The best of both worlds – hybrid radiolocation by conventional direction finding (AoA) and TDOA

Fig. 1: The compact outdoor R&S®UMS300 monitoring and radiolocation system for ITU-compliant monitoring, direction finding and emitter location based on TDOA.

Hybrid radiolocation systems from Rohde&Schwarz combine advanced time difference of arrival (TDOA) with tried and tested direction finding based on conventional angle of arrival (AoA), benefiting from the best of both worlds. A large range of TDOA-capable devices and systems offers scalable solutions for a wide variety of tasks.

TDOA – the concept

Emitter location based on time difference of arrival (TDOA) must meet the same requirements as tried and tested direction finding based on conventional angle of arrival (AoA): A sufficient number of receivers must be positioned around the transmitter to be located. Its signals, which are propagating at a constant speed, reach the receivers at slightly different times because the receivers are normally located at different distances from the point of emission. The coordinates of the transmitter, i.e. its location, can be calculated from these relative time differences.

Mathematical correlation methods are used to calculate the relative time difference of signals arriving at two receivers. This value and the geographic coordinates of the receivers provide the basis for calculating all possible transmitter positions. Transferred to a map, they would lie on a hyperbola. The calculation is then repeated for a second and, where appropriate, multiple receiver pairs. The point at which the hyperbolas intersect is the origin of the signal, i.e. the transmitter site. This intersection principle is also used for radiolocation by means of direction finders, but with the main difference that relevant transmitter sites do not lie on a hyperbola but on a straight line.

This means that a TDOA radiolocation system must consist of at least three receivers providing three hyperbolas (RX1 – RX2, RX1 – RX3, RX2 – RX3, see Fig. 2). More receivers increase accuracy. There is, however, an upper limit for receivers above which calculation time increases drastically without any significant improvement in accuracy. And there are clear parallels to radiolocation by means of direction finders, too. At least two direction finders are required; a third one increases accuracy, while five or more direction finders do not significantly improve results.

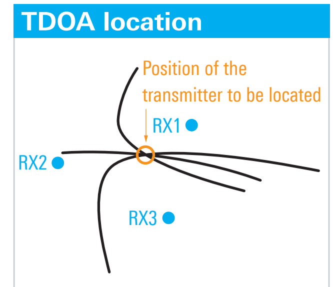

Fig. 2: TDOA location: Three hyperbolas are calculated on the basis of the relative time difference of signals arriving at three receivers. The point at which the three hyperbolas intersect is the transmitter position.

Since electromagnetic waves propagate at the speed of light, system accuracy in the nanosecond range is vital in order to calculate the time differences of arrival. This is why GPS receivers are used. They provide accurate timestamps, which are inserted into the baseband (I/Q) data, and the I/Q data is then used for correlation (Fig. 3). To ensure that calculations provide sensible, unambiguous results, the signals must contain a minimum of information. This is one of the reasons why TDOA is less suitable for unmodulated carrier or CW signals.

The advantages of the TDOA method are particularly revealed in densely built-up urban environments. Typical drawbacks such as reflections and multipath propagation, which create immense challenges for direction finders, are reduced by suitable TDOA algorithms. Complex signal scenarios are frequently prevalent in urban environments. These environments harbor a colorful mix consisting of many emissions; weak transmitters are frequently placed directly adjacent to strong ones, making exacting demands on the linearity, sensitivity and dynamic range of the receivers.

Hybrid TDOA/AoA location – the best of both worlds

Either a TDOA system or an AoA DF system may yield the best results, depending on the signal scenarios and local circumstances. Ideally, both methods should be available at the same time in order to combine their advantages. The new hybrid radiolocation systems from Rohde & Schwarz are ideal for meeting the requirements of both methods and offer a wide range of components for TDOA-based location: the R&S®ESMD, R&S®EB500 and R&S®EM100 monitoring receivers, the R&S®DDF255 and R&S®DDF205 direction finders, as well as the R&S®UMS300 compact monitoring and

