TRANSMISSION CHARACTERISTICS OF FREQUENCY SELECTIVE SURFACE

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INTRODUCTION

The radio spectrum is a finite natural resource and the expanding world knowledge is making use of it by widening the extent of applications. Radio waves (EM waves) transmit different types of data over millions of miles, and in thousands of different ways!

The transformation of this incredibly simple technology to a bedrock technology of the modern world is fascinating! Whether we are talking about a cell phone, a baby monitor, a GPS receiver or any one of these wireless technologies, all of them use radio waves to communicate. In this study, we explore the wireless technology in a totally new perspective to understand how radio waves make so many things possible!

PURPOSE

One of the major issues arising from the increasing use of wireless communication systems is the interference between coexisting channels. Therefore, both reducing interference and developing techniques that allow systems to operate in the presence of interference are essential.

- Reduce interference in wireless indoor environments.
- Maintain data confidentiality and system security.
- Apply antenna designing techniques to enhance the desired signals and to reject interference.

INTERFERENCE

- The next-generation of Wi-Fi has both benefits and drawbacks in terms of interference.
- The data-crowding problems leads to more and more interference, which can slow down connections or shut them down completely.
- Possible sources of interference can be common electronic devices found in homes, which can interfere with a Wi-Fi network operating in the 2.4 GHz ISM band. Examples are:

- Poorly shielded microwave ovens
- Cordless phones

- Bluetooth devices

-Baby monitors

- Wireless keyboards

- Wireless security cameras

INTRODUCTION

- The proliferation of wireless devices in the unlicensed ISM bands cause mutual interference and the degradation of system performance.
- Surrounding an indoor environment with metallic screens prevents the penetration of radio waves and eliminates unwanted external EM waves. This approach would block all desired radio, TV signals, and cellular phone transmissions.
- A promising remedy to such problems is to transform building walls into Frequency Selective Surfaces (FSSs), which deliberately filters out unwanted interference, but still allow desired signals to pass through by applying FSS to walls, ceiling and floor of an indoor environment.

DIAGRAM OF AN IDEAL FSS WALL

TV broadcast signal
Passing through the wall

FSS walls confine Internet signals
and
block undesired internet signals

TV
Transmitter

An ideal FSS wall

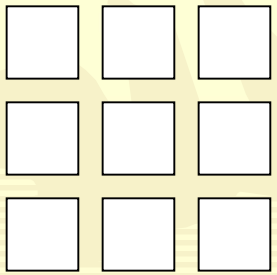
Potential
Security Threat

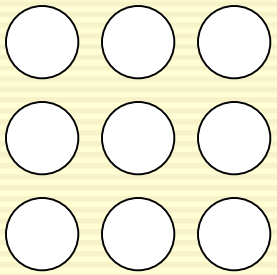
Electromagnetically
designed building

Piggyback
Users

Frequency Selective Surface Fabrication

- Polyethylene Terephthalate (PET), a plastic polymer was used as a substrate to fabricate frequency selective surface.
- A software package designed for planar electromagnetic simulations for conducting scatterer was used to stimulate the FSS.
- The following two patterns (circular and rectangular) FSS were simulated and tested in pervious projects.





Technique Adoptability

Action Plan:

- Initially, the test process was conducted on a small antenna template of frequency 2.4 GHz, using an electroless silver deposition process.
- The objective was to ensure the fabrication feasibility on a Frequency Selective Surface in order to characterize the FSS operating in the 2.4 GHz band frequency.
- After obtaining satisfactory results, it was decided to use a special type of double nozzle silver spray gun to perform the electroless process on larger surface area.

DEFINITIONS

- **Electroless Plating**: A chemical auto-catalytic is a non-galvanic type of time critical, plating method. It involves several simultaneous reactions, without the use of external electric power.
- **Radiofrequency Waves**: Electromagnetic Waves in the range of 3 kilohertz to about 300 GHz, a frequency or wavelength suitable for utilization in radio communication.
- **Log Periodic Antenna:** It is a broadband, directional, narrow-beam antenna that has constant impedance and radiation characteristics; its radiation elements are regularly repetitive as a logarithmic function of the excitation frequency.

