Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
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Facilitating Opportunities for Flexible,	)	ET Docket No. 03-108
Efficient, and Reliable Spectrum Use	)	
Employing Cognitive Radio Technologies	)	
	)	
Authorization and Use of Software Defined	)	ET Docket No. 00-47
Radios	)	(Terminated)
	)	

REPLY COMMENTS OF V-COMM, L.L.C.

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June 1, 2004

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INTRODUCTION AND SUMMARY

V-COMM, L.L.C. (V-COMM)[1] submits these reply comments in response to the Federal Communications Commission's (FCC or Commission) Notice of Proposed Rulemaking (NPRM) and Order seeking reply comments on the above referenced proceeding.[2]

In these reply comments, V-COMM addresses technical issues associated with the comments filed within the FCC's Cognitive Radio (CR) proceeding and considers the potential for harmful interference to Commercial Mobile Radio Service (CMRS) operations caused by non-voluntary sharing of CMRS spectrum bands with unlicensed CR devices.

[1] V-COMM, L.L.C. is a wireless telecommunications consulting company with principal members having over 20 years experience in the wireless industry. We have provided our expertise to wireless operators in RF engineering, system design, implementation, performance, optimization, and evaluation of new wireless technologies. We have extensive industry experience in all CMRS technologies. V-COMM's company information and experiences are highlighted in this report's Appendix A, along with biographies of senior members of its engineering team.

[2] *Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies*, Notice of Proposed Rulemaking and Order, ET Docket No. 03-108 (released December 30, 2003) ("*NPRM*"). Unless otherwise noted, all references to other parties' comments were filed in this proceeding on May 3, 2004.

V-COMM is an independent engineering firm with extensive expertise in CMRS technologies and systems. Through extensive testing and engineering experience, V-COMM has gained valuable insight to the compatibility issues associated with spectrum-sharing technologies and the technologies and systems operating within CMRS spectrum. V-COMM has conducted extensive interference and compatibility tests with spectrum-sharing technologies within cellular spectrum,[3] and has performed extensive noise and interference studies in cellular and PCS spectrum,[4] and documented these results for consideration by the Commission.

Pursuant to a contract with Verizon Wireless, V-COMM has reviewed comments submitted within the FCC's Cognitive Radio proceeding, and prepared these reply comments for submission in the docket. V-COMM addresses the comments filed in the proceeding, and provides a review of the technical issues both in opposition to and in support of the FCC's Cognitive Radio (CR) proposals. V-COMM reviews the technical difficulties and issues raised by many parties opposing non-voluntary sharing of licensed spectrum bands. In addition, V-COMM addresses comments from parties supporting non-voluntary sharing of licensed bands with respect to significant practical issues, technical difficulties and impacts to existing services in licensed bands. We also review comments from many parties opposed to the Commission's proposal to increase the transmit power of unlicensed cognitive devices due to increasing noise floors and interference to unlicensed and licensed bands with increased out of band emissions from these high power unlicensed devices.

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[3] V-COMM has conducted extensive compatibility and interference tests within AT&T Wireless, Cingular, and Verizon Wireless' cellular and PCS networks. In the FCC's AirCell proceeding (ET 02-86), V-COMM has submitted comprehensive engineering reports, filed on April 10, 2003.

[4] V-COMM has conducted spectrum noise and interference measurements within Cingular and Verizon Wireless cellular and PCS networks. V-COMM submitted the "AMPS Noise Floor Study" within the FCC's AirCell spectrum-sharing proceeding (ET 02-86) on April 10, 2003, and the "PCS Noise Floor Study" within the FCC's Spectrum Policy Task Force Report proceeding (ET 02-135) on Sept. 16, 2003.

I. PARTIES SUPPORTING NON-VOLUNTARY CR SHARING OF LICENSED BANDS DO NOT ADDRESS PRACTICAL CONSIDERATIONS OR SIGNIFICANT TECHNICAL DIFFICULTIES

The parties supporting non-voluntary cognitive radio (CR) sharing of licensed spectrum bands are in the minority of the comments submitted in this proceeding ("Supporting Parties"). Comments from Shared Spectrum, IEEE 802, Pulse~LINK, Texas Instruments and Hypres are supportive of using cognitive radio technologies as a means to enable unlicensed devices to share spectrum on a non-voluntary basis in licensed bands. However, as explained below, their proposals are not well thought out, are not based upon detailed analysis or practical considerations, do not consider the significant technical difficulties involved with such proposals, and in some cases appear to be motivated by self-serving interests;[5] allowing their technology free access to valuable licensed spectrum.

As commented by V-COMM and by many other parties in this proceeding,[6] there are significant technical difficulties and many unresolved issues concerning non-voluntary unlicensed CR sharing of licensed bands that will not protect existing licensed services from harmful interference. The parties supporting non-voluntary sharing of licensed bands do not address these significant technical difficulties or any impacts to existing services in their comments. As provided by V-COMM in its filed comments,[7] these include: the hidden node problem (inability of receivers to reliably detect spectrum availability due to local RF propagation considerations); sensing while transmitting problem (inability to receive and

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These spectrum noise studies were also provided as Attachment B and Attachment C to Comments filed by V-COMM in the FCC's Interference Temperature (ET 03-237) comment proceeding on April 5, 2004.

[5] Hypres Comments, page 9, states: "[w]e urge the Commission to take the increased performance available with SME [their technology] into account when considering proposed rules."

[6] See Section II of these reply comments, for a review of parties submitting comments that oppose non-voluntary CR sharing of licensed bands.

transmit simultaneously on the same frequency); differences in receiver characteristics (i.e. receiver bandwidth, noise figure, detector circuits); differences in antenna characteristics (i.e. antenna type, beam width, gain, orientation, polarization); impact of transmissions on victim licensed services; cumulative effects of multiple unlicensed CR systems, inability to distinguish the "primary signals" from other signals and interference in the band; incompatibilities with CMRS networks that employ other cognitive radio algorithms in their licensed spectrum; and unlicensed CR transmissions on adjacent and image frequencies, which are not addressed by any party supporting non-voluntary sharing of licensed bands. Accordingly, any proposal to share licensed spectrum on a non-voluntary basis will result in many "false positives" for spectrum sharing devices that transmit due to incorrect assessments of spectrum availability and cause harmful interference to incumbent licensed services.[8]

In addition, the Supporting Parties do not consider other pertinent issues, including the overall net reduction in spectrum efficiency; costs to incumbents to overbuild networks to maintain services; decrease in the value of spectrum; impact on licensee's willingness to deploy and invest in innovative and advanced technologies; and the significant harm to existing and future services should unlicensed CR devices be permitted in licensed CMRS bands.

