assumption and then using it to argue that a licensing regime based on multiple entry should be rejected by the Commission.

3. SBMS Is Ready Now To Provide LMS On Shared Spectrum.

The Study suggests that uncertainty regarding spectrum sharing will discourage entry of new firms into the LMS market.[41] But SBMS has repeatedly advised the Commission that it is ready, willing and able now to invest resources, capital, time and energy to construct and operate its pending LMS system in Chicago-- a system specifically designed to share the 918-926 MHz band with MobileVision. SBMS is currently reviewing other prospective markets for providing LMS and fully anticipates filing applications for suitable markets in the near term. SBMS' chosen technology will allow it to operate on a shared basis in those markets as well.

SBMS' Quiktrak technology will operate in a shared environment and SBMS is willing to accept licenses on the condition that it share. Nevertheless, spectrum exclusivity will ultimately be required for wide-band LMS systems. The proposal advocated by SBMS will allow new licensee entry, encouraged availability of low cost and other innovative technologies plus the other consumer benefits associated with a competitive market, while incumbent licensees will retain their existing four MHz assignments.

B. SBMS' Exclusive Licensing Proposal Will Accomodate Existing LMS Licensees.

SBMS' Quiktrak system can offer high quality LMS services

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[41] Study at 5.

using only two MHz of wide-band spectrum. As an accomodation to the wide-band incumbents to reconcile the diverse views on licensing in the record of this proceeding, and to expedite an industry consensus, SBMS will accept and, in fact, endorses four MHz allocations of wide-band spectrum.

Exclusive four MHz allocations are consistent with and foster coexistence of the proposed systems of Teltrac and MobileVision.

some unspecified future time.[44] SBMS asserts that it can offer the same service without additional spectrum.

Teletrac's preference for a full eight MHz allocation is also justified by an engineering report which purportedly demonstrates that doubling system bandwidth quadruples system capacity. In the foregoing discussion (supra at Section II), SBMS refuted this notion by demonstrating that, due to multipath propogation and band coherence, reduced bandwidth does not inevitably imply reduced capacity nor does increased bandwidth result automatically in increased capacity. Reflecting its proven performance capabilities with only two MHz, Quiktrak is a tremendous advance in LMS technology.

V- THE QUIKTRAK SYSTEM PRESENTLY PROVIDES COMMERCIAL SERVICE

Contrary to allegations of other parties[45] a two MHz (null-to-null bandwidth) Quiktrak system has been constructed and has been providing commercial service in Sydney (State of New South Wales) Australia in the 400 MHz band for four years. Operated by BAeA, it provides vehicle location and basic two-way messaging

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44/ Old Crows Response at 12. Despite admittedly only using four MHz of its allocation, Teletrac claims that it must have exclusive use of its entire eight MHz allocation. Teletrac Comments at 23. Teletrac never explains how it will use its entire eight MHz while simultaneously accomodating a second LMS operator's high-powered forward links in its own spectrum allocation. Such obvious contradictions seriously undermine the credibility of Teletrac's proposals.

45/ See Teletrac Comments at 19 (alleging that commenters who urge sharing in this proceeding have yet to attract a customer or build a system); see also MobileVision Comments at 35 (alleging that none of the potential entrants into wide-band LMS can point to its own experimental, test or operational experience).

services for fleet management and security to the New South Wales police department, the city of Sydney bus system, the Sydney Harbor ferries, commercial trucking fleets, and other businesses.[46] The second generation 900 MHz band Quiktrak system currently being developed and tested in Sydney is technically superior to the present system and to other radiolocation technologies.

