SONY

Wireless Audio in the Age of DTV

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Introduction

The arrival of Digital Television (DTV) has spurred much rumor, speculation and hype about the impact these broadcasts will have on wireless audio systems. The purpose of this White Paper is to provide hard, factual information about this important topic.

In these pages, you will find a detailed examination of the legal and technical issues involved, presented in an historical context. The facts and figures cited here are derived not only from Sony's long experience in the professional audio and video industry, but from a comprehensive analysis of the new Federal Communications Commission (FCC) regulations made by attorneys-at-law specializing in the field, as well as extensive laboratory testing conducted by RF engineers and other communication systems professionals. This White Paper supplies detailed answers to the four most important questions currently being asked:

Q&A

Q. Will DTV obsolete my existing wireless system?

A. With very few exceptions, the answer is no. In particular, frequency-agile systems—especially those that utilize digital PLL (Phase-Locked Loop) synthesis circuitry and tone key squelch — should have no problem dealing with the new RF landscape.

Q. What about the effect of the new Public Safety allocations?

A. As with DTV, this should have little impact on your existing wireless system, especially if the system permits the use of multiple frequencies.

Q. Will digital transmissions cause greater interference problems?

A. No. If anything, testing indicates that they will induce less audible interference than analog transmissions of equivalent strength.

Q. Will wireless systems continue to be legal?

A. DTV or no DTV, the rules of usage haven't changed.

Historical Perspective

It was no less a pioneer than Alexander Graham Bell—inventor of the telephone—who was responsible for the first experimental wireless audio system, first demonstrated in 1879. Using simple light-beam AM and a selenium-based detector, Bell's design was incorporated in a dirigible communications system in 1932 before sinking into obscurity.

Around the turn of the century, various induction technologies were developed, but wireless microphones did not begin seeing widespread application until the 1930s, when they were regularly used for off-site radio broadcasts. The first FM wireless systems began appearing in the early 1950s and were used widely in television broadcasts of the era. These systems employed vacuum tubes, making them massive, cumbersome and highly visible; however, this changed in the mid-1950s with the introduction of all-transistorized designs, which at last made wireless audio an important adjunct to the movie and entertainment industries. Other important technologies such as heterodyne receiver design, companding noise reduction, and true space diversity, were introduced in the 1960s and 1970s. Sony entered the wireless market in 1979 with its debut of a wide-band FM system which proved to have enormous popularity in the broadcast industry.

Early FM wireless systems used low-band "broadcaster" frequencies in the 26 - 50 MHz range. However, due to the long wavelength at these frequencies, audio dropouts were a recurring problem (compounded by limited RF output power) and the quarter-wave antennas used were inconveniently large. As a result, by the early 1960s, most wireless systems migrated to the VHF high band, utilizing frequencies in the 150 - 200 MHz range. Unfortunately, this band is shared not only by television broadcast channels 7 - 13, but also by many other high-powered RF occupants such as two-way radios and other business and government operations. Consequently, interference and intermodulation distortion became unwelcome companions for many users of VHF wireless systems.

And so, like the nomads of ancient days, manufacturers of wireless systems once again migrated to a more promising vista—the UHF band. Not only was this much less crowded than the VHF band (occupied primarily by the rarely-used television channels 14 - 69), but the FCC also eased the restrictions on RF output power, allowing UHF transmissions of up to .25 watts (in contrast to the maximum .05 watts permissible in the VHF band). In addition, the higher carrier deviation in UHF broadcasts allows for greater dynamic range and increased audio frequency bandwidth, making for a better quality signal. However, the conventional crystal-controlled oscillators found in many wireless transmitters can only operate at certain frequencies, limiting the number of systems that can be operated simultaneously. A more elegant solution is provided by the PLL (Phase-Locked Loop) frequency synthesizer design pioneered and introduced by Sony in 1991. This technology not only allows a single circuit to be "frequency-agile" (thus avoiding interference problems and allowing many systems to operate simultaneously), it also provides extraordinary RF stability, enabling the wireless receiver to tightly lock in on the desired frequency.

