The Use of Radio Fire Detection and Alarm Devices for Compliance with BS 8629 (Evacuation Alert Systems) and BS 5839-1 (Fire Detection and Alarm Systems in Buildings)

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Introduction

Questions have been raised as to the efficacy of wireless radio fire detection and alarm equipment and emergency evacuation systems in real fire conditions. I have been asked to comment on them as they relate to C-TEC equipment and in particular how we should give advice on the correct equipment to use for such systems, especially for evacuation alert systems to BS 8629, which are not fire detection and fire alarm systems, but use the same equipment.

Summary

Radio signal reception is subject to propagation loss between each transmitter and receiver, which is called the 'link budget'. The link budget takes into account the RF power of the transmitter, radio wave losses at that frequency, and local factors such as building losses due to metal (especially in a reinforced concrete structures) and reflective surfaces such as foil insulation on plaster board. These are considered to be "fixed" losses and should be picked up by a proper radio survey before installation.

Changes after installation, such as erecting scaffolding[1] or, moving metal items such as fridge freezers will alter the link budget for the worse.

On top of the fixed losses there are also variable losses such as losses due to water from firefighting, sprinklers and from human bodies, (which are 60% water). The more densely packed the humans, the greater the losses.

The ionisation of material in a flaming fire can also cause significant losses.

These varying losses mean that the ability of a receiver to receive commands from its parent transmitter can change rapidly and unpredictably during an emergency.

It is imperative when designing a system that all the above factors are taken into account and adequate headroom is provided over and above that needed for the system to 'just' work."

Practical considerations

Signal loss has been raised as a matter of concern because each radio installation is preceded (or should be) by a radio survey, which predicts the suitability of any position for siting of a field device for correct operation. However, no account seems to be taken of how this equipment will operate when a fire is burning. This is especially important the more a fire develops, which is the anticipated operational mode of emergency evacuation systems to BS 8629.

What happens in a fire and what is its effect on the equipment used?

The physical phenomena associated with fires and in particular the attenuation of radio signals is well known, but there is little documentary evidence on its quantitative effect in buildings. These effects can be split into three broad groups:

[1] If scaffolding is erected after a radio fire alarm is installed, and interference occurs, it may be necessary to carry out a new radio survey and relocate components or add additional components to ensure reliability.

1. Refractive issues. These are associated with the gas density in the fire and its effect on refraction. The effects of this are generally associated with large open-air fires such as wildfires or bush fires. These effects are significant over large distances but are unlikely to be of significance in buildings and so are disregarded for the purposes of this document.
2. The effects of conductive particles in smoke and other products of combustion. These effects relate to what is in the 'smoke'. Also, human body loss and losses due to water from sprinklers and firehoses. Whilst they can be significant in certain situations, they are disregarded for the purposes of this document.
3. Plasma effect of fires. This is the partial ionisation, often called 'cold plasma', of material caused by high temperatures. It is normally characterised by visible flames from the fire and appears to be a significant source of attenuation of radio signals due to the effects of fire, especially within buildings.

A rule of thumb is that the bigger the fire and the more flames there are, the greater the interference and hence the greater and more variable the attenuation of radio signals.

Current research

- Most research has centred on the effects of bush fires in Australia where these are common.
- However, one paper refers to the effect of flaming fires inside buildings (IEEE-propagation April 2010 [2]). This paper comes from a learned source[3] and is a simulation that predicts relatively large attenuation of signals (10 dB reduction in signal, which is 90%) between 200 MHz and 1 GHz in a building due to cold plasma effects. The EU frequency band for radio fire signals is 860 MHz.
- This example (Fig 1 on page 3) simulates a corridor in a block of flats and will vary considerably dependant on the actual situation.
- A brief summary of this research paper for the purposes of this document is:
  1. The fire had a 1 m radius of flame, which is a relatively modest fire, see Fig 1 on page 3.
  2. The attenuation locally (5 m - 20 m) is predicted to be as high as 10 dB with respect to the no-fire case. This is a 90% reduction in received radio power, see Fig 2 on page 3.
  3. The frequency band of interest covers both the 415 MHz band and 860M Hz bands that are designated for radio fire detection products.
  4. Fig 1 on page 3, shows the shadow effect caused by the cold plasma. It follows that if there are multiple flames then there will be multiple shadows and the effects will be additive.

