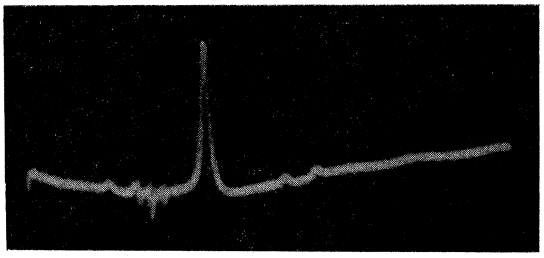

FIG. 1. 3,3 absorption line of $N^{14}H_3$ with superimposed inverted marker ladder just inside inner left-hand fine structure line. Ladder spacing is 267 kilocycles.

taneously to generate appreciable intensities of radiation of three or more frequencies, differing from one another by the frequency of the modulating voltage. The resultant radiation was passed through an absorption cell and slowly swept through the frequency of a spectrum line. The spectrum line then displayed appeared to have been flanked by two or more "ghost" lines, which were separated from the main line by the modulation frequency or a multiple thereof. These "ghosts" were used as calibrated markers with which to measure absolutely the separations of satellite lines.

The former method is difficult to apply when narrow, fairly strong lines cannot be obtained or when there are several closely spaced lines. The method to be described gives a movable marker ladder, of known spacing, independent of the quality of the absorption spectrum being studied. This is achieved through the introduction of the radiation from an auxiliary microwave oscillator into the wave guide leading to the detector crystal. When the main oscillator frequency is swept through the frequency of the auxiliary oscillator, the resultant interference causes a narrow blurred pattern to be displayed on the detector oscilloscope. This pattern is attributable to the audio-frequency noise produced by beating of the radiation from the two oscillators during the moment of near synchronization. Since the relative phases of the two oscillators are random, and since both execute small amplitude, rapid fluctuations in frequency, successive patterns are irregular and dissimilar.

A narrower and more distinct pattern can be obtained if a small amount of power from the auxiliary oscillator is allowed to feed back into the main oscillator. The power fed back results in a pulling of the oscillators into synchronization as they approach the same unperturbed frequency. The relative phases of the two oscillators will be a function of the difference of the unperturbed frequencies so that the same oscilloscope pip pattern is reproduced on successive sweeps. Power can be fed back through the use of a directional coupler and attenuator. The pattern can be made to appear as an increase in signal strength, a decrease in signal strength, or both in succession, by adjustment of the relative oscillator phases by means of a variable length line, or "squeeze section." The pip can be split into a ladder through the application of an intermediate frequency voltage to the reflector of the auxiliary oscillator. The spacing between the pips is the applied intermediate frequency or a multiple thereof. The markers thus obtained have been used with spacings varying from 0.2 to 10 megacycles, and have a width of 50 kilocycles or less. The accompanying photograph (Fig. 1) of a marker ladder displayed with the familiar NH_3 3,3 line and satellites qualitatively illustrates the results obtainable. Visually the marker pips appear sharper than shown in the photograph, which was blurred by small variations during the time of exposure.

It is believed that a similar direct mixing method could be used in the superposition upon microwave spectra of standard frequency markers obtained from frequency multiplier arrays or oscillators stabilized upon standard spectrum lines.

* The research described in this report was supported by Contract No. W-28-099-ac-125 with the Army Air Forces, Watson Laboratories, Air Materiel Command.

[1] Dailey, Kyhl, Strandberg, Van Vleck, and Wilson, Phys. Rev. **70**, 984 (1946).

[2] R. J. Watts and D. Williams, Phys. Rev. **72**, 263 (1947).

Stark Effect in High Frequency Fields

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STARK effect on molecular absorption lines in the microwave region has been reported in which constant or d.c. Stark fields[1] and a.c. Stark fields of frequency up to several hundred kilocycles are used.[2] It is possible to oscillate the Stark field applied to molecules at such a rapid rate that one or many oscillations occur during a single absorption process. In this case ordinary Stark effect breaks down and a new type of spectrum appears.

A solution of the time-dependent wave equation for a molecule subjected to a varying field $E_0 \cos 2\pi\nu_0 t$ can be obtained by perturbation methods, and the effect of the field on its spectrum shown to be as follows:

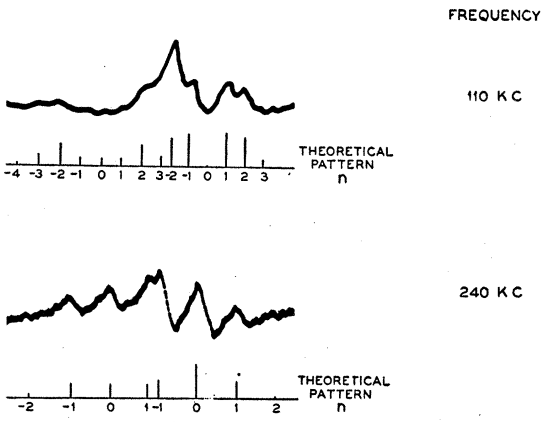

FIG. 1. Stark effect on OCS $J=1\rightarrow 2$ line (25,326 mc) with applied fields of low and high frequency.

