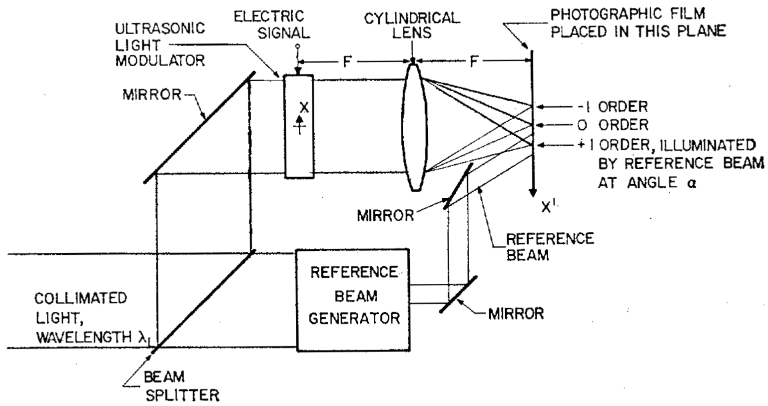

Fig. 1. Holographic recording system.

and Doppler frequency analysis of the ensemble of stored signals occur. In the first step of the holographic technique, the Fourier transform holograms of the required sequence of radar returns are recorded, one at a time, on photographic film. Then, the film containing the images of the required returns is developed and passed into the aperture of a two-dimensional coherent optical spectrum analyzer. It is found that the light intensity distribution in the output plane of the optical spectrum analyzer is analogous to the desired Doppler frequency shift spectra and has the required frequency resolution.

A simplified sketch of the holographic signal recorder is shown in Fig. 1. Each radar return pulse is converted to a one-dimensional traveling spatial transmittance function by means of an ultrasonic light modulator. This transmittance function may be viewed as a one-dimensional scene undergoing constant-speed linear motion. The Fourier transform associated with this moving scene is formed on the photographic film by the cylindrical lens. (The frequency resolution of the Fourier transform of the single radar return is, however, inadequate.) If the interference pattern between the Fourier transform and a plane-wave reference beam were formed, this pattern would produce the Fourier transform hologram of the radar return pulse on the film. However, because the scene is moving, a hologram can be formed in this way only if the exposure time is very short (less than one period of the highest temporal frequency component contained in the radar signal). Limited film sensitivity and laser power make this straightforward approach unrealizable.

It is possible to record the hologram with longer exposure time by compensating the reference beam so that a stationary or quasi-stationary interference pattern is produced. Compensation of the reference beam, which is accomplished by the "reference beam generator" in the figure, involves shifting the carrier frequency of the optical reference beam by means of an ultrasonic light modulator.

Simulated radar signals with known Doppler frequency content were recorded on this system and reconstructed in a coherent optical spectrum analyzer.

8.5 Holographic Gratings of Arbitrary Loss: Theory and Experiment,[1] M. Chang and N. George, *California Institute of Technology, Pasadena, Calif.*

Thick lossy dielectric gratings have been analyzed using a Raman–Nath formalism modified to incorporate losses. Four second order coupled-wave equations are retained for accurate computation of the zero; first-, and second-order diffracted beams for a multitude of practical cases. Significant differences are found in comparison to computations in which only two coupled waves are retained. The entire range of losses and thicknesses encountered for holograms in AgBr emulsions has been studied using this unified approach.

Graphs have been prepared to show the efficiency, power diffracted in the first-order relative to the total incident power versus the index modulation for a wide range of thicknesses and losses. At a given thickness, optimum efficiency requires a specific exposure. The efficiency for an optimum exposure is plotted versus the loss factor with thickness as a parameter.

New experimental data are presented for bleached gratings in which several diffracted orders are measured and compared to our theory for a wide range of index modulation and loss factors. Optimum efficiencies are reported for bleaching methods giving the following dielectric end-products: AgCl, AgBr, AgI, and Ag_2CrO_4. Preexposure flashing of the emulsion has been found to increase the linearity and the saturation density, enabling one to obtain higher index modulations to values consistent with our optimization theory.

[1] This work was supported by the Electronics Division of the Air Force Office of Scientific Research.

8.6 A Binary Hologram Digital Memory, L. F. Shew and J. G. Blanchard, *IBM Corp., San Jose, Calif.*

A semipermanent memory with information stored in the form of one-dimensional binary Fourier holograms[1, 2] has been developed. One byte of data (8 data bits and 1 clock bit) is encoded in each hologram. As a consequence all data combinations are represented by only 256 holograms. The holograms are generated by a computer prior to recording and are written by an electron beam on a strip of photographic film. Readout is accomplished by deflecting a laser beam to a selected track, and decoding of holograms is done by an optical Fourier transform.

The binary holograms used in our digital memory consist of many parallel transparent apertures on an opaque background and are similar to general diffraction gratings. The parameters which characterize their structure control the amplitude and phase of the light emerging from the hologram.

Representation of a data byte in each hologram as a series of n binary aperture is shown in Fig. 1. the ith aperture is characterized by its width $2a_i$ and its position b_i. The reconstruction system performs optically the Fourier transforms of the hologram apertures to yield at a position y in the output plane a light complex amplitude given by the following equation.

Amplitude:

$$A(y) = c \sum_{i=1}^{n} a_i \frac{\sin (Ka_iy)}{(Ka_iy)} \cdot \exp (jKb_iy)$$

with the intensity given by

$$I(y) = | A(y)^2$$

where $c =$ constant and $K = 2\pi/\lambda F$ in which $\lambda =$ wavelength of the light source and $F =$ focal length of the imaging lens.

After the binary holograms have been generated by the computer, they can be plotted or stored in a memory and written on photographic film strips by an electron beam recording system according to the aperture specifications of the holograms.

A reader for the holograms was designed as shown in Fig. 2, and an experimental model was built. It consists of a low-power (3 mW) He–Ne laser which serves as a light source and a switchable total internal reflection light deflector[3] to position the laser beam to the desired track of holograms to be read.

The experimental reader was tested under simulated machine operating conditions. Our results confirm the desirable properties of shift invariance and redundancy of the Fourier holograms. In addition, the experimental reader demonstrated the insensitivity of holographic

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[3] M. E. Rabedeau, "A switchable total internal reflection light deflector," *IBM J. of Research and Develop.*, March 1969.