A New 8-12 KMC Voltage-Tuned Sweep Oscillator For Faster Microwave Evaluations

ONE of the tools that has been needed in the microwave region has been a flexible sweep oscillator. In addition to conventional uses, such an oscillator, when combined with the proper external components, has special value in the microwave region in that it permits rapid wide-range evaluations to be made not only of reflection but of gain, attenuation, and other network transfer characteristics as well.

The new -hp- 8.2 - 12.4 kmc sweep oscillator shown in Fig. 1 has been designed for such applications and to that end provides any amount of sweep width up to 4.2 kmc at a wide range of sweep rates. A special feature of the sweep is that it is linear over the entire 8.2 - 12.4 kmc band. Output power is relatively high — a specified minimum of 10 milliwatts over the complete range — so as to be suitable for measurement work. The flexible sweep width and rates are obtained by use of a backward wave oscillator tube, a tube that has the substantial advantage of being voltage tuned. Use of this tube also permits the instrument to be capable of both amplitude and frequency modulation. These modulation capabilities further make the instrument suitable for forming into a general-purpose swept or non-swept signal generator by use of an external calibrated attenuator.

The flexibility of the new oscillator is indicated in detail by the controls provided on the panel (Fig. 1). The main frequency dial is a large six-inch dial which is accurate within a few percent. An 8:1 rim drive vernier is provided for fine frequency adjustment.

The sweep controls are located at the upper right of the panel. The upper control adjusts the sweep *rate* (i.e., rate of change of r-f frequency) in five decade steps from a minimum rate of 40 megacycles/second* to a maximum of 400 kilomegacycles/second. This range thus includes rates that are slow enough (1 sweep

*i.e., a change in one second of 40 megacycles.

Fig. 1. New -hp- Model 686A voltage-tuned sweep oscillator provides c-w, f-m, a-m and swept outputs over 8.2 - 12.4 kmc range. Sweep widths as wide as full band can be selected at a wide range of rates to suit measurement conditions.
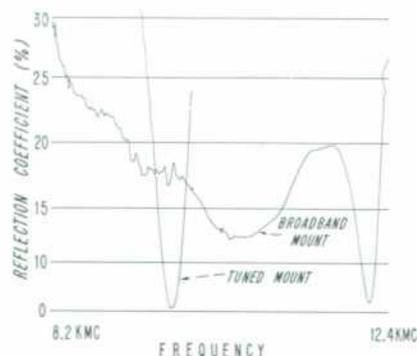

Fig. 2. Record of reflection coefficient magnitude of broadband and tuned bolometer mount. Such permanent records can be made in a minute or two using new sweep oscillator with system described in text.

per 100 seconds) for high measurement resolution on even the most selective systems and rates that are high enough (100 sweeps per second) to provide excellent oscilloscope displays, as will be described later.

The lower sweep control is a two-part control of which the outer selects in seven steps frequency deviations from 3 mc to 4.2 kmc. The inner control enables any deviation between the fixed steps to be obtained. Deviation occurs from the indicated main dial frequency to-

ward a lower frequency and is essentially linear, an important convenience for measurement work. The linear sweep has been obtained by deriving the sweep voltage from an exponential RC discharge curve which matches the exponential character of the BWO voltage vs frequency curve.

The *Sweep Selector* switch at the lower right of the panel provides for either recurrent or triggered sweeping. Triggered operation can occur either from a signal applied to a panel connector or from a manually-operated panel push switch. In all cases a sweep out sawtooth is provided for horizontal deflection of an oscilloscope or X - Y recorder. External triggering will occur from an external positive signal of 10 volts minimum amplitude.

External sweeping is accomplished by applying a suitable voltage to the BWO helix via the panel *Helix Mod.* terminal. This voltage can be a sawtooth, triangular wave, sinusoid or other desired wave. The modulation characteristic ranges from about 0.2 volt/megacyle at the low frequency end of the range to about 0.5 volt/megacyle at the high frequency end.

