A NEW FILTERING TECHNIQUE FOR IMPROVED EARTH RESOURCES SURVEY

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ABSTRACT

A noval method to improve the 'tonal signature contrast' (TSC) of the earth resources imagery obtained over an integrated band of visible and near IR regions of the spectrum is presented. This adopts filtering of the optical frequencies over selective regions and was found to give 75 % enhancement in 'TSC' over the classical methods. If used as an onboard smart sensor for image classification, the present system will be simple and most effective.

INTRODUCTION

Remote sensing primarily records electromagnetic energy that emanates in a wave like motion from features on the surface of the earth. Radiation usually is not merely at one wavelength or even within one band (narrow range) of wave length but in a great many bands throughout most of the electromagnetic spectrum. The specific composition of imagery emanating from a given type of feature (for example, rock type, kind of soil, species of these or variety of crop) depends largely on the atomic, molecular and macro molecular composition of the features. Consequently, each type of feature tends to exhibit a unique 'tone signature' the combination of brightness values seen in the series of multiband photographs. When considered over the visible and near IR region (Panchromatic band), the 'tonal signature' of the three basic features *viz* Water bodies, Vegetative bodies, and Land bodies are different each having a range of values. In general, the mean values for the water bodies will have the lowest, the land bodies, the highest, and the vegetative bodies, the intermediate values and so these are normally identified in the photographs through their tonal values. But under certain conditions, these range of values overlap and hence, the features become indiscriminatory. Because of this use of panchromatic band is of little interest for spectral studies. Nevertheless, its importance lies more in photo interpretation, etc., and has been used in number of satellite systems[1].

For this two kinds of panchromatics are commonly used, 0.5–0.7 microns and 0.5–0.9 microns. The choice of a band between 0.5–0.9 microns can help to identify a class of object on the earth but also creates a risk of confusing it with another. For example, in this region, the discrimination between vegetation and soil hardly becomes perceptible. On the other hand, the use of the band from 0.5–0.7 improves the differentiation between vegetation and bare soil rocks of artifacts but makes the contrast between different types of vegetation less perceptible. Also there is a heavy risk of confusing the same class of vegetation with water bodies. In this context, Begni[2] pointed out that the panchromatic band is an extremely useful tool, but no single band exhibits significantly higher superiority over the other. In an attempt to increase the tonal signature contrast and hence, the discrimination of different features on the earth obtained through panchromatic band, a method of selective filtering technique is explored. In this paper, the detailed analysis of the system and its features are discussed.

Tonal signature contrast and its improvement through filtering technique

When solar radiation is incident on the matter, part of the radiation is reflected, part transmitted and a part of it absorbed depending on the atomic, molecular and surface features of the objects. Consequently, each type of a feature, on the earth tends to exhibit a unique 'tonal signature' which is normally derived through the spectral signature of the feature. The profile of the reflected radiation for any object can be written as

$$R(\lambda) = \frac{A_0}{2} + \sum_{n=1}^{5} [A_n \cos 720(\lambda - 0.4) + B_n \sin 720(\lambda - 0.4)] \quad (1)$$

Where $R(\lambda)$ is the reflectance at wavelength λ and A_n, B_n are the constants. By appropriate selection of A_n and B_n, one can generate a series of curves, representative of the spectral signature of different features on the earth, such as water, soil/rock and vegetative bodies. In figure 1a are shown the typical curves derived through this system. These are in close agreement with the values obtained under 'insitu' conditions[3]. Then, the tonal signature contrast factor 'C F' for two adjacent features, over a specified spectral range, can be defined as

$$\mathrm{CF}_{(1,2)} = \frac{R_1 \sim R_2}{R_1 + R_2 + \dfrac{2\pi L}{ET(A)}} \quad (2a)$$

Where E is the illumination in lux due to sun and sky. $T(A)$ the atmospheric transmittance, L the atmospheric luminescence and R_1, R_2 are the reflected radiations from the features 1 and 2 respectively and integrated over a band of spectral range λ_1 to λ_2. In this, since L is significantly small compared with E, the term $2\pi L/ET(A)$ can be neglected.

For a constant $E, T(A)$, and L, the two features photographed through a band λ_1, to λ_2 can be discriminated from one another when the value of CF is sufficiently large. As has been pointed out earlier, in the panchromatic band, the main confusion in identification arises between land and vegetation, vegetation and water systems. For the convenience of further analysis, the CF for land and vegetation, vegetation and water are specifically defined as

