As a marriage celebrant, how many watts per guest do you need for your public address (PA) system?

Summary of Findings

Imagine you walk into a store wanting to buy a public address system and the salesman asks "How many guests will you be needing to address in the open?" Imagine you reply "maybe 250" and the salesman then says "You will need a 250 watt PA system then"

This statement would be made on the rule of thumb often quoted that you will need 1 watt per person.

The findings of this paper are that this cannot be the case for 3 simple reasons.

1) It implies that the relationship between wattage and number of guests is a linear one. Double the number of guests and you double the wattage. Halve the number of guests and you halve the wattage. This is simply not true.
2) The wattage quoted is the wattage consumed by the system, not what is delivered to the speakers and thus an inefficient system may appear on the surface to be more powerful. Also many systems quote "maximum watts" or "peak watts" as a marketing ploy. The true measure of watts consumed is "watts rms" which is approximately 2/3 of watts max or watts peak.
3) Turn on a 5 watt barrel speaker and see if it can only be heard clearly by 5 people. The answer if fairly clear – more people can hear it clearly.

This paper finds that once watts rms has been correctly quoted, then the rule of thumb of 1 watt per guest is not only not linear, but is also overkill for a marriage celebrant operating in any normal outdoors environment.

Preface: the question of how many watts per guest is often asked and some rules of thumb have been quoted. No papers exist (that I could find) that were specifically written around the unique requirements of an Australian marriage celebrant.

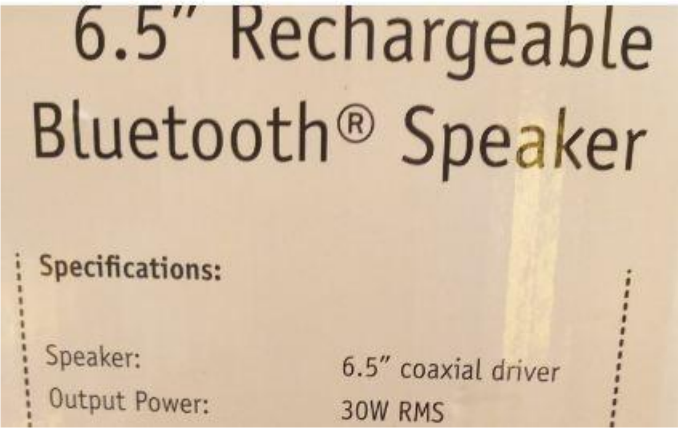
This short paper cannot provide a clear answer to this question for several reasons, the main one being that there are simply too many variables to consider. Whilst I have an engineering background, it is **not** in audio engineering and audio engineering is an extremely complex area of science requiring years of study and an equivalent level of mathematics. Thus the objective of this paper is not to provide recommendations to the celebrant that may be technically proven incorrect by a qualified audio engineer, but rather to provide some real guidelines based on my own experiential data and to make the celebrant aware of some pitfalls in simply even considering a measurement of watts per guest when considering the selection of a PA system. This paper in no way recommends purchasing any specific style of PA, it simply provides some guidelines and background information to challenge the notion of watts per guest.

Why watts per guest?

Watts is the electrical energy being consumed by a PA system. In motor vehicle terms it is the equivalent of litres of fuel consumed. To ask someone "what distance can a car travel on 50 litres of fuel?" cannot be answered if the efficiency, weight and gearing of the vehicle turning fuel into miles covered is unknown.

