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The University of Washington—Center for Quantitative Sciences
The University of Costa Rica—Centro de Investigación en Ciencias del Mar y Limnología
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A STUDY OF BAND NOISE ASSOCIATED WITH LANDSAT BATHYMETRIC IMAGES

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e Fisheries Stock Assessment CRSP (sponsored in part by USAID ant No. DAN-4146-G-SS-5071-00) is intended to support llaborative research between U.S. and developing countries' iversities and institutions on fisheries stock assessment and nagement strategies.

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A STUDY OF BAND NOISE ASSOCIATED WITH LANDSAT BATHYMETRIC IMAGES

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ABSTRACT

This report relates to the utilization of satellite imagery for the purpose of better defining certain marine habitats based on depth zones. These habitats are relevant to fisheries stock assessment because unique fish assemblages are often associated with particular depth zones. More specifically, the material which follows addresses a method for more precisely defining the depth zones derived from multispectral scanner data by minimizing band noise. A sample of seven sets of scanner data from Philippine coastal areas are used for the analyses.

INTRODUCTION

Bathymetric images from Landsat Multi Spectral Scanner (MSS) data can be produced using the method described by Bina et al. (1978). The method involves the creation of four zones which are dependent upon the depth of penetration for each MSS band. Before each zone is derived, MSS signals are sampled over a known clear deep water area. The signature of the deep water area represents spectral limits to which no discernible signal is returned from the bottom. The zones are:

Zone 1: Signal on MSS 4-7 (exposed areas)

Zone 2: Signal on MSS 4-6
No signal on MSS 7

Zone 3: Signal on MSS 4-5
no signal on MSS 6 & 7

Zone 4: Signal on MSS 4
no signal on MSS 5, 6 & 7

Jupp et al. (1985) associated these zones to depth ranges to produce the bathymetric images.

Band 4 zone: (Zone 4) 15-5 meters depth
Band 5 zone: (Zone 3) 5 meters - 50 centimeters depth
Band 6 zone: (Zone 2) less than 50 centimeters

All the depth ranges above were acquired in clear water. Bathymetric images produced by this technique have been used for the whole of the Great Barrier Reef in Australia.

Using the band zonation technique described above, certain extraneous noises (such as spikes and dropouts) can be detected in noisy bathymetric images. This type of band noise was studied and its characteristics identified. To test the method, several MSS images were taken into consideration placing importance on the extent of the noise encountered. Although there is no attempt to correct the images using the method, procedures are laid out to correct such errors.

MATERIALS

The computer hardware used was an IBM PC/AT with 1.7 megabytes internal memory. The work station included a monochrome (text) display adapter as a command console and an analog RBG monitor with a resolution of 512 x 480 pixels to display the images. The imaging software was a Decision Images System Resource package version 1.1. Commands can be sent to the machine by using either the digitizing tablet as a menu pointing device or the keyboard. A Cipher drive was used to read the digital images stored in computer compatible tapes (CCTs).

Seven available tape subsets of 512 x 512 pixel resolution were selected to test the method (see Figure 1). The dates associated with each image correspond to the acquisition times.

Programming was done using the Turbo Pascal compiler version 3.0.

METHODS

The methods will be treated in two parts. The first part covers the discussion and mechanics of the Band Overlay Correction Matrix (OCM). The other part centers on the methodology of the application of the OCM to the test images.

The overlay correction matrix

The Overlay Correction Matrix (OCM) is a table containing codes (called matrix correction codes) which specify how a particular pixel in an image is to be corrected. Thus, each OCM cell has a one-to-one correspondence to the pixel in an image to be corrected. To be able to create the matrix correction codes, the band errors noise should be identified.

