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SESSION M-3: Radio Astronomy

M-3.3: A 100-Channel Digital Autocorrelation Receiver for Observation of Spectral Lines

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A 100-CHANNEL digital autocorrelation receiver has been built and put into operation at NRAO for purposes of observing spectral lines. It is based on a spectral line receiver as developed by S. Weinreb [1]. As shown in figure 1, the received signal is used to digitally produce a 100-point autocorrelation function. This function is recorded, read into a computer, and Fourier transformed back to the power spectrum.

The system is operated as a one-cycle-per-second switched receiver with a 10-second integration time. During one-half second the spectral line is observed and during the other half second a background frequency is observed. The bandwidth to be observed is switch selected by choosing one of four filters (2.5 Mc, 625 kc, 250 kc, 62.5 kc) operating at a 5 Mc IF. This selection also applies an appropriate local oscillator to the last mixer such that the lower 20 dB point on the bandpass is at zero frequency. This video signal is greatly amplified and clipped to provide a rectangular wave whose only correlation with the input signal is the zero crossing information.

The clipped signal is sampled with a very narrow pulse at a rate which is twice the frequency of the upper 20 dB point on the bandpass in use, e.g., 5 Mc sampling rate for the 2.5 Mc bandpass. The output of the sampler is fed into a 100-bit shift register which at all times contains the previous 100 samples. The sampler also feeds a synchronous detector whose output is combined with each of the previous one hundred bits, from the shift register, in one hundred multipliers. The synchronous detector output consists of a signal equal to its input for one-half second, and equal to the complement of the input for the other half second. The multipliers are 1-bit multipliers, such that their output is plus one if the synchronous detector output is the same as the shift register output, i.e., correlated. If the synchronous detector and shift register outputs are uncorrelated, the multiplier is a minus one. Each multiplier output is fed into a counter.

To integrate for ten seconds at the widest bandwidth (highest sampling frequency) the counters must be 26 bits long. The 16 most significant bits are recorded and the ten least significant bits, which are RMS variations, are discarded. A method was evolved for storing the counter numbers in magnetrostrictive delay lines and counting into the stored number each time it circulated around the line. With this process, ten delay lines were able to replace 1600 counter flip flops.

At the end of a 10-second integration, the counters (delay lines) are dumped into one 1600-bit delay line for storage. All circuits are cleared and reset and the next 10-second integration begun. Meantime, the counter data in the 1600-bit delay line is shifted one counter at a time into a 16-bit shift register from whence it is scanned and recorded on magnetic tape. The data is also kept in storage in the dėlay line for ten seconds and is available on a display for testing purposes.

