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A 3800-7600 MC Signal Generator Using A Parallel-Plane Type Resonator

ONE of the basic equipments necessary to development work in any frequency range is a signal generator. Being basic, any new signal generator must be carefully designed and its design is always interesting to the engineer working with the particular frequencies generated by the source.

-hp- policy with regard to measuring equipment has consistently been to provide in such equipment the advantages of high accuracy, broad frequency ranges, direct-reading controls, and other general convenience of operation. This policy has been especially apparent in the -hp- line of UHF instruments which, in general, have all covered broad bands and have read directly in frequency and power as contrasted with the use of charts and graphs.

These same features are included in the new -hp- Model 618A 3800-7600 megacycle signal generator. The frequency dial reads directly in megacycles to an accuracy of within ½ of 1%, while the power output control reads directly in power to an accuracy of within 2 db. One milliwatt of power is available at all frequencies and is adjustable down to at least —107 dbm or 1 microvolt by means of the direct-reading output attenuator. The instrument provides either cw or square-wave modulated output. Square-wave modulation can be obtained at frequencies from 400 to 1000 cps by means of an internal square wave generator. In addition to internal modulation, the oscillator can be modulated by external pulses as short as approximately 0.5 microsecond or by external sine-wave voltages to give fm modulation.

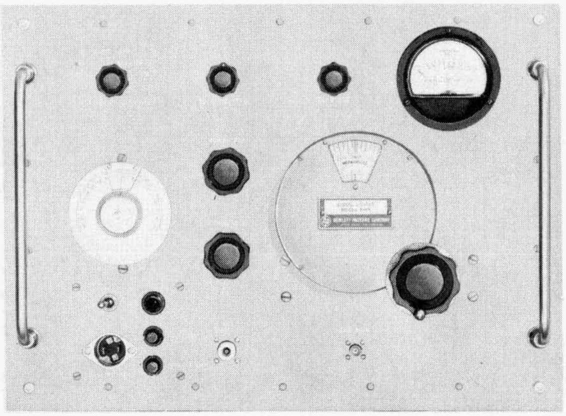

Figure 1. *Panel view of -hp- Model 618A 3800-7600 Mc Signal Generator.*

A feature of special interest in the design of the Model 618A is the adaptation of the parallel-plane type transmission line[1] to an oscillator circuit. The parallel-plane line was originally developed for use in slotted line measurements to provide a section having high accuracy and an unusual degree of mechanical rigidity. For the frequencies at which the Model 618A operates, the parallel-plane configuration is especially suitable because of the relative ease of avoiding the parasitic resonances that occur when physical dimensions approach electrical dimensions.

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[1] W. B. Wholey and W. N. Eldred, *A New Type of Slotted Line Section*, Proceedings of the I.R.E., Vol. 38, No. 3, March, 1950.

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PARALLEL-PLANE OSCILLATOR

Low-power oscillators that operate at ultra-high frequencies in general consist of a reflex klystron and a shorted coaxial resonator. The latter is ordinarily a section of rigid coaxial line of circular cross-section with an adjustable shorting element that tunes the resonator. In the 3800-7600 mc range where the new signal source operates, the physical size of any practical resonator must necessarily be small. For example, a resonator for use in the 3800-7600 mc range varies in inside physical length from approximately 6 cm at the lowest frequency to approximately 3 cm at the highest frequency. Such small size leads to difficulties in incorporating suitable internal devices to suppress the undesired oscillations and parasitics that can occur in a wide-band cavity-resonator type oscillator. External suppressors can be coupled into the resonator, but such devices are usually effective only over a narrow frequency band, whereas wide-band suppressors are usually required.

An examination of the recently-developed parallel-plane transmission line indicated that this line offered advantages when adapted for use as a resonator in the 3800-7600 mc range. For one thing, the circumferential parasitic resonances that can occur in nearly any phase around the periphery of the circular tuning element in a circular coaxial resonator are confined to definite phases around the periphery of the rectangular plunger of a parallel-plane resonator. Since their phase is confined, such parasitics become susceptible to control. As a matter of fact, it appeared and later proved to be practical to use peripheral plunger resonances in such a way as to damp out higher-order tube oscillations of an undesired nature. Such an arrangement is a two-fold advantage in that neither peripheral suppressors nor higher-order suppressors are required, since an undesired parasitic resonance damps out an undesired resonator oscillation.