[2] A.C.M. Austin, "Wireless channel characterisation in burning buildings over 100–1000 MHz", IEEE Trans. Antennas and Propagation, vol. 67, no. 7, pp. 3265–3269, July 2016.

[3] Andrew C. M. Austin, Senior Lecturer, Department of Electrical, Computer, and Software Engineering, The University of Auckland

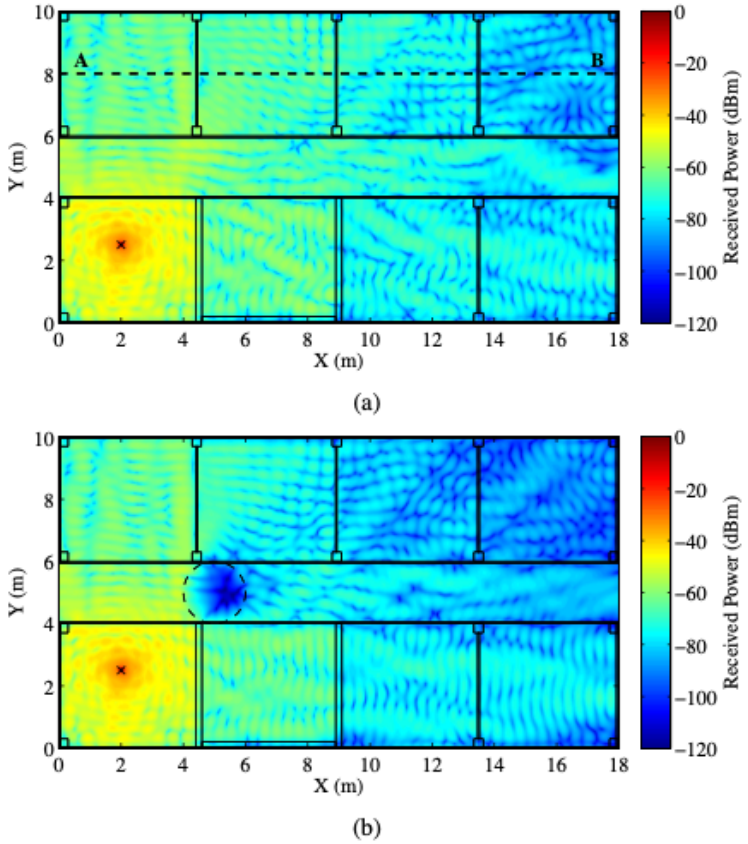

Fig. 1. Power recorded on a slice positioned 1.3 m above the floor at 450 MHz (a) without fire and (b) 1 m radius fire, contained within the dashed locus (- - -) with $f_p = 850$ MHz and $\nu = 10^{10}$ Hz.

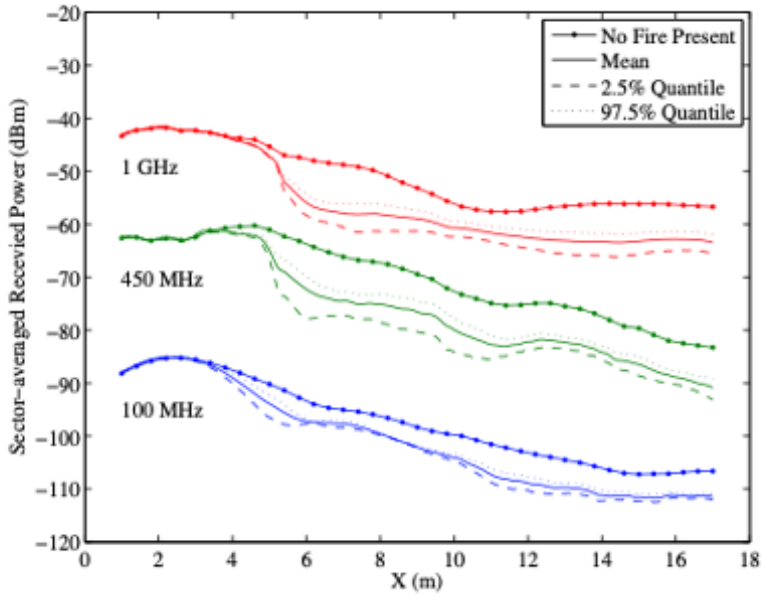

Fig. 2. Uncertainty in the power recorded along the line **AB** due to randomness in the electrical properties of the fire at 100, 450 and 1000 MHz.

