A Proposal for Efficient Use of the Television Spectrum

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Abstract

It is widely recognized that broadcast spectrum is utilized inefficiently. The principle technical cause of this inefficiency is inexpensive receiver design. In addition, the economics of the industry are such that users do not pay the opportunity costs of spectrum associated with these receivers. In this paper, I develop an approach that would internalize the spectrum opportunity costs so that consumers will make decisions that are economically more rational in terms of their choice of the program delivery channel.

Introduction

It should not come as a surprise that television spectrum is poorly utilized. Hazlett cites an average 25% usage (Hazlett 2001) in the United States, though this figure varies considerably among localities (in general, one would find higher utilization in urban areas than rural areas). This inefficiency occurs because channels are assigned so that adjacent channel interference for receivers in each station's viewing areas is minimized. Adjacent channel interference occurs because the "front end" filters of television sets are not particularly sharp (see Figure 1). Sharper filters, which would be more effective at eliminating adjacent channel interference (see Figure 2), have historically been more expensive. In a network industry like broadcasting, it is well known that inexpensive receivers are key to the successful establishment of the industry, and that historical practices and norms carry tremendous inertia, technologically, institutionally, economically, and from a regulatory perspective (Horwitz 1988).

Thus we end up at the current situation: spectrum with excellent technical characteristics is underutilized. If this level of utilization were economically rational, then this would be of no particular concern. However, this is not the case. Many industry observers and participants have pointed out the need for additional spectrum to support third generation mobile (3G) system in the US. Thus, it seems clear that creative approaches to spectrum utilization are necessary.

Despite a rapid transition to cable and satellite based program delivery, making substantial changes to the over-the-air broadcast system is politically challenging. The difficulties are rooted in the public interest aspects of broadcasting as well as the entrenched economic interests of the broadcast industry. From a public interest perspective, over the air broadcasting is important because this program delivery channel is not controlled by a single commercial or governmental entity, so that diversity in content is more likely to occur. From the perspective of entrenched economic interests, broadcasters have made substantial economic investments in production and transmission facilities, and are loathe to place these investments at additional financial risk.

As Hatfield pointed out (Hatfield 2001), the problem is not one of transmitters but receivers. Purchasers of receivers currently do not experience the opportunity cost of alternate spectrum uses. If these opportunity costs were fully internalized into the economics of the broadcast industry, we might find that consumers would make different choices regarding the channel over which they receive programming, and, depending on how payoffs are structured, find broadcasters more willing to move to different organizational forms. In this paper, I propose an approach by which the opportunity costs of spectrum use may be more fully realized by consumers.

The Technological Approach

For this paper, I posit an optional, add-on, prefilter that can be placed by consumers between the antenna and the input to the TV receiver. This prefilter would function as a kind of "set-top box" for over the air receivers, and could easily be incorporated into the set itself in future. Note that this function could be performed by another home entertainment component as well (a VCR, DVD player, etc.).

The purpose of this prefilter is to sharpen the selectivity of existing television receivers. Consumers would select the filter quality that corresponds to their quality preferences. These prefilters could be dedicated hardware devices or software for a DSP-based filter.

In the last decade, advances in semiconductor electronics have made digital signal processing (DSP) viable for an increasing range of applications. These have included software radios, modems, etc. Today, a DSP-based approach is favored by engineers whenever possible because of the production economics. Using DSPs has another side effects that can be beneficial: the functions of a "device" can be changed without hardware changes. Thus, for example, a modem can be upgraded to a higher speed or a new standard by a software download rather than a hardware change. If the filter is DSP-based, the sharpness of the prefilter can be controlled by software rather than being hard wired. For example, the sharpness of the filter could be determined by software on small plug-in modules (similar to Nintendo Gameboy cartridges), DVDs, CD-ROMs, or modem-based downloads.

Technically, the prefilter would most likely contain a front end filter and a demodulator for selectivity and conversion to the Intermediate Frequency (IF) for television, the programmable filter, and a re-modulator to a fixed television channel (see Figure 3). As described above, the user would connect this device between the television's antenna and the input on the back of the set. The television would then be tuned to a present channel (eg. channel 3 or 4, much like a VCR or cable set-top box)., and users would interact with the prefilter to select channels.

System Operation

Given this functionality, the portions of the VHF and UHF spectrum that are currently unused (or reserved as guard bands) could be allocated to other uses. For the purposes of this paper, I assume that this alternate use would be mobile communications, but it could used for various purposes. Further, I assume that the alternate uses of the spectrum will involve spread spectrum systems. The primary reason for this assumption is that a communication via a spread spectrum signal appears as noise to stations that are not party to the communication. In this situation, the television receivers would perceive this added spectrum use as noise rather than as a coherent interferer. For a broadcast receiver, this would become “snow” on the picture or a “hiss” on the audio, rather than another program occasionally breaking in.

