IFUSP/P-44

PULSE SUPERPOSITION VELOCITY MEASUREMENTS AT HIGH PULSE REPETITION RATES*

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*Supported By FAPESP

SUBMITTED TO-THE REVIEW OF SCIENTIFIC INSTRUMENTS

A B S T R A C T

A pulse echo system operating in the low megahertz range for the continuous and automatic measurement of the ultrasonic velocity is described. The unique feature of the system is that the pulsed rf oscillator has been replaced by an ordinary pulse generator, whose pulses, when applied to the transducer, excite pulses of rf in the sample. In this way, one can employ the frequency modulation and automatic frequency control techniques generally used in this kind of system, without, however, the limitations on the pulse repetition rate which are imposed by commonly used pulsed rf oscillators.

Since McSkimin[1,2] introduced the pulse superposition technique for measuring very small changes in the velocity of ultrasonic waves, a number of authors[3-5] have proposed modifications of this method to continuously record relative velocity changes as small as 10^{-8}. In this letter we wish to consider a problem which may be encountered in the construction and use of such systems, namely, that of achieving sufficiently high pulse repetition rates. This may be a serious problem in certain experimental situations, since many commonly encountered rf pulse generators have limited pulse repetition rates. In our system, the pulsed rf oscillator has been replaced by an ordinary pulse generator (Hewlett-Packard 214A), whose pulses, when applied to the transducer, excite pulses of rf in the sample. The pulse generator has a maximum repetition rate of $\sim$1 MHz and therefore the limitation on the repetition rate of the system is essentially determined by the recovery time of the rf amplifier and by the width of the rf pulses generated.

The technique of applying a pulse to a transducer to excite an rf pulse in the sample, sometimes referred to as shock excitation of the transducer, has been discussed previously.[6] The basic idea is that the application of a short pulse to a transducer will cause it to ring down in a time determined by the Q of the loaded transducer. Since Q is rarely less than about ten, the result is an rf pulse in the sample with a frequency near the resonant frequency of the transducer. Varying slightly the length of the driving pulse allows one to superpose constructively the rf generated by the rising and falling edges of this pulse, and thereby obtain an rf pulse of maximum amplitude.

The frequency of the rf pulse, however, is fixed and cannot be varied. This fact represents a slight limitation of the system, since it is necessary to change the transducer to obtain an rf pulse of different frequency.

A block diagram of the experimental arrangement is shown in Fig.1. The system is essentially a modification of the McSkimin method, employing frequency modulation and automatic frequency-control technique to lock on resonance.[2] The pulse repetition rate of the system is determined by a voltage controlled oscillator which is being frequency modulated, generally at ∿ 400 Hz. This oscillator triggers the pulse generator, whose pulses (∿ 50 ns . in width and 10-100 V. in amplitude) are then sent to the sample. After the returning signal is amplified and detected. it passes to a boxcar integrator with a very short effective time constant (∿ 1 ms.) . The boxcar not only serves as an echo selector but also provides a measure of prefiltering, which is helpful in preventing overload of the lockin amplifier. After passing through a twin tee filter centered at the seocnd harmonic of the modulation frequency, the output of the boxcar is applied to the lockin - amplifier for phase sensitive detection. Finally, the dc error signal from the lockin is summed with the lockin reference oscillator output and the result is fed to the frequency control input of the oscillator, completing the control loop. The resonant pulse repetition rate is measured with a frequency counter, whose significantly varying decades are converted to an analog signal and continuously recorded.

Shown in Fig.2 are experimental results for the fractional change in the sound velocity, $\frac{\Delta V}{V}$, in a sample of bismuth. The de Haas-van Alphen oscillations in the sound velocity are evident. These data were obtained with the system operating in the p = 2 mode[1] and the pulse repetition rate was $\sim$ 144 kHz. We note that the system was quite insensitive to attenuation changes. A 2 dB change in the echo height produced a variation in the repetition rate corresponding to a velocity change smaller than the noise level ($\frac{\Delta V}{V} \sim 5 \times 10^{-6}$) of the trace of Fig. 2.

We have found the versatility associated with the availability of high pulse repetition rates to be convenient, beyond its obvious usefulness with small samples. The sensitivity and stability of a pulse superposition velocity system depend upon the shape of the resonance cuve,[2] which, in turn, depends upon sample attenuation and the quality of the acoustic bond. Thus, to obtain a sharply peaked resonance curve, it is always desirable to operate in the $p = 2$ mode, rather than with $p = 3,4.....$ This is especially true for samples with an appreciable attenuation. This option is available from the simplified system described above.

The authors wish to acknowledge helpful conversations with Prof. P.L.Donoho.