$$\mathrm{CF}_{(L,V)} = \frac{R_L - R_V}{R_L + R_V} \quad (2b)$$

$$\mathrm{CF}_{(V,W)} = \frac{R_V - R_W}{R_V + R_W} \quad (2c)$$

where R_L, R_V and R_W are the integrated reflected

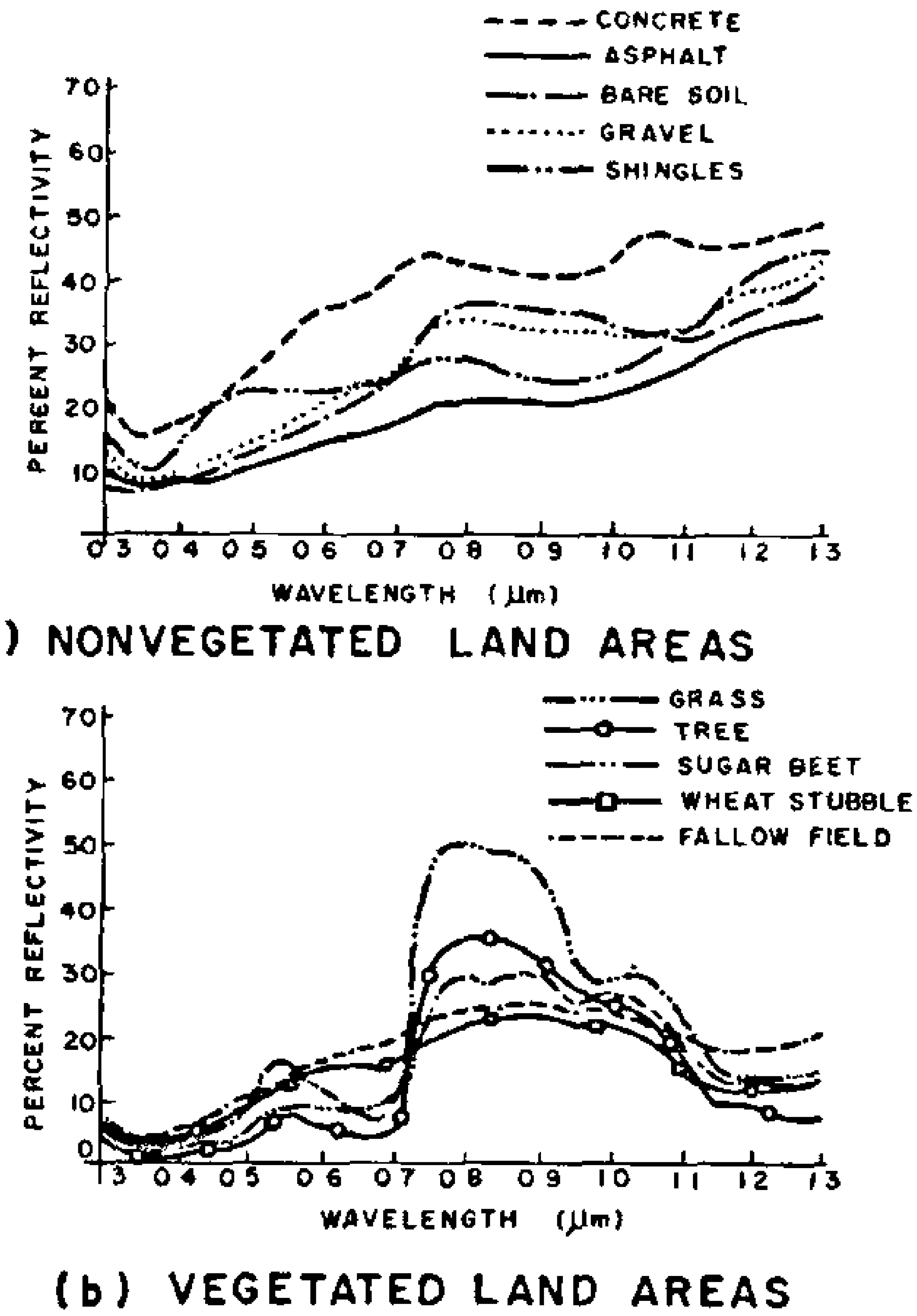

Figure 1a. Curves Showing Spectral reflected Radiance of Water, Vegetation and Land bodies.

radiance of land, vegetation and water bodies respectively.

For the conventional panchromatic systems, the values of $\mathrm{CF}_{(L,V)}$ and $\mathrm{CF}_{(V,W)}$ tend close to zero and often becomes negative. In order to get optimum 'CF' multiband, multispectral imagery are employed. But the narrow band imagery introduces its own intrinsic problems such as low signal to noise ratio. The other possibility of improving CF in a broad band system can be through a selective filtering of the signal at the frequencies which are of less importance. This is outlined below:

The frequency response of any optical filter can be characterised in the wavelength interval λ_1 to λ_2, by an expression

$$F(T_\lambda) = \frac{A_0}{2} + \sum_{n=1}^{n=j} \left[A_n \cos 2\pi n \frac{\lambda - \lambda_1}{\lambda_2 - \lambda_1} + B_n \sin 2\pi n \frac{\lambda - \lambda_1}{\lambda_2 - \lambda_1} \right] \quad (3)$$

where $T_{(\lambda)}$ is the transmission at a given wave length λ. Then from (1) and (3) it can be written as

$$R^*_{(\lambda)} = R_{(\lambda)} \times F(T_\lambda) \quad (4)$$

where $R^*_{(\lambda)}$ is the filtered output of the input scan $R_{(\lambda)}$ and $F(T_\lambda)$ is the filter operator. In principle, filter operators which act on the data either to decrease or eliminate entirely certain contained frequency can be designed. This is very useful when the deleted frequencies are unwanted or known to be in error. Unfortunately, in the visible and near infrared region which are normally used for optical remote sensing technique, most frequency components are composed of useful information and there is no way to selectively delineate these frequency components. Nevertheless, weightage factors can be assigned for each of the frequency components, and based on it, optical filters can be designed to improve the 'TSCF' and this is outlined below.