The two principle approaches to spread spectrum are code division multiple access (CDMA) and frequency hopped spread spectrum (FHSS). CDMA systems spread the information signal over the transmission band by combining the signal being transmitted with a code that is unique to that communications session. Without going into the details, this process provides for uniqueness in addition to diffusing the relatively narrow information signal over a wide transmission band. In most applications, CDMA systems assume that the entire transmission band is available. In the proposed approach, this would not be the case, as the transmission band would be the VHF and UHF bands. Since no attempt is made to vacate these of current users, a CDMA system would have to be constructed that filters the signal energy out of the incumbent television channels at the transmitter (both base station and mobile) so that they do not interfere. Researchers have examined the processing gain for CDMA systems when certain frequency bands are removed from the transmission band <cite>. The net conclusion is that direct sequence spread spectrum systems (such as CDMA) can be used in this overlay fashion if there aren't too many "notches" in the transmission band. The main challenge with using CDMA in this application is that the mobile units would have to be aware of the local preexisting channelization. While this could be done, it would require the development of a standard protocol for communicating this information between the base station and the mobile unit, and would require programmable filters in the mobile units, both of which would raise the cost and complexity of the mobile devices.

For this reason, a frequency-hopping spread spectrum system could be a better choice. In frequency hopping systems, transmission spectrum (i.e., VHF/UHF band) is subdivided into a large number of small channels. For each communications session, the actual transmission hops rapidly from one of these small channels to another in a unique sequence that is established by the base station. The base station and the remote hop simultaneously to the same next channel in a way that appears random to stations that are outside of the communications session. For the VHF/UHF overlay, the base station can simply avoid the channels that are occupied by over the air broadcast television, so that remotes need not have local knowledge beyond their hop sequence. Thus, FHSS might be a less expensive approach.

Discussion

Under the approach being proposed here, regulators could auction unallocated bandwidth in the VHF and UHF. If these previously unallocated channels are lightly utilized, existing television receivers would likely experience minimal signal degradation, so viewers may not find it necessary to opt for the pre-filters described above. Such light use is most likely to occur in rural areas, where spectrum demand is lower than in urban and suburban areas[1].

When demand for spectrum is higher, the quality of television signals received over the air would degraded. As discussed above, this degradation would appear as "snow" or "hiss" and could be eliminated by the prefilters that consumers would be able to purchase. These prefilters

[1] While this makes good economic sense, it could make a proposal like this more difficult to implement in practice, as many more voters are affected in urban areas than in rural areas.

could come in a variety of forms, as noted above, and with various degrees of selectivity. Consumers would choose a filter sharpness that matches their quality preferences, as it is likely that sharper filters would be more expensive[2].

Filter vendors would sell and price their product in a competitive market. Some may choose to sell a device at a given price, while others may choose a subscription model. Prefilters could be bundled with other services or devices. For example, mobile telephone service providers may wish to distribute prefilters to reduce the potential political opposition to this approach, and attribute it to spectrum acquisition cost.

Analysis

One of the principle advantages of this approach is that it would support the policy goal of economically efficient spectrum usage. Spectrum usage would be more efficient because channels that are currently unused could be used for new purposes. A degree of regulatory involvement may still be necessary, however, because practical filters cannot be designed that are perfect[3]. Thus, regulators must weigh the tradeoff between the establishment of a guard band geared toward best technology practices and quality losses that cannot be remediated[4]. Continuing with a guard band is basically a modification of the current approach, albeit with narrower bands, and would therefore be subject to

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[2] It is very likely that this would be the case even if the cost of producing filters of various sharpness are similar. Varian and Shapiro refer to the example of ink jet printers that are deliberately slowed down for the purpose of inducing quality-based price discrimination. <cite>

[3] A "perfect" filter would exactly conform to the frequency profile of the channel. In Figure 1b, such a filter would be vertical lines instead of having the finite slopes pictured.

[4] This could be aided by laboratory tests demonstrating the quality losses.

the same political pressures that exist today. Accepting a quality loss would have public interest implications, and should be made after testing for the severity of the effect.