The *Anode Mod. Selector* control is provided to permit a variety of types of amplitude modulation to be obtained. In the *Int.* position the oscillator is square-wave modulated at a rate which can be varied from 400 to 1200 cps by the control which
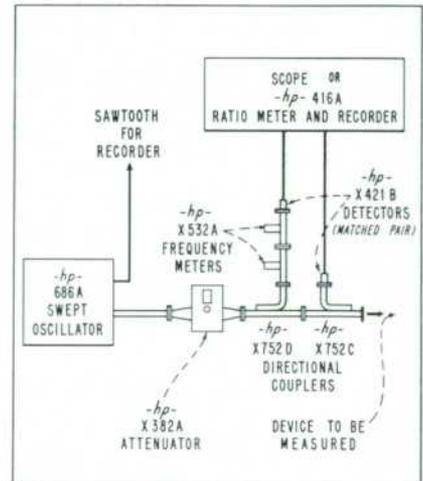

Fig. 4. *Equipment arrangement for measuring reflection coefficient magnitude in either permanent form or as viewed on meter or oscillator trace. Wavemeters in incident arms are used to insert marker pips at desired points.*

is concentric with the switch knob. In the *Pulse* position the r-f is biased off and can be turned on by a positive pulse of 10 volts minimum amplitude. In the *Ext.* position the r-f level is the same as the normal c-w level so that the circuit is prepared to be amplitude-modulated by external sine or other common waves. A voltage change of —20 volts reduces the r-f from rated level to zero.

Controls and a metering system are provided at the left of the panel for monitoring the magnet and electrode currents in the tube. Normally no adjustment of these is necessary.

SWEPT POWER RATIO METERS

As suggested earlier, one of the valuable uses for a microwave sweep oscillator lies in its ability to permit rapid measurements of microwave device performance over a range of frequencies. The use that usually comes to mind is the measurement of reflection* or VSWR with a reflectometer, but often overlooked is the fact that a reflectometer or ratio meter is equally valuable for measuring attenuation, gain, and other network transfer characteristics over a wide range and in rapid fashion. The ratio meter system is also ideal for measuring the magnitude of scattering matrix coefficients when it is
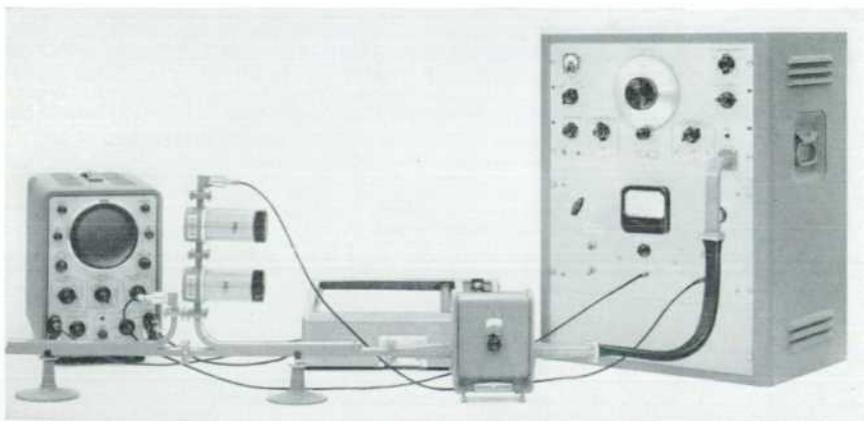

Fig. 3. *Complete setup for measuring magnitudes of reflection coefficient and transfer characteristics either in permanent record form or as viewed on scope.*

