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TELECOMMUNICATIONS INDUSTRY ASSOCIATION

March 17, 1995

William F. Caton, Acting Secretary
Federal Communications Commission
1919 M. Street, N. W. Room 222
Washington, D. C. 20554

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF SECRETARY

Re: ET Docket 93-235, ex parte
Additional Frequencies for Cordless Telephones

Dear Mr. Caton:

The attached report was prepared by the Telecommunications Industry Association Mobile & Personal Communications Division Consumer Radio Section at the request of Mr. Thomas E. Goode, of the Utilities Telecommunications Council, and Mr. Joseph M. Sandri, representing the American Petroleum Institute.

Please associate this material with the record of the above-referenced proceeding. If there are any questions regarding this matter, please contact the undersigned.

Respectfully submitted,

Daniel L. Bart
Vice President, Standards and Technology

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March 17, 1995

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On behalf of the TIA Mobile & Personal Communications Division's Consumer Radio Section, I would like to thank you for meeting with us last week and sharing your views on the interference issues in ET Docket No. 93-235.

At that meeting, you requested that we prepare a "white paper" discussing the potential for interference from cordless telephones to the Private Land Mobile Radio Services ("PLMRS"). That paper is enclosed, and discusses the possibility of interference from cordless telephones to PLMRS base stations. As you know, in our Reply Comments (filed December 22, 1993), we provided an analysis of the potential for interference from a cordless telephone to a PLMRS mobile unit.

It was my understanding at our meeting that you intend to circulate this paper to your engineering contacts. If, after reviewing the enclosed paper and our Reply Comments, you or your engineering contacts have further questions or concerns, please do not hesitate to contact me.

Best Regards,

Jay E. Padgett
Chairman, TIA Mobile & Personal
Communications Division
Consumer Radio Section

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ON THE POTENTIAL FOR INTERFERENCE FROM CORDLESS TELEPHONES TO THE PRIVATE LAND MOBILE RADIO SERVICES

Dr. Jay E. Padgett
Chairman, TIA Mobile & Personal Communications Division
Consumer Radio Section

March 17, 1995

INTRODUCTION

In the Notice of Proposed Rule Making (NPRM) in ET Docket No. 93-235,[1] the FCC proposed to allow cordless telephones to operate, on a secondary basis, on selected frequencies near 44 and 49 MHz that are allocated to the Private Land Mobile Radio Services (PLMRS). The NPRM was adopted in response to a Petition for Rule Making filed by the Telecommunications Industry Association (TIA) in August 1992. In Comments on the NPRM, concerns were raised by PLMRS user groups that there would be interference from cordless telephones to PLMRS operations, as well as from PLMRS to cordless.[2] During a meeting on March 7, 1995 between TIA and PLMRS representatives,[3] the PLMRS representatives explained that their primary concern was interference from PLMRS systems to cordless telephones. However, they requested that TIA prepare a paper discussing interference from cordless to PLMRS. The purpose of this paper is to respond to that request.

In its Reply Comments on the NPRM, TIA discussed the potential for interference from a cordless telephone to a PLMRS mobile unit, because it is possible for a mobile unit to be positioned relatively close to a cordless telephone. TIA demonstrated that due to the low power levels radiated by cordless telephones, a PLMRS system designed to be reliable in the presence of man-made background noise, such as ignition noise from the vehicle, should not be adversely affected by cordless telephones.[4] Since the potential for interference from cordless

1. Federal Communications Commission, Notice of Proposed Rule Making, ET Docket No. 93-235, "Amendment of Parts 15 and 90 of the Commission's Rules to Provide Additional Frequencies for Cordless Telephones," Adopted August 20, 1993; Released September 17, 1993.
2. *See* the Comments of the American Petroleum Institute, Forest Industries Telecommunications, and the Utilities Telecommunications Council.
3. *See* the meeting notes filed by TIA under an *ex parte* letter on March 13, 1995, ET Docket No. 93-235.
4. *See* Reply Comments of the TIA Mobile & Personal Communications Consumer Radio Section, ET Docket No. 93-235, filed December 22, 1993.

telephones to a mobile unit already has been discussed in detail, this paper will focus on the potential for interference to a PLMRS base station.

