USING SDR TO EMBED WIMAX CHANNELS WITHIN THE TETRA FRAMEWORK

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ABSTRACT

In recent years there has been a move to increase the data capabilities of TErrestrial Trunked Radio (TETRA) so as to provide secure broadband data capabilities. An initial enhancement (TETRA Enhanced Data Service, TEDS) has been agreed but there is a need to access additional spectrum. An investigation was carried out by European Telecommunications Standards Institute (ETSI) has concluded that a single standardised frequency band cannot be agreed and the concept of a tuning range for enhanced TETRA services can be deployed is gaining acceptance. In addition to needing flexibility in frequency, the enhanced TETRA services allows for more flexibility in the communication modes used so as to provide adaptability in applications. We propose that it is possible to deploy Software Defined Radio (SDR) technologies into the basestation to economically provide this level of flexibility, and to further extend the capability of TETRA services by deploying a WiMAX channel into the proposed TETRA tuning range and deliver true broadband data service while simultaneously support the original and enhanced TETRA services.

1. INTRODUCTION

TETRA is a Private Mobile Radio (PMR) standard that has been developed by the European Telecommunications Standards Institute (ETSI) for the needs of the transport, civil and emergency services [1]. TETRA, first deployed in 1997, offers capabilities equivalent to the second generation of mobile phones with voice and limited data capabilities. TETRAPOL is another PMR standard, as developed by Matra Nortel Communications. TETRA and TETRAPOL are competitors in the market of PMR in Europe, in this paper we focus on TETRA services due to it is a more recent standard than TETRAPOL. We will compare the radio characteristics between TETRA and TETRAPOL later in this paper (Table 1).

There is increased interest in delivery broadband data services over the TETRA network, for example video imagery of accident scenes. An enhanced form of TETRA (TEDS) has been agreed which can offer data rates of up to 600 kbps [2]. However successful deployment of TEDS requires additional spectrum to be allocation and this has proved to be problematic. In addition to the difficulty in agreeing a standardised spectrum allocation, enhanced TETRA supports a range of communication modes depending on individual user bandwidth and signal quality. This implies a greater complexity on the radio systems. Though the new TETRA services will offer improved capabilities, it is necessary to provide backward compatibility with existing TETRA users in the over 1000 currently deployed networks around the world [3]. The greatest challenges will be experienced by the TETRA basestations which must support new and legacy systems. SDR and specifically in the concept of flexible hardware transceiver systems, offers an economical solution to both the challenges of implementing TEDS and supporting legacy systems, and provides a development route for new TETRA services.

In this paper we will provide an overview of the spectrum requirements for enhanced TETRA services and show that a WiMAX sub-channel can be integrated into the TETRA framework for true broadband services on demand. The paper will then present the requirements for a reconfigurable SDR platform with an investigation of various radio architectures to support the proposed and legacy schemes; plus the design challenges for this experimental platform.

2. SPECTRUM AND MODULATION REQUIREMENTS

TETRA services were initially deployed in Europe in a 20 MHz band between 380 and 400 MHz as two 5 MHz bands with a 10 MHz duplex separation [1]. The majority of deployed networks operate in this band though other frequency ranges have been used for deployments in Asia and South America. To deploy the new enhanced TETRA data services additional spectrum is required to complement the existing band. An investigation by the European Telecommunications Standards Institute (ETSI) has concluded that a single standardised frequency band cannot be agreed. The Electronic Communications Committee (ECC) within European Conference of Postal and

Telecommunications Administrations (CEPT) has proposed a "tuning range" within which enhanced TETRA services can be deployed [4]. It recommends three bands within that tuning range, including the original TETRA band, as shown below (Figure 1). The tuning range requirements are further complicated as non-European deployments have used other frequencies ranges. One particularly interesting aspect is the Federal Communications Commission (FCC) proposed national public service network at 758-793 MHz [5] which would be attractive to any future TETRA-type network.

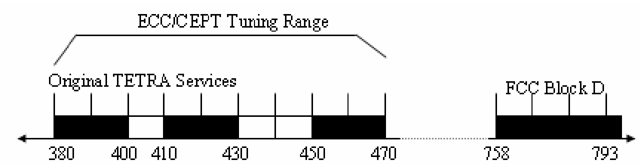

Figure 1 system tuning range

Within each 5 MHz slot, the new standard allows us to migrate from the existing 25 kHz TDMA $\pi/4$ DQPSK modulated channels to a range of other modulation schemes, (such as multi-level QAM and multi-carrier schemes, for example OFDM) and a range of signal bandwidths (25, 50, 100, 150 kHz).