It is important for the FCC to consider these issues when reviewing its spectrum policies and not rely upon undeveloped, unproven technologies to increase access to licensed spectrum bands. At this point, cognitive radio technologies should only be permitted in existing and future CMRS spectrum under control by licensed operator, thus allowing the licensed operator to

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[7] V-COMM Comments, Section V (pages 41-51).

[8] The impact to existing licensed CMRS systems include loss in voice, data and E911 location services as a result of loss in coverage range for its network, loss in capacity to meet customer demands for service, degradation in quality of service for its customers (i.e. degraded voice quality, increased obstructions in

prevent harmful interference to the network and internalize the costs of such potential interference. This allows the licensee to fully utilize the spectrum for its use, and the flexibility to use it to the fullest extent possible for secondary market applications (spectrum leasing).

Shared Spectrum. Shared Spectrum is an avid supporter of non-voluntary sharing of licensed spectrum bands with unlicensed CR and interference temperature based devices. In its comments, Shared Spectrum proposes to share licensed spectrum bands on a non-voluntary basis facilitated by smart radios that can be operated with a centrally controlled system that can adapt to the environment, and states its "open loop" interference temperature architecture can achieve greater access to licensed spectrum bands while preventing interference. However, Shared Spectrum does not provide detailed information, analysis or consideration of the technical flaws, difficulties and other practical concerns associated with its proposals to access licensed bands and the impact to existing licensed services.

Shared Spectrum introduces its comments with the statement that it conducted spectrum occupancy surveys (which it has not provided to the Commission)[9] "that indicate that spectrum utilization is low in most bands, even urban areas."[10] However, Shared Spectrum does not provide any details of its testing, nor the resultant data from the studies it conducted, nor does it indicate which bands in which it measured high or low utilizations. V-COMM does not agree with this assessment for the cellular and PCS bands. As indicated in our comments and supported by empirical data provided to the Commission,[11] very high spectrum occupancy

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service, increased dropped connections), and significantly reduced throughputs and increased latency for customers with data connections.

[9] Shared Spectrum did not provide its spectrum survey data to the Commission in this proceeding, or reference any other proceeding in which such information may be found.

[10] Shared Spectrum Comments, page 1.

[11] V-COMM Comments, pages 42-46.

currently exists in licensed CMRS bands, and can be expected to increase in the future as well, with increasing subscriber demands for voice and data services.

Shared Spectrum proposes to share licensed bands on a non-voluntary basis facilitated by smart radios that can be operated with "*central control* over the software in each transceiver so that the software can be adjusted *instantly* to respond to any harmful interference that may be experienced."[12] Shared Spectrum states that the software can readily adjust operating parameters to adapt to the environment, responding to market demands in an evolutionary way,[13] and cognitive radios can be used to estimate the functional elements of path loss and other environmental conditions (propagation effects, cumulative effects, noise environment) to facilitate greater spectrum access with its "open loop" interference temperature based proposal.[14] However, as stated above, Shared Spectrum does not provide any detailed information, analysis or consideration of the technical flaws, difficulties and other practical concerns associated with its proposal.

Shared Spectrum does not explain how its "central control" concept can respond to the environment, how harmful interference is detected, monitored and controlled by the system, much less how it can *instantly* respond to the needs of the affected victim systems. Practically no details are provided concerning its proposed system; there is no detailed analysis; no technical evaluations; and no consideration of practical issues or the impacts to existing systems. It assumes the interference issues will simply work themselves out, without providing any detailed analysis, engineering, practical or technical considerations to base its theories. For the FCC to base its spectrum policies upon unproven theories, concepts and models, as outlined in this

[12] *Id.*, page 2, (emphasis added).

[13] *Id.*

[14] *Id.,* pages 4-8.

approach, would not ensure the integrity of existing services operating in licensed bands. Before the FCC considers such proposals further, it must have before it a thorough analysis of the detailed and technical issues involved, and the results of real-world comprehensive compatibility tests under a variety of operating conditions and environments. In addition, given the high probability of interference to incumbents, the FCC must develop and be prepared to enforce strict interference controls and interference resolution mechanisms.

In addition, Shared Spectrum states its "open loop" interference temperature architecture allows unlicensed devices to estimate the RF environment and adjust transmissions to avoid interference. V-COMM addressed the technical flaws associated with its "open loop" interference temperature architecture in our Reply Comments in the Interference Temperature docket.[15] These flaws include that it is unable to prevent harmful interference to incumbents and to properly estimate path loss and other network parameters, and does not take into account other factors including multiple users, and interference mitigation and resolution.[16] Its method relies upon the faulty assumption that an unlicensed device can properly estimate path loss from a victim transceiver to an unlicensed device without taking into account many factors which will prevent the proper assessment of this path loss, including that the transmitter power levels of licensed sites are unknown and vary according to a number of unpredictable and unknown factors; the forward and reverse links utilize different frequencies having different propagation and multi-path fading characteristics; the approach does not assess the cumulative effects or whether the interference temperature is already reached or take into account other radio characteristics, which will ultimately lead to many erroneous assessments of spectrum

[15] See *Reply Comments of V-COMM, L.L.C.* submitted in the Interference Temperature proceeding (ET Docket No. 03-237) on May 5, 2004.

[16] *Id.*, pages 18-23.

availability, and has the potential to cause substantial harmful interference to incumbent licensed systems. Therefore, it would be inappropriate for the Commission to adopt Shared Spectrum's open loop approach. Also, the proposed approach does not address any regulatory enforcement issues, methods to address rogue unlicensed devices, or issues involved with interference mitigation and resolution, should harmful interference occur.

Shared Spectrum also provided hypothetical probability plots (not actual measurements), while assessing an appropriate interference temperature limit for spectrum bands,[17] and *believes* it is representative of its experiences over the last several years. However, since Shared Spectrum does not provide the details of its study, the whereabouts of the measurement locations, the technical parameters used, and the actual results of the measurements, the Commission cannot rely upon such information. Thus, it would be invalid to analyze it for any spectrum policy considerations or assessments of spectrum uses.

Lastly, Shared Spectrum posits that its dynamic sharing proposals will bring substantial public benefits, including one short-term benefit with a specific proposal for public safety agencies to respond to major incidents such as terrorist attacks, large forest fires and airplane crashes.[18] It claims it could utilize existing spectrum bands to provide high bandwidths (50 Mbps) to these agencies, it could setup and deploy operations in short notice (within hours at large incidents), and can operate and transmit in bands at levels that would provide coverage to distances up to 20 km from a single access point. However, Shared Spectrum does not explain or provide any technical analysis or engineering studies to suggest how interference would be avoided to existing services in the bands, which frequencies bands could support such sharing and how, nor any other practical details.