SYSTEM PARAMETERS AND RECEIVED INTERFERENCE

It is assumed here that the PLMRS base station has an antenna elevated 300 feet above terrain, an antenna gain of 6 dBi, and an effective isotropic radiated power (EIRP) of 300 watts (54.8 dBm). The effective intermediate frequency (IF) noise bandwidth is assumed to be 20 kHz. The proposed rules for cordless telephones specify a maximum field strength of 10 mV/m measured at 3 m, which translates to an EIRP of 30 μW (-15.2 dBm), or an effective radiated power (ERP) of 20 μW (-17 dBm). Because the cordless telephone antenna is less than a quarter-wavelength, it is loaded, and its efficiency is reduced due to loading coil losses. It will be assumed here for discussion purposes that the antenna "gain" for the cordless telephone is -10 dBi; i.e., a 10 dB effective loss in received signal relative to an ideal isotropic antenna. The actual loss may be somewhat greater for the handset, and less for the base (which has a longer and more efficient antenna than the handset). The cordless telephone is also assumed to have an IF noise bandwidth of 20 kHz. As will be seen, the base station elevation and gain, and the cordless telephone antenna "gain" can be chosen almost arbitrarily without affecting the main conclusion.

For a 20 kHz noise bandwidth, the noise floor[5] in dBm is $-131 + F$, where F represents the noise added by the receiver and the environment. While overall receiver noise figures typically are in the range of 6 to 8 dB (which are used in "receive sensitivity" calculations), noise in the frequency bands of interest often is dominated by ambient man-made noise. As shown in Fig. 1, the effective man-made noise factor F_a at frequencies near 50 MHz is about 32 dB for the suburban environment and 46 dB for the urban environment.[6] It should be noted that the values given in Fig. 1 are *median* values; that actual environmental noise at a particular place and time is obviously variable. Moreover, frequencies in the range of interest here are subject to "skip" (propagation via reflection from the ionosphere), whereby a PLMRS base station can receive interference from another high-power base station several thousand miles away. A system designed for high reliability, such as a PLMRS system, must incorporate sufficient margin in the link budget to overcome "worst-case" (or nearly so) conditions. It therefore does not seem unreasonable to assume that a well-engineered PLMRS system would incorporate a man-made noise/interference margin of at least 30 dB. This would mean that

5. Thermal noise, excluding any device or environmental noise, is kT_0B, where k is Boltzman's constant (1.38×10^{-23} watts/Hz/°K), B is the noise bandwidth, and T_0 is the reference temperature, typically taken as 290°K. For B = 20 kHz, kT_0B is -131 dBm.

6. Fig. 1 is reproduced from Fig. 1, p. 29-2 of *Reference Data for Radio Engineers*, Sixth Ed., Howard W. Sams & Co., 1981.

the effective noise floor for link budget calculations is -101 dBm plus the antenna gain, or -95 dBm for a 6 dBi antenna gain.[7] A signal received from a cordless telephone radiating the maximum -15.2 dBm EIRP will be above -95 dBm if the path loss is less than 85.8 dB (again, the antenna gain of the PLMRS base station has been taken into account). With this path loss, the signal received by the cordless telephone from the PLMRS transmitter is 54.8 dBm - 85.8 dB - 10 dBi = -41 dBm. If the cordless base and handset are separated by 3 meters, the power received by the cordless base from its handset is (coincidentally) about -41 dBm, assuming the handset is radiating the maximum allowed power, and accounting for the 10 dB antenna system loss. If a 10 dB carrier-to-interference ratio is required for the cordless base receiver to "capture" the channel, then the interference can be no greater than -51 dBm for the channel to be usable to the cordless telephone. This means that the path loss from the PLMRS transmitter to the cordless telephone must be at least 95.8 dB. In that case, the power received by the PLMRS base unit from the cordless telephone is -15.2 dBm - 95.8 dB + 6 dBi = -105 dBm, which is 10 dB below the assumed environmental noise threshold at the PLMRS base. Clearly, if the cordless base and handset are separated by more than 3 meters, then the cordless telephone will have a lower tolerance for interference, and the path loss to the PLMRS base station must be even greater.