*J. K. Hunton and N. L. Pappas, *The -hp- Microwave Reflectometers*, Hewlett-Packard Journal, Vol. 6, No. 1-2, Sept.-Oct., 1954.
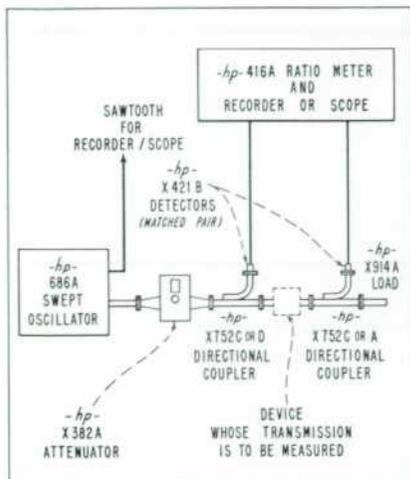
Fig. 5. *Equipment arrangement for measuring attenuation, gain, isolation or other transfer characteristics.*

desired that a transmission-line network be described in terms of such coefficients.

Figs. 4 and 5 show typical measuring setups for measuring these parameters with power ratio measuring systems which are formed from basic reflectometer components. In these setups a small sample of the incident modulated power from the oscillator is split off by a wide-range directional coupler and applied to one of a pair of matched crystal detectors. The detector output is then applied to one input of either the ratio meter or oscilloscope, as described later.

The main portion of the incident power continues down the main guide and is applied to the device under test. If reflection coefficient is being measured, a second directional coupler is inserted ahead of the measured device to return a sample of the reflected power to the second input of the ratio meter or oscilloscope. If attenuation or gain is being measured, the second directional coupler and detector are connected at the output of the device. The ratio meter or oscilloscope then displays the ratio of the two powers directly, either in terms of reflection coefficient or in power ratio in db. When the oscillator is swept, then, a continuous indication of the quantity being measured will be displayed.

GO-NO GO AND PERMANENT RECORD DISPLAYS

The wide range of sweep rates provided on the new sweep oscillator makes it easy to display component performance in either of two forms. One form is a rapid go-no go oscilloscope indication suitable for routine measurements by non-engineering production personnel. The second form is a permanent-record type display obtainable with an X - Y recorder. This type of display is valuable in design work since it gives a record for analysis, but it is also valuable in many production applications where a permanent record is desired. Permanent-record displays are also simple and can easily be made by non-engineering personnel.

Rapid oscilloscope displays are obtained merely by connecting the output of the incident wave detector to the X system of the oscilloscope and by connecting the output of the remaining detector to the Y system. The oscilloscope display will then be a trace (Fig. 7) which at
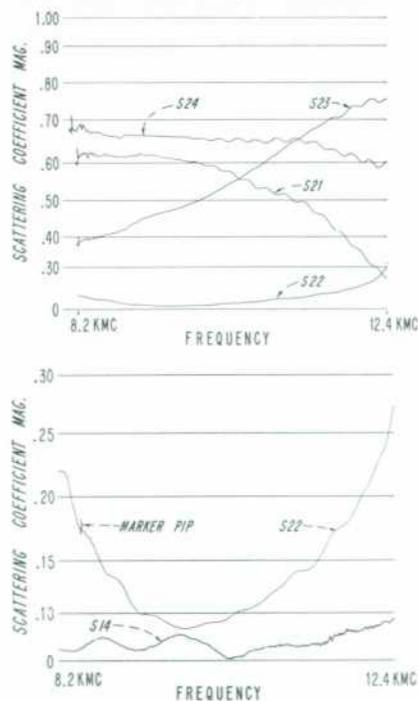

Fig. 6. *Records made of magnitude of scattering coefficients of hybrid-tee using arrangements of Figs. 4 and 5. Arms 1 and 4 are H and E arms, respectively, 2 and 3 the side arms. Such records can be made in only a few minutes. Marker pips are from wavemeters and can be used to define frequency ranges of special interest.*

