Four steps to understanding PMSE [*1] frequency requirements

Step one – Getting to know the application

- **Why wireless?**

  The application:

  A microphone is used to amplify people or instruments, so that they can be heard and understood over longer distances. For this, a microphone receives sound waves and converts these into electrical signals, which modulate a radio transmitter. The transmitter signal is received, following wireless transmission, by a receiver and passed on to a sound studio for processing.

  - ***Freedom of movement***

    Wireless microphones allow people speaking to combine high-quality audio transmission with freedom of movement.
  - ***Flexibility***

    Wireless microphones make it possible to hold events in almost any location.
  - ***Efficiency***

    Wireless microphones can significantly reduce installation costs.

- **Monitors**

  A sound studio provides an audio signal for the speaking person, which modulates a special monitor transmitter. The transmitter's signal is received by a small receiver worn on the body of the person speaking which is connected to their earpiece. In this way the person can monitor their work and also receive instructions from the producer or additional information (e.g. translation).

- **Infrastructure**

  It is rare for just one transmission line to be used – usually, there are a large number. The technology required for this is installed behind the stage or in separate technical rooms. It is normally not possible to install numerous antennas and cables. Therefore, multiple receivers or transmitters are combined on a small number of antennas. Example: it is not uncommon to find 50 wireless microphones and monitors on a stage. However, it would not be possible to install 50 antennas for this.

- **Equipment worn on the body**

  - ***Accepted size of mobile components***

    Equipment worn on the body must be able to be fitted in as inconspicuous a manner as possible. For many events, this equipment must be attached invisibly as far as is possible.

[*1] PMSE audio tools. Further information given in the section entitled "terminologies" at www.apwpt.org

- ***Battery operation***

  Elaborate costumes prevent access to the microphone technology installed underneath them. The chemical power supply to these must thus ensure multiple hours of operation despite the volume restrictions referred to above.

- **Types of event**
  - ***Presentations and meetings***

    Only a small number of microphone lines, and occasionally monitors, are used in a room or restricted outside area. Flexibility and low cost are emphasised in the planning. The preparation can be kept to a few hours.
  - ***Event production***

    A number of microphone lines in the double figures combined with a single- or double-digit number of monitors are used in one or a small number of rooms, a restricted outdoor area or a combination of the two. These events require careful planning. The technical planning and in particular budgeting will generally require a number of months of work beforehand.
  - ***Major events***

    For major events, the number of wireless transmission lines used often reaches three or four figures. The preparation work may take years. A current example is the 2012 Olympics in London.

- **Built-up areas**

  The types of event described above do not take place in isolation but rather need to cooperate with neighbouring radio usage. In built-up areas in particular, multiple events need to take place in parallel in relatively small areas. This requires a significant degree of coordination and impacts on event costs.

- **Professional event production needs wireless equipment**

  The companies and institutions involved which use wireless equipment to create a socially significant benefit, are largely reliant on radio technology. High availability combined with guaranteed quality, to secure live productions, can no longer be served by wire-based alternative systems. This would endanger the flexibility and cost of the value creation.

Step two – Quality requirements

Even when a large number of microphones are installed, audio transmission without drop-outs or loss of quality must be guaranteed. Wireless microphones are the first part of the production chain, i.e. if just one of many wireless microphones fails, the complete production can fail. ITU-R Report BT.2338 summarized:

"Compression in any form, including dynamic compression, is not desirable during the contribution phase as compression always means losses for the subsequent reproduction latter in the production train.
The demand is to produce loss-less audio with full dynamic range. This production material will be available in highest quality for the distribution via, TV SD/HD, CD, DVD; Blue Ray etc. and future formats can use this uncompressed, un-coded recording to be transferred to any future format.
This is the real challenge for wireless vocal, instrument and atmosphere/environment microphones. This leads to higher channel SAB/SAP bandwidth and increases spectrum demand in order to increase quality to adapt to industry needs and expand the listening experience."