General comments on the of use of radio equipment to EN54-25

- Field devices connected to the control and indicating equipment (CIE) of a fire detection and alarm system are normally connected by cables, but radio/wireless systems are becoming more popular. Fire detection and alarm field devices are normally battery powered and communicate with the CIE either directly or via a hybrid arrangement of wired radio communication hubs.
- Modern radio fire alarm equipment operates in the 860 MHz band, has its power output limited to 10 mW and has to be certified to EN 54-25. This very low power means that the range of communication is limited and is often unpredictable. Hence the need for radio surveys and the strategic siting of 'radio hubs' is necessary.
- Radio alarm systems to EN 54-25 are designed to work with fire detection and fire alarm systems. There is no requirement in EN 54-25 for them to operate satisfactorily under the different and more onerous operating conditions of BS 8629.
- BS 8629 and BS 5839-1 both require a full radio survey prior to the installing of any radio equipment. It is well known in the fire industry that this is often not done due to access difficulties and cost implications, or because the building is new and impossible to survey prior to quotation. This results in poor coverage and frequent faults and false alarms. This is not a fault of the equipment itself.
- Many systems are hybrid installations, in which radio hubs are connected to the wired addressable loop of the CIE, from which the radio hub draws power to operate and then communicates with the wireless field devices. Sometimes wireless devices communicate with several radio hubs in a mesh configuration. This is to try to overcome the range problems caused by the limited permissible power output of 10 mW, which is 20db down compared to, Fire Brigade radios, which are >1 W and so have much greater coverage.
- With fully radio systems such as may be used on building sites the hubs can be also be 'meshed', which can cause further problems if there are multiple developed fires as may be the case when a BS 8629 system is needed.
- The above applies to the use of radio devices for both fire detection and alarm systems (BS 5839-1) and emergency alert evacuation systems (BS 8629).

Fire detection and fire alarm systems

- In the case of fire detection and alarm systems to BS 5839-1, most fires start small and grow larger. Therefore, any interference caused by fire will be low in the early stages and automatic fire detection devices will have triggered well before there are a lot of flames. Consequently, as long as there are not prolonged delays to the cause-and-effect programming of the fire alarm system, radio alarm sounders are likely to be triggered within a short time of the original detected fire event and in any event within 10 minutes of the occurrence as stipulated in EN 54-2. This will, or should have been, taken into consideration during the writing of EN 54-25.
- It also follows that in the case of BS 5839-1 systems there is only likely to be one initial source of fire and therefore one source of interference/attenuation. i.e., any interference due to radio attenuation is likely to be local to the fire event.
- Neither of the above two situations will be the case for BS 8629 systems because they are systems of last resort normally expected to operate in a developed 'Grenfell' type fire situation in which the fire and flames have spread, and the officer in charge feels that the building may fail.

Evacuation Alert Systems to BS 8629

- BS 8629-2019 is a new standard that was written as a consequence of Scottish Legislation for the evacuation of high-rise residential buildings in an emergency. However, the Grenfell Tower Inquiry phase 1 report recommended them for all such buildings, new and existing, and many organisations are looking to use such systems throughout the UK as 'best practice'.
- The introduction of BS 8629 clearly states that evacuation alert systems are NOT intended to be used as a fire alarm system per BS 5839-1.
- BS 8629 systems are intended for operation by the fire brigade incident commander when the tenability of the escape routes and staircase(s) are in jeopardy. In other words, when the fire has developed to a stage where, in effect, stay-put has failed. In these instances, there is likely to already have been an out of control spread of fire to several locations. E.g., spread from one flat to another through inadequate fire barriers between floors, travelling up rubbish shafts, service shafts, and through insufficiently fire stopped openings, etc.
- This is further evidenced in section 8 of BS 8629 'Monitoring integrity and reliability of circuits external to the evacuation alert control and indicating equipment (EACIE)'. This section significantly enhances the protection of wired circuits within flats compared to BS 5839-1 to the extent that no matter how many flats are simultaneously on fire facilities need to be provided to ensure that every flat NOT on fire can still receive a signal to evacuate. This is further explained in Annexe A of BS 8629 and ensures that the integrity of the system is maintained under the expected operating conditions.
- Section 16 of BS 8629 on radio-linked systems is directly copied from BS 5839-1.

