MEASURING OF TRACK VELOCITY AND DRIFT ANGLE

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Abstract

The fundamental problem of air navigation in real meteorological conditions is the fact that the aircraft is all the flight time under the action of wind causing its drifting and changing its velocity. Detailed exploration of possibilities of drifting and velocity changes measuring is not the intention of this article. The article is just pointing out the possible use of a space filtration method for this purpose.

Keywords

track velocity, drift angle, space (spatial) filter, CCD line sensor

1. Triangle of velocities - the keystone of air navigation

An aircraft flying in real meteorological conditions is found in an air mass, which is moving towards Earth's surface with given velocity and direction. This movement of an air mass is called wind. Characteristic feature of wind movement is its vector, whose module **U** represents air mass velocity towards Earth's surface while argument δ is the angle between so-called local meridian and horizon point, the place from which the wind is blowing. The wind acts on the aircraft in the way that changes its velocity towards Earth's surface (comparing with the calm situation) and causing its drifting from pre-selected skyway. As far as pilot or navigator of the aircraft knows the parameters of wind vector and so-called **Real Air Velocity RAV** as well (RAV is the velocity indicated by aircraft velocimeter working on principle of measuring dynamic air pressure) and supposing he knows the value of **track angle TA** (which is an angle between north direction of local meridian and join between projection normal to the surface and target point) than using so-called triangle of velocities. It can construct the flight plan to move the aircraft **t** from point 0 to point B. You can see the situation with both mentioned points together with flight plan in the Fig. 1.

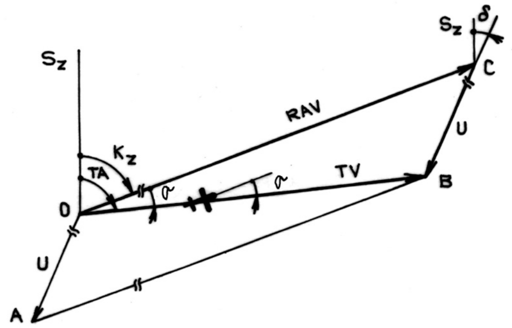

Fig. 1 Scheme of flight planning method

As we can see from Fig. 1, the triangle of velocities is made by vectors **RAV** (real air velocity - module RAV, argument K_Z), **U** (wind vector - module U, argument δ) and **TV** (track velocity - module TV, argument TA). Relative deviation between **RAV** and **TV** is drift angle σ. By known wind vector **U** navigator plans the flight to move the aircraft from point 0 to B. He uses appropriate local map for that purpose. In the map he marks his momentary position 0, finds the target point B and connects both points by line. This is the required flight track. He measures length of abscissa 0B and using the map scale finds the flight length in kilometres. He draws wind vector U at point 0. He connects terminal point of vector constructed this way and point B and draws line parallel with the vector through point 0. This is new parallel line and north direction of local meridian forms and angle K_z. The angle is called geographical flight course. During a flight the aircraft's longitudinal axis must be parallel to this direction, which is possible using onboard compass. We can mark the length of abscissa on the parallel line (it is length of abscissa AB). We will get point C. Because navigator knows measurement of aircraft's real air velocity RAV, he can determine distance OC in kilometres. OC/RAV quotient will allow him to determine time t needed for flying the distance from point 0 to point B. Track velocity TV is done by quotient of distance 0B and flight time, that is TV=0B/t. To fly at done wind conditions from point 0 to point B after time t, aircraft must fly course K_Z at real air velocity RAV. During the flight aircraft's longitudinal axis (or its geographical flight course K_z) is deflected towards the fly track by angle σ, thus drift angle. For detailed information about aerial navigation methods, see work [1].

Problems come when navigator has no information about the wind. There are many methods for measuring drift angle and track velocities, but these methods are usually of high instrument demands, therefore they are not suitable for small aircrafts. Beside this most of those methods require manual operation and those methods are not suitable for navigation of non-piloted aircrafts.

2. The space filtration method

In [2], [3], an interesting method of velocity measurement using space filtration is described. Let's think about following example. We observe a spot light source through moving space grating created from transparent and opaque stripes, which is oriented as obvious from Fig. 2.

