Electromagnetic Noise, the Invisible Pollution

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Executive Overview:

Over the years the world has seen an ever increasing use of machines and more recently electrical and electronic equipment of all manner to support a more productive and enjoyable lifestyle for its occupants. Be they the machines of heavy industrial, transportation (automobiles, trucks, airplanes, trains, …), pleasure (power boats, snowmobiles, motorcycles, …), construction (drills, saws, sanders, welders, nail guns, …), home appliances (washers and dryers, stoves, microwaves, trash compactors, vacuum cleaners, …), or on the electronic side the myriad of consumer electronics devices, PDAs, game boxes, computers or telecommunications equipment all produce electromagnetic radiation as a critical component of their operation. At times these emissions have had detrimental effects on other devices in their proximity and over the years various laws and regulations have been enacted to help reduce the interference that one machine is allowed to impose on another. This approach has largely been effective, though there have been instances of local interference that have only been remedied by either physically separating the interfering components, or eliminating the use of the less valuable element.

Though sometimes annoying to the individual or groups involved, this circumstance has been a very mild problem of limited concern to the general population. The issue addressed by this white paper is that this mildly irritating situation may be deteriorating rapidly with the ultimate potential that much of our existing wireless communications (broadcast and point to point, data and voice) may no longer function. This concern is based on the now exponential growth in the use of the electrical and electronic devices and products described above. This quantitative concern is amplified by the fact that this equipment is also operating in more overlapped (and ever higher) frequency ranges, and the spectrum is increasingly encumbered through the use of overlay and underlay techniques to more effectively utilize previously allocated spectrum.

The even greater challenge is that very little is known about the so called “noise floor”, or the ambient level of naturally occurring and human created unintentional electromagnetic noise in important areas of the electromagnetic spectrum. This roughly mirrors the state of the understanding of the physical environment until the mid-1900s when people began to quantitatively understand and pursue remedies for the pollution problems that had been created through the Industrial Age. In this paper we will investigate in greater depth both the causes for this concern and a proposed approach for addressing the research needed to quantify both the character and the intensity of the current problem as well as the nature of the anticipated challenges of the future.
The Problem:

The problem addressed in this paper is fundamentally a problem of too much of an otherwise good thing. Machines and electronic devices, be they industrial, commercial or personal have, by-in-large, provided the peoples of the world with a vastly improved lifestyle eliminating repetitive uninteresting jobs, improving productivity, enabling efficient transportation from one place to another across town or across the world, providing vastly improved access to information, education, and entertainment opportunities, and importantly providing greatly enhanced access to other people through various communications technologies. In general, the perception has been that the greater the access to and utilization of these devices and technologies, the better one’s personal lifestyle becomes.

Herein lies the problem that will be the focus of by this paper, namely that each of these devices is an emitter of electromagnetic radiation. Whether this is a fundamental or ancillary attribute, the net result is the ever increasing incidence of low level electromagnetic radiation, particularly in heavily populated areas. This radiation occurs in three forms, intentional radiation such as that provided by a cell phone which uses carefully created, directed and managed electromagnetic radiation to send the signals fundamental to its operation, unintentional radiation such as that given off by a vacuum cleaner, an electric drill, or an automobile, and naturally occurring radiation which varies by geography and time.

Historically, there were relatively few devices (emitters) and since the radiation intensity diminishes rapidly (at roughly the square of the distance for a classical radiator), and the power levels were relatively low, this was not a significant problem. Over time, as more devices were deployed and greater use (and subsequently reliance) was made of the spectrum for purposes of intentional radiation (broadcast radio, two-way radio, broadcast television, cell phones, and increasing data communications of all forms – LAN, WAN, satellite) interference problems rapidly grew. The natural component of the noise floor has similarly been largely neglected for terrestrial communication, though it is being selectively studied by various government organizations based on its impact to space based communications (example solar flares).

