EE 160: Principles of Communication Systems
Experiment 6: Wireless reception and power measurement

I. INTRODUCTION

a. Objectives

   i. Set up a wireless link.

   ii. Verify the functionality of three basic digital modulation formats in wireless data transmission.

   iii. Measure the received power and the influence of the environment (multipath).

b. Required reading

   i. Proakis and Salehi, sections 8.2, 8.3 and 10.4

   ii. ADF7020-XDBX Evaluation Note (in web page)

   iii. ADF7020 Datasheet (in web page)

c. List of parts

   i. ADF7020 RF transceiver: Motherboard, RF module and antenna

   ii. SMA RF shielded cables and adaptors

   iii. ADALM-PLUTO software radio

   iv. Desktop personal computer running software to control the transceiver

NOTE:

In this experiment, **TWO** teams are required:
- Team1 consists of group 1 & 2, operating at computer E238-01 and E238-03, using RF Channel Frequency **868.8MHz**.
- Team2 consists of group 3 & 4, operating at computer E238-05 and E238-06, using RF Channel Frequency **868.6MHz**.

Groups 1 and 3 will first set up the ADF7020 as a **transmitter,** by following the instructions in section **V.2**, while Group 2 and 4 will first set up the ADF7020 as a **receiver** following the instructions in section **V.3**.

After measurements are done, Group 1 & 2 as well as 3 & 4 may exchange their roles as transmitter and receiver, if time allows.

