

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 industry are proven and entrepreneurs are seeking new ways to capitalise on their freedom and flexibility. In spite of, or worryingly, because of their success, there is a growing body of misinformation and myth 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.

Effects of Radio Frequency Energy

A major concern is the effect of the radio frequency energy on the body. The majority of DWCS use the S-band whose frequency spread is between 1.97GHz and 2.7GHz. With a wavelength around 13cm, this is part of the so called microwave spectrum and has many users other than Broadcasters. Microwaves are used domestically for cooking food, cell phones, satellite reception etc. As a result it is full of RF energy which, if we could see it, would look like a fog surrounding our daily lives.

The fear is that continued exposure to microwave energy might in the short term lead to complaints such as headaches and dizziness; in the longer term may be a factor in serious illnesses such as brain cancer. Happily, these fears are unfounded. Cancers can be caused by ionising energy such as X-rays and gamma rays whose frequencies are millions of times greater than the microwave frequencies used for communications where changes in the DNA in the body's cells can be caused as part of the ionisation process. Any radiation with correspondingly shorter wavelengths than infra-red does not have enough energy to cause ionisation and has been proven to be non-carcinogenic.

At microwave frequencies, the main effect is to cause heating as a result of the vibration of molecules, particularly water, in a strong RF field, as found in microwave ovens which use powers of hundreds of watts: it is the heat not the microwave energy that causes the damage. DWCS operate at power levels of 100mW or less, as much as 10,000 times lower than a typical microwave oven; too low to have any noticeable heating effect.

Why 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 as wide an area as possible to achieve the best coverage. Therefore their energy is spread over a large volume

Secondly, many people are under the misapprehension that with whip antennas, like the Link Research L340x shown to the right, the whole length of the antenna is radiating energy. **This is not true.** The requirement for the antenna is to be omni-directional in radiation pattern with a beam width of around 78°. This dictates that the antenna type will be based on a half wavelength dipole and therefore the radiating element will be the top 6.5cm. The rest of the whip is just a support to get the radiating element high enough above the cameraman's head for the



Figure 1 - Showing the small size of the radiating element

best coverage therefore the radiating part is far from the cameraman's head.

How much heating effect can a DWCS have?

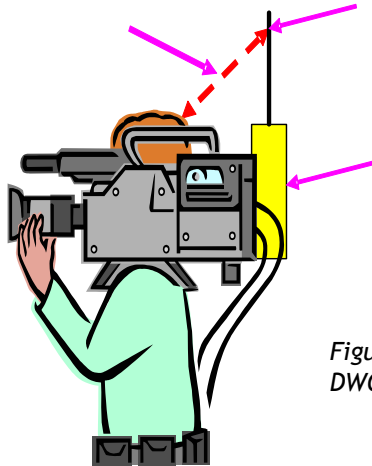


Figure 2 - Typical DWCS deployment

So what heating effect will a DWCS have on the cameraman's head if it is not close to the antenna? 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 mobile telephones transmitting on 900MHz with output powers of up to 2W suggests that a 1°C rise in body temperature may take place when the phone is held next to the ear and that the head therefore must absorb significant amounts of near field RF (wavelength is 30cm at 900MHz, 15cm at 1800MHz) so this is not surprising. But for a DWCS

transmitting at 100mW with the radiating antenna a minimum of 25cm away from the head, any rise in body temperature will be a very small fraction of a degree which is unlikely to be noticed compared with normal variations in body temperature. 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 1cm from the head we can write the expression:

Distance between head and radiating element

Calculating this out shows that typical DWCS radiation is 12,500 times lower than 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. Mobile phone tests centre round measurements of the energy absorbed by the head when using a mobile phone resulting in a Specific Absorption Rating figure often referred to as the SAR figure.

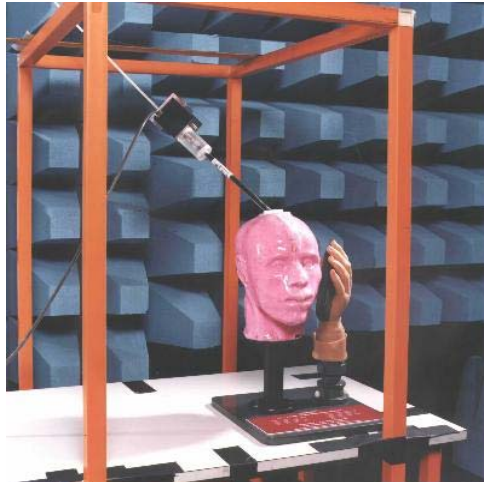


Figure 3 - Typical Specific Absorption Rating, SAR, test rig as used for testing mobile phones

Classical SAR measurements are made with a jig as shown in the illustration. A model of the human head is filled with a material resembling as closely as possible the make-up of the 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, the repeatability of the relationship between the RF source and the head must be very high and there are compromises in the homogenous modelling material. In spite of this, some common standards have emerged and there is now a high degree of harmonisation between EN50361 and IEEE 1528 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	ACA	NZS2772	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 limits are shown below

	Australia	New Zealand	Europe	USA	Japan
standard	ACA	NZS2772	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 it was possible to perfectly couple the output of a DWCS directly to the body to transfer its entire output into the body the resulting figures would be well below the limits. For a person weighing 70kg (11 stone) the power density would be:

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This works out at 0.00014W/kg! This shows just how far below the maximum limit DWCS is.

Our interest today is in the requirements for Australia and New Zealand and although there are two different standards specified, one for each country, the limits are the same for both occupational and non occupational applications. So we don't just have to concern ourselves with the health of the cameraman: we must consider the health of the population at large.

