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Pseudostereoscopy with Radar Imagery

A pseudo effect, although limited, can be observed using like- and cross-polarized images taken simultaneously of the same terrain.

Introduction

The imagery on which this study is based was taken by a Westinghouse AN/APQ 97 system over various parts of the United States. The transmitted pulses were horizontally polarized, and the horizontally and vertically polarized return signals were recorded as separate strip images on 9-inch roll film. As the angle of incidence for both images is the same, it would not be expected that any stereoscopic effect would be experienced, but if the two images are separated and examined under a stereoscope, a model showing a limited amount of relief can be obtained. The same effect can be obtained by the unaided eyes if the uncut strips are viewed first from a distance of about 1 m to obtain fusion, and then brought nearer until the personal limit of divergence of the eye axes is reached.

Abstract: *A pseudostereoscopic model can be obtained by viewing like- and cross-polarized radar imagery strips together under a stereoscope. A similar effect obtainable from pictures of models with differing angles of illumination suggests that variation in shadow size may be a significant factor, and it is shown that there is some theoretical backing for this hypothesis. The phenomenon described makes interpretation of such radar imagery much easier and more reliable, and also makes for easier comparison of like- and cross-polarized imagery.*

The limited nature of the stereoscopy obtained can be seen by comparing radar and photographic images of the same area: for example, examination of Meteor Crater, Arizona, shows that although the height of the crater rim is comparable in both situations (allowing for differences in scale), the depth of the crater appears very much less on the radar image. Presumably this is due in part to the absence of factors which contribute to vertical exaggeration in air photos, but it does seem that, in addition, there is a basic limitation to the degree of stereoscopy attainable. There is no difficulty in distinguishing areas of positive and negative relief—on the imagery of Twin Buttes, Arizona, the mine open pits can be seen as well as the dumps, and in general hills and river valleys appear in their true topographic relationships.

The writer found that pseudoscopic inversion could occur rather easily, but this may be a personal foible.

It was also noted that the range-marks on the radar images consistently appeared to float above the terrain, on about the same level, and the reasons for this are discussed below.

Causes of the Stereoscopic Effect

The two images are produced from the same point in space and, therefore, a true stereoscopic model cannot be created because this requires two slightly differing views of all points in the terrain. The effect must be described, therefore, as pseudostereoscopic. This phenomenon is well-known in the field of optics, and is due to what Valyus[4] calls the secondary factors in stereovision. These are factors which, without actually creating a stereomodel, provide the eye with visual clues which may be interpreted by the brain in terms of depth.

The main factors that yield an impression of depth are:

- Apparent size of objects.

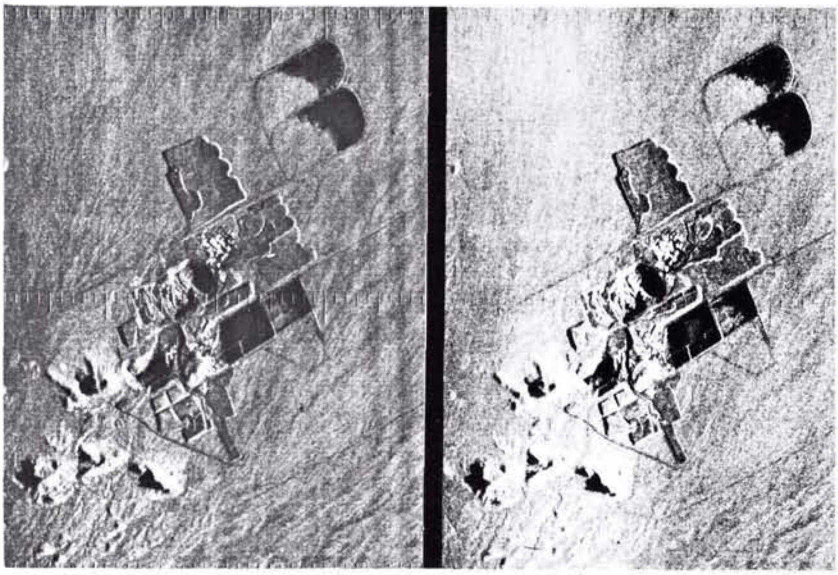

FIG. 1. Radar imagery of Twin Buttes, Arizona: cross-polarized image on the left.

- Linear perspective (convergence towards a *vanishing point*).
- Aerial perspective (decreasing contrast with distance due to atmospheric haze).
- Visible content of space between objects.
- Obstruction of some objects by others.
- Differences in apparent displacement of objects associated with head movements.
- Color contrast.
- Brightness of illumination.
- Distribution of light and shade on surfaces.

Of these, the only one possibly applicable in this case is the last, and it is known that tonal differences between like- and cross-polarized images do occur (e.g., Gillerman[2]). The pseudostereoscopic effect can be produced if there are small differences between the images received by the eyes, and Valyus (op. cit. p. 80) describes several optical devises used to produce such effects. One is the Verant lens device in which both eyes view a picture through a single lens, and the slight distortion is different for each eye, producing a small relief effect. He also states that the same effect can be produced by viewing two copies of the same print under a stereoscope, but the writer was unable to confirm this even when using photos of high relief areas with strong shadows.

