A LABORATORY IN ANALOG COMMUNICATION SYSTEMS

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ABSTRACT

The goal of this work is to design and build a set of RF sub-circuits that will be part of a complete FM transceiver, operating at 24MHz. Each sub-circuit is being characterized by analytical expressions and electrical measurements. This project is intended to be the basis for a undergraduate course in communication systems at Federal University of Santa Catarina (UFSC).

The work is based on a Stanford University undergraduate course called "Analog Communication Design Laboratory".

1. INTRODUCTION

In UFSC there are several courses on theory of communication. The practical course presented here brings to the students some issues related to the difficulties on making a real prototype work. Many points related to non-ideal devices are considered. The students also have the opportunity to visualize by means of practical measurements some basic properties of an FM transceiver. The course "Analog Communication Design Laboratory" of the Stanford University was chosen for being the base of this project. The challenge of this work is to adapt it for Brazilian reality regarding economical issues and devices availability.

A brief theoretical background is presented in section 2. The characterization of the sub-circuits is shown in section 3. Finally, in 4 conclusions are presented.

2. THEORICAL BACKGROUND

The global system is separated into sub-circuits that are characterized by analytical expressions. Each lab session is centered on the characterization of a particular sub-circuits. For each circuit a topology is proposed. However, the student can choose an alternative topology. Figure 1 shows de block diagram of the transmitter. And Figure 2 shows the receiver.

The block called (AUDIO AMP.) is an audio amplifier. This circuit will act as an input stage to the microphone or other type of signal source. The microphone can be a simple electret microphone.

The block called VCO is a voltage-controlled oscillator. This circuit generates an output signal which frequency is proportional to the amplitude of the input signal.

A Colpitts oscillator can be used as a basis for this block. For a Colpitts oscillator to work as VCO, the capacitor of LC tank must be replaced by varactor diode, reverse biased by the input signal. The basic Colpitts topology can be viewed in Figure 3.

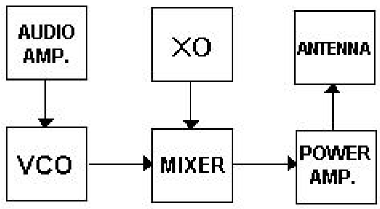

Figure 1: Transmitter diagram blocks

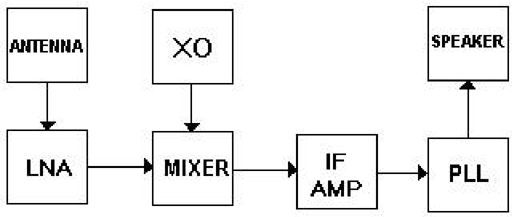

Figure 2: Receiver block diagram

Fully-integrated VCO's can be used. An example is National LM566. The VCO center frequency can be 300kHz. This frequency will be the intermediate frequency.

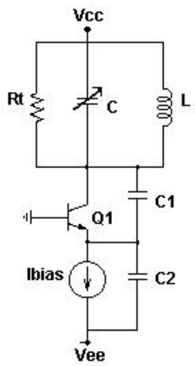

Figure 3: Basic Colpitts Oscillator.

The blocks called MIXER and XO will work together. The XO is an oscillator operating in the carrier frequency (24 MHz) that will supply the MIXER. The result of the operation made by MIXER will have a spectrum with sums and differences between the XO and VCO frequencies. In addition the output will contain the odd harmonics of the carrier signal. Figure 4 shows a general response of a four-quadrant multiplier.

Where f_C is the fundamental carrier frequency, f_S is the modulating signal, $f_C \pm f_S$ are the fundamental carrier sidebands, $f_C \pm nf_S$ are the fundamental carrier sideband harmonics, nf_C are the carrier harmonics and finally $nf_C \pm nf_S$ are the carrier harmonic sidebands.

