ATDI

PSDs, RFs, NFDs, & Interference:

The Challenges of Frequency Reallocation and Narrowbanding in Non-Homogenous Bands

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Current Issues: The National Broadband Plan and Narrowbanding

As the National Broadband Plan and other federal mandates continue to run their course, the search for a frequency assignment in the finite amount of wireless spectrum within the United States becomes ever more contentious; there is only so much bandwidth available to consumers, cellular service providers, emergency workers, corporations, three-letter government entities, and the many other groups vying for a slice of the wireless pie.

In 2009, the US Congress tasked the Federal Communications Commission (FCC) with developing a plan to make broadband access possible for all Americans. As part of this National Broadband Plan, 500 MHz of federal spectrum are to be made available to broadband services within 10 years; 300 MHz of those 500 MHz are to be made available for broadband use within five years. This requirement mandates that government agencies migrate from one frequency band to another, often searching for available bandwidth where there is little space.

Although migration from one band to another is common, narrowbanding within a given band is also a government mandate. While the typical legacy bandwidth of a signal in a channelized frequency band is 25 kHz, the need for bandwidth efficiency requires smaller bandwidths; narrowbanding demands signals that are 12.5 kHz in bandwidth. The narrowbanding initiative requires all public safety systems and business industrial land mobile radio systems to switch to 12.5 kHz bandwidths if they operate in the 150 to 512 MHz radio bands by January 2013. In some cases, super-narrowbanding (6.25 kHz bandwidths) may be required.

The migration of 500 MHz of previously government-owned spectrum and narrowbanding are both likely to cause an increased amount of interference due to the sharing of spectrum between non-homogenous systems. In channelized systems that are occupied by homogenous signals with similar if not identical bandwidths, modulations, and transmission powers, interference can be largely avoided. Once bandwidths, frequency offsets, modulations, and other parameters begin to vary in a non-channelized band, the chances for inter-signal interference grow immensely. This is also readily apparent in the recent switch from analog to digital television broadcasting which has introduced a wealth of newly digitized signals into an increasingly non-homogenous wireless environment.

Concepts and Causes of Interference

A wireless signal can experience interference due to many reasons and from many sources. While environment and equipment noise can have significant impact upon the quality of the reception of a signal, it is often the ‘collision’, or overlap, of two transmissions and their respective bandwidths that ends with one or both signals degraded in quality, at times to the point of unintelligibility at the receiver.

When a signal is transmitted, its energy is not focused solely at one point; there is no such thing as a signal with its total sum power located at one discrete frequency. Due to equipment requirements and limitations, channel characteristics, the need to carry a certain amount of data, and based on modulation, wireless signals have a frequency range, or bandwidth, over which they are transmitted. The power of the signal is spread across this bandwidth; for most systems, the sum total signal power is not spread equally across the signal’s bandwidth. How the total sum power is divided within a bandwidth (and beyond it) is defined as the power spectral density, or PDS, of that signal. Figure 1 shows an example of a power spectral density for a non-specific signal; the PSD curve is in blue. With a gain of 0 dB at the center frequency of 250.000 MHz, one can see that the gain of the signal drops off when moving away from the center frequency to trivial amounts when nearing 50 kHz away from the central frequency in either the positive or negative directions. The PSD in Figure 1 is idealized; most transmitters will show greater variation in how they distribute power at and near their transmission frequency.

The power spectral density of a transmitter must fit within an emission mask if the system is to be allowed to operate. An emission mask is a definition of the amount of power or gain that an emitted (transmitted) signal may possess at various offsets from its center frequency and is usually defined by a government entity tasked with regulating a given frequency band. The mask usually specifies the maximum allowable power or gain at each offset in text format, a table, or a graph. An example of a hypothetical emission mask is represented by the red line in Figure 1. In this case, the hypothetical PSD fits within the mandated emission mask.