The helix type of backward wave tube used in the Model 686A is a form of traveling-wave tube which is designed with emphasis on its ability to serve as a microwave oscillator. In general appearance the helix type BWO and the TWT are much alike. Each consists basically of an electron gun, a metallic helix through which the electron beam passes axially, and a collector electrode. An external axial magnetic field is used to
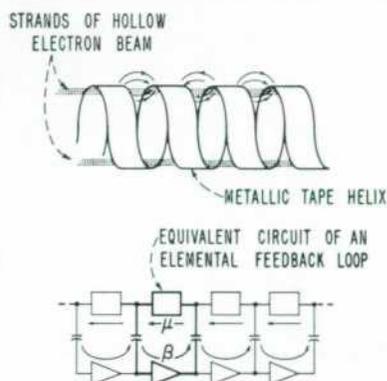
preserve beam focus throughout the tube. In each tube the beam becomes velocity modulated or bunched as it travels through the helix and this bunched beam then transfers energy to the helix wave. In a TWT this energy transfer is primarily to a forward-traveling helix wave, while in the BWO the energy transfer is primarily to a backward-traveling helix wave. This backward wave then transfers energy back to the electron beam in the form of velocity modulation and the tube oscillates.

The reason that a BWO enhances the backward helix wave while a TWT does not is that in a BWO the helix is designed to introduce a periodicity into the axial electric field that any strand of the electron beam (which is made hollow in the BWO) sees as it passes down the tube. This periodic axial field can be resolved into space harmonics or wave components traveling in both directions parallel to the helix axis. The electron beam velocity in the BWO is then made such that it travels in step with one of the components in its direction and periodically reinforces it at the frequency of oscillation. Since this synchronous wave is only a component of the fundamental which rotates backward along the helix, however, the fundamental is the wave that is actually enhanced by the energy transferred from the beam. In practice, some slip occurs between the bunched beam and the synchronous wave component so that maximum energy transfer exists.
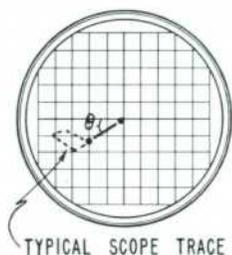
↳ TYPICAL SCOPE TRACE

Fig. 7. *Representation of typical trace obtained when measuring reflection coefficient magnitude with the setup of Fig. 4. Angle formed with the horizontal by projection of left point of trace thru origin is proportional to reflection coefficient. Position of left point typically varies with frequency because ρ varies. Mask or line drawn on tube face with grease pencil can be used to mark a limit for production acceptance tests.*

every point will form with the horizontal axis an angle whose tangent is $10\, E_{2nd\ detector}/E_{1st\ detector}$*. The display is thus related to reflection coefficient, gain, attenuation, or other characteristic under investigation. For go-no go production work, then, all that is required in determining whether or not a device is within established limits is to draw on the

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*This assumes that a 20 db forward coupler and a 10 db reverse coupler are being used. If equal value couplers are being used, the factor 10 will become unity.

SPECIFICATIONS
-hp-
MODEL 686A
SWEEP OSCILLATOR

R-F
  Frequency Range: 8.2 to 12.4 kilomegacycles
  Power Output: At least 10 milliwatts into matched waveguide load. Continuously adjustable to zero by cathode current control.
  Output Impedance: VSWR less than 2:1
  Output Connector: X-Band Waveguide cover flange

SWEEP
  Characteristics: RF Frequency change linear with respect to time and downward from frequency dial setting.
  Triggering: Recurrent; external; or manual.
  Sweep Width: 3 MC to 4.2 KMC in seven steps. Vernier permits continuous adjustment between steps.
  Sweep Rate: 40 MC/sec. to 400 KMC/sec. in decade steps.
  Sweep Time: 0.0105 to 105 seconds for full band sweep.
  Sweep Output: 30 volt peak sawtooth generated during frequency sweep. Available at panel connector.

MODULATION
  Internal: 400-1200 cps square-wave amplitude modulation; peak power equal to c-w level.
  External: Amplitude (anode modulation); thru d-c to 300 KC input change will reduce level from rated output to zero.
    Frequency (helix modulation); panel connector capacitively coupled to helix voltage supply.