Another policy gain of the proposed approach is to foster more efficient economic decisionmaking with regard to the consumer's choice of content delivery channel. The vast majority of consumers in the US have three technological choices for their programming delivery channel (and more choices of service providers): over the air, cable, and satellite. Generally speaking, the cable and satellite based alternatives provide viewers with consistent quality and a larger array of program choices[5]. Over the air broadcasting comes at a much lower direct cost to subscribers, though it does not currently reflect the opportunity cost of spectrum usage (as was mentioned above). The prefilter provides a mechanism by which this opportunity cost can be imputed to consumers. The acquisition of the suitable prefilter would motivate consumers to revisit their choice of program delivery channel. Since the prefilter allows alternate uses of spectrum that would not be available previously, it is a very good proxy for the opportunity cost of spectrum[6]. It is the co-channel interference requirements driven by current generation receivers that is an important cause of today's sparse VHF and UHF spectrum usage.

It is quite possible that the prices and price structures of prefilters will cause many consumers to opt for cable- or satellite-based television programming reception in lieu of over the air reception. Consequently, one possible consequence of this proposal could be a phase out of over

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[5] Note that these delivery channels are not perfect substitutes for each other in practice. For the purposes of this paper, I assume that they are.

[6] It does not represent the full opportunity cost, since the allocated television channel is still "free".

the air broadcasting. This has important consequences both for embedded investments as well as for public policy.

Currently, over the air broadcasters are both content producers and content transmitters. Cable and satellite based service providers have separated these functions to a large extent[7]. If a change like this reduces over the air receivers, it changes the business of the local broadcasters. Regulators may choose to view the investment in transmission equipment as a stranded cost that television stations are allowed to recover, perhaps through taxes or licensing fee surcharges.

The public policy problems are more difficult to resolve. One of the principle benefits of an over the air channel is that, in principle, the transmission system is not privately owned. Private ownership means that the owners of the channel are in a position to determine what content is distributed. In over the air system, this decision is made at the program production level instead of at the conduit level, and as long as there are multiple outlets, the possibility for content diversity may be greater. Many analysts have concluded that content diversity is important in an open society, so this is often considered a public policy goal. Localism is another such goal. If over the air channels disappear, policy solutions such as "must carry" are a possibility, though not without consequence.

Conclusion

I have proposed an approach by which spectrum in the VHF and UHF bands could be reused. I argue that this approach largely internalizes the

[7] There are numerous exceptions here, most notably AOL Time Warner and the interest that AT&T Broadband has in Liberty Media. Despite these investments, there is a

opportunity costs associated with spectrum use inefficiency associated with current over the air broadcasting so that consumers will make economically more efficient choices. Further, this approach is technically feasible and does not require consumers to replace their television sets.

References

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substantial internal separation on an operational level so that these investments are different than those of local broadcast television stations.