The Quiktrak system is revolutionary because it operates on a narrow two MHz bandwidth, four times narrower (and more spectrally efficient) than currently licensed or proposed AVM systems. As developed for 900 MHz, Quiktrak will serve at least as many potential customers as other proposed LMS systems that use far more spectrum. The Quiktrak technology can, within two MHz of spectrum, provide an initial capacity for up to 60,000 location messages per hour. With system improvements that are being developed, system capacity will be increased to 120,000 location messages per hour.[47] Teletrac claims to be able to serve 4,000 locations per minute, or 240,000 message per hour over its eight MHz spectrum allocation.[48] Thus, the Quiktrak system, which at present equals the performance of the Teletrac system (as calculated over the full eight MHz allocation) will achieve twice the performance of Teletrac's wide band system probably before the final rules adopted in this proceeding become effective.

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[46] Exhibit 7 hereto is a representative testimonial from an existing Quiktrak customer.

[47] This increased capacity will be available next year in Quiktrak's second generation.

[48] Teletrac Comments at 7-8.

VI- CONCLUSION

For all the foregoing reasons, the Commission should adopt final rules for wide-band LMS spectrum that are consistent with SBMS' Comments and Reply Comments in this proceeding.

Respectfully submitted,

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Its Attorneys

July 29, 1993

LIST OF EXHIBITS:

Exhibit 1 -- SBMS Alternative Allocation Proposals

Exhibit 2 -- Declaration of Joseph E. Fleagle

Exhibit 3 -- Declaration of Gregory C. Hurst

Exhibit 4 -- Remarks on Comments Made By North American Teletrac and Location Technologies, Inc. (Teletrac) and Pinpoint Communications, Inc. (Pinpoint) to FCC NPRM Docket 93-61

Exhibit 5 -- Affidavit of Keith Rainer

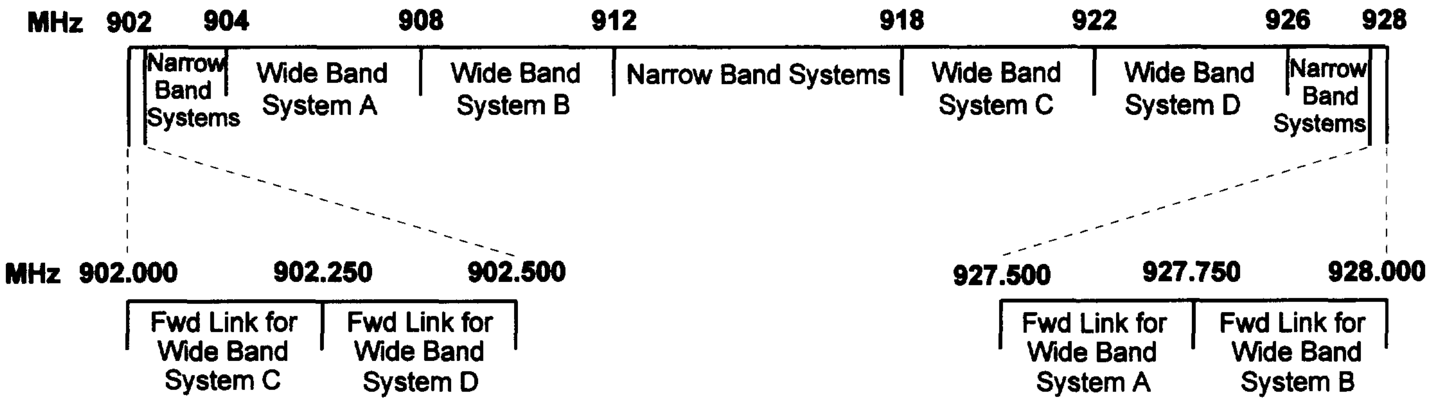
Exhibit 6 -- Declaration of Michael John Yerbury

