Abstract: - In the part of radiolocation focused on one target tracking we can find for example active radar and passive surveillance systems but we cannot find any representative of passive radiolocation area. Therefore this paper is focused on the conceptual design and practical solution of passive radar for one target tracking. The scanning of the area of interest is ensured by an antenna system with a 8x8 Butler matrix.

Key-Words: - Passive coherent location, radar, phased antenna, bistatic reflecting surface, passive coherent radar, Rotman lens, Butler matrix

1 Introduction
The importance of passive radars in today's electronic war continues to grow especially for hidden activities, prevention of own radiation, use of appropriate parts of the frequency spectrum properties and also because of providing very comprehensive and very extensive information about the objects of interest under conditions of very difficult revelation of the own activities. In the passive radiolocation there are two basic principle solutions of the target position destination. Firstly, the multistatic radar, which requires the use of several receiving positions. The using of this number of receivers in mobile military systems makes a lot of complications. Secondly, it is the bistatic radar which uses non-cooperating transmitter. For this version I have developed three conceptual designs and the detailed comparison of them can be seen here [1]. Because two out of the three variants are very demanding as far as design solutions and computation are concerned, and the aim of this paper is a practical implementation, I chose the version with the non-cooperating bistatic radar transmitter, which works in the frequency range of DVB-T [4]. The principle of the target position determination is receiving the signal reflected from the target. As signal sources, civilian TV and radio transmitters, enemy’s radars, etc. can be used. Because the received signals do not carry information about the antenna angles (elevation, azimuth), timestamps, etc., the passive radar uses the usual methods of passive radiolocation.

2 Conceptual solution of passive radar – part of detecting one flying target in the area of interest
First of all it was not possible to find and analyze any method of tracking a single target by a passive radar for tracking one target because this area is still not represented by any known device, and it was the main problem. Therefore I tried to find a solution in the form of a passive radar, which could fill the empty space, just in the area of tracking one target. The procedure for designing, which I chose, is based on the simplicity, practicality and effectiveness at the lowest cost of the whole structure.

2.1 Practical verification measurements
To select the appropriate frequency several measurements were carried out near the Brno city. For the verification theory a small unmanned aircraft vehicle (UAV) has been used; it was equipped with an electromagnetic reflective foil. The reflexive surface of the UAV was approximately 1 square meter of reflective surface and it flew at an altitude 100-200 meters above the ground at a distance about 100m from the receiving antenna. The goal of this measuring was to tune the TV transmitter which had a very weak signal on the horizon. After capturing the UAV to the receiving antenna beam we should receive the strongest signal. The principle of this method is shown in Figure 1.

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From the 11 TV transmitters, which are listed here [1] I chose the transmitter Jihlava-Javorice; its nominal power is 100 kW and its distance from the measuring station is 102km. All measurements were conducted with the goal to select a suitable frequency, which is crucial for practical realization of the radar. The TV transmitter Jihlava-Javorice broadcasts on the frequency 575MHz.

### 2.2 Defining the area of interest by the antenna system

The antenna system for monitoring the area of interest is a key parameter of the system therefore an eight-beam phased antenna system was selected. This allows getting information about the flyby targets in a particular direction without any rotation of the antenna system. In the view of the wavelength it was impossible to use a standard solution as a Rotman lens or system with a fixed phase shift [3]. Butler matrix 8x8 was the most advantageous solution. The matrix contains 12 180° hybrid couplers and 8 phase shifters (RF coaxial cable). Thanks to this configuration, a plane wave is produced in the aperture, which is rotated by a specific angle to a number of sources. In this way for every input an antenna beam at different angle is created. The Butler matrix is a standard MxM system, where M is the number of input/output ports [5]. The number of members of hybrid couplers (H) and phase shifters (F) Butler matrix is given by the following relations:

\[
H = \frac{M}{2} \log_2 M \quad (1)
\]

\[
F = \frac{M}{2} \left( \log_2 M - 1 \right) \quad (2)
\]

I made hybrid couplers using coaxial lines and planar technologies (microstrip and coplanar lines). The advantage of the hybrid coaxial couplers is wideband (up to 1GHz). The main disadvantage is the transmission attenuation and intensity of production.
The disadvantage of planar technology is narrowband applications, but on the other hand the advantage is a very simple repeated implementation. All hybrid couplers were made on the PCB FR-4 material of a 1mm thickness.

The final size of one hybrid coupler is 100x100mm. The size of one plate, which includes four hybrid couplers, is 210x210mm. In the following figure (Figure 6) you can see the complex measurements Butler's matrix. The markers are pointed on the 575MHz which is the frequency of interest, where all of measured waveforms meet.

3 Finalization of passive radar

After compilation all partial blocks of the passive radar, which consists of: Butler matrix, TV tuners, filters type bandpass on central frequency at 35MHz, amplifier ERA-3SM [2], signal detectors AD8309 and LED display panel, I made a few laboratory measurements to verify the functionality the entire system. The measurements showed the high sensitivity of the Butler matrix to the external environment and also the location of phase shifters (RF cables) near structures. The total sensitivity of the radar is at the level of noise, i.e., 120 db!

The final realization of the passive radar you can see in Figure 7. At first glance you can see the dominant Butler matrix and a large passive cooler outside the construction box.

Next I simulated flyby targets intermediate beams of the antenna system, by using laboratory module which I made myself. This module simulated orthogonal head of reflected signal due to the antenna system. The measurement results can be seen in Figure 8. LED indicator panel just confirms the correct operation of passive radar. The device is also ready for connection to analog PC input by eight-channel connector for recording and processing the measured data.
Fig. 8: Indication of a simulated flight through the center of the antenna characteristics

4 Conclusion

The work is focused on passive radiolocation in tracking one target. The first point was the necessary theoretical analysis of the area of passive radiolocation, because in this area a passive monitoring radar cannot be found. The fact that this theory is not used in practice shows the need to verify the practical measurements. The next step was making a radar concept with an emphasis on simplicity and efficiency of the whole structure. I have used, with the advantages described above, the multi-beams antenna system consisting of a known Butler matrix in a planar arrangement, which had secured the sector monitoring area of interest. The receiving part of the radar ends with a simple but illustrative LED display panel on which it can be seen in real-time the received signal intensity in each sector of the antenna array.

The next step in the future will be to create a suitable software environment in the PC and the implementation of tracking targets by means of another antenna with narrow beam.

References: