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

In the Matter of	)	
	)	
Spectrum Policy Task Force	)	ET Docket No. 02-135
	)	
	)	

SPECTRUM POLICY TASK FORCE RESPONSE
BY HYPRES, INC

HYPRES, Inc., is submitting these comments in response to the request for relevant information related to the Spectrum Policy Task Force (SPTF) Report dated November, 2002. In that report a number of recommendations were made to improve spectrum access and utilization. A common theme throughout the report was the potential for emerging technology to enable new approaches to spectrum management and regulation. Our intent in this response is to present HYPRES capabilities in the context of SPTF recommendations, and to describe the role of new technology in furthering Commission objectives.

Overview

HYPRES, Inc. is a manufacturer of exceptionally high-performance and cost-effective electronic devices and equipment using Superconductor Technology. HYPRES has demonstrated digital circuit capabilities that far exceed the performance currently available and forecasted with semiconductors and other implementations. The performance of these circuits enables real-time processing of RF signals in the digital domain at frequencies previously unattainable. HYPRES technology, "**Digital RF**," brings an unprecedented degree of digital processing capability to the RF domain.

In these comments, HYPRES provides information on specific areas where use of **Digital RF** will facilitate implementation of recommendations made by the SPTF. We also make some observations about incentives and motivation to expedite the often arduous process of introducing new technology.

Implementation Enablers

HYPRES **Digital RF** provides infrastructure digital circuit performance to operate in realtime with precision capable of accurate representation of radio frequency signals up to 5 GHz. Capabilities include ultra-high-performance conversion between analog and digital format, 100GHz clock speed, and tera-operations per second processing. Appendix A describes these capabilities in detail.

The following applications are areas where the power of **Digital RF** can be applied to facilitate implementation of recommendations made by the task force.

Transmission

When using digital systems to prepare a signal for transmission it is possible to combine a number of baseline inputs into a composite representation in the time domain. Then a digital to analog (DAC) converter generated signal is used as an exciter signal for a power amplifier (PA) that generates the desired transmission power. Transmission of such highly complex waveforms, however, places a burden on the PA, requiring very accurate amplification to avoid harmonics and intermodulation between components of the signal delivered to the antenna.

This problem can be eliminated by sampling PA output, feeding the results back, and predistorting the digital signal fed to the DAC to compensate for PA non-linearities, providing a spectrally pure carrier. To be effective, however, processing must take place at a speed greater than that which can be achieved with conventional technology. HYPRES's **Digital RF** circuits are capable of minimizing the time delay to provide substantial improvement in the transmitted signal.

The following benefits are derived from this capability:

COST. PAs can be used that are much lower cost than conventional units because their effective efficiency is dramatically increased. Fewer PAs are needed when signals are combined digitally rather than with analog combiners. Power consumption is also reduced substantially.

ACCURACY. The envelope of the transmitted waveform can be controlled to improve inband accuracy of the transmitted signal.

INTERFERENCE REDUCTION. Out-of-band signals can be reduced to the extent desired.

Reception

HYPRES **Digital RF** technology enables receivers of unprecedented bandwidth and sensitivity, and an ability to reduce the effective signal to noise/interference level without adding receiver noise to the signal. Two HYPRES capabilities enable this new performance level:

ADC PERFORMANCE. HYPRES **Digital RF** performance enables analog to digital performance at very high rates with extreme accuracy. This capability enables the converter to be placed very close to the antenna without downconversion to introduce noise. An extremely precise digital representation of the RF waveform is thus available for digital processing. All of the signals in a wide bandwidth are brought in together, and resolved digitally after conversion to the frequency domain.

CORRELATION-BASED RECEPTION. When the waveform of the signal of interest is known, it becomes possible to use correlation techniques to extract the signal and reduce the effective noise level. This is accomplished by correlating the incoming signal with a reference signal over a period of time. The desired information correlates, and is retained, while the noise and interferers do not, and are rejected. This technique trades off noise reduction against the delay introduced by correlating over a number of cycles of the RF waveform. Conventional technology requires delays of seconds to reach useful levels of reduction, but users cannot tolerate delays over one hundred milliseconds for full-duplex wireless voice applications. HYPRES **Digital RF** technology provides substantial noise reduction with delays under one millisecond, thus effectively improving base stations receiver sensitivity. Improved sensitivity permits operation with reduced remote terminal transmit power, resulting in reduced interference, and longer battery life. It also provides extended coverage for rural areas.

Monitoring

The holistic approach to spectrum management advocated by the SPTF report requires more knowledge about spectrum utilization in frequency, space, power, and time than is currently available. It also suggests noise temperature as a local variable that can be used to improve spectrum efficiency. One proposal for filling the need for data is a monitoring network. HYPRES **Digital RF** technology opens a significant new possibility for spectrum monitoring.

In the process of building out network coverage, the wireless service providers have established antenna sites all over the United States. Those sites have a significant potential to play a remote sensor role that has a number of system applications.

Baseline Spectrum Usage. With a high performance front end, base station receivers can sample a wide range of the ambient RF environment on a routine basis. Operating as a background task behind its primary mission of supporting wireless service, the base station receiver can take random samples of the spectrum at a specific frequency and time to determine if an emitter is active, and the power level received. The resultant data point will provide information about the receiver location, sector direction, frequency observed, time of the sample, and information about the received signal. It is also possible to synchronize sampling across a group of base stations so that simultaneous data points are available in subsequent investigations of a specific signal. The sampling rate and duration can be varied to control the volume of data generated and the precision of coverage. Over a period of time the accumulated data will provide a comprehensive picture of spectrum usage in the geography covered by the monitoring facilities. It can also be a resource for investigating spectrum usage during emergencies or disasters.

Spectrum Alerts. Once a baseline picture is developed, it is possible to identify events that are not statistically consistent with the normal case. The presence of an unusual emission or absence of an expected one can trigger an alarm. A faulty x-ray machine might trigger an alert, as might a broadcast station going off the air. The mechanism would have to be band conscious so that normally sporadic signals, such as police radar, would not be seen as an abnormal event. This kind of monitoring could become a service, where notification of the presence or absence of a specific signal provides notification to a subscriber.

Ad Hoc Monitoring. Some of the recommendations contained in the SPTF report are based on the local noise temperature in a given band. Measuring that level and maintaining a record of it is an example of the ability of a monitoring network to perform ad-hoc tasks. This capability could be used to track a fleet of delivery vehicles, locate stolen cars, or perform surveillance for law enforcement organizations.

CONTENT MONITORING. This type of monitoring is characterized by interest in the content of the signal monitored. Network operators with monitoring capability provide the service of capturing the content of specific transmissions. Organizations wanting to collect data contract with the network operator to provide the service over a geographic area. This facility also has the capability to replace the inbound side of a communication system, allowing the remote units to operate with much lower power levels than required to reach a single central receiver site.

Radio Frequency Control and Security

Use of Software Defined Radio (SDR) technology has a number of benefits. It also has the danger that it exposes the possibility of either deliberately or accidentally introducing software that causes a transmitter to transmit outside its authorized band. That, of course, can lead to interference with other operations. The transmitter predistortion facility provided by HYPRES **Digital RF** described above opens a number of possibilities for avoiding improper transmissions.

Unwanted emissions can be caused by improperly installed or degraded transmission lines and antenna elements. They can arise from improper operation, such as overdriving PAs into non-linear portions of their performance curves. Inappropriate software installed in software defined radios can generate a number of operating anomalies. With increased emphasis on etiquette, cooperation, and commons protocols, corrective measures will be needed.

With HYPRES **Digital RF** circuits providing the capabilities mentioned above installed in the infrastructure, a number of opportunities for corrective action arise. The system elements used for transmission predistortion provide a control point that can either correct operational anomalies or shut down transmission altogether. The basis for this security and control capability is implemented by adding a control interface in the predistortion processor. The source of the correction control signals and the security provided to the processing module differentiate the methods.

TRANSMISSION CONTROL. The predistortion process requires a source sensor to sample the analog signal being fed to the antenna, converting it back to digital format, comparing the feedback signal with the original, determining the point by point difference, and distorting the input to the DAC with the complement of the difference. That process will remove the signal distortions introduced between the point of presence of the original signal and the feedback sensor.

It is possible, however to add another step to the digital portion of the feedback loop. This additional step applies rules from an external source that describe the desired transmission envelope, and generates a secondary difference signal if unwanted emissions are found. Both difference signals are then used to generate the difference signal to eliminate them, even if they are present in the original input signal. It is even possible to shut down transmission completely by feeding a signal to the DAC that nulls its output.

RECEIVER-BASED CONTROL. With a control element added to the feedback path, it is not necessary that the source of control reside in the transmit section. With HYPRES's **Digital RF** correlation-based front end sensitivity, the local receiver can be the signal source to generate a secondary difference signal under rules provided to it. The receiver-generated correction operates dynamically — altering the difference signal to the local transmitter, and then testing the received signal to see if the unwanted signal was reduced. If it was not, then some other emitter was at fault.

It is also possible to have several receivers in the same locale coordinate in finding and geolocating the undesired emitter, which may or may not be under control of one of the participating receivers. If it is, then the local transmission predistortion unit can correct the problem.

SECURITY – HYPRES DIGITAL RF REALTIME RADIO CONTROL MODULE (RRCM). The control facilities described above provide the control mechanisms necessary to ensure proper spectrum use. To generate a complete security facility, it is necessary to add a control module, secure communications, and a central authority.

The control module is responsible for receiving commands and waveform descriptions to use as criteria for determining that a correction is necessary. It determines the course of action, and provides commands and data to the transmission control unit to effect the changes.

The secure communications unit is a communications link with a central authority independent of the base station controller or equivalent device. It functions independently to authorize transmission and correct problems in local emissions.

The central authority is associated with the operations and maintenance center, or other central control of the system. It communicates with local control modules over a secure link to provide them with direction on what control measure regimes to instantiate. If the central authority is unable to maintain contact with the RRCM, the default is to raise a local alarm, and then shut down transmissions.

The HYPRES RRCM is a physically secure module providing all of the above functionality with the exception of the central authority. This facility provides a unique operational capability to ensure that spectrum access is not abused. It also make possible a guarantee that introduction of SDR operating software or error corrections will not result in improper emissions.

Problems with handset transmission can also be detected with these techniques. A communication link with the base station controller can be used to identify terminals in violation of the air interface protocols, and either reduce their power or shut them down.

Multi-Service Operation

The HYPRES **Digital RF** capability enables a single network operator to support multiple services. Through a Secondary Markets provision, license-holders can transfer their permission to operate under a particular service set of rules and maintain the operational network to service their customers. There are several advantages of such an arrangement. One is elimination of build out of separate base station sites, especially unsightly towers, for each service, reducing capital expense necessary to initiate a service. Another is reduction in the number of network operators in a geographic, facilitating supervision and reducing the likelihood of errors because of a reduced population of transmitters.

<u>The Need For Commission Support Of Wireless Innovation</u>

We have described the capabilities of HYPRES **Digital RF**, and indicated how they support general goals for wireless communications and enable new capabilities that solve problems and introduce new capabilities. **Digital RF** is not the only emerging technology likely to promote development of personal connectivity through wireless communications. But it is a good example of an innovation that has potential to significantly improve the performance of wireless systems, and enable operators to help the commission meet its objectives.

It is HYPRES's concern that there will be reluctance to move beyond the status quo by a substantial portion of those in a position to adopt the innovation necessary to fulfill the promise of wireless communications. Timely introduction of new technology is important to meeting the challenges faced in optimizing use of RF spectrum. In the section that follows we indicate how the Commission has an opportunity to be the change agent responsible for rapid development of wireless technology.

