The Lenkurt Demodulator

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The Versatile OSCILLOSCOPE

The cathode-ray oscilloscope, once limited to specialized laboratory applications, is finding increased use in the routine maintenance of communications equipment. The oscilloscope or its offspring may be many instruments in one, often permitting rapid, accurate measurements that would be cumbersome or less accurate with traditional methods. This article provides a brief description of the oscilloscope, and several of its applications in telecommunications.

In the early days of telephony, most maintenance and trouble-shooting was accomplished with such simple test instruments as test lamps, buzzers, headsets, and the like. The most complicated piece of test gear encountered in a toll office was likely to be the Wheatstone Bridge, used for locating faults in outside wire and cable plant.

Today's communications equipment is more demanding, requiring laboratory accuracy for many routine maintenance procedures. Certain kinds of signals have characteristics which cannot be measured accurately by the conventional test instruments long used in communications centers. This is particularly true of television, facsimile and most pulse transmission signals in which the waveform itself is all-important.

The cathode ray oscilloscope is actually a "pictorial voltmeter," displaying information about a signal in two dimensions. One dimension usually represents the amplitude or voltage of the signal, while the other can be time, frequency or some other variable. When time is the base, the oscilloscope graphically displays the signal waveform. If frequency is used as a base, the frequency response of a circuit or device under test is shown in a very convenient form.

By contrast, a conventional voltmeter provides only amplitude information, and that only when the signal has the proper waveform. The reason for this is that the voltmeter is a mechanical device in which the meter movement has mass and inertia. This limits the signal frequency which the movement can "follow." Accordingly, most are designed to indicate the average or "effective" value of the current passing through the instrument. This is the root-mean-square or rms value of the alternating signal, which, in the case of sine waves, is .707 times the peak voltage.

Since sound waves and other oscillatory signals usually consist of sine waves or complex combinations of sine waves, the scale of most conventional voltmeters are calibrated for sine waves. If the signal or power source does not provide a sine wave output, however, such instruments will provide erroneous readings.

The oscilloscope, on the other hand, has no "moving parts," but displays its information by the deflection of an electronic beam within the cathode-ray tube. When the beam strikes the coated screen of the tube, the electrical energy is converted to light, and is seen as a small luminous spot. When it is deflected rapidly across the screen, the moving spot gives the illusion of a continuous line or trace.

The electron beam in the cathode ray tube is under the control of two independent voltages applied to the vertical and horizontal deflection plates, respectively. Because the beam has no inertia, it is capable of sweeping from one point on the screen to another, at almost any speed, limited only by the electrical characteristics of the deflection amplifiers. Beam deflection is directly proportional to the voltage applied to the deflection plates, and this is determined by the gain of the deflection amplifiers. By varying the gain appropriately, it becomes possible to expand the presentation on the screen in either direction, and to calibrate the deflection in either direction against known voltage standards.

Wave Form Observation

An important use of the oscilloscope is in the analysis of wave forms, to facilitate in-service alignment or trouble-shooting procedures. However, it is necessary that the operator have a

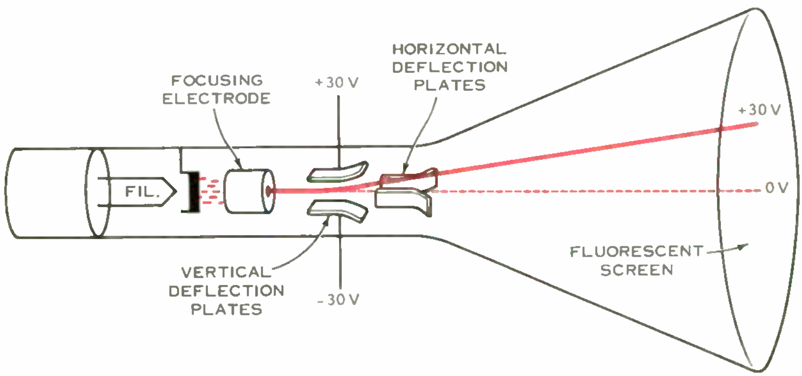

Figure 1. Inertia-free electron beam is deflected in direct proportion to voltage applied to horizontal and vertical deflection plates. Amplifiers raise small voltages to useful values. Accurate measurement of peak voltages is possible by calibrating deflection against known voltage standard.