For design of the filter characteristic, a 'merit function' is used which is defined as follows:

$$\text{M.F} = R^*_{1(\lambda)} - R^*_{2(\lambda)} \quad (5)$$

where $R^*_{1(\lambda)}$ and $R^*_{2(\lambda)}$ are the modified values of $R_{1(\lambda)}$ and $R_{2(\lambda)}$ after passing through the filter.

Starting with an initial design having a uniform broad band response, progressive weightage factors ranging from 0 to 0.85 are assigned for each of the wavelengths in the range λ_1 to λ_2 and the corresponding 'M.F.' values are determined for a given scene. The computation is carried out till the value of M.F. is reached close to unity. Fitting these values in (3), the constants $A_1 \ldots\ldots A_n$, $B_1 \ldots\ldots\ldots\ldots B_n$ are determined and refined till optimum TSCF is obtained. A method of optimising the filter characteristic for obtaining better TSC F is being studied and will be dealt elsewhere.

HYPOTHETICAL SYSTEM RESULTS AND DISCUSSION

Using (1) and appropriately selecting the values of the constants therein, spectral profiles for a typical water, land and vegetative features are generated (figure 1b). These are selected such that the integrated energy over the band 0.45 to 1.0 micron for land and vegetation had nearly equal value. Evidently such features when photographed through the panchromatic band cannot be distinguished and identified. For such a system, using equations 1, 3 and 5, the optical filter is designed.

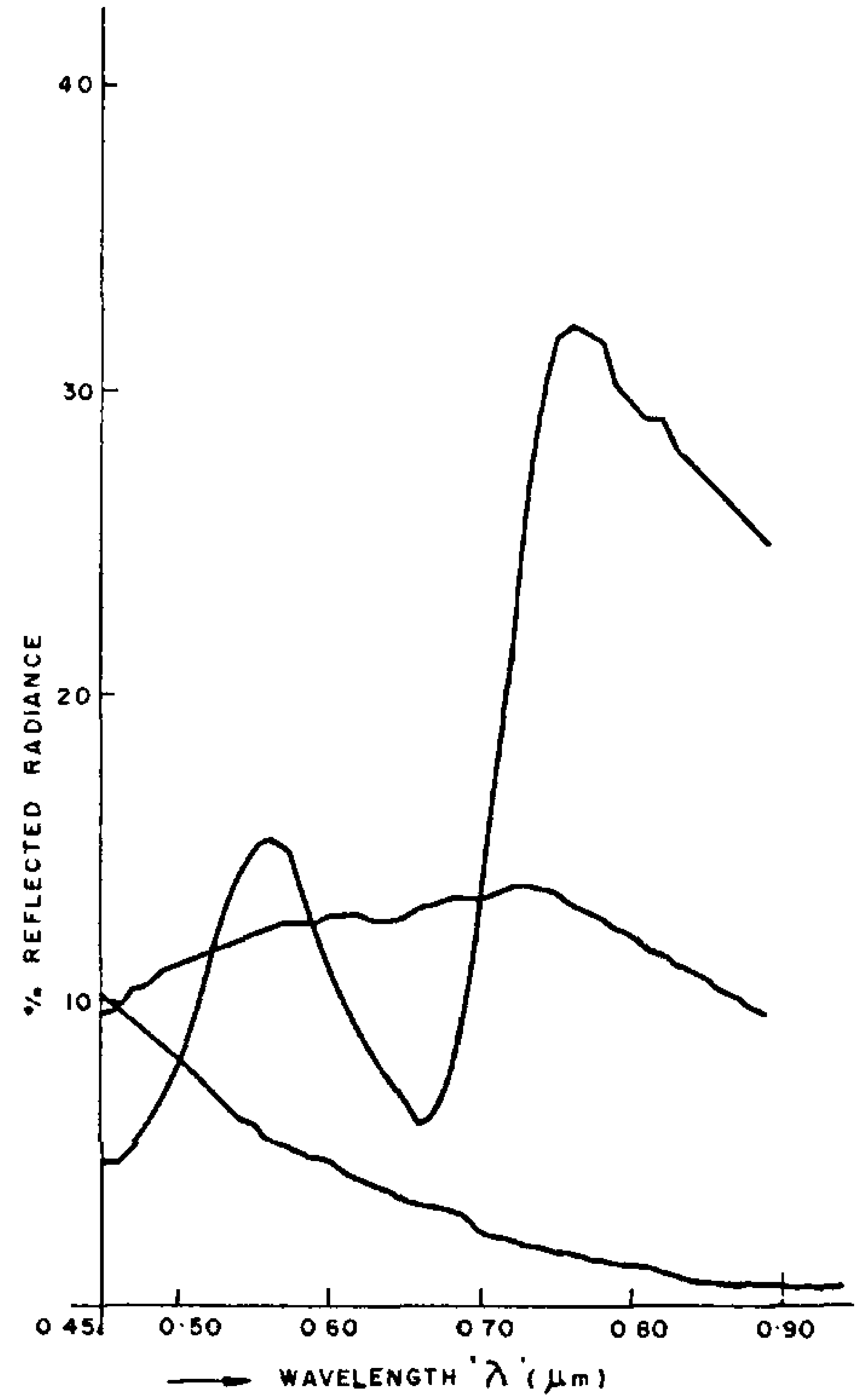

Figure 1b. Typical Signatures of Water, Vegetation and Land bodies, for which the tonal signatures are nearly equal.

