

## DISTINGUISHABLE DETAILS IN AIR PHOTOS

Werner Schubert  
Film AG Wolfen  
Pushkinplatz 1  
Wolfen  
4440

The content of information of air photos must be very high to obtain a possibility of multiple interpretation. One of the most important demands is to distinguish details on a very high level. In general the property "reproduction of details" is used.

This datum is composed of several single parameters. The global parameter "reproduction of details" depends on the following decisive parameters: modulation transfer by objective, focal length of objective, modulation transfer by film and altitude. The main parameter "limiting frequency" is obtained by linking the modulation transfer functions of objective and film. Another important parameter is "true spatial frequency" given by the connection of limiting frequency, focal length and altitude.

The knowledge about the conditions of exposure during a surveying flight especially camera (lens) type, film material and altitude it allows to determine the distinguishing details in air photos.

### KEY WORDS: Reproduction of Details, Air Photos

To prepare surveying flights one had to consider a lot of things because air photos are individual pieces. It is not only a question of weather conditions but also a question of reaching results. We want to get a lot of information from air photos for different fields, e.g. photogrammetry, mapping or interpretation of ecological problems. The most important date is to distinguish details. Clearly distinguishable details are necessary for all kinds of interpretation as for mapping as for agriculture, geology or hydrology. Therefore we must know which factors of influence are objective for good or bad distinguishing of details.

Basis for the following description is the capability of the human eye. Especially such parameters like distinguishing of density, distinguishing of colours and reproduction of details. In a practical way we had to consider those parameters which influence the transfer of information of the system: target - human eye:

- 1 true spatial frequency of the target according to its real geometrical structures and its spectral absorption in relation to the surround
- 2 modulation transfer of the used lens depending on the spatial frequency
- 3 modulation transfer of the used film depending on the spatial frequency
- 4 effective (in film reproduced) spatial frequency
- 5 conditions for viewing the film depending on the frequency character of the human eye

Now we should answer the question how is the interaction between the described parameters.

#### 1. True spatial frequency

Here it is possible to approximate rather simple geometric shapes. We can say that real targets have such simple base structures like rectangle or square as a special shape of rectangle. In this case we get the true spatial frequency

$$R^* = 1/2s$$

( $R^*$  - true spatial frequency,  $s$  - narrow side of target in mm) A special kind are targets with frame-shaped structure. In this case  $s$  is the thickness of the frame. For ellipse and circle the above equation is changed to

$$R^* = 1/d$$

( $d$  - diameter of circle or shorter axis of ellipse) Circles with frame-shaped structure have a true spatial frequency calculated after eq.1.

#### 2. Modulation transfer of lens

To characterize an objective it is not possible to take only one modulation transfer function. Therefore we make a compromise and use the modulation transfer function which describes a beam in a distance of 83mm

from centre. In this case we can evaluate a view circle with a diameter of 166 mm at a film format of 240x240 mm.

### 3. Modulation transfer of film

For films we have the possibility to describe the transfer by one modulation transfer function. According with practical demands the determination of the modulation transfer function by analysis of a reproduced edge is the best one. The modulation transfer functions of the aerial film VF 45 at different densities between edge and surround are shown in figure 1.

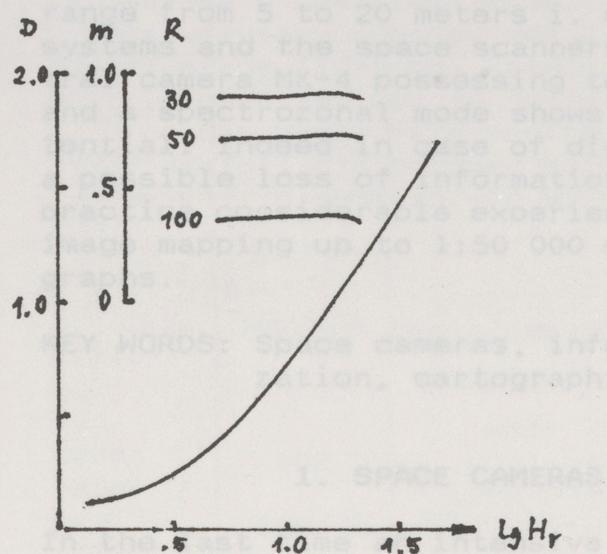


Fig.1 Modulation transfer degrees of VF 45 at different densities between edge and surround