Techniques To Develop Thin-film Silver Patches Using "Electroless Deposition"

My Contribution to the Project:

Electroless Chemical Kit

Solutions A, B, and C from right to left.

STEP 1 5mL sensitizer + 150 mL Deionized water

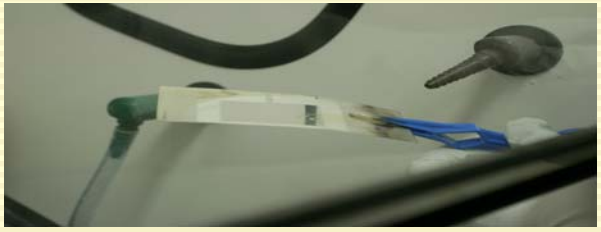
Submerge patch for 1 minute

STEP 2 2.5 mL solution A + 40 mL deionized water + + 2.5 mL solution B + 75 mL Deionized water → Beaker #1

STEP 3 2.5 mL solution C + 75 mL deionized water → Beaker #2

Electroless Deposition Process Continued

STEP 4 Dry the patch using nitrogen

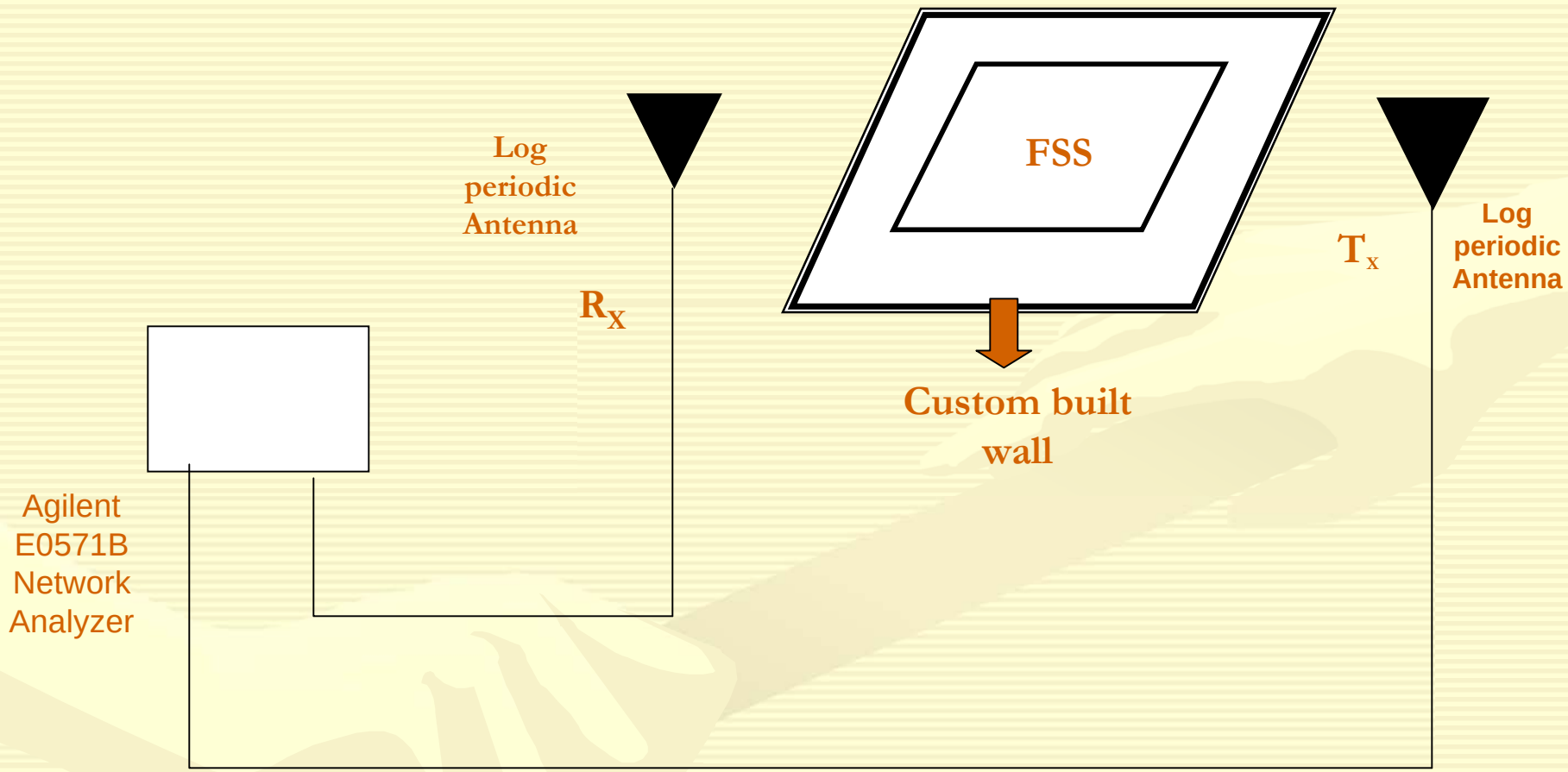


STEP 5 Mix the contents of Beakers #1 and #2 in Dish # 2.
Submerge the patch for 1 minute 30 seconds for Electroless Metal Deposition

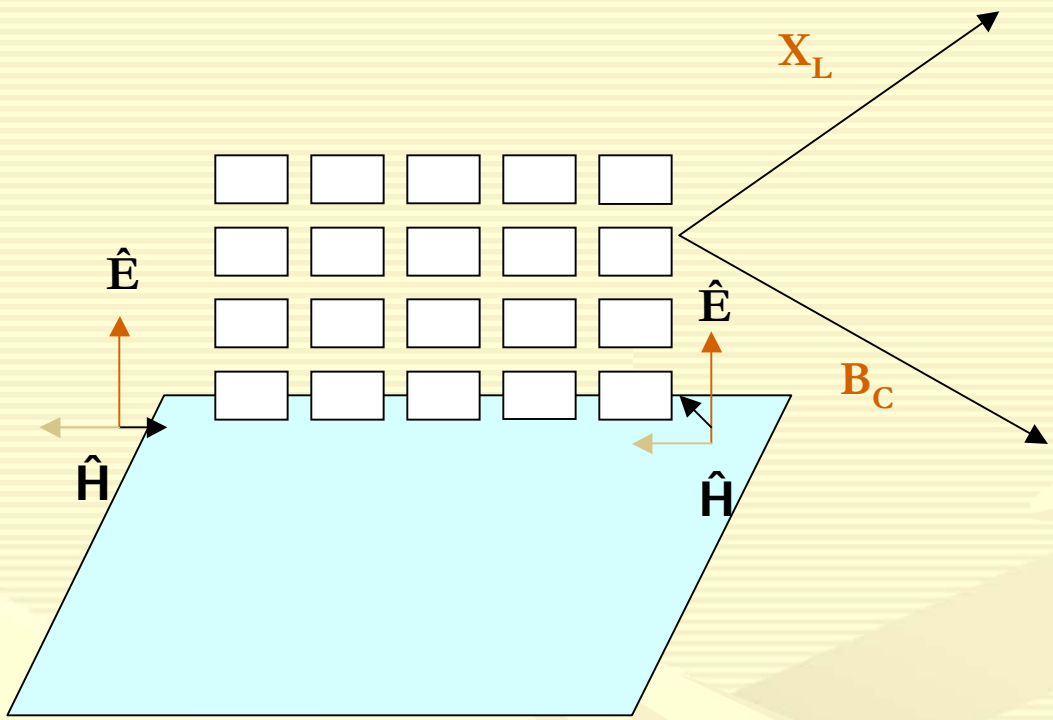
STEP 6 Clean the patch in ultrasound bath

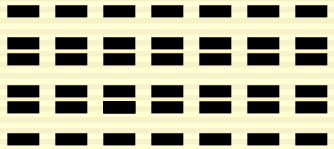
STEP 7 Electroless deposited silver patch

