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APWPT presents 'Creative Spectrum Concept' at European Microwave Week 2013 Nuremberg, Germany

Nuremberg, 11th October 2013 - The Association of Professional Wireless Production Technologies (APWPT) presents a new approach to event spectrum management at a workshop to be held during European Microwave Week, being staged in Nuremberg 6-11 October, 2013. Recognising the increasing and competing spectrum requirements for new and established wireless services, this new visionary concept tackles the issues head on and looks to open up a discussion on the political and technical issues involved.

With wireless audio devices - such as wireless microphones, in-ear monitor systems, security related wireless services and wireless cameras, collectively referred to as PMSE - being at the very heart of modern event production, this new concept seeks to explore a more holistic approach to how spectrum could be allocated and managed at large events in the future. With these large events frequently being broadcast globally, this potential new approach questions the current secondary user status of PMSE. It asks, given the importance of interference free PMSE operations, whether PMSE should be granted primary or co-primary status in certain frequency bands for the benefit of all stakeholders and citizens - be they content producers or content consumers.

The concept also recognises that there are a number of outstanding points that require much further discussion. These include, optimising frequency coordination at events, optimisation of spectrum use during events and how to ensure optimal reliability of all PMSE wireless links. These and further topics of discussion will be covered in detail at the workshop.

Get further information in the attached Vision paper on “Unified PMSE”. This proposal has been designed by Prof. Dr.-Ing. Georg Fischer, Lehrstuhl für Technische Elektronik, University of Erlangen-Nuremberg (FAU), Germany.

About the APWPT

APWPT is an international non-profit organisation, which is representing the needs of all users of the Programme Making & Special Event ("PMSE") sector.

Members of APWPT include PMSE organisations, users and manufacturers. The APWPT directly and indirectly represents far over 25,000 members of the PMSE community in Europe and beyond. PMSE is crucial on a daily basis for the production of content that has received world-wide acclaim and continues to attract a global audience. A vast array of organisations are reliant on radio spectrum for the production of content for Performing Arts, Broadcasting, News Gathering, Independent Film and TV Production, Corporate Events, Concerts, Night Venues, Sports Events, Churches, etc. In addition, other sectors that utilise the current UHF spectrum include the Health Service, Education, Local Government, Political Programming and Conferencing.

For more information about the goals and achievements of the APWPT please visit our website at www.apwpt.org or contact us at

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Vision paper and proposal on

Unified PMSE

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1 Analysis of actual Situation

PMSE today mostly is a secondary service operating in unused TV channels of TV broadcast spectrum. Due to the transition from analogue to digital TV transmission, TV spectrum has been reduced. The possibility to downsize TV spectrum as a consequence to less spectrum demand for digital versus analogue transmission resulting from digital video compression is seen as a reward of digitization, also called “Digital Dividend”. A similar downsizing of necessary spectrum can also be observed with broadcast radio when transitioning from analogue FM radio to digital DAB.

As the spectrum for broadcast is more and more reduced, as a consequence the spectrum for PMSE is also reduced. The spectrum being freed up is given to cellular communication.

The first digital dividend from 790 to 862 MHz has already been lost for PMSE. A second digital dividend from 694 to 790 MHz is currently under discussion. If this happens, it would again lead to a massive loss of spectrum for PMSE operations. Furthermore, there are also considerations to implement a PSS Public Safety and Security radio system in UHF.

Starting from today’s secondary use of broadcast spectrum with PMSE, the present and future Digital Dividend in the UHF spectrum could result in loosing half of the present PMSE spectrum. This is contrary to the trend of increasing spectrum demand for PMSE as productions get more and more advanced and there is also the demand for HD High Definition Audio equivalent to the already installed 24 to 36 bit studio quality. Furthermore Surround Sound productions like Dolby 5.1 also imply more and more wireless links. e.g. DAB+ Bitexpress Campus radio by Fraunhofer IIS and Chair LIKE in Erlangen who are actually running a Dolby surround distribution system. Others broadcasters will follow. Content for such distribution needs to be produced. An appropriate PMSE technology for such productions must be supported by a sufficient quantity of interference free spectrum.