The conclusion is clear: if the signal from the PLMRS base station is weak enough so that the cordless telephone can use the channel, then the cordless telephone is too far away from the PLMRS base station to cause significant interference to the PLMRS base station. Note that this conclusion does not depend on any particular assumptions about propagation path loss vs. distance.

PROPAGATION

To understand the implications of the above calculations on "separation distances" required to avoid cordless-to-PLMRS interference, the relationship between path loss and transmitter-receiver separation need to be understood. Fig. 2 shows path loss vs. distance for several different cases. The "free space" case represents totally unobstructed propagation with no diffraction, phase cancellation due to reflections, etc. The "smooth earth" curve represents the case in which there is a direct path and a ground-reflected path between the transmitting and receiving antennas. The ground-reflected wave is shifted in phase relative to the direct wave at the receiving antenna, due to the path length difference as well as the reflection coefficient. The field at the receiving antenna is the complex phasor sum of the direct and reflected fields. The reflection coefficient depends on frequency and angle of incidence, as well as the

7. Unlike receiver device noise, ambient noise and interference enter the receiver through the antenna, and therefore are subject to antenna gain or loss.

conductivity and relative dielectric constant of the earth, denoted by σ (in mhos/meter) and ε_R, respectively.[8] For the case shown in Fig. 1, it was assumed that $\sigma = 0.01$ mho/m and $\varepsilon_R = 20$.

Both the free space and smooth earth models represent somewhat idealized cases, but are nevertheless useful for establishing reference points. The "Hata" model was derived from analysis of actual propagation measurement data,[9] and gives the median path loss in the form $a + b \log r$, where a depends on frequency and terrain as well as the base and mobile antenna heights, and b depends on the base antenna height. The Hata formulas apply to frequencies between 150 MHz and 1.5 GHz, so application of the Hata model to 48 MHz propagation is an extrapolation. However, it is useful for comparison with the free space and smooth earth models. It should also be noted that the Hata model is defined for distances between 1 and 20 km, which is why the Hata curves in Fig. 2 are only shown for distances greater than 0.6 mile.

Fig. 3 shows the interference power received by the PLMRS base station from the cordless telephone, and by the cordless telephone from the PLMRS base station, using the smooth earth path loss model. It was assumed that both the cordless telephone base station and handset are indoors, and the building attenuation is 15 dB. The other parameters and assumptions are the same as those previously discussed. These curves were computed using:

$$P_{R,LM} = P_{TX,CT} - L_{SE} + G_{A,LM} - A_B$$

$$P_{R,CT} = P_{TX,LM} - L_{SE} + G_{A,CT} - A_B \ ,$$

where P_{TX} and P_R represent the EIRP and received power, L_{SE} is the "smooth earth" path loss, G_A is the effective antenna gain, and A_B is the building attenuation. The "CT" and "LM" designations in the subscripts indicate that the subscripted parameters pertain to the cordless telephone and the PLMRS base station, respectively.

Fig. 4 shows the same relationships as Fig. 3, except that there was assumed to be no building attenuation. Note that in Fig. 4, the absolute distances corresponding to the thresholds are different than in Fig. 3, but the relationship between them will be essentially the same. The use of a different path loss model (e.g., Hata) would yield similar results, although the absolute distances would depend on the specific model as well as assumptions about the type of terrain involved (suburban or urban, for example). In any case, if the cordless telephone is able to use

8. For details on calculating the reflection coefficient, *see* E. C. Jordan and K. G. Balmain, *Electromagnetic Waves and Radiating Systems*, second ed., Prentice-Hall, 1968, chapter 16.

9. M. Hata, "Empirical Formula for Propagation Loss in the Land Mobile Radio Services," *IEEE Transactions on Vehicular Technology*, vol. VT-29, no. 3, August, 1980, pp. 317-325.

the frequency in the presence of the PLMRS signal, it will be too far away from the PLMRS base station to interfere with the operation of a well-designed PLMRS system.