[17] Shared Spectrum Comments, page 11.

It also does not consider any other alternatives to its proposed sharing approach, including use of existing commercially licensed services offered by CMRS operators (i.e. CDPD, and CDMA 1X voice and data services), and other alternatives in spectrum bands allocated by the FCC for public safety use, including bands in the 450 MHz, 700 MHz, 800 MHz, 900 MHz, and 4.9 GHz public safety bands. Many state, city and local municipalities utilize these spectrum bands to address their voice and data needs for reliable public safety operations on an interference-free basis, and overlaying a non-voluntary spectrum sharing scheme can only detract from the reliability of these critical communication systems. Also, public safety entities do not normally utilize networks operating on spectrum on an unlicensed basis for the same reason.

Moreover, Shared Spectrum's proposals only provide high-level hypothetical concepts without providing any detailed analysis, engineering, technical or practical considerations associated with its proposed concepts. It does not scratch the surface of technical issues required for consideration of such spectrum-sharing proposals. Further, it does not analyze the impact to existing services or the potential for harmful interference to incumbents' licensed systems, which Commission should required before it considers such proposals.

IEEE 802. IEEE 802 provided comments in this proceeding supporting non-voluntary CR uses in licensed spectrum bands, which it states is exemplified by the Commission's new U-NII band spectrum rules recently adopted making use of cognitive radio technologies to sufficiently mitigate interference to incumbent radar systems in the 5 GHz band.[19] V-COMM and other parties, however, do not agree with the assessment that sharing mechanisms that may work in one band should be presumed to work in another. There are a multitude of specific factors pertaining to different bands, services, environments, etc. that must be considered before

[18] *Id.,* page 13.

such a conclusion can be reached. Cisco agrees with this assessment and states "DFS should not be transplanted to other sharing situations without rethinking all the factors involved;"[20] Ericsson noted that the Commission's proposed DFS (Dynamic Frequency Selection) and TPC (Transmitter Power Control) combination would not be suitable or effective at detecting signals in mobile environments;[21] and Motorola provided that "exhaustive testing of CRs under numerous scenarios would be required to validate the non-interference claims."[22]

As a means to enable non-voluntary sharing of licensed spectrum bands with cognitive radio technology, IEEE 802 believes that an Incumbent Profile Detection (IPD) capability "can be used to monitor the channel to assure that, should a signal appear in the band whose characteristics match those of an incumbent, the DFS mechanism is triggered to move the cognitive system to another unoccupied frequency."[23] IEEE 802 posits that IPD can enable unlicensed non-voluntary use of licensed spectrum bands using DFS to reliably select unoccupied channels, "thereby guaranteeing operation on a non-interfering basis."[24] However, it does not provide any analysis, review of technical or practical details, or any other specific considerations to the radio environment and services operating in licensed bands, nor does it detail the potential for interference to incumbent systems. It simply states that IPD and DFS can enable such sharing of licensed spectrum on an interference-free basis. One cannot presume this to be the case; it must be studied in detail, thoroughly analyzed and assessed, and rigorously tested to ensure incumbent systems are protected for harmful interference.

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[19] IEEE 802 Comments, para. 4.

[20] Cisco Comments, page 8.

[21] Ericsson Comments, pages 4-5, 16.

[22] Motorola Comments, page 6.

[23] IEEE 802, para. 15.

[24] *Id.*, para. 14.

Further, IEEE 802 believes that IPD can intrinsically provide identification of various signals in bands, including identification of primary and non-primary signal sources and FFT (Fast-Fourier Techniques) to identify other types of incumbents such as cellular systems employing a mix of wideband and narrow band technologies (i.e. GSM and CDMA signals operating in the same band),[25] and states that "IPD is a particularly effective approach where incumbents have very specific spectrum signatures and band occupancy characteristics."[26] However, it does not explain how the feature works, how it will be able to determine spectrum occupancy, how it will be able to distinguish primary signals from other interference signals and other potential third party signal sources in licensed bands. Again, IEEE 802 provides its conclusion without any analysis of the practical and technical issues involved. V-COMM questions the validity of its assessments, particularly for mobile bands, where signals are extremely difficult to detect on a reliable basis, and where it would be highly impractical to develop an unlicensed device that could identify all the primary signals in CMRS bands. The unlicensed device would need to be able to detect and distinguish numerous wireless technologies having different signal characteristics (such as: AMPS, CDPD, NAMPS, SMR, IDEN, TDMA, GSM, GPRS, EDGE, CDMA IS95, CDMA 1xRTT, EVDO, EVDV, CDMA 3x, UMTS, and other secondary uses in licensed CMRS spectrum).

In summary, IEEE 802 does not consider an array of technical issues that prevent proper detection of signals, and results in harmful interference to incumbent licensed services. It does not provide any consideration of the RF issues, hidden node problems, incompatible equipment measurement problems, sensing while transmitting problems, interference on adjacent and fundamental frequencies, impractical measurement techniques, or other practical details involved

[25] *Id.*, para. 19; also see para. 12, 14, 22-24.

– each of which, can result in improper assessment of spectrum occupancy and harmful interference to licensed incumbent bands.

Pulse~LINK. Pulse~LINK provides comments in this proceeding supporting non-voluntary CR sharing of licensed spectrum bands. It proposes a new wireless control system with a beacon or control channel, referred as "Common Signaling Mode" (or CSM), to facilitate sharing of licensed bands between primary and non-voluntary CR unlicensed users. It highlights its proposed CSM method as:

> … a potential method by which disparate wireless technologies could communicate with one another to negotiate the use of spectrum on an interference free basis. The CSM could be a critical factor in enabling technologies such as cognitive radios and viral communications systems by functioning as a signaling protocol between different wireless communications technologies and systems. By functioning as a "least common denominator" communications link between all wireless systems, the CSM could bring about the full capabilities of technologies such as cognitive radio and viral communications systems and allow a harmonious use of spectrum between different and competing wireless technologies.[27]

In addition, Pulse~LINK provides a list of potential features its proposed system *could* offer, and suggests a list of designs attributes that it could include,[28] and states that "[t]he CSM could function as a communications channel for cooperative management of allocated PHY [Physical layers] resources across the time and frequency domains."[29] Pulse~LINK suggests these potential features *could* include: beacon timing and ranging channel; communication link to devices; dynamic power control; network status, health and control information; supporting interference temperature based devices, and a variety of other features.

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[26] *Id.*, para. 16.

[27] Pulse~LINK Comments at section 7.

