# IEEE 802.11
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**TITLE:** **EVALUATION OF INTERFERENCE BETWEEN RADIO LAN AND USA POINT-TO-POINT MICROWAVE AT 1.85-1.99 GHZ**

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## CONCLUSIONS

It is possible to estimate the interference susceptibility of a microwave systems using only facts available on the license. The specific design dimensions of the LAN influence the degree of this possible interference or rather the contours of the area where it may occur. The interference is probabilistic in that the dimensions of the interference area are larger only when the normal microwave signal has faded to levels that occur 0.1 to 1.0% of the time, and then only at traffic peaks in the LAN.

**The same problem has been addressed by CCIR IWP8/13 (now TG8/1), and the underlying assumptions for PCN are considerably different for radio LAN.**

It will be necessary to **confirm the statistical characteristics of the interference with an experiment** which is described later below.

## BACKGROUND

A possible frequency band for co-use between existing users and radio LAN is the Part 94 private system allocation at 1.85-1.99 GHz (see §94.65). This band is attractive, because the present users are documented and stationary, and it is unattractive because they use EIRP of 10 kW or more and because they vehemently express disapprobation at any possibility of independent and potentially interfering use.

A like government service uses 1.71-1.85 GHz.

The radio LAN transmitter output power has been estimated at 1 to 25 milliwatts. The interfering effect is the power sum of all transmitters which are ON simultaneously within the response pattern of a single microwave antenna. The differential power ratio of one-million-to-one is not enough to avoid the need for analysis of the possibility of interference.

For the purposes of the calculation a type of radio LAN is described which will be the proposal of this Committeeman, but which has **no recognition or approval from 802.11**.

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### Location and Use of Part 94 Radio

The high capacity shorter hop microwave is generally at frequencies above 3.7 GHz, and most trunk route microwave uses these bands. The 1.71-1.99 GHz bands are largely used for low-capacity longer-distance paths, though much of the use is motivated by economy since the lower frequency equipment costs less and does not need some of the elaborate diversity arrangements to avoid fading and weather outage required in higher bands.

In Los Angeles, this band is used heavily for microwave links to mountain-top repeaters and mobile radio base stations operated by a diverse group of entities including land transportation and public safety. The band is also used by right-of-way companies including railroads, pipelines and some water, gas and power utilities.

The design fade margin is commonly 30 dB corresponding to in-service probability of 99.9%, however interference calculations always assume a fully faded direct path.

Transmitters are commonly 1 to 10 watts with antenna gain of at least 27 db and up to 36 dB.

The frequency band is partitioned into 10 MHz channels half of which are uplink and the rest downlink. 5 MHz channels are also assigned in the interleaved spaces between the 10 MHz systems. In this way, there is always 70 MHz difference between transmit and receive frequency on any two-way link in the 140 MHz band.

Antenna beamwidth is mostly under 5° at 3 dB down plane polarized and symmetrical between the vertical and horizontal axis.

**Radio LAN System Description**

On the average, there is one radio access-point for every 600 square feet of floor space serving four user stations. The entire system works in a single radio channel in time sequence where access-points and user stations transmit alternately. The channel is 40 MHz wide at 16 dB down. The data is FM modulated CMSK at 8 Mb/s. Using Carson's Rule for bandwidth, the allowable deviation is 12 MHz or a 1.5 modulation index. The allocated bandwidth is 70 MHz per system providing 30 MHz of guard band.

Highest transmitter density assumption is given. Each access-point is in one corner of a 24 by 24 foot square. The diagonal range is 35 feet or 10 meters. The necessary power is 1 milliwatt with a total of 6 dB antenna gain.

For interference reasons, no more than 1/16th of the access-points are used simultaneously, and the same is true of the user stations associated with each access point. Therefore each set of 16 access-point and 64 user stations is seen as one time-shared channel with 1 milliwatt transmitters used consecutively serving 10,000 square feet (1,000 square meters).

The duty cycle for transmitter ON is unlikely to exceed 75% in saturated use, and much less than that at other times.

For a square kilometer, there would be 16,000 access points and 64,000 user stations equivalent to a raw capacity (not considering payload proportion) of 8,000 Mbits/s/□km (1000 x 8). This is a higher density than is likely to be sustained over a large building, though the density can easily exist in some of the office areas (1 employee/160□'). Taking into account duty cycle and the impossibility of large scale high density, interference measurements could well be made assuming 25% transmitter ON time:

**MAXIMUM AVERAGE VALUES**

250 µwatts/1,000 square meters, or
0.25 watts/□km/40 MHz system.
0.00625 µwatts/□km/Hz

The reason for not assuming spread spectrum is that the implementation is thought to be too costly and power consuming for data rates of 4 to 16 Mbits/second, however this consideration might be quite different at some future date.