But the days of analog-only television have ended. In 1996, the FCC launched the DTVera by granting every existing television broadcaster an additional 6 MHz channel to be used for digital transmissions. While many of these allocations will be made in the VHF band, some will also be made in the UHF band. The "core" DTV spectrum is in channels 2 – 51, with channels 60 – 69 slated for early recovery and channels 52 – 59 to be recovered by the year 2006. These reclamations of UHF frequencies are mandated by the fiscal realities of the Balanced Budget Agreement of 1997.

We are currently in an FCC-mandated transition period (scheduled to conclude January 1, 2006), during which time both analog and digital television broadcasts are permitted. The first DTV broadcasts began in November 1998 in selected geographic areas, although commercial broadcasters are not required to begin service until May, 2002 and non-commercial broadcasters are not required to begin service until May, 2003. It is, however, possible (and even probable) that some stations may file for an extension.

Another area of concern to the government has been the rapid expansion of Public Service RF usage (i.e., by police, fire, ambulance, disaster relief, etc.) in the low VHF band and the resultant lack of available space. As a result, the FCC has begun reallocating Public Safety applications to the UHF band, using selected bandwidths in channels 63, 64, 68, and 69 (764 - 776 MHz and 794 - 806 MHz). The specifications for these new allocations were only announced by the FCC in September, 1998, and there are petitions for reconsideration pending. Even if these new allocations are approved, it will

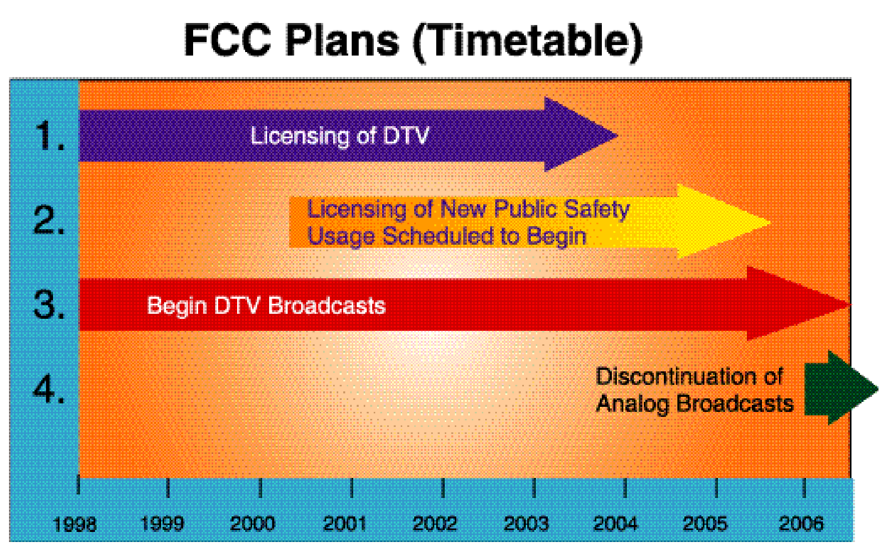


Figure 1: FCC Timetable

likely take many months (if not years) for appropriate equipment to be designed and manufactured, and it may well be years before this new Public Safety equipment is in common use. There are many local financial and political pressures which are expected to significantly delay the timetable for Public Safety usage.

There is no doubt that the initiation of DTV broadcasts and the FCC's new Public Safety allocations will have some impact on both existing and future wireless audio systems. Some wireless systems will be affected more than others, depending largely upon their circuit design, feature set, and frequency range. In the following pages, we will examine the legal and technical issues that will define the future of wireless audio in the coming millennium.

Legal Issues

The FCC is an independent United States government agency which regulates all interstate and international communications by radio, television, wire, satellite and cable.

Its Mass Media Bureau is responsible for AM, FM and television broadcast stations and related facilities. It assigns frequencies and call letters to stations, and designates operating power and sign-on and sign-off times. This bureau also assigns stations in each service within the allocated frequency bands, with specific locations, frequencies, and powers.