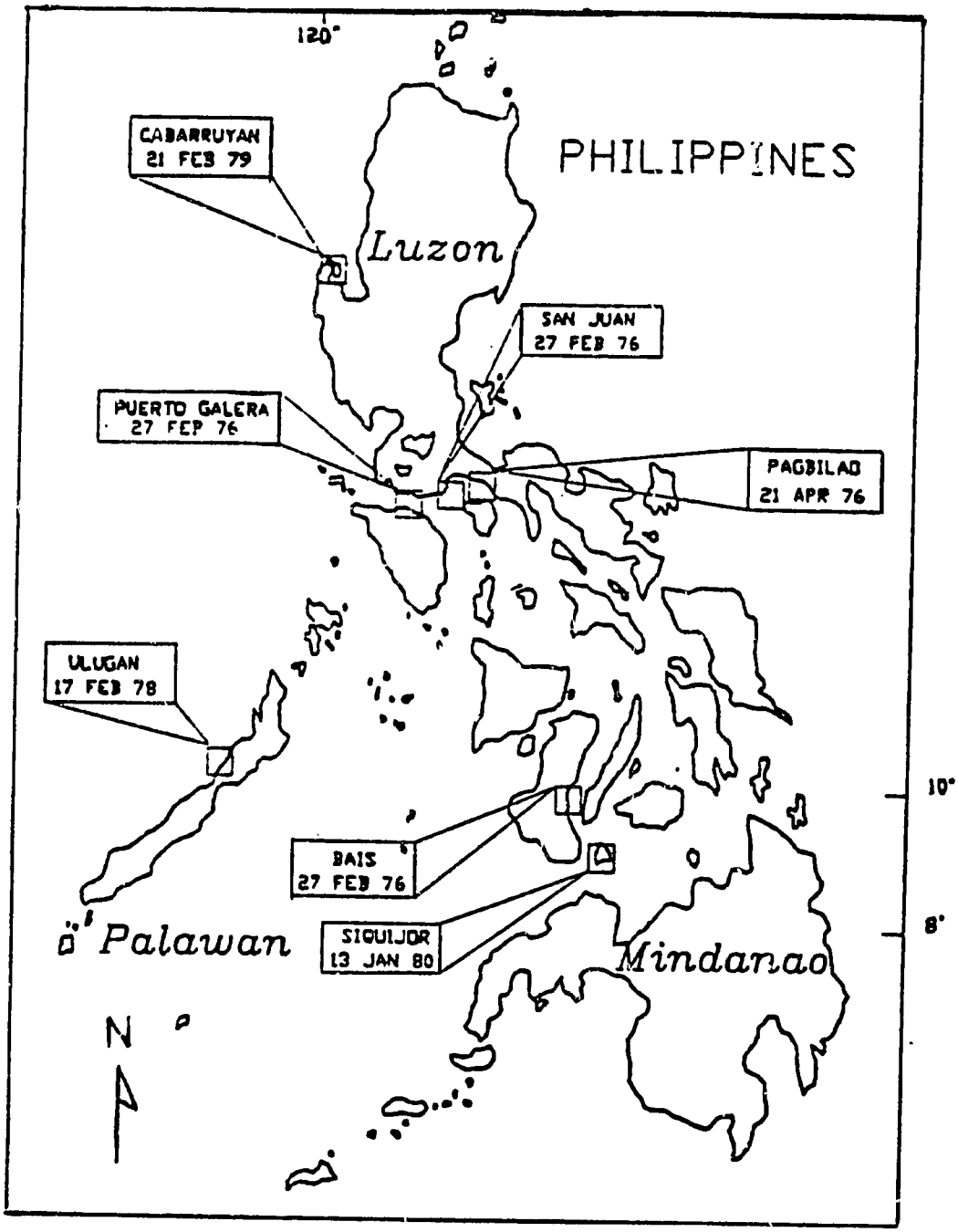


Figure 1. Map showing the locations of the seven test images.

