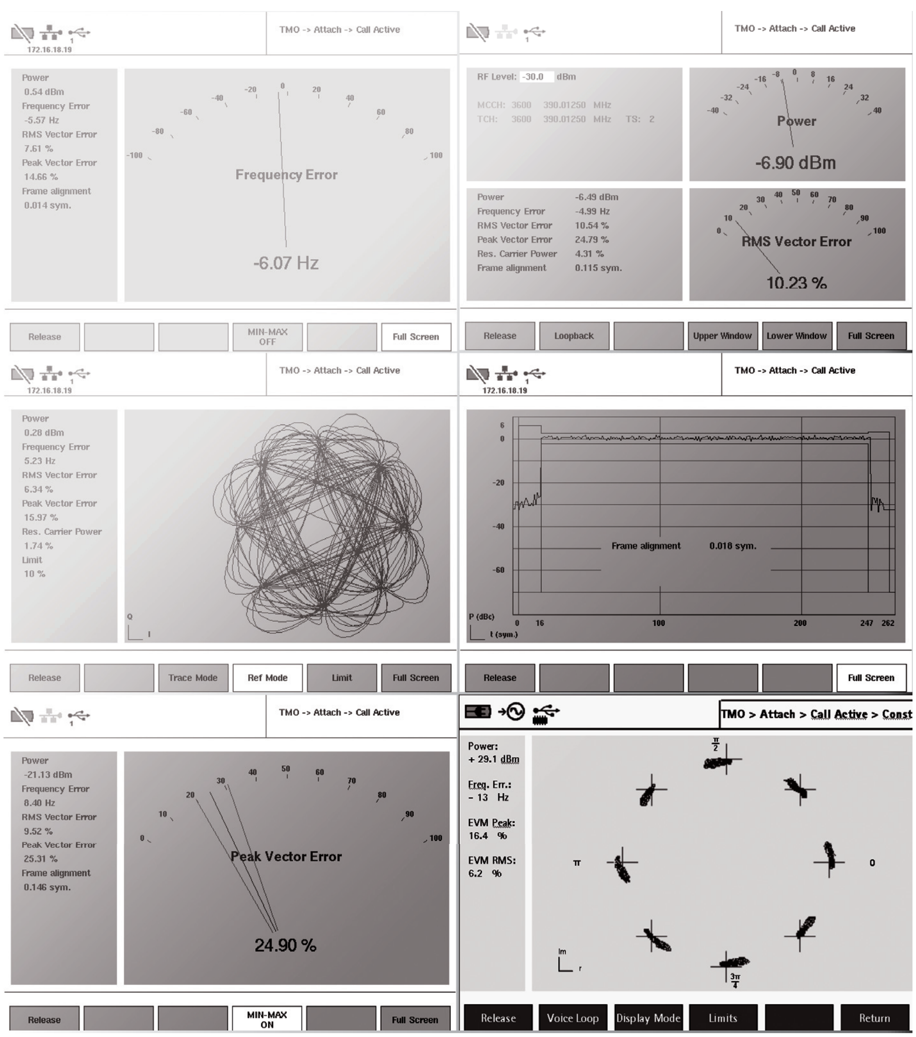
White Paper

Migrating from analogue to digital:
Important measurements on TETRA mobile devices



boosting wireless efficiency

Police, firefighters, rescue staff and other users of mobile services are facing radical new developments: Digital mobile systems conforming to the European TETRA standard are being introduced in increasing numbers of countries and organisations. The crunch point in the migration process is not just the network technology structure: Workflows developed over decades need to be changed, the open channel and the mobile services for public safety organisations we are familiar with today, are a thing of the past. Thousands of users and vehicles need to be supplied with new mobile devices by mobile equipment producers, and even the daily work of mobile engineers will change fundamentally: Thanks to the digital transfer of information, TETRA mobile devices have completely different characteristics to the analogue mobile devices previously in use. What measurements and criteria will determine whether or not a mobile device functions correctly in future?