From a basestation perspective, these new modes offer a number of challenges, specifically maintaining noise and linearity performance over such a range of frequencies and handling the different modes of operation. For interoperability, it is important that basestations are capable of handling any client operating in the different modes, however constructing an RF transceiver with a frequency tuning range in excess of 20% (90 MHz centred on 425 MHz) is difficulty to achieve while retaining linearity and noise performance. If the upper FCC band was to be included, the tuning range would then exceed 50%, increasing the technical challenges further. The existing 25 kHz channels allowed for a highly optimised narrowband design philosophy. The new higher-efficiency schemes are flexible in terms of their bandwidth and receiver sensitivity. To address this issue of varying bandwidths, an optimal solution would be to capture the full signal bandwidth and then undertake signal channelisation and processing in the software or digital domains, following the SDR philosophy. This would place increased emphasis on the linearity, noise performance, and adjacent channel rejection of the RF stages, but would minimise cost and offer increased flexibility.

3. COMBINING WIMAX AND TETRA

Enhanced TETRA allows for channel widths up to 150 kHz, offering users a range of data rates, up to 600 kbps. This is a significant improvement on existing TETRA services, however it does not offer data rates that would support full multimedia transmissions or rapid delivery of large files. Though TEDS has identified a maximum channel width of 150 kHz, there is nothing inherent in the TETRA framework that prevents wider channels to be used. We propose that WiMAX (IEEE 802.16e) offers features that are highly suited to TETRA-type applications such as quality-of-service guarantees and scalable OFDM access. The WiMAX standards allows for 1.25 MHz channel [6] which would allow up to three 1.25 MHz WiMAX channel to be deployed with the remaining spectrum then used to support voice and data services whether using TETRA or TEDS, thus maintaining legacy support (Figure 2).

The key advantage to using the WiMAX standard is scalable OFDM access schemes (OFDMA) where users are dynamically allocated bandwidth as needed for their application, according to their quality of service metric and allow users to obtain bursts of data throughput of up to 6 Mbps when needed. WiMAX presents low cost of delivery of higher data rates over large geographical areas and also perform very well in mobile conditions. With WiMAX's enhanced channel efficiency of up to 5 bits/hertz, creator number of users plus applications can be supplied.

The use of high data rate OFDMA modulations brings into challenging requirements for the transmitter in terms of spectral quality and Error Vector Magnitude (EVM). Also the receiver faces some difficulties. The high EVM required is difficult to attain because it demands a high Signal-to-Noise Ratio (SNR) from the Low Noise Amplifier (LNA), about 35 dB. Other challenges are that the receiver must exhibit low power consumption, high bandwidth and high dynamic range. [7]

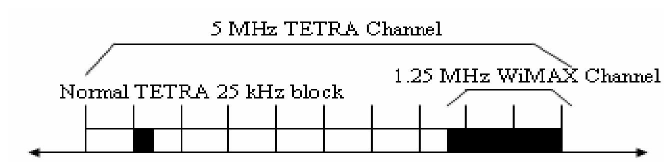

Figure 2 5 MHz TETRA channel

If basestations are to be designed using full channel capture and channelisation in the digital domain, implementing this WiMAX sub-channel requires only a small modification of the software implementation of the physical layer and then subsequently a separate WiMAX stack.

4. SOFTWARE DEFINED RADIO PLATFORM REQUIREMENTS

TEDS requires an infrastructure that can support a tuning range and a wide range of modulation schemes of varying bandwidth. In addition to the identified TEDS frequencies, a range of other frequencies are also likely to be needed to be supported, such as 700-800 MHz. As volumes of TETRA basestations are relatively small, a common platform would be of economic benefit and also allow for improved interoperability of mobile devices. This combination makes a compelling case for use of a software defined radio approach. As TEDS uses similar modulation schemes though at different operating frequencies and channel bandwidths, the challenges for a SDR platform are focused on the RF stages rather than the software framework. Specifically there are demanding receiver requirements on signal sensitivity, adjacent channel rejection, and linearity. These issues were manageable when dealing with narrowband signals at a specific frequency but become much more challenging when dealing with a wide tuning range. One particular issue is the problem of the transceiver filter which must be wideband or reconfigurable in some way. This will limit our ability to minimize adjacent channel interference. To address the issue of varying sub-channel widths, it will be necessary to undertake full channel capture and subsequently digitally undertake channelisation, filtering and de-modulation. If this approach is taken minimizing wideband noise contributions from the electronics and adjacent channels becomes particularly important.

