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COMPATIBILITY STUDY BETWEEN RADAR AND RLANs OPERATING AT FREQUENCIES AROUND 5.5 GHz

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1 INTRODUCTION

This report examines the prospect of co-channel sharing between radar and Radio Local Area Networks (RLANs) operating in the frequency bands around 5.5 GHz. Due to lack of information, the interference potential from the RLAN to the radar is not assessed. Results in this report show that if harmful interference to the RLAN is to be avoided no more than 6 radar can be permitted within a 50 km radius of any RLAN.

2 ASSUMED RLAN PARAMETERS

At the time of writing (September 1992) very little information is available for the RLANs being proposed for sharing with radars at frequencies around 5.5 GHz. Under these circumstances some assumptions have been made regarding the values of key RLAN parameters for use in the sharing study. These parameters are listed in the table below:

PARAMETER	VALUE	COMMENT
Maximum eirp	30 dBm	Based on DECT Tx. Power of 24 dBm, with an extra 6 dB allowance for increased prop^n loss. Value technology limited.
Antenna Gain	2 dBi	0 dBi typical for mobile at 1 8 GHz. extra 2 dB for higher frequency and to overcome prop^n loss. Low cost antenna assumed.
Channel Bandwidth	20 MHz	Scaled from DECT bandwidth and data rate (l.152 Mbits/s). Data rate of l 5 Mbits/s assumed for RLAN.
Maximum Tolerable Interference	-130 dBW/20 MHz	Assumed interference level is equal to thermal noise level.
Required C/I	20 dB	Based on parameter for RLAN at 17 GHz.
Receiver Threshold	-80 dBm	Calculated from other assumed parameters.

Table l. Assumed RLAN parameters for use in sharing calculations.

The parameters given in the table are based on assumptions and they should be changed when information becomes available on the RLAN characteristics and performance.

3 RADAR PERFORMANCE

The following table (Table 2) gives information on the performance of example radar systems currently operational in the band under investigation. The list of radars given is not exhaustive and is merely intended to provide some realistic examples for use in sharing calculation. The numbers and locations of the radars used are not available for use in this study.

RADAR	A	B	C	D	E
PEAK EIRP	98.6 dBW	26 dBW	60 dBW	93 dBW	97 dBW
EMISSION DESIGNATION	3M00PON	15M5PON AN	30M0PON	14M0PON	3M00PON
PRF	300 pps	1200-1300 pps	160-1650 pps	2-3000 pps	300 pps
PULSE WIDTH	5 µs	0.5-1 µs	0.25-1 µs	0.25 µs	2 µs
ANTENNA GAIN	40 dB	0 dB	46 dB	43 dB	43 dB
FIXED/MOBILE/ TRANSPORT	TRANS	MOBILE	FIXED	TRANS	FIXED
TUNING RANGE	5300-5600 MHz	5700-5800 MHz	5400-5820 MHz	5250-5850 MHz	5600-5650 MHz
OPERATIONAL OR TRAINING	BOTH	OPERAT.	OPERAT.	BOTH	OPERAT.
AIRBORNE USE	NO	YES	NO	NO	NO

Table 2. Radar parameters for use in sharing calculations.

4 METHODOLOGY

The method used to calculate the potential for interference from radar systems to the RLAN is based on estimates of the Minimum Coupling Loss (MCL) required between radars and the RLAN. The MCL is defined as the minimum loss required to avoid adversely affecting receiver performance. This is measured between the antenna connector of the interfering system and the antenna connector of the victim receiver (i.e. feeder loss and antenna gain are not included). Equation 1 is used to that the MCL.

$$MCL = P_t + 10 \log_{10} \frac{B_{noise}}{BW_{tx}} - I_r \qquad \text{Equ. 1}$$

Where,

MCL	Minimum Coupling Loss dB
P_t	Maximum Transmit Power, before antenna and feeders (Radar) dB
B_{noise}	Receiver Noise Bandwidth (RLAN) Hz
BW_{tx}	Transmitter Bandwidth (Radar) Hz
I_r	Maximum Permissable Interference at Receiver, after antenna and feeder (RLAN) dB

It should be noted that when the RLAN receiver bandwidth is greater than the transmit bandwidth of the radar, the term $10 \log_{10} B_{noise}/BW_{tx} = 0$.