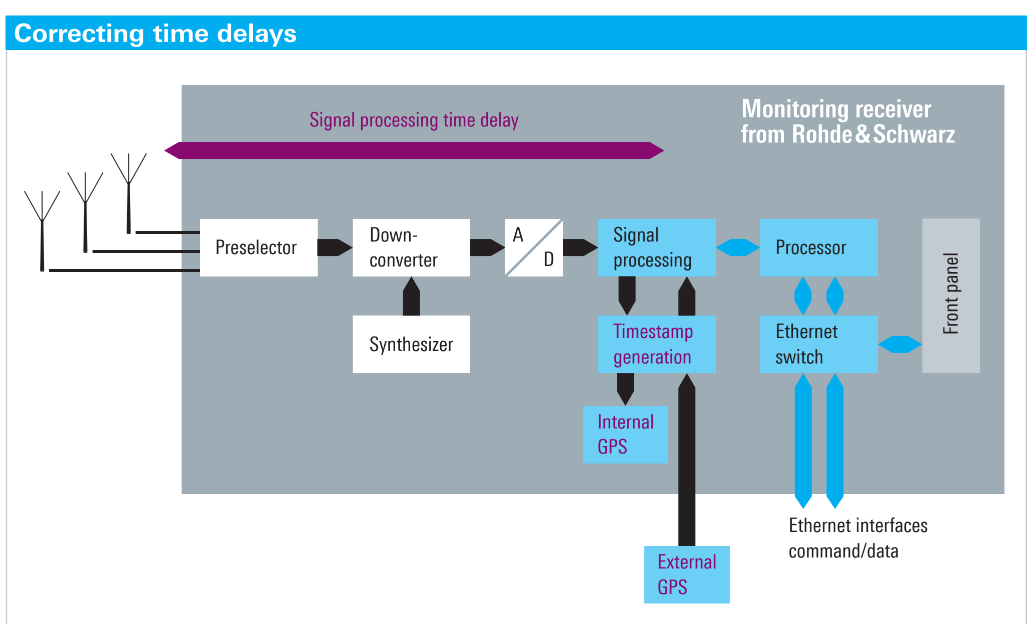

Fig. 3: Rohde & Schwarz devices measure the time delay between antenna input and signal processing. This substantially boosts location accuracy.

radiolocation system (Fig. 1) and the R&S®UMS175 compact monitoring system. To make these devices TDOA-capable, users simply have to connect a suitable GPS receiver (IGT option) and load the latest firmware. Existing devices can be easily retrofitted.

Using a sophisticated method, the Rohde & Schwarz devices calculate the signal delay between antenna input and signal processing and correct the timestamp inserted into the baseband data. This boosts time and location accuracy. In addition, this innovative concept, which is unique on the market, allows users to combine all Rohde & Schwarz devices that support TDOA in any arbitrary configuration to perform emitter location.

The measurements are controlled by the R&S®ARGUS monitoring software. Successful on the market for more than 25 years, this software has become the world standard for all regulators and similar organizations to perform spectrum monitoring tasks. TDOA location can be seamlessly integrated into the numerous measurement and analysis functions offered by this software. The first step in a conventional workflow is to scan a specific frequency band. All transmitters that were found are compared with a reference list that is typically imported from a licence database. Active transmitters that are not in the reference list, e.g. unlicensed ones, are analyzed in greater detail, identified and located. So far, radiolocation has primarily been carried out by means of direction finders. Now, users have a choice between the TDOA method or a combination of TDOA and AoA. They can also perform measurements automatically or interactively.

The R&S®MapView geographic information software is used to select the relevant sensors and display the direction finding and radiolocation results on electronic maps. The software offers a wide range of maps in various formats (free and commercial) and displays the positions of known or licensed transmitters in addition to radiolocation results (Figs. 4 and 5).