- **100% audio duty cycle**
  Unlike when data is transmitted, wireless microphone systems operate with a 100% duty cycle. That means that the signal has to be transmitted at high quality without any interruptions at all times. If this does not happen there will be clearly audible dropouts which will significantly impact on the quality of the event.

- **Dynamic of the audio signal**
  A professional audio signal has a high dynamic and bandwidth. For example, an orchestra can produce a dynamic range of over 120 dB[1]. Nowadays the majority of studio installations can work with this dynamic range to the fullest extent. Wireless systems too are expected to also be able to reproduce this dynamic range. As studios' requirements for increased resolution rise, the need for transmission bandwidth and a wider spectrum also increases.

- **Interference endangers professional productions**
  A radio frequency for wireless microphones is considered to be free from interference when the planned transmission quality and range can be achieved.
  In technical terms this means that at the antenna input of the microphone receiver no interference in the channel in use exceeds a level of -115 dBm and no impermissible interference is received outside of the channel in use.
  It is for now irrelevant what the source of the interference is. Unexpected interference affects the event and can lead to a break in a live production.

[1] This refers to the source dynamic that has to be transmitted and not to the dynamic in the auditorium

- **Audio transmission in real time is a significant challenge**
  When people speaking hear the sound recorded by the microphone again after studio processing, the time delay from the original event is of vital importance. In practice, this time must not exceed a few milliseconds. A delay greater than this can prevent the person speaking being able to monitor themselves in the necessary way or have a disruptive impact on them.

- **Summary**
  It is vital, and in practice by no means trivial, to ensure the necessary production quality.

Step three – intermodulation in practice

- **Intermodulation**
  Intermodulation is a technical phenomenon which arises when there is more than one signal due to non-linearities (distortions) in the components of a transmission segment. Intermodulation means that, especially when multiple transmitters are in operation, a larger number of frequencies is required than is needed for simple audio transmission to guarantee the transmission.

- **Microphone-receiver intermodulation**
  The ever-present non-linearity of transmitters and receivers leads, with multi-channel systems, to internal intermodulation. The reception frequencies affected suffer in terms of quality or become unusable. It should be noted that even signals outside of the receiving channel, including other microphone lines, can interfere with the receiving channel. As well as microphone receivers, the possibility of interference from antenna distributors and any other components must also be taken into account.
  Frequencies and equipment must be carefully planned to exclude any foreseeable interference with reception.

- **Microphone-transmitter intermodulation**
  If microphones are operated in close proximity, the microphone transmitters will produce interference signals in addition to their intended signal – this is known as intermodulation. Microphone frequencies must be carefully planned to avoid the use of frequencies which are subject to such interference.
  Main performers often wear two transmitters on their body; this presents an especially high risk of intermodulation. This increases when performers stand close to each other during an event. The same applies at press conferences where many wireless microphones are in the same area.

- **Intermodulation in monitors**
  When multiple monitors are connected to a single antenna via a combiner, interference occurs which is related to the microphone intermodulation discussed above. Here again frequencies must be carefully planned to ensure that the frequencies which suffer from such interference are avoided.

- **Intermodulation of microphones and monitors**
  If it is necessary for a performer to wear a monitor, this will be significantly affected by the microphone transmitter which is also worn on the body. As the distance between the antennae of the microphone transmitter and of the monitor receiver is often just a few centimetres, the impact on the monitor receiver can be major. A significant protective distance must exist between the frequency of the microphone and that of the monitor. This will further reduce the number of radio frequencies which can be used.

- **A primary radio service and the secondary users, wireless microphones, share the radio spectrum**
  Microphone lines generally do not have exclusive frequencies but rather use, for example, free broadcast frequencies. In addition, these frequencies can also be occupied by other radio applications, which may include the microphone lines of a neighbouring event. When the available transmission frequencies are being determined, it therefore may well be that in terms of frequency planning certain possible frequencies are already occupied and thus cannot be used. It is always essential to adapt to the frequencies actually available at the site.

