As demonstrated in the statement attached as Exhibit A, for HML systems operating within certain limits imposed by practical protocol and signal flight-time requirements, there is an exponential rather than proportional relationship between occupied bandwidth and throughput. For example, multilateration systems such as PacTel's, which is presumed to use a code-sequence phase-difference measuring scheme, would experience throughput gains as the square of the bandwidth.[36] Thus, moving from 8 MHz to 26 MHz, the entire AVM allocation, allows such systems to experience an increase in throughput capacity of over 10 times greater than that achievable at 8 MHz.

For some other systems, such as Pinpoint's, which employ multiple narrow-pulse multilateration, the relationship is that throughput increases as the *cube* of the bandwidth. Thus theoretically, moving from 8 MHz bandwidth to 26 MHz, could lead to over a *thirty-four-fold* increase in throughput.[37] While it is not possible to achieve all of this increase in practical systems because of conflicting requirements resulting from other system-imposed restrictions, like worst-case delay spread, minimum signal flight times and signalling protocols, significant, non-proportional gains in throughput can be realized by using the widest practical bandwidths.

The implications for sharing and efficient spectrum use are readily apparent. Among wideband systems, the number of systems that can enter any given market

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[36] Jackson Affidavit, FCC File Nos. 347483 - 347502 at ¶ 21 (Apr. 6, 1993).

[37] Even if noise conditions limit the available bandwidth to 18 MHz, the increase in throughput would be over eleven times that achievable at 8 MHz, more than twice the increase with a phase-difference measuring system.

would increase dramatically as the spreading of bandwidth is maximized, spurring competition. This ability to accommodate additional entrants can also act as a brake on speculation, as a rather high number of parties would have to build systems before existing operators would have a strong incentive to buy them out.

Moreover, the incorporation of the forward link in the same wideband used for position fixing can make sharing with local-area systems easier as well because of the proportionately shorter time the forward link needs to communicate with the mobile. As a result, the intermittent signals from tag readers would be less likely to cause interference to wide area base station transmissions to mobiles.[38]

Perhaps even more important are the implications for IVHS. In order to monitor traffic flow over a large area, so as to make traffic management feasible, a large capacity will be necessary in major urban areas. For example, an urban area with a population of 1,000,000, which would contain approximately 770,000 registered vehicles, would require vehicle location capacity to accommodate 277,200 polls/location fixes per hour of peak traffic. This conservative estimate is calculated on the basis of only 19,250 vehicles equipped with location technology (i.e. only 2.50% of the registered vehicles in the urban area would participate in an IVHS program), thus

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[38] For example, an increase in forward link bandwidth might reduce a base station transmission to a particular mobile from 40 ms to 10 ms transmission from the wide-area base station. A local-area system reader pulse of 10 ms would have wiped out the entire 40 ms pulse, whereas a 10 ms transmission from the wide-area base station would be more likely to go through without interference by the reader's pulse.

resulting in a measure of 11,550 equipped vehicles on the road during peak hours.[39]

co-channel noise, at this time we believe that these are generally not reasonable or cost-effective solutions. Accordingly, we propose that narrow-band LMS systems not be licensed on the bands currently occupied by wide is almost 20 dB above the level achieved by PacTel on its system.[44] Because the mobile radios will be powered up for transmissions of less than 10 ms on a very intermittent basis, such power levels will not greatly affect the price of the radios. Finally, increased mobile power may reduce the necessary number of fixed stations, lowering overall system costs.

Power management is an important aspect of achieving efficient use of the 902-928 MHz shared resource. Radio-location system operating in the 902 to 928 MHz band will be co-channel sharing the band with many other services, including, but not limited to Part 15 low-power and spread spectrum users, and local-area systems like back-scatter tag readers. While the suggested power levels used by these systems are relatively low, their effect is far from insignificant to the operation of wide area system, like those of Pinpoint or Pactel. It seems from Pactel's previous representations that the application approach taken by Pactel was to use relatively low power (in the hopes that) they would have a relatively quiet (i.e. relatively low background noise or interference level) band in which to operate. Since the noise and interference levels have turned out to be substantially larger than they expected, they are now seeking ways to manage the band's noise level by seeking exclusivity means.