Wireless communications promise to play a critical role in the high level of personal connectivity envisioned for the future. Mobile telephone service has seen one of the fastest adoption rates in the history of communications systems. The acceptance of mobile phones has clearly demonstrated that people will pay for services they find valuable, and that there is a viable economic justification for wireless services. This emerging market has also demonstrated that bandwidth in the RF spectrum, at one time considered abundant and free, has a definite economic value that must be recognized.

There are a large number of stakeholders in the area of wireless systems, and they have differing perspectives and economic motivations. Some want to change legacy access to spectrum and accelerate introduction of new systems. Others have a vested interest in extending the effective life of existing installations, and avoiding the expense associated with change, even though that change is critical to realizing needed improvements.

The task of inserting new technology is not an easy one, particularly in the face of conflicting interests and perspectives of current and prospective participants. This is especially true in qualitative areas, such as improved accuracy of transmitted signals, where the economic benefits are less substantial. It is imperative that the process resolving these conflicts involve stakeholders from all the constituencies, require that their positions be made known and placed on the table, and that a spirit of compromise rather than rigidly held positions prevail.

Development of new technology is a costly and uncertain process. Introduction of many proposed innovations offering substantial performance improvements over existing systems is dependent on installation of new RF equipment. Incumbent system owners, however, may not feel that they have adequate economic incentive to proceed with such replacement. The resulting market trends are lower than could be realized with the benefits of new technology adoption. Combined with the current uncertainty about technology in the investment community, investment in innovation is being inhibited to an alarming degree.

The Department of Defense, including its technology investments through DARPA, is moving out to meet its needs. But the commercial market is much larger, and operates with economic drivers that make it more efficient. There is a need to balance use of the single RF spectrum, with its wireless mobile capability, against the myriad replication of spectrum represented by fiber connections with fixed terminations. The Commission has an opportunity to move more aggressively to introduce "sunset" provisions that will emphasize use of the RF spectrum for local and mobile connections. Fixed point-to-point operations, such as terrestrial TV broadcast, should be accommodated over the abundant bandwidth provided by landlines.

The commission also has an opportunity to be proactive in publishing requirements for new system capabilities that will stimulate innovation and introduction of new technology. Enhanced capabilities provide a basis for new applications and economic growth.

Incentives and Motivation for Improving System Performance

With any new technology there is a period of adoption, as the technology is applied to a variety of applications, and its capabilities characterized. With use comes familiarity and security in its capabilities. That adoption period varies greatly in length with various specific cases.

We have described the HYPRES **Digital RF** technology, presented a number of capabilities it enables, and described some of the inhibiting factors to introduction of new technology. HYPRES's capabilities are directly supportive of the directions for spectrum management described in the SPTF report. HYPRES feels that it would be appropriate for the Commission to develop future programs based on these capabilities, and to motivate spectrum users to adopt them by providing incentives.

If base stations with the performance enabled by HYPRES **Digital RF** were in wide use, spectrum pollution would be substantially reduced, and the ambient noise floor would be generally lowered. But system operators have little incentive to operate their transmitters more cleanly in areas other than in-band interference, where they are interfering with their own services. They will push for reduced regulatory limits on out-of-band emissions in order to use less capable power amplifiers to reduce cost. They will also try to improve service by driving the amplifiers to higher power levels, where their characteristics are less linear and more prone to spurious emissions.

We propose a solution similar to that used in regulating air pollution. There are certain minimum levels of acceptable pollution, but in some cases factory operators have an option of either installing scrubbers or buying emission rights from other local factories who have lowered emissions. The course of action is their economic decision, but the end result is a controlled level of pollutants without the negative economic impact of shutting down older facilities.

We propose that system operators be provided with an economic incentive to operate their transmitters with a cleaner signal. One such approach in areas where spectrum is auctioned is to offer a substantial discount from the auction price for lowered interference. This method is particularly effective where payment for use of spectrum is on a monthly or periodic basis ("rented") rather than one-time up-front ("owned") basis. The operator could pick any one of a number of improved signal characteristics. The better the signal they agree to use, the greater the discount from the final auction price of spectrum. The discount should be economically sufficient to incentivize the operator to transmit with a cleaner signal, and should have graduating scale depending on spectral purity.