Advantages of the Rohde & Schwarz solution

Implementing an optional TDOA functionality in the latest generation of receivers and direction finders from Rohde & Schwarz has the following key advantages:

- **High-quality devices ensure higher location accuracy**
  High-quality, ITU-compliant devices are a must for successful TDOA location, especially when it comes to signal scenarios in large cities. High sensitivity and a wide dynamic range make it possible to accurately measure even weak signals in close vicinity to strong transmitters.

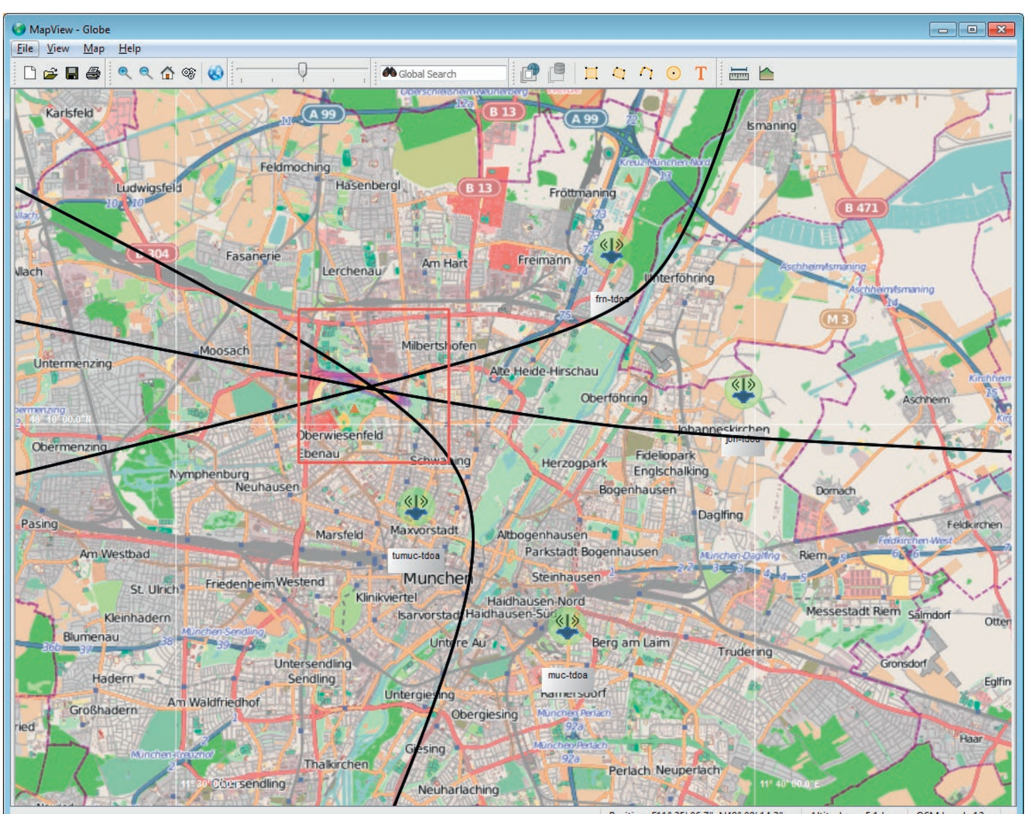

Fig. 4: Display of the TDOA results as hyperbolas and heatmap.

The accuracy of a TDOA location increases with extended signal bandwidth and a better signal-to-noise ratio (S/N). The narrower the signal, the less accurate its location. The high sensitivity of the Rohde & Schwarz receivers creates a higher S/N ratio and provides more accurate radiolocation results. In many cases, it is the high sensitivity which makes radiolocation possible at all. The high sensitivity also compensates for the bandwidth-related inaccuracy, i.e. high-quality devices locate narrowband signals with higher accuracy.