The FCC's Wireless Telecommunications Bureau regulates stations serving the communications needs of businesses, individuals, nonprofit organizations, and state and local governments. It is responsible for all domestic wireless telecommunications except those involving satellite communications. The Bureau is also responsible for rule making and regulatory matters concerning Public Safety, Industrial, Land, Transportation and other private mobile services, including Aviation, Marine, and "Amateur" services.

All commercial radio and television broadcasters (both analog and digital) are licensed by the Mass Media Bureau, and all Public Safety broadcasters (such as police, fire, ambulance, and disaster relief services) are licensed by the Wireless Telecommunications Bureau. The frequencies assigned to each of these broadcasters are published by the FCC and are readily available to the public. Such licensed applications are known as "primary" users. Other low-power RF applications—such as wireless audio systems—do not have to be licensed, but are allowed to operate as "secondary" users. Secondary usage is legal and authorized when it does not cause interference to primary usage, and as long as secondary users defer to primary users. Interference *from* secondary users such as analog wireless systems onto primary users is highly unlikely, given that DTV and Public Safety transmissions operate at a much higher power level and over significantly greater distance than wireless audio. In addition, the fact that these transmissions are digitally keyed to ignore other signals further reduces the likelihood of interference from secondary users.

The new rulings and frequency reallocations made by the FCC in compliance with the Balanced Budget Agreement of 1997 have upheld the continuing authority of wireless manufacturers and users to operate as they have previously, stating, "We will continue to permit broadcasters to use vacant television channels for the operation of wireless microphones and other secondary uses."* In short, wireless audio systems are and will continue to be legal so long as their operation does not interfere with that of primary users.

Another recent legal development with possible ramifications for wireless users is the FCC's decision to permit biomedical telemetry devices in hospital facilities to operate as secondary users (thus without a license) but at increased RF output power. These devices will utilize selected frequencies not only in the VHF band, but also in the UHF band, operating in the 174 - 668 MHz range (channels 7 – 46). Wireless systems using these frequencies may therefore encounter interference when operated near health-care facilities. It is worth noting that Sony wireless systems operate in a higher frequency range, from 770 - 806 MHz (channels 64 – 69), outside the areas of possible interference from such systems

** FCC document, Part 74, DTVMO&O*

Technical Issues

Band Occupancy

Problem-free wireless audio is most likely to occur in bandwidth areas that are relatively free and clear of other RF traffic. While the new FCC allocations for DTV and Public Safety will make the UHF band more crowded than it was in the past, technical issues such as shorter wavelengths (making for shorter and less obtrusive antennas), higher permitted transmitter output power and greater carrier deviation (enabling increased dynamic range and audio frequency bandwidth) still make UHF a better choice than VHF for wireless audio.

To date, the FCC has assigned DTV channels to more than 90% of existing television stations (these are listed on the Internet, at: http://www.fcc.gov/oet/dtv/start/dtv2-69.txt). The vast majority of the 1600 FCC-allocated channels (to date) have been made in the 54 - 770 MHz range (VHF channels 2 - 13 and UHF channels 14 - 63). As DTV stations come on line, they will displace existing low-power TV operations and TV translators.

As shown in figure 2 below, Sony wireless products operate in the 770 - 806 MHz range (UHF channels 64 - 69). Only a handful of DTV allocations (fewer than 1% of the total) have been assigned to channels 64 - 68 in selected geographic areas, and there have been no DTV allocations to channel 69. Indeed, the FCC has publicly stated its desire to keep these channels largely free of DTV and NTSC activity because of its intention to recover them at an early date. Even in those locations having DTV allocations in channels 64 - 68, the extraordinary frequency-agility of Sony wireless systems (which provide 282 different operating frequencies) ensures that there will be sufficient free RF space to operate them without difficulty.