To ameliorate the situation for human generated interference, various laws and regulations have been and are being put in place to insure that interference is minimized by constraining both the frequencies that a given product type could use, and the level of acceptable radiation that any given device could emit to affect its intended purpose. This regulatory approach has worked relatively well over the past several decades, but the current exponential growth in devices, the increasing overlap between the frequencies intentionally or unintentionally used by various devices (example the internal data bus in personal computers which is approaching the spectral range used by public safety radios and cell phones), and the advent of new classes of devices (such as ultra wideband) suggests the potential that this approach may be nearing the end of its effective life. Specifically, to better utilize the “scarce” spectrum available for communications, various overlay and underlay techniques are being proposed, approved and deployed, adding to
the general electromagnetic noise level and the interference level or “temperature” (i.e. the portion of the random noise that actually has the frequency, magnitude, in some cases wave form to disrupt and existing signal) across wide ranges of electromagnetic spectrum.

Further, anecdotal evidence suggests that at least in certain spectral regions (most notably the unlicensed 2.4 GHz spectrum used for such devices as microwave ovens, sulfur lamps, portable phones, WiFi local area networks and Bluetooth), and in certain geographies (such as a home or apartment building heavily occupied by 2.4 GHz based devices, inside computer centers or even worse in computer development labs, or in heavy industry plants), the ambient electromagnetic noise level or interference temperature has risen to such a degree that normal use of certain devices (such as cell phones) is simply not possible. The difficulty here is that with a few focused exceptions, there has been little or no work done to characterize the noise floor and/or the related interference temperature even in the simplest case of a single point in space and time.

This lack of information is exceptionally concerning since the real interest from both a theoretical and from a practical policy development point of view is in understanding both the short and long term changes that are occurring in the noise floor, and the variation of the interference temperature over daily, weekly and seasonal cycles. In the case of the noise floor, the real concern is more fundamentally gaining a solid understanding of not only the character of the changes themselves, but also the rate at which these changes are occurring. Assuming that the anecdotal evidence and the limited set of measurements that suggest a growth in the noise floor and the interference temperature are born out, we will want to know when certain classes of existing communicating devices and services will no longer be functional as a basis for making policy decisions on how to deal with these issues.

In another important dimension, since the real world environment is extraordinarily complex and measurements are very difficult to obtain for any particular point in time and space, it is highly desirable to be able to generate computer models of these complex noise environments to better understand the various “cause and effect” relationships that exist. Unfortunately, it is also very difficult to develop the simulation and modeling tools that will be able to analyze these effects when no general modeling capability exists to handle environments with numerous emitters. Furthermore, no standards currently exist for characterizing the electromagnetic emissions of devices to use in models either. Beyond the understanding of existing environments, the ability to predict changes in the noise floor and the interference temperature in newly specified or modified environments given the proposed presence and proximity of a specific set of devices is extremely desirable, but unavailable at this time.
The Proposal:

The obvious proposal is to resolve this important unsatisfied need by producing the required simulation and modeling capability. This would include the development of a standard means of characterizing any emitting device, the creation of a database capable of storing models for common emitters, and the development of the simulation and modeling environment itself. With the availability of this capability the database itself, which should be widely available through the internet, would need to be developed and properly managed to support the actual modeling of various environments. This would in turn enable the understanding both in the abstract and in the specific, how the noise and interference temperature regimes would operate. Though this is an extraordinarily challenging research task it should be manageable if it is pursued in a series of well structured stages. In the opinion of the author, the stages in the development of the capability should be divided into the following tasks.

Logically, the first task that needs to be pursued is the actual refinement of the proposal described in the rest of this white paper, on the careful assessment of the human resources (including skill profile), as well as the computing and instrumentation resources that would be required to achieve each stage of the research task. To successfully accomplish this, a deeper review of the applicable research work currently being pursued by others will be required as well as the identification and assurance of appropriate commitments from a variety of others for the use of their applicable and available assets.

