Health and Safety Issues relating to Digital Wireless Camera Systems

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Abstract

Digital wireless camera systems, DWCS, are becoming widely adopted by the Broadcast Industry because of the freedom of movement they afford the cameraman. In addition, digital error correction and modulation techniques greatly extend their range and application making them a very versatile tool.

Concerns have been expressed about the effects of exposure of the cameraman to the RF fields radiated by the transmitter. This paper will address those concerns and look at the significant issues relating to the use of DWCS and assess their impact on product design. However, the buck does not stop here. Producers and Managers in the industry must assess their codes of practice and formulate clear guidelines that can be applied in any situation where wireless cameras and related technology may be used. Perhaps this is the greatest challenge, or maybe there's no challenge at all!

Introduction

Digital wireless camera systems, DWCS, are an everyday tool for the sports journalist and news reporter and they are beginning to find their way into the mainstream studio environment. Their technology and benefits to the broadcast industry are proven and entrepreneurs are seeking new ways to capitalise on the freedom and flexibility they afford. In spite of, possibly even *because of* their success, there is some misinformation surrounding their operation particularly with respect to Health and Safety issues. This paper seeks to address some of the concerns raised, many of which are not new, and put them in their true perspective allowing people to make informed judgements.

Health Effects of Radio Frequency Energy

One major concern for operators of wireless cameras is the effect of the radio frequency energy on the body. The majority of DWCS operate in the S-band: 1.97GHz and 2.7GHz. With a wavelength around 13cm, this is part of the microwave spectrum, and has many users other than Broadcasters.

Domestic appliances operating at microwave frequencies include mobile phones, satellite television systems, and the ubiquitous microwave oven. If we could see the microwave energy all around us at any one moment, it might well resemble a fog surrounding our daily lives.

At microwave frequencies, the main effect is *heating*. This is through the vibration of molecules – typically water - in fast changing electric and magnetic fields.

This is a very subtle but fundamentally important point – often missed in discussions on human exposure to RF. If microwave radiation is going to have any nasty effect on you – it won't be some subtle modification of your genetic material leading to some insidious, debilitating condition. You are going to get burned.

So as not to appear as some sort of apologist for the radio transmission industry – I will acknowledge that the issues of health effects of RF is anything but clear cut in the public domain. Not a month goes by that we don't hear of some community group lobbying a major telco to not position an installation i.e. *a mobile phone tower* close to some area where the group perceives there to be some special risk i.e. *a kindergarten*.

I was interested to read this article in the Sydney Morning Herald Health & Science supplement on 26th February this year. "CLOSE SHAVE: New research suggests that continued exposure to low level electromagnetic fields may damage brain cell DNA…"

I have also seen several articles in newspapers this year with similar startling revelations – that RF causes a change in brain membrane permeability. This in itself isn't a problem – except that – according to the articles - it leads insidiously to increased susceptibility to brain attacking toxins and pathogens.

While I am inclined to dismiss these types of studies, I shouldn't underplay the very real and particular hazards associated with the heating effects of RF. An RF burn can be very nasty indeed. You don't see where you got it from. You see an antenna, or a piece of open waveguide – but what is to say it is turned on or off? You probably won't see the burn – because it may occur underneath the surface of your skin. You may not even feel it.

At the end of the day – we as professionals working with RF need to arm ourselves with information. Studies commissioned or endorsed by the World Health Organisation are probably as good a source as any. I would strongly suggest that if you haven't done so already – get hold of a copy of the ARPANSA Radiation Protection Standard No 3 – *Maximum Exposure Levels to RF Fields*. It will go a long way towards reassuring you that health effects of exposure to RF have been studied in great detail. The overwhelming consensus is that there is insufficient evidence to suggest there are risks other than those associated with heating. Most importantly – the risks associated with heating can be controlled.

DWCS operate at power levels of 100mW or less, as much as 10,000 times lower than a typical microwave oven. This is too low to have any noticeable heating effect.

