The new TETRA SDR repeater

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The most important thing will build is trust
The New TETRA SDR Repeater

Introduction
The new digital TETRA repeater from Cobham Wireless offers an impressive list of features thanks to the use of Software Defined Radio (SDR) technology. The standard SAW filter technology so far being used in analogue products has been replaced by digital filtering technology. The new concept offers higher performance and flexibility and makes it possible to add future enhancements and new functionality by simply downloading new software to the product.

TETRA repeaters go digital
Trunked Mode Operation (TMO) repeaters are used to extend the network coverage into buildings or to fill in gaps in outdoor coverage. Until now, the existing products have used SAW filters to select the channels or the frequency band segment of the TETRA network. This approach resulted in channel selective TETRA repeaters rather complex when 4 or more channels are required. The SAW filters deployed are only available at certain fixed frequencies (intermediate frequency filters), requiring a down and up conversion concept for each channel. Thus the large number of components needed in a multi-channel SAW filter solution results in reduced reliability, higher cost, higher power consumption and larger size of the equipment compared to the new digital filtering solution.

With the help of digital filtering a new family of products has become available. The digital filtering concept requires only one down and up conversion per signal path, regardless of how many channels or frequency segments need to be filtered. The down converted frequency band is passed to an analogue to digital converter (ADC) which converts all RF signals in the frequency band to digital values representing the sum of all RF signals at any given time. The digital values are fed to a digital signal processor (DSP) which looks for and selects the digitized RF signals that should pass through the filter chain. The digital results of the mathematical processing are passed on to the digital to analogue converter (DAC) which reconstructs an RF waveform consisting of the RF signals that are allowed to pass the filter. The DSP has a tremendous processing power and can either pass or reject various frequency bands and even shift the frequency of passed signals. In total the DSP architecture within the new digital TETRA repeater can handle up to 16 channels. Further the DSP can attenuate different RF signals in relation to their relative signal amplitudes and acts as an equalizer and automatic level control unit. The automatic level control action (ALC) is extremely fast and makes it possible to implement squelch functions and time slot based ALC functions for the uplink path. The squelch function reduces the gain of the repeater in the uplink path for all unused time slots on each channel amplified by the repeater. This eliminates the sensitivity reduction caused by conventional repeaters that constantly transmit noise towards the base station in the uplink path. The time slot based ALC function reduces the near-far effects of conventional repeaters. A strong signal from a handheld radio near the repeater causes the ALC to reduce the uplink gain for several subsequent time slots. Another handheld radio further away from the repeater which uses a second time slot will also be affected by the gain reduction, and the call may not get through. The very fast acting ALC equalizes the signal levels between the two calls, resulting in fewer dropped calls and higher reliability of communication.

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SDR technology in combination with the most modern DSP components makes it possible to create filter functions that are the best combinations of two important filter parameters – filter selectivity and filter propagation delay. The big advantage of digital filter technology is that filter characteristics can be changed by the software without any need to change the hardware. This means that service providers are uniquely able to configure the repeater between either low delay (for example, rural areas with little radio interference) or high selectivity (for example, urban areas with large quantities of RF “noise”) filter parameters to ensure the most effective signal delivery, rather than traditionally buying separate pieces of equipment.

**New off-air TETRA repeaters solutions**

Off-air TETRA repeaters are frequently used to pick up signals from the outdoor network and radiate them into buildings. Network operators often stipulate channel selective repeaters for in-building applications. A channel selective repeater can be programmed to only pass the channels of a dedicated donor base station. This makes hand-over functions more predictable and the added traffic in the repeater coverage area is loaded onto a selected base station. In some other applications, the repeater could benefit from being able to pass several base stations into the repeater coverage area. This can be achieved by adding more channels to the repeater (8 or even 16 channels), or the repeater can be operated as a band selective unit which passes and amplifies all signals present in one or several sub bands within the licensed frequency band. It is possible to change the functionality of the repeater to all these variants with the new Digital TETRA SDR repeater by simply downloading the appropriate software version!