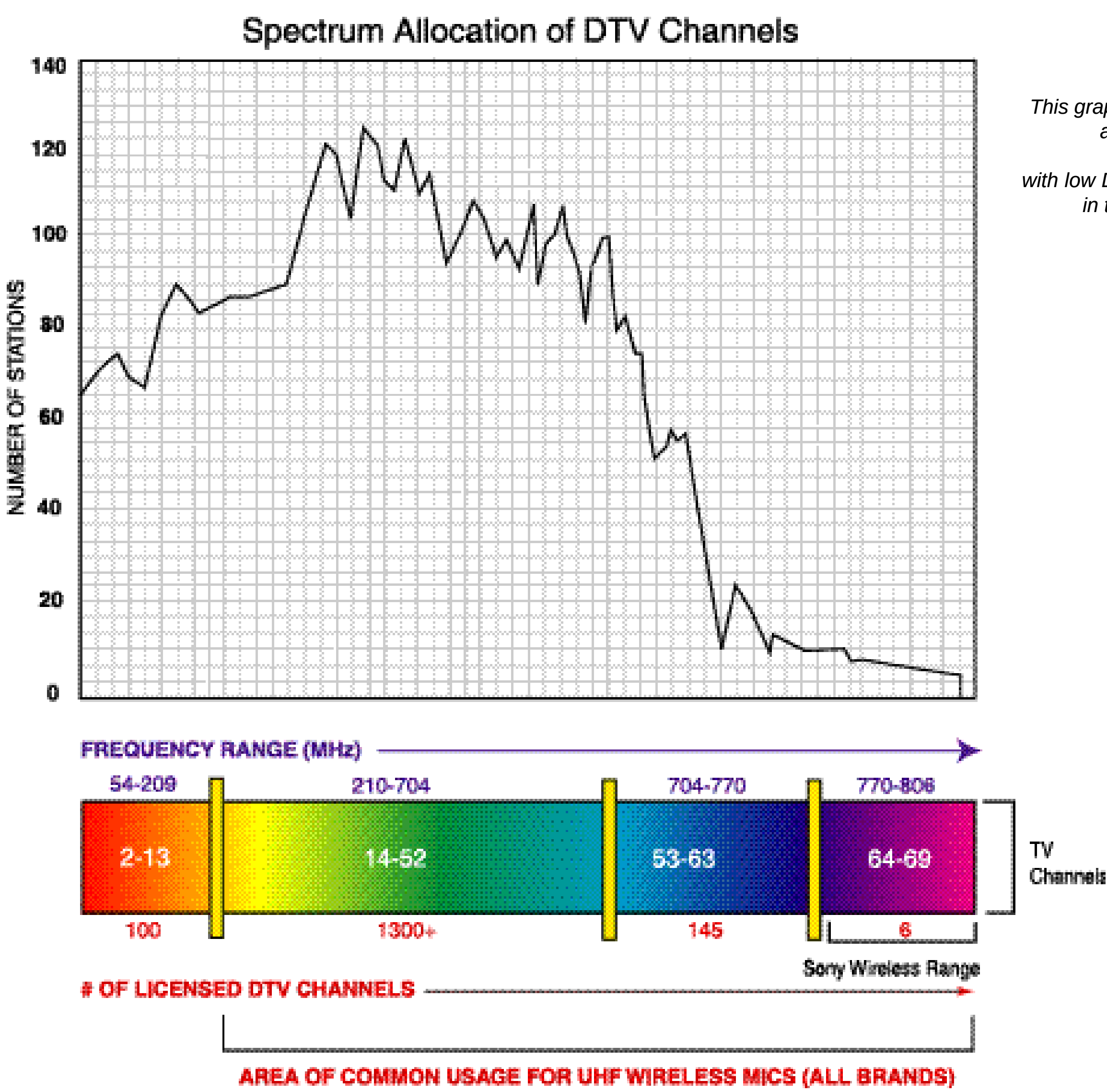


Figure 2:
This graphic shows DTV allocation across UHF spectrum with low DTV occupancy in the Sony Range

As shown in figure 3 below, the new Public Safety allocations within UHF channels 63, 64, 68, and 69 (764 - 776 MHz and 794 - 806 MHz) have been organized into wideband channels (carrying high-speed data such as images and video) and narrowband channels (carrying voice and other slow-speed data). There are also wide- and narrow-band interoperability channels (used for communications between different jurisdictions on a local and regional basis), and wide- and narrow-band reserved channels (8.8 MHz of spectrum held aside for future expansion). Two or four contiguous narrowband (6.25 kHz) channels may be used in combination as 12.5 kHz or 25 kHz channels, respectively, and two or three contiguous wideband (50 kHz) channels may be used in combination as 100 kHz or 150 kHz channels, respectively.

