Laboratory #7

Interference in Cellular Radio Systems

By: Timothy X Brown, Olivera Notaros, Nishant Jadhav
TLEN 5320 Wireless Systems Lab
University Of Colorado, Boulder

Purpose

This experiment allows the students to study co-channel and adjacent channel interference.

Note: This lab uses three different sets of walkie-talkies. Two sets are of better quality, equipped with noise suppression and an improved range, and one is a low-quality walkie-talkie system. Every walkie-talkie system works as a set of two devices, one transmitting and the other receiving at any time (half-duplex link). Each system has a limited range, and works at the same frequency as the other. The use of low-quality systems will enable us to work faster, as these systems don't have sophisticated noise-reduction and interference-reduction schemes. By working with two systems we can simulate the operation of two cell site transmitters working at the same frequency, but at different locations.

Equipment

- Spectrum Analyzer Agilent ESA–L1500A: 9 kHz-1.5 GHz
- Signal Generator Agilent E4400B: 250 kHz – 1 GHz
- Antennas made in the second experiment
- Walkie-talkie systems provided
- Audio source (radio)

Introduction

The range of every wireless system strongly depends on the path loss, noise, and interference. Outdoor communication over a clear, flat terrain provides a much longer range in every system. Indoor communications are more critical and depend on the walls and other obstructions. Some values for indoor attenuation have been measured in the experiment: "Indoor Radio propagation".

Two independent systems, simultaneously working on the same frequency can operate efficiently if they are separated by a distance that allows sufficient attenuation of their signal strengths. If the distance between these systems gets smaller than the critical limit, the quality of the received signal in both the systems significantly decreases and end-users experience poor signal quality.

In order to describe the quality of a received signal several different ratios are introduced:

- S/N - signal-to-noise,
- S/I - signal-to-interference,
- C/I - carrier-to-interference, and
- SINAD - signal-to noise and distortion.

The selection of a ratio for a given system depends on the system design and the desired results.

Furthermore, the interference in radio systems is divided in into *co-channel interference* and *non-co-channel interference*. Non-co-channel interference includes *adjacent channel interference and intermodulation interference* produced by nonlinear elements (e.g. amplifiers).

This lab explores co-channel interference and adjacent channel interference (as one of the more important of non-co-channel interferences).

PRE-STUDY

Exercise 1

Survey the range of frequencies used by commercial walkie-talkies

LAB PROCEDURES

Determining the characteristics and range of the system

Using one walkie-talkie transmitter and the spectrum analyzer determine the walkie-talkie's carrier frequency, bandwidth, and modulation type.

Using one transmitter–receiver set, determine the system range, with and without attenuation (indoor and outdoor communication, respectively). With one walkie-talkie working as a transmitter and the other as a receiver, two students should start as close as possible and go as far as it takes for the link to break off. Measure the distance between them.

Use the spectrum analyzer to measure the signal level close to the transmitter and at the maximum range in order to determine the permitted signal attenuation for a given system.

Place both walkie-talkies and the antenna connected to the spectrum analyzer as close as possible. Start transmitting signals from one device. Measure signal levels received over the spectrum analyzer. Move the transmitting device away. When the link breaks off, measure the received signal level. The difference between two signal levels is permitted signal attenuation. Receiving antenna should be as close to the spectrum analyzer's antenna as possible. You have to observe the quality of a received signal level all the time, so be sure not to obstruct the signal path with your head. In order to be able to determine the signal quality and break off point more clearly, try the experiment by transmitting voice, music, and only carrier signal (just pushing the transmit button).

Measuring the carrier-to-interference ratio

The carrier-to-interference ratio is very important in cellular systems in order to determine the maximum allowed interference level for which the system will still work.

Measurements have to be done with equipment concentrated at three points (A, B, and C). The equipment should be arranged as shown in Figure 1:

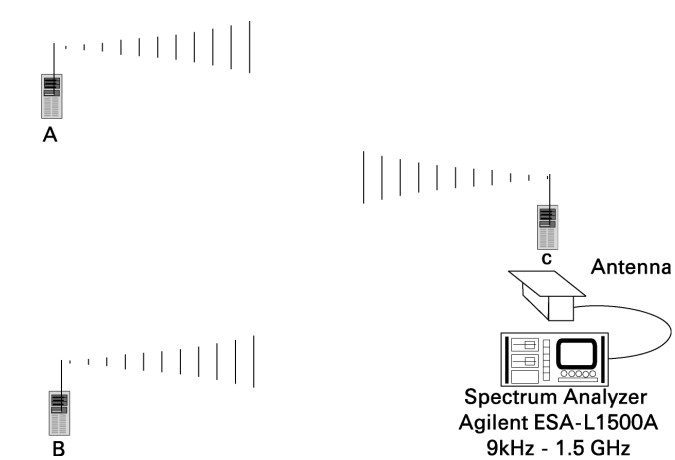

Figure 1.