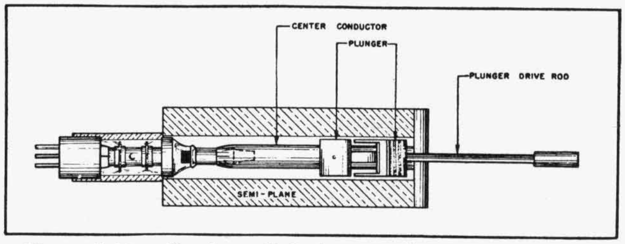

Figure 2. *Details of parallel-plane oscillator. An RK 5721 reflex klystron is used.*

Figure 2 shows the physical configuration of the parallel-plane oscillator, and Figure 3 the resonator itself in cross-section. The parallel-plane resonator is made electrically equivalent to a circular coaxial line through use of the conformal transformation w = tan z. Thus, each of the parallel semi-planes is equivalent to one half of the outer conductor of a conventional coaxial line.

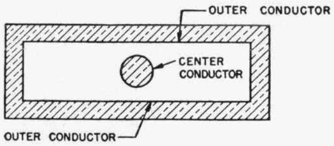

Figure 3. *Cross-section of parallel-plane resonator.*

PLUNGER RESONANCES

The plunger used in the parallel-plane resonator of the Model 618A is a non-contacting type and therefore leaves a small gap between the periphery of the plunger and the inside surfaces of the outer conductor, as illustrated in Figure 4. This gap with its two flat conductors acts as a transmission line and, in the frequency range of the Model 618A, has a two-cycle and a four-cycle resonance; that is, the gap resonates at frequencies corresponding to one-half and one-fourth of the electrical length of the periphery of the plunger. These resonances are illustrated in Figure 4, where one-half of the peripheral transmission line is drawn as if it were unfolded. The methods used to control plunger resonances are described later.

A similar gap exists between the center conductor and the plunger. However, no resonances occur in the frequency range of the Model 618A in this inner gap.

OSCILLATOR FREQUENCY PLOT

A frequency plot of the parallel-plane oscillator, when uncompensated, shows that four resonances exist or are likely to exist throughout portions of the frequency band. This situation is indicated in the tuning plot of Figure 5. First, the two plunger resonances occur at approximately 3500 and 7000 megacycles, their frequencies being unaffected by the position of the plunger in the resonator. The effect of these parasitic resonances is to absorb power whenever the oscillator is tuned to their approximate frequency, usually damping out the desired oscillation and causing a "hole" in the tuning range.

The upper sloping line in Figure 5 is a plot of the desired oscillations. At the long wavelength end of the band, the repeller of the klystron is operated in the $1\frac{3}{4}$ mode. At the point indicated by the note in Figure

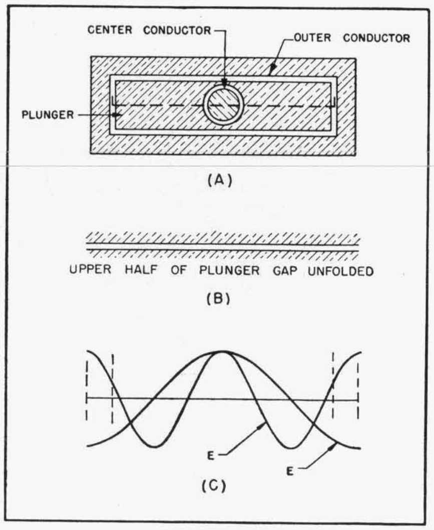

Figure 4. *Cross-section of parallel-plane resonator showing plunger gap and peripheral resonances.*