A quick search of some internet sites will suggest that 1 watt per guest is a good rule of thumb. Such rules of thumb ignore several basic tenets of logic. They are

- Guests do not hear watts. Watts is a measure of electrical power consumed by a PA system. Much of the power is simply turned into heat energy, in both the amplifier and the speakers, and not into sound energy. What creates the sound in the guest's head is a difference or ratio in air pressure against the background pressure, measured as a ratio of pascals of pressure. This difference is created by electrical current flowing through the speaker coil as a result of a modulated voltage provided across the speaker coil, and is a function of many variables including the positioning of the speaker relative to the listener, the speaker geometry, the speaker frequency response and the sensitivity of the speaker to the electric current flowing through the voice coil.
- Different efficiencies of the speakers will result in significant differences in the sound actually heard by any particular guest. This could vary by as much as 8dB, or almost twice as much sound pressure between an efficient and an inefficient speaker.
- Watts can be measured as power into a PA system measured as watts (peak); watts (max) or watts (rms), and only a small proportion of these watts actually make it to the speaker itself (see experiential data later in this paper). The benchmark measure of watts is watts (rms) and reflects the actual energy consumed over time. Watts peak and watts max refer to watts consumed for a very short period of time and should be ignored as they are more of a marketing tool than a reflection of how the system will perform. Technically watts (rms) is watts (peak) divided by 1.414 however as we do not listen to a pure sinusoidal tone this is not necessarily correct. A safer option is to simply halve the watts (peak) to get watts (rms). A reputable brand manufacturer or supplier should quote watts (rms).



- The measure of watts per guest suggests a linear relationship exists between the number of watts and the number of guests. Double the watts and you double the number of people who can hear the sound? No. The actual sound heard is a combination of sound intensity and sound pressure, sound intensity decreases as you move away from a speaker at a different rate than sound pressure. The maths here is very complex so I will simply state that suggesting a linear relationship (double the number of watts for double the number of guests) exists is not the basis for a good rule of thumb. Also one must note that as the power consumed is doubled, the sound pressure level is not doubled. It is not that simple.

- The speaker radiates sound in a 3 dimensional conical volume of space, with a base angle that might typically be around 90 to 100 degrees with sound decreasing outside that envelope. As the sound decreases to the sides of the envelope, the volume may still be quite acceptable to some guests.
- Guests at an outdoor wedding ceremony arrange themselves in varying patterns. A typical arrangement might be with 4 rows of chairs, 8 seats wide at the front with an aisle down the centre, with the remaining guests standing behind the chairs. The guests standing may arrange themselves into a conical shape with each row having a longer arc length than the previous row. In some outdoor settings, all guests may be seated in neat rows of 8 or 10 chairs wide. These various arrangements alone makes the suggestion of response of watts to number of guests non-linear.
- The method of measuring the sensitivity of loudspeakers is called the speaker sensitivity. It is the number of dB at 1 metre from the speaker when 1 watt of electrical power is passed through the voice coil. A typical reading might be 88dB. This is in excess of the volume a human can listen to (85dB) for a prolonged period of time without causing hearing loss. So 1 watt delivered to the voice coil makes a lot of noise at 1 metre, although of course we do not sit only 1 metre away – the closest guests to the PA at most weddings may be 3 metres away. That said pushing 1 watt through a loudspeaker voice coil still makes a very loud sound (see experiential data later in this paper).
- Remember the prime purpose for a celebrant is for the spoken word to be heard, not music. Therefore the gain of the microphone input is important. Look for 60dB gain on the mic input. There are normally 2 mic inputs for a PA although some systems have an integrated wireless mic receiver. One being an XLR (3 socket black plastic housing) and the other being a ¼" jack socket, and note some modern Pas have an integrated XLR and ¼" jack in the same fitting. If you are using both a hand held mic and a hands free mic you will require two mic inputs. That said, often a wireless mic will offer a line input voltage from the receiver where it can be plugged in to a standard line in jack. In this regard if you are not familiar with the technical side, a qualified sales person at a store front will be your best asset here in ensuring the mic set you purchase can be accommodated for both hands free and hand held microphones. Some PA systems offer 50dB gain on the mic input. Whilst this will work fine for some mics, some mics will struggle to provide an adequate volume. Why not simply wind up the volume if the watts are there? The reason is that as you wind up the volume, and if the input signal is weak, then background noise and internal distortions from the PA are also amplified giving a loud sound but a very unprofessional sound with lots of background distortions.