The spectral characteristic of the resultant filter is shown in figure 2. Through (4), the modified profile of the system after passing through the designed filter is calculated and the results are shown in figure 3.

The TSCF for the system before and after filtering are calculated and are given in the table 1. Similar TSCF of the system over narrow bands

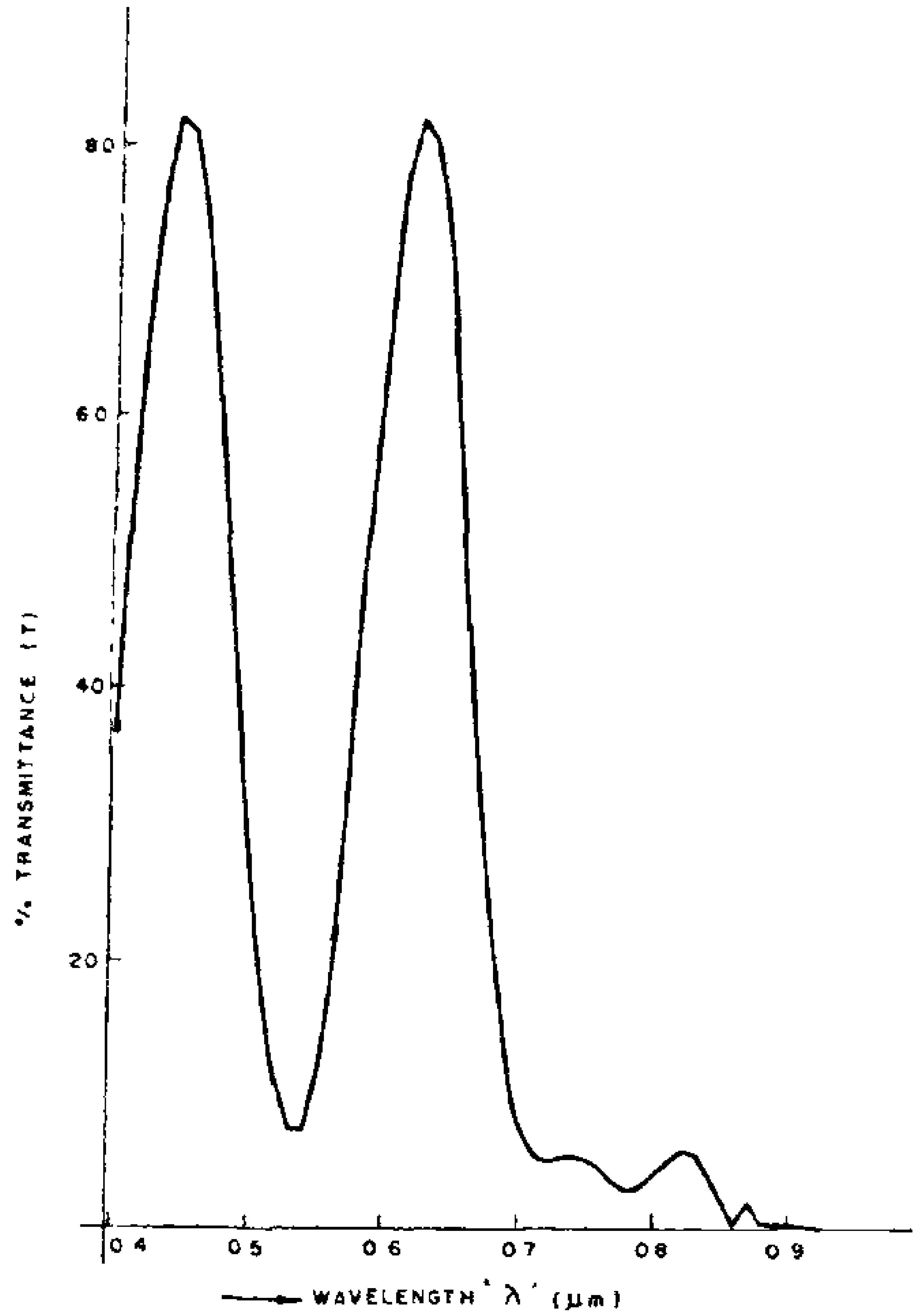

Figure 2. Spectral Characteristic of the designed filter.