REFERENCES

1. H.J.McSkimin, J. Acous. Soc. Amer. **33**, 12 (1961)
2. H.J.McSkimin, J. Acous. Soc. Amer. **37**, 864 (1965)
3. J. Holder, Rev. Sci. Instr. **41**, 1355 (1970)
4. D.Read and J.Holder, Rev. Sci. Instr. **43**,933 (1972).
5. L.R. Testardi and J.H. Condon, Phys. Rev. B **1**, 3928 (1970). See also, L.R.Testardi and J.H. Condon, in Physical Acoustics, ed. Warren P.Mason and R.N.Thurston (Academic Press, New York, 1971), Vol. VIII.
6. A.G.Beattie and G.A.Samara, J.Appl. Phys. **42**, 2376 (1971).

FIGURE CAPTIONS

Fig. 1 - Block diagram fo the pulse superposition velocity measurement system.

Fig. 2 - Experimental results in a single crystal of bismuth, obtained with the system of Fig. 1.

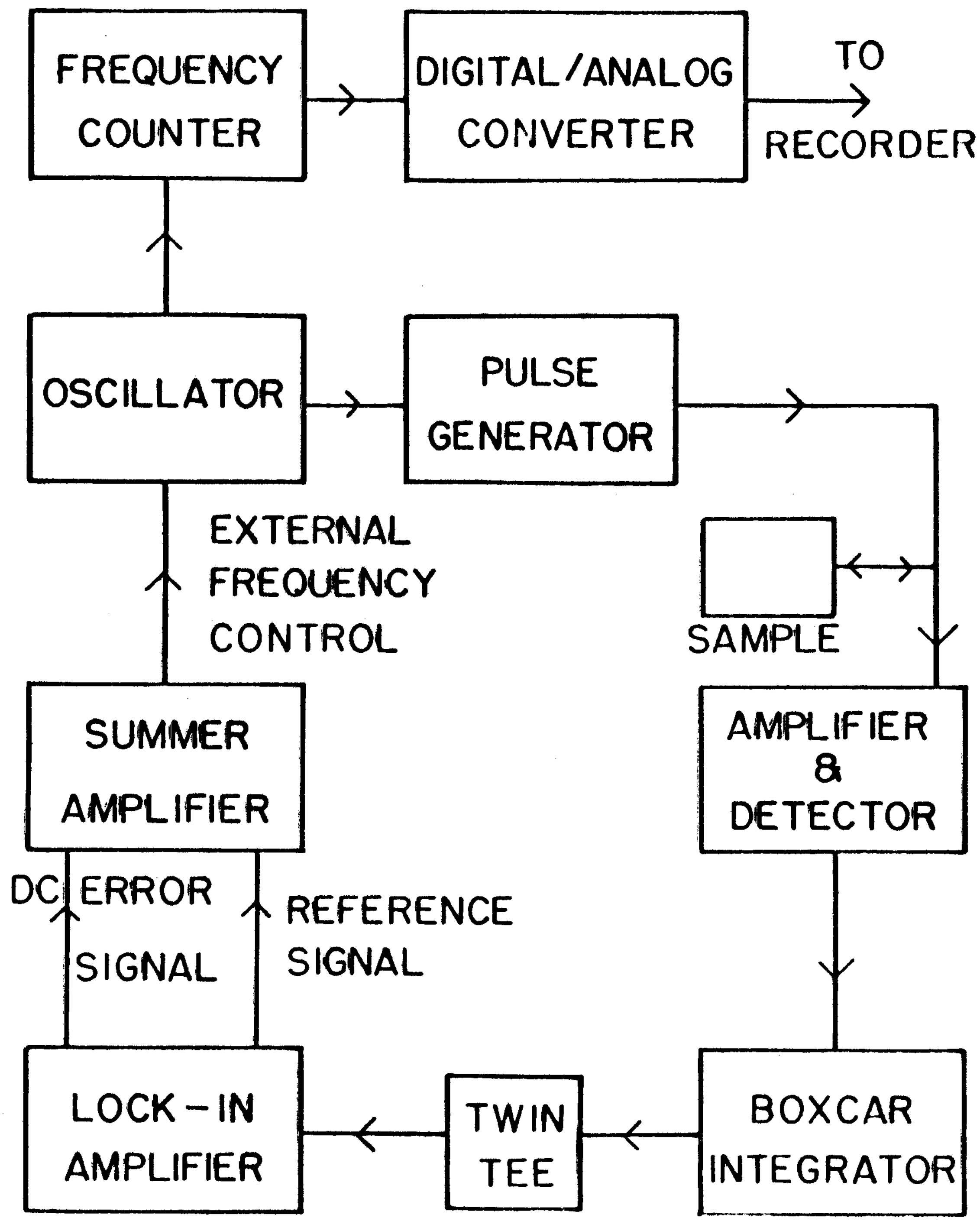
FREQUENCY COUNTER
DIGITAL/ANALOG CONVERTER
TO RECORDER
OSCILLATOR
PULSE GENERATOR
EXTERNAL FREQUENCY CONTROL
SAMPLE
SUMMER AMPLIFIER
AMPLIFIER & DETECTOR
DC ERROR SIGNAL
REFERENCE SIGNAL
LOCK-IN AMPLIFIER
TWIN TEE
BOXCAR INTEGRATOR

