14

Demonstration of Amplitude Modulation

In this lecture, we demonstrate many of the concepts and properties discussed and developed in several of the previous lectures. The demonstration centers around a number of signals displayed in both the time domain and the frequency domain using a signal generator, an oscilloscope to view the signal in the time domain, and a spectrum analyzer to view the signal in the frequency domain. The spectrum analyzer computes the spectrum digitally using a microprocessor. A segment of the time waveform is captured, digitized, and stored in a digital memory. A microprocessor then computes the Fourier transform for this segment. As the signal evolves in time, successive segments are captured and processed in this way. Consequently, the spectrum analyzer displays the Fourier transform of successive segments of the signal, so as the signal changes its characteristics and spectral content, these changes are reflected in the spectrum analyzer output. For example, with a sinusoidal signal the spectrum analyzer displays a narrow line at the frequency of the sinusoid. If this frequency is slowly changed, the location of the spectral line on the analyzer display shifts position accordingly.

Simultaneously looking at the signal and the spectrum analyzer output helps us to visually correlate properties and characteristics in the time domain and frequency domain. As one example of this, we return in this demonstration lecture to the Fourier transform property of time and frequency scaling. In a previous lecture we demonstrated this property with the glockenspiel, illustrating in particular that if we recorded a note and replayed it at half speed, it would sound an octave lower in frequency. With the equipment that we have available to us in this demonstration lecture, we can visually illustrate time and frequency scaling of the glockenspiel note.

One of the principal demonstrations in this lecture illustrates amplitude modulation with a modulator box. This box has an external input for the modulating signal and a choice of three carrier signals: sinusoidal, triangular, and square wave. By looking at the modulated signal in both the time domain and the frequency domain, we can observe in both domains the effect of changing the percent modulation, or equivalently the amount of carrier injected, and

the effects of changing the input frequency, the carrier frequency, and the carrier wave shape. In demonstrating amplitude modulation, we first use simple modulating waveforms from the signal generator. As a final demonstration, we examine the modulated and demodulated waveforms characteristic of an AM radio.
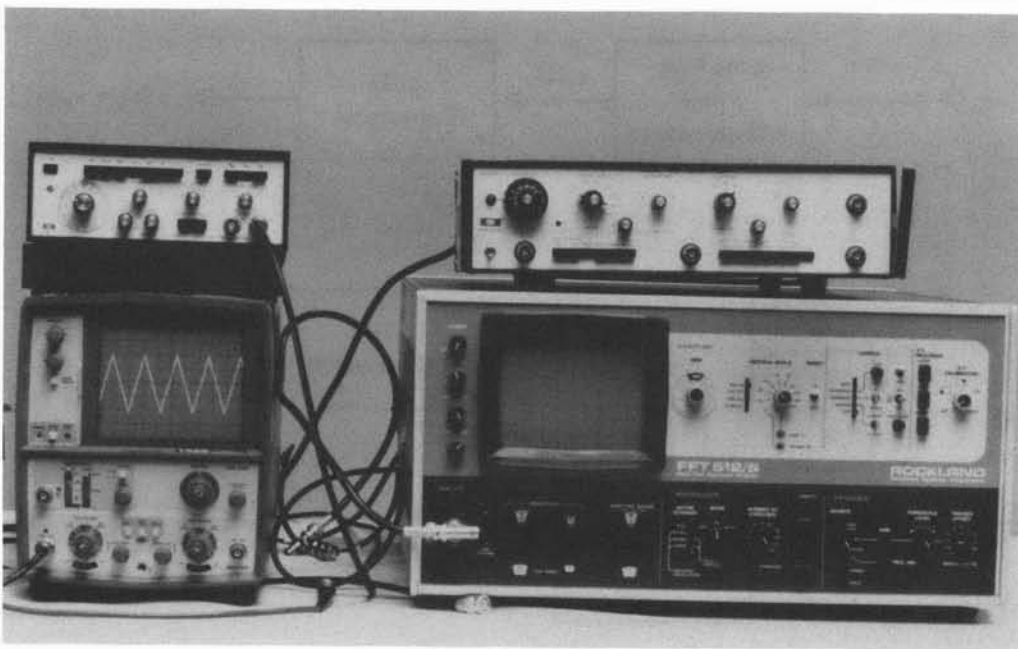
Suggested Reading

