Paper

A Brief Description of BMR Portable Seismic Tape Recording Systems

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Current methods of interpreting seismic data from earthquake or explosion sources in terms of geological structures use both the kinematic and dynamic information in the data. This requires that the characteristics of the systems used for recording and analysing ground motion be well known, and in recent years this requirement has been allied with the many developments in electronic engineering and tape recording to produce a generation of field equipment which is both portable and rugged (Dibble, 1964; Mereu & Kovach, 1970; Muirhead & Simpson, 1972; Crowe, 1973; Long, 1974). Most of this equipment has been designed and built by research groups and therefore was not easily available for purchase. Those systems which were available commercially were generally very expensive for the tasks required of them.

About 1970, therefore, the Bureau of Mineral Resources, Geology and Geophysics (BMR) decided to produce a system for its own purposes. The general requirement was for a seismic recording system which was portable, rugged, and would have an unattended endurance of about one week on an intermittent basis. The recording system had to be capable of use in any of the climatic conditions likely to be encountered in Australia and Papua New Guinea. The systems had to produce high quality recordings of ground motion which could subsequently be digitised and accessed to a digital data storage and retrieval system.

Twenty one sets of seismic tape recording equipment were subsequently built by BMR, each containing a seismometer, amplifier, modulator, calibrator, crystal clock, radio time signal receiver, and four-track tape deck. The systematics of the recording and playback facilities are illustrated in Figure 1 and the field recording equipment is shown in Figure 2. This Technical Note briefly describes the characteristics required by the seismologist for field operation and interpretation of ground motion, but does not attempt to describe the electronic design and circuitry.

Since 1971 these seismograph systems have been used extensively on explosion seismic surveys in the Australian region (Denham & others, 1972; Finlayson & others, 1974, 1977, 1979, 1980; Collins, 1978; Drummond, 1979). The ability to maintain essentially the same characteristics in all recording systems, coupled with the frequency modulated tape recording system, enables the recovery of reliable ground motion data from widely separate locations. This is essential for any interpretation involving the relative amplitudes along recording station lines which may be 300-500 km in length.

Seismometers and amplifier

Willmore Mk II or Mk IIIA short-period seismometers are used with the free period adjusted to 0.7 s. A calibration coil and magnet have been fitted to the indicator rod of each Mk II seismometer; a calibration coil wound concentrically with the signal coil is used on the Mk IIIA seismometers.

The seismometer amplifier is a BMR type TAM5 very low frequency AC coupled amplifier with a maximum gain of 120 dB (10^6) switchable in 6 dB steps from 48 dB to 120 dB. The amplifier has two outputs, the high-gain as selected and the low-gain 24 dB below the selected level. Five switched bandpass filter settings are available: 0.01-0.2 Hz, 0.01-20.0 Hz, 0.1-10 Hz, 1.0-5.0 Hz, and 1.0-100.0 Hz. For explosion seismic recording the bandpass filter is usually set in the range 0.01-20.0 Hz.

The frequency responses of the TAM5 amplifier itself, and of the seismometer plus amplifier system, are shown in Figure 3. The displacement magnification of the seismometer plus amplifier as a function of frequency is shown in Figure 4. The average sensitivity of the Mk II seismometers is 5.7 V per $m.s^{-1}$ and for the Mk IIIA seismometers is 5.05 V per $m.s^{-1}$. The damping factor of the seismometer is typically 0.52. At 7.5 Hz, the predominant frequency in quarry blast signals, the displacement magnification is 2.6×10^7 volts per metre for a TAM5 set at 72 dB with a bandpass filter setting of 0.01-20.0 Hz and a Willmore Mk II seismometer. The system performance in the field can be assessed using pulses from a BMR type SSC–1 calibrator applied to the seismometer.

Modulation and recording

The two gain levels from the TAM5 amplifiers are frequency modulated (fm) for recording on slow-speed tape recorders. Two types of recorders are used: highly modified Akai ¼-inch tape recorders, and Precision Instrument (PI) type 5107 ½-inch tape recorders. Both types record at a tape speed of 1.488 mm/s (15/256 in/s) with a fm centre frequency of 105.5 Hz. A maximum frequency deviation of ± 40% is produced with a signal of ± 1.4 V to the modulator input. The frequency response of the modulation-

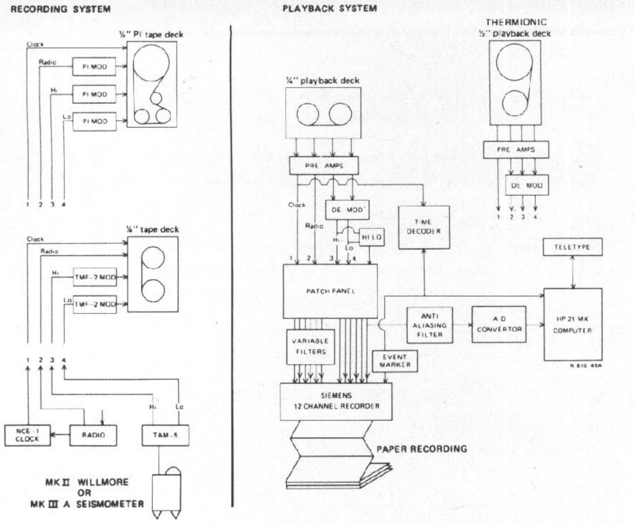

FIGURE 1
BMR portable seismic tape recording systems and playback systems.