DWCS RF emissions have no discernable heating effect

The very low power levels at which DWCS operate are the main reason why they are incapable of causing measurable heating within the body, but there are additional factors which reduce the heating effect even further.

Firstly DWCS transmit antennas are designed to radiate their energy over a wide area. Therefore their energy is spread over a large volume. The power flux density around the antenna is kept low.

Secondly, only part of the antenna is radiating energy. The requirement for the antenna is to be omni-directional, with a beam width of around 78°. This dictates that the antenna type will be based on a half wavelength dipole. The radiating element is the top 6.5 cm. The rest of the whip is just a support to get the radiating element high enough above the cameraman's head for the best coverage. The radiating element is far from the cameraman's head.

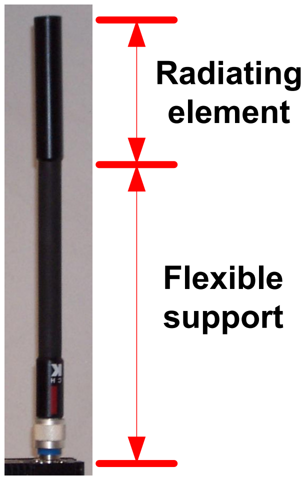

Figure 1 ~ Shows the small size of the radiating element

What heating effect does a DWCS have?

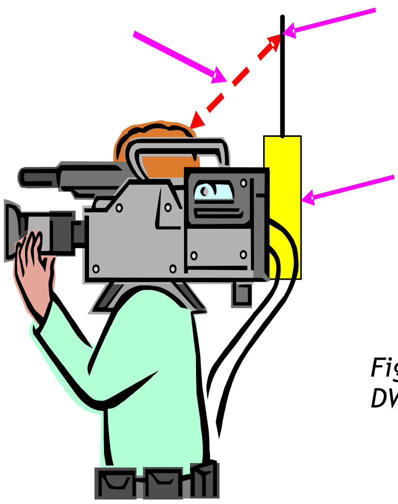

Figure 2 ~ Typical DWCS deployment

So what heating effect will a DWCS have? This very much depends on the power output of the transmitter. Typical output powers of DWCS are around 100mW and can be varied downwards to as little as 10mW.

Research done with 2 W, 900 MHz mobile telephones suggests that a 1°C rise in tissue temperature may take place when the phone is held next to the ear. But for a DWCS transmitting at 100mW with the radiating antenna a minimum of 25 cm away from the head, any rise in body temperature is negligible compared with normal temperature variations. If we compare a typical DWCS output of 100mW at a distance of 25cm from the head with a mobile phone output of 2W at 1 cm from the head, we can calculate the resulting power flux density scaled by a factor of 0.1W / 2W and by 1cm / 25cm. (In the near field, around a whip antenna power flux density might be approximated as being inversely proportional to distance.

This very rough approximation suggests power flux density is 500 times lower than for a mobile phone!

The distance is of course reduced when the cameraman takes the camera off his shoulder and puts it under his arm or holds it down even lower. Under these circumstances, with a standard antenna, more of the power will be absorbed by the body and the radiation pattern of the antenna seriously disturbed as a result of the antenna coupling to the body. However, the antenna tuning will be affected resulting in a reduction in radiated power, depending on how the camera is held, the body is likely to be outside or very nearly outside the near field so the RF effects will be lower. Added to this, the greater body mass nearer the antenna means the actual power levels absorbed become relatively lower per cubic centimetre or kilogramme of body mass. Even holding the antenna against the body the effect is still 20 times lower than a mobile phone radiating much the same power levels as DWCS.

Measuring the radiation levels

A great deal of research has been done by the mobile phone industry to look at the effects of radiation on the body, but the results are not easily applied to DWCS. The frequencies studied are lower than those used by DWCS, although 3G phones will use segments in the S-band. Where your typical EMR Surveyor will test compliance with exposure boundaries by measuring Electric and Magnetic fields, mobile phone tests centre round measurements of the energy absorbed by the head when using a mobile phone - resulting in a *Specific Absorption Rate* figure.