However, there are other means for achieving the successful operation of wide area system, notwithstanding the co-channel operation of the other local-area and Part 15 systems and devices. One of these is by appropriate power or signal level

[44] PacTel is currently using 5 W transmitters with an antenna gain of -10 dB.

management of the wide-area and local-area systems in relation to each other. Exhibit C shows the effect of changing the distance between a wide area base station and a local-area tag-reader station on the size and extent of the signal "black-out" zone experienced by a wide-area mobile in the vicinity of the reader station. The size of the "black-out" zone can be changed by changing the ratio of the power of the reader station in relation to the power of the base station, or by changing the distance of the base station from the reader station. Similar effects occur relative to the communication range experienced by the wide-area base station in response to jammer interference from the reader station.

Since the local-area systems are generally relatively short range, and operate with relatively high (receive) signal levels (typically -10 to -20 dBm) resulting from +23dBm illumination levels, field measurements by Pinpoint have shown that there is little likelihood that they will suffer undue interference from relatively high-powered, wide-area base stations, suitable placed in relation to them (1000 to 3000 ft. away, on structures from 100 to 300 ft. height). However, in order to maintain reliable operation of the wide-area systems over the communications ranges needed for economic infrastructure deployment, typically greater than 5 miles average spacing between base stations, the base station power levels will need to be able to operate up to 5 kilowatt ERP in order to be able to ensure that the mobile's will be able to receive the base signals while near to local-area system noise/jamming sources. This will be especially true as more part 15 devices enter the 902 - 928 MHz band. Conversely, there seems to also be a need for a part of the band in which low powered wide-area networks (such as Pactel teletrac) may operate. While the same principles of power level management still hold true, the relative power levels referred to above are much too high for the power levels used by the low-powered wide-area systems, and so power levels used by the local area systems in that part of the band used by the low-powered wide-area systems would need to be reduced accordingly.

Therefore, by managing the relative power levels used by the wide-area systems in relation to the local-area systems, both can enjoy adequate levels of service availability and reliability. However, for this to work, the band plans, including the power levels in each band need to reflect this management scheme.

A second primary factor in improving system robustness, and reducing the interference susceptibility of wide-area to local-area systems, is for HML operators to judiciously select base station configurations. Given existing applications of local-area systems, such as automatic toll booths and airport terminal traffic management, site selection by wide-area system operators can take into account the location of some potential black-out areas, as well as existing local-area operations, further diminishing their potential interfering effect.

Other techniques exist for alleviating the interference potential between local-area and wide-area systems. For example, notch filters and interference suppression systems may be used to counter the energy from local-area systems falling within the wide-area signals. These methods would be most effective at base station receivers, where the noise environment is relatively stable, and in response to narrowband local-area systems, which appear by far to be the most prolific to date.

Another method for countering the black-out areas created by local-area operations is simply through retransmissions, as necessary, by wide-area system base stations and mobiles. It would be a relatively simple matter for a base station to determine that its transmission was not received given the absence of a response from the mobile and vice versa. Particularly as throughput capacity goes up with increasing bandwidth, the effects of retransmission's on total volume will be minimal. Further, as black out areas are reduced through reasonable power levels and the careful location of base station sites, as described above, the need to retransmit will decline.

In conclusion, while a certain amount of interference may occur between wide-area and local-area systems, the degree of conflict has been overstated by PacTel and others. The Commission should not be misled. Numerous readily available adjustments and techniques allow wide-area systems to improve robustness and reduce drastically the potential adverse affects of co-existence with local-area systems. The basic result is that high quality wide-area AVM service can be provided in shared spectrum.

D. THE COMMISSION SHOULD ADOPT A BAND PLAN THAT MAXIMIZES THE BANDWIDTH AVAILABLE FOR WIDE AREA SYSTEMS

The three conditions explained in the previous sections support a wide-area allocation that allows for maximum bandwidth and, given the need to accommodate the spectrum requirement of local-area systems, that incorporates sharing with local-area systems. First, the more spectrum available to a wide-area system, the greater its throughput capacity by an exponential factor. Second, wide-area systems can share now. Third, wide-area systems can tolerate the presence of local-area operations without sacrificing high-quality service.

