REPORT ITU-R M.2034*

Impact of radar detection requirements of dynamic frequency selection on 5 GHz wireless access system receivers

(2003)

1   Introduction

Recommendation ITU-R M.1652 recommends that, in order to facilitate sharing with radars, mitigation techniques be implemented by wireless access systems including radio local area networks (RLANs) (WAS) in the bands used by radars at 5 GHz. It describes a mitigation technique, named dynamic frequency selection (DFS), which requires a radar detection mechanism to be implemented. In addition, the Recommendation also gives the detection and response requirements with which the DFS should comply with.

This Report considers how radars operating in the 5 GHz band can be detected by WAS without extreme constraints on the RF front-end design or on the system capacity of the WAS.

Radar detection may only be possible during the time there is no active transmission in the WAS cell. During channel availability check time, there is no transmission for a significant time (e.g. 60 s). During in-service monitoring the detection can take place during moments of no uplink or downlink traffic.

The detection of a radar pulse of power above the so-called DFS threshold triggers a DFS procedure, and the access point must leave the channel within a short delay. In this Report the interplay of DFS threshold T_{DFS}, WAS false alarm rate and radar detection failure rate by WAS are presented and discussed from the point of view of implementation of radar detection in a WAS receiver.

2   Abbreviations and acronyms

ACT: (channel) availability check time

DF: detection failure probability

DFS: dynamic frequency selection

FA: false alarm probability

OFDM: orthogonal frequency division multiplexing

PDF: probability density function

PRF: pulse repetition frequency

RLAN: radio local area network

RSS: received signal strength

T_{DFS}:   DFS threshold

WAS: wireless access system

---

*   This Report was jointly prepared by Radiocommunication Study Groups 8 and 9, and any futher revision will also be undertaken jointly.

3   Assumptions and methodology

Radar detection by a WAS is characterized by two performance metrics:

3.1   Detection failure probability (DF)

This is the probability that a radar is present in the channel but no radar pulse is detected by the WAS. DF must be as low as possible not to interfere with radars. A value of $DF = 1\%$ is set as a target. The probability of detection varies with the power of the radar signal relative to the detector threshold setting in the receiver – a higher power level increases the detection probability.

3.2   False alarm probability (FA)

This is the probability that when a radar signal is not present in the channel, interference pulses are detected by the WAS, triggering an unnecessary DFS procedure. This can happen when a noise or interference burst is mistaken for a radar pulse. Such a burst may be caused by WAS devices in the vicinity operating on the same channel or on the adjacent RF channels of the WAS system. A high interference/noise floor ratio in the WAS receiver will obviously increase the FA. However, this probability should be low as possible in order not to trigger unnecessary DFS procedures, which would severely limit the WAS capacity especially in dense deployment scenarios. During channel availability check time, it is sufficient to be sure that the channel is not measured as occupied for some small percentage of the time. It will be seen that this percentage is a very sharp function of the WAS DFS threshold setting, with a few dB altering the FA probability by many orders of magnitude.

The WAS performs power measurements averaged over a duration rss_meas_duration, the measurements signal_rss being spaced by the averaging duration. Therefore, during channel availability check time (ACT), for example, the number of measurements performed is:

$$nb\_trials = round \, (ACT/rss\_meas\_duration)$$

The radar signal is received at a level of radar_pulse_power (dBm), (equivalent to T_{DFS} in the notation of Recommendation ITU-R M.1652) and pulses have a duration of radar_pulse_duration (ns). The radar signal bandwidth (MHz) is denoted by B. Many radars send pulses periodically, at a pulse repetition frequency (PRF) rate. For a rotating radar, the WAS will periodically receive a burst of pulses, such that the number of pulses occurring during the channel ACT, denoted by nb_RADAR_pulses_per_ACT will be greater than one. The 5 GHz orthogonal frequency division multiplexing (OFDM) RLANs sampling period used is $T = 50$ ns.

4   Detection criteria

The detection criterion used here is based on absolute signal power measurements. If the measured power exceeds a certain threshold, then a radar is assumed to be detected.

It is assumed that the signal samples are averaged white Gaussian noise. Therefore, a measurement performed during rss_meas_duration consists of (rss_meas_duration/T) independent complex

Gaussian variables. Thus, the probability density function (PDF) of the noise is χ^2 centred on noise_floor with:

$$\text{noise\_free\_deg} = 2\text{rss\_meas\_duration}/T$$

degrees of freedom.