There are prognoses that in future the whole frequency range from 400 to 3000 MHz will all be directed to cellular communication. Potential replacement spectrum stated today like e.g. the L-Band therefore in the future could also be assigned to cellular mobile communication.

With the advent of WSD (White Space Devices) also wanting to use white spaces of UHF spectrum, a further challenge arises: How can a high quality production be ensured as WSD are difficult to coordinate with PMSE applications? Geolocation databases are not a must for every WSD. Also the business Case for coordination databases is far from clear.

Furthermore regulators are assuming a massive growth of M2M Machine to Machine communication in the order of 30.000 units per square km. Such an estimated high density of

WSD devices will make it difficult to achieve a low interference level for high quality PMSE links.

It can be stated that because of the above reasons, the historical situation for PMSE being a secondary service will no longer support high quality wireless productions and will not be able to keep track with the growing PMSE demands. Therefore it can be concluded that the loss of free broadcast spectrum is a major problem with PMSE.

Traffic growth in PMSE happens as in cellular as a consequence of microelectronic integration described by Moore's law offering new possibilities for ever enriched and ever immersive production. [1] talks about "Edholm's law of bandwidth", which states that the data rates in communications are growing by the same rate as Moore's law of microelectronics – doubling every two years. A CISCO report states that data volume is growing twice as fast as Moore' and Edholm's law with a doubling per year.

There is no reason why to assume that communication rates and data volumes should not grow at the same rate for PMSE as for cellular or fixed line. Starting from this fact it is obvious that PMSE applications will run into severe spectrum shortages in the future.

The only solution to the problem is to achieve primary or co-primary [2] status for PMSE applications in regulation. However, today PMSE spectrum is very fragmented. This situation is a consequence of the historic development of PMSE applications and regulations. But now it is time to revisit the status and honour the socioeconomic relevance of PMSE as depicted in [2], [3] and [4].

There is a huge variety of PMSE applications and a nearly infinite number of mixtures of different PMSE applications, not using just one area of spectrum and talking with one voice in standardisation and regulation. PMSE includes a huge span of applications like Audio, Video, Intercom, Effect control and safety. Each application uses a certain individual piece of spectrum.

The cultural and creative sector (CCS) today is composed out of 80% small and micro-sized enterprises. A setting of large cultural entities would be opposite to the typical ambition of the CCS to be independent and uncontrolled. Having only a few large cultural entities would be a big loss for CCS and would significantly reduce diversification and cultural broadness.

Also, events by the CCS are typically nomadic and teams are composed on project basis. This makes it difficult to have one entity to stand up and articulate the PMSE needs by the CCS.

APWPT tries to act as a voice for the PMSE needs of the CCS, but of course does not claim to reflect the complete width of CCS.

A common spectrum pool does not exist for "creative spectrum" supporting all PMSE applications.

2 Specialities of PMSE Applications

As PMSE is used during production of media that is distributed instantaneously (live or later there exists a high quality requirement. Of course, the raw media material captured during production has to be at least of the highest quality level in order that it can be used later for distribution. However, in reality it is of even higher quality, like studio quality, to allow for sound processing in mixing consoles. The raw media material from production typically is archived, so that it can be revisited and re-mastered. e.g. some Beatles songs were produced many years later in enhanced stereo.

There has to be some margin of the raw material compared to all quality derivations to allow for conditioning the raw material with distribution for the purpose of “sound composition”.

Audio studio quality is minimum equivalent to 24 bit and 192 kSa/s. A CD already is a downscaled version in terms of 16 bit 44.1 kSa/s. Orchestra source dynamics can exceed 100 dB, which is already larger than 96 dB, typical to what a CD supports in a best case scenario. Although a typical audience may not sense such a high dynamic range, raw material must be captured with higher dynamic to arrange spatial sound and compose the sound within mixing.