Based on these three conditions, Pinpoint submits that the Commission should open the entire 26 MHz to *all* AVM systems, whether wide-area or local-area. Wide-area systems should be subject to the following power limits: 5000 W ERP for base stations and 50 W ERP for mobiles. Local-area systems should be subject to more stringent limits, 30 W ERP for base stations and 1 W ERP for mobiles and antenna heights of 10 meters or less above ground.[45] Figure 1, attached hereto, illustrates Pinpoint's preferred band plan.

There are numerous benefits to this plan, which is effectively an extrapolation of the current interim band plan. Wide-area systems would have unlimited flexibility, within the constraints of the AVM allocation, to implement systems of various wide bandwidths.[46] Most importantly, Pinpoint asserts, wide-area systems will be able to maximize throughput capacity by employing bandwidths up to 26 MHz, which will both accommodate the high-volume requirements of IVHS as well as facilitate competition among the greatest number of operators. In contrast, under the *NPRM*,

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[45] Pinpoint understands that some local area systems may incorporate highway beacons to send instructional messages to units being located. In order to operate effectively, these beacons will have to have a coverage area of several lanes, as many as eight or ten. Thus a higher power limit for such beacons might be appropriate but such uses should be restricted to the uppermost and lowermost portions of the band, for example 902-906 and 924-928 MHz.

[46] *See infra* pp 34 - 37 discussing sharing negotiations.

wide-area systems would be limited to an 8 MHz bandwidth, which is the minimum acceptable bandwidth for IVHS applications.

Local-area systems would also have maximum freedom to select their frequencies. This will permit wideband local-area systems to maximize their data rates as well as to select multiple channels with the greatest freedom as their particular applications require. In cases of interference experienced by such systems, they would have considerable flexibility to adjust their frequencies of operation. Under the *NPRM*, in contrast, wideband local-area systems would effectively be relegated to the 912-918 MHz sub-band with much less freedom to move. Narrowband local-area systems should have sufficient spectrum space to deploy as many readers as needed at a given site. Indeed, if a 1 MHz separation between local area base stations is required, up to twenty-six frequency-diverse stations could be installed in a given site. Further, under this arrangement, in a typical situation where fewer base station frequencies will be needed, local-area operators will have more flexibility to move to new frequencies in cooperative response to actual cases of harmful interference to other AVM operators.

However, Pinpoint is aware that some wide-area licensees claim an inability to co-exist with local area operations. Pinpoint believes that such assertions have only stated the adverse effects of local area systems in relation to the power levels chosen by those systems and that with different approaches high-quality wide-area service is nonetheless achievable in their presence. Should these operators provide a more convincing demonstration of the need for a more quiet noise environment, the FCC may conclude that some accommodation should be made for low-power wide-area licensees.

Recognizing that such systems appear to require 4 MHz or less spectrum to operate,[47] Pinpoint proposes the following modifications to the band plan outlined above should persuasive evidence from PacTel and others be forthcoming:

- In the 907-909 and 921-923 MHz sub-bands, power from local-area base stations and mobiles would be limited to 50 mW ERP, and
- In the 906-907, 911-912, 920-921, and 923-924 MHz sub-bands, local-area base stations and mobiles would be limited to 200 mW ERP and 50 mW ERP, respectively.

In this way, the noise from local area system base stations would be reduced by almost 30 dB in those bands currently used by wide area systems claiming to need a much lower operating noise level. This alternative band plan is depicted in Figure 2, attached hereto. Under this plan, wide-area systems such as Pinpoint that wish to spread over more than 8 MHz band in order to obtain the significant throughput advances would be free to do so, consistent with the need to share with other wide-area systems.

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[47] PacTel Reply to Oppositions to Application for Review and Petition for Stay at 9 (filed June 21, 1993).

IV. SHARING SHOULD BE IMPLEMENTED BY OPENING WINDOWS FOR APPLICATIONS FOLLOWED BY A NEGOTIATED SHARING AGREEMENTS AMONG QUALIFIED APPLICANTS

As explained above, sharing among wide-area systems is possible now and is practical. Pinpoint has described earlier how sharing might, as a technical matter, be

    - A firm financial commitment of sufficient resources to build and operate for one year, without revenues, a minimum acceptable system covering at least 25 square miles of the market with position-fixing capability.