**THE CCIR INTERFERENCE ESTIMATE**

The June 1990 final report ("the report" hereafter) of CCIR IWP8/13-54 (Harrogate, UK 11July90) attempts to arrive at interference level contours as a ground footprint extending a few to many kilometers in front of the antenna. It derives levels based on faded worst case signal levels and maintenance of BER in digital microwave radio systems which are wider bandwidth and higher capacity than are used in the USA in the 1.7-2.3 GHz region. Regardless of these major differences in starting premises, it is important and useful to examine the methodology used.

Three types of systems are considered in the IWP report:

Mobile (R1); Personal (R2) Indoor, Outdoor

This discussion will cover only the personal (R2) interface with primary focus on personal indoor. The personal outdoor is relevant to the FCC NOI PCN proceeding (90-314) since it is competing for the same frequency space.

A major premises of the report is sufficient capacity to provide the entire telephone service by wireless within a commercial building.

**Parameters of R2 Interface and Radio LAN**

Shown in Table I are some of the R2 parameters from the report with an added column for Radio LAN. An implied radio range has been added in ( ) based on center-illuminated square cells with the area given.

The main differences between in-building LAN and PCN are in bandwidth and range. Shown in Table II (on the following page) is the conversion of these dimensions into power flux densities.

### TABLE I -- EXAMPLE PARAMETERS FOR FPLMTS IN AN URBAN AREA

| | R2 Interface | | USA RADIO LAN |
|---|---|---|---|
| | Indoor | Outdoor | |
| Base Station EIRP(3) | 3 mW | 20 mW | 1 mW |
| Duplex bandwidth per channel | 50 kHz | 50 kHz | 40 MHz |
| Antenna Height(1,2) | 1-2 m | 1-10 m | 1.5-2.5 m |
| Cell Area and Implied Range | 600 $m^2$ -- (17 m) | 16000 $m^2$ -- (90 m) | 50 $m^2$ -- (5 m) |

NOTES: 1) The height is the height of the antenna above the floor.
2) R2, indoor is in a multi=story building.
3) These are the estimated equivalent power levels per traffic channel bandwidth, independent of access method.

### TABLE II -- POWER FLUX DENSITIES FOR FPLMTS

| | R2 INTERFACE | USA RADIO LAN |
|---|---|---|
| EIRP | 3 mW (indoor) | 1 mW peak each station |
| Traffic density | 20000 E/□km (indoor)(1,4)<br>640 Mbits/sec/□km | 8000 Mbits/sec/□km peak<br>2000 Mbits/sec/□km average |
| Assumed Bandwidth Allocation | 60 MHz | 40 MHz @ -16 dBC/70 MHz |
| Estimated PFD | 1.5 μW/□km/Hz(2,3) | 0.025 μw/□km/Hz (pk)<br>0.00625 μw/□km/Hz (av) |

NOTES: 1) These values take into account the small cell sizes likely to be used in an urban environment.
2) The effects of antenna gain and cell sectorization may reduce these values significantly.
3) The PFD are given for the urban areas of highest traffic concentration.
4) This has been derived from the estimate of 20000 E/sqkm/floor considering that an observer at a distance would see the equivalent of one floor averaged over a square kilometer when the geographic distribution of buildings and attenuation through building structures is taken into account. This figure takes into account the vertical frequency reuse of FPLMTS in buildings.

The R2 indoor capacity is shown as:

20,000 Erlangs/sq km =
0.2 E/(10 sq m or 100 sq ft)

This corresponds to one telephone per 150□′ which is in use 30% of the time. This is about the capacity needed to replace the entire wired telephone system with radio.

The capacity of the plan, considering that it is full duplex and that a voice channel is transferred at a 16 kbits/sec rate, may be estimated as follows:

20,000 x 2 x 16 kbits/sec =
640 Mbits/sec/□km

The capacity and power density for radio LAN is estimated on the previous page and the results are shown here.

The average capacity of the radio LAN is 3.125 times the digital capacity of the R2 system (2000/640), and the radio LAN operates at 1/240th of the power density (.00625/1.5). **The overall productivity of the radio LAN is 750 times greater than the PCN** each in their own system bandwidth and for the assumptions made.