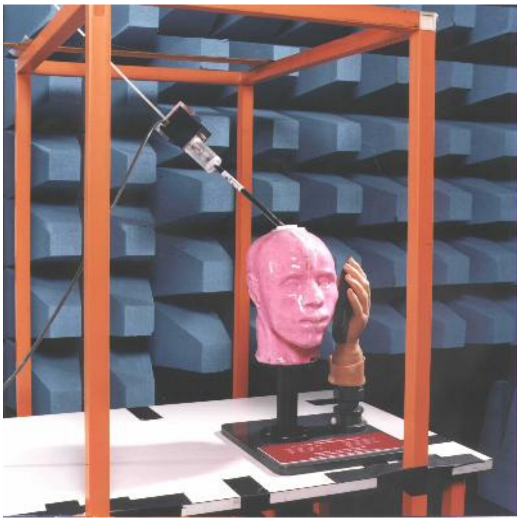

Figure 3 – Typical Specific Absorption Rating, SAR, test rig as used for testing mobile phones

Classical SAR measurements are made with a jig as shown in the illustration above. A mould is filled with a material that closely approximates the dielectric properties of the human head. Into this are inserted probes which measure the E-field strength moving on a very precise three dimensional matrix. This is a complex process because the probe positioning has to be very accurate. In spite of this, some common standards have emerged and there is now a high degree of harmonisation between standards around the world in the way in which measurements are achieved. But there is still wide variation on the SAR limits in different countries for occupational and non occupational exposure as can be seen in the following tables.

The International Committee for Non-Ionising Radiation Protection (ICNIRP) sets general guidelines which are globally accepted, but some countries have set more aggressive limits.

ICNIRP SAR Limits	Occupational	Non occupational
Whole body	0.4W/kg	0.08W/kg
Head and trunk	10W/kg	2W/kg
Hands and feet	20W/kg	4W/kg

Regional occupational limits with their standards are shown below

	Australia	New Zealand	Europe	USA	Japan
Standard	ARPANSA	NZS2772.1	ENV50166	ANSIC95.1	TTC/MPT
Whole body	0.4W/kg	0.4W/kg	0.4W/kg	0.4W/kg	0.4W/kg
Peak	10W/kg	10W/kg	10W/kg	8W/kg	8W/kg
Averaging time	6 min	6 min	6 min	6 min	6 min

Regional non occupational /general public limits are shown below

	Australia	New Zealand	Europe	USA	Japan
Standard	ARPANSA	NZS2772.1	ENV50166	ANSIC95.1	TTC/MPT
Whole body	0.08W/kg	0.08W/kg	0.08W/kg	0.08W/kg	0.04W/kg
Peak	2W/kg	2W/kg	1.6W/kg	1.6W/kg	2W/kg
Averaging time	6 min	6 min	6 min	30 min	6 min

It is worth pointing out here that if was possible to perfectly couple the output of a DWCS directly to the body, the resulting figures would be well below the limits. For a person weighing 70 kg the power density would be

0.1 W/70 kg = 0.0014 W/kg

This is well below the limit of 0.4 W / kg.

Indeed – we might calculate the theoretical minimum mass of tissue which – when coupled perfectly to a 100mW of RF power – sees the 4 W/kg limit exceeded:

0.1 W / **x** kg = 0.4 W/kg

x = 0.1 / 0.4 = 0.25 kg

When we consider SAR measurements in relation to DWCS, there are a number of factors that effect readings. The most important are indicated in the diagram below.