There is no data available on received signal characteristics or statistics of a radar pulse, propagated over an urban, rural or other environment. In some cases, the radar pulse duration can be shorter than rss_meas_duration. The radar signal bandwidth is normally smaller than an OFDM signal bandwidth of 18 MHz, so that radar pulse samples collected during the power measurement will be correlated. If the radar pulse was sampled at a rate of $T\_RADAR = 1/B$, the samples would be uncorrelated. It is assumed here that the PDF of the power when measuring a radar pulse is χ^2 centred on:

$$\text{meas\_avg\_radar\_power} = \text{radar\_pulse\_power} + 10 \cdot \log_{10}(\min(\text{radar\_pulse\_duration}, \text{rss\_meas\_duration})/\text{rss\_meas\_duration})$$

with degrees of freedom equal to:

$$\text{radar\_free\_deg} = 2 \cdot \text{round}(\min(\text{radar\_pulse\_duration} / T\_RADAR, \text{rss\_meas\_duration} / T\_RADAR))$$

The PDF of the power measurements noise_rss_pdf and radar_rss_pdf are plotted in dBm in Fig. 1 for a radar of type K received at a level of –67 dBm, and an interference/noise floor of –84 dBm (see § 5).

Once the two distributions noise_rss_pdf and radar_rss_pdf are known, the DF and FA probabilities can be computed.

$$DF = (\text{prob}(\text{radar\_rss\_pdf} < \text{rss\_threshold}))^{\text{nb\_RADAR\_pulses\_per\_ACT}}$$

$$FA = 1 - (1 - \text{prob}(\text{noise\_rss\_pdf} > \text{rss\_threshold}))^{\text{nb\_trials}}$$

Note that rss_threshold is the WAS receiver RSS threshold setting, whose value should be set between noise_floor and meas_avg_radar_power such as to meet the required DF and FA probability criteria.

5   **Results**

The following values are used in the calculations:

rss_meas_duration = 1 μs
radar_pulse_power = –67 dBm, –64 dBm, –62 dBm
radar_pulse_duration = 1 μs
interference/noise_floor = –84 dBm
$B = 4$ MHz
$ACT = 60$ s
nb_RADAR_pulses_per_ACT = 1, 10

Figures 1 to 6 plot FA and DF using various values chosen from the above list.

It can be seen that the form of DF steepens as the number of pulses increases. Increasing T_{DFS} by a number of dB moves the DF curve the same number of dB along the x-axis.

It should be noted that an interference/noise floor increase will move the FA curve horizontally to the right also.

FIGURE 1

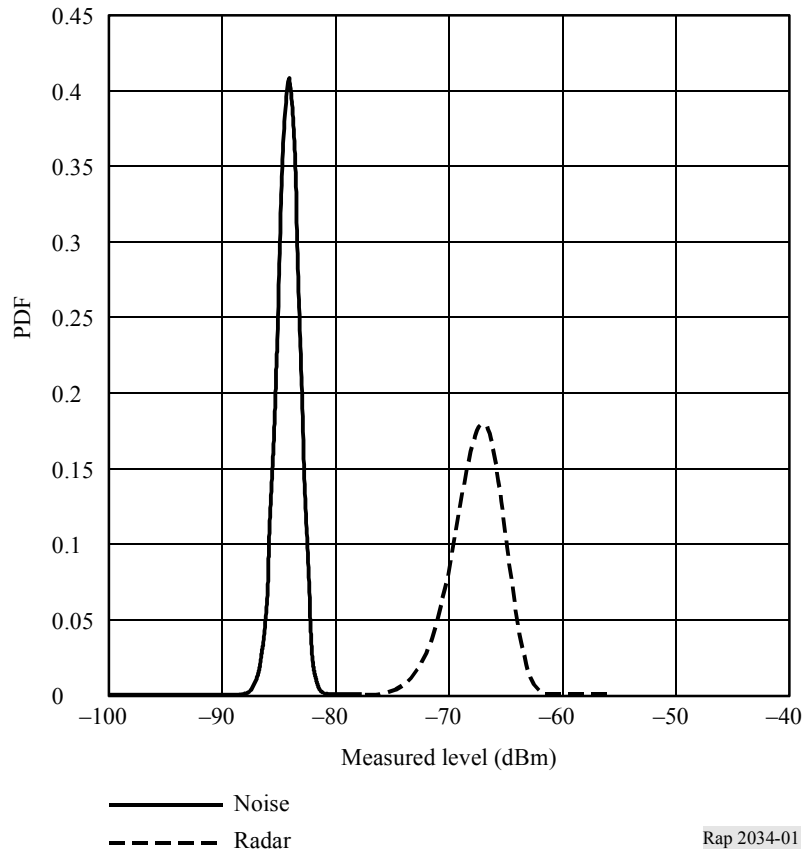**PDF of the power levels of radar pulses and interference/noise floor**