Aside from bandwidth, sampling rate and dynamic range, there exists a very demanding requirement in terms of ultra-low latency with wireless PMSE. Considering a drummer using a wireless microphone and a wireless in ear monitor for hearing back the mixed monitor signal from the mixing console, round trip (Two-Way) delay should not exceed 5 ms as otherwise the drummer will get irritated. This delay is audible to him or her. The case with PMSE is very different from other communication systems, as the information source and sink are co-located. Above round trip delay requirements can be interpreted as allowing maximum 2 ms per wireless PMSE link and 1 ms in the mixing console. On the opposite in mobile communications a latency of 200 ms One-Way is still tolerated.

However, as stated earlier, PMSE applications also include effect control. In certain scenarios effect control (telecommand / remote control) even demands less than 1 ms latency.

When multimedia is to be produced, also audio, video and effect control have to be kept in sync. Latency variations result in severe irritations. With a drummer, video and audio must be kept in snyc with less than 10 ms, a news speaker requires sync of lips and audio with less than 50 ms. For comparison round trip delay at IP level (ping command) inside LTE cellular networks at best is 15 ms, a normal phone call can have up to 400 ms in roundtrip. In order to avoid the irritation induced by that, every telephone system uses an echo canceller. With music echo cancellers are not an option as the artist has to sense the mixed sound.

What can also be very irritating is when the latency is not constant. e.g. the scheduler in a wireless communication system often is commanded to act opportunisticly to schedule data transmission only when the channel condition is good, which of course will lead to severe latency variations. When doing multi-channel Audio processing e.g. to capture surround sound, the latency in all channels has to be aligned down to the ms range as otherwise there will be acoustic holes and there will be perceptual irritations with regards to the location of the audio source.

Another largely unknown aspect with PMSE is its highest demand for availability. Drop-outs cannot be accepted as most productions cannot be repeated. In addition, interruptions can cause problems in the final mixed spatial sound. Productions are unique events. They cannot be repeated. This is different from internet browsing via cellular, where simple reload of data can be done when a wireless link drops. Therefore highest availability of the wireless link is required with PMSE. This is known as a 100% duty cycle.

3 Expectations on Digitization of PMSE Services

There is a big push to transition from analogue to digital PMSE with audio applications. The expectation is that digitization will allow for a saving of spectrum. Surprisingly this is not the case in PMSE compared to the case with terrestrial TV when transitioning from analogue TV to digital DVB-T. The reason is that most of the gains with digital TV come from video compression and not from the switchover from analogue to digital transmission. An analogue transmission like SSB (Single Sideband) transmission can get 0 dB close to the theoretical maximum spectral efficiency given by the Shannon bound. In conclusion it can be said, that the gains from digitization mainly come from data compression (source coding) and not from the transmission scheme whether analogue or digital.

Furthermore aside of gains drawn from compression (source coding) with digitization, there is a price to pay for digitization like signalling and synchronization. This can be considered as an overhead which could even lead to increased spectrum demand. Signalling overhead (Resource management and Synchronisation) has to be outweighed by the gains from compression. Therefore, in essence, digitization only pays off if more spectrum saving is drawn from compression than extra spectrum has to be spent for signalling and synchronisation.

But this directly implies that digitization (from the perspective of the radio spectrum savings) is only attractive with higher compression factors. In this context it should not be forgotten that analogue wireless microphones already comprise of a compander system which is roughly equivalent to a 2:1 compression. Therefore for digitization to become attractive compression factors beyond roughly 3:1 are needed.

Aside of spectrum implications with digitization, there is also the effect that digital allows for a more stable production quality. In analogue systems audio quality follows RF quality, whereas in digital systems quality is high as long as the radio link quality is above a certain threshold. Falling below this threshold will immediately lead to a drop out. Therefore it is a must for digital links to keep interference low, as otherwise a total drop-out could result. In analogue systems interference will lead to strong background noise. Both are unacceptable.

