Engineering Sciences 151
Electromagnetic Communication
Laboratory Assignment 1
Fall Term 1998-99

MODULATION AND DEMODULATION

OBJECTIVES:

To gain some experience with information encoding schemes and to explore the spectral characteristics of typical communication signals.

EQUIPMENT:

Tektronix, Model 5L4N, Audio frequency spectrum analyzer
Tektronix, Model 2230, 100MHz Dual-channel storage oscilloscope
Tektronix, Model 2213A, 60MHz Dual-channel oscilloscope
Tektronix, Model FG502, Function generators
Tektronix, Model DC504, Counter/timer
Hewlett-Packard, Model 33120A, 15 MHz Function/arbitrary waveform generator
Hewlett-Packard, Model 200CD, Wide range audio oscillator
General Radio, Model 1398-A, Pulse generator
Bausch & Lomb, Model VOM7, 500 mV Chart recorder
Krohn-Hite, Model 3550, Filter
Realistic, Model MC-100, Dynamic microphone

1. THE TEKTRONIX AUDIO FREQUENCY ANALOG SPECTRUM ANALYZER:

The first task is to gain familiarity with the operation of the Tektronix, 5L4N Spectrum Analyzer. This audio frequency instrument is a somewhat dated piece of electronics (circa 1976) which has significant limitations, but it does offer a very accessible means of studying the spectral representation of signals of interest in communication. In fact, the analyzer operates much like a heterodyne communication receiver and, in that sense, it is useful to understand how it works.