- Finally, and most importantly, if a nervous groom whispers into the mic, then even the best PA will not allow him to be heard properly. One of the biggest variables here is the way the person projects their voice into the microphone to generate a decent signal to the amplifier. A relaxed celebrant used to public speaking may be heard fine but a nervous groom may be a different case.

  Summary: I have identified above some reasons why I believe a linear relationship between the number of watts and the number of guests may not be a reasonable rule of thumb and could lead to a celebrant buying a much larger system than is ever going to be required.

Let us now consider what is unique about the situation for a marriage celebrant.

Audio engineers designing a speaker layout for an airport terminal may have to work to a specification that says that announcements can be heard by all visitors to the airport within a certain tight range of sound level – maybe 6dB between loudest and softest. Audio engineers designing a speaker system for an outdoor rock concert will want thousands of guests to hear very loud music with good fidelity covering a very wide frequency range. Some speakers are optimised for low frequency response, others for high frequency and mid-range for exactly that. Each speaker will consume power. Woofers are typically very inefficient with much of the wattage being dissipated as heat.

The following bullet points apply to a marriage celebrant's PA and are possibly unique to celebrants

- A marriage celebrant is not required to provide high fidelity music, only the human voice. The human voice covers a very narrow frequency range and it is a frequency range that most mid-range speakers can handle with reasonable efficiency.
- The human ear is more efficient at receiving sounds in the frequency range of the human voice than at higher frequencies that are common in high fidelity music.
- A celebrant is required to be heard clearly by the people at the back of the venue whilst not causing audible discomfort to guests near the front. The 6dB range specification that might apply to an airport PA system can be broadened to more like a 25dB range for a ceremony (50dB to 75dB).
- A celebrant will set up a PA in a wide variety of outdoor environments ranging from an enclosed area with no wind to a beach setting with "white" noise of the surf in the background and a breeze blowing towards the speaker. Please note beach weddings are a special case and will require a PA that is both easily transportable and yet very efficient. This paper does not attempt to address beach weddings.
- A celebrant in general will mount the PA on a stand just above head height of the guests. The celebrant does not have the luxury of mounting the speakers well above the guests on a solid gantry with the speakers then tilted down (ideal situation). Such an option would greatly enhance the ability of guests to hear clearly.

A useful web site at https://www.crownaudio.com/en/tools/calculators#amp_power_required does provide a means of assessing the power required from a PA system outdoors that is not too distant from the experiential data observed in the next section of this paper. Remember that we do not plan to deafen our audience with loud music and typically our audience will be within 20 to 25 metres of the bride and groom so they can see what is going on. Based on the following equation provided by crown audio on the above mentioned web site,

Equations used to calculate the data:

dBW = Lreq - Lsens + 20 * Log (D2/Dref) + HR

W = 10 to the power of (dBW / 10)

Where:

Lreq = required SPL at listener

Lsens = loudspeaker sensitivity (1W/1M)