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

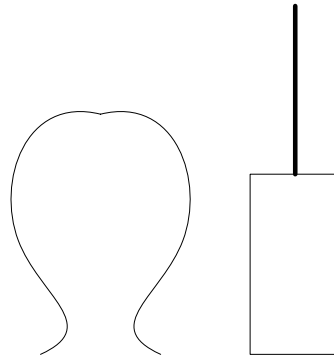


Figure 4 - Environmental factors affecting SAR

As environmental factors can considerably alter the SAR figures it is difficult to compare DWCS of different manufacture. Laboratory figures are fine for comparisons, but the real world is very different especially as different manufacturers have their own preferred designs and manufacturing methods and no two cameramen are built the same way.

However, responsible manufacturers such as Link Research are producing longer antennas that raise the radiating portion of the antenna even further from the head. Whilst this further reduces the power absorption, it compromises the flexibility of operation in that if the cameraman puts the camera transmitter on his shoulder in an indoor scenario, he cannot freely roam through doorways or low hanging lighting rigs without having to bend his knees. The resulting picture presentation would be unacceptable to most viewers and shows that as one health and safety issue is addressed, it opens the potential for another.

Many believe, wrongly, that the power output of the DWCS should be raised to 1 watt, ten times more than that of LinkXP. The arguments outlined above are ignored on the grounds that the signal is more likely to "get through" and this is the reason why some manufacturers use higher output powers between 500mW and 1W. Link Research believes this is irresponsible because of the increased radiation risk for the cameraman, even though that risk is very small.

Higher power requirements

There are of course applications where higher powers need to be used. Again the question arises of how much power is needed. A power amplifier can be used to boost the transmitter output enabling much greater distances to be covered.



Figure 4 - Rucksack mounted system showing long antenna with radiating section well above the cameraman's head.

This is not without its own problems as most 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 emitted spuri is well within acceptable levels and the wanted signal is not distorted. Any distortion will negate the forward error correction resulting in no pictures or sound. To achieve this, most amplifiers are under-run or backed off to ensure they operate in the linear region of their response curve, hence the high power consumption. High power consumption means shorter battery life requiring frequent changes, or use of bigger batteries or generators etc. The logistics of managing the extra equipment and power requirement defeat the greatest benefit of DWCS, their "go anywhere" capability. Also cameramen don't like the additional weight and balance problems that adding a power amplifier to the camera rig bring to say nothing of the possible additional radiation hazards. So what is the answer?

In the majority of long range applications, the camera movement is fairly restricted so the best solution is to restrict the output power and use directional antennae with gain to fulfil the link budget requirements. To keep the cameraman happy, 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 just be great enough to make the link secure. Running high powers "just to make sure" is irresponsible to other users because it tends to raise the general noise floor and if not done with care, may produce distorted signals which generally pollute the local RF spectrum. The 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, higher powers are a must and airborne systems fit into this category. Using high powers 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 a number of other very important RF systems. 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. Some systems radiate significant energy so great care has to be taken when positioning antennas for the DWCS to ensure EMC compatibility and aircrew safety. A helicopter falling out of the sky poses a significant health and safety issue to a potentially large number of people. However, successful completion of the air approvals process shows that the risks have been properly assessed and designed out of the system.

Getting the best performance without raising the power levels

It must be remembered that DWCS performance is not just determined by output power alone. Well designed DWCS exploit the power of digital systems to add and use error correction coupled with the benefits of diversity reception and efficient antenna design. This enables a significant increase in the range of the system without increasing the power levels. In this way, 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. At Link Research we have invested heavily in research and development of antennas, modulation schemes, transmitters and receivers to achieve class leading coverage and picture quality without increasing the output power.

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 only adds to the background noise so is not a viable option, and potentially not safe for the cameraman, therefore we must look to the receiver to improve system performance.

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



Figure 5 - Typical analogue system showing the very directional antenna and telescope used to align it with the transmitter

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 so 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.

The weight problem ~ another misconception

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.

Power consumption also has an impact on the size of battery used. Whilst the producer may want maximum times between battery changes, the cameraman will be concerned about keeping the weight of the battery to a minimum to protect his shoulder. 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 is to use a heavier battery which may weigh between 1.5kg and 2.5kg 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. Use of some of the fancy rigs from which the camera is hung and which are supposed to spread the weight evenly across both shoulders does not help either; the camera rig must still be correctly balanced.

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 and like transmitter output power, the wrong arguments are frequently put forward and accepted "because they appear to make sense".



Figure 5 - Fully loaded Steadicam

To sum up, there are many potential health and safety issues relating to the use of DWCS, none of which are really new. Most 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 allows great flexibility of shot position and a good cameraman is always looking for some spectacular framing. What must not happen is that in the pursuit of this, the cameraman is allowed to roam into hazardous environments. He can get close up to the battle but in so doing he risks getting shot! Producers must understand this and not lose sight of their responsibilities towards the cameraman. Managers have a responsibility to work with producers, TV production companies and camera crews to make sure that safe working practices are employed. As has been shown in this paper, using DWCS should not present any new challenges. We've "been there" before with analogue camera systems; with digital it will be even easier so we will be able to keep on working with existing codes of practice. There is not the same fuss being made about Bluetooth devices or wireless LAN's, both of which work in the same band as DWCS and at potentially higher powers. Moreover, they are much more widely deployed than DWCS. OK so the cameraman's got a headache: first ask yourself what was he drinking at the bar last night?

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