Non-metallic FSS Prototype Test Setup Model

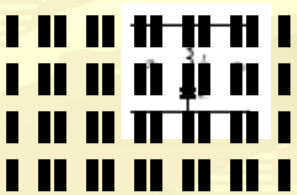


Equivalent Circuit Modeling





Inductive Part



Capacitive Part

Equivalent circuit model for the square loop FSS

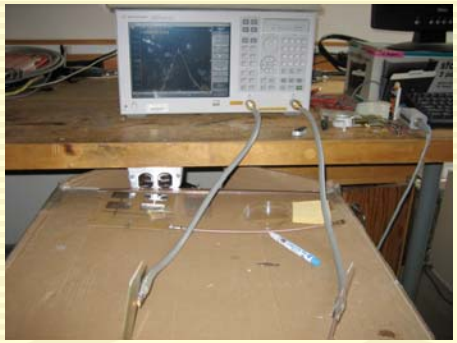
FSS behave like a filter where the frequency response is dependent on the surface material and the conductive pattern.

Modifications in the Experimental Set-up

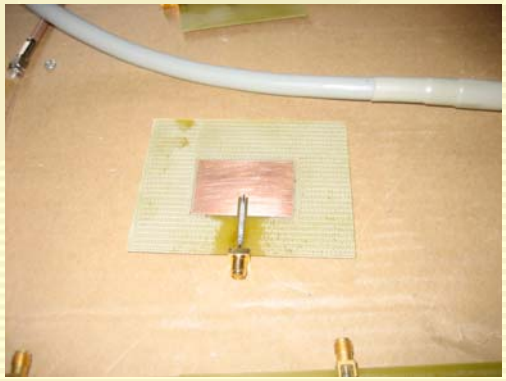
- The big picture of fabricating FSS had to revised due to delivery delay of the silver-spray-gun.
- The experiment was limited to testing the fabrication procedure on a 2.4 GHz patch antenna. Thus, creating a path for the future fabrication and testing of FSS in GHz range.
- The obtained satisfactory results confirm the feasibility and functionality of FSS developed based on electroless deposition process on PET substrate operating in the required frequency.

MEASUREMENT PROCEDURE AND ANALYSIS

- Two copper patch antennas on PCB were used to characterize the performance of an electroless deposited antenna. The antennas were connected to the input and output of the Agilent network analyzer. The output serves as the transmitter, and the input serves as the receiver.



- A previously measured copper antenna was used as a reference to measure the radiation performance.



Reference Cu antenna

Measurement Procedure And Analysis Contd.

- The fabricated silver patch antenna was tested using a network analyzer to determine its radiation properties.


silver patch antenna

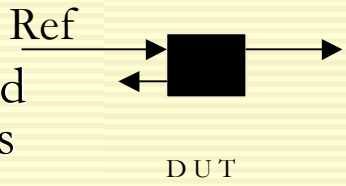

Testing with silver patch antenna

- The experimentation was repeated for a previously fabricated copper antenna to determine the radiating ability, and power loss using the same set-up.

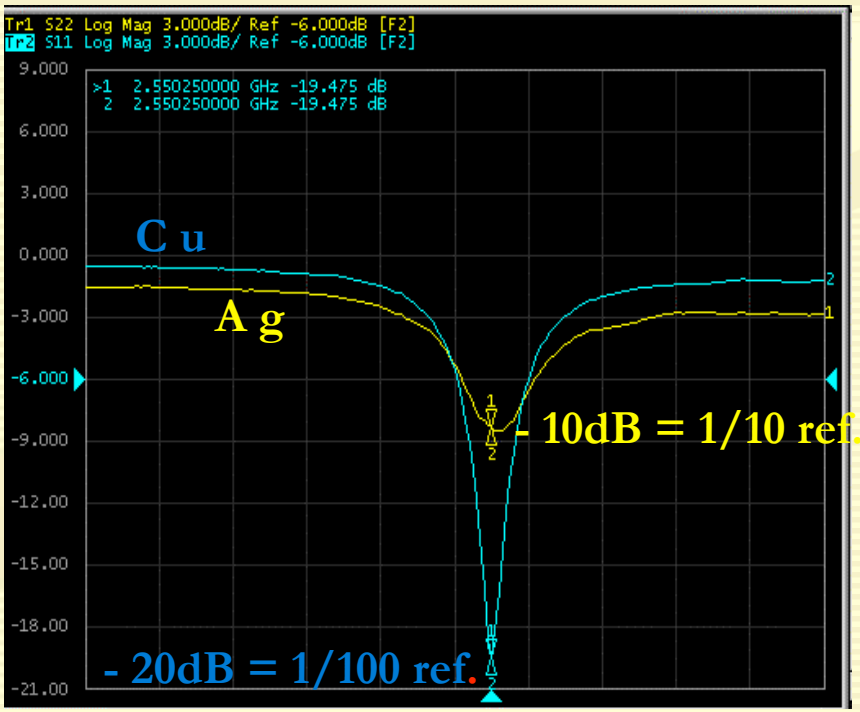

copper antenna

Measurement Procedure And Analysis Contd.