D2 = loudspeaker-to-listener distance

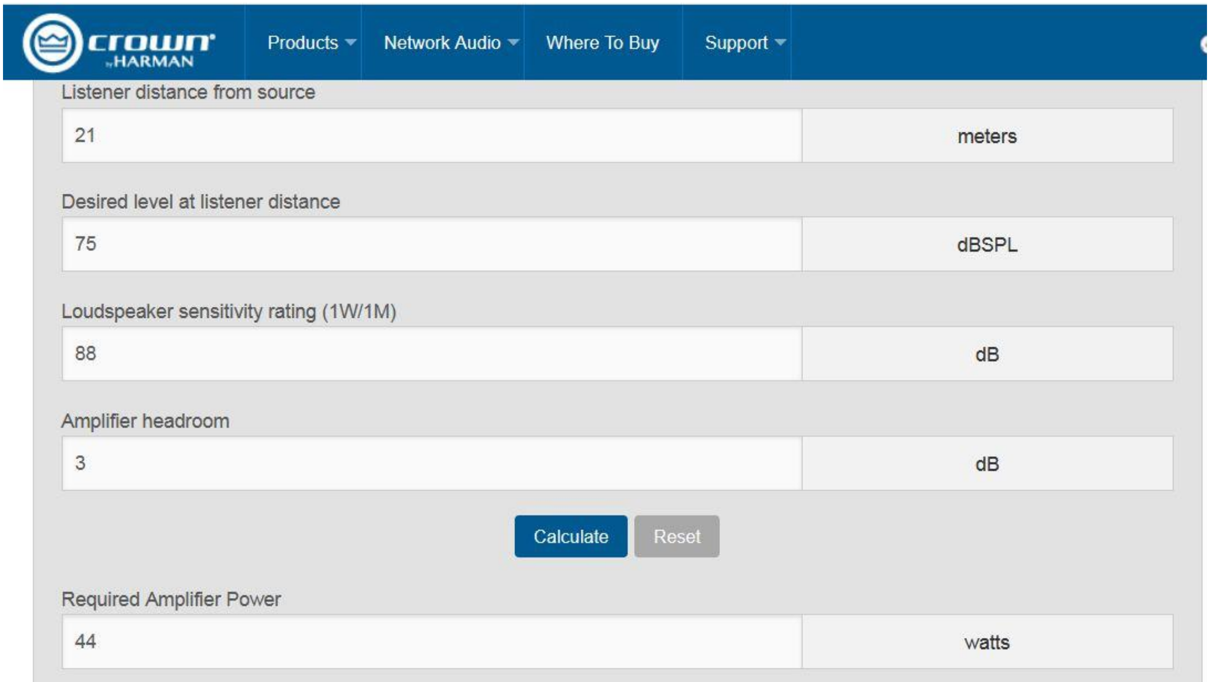
Dref = reference distance

HR = desired amplifier headroom

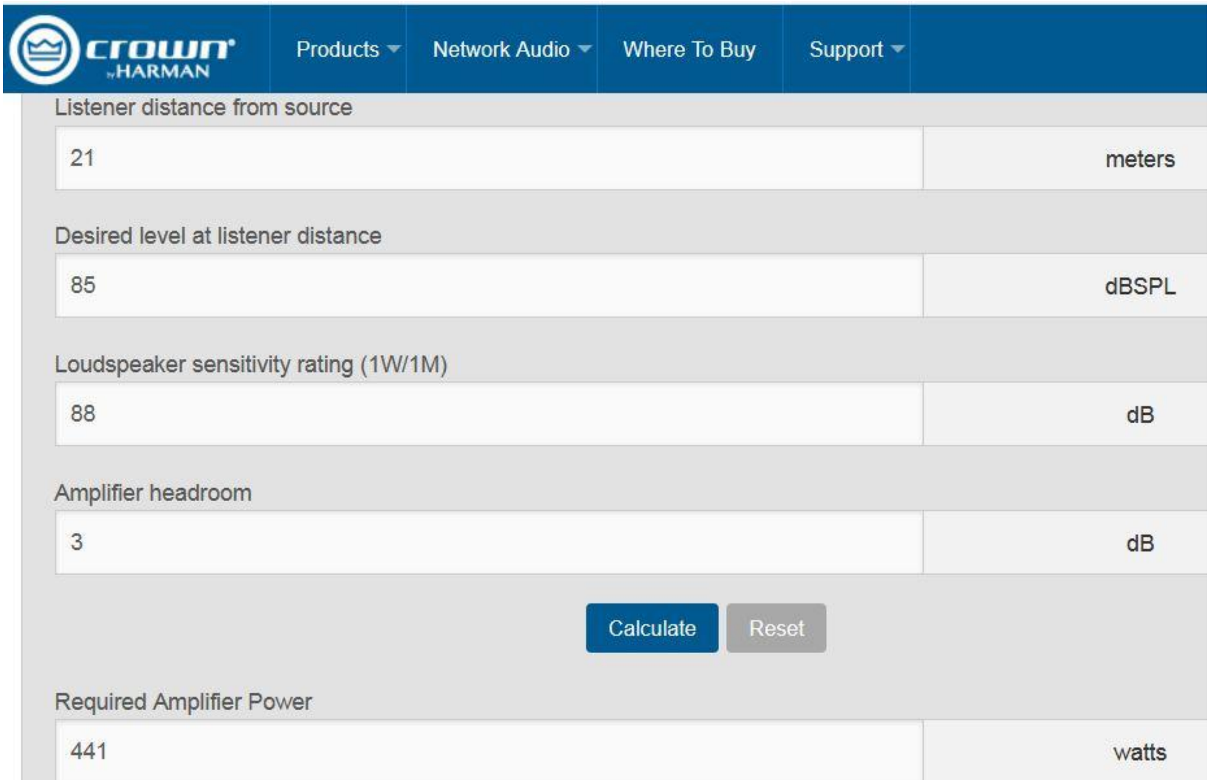
dBW = ratio of power referenced to 1 watt

