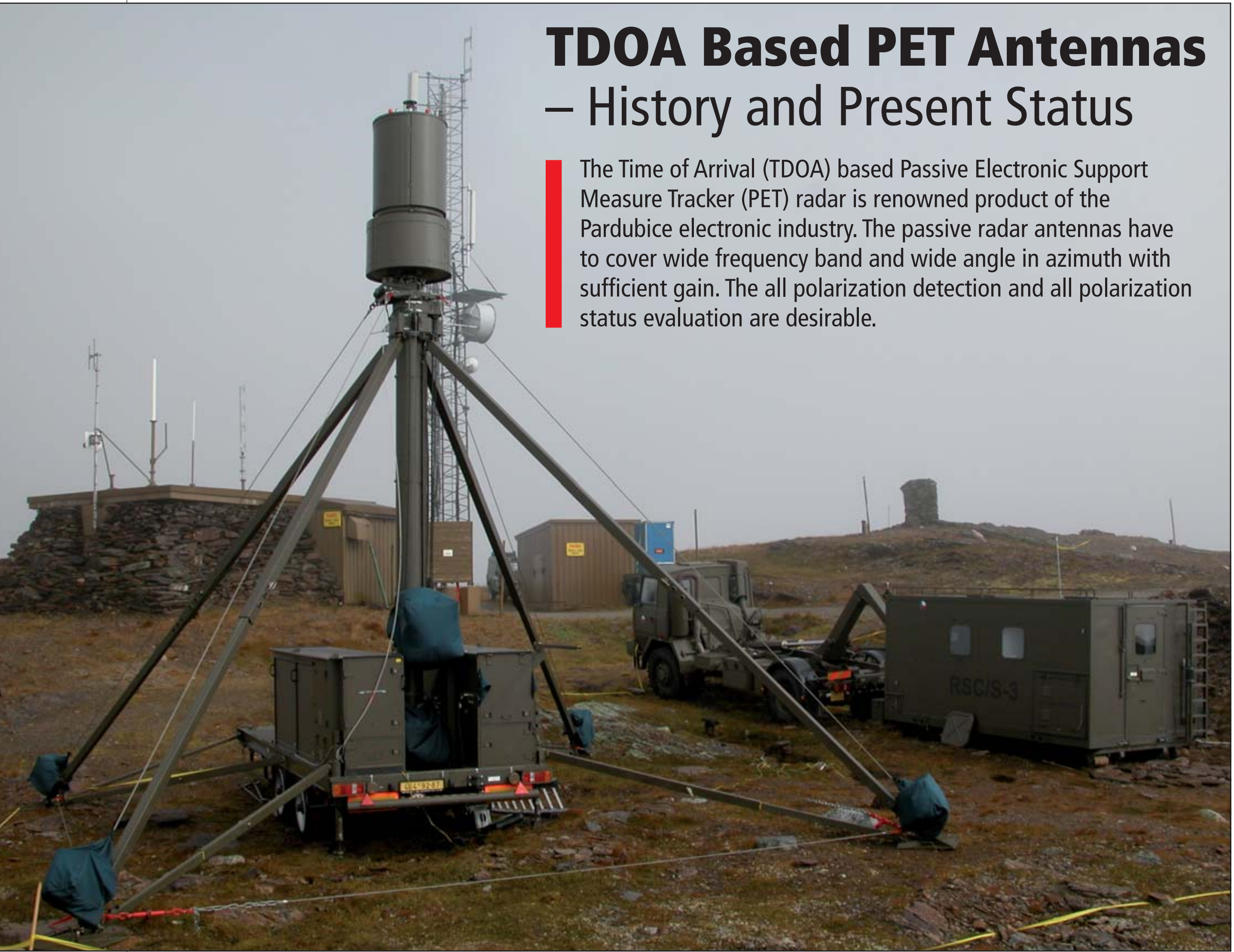


TDOA Based PET Antennas – History and Present Status

The Time of Arrival (TDOA) based Passive Electronic Support Measure Tracker (PET) radar is renowned product of the Pardubice electronic industry. The passive radar antennas have to cover wide frequency band and wide angle in azimuth with sufficient gain. The all polarization detection and all polarization status evaluation are desirable.

