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April 17, 2003

Dear Friends and Colleagues,

I have attached a copy of a report of the study I recently conducted for MSTV and NAB. The report is titled: *Exploring the Feasibility of Sharing TV Band Spectrum with Unlicensed RF Devices.* It was filed with the FCC by MSTV on April 17th as an attachment to their comments on FCC ET-Docket 02-380, an NOI *REGARDING ADDITIONAL SPECTRUM FOR UNLICENSED DEVICES.*

If you are not familiar with this FCC proceeding, I have attached a copy of the FCC news release on the docket. Briefly, The FCC is exploring options for additional spectrum to support the expected growth in unlicensed devices such as cordless phones and wireless local area networks. MSTV/NAB asked me to explore the technical and economic feasibility of sharing spectrum between new unlicensed devices and licensed TV broadcast operations.

I hope you find the attachment to be of interest, and I would appreciate any comments you might have.

Regards,

NEWS

Federal Communications Commission
445 12th Street, S.W.
Washington, D. C. 20554

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FOR IMMEDIATE RELEASE
December 11, 2002

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FCC BEGINS INQUIRY REGARDING ADDITIONAL SPECTRUM FOR UNLICENSED DEVICES

As part of the ongoing effort to promote efficient use of spectrum, the FCC today asked for public comment on the possibility of permitting unlicensed transmitters to operate in additional frequency bands. Such changes could allow the development of new and innovative types of unlicensed devices. This inquiry examines new and creative ways to utilize the spectrum resource more efficiently by considering new spectral frontiers for unlicensed use.

In a Notice of Inquiry approved today, the Commission stated that the current rules for unlicensed transmitters have been a tremendous success. A wide variety of devices have been developed and introduced under those rules for consumer and business use, including cordless telephones, home security systems, electronic toys, anti-pilfering and inventory control systems, and computer wireless local area networks. The success of those rules shows that there could be significant benefits to the economy, businesses and consumers in making additional spectrum available for unlicensed transmitters. Unlicensed transmitters may be operated under the provisions of Part 15 of the Commission's Rules. Part 15 transmitters generally operate on frequencies shared with authorized services at relatively low power, levels and must operate on a non-interference basis.

The Notice seeks comments on whether unlicensed operations should be permitted in additional frequency bands. Specifically, it seeks comments on the feasibility of allowing unlicensed devices to operate in the TV broadcast spectrum and locations and times when spectrum is not being used. It also seeks comment on the feasibility of permitting unlicensed devices to operate in other bands, such as the 3650-3700 MHz band, at power levels higher than other unlicensed transmitters with only the minimal technical requirements necessary to prevent interference to licensed services.

The Commission noted that there have been significant advances in technology that may make it feasible to design new types of unlicensed devices that are able to share spectrum in the TV bands without causing interference to licensed services operating in those bands. Advances in computer technology make it possible to design equipment that could monitor the spectrum to detect frequencies already in use and ensure that transmissions only occur on open frequencies. The low cost of GPS equipment could allow a device to determine its location and use information from a database to determine whether there are any licensed operations in its vicinity. Equipment can be designed that is frequency agile, with the capability of changing frequency as needed to avoid interference to licensed users.

Action by the Commission December 11, 2002 by Notice of Inquiry (FCC 02-328). Chairman Powell, Commissioners Abernathy and Copps, with Commissioner Martin approving in part and dissenting in part, Commissioner Adelstein not participating and Chairman Powell, Commissioners Abernathy, Copps and Martin issuing separate statements.

OET Docket No. 02-380

- FCC -

Exploring the Feasibility of Sharing TV Band Spectrum with Unlicensed RF Devices

Final Report to:

Maximum Service Television (MSTV) and The National Association of Broadcasters (NAB)

April 17, 2003 (V1)

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Reference 030317-1

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1 Introduction

This project was jointly commissioned by MSTV and NAB to explore the feasibility of sharing licensed television (TV) broadcast spectrum by means of a dual allocation of this spectrum to unlicensed devices.

The FCC has released a Notice of Inquiry (NOI) dated December 20, 2002 titled ET-Docket No 02-380: "Additional Spectrum of Unlicensed Devices Below 900 MHz and in 3 GHz Band". This NOI invites comments regarding obtaining this new spectrum from several sources. Among the possibilities mentioned in the NOI was to share spectrum with current VHF and UHF TV broadcast operations. The purpose of this project was to explore the feasibility— both from:

1) The perspective of potential harmful impacts to licensed TV services, as well as

2) The perspective of the value of shared spectrum to users and manufacturers of new unlicensed radio frequency (RF) devices

There can be no question that the provisions of Part 15 of the FCC rules allowing unlicensed low power communications in the Industrial Scientific and Medical (ISM) bands[1], has resulted in successful and popular new products ranging from cordless phones to wireless local area networks (WLANs). Given the growth and popularity of today's ISM unlicensed devices, it is reasonable for the FCC to explore the possibility of obtaining new spectrum to support future expansion and growth. However, the recent allocation of substantial spectrum for unlicensed purposes in the so called "User PCS Band" was well intentioned but has failed to live up to expectations to encourage usage by new unlicensed devices[2]. Since the FCC regulations for User PCS band equipment required additional cost and complexity to implement a complex "spectrum etiquette"[3], there are reasons to be concerned that unlicensed equipment sharing the

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[1] In particular 47CFR15.247 as employed for direct sequence spread spectrum devices as well as 47CFR15.249 as typically employed for narrow band devices.

[2] Federal Communications Commission, Spectrum Policy Task Force Report of the Spectrum Rights and Responsibilities Working Group, November 15, 2002, excerpt: ••• *Moreover, not all unlicensed bands have been as successful as 2.4 GHz. In the unlicensed PCS band, for example, there has been very little development of unlicensed technologies,••• UTAM assesses a fee on each unlicensed PCS product and directs the money toward the incumbent relocation effort ($20 in 2001). The economic non-viability of this compensation mechanism plus the lack of development of equipment for use in the unlicensed band have combined to inhibit development of a narrowband PCS service.•••*

TV band may also fail due to a similar inability to support the extra cost and complexity necessary to control interference to licensed broadcast TV services.

For the purpose of this project, feasibility is defined as a need for any unlicensed product concept to pass three tests:

1) Does the technology exist to implement an unlicensed RF device so the that there is no annoying interference to TV receivers located within the FCC definition of both digital TV and analog Grade A and B service areas?

2) Assuming new rules that prohibit operation of unlicensed devices to protect TV broadcast operations, will these new rules result in a material increase of new unlicensed spectrum, and

3) Will the best alternative technical approach result in an unlicensed product which is both economically practical, convenient to use, and able to deliver performance comparable to typical unlicensed devices in today's ISM bands?