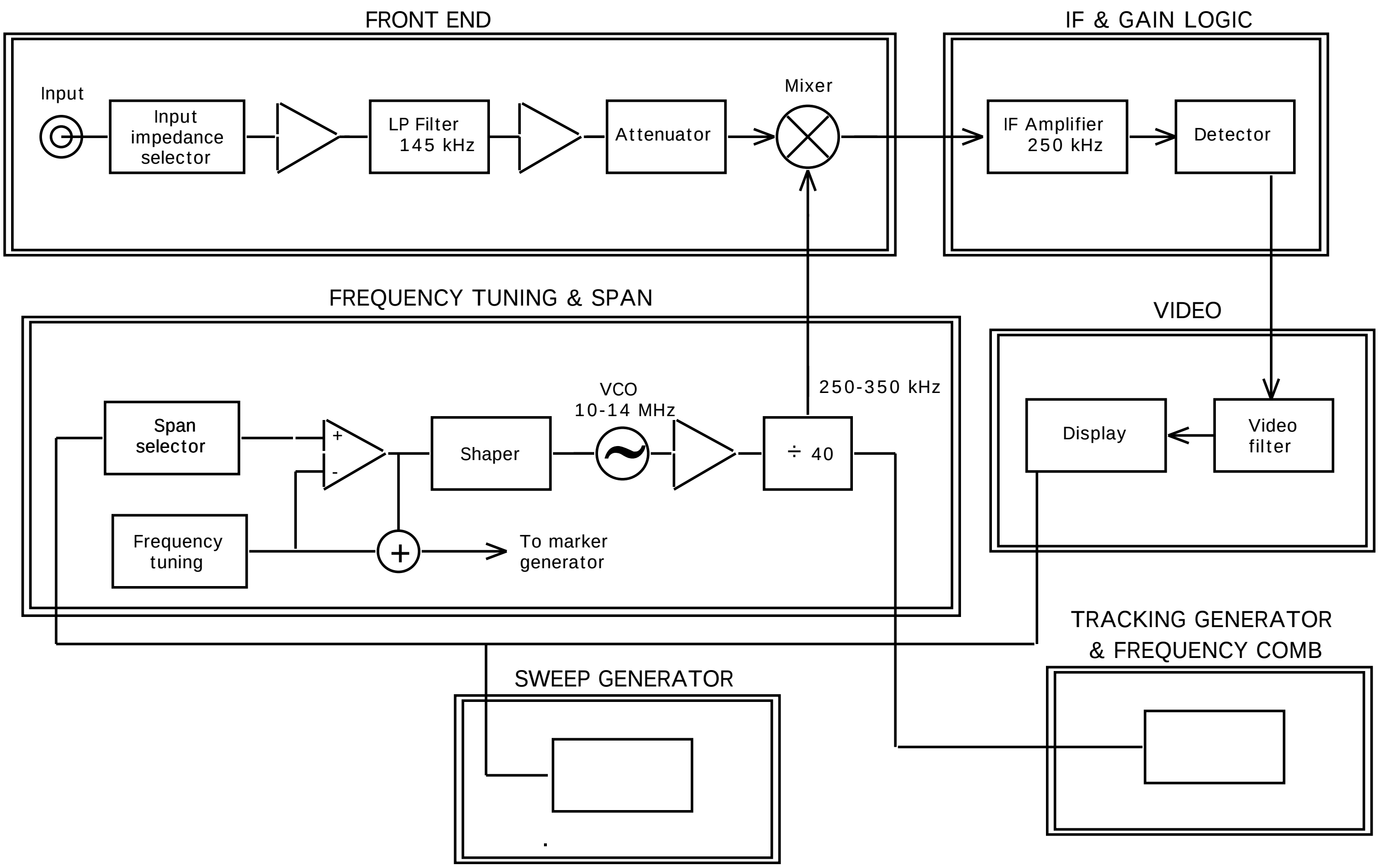
As illustrated in the block diagram on the next page,[1] the signal to be analyzed ("input") is first band-limited by a low pass filter with a roll-off frequency of 145 kHz. This band-limited signal is mixed (heterodyned) with a variable local oscillator signal f_{LO}. **Mixing is a nonlinear operation** which, among other things, produces an upward shift of each and every frequency component of the input signal -- *i.e.* $V(f) \quad V(f_{\mathrm{LO}} \pm f)$. The "IF" (intermediate frequency) module is essentially a very narrow band pass filter (with a center frequency of 250 kHz) followed by a demodulator. Thus, **only the frequency component** $V(f_{\mathrm{LO}} - 250\text{ kHz})$ gets through the filter and appears at the output of the demodulator (and eventually as single point on the video display). A portion of the input signal's frequency spectrum is then obtained by sweeping the voltage controlled local oscillator over a frequency range from $f_{\mathrm{LO}}^{\min}$ to $f_{\mathrm{LO}}^{\max}$ -- *viz.* the spectrum from $f_{\mathrm{LO}}^{\min} - 250\text{ kHz}$ to $f_{\mathrm{LO}}^{\max} - 250\text{ kHz}$. The starting spectral frequency -- *i.e.* $f_{\mathrm{LO}}^{\min} - 250\text{ kHz}$ may be set to any value between 0 and 100 kHz by adjusting the "frequency tuning" controls on the front panel of the analyzer and the range or width of the spectrum obtained -- *i.e.* $f_{\mathrm{LO}}^{\max} - f_{\mathrm{LO}}^{\min}$ -- is determined by adjusting the front panel "span" control.

In principle, one could use a variable frequency band pass filter as the basic tuning element in a frequency analyzer. However, it is very difficult to build such a filter. Heterodyne

[1] A more detailed block diagram is available in the Photonics Lab in Cruft Basement.

systems, such as the 5L4N analyzer, take advantage of the fact that variable frequency oscillators are relatively easy to build.

BLOCK DIAGRAM OF ANALOG AUDIO FREQUENCY SPECTRUM ANALYZER:



Measurements and observations:

a. Connect the internally derived 5 kHz marker signal to the analyzer INPUT and observe the frequency comb (or picket fence) of markers displayed.

b. Connect the a Hewlett-Packard, Model 33120A, 15 MHz Function/arbitrary waveform generator [2] to the analyzer INPUT and monitor the input signal on a 100MHz Dual-channel storage oscilloscope. Adjust the 33120A and 5L4N controls to get good displays of sinusoidal and square wave signals at several frequencies. Connect the 5L4N's VIDEO OUT signal to a Bausch & Lomb chart recorder to obtain hard copies of observed frequency spectra.

c. The notion of a 4kHz voice or telephony channel is a very central one in the organization of communication systems. To get some idea of what this means connect the Realistic MC-100 dynamic microphone to the analyzer INPUT. Estimate the bandwidth of your time averaged speech pattern by setting the display to storage mode and reading some suitable material into the microphone.