[28] *Id.,* section 3 and section 5.

Besides listing the potential attributes of its proposed CSM method and describing high-level conceptual views on the benefits of the proposed system, however, Pulse~LINK does not address any detailed, technical, practical or critical issues concerning matters relating to sharing licensed spectrum bands on a non-voluntary basis, and not causing harmful interference to existing services in licensed bands. It does not address a number of critical issues including: how the system will work (it does not provide any details); who will design, operate and maintain it (it does not suggest these); who will control, enforce and resolve any interference issues (does not address these issues), who pays to develop and maintain such a working system (no consideration to costs; it would be highly impractical to implement);[30] the new system would be less spectrally efficient because it requires additional spectrum just to communicate to all the different primary and secondary unlicensed CR devices; it cannot ensure quality of service to existing licensed services; it cannot correctly assess availability of spectrum due to a variety of RF issues (i.e. hidden node), adjacent channel and fundamental frequency interference issues, receiver and antenna characteristics, and environmental issues, which will result in harmful interference to incumbent licensed services.

In short, Pulse~LINK does not address any of the significant issues that would be required to ensure existing services are protected from harmful interference, and it does not consider the practical details of its proposed system. It simply presumes that interference cannot happen. Obviously, the Commission cannot take the same view.

Texas Instruments. Texas Instruments also provided comments that advocate non-voluntary CR sharing of licensed spectrum bands in a similar manner. It suggested that a

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[29] *Id.*

"control channel network" can regulate access to *all* spectrum bands, "as a function of frequency, time and location,"[31] stating that compliant CR devices and base stations could use "some form of geolocation technology," could monitor both spectrum and control channels for available timeslots and codes, communicate with the control channel network stating its intention to use available spectrum including its duration and location, and the control channel network could include a "clearinghouse function that includes a map or database of spectrum availability."[32] And, it simply states this proposed mechanism "enables the user to access available spectrum."[33]

However, similar to Pulse~LINK's proposed CSM method, Texas Instrument's proposed control channel network does not address any practical, technical or detailed issues associated with its proposed approach. It only provides high-level conceptual and theoretical possibilities, with no analysis to conclude its proposal is technically or practically feasible for non-voluntary sharing in any licensed spectrum band.

Hypres. Hypres provided comments in this proceeding supporting sharing of licensed spectrum bands in cooperative and non-voluntary CR modes through a variety of conceptual models based upon spectrum monitoring and utilization of beacon control channels, claiming its Superconductor MicroElectronics (SME) technology can enable and facilitate more efficient spectrum management.[34]

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[30] Pulse~LINK does not consider the costs involved to convert systems to utilize its proposed CSM channel. For CMRS systems, the costs would be in overwhelming, with infrastructure and handset costs in the hundreds of billions to replace.

[31] Texas Instruments Comments, pages 1, 6.

[32] *Id.*

[33] *Id.*

[34] Hypres also provided comments in the Interference Temperature proceeding (ET Docket No. 03-237) on April 5, 2004. V-COMM provided reply comments in the same proceeding on May 5, 2004, addressing Hypres' interference temperature based proposals.

Hypres states its proposed approach has the capability to support direct monitoring, and is ideal for the beacon approach with reasonable response time for fail-safe provisions.[35] Further, it provides that its "spectral monitoring provides an opportunity to detect changes in the local spectral environment, and can serve as an enforcement tool."[36] Hypres includes, in its comments, high-level conceptual radio modules to support monitoring, stating it provides "total spectrum management," and claims its unique spectrometer sensing capabilities with intelligent controllers can sniff, find and transmit on available spectrum while changing frequencies on the fly in real-time.[37]

However, Hypres provides no specific technical or engineering analysis of the impact to incumbent systems in connection with its proposed approach; it only provides high-level conceptual models to the Commission.[38] Further, no practical details are considered, no technical analysis is provided, nor explanations relating to how it will work in real-world environments while preventing incorrect assessment of spectrum availability and addressing the multitude of RF environmental issues as outlined by V-COMM and many other parties in this proceeding, nor does it address how it will prevent harmful interference to existing services in any licensed spectrum band.

Even Shared Spectrum (a proponent of non-voluntary sharing of licensed spectrum) offers reservations concerning the practicality of the network monitoring approach:

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[35] Hypres Comments, page 6.

[36] *Id.*, page 13.

[37] *Id.*, page 7. Hypres states "[i]n effect, we "sniff" the spectrum with great precision, find available spectrum (in one piece or in parts), transmit in the available spectrum with high spectral density, and change it (on the fly) in real time."

[38] For example, Pulse~LINK provides new terms and models such as "trusted agents," links to "central authority" to address security issues, and other "spectrometer" and "synchronizer" conceptual ideas that it claims will enable sharing of licensed spectrum bands.

> Because of the limited applicability and the practical difficulties (cost of the Monitoring Sites, getting the data back to the Transceiver, and calibrating the Monitoring Sites), we believe that the Closed-Loop architecture is workable in only a few scenarios, and should not be the basis for using the Interference Temperature concept.[39]

Sprint also disagrees with the network monitoring approach and states "[t]he "direct" interference control mechanism might be workable in theory, but would involve so many technical, engineering and cost challenges that the approach is not feasible as a practical matter."[40] Hypres does not begin to delineate what will be involved in the actual development of is proposed system, including the R&D costs, the interconnection to the various deployed systems, spectrum requirements for communicating to the spectrum-sharing devices, nor the potential harmful impacts to incumbent licensed systems, services and subscribers.

II. MANY PARTIES OPPOSE NON-VOLUNTARY SHARING OF LICENSED BANDS

Many parties from the wireless industry, including service operators, equipment providers, industry associations and government entities, agree that unlicensed CR devices can cause disruptions to existing services in licensed bands if non-voluntary CR sharing is permitted. The issues provided by many parties include: causing uncontrollable harmful interference to licensed bands; decreasing coverage, capacity and service quality for CMRS customers; incompatibilities with existing cognitive radio technologies and future secondary market deployment in licensed bands; security issues for rouge devices; and difficulties of unlicensed

[39] See *Comments of Shared Spectrum*, page 6, in the Interference Temperature proceeding (ET Docket No. 03-237) filed on April 5, 2004.

[40] See *Sprint Corporation Comments*, page 32, in the Interference Temperature proceeding (ET Docket No. 03-237) filed on April 5, 2004.

applications in licensed mobile service bands.[41] These issues are further outlined below. Based upon our analysis above and the response from the industry, CR technology should be reserved for unlicensed bands, and voluntary arrangements in licensed bands, to protect incumbent licensed systems from harmful interference.