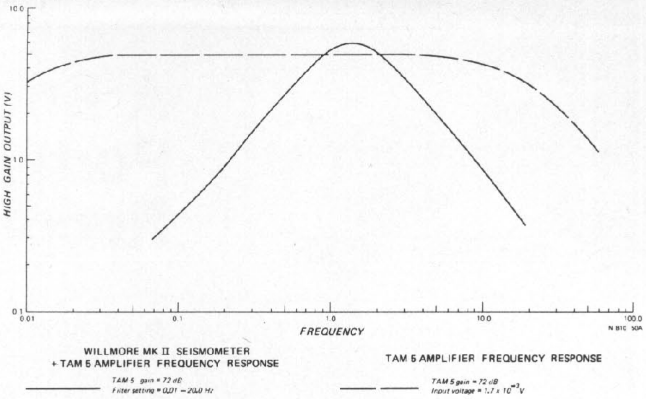

FIGURE 3

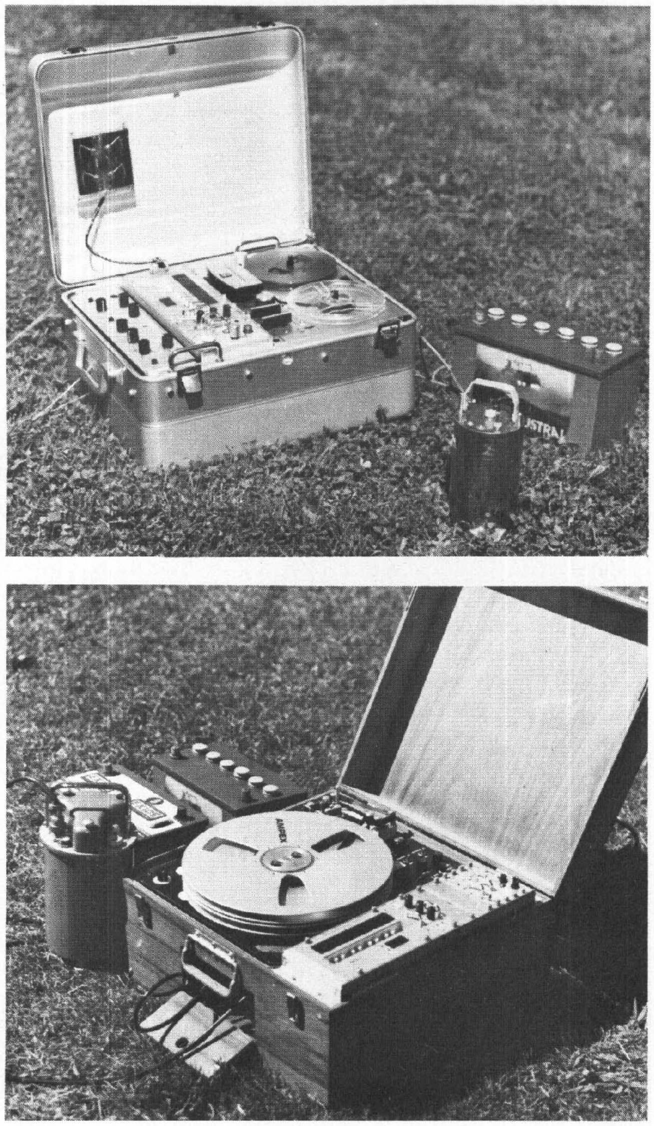

FIGURE 2
BMR portable seismic tape recorders, a) ¼-inch tape system, b) ½-inch tape system.