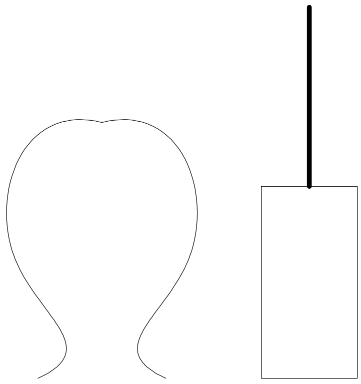

Figure 4 – Environmental factors affecting SAR

As environmental factors can considerably alter the SAR figures, great care must be taken when comparing various Digital Wireless Camera Systems. Different manufacturers have their own designs, and no two cameramen are built the same way.

Manufacturers such as Link Research use antennas with a radiating element far enough up and away from the operator, and with such broad radiation patterns that power levels are kept low.

But what if you need to boost power levels?

Higher power requirements

Figure 5 – Rucksack mounted system showing long antenna with radiating section well above the cameraman's head.

There are of course applications where higher powers need to be used. A power amplifier can be used to boost the transmitter output enabling much greater distances to be covered. Unfortunately *upping the power* leads to a range of new problems.

Power amplifiers suitable for operation with DWCS are very power hungry. Digital systems demand that the power amplifier is very linear so that the level of spurious emissions controlled. Any distortion will negate the forward error correction, interfering with picture & sound. To fix this, most amplifiers are under-run or backed off to ensure they operate in the linear region of their response curve. Unfortunately an under-run amp doesn't necessarily mean lower power consumption.

High power consumption means shorter battery life, requiring frequent changes, or use of bigger batteries or generators. The logistics of managing the extra equipment and power requirements defeat the greatest benefit of DWCS, their "go anywhere" capability. So what is the answer?

In the majority of applications, the camera movement is restricted, so the best solution is to restrict the output power and use a directional antenna with gain to fulfil the link budget requirements. The transmitter and power amplifier need to be mounted in a back-carried frame or rucksack. A much longer antenna is used raising the radiating element much higher above the cameraman's head eliminating any radiation hazard, which in a crowded situation, has the added benefit of increasing the range. Depending on the battery type preferred, two or three batteries can be fitted to the backpack increasing the "on air" time which because the weight is evenly distributed, does not create an excessive load.

Link Research firmly believes that the power in a digital link should be just great enough to make the link secure. Running high power "just to make sure" is irresponsible. It raises the general noise floor – polluting the local RF spectrum and if not done with care, may produce distorted signals. Increased power output is a potential health and safety issue because of the increased RF field strength. This is the reason why Link Research has chosen to employ relatively low powered Power Amplifiers and compliment them with a range of antennas whose gain ranges from a 5dBi to 15dBi. Users have found this philosophy suits their applications and budgets very well.

For some applications, such as airborne systems, higher powers are a must. Increasing power will get the extra distance required, but brings with it a problem requiring careful planning. Aircraft systems are installed in a relatively small space which has to be shared with other electronic devices. Ground-to-air communication for air traffic control, radar for both weather and other aircraft recognition, and talk-back for the broadcast system are but a few. In addition there is the Fadec computer used to control twin-engined helicopters which is usually placed near the rear of the aircraft. We are talking about EMC: Electromagnetic Compatibility. Successful completion of the air approvals process sees the risks of interference being identified and *controlled* - ideally by being designed out of the system.

Getting the best performance without raising the power levels

So just how much power is required by a DWCS to deliver good performance? Well if you consider a room full of people all talking at the same time, there will be a high level of background noise. If you want to have a conversation with your neighbour, you will have to talk loudly enough to overcome the background noise or your neighbour will have to listen harder to hear what you say. DWCS operation is very similar in that you can choose to put more power into the transmission or you can use improved reception techniques at the receiver. Increasing the output power increases background noise, as well as human exposure to RF. Therefore it is worth looking to the receiver to improve system performance.

Figure 6 ~ Typical analogue system showing the very directional antenna and telescope used to align it with the transmitter.