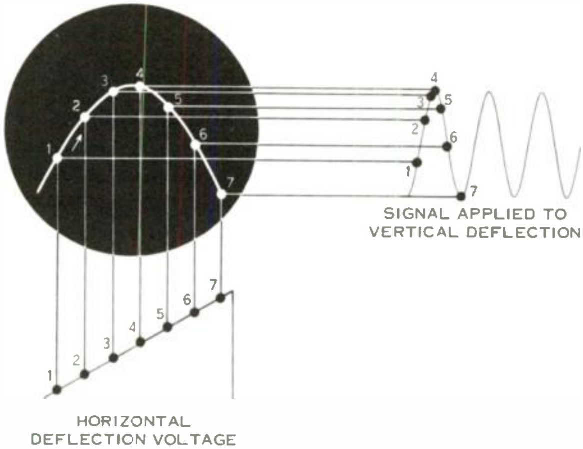

Figure 2. Linear horizontal sweep voltage deflects beam from right to left, permits expansion of waveform applied to vertical plates. When triggered by signal peaks, waveform on screen is stationary.

thorough knowledge of the correct operation of the equipment under test, in order to know what type of signal wave form to expect at various circuit stages. It is also necessary that the operator be familiar with the limitations of the oscilloscope he is using, since if for example, the bandwidth capabilities of the input amplifiers are exceeded, the oscilloscope cannot respond faithfully to the input signal.

When the oscilloscope is used for wave-form observations, the signal under test is applied to the vertical input, and a "sweep" voltage is applied to the horizontal input to drive

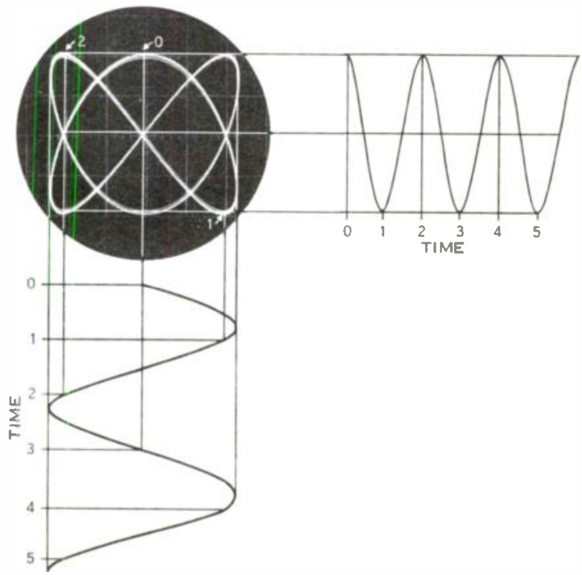

Figure 3. Typical Lissajous Figure resulting from two sine wave signals applied to horizontal and vertical plates. Figure is stationary when a fixed phase and frequency relationship exists between signals. Frequencies shown have a frequency relationship of 3:2, determined by counting "peaks" along horizontal and vertical edges.

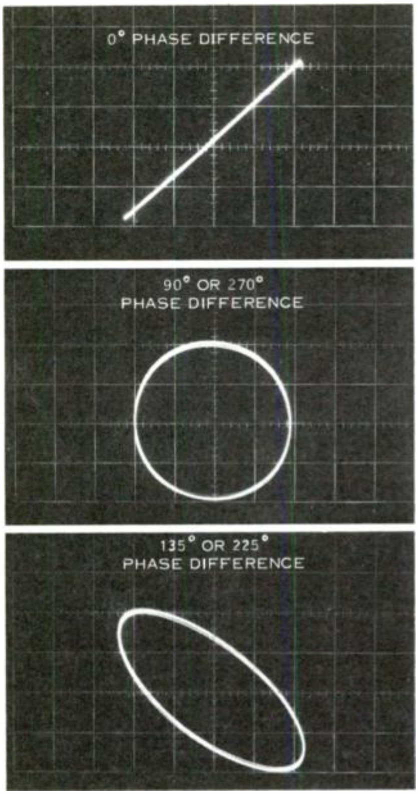

Figure 4. Lissajous Figures resulting when frequencies are equal but differ in phase. Top to bottom, phase differences are 0°, 90°, 135°.