It also should be noted that changing the antenna gain assumptions will not change this conclusion. For example, if the PLMRS antenna gain is increased to 9 dB, both the lower curve and the environmental noise level will increase by 3 dB, so the distance at which the curve crosses the environmental noise level will remain constant. If the PLMRS ERP is unchanged (i.e., the PLMRS transmit power decreases by 3 dB), the upper curve will not change. If the cordless antenna gain is changed, the upper curve will move, but the "maximum tolerable interference" level will move by an equal amount, and again, the corresponding distance will stay the same.

It should be emphasized that the assumption of a 3-meter separation between the cordless base and handset, and the corresponding free-space path loss (about 15 dB) is optimistic. The cordless telephone user often will be further than 3 meters from the cordless base, and may well be in a different room with no line-of-sight path between the handset and base. In that case, the propagation path will be subject to additional losses due to diffraction, reflections, and penetration through walls, as well as the increased separation. In addition, multipath can cause signal fades on the order of 15 to 20 dB. Therefore, the path loss between the cordless base and handset could easily be on the order of 30 to 40 dB. A 40 dB path loss would reduce the "tolerable interference" threshold to about 25 dB below that shown in Figs. 3 and 4, to -76 dBm. This serves to provide the PLRMS base station with an additional margin of protection from cordless telephone interference.

THE INTERFERENCE-AVOIDANCE REQUIREMENT

The NPRM proposes a requirement that a cordless telephone using the proposed new frequencies "incorporate an automatic channel selection mechanism that will prevent establishment of a link on an occupied frequency."[10] While no absolute threshold levels are specified, the calculations discussed above suggest that for its own protection, a cordless telephone using an absolute received signal strength threshold should not set the threshold near the top if its dynamic range.[11]

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10. *See* NPRM at p. 4 (Appendix).

11. There obviously is a tradeoff involved in setting absolute threshold levels. A low threshold (i.e., -100 dBm) would provide the cordless telephone with more protection from interference during a call as the user moves around and the received signal level changes, but could result in unacceptable "blocking" levels in high-noise environments (as shown in Fig. 1, urban ambient noise factors can exceed 40 dB). Conversely, high thresholds (e.g., -60 dBm) would result in lower blocking probabilities but higher probabilities of mid-call interference as the cordless handset moves away from its base station. Regardless of the exact interference avoidance protocol or thresholds used, the PLMRS base station will be protected as shown above.

It might be argued that the high PLMRS signal levels received by cordless telephones near PLMRS base stations could lead to chronic interference with cordless communication, resulting in complaints by cordless users. However, if the activity factor of the PLMRS base is reasonably high and the cordless telephone is well-designed, this should not be the case. If the cordless telephone attempts to establish a link when the PLMRS base transmitter is active, it will avoid the frequency (and presumably try another one). If interference occurs during a call, the cordless user must change frequencies to continue the cordless communication. In either case, the cordless telephone will have been removed from the PLMRS base station frequency. The cordless telephone should "remember" either the highly-interfered frequency, or the clear channel, or perhaps both, and make the next call attempt on a different frequency.

CONCLUSION

This paper has discussed the potential for interference from cordless telephones to PLMRS base stations. When the operating parameters of cordless telephones and PLMRS systems are considered, it is clear that interference from cordless telephones to a PLMRS base station should not be a concern, if the PLMRS system is engineered for reliable operation in the presence of normal interference phenomena, such as atmospheric "skip" and ambient man-made environmental noise. In the presence of the high-power PLMRS base station transmission, the cordless telephone will be unable to operate on the PLMRS frequency (even if the cordless base and handset are only 3 meters apart) if the cordless telephone is near enough to the PLMRS base station to cause significant interference. A well-designed cordless telephone, incorporating an interference-avoidance mechanism as proposed in the NPRM, will avoid using frequencies assigned to nearby PLMRS base stations. Regardless of the exact interference-avoidance mechanism used by the cordless telephone, the PLMRS base station will be protected from cordless telephone interference simply because of the 70 dB difference between the power radiated by the PLMRS base station and that radiated by the cordless telephone.