Exhibit 7 -- Correspondence From Rothmans of Pall Mall Australia Limited

EXHIBIT 1

SBMS ALTERNATIVE
ALLOCATION PROPOSALS

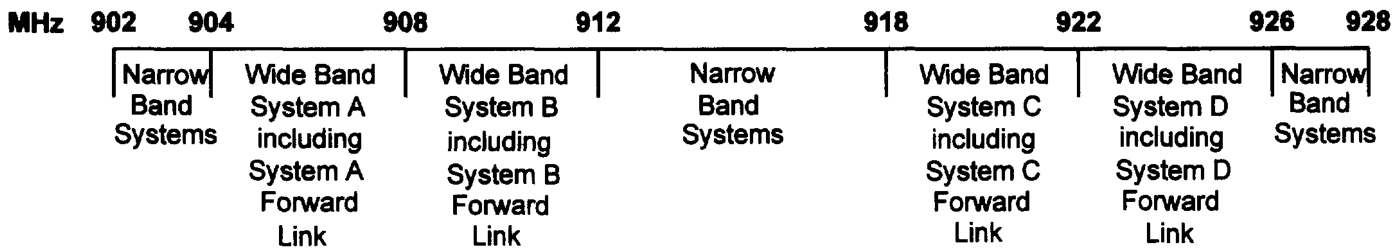
Recommended Allocation—Forward Links for Wide Band LMS Outside All Other LMS Use



Placing the forward links in a separate spectrum from the wide band channels minimizes interference on location and status messages. This configuration provides frequency separation between the forward and return links, and it protects the forward link from other LMS signals.

Each wide band system will be allotted 250 KHz for use by forward links. Of the 26 MHz of LMS bandwidth, this allocation method uses 17 MHz for all wide band systems combined and 9 MHz for narrow band systems.

Alternative Allocation—Each Wide Band System Has Forward Link Within Its Own Channel



If the Commission decides to require wide band operators to locate their forward links within the proposed 16 MHz wide band system frequencies, the desired configuration would be to have each wide band system operate its own forward links within its allocated 4 MHz band. Each wide band LMS provider would have control over the forward link within its wide band. Since the wide band operation will perceive the forward link as an interfering signal, this configuration allows the licensee to engineer a solution to the interference. The benefits of designing around a controllable interference source is greater than the advantages of frequency separation between the wide band operation and the forward link.

SBMS strongly believes the Recommended Allocation above is *by far* the most efficient and intelligent use of the 902 to 928 MHz LMS frequencies. The Alternative Allocation, while workable, is much less desirable.

The licensee of each wide band channel will decide the bandwidth and placement of the forward links within that 4 MHz wide channel. In this configuration, wide band operations are allotted a total of 16 MHz of bandwidth; narrow band systems occupy 10 MHz total bandwidth.

EXHIBIT 2

DECLARATION OF JOSEPH E. FLEAGLE

BEFORE THE
FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D. C. 20554

RECEIVED
JUL 29 1993
FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

In the Matter of	)	
Amendment of Part 90 of the Commission's Rules To Adopt Regulations for Automatic Vehicle Monitoring Systems	)))))	PR Docket No. 93-61 RM-8013

To: The Commission

DECLARATION OF JOSEPH E. FLEAGLE

I, Joseph E. Fleagle, hereby declare as follows.

1. I am a member of the technical staff of Comtrak, a subsidiary of E&S Corp., where I have been employed since 1979. I am presently serving as the Comtrak technical representative at British Aerospace Australia in Sydney, Australia, working with the developers of the Quiktrak LMS system.

2. I have a Bachelor's degree in Electrical Engineering from The Johns Hopkins University.

3. Following the completion of my Bachelor's Degree and a period of service in the U.S. Navy, I began employment with the Hazeltine Corporation. While at Hazeltine, I worked on the final development and field testing of a classified IFF (Identification Friend or Foe) system, which subsequently saw service in the Vietnam war.

4. In 1969, I left Hazeltine and began employment with Wagner Electric Corp. in St. Louis. At Wagner, I directed the development and testing of an anti-skid braking system for air-braked vehicles, which was subsequently placed into volume production. I am inventor or co-inventor on 12 US patents related to anti-skid technology.

