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Performance of the Image Statistics Decoder in Conjunction With the Goldstone–VLA Array

H. C. Wang and G. H. Pitt III
Communications Systems Research Section

During Voyager's Neptune encounter, the National Radio Astronomy Observatory's Very Large Array (VLA) will be arrayed with Goldstone antennas to receive the transmitted telemetry data from the spacecraft. The telemetry signal from the VLA will drop out periodically, resulting in a periodic drop in the received signal-to-noise ratio (SNR). The Image Statistics Decoder (ISD), which assumes a correlation between pixels, can improve the bit error rate (BER) for images during these dropout periods. Simulation results have shown that the ISD, in conjunction with the Goldstone–VLA array can provide a 3-dB gain for uncompressed images at a BER of 5.0×10^{-3}.

I. Background

Throughout the Voyager mission, the DSN has been used for telemetry reception. As Voyager approaches Neptune, the signal must travel a long distance to reach earth, resulting in a low received SNR. In order to assure that the received Voyager data still achieves an acceptable BER, the National Radio Astronomy Observatory's Very Large Array (VLA) in the high New Mexico desert can assist the DSN station at Goldstone in receiving the Voyager telemetry data during Neptune encounter [1]. However, VLA telemetry has a dropout period of 1.6 millisec every 52 millisec. In [2], it was concluded that due to the loss of data in the dropout periods, the VLA alone would not be able to support the (7,1/2) convolutional code for providing an acceptable BER for Voyager telemetry data.

Arraying the VLA with Goldstone antennas will result in a 3-dB gain in SNR, except during the VLA dropout period.

II. BER Improvement Using the ISD

The Image Statistics Decoder (ISD) has been developed for decoding uncompressed images [3]. When decoding uncompressed images, the ISD has superior BER

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performance over the Maximum-likelihood Convolutional Decoder (MCD) which is currently used for decoding all data from Voyager. The ISD's algorithm is based on the fact that adjacent pixels in an image are very similar in their intensities; hence, a pixel is likely to be close to its neighbors in intensity. During the VLA's dropout periods, only Goldstone will receive the signal from Voyager. Were the SNR to drop to a point where the MCD could not decode the data at an acceptable BER, the ISD may be used for decoding the data. In addition, during other situations when the received SNR dropped too low for the MCD to decode a recognizable image, the ISD could also be used as an alternative to the MCD.

It should be pointed out that due to the large amount of computations and comparisons the ISD needs, as well as the fact that it currently only exists in software, the ISD is much slower than the MCD. The ISD takes three days on a SUN 3/260 to decode one image. Table 1 in [2] shows the speed of the ISD with different computers.

III. Simulation

Simulations have been performed of image reception at Goldstone alone and of an equal aperture Goldstone–VLA array. In each case, the MCD and the ISD were used on identical data. An image of the Uranus moon Miranda (Fig. 1) was provided by the Voyager project. It was first packed into image frames, which were then packed into playback frames. After the playback frames were convolutionally encoded (just as the spacecraft would do), Gaussian noise was added to the stream of data. For the Goldstone-alone case, the noise was stationary; for the Goldstone–VLA case, the SNR ratio was dropped by 3 dB for 1.6 millisec every 52 millisec to simulate the VLA telemetry dropout. These simulated received telemetry streams were then decoded in software, either with an MCD or with the ISD inside images, and with MCD outside images. After decoding, the nonimage parts of the frame were stripped off, and the resulting image was compared to the original image to compute bit and byte error rates.

Figure 2 shows the BER for both decoders. The Goldstone stand-alone system has a constant SNR, while the Goldstone–VLA array is at its nominal level 97 percent of the time and 3 dB lower during the dropout period.

In the simulated SNR range, the ISD always has a better BER than the MCD. In particular, at a bit error rate of 5.0×10^{-3}, which is the maximum acceptable BER for image reception, the ISD has about a 3-dB gain. Note the steeper slope of the ISD curves at low SNRs. A conjecture for this phenomenon is a higher performance gain from a few good pixels among a large number of bad pixels at low SNRs. This is in contrast to the high SNR case where most pixels are good, hence yielding a lower performance gain with the addition of the same number of pixels. Figure 2 also shows that both the MCD and the ISD for the Goldstone–VLA array lose about 0.2 dB when compared to Goldstone alone at the same nominal SNR.

References

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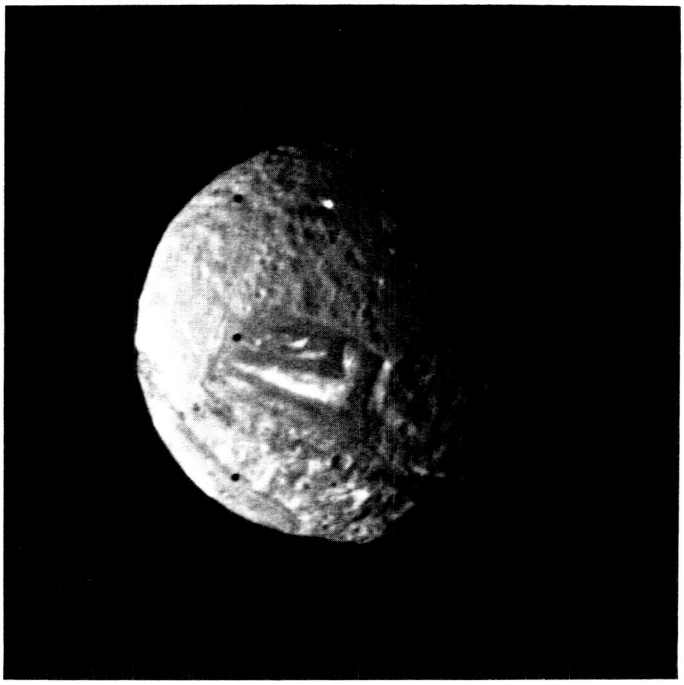

Fig. 1. Miranda.

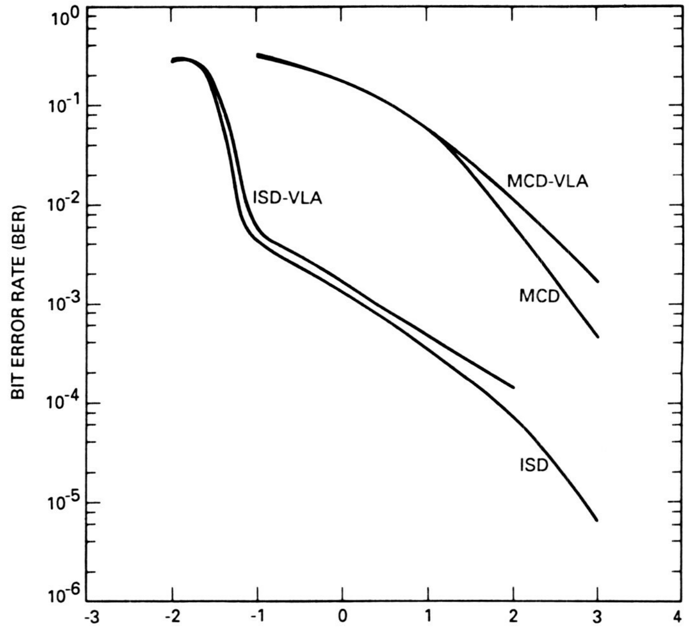

Fig. 2. ISD and MSC performance compared at nominal SNR.