A RF Laboratory and Lecture Course for Wireless Communications

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Abstract: A laboratory course and a lecture course were developed for the RF portion of a 900 MHz, FM or FSK half duplex transceiver system. A modular approach was selected for the laboratory course, which consisted of chipset subsystems, discrete components, and parts of our own design. After each module was designed and tested, they were integrated for system evaluation as a transmitter or a receiver. The key parameters in the system can be conveniently controlled to demonstrate their significance for the system.

For the transmitter arrangement, the FM or FSK modulated signal is upconverted to 900 MHz by a programmable frequency synthesizer, which was also used as the local oscillator for the receiver system. The output signal was amplified to about 0 dBm, which is the FCC limit of the transmitted power for this band.

The RF receiver block diagram was a dual conversion design, since most modern cordless phones and wireless systems use the same arrangement. The first down conversion was to produce a relatively high intermediate frequency (IF) at 86.8 MHz. The second IF was at 10.7 MHz. The system was used to demodulate both FM and FSK signals.

AT the end of these two courses, the students will gain experience in the following areas: FM and FSK modulation and demodulation, low noise amplifier and power amplifier, mixer and upconverter, voltage controlled oscillators, phase locked loops and frequency synthesizers, antennas and wave propagation, transmitter and receiver systems, software simulations for transceivers.

The transmitter and receiver systems provided for the course can also be integrated with other peripheral components to form many possible wireless systems.

Keywords: Electronic, curriculum, laboratory, telecommunication, wireless.

1. Introduction

Rapid growth in wireless communications and related wireless systems over the past few years is expected to continue well into the 21^{st} century. This growth is being recognized worldwide by industry and education entities to be one of the most important areas of needed educational curricula. Many concerns have been raised over a shortage of trained RF workers in the wireless area.

To meet this demand, we have developed a laboratory course and an associated lecture course in the RF wireless communication at the California Polytechnic State University, San Luis Obispo. The 10 week courses are organized as senior technical electives, and students are assumed to have knowledge in basic electronic circuits, control systems, transmission lines, network analyzer and spectrum analyzer.

We first selected a suitable laboratory course, which was based on a 900 MHz, half-duplex transceiver system for transmitting and receiving FM or FSK (Frequency Shift Keying) signals. A lecture course was then used to discuss the necessary background and principles of the experiments, which will be performed in the laboratory course. The industrial, scientific and medical (ISM) frequencies in the 900 MHz region have been extensively used for a wide array of communication systems, from medical and industry telemetry to consumer communications. Therefore, many components used in the transceiver for the course are readily available with a reasonable cost.

There are two approaches to implement the transceiver system. One approach is to use a system that has been fully realized in a small integrated circuit chipset. Although the chipset satisfies such system requirements as output power, frequency, noise figure, etc., student will learn very little about the design and interface issues of wireless communications using this approach. Therefore, we choose a different approach with a modular construction. The modules consist of frequency synthesizers and IF chipset subsystems, discrete amplifiers, mixers and filters, and some of the laboratory designed attenuators and low frequency filters. After each module is designed and tested, they will be integrated for system evaluation as a transmitter or a receiver. The key parameters in the system can be conveniently controlled to demonstrate their significance for the system.

2. The transmitter

The block diagram for the transmitter is shown in Figure 1. The FM or FSK modulation signal was applied to the low frequency VCO first, and was upconverted to the required transmitting frequency of 902.5 MHz. Before the signal reached to the antenna, it was amplified and filtered to an approximate power level of 0 dBm, which is the FCC limit of the transmitted power for this band. The low and high frequency VCOs are controlled by a dual frequency synthesizer chipset. Frequency synthesis has many applications in communication systems, but one of its most widely used applications is in implementing phased-locked oscillators. The major advantage of frequency synthsis is that only one high stability low noise signal from the crystal oscillator is required to generate higher frequency signals with comparable stability and noise performance. The synthesizer used in transmitter block diagram in Figure 1 is a National Semiconductor LMX 2330 dual frequency chipset, which can independently control two separate VCOs. Five major components are involved in the synthesizer chipset: The reference oscillator, the phase detector, the loop filter, the VCO, and the dual modulus divider. Since the phase detector and frequency dividers are contained on the LMX 2330 chipset, and the two VCOs were purchased, the focus of the design effort was on the loop filters. The loop filter is a very important component and can affect several loop attributes such as FM and FSK modulating frequency response, lock-up time, stability and phase noise. In this project, an attempt was made to optimize FM and FSK modulating frequency response and the phase noise, rather than the lock-up time.

