct balance of time commitment and effort from the student.

In this work, an in-class demonstration of basic antenna concepts is developed and implemented. The objectives of this demonstration are to: (a) show the phenomena of wireless communication using two antennas, (b) demonstrate the behavior of the radiation pattern of the antennas by changing the orientations, (c) test the polarization concept by rotating the antennas, and (d) introduce the polarizer concept, and show its effect on the transferred power. The demonstration was implemented in an electromagnetics class of 40 students towards the end of the semester. Initial discussion of basic antenna parameters already was previously held in a classic lecture method.

The demonstration was given to 40 students taking the course *EEL 4471 Electromagnetics* at the Department of Electrical Engineering, University of South Florida. A survey was performed to measure the level of success of the demonstration. The percentage of students that stated that they had a very good understanding of the antenna radiation and polarization concepts changed from 20% before the demonstration, to 92.5% after the demonstration. Furthermore, 77.5% of the students strongly agreed that the activity should be implemented in future semesters. The course pre-requisites are: PHY 2049 (General Physics), MAP 2302 (Differential Equations), and ENG 3420 (Engineering Analysis).

II. Demonstration objectives and concepts

The demonstration described in this paper is intended to be implemented towards the end of the semester of undergraduate electromagnetics courses after the basic concepts related to electromagnetic radiation and antennas have been covered. The general approach is to show those principles in action, by using a simple setup that is brought to the classroom. Special attention is given to keep the explanations as simple and clear as possible, and showing the principle in action.

Main objectives of the demonstration:

- To show the phenomena of wireless communication.
- To introduce the concept of signal modulation.
- To explain the concept of antenna radiation pattern, and to show how the relative angle of the antennas affects the signal transmission.
- To present the concept of antenna polarization.
- To introduce the concept of wire grid polarizer.

III. Demonstration description

Fig. 1 shows the in-class setup, where a signal generator is connected to a transmitter antenna, and the signal is then received by a second antenna that is connected to a spectrum analyzer that is located on the opposite side of the classroom. An audio signal (music) is sent using the signal generator using frequency modulation (FM). This signal is received, demodulated, and played through a built-in speaker in the spectrum analyzer. The use of music is intended to attract the attention of the students. The audio device was voluntarily provided by one of the students (a cell

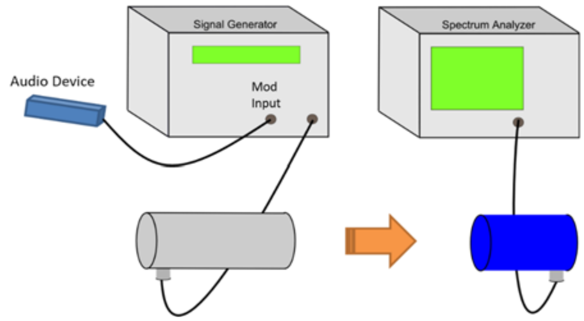


Fig. 1. Demonstration setup. An audio signal is sent from one side of the room to the other.

phone), which further increased the attention of the group. Note that discussion throughout the activity was encouraged, and students could ask questions at each point, and come and test their question with the antennas if desired.

III.a. Equipment:

The equipment required for the demonstration is listed in this subsection. This equipment was readily available to the instructors. Note that the hardware can be greatly simplified using a low-cost FM modulator to transmit the signal and an FM receiver with an audio amplifier on the other end. The RF frequency can be adjusted accordingly.

Equipment list:

- Signal Generator. HP 8648C. - Spectrum Analyzer. HP 8595E.
- Two tube antennas. Astron P209 and P2412. - Two coaxial cables with SMA connectors.
- 3.5 mm audio to BNC adapter connector. - Audio device with 3.5 mm output. -Wire grid polarizer.