CMRS provider Cingular commented that non-voluntary third party cognitive radio (CR) use of licensed spectrum:

> … would disrupt the licensee's own internal management of its radio network, potentially upsetting the spectrum efficiency benefits the licensee has already derived from its own use of a carefully managed cognitive radio technology and making it much more difficult, if not impossible, to lease the use of the spectrum to others in the secondary market. [42]

It points outs that existing operations in CMRS bands already utilize cognitive radio technologies.[43] Additionally, as Verizon Wireless indicates in its comments, "promoting unlicensed cognitive radios in licensed bands will lead to increased interference with CMRS services,"[44] and thus cause operators billions to cope with the interference and degraded service quality, and impair a licensee's ability to deploy new services to meet customers' demands.

The Cellular Telecommunications & Internet Association (CTIA) also expressed concerns regarding the introduction of unlicensed devices in licensed CMRS bands, and states

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[41] See comments from parties including Cingular Wireless ("Cingular"), Verizon Wireless, Motorola, Ericsson, CTIA, Access Spectrum, New York State Office for Technology ("NY State"), and the National Public Safety Telecommunications Council ("NPSTC").

[42] Cingular Comments, pages 2-3.

[43] Cingular states "[i]n fact, cellular and PCS systems have always depended integrally on cognitive radio technologies (e.g., dynamic power control and frequency selection based on real-time measurement of the radio frequency environment, adaptive modulation and coding schemes, protocols for data collision avoidance, error detection and correction, interaction with other devices) that have been at the core of cellular network design from the very start," Cingular Comments, page 3. Motorola further highlights the cognitive radio aspects of CMRS system using EDGE, TDMA, GSM and CDMA technologies. Motorola Comments, page 3.

[44] Verizon Wireless Comments, page 5.

> … [it] would degrade the coverage and capacity of existing networks and undermine incentives for licensed CMRS carriers to deploy more spectrum-efficient technologies in the future.[45]

CTIA also outlined that CMRS systems "are in fact more susceptible to third party interference than less sophisticated technologies,"[46] and future cutting-edge technologies that operate with a lower signal-to-interference ratio may not be deployed should unlicensed secondary uses detract from the quality of these offerings.[47] CTIA proposes that a better way to facilitate spectrum access opportunities in CMRS bands is to "foster a robust secondary market that enables private parties to voluntarily negotiate spectrum leasing arrangements that take advantage of new technological capabilities, including cognitive radio."[48]

Access Spectrum, a band manager supporting voluntary spectrum access in licensed bands, also addresses problems of increasing noise floors with non-voluntary CR sharing of licensed spectrum bands, stating "the addition of unlicensed devices, along with the commensurate rise in the noise floor, may impede the ability of licensees to implement their own low power services in competition with unlicensed devices."[49]

Nextel Partners, providing mobile services to small to mid-sized markets, also expressed concerns of interference and disruptions to heavily utilized CMRS services, and states:

> In general, CMRS bands are heavily utilized by incumbent users, and contain little "white space" or unused spectrum. CMRS providers use sophisticated techniques to manage their licensed spectrum, and the introduction of opportunistic devices on a non-voluntary basis is likely to cause disruption, make system growth problematic, and result in increased levels of interference.

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[45] CTIA Comments, page 2.

[46] CTIA Comments, page 6.

[47] *Id.*

[48] *Id.*, page 7.

[49] Access Spectrum Comments, page 4.

V-COMM agrees with this assessment, and provided empirical data to the Commission in this proceeding from the National Telecommunications & Information Administration's (NTIA) and V-COMM's spectrum studies showing high utilizations of cellular spectrum bands with little to no white spaces available at this time, and even less expected with future customer demands for voice and data services in these licensed bands.[50]

Wireless equipment providers also provided concerns that licensed mobile service bands are inappropriate for non-voluntary CR sharing, citing radio environment difficulties and the potential for interference to existing services. Motorola states that "[e]xhaustive testing of CRs under numerous scenarios would be required to validate the non-interference claims",[51] it would be inappropriate to consider non-voluntary uses in CMRS bands for technical reasons, and:

> Mobile services present the most challenging environment for implementing cognitive radios in a way that does not present an interference threat to the licensed service. The mobility of service users in mobile bands makes it impossible for current generation cognitive radio technology to model accurately the interference environment on a dynamic basis.[52]
>
> … a host of challenges such as antenna shadowing, path loss uncertainty, varying antenna patterns, varying levels of detector sensitivity, and incompatible transmission formats, all combine to make it impossible to predict whether measurements accurately reflect radio activity in a given radio environment.[53]
>
> Among the most notable challenges that will confront an unlicensed CR accessing licensed bands are 1) the difficulty in detecting and properly classifying the transmissions of the primary user, 2) the difficulty in predicting and responding to future channel activity by primary users, 3) the difficulty in determining the incumbent's receiver locations, and in estimating path loss and

[50] V-COMM Comments, pages 42-46.

[51] Motorola Comments, page 6.

[52] *Id.*, page 9.

[53] *Id.*, page 10.

> contributions from itself and other interferers at the primary receivers. [54]

In addition to these technical challenges for improper assessment of spectrum availability and interfering with co-channel operations in CMRS bands, Motorola adds that transmissions from adjacent channel and image signals of CR device also can inadvertently degrade licensed services, even when correct assessments are made by CR device for co-channel spectrum occupancy.[55]

Ericsson agrees that "significant research is necessary to determine what specific role a cognitive radio technology can potentially play without the risk of creating additional interference and unreliability."[56] Other comments from public safety entities also agree.[57] Ericsson further outlines the serious problems with unlicensed non-voluntary CR applications in licensed mobile bands:

> Determining spectrum use in a dynamic RF environment poses serious problems … the ever-changing nature of the mobile environment and the significant difficulties in quantifying the interference temperature environment in real-time, limit the ability to identify, prevent, and curtail interference to the licensee. In the same way, the mobile environment will also limit the ability of a transmitter to detect, in real-time through cognitive radio technology, whether spectrum is sufficiently "unused."[58]

In addition, some parties including Cingular and New York State's Office For Technology addressed the use of specialized detectors to mitigate the hidden node problem, but

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[54] *Id.*, page 13.

[55] *Id.*, page 13-14, "Even if a CR successfully monitors a channel and determines that it is vacant, operation on an adjacent or alternate channel or some image frequency can still degrade communications for the primary user."

[56] Ericsson Comments, page 21.

[57] NY State Comments, page 14, express the need to "thoroughly test and validate these technologies to ensure they will not cause harm to Public Safety or critical infrastructure operations."