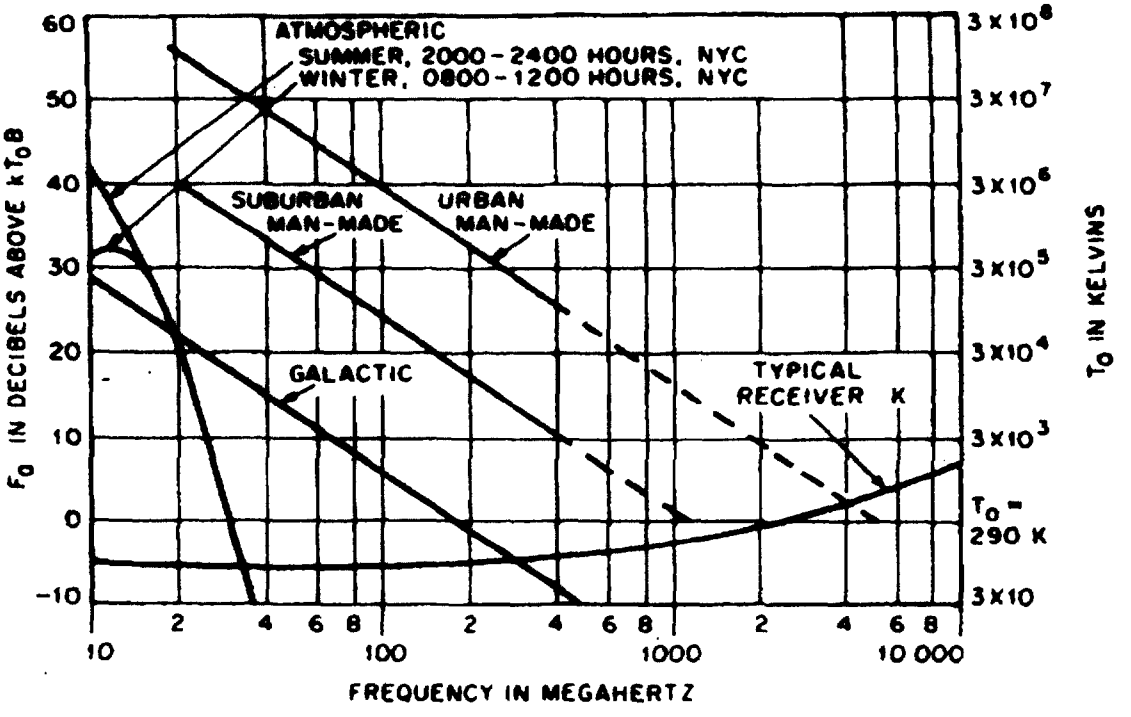

Figure 1: Median values of average noise power expected from various sources (omnidirectional antenna near surface). [Reproduced from Fig. 1, p. 29-2 of *Reference Data for Radio Engineers*, Sixth Ed., Howard W. Sams & Co., 1981.]