III.b. Preparation:

To prepare for the demonstration, the instructor needs to perform the following steps before the class time:

i) Connect the antennas to the devices as shown in Fig. 1. Connect the P209 antenna (8'' length) to the spectrum analyzer and the P2412 antenna (16'' length) to the signal generator using the coaxial cables.

ii) Turn on the Spectrum Analyzer (HP 8595E) and the Signal Generator (HP 8648C). Connect the audio device to the generator's modulation input, by using the adapter (Fig. 1).

iii) Set up the signal generator: In the function keys, press **Frequency**. Set the frequency to 2.5 GHz. Press the **FM** key. Set the peak frequency deviation to 100 KHz. Press the **Amplitude** key, and set the power to -55 dBm. In the modulation source buttons, press **Mod ON/OFF**. Now press the **Ext DC** key. You should see in the window a warning that shows **LO** or **HI**. This represents the modulation signal intensity. Press the **RF ON** key. At this point, the antenna is transmitting the signal.

iv) Set up the Spectrum Analyzer: a) Press the **Frequency** key. In the window select **Center Frequency**. Set the center frequency to 2.5 GHz. Press the **Span** key. Set the spam to 500 KHz. At this point, you should see the noise floor at approximately -75 dBm. The power level will depend on the antenna separation and signal multipath. A separation of around 3 m is recommended. In the instrument state panel, press the **Aux Ctrl** key. In the window select **Demod**. Turn on the demodulation **Demod On**. In the window, select **Demod FM**. Set Speaker to **ON** selecting the **Speaker** option. Set the **FM Gain** to 100 kHz (FM maximum deviation). Set the **Dwell** time to 10 s.

III.c. Demonstration parts:

Wireless communication phenomena:

In this part, it will be shown how the audio signal can be transmitted using the antennas and listened on the other side of the room. Some of the questions that can be addressed in this part of the demonstration are: What is electromagnetic radiation? How is the signal going from one antenna to the other? Why do we need to transmit at RF Frequencies? Why don't we just transmit the audio signal directly? What is frequency modulation?

The specific steps to follow are:

i) Point the antennas one to each other, with a separation of 1m approximately. Turn on the audio device. You should now start hearing the music. Turn the volume knob to the desired level. If the volume is too low set the FM Gain to 50 KHz. If the signal quality is bad (has too much noise) increase the power level of the signal generator.

ii) At this point, you should be hearing the music that is being reproduced in the audio device, on the speaker of the spectrum analyzer.

Radiation pattern effects:

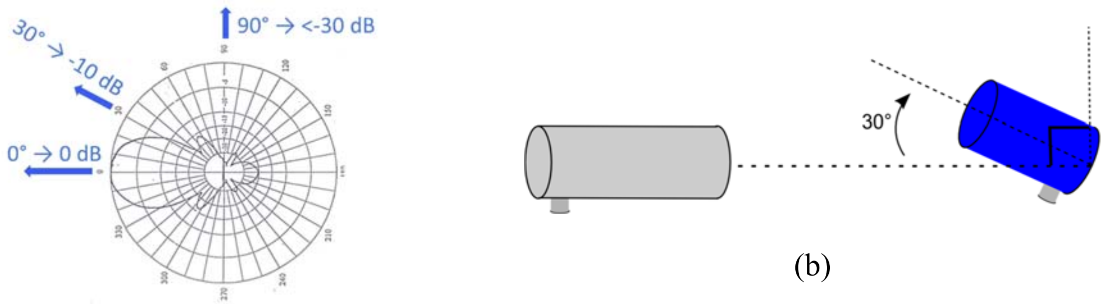
The power level of the signal generator needs to be properly adjusted, so the changes in the gain of the antenna due to its rotation can be directly perceived by the quality of the audio signal. These questions can be given to the students, and collectively answered: How does the antenna distribute the energy in the space? What is antenna directivity? What is a highly directive antenna? What is an isotropic antenna? For a directive antenna, what happens if we deviate from the angle of maximum directivity?

The steps to follow in this part are the following:

i) Set the antennas pointing one to each other. You should hear the audio signal strongly. Fig. 2(a) shows the radiation pattern of the tube antennas, and the different normalized gain values for the 0°, 30°, and 90° angular orientation of the receiver's antenna.

ii) Rotate one of the antennas approximately 30°, as shown in Fig. 2(b). You should still be listening to the audio signal, but with less quality (less received power).

iii) Rotate one of the antennas approximately 90°. You should now not hear any signal.