5. In 1979, I left Wagner to join E&S Corp. At E&S Corp., I performed on a variety of programs, including radar development, a classified terrestrial tactical communications system which included packet radio , and a classified spread spectrum intercept development program. I have taken short courses in electronic warfare, radar system design, and spread spectrum communications as part of my employment.

6. I have participated in the preparation of the paper entitled " Remarks on Comments by North American Teletrac and Location Technologies, Inc (Teletrac) and Pinpoint Communications, Inc (Pinpoint) to FCC Docket 93-61". I have reviewed the final document and declare that it is true and correct to the best of my knowledge, information, and belief. In addition, I wish to offer the following comment on the issue of spectrum sharing between LMS systems.

whose amplitude varies inversely with the fourth power (typically) of the distance between the mobile and the receiver. It is impossible that a single transmission from a mobile will block the competing system receivers over the entire service area of the competing system. Indeed, depending on the process gain advantage existing between the two competing systems, none or at most one of the remote receiving sites may be affected.

An individual transponder is seldom required to be located more frequently than every 15 seconds, and usually much less frequently than that. If a particular transponder emission did interfere with a remote receiver site, some period of time would elapse before that transponder was again addressed and another burst of interference caused.

On the other hand, Part 15 devices such as wireless LAN's, which are permitted to employ up to 1 watt of transmit power, are frequently fixed in location and may transmit for extended periods of time. Depending on the exact carrier frequency and modulation format of the Part 15 device, most or all of its power may appear within the bandwidth used by the LMS system mobile component. Such Part 15 emitters may be installed quite close to the receiving sites of an LMS system, and thus will have a range advantage over the mobile elements of the LMS system. Nevertheless, no LMS operator to date has expressed serious reservations about coexistence with Part 15 devices. Indeed, only Teletrac has even recognized that it is a problem which must occasionally be dealt with.

If the ERP of the wideband mobile component of LMS systems is limited to the 1 to 10 watt range, so as to be competitive with or a bit greater than the Part 15 devices, it appears that sharing can work. A shared channel between multiple LMS systems employing low power mobile units with similar levels of ERP is no more threatening from an interference standpoint than the presently existing sharing with Part 15 devices.

At some point, of course, proliferation of systems and Part 15 devices will increase the noise power within the LMS bands to the point where performance of any individual system will degrade to a point where the system is no longer viable. Thus, some future limitation should be placed on the number of LMS operators assigned to any one band segment. We do not believe that the time is yet ripe for such limits. It would also be desirable to maintain or even reduce the power limits for Part 15 devices to reduce the rate of interference buildup in the LMS bands.

Some coordination between LMS system operators would be desirable to ensure that the code rates, lengths, and sequences chosen for the various systems have low cross correlation, so that the process gain inherent in direct sequence spread spectrum systems can be used to full advantage in discrimination against transmissions of competing LMS systems.

As a case in point of how sharing might work, Southwestern Bell Mobile Systems has applied for a license to operate a Quiktrak LMS system in the Chicago area. The Quiktrak system employs a mobile transmitter which produces an ERP of 0.5 to 8 watts, depending on the antenna type used. The output signal is direct sequence spread spectrum with a 1 MHz chip rate, providing a null to null bandwidth of 2 MHz, on a carrier frequency of 919 MHz.. 99% of the signal power is contained within the 2 MHz bandwidth. Meanwhile, MobileVision has been licensed to operate an LMS system on 922 MHz in Chicago.

The choice of carrier frequency for the Quiktrak system was deliberately made to minimize the spillage of energy into the MobileVision center frequency range, in anticipation that the residual sidelobe energy would be buried under the noise from Part 15 devices and other users. Likewise, the sidelobe energy from the MobileVision would appear as low level noise to the Quiktrak system. With the difference in code rates, the full process gain of the Quiktrak system would be available to deal with signals resulting from the MobileVision transponders and the background noise resulting from Part 15 devices.

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct. Executed on July 28, 1993.