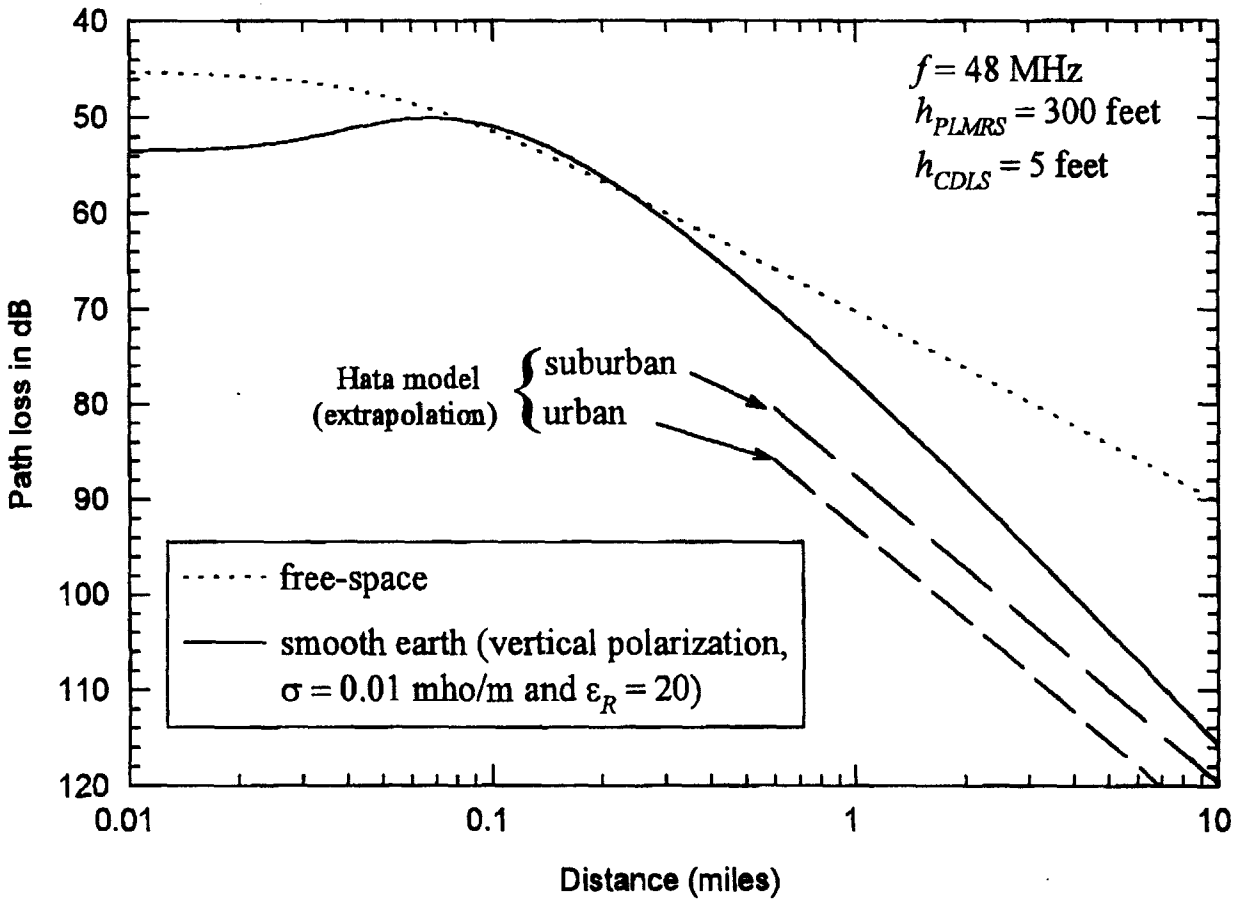
40
50
60
70
80
90
100
110
120
Path loss in dB
0.01
0.1
1
10
Distance (miles)
$f = 48$ MHz
$h_{PLMRS} = 300$ feet
$h_{CDLS} = 5$ feet
Hata model (extrapolation)
suburban
urban
free-space
smooth earth (vertical polarization, $\sigma = 0.01$ mho/m and $\varepsilon_R = 20$)

