AN AUTOMATIC DYNAMIC SPECTRUM ANALYSER FOR VIDEO TAPE RECORDED SIGNALS

By G. R. A. Ellis*

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Abstract

A time-expansion sweep frequency spectrum analyser is described for signals in the 0–3 MHz frequency range. It is based on a standard video tape recorder used in the single frame replay mode. With a time-expansion ratio of 400 between the record time and replay time, a frequency resolution of 10 kHz together with a time resolution of 0·5 ms is realized. An example of the spectra of Jupiter radio bursts made with the analyser is presented.

The investigation in radio astronomy of rapidly changing wide band signals from sources such as pulsars, the Sun, Jupiter, and flare stars typically requires a detailed knowledge of the way the signal intensity changes with wave frequency and time. The spectrum analysers most extensively used for this purpose have been the sweep frequency type and to a lesser extent the multichannel analyser. In the sweep frequency analyser, a single filter of bandwidth Δf is swept across the frequency range f of the signal in time T_r. Its effective time resolution is

$$T_r = (f/\Delta f) \times 1/\Delta f,$$

which thus falls short of the best possible resolution $1/\Delta f$ by a factor $f/\Delta f$, usually of the order 10^2–10^3. In addition, the signal in a particular bandwidth is sampled only for the fraction $\Delta f/f$ of the total time and the signal to noise ratio is correspondingly poor. The multichannel analyser with several hundred filters of bandwidth Δf, on the other hand, has the advantage of being able fully to use all the signal and of attaining the optimum time resolution. It is, however, inflexible and expensive, but nevertheless is a very useful instrument for some applications.

A third type of analyser, which is essentially a hybrid of the two described above, is the sweep frequency time-expansion analyser. In this, the broadband signal occurring in a given time interval is stored on magnetic tape and subsequently passed N times through a single filter, the centre frequency of which is gradually changed through the whole frequency range. The analysis necessarily takes N times as long as the original recording time ($N \sim 10^2$–10^3), but the overall result may be similar in time and frequency resolution to that of a multichannel analyser of N channels, although without its complexity. Where the phenomenon being studied lasts only a few seconds, the time expansion is of small account. This type of analyser has been used in the past for signals in the audio frequency range (0–10 kHz) with an audio tape recorder suitably modified in the tape transport mechanism to permit the multipass operation

* Department of Physics, University of Tasmania, P.O. Box 252C, Hobart, Tas. 7001.

(Dowden 1965). It has been pointed out by Dowden (personal communication) that a video tape recorder might similarly form the basis for a time expansion analyser for signals in the video range (0–3 MHz).

The best time and frequency resolutions so far attained with sweep frequency and multichannel analysers at radio frequencies have been 10 ms and 30 kHz respectively in observations of solar and Jupiter emissions (Gordon and Warwick 1967; Ellis 1969; Riihimaa 1971), although it has been known from single frequency observations that, at least in the Jupiter radiation, much finer frequency–time detail exists. Slee and Ghent (1967), for example, discovered sub-millisecond Jupiter bursts which they speculated might have been caused by emissions that changed rapidly in frequency, while millisecond bursts have been observed on many occasions (Riihimaa 1971).

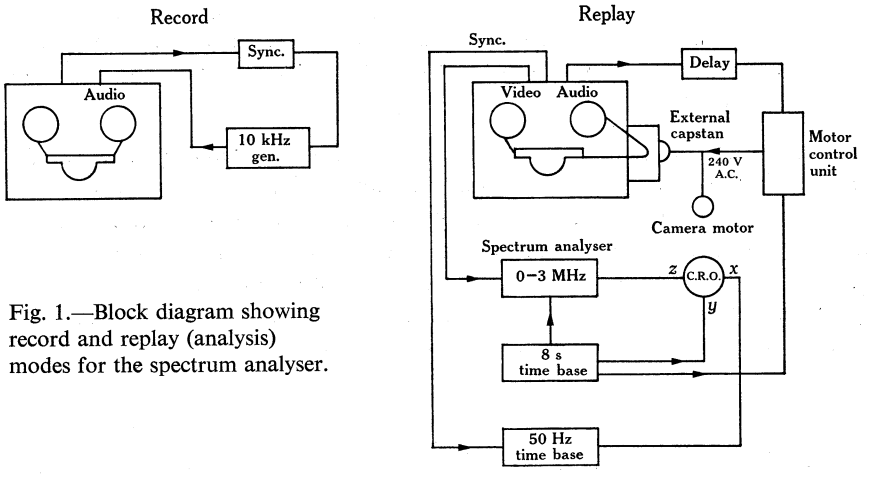

Fig. 1.—Block diagram showing record and replay (analysis) modes for the spectrum analyser.