The TDOA based passive radar is based on the simultaneous receiving of the targets emissions at receivers deployed apart from each other. The exact time measurement (10 ns rms) allows computing the target position by transformation from the hyperbolic to the Cartesian space. In the other words, the hyperboloid is defined as the surface with the constant distance difference from two defined points (foci). The targets position is defined as the intersection of several hyperboloids. That is why the TDOA based passive radar is sometimes called hyperbolic system.

The Czech Military TDOA Based Passive Radars

The five generations of TDOA based passive radar are considered in Czech industry: KOPAC, RAMONA, TAMARA, VERA S/E, VERA-NG

The name KOPAC is the abbreviation from the Czech wording to Correlation Intelligence (KOrelačni PAtraC). The prototype was built in the early 60s and used during the Berlin crisis in 1961.

The second generation TDOA based passive radar was called RAMONA as the abbreviation of the Russian wording to the Fast Tunable Radio Apparatus (Радиотехническая Апаратура Мгновенной Настройки). The RAMONA was exported to the Warsaw pact countries and to Syria between 1980 and 1986. RAMONA was develo-

From left to right: KOPAC, RAMONA and TAMARA systems

ped in Military Research Institute VU 060 and manufactured in TESLA Pardubice. Its NATO reporting name is "Soft Ball".

The third generation TDOA based passive radar was called TAMARA as the abbreviation of the Russian wording to the Fast Tunable Automatic Intelligence Apparatus (Техническая Апаратура Мгновенной Автоматической Разведки).

TAMARA was exported to the Warsaw pact countries and to Oman between 1986 and 1991. The TAMARA was developed and manufactured in TESLA Pardubice. Its NATO reporting name is "Trash Bin".

The abbreviations RAMONA and TAMARA sound like a female names – who knows, if there is some coincidence?

The names of the fourth and fifth generation VERA S/E and VERA-NG originated in the real person – Col. (Ret.) Vera Perlingerova – who greatly contributed to the restart of passive radar usage by Czech Armed Forces.

The abbreviation "NG" means the Next Generation. Both VERA generations are developed in the company ERA a.s. based in Pardubice, as the TESLA Pardubice successor in the passive radar products. The VERA products are both used by the Czech Armed Forces and exported throughout the world.

The biggest ERA a.s. company marketing success is a NATO tender victory in 2013 for delivery the Deployable PET to the NATO Communications and Information Agency (NCIA). This is the first TDOA based passive radar procurement by NATO and the first breakthrough into NATO armament by Czech and new NATO members industry in the area of advanced radio electronics.

Manhandling of the VERA-NG radar at the Unified Vision 2014 exercise in Norway.
Title photo: VERA-E system on exercise in Norway in 2006.

The Antenna Design

The TDOA based passive radar design is influenced by the requirements specific to the TDOA radar.

The main task is to cover the required frequency range. The upper frequency limit is stabilized at 18 GHz due to the hyperbolic principle limitation caused by the above 18 GHz bands propagation properties. The lower frequency is enlarging towards the VHF band due to the advance in the signal processing against the radio sources operating there.

To realize hyperbolic principle of the geolocation, the azimuth beam width would be quite wide (more than 120°/10 dB and elevation angle does not to be so high to realize the sufficient antenna gain. So the fan beam spread in horizontal plane is preferred.

To increase the probability of radar detection, two orthogonal polarizations should be processed ideally. The most spread polarizations in electronic warfare are the linear (vertical and horizontal) and circular (left and right).

To increase the effectivity of the Non Cooperative Target Identification (NCTI), the polarization status of the incoming signal waveform would be measured. This leads to the common phase center for the both orthogonal polarizations antennas.

1st Generation KOPAC

Since the proof of concept approach was operating at specific radar bands L, S and X, the antenna design and receiver design was based on the standard primary radar components.

2nd Generation RAMONA

The dual shape reflector antennas were used to cover the band 0.8–18 GHz.

