Thoughts on Military Spectrum Relocation Strategy

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***Abstract** - A move has begun by the government to relocate incumbent military radio frequency bands to accommodate the expanding broadband wireless industry. This move potentially poses tremendous challenges to the Department of Defense (DoD) in cost, disruption in service and degradation to the existing military communication infrastructures [1], [2]. New thoughts on a usage characteristics centric spectrum management concept and usage are discussed in this paper. Broadband wireless vis-a-vis military tactical radios usage has unique and different coverage requirements. Thus, by considering their respective complementary coverage and usage needs, together with the military's ability to apply Dynamic Spectrum Access (DSA) and the emerging spectrum fragmentation approaches, an optimum future spectrum allocation strategic plan can be formulated. A study of the possibility and suitability of relocating military usage of frequencies to lower than 2 GHz is warranted*

***Keywords**- Spectrum, Dynamic Spectrum Access, Spectrum Fragmentation, CMOS, TTL, CDPD, FCC, NPRM, AMPS, Pico, Femto, Microcells.*

Introduction:

The proliferation of wireless usage closely follows the cost curve of consumer radio equipment. In the early 1900's, when most of available receiving equipment consisted of crystal sets and simple vacuum tube radios, spectrum management was mainly concerned with lower megahertz spectrum usage. As the consumer electronics design and manufacturability advanced, affordability of the radio equipment dictates the spectrum demands. The last two decades have seen significant advances in microelectronics and digital communications technology, which enabled widespread wireless use into to the microwave frequencies. The corresponding demands for these frequency bands with significant private investment support are now evident.

Since the advent of bulk Complementary Metal Oxide Semiconductor (CMOS) microelectronic design in mixed signal circuitry at the GHz range, the technology has brought extremely low cost cellular and Personal Area Network (PAN) wireless devices into the marketplace. These devices are capable of operating at and beyond 5 GHz. Therefore, the wisdom of spectrum allocation strategy driven by historical consumer radio affordability and technological progress throughout this century should be reassessed. Availability of frequency spectrum is of the utmost importance in military operations. Likewise, commercial cellular and broadband data service industries are looking to expand their services, such as 4G, world-wide. They have also looked to the federal government [3] and world-wide bodies for assistance. Spectrum must be shared by both commercial industry, government, and the military. World-wide agreement on frequency bands that harmonizes both commercial wireless industry and military usage is needed.

Fundamentally, frequency of operation and the required contiguous bandwidth segments for the wireless services are the central concerns of spectrum management efforts. The operating frequency drives the antenna design and the propagation characteristics. The eventual frequency band assignment and the likelihood of its timely adoptability are also an important consideration. Unlike commercial enterprises, military radio asset development and acquisition processes are significantly different from those of the commercial endeavors. Military development is heavily burdened with Information Assurance (IA) requirements, Electronic Warfare (EW) concerns and other factors. It is difficult for military development tasks to be technologically agile in contrast with commercial industries' ability to seasonally change product models and introduce new product. Furthermore, the models of commercial wireless product usage, based on factors such as wireless propagation, product packaging, and antenna design are distinctively different from their military counterparts.

Thus, in order to arrive at an optimum spectrum management plan independent of the equipment affordability curve bias, a further study is warranted to consider all the above factors.

Review of the Path of Spectrum Needs:

In the past two decades, there was a congruence of significant technological advances in mixed signal microelectronics and advanced digital communications theory [4]. Microelectronics has progressed from MOS and Transistor-Transistor logic (TTL) to mixed signal bulk CMOS with the inclusion of all lumped elements as well as on-chip inductors in the nanometer geometry domain [5]. In early 2000, there was a perceived huge potential consumer service demand that would be propelled by low device production costs. The pace of investment led to a widespread creation of small start-up technology companies fueled by private venture capitals that further hastened the art. In concert with the ability to produce very low cost, high functionality consumer devices, communication service enterprises had been successful in preparing the groundwork for digital cellular phone services [6], [7] that started an exponential penetration of the worldwide cellular phone market, as reported by International Telecommunication Union (ITU). Figure 1 shows a representation of the ITU data.

To satisfy the need for a quick turn-around spectrum assignment from the traditional lengthy Federal Communications Commission (FCC) public Notice of Proposed Rulemaking (NPRM) process [4], in 1993, US Congress passed the Omnibus Budget Reconciliation Act to give the FCC authority to use competitive bidding. Since 1994, the FCC has conducted auctions of licenses for bands of frequency spectrum. The privatization of ownership of frequency spectrum became possible by the Balanced Budget Act of 1997 that US Congress extended and which expanded the FCC's auction authority to resolve mutually exclusive applications.