The largest part of this great difference results from the following major differences in assumptions:

Fade margin: Optical vs. shadowed path
Path length: 5 vs. 35 meters
(10 meters with corner illumination)

### TABLE III -- 2 GHZ FIXED RADIO-RELAY SYSTEM CHARACTERISTICS

| | | |
|---|---|---|
| Hop length | 80 | km |
| Minimum fade margin | 30 | dB |
| Antenna diameter | 3 | meters |
| Antenna gain | 33 | dBi |
| Transmitter power at antenna flange | 7 | W |
| E.i.r.p. | 40 | dBW |
| Noise figure F | 3 | dB |
| Channel bandwidth (wideband system) | 29 | MHz |
| (narrowband system) | 1 | MHz |
| kT at 300 K | -204 | dB(W/Hz) |
| Noise bandwidth B | 25 | MHz |
| N = kTBF + cable loss | -120 | dB(W/25MHz) |
| Modulation scheme | 64 | QAM |
| Carrier-to-noise ratio C/N at BER = $10^{-3}$ | 20 | dB |
| Carrier-to-noise ratio C/N at BER = $10^{-10}$ | 25 | dB |
| Carrier at BER = $10^{-3}$ | -100 | dBW |

NOTE: "For this example, an 80 kilometer hop designed for a flat Earth surface would require the antennas to be mounted about 100 meters above the ground. (The radius of the first Fresnel ellipsoid equals 47.5 m and the Earth bulge equals 52.9 m with an effective Earth-radius factor k=4/3.) The radiation pattern of a 3 m diameter antenna which satisfies the requirements for this hop has been used as an example."

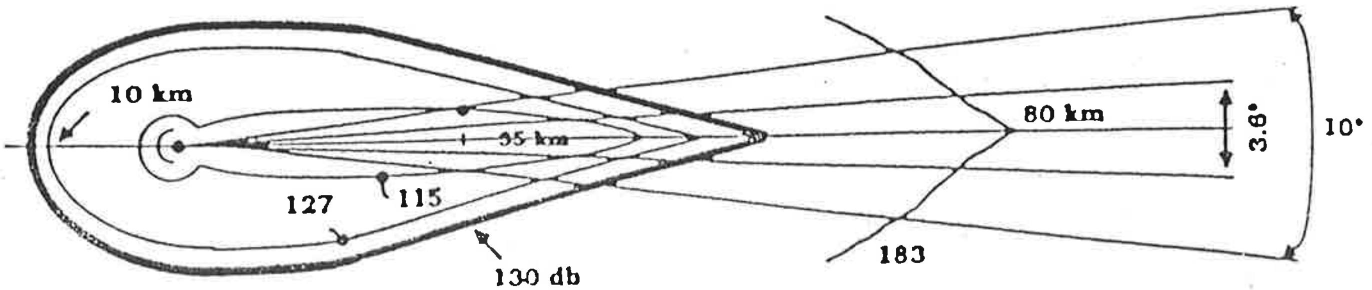
**Parameters of CCIR Microwave System**

For interference to the microwave system from the personal and base transmitters of the PCN system, the very reasonable procedure followed is to estimate the response of the microwave system to the noise power generated by the R2 interface system.

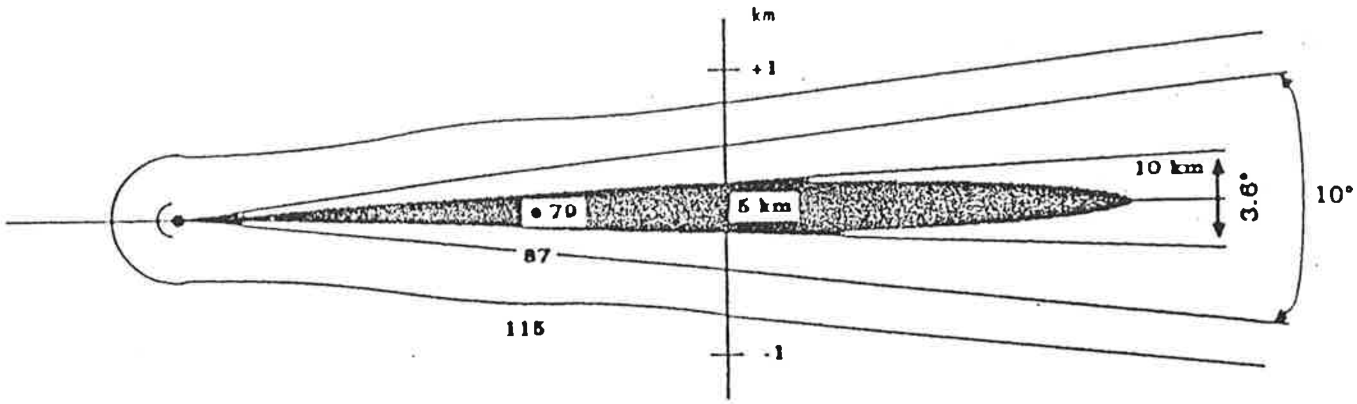
Table III is copied from Annex 1/Table I for a 2 GHz system using 64 QAM digital transmission. The assumed bandwidths of 1 and 29 MHz do not match USA practice which is 5 and 10 MHz. The 3 meter antenna assumed for a very long path is larger than the most common USA antennas which are 1.8 and 2.4 meters with slightly wider beamwidths (4.5 & 6°) and lower gain (28.6 & 31.1 dB).