With the completion of this in-depth proposal, the next effort would be to develop the specifications and standards for the characteristics of the device models to be created. This would include the standardization of the measurement techniques and a clear description of the data to be captured and the requirement of the number of devices to be measured to insure that measurements are statistically representative of the individual device over a range of usage circumstances and over the variation of devices produced by the provider of the device. Ideally, this could over time serve as the basis for a standard that would be used by all applicable device producers to characterize their products.

The third task would be to create the actual database that would be used to store the information to be created in the standard. Particular attention would need to be taken in the nature of the database to insure that the information was readily accessible. The primary and secondary directories for the database would therefore require significant attention. Insuring that not only the internal structure, but also the external web based accessibility were properly cared for would be another key element of this effort.

The fourth major task would be to actually characterize a small, but representative class of popular devices including a few of popular cell phones, a few laptops, a couple of PDAs, one or two implementations of WiFi (IEEE 802.11b based devices), perhaps a microwave oven, and so on. These would then be loaded into the newly established database both to insure that the database is properly structured and to begin the capture process for what is anticipated to be an ever increasing number of devices. This early
capture and storage process should enable the database structure and the interface to be tested and enhanced.

The fifth and initially perhaps the largest and most difficult task will be to put together the simulation and modeling environment itself. Much care will be required to produce an environment capable of properly analyzing the complex interactions between the electromagnetic environment produced by each individual device. There are many simulation environments that have already been produced for various specific purposes such as the establishment of the site for a new cell tower or public safety radio tower. Others exist to model the emissions around cell phones or other emitting devices. The challenge here will be to generalize these environments to handle the breadth of the frequency ranges of interest, to handle multiple emitters, to accommodate a variety of physical environments including the various reflecting and absorbing elements contained in any real space, and to enable the movement of the various elements within the specified environments.

The sixth challenge will of necessity be to assess the validity of the results obtained from the simulation tool compared to the measured results in comparable real world environments. This will require the creation of such “real world environments” and the careful measurement of the interactions of various pre-characterized emitters in the environments. The actual observed results will then be carefully compared with the simulated results and used to tune and over time perfect the modeling capability.

The seventh significant challenge involves the assurance that a human friendly environment is being established for both the database itself and the simulation and modeling environment to allow a variety of researchers to pursue future experiments efficiently and effectively. This effort will be sufficiently important that it should be partitioned as a separate task to be performed by experts in human interaction separated from the developers of the database capability and the simulation and modeling tool.

The eighth and final task will be to come up with a scheme for standardizing and automating the process of capturing the electromagnetic profile for each of the devices of interest. Since it will ultimately be important to have as many popular devices characterized and added to the database as possible, and to do so as quickly and efficiently as possible, this task will be an important adjunct to the mainline research effort. It is likely that government regulation may ultimately be required to insure that this information is provided in a timely manner for all devices of interest.

In addition to the discrete tasks, an oversight effort will be required to insure that all the tasks are pursued in a consistent, well coordinated manner. This will be especially important if these tasks are pursued as envisioned by a variety of geographically dispersed institutions. This oversight effort should also serve as the primary place for users of the capability to obtain needed training and information to enable them to be able to fully utilize the capabilities produced by this research effort.
Summary:

This white paper has presented a potentially severe problem which may inflict increasing damage to our wireless infrastructure in terms of the dramatic reduction in both the quality and availability of capabilities and services, and in terms of the unanticipated expense to attempt to remedy this decline. Given the fact that this infrastructure increasingly affects all aspects of our daily lives, from public safety and emergency services, to medical care, to education, communications, and pleasure, the threat represented in the paper may have dramatic, wide spread human impact. To address these issues the paper proposes a broad based research agenda to be pursued in multiple research centers across the United States and potentially the world to first understand the nature and extent of the current issues, and specifically the rate of increase in the electromagnetic noise floor and related interference temperature. It is hoped that through the pursuit of this agenda, the current noise pollution issue will be fully understood enabling appropriate actions to be taken to both preserve and enhance our wireless infrastructure thereby enhancing the quality of life for the peoples of this planet for years to come.