Another expectation of digital wireless microphones is that digital transmission is more robust and less susceptible to fading than analogue. This is only true if wide interleaving and channel coding is used. But interleaving and channel coding means that the data to be transmitted is spread in time, thus diversity in time domain is explored. So interleaving as a means of increasing robustness of transmission comes at the price of increased latency which is not acceptable for most PMSE applications. In this context it should also be discussed, that the theoretical Shannon bound for wireless transmission assumes infinite interleaving which would mean infinite latency. It can be concluded therefore that there is a trade-off between interleaving thus robustness versus latency. Findings with other wireless communication systems can therefore not be transferred one-to-one to PMSE.

As compression and not the transmission scheme itself (digital modulation and coding) is crucial for the benefits from digitization, the question is about compression schemes. Therefore it has to be asked: How much compression can be achieved while still meeting the high quality demands of PMSE?

4 Compression, a means for overcoming spectrum shortage?

As less spectrum is available for PMSE, higher interference risks arise and PMSE has demand for further growth, the question is: What is the right strategy, to cope with the situation? As discussed above, digitization only makes sense and relaxes the spectrum situation if sufficiently high compression factors can be achieved. As compression is always associated with some information loss, in the early implementations of digital microphones, only uncompressed audio was transmitted thereby standing behind analogue microphones, that already used the compander technique being equivalent to 2:1 (or slightly above) compression. Digital microphones in the beginning needed even more spectrum than analogue.

Audio codecs like video codecs can be classified in different ways. There are the lossy codecs like mp3, where benefits from psycho-acoustic effects can be drawn. High compression factors like 25:1 are obtainable. However, using lossy codecs during production is problematic, as a high quality derivate cannot be created for distribution. Also, if the distribution is using a further codec, then artefacts will arise due to operation of two codecs in series. As a consequence using lossy codecs during production to obtain high compression factors that help on saving spectrum is not an option.

The next class of codecs are the “near lossless codecs”. They are almost reversible. The information that is lost is limited. Also using a near lossless codec in production can be combined with another codec in distribution. Due to near perfect reconstruction, strong artefacts will not arise.

The amount of compression depends on the signal source’s level of detail. So if the audio or video signal is rich in detail then there is less possibility to compress. If the level of detail is low, high compression is obtainable. This means that the data rate at the output of the source coder is a consequence of the level of detail in the information source. Therefore, we have to conclude that a codec that targets high quality and high compression at the same time will always be a variable rate codec.

As with low latency constraints in PMSE a buffer cannot be used to smooth the data rate variations, the data rate of the wireless transmission scheme would have to handle a variable rate or be sized for the maximum peak data rate. However sizing the digital transmission scheme for the peak rate produced by the source coder would not deliver the savings in terms of spectrum consumption.

As a consequence we have to state that we need a physical layer digital transmission scheme that is optimized for variable rate codecs. This statement applies in the same way for audio as it does for video, effect control and safety.

5 Applications with Production

Let us now discuss the broad span of PMSE applications.

5.1 Audio

The first class of applications are audio related. These according to ITU definitions include for example:

- Mobile audio link
- Portable audio link
- Radio microphone

- In-ear monitor
- Talk-back, intercom
- Temporary point-to-point audio link

The dynamic range and latency requirements differ somewhat between various applications in this class, thereby providing a certain degree of freedom when handling several services at the same time. e.g. with a large show like ESC (European Song Contest) hundreds of Audio links may be on air.

Due to raising interest in surround sound and HD High Definition audio and studio quality production there is increasing demand for more and more advanced wireless audio links leading to increased spectrum demand.

5.2 Video

Video applications include also a large span of applications, either for capturing an event or for organizing certain routines in performance.

More and more cameras are connected wirelessly to generate an immersive impression with the spectators. Today cameras often are operated in 2-3 GHz band. However, this band also gets more and more crowded and may be assigned to cellular in future. Sufficient protection cannot be achieved as the spectrum licenses, as they are secondary, don't give sufficient quality guarantees.