[58] *Id.*, page 16 (footnote omitted).

found significant limitations with respect to mobile bands, multi-path propagation, receiver and antenna characteristics, and other incompatibilities that outline the technical short-comings and ineffectiveness of these technologies. NY State offers that even "a 30 – 40 dB improvement will not be sufficient in the UHF bands where topographic signal path attenuation and directional antennas can easily negate that level of sensitivity improvement."[59] Cingular states:

> These detectors are not practicable for cognitive radios sharing spectrum with licensed CMRS operations, however, because of the longer sensing times involved (as much as several seconds). In CMRS, licensed transmitters vary their transmitting power up to hundreds of times per second, and in some access technologies (such as GSM), hop frequencies many times per second as well.[60]

V-COMM agrees with these assessments. Shared Spectrum, a proponent of unlicensed sharing of licensed bands, also acknowledges the variation in local radio propagation environments "can be 50 dB to 60 dB different"[61] for the victim licensed spectrum user, which acknowledges the difficulties even under circumstances when CR devices use specialized detectors to measure static licensed signals with longer sensing times.

Additionally, the National Public Safety Telecommunications Council ("NPSTC") raised two critical security issues for unlicensed CR devices sharing licensed bands, which are the prevention of unauthorized updates in software, and causing interference accidentally or intentionally to licensed spectrum users.[62] For example, NPSTC states that CR devices could be mass-programmed over the air and result in significant disruptions to existing communications systems, which underlies critical concerns of such unlicensed CR proposals.

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[59] *Id.*, page 8.

[60] Cingular Comments, page 14.

[61] Shared Spectrum Comments, page 5, in the Interference Temperature proceeding (ET Docket No. 03-237) on April 5, 2004.

[62] NPSTC Comments, page 9.

> … large numbers of radios could be modified simultaneously, such as through a software download over the Internet or other connected network to remotely programmable devices resulting in a widespread disruption to other services…
>
> … perhaps tens of thousands, could be simultaneously modified through a virus introduced into a commercial cellular system, or through devices interconnected to the Internet.[63]

Cognitive radio proponents IEEE-USA, Cisco and Alvarion also point out the challenges and difficulties that must be overcome with unlicensed non-voluntary use of license bands. IEEE-USA strongly recommends confirming reliability and practicality of CR technology, the need to resolve numerous technical issues including field testing, the need to know how harmful interference can be determined, cumulative effects, what operations will ensure no harmful interference to licensed users, and the need for interference resolution mechanisms.[64]

Cisco, recognizing the priority for the Commission is to first protect licenses from harmful interference,[65] believes a significant effort would be required to ensure CR devices do not interfere,[66] and does not recommend non-voluntary unlicensed uses in existing licensed bands due to the "potential for disruptions to existing business models."[67] Cisco also points out the basic engineering problems with creating a device "… whereby the cognitive transmitter can identify or sense those receivers":

> This is not a problem that has a ready-made, operationalized solution. As if that were not difficult enough, local propagation conditions vary significantly in time and space. These localized differences can prevent a transmitter from determining interference conditions at the receivers the transmissions might affect. Frequency selection based on RF energy measurements -- even if

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[63] *Id.*

[64] IEEE USA, para. 2.

[65] Cisco Comments, page 2.

[66] *Id.*, page 4.

[67] *Id.*, page 6.

> these can detect signals below the local noise level -- may not be sufficient to determine a choice of operating frequency.[68]

Also, Alvarion raises the issue that "there are no mechanisms compatible between vendors which allows for sharing of the spectrum while maintaining QoS to time sensitive applications,"[69] and outlines the difficulties in using GPS for unlicensed CR uses in licensed bands because it would be unreliable and not provide accurate information due to shadowing by trees and buildings.[70] IEEE 802, another CR proponent, also acknowledges the difficulties in utilizing GPS with unlicensed CR devices to determine the location of the devices, stating that GPS would be unreliable and can also result in human error when databases need reprogramming.[71] For the same reasons that GPS is unreliable (the shadowing of trees and buildings) the cognitive radios' sensing of the environment will also be unreliable, and thus no effective solution remains for unlicensed CR devices to share licensed bands on a non-voluntary basis.

III. MANY PARTIES OPPOSE INCREASING TRANSMITTER POWER OF UNLICENSED DEVICES

Many parties from the wireless industry, including mobile service operators, wireless equipment providers, industry associations and unlicensed equipment providers, address significant technical issues regarding the potential for disruptions to existing systems in licensed and unlicensed bands as a result of increasing transmit power levels for unlicensed CR devices. These include: increasing noise levels and disrupting existing operations in unlicensed bands; and increasing noise levels and disrupting existing operations in licensed bands due to increased

[68] *Id.*, page 9.

[69] Alvarion Comments, page 3.

[70] *Id.*, page 5.

out of band emissions from higher power unlicensed CR devices. Based upon the response from the industry, the Commission should not increase power limits for unlicensed devices and should further investigate these issues to fully address the many unanswered and significant technical issues that are raised by the parties, including the impacts to existing services in both unlicensed and licensed bands, prior to considering any proposal to increase power limits for unlicensed devices. At a minimum, the Commission should not permit out-of-band emissions to exceed current limits for unlicensed devices, to ensure existing services in licensed bands are not subject to increased levels of noise and are protected from harmful interference.

The Cellular Telecommunications & Internet Association (CTIA) is opposed to increasing the emissions for unlicensed CR devices, as it will raise the noise floor in licensed spectrum, such as CMRS bands, which are more susceptible to interference due to their intensive use of spectrum.[72] CTIA notes that the NPRM does not contain meaningful analysis regarding interference risks to in-band and out-of-band licensees, which would be required before considering any proposal to increase emissions for unlicensed users of cognitive devices.[73] Further, CTIA has specific concerns regarding increasing out-of-band emissions with the Commission's current definition for out-of-band emissions (OOBE) for unlicensed devices at 20 dB below the in-band power level. Accordingly, CTIA believes the Commission, at a minimum, must not allow OOBE to exceed existing limits.[74]

The National Association for Amateur Radio, also known as the American Radio Relay League (ARRL), also opposes the increased emission limits proposed by the Commission.

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[71] IEEE 802 Comments, para. 24.

[72] CTIA Comments, page 5.

[73] *Id.*, page 2.