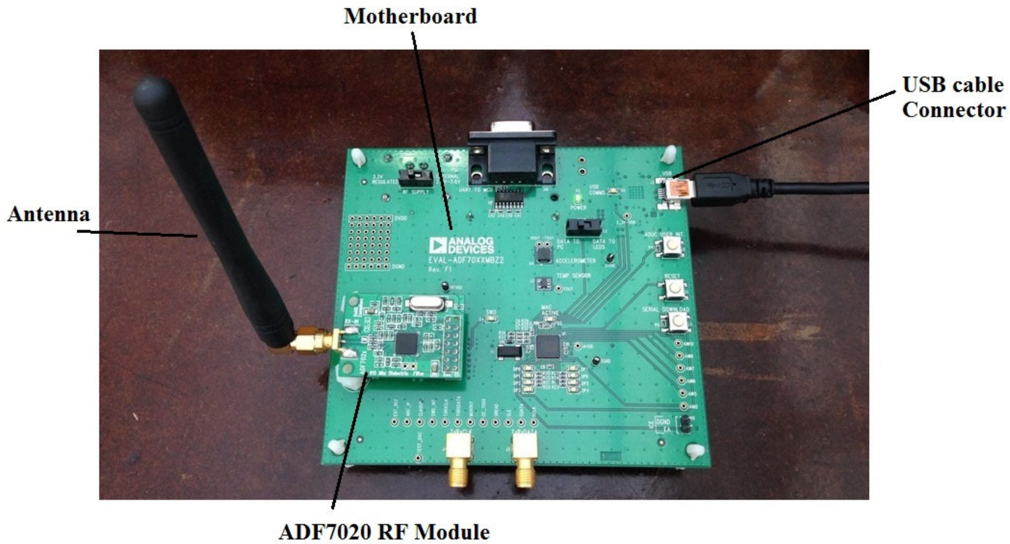

Figure 6.1: The ADF7020 wireless RF transceiver

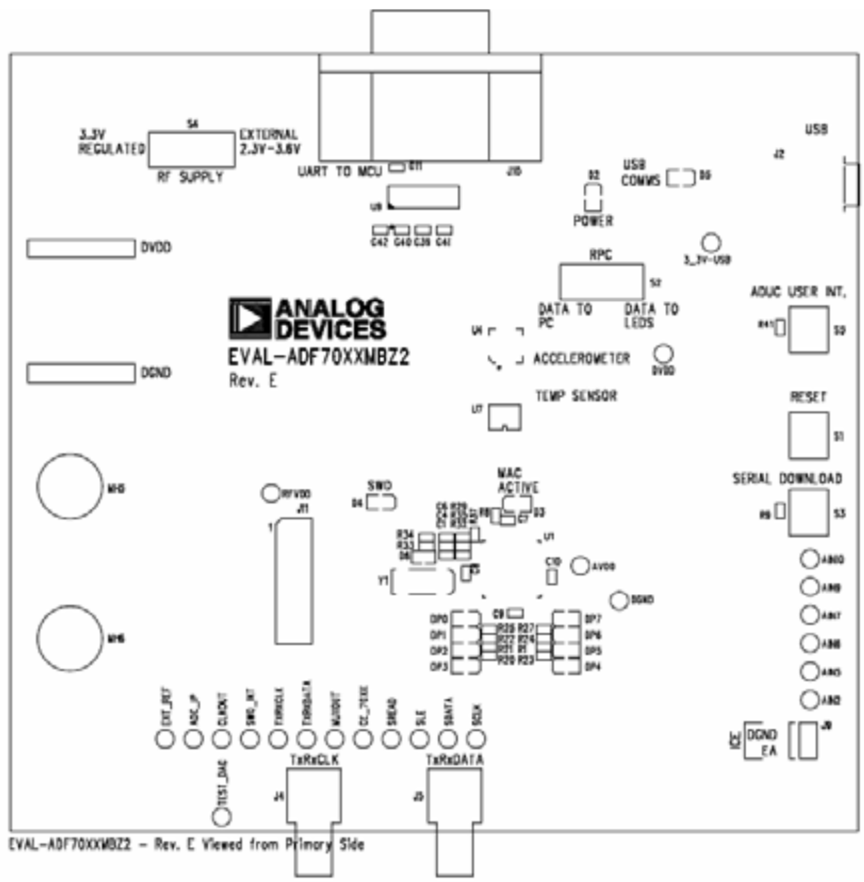

Figure 6.2: Schematic of the ADF7020 motherboard

II. THEORY

The receiver of a digital modulation system contains a downconverter, a correlator or matched filter and a decision device. Downconversion of wireless (bandpass) signals is accomplished with the aid of a coherent detector, like the one used in experiment 4. A correlator is a device that detects the energy of a reference pulse $\psi(t)$ in the received signal. An alternative LTI system used to detect energy is the matched filter. When properly sampled at multiples of the bit duration T_b, the correlator and the matched filter are equivalent in that they produce the same output. Modulation formats ASK and OOK have the same type of correlator/matched filter for an NRZ pulse. For FSK modulated signals an envelope detector can be used. This is an attractive feature that explains the popularity of FSK modulation in low-rate wireless communication systems.

III. INSTRUMENTS AND MATERIAL

In this experiment, a wireless RF transceiver is employed. The desktop PC located in the workbench will be used to run a graphical user interface (GUI) that controls the ADF7020 RF transceiver. Figure 6.3 below shows a screen shot of the interface.

IV. PRE-LAB WORK

Successful completion and report from experiment 5 are required.

V. MEASUREMENTS

The initial steps required to power on the ADF7020 are the same as in experiment 5. In this experiment, two ADF7020 transceivers are used. One transceiver acts as a transmitter (Tx) and the other as a receiver (Rx). Both devices are connected to a power supply, and their signal connectors to an oscilloscope (receiver) or a function generator (transmitter). The basic set up is illustrated in Figure 6.4. **Please make sure to perform the hardware setup for both Tx and Rx transceivers.**