Review:

Section 4.6.5, Time and Frequency Scaling, pages 207–208

Section 7.1, Continuous-Time Sinusoidal Amplitude Modulation, pages 449–459

Section 7.2.2, Sinusoidal Amplitude Modulation for Communications: Frequency-Division Multiplexing, pages 461–464

Section 7.6, Continuous-Time Frequency Modulation, pages 479–487

DEMONSTRATION 14.1
Overall equipment configuration. Left: the signal generator and the oscilloscope for the display of time waveforms. Right: the modulator (top) and the Rockland Systems spectrum analyzer.
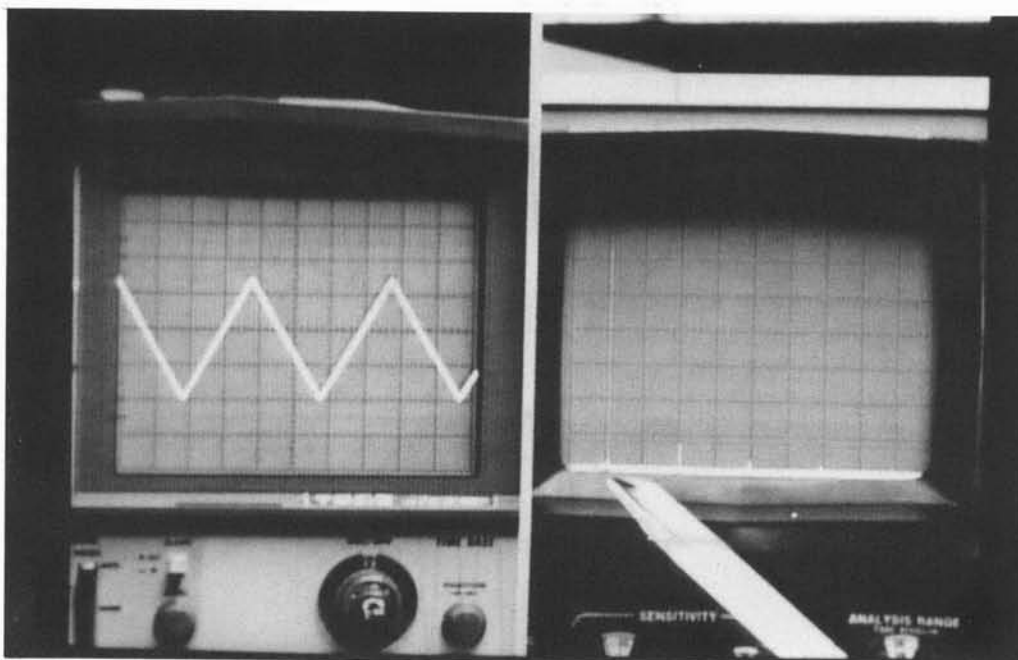
DEMONSTRATION 14.2
A triangular wave displayed in the time domain (left) and frequency domain (right).