(a) (b)

Fig. 2. (a) E-Plane radiation pattern of the tube antenna (P2412)[8]. (b) Angle of rotation of the receiver's antenna.

<u>Wave polarization</u>

This part of the demo is dedicated to explaining the concept of antenna polarization. The main questions to address are:

- What is antenna polarization?
- What is the polarization of the tube antennas?
- What is the optimal antenna orientation for maximum power transfer?
- What happens if we rotate the receiver's antenna by 90°, as shown in Fig. 3?
- What is a wire grid polarizer?
- What happens if we change the orientation of the polarizer?

The steps for the polarization part are:

i) Point the antennas one to each other, with the same orientation. This is the point of maximum power in the receiver.

ii) Start rotating the receiving antenna as shown in Fig. 3, until they are in perpendicular orientation. You should not hear any signal at the receiver at this point.

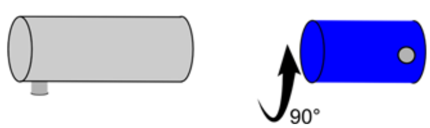


Fig. 3. Rotation orientation for polarization demonstration.

iii) Repeat step i). Now put the polarizer in front of the receiving antenna with the grid in horizontal position, as shown in Fig. 4(a). You should have a slight change in the received power, but the signal should still being reproduced.

(a) (b)

Fig. 4. Positioning of the wire grid polarized on the receivers antenna.

iv) Now change the orientation of the grid, so the wires are now in vertical position (Fig. 4(b)). The signal should disappear on the spectrum analyzer. You can take out and in the polarizer several times to notice the change in the received signal power.

IV. Results

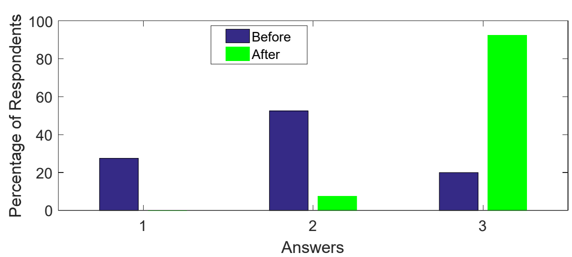
A survey was performed before and after the demonstration was performed, with the purpose of capturing its effectiveness. The questions asked is: *what is your level of understanding of antennas radiation and polarization?* The possible answers are listed in Table I.

Table I. Possible answers to the student survey.

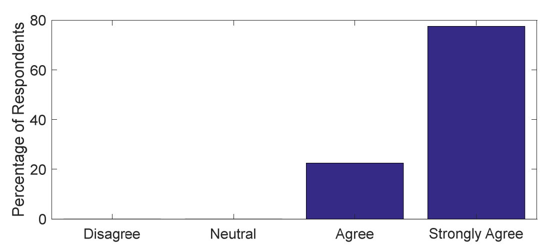
Question Number	Answer
1	I don't feel like I have a very good understanding at this point.
2	It sort of makes sense.
3	Very clear.

The results from the described survey are shown in Fig. 5(a) Note that the majority of the students (80%), did not have a clear understanding of the radiation and polarization concept before the demonstration. This changed drastically to where 37 students (92.5%) believed that they had a clear understanding after the activity was finished.

The students were asked after the activity, on whether they agree or not with performing the demonstration in future semesters (Fig. 5(b)). All the students either agreed or strongly agreed with maintaining the demo in future semesters.



(a)



(b)

Fig. 5. (a) Registered answer to the survey asking: *what is your level of understanding of antennas radiation and polarization?* Before and after the demonstration. (b) Percentage of responses to the question: This demonstration should be performed in future semesters.

V. Conclusions

It is shown in this work that in-class demonstration can be a valuable tool to improve the understanding of complex concepts. In particular, it results very effective when the students can sense (hear in this case) the effect of the experimentation by themselves. Also, the approach where student participation and discussion was encouraged resulted in higher levels of attention and increased the curiosity; which was evidenced by the multiple questions asked by them. It is also seen that students appreciate the use of such demonstrations.

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