Joseph E. Fleagle

EXHIBIT 3

DECLARATION OF GREGORY C. HURST

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Ammendment of Part 90 of	)	PR Docket No. 93-61
the Commission's Rules to	)	RM-8013
Adopt Regulations for	)	
Automatic Vehicle	)	
Monitoring Systems	)	
	)	
To: The Commission	)	

Declaration of Gregory C. Hurst

I, Gregory C. Hurst hereby declare as follows:

1. I am a member of the technical staff of British Aerospace Australia Limited (BAeA) where I have been employed on the development of the *Quiktrak* location and monitoring system since November 1992 when BAeA acquired all rights to the *Quiktrak* technology from Advanced Systems Research Pty Limited (ASR) and Lend Lease Corporation Limited (LLC). During the period September 1985 to October 1992 I was employed by ASR during which time I was co-inventor and developer of the *Quiktrak* system and associated technology.

2. I have a Bachelor of Science degree and Bachelor of Engineering (1st class honours) degree from the University of New South Wales.

3. Following graduation I spent 9 years in the School of Electrical Engineering, University of New South Wales, where I participated in research programs in digital communications and was a member of the teaching staff in the fields of electronics and communications systems design.

4. In the period 1982 to 1985 I was employed at the Commonwealth Scientific and Industrial Research Organisation, Division of Radiophysics, where I developed remote electronic identification systems for the identification of livestock and other animate and inanimate objects.

5. In 1985 I helped found ASR, a research and development company formed to exploit

[redacted]

maximum is bounded by the characteristics of the operating environment. The *Quiktrak* system design recognises this reality in using a 1 MHz clock to drive the spreading code, resulting in a null-to-null bandwidth of 2 MHz and a -3 dB bandwidth of approximately 1 MHz. This is the realistic maximum bandwidth that can be usefully employed in the LMS environment. In fact the whole of this bandwidth is not usefully utilised when the mobile is located in the most cluttered urban environments, however, these account for only a small proportion of the normal coverage area of a typical LMS system and hence the inefficiency can be tolerated and compensated for in increased base station density in such regions.

The process gain inherent in a direct-sequence spread-spectrum system is fundamentally determined by the ratio of signal bandwidth to post correlation (or de-spread) about 100 miles) and hence the spectral lines in the signal are spaced at 2 kHz. Since signals located in the gaps between the lines are positioned outside of the passband of the post-correlation filter following signal de-spreading in the receiver, it is possible to use this signal space without interference to the spread-spectrum receiver. Thus within the *Quiktrak* system multiple simultaneous transmissions are used with the signals offset from one another by small amounts relative to the signal bandwidth. By this technique it is possible to achieve the very high levels of interchannel isolation (around 70 dB) required to overcome the near-far effect inherent in an LMS system relying on multilateration to achieve signal location. In the *Quiktrak* system designed for operation at 900 MHz signal offsets in multiples of 250 Hz are used to provide up to six tracking channels (using this unique FDMA technique) with the remaining spectrum being used to provide a spread-spectrum channel for data transmissions from the mobiles. In this way the capacity is increased by a factor of six over that gained by the use of TDMA alone. Since the data channel may be used without any significant interference to the tracking channels, a spread-spectrum data transmission system is overlaid on the tracking system for efficient utilisation of the occupied bandwidth of 2 MHz.

I declare under penalty of perjury under the laws of the United States of America that the forgoing is true and correct. Executed on 28 July 1993.

Gregory C Hurst

Gregory C. Hurst

EXHIBIT 4

Remarks on Comments Made By North American Teletrac and Location Technologies (Teletrac) and Pinpoint Communications, Inc. (Pinpoint) to FCC NPRM Docket 93-61

Remarks on Comments Made by
North American Teletrac and Location Technologies, Inc. (Teletrac) and
Pinpoint Communications, Inc. (Pinpoint)
to FCC NPRM Docket 93-61

1. Introduction

The remarks contained in this document refute the assertions made by Teletrac and Pinpoint on the relationship between signal bandwidth and system location-rate capacity in wideband Location and Monitoring Services (LMS) systems. In their submissions, both Teletrac and Pinpoint arrived at the same conclusion that capacity in a noise-limited system is proportional to the square of the bandwidth. Pinpoint has taken its analysis further and claims that where a narrowband noise-like interferer limits performance, capacity is proportional to the cube of the bandwidth. Much of the subsequent arguments of both organisations rely on these conclusions.