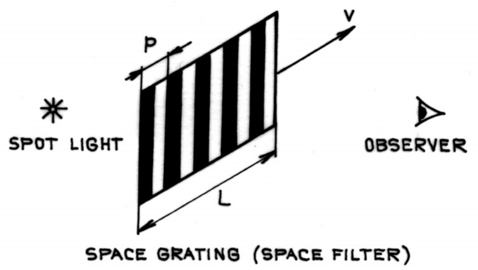

Fig. 2 Simulation of space grating usage for detection of velocity v.

In situation when the grating is moving at uniform velocity **v**, it will appear to observer that the light source is "blinking". If the opaque strip covers a light source, observer will perceive it as switched off; if the grating moves by p/2, it uncovers light source for observer and he will see it. For this case we can determine the frequency of blinking as

$$f = \frac{1}{t} = \frac{1}{p/v} = \frac{v}{p} \quad , \tag{1}$$

where f is frequency of "blinking" of the light source, t is time, v is uniform velocity of space grating movement and p is grating spacing or distance of its stripes. From relation (1) we can determine the speed of moving grating

$$v = p f \quad . \tag{2}$$

More complicated case occur in situation, when through space grating the observer observes moving Earth's surface instead of the spot light source. In [2], we can find complex analysis of the problems and methods of raster light sensitive CCD sensor usage to determine grating movement velocity towards Earth's surface even in this case.

Open literature tells that the method of determining velocities using space filtration is practicable only when relative movement is oriented upright to grating arrangement. Hence, the method of measuring velocities is used when the above mentioned orientation is guaranteed, e.g. in case of measuring velocity of liquid flow in transparent piping, movement measuring of transport belt and so on.

As shown in Fig. 1, measuring track velocity of flying aircraft using this method isn't be possible since grating is properly oriented towards geographical course of aircraft but not towards the its track. Let's study the case in Fig. 3.

Fig. 3 shows that turning the grating towards object velocity vector, whose velocity we want to measure, is causing an effect as if the grating spacing has increased from measurement p to measurement x = p / cos σ. Turning the space grating by angle σ has the same effect as usage of properly oriented grating with strip spacing increased from *p* to *x*. Therefore, direct measuring of speed using this turned grating is affected by great error and is impossible. Nevertheless, let's notice the fact that frequency of blinking will change in the case of turning the grating. By observing the frequency for different grating orientations we can find that at correct orientation the frequency is of the highest level and turning the grating causes decreasing the frequency. And this is the fact we can use for our purposes.

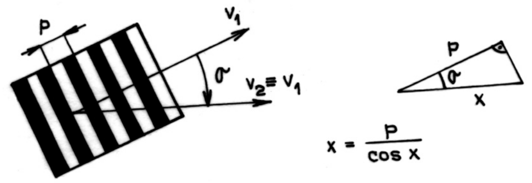

Fig. 3 Simulation of grating movement turned by angle σ.

If a system for measuring the velocity by space grating is put into aircraft so that the system can be turned towards aircraft longitudinal axes and a calibrated scale shows the value of the turning. If we turn the grating during the flight, the indicated velocity would change and would be at its maximum when the space grating is properly orientated towards the track velocity vector. For space grating oriented such a proper way the system would indicate correct aircraft's track velocity value and then the turning angle of grating towards longitudinal axes of aircraft is directly the drift angle. A user of such speed-measuring system can during the flight simultaneously determine both module of track velocity TV and value and orientation of drift angle at any position and any time. Since aircraft velocimeter indicates RAV and onboard compass shows geographical course K_Z, we have all the necessary readings for aircraft navigation using triangle of velocity vectors. It means that knowledge of wind vector is not required for this purpose. The only restriction of this system is necessity to "see" the Earth's surface. As CCD line sensors can operate in close infrared spectral band, it is possible to use the system even for night navigation.

When the system is used with servo which automatically turns the grating to find the orientation at which indicated velocity value would be at its maximum and it would read the angle of turning grating against aircraft's longitudinal axes, we get no operator demanding navigation system suitable even for usage in non-piloted aircrafts. Next period of grant solution will concentrate on this fact.

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