2 Approach

2.1 Basic Approach

In order to offer an opinion regarding technical and economic feasibility, the following process was employed:

1) Search for alternative technical concepts suitable to build unlicensed devices that would seek to avoid, or mitigate, interference with licensed broadcast TV operations.

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[3] Comments filed by Blooston Law, supporting petition of UTStarcom to allow its "Community Wireless Network" to operate in the 1910-1930 MHz unlicensed personal communications service (UPCS) band, excerpt: •••*When the Commission allocated the 1850-1990 MHz band to PCS in 1994, it carved out the 1910-1930 MHz portion for UPCS—designed to offer an array of potential offerings such as low-power, in-building, portable devices and services, such as wireless local area network (LAN), cordless private branch exchange (PBX), and wide area network (WAN) gateway applications. To avoid potential interference, the FCC divided the UPCS spectrum into two equal blocks to accommodate asynchronous data (1910-1920 MHz) and isochronous voice (1920-1930 MHz). The Commission also approved a "spectrum etiquette"—a set of rules for allowing widely differing "nomadic" and "non-nomadic" applications and devices to gain fair access to the spectrum. However, as the FCC has acknowledged, the vision of UPCS never materialized: The Commission has approved only 45 devices for use in this spectrum. In fact, the most underused portion is the 1910-1920 MHz asynchronous data sub-band.*•••

2) Develop an understanding of:
   - Emission bandwidths and energy levels for examples of popular narrow band and spread spectrum unlicensed devices now used in the ISM bands, e.g.
     - Cordless phones
     - WiFi/802.11b compatible wireless local area network devices
   - The costs of manufacture of such ISM devices

3) Using the above example narrow band and noise like spread spectrum ISM devices as being likely to represent the emissions of new unlicensed devices, perform engineering computations to determine the potential for interference to licensed TV services with and without incremental interference control technologies

4) Perform economic analysis to determine if the incremental costs associated with the interference control means employed in these new unlicensed devices are material and likely to inhibit the acceptable of these new unlicensed devices

5) Reach a conclusion regarding technical and economic feasibility of sharing the TV band with unlicensed RF devices within the limits of reasonable risks

2.2 Assumptions and Analysis Criteria

In performing this project, we attempted to make assumptions that were reasonable and supportable. Because radio propagation is statistical in nature and further because there is a wide variation in the performance of the installed base of TV receivers it is not possible to reach an absolute deterministic conclusion regarding feasibility. Where there are a range of possibilities, we present and discuss the issues prior to rendering an opinion so that the analysis criteria and basis for our opinion can be understood.

3 Technical Analysis

3.1 The TV Broadcast Band

During the transition from analog to digital TV it is necessary to consider the potential for interference to both transmission systems from unlicensed devices. The starting point for such an analysis is to examine the technical characteristics of the unlicensed RF devices and the interference thresholds of today's TV broadcast services and typical TV receivers. In Table 3-1 we compile the technical parameters we will need in order to perform an interference analysis. These parameters include a combination of frequencies allocated, service area field strength limits, median levels of background noise, radio propagation assumptions, and typical receiver noise figure assumptions needed to compute the noise floor.

The characteristics in Table 3-1 are useful for determining the interference protection criteria for co-channel, or other in-band forms of interference.

The assumptions employed in the analysis were to limit the levels of co-channel interference for narrow-band, or CW, signals to 45 dB below the visual carrier reference so as to keep the impairment to the level judged to be slightly annoying[4]. The comparable co-channel assumption for narrow-band, or CW, signals was an interfering signal level 10 dB below the desired signal[5].

Table 3-1 Technical Characteristics of Broadcast TV Services and Typical TV Receivers

Item	VHF Bottom	VHF Top	UHF Bottom	UHF Top	Source
Channel #	2	13	14	69	FCC
From (MHz)	54	210	470	800	FCC
To (MHz)	60	216	406	806	FCC
Visual Carrier (MHz)	55.25	221.25	471.25	801.25	FCC
Aural Carrier (MHz)	59.75	215.75	475.75	805.75	FCC
Grade A-F(50,50) Field Strength (dBμ)	68	71	74	74	FCC
Grade B-F(50,50) Field Strength (dBμ)	47	56	64	64	FCC
Digital TV Field Strength (dBμ)	28	36	41	41	FCC
Location Variability Factor F(90,50) (dB)	10	10	15	15	FCC
Grade A Receiver Noise Figure (dB)	12	12	15	15	FCC
City Median Background Noise (dB above kTB)	30	10	3	0	Skomal
Rural Median Background Noise (dB above kTB)	20	5	0	0	Skomal

Source: FCC and Man Made Radio Noise by E. Skomal

In the case of broad-band, noise like, interfering signals we employed the same desired to undesired (D/U) protection ratio for both analog and digital TV. The criteria was to keep interfering signal levels such that the noise floor within the desired TV channel was degraded by no more than 1 dB.

It is also possible that out-of-band signals might also cause interference to licensed TV services. There is potential for such interference from harmonics of the unlicensed device, spurious responses by the TV receiver (e.g. the image response), overload due to non-linear effects, and from the finite selectivity of the TV receiver's IF response. For the purpose of this out-of band analysis, only the potential impacts of adjacent channel selectivity was analyzed. In Figure 3-1 below we illustrate the channel spacing typical of both VHF and UHF TV assignments. There is no mandated technical standard for analog TV receiver selectivity however, most receivers in use today are designed to operate on multi-channel cable TV systems. In such a case, these receivers are designed to provide acceptable performance in the presence of upper and lower adjacent channels. In such cable systems, the aural carrier is typically reduced by 17 dB[6] referenced to the visual carrier based on the typical IF selectivity of modern TV receivers. Since the aural carrier is narrow-band relative to the visual signal, we assume that this 17 dB signal level at 1.5 MHz below the visual carrier is a reasonable criteria to use for a maximum

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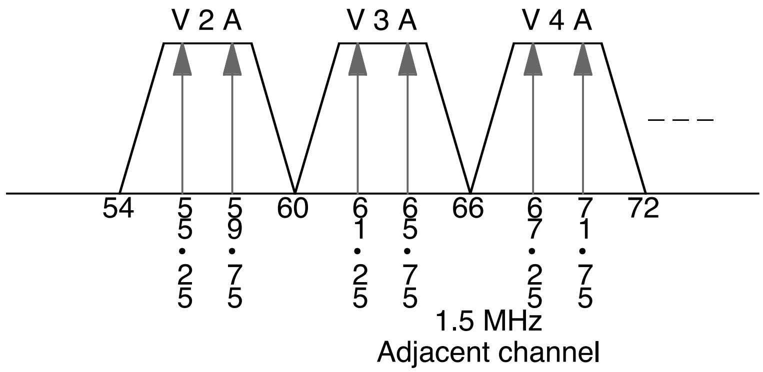
[4] Subjective Assessment of Cable Impairments on Television Picture Quality by Jones and Turner, Cable TV Labs IEEE Transactions on Consumer Electronics, November 1992

[5] Preliminary DTV Field Test Results And Their Effects on VSB Receiver Design by Gary Sgrignoli, Zenith Electronics Corporation, ICCE ’99 Conference Paper

[6] See for example, Modern Cable TV Technology by Ciciora et al. The book reports: that based on testing of 35 TV receivers, 32 demonstrated acceptable pictures when subjected to a lower adjacent aural carrier level 17dB below the visual carrier picture level.

allowable interfering signal level. In the case of digital TV, we use an assumption of 37 dB[7] as a requirement as a comparable criteria for a maximum allowable interfering signal level in the adjacent channel.