Once the MCL has been calculated it may be converted to a required propagation loss by taking account of any antenna gain or feeder loss between the radar and the RLAN.

$$Prop^n\ Loss = MCL + G_t - L_{ft} + G_r - L_{fr} \qquad \text{Equ. 2}$$

Where,

$Prop^n$ Loss	Required Propagation Loss
G_t	Gain of the radar antenna (see Table 2)
L_{ft}	Radar feeder loss (assumed = 0 dB)
G_r	Gain of RLAN antenna (2 dBi)
L_{fr}	RLAN feeder loss (assumed = 0 dBi)

Assuming free space propagation, then Equation 3 can be used to determine the required distance separation.

$$d = \frac{\lambda}{4\pi} 10^{\frac{Prop^n loss}{20}} \qquad \text{Equ. 3}$$

Where all symbols have their previous meanings and,

λ	Wavelength (evaluated at 5.5 GHz)
d	Required separation distance

It should be noted that use of free space propagation formula to calculate required separation distances gives the worse case situation.

5 RESULTS

Using the methodology outlined above and the parameters in Sections 2 and 3 the following table of results is produced.

RADAR	MCL (dB)	GAIN AND FEEDER LOSS (dB)	PROP^{N} LOSS (dB)	DIST. AT F = 5.5 GHz (1×10^3 km)	DIST. TO RADIO HORIZON (see CCIR REC. 238)
A	188.6	42	230.6	1470.0	51.4[1] km
B	156	2	158	0.344	346.6[2] km
C	142.2	48	190.2	14.0	51. 4[1] km
D	180	45	225	772.0	51. 4[1] km
E	184	45	229	1223.0	51. 4[1] km

Table 3. Required distance separations for RLAN sharing with various radar systems.

If the distance to the radio horizon is taken as the limiting factor in determining the range over which a radar can cause interference to the RLAN, there is a potential interference zone of approximately 50 km around every land based radar and 350 km from the airborne radar.
Details of the number of radars in the band are not known. However, given the transportable and airborne nature of radar usage in this band it should be assumed that there is a potential for interference from the radar to the RLAN.

Further work is required to determine the precise interference environment of the band under investigation.

6 DURATION OF INTERFERENCE BURSTS

In previous compatibility studies between RLANs and radar (e.g. Study at 17 GHz) advantage was taken of the pulsed nature of the radar transmission and the RLANs' ability to withstand interference so as to permit sharing. A number of factors influence the period of time over which interference occurs to the RLAN as a result of the radar transmission. These include: radar Pulse Width (PW), the Pulse Repetition Frequency (PRF), the scanning nature of the radar and whether or not frequency hopping is employed by the radar information is not available on the latter two.
The RLAN has to endure an interference burst of duration PW, PRF times per second. The effect of this on the RLAN design can be seen from the worked example below.

Worked Example - Interference from a single type A radar to an RLAN
The RLAN performance will be constrained by two types of interference. These are interference from the radar and interference due to the systems' own inherent performance limitations (i.e. the interference if no RLAN were present).

Interference due to radar
From Table 2, it can be seen that a single radar of type A transmits bursts of 5 µs duration, 300 times per second.
Taking an RLAN data rate of 15 Mbits/s and assuming no synchronisation between the radar and the RLAN gives:
76 bits in error/5 µs, this occurs 300 times per second.
22.8 kbits/s are in error due to the radar transmission.

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[1] The distance to the radio horizon is calculated assuming a flat spherical earth and a radar pointing towards the horizon at a height of 30 m and an RLAN at a height of 50 m.

[2] Aircraft height of 6000 m is assumed and an RLAN height of 50 m.