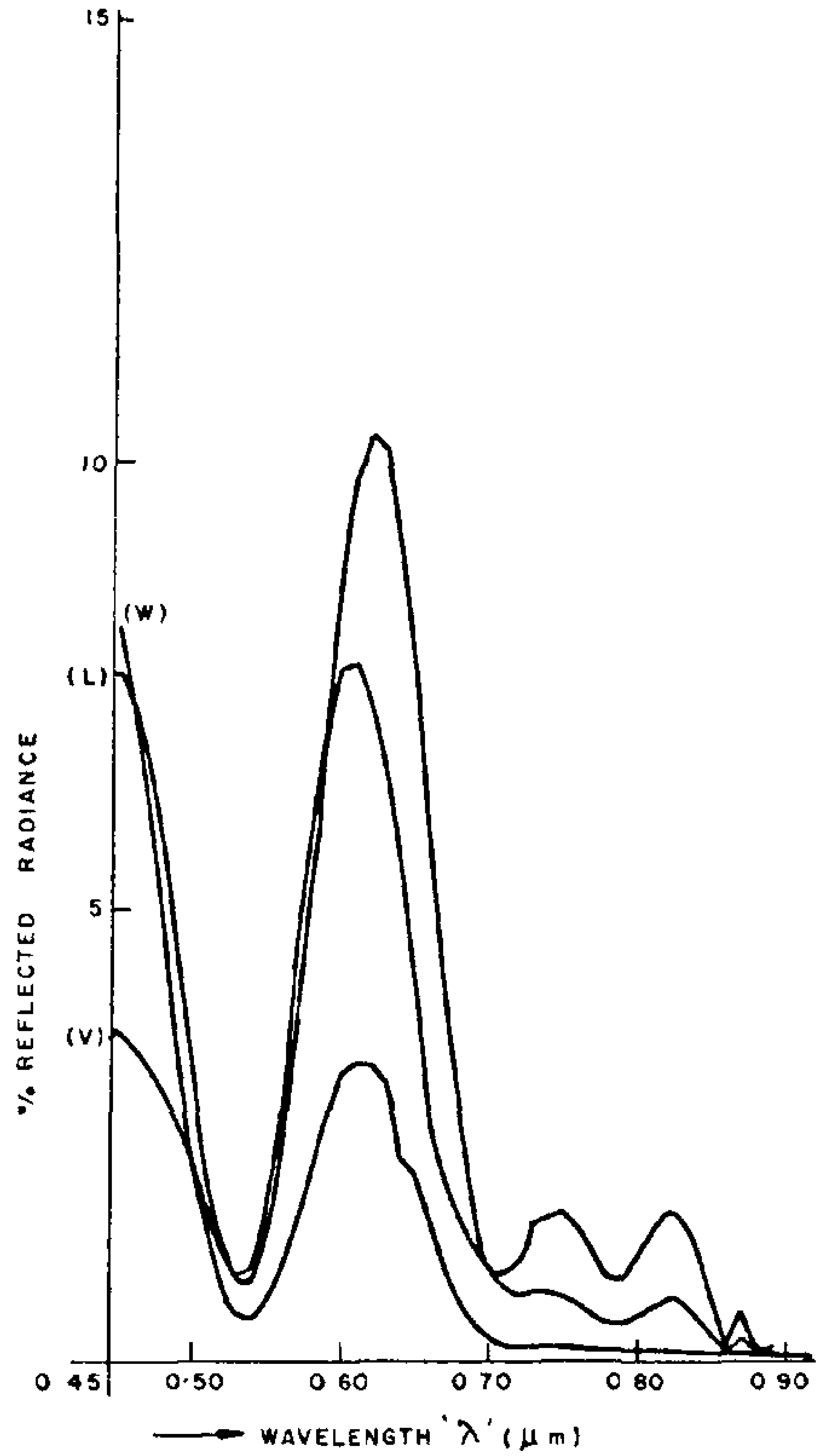

Figure 3. Modified curves of the data shown in figure 1b, after passing through the filter.

corresponding to the Landsat bands, are also calculated for comparison and projected in table 1. It is clear that the filtering technique can significantly improve the TSCF and hence the imagery obtained through this, becomes more discriminatory.

Depending on the condition of the feature, each type of the three main features *viz* land, water and vegetative bodies will have a spread in their spectral characteristics. By appropriate selection of the constants these profiles can be generated from (1) and these are shown in figure 4. The corresponding results after passing through the above filter are shown in figure 5. The spread of the integrated values with and without filter are shown in figure 6. Obviously in the single band (0.45 to 1.1 nm) the water bodies though are delineated, there is considerable overlap for the soil and vegetations. Similarly in any of the Landsat bands also this overlap is considerable though in certain bands it is less. In panchromatic bands all the three bodies had overlap suggesting that however, useful they may be for photo interpretation it may be difficult to remove the overlap and hence, the uncertainty in feature identification and discrimination. On the other hand, the same data when passed through the selective filter, the overlaps have been removed. Taking these base values, the TSCF is calculated for all the bands considered and these are shown in table 2. To calculate the TSCF limits, the following procedure is adopted. As shown in figure 6 each of the three main features,

Table 1 *Comparison of TSCF values for typical land, vegetation and water bodies.*

Spectral Band in (μm)	Tonal Signature Contrast Factor (CF)	
	Between $CF_{(L,V)}$ Vegetation and Land	Between water and Vegetation $CF_{(V,W)}$
0.45–1.1	−0.125	+0.58
0.5 –0.9	−0.152	+0.60
0.45–0.7	−0.06	+0.45
0.45–0.52	0.0	+0.07
0.52–0.6	−0.06	+0.44
0.63–0.69	−0.07	+0.65
0.76–0.9	−0.41	+0.95
Through the present system	±0.20	±0.40