Of course, not every general use or interoperability channel will be utilized in every geographic area, and the presence of reserved channels ensures that there will be at least 8.8 MHz of clear spectrum within each of these four UHF channels in *all* geographic areas, at least throughout the transition period (which ends January 1, 2006). It is worth noting that Sony wireless products also utilize selective frequencies within UHF channels 65, 66, and 67 — channels that remain completely free of Public Safety allocations.

Historically, Public Safety allocations have taken a long time to get online because they have to go through local budgeting cycles and because new equipment has to be developed; for these reasons, an FCC spokesperson has stated that it will be "a few years…before we see significant Public Safety usage." Also, all new Public Safety and DTV usages must be licensed by and registered with the FCC, so, as in the past, it will be a simple matter to determine which frequencies are authorized for use in any given geographic area, enabling effective channel planning.

FCC New Public Safety Band Spectrum & Channels

Designated Purpose	Amount of Spectrum	Narrowband (6.25 kHz)	Wideband (50 kHz)
General Use	12.6 MHz (52.5 %)	7.8 MHz (1248 channels)	4.8 MHz (96 channels)
Nationwide Interoperability	2.6 MHz (10.8 %)	0.8 MHz (128 channels)	1.8 MHz (36 channels)
Reserved For Future Use	8.8 MHz (36.7 %)	3.4 MHz (544 channels)	5.4 MHz (108 channels)
TOTAL	24 MHz (100 %)	12 MHz (1920 channels)	12 MHz (240 channels)

Figure 3.

The Nature of Digital RF Transmissions

Digital RF transmissions differ in a number of ways from analog RF transmissions. Perhaps the most significant difference is that, due to the large amount of encoded data, digital transmissions require greater amounts of bandwidth. DTV, for example, occupies almost all of the 6 MHz of spectrum in each channel (the new Public Safety broadcasts, which will also be digital, occupy a much smaller bandwidth—typically 25 - 60 kHz). Another important difference is the dispersion of energy within the occupied bandwidth, as shown in figure 4 below. In digital transmissions, the energy is equally dispersed (except for the front-end pilot tone). This differs significantly from analog TV transmission, which is broken into video, audio and control signal carriers, each of which creates a higher energy spike. These carrier signals are located at different points within the 6 MHz range and are not of equal energy at all points. However, there are areas within an analog TV signal which are of low enough energy to enable a wireless mic system to "punch holes" through it.