Requirements

The definition of the TETRA air interface, in other words the description of the mobile technology being used, has also been specified by ETSI in the European standard EN 300 392. EN 300 394 belongs to the same family of standards and represents the test specifications for complex acceptance tests on newly developed mobile devices and base stations – this means that test instructions for device repairs and tests can be derived from these specifications.

Unlike with analogue radio – where a signal generator and a measurement receiver is sufficient to test a mobile device – one measurement device for TETRA (Figure 1) needs to simulate one base station and initiate a registration with the mobile device so that it transmits actively. This will only be successful if the control channel transmitted by the measurement device contains exactly the same network parameters (MCC and MNC, in other words the country identifier and a network identifier) as the mobile device. In addition, the tester must use frequencies which the mobile device is also using for the main control channel (MCCH) and traffic channel (TCH). In many European countries, two frequency ranges, each with 400 channels, have been allocated for digital trunked radio: The ranges 380 to 400 MHz for public safety and security networks, and 410 to 430 MHz for private radio networks, each with 10 MHz duplex spacing and many of them applying a 12.5 kHz channel offset. For a complete test, a mobile device should be tested once each on one channel on the upper and lower band limits and in the centre of the band.

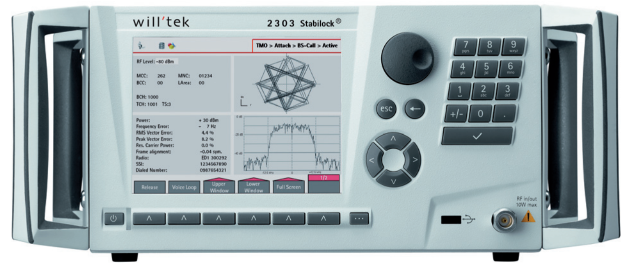


Figure 1: A measurement station for TETRA mobile devices

If these parameters are correctly set on the measurement device and the network simulation is started, the mobile device registers itself on the measurement device within a short space of time. Here it also transfers several pieces of important information, namely the device class and functions present such as activated encryption and the maximum transmission performance possible. The call groups active in the mobile device are also registered on the network – in this case the measurement device – or displayed there. This information can be used as the initial results of the device test, as these call groups form an important part of device addressing: If a group is forgotten when programming a device in the mobile production site, this can result in the device answering an individual call, but not a group call, and this must not be allowed to happen during use. For this reason, a test call should be used to check whether or not all relevant groups are correctly present on the device. This test call is necessary in any case to start the measurement of the technical mobile parameters, which allows continuous transmission from the mobile device.

Transmitter measurements

If a duplex call is set up, the mobile device is in transmission mode immediately; with a simplex call the push-to-talk button also needs to be pressed so that the measurement results of the transmitter message are displayed. Only on first glance is the measurement of the **transmission performance** comparable to analogue radio, however: Due to TDMA (Time Division Multiple Access) operation used by TETRA with its four time slots, the mobile device does not transmit continuously, but only for 14.167 ms during a TDMA frame of 56.67 ms in length. The measurement of the transmission performance is carried out during this active time slot. Technologically this is no longer a problem, as even GSM at over 15 years old works using significantly shorter time slots. However, a test must still be conducted as to whether the TETRA mobile device transmitter ramps up to and down from the required output level within the defined time intervals, without overloading or underloading. This test is carried out using the **power-time template measurement**, in which the transmitter being switched on and off is measured across the required time within a tolerance corridor, and displayed graphically. The tolerances are given in EN 300 392 section 6.4.5. The mobile device fails the test if it does not meet the tolerances. Outside the assigned time slot (**non-active transmit state**) the transmission output must also fall below a defined minimum, a maximum of –70 dBc or absolute maximum –36 dBm relative to the carrier is permissible.