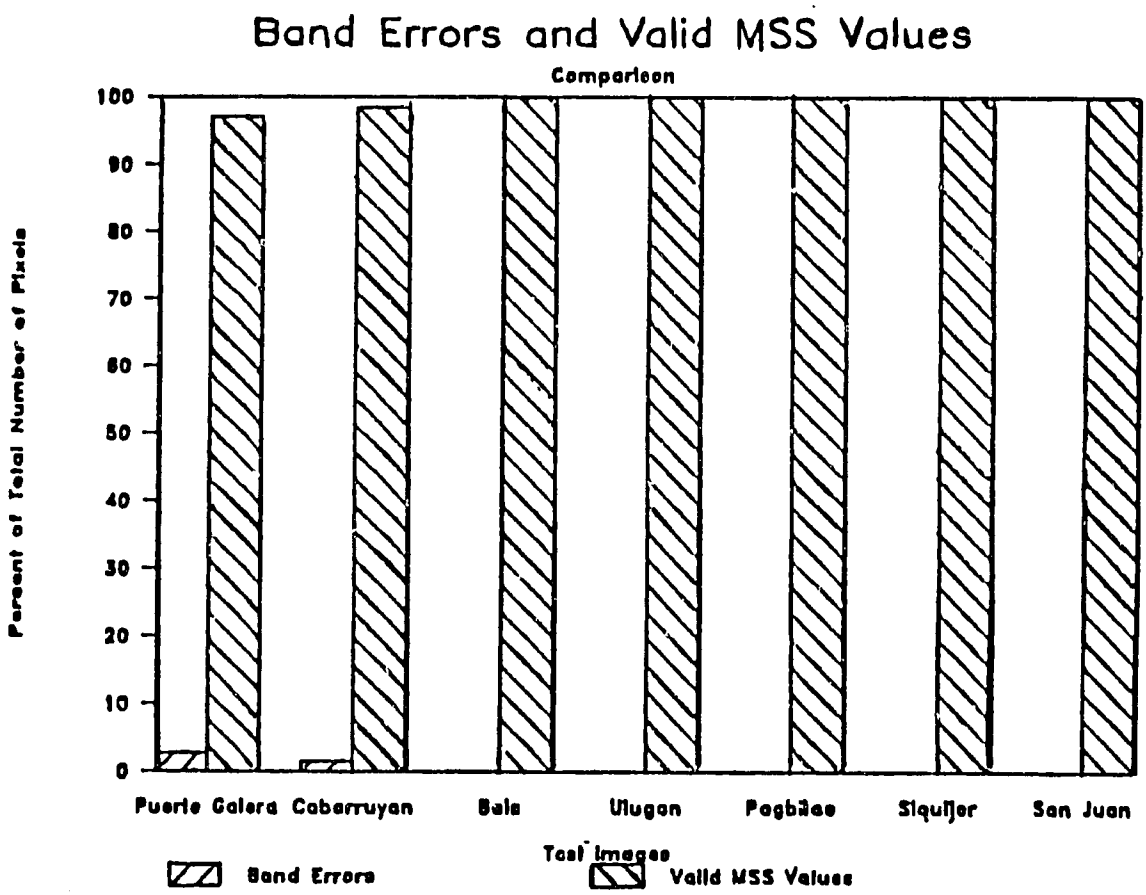


Figure 2. Graph showing the comparison between band errors and valid MSS values in the images tested.

Valid MSS values and band errors

An MSS pixel is considered to be valid if it satisfies values indicated in Table 1. The rows in the table refer to the major band zones and columns to the four MSS channel signals. The major band zones are consistent with the definition given by Bina et al. (1978) and Jupp et al. (1985). A value of '1' indicates that a signal is present while a value of '0' indicates its absence. The series of 1's and 0's for each band zone can be treated as binary numbers for coding purposes. For readability, an additional (rightmost) column is added to convert the binary codes into hexadecimal (base 16) notation. From this point onwards, band error codes will be represented in hex notation.

Table 1. Valid MSS signal values. 1-signal present 2-signal absent

Major Band Zones	Signal on Band 4	6	6	7	Hex
Exposed	1	1	1	1	F
Band 6 Zone	1	1	1	0	E
Band 5 Zone	1	1	0	0	C
Band 4 Zone	1	0	0	0	8
Deep Water	0	0	0	0	0

The maximum number of codes that can occur on a four channel image is 16 (hex F). Five of these codes correspond to the valid MSS values previously discussed (i.e. F,E,C,8, and 0). A listing of these codes is enumerated in Table 2.

Table 2. Possible band signal codes.