    - Use of a demonstrably proven technology -- through commercial or experimental operation -- that meets minimum throughput and robustness criteria.[51]

    - Legal qualification to be a licensee.[52]

- The FCC would review applications to determine that showings had been [illegible] announcement shall be given 120 days before the operations commence)[54];

- If all of the members of the sharing group agree to a plan, it would be submitted to the Commission for approval; sharing plans would be deemed approved by the Commission unless the sharing group were notified by the Commission within 60 days after submittal of the plan that such automatic approval was being withheld and that the plan would only be approved by the Commission after submission of answers to questions posed by the Private Radio Bureau.

- If unanimous agreement could not be obtained by all members of the sharing group before the end of six months, the FCC will grant the applications and require that the members of the sharing group each receive allotments of one-half second of air time on a regular, periodic basis, the interval between air-time slots for a given licensee to be determined by the numbers of sharing group members.[55] The time-

- No authorization may be assigned or control of any company holding an authorization transferred if a minimum acceptable system under that operation is unbuilt.

- No rights acquired as a tentative licensee may be assigned or transferred, directly or indirectly (e.g. through a transfer of control of the entity holding the status of tentative licensee or the parent thereof).

- Failure to make the payments required under the sharing plan or to operate in compliance with the sharing plan shall be grounds for the revocation of the license.

Under this arrangement, the tentative licensees would have the incentive to negotiate in order to maximize the amount of air time available to them, *e.g.* by combining frequency division with time division multiple access if two systems could operate during the same time slice. The default sharing plan would give all licensees an incentive to agree upon a better plan by reducing their air-time, and hence their throughput. Thus, it would deter a tentative license from acting as "spoiler."

A speculator would be deterred because of the need to have a demonstrably proven technology, the need to construct a minimum acceptable system before assignment and transfer, and the need to pay for the costs of sharing even if its system were not constructed.

The plan provides for an eighteen-month construction period. In some instances, this may be an insufficient amount of time. For example, one licensee may have authorizations in twenty, thirty, or even fifty markets. Accordingly, Pinpoint submits that the rules should provide for extended implementation -- up to three years (five years in certain, independently justified cases) -- when any of the following three showings is made at the time of application:[57]

- The planning, approval, funding, purchase, and construction of the licensee's systems require a multi-year cycle. (While this situation might most commonly arise with governmental applicants, non-governmental entities could qualify for an extended period on this basis.)

- The size, complexity, or purpose of the systems warrants an extended period.

- The coordination or integration involved in a network of wide-area LMS systems requires an extended period.

In considering requests for extended periods, the Commission should consider the degree to which an extension might impede competition among LMS systems. In this regard, the Commission should not grant extended construction schedules longer than five-years. If, at the end of an extended schedule, some of a licensees systems remain unbuilt, the licenses for the unconstructed sites should automatically expire and that licensee's allotments of time in each affected market should go equally to each remaining licensees in the sharing group.

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[57] Existing licensees should be given the opportunity to request extended construction periods under these criteria for sixty-days following the publication of a final rule.

V. CONCLUSION

The proceeding affords the Commission an opportunity set the stage for a variety of useful AVM services. Pinpoint urges the Commission to eschew the duopoly structure set forth as an alternative in the *NPRM* and to adopt regulations that foster sharing and efficient use of the band, in order to bring innovative technology to the American public in a competitive environment.