This paper describes a time-expansion video recorder spectrum analyser which can provide the time and frequency resolution of a multichannel analyser over a 3 MHz bandwidth, i.e. to the limit $T_r \geqslant 1/\Delta f$. The actual choice of T_r and Δf may be made within a wide range, depending on the characteristics of the signal and the amount of post-detection averaging required. The equipment described here has been used routinely to analyse Jupiter radio bursts in the 15–17 MHz frequency range to a time resolution of 0·5 ms and a frequency resolution of 10 kHz but would have many applications where high resolution spectrum analysis of radio frequency signals is necessary.

In the standard helical scan video recorder the broadband signal is recorded along diagonal strips of the tape by a pair of rotating heads, each strip storing a 20 ms time segment of the signal which normally contains the information in one T.V. picture frame. The tape may be replayed in the single frame mode with the tape transport mechanism stopped, a particular 20 ms segment of tape then being repeatedly scanned by the rotating heads. The recorder may be used for time expansion spectum analysis by allowing a slowly sweeping single channel analyser to examine this repeated signal. At the end of the frequency sweep, the video tape is moved on one strip width and the process repeated. The only modification to the recorder needed is an external intermittent tape drive capstan. If this is disconnected, the recorder may be used in the normal way. Figure 1 shows a block diagram of the equipment.

It is also necessary to provide some means of synchronizing the intermittent tape drive to the width of the strips on the tape. The most satisfactory solution found was, during the initial recording process, to use the sync. pulse generated by the recorder for camera synchronization to produce a short burst of oscillations at 10 kHz in an external circuit. This was then recorded on the audio track at the edge of the tape. When replaying the tape in the single frame mode, the external tape transport motor was switched on by the flyback impulse of the spectrum analyser sawtooth voltage and switched off when the audio magnetic head detected the previously recorded 10 kHz burst. This arrangement provided sufficiently accurate registration of the rotating head system with the recorded strips on the tape.

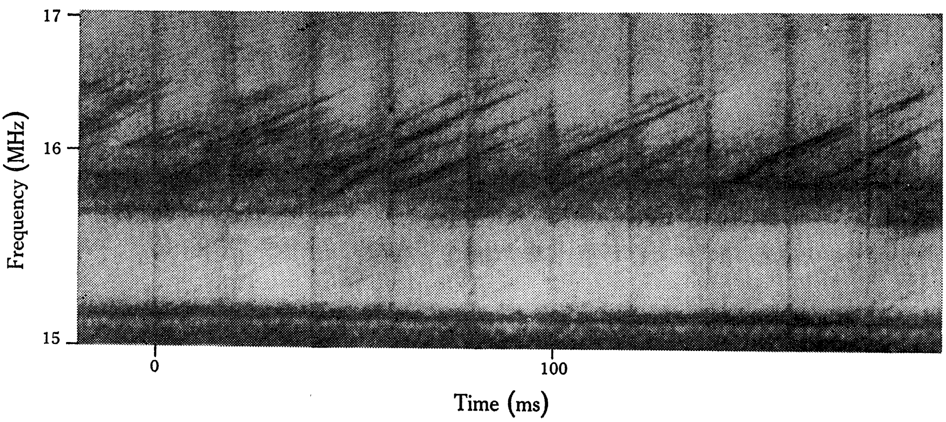

Fig. 2.—Example of the spectra of the Jupiter radio bursts from 15–17 MHz recorded at Hobart on 18 June 1972. The 20 ms segments of the signal can be seen clearly. The frequency resolution was 10 kHz and the time resolution 0·5 ms.

An example of the spectra of 15–17 MHz bursts from Jupiter, recorded at Hobart on 18 June 1972, is shown in Figure 2. In the present application, the spectrum analyser had a sweep time of 8 s and a frequency resolution of 10 kHz. The post-detection time constant was 0·5 ms and the frequency range of the sweep 2 MHz. Most recordings were made with an initial signal frequency range of 15–17 MHz. The signal amplitude from the analyser was displayed on several cathode ray oscillographs, both amplitude and brightness being used. In the normal display, a 50 Hz time base synchronized to the head rotation period of 20 ms provided the time axis, while an orthogonal time base of 8 s provided the frequency axis. The film was moved intermittently in synchronism with the tape transport. The time expansion, 8 s for every 20 ms of signal, gave a spectrum similar to that which would have been obtained with a 400-channel analyser operating in real time. It should be noted that even with a multichannel analyser, video recording of the signal would still have been necessary since it would not have been practical or economic to carry out a live spectrum analysis to a time resolution of milliseconds on the sporadic Jupiter radio bursts.

Acknowledgment

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