Many of the USA systems are older using SSB multiplex FM modulated rather than newer digital medium systems. The USA high capacity systems are usually at frequencies above 3.7 GHz. The 2 GHz systems are usually long path, light capacity and they are often chosen where minimum coast is a major requirement.

A USA system would have about 4 dB more sensitivity from less bandwidth, 2 dB less antenna gain and require 3 dB less C/N for 16 QAM or SSB/FM. This is 5 dB more sensitive on balance.




a)




b)

Figure 1 The Spatial Signal Distribution (ray path transmission loss)
Fixed 3m diameter antenna with 33 dBi gain, h = 100m
Mobile antenna with 0 dBi gain. h = 1m flat terrain.

**Interference Contours**

Shown in Figure 1 is the contour figure from the report. It is slightly narrower than the same type of diagram for a USA microwave.

The 87 dB ray path loss contour is of particular interest. It is 9 km long and about 300 meters wide at the widest point. The area is about 1.4□km.

**Interference from LAN to Microwave**

From Annex1/3.2.1, it is concluded that "the integrated interference from all of the mobile stations operating within the area must be less than -126 dBW. At the 87 dB contour the sum of the power from all mobile stations must not exceed -47 dBW." This is ~20 μwatts in the bandwidth of the microwave system. As shown below, a 1□km system of either type creates far more power than this.

Using USA bandwidth and the power density from Table II for R2 indoor, the total power for a square kilometer is:

PCN:

1.5μW/□km/Hz x 1□km x 10 MHz = 15 W

LAN:

.00625 μW/□km/Hz x 1□km x 10 MHz = 0.0625 W

## TABLE IV – CCIR LINK POWER AND LEVEL BUDGET

**ANNEX 1** This annex presents an example of a link budget to estimate the permissible levels of interference to the FPLMTS. The values in the table relate to a time division duplex, time division multiple access system.

| PARAMETER | | INDOOR PERSONAL | OUTDOOR PERSONAL | RADIO LAN | |
|---|---|---|---|---|---|
| RANGE | r= | 25 | 125 | 10 | m |
| TRANSMIT POWER | Pt= | 3 | 20 | 1 | mW |
| | | 5 | 13 | 0 | dBm |
| BASE ANTENNA GAIN | Gt= | 0 | 0 | 3 | dBi |
| MOBILE ANTENNA GAIN | Gr= | 0 | 0 | 3 | dBi |
| PATH LOSS (note 1) | Lp(r)= | 70 | 80 | 57.5 | dB |
| NOMINAL RECEIVE LEVEL | | -65 | -67 | -51.5 | dBm |
| SHADOWING MARGIN (note 2) | Ms= | 14 | 14 | 0 | dB |
| FADE MARGIN (note 3) | Mf= | 15 | 15 | 10 | dB |
| MINIMUM RECEIVE LEVEL (note 4) | C= | -94 | -96 | -61.5 | dBm |
| REQUIRED C/(N+Ii+Ie) (note 5) | CNR= | 13 | 13 | 21 | dB |
| MAXIMUM (N+Ii+Ie) | | -107 | -109 | -82.5 | dBm |
| BANDWIDTH | Bw= | .050 | .050 | 40 | MHz |
| THERMAL NOISE IN BW | | -127 | -127 | -92 | dBm |
| NOISE FIGURE | | 5 | 5 | 10 | dB |
| THERMAL NOISE | N= | -122 | -122 | -82 | dBm |
| TOTAL INTERFERENCE ALLOWANCE | (Ii+Ie)= | -107 | -109 | NA | dBm |
| ASSUME 10% EXTERNAL INTERFERENCE | MAX Ie= | -117 | -119 | NA | dBm |

NOTES:
1. Lp(r) = 21 + 35 LOG (r) at 2 GHz suitable for office environment ranges beyond a few meters.
   38.5 + 20 log (r) line of sight free space path loss for outdoor applications.
2. Ms = 14 dB for coverage of 95% of cell periphery when shadowing obeys a log normal distribution with a standard deviation of 8 dB.
3. Mf = 15 dB for less than 0.1% outage time during a call using two channel diversity where fading obeys the Rayleigh distribution.
4. C = minimum received carrier power level.
   = p + Gt - Lp(r) - Ms - Mf + Gr
5. CNR = minimum carrier to total noise plus interference ratio.
   = C/)W+Ii+Ie

### Fade Margins for User Station

Table IV above, was prepared for calculation of the interference to the PCN system from the microwave system. Many of the items in this tabulation are developed for the radio LAN in another concurrently submitted 802.11 contribution titled: "Radio LAN System Power Budgets and Levels." This tabulation brings out many of the major differences between PCN and radio LAN.

For PCN, the shadowing and fade margins are 14 and 15 dB respectively. The same value is 19 dB smaller for radio LAN. This is a direct consequence of optical vs. bounce propagation. The shorter, optical radio path assumed is a further 12.5 dB advantage for LAN. Simultaneously, the radio sensitivity in the LAN is 5 dB inferior which results in an offsetting increase in transmitter power already taken into account.

The totals shown in the radio LAN column for required C/(N+Ii+Ie) and thermal noise should not used in other contexts since there may be a need for consistency with incompatible sets of assumptions.

**METHOD FOR APPROXIMATE ANALYSIS OF LAN INTERFERENCE**

A different approach to the interference analysis is take which is matched to the radio LAN. The concept is that each system is evaluated and rated in power contribution to a background noise level at the microwave receiver. The gross factors to consider are:

1) The number of access points in the system as a measure of SIZE.
2) The number of stations in the system as a measure of USAGE.
3) The location of the system as a measure of the PATH LOSS between the LAN and the microwave receiver.
4) The sufficiently probable NECESSARY LEVEL of the desired signal at the microwave receiver.

The results are a tabulation in which the following factors are listed and appropriately combined to produce the result in item E:

A) the noise generated by the LAN system multiplied by the number of such systems and weighted by their prospective air-time utilization.
B) The sensitivity of the microwave receiver and the level at which its apparent background noise level is degraded by 3 dB.
C) The minimum margin signal level in the microwave system necessary to override any additional noise and based on a realistic outage probability.
D) The necessary path loss between the radio LAN and the microwave antenna necessary to keep the degradation to the defined limit.
E) The definition of the locations relative to the microwave system where this desired limit can be met.

The key consideration for the microwave system is the margin that is actually available and the probability of decreased signal level. The tolerable interference level is typically 30-40 dB higher than calculated from receiver sensitivity because the evaluation is always performed assuming a fully faded microwave signal.

Interference may be viewed in two ways:

1) as a degradation of the receiver sensitivity, or
2) as the highest level relative to that of the desired signal at which no degradation will occur.

The second method is preferable since most microwave systems are operated with excessive rather than minimal margin. Given that most of these microwave systems are operated with excess margin, there is then the question of whether it can be spent on tolerance to other co-channel systems. It is spent this way, if the other interfering systems are distant or separated like-type microwave systems.

**Microwave Fade Margin**

radio system planners usually include non-obvious extra margin on the basis that radio system design is rarely criticized for too much signal. The following table is a common place "rule of thumb" for path margin:

| | | |
|---|---|---|
| 90% | = | 10 dB |
| 99% | = | 20 dB |
| 99.9% | = | 30 dB |
| 99.99% | = | 40 dB |

These numbers are fair for 30 miles at 6,000 GHz, and are pessimistic for lower frequencies and shorter paths. They may be appropriate for very long paths at lower frequencies.

Fades are mostly induced by weather conditions. Beside rain and snow, there is temperature inversion and atmospheric layering. There is sometimes long distance interference. None of these conditions correlate with traffic peaks between computers in offices and factories.

It is possible to believe that the probability of a microwave signal being 20 dB below normal is 1% or less at 1.9 GHz depending on path length. 20 dB margin is considered fair weighting.

**Sensitivity of a Microwave Receiver**

In order to estimate the probable signal level, it is possible to start with the receiver sensitivity and determine what the signal level must be with ample margin. This is doubly pessimistic. To assign numbers to this relationship, the input factors are discussed below.