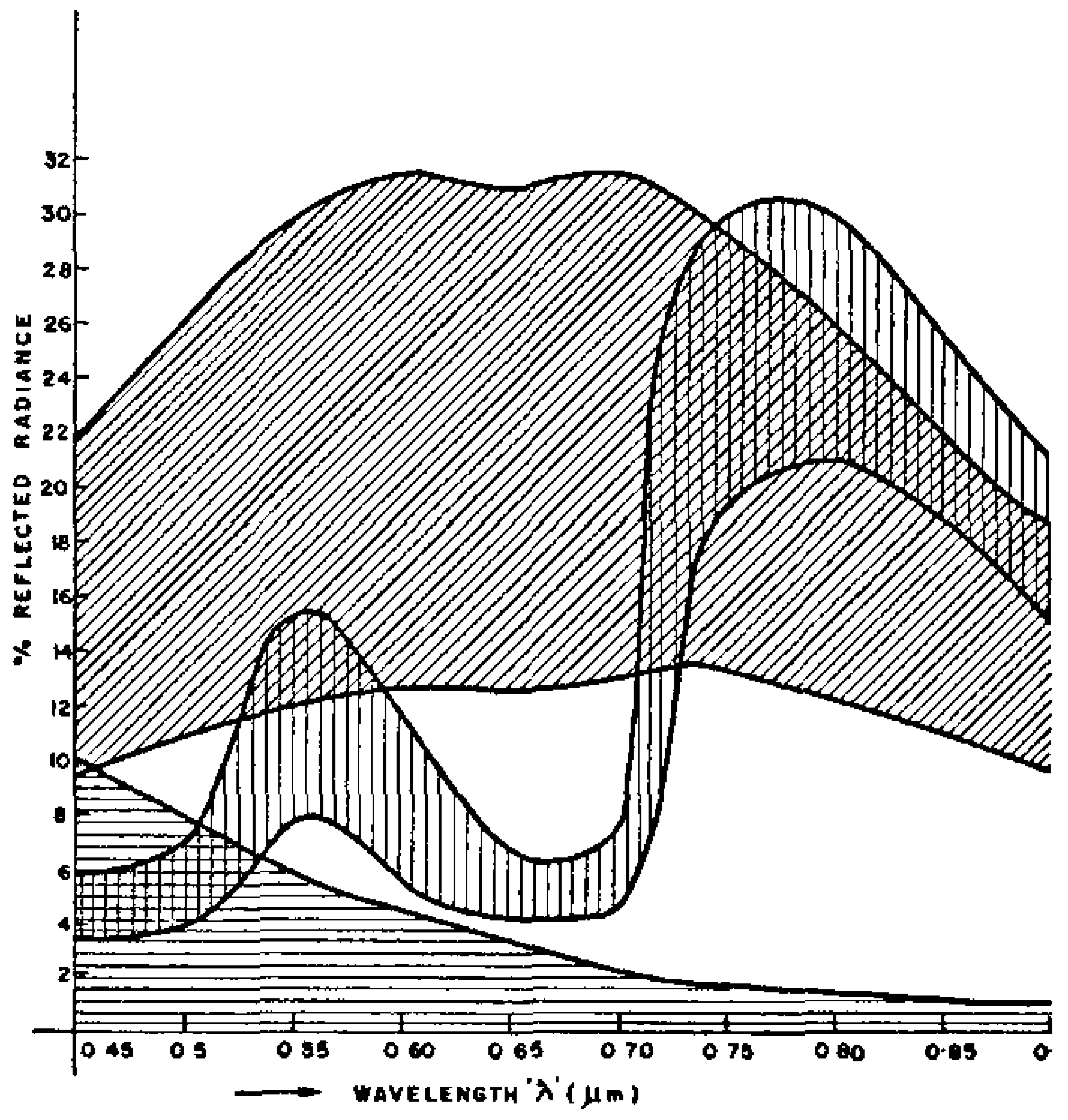

Figure 4. Curves showing the dispersion in the spectral profiles of water, vegetation and land bodies under different conditions.

depending on the condition will have a minimum and maximum integrated radiance value in a particular band, which may be designated as W_{min}, W_{max}; V_{min}, V_{max} and L_{min}, L_{max} for Water, Vegetative and Land bodies respectively. Then