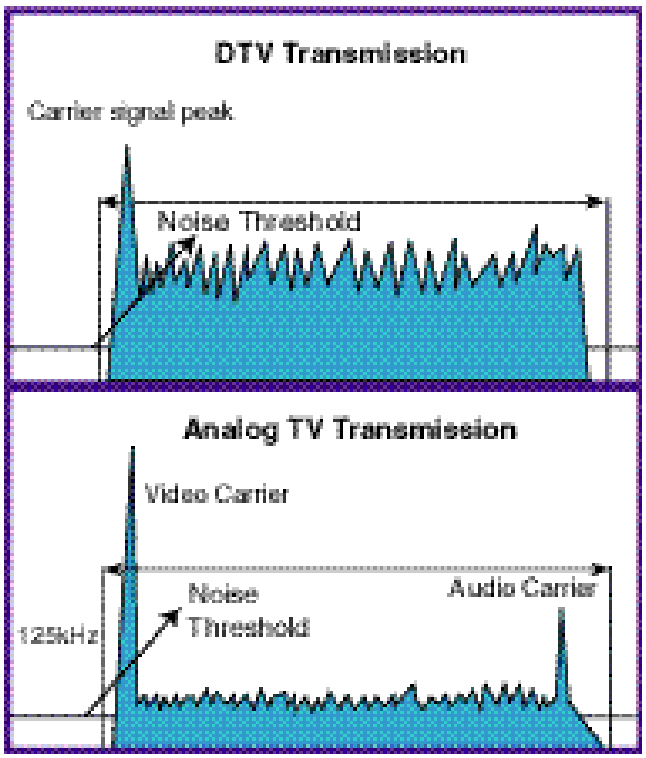


Figure 4: Illustration showing energy dispersion in digital vs. analog broadcast signal

It is also worth noting that lower power digital RF signals (such as those used for Public Safety) are absorbed by building materials to approximately the same degree as analog RF (typical RF level attenuations range from 10 to 30 dB), so that, even after all the new allocations are operational, roughly the same amount of beneficial shielding will occur when operating a wireless system indoors. Also, local digital RF activity can be determined with the use of an on-site scanner, same as with local analog broadcasts.

Digital Interference

The key factors that determine the amount of potential interference from digital RF transmissions are much the same as the determinants in analog interference:

- *Distance from the interfering transmitter.*
- *Degree of wireless transmission strength relative to that of the interfering signal.*
- *The position and directionality of receiver antenna*s.

Because DTV signals operate under much tighter specifications for out-of-band emissions than analog TV broadcasts, a wireless system operating on an adjacent channel (for example, a system operating on channel 68 in an area where there is a DTV transmission on channel 67) should not experience interference. Sony engaged the services of an independent laboratory* to test this and the results were as follows:

"The interference potential is greater when the undesired (interference) signal is directly on the operating frequency of the receiver under test...The measurement data shows that 1% audio distortion can be seen when the undesired signal is approximately 11.4 dB above the desired input signal, as measured at the receiver's antenna input port. However, *no degradation of the simulated desired wireless carrier was observed when the DTV signal was placed in the next 3 adjacent channels.* (italics ours) The undesired DTV signal was tested to a level 35 dB above the simulated desired carrier level."

Sony's testing also indicates that the nature of interference caused by digital transmissions is very different from that caused by analog transmissions—and may not be nearly as severe or as critical. In many cases (depending upon signal strength), instead of masking or dropout problems, there will simply be a slight increase in the noise floor and/or a decrease in operating range.

Digital wireless transmission uses an FSK (Frequency Shift Keyed) signal** broadcast over a standard UHF carrier, so while the audio information itself is not vulnerable to interference, the carrier *can* be. However, just as digital broadcast systems are keyed to reject any other potentially interfering signal, so too are analog wireless systems which incorporate tone key squelch circuitry (a feature in all Sony wireless products). The transmitters in these systems place a 32 kHz pilot tone alongside the RF carrier. This is then picked up by the receivers to 'lock' the tuner onto the signal and ignore any other spurious RF which does not have this tone. Thus, tone key squelch-equipped systems will view digital interference as background noise and should be able to completely ignore it.

** Carl T. Jones Corporation, "RF Interference Measurements & Studio" testing conducted for Sony Corporation, September 1998.*

***Frequency shift keying is a form of frequency modulation in which the modulating wave shifts the output frequency between predetermined values.*

Interference from Public Safety broadcasts has always been an issue and is possibly of greater concern, but it is worth noting that these transmissions will typically be intermittent, localized, and much lower-powered than DTV (no more than 1 kW, but typically 200 - 300 W). Also, as noted previously, they will occupy much less bandwidth than DTV (an average of about 50 kHz, with possible stacking of signals, bringing the maximum bandwidth per service to about 150 kHz). As with DTV, Public Safety channels will be licensed and regulated by the FCC and therefore relatively easy to avoid when creating your wireless channel plan.

