A NEW COMPLETELY DIGITIZED FILTER MAGNETOGRAPH

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Abstract. The optics and electronics of a new filter magnetograph will be described. The instrument uses a Zeiss 0.13 Å birefringent filter to isolate magnetic sensitive lines. All four Stokes parameters can be measured. A Westinghouse SEC vidicon WX 30 654 serves as the detector. The data are completely digitized and transmitted in real time into a Univac 1108 computer.

The instrument is under construction as a joint project of the Naval Research Laboratory, Washington, D.C. and the Marshall Space Flight Center, Huntsville, Alabama. It has been designed to obtain magnetograms of active areas on the Sun with a time resolution of 10 s, a spatial resolution of 1 arc s and a magnetic accuracy of 20 G. The instrument should be capable of accumulating as much quantitative circular and linear polarization measurements as possible to search for short time field changes. The data handling therefore was an equally important part of the design as the outline of the magnetograph itself.

Only a magnetograph using a television type sensor and a filter can meet these requirements, if attached to a small size solar telescope.

Similar magnetographs have been constructed or are under construction by Giovanelli and Ramsay (1971), Janssens (1971) and Smithson and Leighton (1971).

Livingston's approach to increase the information collecting capacity of a Babcock type magnetograph by placing 40 pairs of detector along the slit is not practical for our application, because it would require permanent access to a large telescope and a large spectrograph.

1. The Optical System

Figure 1 shows a schematic diagram of the optics. A 30 cm cassegrain telescope (2,3) serves as an image forming system. A heat reflection interference filter (1, band-width 300 Å) in front of the cassegrain telescope avoids excessive heating of the secondary mirror. In order to reduce the instrumental polarization and avoid any long term changes of it, a cassegrain telescope has been chosen. The polarimeter is attached straight to the telescope to eliminate any reflections other than normal incidence in front of the polarization analyzer (10). A tilted glass plate allows compensating of the residual instrumental polarization. Accurate calibration for circular and linear polarization can be obtained by introducing a tilted glass plate (7) and a quarter wave-plate (8). The polarization analyzer (10) consists of two quarter wave-plates and two KD*P crystals to allow measurements of all three Stokes parameters. A Zeiss birefringent filter (half-width 0.13 Å) separates the magneticly sensitive line Fe I 5250 Å. The filter is tunable over a range of ± 8 Å with an accuracy of better than 0.02 Å to

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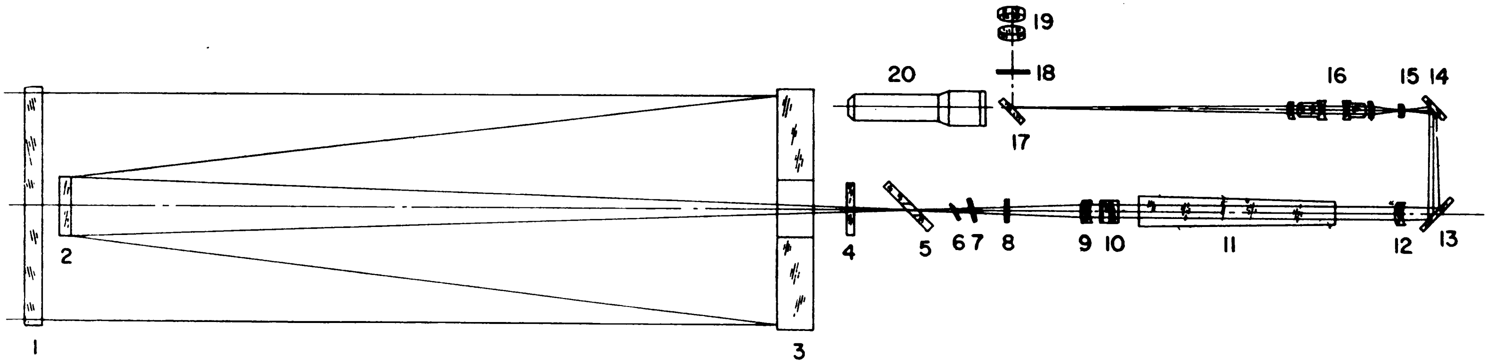