ARRL states the proposal to increase unlicensed emissions (to 6 watts of transmitter output power and 24 watts EIRP) is ill-advised, and "cannot not under any definition be considered either "low power" or "Part 15" device."[75] For example, in comparison, the transmitter power level of 6 watts is equivalent to the transmitter power level of a CDMA base station operating in commercially licensed CMRS bands.[76] ARRL states that "the range and interference contours of such transmissions would clearly extend far beyond the boundaries of whatever the configuration of the device would deem a 'rural area'."[77] Further, ARRL offers "there is no plan or regulatory technique which can successfully limit the deployments of these devices to rural areas," and "neither is there apparently a safe means of deployment of high power unlicensed devices and systems, which would be operated by non-technical individuals who are not skilled in managing the environmental effects of RF energy."[78]

The Society of Broadcast Engineers (SBE) points out a significant issue concerning the additional interference resulting from unlicensed systems utilizing higher power antennas (i.e. 10 to 20 dBi antennas), which are widely available in retail stores[79] and would invariably be integrated to these higher power devices. SBE also points out dozens of articles on existing

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[74] *Id.*, page 9. Also, CTIA offers that increased noise levels in CMRS bands would decrease system coverage and capacity, increase risk of dropped calls and lower quality calls, reduce data throughput, and weaken licensees' incentives to make more efficient use of their spectrum. CTIA Comments, page 5-6.

[75] ARRL Comments, page 3, 14.

[76] The transmitter power level of 6 watts is equivalent to the transmitter power level of a CDMA base station, as referenced to the input port of the transmit antenna.

[77] *Id.*

[78] *Id.*, page 13.

[79] SBE Comments, page 3. It also states that "[r]eadily available online literature makes promises of communication distances of "up to 20 miles" with existing (1-watt TPO) power limit."

unlicensed band interference, and states that the Commission's proposed 8 dB increase "would be guaranteed to be the straw that breaks the camel's back."[80]

Equipment providers Ericsson and Motorola also address increased risks of interference to in-band and out-of-band operations, which could, for example, block lower power devices from operating in unlicensed bands and result in certain devices not being able to operate,[81] and the clear need for more interference studies to be performed to determine interference risks conclusively.[82] Motorola adds that the Commission's proposal for defining "unused spectrum" does not have a substantial basis and if adopted would not protect existing unlicensed operations.[83]

Unlicensed broadband equipment providers also raise significant concerns with respect to the Commission's proposal to increase unlicensed emissions limits. Intel urges the FCC to be cautious, and states that the "increase in power in the 900 MHz and 2.4 GHz bands would likely result in significantly more interference and suboptimal quality of service."[84] Alvarion states that the impact could have a "destabilizing effect" on existing broadband operations in unlicensed bands, and many wireless broadband subscribers will be subject to increased interference from nearby high power transmitters.[85]

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[80] *Id.,* pages 3-4.

[81] Ericsson Comments, pages 16-17, 19.

[82] *Id.*, page 17. Motorola Comments, page 8.

[83] *Id.*, page 8, footnote 11.

[84] Intel Comments, page 4.

[85] Alvarion Comments, page 4. Alvarion also points out the need for sufficient adjacent channel attenuation to prevent interfering with system operating on adjacent spectrum channels.

IV. CONCLUSION

For reasons provided above, V-COMM respectfully requests the Commission to consider these issues when reviewing its spectrum policies concerning non-voluntary unlicensed Cognitive Radio sharing of licensed spectrum bands. The Commission must carefully consider the effects of new spectrum-sharing devices on increasing spectrum noise floors and causing harmful interference to existing licensed communication services. The Commission's objective to increase and improve the use of radio spectrum with cognitive radio technology is better met by protecting licensed services from the effects of harmful interference and facilitating opportunities through secondary market arrangements.

Respectfully Submitted,

V-COMM, L.L.C.

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June 1, 2004

APPENDIX A – COMPANY INFORMATION & BIOGRAPHIES

V-COMM is a leading provider of quality engineering and engineering related services to the worldwide wireless telecommunications industry. V-COMM's staff of engineers are experienced in Cellular, Personal Communications Services (PCS), Enhanced Specialized Mobile Radio (ESMR), Paging, Wireless Data, Microwave, Signaling System 7, and Local Exchange Switching Networks. We have provided our expertise to wireless operators in engineering, system design, implementation, performance, optimization, and evaluation of new wireless technologies. Further, V-COMM was selected by the FCC & Department of Justice to provide expert analysis and testimony in the NextWave and Pocket Communications Bankruptcy cases. V-COMM has offices in Blue Bell, PA and Cranbury, NJ and provides services to both domestic and international markets. For additional information, please visit V-COMM's web site at www.vcomm-eng.com.

BIOGRAPHIES OF KEY INDIVIDUALS

Dominic C. Villecco
President and Founder
V-COMM, L.L.C.

Dominic Villecco, President and founder of V-COMM, is a pioneer in wireless telecommunications engineering, with 22 years of executive-level experience and various engineering management positions. Under his leadership, V-COMM has grown from a start-up venture in 1996 to a highly respected full-service consulting telecommunications engineering firm.

In managing V-COMM's growth, Mr. Villecco has overseen expansion of the company's portfolio of consulting services, which today include a full range of RF & Network design, engineering & support; network design tools; measurement hardware; and software services; as

well as time-critical engineering-related services such as business planning, zoning hearing expert witness testimony, regulatory advisory assistance, and project management.

Before forming V-COMM, Mr. Villecco spent 10 years with Comcast Corporation, where he held management positions of increasing responsibility, his last being Vice President of Wireless Engineering for Comcast International Holdings, Inc. Focusing on the international marketplace, Mr. Villecco helped develop various technical and business requirements for directing Comcast's worldwide wireless venture utilizing current and emerging technologies (GSM, PCN, ESMR, paging, etc.).

Previously he was Vice President of Engineering and Operations for Comcast Cellular Communications, Inc. His responsibilities included overall system design, construction and operation, capital budget preparation and execution, interconnection negotiations, vendor contract negotiations, major account interface, new product implementation, and cellular market acquisition. Following Comcast's acquisition of Metrophone, Mr. Villecco successfully merged the two technical departments and managed the combined department of 140 engineers and support personnel.

Mr. Villecco served as Director of Engineering for American Cellular Network Corporation (AMCELL), where he managed all system implementation and engineering design issues. He was responsible for activating the first cellular system in the world utilizing proprietary automatic call delivery software between independent carriers in Wilmington, Delaware. He also had responsibility for filing all FCC and FAA applications for AMCELL before it was acquired by Comcast.

Prior to joining AMCELL, Mr. Villecco worked as a staff engineer at Sherman and Beverage (S&B), a broadcast consulting firm. He designed FM radio station broadcasting systems and studio-transmitter link systems, performed AM field studies and interference analysis and TV interference analysis, and helped build a sophisticated six-tower arrangement for a AM antenna phasing system. He also designed and wrote software to perform FM radio station allocations pursuant to FCC Rules Part 73.