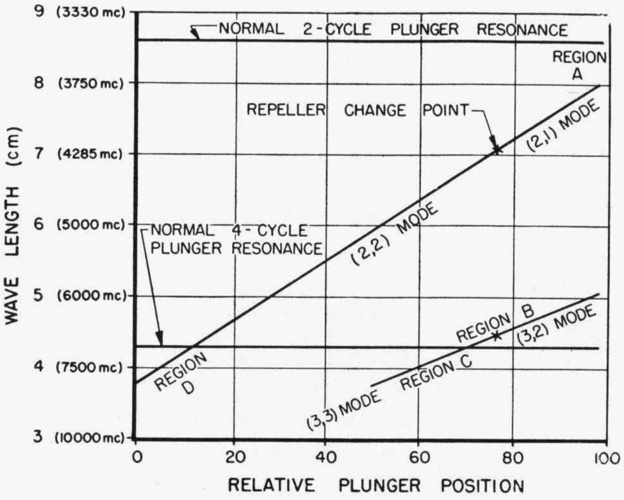

Figure 5. *Frequency plot of uncompensated parallel-plane oscillator.*

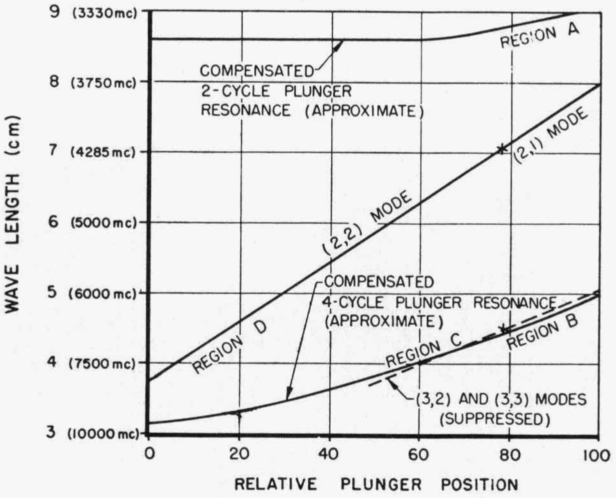

Figure 7. *Frequency plot of compensated parallel-plane oscillator.*

5, the repeller mode is changed to the $2\frac{3}{4}$ mode and in this mode operated down to the short wavelength end of the band.

The lower sloping line in Figure 5 is a plot of interfering modes of oscillation. The interfering modes are higher-order modes that track with the desired mode throughout the tuning range. This condition is further illustrated in the partial mode plot of Figure 6. At the long wavelength end of the band the undesired (3,2) mode ($5\lambda/4$ resonator, $2\frac{3}{4}$ repeller) almost exactly superposes the desired (2,1) mode ($3\lambda/4$ resonator, $1\frac{3}{4}$ repeller). At the point where the repeller voltage is changed so that operation on the (2,2) mode is obtained, there is danger of undesired oscillation in the (3,3) mode that closely follows the (2,2) mode.

The practical effect obtained from this situation is that at nearly any setting of the plunger the circuit will tend to oscillate at either of two frequencies, depending upon the conductance offered by the resonator. In a typical condition the circuit may oscillate at one frequency for a time and then shift to a different frequency in the other mode. This effect is especially pronounced in pulse operation.

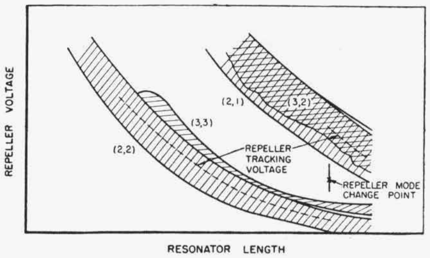

Figure 6. *Partial mode plot of oscillator.*

As in most cavity resonators, the suppression of plunger resonances and undesired oscillations is a major design problem. It is from the standpoint of suppression of undesired oscillations that the parallel-plane oscillator shows a marked advantage over a conventional coaxial-line oscillator in the frequency range under consideration.

RESONATOR AND PLUNGER COMPENSATION

Figure 7 shows a frequency plot similar to that of Figure 5 but after suppression has been effected. The undesired (3,2) and (3,3) modes have been completely suppressed but are indicated in dashed lines for reference purposes.

In region B of Figure 5 the four-cycle resonance of the plunger is somewhat higher than the undesired (3,2) and (3,3) modes. By lengthening the periphery of the plunger when it is at settings corresponding to region B, the peripheral resonance can be made to coincide with and thus damp out the undesired modes. This has been done by slotting the resonator wall at A and A′ as shown in Figure 8. The slots inductively load the peripheral transmission line, lowering the resonant frequency to the point where the (3,2) and (3,3) modes are damped out in region B. To cause the peripheral resonance to track with the spurious modes, the depth of the slots are tapered so that as the plunger is moved the effective length of the peripheral transmission line is changed the proper amount.

In region C of Figure 5, the four-cycle resonance of the plunger is somewhat lower than the undesired (3,3) mode. Thus, when the plunger is at settings corresponding to region C, the length of the peripheral line must be shortened. This is accomplished by placing high-impedance sections in the end walls of the resonator, as illustrated in Figure 9. These sections have the effect of dividing the peripheral line into two

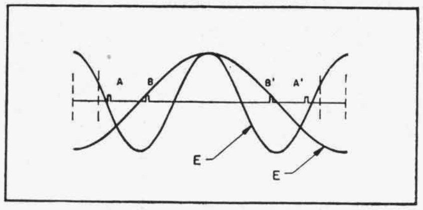

Figure 8. *Slots in outer conductors to change natural frequency of peripheral line. Depth of slots is tapered to provide wide-band control.*

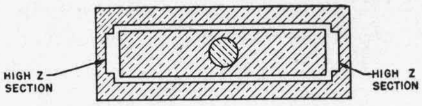

Figure 9. *High-impedance sections placed in end walls to raise natural frequency of four-cycle resonance.*

parts, each of which are physically shorter than half of the original line. Thus, in region C the natural four-cycle resonant frequency of the plunger has been increased to coincide with and damp out the (3,3) mode.

