Laboratory Assignment:
Small-Scale Fading and Diversity

Georgia Tech Emag

Names: ______________________ ______________________

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Objective

This laboratory assignment will use the network analyzer as a channel sounder, measuring small-scale fading between two antennas in the microwave bands. Student teams will then analyze this data and design an antenna diversity system for meeting a communications specification in this type of radio channel.

Preparation

Before coming to the laboratory to perform this assignment, the students should prepare the following:

- Complete laboratory assignment 2 so that all group members are familiar with the operation of the network analyzer.
- Read notes on small-scale fading PDFs.

Write-Up

The students performing this laboratory must submit their documented procedures and analysis in a *concise* laboratory write-up. All group member names must appear on the front page. The write-up will be graded on

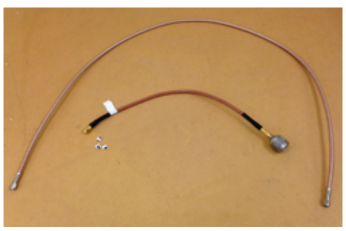
- Completeness and Technical Correctness
- Technical Writing and Readability
- Conciseness

Equipment Guide

network analyzer

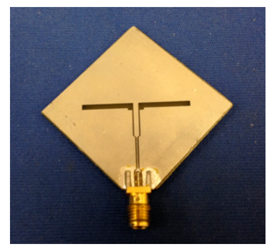
RF signal generator

calibration kit



assorted coaxial cables

connectors/adapters



5.8 GHz slot antenna

Procedure

In this procedure, the student team turns the network analyzer into a channel sounder that can record small-scale fading profiles. The team is charged to take some representative indoor fading measurements (line-of-sight and non-line-of-sight), analyze the data, and make predictive designs for diversity antennas.

1. Turn on the network analyzer and allow several minutes for the equipment to initialize and warm-up. Press the [**Sweep Setup**] console button and change the [**Power**] so that the network analyzer is exciting at its maximum 10 dBm of power. This will provide the "channel sounder" with some additional range within the room.
2. Take the two 5.8 GHz slot antennas and measure their return losses to find the *exact* center frequency. This will be the operating frequency for the rest of the measurements.
3. Attach a long 10-ft SMA cable to each port of the network analyzer and perform a calibration so that the network analyzer's measurements are referenced to the ends of the two lines.
4. Place the network analyzer in zero span mode at the center frequency that you measured in step 2. Press the [**Sweep**] console button and slow down the sweep speed to 5 seconds. This will allow for a slow measurement that collects many

instantaneous received power samples at the center frequency. Press the [**Scale**] button and adjust the reference level of the analyzer so that 0 dB is near the top of the screen. Set the scope to take an s_{21} measurement.

5. Plug in your group's memory stick into one of the USB ports in the front of the analyzer. Before attaching the microwave antennas, take a 5s collection with just disconnected, open-ended cables attached to the network analyzer. This measurement is almost entirely noise, but will help define the lower-end sensitivity of the measurement system. During post-processing, convert the s_{21} profile to linear scale, take the linear average of all recorded values, and convert this back to the logarithmic dB value. This final value is the *noise floor* of the system – any subsequent instantaneous measurement that approaches this noise floor value within 3 dB should be discarded.
6. To make a small scale fading channel measurement, fix the transmit antenna (connected via the able to port 1) in a location by holding the end of the cable several inches below the antenna (or duct-taping it to a piece of lab furniture). Have one teammate hold the receiver antenna (connected via the cable to port 2) at a pre-determined distance from the transmitter. After triggering a single sweep from the [**Trigger**] menu, gently wave the receiver antenna around a local area – an imaginary, horizontal disk of radius 10 wavelengths – all the while keeping the same orientation/polarization of the antenna. Save the data to the USB thumb drive. Repeat this once more for the location (for additional data) and save the results.
7. Measure two line-of-sight channels with the procedure outlined in step 6. Make a sketch of the laboratory room and mark where each transmitter-receiver antenna pair is (roughly) when a location is measured. Try a measurement over a short distance (approximately 1-2m of TR separation distance) and a longer distance (approximately 3m of TR separation distance or more).
8. Measure two non-line-of-sight channels. Be careful with this measurement. If it looks like the insertion loss consistently hovers near the noise floor calculated in step 5, you should choose another transmitter or receiver location with slightly higher average received power.
9. Clean up your lab station, carefully putting everything back in its place. The data may be analyzed offline.

Analysis

1. For each transmitter and receiver location, collect all the data, convert all points to linear, and graph a histogram of the linear received signal strength. Calculate the linear mean and variance of the power in each of the 4 measured locations.
2. From the mean and variance, estimate the Rician K-factor of each propagation environment. You will need to either derive or research this result (I will not give it to you). Cite any sources used in this portion of the analysis. Note: if you calculate any negative linear values of K, simply round up to 0. Question to

answer in report: what factors may make this possible to observe and calculate in the measurements?

3. Pick your best channel's K-factor (highest K) and your worst channel's K-factor (lowest K). Plot the outage probability (the probability that the communications link will not have enough power to operate) for a single antenna whose average fade margin varies between -10 dB and +15 dB. Plot the worst and best channel curves on the same curve, making the outage probability axis logarithmic.
4. Repeat the analysis in 3 for the worst channel, using 1, 2, 3, and 4 switched-diversity antennas (switch and examine).
5. Repeat the analysis in 3 for the worst channel, using 1, 2, 3, and 4 diversity antennas in a maximum ratio combining receiver.
6. A 5.8 GHz commercial wireless device is expected to operate with a +5 dB single antenna fade margin with at least 95% reliability indoors. The cost for manufacturing the device increases $2.00 for each RF chain and $0.60 for each antenna added to the radio receiver. Under the worst case fading scenario, what cost-minimizing design recommendation would you make to the manufacturer for the device's antenna system.