In this analysis it is assumed that the interference is objectionable if it is sufficiently above the microwave receiver sensitivity threshold to cause noise or digital errors. The CCIR used 24 dB for 64QAM. This estimate uses 18 dB for 16QAM and FM. This arbitrary decision avoids the need to relate BER goals to signal level or to details of the modulation. The only remaining unspecified parameter is the channel bandwidth of the microwave receiver as follows:

| | |
|---|---|
| Noise bandwidth: | BW = 5, 10, 40 MHz |
| Boltzman noise power: | $= 1.6 \times 10^{-20} *$ BW |
| | = -98 dBm @ 10 MHz |
| Noise figure: | NF = 3 dB |
| Required C/N minimum: | C/N = 18 dB |

The receiver interference (and signal) sensitivity estimate contains the elements shown above. The noise power is equal to -95 dBm and the desired signal must be at least -77 dBm. With 30 dB margin, the desired signal is likely to be at least -47 dBm 99.9% of the time.

The required signal input level capable of causing interference must be less than the actual value of the signal by the required margin which may be 15-24 dB below -50 dBm. The microwave system operators would assert that the permissible level is 15-24 dB below -80 dBm is 0.1% probable.

Opinion: 18 dB below 20 dB (99% probability) below the typical level of the desired microwave system is a suitable maximum for the aggregate radio LAN noise in the microwave receiver. Accordingly, the following tabulation is the result of this assumption.

**TABLE V -- RECEIVER INTERFERENCE INPUT LEVELS VS. BANDWIDTH**

| Bandwidth-MHz: | 5 | 10 | 40 |
|---|---|---|---|
| Level-dBm: | −88 | −85 | −79 |

Following carefully what has been done, it will be seen that the required C/N has dropped out meaning that its value does not matter. The question can be considered on two factors:

1) The degradation of the receiver noise figure
2) The difference between the actual and minimum C/N levels.

The same result would be obtained by assuming that the tolerable interference level is the same as the receiver internal noise increased by 10 dB, the difference between design margin and assumed minimum margin (now called "excess" margin). There is a 3 dB error if these two margins are equal because the receiver noise has then been doubled.

**Effect of Microwave Antenna Pattern**

The exposure of the microwave receiver input is also a function of the directivity and power gain of the antenna to which it is connected. This function is entered only in the final budget since it is system dependent, but some of the factors are now discussed.

Microwave antennas are usually on towers or building roofs so that the beam passes well above local obstacles. An interferer is unlikely to be at the center of the beam or even near it except at the horizon on flat terrain or at a distance where spreading takes place. The beamwidth and pattern shape are factors in evaluating location in the interference level created. The susceptibility contours are of the shape previously shown in Figure 1. US systems use smaller antennas for economic reasons resulting in slightly wider beams and slightly less sensitivity.

Table VI, below, is the relationship between size, gain and beamwidth from the catalog of a commercial antenna supplier. FCC specifies to quality levels of antenna which are noted but not significant in this context.

**TABLE VI**
**CHARACTERISTICS OF 1.9 GHZ ANTENNAS**

| SIZE | GAIN | BEAMWIDTH | FCC |
|---|---|---|---|
| 6 ft 1.8 m | 28.7 dB | 6.0° @ -3 dB | B |
| 8 2.4 | 31.2 | 4.5 | A |
| 10 3.0 | 33.2 | 3.7 | A |

A simple and convenient formula for the pattern of a circular paraboidal microwave antenna with typical non-uniform illumination is not known, mainly because it depends on the pattern shape of the illumination antenna, however approximate formulas for the half power points and first nulls for a uniformly illuminated reflector are available for use as a first estimate:

$$BW_{-3\,dB} = 58/D_\lambda \qquad BW_{1st\,null} = 70/D_\lambda \text{ degrees}$$

For a dish diameter of 2.4 meters at 1900 MHz (15.8 cm), the angle between the first nulls is 10.7°. Beyond this angle the antenna can be assumed to have a gain of less than 0 dB.

**Radio LAN Transmitter Radiation Levels**

The path loss at 1.8 GHz in free space is 57.5 dB at 10 meters between isotropic antennas. The interference level of a 0 dBm transmitter is increased by 6 dB from LAN antenna gain, and it is decreased 6 dB because only 1/4th of the transmitted power is within the bandwidth of a 10 MHz wide microwave receiver.

At 10 meters, the signal level to an isotropic receiving antenna from a net 0 dBm transmitter is -57.5 dBm. (-58 dBm used below)

**Path Loss Beyond 10 Meters**

It is possible that the remaining path to a microwave antenna is optical, but it is more likely that there are obstacles like building walls and other buildings in the way. The propagation might be 12 dB/octave of distance for lightly obstructed propagation rather than 6 dB/octave for free space.

These two types of propagation are recognized in Table IV--Note 1. The "35 LOG" function is corrected for cluttered paths, and "20 LOG" for unobstructed paths. The Table IV approach uses two formulas. In contrast, the proposed method uses free space for up to 10 meters or the maximum LAN path length, and then uses the cluttered formula beyond (at 40 rather than 35 dB per decade). For example: 40 dB increase in propagation loss on a cluttered path requires one decade of distance increase. There is very little difference in the final outcome between the two methods.