Figure 2

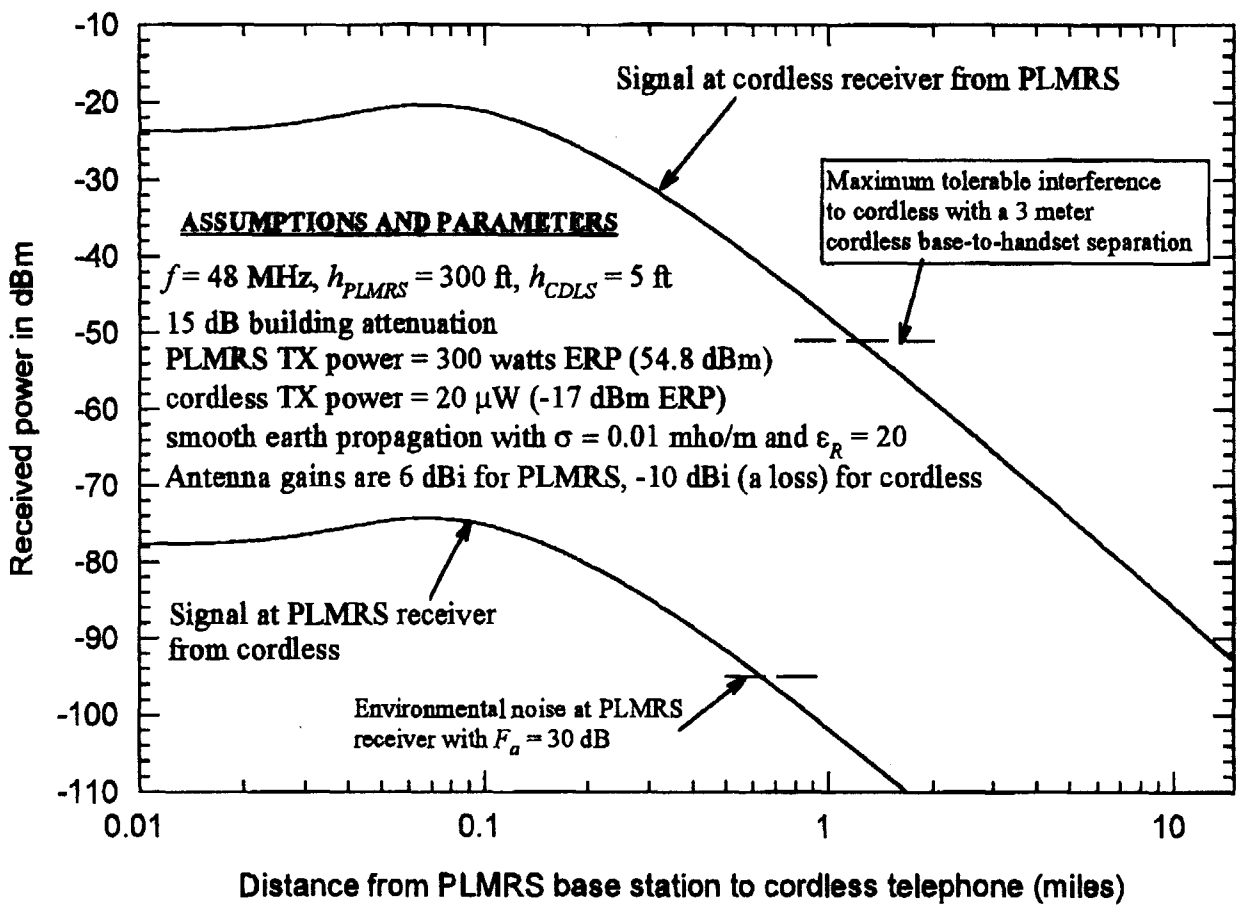
Signal at cordless receiver from PLMRS
Maximum tolerable interference to cordless with a 3 meter cordless base-to-handset separation
ASSUMPTIONS AND PARAMETERS
f = 48 MHz, h_PLMRS = 300 ft, h_CDLS = 5 ft
15 dB building attenuation
PLMRS TX power = 300 watts ERP (54.8 dBm)
cordless TX power = 20 μW (-17 dBm ERP)
smooth earth propagation with σ = 0.01 mho/m and ε_R = 20
Antenna gains are 6 dBi for PLMRS, -10 dBi (a loss) for cordless
Signal at PLMRS receiver from cordless
Environmental noise at PLMRS receiver with F_a = 30 dB
Received power in dBm
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
0.01
0.1
1
10
Distance from PLMRS base station to cordless telephone (miles)