An on-frequency off-air repeater is programmed to pass the channels of one or several base stations with no frequency change. In the areas near the border of the repeater coverage, both direct signals from the base station and signals passing through the repeater can be received by a handheld radio. The signals through the repeater are delayed by the filtering action of the repeater, both the analogue and the digital variant. If the time difference between the direct signal from the base station and the repeater signal is over a critical value, interference between the two signals can occur. The acceptable signal delay difference is less than one quarter of a symbol length. This critical delay limit is around 14 micro seconds. In order to avoid the inter-symbol interference (ISI), the repeater should therefore have a total internal delay of less than 14 us. The new CSR438 repeater product comes with selectable filters, one optimized for lowest delay (about 11us) and one optimized for filter selectivity (delay about 14us). Both filters meet the ETSI TETRA filter selectivity requirements for TMO repeaters. The lowest delay filter can be used in areas where the overlapping coverage condition is most likely to happen. For in-building coverage applications in urban areas, the high selectivity is most useful and the overlapping zones are normally reduced to the entrance halls of the building.

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The two standard filter types supplied with the Cobham Wireless Digital TETRA SDR repeater are optimized for the present TETRA standard. As new base stations and handheld radios compliant with TETRA Enhanced Data Services (TEDS) become available, the CSR438 can be upgraded with wider filters for high speed data TEDS by simply downloading the new software to the repeater.
Off-air on-frequency repeaters need a high isolation between the donor and server antennas in a system. The antenna isolation must be at least 10dB higher than the gain of the repeater system in order to avoid oscillation or feedback in the system. The most common ways to achieve antenna isolation is to use highly directional antennas, point them in opposite directions, place them at different heights and use building structures as additional "shields" if possible. Even with these measures it is still a significant operational challenge to get good isolation at low UHF frequencies.

A concept which Cobham Wireless has pioneered and which has subsequently become very popular with GSM operators worldwide is the frequency shifting or frequency translating repeater. The concept is based on the fact that shifting the frequency of the signal passing through the repeater lowers the risk of oscillation. If the repeater attenuates the shifted output signal which couples back to the input, the repeater can be made literally oscillation safe.

The frequency shifting repeater moves the output frequency to another channel in the licensed band. This is done for both the uplink and the downlink path. However, simply shifting the output frequency does not work in GSM and TETRA systems. The base station system information which is transmitted on the Main Control Channel (MCCH) directs all handheld radios to the allocated channels. In order to make the frequency shifting concept work, the frequency shifting is done twice.

The repeater system consists of two units. The donor unit picks up the base station downlink signal and shifts the channel to another free channel in the band. This shifted "link" signal is transmitted over to the remote unit, placed near the planned coverage area. The remote unit picks up the shifted downlink signal from the donor and shifts it back to the base station channel frequency. In the repeater coverage area the handheld radios are receiving the base station channels on the correct frequencies. With its new Digital Tetra SDR Repeater Cobham Wireless is bringing this concept into the world of Tetra networks making deployments much more cost effective by reducing the number of base stations required to give a stated level of coverage. The reduced risk of oscillation allows the use of higher gain in the frequency shifting repeater. Therefore, a weaker received signal can be amplified up to full output power. A frequency shifting repeater can extend the TETRA base station coverage up to 57 km from the base station site, the distance limit in a TETRA system.

The concept, used by over 120 GSM operators and Cobham Wireless customers worldwide, is ideally suited for TETRA rural coverage applications. An existing base station with its own coverage area can also feed a frequency shifting donor unit. The donor unit can be installed at the base station site with a direct connection to the base station via RF couplers. The donor unit can also pick up the base station signals remotely over a donor antenna.

A very popular frequency shifting repeater configuration uses an opposite sector of the base station site which is selected as donor. The remote unit of the repeater system provides coverage from another sector which eliminates the problems with ISI in the overlapping zone between the base station coverage and the repeater coverage.

The frequency shifting repeater concept makes it possible to use higher gain values than what is normally usable. It is also the only TMO repeater type which can be used with an omni antenna as server antenna for coverage of an area around the repeater site. Rural coverage over large areas is now possible using a much smaller number of base stations and thus at much lower costs with the help of the new Cobham Wireless CSFT438 product!