In video there is also a trend towards 3D TV and HD Video also leading to traffic growth and thus an increased spectrum demand.

5.3 Effect Control

This class of applications is called "Telecommand / remote control" according to the ITU regulations. It includes effects like controlling large LED displays, switching on/off fog machines, lasers, motors, moving lifting ramps, fire and so on. There is increasing interest in making events more and more immersive, thus implementing more and more effects that again lead to traffic growth with these kinds of PMSE applications.

5.4 Safety

A new class of applications is arising, which is related to job safety. It is called "Worker protection communication". This may include Audio, Video, Machine control and others.

Systems in use so far sometimes use 2.4 GHz ISM band, which is questionable, as ISM band operation does not allow for quality guarantees. This is dangerous with safety applications.

Again, here traffic is increasing over time given more stringent safety rulings and more advanced performance shows (Stunts, Action Play).

6 Proposal for a more efficient spectrum use

6.1 Rationale

With above chapters it has been shown that there is a large span of applications which are all related to the Cultural and Creative Sector (CCS). Today, each PMSE application follows a different spectrum and transmission strategy. To overcome the fragmentation in PMSE as stated in the analysis of the actual situation, it would make a lot of sense to align strategies and work towards one unified Creative Spectrum of primary or co-primary status, whereby a producer decides how that block of spectrum is divided between the various PMSE applications.

A primary or co-primary status with Creative Spectrum will ensure the availability of PMSE as a high quality production tool in the value creation chain of the Cultural and Creative Sector. Primary or Co-primary status is a prerequisite for the Unified PMSE proposal presented here.

6.2 Technical Approach

As stated in chapter 4 “Compression, a means for overcoming spectrum shortage?” providing high compression and high quality PMSE services, always forces the use of near lossless variable rate codecs for audio and video. In order to draw spectrum gains, the spectrum consumption also has to become variable requiring a physical layer transmission scheme that can quickly react to varying data rates. Buffering would not be an option due to the very stringent latency constraints. Furthermore, buffering variable rate streams would result in latency variation loosing sync between several audio channels and between audio and video. Therefore, the capacity of the digital transmission scheme has to follow the varying data rate generated by the multiple codecs.

However, on the other side it is very unlikely that all codecs, for all audio and video channels, produce their peak rate at the same time. Due to the central limit theorem, there will be a smoothing of the data rate sum of all codecs. The more variable data streams are summed up, the smoother the sum gets. So the variation of the sum becomes less, the more wireless links are handled simultaneously. This implies that it is most beneficial if all applications share one spectrum – the creative spectrum - the number of streams gets larger. Information theory wise the smaller variation obtained is called statistical multiplexing gain.

We can conclude managing all wireless PMSE applications in one shared “Creative Spectrum” provides the highest statistical multiplexing gain.

6.3 Advantages

What are the benefits from such an approach of a shared „Creative Spectrum“?

- Statistical multiplexing will be explored providing very high gains in terms of spectrum savings with the long term PMSE traffic growth going on.
- The use of variable rate codes will allow for high compression factors and at the same time high quality
- The fast adaption of transmission capacity will meet the low latency requirements by PMSE
- Audio and video links will be kept in sync increasing quality of production
- Exploring statistical multiplexing gain will lead to highly efficient spectrum usage thus providing a solid basis for justifying primary or co-primary status.

6.4 Prerequisites

The approach of one block of creative spectrum being explored highly efficiently through statistical multiplexing gain has certain prerequisites that are listed in the following:

- The spectrum fragments actually being used or cleared in future for PMSE must be bundled as one spectrum managed by one radio resource management. In other communication systems this is called inter band carrier aggregation.

