is then switched to either a (straight) PCM chain, the IGS data compressor, or the C-F data compressor. At the *receiving* end, data from any one of the three channels is presented to the 6-bit D/A converter, which yields the corresponding analog output.

The equivalence of the analog and the 6-bit-PCM pictures is demonstrated in Fig. 5. This figure also compares 3-by-3-bit (3 most-significant bits transmitted, 3 least-significant bits retained for cumulative addition) IGS processing and 3-bit PCM pictures. (Figs. 5 through 9 are presented primarily for comparison purposes. Since some detail has been lost in reduction and reproduction, they are not ideal representations of the various transmission methods.) It can be seen that although the IGS system transmits the same number of bits as the conventional 3-bit system, it eliminates the contouring effect and permits the detection of smaller intensity variations in the original scene. Although the IGS system approaches the accuracy of the 6-bit system and requires only half the number of bits, an intensity dot pattern is noticeable in the IGS picture. By adding lighter gray levels to individual picture elements, the IGS system has improved the *large area* gray scale rendition over that of the 3-bit system, but the intensity variations are not completely averaged by the human eye. Certain applications might well use the IGS pictures without further refinement. However, additional processing of the data at the receiver could average the data in its electrical form before display. This processing would produce a more subjectively pleasing picture, but it would reduce the limiting spatial resolution of the system.

The tradeoff that can be made with the IGS system between bandwidth saving and resultant picture fidelity is shown in Fig. 6. If the original 6-bit word is separated into 4 most-significant bits and 2 least-significant bits so that 4 bits per picture element are transmitted and displayed (16 possible levels) and 2 bits are retained to supplement succeeding elements, the fidelity of the reproduced picture can be increased while realizing only a 1.5:1 saving. A 2:1 saving is provided by the 3-by-3-bit form of the IGS system. Alternatively, the 2-by-4-bit IGS configuration can provide a 3:1 compression with pictures that are less accurate, but which are substantial improvements over 2-bit pictures of comparable bandwidth.

The results of C-F system processing are shown in Fig. 7. While transmitting only half the number of bits, this system reproduces pictures which are almost as good as those of the 6-bit system. Shown for comparison with the 3-bit PCM picture is the picture resulting from the display of only the coarse data; i.e., the data was not refined with the 3-least-significant bits available during fine-data transmission. Of the more than 340,000 elements in the C-F picture, 80 to 90% are represented with fine information (6-bit accuracy) and the rest with 3-bit accuracy. The coarse elements can be distinguished from the fine by the received data, and a C-F overlay picture can be generated (e.g., by displaying black when coarse and white when fine) to aid in identifying the two accuracies.

Representative IGS and C-F meteorological pictures are compared in Fig. 8 along with straight 6-bit and 3-bit pictures. Although both the IGS and C-F systems require the same bandwidth (in the 3-by-3-bit configuration of each system), the C-F system reproduces a picture with greater fidelity. However, the C-F system is about three times as complex as the IGS system and employs more sophisticated data coding.

The C-F system processing of another type of subject matter is shown in Fig. 9. The *flecks* in the upper left-hand portion of the C-F picture are accentuations of small signal variations about the threshold level between two coarse quantization levels. These variations cause the system to remain in the coarse mode of operation. They could be eliminated by additional processing of the data at the transmitter before coarse-fine encoding to discriminate between *meaningful* signal variations and *noise.* In this picture the C-F system again represented 80 to 90% of the elements with 6-bit accuracy. Of the remaining elements, all but a few are accurate to 3 bits; these few were reduced to 2-bit accuracy to prevent an unwanted signal code from being transmitted. The probability of an intensity change of about one-half of the black-to-white range occurring from one element to the next is quite small; it occurred only a few times in the scene in Fig. 9 and did not occur at all in Fig. 7. These large-amplitude changes most likely occurred at the transition between a near-white area at the edge of the picture and the black (blanked) retrace interval whose encoding was not disabled.

CONCLUSIONS

Digital techniques can be used to advantage in many space-TV applications. For the video SNR normally required (in the range from about 30 dB to about 50 dB, peak-to-peak, black-to-white video-signal swing-to-RMS noise ratio), the transmission power and bandwidth required for analog-FM and PCM-PSK transmission are about the same. Compression of the digital data to increase the efficiency of digital-TV storage and transmission is possible.

Two new digital-TV data compression techniques have recently been developed at the RCA Space Center. Each provides a 2:1 compression over 6-bit PCM. One is an elementary technique (the IGS system) which provides fair pictures; the other (the C-F system) is a more elaborate but still relatively simple technique which provides excellent pictures. The 2:1 reduction in data permits a given digital storage system to store twice the number of pictures that could be stored using noncompressed data; similarly in any mission the same number of pictures can be transmitted in half the time, or twice as many pictures can be transmitted in the original time. Alternatively, spatial resolution can be increased 40%.

To obtain substantially higher compression ratios, time buffering must be employed. The development of a hybrid system employing the coarse-fine system with time buffering of the fine data is now being pursued. Initial measurements have indicated that this system can achieve a 10:1 data compression on the average for subjects like the lunar pictures shown in Fig. 9.

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