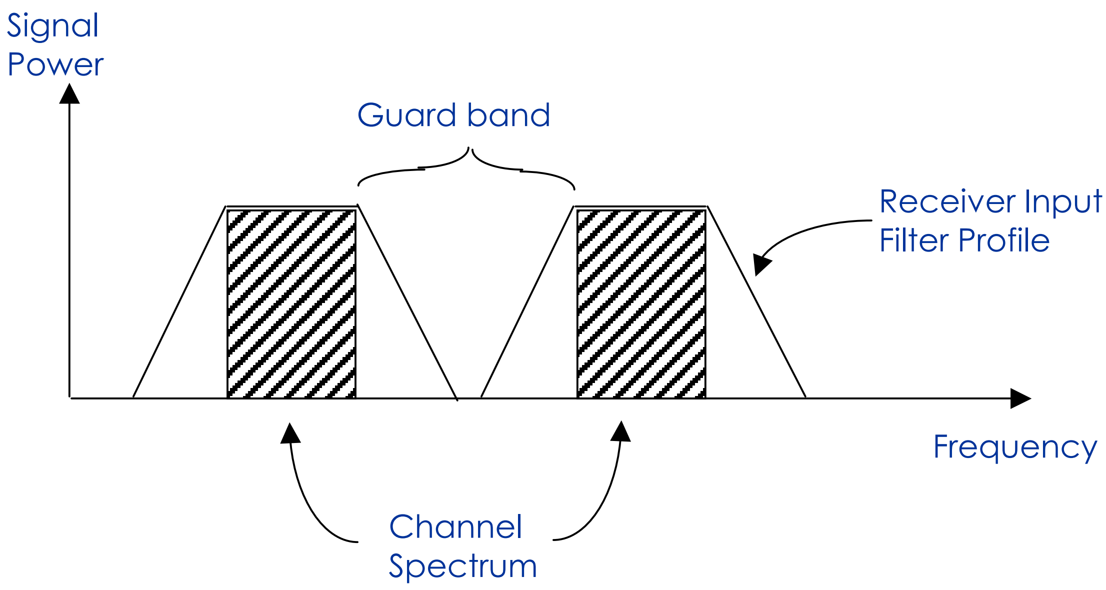

Figure 1 – Present Situation

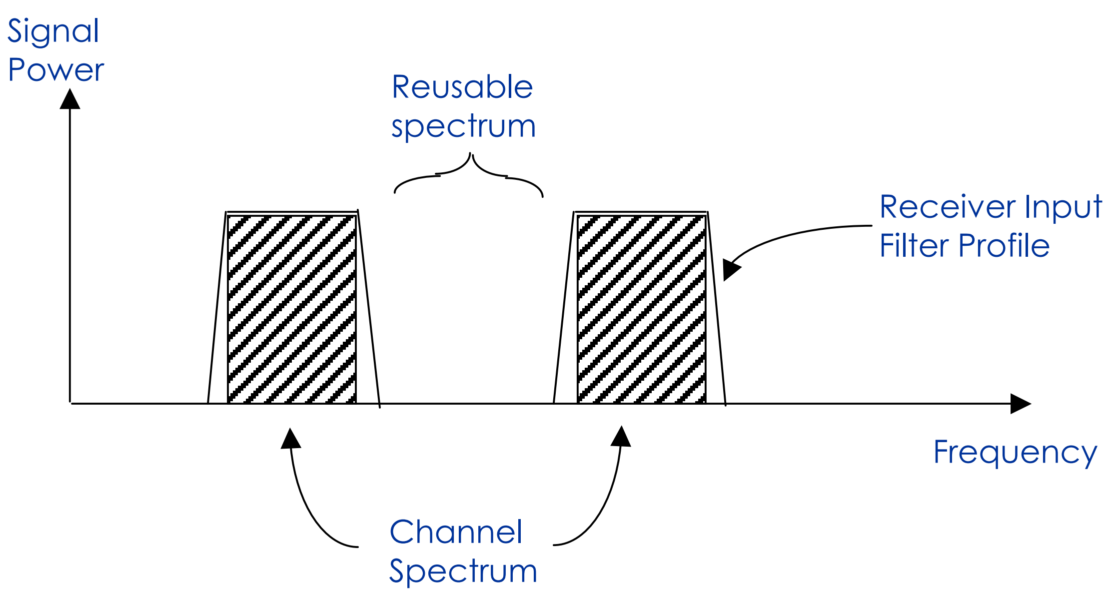

Figure 2 – Proposed Approach

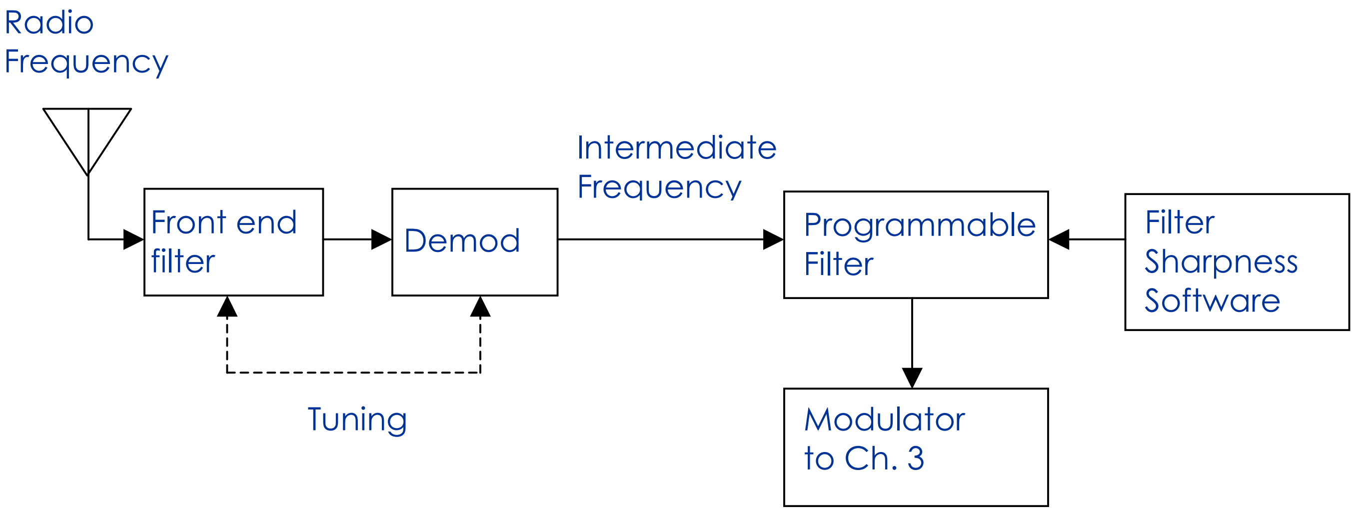

Figure 3 - Possible Prefilter Architecture