For compensation of the radio signal runtime, the entire burst is sent slightly earlier or later to arrive at the base station at exactly the correct time. If this technology, known as **frame alignment**, does not work perfectly, it could be that the mobile device transmits during a neighbouring time slot and thus interrupts the communication of other subscribers. The associated parameter is determined using measurement technology and displayed in the unit of symbol periods.

The transmission performance can be set in defined stages. These are controlled by TETRA radio devices as part of a power control process dependent on the reception level (Open Loop Power Control). The tester should determine the performance class of the TETRA mobile device automatically depending on the signal level.

A **frequency error** of the carrier is also more critical with the TETRA signal than in the analogue world. Whereas the incorrect position of the analogue carrier in most cases "only" results in the signal being distorted, a deviation of over 100 Hz in the digital TETRA signal can result in it no longer being possible for the signal to be evaluated or a connection to be established. TETRA mobile devices are fitted with automatic frequency correction (AFC), however, which modifies the mean frequency of the mobile device transmitter to that of the base station; this functions with most mobile devices up to an offset of one kilohertz. As the AFC plays such an important role, testing this function is also part of the list of criteria to be checked.

Modulation measurements

The measurement of modulation quality will also become considerably more complex in future. In the world of analogue public safety and security radio, the important criterion for this was the frequency deviation, in case of an error there was a risk here of either distortion or the signal being too quiet. With the modulation type π/4-DQPSK chosen for TETRA, the voice information is not transmitted continuously with the frequency deviation, but is digitised and coded as a bit sequence. The carrier of the TETRA signal is phase-modulated in stages, with a modulation stage ("symbol") each transmitting two bits.

B(2k–1)	B(2k)	Dφ(k)
1	1	-3π/4
0	1	+3π/4
0	0	+π/4
1	0	-π/4

Table 1: Permitted phase shifts with π/4-DQPSK (source: EN 300 392-2)

Table 1 shows the permitted phase changes and Figure 2 shows the characteristic image of the **constellation diagram** representing the phase pattern, and therefore the method for how information is transmitted via DQPSK in a Cartesian coordinate system. Both axes mark the complex level here, the direction of the vector marks the phase, and the length of the vector marks the transmission performance. Even at first glance, this image reveals much regarding the modulation quality: Typical problems here include the "pumping" of the circular structure, which then appears more egg-shaped (Figure 3), or a wiping of the individual decision points for the modulation vector along the circuit (Figure 4). The nominal deviation itself in turn gives an (error) vector (Figure 5), the magnitude of which produces the actual numerical measurement value for the modulation quality as an **error vector magnitude.** Under no circumstances should a phase pattern run through the origin point of the constellation diagram. This would mean that the transmission power returns to zero, which is simply not feasible with this modulation type and actually constitutes one of the advantages of this technology. The circle's centre point must remain free, resembling the picture of an eye.

