GEOLOGICAL AND GEOMORPHOLOGICAL STUDIES IN THE RORAIMA STATE (BRAZIL) BY SIR-B (SHUTTLE IMAGING RADAR) DATA: PRELIMINARY RESULTS USING FILTERING TECHNIQUES

Hermann Johann Heinrich Kux
Gerald Jean Francis Banon
Luciano Vieira Dutra
Liu Chan Chiang
Instituto de Pesquisas Espaciais - INPE
Caixa Postal 515, 12201 - São José dos Campos, SP, Brasil

SUMMARY

In this paper the preliminary results on the evaluation of spaceborne radar (SIR-B) data for geological and geomorphological studies are presented. Two speckle reduction algorithms (Sigma and Lee) are described and applied to a SIR-B scene, from an important geological province (Guiana Shield) in northern Brazil.

1 - INTRODUCTION

In the coming years several multiparameter orbital SAR systems will be launched (Table 1), and an enormous amount of sensor data from land and sea will be available for research and thematic applications.

In order to properly evaluate these data, several studies have to be performed by the user community, using existing data sets to:

a) analyse and evaluate physical parameters of relevance from targets of interest like dielectric constants and roughness;

b) study the characteristic multiplicative noise of SAR images ("speckle") specially on how to reduce or eliminate it without blurring the image, using for example, adaptive filters.

c) develop algorithms (e.g. for thematic classification) that would permit a synergistic approach for the use of data obtained as well by optical (TM, SPOT) sensors as by active microwave (radar) systems.

At INPE, presently these three types of study are being performed. In this paper, however, only the preliminary results on the application of two filters, adapted from Lee (1981, 83), to reduce speckle at SIR-B images will be presented.

Following a short description of the SIR-B mission, both filter types are

TABLE 1: OVERVIEW OF SAR MISSIONS

MISSION	LAUNCH DATE	COUNTRY OR ORGANIZATION	MISSION DURATION	ORBIT OR INCLINATION	ORBIT ALTITUTE (km)	FREQUENCY band*	POLARIZATION	LOOK ANGLE	NOMINAL RESOLUTION (m)	SWATHWIDTH (km)
SEASAT-A	jun 1978	USA/NASA	3 months	polar 108°	794	L	HH	20°	25	100
SIR-A	nov 1981	USA/NASA	5 days	38°	252	L	HH	47°	40	50
SIR-B	out 1984	USA/NASA	8 days	57°	250	L	HH	15-60°	20-50	20-50
SIR-C	1992 1993 1995	USA/NASA FRG/DFVLR ITALYA/PSN	7-10 days 3 times	polar	225	L,C,X	HH,VV HH,VH	15-55°	15-50	15-90
EOS/SAR	1995/1997	USA/NASA ESA JAPAN	10 years	polar	542-824	L,C,X	HH,VV HV,VH	6-60°	20-500	30-700
ESA/ERS-1	1991	ESA	3 years	quasi polar 98,5°	785	C	HH	23°	30	80
J-ERS-1	1991	JAPAN	3 years	sun-synchronous	570	L	NS**	33°	25	75
RADARSAT	1994	CANADA	3-5 years	99,48°	1001	C	NS	30-45°	25	150

* band L = 1,275 GHz; band C = 5,3 GHz; band X = 9,5 GHz

** NS = non specified

Source: Ulaby, Moore & Fung (1986), modified

briefly described. The applicability of this procedure to enhance images of geological/geomorphological interest will be discussed.

2 - THE SIR-B EXPERIMENT

The Shuttle Imaging Radar-B, flown on October 1984, aboard "Challenger" similarly to its' predecessor, SIR-A was an L-band (1,282 GHz = 23,4 cm wavelength) system. The objective of the second shuttle radar mission was to evaluate quantitatively the relationship between backscatter against the response of incidence angle and over different terrain types. In order to perform this task, the antenna was designed to be tilted in one-degree increments over a 15^{o} to 60^{o} range of look angles.

In comparison to SIR-A, the second SIR experiment had a facility to digital record data. This permitted an improved dynamic range and a higher spatial resolution vis-à-vis the former SAR system. For further information on this imaging radar system as well as on experiments performed with SIR-B data, it is referred to Cimino et al. (1986).

3 - THE "SPECKLE" PROBLEM IN SAR IMAGES

"Speckle" can be considered a randomic and multiplicative noise in SAR images, since the noise level increases with the average grey level of the area under study. Lee (1987) characterizes the two principal speckle reduction techniques:

a) Image enhancement techniques that average various registered, but independently processed (e.g. multi-look processing) scenes, such as Goodman (1976) and Porcello (1976);

b) Speckle reduction techniques applied after image formation (Lee 1981, 1983, 1986, 1987, Frost et al. 1981).