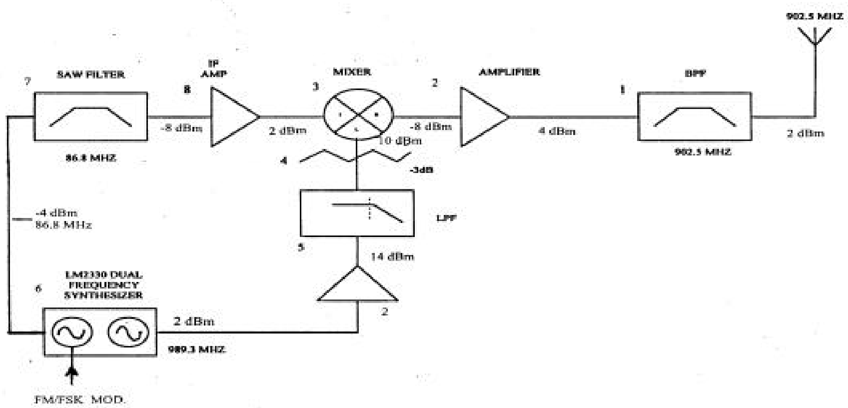

Fig.1 Transmitter block diagram

A second order passive loop filter [1] shown in Figure 2 was used for the synthesizer design. The component values in Figure 2 were calculated based on a phase margin of 45°, and a loop bandwidth of 5 kHz for the high frequency VCO: $C_1 = 2.78$ nF, $C_2 = 13.41$ nF, and $R_2 = 5.73$ kΩ

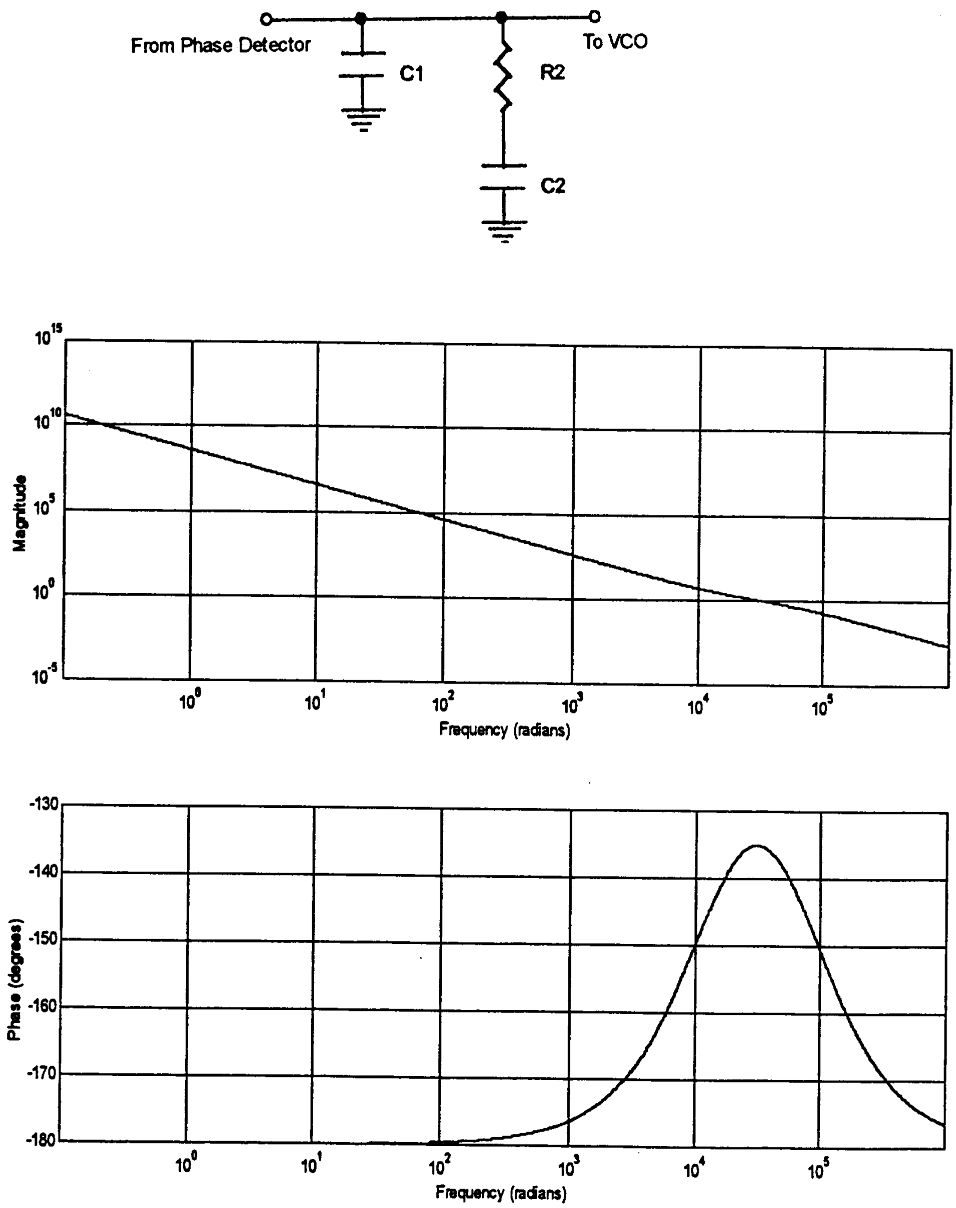

Fig.2 The loop filter and it' s response

In addition to the VCOs and synthesizers, other various discrete components were also used in the transmitter block diagram. These include low pass and bandpass filters, low frequency and high frequency amplifiers, and 3 dB attenuators. A summary of the performance for each component in the transmitter is given in Table 1.