Figure 3-1 TV Channel Spacing Showing Adjacent Channels



3.2 Characteristics of Example ISM Unlicensed RF Devices

The 2nd data set that is necessary to perform an interference analysis, is the typical characteristics of the unlicensed devices that are likely to be deployed in the TV bands. Because the nature of impairment to licensed TV broadcast services is likely to be different for narrow band, or CW, signals versus broad-band or noise like spread spectrum sources; we have assembled the characteristics for both modulation types. While there are many possible types of unlicensed devices, the most popular examples from both the narrow band and broad band category are cordless phones and wireless LANs respectively. The characteristics, that we require to do further analysis are listed in Table 3-2.

We have made the reasonable assumption that the characteristics for unlicensed devices sharing the TV broadcast band will be comparable to today's unlicensed devices in the ISM band in order to be competitive. The choice of a cordless phone is representative of an other narrow band, or CW, low power device that would comply with FCC 47CFR15.249 in the ISM band. The choice of an IEEE 802.11, WiFi, wireless LAN is representative of a broad band noise like spread spectrum device that would comply with FCC 47CFR14.247 in the ISM band. In Figure 3-2 we show the spectral distribution for an IEEE 802.11 compliant WiFi. Device[8]. It should be noted that the sin(x)/(x) spectral distribution is 22 MHz wide between the first major lobes. Since the broadcast TV assignments are 6 MHz wide, a WiFi device will cover about 4 TV channels with a noise like signal. Any one TV channel will experience approximately 1/4 of the noise energy from a WiFi device within range.

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[7] Preliminary DTV Field Test Results And Their Effects on VSB Receiver Design by Gary Sgrignoli, Zenith Electronics Corporation, ICCE ’99 Conference Paper

[8] See IEEE 802.11 Handbook, A Designer's Companion, by O'Hara and Petrick.

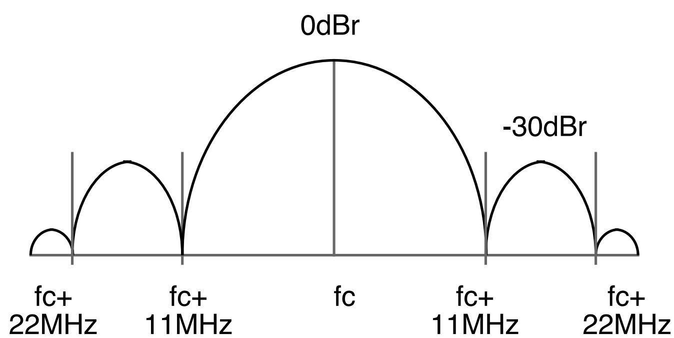
Table 3-2 Typical Characteristics of Popular Unlicensed Devices in The ISM Band

Item	Narrow Band Cordless Phone	WiFi 802.11b Wireless LAN	Source
Operating Frequency (MHz)	2400-2483.5	2400-2483.5	FCC
FCC Rules	47CFR15.249	47CFR15.247	FCC
FCC Energy limit for fundamental	50 mV/M@3M	1 watt	FCC
FCC Energy limit for harmonics	500 mV/M@3M	500 uV/M@3M	FCC
FCC Energy limit for out of band	<50dB below fund	<8dBm in 3KHz BW	FCC
Typical bandwidth	~25KHz	22MHz	IEEE
Typical out of band limit	same as FCC	<50 dB below peak	IEEE
Typical max power	FCC limit	100mW	IEEE
Emission type	Narrow Band ~CW	BB DSS Noise Like	IEEE
Penetration of US Households YE'02	81%	62% (note1)	CEA
Metro Area Households/square-mile	115	115	Census
Metro Area Households/linear mile	75	75	Computed

Source: FCC, USA Census, & IEEE 802.11 Handbook by O'Hara et al

note 1: potential penetration based on current PC penetration

Figure 3-2 Spectral Distribution for IEEE 802.11 Compliant WiFi Device



With regard to the WiFi example, it is noted that FCC rules allow up to 1 watt operating power but that typical power is limited to 100 mW so that the device conforms to limits that are lower in many international locations. The analysis was performed for both power levels, but only the 100 mW analysis is presented, since the same conclusion is reached even with the lower power levels.

Table 3-2 also includes information to allow estimation of the adoption of new unlicensed devices sharing TV band spectrum. Data reported by The Consumer Electronics Association (CEA) was used for both cases[9]. The parameter selected for forecasting the adoption of new cordless phones is the current penetration for today's cordless phones. The assumption here is that this is not just an upper limit if 100% of phones move over, but since these phones are very inexpensive and have a short lifetime, that this level of penetration would be reached in a short time. In the case of wireless LANs, it is more problematic to estimate the penetration since WiFi deployment in home networks is still in an early stage. To set a realistic limit on the penetration of wireless LANs in the home, the current penetration of home computers was used as a proxy for the ultimate penetration of home wireless LANs. This level of penetration will overstate the population of these devices in the near term, but is a realistic limit for penetration given the expected growth of home networks.

The table also includes population and household density numbers to be used to estimate the impacts of multiple interfering devices. The analysis approach employed starts with the computation of the impact of a single interfering device and then considers the impact of multiple devices which might be within range of the TV receiver under consideration.

3.3 Analysis Theory

There are two modulation types under consideration based on cordless phones as a narrow band example and WiFi compatible wireless LANs as a broadband example. Since during the near term and medium long term, there will continue to be both analog and digital broad TV services it is necessary to perform the analysis for both types of unlicensed devices modulation for each of the two services— analog and digital TV. Common to each analysis was to consider the impairment on licensed TV broadcast operations using signal levels generally encountered at the edge of the TV station service area. In the case of analog TV signals the Grade B contour was used.