**TRANSPARENCY
14.1**
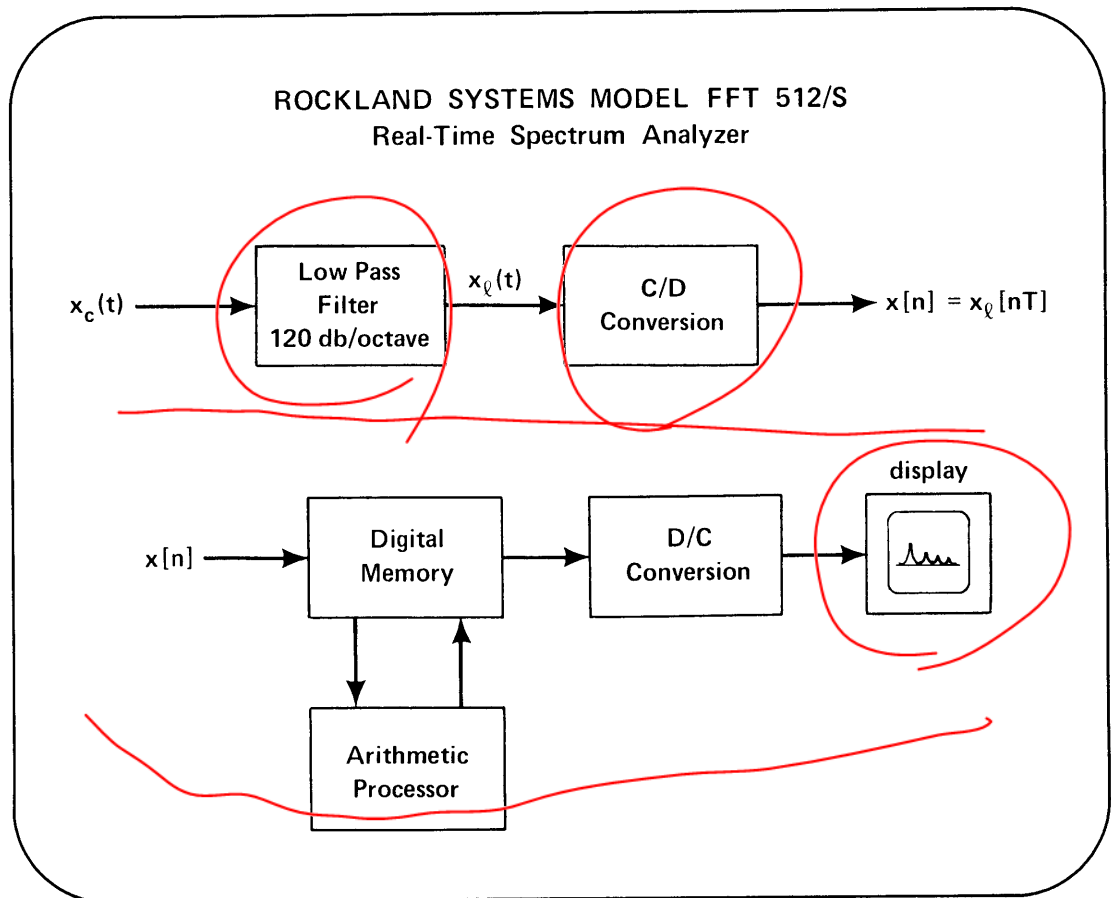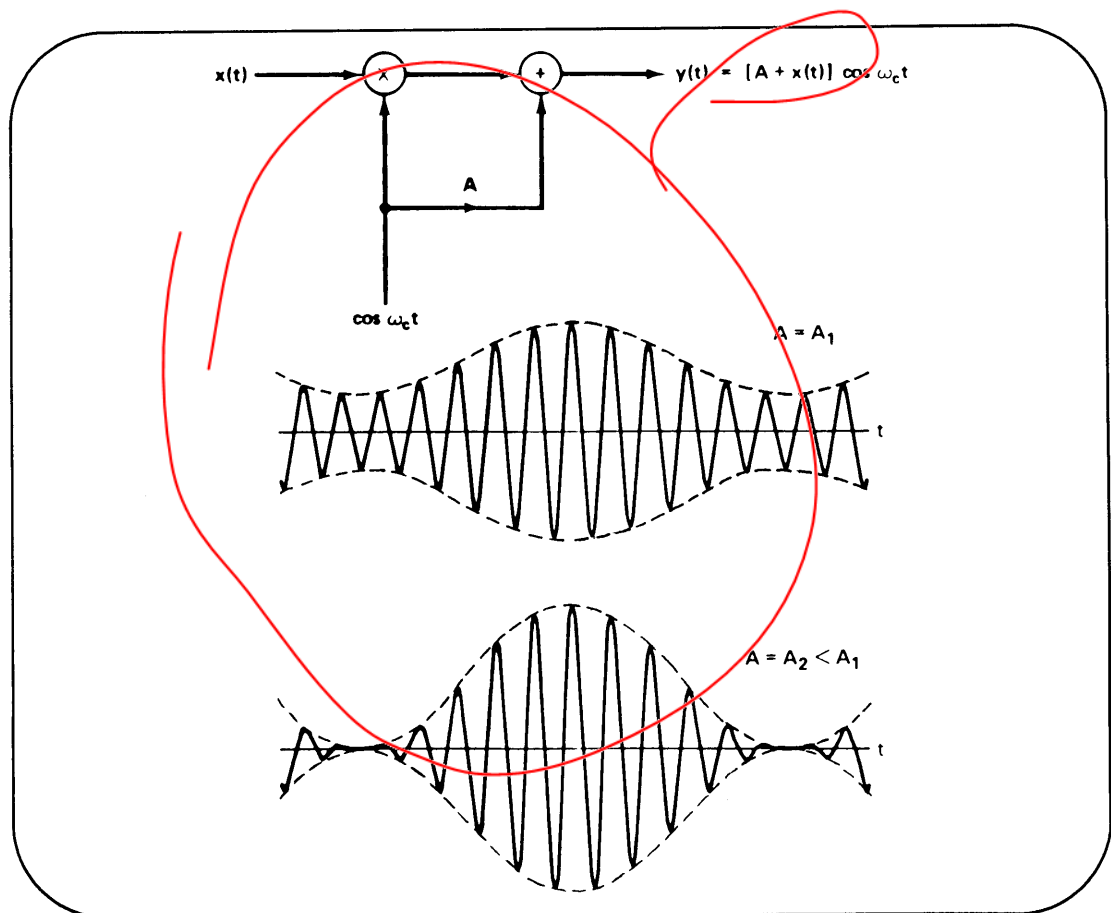