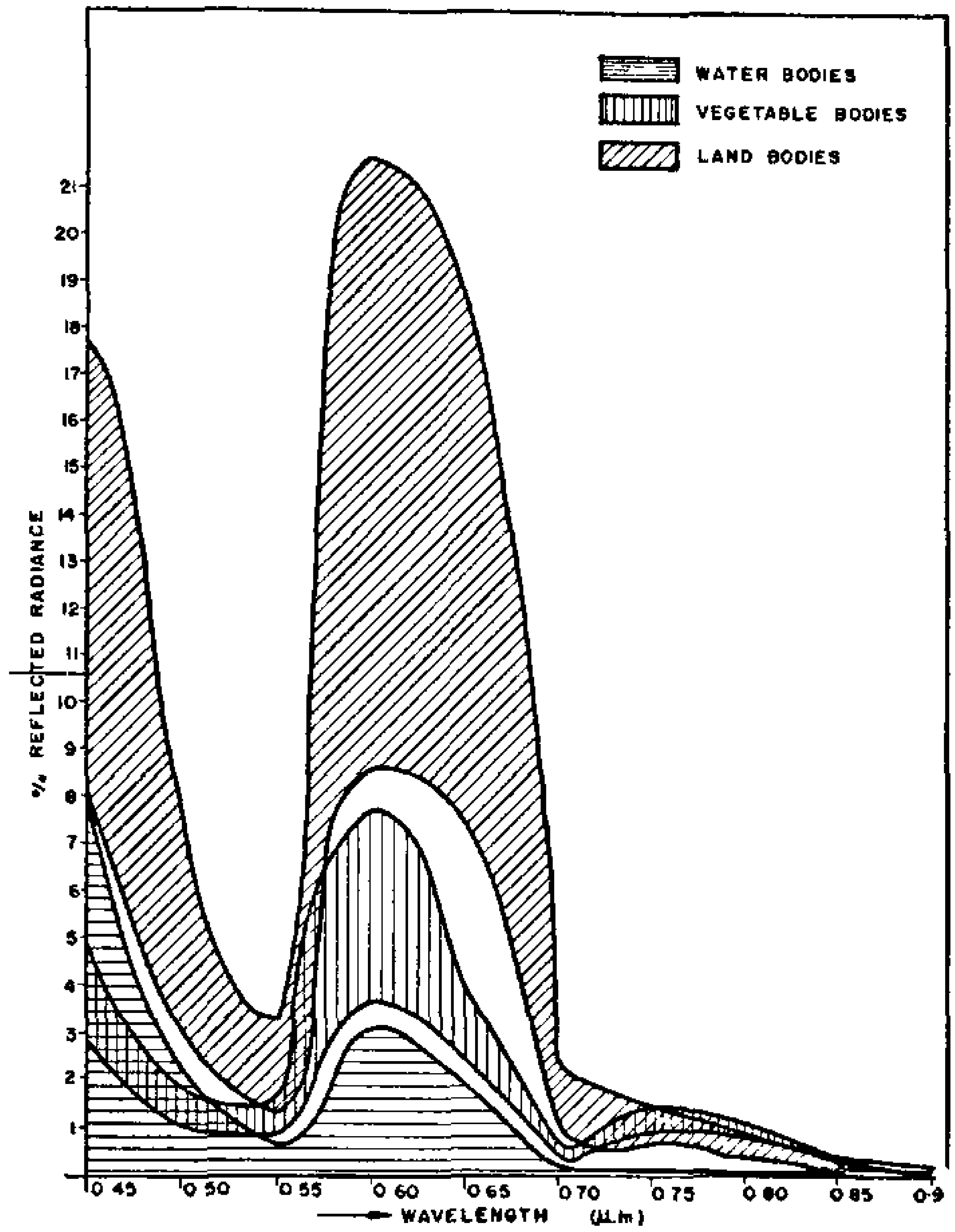

Figure 5. Modified curves for the data shown in figure 4 after filtering.

the lower limit is considered between (W_{max}, V_{min}), (V_{max}, L_{min}) and the maximum limit between (W_{min}, V_{max}), (V_{min}, L_{max}). Obviously, the lower limit corresponds to an extreme situation where the maximum likelihood of misinterpretation/indiscrimination occurs. As can be seen from table 2, specifically for Land and Vegetative bodies, all the bands had negative TSCF, while the present system alone has positive value. This implies that for a given worst situation, the new filtering technique can imporve identification and classification of the earth features. On the other hand, between water and vegetation, the present system is not better than most of the Landsat band, but definitely has an edge over the panchromatic band 0.5–0.7 microns. This is due to the fact that the present filter is specifically tailored to improve the discrimination between land and vegetation because, the water bodies are in any way discriminable from others due to their low irradiance levels. But the