In region D the problem is to raise the natural frequency of the four-cycle plunger resonance to a frequency higher than that of the highest desired (2,2) mode frequency. The same compensation used in region C is also effective in region D, although still additional compensation is necessary to raise the peripheral resonance to yet a higher frequency. This is done by placing relatively wide slots in the outer conductors. The result is shown in region D of Figure 7, where the plunger resonant frequency is seen to be higher than the highest desired frequency (3.94 cm or 7600 mc) of the (2,1) mode.

The last compensation is that necessary to move the two-cycle peripheral resonance in region A to a lower frequency so as to avoid loss of power at the low-frequency end of the band. This is done by inserting slots B and B′ in Figure 8 to lengthen the peripheral electrical dimension.

The compensated resonator offers the characteristics shown in Figure 7. The peripheral resonances have been moved to frequencies such that they are not excited by the desired mode. In the case of the four-cycle peripheral resonance, it has been adjusted so that it damps out the undesired (3,2) and (3,3) modes leaving the desired (2,1) and (2,2) modes free and clear.

It is also possible for the resonator to excide odd-number resonances in the peripheral gap around the plunger. These resonances are excited by eccentricities in fabrication or assembly of resonator parts. Suitable lossy material is included in the resonator plunger to damp out any tendency for such resonances to occur.

In the uncompensated oscillator certain other oscillations on higher order repeller and cavity modes can exist at some frequencies. However, the same resonator compensations described above fully damp these interfering modes.

FREQUENCY DRIVE SYSTEM

The tuning characteristic of a cavity resonator is essentically straight-line wave-length. However, it is commonly preferred that the tuning dial of a signal source be calibrated directly in frequency. To avoid the "crowding" in frequency calibration that occurs at the high-frequency end when a straight-line wave-length system is calibrated in frequency, a special drive arrangement is used in the Model 618A to give a linear frequency calibration.

The linear frequency drive arrangement also simplifies the tracking of repeller voltage with frequency, because the repeller voltage vs. frequency characteristic is linear. Thus, a simple linear potentiometer that is ganged with the shaft for the frequency dial can be used to control the repeller voltage. The drive arrangement results in a 13-inch linear calibration with calibrated points every 50 megacycles. The frequency calibration is accurate within ½ of 1%.

OUTPUT SYSTEM

Power from the oscillator is coupled to the panel connector by means of a loop operating in a piston attenuator. The mechanical arrangement used to operate the attenuator is similar in principle to that used on the -hp- Models 614A and 616A UHF Signal Generators where the output voltage or power level is at all times indicated directly on a dial. No frequency corrections are necessary for the attenuator, since the attenuation constant varies only a negligible amount throughout the frequency range. The output system is accurate within approximately 2 db over the frequency range when working into a matched load.

MODULATION CHARACTERISTICS

An internal modulating system is included in the Model 618A so that square-wave modulation can be obtained over a range from 400 to 1000 cps by means of an internal square wave generator.

Either pulse or fm modulation can be obtained through the use of external sources. The rise time of the modulating system in the Model 618A is approximately 0.2 microsecond and the decay time is about the same, so that modulation by pulses as short as approximately 0.5 microsecond can be obtained. A minimum of 15 volts peak is required for pulse modulation.

External fm modulation can be obtained at audio frequencies from 20 cps to 20,000 cps. Approximately 5 volts rms are required at the input jack for external fm modulation.

—W. D. Myers

SPECIFICATIONS
MODEL 618A
SIGNAL GENERATOR

FREQUENCY RANGE: 3800 to 7600 mc.

CALIBRATION ACCURACY: Within ½ of 1%.

POWER OUTPUT: 1 milliwatt maximum into 50-ohm load.

OUTPUT CONNECTOR: Type N Jack (UG-23B/U).

OUTPUT ATTENUATOR: Continuously variable and calibrated from 0 to at least −107 dbm. (.224 volts to 1 microvolt).

OUTPUT POWER ACCURACY: Within approximately 2 db into matched load.

INTERNAL MODULATION: Can be modulated from internal square-wave generator over the range from 400 to 1000 cps.

EXTERNAL PULSE MODULATION: By either positive or negative pulses from 0.5 microsecond to square wave. Rise and decay time approximately 0.2 microsecond each. 15 volts or more peak drive required.

EXTERNAL FM MODULATION: By external voltages from 20 cps to 20 kc. ±10 mc deviation obtainable at most carrier frequencies. Approximately 5 volts rms drive required.

POWER SOURCE: Operates from nominal 115-volt, 50/60 cycle source. Requires 250 watts.

DIMENSIONS: 14½″ high, 19″ wide, 18½″ deep.

SHIPPING WEIGHT: 110 lbs.

PRICE: $2250.00 f.o.b. Palo Alto, California.

Data subject to change without notice.