This can be done in two ways; by using *diversity reception* or using *directional antennas*. For general outside broadcast work at sports venues or at breaking news *events diversity reception* is most suited. By the very nature of RF propagation, the energy radiated by the transmitter will be reflected off many surfaces. Thus the receiving antenna will "see" waves coming from many sources with different length propagation paths at the same time. Sometimes the reflected waves will cancel each other out giving a flat fade where reception is either lost or seriously impaired. If the cameraman is roaming this is a dynamic problem, one that analogue users are very familiar with. Their solution is to use a directional antenna that tracks the camera receiving only the direct path radiation but this requires an extra man to point the antenna very accurately at the transmitter. This is a very demanding task requiring the use of a sighting telescope to make sure the antenna is always correctly aligned, a task requiring intense concentration, often in a hunched up position. Not surprisingly the link can easily be lost. This was a common feature of analogue systems, one that has been lost now that DWCS with diversity reception is used. So what was a health and safety issue in analogue days has ceased to be in the digital era.

DWCS performance is not just determined by output power alone. A well designed system includes efficient antenna design, exploits digital technology through the use of error correction, and may also include diversity reception. This enables a significant increase in the range of the system without increasing the power levels.

Link Research has invested heavily in research and development of antennas, modulation schemes, transmitters and receivers to achieve leading coverage and picture quality without increasing the output power. Correctly set up, a DWCS with an output power of 100mW can give similar performance levels to an analogue system running 4W output but without the picture impairment typical of analogue systems.

The weight problem ~ an issue of balance

It was mentioned earlier that the output power of most DWCS is around 100mW. This figure has been carefully chosen not only in response to the power safety issue outlined above, but also to enable the longest use from a typical camera battery. The overall power consumption of the DWCS will be around the same as the camera, slightly less if a VTR section is included. Thus with a total power consumption not exceeding 40 Watts, perhaps slightly more if a fill-in light is used, most camera batteries will have a life of at least 45 minutes: with the higher capacity batteries often used today, battery life can be between 1½ and 2 hours. This keeps the number of batteries a cameraman must take with him to a reasonable level, keeps the number of power-downs whilst the battery is changed low and avoids having to keep big charging resources close.

Figure 7 ~ Fully loaded steadycam

Power consumption also has an impact on the size of battery used. Whilst long battery life has obvious attractions, the cameraman will be concerned about keeping the weight of the battery to a minimum. However, this is a misconception because the main problem is not the all-up weight, but the balance. Modern cameras are becoming smaller and lighter, but lenses are essentially the same giving the camera a front heavy feel. This causes the cameraman to place his feet awkwardly to try and keep a comfortable balance resulting in back strain and general fatigue. The answer – paradoxically - is to use a heavier battery which may weigh between 1.5 kg and 2.5 kg depending on manufacturer and model. Thus, correct balance can be achieved with the added bonus of around 2 hours running time giving a happy cameraman because his back does not hurt, he’s not generally tired and he does not need to carry a lorry load of batteries around.

Steadycam operators are rightly even more concerned about battery weight because this can contribute significantly to the overall weight of the rig where the weight is distributed on the waist and back braces. How long a cameraman can or should carry a particular weight is yet another health and safety issue and has been the subject of much discussion over the years. Like transmitter output power, the wrong arguments are frequently put forward and accepted.

Summary

To sum up, there are health and safety issues relating to the use of DWCS, none of which are really new, all of which have been comprehensively addressed by leading DWCS manufacturer Link Research.

People tend to concentrate on the RF radiation issue, but by careful selection of output power and antenna design this can be reduced well below the limits set by the standards. Link Research is firmly committed to designing out the health and safety issues and has fully exploited all the benefits of digital systems to this end.

What is really at issue is not the technology, but the way in which it is used. DWCS allow for improved flexibility and ease of use, but as has hopefully been shown in this paper, not at the expense of increased risk. We’ve “been there” before with analogue camera systems; with digital it will be even easier to keep on working safely and in compliance with codes of practice.

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