- S_{11} graphical representation indicates the comparison reflection ability of cu (sample) and Ag with reference to Cu_{ref}
- Silver antenna transmitted ≈90% signals, (power loss is 1/10 th of reference value).
- Copper antenna transmitted ≈99% signals, (power loss 1/100 th of reference value).



S_{11} **Cu + Ag**



1.5 **2.5** **3.0**

GHz

Measurement Procedure And Analysis Contd.

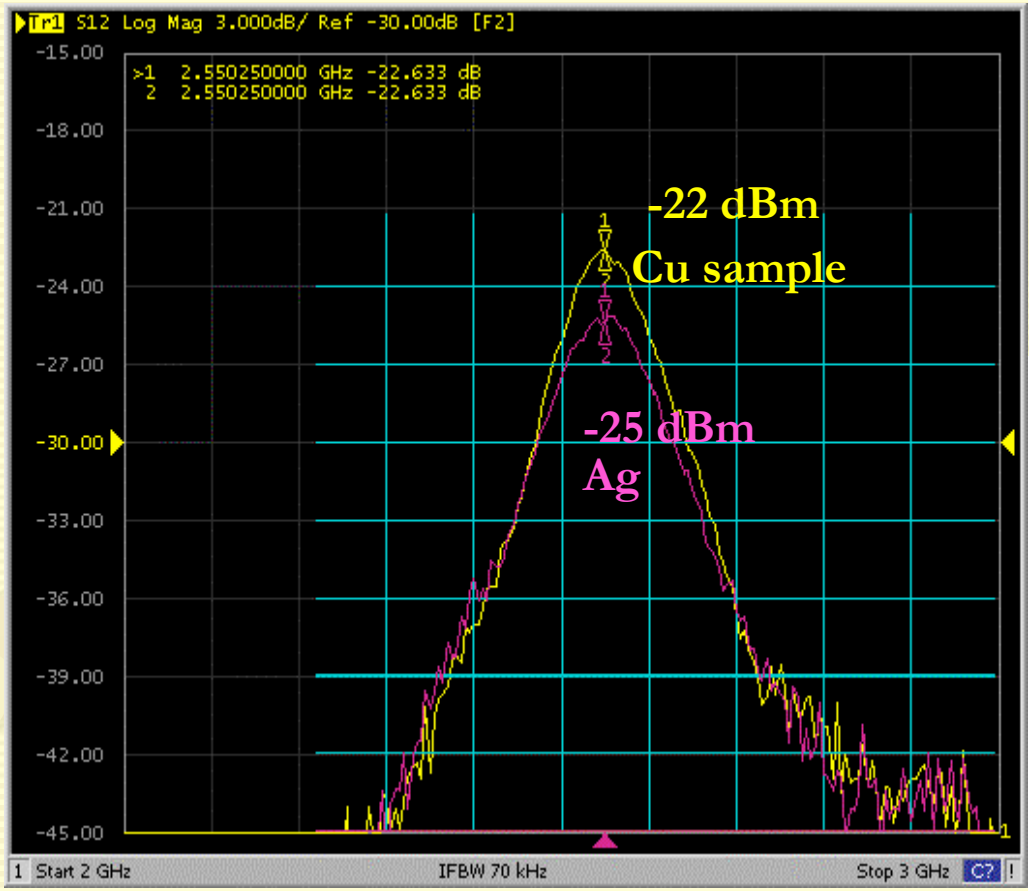
S_{21} - graphical representation indicates power received of Cu (sample) and Ag (silver) respectively.