A. The walkie-talkie working as a transmitter and an audio source (e.g. radio or person talking)

B. A second walkie-talkie as an interference source and

C. The spectrum analyzer with the antenna attached and a walkie-talkie as a receiver.

Setup A and C separated by several meters. Use the spectrum analyzer to measure the received signal from A at C. Measure the transmitted signal level with two walkie-talkie units linked (one should transmit at all times, and the other should receive). Then, without moving A or C, turn on walkie-talkie B. One student should monitor the signal quality at C. Transmit carrier signals from B at different distances. At certain point the receiving unit will no longer be able to receive a clear signal. Measure B's signal level received by the spectrum analyzer (with transmitter at A turned off). Calculate the difference between two levels.

Repeat the measurement for several different orientations of A, B and C. For each geometry sketch the positions and record signal levels.

Determining the (co-channel) interference-free geometry

Compute the near-field distance d_1 and free space path loss distance d_2. Using both the systems determine which geometry allows simultaneous communication without co-channel interference (the smallest distance for which two independent systems can operate at the same frequency without recognizable interference).

The test should start with two systems being far apart and operatingindividually. The systems should move parallel, one towards the other, as shown in Figure 2. The goal is to determine the interference-free zone *y* for a given distance *x* between transmitter and receiver.

Repeat measurements for several different distances (*x*).

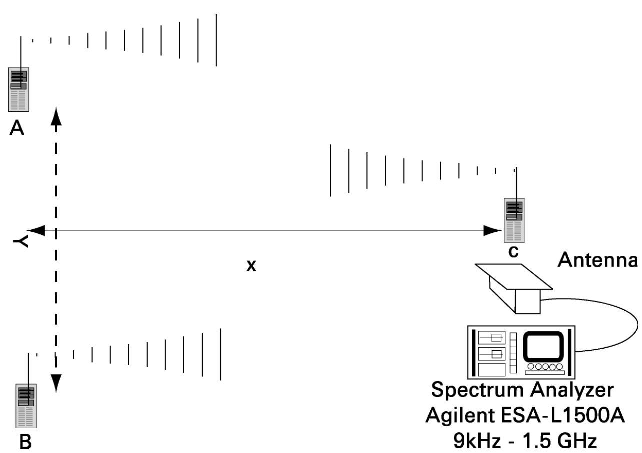

Figure 2

The adjacent channel interference

Using one walkie-talkie and the signal generator as a source of an interfering signal, the sensitivity of a given system to the interference caused by systems operating at other frequencies could be examined. The frequency sensitivity of any equipment can be represented with the curve interfering frequency – minimum interfering signal level with set of different curves depending on the distance between those two units.

Activate one walkie-talkie. Switch on the signal generator and generate a sine wave at the carrier frequency of the walkie-talkie. Find the level of the largest transmitted interfering signal that can not be received by the walkie-talkie. Repeat for several frequencies up to 10 kHz on each side of the carrier frequency. Note that after a certain, critical frequency, the interfering signal can not disturb the communication, even with high level of the output signal. Try to determine the critical frequency.

POST-LAB (GROUP) EXERCISE

Exercise 2

Look at the FCC Rules and regulations – Part 2 and Part 15 and discuss frequency, bandwidth, and modulation of the given system. Comment the interference caused by other systems working at adjacent frequencies.

Exercise 3

Calculate carrier-to-interference ratio for the walkie-talkie system.

Exercise 4

Describe the system range and interference-free geometry. Plot y vs. x (with logarithmic scale for y).

Exercise 5

Plot a curve of interfering power vs. frequency for the adjacent channel interference. What are the ways of reducing co-channel and adjacent channel interference in radio-relay and in cellular systems?

REFERENCES

Books

1. T.Rappaport *Wireless Communications: Principles and Practice*, Prentice Hall, 1996
2. W.C.Y.Lee, *Mobile Cellular Telecommunications*

Web sites

1. FCC Rules and Regulations are listed at http://www.fcc.gov