The Pickholtz report (Appendix 1 of the Teletrac submission) cites the 'Cramér-Rao bound' in order to develop a tradeoff analysis that concludes, *inter alia*, that a doubling of system bandwidth can result in a quadrupling of system location capacity. According to the report, this is to be accomplished by trading bandwidth for a shortened response from a mobile unit while maintaining the same accuracy. This result is central to Teletrac's economic argument for assignment of the full 8 MHz band to a single user, on grounds that the shorter response allows more transmissions per unit time which means greater capacity. However, as we shall elaborate below, in practical LMS systems, this bound is not the only constraint on system capacity and when this fact is taken into account a very different conclusion is reached.

2. Bandwidth versus System Capacity

The Pickholtz report (pages 17 and 18) uses the Cramér-Rao bound to establish a lower limit for time-of-arrival error. This is expressed as an inequality which defines the best that can be achieved, irrespective of the techniques employed. We concur with this result.

However, in proposing system tradeoffs, it is dangerous to draw general conclusions from this inequality alone without considering all the factors which come into play to limit performance. The Cramér-Rao inequality is a useful tool for designers wishing to gauge the performance of their systems against an absolute, theoretical limit but it provides no guidance as to how the limit may be approached. For various reasons, a much higher limit is set in practical LMS systems.

Our experience, gathered over several years with an operational LMS system and well supported by the literature on mobile radio propagation, demonstrates that this is not a valid conclusion for terrestrial LMS systems.

The practical situation under examination in Teletrac's submission concerns a doubling of signal bandwidth from 4 MHz to 8 MHz in the 900 MHz frequency range. The tradeoff analysis in the Pickholtz report is based on the Cramér-Rao inequality and implicitly assumes that signal coherence is maintained over the whole of the occupied bandwidth. This is a reasonable assumption for line-of-sight propagation paths which are not dispersive, that is, where multipath effects are negligible. However, terrestrial LMS systems of the type being considered here almost always operate in cluttered environments where radio propagation from mobile transmitters to base receivers is multipath in character and rarely line-of-sight. In these circumstances so-called delay spread (Δ) must be taken into account.

Delay spread refers to the fact that signals from a mobile unit travel by different paths expected from an application of the Cramér-Rao bound. Indeed, once the signal bandwidth has been increased beyond the point where its components at the opposite band edges lose coherence, the signal-to-noise ratio will be reduced, together with the potential location-rate capacity, for a given accuracy.

The *Quiktrak* system proposed by Southwestern Bell Mobile Systems, Inc. uses a signal bandwidth of 2 MHz. This choice is itself a tradeoff which acknowledges the fact that in suburban and rural areas coherence bandwidths are more closely matched to the system bandwidth than in urban and central business districts which constitute a small proportion of the total coverage area. In these districts the disparity may be compensated by an increase in the density of receiving sites.

It is known that Teletrac currently uses a 4 MHz bandwidth (Teletrac response at 24, footnote 27) and suffers 5 dB of what has been called 'implementation loss' (Pickholtz study at 23). We venture to suggest that part of this loss may be attributable to lack of signal coherence and, because of this requirement for coherence, it is reasonable to expect that the 'implementation loss' will increase still further if the signal bandwidth is expanded to 8 MHz.

In the Pickholtz report, at 34, it is claimed that dividing a band into two sub-bands results in a 50% loss of capacity. However, in a scattering environment typical of urban and suburban areas, the converse is actually true for the following reasons.