Rap 2034-01

FIGURE 2

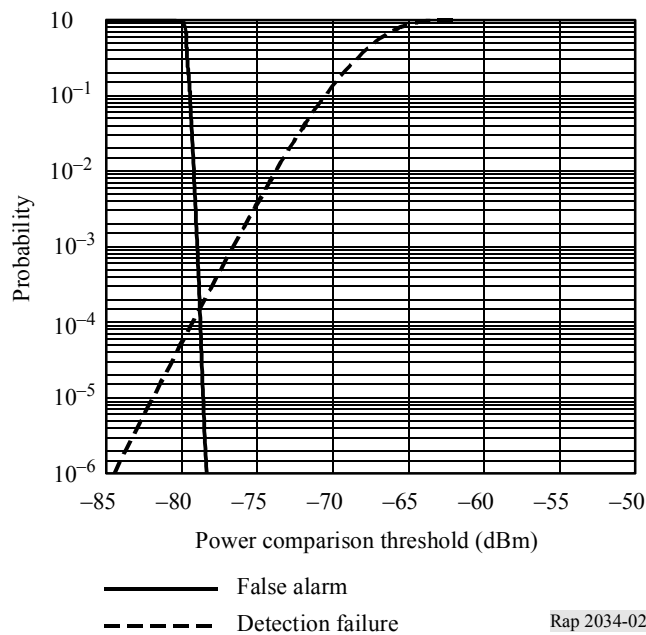**DF and FA, single radar pulse, $T_{DFS} = -67$ dBm**

Rap 2034-02

FIGURE 3

DF and FA, 10 radar pulses, $T_{DFS} = -67$ dBm

Power comparison threshold (dBm)

—————— False alarm

- - - - - Detection failure

Rap 2034-03
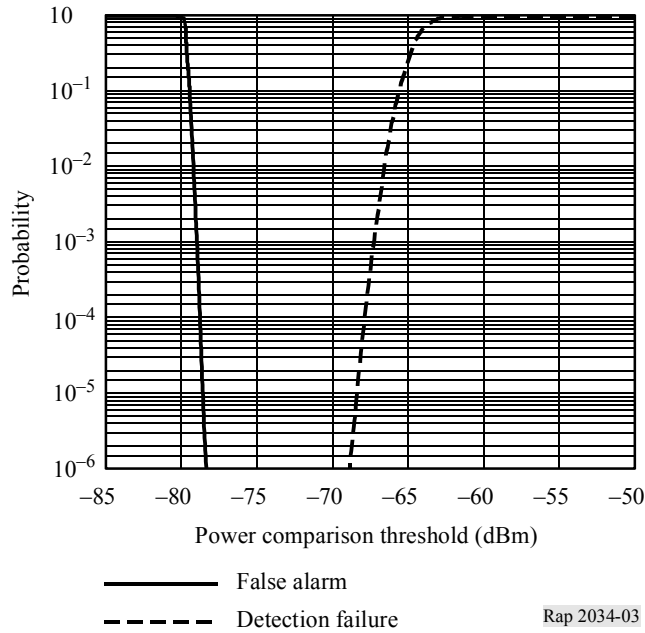
FIGURE 4

DF and FA, single radar pulse, $T_{DFS} = -64$ dBm

Power comparison threshold (dBm)