**Trial Estimate**

Enough factors have been defined for a gross estimate of the necessary distance between the microwave receiver and the LAN transmitter. The assumptions given above are used, and one interference unit of 1,000 square meters is assumed.

| | | |
|---|---|---|
| Receiver interference threshold: | – 85 | dBm |
| Antenna gain: | – 31 | dB |
| Air interference sensitivity: | – 116 | dBm |
| LAN xmtr power @ 10 m: | – 58 | dBm |
| | ===== | |
| Minimum air path loss: | 58 | dB |

The interference sensitivity is that of the receiver increased by the antenna gain. The difference between the LAN transmit level at 10 meters and the microwave receiver air sensitivity is the path loss below which there will be interference.

In free space, 58 dB is an 800x factor on distance starting from 10 meters or 8 km. In a cluttered environment, 58 db is a 28x factor or 280 meters. The cluttered environment is not probable at such a short distance, since the beam will pass overhead from the clutter objects. Also, it is not very likely to have an optical path at a distance of 8 km.

| | |
|---|---|
| Interference distance-free space: | 8.0 km |
| Estimated unusable area: | 5 □km |
| Interference distance-clutter: | 0.2 km |

Once the interference range is out to a few kilometers, it does not take much of an rf level change to make big geographic distance changes. This is particularly true for lateral movement close to the center of a narrow beam.

If a number of interference units, say 20, covering proportionally more area were used, there would be a 13 dB increase in total transmitter power that would increase the cluttered interference range by 2.1x and the unobstructed path by 4.5x. (20 interference units would cover 100,000□ft and serve about 600 desks with 160 Mb/s of capacity). With this large an areas, it is probable that a large portion of the area would be shielded, and therefore not contribute to the power sum as assumed.

## FURTHER INTERFERENCE LEVEL CONSIDERATIONS

The interference question is too sensitive to simply pile worst-case on worst-case. On a simple geographical argument, it is clear that only a small percentage of real estate in front of each link antenna is a candidate for interference. It is essential to evaluate some of the probability factors that will reduce the actual levels below the general worst case.

### LAN Traffic

The business, "housewives," "school kids," and "Mother's day" busy hours are well known to telephone traffic analysts. In LAN, there is a traffic peak on late Friday afternoons when everyone stores their work. Even this singular interval is not normally a saturating load, but is still bursty in the detail.

It is the nature of normal LAN traffic to be bursty. The design is motivated more by fast response to please users than it is by efficiency in the use of transmission facilities. This leads to very high peak-to-average ratios. LAN duty cycle averages over any period of time is unlikely to go as high as 10%. The intensive bursts are more likely the result of a single user down-loading files, than a rare coincidence of the work peaks of many users.

For an 8 MHz LAN, with 64 users per system, it is asserted that active medium duty cycle will be under 10%. Depending upon the design of the access protocol question, the system may be 5% active with no traffic at all. It is now asserted that 25% peak activity is a high and sufficient number for the power addition of many LANs. This factor was used in the average power density estimates shown in Figure II.

### Pointed and Omni-directional Antennas

It is easy to assume that all radio LAN antennas are omni-directional, but it is not likely in high rate systems. Some mobile equipments may require such antennas, but most of the radio LAN stations may be movable rather than mobile. Temporarily located fixed units will gain greatly on intersymbol interference from using pointed antennas with 30° vertical and horizontal beam width.

It is now possible to assume such antennas are randomly pointed with respect to a particular microwave station with something like 10-to-1 that the orientation is not interfering. This is the same as reducing the summed power level by 10 dB.

It is also likely that access-point will use selected directive antennas and thus be included within the same probability rule.

### Adaptive LAN Transmit Power Levels

It is unlikely that all radio LAN transmitters are at extreme range from an access-point. It would be possible and desirable to include adaptation which would reduce battery drain when the range is shorter. Not only would this provide advantage to the LAN operation, it would also reduce the average power sum of all transmitters used in computing interference levels.

Downward steps of 3, 6 and 9 dB would make a significant difference in interference and power consumption. A fade margin of 10 dB is included in the LAN level budget, and it will not always be needed.

**Use of Uplink (Transmitting) Frequencies**

An obvious strategy is for the LAN to work in the half of the band used nearby for uplink (transmitting). There are then no or few receivers to be interfered with, however the LAN will be in difficulty receiving with much higher power interfering transmitters.