The analysis approach for the cordless phone example of a narrow-band, or CW, interfering device was as follows:

- Assume a single interfering device is transmitting at the maximum power level allowed by FCC 47CFR15.249 (i.e. a field strength of 50 mV/M at 3 meters).
- Include the Figure 3-3 location variability factor[10] to increase the effective transmitter power of the interfering device to account for a correction from 50% of the locations to 90% of the locations.
- Using a free space propagation model employing equations (1) through (3) in Figure 3-4 compute the required separation distance to keep the interfering signal level below the co-channel or adjacent channel D/U protection ratio of slightly annoying impairment.

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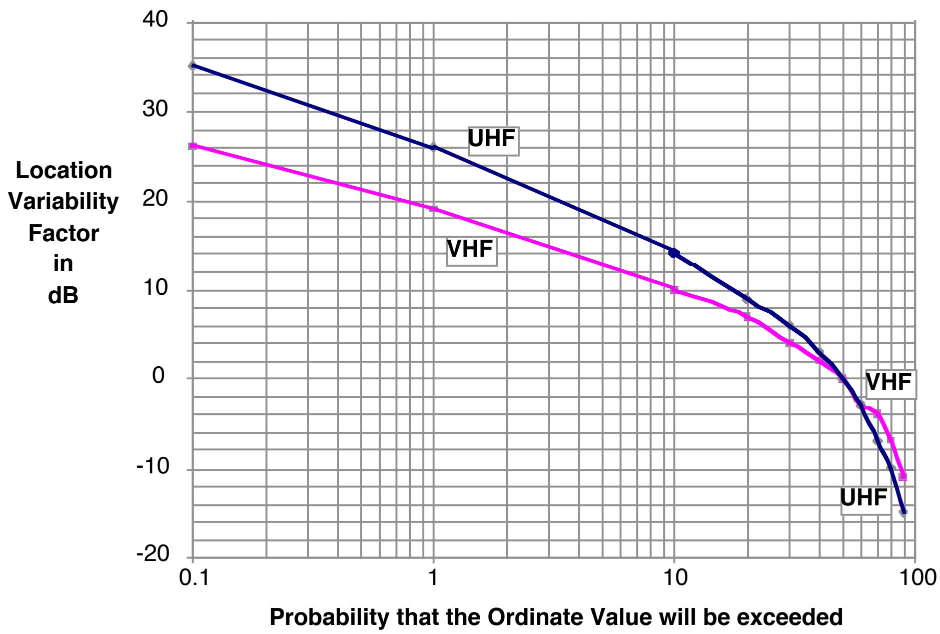
[9] See CEA Market Research, US Consumer Electronics Sales & Forecasts, 1998-2003, Issued January 2003, page 30, US Household Penetration of Consumer Electronics Products.

[10] Assumption based on Log-Normal shadowing such as used in FCC 47CFR73.699 and plotted in FCC Report R-6404, Technical Factors Affecting the Assignment of Facilities in The Domestic Public Land Mobile Radio Services, by Roger Carey.

- If the required distance exceeds the free space radio horizon using a 4/3 earth assumption in Figure 3-4 reduce the required separation distance to the radio horizon limit.
- To consider the impact of multiple interfering sources employ a simplified approximation based on the household density and percent adoption of the devices as presented in Table 3-3. The approximation was to consider that the nearest interfering devices would surround the protected TV receiver by the protection distance and only nearest devices along the perimeter ring would contribute interference as the RMS sum of each device. This analysis in Table 3-3 results in an adjustment factor that suggests an additional margin of protection that should be applied.

Figure 3-3 Location Variability Factor



Source: Adapted from FCC Data

Figure 3-4 Free Space Propagation Model with Radio Horizon

(1) $$Pd=\frac{Pt\ G}{4\pi\ R^2}$$

where Pd=Power density at receiver antenna (dB watts/meter^2)
Pt=transmitted power (watts)
R=distance between transmitter and receiver (meters)
G=gain of receiver antenna (=1.64X for dipole)

(2) $$Pd=\frac{E^2}{120\pi}$$ where E is field strength (volts/meter)

(3) $$Pload=Pd\ \frac{\lambda^2 G}{4\pi}$$

where Pload=Power delivered to receiver as a load on the antenna (watts)
λ=wavelength (meters)
G=gain of receiver antenna (=1.64X for dipole)

(4) $$D=2.83\sqrt{H}$$

where H=equal height of both receive and transmit antenna above ground (feet)
D=radio horizon in miles based on 4/3 earth model

Table 3-3 Multiple Interference Source Approximation

Multiple Interference Sources Approximation

Radius Miles	Perimeter miles	Density hh/mile	Adoption Percent	Adjustment Factor dB
0.25	2	75	81%	10
0.5	3	75	81%	11
1	6	75	81%	13
2	13	75	81%	14
3	19	75	81%	15
4	25	75	81%	16
5	31	75	81%	16
12	75	75	81%	18

The analysis approach for the WiFi/802.11 wireless LAN example of a broadband, noise like, interfering device was as follows:

- Assume a single interfering device is transmitting at the typical power level (i.e 100mW) for common devices (but less than the limit of 1 watt allowed by FCC 47CFR15.247).

- Scale the power down by the ratio of the bandwidth of the interfering device to the bandwidth of the TV channel (i.e. 22 MHz for WiFi divided by 6 MHz for a TV channel) to account for the broadband device having a bandwidth of noise that is wider than the TV channel.
- Include the Figure 3-3 location variability factor to increase the effective transmitter power of the interfering device to account for a correction from 50% of the locations to 90% of the locations.
- Compute the noise floor of receiver at channel 2, 13, 14, and 60 to cover the VHF to UHF range. Employ the Table 3-1 receiver noise figure and excess rural noise sum as the basis for the noise floor.
- Compute the additional allowable noise contributed by an interfering broadband device which results in a 1dB degradation of the noise floor.
- Using a free space propagation model employing equations (1) through (3) in Figure 3-4 compute the required separation distance to keep the interfering signal level below the limit of 1 dB degradation of the noise floor.
- If the required distance exceeds the free space radio horizon using a 4/3 earth assumption in Figure 3-4 reduce the required separation distance to the radio horizon limit.
- To consider the impact of multiple interfering sources employ a simplified approximation based on the household density and percent adoption of the devices as presented in Table 3-2. The approximation was to consider that the nearest interfering devices would surround the protected TV receiver by the protection distance and only nearest devices along the perimeter ring would contribute interference as the RMS sum of each device. This analysis in Table 3-3 results in an adjustment factor that suggests an additional margin of protection that should be applied.