- A new transmission scheme and thus physical layer is needed that is scalable from small to large events and allows for a broad span and mix of data rates from very low rate services like on/off effect control up to HD video.
- The radio resource manager of the new physical layer has to be able to assign and release radio resources very fast in a ms regime. Very fast signalling is necessary. Such a scheme is not available today. Research in this area is therefore needed.

7 New Technical System concept

In the following, a new system concept proposal is sketched. This concept must be scalable to support the range from small to large events. Furthermore, it must be able to handle a diverse mix of PMSE applications with variable rate to explore statistical multiplexing gain.

7.1 Overview

Each event must have a central radio resource management that assigns and releases radio resources to PMSE applications, which may be video, audio, effect control or safety related, highly dynamically in the order of a ms regime. The radio resource management thereby explores spectrum which may be fragmented and have specific individual characteristics.

Devices like portable microphones, in-ear monitors, talk back systems and cameras have to be able to aggregate spectrum, which may be spread around i.e. be fragmented.

7.2 Requirements for a new PHY

The requirements on a new physical layer that is suited to explore statistical multiplexing gain with multiple data streams of variable rate are challenging. It must be able to quickly follow fast changes of source coder output rate. That requires fast signalling in both up and downlink.

For comparison, radio blocks in GSM have 20 ms, in UMTS there are 15 slots in 10 ms and in LTE the minimum resource to be scheduled is a 1 ms subframe. However schedulers in cellular networks don't react that fast today. They are optimized for fairness between users and throughput, not for fastest reaction. Therefore a specific development for PMSE is necessary.

What furthermore is required from a new PHY is to be efficient in terms of signalling overhead whether low rate or high rate applications are operated. This might be the case if a simple remote on/off effect control is combined with HD video.

A new PHY must also be able to aggregate spectrum in different bands if a high data rate peak is to be supported. So essentially intra and inter band carrier aggregation is to be supported. Inter band carrier aggregation would require simultaneous operation in different RF bands which will add complexity. Further study is needed as to whether Inter band CA can be made optional to keep costs down. However, thanks to Moore's law, RF sampling, tuneable antennas and tuneable band-pass transceiver architectures get more and more cost attractive.

7.3 Scalability

In order to support small and large events, there must be a possibility to operate a wireless link without a central instance like the radio resource manager. This is called "direct mode" or "ad hoc mode" in communications.

8 Relation to actual Cognitive PMSE activities

This proposal for Unified Spectrum can be seen somehow as a further evolution of actual activities on cognitive PMSE. With C-PMSE radio resources are assigned and released based on interference conditions and changes in a geolocation map. This may be done at a day, or an hour scale or maybe down to a minute scale. With the proposal above assignment and release of radio resource will become much more dynamic, possibly in a scale of milliseconds.

9 The future of PMSE – immersive perception

It is time to develop a vision for PMSE, where it should evolve to in future. Formulating visions help in streamlining research and providing arguments for necessary decisions at development, regulation and standardization and production,that have to be made at a time far ahead of commercialisation.

What is the future of PMSE and what could it be? A fully immersive production. An immersive telepresence for the spectator, audience or the end consumer, who is fully engaged with the event or performance. The atmosphere of an event or performance is transported wirelessly, whereby the "atmosphere" is a complex artistic composition out of audio, video and effect control. The "presence" of an artist is transported wirelessly.

The end consumer with distribution (audience, listener and spectator) feels she/he is at the location of the production. His/her experience will become similar to being present in person at an event. Imagine something like "Holodeck" in Star Trek.

In order to achieve such an immersive perception for the end consumer, all PMSE applications have to play together, which would be supported by the approach of one block of Creative Spectrum.

10 Summary

This vision paper has sketched a paradigm shift in PMSE spectrum usage. It proposes to handle all kinds of PMSE applications in one block of shared spectrum, called the "Creative Spectrum", which may be fragmented.

In order to meet the high quality objectives, usage of variable rate source coders for audio and video is proposed. This demands a new physical layer for PMSE applications that is able to schedule radio resources highly dynamically.