Respectfully submitted,

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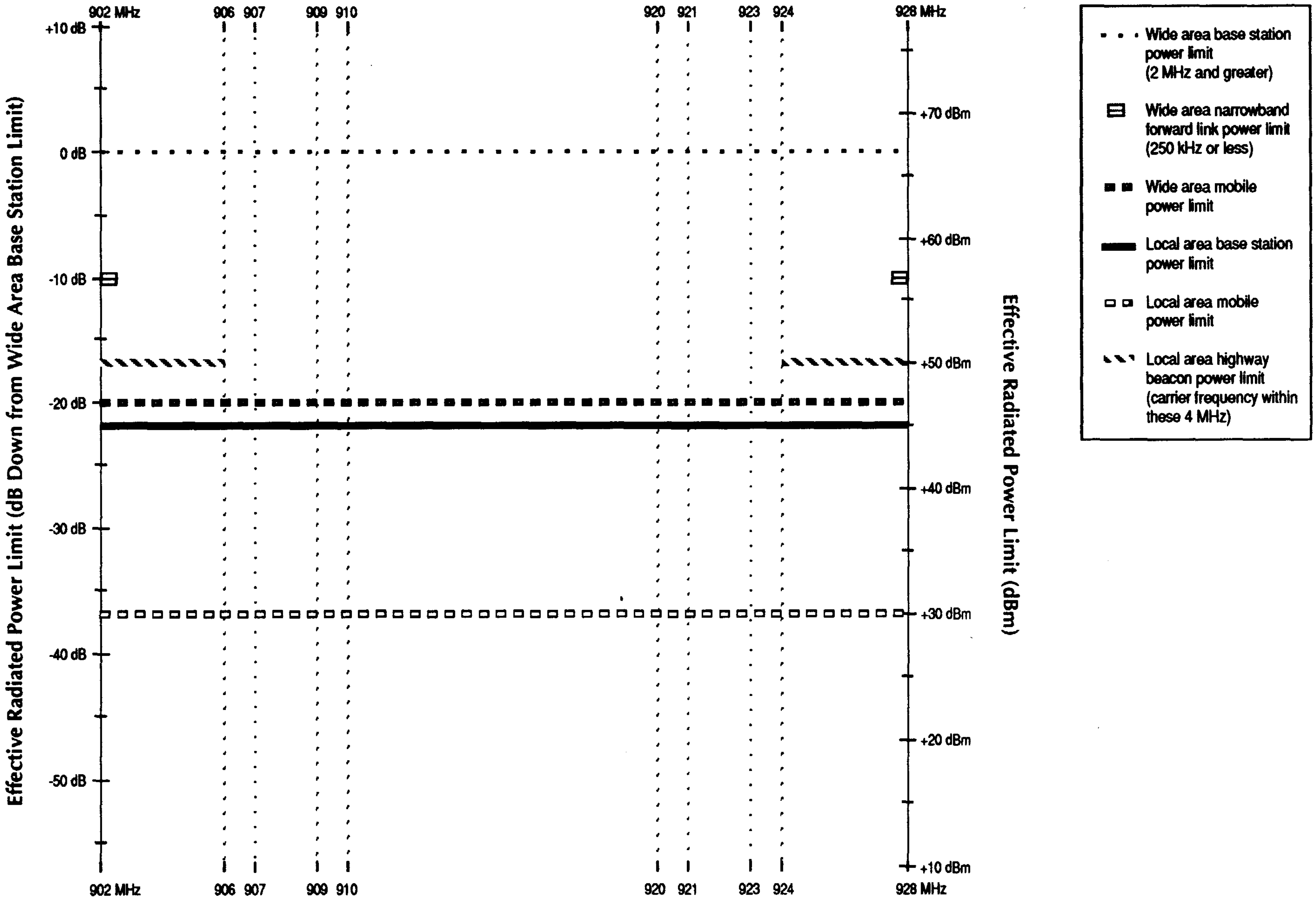

Figure 1: Proposed Power Limits for LMS Systems in the 902-928 MHz Band (Preferred Plan)