3.4 Analysis

3.4.1 Narrow Band Cordless Phone Example Interference to Digital TV

Following the analysis approach described in the previous section for the case of a narrow band device to a digital TV receiver, we first compute the required free space separation distance for a single interfering device. The results of the analysis in Table 3-4 show that the co-channel distances vary from 37 miles at channel 2 to 15 miles at channel 69. Since these free space results exceed the radio horizon in Figure 3-4, we reduce the protection distance to the radio horizon. Since there is a possibility that both the TV receiver and the interfering device might be on the 2nd floor (or higher) of a typical single family residence, a figure of a 20 foot elevation for both devices yields a radio horizon of 13 miles. Building penetration loss might well reduce this protection zone, but in the case of wood frame buildings, there could well be little to no such loss.

To consider the impact of multiple sources, we apply the approximation in Table 3-3 which shows a need to apply an additional 18 dB of protection for such devices. This implies an increase in the protection exclusion zone from 13 miles to on the order of 100 miles.

The same process was employed for adjacent channel interference using an additional factor of 37 dB to account for the receiver selectivity. In this case Table 3-4 shows a required protection distance of 0.2 miles at channel 2 and 0.1 miles at channel 69. Applying the adjustment of 18 dB for multiple sources the protection exclusion zone for adjacent channels increases to on the order of 1 mile at channel 2 and 0.5 mile at channel 13 and higher.

Table 3-4 Narrow Band Cordless Phone Example Interference to Digital TV

Maximum Allowed Power at 2400MHz under FCC 47CFR15.249 NarrowBand Cordless Phone Example

E Xmit Limit	Pd	Distance		Pt	Pt
mV/M	watt/sq-M	Meters	Gain	Watts	mW
50	6.6E-06	3	1.64	4.57E-04	0.46

Free Space Interference Threshold for Co-Channel Digital TV

	FCC Limit	CW D/U	Loc Var	Adjusted	E Limit	Pd	Required	Required	Required
Channel	F.S. dBu	Ratio dB	dB	F.S. dBu	v/M	W/sq-M	Distance M	Distance ft	Distance miles
2	28	10	10	8	2.51E-06	1.67E-14	5.97E+04	195919	37
13	36	10	10	16	6.31E-06	1.06E-13	2.38E+04	77997	15
14-69	41	10	15	16	6.31E-06	1.06E-13	2.38E+04	77997	15

Free Space Interference Threshold for Adjacent Channel Digital TV

	FCC Limit	Loc Var	Selectivity	Adjusted	E Limit	Pd	Required	Required	Required
Channel	F.S. dBu	dB	dB	F.S. dBu	v/M	W/sq-M	Distance M	Distance ft	Distance miles
2	28	10	37	55	5.62E-04	8.39E-10	2.67E+02	875	0.2
13	36	10	37	63	1.41E-03	5.29E-09	1.06E+02	348	0.1
14-69	41	15	37	63	1.41E-03	5.29E-09	1.06E+02	348	0.1

Radio Horizon in Miles Based on Equal Height Rx and Tx Antenna

Height	Horizon
Feet	Miles
6	7
10	9
20	13

3.4.2 Narrow Band Cordless Phone Example Interference to Analog TV

We repeat the analysis of the previous section for NTSC analog broadcast TV. As above, we first compute the required free space separation distance for a single interfering device. The results of the analysis in Table 3-5 show that the co-channel distances vary from 234 miles at channel 2 to 59 miles at channel 69. Since these free space results exceed the radio horizon in Figure3-4, we reduce the protection distance to the radio horizon of 13 miles as in the above section.

To consider the impact of multiple sources, we again apply the approximation in Table 3-3 which shows a need to apply an additional 18 dB of protection for such devices. This implies an increase in the protection exclusion zone from 13 miles to on the order of 100 miles.

The same process was employed for adjacent channel interference using an additional factor of 17 dB to account for the receiver selectivity. In this case Table 3-5 shows a required protection distance of 33 miles at channel 2 and 8 miles at channel 69. Applying the adjustment of 18 dB for multiple sources the protection exclusion zone for adjacent channels increases to on the order of 260 miles at channel 2 and 65 miles at channel 14 and higher.

Table 3-5 Narrow Band Cordless Phone Example Interference to Analog TV

Maximum Allowed Power at 2400MHz under FCC 47CFR15.249 NarrowBand Cordless Phone Example

E Xmit Limit	Pd	Distance		Pt	Pt
mV/M	watt/sq-M	Meters	Gain	Watts	mW
50	6.6E-06	3	1.64	4.57E-04	0.46

Free Space Interference Threshold for Co-Channel Grade B Analog TV

Channel	FCC Grade B F.S. dBu	CW D/U Ratio dB	Loc Var dB	Adjusted F.S. dBu	E Limit v/M	Pd W/sq-M	Required Distance M	Required Distance ft	Required Distance miles
2	47	45	10	-8	3.98E-07	4.20E-16	3.77E+05	1236165	234
13	56	45	10	1	1.12E-06	3.34E-15	1.34E+05	438608	83
14-69	64	45	15	4	1.58E-06	6.66E-15	9.46E+04	310511	59

Free Space Interference Threshold for Lower Adjacent Channel Grade B Analog TV

Channel	FCC Grade B F.S. dBu	CW D/U Ratio dB	Loc Var dB	Selectivity dB	Adjusted F.S. dBu	E Limit v/M	Pd W/sq-M	Required Distance M	Required Distance ft	Required Distance miles
2	47	45	10	17	9	2.82E-06	2.11E-14	5.32E+04	174613	33
13	56	45	10	17	18	7.94E-06	1.67E-13	1.89E+04	61955	12
14-69	64	45	15	17	21	1.12E-05	3.34E-13	1.34E+04	43861	8

Radio Horizon in Miles Based on Equal Height Rx and Tx Antenna

Height Feet	Horizon Miles
6	7
10	9
20	13

3.4.3 Broadband Interference to Both Analog and Digital TV

As was previously indicated.the approach employed was to determine the protection distance for 1 dB degradation of the TV receiver noise floor. Since the bandwidth in both analog and digital cases is 6 MHz, the same analysis was employed for both modulation types. The results of the analysis in Table 3-6 below, show protection distances that vary from 336 to 76 miles on a free space basis which would reduce to the radio horizon of 13 miles as previously described. Applying the adjustment of 18 dB for multiple sources suggests a need for a protection zone of hundreds of miles.