GENERAL
  Power Requirements: 115 volts 50/60 cps; approx. 375 watts.
  Dimensions: Cabinet mount: 12½"h x 19⅝"w x 17¼"d; rack mount: 10½"h x 19"w x 17"d.
  Price: -hp- Model 686A (cabinet mount) $2265.00; Model 686AR (rack mount) $2250.00. Prices f.o.b. Palo Alto, California.
  Data subject to change without notice.

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oscilloscope face a line that corresponds to the maximum reflection or other value that can be allowed. By observing the oscilloscope while the oscillator is sweeping, the performance of the device under test with respect to established limits can be quickly determined.

Performance records in permanent form can quickly be made over the full 8.2 - 12.4 kmc range by using the combination of the -hp- 416A Ratio Meter with an X - Y or strip recorder. For this work the slowest sweep of the oscillator is used so that even the fastest change in device response will be substantially slower than the response time of either the recorder or the ratio meter.

MARKER PIPS IN RATIO MEASUREMENTS

Often when making measurements such as those described above it is desirable to have marker pips of accurately known and adjustable frequency for reference purposes. These markers can easily be obtained by inserting two wave meters in the incident arm of the ratio meter, as indicated in Fig. 4. Using the -hp-X530A or X532A wave-meters, each of these markers can be set to occur anywhere within the 8.2 - 12.4 kmc range and are known accurately within ±0.1% or better. Fig. 6 shows how the marker pips appear on a typical recorded measurement.

CONSTANCY OF OUTPUT POWER

Provision is made in the instrument for stabilizing the output power by external means, although for ratio meter use this is unnecessary since output power variations are rated as being not more than 3 db over any 250 mc range and not more than 6 db over the full 8.2 - 12.4 kmc range. Stabilization involves a flat-response sampling detector, and a high-gain amplifier.

Where stabilization is desired, it can be applied to the modulating electrode (anode) which is brought out to a panel terminal through a direct-coupled isolating amplifier.

The terminal has a characteristic such that approximately —0.5 db change in r-f output is obtained per volt change at the terminal.

— *P. D. Lacy and Daniel E. Wheeler*

BWO'S (Cont'd from P. 3)

An analogy that describes how reinforcement of the backward wave occurs is indicated in the accompanying illustration. Represented therein are several turns of the helix tape together with an axial filamentary strand of the electron beam. Between turns of the helix there exists an axial electric field component of the helix wave which acts on the electron beam. Underneath the helix tape, this field is much weaker than between the turns since an electric field cannot exist parallel to the surface of a conductor. As the beam travels down the tube, then, it is exposed to the helix wave field periodically rather than continuously.

This configuration can be considered to be equivalent to the feedback system shown in the lower part of the illustration. In this illustration the coupling capacitors permit the interaction that occurs between the between-turns E_z fields and the electron beam. The unilateral amplifier in the β-circuit represents the gain in a short length of the electron beam, and the transmission line section represents the path that the fundamental helix wave must follow backward along one turn of the helix. Thus, at some frequency the phase shift (electron transit time) in the β-circuit (electron beam) plus that in the μ-circuit will make the section regenerative so that it provides more energy for the next section to the left than was received from the preceding section at the right. At the same time this energy produces at the left the bunching of the beam which is necessary to reinforce the wave at the next section to the right. When sufficient gain (electron beam density) exists in the β-circuit, the chain of sections will then oscillate.

It should be noted that the configuration shown can merely be considered to be one increment of a continuous action that extends completely around each turn of the helix and throughout the full length of the helix. It should further be noted that by changing the electron beam velocity the oscillation frequency of the tube is changed. The tubes are thus voltage tunable.

The advantages of BWO's lie in the fact that they can operate over a wide microwave frequency range and that their voltage tuning feature enables them to be swept and frequency modulated. They can also be amplitude-modulated by means of an electrode (anode) in the gun. The tubes thus offer a high order of flexibility and are free of many of the limitations of mechanically swept systems and klystrons.