### 4. Effective (on film reproduced) spatial frequency

Air photos show reduced targets. The reducing scale depends on the focal length of the used objective and the altitude. It is the relation between target size and picture size

$$y/y' = (h_0/f) - 1 \quad (3)$$

( $y$  - target size,  $y'$  - picture size,  $h_0$  - altitude,  $f$  - focal length) To get the effective spatial frequency we had to multiply the true spatial frequency with the reducing scale

$$R_h = R^* (y/y') \quad (4)$$

( $R_h$  - effective spatial frequency,  $R^*$  - true spatial frequency,  $y/y'$  - reducing scale)

### 5. Conditions for viewing the film

The viewing of air photos is generally like an optical enlargement of the origin. This can be either visual viewing or making a copy. The observation of distinguishable details depends on the enlargement scale of the used objective (of the enlarger) and its modulation transfer function. According to distinguishable details the enlargement of air photo is a displacement of the spatial frequency to a lower frequency

$$R_v = R_h / F \quad (5)$$

( $R_v$  - visual effective spatial frequency,  $R_h$  - effective spatial frequency,  $F$  - enlargement scale) The visual effective spatial frequency has a maximum of 10 lp/mm. Together with usual enlargement scales up to 15 we get a value of 150 lp/mm which is exceeding the limit of the system objective/film. Thus we can say that differences up to this spatial frequency, indeed, are visually observed.

The limit where we can distinguish details is described by this spatial frequency of the system objective/film where the modulation grade is 0.10. This spatial frequency we call limiting spatial frequency. The limiting spatial frequency is obtained from the resulting modulation transfer function which is the link of the modulation transfer functions of objective and film. For two real systems, camera LMK from Carl Zeiss Jena with aerial film VF 45 from ORWO Wolfen and camera MSK 4 from Carl Zeiss Jena with aerial film VF 45 from ORWO Wolfen, the system modulation functions with their limiting spatial frequencies are shown in figure 2.

1 VF 45/LMK  
2 VF 45/MSK 4

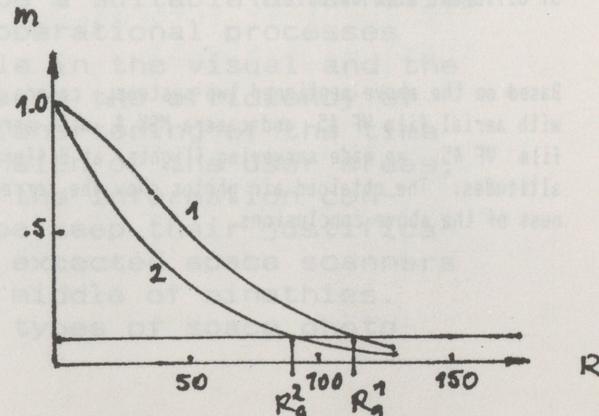


Fig.2 System modulation transfer functions of LMK/VF 45 and MSK 4/VF 45

If we connect the equations 3 and 4 with a new equation 6 where the effective spatial frequency is substituted by the limiting spatial frequency thus we have a basis for planning surveying flights

$$R_g = R^* \left[ \frac{1}{(h_g/f)} - 1 \right] \quad (6)$$

( $R_g$  - limiting spatial frequency,  $R^*$  - true spatial frequency,  $h_g$  - altitude,  $f$  - focal length) Dependend on a desired result of a surveying flight we can forecast some conditions

obtainable distinguishing details for given altitude objective and film

$$R^* = R_g \left[ f / \left( h_g - f \right) \right] \quad (7)$$

highest altitude for a reproduction of details to be obtained and given objective and film

$$h_g = f \left[ \left( R_g / R^* \right) + 1 \right] \quad (8)$$

necessary objective for given altitude and reproduction of details to be obtained

$$f = h_g \left[ R^* / \left( R_g + R^* \right) \right] \quad (9)$$

necessary film material for a reproduction of details to be obtained and given altitude and camera (objective)

$$m^F(R_g) = 1 / [10 m^D(R_g)] \quad (10)$$

( $m^F(R_g)$  - modulation grade of film at limiting spatial frequency,  $m^D(R_g)$  - modulation grade of objective at limiting spatial frequency) Based on the value of  $m^F(R_g)$  we can look into the data sheets of different film materials.

Based on the above mentioned two systems, camera LMK with aerial film VF 45 and camera MSK 4 with aerial film VF 45, we made surveying flights at different altitudes. The obtained air photos show the correctness of the above conclusions.