Table 1. Summary of performance for each component in transmitter

Item	Description	Performance	Remark
1	RF bandpass filter	Insertion loss = 1.7dB @ 902.5 MHz	Samples from Murata Co.
2	Power amplifier	Power output = 14 dBm and gain = 12 dB @ 900-1000 MHz	Donated by Watkins Johnson Co.
3	RF mixer or upconverter	Conversion loss = 10 dB @ 900 MHz	Donated by Watkins Johnson Co.
4	3 dB attenuator	Insertion loss = 3 dB @ 989.3 MHz	Our own design
5	1 GHz low pass filter	Insertion loss = 0.6 dB @ 985 MHz	Our own design
6	Synthesizer and VCO assembly	Power output = 2 dBm @ 989.3 MHz Power output = -4 dBm @ 86.8 MHz	National Semiconductor Co.
7	SAW filter	Insertion loss = 4 dB @ 87 MHz	Donated by Agilent Co.
8	IF amplifier	Gain = 10 dB @ 87 MHz	Donated by Watkins Johnson Co.

3. The receiver

The architecture for the receiver block diagram shown in Figure 3 is almost the mirror image of the transmitter. The receiver experiments begin with the IF demodulation system which is a Philips SA 626 chipset. With the addition of two ceramic filters at 10.7 MHz, and a phase shift network of 90° for the quadrature detector, the chipset was tuned to receiver the 88-108 MHz FM band signals. An audio amplifier or data slicer was added to form either a FM or FSK system.

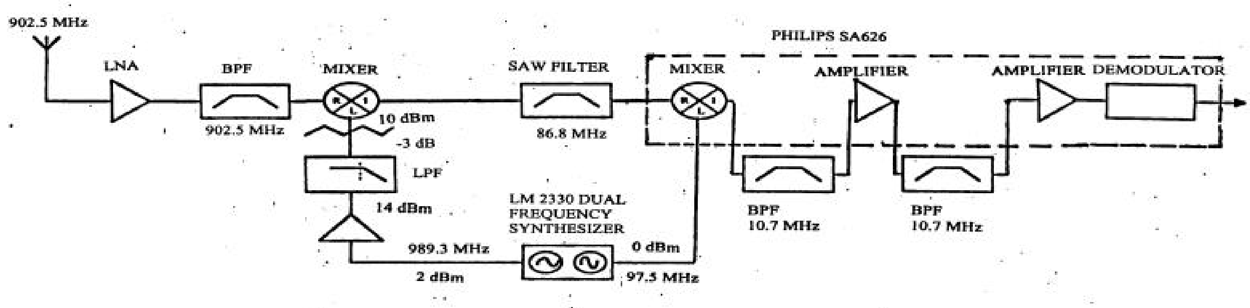

Fig.3 Receiver block diagram

As the next step, the front end components in Figure 3 were added to complete a 902.5 MHz receiver system. The IF frequency of 86.8 MHz was carefully selected to minimize spurious response from various harmonics generated from the mixer and the local oscillator to the first mixer, which was also used as the upconverter in the transmitter block. Bandpass filters were used to reject image frequency and other spurious frequencies. As indicated in Figure 3, many components used in the receiver block are the same as those in the transmitter with the exception of the Philips SA 626 chipset and the low noise amplifier, which has a noise figure of 2.7 dB and gain of 12 dB at 902.5 MHz.

4. Laboratory and lecture courses

Based on the discussions of RF receiver and transmitter block diagrams, the following experiments for the laboratory course will be offered:

1. RF low noise amplifier and power amplifier.
2. Mixers and upconverters.
3. RF bandpass filter, RF lowpass filter, IF SAW filter, IF lowpass filter, and 3 dB attenuators.
4. VCO, phaselock loops, and frequency synthesizers.
5. Integration of the transmitter and the receiver.
6. Software simulations to predict integration performance of the transmitter and the receiver.

To complement the laboratory course, the lecture course will contain the following topics to enhance the understanding of the relevant issues encountered in some typical wireless communication systems:

1. An overview of various wireless communication systems.
2. Link budget.
3. Transmitter and receiver architecture considerations.
4. Antennas, multipath and wave propagation.
5. Transmitter components.
6. Receiver components

Many books [2-4] have published in this field and can be potential candidates for the lecture course.

5. Conclusions

A laboratory course and a lecture course on a FM/FSK 900 MHz half-duplex transceiver system have been developed. The transmitter and receiver systems provided for the laboratory course can also be integrated with other peripheral components to form spread spectrum, remote control, telemetry and RFID and many other possible wireless systems.

6. References

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