Hex	Binary	Comment	Band Error Type	Correction
0	0000	Valid MSS signal	-	-
1	0001	Band 7 error	Simple error	Omission
2	0010	Band 6 error	Simple error	Omission
3	0011	Possible error on all bands	Complex error	Inclusion
4	0100	Band 5 error	Simple error	Omission
5	0101	Possible error on all bands	Complex error	Inclusion
6	0110	Possible error on all bands	Complex error	Inclusion
7	0111	Band 5 error	Simple error	Inclusion
8	1000	Valid MSS signal	-	-
9	1001	Possible error on all bands	Complex error	Inclusion
A	1010	Possible error on all bands	Complex error	Inclusion
B	1011	Band 5 error	Simple error	Inclusion
C	1100	Valid MSS signal	-	-
D	1101	Band 6 error	Simple error	Inclusion
E	1110	Valid MSS signal	-	-
F	1111	Valid MSS signal	-	-

The error codes in Table 2 can be classified as simple errors and complex errors.

Simple errors are band noise which can be readily corrected. This type of error has one channel that contains the noise. The band error codes corresponding to the simple error type are 1,2,4,7,B, & D.

On the other hand, in complex error type codes the channel containing the noise cannot be determined (i.e. the error can possibly occur in all four channels). In this case, all four MSS channels are assumed to contain the noise. The band error codes classified as complex error types are 5,6,9,A & 3.

Correcting band errors

The correction of simple errors is outlined in Table 3.

Table 3. Correcting simple errors.

Band Error Code	Corrected Value	Remarks
1 (0001)	0 (0000)	Band 7 anomalous signal
2 (0010)	0 (0000)	Band 6 anomalous signal
4 (0100)	0 (0000)	Band 5 anomalous signal
7 (0111)	F (1111)	Band 4 missing signal
B (1011)	F (1111)	Band 5 missing signal
D (1101)	F (1111)	Band 6 missing signal

The only resultant valid MSS value codes possible are hex 0 and F. Complex errors can be corrected by using various methods similar to filtering algorithms like the low pass spatial filtering technique described by Avery et al. (1985).

Band error correction can be divided into two main types namely, correction by pixel omission or correction by pixel inclusion. Pixel omission involves the substitution of the current pixel value (considered as noise) by the minimum pixel value for that channel. Band errors involving pixel omission for their correction are simple error codes 1, 2 & 4. Those errors involving pixel inclusion are simple errors 7, B & D, and all complex errors.

Matrix correction codes

Matrix correction codes are stored in an overlay correction matrix. This matrix has similar dimensions to the image being corrected. The matrix correction codes specify

the type of correction to be applied to a pixel (Table 4). Matrix codes 1 to 3 are correction codes involving pixel omission. Matrix correction codes 4 to 7 are correction codes using pixel inclusion. Codes 4 to 6 are reserved for simple errors and code 7 for complex errors. Matrix code 0 signifies no error.

Table 4. Matrix error codes

Matrix Correction Code	Description
0	No Error
1	Correct Band 5 by pixel omission
2	Correct Band 6 by pixel omission
3	Correct Band 7 by pixel omission
4	Correct Band 4 by pixel inclusion
5	Correct Band 5 by pixel inclusion
6	Correct Band 6 by pixel inclusion
7	Correct all bands by pixel inclusion

Application of the OCM method

Image subsets

Seven 512 x 512 subsets were selected to test the OCM matrix. The only criterion in the selection was that the images should as much as possible contain submerged areas including deep water. Deep water areas are depths beyond the band 4 zone (usually greater than 15 meters) where no discernible signals are returned. The signals in the deep water area are important since they establish the minimum base values for each channel used during correction. In other words, the minimum base values taken in deep water is a means to calibrate the OCM program. Image enhancements were omitted to preserve the original digital values. The original digital values were quantized 0-127.

The OCM program

The main specifications of the computer program that creates the OCM were designed to be as general as possible. However, due to the high dependency of the program to the digital image processing system file formats, some system dependent specifications were unavoidable. The main specifications of the program are as follows:

Main OCM program specifications

A. An image pixel is to be processed simultaneously on the four MSS channels to determine its band error code and consequently its matrix correction code.