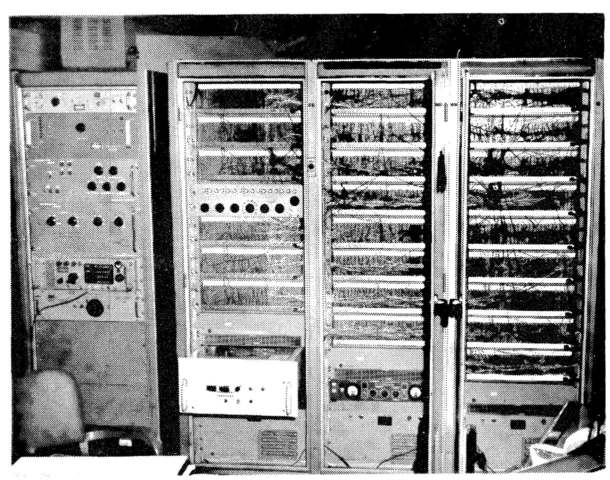

***FIGURE 1*—NRAO 100-Channel Digital Autocorrelation Receiver.**

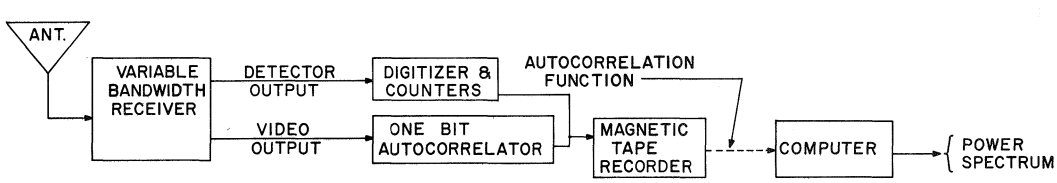

***FIGURE 2*—Digital Autocorrelation Receiver Block Diagram.**

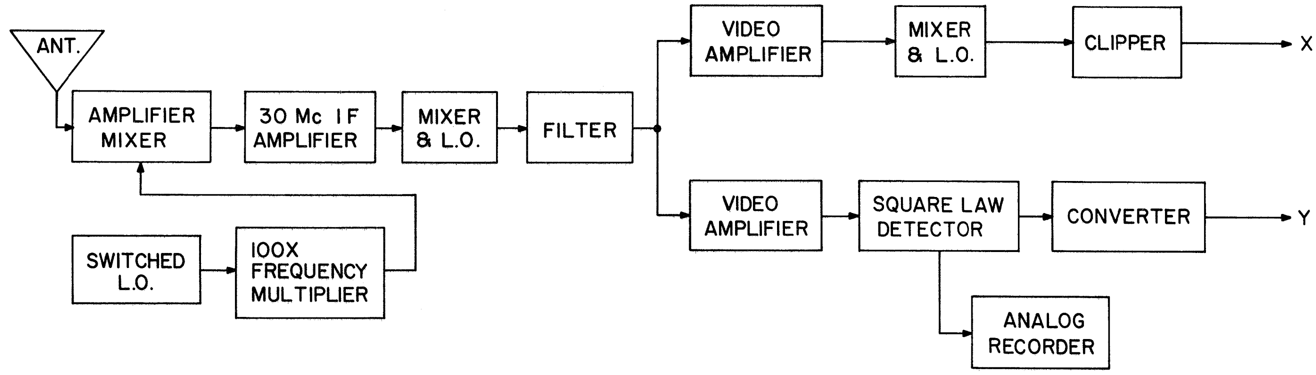

FIGURE 3—**RF-IF-Video System of Digital Autocorrelation Receiver.**

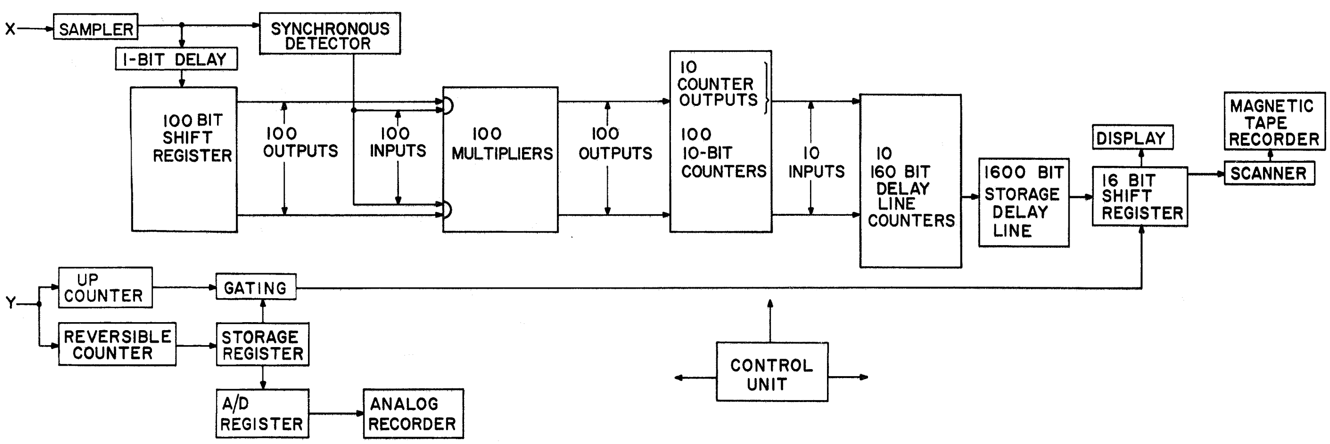

FIGURE 4—**Digital System of Digital Autocorrelation Receiver.**

The analog bandpass filtered 5 Mc IF signal follows another path, in addition to the one described above, through a square law detector, whose output is fed to a pen recorder and a voltage-to-frequency converter. The converter output feeds two counters. An up counter counts when the local oscillator is set to receive the background frequency. The reversible counter counts up when the LO is on the hydrogen frequency and down when the LO is on the background frequency. At the end of a 10-second integration, the reversible counter contains a number representing the average hydrogen energy in the total receiver bandpass. Both counters are then recorded on tape.

The tape now contains 100 points of a 10-second integration autocorrelation function and two counter numbers, one representing the total background, antenna and receiver input noise power and the other representing the total hydrogen noise power. The tape information is inserted in a computer where it is given a clipping correction, filter weighting function and then Fourier transformed to a power spectrum. The mathematical procedure is well described in reference [1].

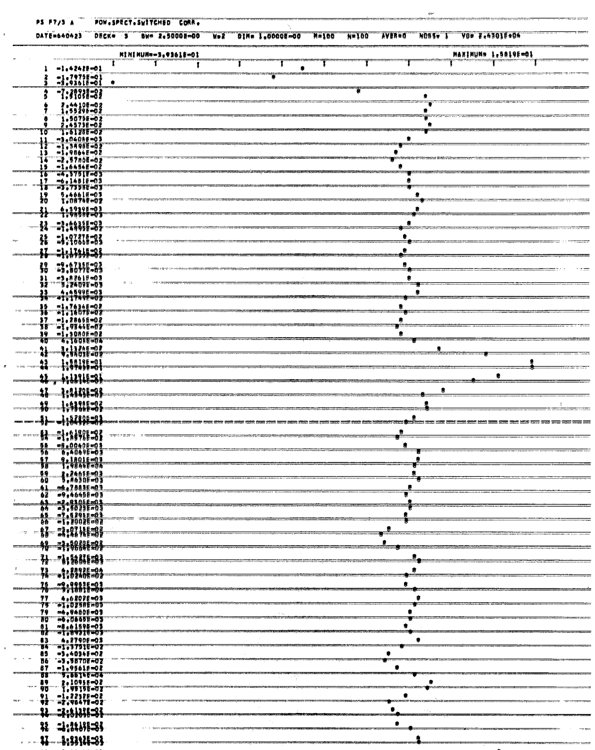

FIGURE 5—**Power Spectrum of Taurus (10-Second Integration) As Observed on Digital Autocorrelation Receiver.**

The author wishes to express his gratitude to S. Weinreb for original suggestion of the project, and help throughout the project. Also, thanks are due to C. Bare for design of the square law detector and clipper and J. Parker for aid in design, construction and checkout.

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1. Weinreb, S., "A Digital Spectral Analysis Technique and Its Application to Radio Astronomy", MIT, Research Laboratory of Electronics, Technical Report 412; August 30, 1963.