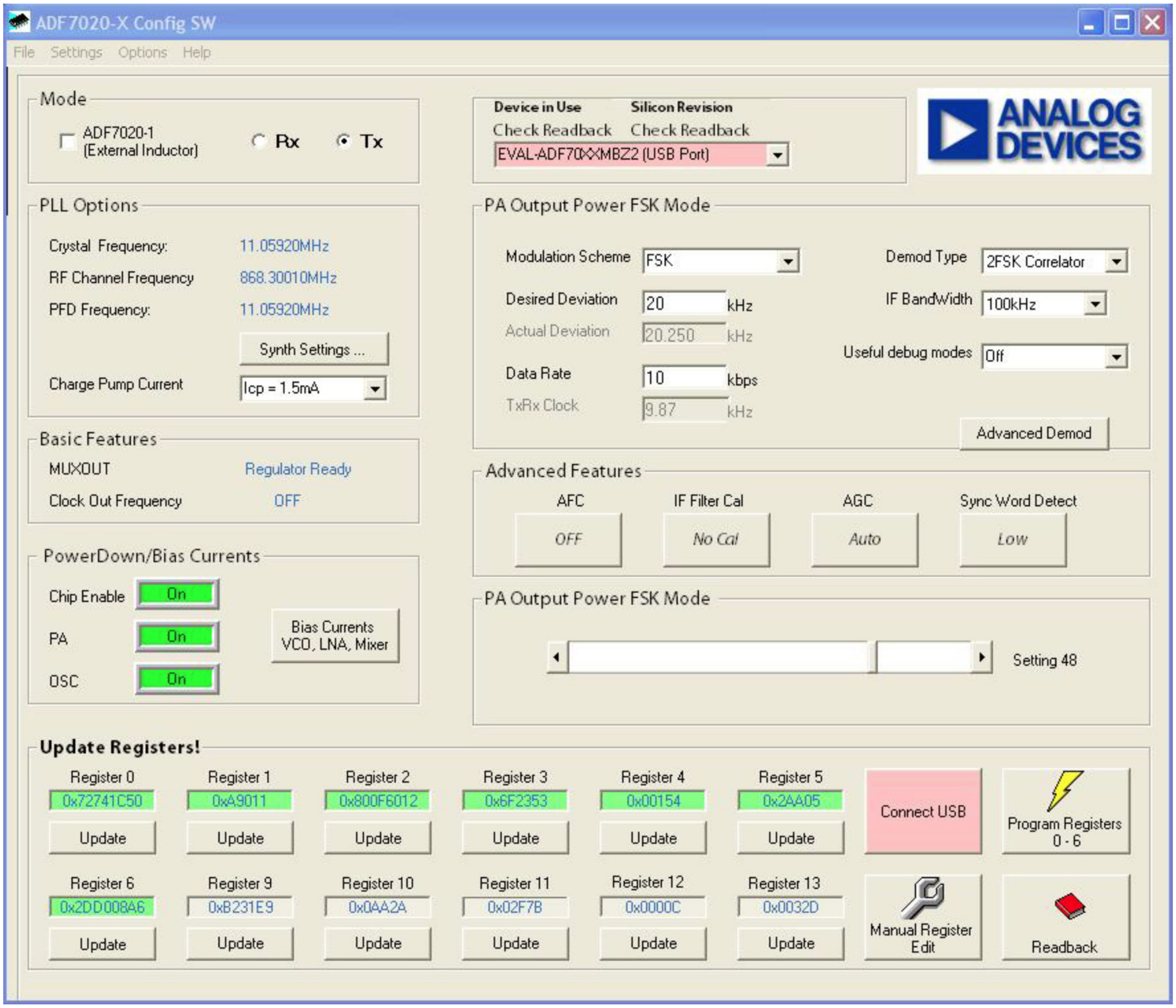

Figure 6.3: Screen shot of the ADF7020's GUI

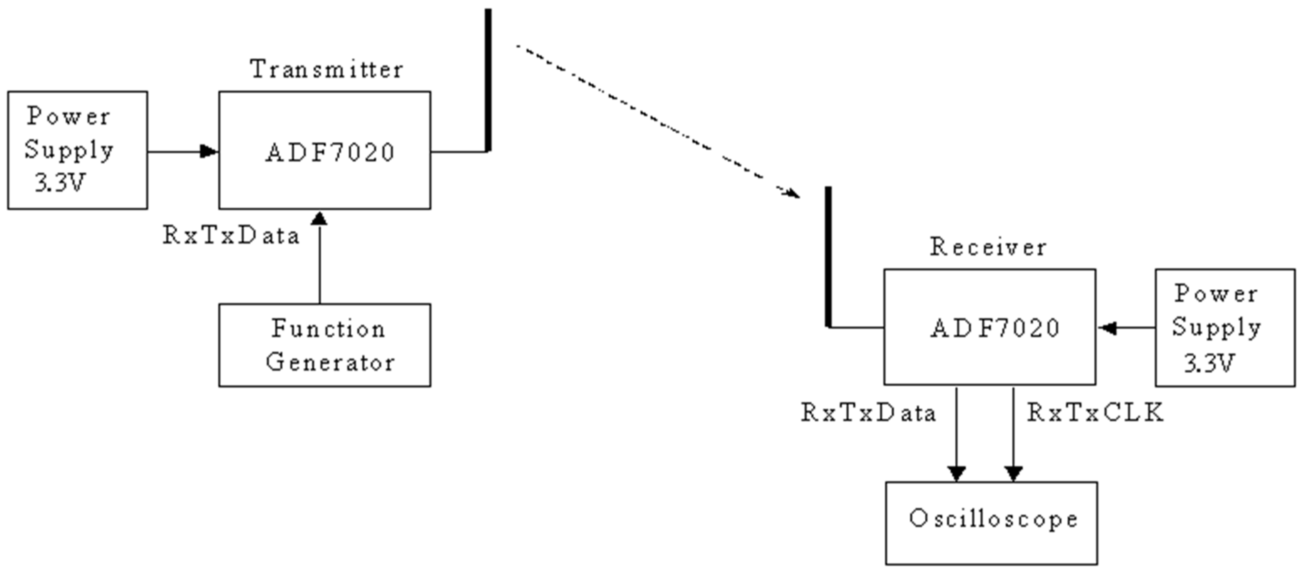

Figure 6.4: Wireless Transmission Link Setup

V.1 Hardware and software setup

These are the same as in experiment 5 with the antenna connected to the RFout pin of the RF transceiver, and using the ADALM-PLUTO radio, a software defined radio receiver, along with a MATLAB Simulink model in the PC to observe the transmitted spectrum. Please refer to the procedure manual of experiment 5.

V.2 Transmitter GUI setup

1. Click on the “Connect USB button” which is in pink color.
2. Select the option **Tx** mode
3. Configure the function generator to produce a 3V DC p-p square-wave with a frequency of 4.8 KHz.

4. Click on the “Off” text in ClockOut Frequency and set the dial to 8 div. This sets the clock frequency of the ADF7020 daughter board to 1.38 MHz. Hit the “Return to Front Panel” button.
5. Click on “Synth Setting” and set:
   Channel Frequency (around 868.6 MHz or 868.8 MHz)
   Fcrystal = 11.0592MHz

   FPFD = 11.0592MHz

   Click on the “Calculate” and “Return to Panel” buttons successively
6. Choose the FSK Modulation (FSK will be our first modulation for this experiment)

   Fix Desired Deviation = 20 kHz

   Fix Data-Rate = 9.6 (kbps)

   Set PA level to 48

   Adjust IF Bandwidth = 150 kHz
7. Click the “Program Registers 0-6” button and the “Updated” button of the other registers when needed (the box will turn green) to load the settings.
8. Connect the RTL-SDR USB to the computer, and observe the signal coming out of the ADF7020 transmitter on the pc using the “SDR#” software. Instructions on how to do this are given in experiment 5 section V.7.
9. To ensure that the transmitter outputs the correct frequency and level, connect the antenna port (labeled “Rx-in” in the RF module) to the spectrum analyzer. After checking the output signal, re-connect the antenna to create a wireless transmission link.