Comments and observations

- BS 5839-1 requires radio devices for fire detection and alarm systems to be certified to EN 54-25. EN 54-25 was specifically written to cover the use of radio systems for the purposes of a fire detection and alarm system and will have taken into account the limited influence of plasma effects on a developing fire in its early stages. Providing the manufacturers guidelines are followed and a full radio survey is carried out, its use should be perfectly acceptable in fire detection and alarm systems.
- EN 54-25 systems are limited through regulation to an output of 10 mW ERP (Effective Radiated Power). This is a very low power compared with say Fireman's walkie talkies, which have an ERP of >1 W, which is 100 times greater than fire alarm devices. This makes them relatively poor at penetrating solid objects and makes the provision of a multiplicity of radio hubs essential to pick up these very low signal levels.
- In order to overcome the plasma effects of a flaming fire it will be necessary to increase the signal transmit power by at least an order of magnitude. However, this is not allowed for equipment certified to EN 54-25.
- According to the referenced research paper the level of attenuation will increase as the fire develops beyond a 1 m radius of flame. The level of attenuation will be high and indeterminate.
- The operating conditions of fire are virtually impossible to emulate in a non-destructive manner. Any interference in a building is completely indeterminate and likely to be disruptive under normal operating conditions dependant on the level and distribution of fire present at the time. This is significantly more relevant to BS 8629 systems compared with BS 5839-1 systems.
- It is worth noting that these observations as regards BS 8629 also apply to a large extent to the situation of temporary fire alarm systems as defined in the NFCC Simultaneous Evacuation Guidance 1/10/2020. Also, the attenuation effects of external metal scaffolding in these temporary works will be of further concern.

- This document does not take into account the effect of any other phenomenon other than plasma effect, especially the liberal use of water to extinguish fires.
- Multiple path transmission and reception will be no guarantee of improving the reception in an indeterminate situation where the spread of fire at the time of operation is unknown. This applies particularly to BS 8629 systems in which the requirements of section 8 require the system to be operational in every flat that is not consumed by fire even if all flats except one are consumed by fire.

Conclusions

1. The effects of multiple flat fires are taken into consideration to define the special operating conditions of BS 8629 wired systems in section 8 of the standard.
2. The effect of flaming fires of >1 m radius on the attenuation of radio signals in buildings can be much more than 90% of power (10 dB), dependant on the extent and spread of the fire at the time at which the system is designed to operate.
3. It is likely when all fire phenomena are taken into consideration the total amount of attenuation to radio signals due to fire will be higher than that as outlined above.
4. Interference to radio signals by a flaming fire of 1 m radius is likely to cause substantial disruption to the reception of radio signals by equipment required to operate during a fire condition using current equipment and design techniques. This may be enough to cause malfunction under the conditions covered in BS 8629.
5. Further research into the effects of signal attenuation of fire on radio fire equipment to EN 54-25 is needed to accurately quantify the effects of attenuation of radio signals caused by fire plasma and other effects (especially water) likely at the time of operation.
6. In the meantime, the installer and/or the manufacturer of the radio equipment should guarantee that it will operate reliably under the fire conditions likely to be present when required to operate as defined by section 8 of BS 8629.

C-TEC's position

1. C-TEC manufacture EACIE systems to BS 8629 and fire alarm control equipment to EN 54-2/4 suitable for use with fire alarm systems to BS 5839-1. All this equipment is suitable for use with C-TEC CAST and Apollo XP95/Discovery protocols, including the hybrid radio parts of these systems to EN 54-25.
2. C-TEC continues to approve the use of radio equipment to EN 54-25 for use with our control equipment per BS 5839-1, subject to a satisfactory radio survey.
3. C-TEC does not approve the use of its BS 8629 equipment with radio alarm systems unless the radio system vendor guarantees operation of their equipment under prolonged and multiple fire conditions to a level likely to overcome any attenuation of signals that may be caused by fires that are envisaged in BS 8629 section 8.
4. Until further information and assurances are available, C-TEC only advises the use of a wired system to comply with the requirements of BS 8629.

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