Fig. 1

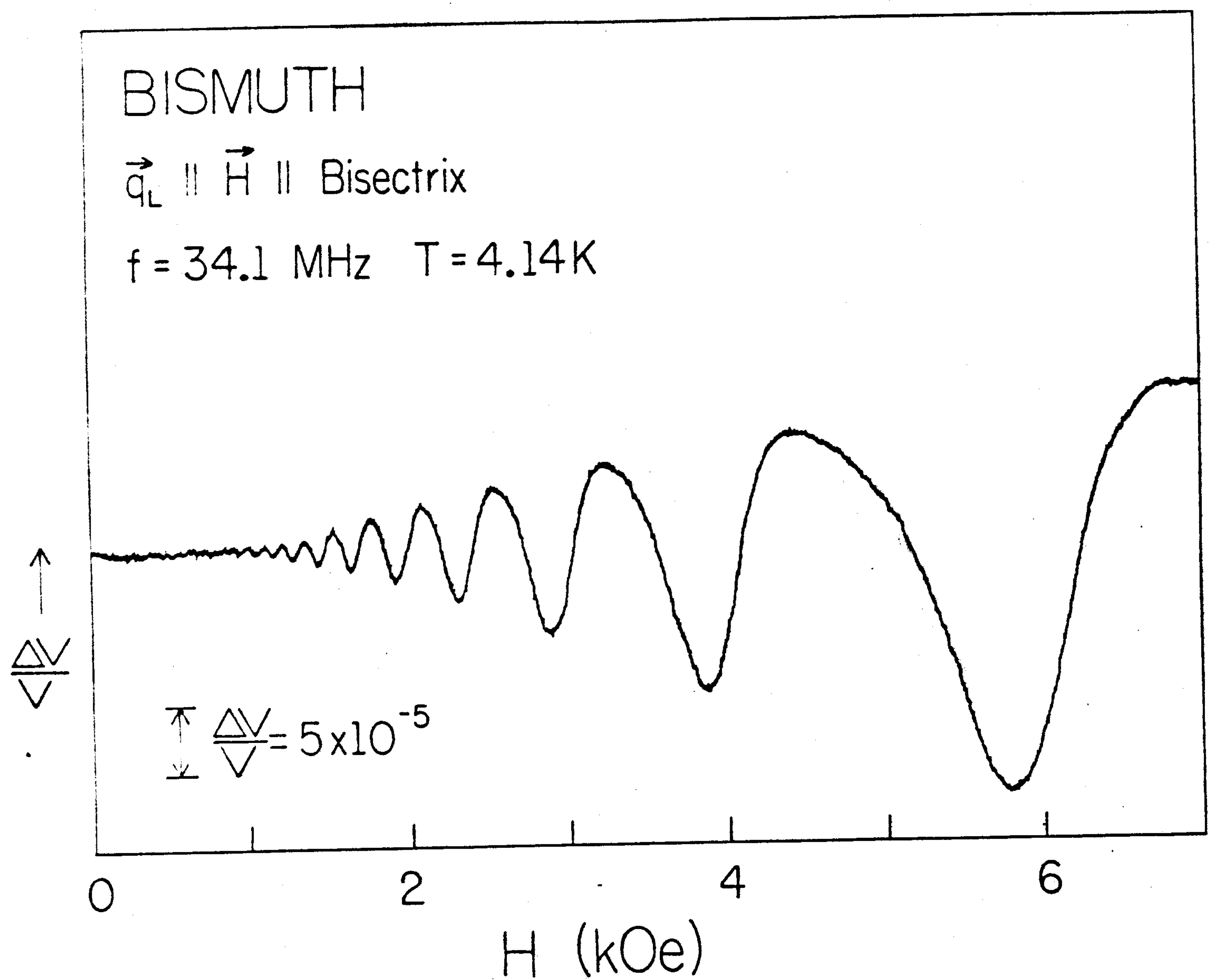
BISMUTH
$\vec{q}_L \parallel \vec{H} \parallel$ Bisectrix
f = 34.1 MHz T = 4.14K
$\frac{\Delta V}{V} = 5 \times 10^{-5}$
$\frac{\Delta V}{V}$
0
2
4
6
H (kOe)

Fig. 2