Block diagram of
Rockland Systems
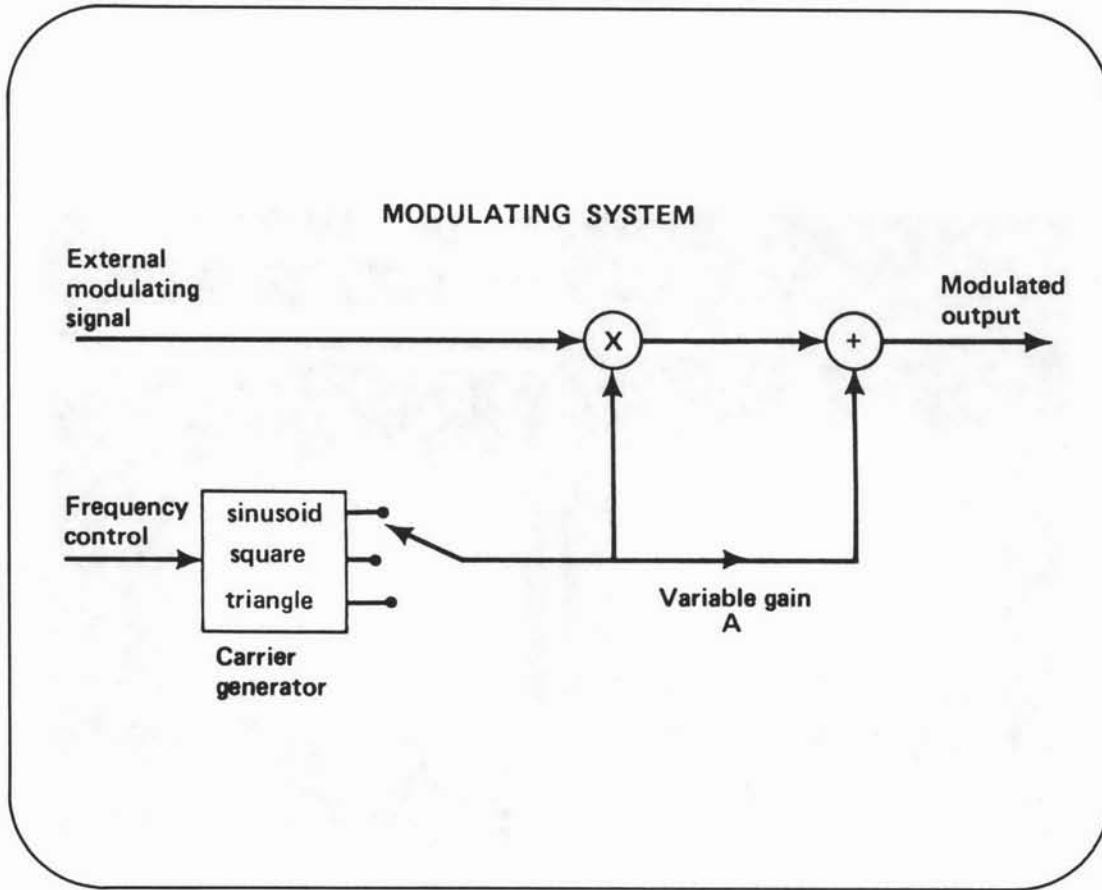