W = power required

and using their calculator for a 75dB sound pressure level at 21 metres with a standard speaker offering 88dB sensitivity with 3dB head room to avoid clipping of the sound, this equation yields a required amplifier power of 44 watts - see screen grab below.



Now if I increase the desired sound level to 85 dB (which is the type of level you might target at a concert where the sound is to be too loud to talk over) at the same distance, then you will need approximately 441 watts



However, we are talking of only needing 50dB at 21 metres. At this level, the equation actually becomes almost meaningless giving a result approaching zero. Why? Because the wattage that is required only needs to be very small to provide 50dB at 21 metres. The experiential data in the next section establishes this from actual measurements.

The calculator above ignores many of the variables mentioned earlier in this paper, particularly the level of input signal voltage however it clearly identifies that a linear relationship does not exist between watts and number of guests. *Please refer to the glossary for the difference between dB and dBa*

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<u>A small survey</u>

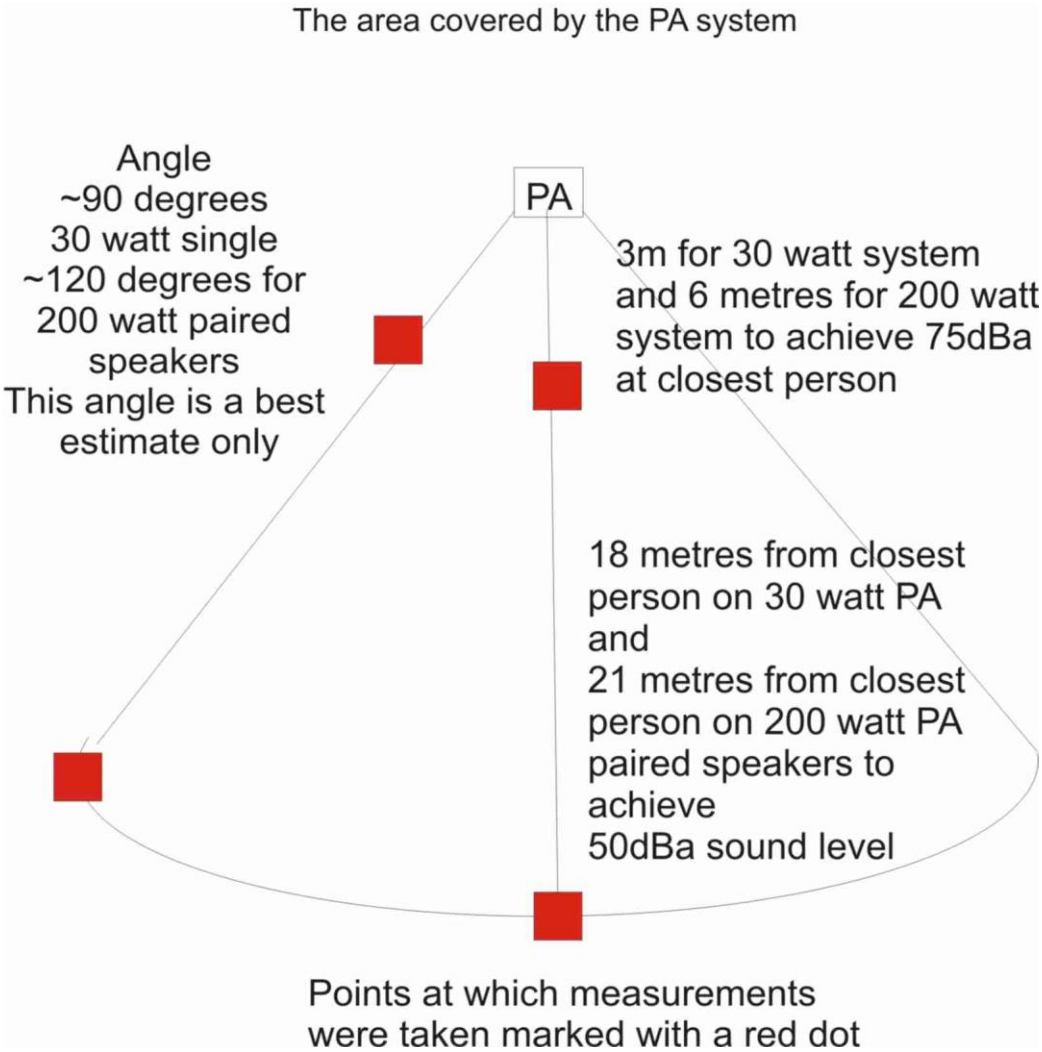
I surveyed a small number of celebrants asking them to report on the watts (rms) of their PA system, the max number of guests they believe the PA worked well for and the power level setting on their PA system at the time. Whilst this was a very small sample, what became apparent was a huge variety of results with the ratio of watts per guest ranging from ½ watt (rms) per guest to 1/6 of a watt (rms) per guest with guest sizes being typically in the range of 100 to 150 – a typical gathering for a well attended outdoor wedding. The results however clearly identified that 1 watt per guest was both overkill and non-linear for the various situations in which they had used their PA systems.