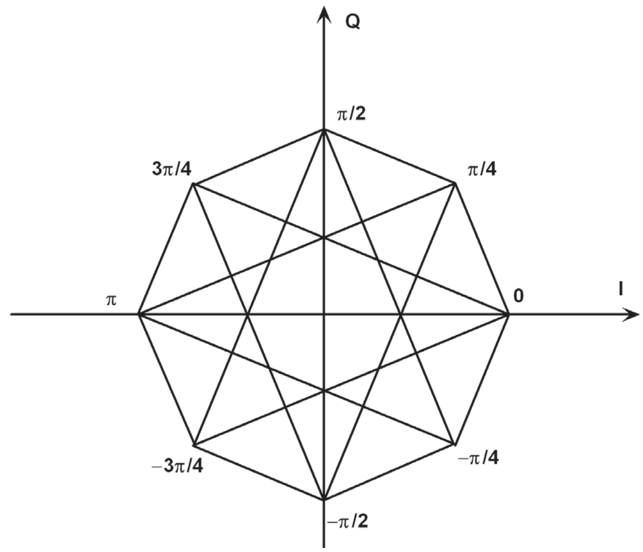


Figure 2: The constellation diagram is produced from the permitted phase shifts

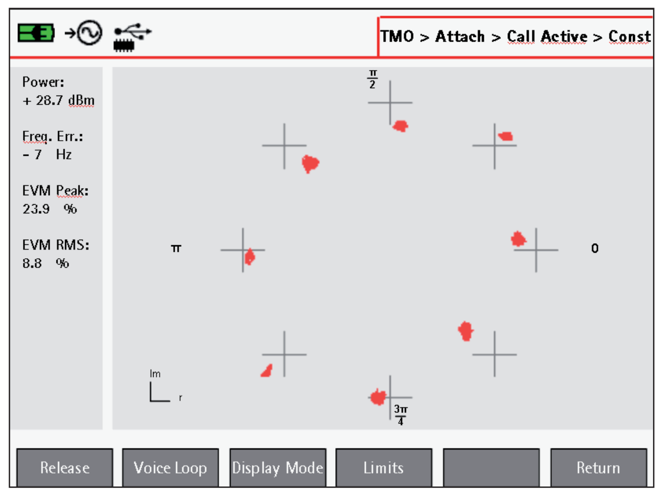


Figure 3: Distorted constellation diagram; the circle becomes "egg-shaped"

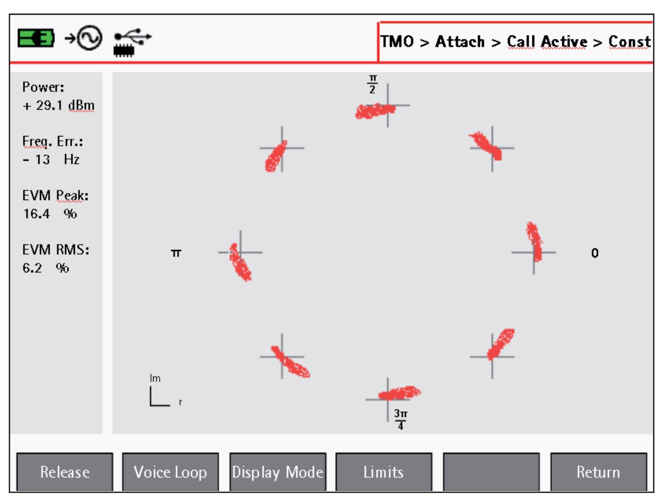


Figure 4: The decision points shift due to jitter in this constellation diagram

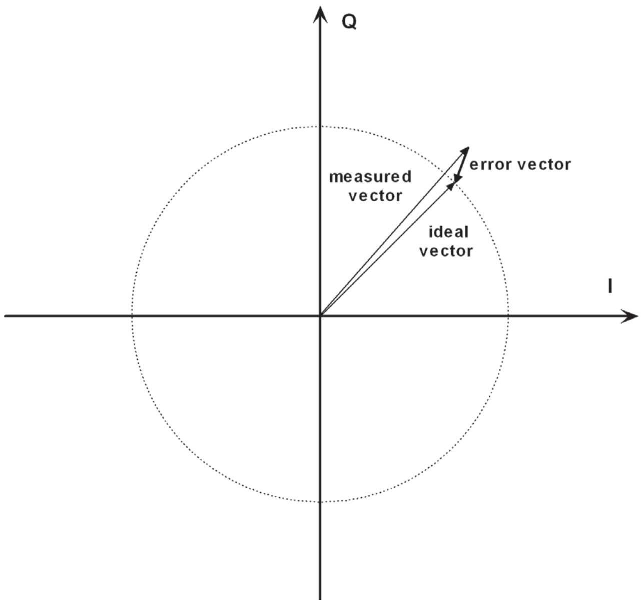


Figure 5: Determining the error vector (EVM)