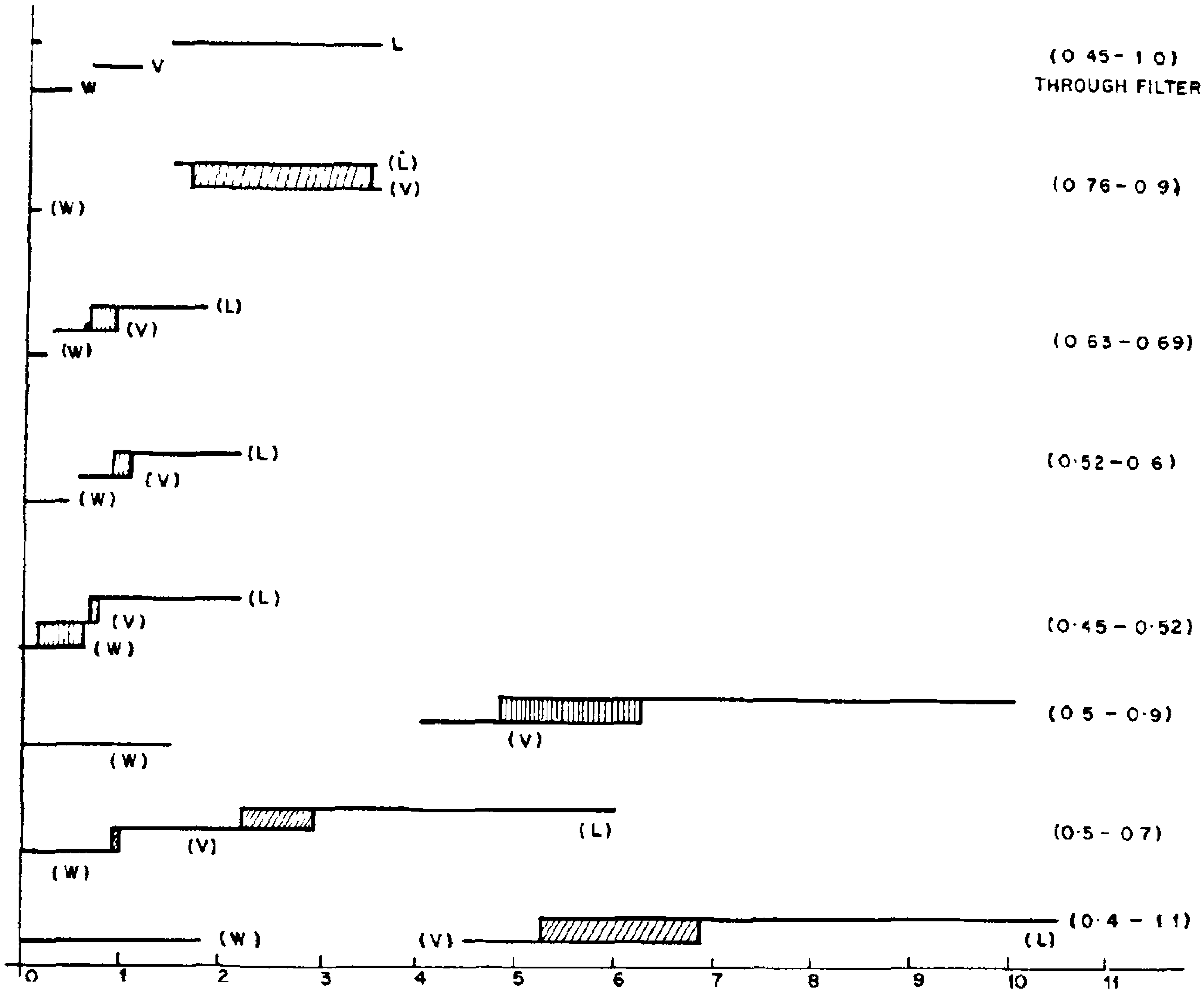

Figure 6. Spread in the integrated energy of (in different bands) the three main earth features, *viz* Water Vegetation and Land bodies. The shaded area shows the region of uncertainty in photo interpretation.

emphasis can be shifted for more discrimination between water and vegetative bodies or a trade off in between depending on the requirement. The maximum limits are fairly good and same for all the bands. This particular value is not having much significance but projected to emphasize the fact that at other extreme condition which rarely occurs, many of the bands are good. It is very clear the new filter can significantly improve the TSCF. This clearly demonstrates to the fact that by selective filtering technique, it is possible to delineate the different features and hence, easy identification/classification, of the different features of the earth obtained through remote sensing systems is possible.

In recent times, it is proposed to use the polarisation technique[4] also in the remote sensing of the earth resources. From a detailed analysis on this technique, Gausman[5] has suggested that there is little need to measure the polarisation response of the earth features with high wavelength/band resolution, a polarisation sensor having the entire visible region or large portion of it might suffer. But if this is to be so, the panchromatic band, with polarisation filter can further reduce the contrast and hence, the

Table 2 *Spread of TSCF values for land vegetation and water bodies under different conditions.*

Spectral Band in (μm)	Spread in TSCF for different systems: Between $CF_{(V,L)}$ Vegetation and Land	Between $CF_{(W,V)}$ Water and Vegetation
0.45–1.1	−0.13– +0.45	+0.44 – +0.58
0.5 –0.7	−0.06– +0.70	+0.001– +0.45
0.5 –0.9	−0.15– +0.43	+0.53 – +0.65
0.45–0.52	0 – +0.76	−0.54 – +0.10
0.52–0.6	−0.06– +0.64	+0.11 – +0.44
0.63–0.69	−0.07– +0.77	+0.13 – +0.65
0.76–0.9	−0.41– +0.32	+0.88 – +0.95
Through the present system	+0.2 – +0.71	+0.15 – +0.45

objective may be lost. But with the present filter, the situation can be improved and the additional benefits of the polarisation technique can be optimumly used.

The system with the filter can also be used as a smart sensor onboard satellite system for identification/classification of the features on the earth. A detailed study pertinent to this is being carried out.

CONCLUSION

Weighted optical filtering technique explored for the test first time, has been found to be successful in improving the tonal signature contrast factors of the earth features photographed through an integrated band. The principle can be extended to any broad band photographic technique employed in areal and space borne system.

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1. Panchromatic Band has been used in number of satellites. Few of them are NOAA (USA), SPOT (FRANCE), GEOS (USA), GMS (JAPAN), INSAT-1A (INDIA), METEOSAT (ESA) etc.
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