The experiment

I have a sound meter that will measure the sound (in dBa) from a standard quality PA system rated at 30 watts (rms). A second set of experiments was conducted in the same location using a pair of 100 watt speakers side by side driven by a 250 watt amplifier. The sound meter mounts to a tripod to reduce noise from handling. The small PA chosen has only a single 6.5 inch speaker and an AC (rms) voltmeter is attached across the speaker. By measuring the voltage across the speaker and knowing the impedance of the speaker (6 ohms) the watts being consumed by the speaker can be calculated. *For any one with a good electrical knowledge, I am assuming the impedance and resistance are the same as I am only testing at very low frequencies.* In the second experiment the pair of speakers each has a 4 ohm impedance with 88dB sensitivity. It is an approximate experiment not conducted under strict scientific discipline, however it does provide a guide. Once again the objective here is to generate a guide for the celebrant – this is not a scientific paper.

I first placed a voltmeter across the loudspeaker in my PA. That allowed me to read wattage consumed as the impedance was known.

A sound level meter was placed either 3 metres or 6 metres from the centre of the loudspeaker (see diagram below). This simulated the closest audience member to the speaker. The photo below shows the set up at Jamieson Park, Penrith at sunrise with no wind.



A pre recorded 250Hz tone was chosen. This is in the frequency range of a female person speaking.

Once the wattage to achieve 75dBa at the closest guest (the upper limit for audible comfort) had been set (at 3 metres from the small PA and 6 metres from the larger PA), the sound level meter was then moved away and to the sides to identify the 50dBa envelope (50dBa being the lowest sound level I consider reasonable for a wedding to hear).