Interference due to RLAN system performance
Assuming a system error (number of errors in normal RLAN operation without any radar interference present) rate of 1 in 10^3 for the RLAN, and assuming that these errors are random. Gives an average error rate of:
15 kbits/s (i.e. 1 error per 66.7 µs)

Total error rate
Equation 4 is used to evaluate the number of errors that occur per second.

$$Error_{total} = Error_{burst} \text{ X PRF} + Error_{system} \qquad \text{Equ. 4}$$

Where,

$Error_{total}$ Total number of errors per second
$Error_{burs}$ Error due to a single radar pulse
PRF Pulse Repetition Frequency
$Error_{system}$ Error due to inherent system performance

$$Error_{total} = 76 \text{ x } 300 + 15 \text{ x } 10^3$$
$$= 37.8 \text{ kbits/s/radar}$$

Given the error rate per radar, it is possible to evaluate the number of radars which can operate within a given radius of the RLAN, before the interference environment becomes such that the RLAN can no longer operate. Assuming that the RLAN can meet its performance targets with an error rate of 1 in 10^2 (same as for RLAN at 17 GHz). Using Equation 5 and noting that the total acceptable error rate is 150 kbits/s.

$$\text{No. of radars} = \frac{Error_{accept} - Error_{system}}{Error_{radar}} \qquad \text{Equ. 5}$$

Where,

No. of radars Number of radars within the Radio Horizon
$Error_{accept}$ Total acceptable error rate (150 kbits)
$Error_{system}$ Number of error due to RLAN operation when there is no radar interference (15 kbits)
$Error_{radar}$ Number of errors due to radar transmission (300 X 76)

Therefore,

$$\text{No. of radars} = \frac{150 \text{ x } 10^3 - 15 \text{ x } 10^3}{\bullet\ 22.8 \text{ x } 10^3} = 5.92\ (5)$$

From the above it can be seen that up to 5 radars could operate within a 50 km radius of the RLAN. Table 4 shows the results for the other radars listed.

RADAR	PRF	$Error_{radar}$	$Error_{system}$	$Error_{total/s/radar}$	No. of radars/dist. To Radio Horizon
A	300	22.8 kbits/s	15 kbits/s	37.8 kbits/s/rad	5 per 50 km
B	1300	20.8 kbits/s	15 kbits/s	35.8 kbits/s/rad	6 per 340 km
C	1650	26.4 kbits/s	15 kbits/s	35.8 kbits/s/rad	5 per 50 km
D	3000	14.25 kbits/s	15 kbits/s	29.25 kbits/s/rad	9 per 50 km
E	300	9.3 kbits/s	15 kbits/s	24.3 kbits/s/rad	14 per 50 km

Table 4. Performance degradation of RLAN sharing with various radar systems.

7 CONCLUSIONS

This report has studied the possibility of RLANs sharing with radar in the radiolocation bands around 5.5 GHz and has assessed the potential for interference from radar systems to RLANs. Using free space propagation formula, the required separation distance between radars and tile RLAN is limited by the Radio Horizon (50 km for ground based radar and 340 km for airborne radar). However, this is the worse case and does not take into account terrain or building attenuation. Further calculations show that the RLAN could tolerate interference from between 5 and 14 radars at a given time. This is unlikely to reflect the majority of situations where RLANs will be used (mainly urban areas at some distance from radar installations), and the distribution of radars will probably be less than 5 within 50 km. Where an RLAN is operating within line of sight of one or more radars, the system throughput will be reduced but still within acceptable limits.

Ideally, further studies are required to provide RLAN equipment designers with an assessment of the interference environment in the 5.5 GHz band. However, given that radar systems are mainly used for defence purposes and the transportable character of the radar, some difficulties may be anticipated in obtaining a complete picture.

This report has made no attempt to calculate the interference potential from the RLAN to the radar. Additionally, taking into account the relative power levels of radars and RLANs, radar systems will, in effect, create their own exclusion zones.