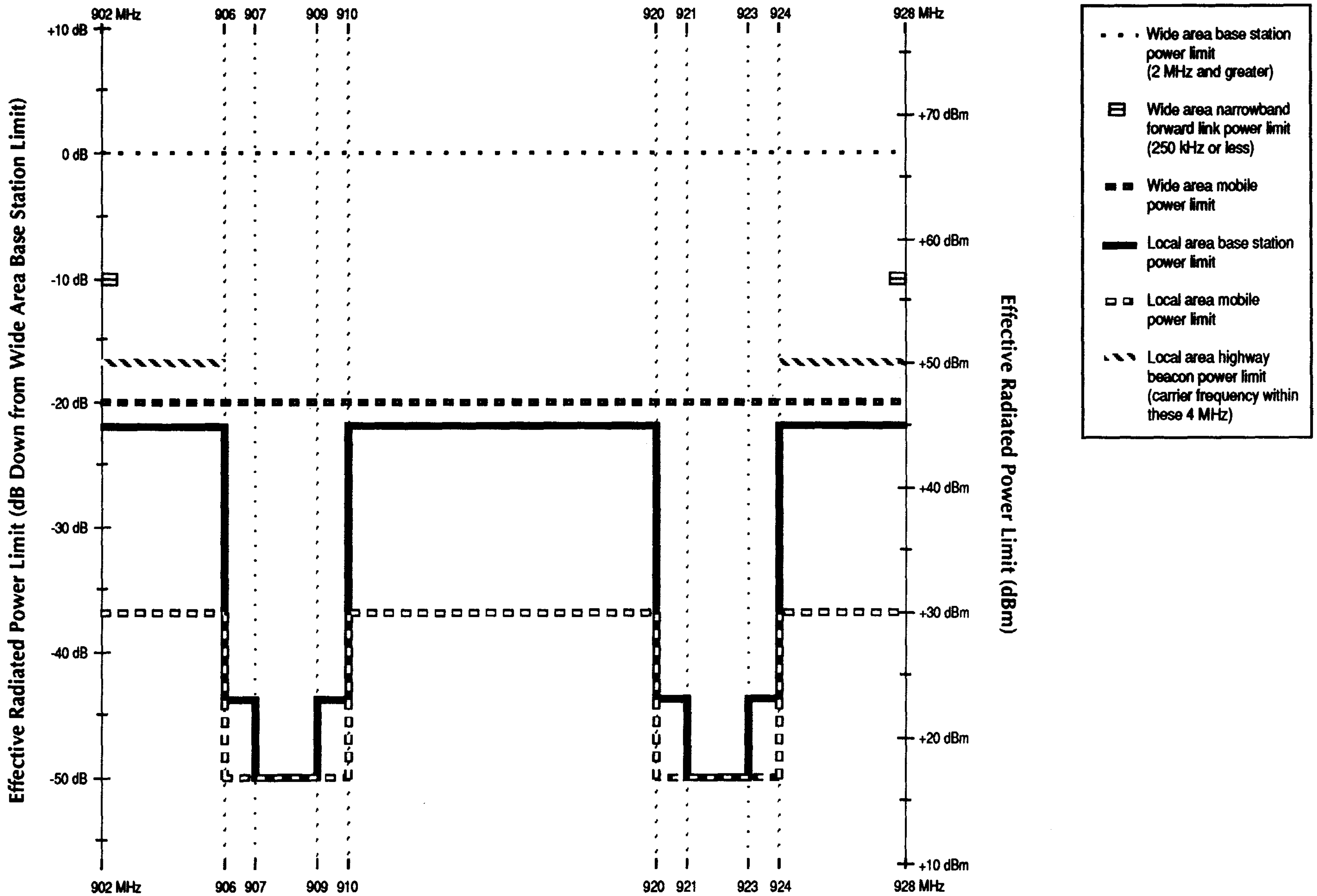

Figure 2: Proposed Power Limits for LMS Systems in the 902-928 MHz Band (Alternative Plan)

TAB

Exhibit A

The relationship between Position-fixing rate & Occupied Bandwidth in AVL Systems

By Louis Jandrell
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Introduction

This monograph provides an overview of the factors that limit the rate with which a particular approach to automatic vehicle location (AVL) systems may operate. In this case rate will mean the number of position fixes to within the target resolution and accuracy per unit time, under specified conditions of interference and noise, and at a prescribed maximum signaling range. The analysis shows that for a fixed signal-to-noise (or signal-to-jammer) ratio at the receiver input, the fixing rate varies with the cube of the available bandwidth in narrow pulse (i.e. wideband) correlating ranging systems. Accordingly, to maximize spectrum efficiency among wide-band area users, the largest possible bandwidth should be employed within practical bounds.

Position Fixing procedure

CW (Narrow-band) Systems

These systems typically estimate the apparent signal flight time from the change in phase of the received signal from a reference phase. In order to ameliorate the effects of fading due to multipath distortion, which is a narrow band coherence phenomenon, band-widening steps are taken, such as using wide-band fm or spectrum spreading with PN code using PSK or MSK modulation. In the case of PN sequence modulation the phase shift of the sequence is sometimes used to estimate travel time. The signals do, however, suffer from multipath induced phase distortion, which cannot be eliminated from the narrow band result, since the phase measurement is made on the sum of the received multipath signals, which all occupy exactly the same band.