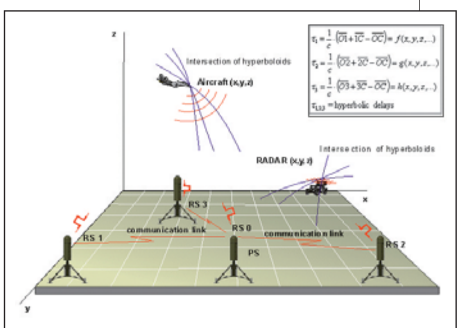
The reflectors were focused in vertical plane and defocused in horizontal plane to reach wider beam width in the azimuth. The demands for 4 basic polarizations (V, H, Circ. L and Circ. R) receiving was solved by the primary feeder rotation by 45° to provide slant polarization. The primary feeder was solved by the log-per structure at lower band and by waveguide horn at higher bands. The vertically polarized SSR/IFF transponders at frequency 1090 MHz were received by the 4 dipoles linear array with cylindrical reflector.

3rd Generation TAMARA

The hog horn concept covered all higher bands and the dipole flat arrays covered the lower bands.

The vertical polarization and horizontal polarization signals were received separately by separated antenna and receiver chains. Each polarization antenna occupies extra aperture and the phase centers were not collocated up to 8 GHz. Two hog horns covering frequencies above 8 GHz use the same aperture and the waveguide structure for both V and H polarizations. The signals were separated by the polarization divider on the antenna outputs. The SSR/IFF antenna was optimized to high gain by use of 4 elements. The same frequency band antennas occupied the same volume again in the opposite corner

TDOA based passive radar principle



of the antenna unit. Each antenna array received the dedicated polarization (V and H) by half aperture and gain.

4th Generation VERA

The VERA antenna unit is based on TAMARA antenna design with the aim to save the volume, mass and price. So the concept of both polarizations receiving was abandoned.

Three hog horn antenna covers the band 4–18 GHz. To reach the slant polarization, the special radome containing the wire net is used.

The antennas covering 1–4 GHz are solved as linear arrays of flat spiral antennas, which produce circular polarization. Beside the non-uniform polarization antenna design across the whole frequency band 1–18 GHz, the performance against the cross polarization is limited. The SSR/IFF occupied again extra volume and it was solved as 4 element patch array.

The additional log per is visible on the latest VERA models to cover a part of the UHF band.

5th Generation VERA-NG

During the VERA Next Gen antenna unit specification, the further improvements in antenna performance were required:

- Further volume reduction
- Further mass reduction (human manipulation required)
- Further frequency enlargement towards lower spectrum end (up to VHF including)
- All polarization performance by one aperture and volume.
- The antennas have to feed two receiving chains independently
- Polarization status measurement ability (collocated phase centers)
- In-built monitoring signal defined injection to provide end-to-end system operational tests and simulations

VERA-NG system

The printed conformal clover leaf dipoles providing slant left and slant right linear polarization were designed as the component of two independent linear antenna arrays at one particular unit. Both arrays have orthogonal polarization and share one common phase center. The number of element depends on the frequency band with respect to the desired gain and built-in volume available. The clover leaf element design remains same to all frequency bands, so the system performance does not changes through very wide frequency band 87.5 MHz – 18 GHz significantly.

The 2–4 GHz antenna contains 8 elements too; the band from 4 GHz to 18 GHz is covered by the 16 element antennas.

The antennas below 1 GHz are single element design and they are radio transparent to higher frequencies to save the volume in the antenna unit.

The antenna below 500 MHz is solved as active one with solid state impedance converter, desymetrizator and amplifier.

Each antenna subsystem contains in-built directional couplers to both polarizations outputs to injection of testing signals.

The SSR/IFF signals with vertical polarization are received by the 1–2 GHz antenna, where the co-phase signal summing creates vertically polarized antenna with sufficient gain.

The antenna arrays allow tailoring the vertical pattern towards to the ideal cosec² pattern.

The Czech Armed Forces with VERA-NG participated in various NATO exercises.

Both antenna units' designs are divided by 25 years' time gap. The mass is reduced from 1200 kg to 100 kg, the band is wider and both polarizations are processed with collocated phase centers. The substantial mass reduction between the 3rd and 4th generation is caused by the vacuum tube technology replace by solid state one (from 1200 kg down to 300 kg). The substantial mass reduction between the 4th and 5th generation is caused by the complete antenna redesign to the clover leaf printed antennas (from 300 kg down to 100 kg).

Libor SLEZÁK

Photos: ERA a.s.