Mr. Villecco started his career in telecommunications engineering as a wireless engineering consultant at Jubon Engineering, where he was responsible for the design of cellular systems, both domestic and international, radio paging systems, microwave radio systems, two-way radio systems, microwave multipoint distribution systems, and simulcast radio link systems, including the drafting of all FCC and FAA applications for these systems.

Mr. Villecco has a BSEE from Drexel University, in Philadelphia, and is an active member of IEEE. Mr. Villecco also serves as an active member of the Advisory Council to the Drexel University Electrical and Computer Engineering (ECE) Department.

Relevant Expert Witness Testimony Experience:

Over the past five years, Mr. Villecco had been previously qualified and provided expert witness testimony in the states of New Jersey, Pennsylvania, Delaware and Michigan. Mr. Villecco has also provided expert witness testimony in the following cases:

- United States Bankruptcy Court

- NextWave Personal Communications, Inc. vs. Federal Communications Commission (FCC) **

- Pocket Communications, Inc. vs. Federal Communications Commission (FCC) **

** In these cases, Mr. Villecco was retained by the FCC and the Department of Justice as a technical expert on their behalf, pertaining to matters of wireless network design, optimization and operation.

David K. Stern
Vice President and Co-Founder
V-COMM, L.L.C.

David Stern, Vice President and co-founder of V-COMM, has over 20 years of hands-on operational and business experience in telecommunications engineering. He began his career with Motorola, where he developed an in-depth knowledge of wireless engineering and all the latest technologies such as CDMA, TDMA, and GSM, as well as AMPS and Nextel's iDEN.

While at V-COMM, Mr. Stern oversaw the design and implementation of several major Wireless markets in the Northeast United States, including Omnipoint - New York, Verizon Wireless, Unitel Cellular, Alabama Wireless, PCS One and Conestoga Wireless. In his position as Vice President, he has testified at a number of Zoning and Planning Boards in Pennsylvania, New Jersey and Michigan.

Prior to joining V-COMM, Mr. Stern spent seven years with Comcast Cellular Communications, Inc., where he held several engineering management positions. As Director of Strategic Projects, he was responsible for all technical aspects of Comcast's wireless data business, including implementation of the CDPD Cellular Packet Data network. He also was responsible for bringing into commercial service the Cellular Data Gateway, a circuit switched data solution.

Also, Mr. Stern was the Director of Wireless System Engineering, charged with evaluating new digital technologies, including TDMA and CDMA, for possible adoption. He represented Comcast on several industry committees pertaining to CDMA digital cellular technology and served on the Technology Committee of a wireless company on behalf of Comcast. He helped to direct Comcast's participation in the A- and B-block PCS auctions and won high praise for his recommendations regarding the company's technology deployment in the PCS markets.

At the beginning of his tenure with Comcast, Mr. Stern was Director of Engineering at Comcast, managing a staff of 40 technical personnel. He had overall responsibility for a network that included 250 cell sites, three MTSOs, four Motorola EMX-2500 switches, IS-41 connections, SS-7 interconnection to NACN, and a fiber optic and microwave "disaster-resistant" interconnect network.

Mr. Stern began his career at Motorola as a Cellular Systems Engineer, where he developed his skills in RF engineering, frequency planning, and site acquisition activities. His promotion to Program Manager-Northeast for the rapidly growing New York, New Jersey, and Philadelphia markets gave him the responsibility for coordinating all activities and communications with Motorola's cellular infrastructure customers. He directed contract preparations, equipment orders and deliveries, project implementation schedules, and engineering support services.

Mr. Stern earned a BSEE from the University of Illinois, in Urbana, and is a member of IEEE.

Sean Haynberg
Director of RF Technologies
V-COMM, L.L.C.

Sean Haynberg, Director of RF Technologies at V-COMM, has over 14 years of experience in wireless engineering. Mr. Haynberg has extensive experience in wireless system design, implementation, testing and optimization for wireless systems utilizing CDMA, TDMA, GSM, AMPS and NAMPS wireless technologies. In his career, he has conducted numerous first office applications, compatibility & interference studies, and new technology evaluations to assess, develop and integrate new technologies that meet industry and FCC guidelines. His career began with Bell Atlantic NYNEX Mobile, where he developed an in-depth knowledge of wireless engineering.

While at V-COMM, Mr. Haynberg was responsible for the performance of RF engineering team supplying total RF services to a diverse client group. Projects varied from managing a team of RF Engineers to design and implement new a PCS wireless network in the NY MTA; to the wireless system design & expansion of international markets in Brazil and Bermuda; to system performance testing and optimization for numerous markets in the north and southeast; to the development and procurement of hardware and software engineering tools; to special technology evaluations, system compatibility and interference testing. He has also developed tools and procedures to assist carriers in meeting compliance with FCC rules & regulations for RF Safety, and other FCC regulatory issues. In addition, Mr. Haynberg was instrumental in providing leadership, technical analysis, engineering expertise, and management of a team of RF Engineers to deliver expert-level engineering analysis & reporting on behalf of the FCC & Department of Justice, in the NextWave and Pocket Communications Bankruptcy proceedings.

Prior to joining V-COMM, Mr. Haynberg held various management and engineering positions at Bell Atlantic NYNEX Mobile (BANM). He was responsible for evaluating new technologies and providing support for the development, integration and implementation of first office applications (FOA), including CDMA, CDPD, and RF Fingerprinting Technology. Beyond this,

Haynberg provided RF engineering guidelines and recommendations to the company's regional network operations, supported the deployment and integration of new wireless equipment and technologies, including indoor wireless PBX/office systems, phased/narrow-array smart antenna systems, interference and inter-modulation analysis and measurement, and cell site co-location and acceptance procedures. He was responsible for the procurement, development and support of engineering tools for RF, network and system performance engineers to enhance the system performance, network design and optimization of the regional cellular networks. He began his career as an RF Engineer responsible for the system design and expansion of over 100 cell sites for the cellular markets in New Jersey, Philadelphia, PA; Pittsburgh, PA; Washington, DC; and Baltimore, MD market areas.

Mr. Haynberg earned a Bachelor of Science degree in Electrical Engineering with high honors, and attended post-graduate work, at Rutgers University in Piscataway, New Jersey. While at Rutgers, Mr. Haynberg received numerous honors including membership in the National Engineering Honor Societies Tau Beta Pi and Eta Kappa Nu. In addition, Mr. Haynberg has qualified and provided expert witness testimony in the subject matter of RF engineering and the operation of wireless network systems for many municipalities in the State of New Jersey.