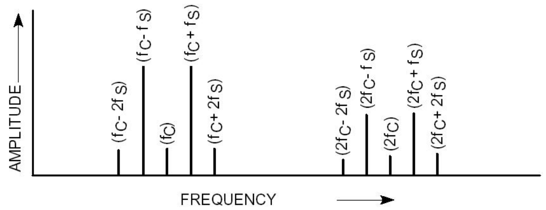

Figure 4: General frequency response of MIXER.

The useful output of the mixer, the modulated signal, is ate frequency $f_C + f_S$.

The block called POWER AMP is the output stage that supplies power to allow transmission for large distances. There are many classical topologies for power amplifiers and anyone can be used [2]. The ANTENNA is connected to the output of the power amplifier. These are the most important blocks that form the FM transmitter.

Figure 2 shows the parts of the receiver.

The ANTENNA receives a little portion of the signal transmitted by the transmitter circuit. The low noise amplifier makes the amplification of the received signal, adding low noise and distortion.

The MIXER has the same function as the transmitter MIXER, but now its output will generate an FM signal with a center frequency of 300kHz. This frequency is the IF, previously mentioned. The XO oscillates at 24MHz as in the transmitter side. Note that the received original spectrum is preserved and only a frequency shift is realized.

A passive 4^{th} order Butterwoth filter plus an active gain stage forms the IF AMP block. This block selects only the frequencies of interest, around the IF frequency, with a band pass filter with a center frequency of 300kHz.

The next block is the main part of the receiver, the Phase Locked Loop (PLL). This component is the dual part of the VCO. The magnitude of the output signal is proportional to the phase difference between the input signal and a reference signal. Many available PLL's have a VCO to generate the reference signal. The block diagram of a basic PLL can be viewed in Figure 5 where PD is a phase detector, LPF is a low pass filter and the loop has a VCO. An example of PLL is the National LM565.

Finally the output of PLL is connected to a speaker.

3. CHARACTERIZATION

All sub-circuits, discussed before, must be designed and implemented. This is the main objective of the course.

In order to design sub-circuits basic knowledge of electronics will be required. For example, some impedance match are needed between blocks for eliminating undesired reactive components at high frequencies and to provide the maximum power transfer

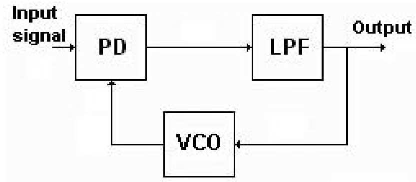

Figure 5: Basic PLL block diagram

Each block must be characterized by electrical measurements. This work is going to serve for knowing the responses of each block. Note that some signals are very important to understand the concepts related to communications systems. For example measuring the inputs and outputs of the two MIXERS, frequency shifts showed in Figure 3 can be observed. The signals of PLL's are very important too.

The great merit of this didactic work is that while the transceiver is designed and prototyped, the concepts about amplifiers, filters and oscillators can be learned from a practical viewpoint. Also characterization should be made using a set of measuring equipments as multimeters, oscilloscopes, function generators and spectrum analyzer. These equipments are very important to develop any activity in electrical engineering.

4. CONCLUSION

This kind of initiative is very important for the teaching in Brazilian universities where, in many cases, the communication systems programs curricular are composed just with theoretical courses. The students should know that on practical experiences many differences from the basic theory, appear. However, they have few opportunities to really face these differences.

From a didactical viewpoint, the practical experiences have a fundamental importance in the undergraduate courses. Students are greatly stimulated and learn a lot by designing circuits and making then actually work.

The project is being adapted for the Brazilian reality. The circuits were designed and they are currently being characterized. The approximated cost to build a transceiver is about US$ 50,00. It was necessary to contact three different suppliers to find all the parts.

5. REFERENCES

[1] A. Tung., R. Dutton., "Circuit Orientation and Lab Schedule," http://eeclass.stanford.edu/ee133/.

[2] A. S. Sedra., K. C. Smith., *Microelectronic Circuits*, Oxford, New York, 1998.