- **Flexible combination of TDOA method and direction finding (AoA)**
  Users can select between the TDOA method, direction finding (AoA) and the hybrid solution depending on the situation and always have the best method at their fingertips.
- **In times when no radiolocation tasks have to be performed, systems can be used for other ITU-compliant measurements**
  Emitter location is an important task, but experience shows that it requires only a minor portion of the time. Pure TDOA sensors are largely useless for the rest of the time. Devices and systems from Rohde & Schwarz with optional TDOA capability, by contrast, can be used around the clock for a wide range of additional monitoring tasks. All these TDOA-capable devices and systems can be configured in any combination, enabling users to select the optimum device for their main task.
- **Including TDOA functionality in existing hardware obviates the need to find new sites**
  It is more and more difficult to find suitable sites for additional monitoring stations. Since existing stations can be easily enhanced, there is no need to spend time and effort in finding sites and in providing the necessary infrastructure such as electricity or connection to network and communications equipment.

Summary

The basic concept of TDOA location is not new. Transmit signals with ever expanding bandwidth, compact, high-performance receivers, global coverage of highly accurate time and position information based on GPS, as well as an ever faster communications infrastructure are good reasons for believing that TDOA will now become a technological and economic success. With its large range of TDOA-capable devices and systems, Rohde & Schwarz offers scalable solutions for a wide variety of tasks. In particular, the combination of TDOA with direction finding based on conventional angle of arrival (AoA) offers the optimum solution for almost any application. This enables all transmitters to be located rapidly and reliably at any time.

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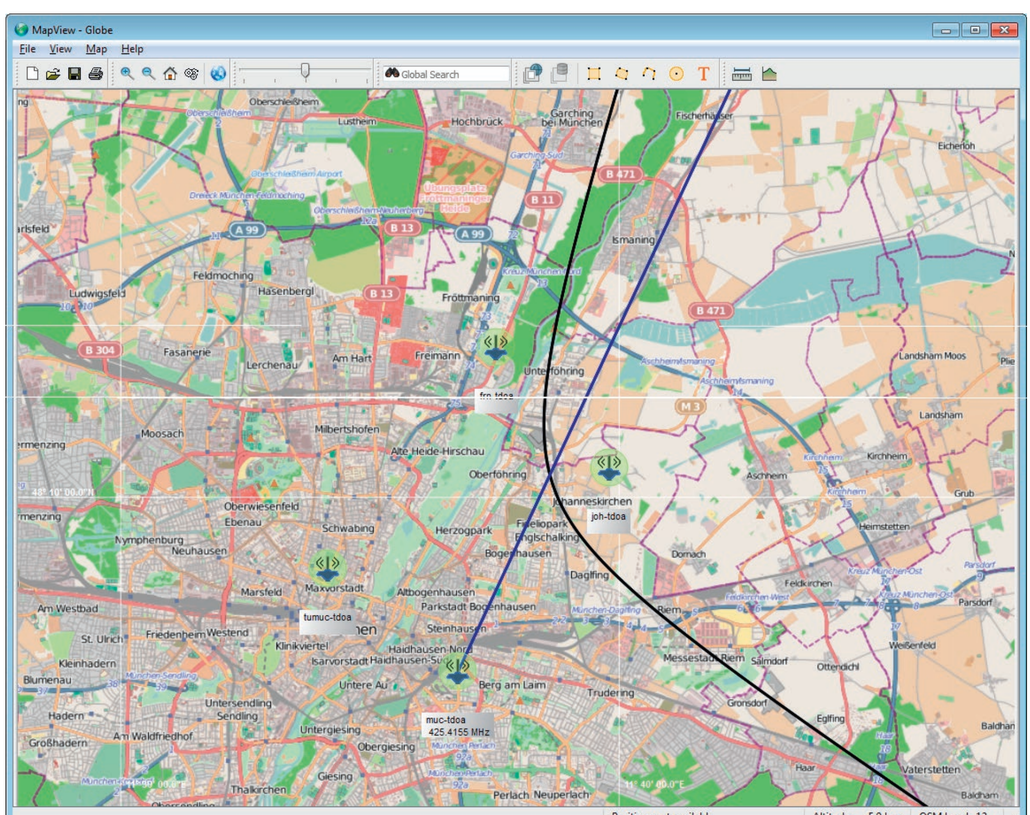

Fig. 5: Hybrid radiolocation using hyperbolas and line of bearing.