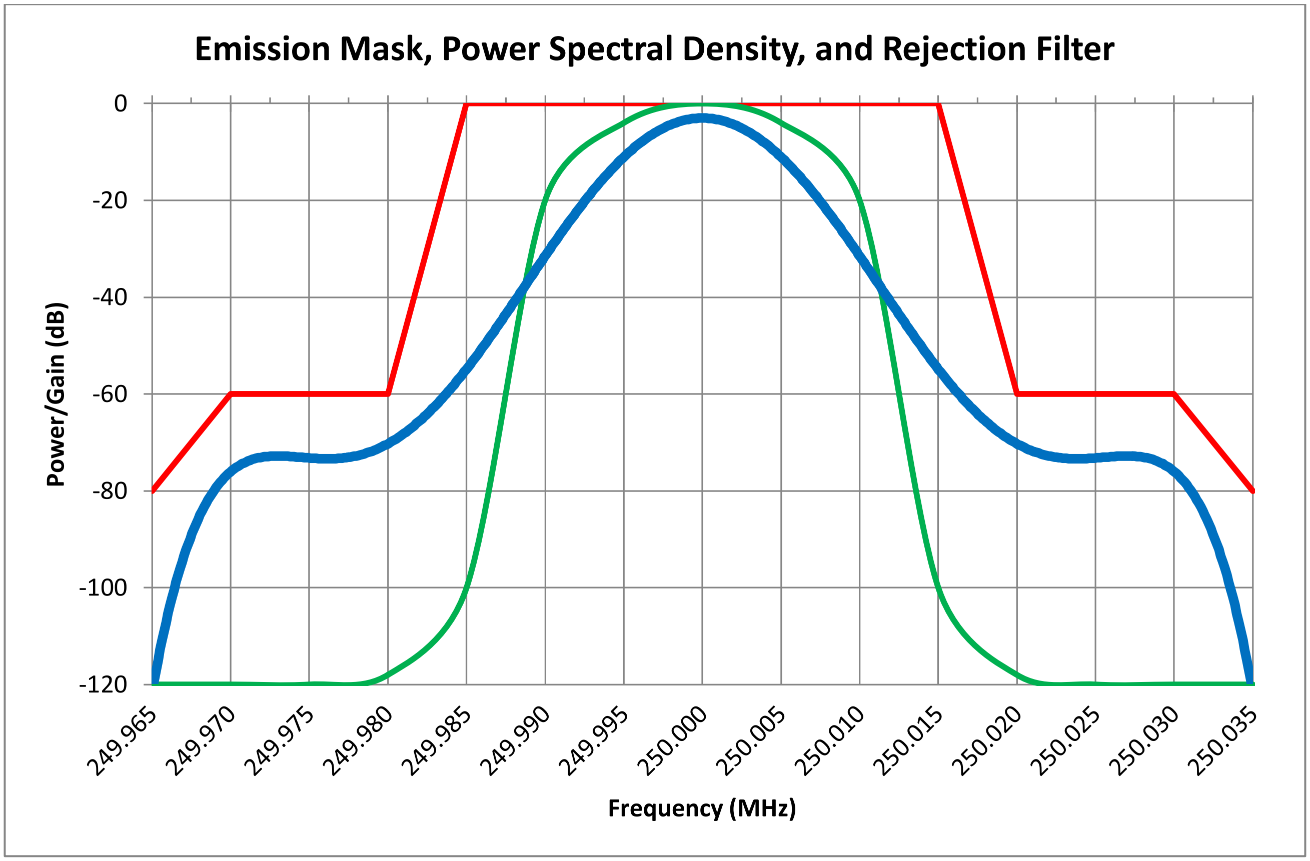

Figure 1: Emission Mask (red), Power Spectral Density (blue), & Rejection Filter (green)