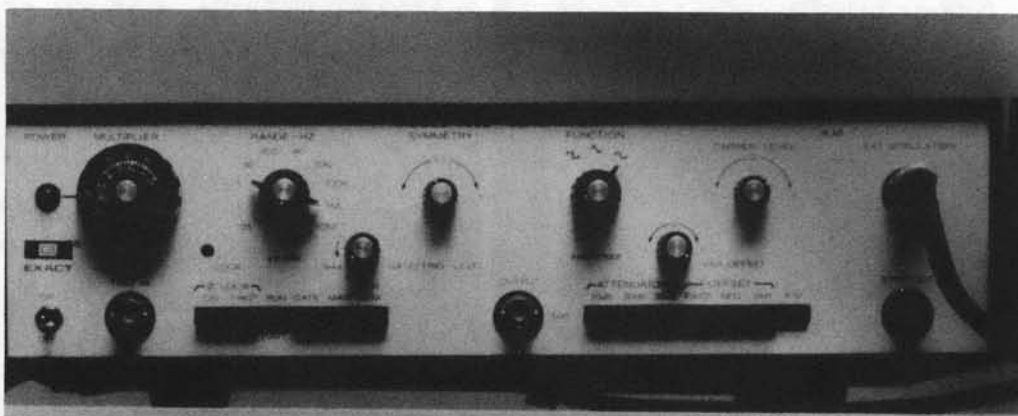Model FFT 512/S
spectrum analyzer.