- **Summary**
  Which frequencies are actually available in a given spectrum is restricted by numerous changing factors. Thus, much more usable spectrum is required than would be expected by simply adding up the amount of transmission bandwidth used. A simple mathematical relationship between the intended number of microphones and the radio spectrum which this will require exists only when exclusive, interference-free frequencies are available.

Step four – The necessary PMSE spectrum

- **Basic methods of frequency allocation**
  - ***Guaranteed intermodulation-free frequencies – the standard situation!***
    This safe method will be the first choice of every system planner. Only when there is a shortage of frequencies will other variations of frequency planning and their disadvantages need to be considered. No generally applicable method for calculating IM [intermodulation]-free frequencies has to date been published or is known of. Rather, manufacturer-dependent and proprietary calculation methods are used.

  - ***Linear frequency distribution – almost never an option***
    The use of a linear frequency distribution pattern results in a rapid increase in intermodulation effects in the microphone channels. This interference significantly reduces quality and range. Therefore, a linear frequency distribution pattern is used only in rare cases, when it is necessary to have large numbers of lines and reduced range and quality are acceptable.

- **Estimating PMSE spectrum requirements**
  A basic rule is that as the number of microphone lines increases, the requirement for radio spectrum rises rapidly. As conditions are affected by both local factors and the type of event in question, however, no set amount of radio spectrum can be defined.

- The following organisations provide an idea of the amount of spectrum required:
  The European Telecommunications Standards Institute (ETSI) provides, in System Reference Document TR102546, a description of professional event production, the technology used and the amount of spectrum required:
  http://www.apwpt.org/downloads/tr102546v111202completecompressed.pdf

  Study by the University of Hanover on behalf of the German Federal Network Agency This study defines the minimum required amount of unoccupied, interference-free UHF frequency for daily PMSE use as being 96 MHz. This is calculated in part on the basis of spectrum measurements in central Berlin:
  http://www.apwpt.org/downloads/considerationsonthefrequencyresourceofprofessi.pdf

  CEPT Report 30
  This report finds that up to 150 MHz of UHF frequency is used for daily productions.

  Information from the UK communications regulator concerning preparations for the 2012 Olympics. Ofcom states that for the Olympics the whole of the UHF TV range from 470-862 MHz will be required:
  http://www.apwpt.org/regional-information/united-kingdom/2012/index.php

Additional information on the APWPT

Who we are?
APWPT is an international non-profit organisation, which is representing the needs of all user of the PMSE sector. Members of APWPT include PMSE organisations, users and manufacturers.

What do we do?
The PMSE sector is critical to the production of content for live entertainment of all genres. This sector extensively utilises wireless equipment such as Wireless Microphones, Wireless In-Ear Monitor Systems, Wireless Talk Back Systems and Wireless Instrument Systems.
For over sixty years wireless products have been used in the entertainment industry. In the past thirty years there have been vast improvements in production value and safety levels as a result of advances in wireless technology.

How do we do it?

The PMSE sector currently relies on the spectrum interleaved between existing TV broadcasts, to enable the use of Radio Microphones, In-Ear- Devices and other short-range wireless devices. This equipment is an essential component of the European Entertainment Industry. Due to their efficient use of spectrum, radio microphones (they do not cause harmful interference and engineers create very defined frequency plans) are hardly noticed.

Who benefits from our activities?

On a daily basis this sector is responsible 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…** In addition, other sectors that utilise the current UHF spectrum include the Health Service, Education, Local Government, Political Programming and Conferencing.

In addition, these technologies play a vital role in helping to improve security and safety levels within the Entertainment Industry and other sectors. Their benefits include improving the management of electrical safety, the reduction of noise levels, the development of safety in communications and reducing trip hazards as well as providing an essential tool for the security orientated services.

Its wireless equipment and the spectrum it operates on are crucial to the European Entertainment Industry.

Further information on our Webpage: www.apwpt.org or via mail: info@apwpt.org