Received power of Ag = -25dBm

Received power of Cu_{sample} = -22 dBm

Transmitting antenna and power level never changed.

S21



CONCLUSIONS

- Copper as the surface material proved to be very efficient, it radiated approximately 99% of transmitted signals.

  It also indicated minimum return loss 0f - 20 dB.
- On the other hand, the silver patch antenna was almost as good as a copper antenna as it radiated approximately 90% of the input signals. Which indicates a return loss of -10 dB.
- It confirms the feasibility application for a frequency selective surface operating in the same frequency value of 2.4 GHz.
- Hence, further development in FSS can be done using electroless silver deposition in multi GHz range.

FUTURE RESEARCH

- To develop new fabrication procedures and materials for high frequency FSS.
- To investigate the difference in performance between healthy and semi-corroded FSS.
- To fabricate wall papers, virtually transparent FSSs windows, doors, blinds, and curtains to reduce signals diffracting around windows and doors.

ACKNOWLEDGEMENTS

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Radio Frequency Waves In A Classroom

- This lesson is designed to expose the students to the world of wireless communication; its application in the day-to-day gadgets to make our life comfortable and more efficient; and further to explore the potential applications.
- This lesson is spread over a period of two weeks, can be modified depending upon the requirement.
- The adopted methodology is a combination of lectures (including guest lecture program), discussions, team work, theoretical exploration, visit to GA Tech EECE lab, followed by a web-based project.

National & Georgia Performance Standards

- Inquiry, Process and Problem Solving; uses science process skills in laboratory including observation, classification, communication, and prediction, inference, collecting and analyzing the data.
- SCSh2 Students will use standard safety practices for all classroom laboratory and field investigations.
- SCSh3 Students will identify and investigate problems scientifically
- SCSh4 Students will use tools and instruments for observing, measuring, and manipulating scientific equipment.
- SCSh5 Students will demonstrate the computation and estimation skills necessary for analyzing data and developing reasonable scientific explanations.
- SCSh8 Students will understand important features of the process of scientific inquiry. materials.

LESSON SCHEDULE

Lesson is divided into subunits and students are expected to work in pairs.

Approach/Methodology

- **Day 1:** To introduce the concept of wireless communication initiate the discussion by brain storming questions to elicit answers related to the concept of wireless communication and its day-to-day applications.

  (The expected answers are: wireless, or Wi-Fi technology, connecting computer to the network without cables, cordless phone, TV and radio broadcasting and receiving technology, remote control, remote controlled toys and robots, the garage door opener, door locks, sensors, key-less entry technology, cell phone, radar, satellite communication, RF tags, barcodes, etc.)

- **Day 2:** The lesson is expanded by giving the class an assignment to write the background and the principle behind the working of any one of the wireless communication gadgets/equipments of their choice.

  (Students are allowed to retrieve the necessary information from internet)

Contd.

- **Day 3:** The class is exposed to the concept of 'Frequency Selective Surface' (FSS) by an activity: To read the signal strength of a cell phone in different indoor environments to verify whether it has same number of bar lines in an elevator, in the computer lab, gym, and different parts of the school building. Compare and discuss for 'why' and 'how?' It is followed by a power point presentation on FSS, explaining the principle, methodology and the results relating the significance of the findings to the real world applications.
- **Day 4:** A guest-speaker from Georgia Tech, Propagation Group will be addressing the class on multi-path channels and on frequency bar codes.
- **Day 5:** Visit to Georgia Tech- Electrical and Computer Engineering -The Propagation Group Lab.

Contd.

- **Day 6 & 7**: Students to work on the power point presentation. (The presentation to include: understood details about wireless communication, the working principle of a gadget that they have chosen to research, what they think about FSS, disadvantages or of wireless technology, and potential applications.)
- **Day 8**: Students are asked to present a power point presentation to demonstrate their knowledge of understanding on wireless communication and technology.

ASSESSMENT

- This Unit addresses the needs of multiple learning styles as it incorporates many different approaches to teaching and learning the same concept.
- A combination of project rubrics, informal assessment (question and answer), and formal assessment (objective quizzes) is suggested.
- Student's work is assessed based on their presentation proficiency on a 5 – 1 scale.