At INPE, Ii & Banon (1988) performed initial studies on speckle reduction from SAR-580 images using Lee (1981, 1983) and Frost et al. (1981) filters. The former presented better results, and will be used on this study for SIR-B data.

4 - SIGMA FILTER

The sigma filter proposed by Lee (1983) is based on the sigma probability of a gaussian distribution. The pixel to be processed is changed by the average of the neighbor pixels in a 3 x 3 window. These grey levels are within the limit of two standard deviation of the pixel considered.

So, if X denotes the original image, its'filtered version Y is given, at any pixel location (i, j), except at the border, by

$$Y(i,j) \quad \frac{\sum_{(k,\,1)\ \varepsilon\ W(i,j)} \sigma_{(i,j)}^{(k-i,\ 1-j)\ X\ (k-1)}}{\sum_{(k,\,1)\ \varepsilon\ W} \sigma_{(i,j)}^{(k,1)}}$$

where: W is a 3 x 3 window, centered at (0,0)
W (i,j) is this window centered at (i,j)

and

$$\sigma_{(i,j)}^{(k,1)} = 1$$

$$(1-2\sigma)\ x\ (i,j) \leqslant x\ (i+k,\ j+1) \text{ if } \leqslant (1+2\sigma)\ x\ (i,j)$$

and

$\sigma_{(i,j)}^{(k,l)} = 0$ otherwise i.e. for any $(k,l) \in w$, and where σ is the ratio of the local standard deviation of X and the local mean of X is a featureless area.

5 - LEE's FILTER

Lee (1981) proposed another filter, defined as follows: If X denotes the original image, its' filtered version Y is given by:

$$Y = \left(1 - \frac{V_W}{V_W + V'_W} \right) . M_W + \frac{V_W}{V_W + V'_W} . X$$

where M_W and V_W are respectively the mean and variance version of X, by using a 5 x 5 window and where V'_W is given by

$$V'_W = \left(\frac{M_W}{m} \right)^2 . v$$

with m and v being respectively the empirical mean and variance of X.

6 - DISCUSSION OF RESULTS

Both filters present a good speckle reduction, when visually compared (figures 1-3). As for the sigma filter, the value of σ found was 4,66. It is quite different from the value estimated by Lee (1983) using SEASAT data. This is probably due to the fact that the area of study is a mountainous terrain presenting characteristic features such as shadows and layover.

The Lee filter (photo 3) presented higher efficiency as to speckle reduction, than the sigma filter, since the noise was reduced, but keeping the borders. A slight blur was yet noticed. This could be related to the window size that is bigger at the former (5 x 5) than at the latter filter.

7 - CONCLUDING REMARKS

The following steps of this work will be to study the geology and geomorphology from the Guiana Shield, which is partially covered by the SIR-B image. The filtered SIR-B image will be registered to the corresponding TM-scene and to the UTM grid, in order to combine linear terrain features (ridges, slopes, faults, ...) obtained by SAR, with photo-geomorphologic and -geologic mapping units, to be obtained by TM-data.

The rectification of these data sets will result in a raster data base that could be used for cartographic feature extraction. This procedure has been used by Welch & Ehlers (1988) in Georgia and presented good results.

Other speckle reduction algorithms, such as recursive median filters, could be implemented and used in future experiments.

ACKNOWLEDGMENT

The authors acknowledge the work from Miss Silvia S. Ii at the computer in order to prepare both filters used. The SIR-B image (data take KI-086.10) was kindly delivered by JPL-Jet Propulsion Laboratory.

REFERENCES

CIMINO, J.B.; ELACHI, C. and SETTLE, M., 1986, SIR-B - The second shuttle imaging radar experiment. I.E.E.E. Transactions on Geoscience and Remote Sensing. 24(4), 445-452.

FROST, V.S. et al., 1981, An adaptive filter for smoothing noisy radar images. Proceedings of IEEE, vol.69 (1).

GOODMAN, J.W., 1976, Some fundamental properties of speckle. J.Optical Soc.Am., vol.66(11), 1145-1150.

II, S.S. and BANON, G.J.F., 1988, Comparação do desempenho entre vários filtros para a redução do ruído "speckle" em imagens de radar. Anais *V Simpósio Brasileiro de Sensoriamento Remoto*, 11-15 Out. 88, Natal-RN, vol.3, 565-571.

LEE, J.S., 1981, Speckle analysis and smoothing of Synthetic Aperture Radar Images. Computer Graphics and Image Processing; 17: 24-32.

LEE, J.S., 1983, A simple speckle smoothing algorithm for synthetic aperture radar images, IEEE Transactions on Systems, Man and Cybernetics; SMC-13(1): 85-89.