As important as the power spectral density and its adherence to an emission mask is for a transmitter, receivers have a similar parameter that determines the amount of power the receiver will accept at a given center frequency and various offsets from that center frequency. This filter is called a receiver rejection filter, or RF for short, and is represented by the green curve in Figure 1. Rejection filters are important in limiting the amount of interference that a receiver experiences from offset signals as only signals that are at or near the center frequency the receiver is tuned to are received at full power while others are significantly attenuated. Assuming no attenuation, the convolution of the power spectral density and the rejection filter yield the signal that the receiver processes; this is known as Net Filter Discrimination (NFD), Frequency Dependent Rejection (FDR), Interference Rejection Filter (IRF), or Off-Channel Rejection (OCR). The various names come from the many regulatory bodies that define and set standards for adjacent channel interference, including the ITU, FCC, Industry Canada, and others.

Analyzing NFDs & Interference with the Correct Tool Set

ATDI's 20 year existence in the field of radio frequency / telecommunications engineering and software development has led to a deep understanding of wireless interference and its appropriate simulation and evaluation in computer software. A prime example of this is IRF Calc, a module that takes as inputs the PSD and RF for a system and computes the resultant NFD curve. Both the inputs and the output NFD can be saved for later use and imported directly into ATDI's HTZ Warfare and ICS Telecom RF simulation suites for detailed network analysis.