(1) When ν_0 is much smaller than the half-width of the molecular absorption lines, each Stark component appears to follow the oscillating field. Thus if a particular component shows only second-order Stark displacement of magnitude $\Delta\nu = aE^2$ in a static field of strength E, in the a.c. field, its displacement as a function of time will be $aE_0^2 \cos^2 2\pi\nu_0 t$.

(2) When ν_0 is of the same order or larger than the half-width of the absorption line, each Stark component breaks up into a number of fixed lines with spacings determined by the frequency ν_0 and relative intensities by the ratio of ν_0 to the magnitude of the Stark displacement. Thus, assuming only second-order Stark effect as in case (1), frequency shifts of lines produced from a single Stark component are given by $aE_0^2/2 \pm 2n\nu_0$ where n is any integer. Intensity of any line corresponding to a particular value of n is given by $IJ_n^2(aE_0^2)/(4\nu_0)$, where I is the intensity of the Stark component for a static field. Thus if ν_0 is very large, $aE_0^2/4\nu_0$ is small, and all components are of small intensity except the one for $n=0$. Each Stark component appears then as a single line displaced an amount $aE_0^2/2$, the average of its displacement if it "followed" the field. If $aE_0^2/4\nu_0$ is not small, a number of lines corresponding to various values of n may be observed. Similarly, for first-order Stark effect of magnitude bE in a static field, frequency shifts become $\pm n\nu_0$ and corresponding intensities $IJ_n^2(bE_0)/(\nu_0)$.

Figures 1 and 2 show the variation in Stark pattern of the $J=1\rightarrow 2$ line of OCS with variation in frequency ν_0 of the applied field. Stark effect, which in this case is second order, was obtained and observed in the usual way on an oscilloscope trace. The gas OCS was chosen to demonstrate this effect because of its convenience and because no complications arising from nuclear quadrupole effects are present. Part of the gas-absorption path was not subjected to an electric field, which produced a weak undisplaced line as a reference in addition to the two Stark components shown under d.c. field at the top of Fig. 1. All spectra shown are on the same frequency scale and at about the same pressure (6×10^{-3} mm Hg) of OCS. Relative intensities of the spectra for various applied frequencies are not accurately represented. From Fig. 1 it is evident that at 1 kc the two Stark lines simply follow the field, the d.c. field strength and the peak a.c. field for a given displacement being the same. At 1200 kc the pattern resembles the d.c. pattern, peak voltage being $\sqrt{2}$ times the d.c. voltage required for the same displacement. Figure 2 shows intermediate conditions. At 110 k.c. the Stark lines no longer "follow" the field, although the general intensity distribution is similar to that expected for the same field intensity at lower frequency. This is because intensity for the lines for which $n=0$ is small, the main intensity falling at $n=1$ or 2. At 240 kc the lines corresponding to $n=0$ are most intense, although those for $n=1$ are still prominent. Theoretical intensities are plotted below each spectrum for comparison. In every case extra intensity at the center of the pattern is due to the undisplaced line of gas not subjected to a field.

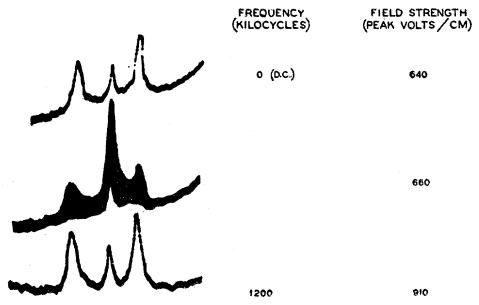

FIG. 2. Stark effect on OCS $J=1\rightarrow 2$ line (24,326 mc) showing additional lines produced by fields of intermediate frequencies. Peak field strengths of both fields are 640 volts/cm.

The Stark patterns obtained at any one frequency vary considerably with field strength, some cases displaying several more lines than those shown here. In every case the positions and relative intensities of lines appear to agree well with theoretical expectations described briefly above. This agreement provides a new test of the time-dependent wave equation.

[1] Dakin, Good, and Coles, Phys. Rev. **70**, 560 (1946).
[2] R. H. Hughes and E. B. Wilson, Phys. Rev. **71**, 562 (1947).

Excess-Defect Germanium Contacts

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IN a recent letter,[1] L. Sosnowski describes interesting rectification and photo-voltaic effects in lead sulfide films attributed to an internal potential barrier at the contact between N-type (excess) and P-type (defect) regions of the film. It is also suggested that such effects might be expected to occur in germanium and silicon.

This is indeed the case for germanium. In the course of a NDRC project for the development of germanium point contact rectifiers, photoelectric effects were found[2,3] which were shown to be due to just such internal transitions between N- and P-type regions. Figure 1 illustrates "photo-

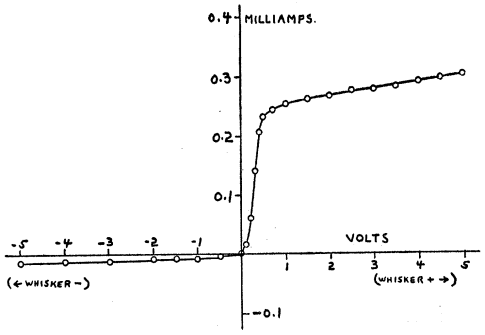

FIG. 1. Current-voltage characteristic of a germanium "photo-diode" (25°C).