The means to monitor conformance to their agreed-upon performance is provided by the monitoring capability proposed in our preceding comments. We suggest that spectrum monitoring can be another service offering provided by network operators with their existing infrastructure and available background processor time.

We propose that this is a win-win situation. Operators win because they make their own economic trade-offs, with prospects of lowered cost, and have the side benefit of better performance in their networks. Regulators win because the overall quality of spectrum usage is improved and the monitoring system provides much improved data on current spectral conditions. Equipment manufacturers win because a market arises for improved equipment performance, generating the cash flow needed to develop new technology.

Conclusion

We have cited a number of approaches to supporting the findings of the Spectrum Policy Task Force by introducing system improvements based on HYPRES **Digital RF**. Those enhancements also provide significant economic and performance benefits that accrue to the operators, suppliers and users. We urge the Commission to take steps to expedite introduction of these capabilities and the policies that they make viable. We also recommend that operators and service providers be given incentives by the FCC to employ next generation technologies that have the potential of materially affecting these critical issues and garner the benefits accrued to all of the stakeholders

Respectfully submitted,

Jack Rosa
CEO and President
Vice Chairman, Board Of Directors
HYPRES, Inc. **January 27, 2003**

APPENDIX A

HYPRES Technology

HYPRES has demonstrated a superconductor technology that is fundamental to the performance requirements needed to implement the suggested operations, and also provides a number of operational benefits to system operators. HYPRES technology is able to produce the following:

Simultaneous wideband and high-fidelity digitization — Capability of producing 14 to 24 effective (true) bits with 100 to 160 dB Spur Free Dynamic Range (SFDR) over the 100 kHz to 2 GHz range (a 20,000 to 1 bandwidth).

Ultra-high Analog to Digital Converter (ADC) resolution — Capability of producing over 20 effective (true) bits with an SFDR exceeding 130 dB for 3G/4G bandwidths (60 to 100 MHz) at > 2 GHz level carrier frequencies.

Extremely Low-noise, High-sensitivity, and ultra low Bit Error Rate (BER)— Noise-free **Digital RF** front-ends (<< 1^{o} K noise temperature) with sensitivities of -140 to -180 dbm and Bit Error Rates (BER) less than 10^{-15}. Performance capable of correlation based receiver techniques to improve signal to noise /interference level.

Extreme sensitivity enabling unprecedented flexibility for monitoring the digital environment – A combination of extreme sensitivity and very fast processing capability adequate to examine designated portions of spectrum, defined dynamically by software directives, in real-time. Thus the infrastructure is capable of detecting the spectral footprint of in-band and out-of-band emitters, identifying inappropriate transmissions and providing real-time notification of violations and spectral anomalies.

Spectrally-pure carriers –HYPRES high stability multi-GHz clocks coupled with our inherently-perfect Digital to Analog Converters (DAC) provide spectrally-pure GHz-frequency carriers for transmission via a single or multiple high-power amplifiers (HPA).

Ultra-Linearized Single HPA – Capability to directly synthesize digitally pre-distorted wideband waveforms for transmission, enabling multi-carrier operation via a single HPA, simultaneously optimizing in-band performance and minimizing out-of-band spurious effects far beyond current (or forecasted) technologies can achieve. This also represents a significant reduction in initial and operating cost, due to much higher HPA efficiencies.

Low-power Tera-OPS DSP – Execution of Digital Signal Processing operations at clock speeds greater than 100 GHz, including picosecond RAM/ROM access operations and programmable digital filtering, while dissipating only 1 mW/chip.

Ultra-high Reliability & Durability – Similarly packaged, superconducting products currently deployed in wireless communication base stations have exhibited up-times in excess of 99.998%.