The benefit will be exploration of statistical multiplexing gain that will be key in coping with the increasing demands in PMSE traffic.

11 Proposed Actions

In order to make the above vision real, consultation between the various parties involved in PMSE manufacturing, operation, regulation and standardization is needed. A workshopshould be held,where the above proposal is presented and discussed. This could serve us in going forward.

Activities in the area of Audio, Video, Effect and Safety PMSE applications need to be merged. The different PMSE communities need to join forces and talk with one voice.

Basic research on quantifying the potential gains by statistical Multiplexing of multiple Audio, video, effect and safety related data streams needs to be conducted. This could e.g. be managed by the Science Section of APWPT.

Research and development activities on a new physical layer that provides very low latency and can highly dynamically adapt to variable rate source codecs is needed.

Developments in the area of frequency agile radio hardware are needed, whereby agility in terms of instantaneous bandwidth and centre frequency is needed.

Implementation studies need to be carried out to better understand complexity and cost implications of the above proposals.

Work in standardisation and regulation should use the obtained statistical multiplexing gain as a justification for primary or co-primary status for PMSE. Efficiency of Spectrum use will significantly be enlarged by the "Unified PMSE" Technology.

Hereby the socioeconomic benefits of the cultural and creative sector can serve as a strong argument, [3] and [4] for instance, state economic growth rates in the order of 7% per year. Unified PMSE Technology combined with an initiative for one "Creative Spectrum" will strengthen the position and overcome the weakness implied by today's fragmentation.

12 Literature

[1] Steven Cherry, EDHOLM'S LAW OF BANDWIDTH - Telecommunications data rates are as predictable as Moore's Law, IEEE Spectrum, Juli 2004, p58-60

[2] Prof. Dr.-Ing. Thomas Kürner, Prof. Dr.-Ing. Ulrich Reimers, A study of future spectrum requirements for terrestrial TV and mobile services and other radio applications in the 470-790 MHz frequency band, including an evaluation of the options for sharing frequency use from a number of socioeconomic and frequency technology perspectives, particularly in the 694-790 MHz frequency sub-band, Final report, 21. January 2013, downloadable from: http://www.bmwi.de/EN/Service/publications,did=556500.html

[3] New information on the situation of the creative industry in Germany:
- Deutscher Bühnenverein:
http://www.buehnenverein.de/de/publikationen-und-statistiken/26.html?det=353
- 50.000 performances per year showing 5000 different productions
New Meeting and Event Barometer for business meetings in Germany

[4] Meeting- & EventBarometer 2013
http://evvc.org/de/startseite/meeting-eventbarometer-2013-2.html
Germany is again worldwide Nr 1 in the staging of events.
The participants at events has risen 7.2% since 2012

13 About the author

The author is a professor for electronics engineering at University of Erlangen-Nürnberg (FAU) at the institute for Electronics Engineering (LTE). The institute is known as the birthplace of the mp3 Audio codec that later was commercialized by Fraunhofer IIS. Also the Audiolabs, a joined initiative by FAU and Fraunhofer IIS, are located in Erlangen. The Audiolabs comprise 6 professors that are engaged in Audio coding and psychoacoustics.

FAU is offering an international Master course CME on Communications and Multimedia Engineering.

The author has studied Electrical Engineering with focus on communications and RF at RWTH Aachen University. His PhD work was on a receiving system for mobile reception of satellite broadcast TV. He has an 11 years experience in the cellular industry due to working as a researcher in the area of basestation RF design and radio network planning in Bell Labs Research of Alcatel-Lucent.

Furthermore the authors has served as Chairman in ETSI SMG 2 WPB EDGE for the physical layer standardization of the GSM-EDGE system and now also acts as chairman for ETSI STF386, which deals with cognitive PMSE systems.

The Author also serves as consultant to APWPT within its science section.

Furthermore he acts as a reviewer in various EU and German national projects that deal with Small Cell deployment, Digital Dividend and dynamic spectrum management.