To develop a new system suits our proposal, the main radio characteristics of the TETRA, TEDS, TETRAPOL and WiMAX standards are studied as follow:

	TETRA	**TEDS**	**TETRA POL**	**Mobile WiMAX**
Frequency (MHz)	380-410	350-470	80/380/ 450	410-470, 758-793
Spectrum Allocation	Two 5 MHz bands	additional 5 MHz bands	similar to TETRA	similar to TETRA
Duplex Spacing (MHz)	10	10	similar to TETRA	similar to TETRA
Channel BW (kHz)	25	25-150	<8	1250
Channel Spacing (kHz)	25	matches channel spacing	10/12.5	50-100
Access Scheme	TDMA FDMA	TDMA FDMA	FDMA	SOFDMA
Modulation	π/4 DQPSK	π/4, π/8 DQPSK up to 64 QAM	GMSK	QPSK, up to 64 QAM
Tx Power (dBm)	28 to 46	similar to TETRA	42	similar to TETRA
Rx Sensitivity (dBm)	-103 to -106	similar to TETRA	-113 to -111	-90.8
Efficiency (bits/Hz)	1.4	<3.5	similar to TETRA	3-4

Table 1 Compare radio characteristics of TETRA, TEDS, TETRAPOL and WiMAX

RF specifications of the physical layer are also studied. However, TETRA and WiMAX are two different standards, the terminologies of the system specifications are described quite differently (TETRA is an ETSI standard, WiMAX is an IEEE standard). Firstly, we list all the specifications with different modulation schemes and also with different bandwidth, comparing among TETRA BS/MS (basestation / mobilestation), TEDS BS/MS, TETRAPOL BS/MS and mobile WiMAX BS/MS. To compromise that, we reduced our table to TETRA 25 kHz π/4QPSK vs TETRA 25 kHz 16QAM vs WiMAX 802.16-2005 1.25 MHz 16QAM for basestation as follow:

	TETRA 25 kHz π/4QPSK	**TETRA 25 kHz 16QAM**	**WiMAX 802.16-2005 1.25 MHz 16QAM**
Signal Dynamic Sensitivity (dBm)	-106	-106	-91
Signal Dynamic Sensitivity (dBm / Hz)	-150	-150	-152
Signal Static Sensitivity (dBm)	-115	-109	
SNR/CNR @ BER = 1e-4 (dB)	15	20	24
NF (dB)	10	10	7 (MS), 4(BS)
C/Ic (dB)	19	19	24
Linearity IIP2 (dBm)	37	37	21
Linearity IIP3 (dBm)	-5	-5	-13
ACPR (dBc)	-60 @ 25 kHz offset -70 @ 50 kHz offset -70 @ 75 kHz offset	-55 @ 25 kHz offset -65 @ 50 kHz offset -67 @ 75 kHz offset	-80
Tx Dynamic Range (dB)	80	80	50
EVM (%)		<3 / < 1	<=3

Table 2 Compare RF specifications of TETRA and WiMAX

To explore the viability of this approach, a low-cost demonstrator is going to be developed according to an initial suggestion for an integrated wideband transceiver as shown below (Table 3) that can offer the necessary tuning range and channel capture. It is challenging to produce common specs as different standards and modulation schemes are involved in each channel. Linearity and dynamic range are key transceiver criteria.