LEE, J.S., 1986, Speckle suppression and analysis for synthetic aperture radar images, Optical Engineering, vol.25 (5):636-643.

LEE, J.S., 1987, Statistical modelling and suppression of speckle in synthetic aperture radar images. Proceedings *IGARSS'87 Symposium*, Ann Arbor, 18-21 May, 1987, vol.II: 1331-1339.

PORCELLO, L.J. et al., 1976, Speckle reduction in synthetic aperture radar, Journal Optical Soc. Am., vol.66(11): 1305-1311.

ULABY, F.T.; MOORE, R.K. and FUNG, A.K., 1986, Microwave Remote Sensing - active and passive, vol.3, Artech House, Inc., Washington, 1097 p.

WELCH, R. and EHLERS, M., 1988, Cartographic feature extraction with integrated SIR-B and Landsat-TM images. Internat. Journal of Remote Sensing, vol.9 (5):873-889.

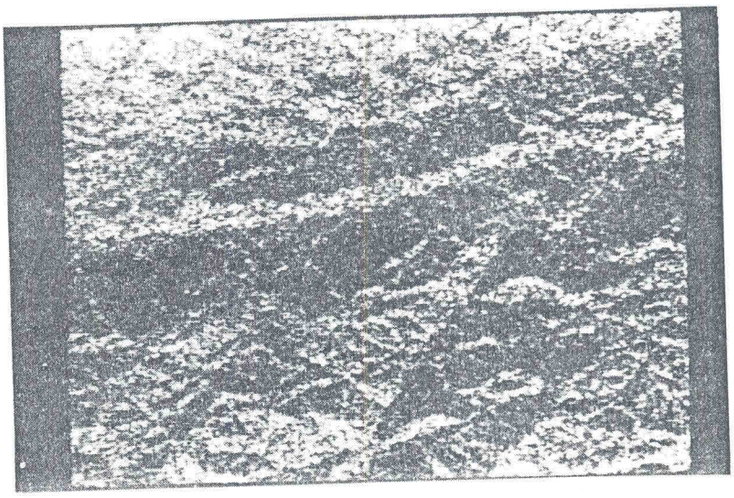

Fig. 1 - Original SIR-B scene.

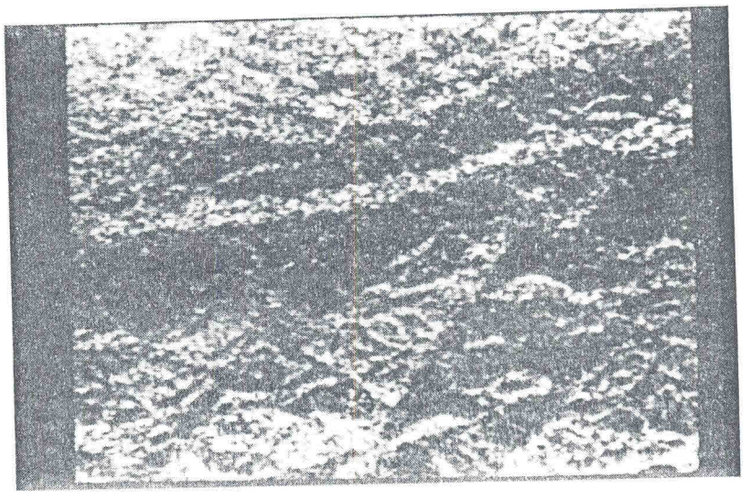

Fig. 2 - Same scene, σ filtered.

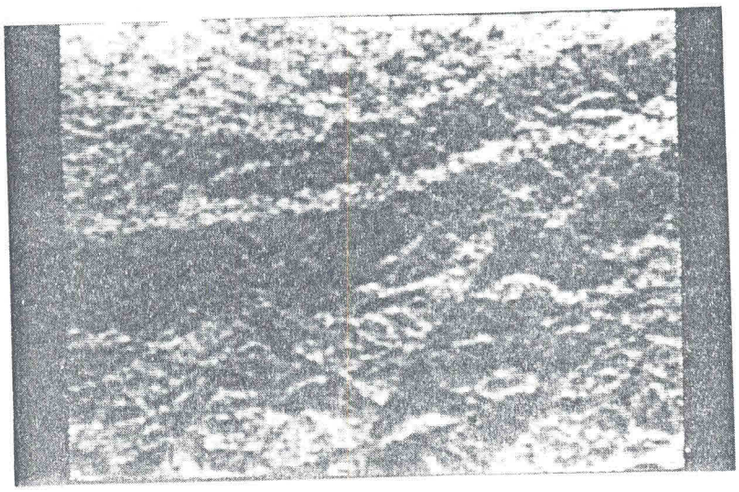

Fig. 3 - Same scene, LEE filtered.