The results are tabulated below

Wattage to achieve 75dBa at closest guest in watts (rms)	Distance to closest person to achieve 75dBa metres	Distance from centre of speaker to minimum 50 dBa in metres	Estimated angle of edge of 50dBa envelope Degrees *estimate only	Calculated area of guests receiving 50dBa to 75 dBa in square metres
1.4	3	22	90	254
4.2	6	24	110	311

A few checks and balances are worth mentioning here. The power going to the single speaker was calculated at 1.4 watts. The power calculated to be consumed by each of the pair of the speakers was 2.1 watts per speaker however the distance to the first person was increased to 6 metres to achieve 50dBa at 21 metres from the first guest. This was done to simulate a larger audience with a more powerful PA by moving the speaker further away and then increasing the volume.

Two things become apparent here.

Firstly an area of 254 square metres can hold a varying number of guests both seated and standing however fitting well over 100 guests into such an area would seem a reasonable estimate. There are many variables to consider in working out how many guests can fit within a defined area of land.

Secondly with a more powerful PA placed further away from the closest guest, the angle of coverage increases to accommodate a larger area. So placing the speaker further back and drawing a little more power can increase the number of guests hearing the PA whilst not having to stand further back from the bride and groom.

In the case of the more powerful PA, the system was measured to be drawing 5.2 amps at 12 volts, or 62 watts whilst only delivering 4.2 watts to the two speakers. This efficiency level is not unusual.

<u>Conclusion:</u>

The closest rule of thumb one might consider is watts **per square metre** covering an area from 3 to a maximum desired number of metres.

For a wedding outdoors in an open field with 100 to 110 guests arranged in a typical arrangement, and assuming no wind blowing, a 30 watt elevated PA system of average efficiency should suffice. A 200 watt system on its own running at 25% capacity could possibly only cover 150 to 200 guests if one **did not wish to cause audible discomfort to the guests sitting closest.** A 200 watt system would need to be placed a long way back in order to accommodate a huge crowd and would be better split into a pair of 100 watt PA systems (master and slave) positioned to cover the audience from different angles.

Using 1 watt per guest for a PA will most likely result in a larger and more expensive PA system than might be required for a celebrant. The huge number of variables and the science behind sound pressure levels is such that the best rule of thumb is to ……. **simply observe other celebrants' PA systems, how they perform in certain environments and if they perform satisfactorily,** then consider not just the same brand but the same model.

Plain English Glossary

- dB is a measure of the ratio of pressure on the ears from the loudspeaker compared to the background air pressure
- dBa is a weighted measure of sound pressure based on the human ear which does not have a linear response to changing frequencies. At 1000 Hz (above the range of human speech but not vastly different) dB and dBa are equal.
- Sound pressure is the air pressure that strikes the ear. It is referred to as SPL (sound pressure level). That is what is measured and reported in dB when compared to background pressure. Why are we interested in background pressure? Well this can vary with altitude and temperature.
- Watts – the voltage across a speaker coil multiplied by the current flowing through the voice coil (or the voltage across the entire PA system multiplied by the current flowing through it)
- Watts (peak). Sound waves are fundamentally sinusoidal. A woman speaking may have a voice frequency of 200 cycles per second. That means the power at the peak of the sinusoidal wave will occur momentarily and only once every 5 milliseconds. So the quoting of peak power is quite meaningless.
- Watts (rms). RMS stands for root mean squared and basically refers to the peak power divided by the square root of 2 (1.414). This equates to approximately 70% of the peak power and is a measure of the energy or power assuming a complete sin wave (a pure tone). Of course speech and music causes a disruptive combination of different sin waves of different amplitudes and frequencies. That is how speech and music is made. However the RMS figure assumes a pure tone and that is what is used in measuring the efficiency and sound distribution of a speaker.