Compatibility with Existing Systems – Although revolutionary in operation, HYPRES **Digital RF** products can occupy existing 19 in. racks and interface to any standard bus configuration at a maximum speed limited only by bus performance.

"The technology is so accurate, it defines the volt,
and so sensitive, it can measure brain currents,
and so fast, it can directly convert RF signals"

HYPRES technology offers many benefits to users in a variety of application areas. The following benefits accrue to operators of wireless networks and the FCC:

Lower Capitalization per Base Station – One digital radio performs the tasks of many conventional protocol-and frequency-specific base station radios. For example, the critical communication equipment is reduced by about 90% to about 10% of a traditional GSM base station. A single universal platform can be configured dynamically and/or periodically (in the factory or in the field) to suit many different services, independent of communication bandwidth or standard. This versatility significantly reduces the cost of base stations and the infrastructure provider's spares inventory needed to accommodate multiple protocols.

Reduced Infrastructure Capital Expenditures – HYPRES technology significantly expands base station range coverage, enabling a significant reduction of the total number of base-station sites required, thereby reducing total network capitalization by an order of magnitude. Our technology enables wideband 3G performance with 2G base-station range.

Reduced Operating Expenses – Fewer base stations translates into fewer (costly) connected landlines and less power consumed. Less power consumed per base station is a significant further reduction. High reliability and nearly maintenance free operation further reduces operating cost. Resistance to surges and lightning strike effects means far less repair cost.

Enhanced Revenues and Margins – Because of the higher receiver sensitivity, resolution, and processing speed enabled by the HYPRES technology, more traffic for a given bandwidth allocation is possible, allowing additional users and/or services to be added at will, without upgrading the infrastructure. Our superior interference rejection results in higher call quality, few dropped calls, and, in turn, increased customer usage.

Boost Spectral Efficiency – Current state-of-the-art wireless systems only provide 0.5 to 0.8 bits/sec/Hz, in terms of their ability to exploit (i.e., generate revenue from) an allocated bandwidth. In contrast, the HYPRES approach can provide more than 8 bits/sec/Hz, a 10-fold improvement, vastly accelerating the return on investment for costly spectrum licenses.

Adaptability – Because the HYPRES technology enables universal interoperability among legacy, current, and future wireless protocols, it enables an agile business model that can quickly adapt to meet changing market environments and rapidly accommodate new initiatives (such as spectrum sharing, etc). Our hardware will accommodate generations of software upgrades and changes.

Extended Mobile Battery Life -- HYPRES base station products significantly extend the life of the battery of the mobile terminals**.** Transmit function consumes most of the power in a mobile terminal. The ultra high performance enabled by the HYPRES base station technology enables adequate link margin at a lower level of transmit power from the mobile units.

These performance characteristics permit the location of the ADC to a position adjacent to the antenna for reception and the corresponding DAC adjacent to the PA for transmission. This enables the next generation of true Software Defined Radio (SDR) technology throughout the base station, and facilitates development of near real-time frequency agile performance.[1] HYPRES technology totally supports the objectives of the commission.[2]

[1] FCC 00-41, Policy Statement In the matter of Principles for Promoting the Efficient Use of Spectrum by Encouraging the Development of Secondary Markets, Adopted November 9, 2000 (hereafter 'PS'), Par. 35, 36.
[2] FCC 00-401, WT Docket No. 00-230, Notice of Proposed Rulemaking in the same matter, Adopted November 9, 2000 (hereafter 'NPRM'), Par. 3,4

HYPRES technology is an advanced superconductor technology, where electrical current flows indefinitely and fundamental performance characteristics are derived from quantum principles. Digital logic building blocks using this technology provide digital circuits with much higher performance than can be achieved with semiconductor circuits. The first ADC produced by HYPRES, using relatively crude 3-micron lithography technology, outperformed the best semiconductor ADCs in every aspect.

Superconducting technology has already been embraced by the wireless community, demonstrating excellent performance characteristics and outstanding reliability. We feel that this technology is essential to widespread use of SDR technology.