GENERAL PHYSICS

I. MOLECULAR BEAMS*

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A. HIGH-RESOLUTION MEASUREMENTS WITH A TWO-CAVITY MASER – ANALYSIS OF UNRESOLVED SPECTRA

The resonance pattern produced by the two-cavity maser spectrometer[1] for a single molecular resonance line is the typical "Ramsey" line shape shown in Fig. I-1, and it may be easily analyzed to determine the resonance frequency. There are many cases in the ammonia inversion spectrum, however, in which the resonance lines are so close that these patterns overlap and the lines are not completely resolved. In order to analyze such cases a computer program was written to perform a least-squares fit to the experimental spectrum by using a superposition of the known single-line resonance patterns. This program was used successfully to determine the amplitudes and frequencies of three overlapping lines.

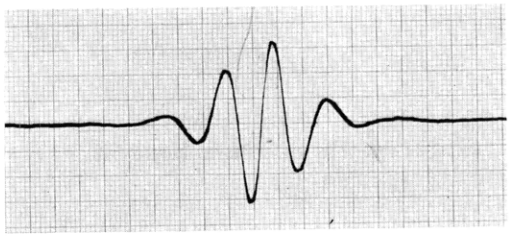

Fig. I-1. Single line Ramsey function with $\phi = 0$.

One case that was analyzed successfully is the main line ($\Delta F = \Delta F_1 = 0$) of the $J = 3$, $K = 3$ inversion transition. The signal-to-noise ratio is very good in this case (1000/1). The resonance pattern for a single line can be accurately represented by the function $A \exp\left(-b(f-f_o)^2\right) \sin(\pi(f-f_o)/\Delta f - \phi)$. This spectrum contains three overlapping functions of this form. We have assumed that these functions are linearly superposed, since the microwave receiver response is linear and the microwave power from the molecules is considerably less (20 db less in the second cavity) than the stimulating signal. The experimental spectrum (circled points in Fig. I-2) is divided into two parts, and the part containing the line that is least influenced by the others is used to determine values for the phase ϕ_1, the frequency f_1, and the amplitude A_1 which give the best fit to that part of the spectrum. We assume that the phase ϕ will be the same for all three components, so we use the value of ϕ_1 for the phase of the other components. The second part of the spectrum is then used to determine the frequencies and amplitudes of the second and third components, while the amplitude and frequency of the first component are held constant. Then the first part is corrected for the influence of the second and third

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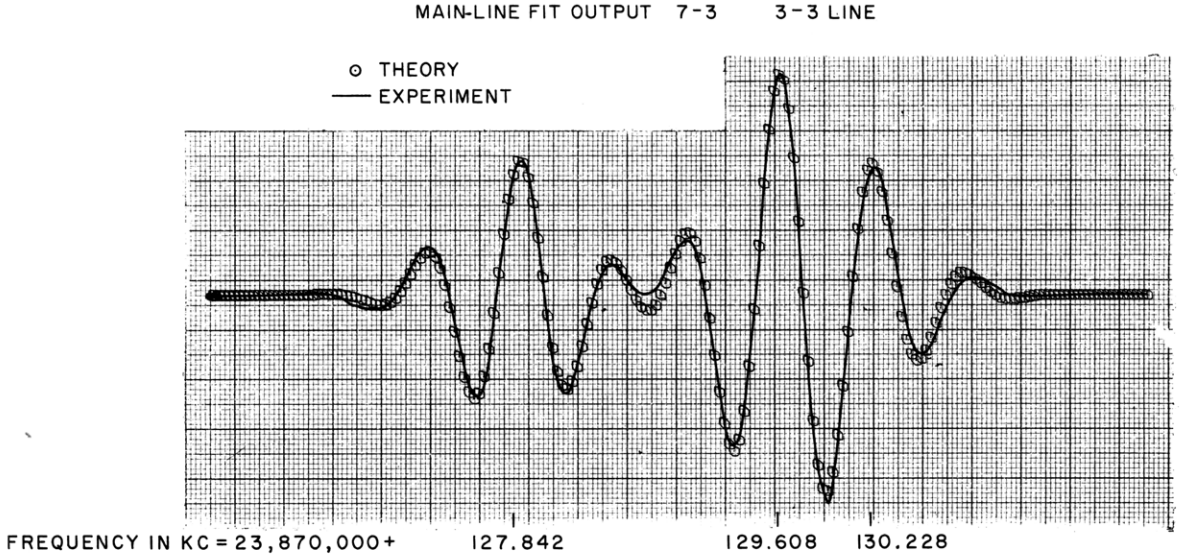

Fig. I-2. Results of the fit procedure for one set of data. Circles represent experimental points, line is theoretical curve which gives best fit.

Table I-1. Results of the fit procedure for three sets of data.

MAIN LINE FIT RESULTS 3 - 3 LINE

FREQUENCIES IN KC

FIT RESULT	AVERAGE	F1
23,870,127.842	23,870,127.88167	3
23,870,127.895	23,870,127.88167	3
23,870,127.908	23,870,127.88167	3
23,870,129.608	23,870,129.61700	4
23,870,129.608	23,870,129.61700	4
23,870,129.635	23,870,129.61700	4
23,870,130.228	23,870,130.22367	2
23,870,130.204	23,870,130.22367	2
23,870,130.239	23,870,130.22367	2

STANDARD DEVIATION = .01992

components and a better value of ϕ_1 is obtained. This procedure is repeated many times to minimize effects of interdependence of the variables.

This whole fit is then carried out for various values of b and Δf, and then the fit giving the smallest standard deviation over the whole pattern is chosen. ϕ, Δf, and b are assumed to be the same for all three components in one experimental curve. These parameters may be varied experimentally, ϕ may have any value from 0 to 2π, but Δf and b may only be varied by ±20 per cent. The typical molecular resonance linewidth, Δf, for the present device is 350 cps and $1/b \cong (2\Delta f)^2$. The result of one of the fits is shown in Fig. I-2. Table I-1 shows the results of fits to three different sets of experimental data which had different values of ϕ, Δf and b. The standard deviation of the frequencies of the component lines in these fits was 20 cps.

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