As a consequence of the need for coherence, little or no benefit accrues from increasing system bandwidth beyond about 2 MHz because the additional frequency components add incoherently in a scattering environment. Hence a system using a contiguous 8 MHz band would have no greater capacity than one using a 2 MHz sub-band, all other parameters being equal - but four such 2 MHz systems could be accommodated in the 8 MHz band and supply four times the capacity. The Pickholtz argument only begins to apply when the system bandwidth is less than the coherence bandwidth which, as we have pointed out, is likely to be less than 2 MHz.

It is worth noting that the only experimental evidence in the Pickholtz report relates time-of-arrival error to signal-to-noise ratio (Figure 5 at 23). These results are presented, presumably, in order to confirm the applicability of the Cramér-Rao inequality. However, it should be noted that nowhere in his report is the relationship between time-of-arrival error and signal bandwidth supported by experimental evidence.

Another effect further mitigates against achieving higher capacity via shorter transmitted pulses in conjunction with increased system bandwidth. A brief (say 0.01 to 0.02 seconds) transmission may be considered to provide a 'snapshot' or sample of the radio propagation paths to the receivers at the instant the transmission was made. There is no assurance that a direct path to any receiver exists. On the contrary, it is highly likely that the signal reaching a receiver at that instant comprises a large number of multipath signals; this fact results in an inaccurate time-of-arrival measurement. On the other hand, a longer transmission effectively samples a multiplicity of propagation paths if the vehicle is in motion because, at around 900 MHz, only a few meters of travel is enough to alter multipath propagation significantly in an urban or suburban environment. Such samples taken during vehicle motion can be averaged incoherently to produce a better estimate of the vehicle's location. The somewhat counter-intuitive idea that moving vehicles can be located more accurately than stationary ones has been shown to be true, particularly in urban areas, by test results on the Sydney *Quiktrak* system. The Pickholtz report (at 36) addresses the question of lengthening transmission time, but only in terms of improving measurement accuracy by increasing signal-to-noise ratio. As we have just remarked, in practical LMS systems significant additional benefits accrue from the use of longer transmissions.

With regard to the statement attached as Exhibit A to the 'Comments of Pinpoint Communications Inc.', authored by Louis Jandrell, we make the following observations. It is apparent (at 2) that Jandrell is aware of the importance of multipath effects, yet his analysis of the relationship between signal bandwidth and system location-rate capacity neglects the effects of multipath (at 6). As a consequence the conclusions are similar to those of Pickholtz, although Jandrell uses the claimed benefits of wider bandwidth to recommend time-division-multiplexing between users of the whole band. For the reasons we have outlined here, these conclusions are not relevant to practical LMS systems.

An extremely important and fundamental fact underlies our comments in this submission. The performance of wideband LMS systems operating in the vicinity of 900 MHz is dominated by the effects of multipath propagation and not by interference or noise in the classic sense. When a mobile is operated in a cluttered environment, as is usually the case, any location-performance analysis based on additive white Gaussian noise (AWGN) and interference alone is both inappropriate and inadequate.

3. References

(1) Cox, D. C. and Leck, R. P. "Correlation Bandwidth and Delay Spread Multipath Propagation Statistics for 910 MHz Urban Mobile Radio Channels" IEEE Transactions on Communications, Vol. Com-23, November 1975.

(2) Turin, G. L. *et al* "A Statistical Model of Urban Multipath Propagation" IEEE Transactions on Vehicular Technology, Vol. VT-21, No. 1, February 1972.

(3) Engel, J. S. "Effects of Multipath Transmission on the Measured Propagation Delay of an FM Signal" IEEE Transactions on Vehicular Technology, Vol. VT-18, No. 1, May 1969.

(4) Clarke, R. H. "A Statistical Theory of Mobile-Radio Reception" The Bell System Technical Journal, Vol. 47, July-August 1968.

EXHIBIT 5

AFFIDAVIT OF KEITH RAINER