The age of government spectrum auction is now upon us.

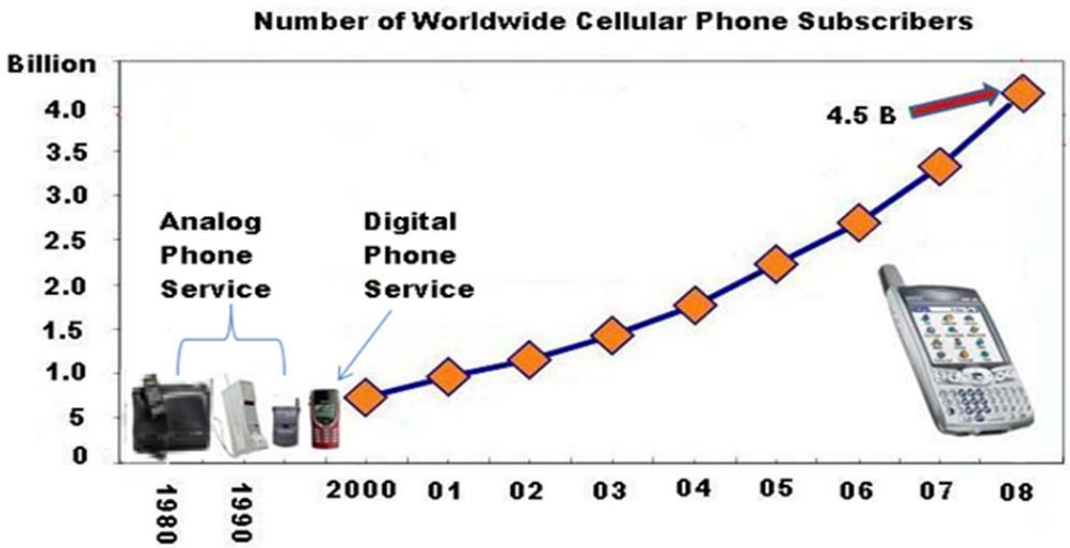

Figure 1: ITU data [8] shows that byDecember 2008, there were 4.5 Billion cellular phone subscribers worldwide, a 61% of penetration of the world population.

Individual video upload services of popular social networking applications require an expansion of commercial cellular phone services. The current thick downlink and thin uplink architecture must be supplemented with a thick uplink capability. In the immediate future, high user density per unit area services will be deployed, especially in dense urban areas. It is foreseeable that an additional 500 MHz of contiguous spectrum bandwidth is needed. A June 28, 2010 Presidential memorandum was sent to the Heads of the Executive Branch to this effect. There are applicable Pico and Femto studies that solve the thick uplink problem [9], [10]. Nevertheless, continued frequency spectrum demands with significant private financial support will persist and accelerate [11], [12].

Usage characteristics of Commercial and Public Broadband Wireless devices:

In the high usage cellular telephone system architecture, the most important goal is to permit the highest possible user density per unit area. It is clear that in order to maximize the data transport density, which is determined by the number of bits per unit area of coverage, the cell coverage range should be as small as possible. Traditionally, cell towers achieve this goal by using 3 sectional antennas with 120^{o} radial segments and 3 to 7 times frequency reuse factor to improve the number of users served per unit area.

The modern day approach is to deploy Pico and Femto microcells so that accurately defined cell boundaries can be maintained while at the same time providing the desired maximum user uplink capacity potential. GHz range frequencies favor such cell layout designs, with shorter wavelengths comparable to public usage physical dimensions. Indeed, the prevention of long reach propagation is desirable. Commercial wireless providers have fixed infrastructure approaches to maximize efficient reuse of frequencies by means of output power control and directional antennas. The key reasons favoring higher frequency bands (beyond L-bands) are:

1. The trend towards reducing propagation ranges (i.e. more base stations or access points) to increase per unit area density for maximum usage capacity.

2. Antenna gain increases with carrier frequencies increase allow better high density usage control in propagation.
3. Consumer desire for ever smaller devices. Higher frequency facilitates smaller packaging designs.

Military communication usage characteristics:

Tactical radios typically require maximum possible communication range in operations and commonly expand into wide coverage areas. In contrast, maximum usage density per unit area is much less important. Undoubtedly, the HF band has been invaluable since modern tactical radio introduction over a half century ago.