Table 3-6 Broad Band Wireless LAN Example Interference to Analog and Digital TV

Analysis of Interference from WiFi Device in TV Band

	Chan 2	Char 13	C 14 UHF	C 69 UHF	Source		
Frequency (MHz)	54	210	470	800	FCC		
Receiver NF (dB)	12	12	15	15	FCC	bw=	4.00E+06
Excess Rural Noise (dB)	20	5	0	0	Skomal	t=	294
Rx noise (watts)	2.57E-13	2.57E-13	5.13E-13	5.13E-13	calculated	k=	1.38E-23
Background noise (watts)	1.62E-12	5.13E-14	1.62E-14	1.62E-14	calculated		
Total noise (watts)	1.88E-12	3.09E-13	5.29E-13	5.29E-13	calculated		
Additional Noise to Degrade S/N by 1dB Threshold (watts)	4.89E-13	8.02E-14	1.38E-13	1.38E-13	calculated		
Additional Noise to Degrade S/N by 1dB Threshold (dBw)	-123	-131	-129	-129	calculated		
Transmitter Power Output (watts)	0.1	0.1	0.1	0.1	802.11		
Scaling from 22MHz to 6MHz bw (watts)	0.027	0.027	0.027	0.027	calculated		
Scaling from 22MHz to 6MHz bw (dBw)	-16	-16	-16	-16	calculated		
Location Variability Factor (dB)	10	10	15	15	FCC		
Required Propagation Loss (dB)	117	125	128	128	calculated		
Protection Distance (meters)	541246	343566	208390	122429	calculated		
Protection Distance (feet)	1775741	1127185	683693	401670	calculated		
Protection Distance (miles)	336	213	129	76	calculated		

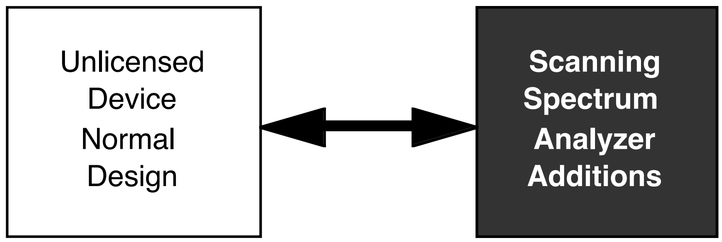
4 Alternative Technical Approaches to Control Interference

We believe there are two generic approachs to design an unlicensed device to avoid interference and both approaches add significant complexity to today's ISM unlicensed devices.

Approach 1: Build in a TV spectrum analyzer to scan the ambient RF environment and map the location and signal strength of any TV stations within the local service area. This approach is shown in Figure 4-1. In this approach the assumption is that the unlicensed device includes the equivalent of a TV tuner connected to a TV antenna comparable to that in a typical residence which scans the entire band and notes signals within the analog or digital coverage area that are above the service contour threshold. The device then takes note of these channels and applies rules to avoid co-channel, adjacent channel, and other taboos for harmonics and spurious responses. It is noted that unlike the requirement set for the unlicensed User PCS band, it is not adequate to look just within the occupied bandwidth of the unlicensed device since there is potential for adjacent channel and other out of band interference to licensed TV services.

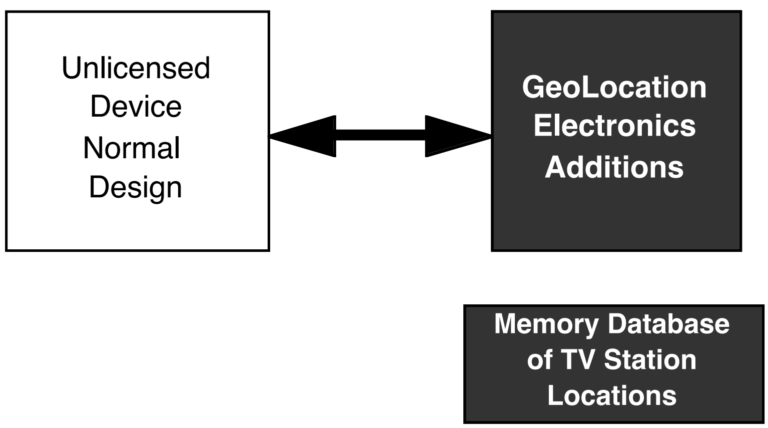
Such an approach is not without risk due to the so called "hidden terminal problem" in which the TV receiver subject to interference could be located between the unlicensed device and the licensed TV station. In such a case the unlicensed device might be too far away to hear the license TV station. Another concern is that the need for a high quality external antenna on the unlicensed device might not be an acceptable industrial design.

Figure 4-1 Scan and Avoid Approach to Control Interference



Approach 2: Provide location specific technology into the unlicensed device so that it can geolocate itself and then use a memory lookup of assigned TV signals within the local service area. This approach is shown in Figure 4-2.

Figure 4-2 Location Based Database of Licensed TV Broadcast Stations



In this approach, the unlicensed device determines the location of operation by means of data included at time of manufacture or installation, or perhaps using a geolocation technology such as GPS. It then refers to a database of licensed TV stations and uses rules as above to avoid impairments to licensed TV broadcast services.

We regard this approach as not acceptable for a number of reasons. The use of GPS implies an outside antenna which would make the approach not acceptable for typical unlicensed devices. The approach of configuring the location of use in advance of operation is not acceptable since the device could be moved or new licensed TV channels could be authorized after the device is sold.

5 Economic Analysis

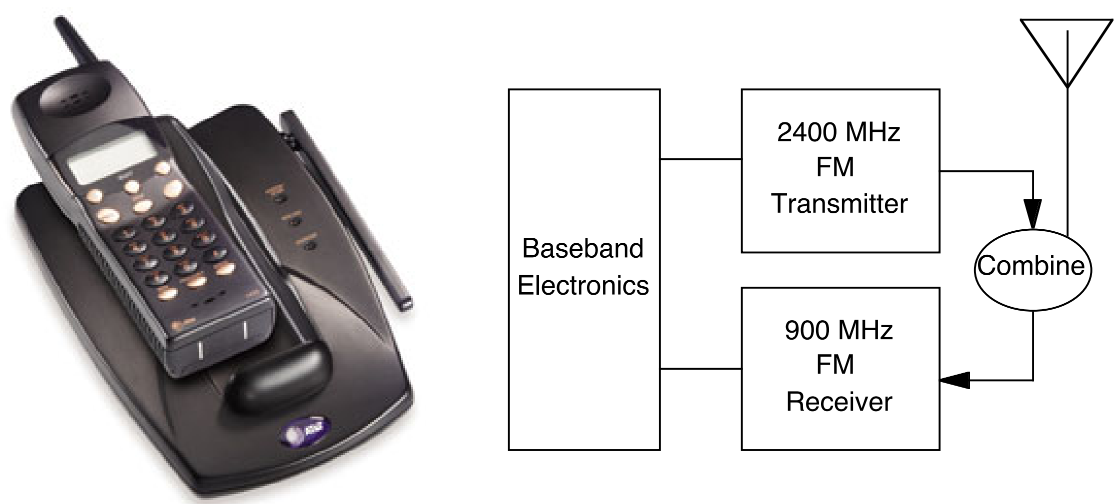
The basic approach employed for estimation of the incremental cost additions to a basic ISM typie device was to first explore the typical prices of today's ISM unlicensed devices such as the cordless phone and WiFi LANs used in the interference analysis. We then considered the cost and complexity of the best available technical approach, Approach 1 above. By adding the price of an existing mature ISM device to the estimated prices of the less mature incremental additions to implement approach 1, we develop an estimate of the entry price of a new unlicensed device in the TV broadcast band. By considering the historical learning curve cost reductions in past ISM devices, we can estimate the comparable cost reductions in the new unlicensed TV band devices should they develop to the same volumes comparable to today's ISM devices.