Narrow Pulse (Wide-band) Systems

Wideband systems on the other hand rely on the measurement of the actual arrival time of (say the leading edge of) relatively narrow pulses for estimate of the travel time of ranging signals. Since narrow pulses are inherently wide band, they do not suffer from multipath induced fading in the quite the same way as do narrow band CW signals. They are however accompanied by multiple echoes that can be discriminated against temporally to minimize the effects of their distortion on the arrival time estimates.

Travel times

Bearing in mind the speed of light is about 5.3 microseconds per mile, practical, terrestrially based AVL systems experience signal travel times over a range of tens of nanoseconds to less than a hundred microseconds. Measurement in these ranges occurs with each position fix measurement.

Multipath effects

At the frequencies available for AVL systems, buildings and other man-made structures, as well as certain weather features, like cold fronts, effectively reflect the radio signals. Therefore, receiving equipment is subjected to receiving both the desired signal, and multiple copies (or echoes) of the signal arriving via alternative routes. The sum of these signals at the receiver can cause signal fading (as the vector sum of the signals passes through maximums and minimums), and phase distortion (since the sum of identical frequency sine waves with different amplitudes and phases is just another sine wave with a different amplitude and phase).

Scattering & Accuracy

In typical urban environments it is rare that communication occurs along the line-of-sight between the transmitter and receiver. Therefore, the signals that reach the receiver are usually those that have arrived there via some possibly multi-reflected path. Such a path is called a scattered path, and clearly the distance traveled by the signal over such a path is longer than the direct line-of-sight path. Therefore the ultimate accuracy with which the range can be measured will depend on the amount of scattering the signal undergoes, and the steps taken to bound the errors created by the apparent lengthening of the ranging signal's travel.

Delay Spread

A way of characterizing the multipath character of a communication environment is by a value called the delay spread, which is an estimate of how echo-ey the environment is. It quantifies the length of time that significant echoes continue to be returned from the environment after a signal is transmitted through the environment. The delay spread is largest in modern, high-rise metropolitan urban areas, where the worst case delay spread reaches about 3 microseconds. This value means that significant echoes may continue to beyond about 10 microseconds.

Inter Symbol Interference (ISI)

The multipath echoes limit the minimum duration for a data symbol.

Certain systems, such as narrow pulse ranging systems can, however, use correlation processes, based on a priori knowledge of the signal being detected.

The fixing-rate relationship to bandwidth

As the preceding discussion demonstrates, there is a functional relationship between the rate at which position fixes can be obtained and the available signal bandwidth, input s/n ratio and the required location resolution. The following analysis develops this relationship quantitatively. The terms used throughout this discussion and our symbolic notation for them are defined below:

t_a	Time of arrival which would be measured in the absence of noise (seconds)
$\hat{t}_a$	Estimated time of arrival (seconds)
A_p	Noise-free peak signal amplitude out of correlator (Volts)
$A(t)$	Noise-free signal amplitude at time t (Volts)
$n(t)$	Correlator output noise random process (Volts)
η	Threshold value used to declare time of arrival (Volts)
S_{out}	Peak signal power at the correlator output (Watts)
N_{out}	Noise power at the correlator output (Watts)
T_r	Signal rise time (seconds)
B_{ss}	Available spread spectrum signaling bandwidth (Hz)
$\left(S/N\right)_{in}$	Peak signal power to noise power ratio at correlator input
$\left(S/N\right)_{out}$	Peak signal power to noise power ratio at correlator output
M	Number of independent correlation measurements to be taken
R	Desired timing error standard deviation (seconds)
T_s	Symbol period (a correlator sequence comprises one symbol)
PG	System processing gain
F_{msr}	Maximum position fixing rate (fixes per second)

The system used to measure arrival time is depicted in Figure 1. At the transmitter, each transmitted symbol is spread to a wide bandwidth prior to transmission. The signal is bandlimited by the prescribed allocation. Signal degradation is imposed by multipath, environmental noise, interference, and receiver thermal noise. This discussion neglects the effects of multipath, environmental noise, and interference on the received signals. The primary aim of this analysis is to quantify the fundamental position fixing rate limitation imposed by a channel bandwidth constraint.