V.3 Receiver setup

1. Connect the antenna to the receiver and use the USB cable to connect the motherboard to the computer.
2. Using the ADF7020 GUI software, select **Rx** test mode.
3. In “Synth Settings” select the RF Frequency (around 868.6 MHz or 868.8 MHz) to match the signal generator output frequency at the transmitter.
4. Modulation options:

FSK Modulation
Desired Deviation = 20 kHz
Data-Rate = 9.6 (kbps)
Demod Type = Linear
IF Bandwidth = 150 kHz

Select the “Advanced Features” button and click the “AFC” button to turn it on.

This will compensate for errors in the crystal if the error at RF is less than +/-50 kHz. Click “Program Registers” on the GUI window

5. Probe the RxTxData pin and RxTxCLK pin by using an oscilloscope. They should output 3V DC p-p square-waves signals with frequencies of 4.8 kHz and 9.6 kHz respectively.

Fig. 6.5 shows the signals at the RxTxData and RxTxCLK pins in the receiver as measured by the digital oscilloscope with the FSK modulation format setup. These 3V DC p-p square-waves signals have frequencies equal to 4.8 kHz (demodulated data) and 9.6 kHz (data clock) respectively.

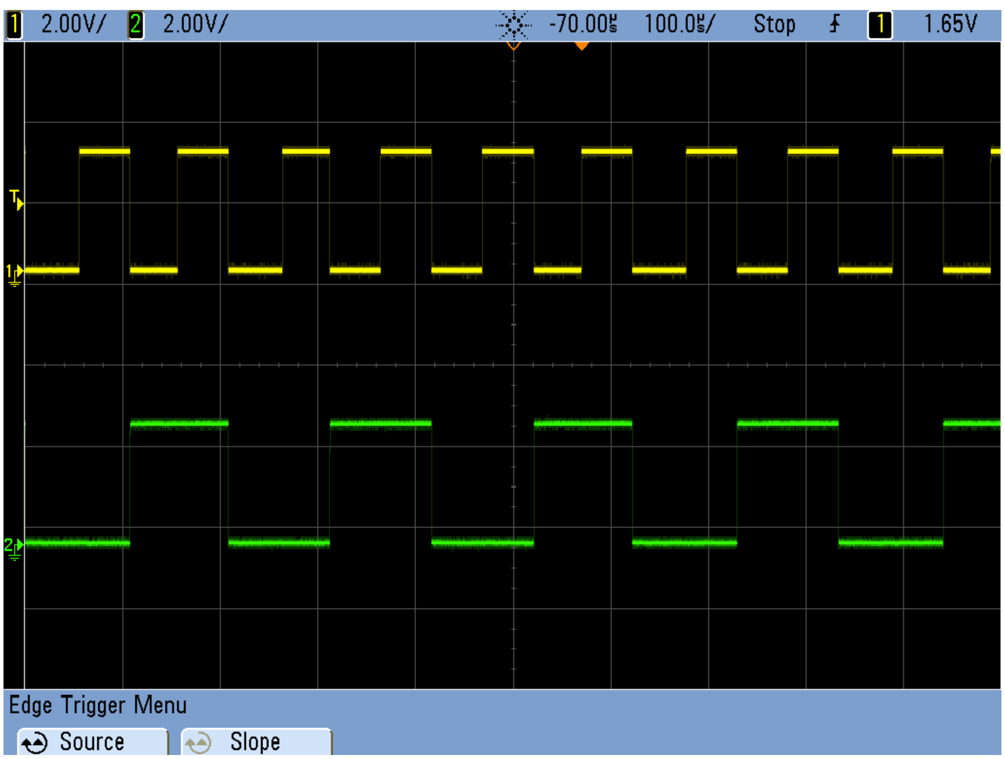

Figure 6.6: Transmitted signals detected by the receiver (RxTxCLK above, RxTxData below)