5.1 Costs of Typical ISM Band Unlicensed Devices

5.1.1 Cordless Phone Narrowband RF Device Example

We note that The Consumer Electronics Association reports an average factory price for a cordless phone of $43 in 2003. Since this is factory (not retail) price and since it includes many low cost phones outside of the ISM band, we selected a typical phone in the ISM band as an example. This Lucent Model ATT1430 phone in Figure 5-1 is typical of an ISM phone and has a retail street price of above $80.

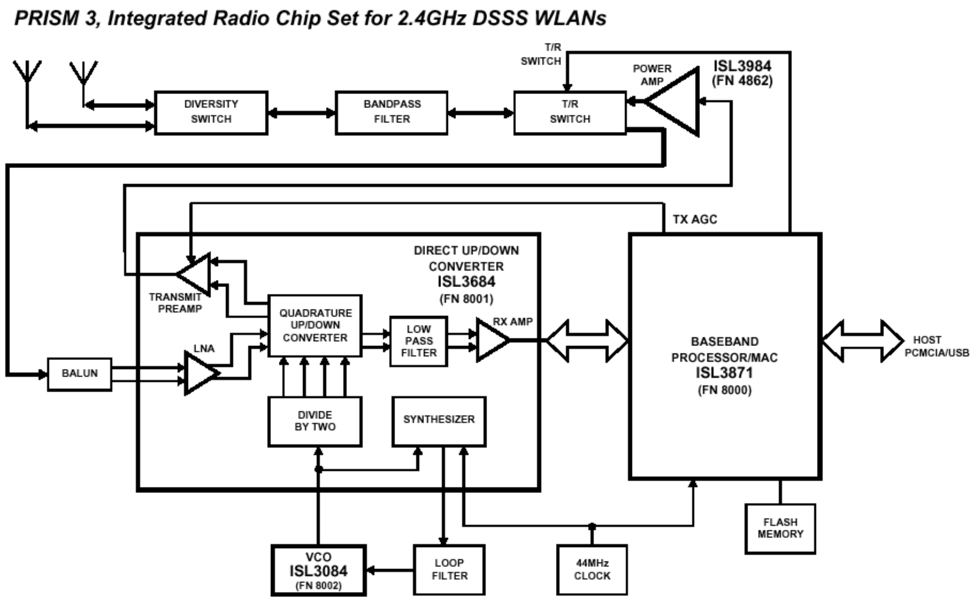
Figure 5-1 Cordless Phone Narrow Band RF Device Example



5.1.2 WiFi/802.11 Wireless LAN Spread Spectrum RF Device Example

WiFi wireless LANs are a less mature product than cordless phones. There have been many new chipsets that have driven the costs of PC Card form factor devices from the several hundred dollars prices to retail street prices today on the same $80 order of the cordless phone example above. A recent research report[11] indicates that WiFi chipsets have declined in the last two years to a forecast $10 in 2003 from a cost of $43 in 2001. An example of a chip set in the $10 range is shown in Figure 5-2 based on The Intersil Prsim 3 chip set.

Figure 5-2 Wireless LAN Broadband Device Example



5.2 Cost Model of Best Alternative Technical Approach

Since we have selected Approach 1 as the best alternative technical approach, we explored the likely incremental price for the equivalent of a TV Tuner and associated electronics needed to measure signal strength and control an unlicensed device. We employed the basic block diagram in Figure 5-3 as a basis for estimation of this incremental price.

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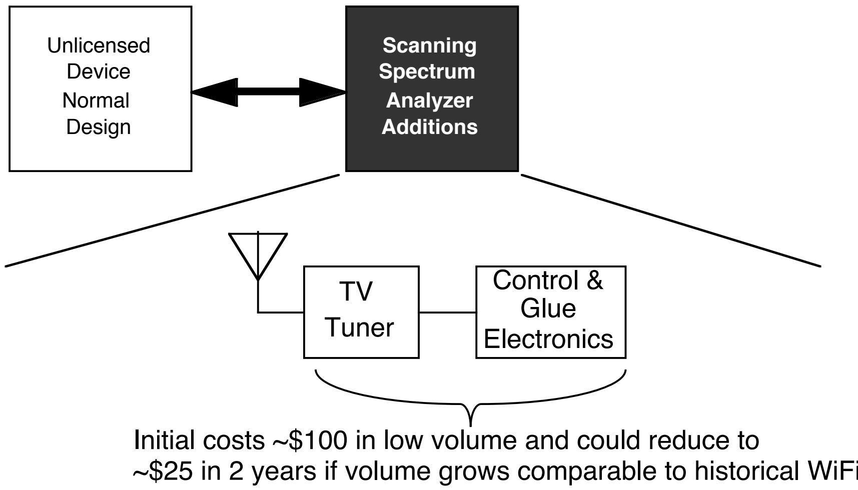
[11] See WiFi Report by Russ Craig, Aberdeen Group, November 2002.

Figure 5-3 Cost Model for Unlicensed TV Band Device Using Best Known Approach



As an estimate of the cost of TV tuner plus associated electronics designed for consumer use but still in modest manufacturing volumes, we explored the TV Tuner cards designed to plug into a personal computer. These products are available from several manufacturers and have retail street prices on the order of $100[12].

Following the approach previously discussed, we conclude a reasonable price at the time of market entry for a new unlicensed device in the TV broadcast band would be the sum of $80 of today's ISM device costs plus $100 for the incremental interference avoidance electronics. If the TV band unlicensed device were to decline in cost as rapidly as the WiFi chip set prices noted above, the retail price for a mature TV band unlicensed device might well decline from $180 at market entry to perhaps $105 at high manufacturing volumes.

6 Summary and Conclusion

6.1 Best Technical Approach and Feasibility

Because of what we regard as unacceptable technical risks, we do not consider a technical approach that requires factory or user programming so as to avoid local TV services to be acceptable. We also rule out self configuring geolocation technologies based on GPS to be

[12] TV on a PC? It's all in the cards , J.D. Biersdorfer, NEW YORK TIMES NEWS SERVICE 28 October 2002 The San Diego Union-Tribune, Excerpt: • • •Several companies like Hauppauge, Pinnacle and ATI sell basic cable-ready TV tuner cards for $100 or less.

unacceptable since the ability to operate indoors is unlikely. In any event, a location specific approach is likely to be more complex and expensive than the next best alternative.