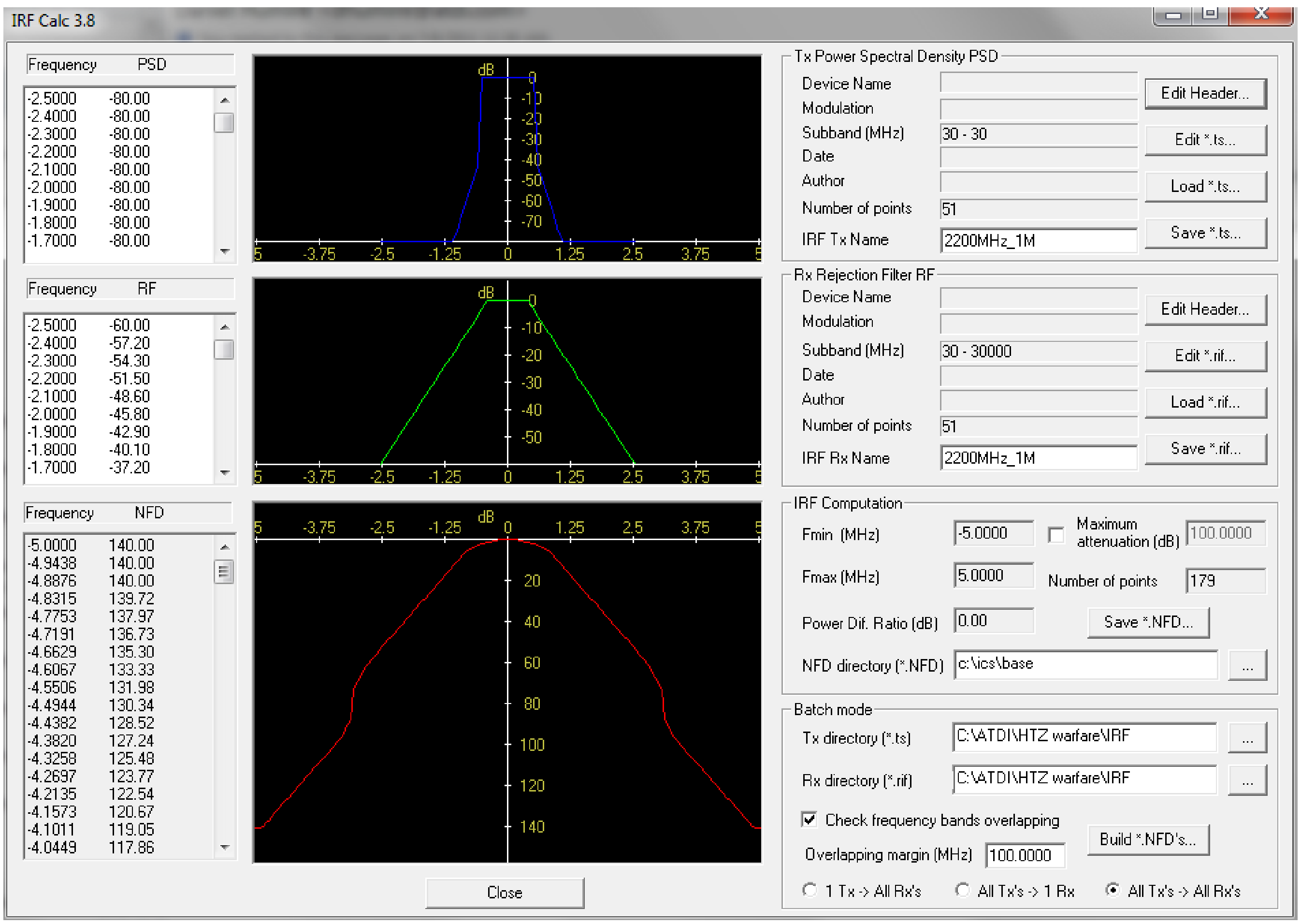

Figure 2: NFD Calculation in ATDI's IRF Calc

Figure 2 displays the IRF Calc module where the blue curve represents the power spectral density, the green curve the rejection filter, and the bottom red curve the net filter discrimination. After saving as a .NFD file, the resultant net filter discrimination may be directly applied to a station in HTZ Warfare / ICS Telecom in its parameters box, as seen in Figure 3. After being thus realized, the relevant rejection factors from the unwanted emissions are automatically applied in all interference and frequency assignment functions.

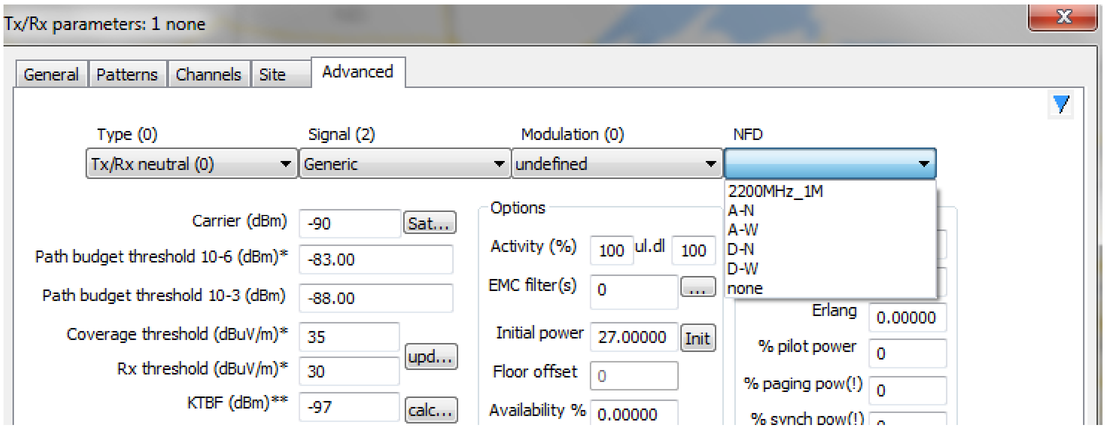

Figure 3: NFD Selection in HTZ Warfare / ICS Telecom

These capabilities coupled with extensive in-house know-how at ATDI have led to a string of recent successes in interference analysis, frequency plan validation, and frequency nomination with customers from the US Department of Homeland Security, the US Department of Interior, and many others.

As broadband and general wireless signal usage continues to increase, the amount of spectrum available and the separations between signals will continue to shrink, thus making interference studies in non-homogenous spectrum bands imperative. Only through timely and proper analysis will interference be minimized and the greatest possible access granted to the wireless spectrum pie.

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