Military tactical operations are characterized by a small number of mobile units dispersed over wide ranges and a distinctive lack of reliance on fixed infrastructure. The superior propagation characteristics of VHF and UHF in terrains and foliage encountered by tactical operations are considered ideal for military usage. Urban propagation in these bands is shown in Figure 2.

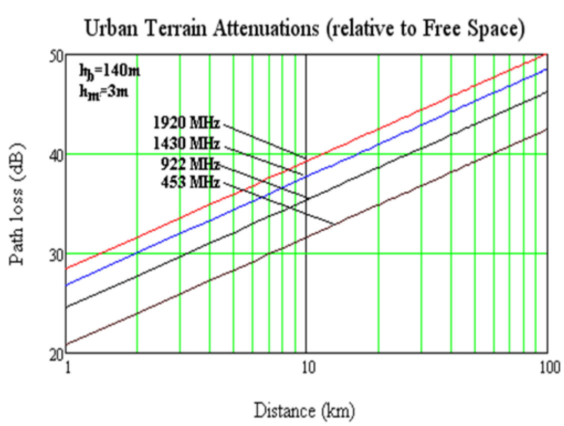

Figure 2: Typical COST-231 attenuation versus frequency calculations for urban area relative to free space as reported in [13].

Flexible and mobile communications infrastructure is an enabler for military capability for applications from smart weapons to the real-time reach-back from the platoon leader to levels of national intelligence. The ability to provide network connectivity greatly enhances shared command and control to the tactical edge. This enables more information transfer, and information travels farther. The modern DoD waveforms, such as that of Joint Tactical Radio system (JTRS) networking radios, for ground and air vehicles with greater spectral efficiencies will likely require directional antennas for a transition out of VHF and UHF frequencies to GHz range frequencies. For portable equipment, multiple antenna selection may also be needed, which greatly impedes tactical operations.

Integration of antenna subsystems beyond the L-band frequencies on military platforms can be very expensive. Redesigning radio systems currently located in broad contiguous spectrum into new, possibly narrow, non-contiguous higher frequency segments is dependent on the frequency relocation transitional approaches, which presents logistical issues. Most military platforms have limitations in hosting multiple fixed antennas to cover widely spaced frequency bands. For example, fighter aircrafts do not have much flexibility in installing multiple antennas.

Technology Flexibility in Spectrum Utilization:

Two decades ago, the ubiquitous consumer Cellular Digital Packet Data (CDPD) services [4] within CONUS and a few other countries utilized the parasitic usage technique within the Advanced Mobile Phone System (AMPS) 824-849 MHz and 869-894 MHz spectrum by detecting the one second delay in AMPS call request and call setup. CDPD was able to fully harness the idle AMPS spectrum as a consequence of traffic blocking statistics as required by AMPS services. It seamlessly co-exists with AMPS spectrum usage. This is an existence-proof example of modern digital communication system's ability to implement DSA and spectrum fragmentation usage in the consumer arena. These implementation techniques and other sophisticated digital communication processing technologies are uniquely suited to military radio usage models. In particular, they are conducive for military radio usage to co-exist with VHF and lower UHF civilian Land Mobile Radio (LMR) bands scattered within 138-960 MHz. [14]

Probable Optimum Spectrum Relocation Strategy:

The move of public spectrum usage towards higher frequency bands is a natural and suitable progression. However, legacy public frequency bands in VHF and particularly the UHF AMPS cellular bands are very well suited for military co-use. A possible military use of public fixed mobile band of 698-960 MHz in exchange for the upper L-band would benefit both the public and the military users with the mutual usage advantages discussed above. Recently, CENTCOM in its December 18, 2009 memo regarding the 1750 -1850 MHz spectrum loss to wireless, has also suggested the possible military use of UHF as discussed above.

The expected commercial return-on-investment from suitable frequency band allocations can possibly exceed the buy-down cost of replacement of existing not-at-the-end-of-life military infrastructure and that may be inclusive of military space assets.

Conclusion:

Revisiting the legacy spectrum management paradigm in contrast with a frequency assignment strategy based on the current advancement of wireless communication technology rationale is timely. A suitable assessment of the overall world-wide frequency plan by revisiting historical based frequency assignments and matching the frequency usage with the intended services can benefit both future commercial and military wireless users.

Possible relocation and exchange of privately owned frequency bands below 2 GHz for suitable return-on-investment compensated S band and above that suit commercial service needs should be studied to arrive at an optimum disposition of this valuable resource. Military spectrum usage can also adapt to co-use, temporary need-to-use and dedicated use basis. Moreover, by carefully tailoring the usage model with the respective frequency characteristics, it can further facilitate the appearance of yet unexplored innovations.

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