—————— False alarm

- - - - - Detection failure

Rap 2034-04
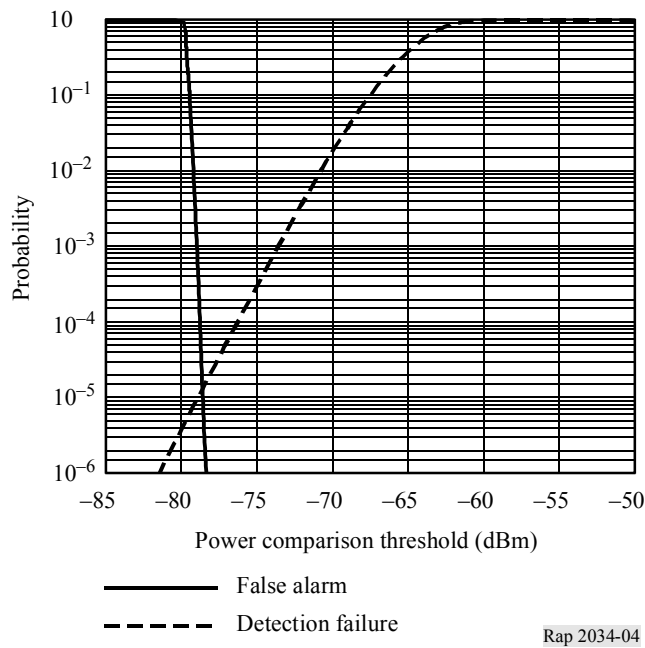
FIGURE 5

DF and FA, single radar pulse, T_{DFS} = –62 dBm
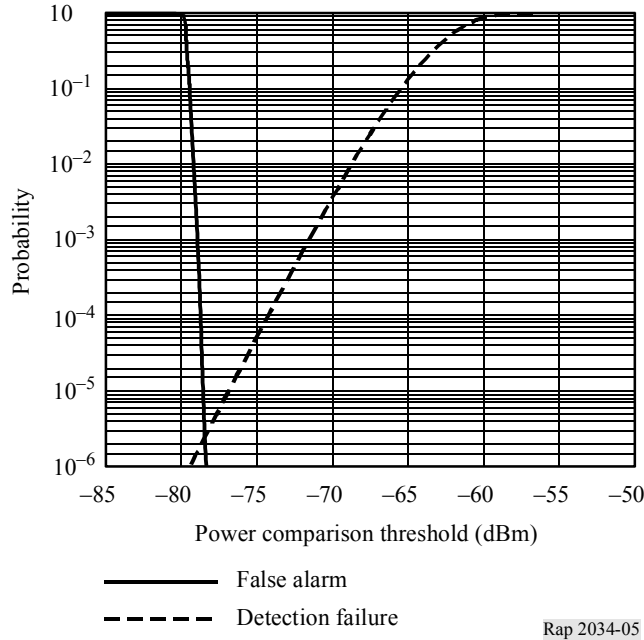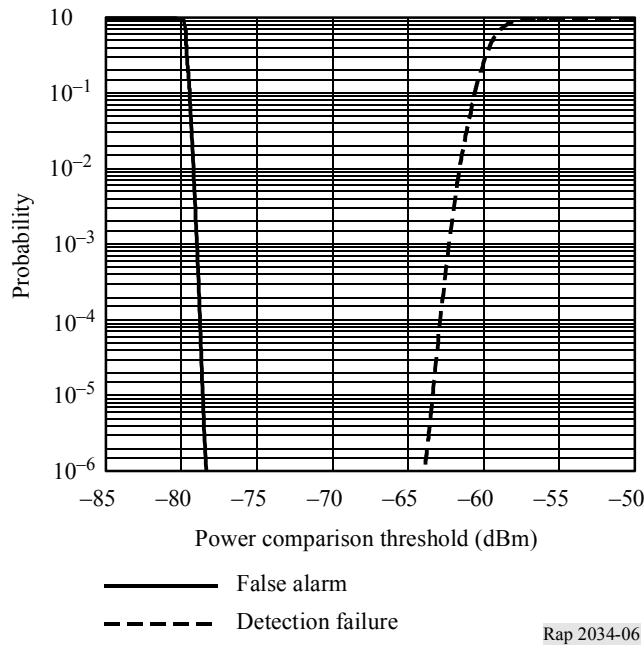

Rap 2034-05

FIGURE 6

DF and FA, 10 radar pulses, T_{DFS} = –62 dBm

Rap 2034-06

6   Summary of simulation results

False alarm rate

The FA rate in the WAS receiver with interference/noise floor −84 dBm is 1% for a receiver detection level (rss_threshold) of −79 dBm (Fig. 2). The curve falls very sharply, but in order to ensure acceptable service quality level during WAS transmission when in normal operation, the FA should be several orders of magnitude lower. Detection circuit implementation margins are not included, and the interference floor is assumed to be equal to the highest receiver sensitivity, corresponding also for example to interference from an adjacent channel access point 30 m distant.

Radar detection performance

If only one pulse is detected, with the radar signal level −67 dBm, the detection failure rate DF is 1% with rss_threshold −74 dBm. (Fig. 2). Thus there is less than 2 dB only of margin for the FA and DF for rss_threshold set to a value between the two criteria. In practice, variations in operating conditions will easily cause this narrow margin to be exceeded. In addition, the typical tolerance specified for RSS measurements being ± 5 dB in the 5 GHz RLAN standards and the cost of implementing tighter tolerance in devices manufactured in large scale production would be prohibitive.

If several radar pulses are available, detection probability improves.

The effect of increasing the radar signal level that must be detected is shown in Figs. 4, 5 and 6 for T_{DFS} of −64 dBm and −62 dBm. Figure 6, where 10 pulses are detected with $T_{DFS} = -62$ dBm yields an improved margin for implementation.

———————————