Figure 3

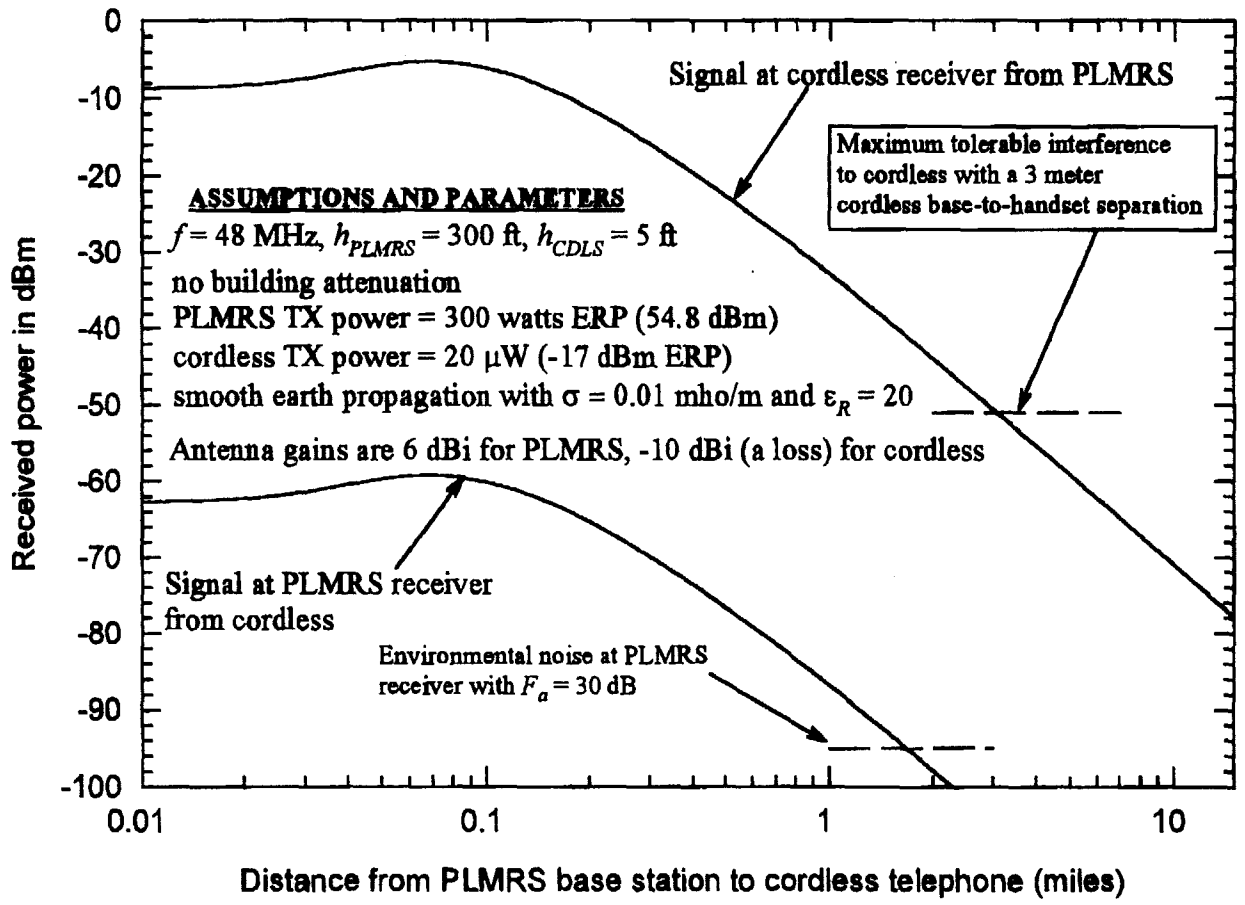
Signal at cordless receiver from PLMRS
Maximum tolerable interference to cordless with a 3 meter cordless base-to-handset separation
ASSUMPTIONS AND PARAMETERS
f = 48 MHz, h_PLMRS = 300 ft, h_CDLS = 5 ft
no building attenuation
PLMRS TX power = 300 watts ERP (54.8 dBm)
cordless TX power = 20 μW (-17 dBm ERP)
smooth earth propagation with σ = 0.01 mho/m and ε_R = 20
Antenna gains are 6 dBi for PLMRS, -10 dBi (a loss) for cordless
Signal at PLMRS receiver from cordless
Environmental noise at PLMRS receiver with F_a = 30 dB
Received power in dBm
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
0.01
0.1
1
10
Distance from PLMRS base station to cordless telephone (miles)

Figure 4