B. The matrix correction codes are to be stored in an overlay correction matrix file using the image file format used by the system.

C. A frequency table of the band errors encountered should be produced after an OCM file is created.

Testing the OCM method on the sample images

The objective of the OCM test is to find out the frequency of each type of band error. There is no attempt to use the OCM to correct the test images.

In preliminary processing, all the images were scanned to get all the minimum digital numbers (DNs) on each channel. These values represent the minimum base values for the channels to calibrate the OCM program.

The next processing step is determining the band error code for each image pixel. The channels are simultaneously processed. Each pixel value of a channel is subtracted by the minimum base value for that channel. The resulting DN from each channel is then tested for the presence or absence of a signal. A DN value of zero represents an absence of signal (code 0). Any other value represents information (code 1). The 1's and 0's (presence and absence of signal) for each channel are then arranged with the leftmost digit (most significant bit, MSB) signifying band 4 channel and the rightmost digit (least significant bit, LSB) as band 7 channels similar in format as shown in the Table 1. These four bit numbers now represent the band error code.

The matrix correction codes are then determined from the newly generated band error codes. The process starts by deciding whether the band error code is a valid MSS value or an actual error. To do this, the program compares the band error code to the valid MSS value codes. If it is a valid MSS value, a matrix correction code of 0 (i.e. no error) is assigned. For actual errors, the band error code is determined whether it can be corrected by pixel inclusion or pixel omission. For pixel omission correctable band error codes 1, 2 & 4, matrix correction codes 3, 2 & 1 are assigned respectively. Pixel inclusion correctable errors are either of the 7, B & D simple error group or of the 5,6,9, A & 3 complex error types. The 7, B & D band errors are assigned 4,

5 & 6 matrix correction codes while the 5,6,9, A & 3 group is assigned the matrix code 7.

RESULTS

The frequency tables produced from the sample images are summarized in Plate 1. The band error codes are ranked according to decreasing percentages from left to right on the horizontal axis. Of the seven images, only Cabarruyan and Puerto Galera had erroneous pixels greater than two percent of the total number of pixels. The rest of the images contained noise but did not affect the images greatly.

The band error codes that were not encountered on the test images were error codes 1,4, 5 & 9. This may be so because the number of test images may have not been a representative sample group.

Band error code D(1101) had the greatest occurrence in all seven test images combined. It is the primary error in the test images Puerto Galera, Cabarruyan, Ulugan and Siquijor.

The ranking from highest to lowest occurrences of the different band error codes is D,A,7,6,B, 1 & 2. Band error code D comprises more than 90% of the error codes encountered. The top five band error codes can be corrected through pixel inclusion.

All band error codes encountered in the test images were less than ten percent of the total number of image pixels as shown in Figure 2. The exact error percentages are as follows: Puerto Galera 2.89%, Cabarruyan 1.63%, Bais 0.09%, Ulugan 0.03%, Pagbilao, Siquidjor and San Juan with 0.01%. An error frequency of approximately two percent of the total pixels can degrade the image considerably (see Figure 3).

There is still a need to study a significant number of images to really prove the usefulness of the method and to fully study the behavior of the band errors that are associated with MSS images.

The OCM method provides a way of evaluating the quality or "cleanness" of an image used for further bathymetric processing. It may provide a correction procedure for Landsat derived bathymetric images in the future.