the beam across the face of the tube at a constant speed for a known period of time. The horizontal sweep normally deflects the beam from left to right, and upon reaching the right edge of the tube screen, retraces and starts the next sweep from the left. It is generally calibrated in terms of the time required for a given distance or beam travel across the screen. Thus, the horizontal sweep is sometimes known as the *time base.*

The horizontal sweep is normally produced by a "sawtooth" generator, which is usually an integral part of the oscilloscope. The output from the sawtooth generator typically consists of a steadily rising voltage followed by an extremely rapid drop to zero. This rapid drop returns the beam to the left where it begins the next horizontal sweep. By varying the duration of the ascending portion of the sawtooth, it is possible to compress or expand the signal under observation. In the best oscilloscopes, special effort is made to keep the sweep voltage as uniform and linear with respect to time as possible, thus avoiding distortion of the displayed waveforms.

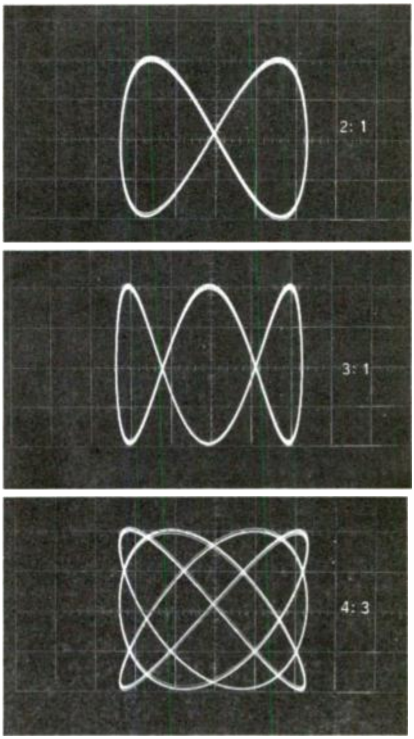

Figure 5. Lissajous Figures can be used to measure unknown frequency if signal generator output is applied to one set of deflection plates, adjusted to obtain stationary pattern. Frequency ratios shown are, top to bottom, 2:1, 3:1, 4:3.

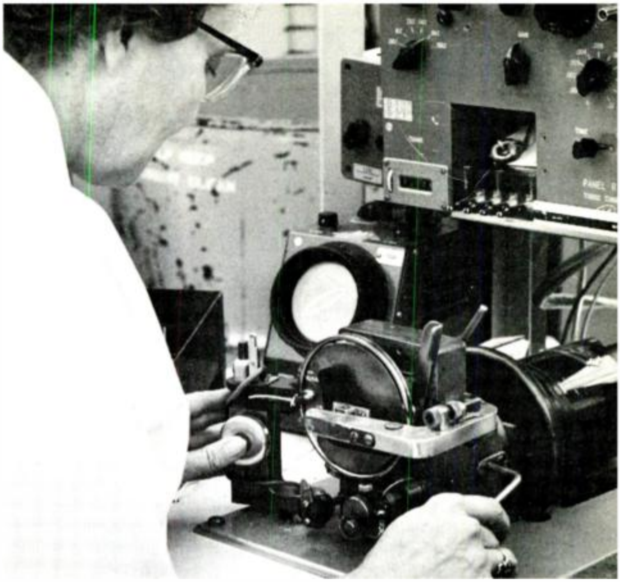

Figure 6. Oscilloscope helps achieve precise inductance value in manufacture of toroidal inductors at Lenkurt. Inductive phase shift from toroid being wound is compared with that from standard inductor (on shelf). When straight line appears on oscilloscope screen, inductances are equal.

Lissajous Figures

The horizontal and vertical deflections are entirely independent of each other, thus making it possible to compare the phase and frequency of two signals by applying each to one of the deflection inputs of the oscilloscope. The resulting pattern displayed on the face of the cathode ray tube, called a "Lissajous Figure," takes on certain characteristic forms when the two signals bear certain relationships to each other. For instance, if the two signals are sinusoidal and of exactly the same frequency, phase and amplitude, the interaction of the two deflecting signals on the beam will result in a straight, diagonal line appearing on the screen, as indicated in Figure 4(A). If the deflecting signals are of the same frequency, but out of phase, an elliptical or circular pattern will be created, depending on the phase difference. Other typical patterns are shown in Figures 3 and 5.