1. heat reflection filter, halfwidth 300 A
2. Cassegrain mirror
3. primary mirror
4. fused silica window
5. field of view aperture stop, auxiliary mirror
6. instrumental polarization compensation
7. calibration plate
8. /4 plate for L. Z. E. calibration
9. collimator lens
10. polarization analyser

11. birefringent filter
12. collimator lens
13,14. folding mirrors
15. field lens
16. relay lens
17. flip-in mirror for eyepiece monitoring
18. reticle
19. eyepiece
20. SEC vidicon

Fig. 1. Real time solar magnetograph, optics schematic.

allow polarization measurements in different parts of a line and also in different lines in the neighborhood of 5250 Å. The filter and the polarization analyzer are used in a collimated beam. Two different relay lenses at (16) can be used to project the solar image onto the faceplate of the TV tube. The field of view of the instrument is 5×5 arc min^2 or 2×2 arc min^2.

2. The Sensor

In order to obtain a maximum signal-to-noise ratio, a Westinghouse SEC vidicon WX 30654 has been chosen as receiver. This tube has a high target storage capacity. Furthermore, the line scanning density has been reduced to 45 TV lines cm^{-1}. (This corresponds to one picture element per arc second in the case of the 2×2 arc min field of view.) We should obtain a rms signal-to-noise ratio of 200:1 for each picture element. It has been shown theoretically that this signal-to-noise ratio can be achieved. Laboratory measurements using a similar but smaller SEC vidicon WL 30691 have confirmed the calculated values. We also obtain a nearly 100% transfer modulation function by operating the tube with this low scanning density. The magnetic resolution in one pair of polarized images will be ± 20 G.

3. The Electronic System

Figure 2 and Figure 3 show a very simplified electronic block diagram. The camera tube is a part of the data system rather than an independent variable. A particular part of the image is addressed by the programmer via sweep circuits. At the appropriate

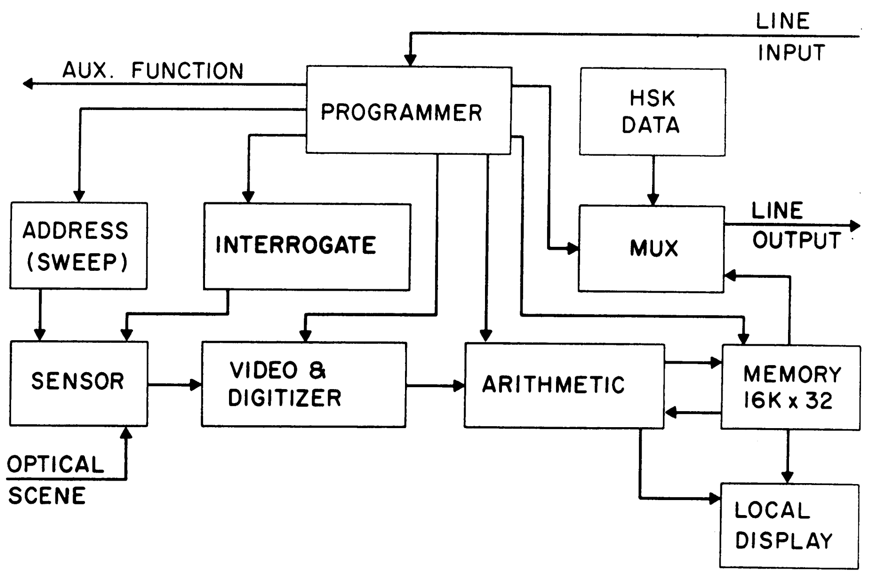

Fig. 2. Real time solar magnetograph, block diagram of electronics, located near the telescope.