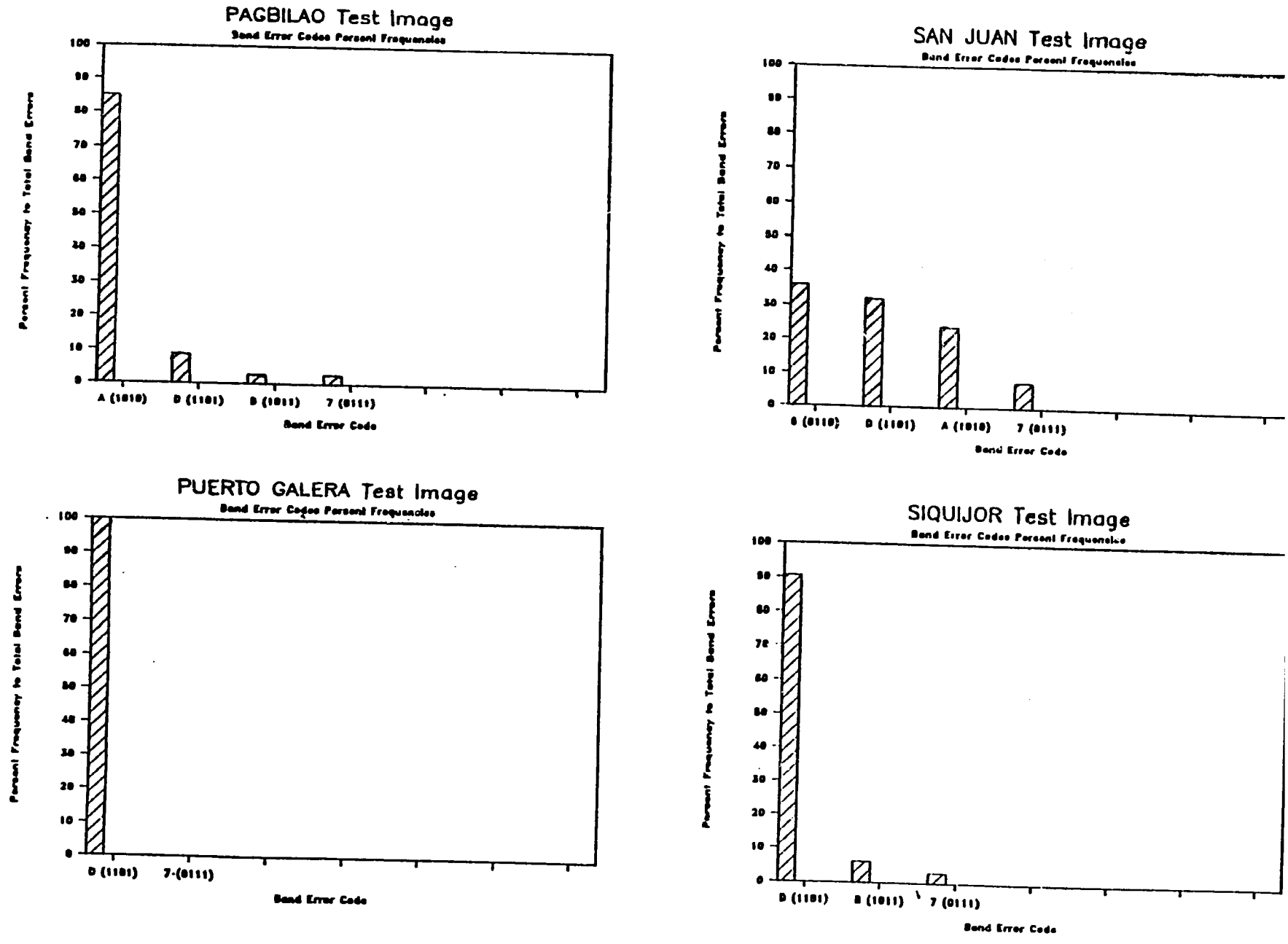
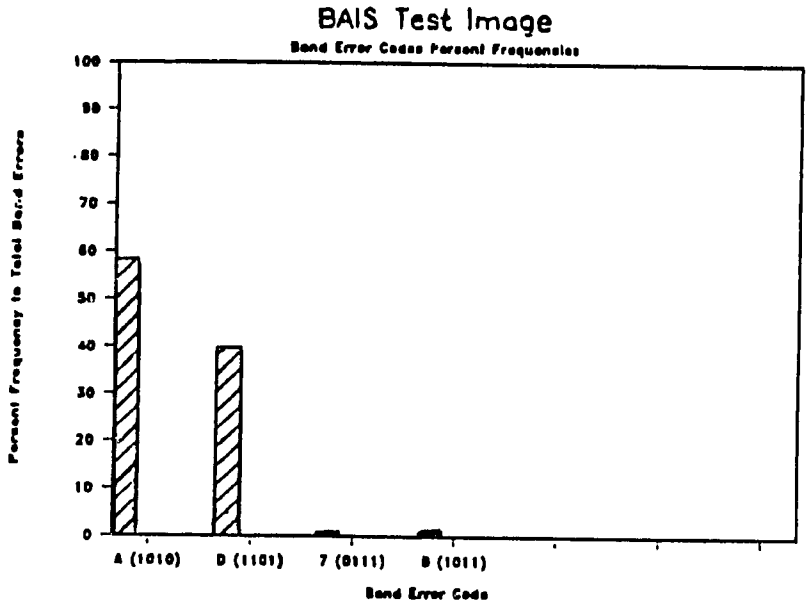
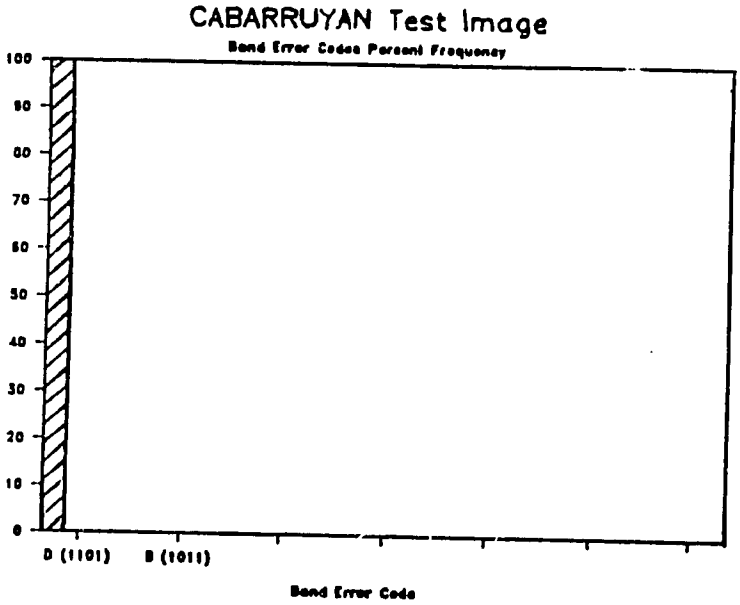
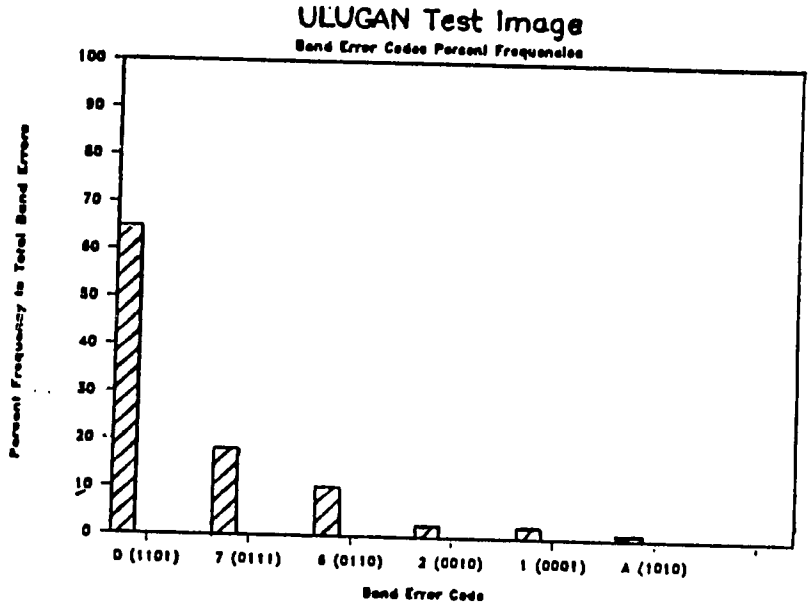


Plate 1: Band error codes percent frequencies from the seven test images.

Plate 1: Continued







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