V.4 Measurement of received power

1. With the setup of part V.3 (FSK), place a metallic object (available in the lab) or a cell phone in proximity to the receiver antenna and notice changes in received power levels. In order to measure the power content of the received signal go to "**Settings > Read back > RSSI**" in the GUI. (NOTE: RSSI stands for **R**eceived **S**ignal **S**trength **I**ndicator.) If possible, try different placements of the metallic object around the antenna until the received power level drops to below –90 dBm. If this is not possible then record the smallest result. NOTE: You need to wait one or two minutes between readings (pressing the button) or else the measured power level may not be accurate.
2. Change the PA levels to 1, 7, 15, 31 and 63 and record in each case the RRSI value. Notice the random nature of the RSSI (received power level) readings.
3. Using an external signal for a Data Rate of 9.6 kbps (a square waveform at 4.8 kHz) and the transmitter in ASK mode, set the center frequency to 868.6 MHz or 868.8 MHz and maximum transmitted power (with PA low and high levels at 34 and 62 respectively).
4. Set the receiver to ASK mode with 150 kHz IF bandwidth and center frequency equal to 868.6 MHz or 868.8 MHz (the same as the transmitter). Measure the power of the received signal. You may have to read the value several times and record the maximum.
5. Now change the center frequency at the transmitter to 858.6 MHz or 858.8 MHz and measure the received power again. This is the sensitivity level of the receiver. (Typically below –80 dBm.)
6. With the center frequency at the transmitter back to 868.6 MHz or 868.8 MHz, change the PA level to the settings (25,47) and measure the received power. Repeat for transmitter PA settings (23,31) and (8,11).

V.5 Effects of changing the bit rate, transmitted power and modulation format

1. At the transmitter and without changing the Data Rate in the GUI, change the PA levels to 25 and 47 and the frequency of the external square waveform signal to 2.4 kHz. Observe the demodulated waveform RxTxData at the receiver. There should be a noticeable jitter. This is due to errors in the demodulated bits. Repeat the observation with the external square waveform at 1.2 kHz.

2. Turn on and off the PA at the transmitter and observe the effects that this has on both the received power and the demodulated waveform.
3. Return the frequency of the square waveform to 4.8 kHz.
4. Change the modulation format to OOK and repeat steps 1 through 3 above for power levels 3, 5 and 50.
5. Change the modulation format to GOOK and the Data Rate to 9.6 kbps (to set the parameters, refer to experiment 5 section V.4) and repeat steps 1 through 3.

V.6 Performance of FSK modulation

1. Change the transmitter mode back to FSK and the receiver to FSK linear demodulator. Use a square waveform at 2.4 kHz as external signal and make sure that the bit rate remains 9.6 kbps with a frequency deviation of 4.8 kHz.
2. Set the transmitted power PA setting to 63 and measure the received power. Use an IF bandwidth of 100 kHz. Look for effects on the demodulated waveform. Repeat for PA settings: 31, 7, 3 and 1.
3. With the PA level equal to 63, change the frequency deviation to 50 kHz, 100 kHz, 150 kHz and 200 kHz. The highest value of frequency deviation should produce flickering of the demodulated data due to errors in the demodulated bits.
4. Set the transmitter waveform such that the bit rate is equal to 4.8 kbps with frequency deviation to 4.8 kHz. At the receiver, set the format to FSK **correlator** demodulator type. Confirm that the demodulated waveform is correct. Now change the frequency deviation to 2.4 kHz and confirm that the received signal is incorrect. Repeat and compare with a linear demodulator.

V.7 Broadcasting and effects of distance between transmitter and receiver

Set one transceiver to FSK modulation with the other three transceivers set as receivers, all with the same carrier frequency. Observe both the spectrum in the RTL-SDR **and the RSSI** at the receivers. All groups will share these measurements. The first group to act as transmitter shall be the one furthest away from the lab entrance; all other groups will be receivers. Then, if time allows, you may give the role of the transmitter to each of the other groups.

VI. ANALYSIS OF RESULTS

1. Comment on the effect that different demodulator types have in the received signal quality.
2. Discuss and comment the effects that the environment (surrounding objects) has in the received power measurements.
3. Explain why the received power levels change in a seemingly random fashion.