Figure 6: TETRA test chamber with aerial coupler

Receiver measurements

The new measurement process for determining the receiver sensitivity can also be compared with that previously used for analogue radio. Whereas in the analogue case a test signal produced by a signal generator is reduced until a minimum signal/noise ratio (S/N or SINAD) for the voice transmission has been reached, the bit error rate is used to determine the sensitivity threshold when determining the sensitivity of digital receivers. In this case, too, a signal generator is used, which has been modulated with a bit sequence specified in the TETRA standard (T1 test signal) and its RF level is lowered slowly and continuously. Unlike with analogue radio, the bit error rate increases suddenly, indicating how important the error correction in the TETRA receiver is: If the reception level is too low, no further decoding can be carried out. Standard TETRA mobile devices are still exceptionally sensitive with a dynamic sensitivity of approx. –103 dBm (static –112 dBm).

Unfortunately, not all mobile device manufacturers are supporting the standardised test signal, which is why an additional test procedure has been accepted: the **paging sensitivity**. The measurement of the bit error rate has been replaced here with a repeated request to the mobile device to re-register. The RF level at which the mobile device responds for the final time is taken to be the sensitivity threshold. This method is slightly less accurate than the bit error rate test, but functions with all devices regardless of manufacturer. High sensitivity also suggests the use of a shielded environment when determining the device sensitivity. For this purpose, the industry offers compact test chambers (shield boxes) which do need to have a shielding of at least 80 dB, however, to avoid both the effects of radio networks transmitting in the environment, and the interference of these radio services from the mobile device transmitting at maximum output power due to the open loop power control. Within these test chambers, aerial couplers can also be used, which simplify the handling and which render a direct link-up of the mobile devices to the measurement device via special plugs unnecessary (Figure 6).

What else is changing?

For testing mobile devices there are further specifications in the TETRA standard, such as test tones for determining transmission quality or various test loops. Unfortunately, not all of the equipment manufacturers keep to the specifications in the standard. The simplest and fastest way to assess the transmission quality is a voice loop in the measurement device, so that the microphone and loudspeaker are also tested in this end-to-end test: The words spoken into the microphone are reproduced on the mobile device speaker with a short delay. Naturally a duplex call needs to be established first, in this case, to ensure bidirectional communication.

What is often problematic in the testing of TETRA terminals is the air interface encryption conforming to TEA 1 to 4; in this process the user data and signalling is actually encrypted on the air interface, which means that a measurement device cannot establish a connection without knowing codes and algorithms. TETRA mobile devices can therefore only be tested initially in unencrypted clear mode, so it needs to be possible to operate them unencrypted on at least one channel. The only possible remedy would be if the codes and algorithms were also to be stored in every mobile device tester, which is at present not particularly feasible and which would in any case not conform to the security philosophy inherent in TETRA.

Devices with end-to-end encryption of the user data can also be tested without problems, as in this case the signalling is transmitted unencrypted. However, it should be a rare thing to come across devices which are not yet also encrypted according to TEA.

Special cases

In the case of repairs, primarily when replacing components, the transmitter and receiver frequently need to be re-calibrated. For this purpose, TETRA mobile measurement stations can also be used as precise signal generators and analysers, without the mobile devices logging on and without a connection being established. Measurements on TETRA base stations also function in a similar way, and even these do not take place in normal network operation, but in a special service mode in which the BS is started before the transmitter and receiver are tested. If the MS tester masters the reverse frequency position – like a mobile device, in other words, with transmission in the lower band, reception in the upper band – this means that most measurements can also be made on the BS.

Outlook

Mobile equipment engineers at safety organisations and commercial operations will be able to adapt quickly and safely to the new requirements with powerful measurement technology. Automatic measurement processes which can even be used by the personnel themselves to check their own mobile devices, and management systems for terminal programming help to maintain an overview, even with high unit quantities, and to document the device status correctly and sustainably. Ultimately, TETRA II is already on the starting blocks and together with OFDM technology, represents the latest revolution for the air interface!

Read more about TETRA at

www.willtek.com/tetra

www.willtek.com/english/technologies/tetra

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