ROCKLAND SYSTEMS MODEL FFT 512/S
Real-Time Spectrum Analyzer

$x_c(t) \longrightarrow$ Low Pass Filter 120 db/octave $\xrightarrow{x_\ell(t)}$ C/D Conversion $\longrightarrow x[n] = x_\ell[nT]$

$x[n] \longrightarrow$ Digital Memory $\longrightarrow$ D/C Conversion $\longrightarrow$ display

Arithmetic Processor

**TRANSPARENCY
14.2**
Illustration of
waveforms associated
with sinusoidal
amplitude modulation.

$x(t) \longrightarrow \times \longrightarrow + \longrightarrow y(t) = [A + x(t)] \cos \omega_c t$

A

$\cos \omega_c t$

$A = A_1$

t

$A = A_2 < A_1$

t

MODULATING SYSTEM

External
modulating
signal

Modulated
output

Frequency
control

sinusoid

square

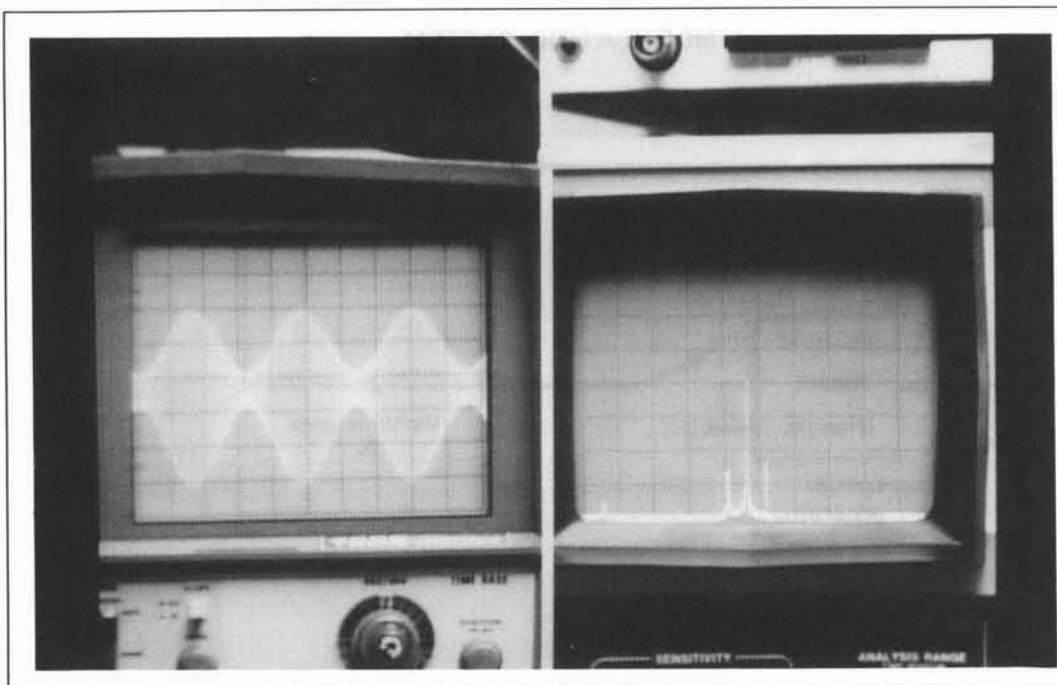triangle

Carrier
generator

Variable gain
A

DEMONSTRATION
14.3
Closeup of the
modulator control
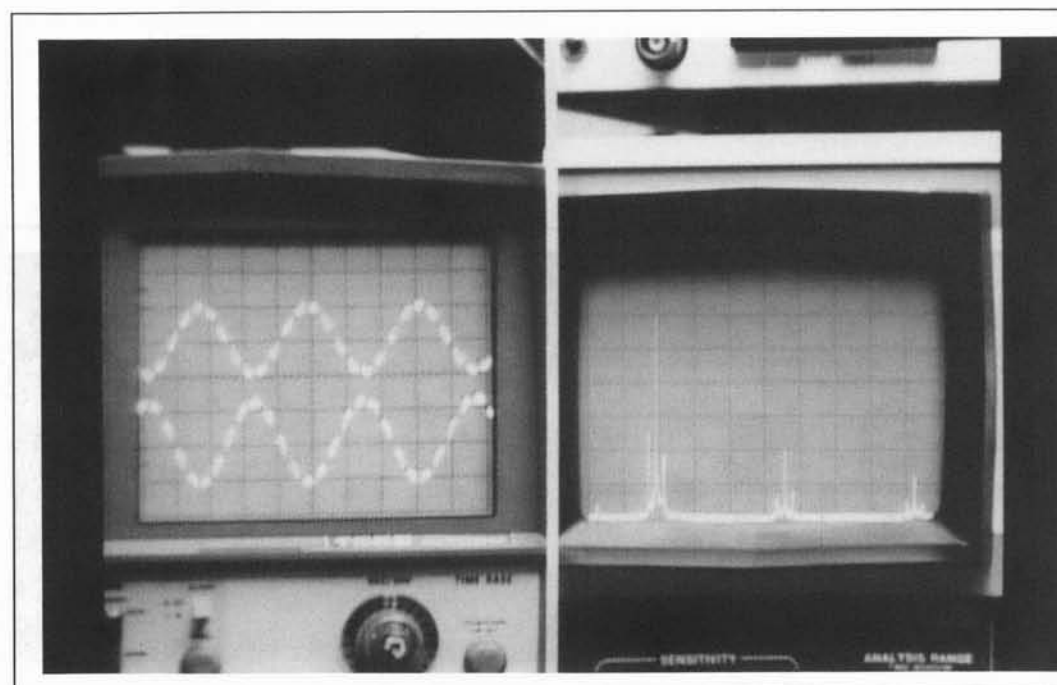panel.