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time, the SEC target is interrogated, and the stored information read, digitized, and held in a register. At the completion of this function, the programmer calls up from memory past history of the address in question, adds the new information and places the new number back at its assigned location in the core memory. This process repeats

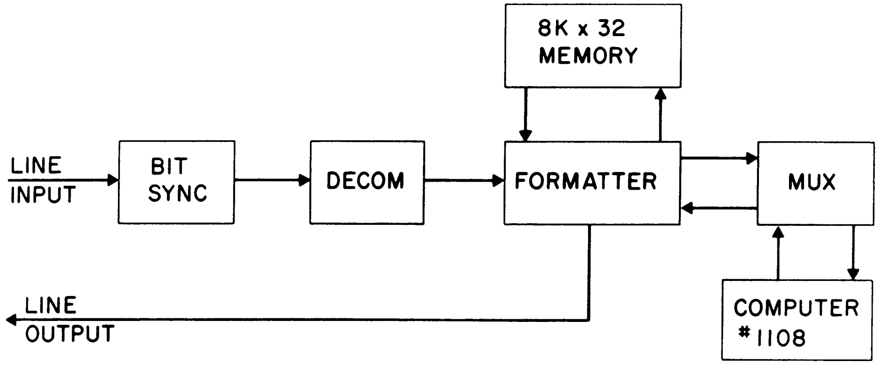

Fig. 3. Real time solar magnetograph, block diagram of electronics, located near the computer.

until the entire data frame is read into the core memory, at which time several options are available. Some of these options are: (1) the data field may re-cycle with the sensor input either on or off, (2) a sensor polarizing data field may be executed, (3) this portion of the data system may stop awaiting some external event, such as changing of the KDP voltage, indexing the birefringent filter, data dump, etc.

Two KDP crystals in front of the birefringent filter act as polarization analyzer. Discrete voltage level combination applied to those crystals result in different phase shifts of the analyzer combination, which are $-\lambda/4$, 0, $+\lambda/4$ and $+\lambda/2$. The target of the SEC vidicon is exposed to light of one of the specific phase shifts of the analyzer, which is controlled by the programmer. After readout, digitization and dump into one half of the memory, the programmer switches the analyzer into another phase shift. The target is then exposed to this opposite polarized scene which is digitized and dumped into the other half of the core memory. Subsequent images of the same analyzer phase shift can be added in the memory to enhance the signal-to-noise ratio.

The contents of the memory can be displayed as an analog image in rapid sequence on an oscilloscope screen and reloaded into the memory. This allows a quick visual evaluation of the image quality, which is determined by the seeing characteristics of the atmosphere during target exposure. Unwanted images can be disposed immediately and replaced by new exposures.

At convenient intervals, housekeeping data such as filter settings, local time, etc. must be added to the data stream so that identification can be made. This is accomplished by a conventional digital multiplexer.

A Receiver/Formatter unit is located at the computer central, located some 10000 ft away from the observatory tower. Since the signals from the tower have been seria-

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lized for transmission through a coaxial cable, a means must be provided for recovering the original reference. This is accomplished by use of a bit synchronizer. A decommutator is used to group convenient numbers of bits for parallel presentation to the Formatter. The Formatter performs the function of controlling the 8KX32 memory where a complete data frame may be placed while awaiting time on the computer. This step is necessary because the computer is time shared via the multiplexer, and entry cannot be guaranteed at any specific time.

References

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Janssens, T. J.: 1971, in 'Astronomical Use of Television Type Image Sensors', Princeton Univ. Press, in press.

Smithson, R. C. and Leighton, R. B.: this volume, p.76.

Discussion

Severny: Would you think that magnetograph records of Hα are not reliable for measurements of the chromospheric field? It gives still reasonable data when used in a proper way.

Brueckner: Yes, we are planning to have besides the 5250 filter an Hα filter.

Dunn: Do you think it will be necessary to make a point-by-point correction? If you make such a correction what signal-to-noise do you expect.

Brueckner: We think that a correction is only necessary for the large scale change in sensitivity of the tube. The small scale sensitivity changes are less than 2% (from one to the next image element). A great deal of effort has been invested into the circuits to make sure that the reading beam of the tube scans with very high accuracy in order to eliminate the small scale fluctuations by subtraction of the opposite polarized images.

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