Another method of producing a pseudostereoscopic effect is to view photographs of the same area illuminated at different angles. Natural terrain examples of this are rare, but Hackman,[3] investigating the effect of changing angles of illumination for geological interpretation, published a series of photographs of a relief model with illumination at incidental angles varying from 20° to 90°. Stereoscopic fusion of any two of these photographs (with the exception of the 90° one) whose angles of illumination differ by 10°, produces a well-marked pseudostereoscopic effect, which is presumably due to the differences in shadow length. These differences substitute for differences in camera position in providing the brain with clues through which a three-dimensional model can be created. If, therefore, the differences between like- and cross-polarized radar images include a factor by which differences in shadow length are produced, this could be a contributory factor towards creating a pseudostereoscopic effect. That such might be the case is suggested by a prediction of Fung's theory[1] that as a grazing angle of incidence is approached in the incident plane, while at the same time the slope normal to the plane of incidence increases markedly, the cross-polarized reflection increases rapidly while the like-polarized return remains constant or diminishes. Conversely, major slope changes in the incident plane, without a change in the slope at right angles, produce changes in the like-polarized return greater than those in the cross-polarized return.

Such changes in return signal will naturally produce density (i.e., tonal) changes in the photographic image, and one effect of this could be to produce differences in the area and near-edge definition of shadows between like- and cross-polarized images, particularly on rounded hill-tops. Such differences do seem to occur, but are very small, and their contribution to the pseudostereoscopic effect is difficult to assess.

Apart from this edge-effect, though, the tonal differences on slopes are sometimes quite marked, for example on slopes facing the line of flight, when the diminished return from the cross-polarized component frequently shows detail, compared to the *burnt out* highlights on the like-polarized component due to the very strong return. This contributes substantially to producing the differences between the images which could cause the pseudostereoscopic effect.

An effort was made to duplicate the pseudostereoscopic effect using air photos. Using a single negative, there are two ways of varying the final prints, first by varying the exposure, and second by varying the contrast of the printing paper.

A series of prints were made from a single air photo negative, using paper of varying hardness and varying the exposure times. The resulting prints showed considerable variation in the amount of detail recorded in the shadows and highlights, but even combining the most widely differing prints under the stereoscope produced no impression of relief. It is concluded, therefore, that differences in the degree of detail, or tonal values, do not in themselves produce a pseudostereoscopic effect.

Examination of the range marks on the imagery showed that two factors are probably responsible for their apparent *floating* above the terrain. First, each mark consists of a light bar with a dark band (or *shadow*) on its far-range side. The *shadows* are stronger and wider on the cross-polarized image than on the like-polarized one, and this gives a situation similar to that in Hackman's terrain shadow photographs. Probably more significant than this, though, is the fact that the two sets of range marks are displaced slightly with respect to the photographic detail, i.e., parallax is present which is interpreted by the brain as a height difference.

Conclusions

- ★ A pseudostereoscopic effect can be observed using like- and cross-polarized images taken simultaneously of the same terrain.
- ★ The stereoscopic effect is limited, and large height differences are greatly reduced.
- ★ Similar effects can be produced by using pairs of photographs in which the angles of illumination differ.
- ★ The cause of the pseudostereoscopic effect probably lies in small differences (other than angle of view) between the two images, and these may be produced by (*i*) differences in the shadow outlines and areas due to predicted differences in like- and cross-polarized returns where slope changes occur. These differences appear very small, and (*ii*) tonal differences between the two images due to inherent differences in return

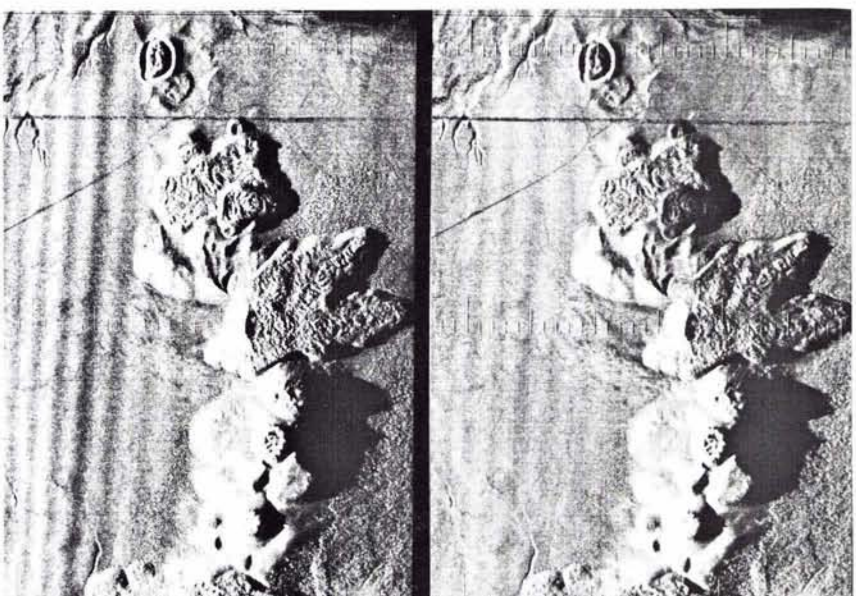

FIG. 2. Radar imagery of Mono Craters, California: cross-polarized image on the left.

signals in certain circumstances. It seems unlikely that this effect alone can produce a pseudostereoscopic effect.

- ★ Most interpreters will probably find the imagery easier to work with under a stereoscope, since binocular vision is fully utilized, and the interpretations will be more accurate and more complete since a significant amount of three-dimensional information is added.
- ★ The differences between like- and cross-polarized images can be more easily found by using a stereoscope and rapidly blinking alternate eyes. Areas of difference then appear and disappear, whereas areas of no change remain constant.

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