DEMONSTRATION 14.4
Sinusoidal amplitude modulation with a sinusoidal carrier displayed in the time domain (left) and frequency domain (right).
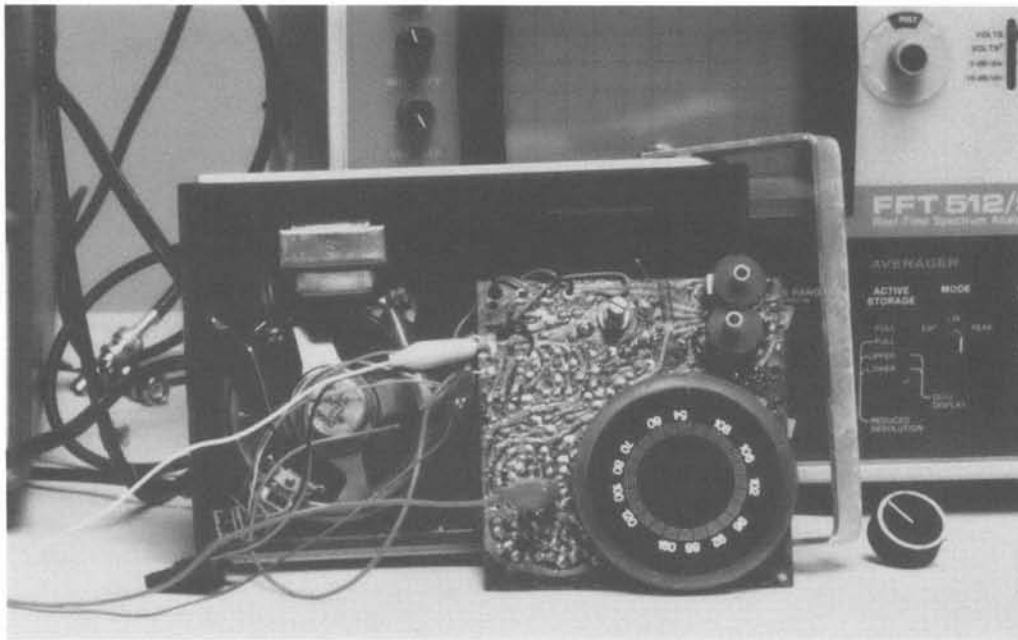

DEMONSTRATION 14.5
Sinusoidal amplitude modulation with a square-wave carrier displayed in the time domain (left) and frequency domain (right).

DEMONSTRATION 14.6
AM radio receiver.

MIT OpenCourseWare
http://ocw.mit.edu

Resource: Signals and Systems
Professor Alan V. Oppenheim

The following may not correspond to a particular course on MIT OpenCourseWare, but has been provided by the author as an individual learning resource.

For information about citing these materials or our Terms of Use, visit: http://ocw.mit.edu/terms.