An unknown frequency can be identified by applying it to one input of an oscilloscope and connecting a variable signal generator to the other. The known frequency is varied until a stable pattern is obtained, and the frequency ratio between the two signals determined by counting the vertical and horizontal "peaks" of the resulting Lissajous figure. This technique can be used to tune or calibrate oscillators, carrier or pilot frequency generators, or identifying unwanted parasitic frequencies in a circuit.

Specialization

The overall versatility and usefulness of the oscilloscope makes it one of the most valuable test instruments obtainable. Many tests—frequency response, for instance—are extremely time consuming when performed in conventional ways. To help overcome this situation, many modifications of the basic oscilloscope have evolved to increase its utility for particular applications, and to permit specialized tests to be made faster and more accurately.

One such oscilloscope provides two separate traces, each with its own input, thus permitting a simultaneous comparison of two waves. Thus, it is possible to compare the input and output waveforms of an amplifier, filter, or other device, and to check such characteristics as phase shift, distortion, and gain. This may be accomplished by using two or more electron guns in the same cathode ray tube, or by a switch that transfers each signal, alternately, to the oscilloscope vertical deflection input. Manual switching may be used, but electronic switching permits simultaneous viewing and comparison of the two signals, due to the persistence of the trace on the tube screen. These instruments, known as dual-beam and dual-trace oscilloscopes, respectively, have separate controls on each channel, which permit independent adjustment of amplitude and zero reference point for each. Thus, both signals can be placed one above the other, vertically, to permit waveform comparison.

Another interesting offshoot of the oscilloscope is the Level Tracer, shown in Figure 7, a transmission measuring set for voice-frequency lines. Using a built-in oscilloscope as a readout device, the instrument permits direct display of the amplitude response, impedance, and return loss of a circuit, as a function of frequency.

The instrument is a development of the traditional transmission-measuring technique where a test tone is transmitted at a constant level at different frequencies over the pass-band of the line. The level of the received signal can then be measured with a voltmeter, and the results recorded. If a sufficient number of measurements are made in this manner, it is possible to create a graph showing the frequency response of the line. This is, of course, very time consuming.

The Level Tracer performs these transmission line tests automatically by sweeping the transmitted frequency through the voice frequency pass-band, and the measured result is displayed as a function of frequency versus amplitude on the face of a cathode-ray tube. A motor-driven variable-frequency oscillator sweeps the v-f band from 200 to 4000 cps, delivering a constant signal level to the line. The receiving section consists of a detector-amplifier the output of which appears on the cathode-ray tube as vertical deflection. Horizontal deflection is under the control of the variable-frequency oscillator in the transmitting section. A fairly fast sweep rate plus the relatively long image persistance factor permits the entire response characteristic to be viewed.

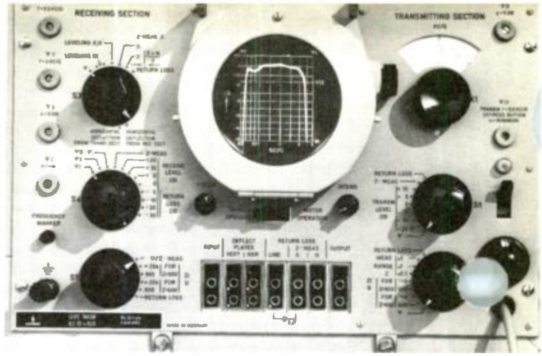

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Figure 7. "Level Tracer," an offshoot from the oscilloscope, speeds up many kinds of tests. Circuit frequency response is shown.

The instrument has proven valuable in performing cable and wire circuit acceptance tests. Although the Level Tracer is designed for voice-frequency circuits, similar instruments are available which operate at carrier frequencies.

It would be a mistake to regard the oscilloscope as a revolutionary instrument which makes obsolete existing maintenance procedures and equipment. In reality, it and its relatives are versatile instruments that supplement older methods, often permitting faster testing. As television and pulse transmission become more common, the oscilloscope can be expected to assume a position of primary importance among test equipment. •

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