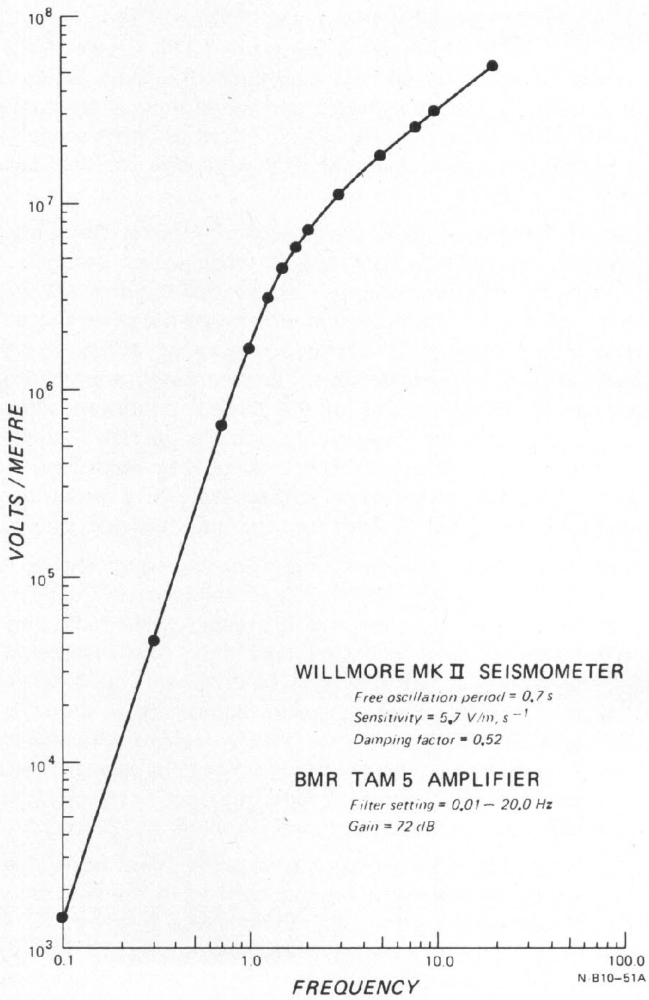

FIGURE 4
Displacement magnification of BMR seismic tape recording systems, with respect to frequency.

record-demodulation system is flat within the range DC – 19.5 Hz. The modified Akai recorders use BMR type TMF-2 modulators; the PI recorders use modulators built in by the manufacturers.

Crystal Clock

A BMR type NCE-1 crystal controlled clock is incorporated in each set of equipment, and an IRIG serial time code is recorded on a third tape channel. The frequency standard is derived from a Vectron temperature compensated crystal oscillator (TCXO), and this provides a 50 Hz carrier frequency for tape recording; the time code is an amplitude-modulated signal superimposed on the carrier. An accuracy of ± one part in 10^7 (± 8 ms per day) in the temperature range 0-50°C is typical for the clock. An LED display, in addition to showing days, hours, minutes, and seconds, also shows the difference between the clock time code and a radio derived time signal. Clock time can be synchronised with the radio time-signal using advance and retard buttons.

The clock can also be programmed to switch on and off the recorder and radio to extend the endurance of field recording. This facility is used when survey staff either detonate their own shots or know the time periods within which quarries fire shots.

Radio time-signal receiver

The fourth recorder channel is used to record a standard radio time-signal transmitted on 4.5, 7.5, and 12.0 MHz by station VNG operated by Telecom Australia from Lyndhurst in southeast Australia (Australian Post Office, 1973). The signal is received by a modified Labtronics type 21B time-signal receiver which is crystal locked to the selected frequency.

Power requirements

The power for the systems is provided from 12V lead-acid batteries. The equipment which uses the modified Akai tape deck requires a current of 0.6 A when only the clock is functioning, and an additional 0.4 A when recording is in progress. Thus, when two 80 Ah batteries and a 548 m (1800 ft) tape are used, the endurance for recording 12 hours per day is about 8.3 days. Planned improvements to the clock and tape-drive systems should reduce power consumption to about 15% of its present level.

Playback system

Playback of the ¼-inch tapes is achieved through BMR design playback equipment. Playback tape speed is possible at 4, 8, 16, and 32 times the recording tape speed and can be locked to the 50 Hz clock signal on the tape to make allowance for small variations in recording speeds. The clock time code on tape is continuously decoded and displayed through a BMR type NTD1 decoding unit. Signals from tape are amplified, the seismic channels are demodulated, and all channels are fed to a patch-panel and hence to a Siemens Oscillomink 12-channel analogue chart recorder (Fig. 1). Tape jitter on recorders can be eliminated by subtracting the low-gain seismic signal from the high-gain signal. Signals can also be filtered using a bank of Rockland Model 452 dual HI/LO variable filters. The playback of ½-inch tapes is achieved at 4 times the nominal recording speed through a Racal Thermionics type T8300 tape reproducer, and signals are fed to the patch panel mentioned above.

One seismic channel from the patch panel can be fed through an anti-aliasing filter to an analogue-to-digital converter and hence to a BMR data acquisition system incorporating an HP 21MX computer. Data files are created for each event being interpreted, each file containing a header which incorporates all relevant survey information about shot number, recorder number, distance, gain, etc. With ¼-inch recordings, playback speed is commonly 8 times record speed, and usually about 3 minutes of record is digitised with a sampling interval of 2 ms. A suite of programs exists to edit data files and compile seismic record sections.

Acknowledgements

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