	Combined TETRA, TEDS, TETRAPOL and WiMAX
Receiver	
Signal Sensitivity (dBm)	-106
Signal Sensitivity (dBm / Hz)	-152
Maximum Acceptable Signal (dBm)	-30
SNR/CNR @ BER = 1e-4 (dB)	24
NF (dB)	7 (MS), 4(BS)
Linearity IIP2 (dBm)	37
Linearity IIP3 (dBm)	-13
ACPR (dBc)	-70 @ 75 kHz offset
Transmitter	
Tx Power (dBm)	42
Tx Dynamic Range (dB)	80
EVM (%)	<3

Table 3 Combined system specs for transceiver

One of the challenges of designing a combined communication systems is that it must remain compatible with legacy TETRA services. This is particularly challenging as the TETRA specifications were designed for very narrowband 25 kHz channels, specifically the figures on linearity and sensitivity. High sensitivity is needed as TETRA basestations are not typically as densely populated as comparable mobile telephony systems. Complicating the matter is the needs for TETRA clients to be capable of sustaining high receive power levels when close to such basestations [8]. The basis of our analysis was the need to be compatible with legacy systems but accepting that some compromises would be needed on adjacent channel specifications as the legacy values are not appropriate to our wideband solution. As we are focussed on basestation radios, we are also assuming that receive power levels can be assumed to be low.

5. CANDICATE RADIO ARCHITECTURES

For our investigation of the combined radio system, we propose to adapt an existing SDR platform developed for mobile communications, operating in the frequency range 1.8 to 2.4 GHz (Figure 3). This platform functions, sub-optimally, in the range 380-480 MHz and requires further work to meet linearity and noise requirements. The main issues that need to be addressed are attenuation induce due to matching networks; oscillator performance, and linearity. This platform works with the software framework developed within the Centre of Telecommunications Value Chain Research and is being integrated with the OSSIE framework developed by Virginia Tech.

This platform will let us investigate various radio architectures that are amenable to the TETRA-WiMAX system. Our two candidate architectures are a homodyne (direct-to-RF) transmitter and receiver, or a homodyne

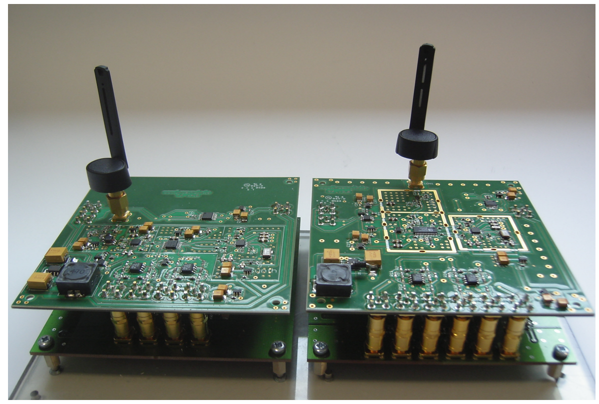

Figure 3 Low cost experimental SDR system from IMWS NUIM

transmitter with a heterodyne receiver. With the development of modern transmitters, the direct-to-RF transmit path is an increasingly mature technology and with new developments in wideband mixers and PAs, achieving the needed reconfigurability will be relatively straightforward. For the receiver, the challenges are more difficult. In any implementation there will be a strenuous sensitivity and linearity requirement. This will be complicated by reasonability large tuning range. While our SDR platform is currently configured to support a direct-from-RF architecture, this approach faces challenges in terms of linearity, noise and DC offset cancellation. An alternative approach, which we prefer, is to use a more traditional two-stage approach with a low frequency IF stage. This offers advantages for our design in that we have a fixed 5 MHz low IF slot with a flexible RF frequency. The RF stage can then be optimised for tuning, linearity and noise, while the IF stage can use fixed filters to achieve the needed adjacent channel rejection. The following table lists some of the advantages and disadvantages for the two approaches for the receiver stage:

	Direct	Low-IF
Adv	• Fewer components • simple frequency plan for multistnadard, • high integratability, no image problem	• more reliable performance • flexible frequency plan • no DC offset • no 1/f noise issues • high blocker and interferer rejection • improved tunability
Dis	• LO leakage and DC offset issue • 1/f noise • Vulnerability to blocker and ACPR issues • More challenging RF filters	• More components • Potentially more power • IF bandwidth typically fixed

Table 4 Summary of Tx/Rx architectures suitable for our system

6. CONCLUSION

In this paper, we propose to show how a WiMAX sub-channel can be integrated into a TETRA channel with minimal effort when a software-defined-radio philosophy is followed. This merger of technologies will enable TETRA users to avail of data rates beyond what is proposed by the current proposals with minimal additional cost for either the user or the basestation provider.

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