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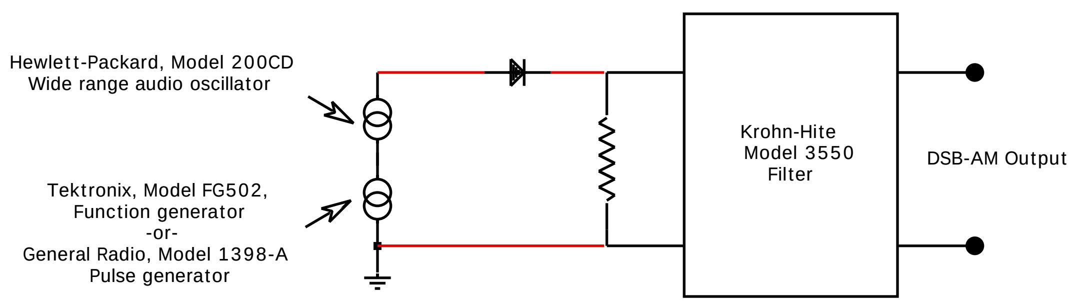
2 You will find this to be a truly wonderful machine!

d. Repeat c. using a musical signal from a broadcast receiver.

2. DSB-AM MODULATION -- Characteristics of a simple DSB-AM modulator:

The next task is to build a simple AM modulator using the signal from the floating Hewlett-Packard audio oscillator as the "carrier" signal and the signal from either a Tektronix, Model FG502, function generator or the General Radio, Model 1398-A, pulse generator as the "modulation" signal.[3] As illustrated in the figure below, the two signals are to be applied in series across a combination of a resistor in series with a diode, as illustrated above. The Tektronix 60MHz dual-channel oscilloscope may be used to observe and adjust the signal input, the current through the resistor and the filter output. The Krohn-Hite filter should be adjusted so that the output is a DSB-AM signal. The Tektronix audio frequency spectrum analyzer may be used to observe the frequency spectrum of the input and output signals.

SIMPLE DSB-AM MODULATOR



Measurements and observations:

a. Modulate a 45 kHz carrier signal with a sinusoidal 500 Hz signal from a Tektronix function generator. Measure the frequency spectra of the voltages across (*i*) the two signal sources, (*ii*) the resistor and (*iii*) the output terminals of the filter.

b. Modulate a 45 kHz carrier signal with pulses from the General Radio pulse generator. Measure the frequency spectra of the across (*i*) the two signal sources, (*ii*) the resistor and (*iii*) the output terminals of the filter for pulses with widths of 0.1, 0.25, 0.5, and 1.0 msec.

Report:

a. A summary of results for the sinusoidal modulator.

b. A summary of results for the pulse modulator.

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[3] The issue of "ground" is kind of tricky here and you need to be mindful of an important practical matter. For convenience and simplicity of design, most modern electronic instruments are single sided in the sense that all signals are measured with respect to some fixed potential -- *i.e.* ground. Thus, most garden variety signal generators (and oscilloscopes) have one terminal clamped at ground. In order to build our modulator, as illustrated, one signal source must float and, thus, we had have to make use of a rather ancient signal generator which allows for that option.

c. Discussion of results - *i.e.* do your "experimental" results compare with your "theoretical" expectations?

3. FM MODULATION -- Bandwidth of FM signals:

The final task is to establish the following relationship (the "Carson rule") for wideband FM signals.[4]

$$\text{Bandwidth} \approx 2\left\{\text{Peak frequency deviation+Information signal bandwidth}\right\}$$

The basic idea of the experiment is quite simple. As in the previous sections the bandwidths of various FM signals are measured directly with the Tektronix, 5L4N Spectrum Analyzer. The FM signals are generated with a Hewlett-Packard, Model 33120A, 15 MHz Function/arbitrary waveform generator.

Measurements and observations:

For varying values of peak frequency deviation, measure the effective bandwidth of signals produced by frequency modulating a 45 kHz carrier signal with a 500 Hz sinusoid.

Report:

a. A plot of bandwidth v. peak frequency deviation.

b. A sample hard copy of the spectrum of a wideband signal.

c. Discussion of results.

4 Wideband commercial FM radio stations in the United States use a 75 kHz peak deviation and audio signals band-limited to 15 kHz to achieve 200 kHz channel-to-channel spacing from the net 180 kHz bandwidth.