We suggest the best technology alternative would be one similar to the *spectrum etiquette* mandated for the User PCS band. In this approach, the unlicensed device would be required to scan the licensed TV band to detect and determine if the device is operating inside of digital or grade B analog TV service of any licensed TV station. The device would then use this information together with specific rules to limit emission power and bandwidth so as to limit interference to levels which are not annoying.

While we regard this *sniff and avoid* technical approach to be the best, it is not without unresolved issues and risks. The major risk is that which has been called *the hidden terminal problem.* This problem is due to the possibility that the TV receiver may be located between the licensed TV station and the unlicensed device. In such a case, the unlicensed device may too far away to detect the TV station but not too far from the TV receiver to cause interference. Further analysis may suggest solutions to this problem by using threshold extension techniques to increase the detection sensitivity of the unlicensed device so as to overcome this problem.

Because a TV receiver may suffer interference due to unlicensed emissions outside of the operating channel, due to the limits of TV receiver selectivity spurious responses, or non-linearity it is not clear if there are enough safe acceptable frequencies in a major metropolitan area to provide substantial bandwidth of new unlicensed devices.

Finally there is an open issue regarding packaging of a feasible device. Today's ISM devices generally employ internal antenna to satisfy a need for compact and attractive industrial designs. A TV receiver on the other hand might well employ an outside mounted fixed high gain external antenna. In such a case, the unlicensed RF device would need to employ a comparable external high gain antenna in order to detect the licensed TV broadcast station.

6.2 Economic Feasibility

For the best technology alternative based on the *sniff and avoid* technique above, we estimate the additional end user price at market entry would be on the order of 2.25X the price of today's comparable ISM device. If the new unlicensed device would approach the maturity of today's ISM devices manufacturing learning curve theory would suggest the price could decline to on the order of 1.30X the price of today's comparable ISM device.

6.3 Overall Conclusion

Because it is likely that there will be many unlicensed devices as well as TV receivers that will operate on the 2nd floor (or higher) of a typical home, there will be many devices and receivers operating on the order of 20 feet above the ground. Further because many may be in wood frame homes with little to no building penetration loss, we conclude there is a potential for near free space propagation paths between unlicensed devices and a TV receiver. Our technical analysis indicates that generally both co-channel and adjacent channel interference will be significant up to the radio horizon on the order 13 miles for a single interfering device. When the impacts of multiple devices is considered the zone of protection may need to extend by significant multiples of the single device limit.

Under such conditions the sharing of TV spectrum during the DTV transition period on co-channel and adjacent channel will not be possible in any but the most rural areas. Since the need for additional spectrum for unlicensed devices in rural areas is not a pressing problem, there seems to be little value in authorizing such sharing. In our judgement the little benefit to be gained is not worth the technical risks.

Based on our analysis, we conclude that a technology solution could be realized that would manage interference to licensed TV operation outside a TV stations coverage area— most in rural areas; however, we believe the cost and complexity would greatly inhibit the market acceptance of such a device.

Our analysis in the light of the failure of The User PCS Band to generate new product offerings, suggests a conclusion that sharing the TV band with unlicensed RF devices is not feasible on both technical and economic grounds.

7 Appendix- Qualifications of Stuart J. Lipoff

Mr. Lipoff is a consultant with a practice in TIME (telecommunications, information technology, media, electronics, and ebusiness) industries and technologies. He draws upon his 30+ years of experience in a wide variety of technologies and industries to assist clients with knowledge based consulting services involving complex business decisions.

Mr. Lipoff was employed 25 years by Arthur D Little, Inc (ADL) as VP and Director of Communications, Information Technology, and Electronics (CIE); 4 years by Bell & Howell Communications Company as a Section Manager, and 3 years by Motorola's Communications Division as a Project Engineer. At ADL he was responsible for the firm's global CIE practice. At both Bell & Howell and Motorola, he had project design responsibility for wireless communications and paging products.

Stuart Lipoff has Bachelor's Degrees in Electrical Engineering and in Engineering Physics, both from Lehigh University. He also has received a Masters Degree in Electrical Engineering from Northeastern University, and a MBA degree from Suffolk University.

Mr. Lipoff is a fellow of the IEEE Consumer Electronics, Communications, Computer, Circuits, and Vehicular Technology groups. He is an elected member of the IEEE Consumer Electronics Society National Administration Committee, and was the Boston Chapter Chairman of the IEEE Vehicular Technology Society. He served as 1996-7 President of the IEEE Consumer Electronics Society and is now Chairman of the Consumer Electronics Society Standards Committee. He has also chaired the search committee for Sony supported Mazura Ibuka Award in consumer electronics. As Vice President and Standards Group Chairman of the Association of Computer Users, he served as the ACU representative to The ANSI X3 Standards group. For the Federal Communications Commission's Citizens advisory committee on CB radio (PURAC), he served as Chairman of the task group on user rule compliance. He has been elected to membership in the Society of Cable Television Engineers (SCTE), The Association of Computing Machinery (ACM) , and The Society of Motion Picture and Television Engineers (SMPTE).

Stuart Lipoff holds a FCC General Radiotelephone License and a Certificate in Data Processing (CDP) from the ACM supported Institute for the Certification of Computing Professionals (ICCP). He is a registered professional engineer (by examination) in The Commonwealth of Massachusetts.

Mr. Lipoff holds three USA patents and has published articles in Electronics Design, Microwaves, EDN, The Proceedings of the Frequency Control Symposium, Optical Spectra, and numerous IEEE publications. He has presented papers at many IEEE and other meetings. In the fall of 2000, he served as general program chair for The IEEE Vehicular Technology Conference on advanced wireless communications technology. He has organized sessions at The International Conference on Consumer Electronics and was the 1984 program chairman. He conducted an eight week IEEE sponsored short course on Fiber Optics Systems Design. In 1984, he was awarded IEEE's Centennial Medal and in 2000 IEEE's Millennium Metal.

He is a member of the USA advisory board to the National Science Museum of Israel and has presented a short course on international product development strategies as a faculty member of Technion Institute of Management in Israel. He is also a member of the board of directors of The Massachusetts Future Problem Solving Program.

Mr Lipoff is internationally recognized as an authority and opinion leader in new economy related businesses and technology in the consumer electronics industry and related manufacturing and services businesses. Citations supporting his recognition can be found on his web site at http://www.lipoff.org .