Should a LAN be able to work in the uplink band, it almost guarantees that reciprocal interference cannot occur. The antenna gains are about the same in either direction, but the transmitter power is 30 to 40 dB higher in the microwave equipment. The receiver noise figure in the LAN will be about 10 dB inferior to that in the microwave which would reduce the difference by the same amount. The reason the LAN can work is because the radio path is so much shorter for the desired signals.

It is also imaginable that access-point antennas will be installed to avoid transmitting or receiving in the one or two quadrants facing interfering transmitters.

This consideration is a reason for co-occupying this band with two assignments corresponding to the uplink and downlink groups even though that relationship is not practiced consistently.

**Other Probability Factors for Interference**

There is a 20% probability of LAN antenna being offensively oriented while transmitting.

There is a significant probability of obstruction from walls, fences and building shells.

It is probable that most building interiors will be under the microwave beam and isolated from it by building walls, floors and roof. The probability of exception might be 0.1%.

It is probable that the sensitivity contour of all microwave systems in the aggregate in a large city will cover only a small percentage of the land area of that city.

**INTERFERENCE-BASED COMPARISON AND EVALUATION OF PCN AND RADIO LAN**

The arguable central assumption of the PCN described in Tables I and II is enough capacity to replace wiring in buildings. This is a devastating assumption for estimating interference to existing systems. A more realistic assumption might be that 10% of the total capacity is furnished by wireless or 2,000 E/□km.

Unintentionally, the same thing appears to have been done with radio LAN, but this is not actually the case. In telecom, the peak capacity of the system is fully used in the busy hour. In LAN, the peak capacity is never used continuously.

The necessary peak capacity of a LAN is chosen on the basis or response time. It is sometimes said that file downloading should not take noticeable longer if the source hard disk is accessed via the LAN than if it is local. Sometimes, the peak LAN capacity in the medium is defined by the number of user stations that can share a common medium, but this is not applicable for the particular LAN model chosen. One access-point of 8 Mbits/s is shared by four user stations average, and no more than 8 peak. The usage of one access-point could be telephone of 1.2 E at 256 kbits/sec plus LAN at 36 Mbits/hour = 10 kbits/sec. The very low duty cycle of LAN avoids a serious problem with cellular technology. It allows instant and on-demand transfer of access capacity between fixed radio access-points. The effect of under-used capacity is silent transmitters not under-used per channel equipping. This is likely to apply also to some TDMA systems.

From the point of view of the created interference, the power sum is proportional to actual usage and not the degree and capacity of equipping. This is the primary advantage claimed for spread-spectrum systems, except that it may not be true for base stations which transmit continuously.

> When properly discounted for actual traffic carried to determine transmitter ON time, the LAN system will provide far more communication per unit of radiated power density.

One of the larger and more subtle differences is that connections (telephone voice circuits) are often used to transfer data by modems. The typical function put in packet message form would use far less transmission facilities. The use of a mixed packet and isochronous system will cause load to be moved from circuit-switched to packet intra and inter-premises facilities.

**PROGRAM FOR EXPERIMENTAL DETERMINATION OF INTERFERENCE LEVELS**

A useful experiment would consist of the following parts:

1) Development of a model radio LAN which has:
   a) useful service function,
   b) substantial capacity and coverage area,
   c) interference minimizing protocols, antennas and power levels.
2) Based on factual data on locations of licensed microwave radio systems, prediction of zones of possible interference, and then:
   a) measure interference susceptibility loss contours in two-dimensional mode projected to include effects of exterior walls of areas of probable use,
   b) measure building wall loss within buildings using uplink frequencies of microwave as signal generator,
   c) survey in-use microwave receivers for normal received signal level vs. minimum required level before considering unusual fading.
3) Develop technology for external measurement of microwave environment to determine experimentally based interference probability prediction.
4) Install operating system in context where known interference is possible, and instrument to observe and record simultaneously:
   a) received signal level and IF and demodulated output signal-to-noise ratio of vulnerable receivers,
   b) traffic activity on radio LAN identifying all transmissions (by access-point and by station), and processed into index of total transmitter activity vs. time and into a separation of stations by zone with a sampling interval of less than 1 millisecond.

The obvious goal is to observe interference effects occurring with a probability of less than 1/1000th of the operating time, to correlate those effects with the operating conditions in the LAN if possible identifying specific antenna directions and transmitters responsible.

A further goal is to determine what the actual margins are in the microwave systems, possibly from non-intrusive measurement means, to understand what latitude, if any, exists in adjustments to these systems.

If there is an argument, it would be easier to win if it were against a particular link rather than against an industry as a whole.

The result might be an organized way for radio LAN and point-to-point microwave to coexist in an orderly way.