Although the FCC has left many of the final design issues up to manufacturers and end users, many reliable sources in the industry are of the opinion that these new Public Safety broadcasts will be digital in nature, probably FM, and, due to security considerations, will be "keyed" to ignore (and be ignored by) other systems. Testing conducted by Sony on potential interference problems in this area yielded the following results:

"The interference potential is greater when the undesired (interference) signal is directly on the operating frequency of the receiver under test... The measurement data shows that 1% audio distortion can be seen when the undesired signal is approximately 10 dB below the desired input signal, as measured at the receiver's antenna port. At approximately ±140 kHz removed from the operating frequency of the receiver, the ratio of undesired to desired to create a 1% distortion in the audio quality went to almost 30 dB *above* the desired signal level, at the -140kHz frequency, to over 40 dB *above* the desired signal level, at the +140 kHz frequency."

These tests were conducted for two different frequencies, and for both AM and FM broadcasts. The results for all four tests were essentially identical (see figures 6 & 7 on the next page).

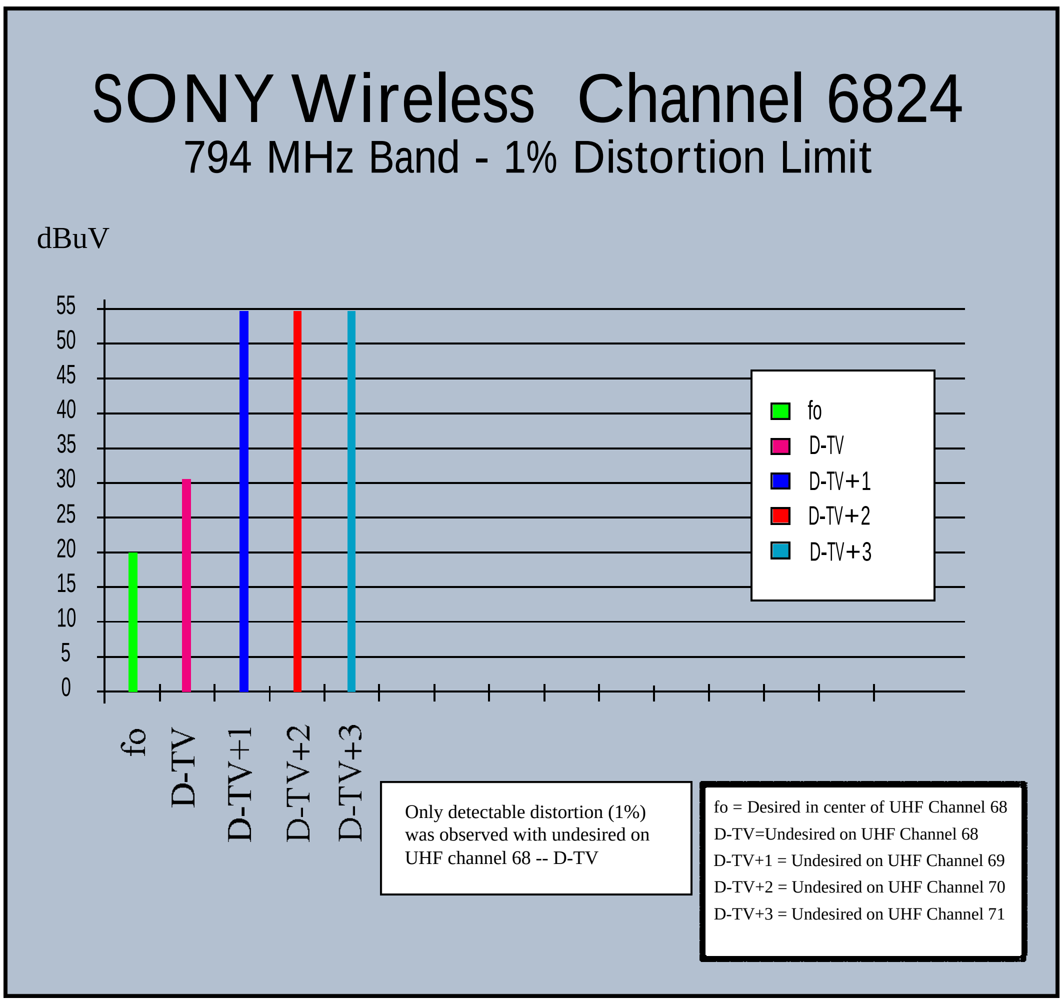
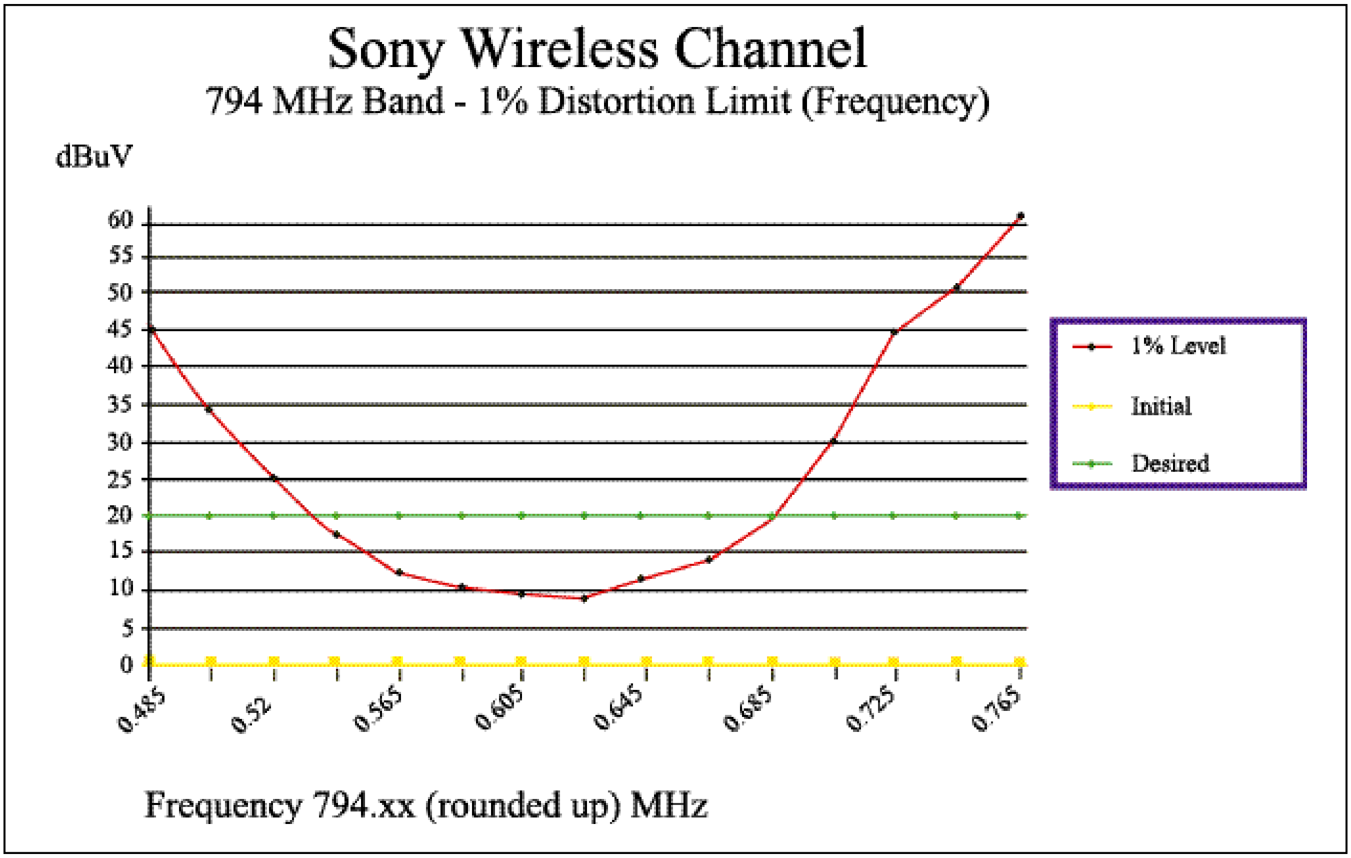
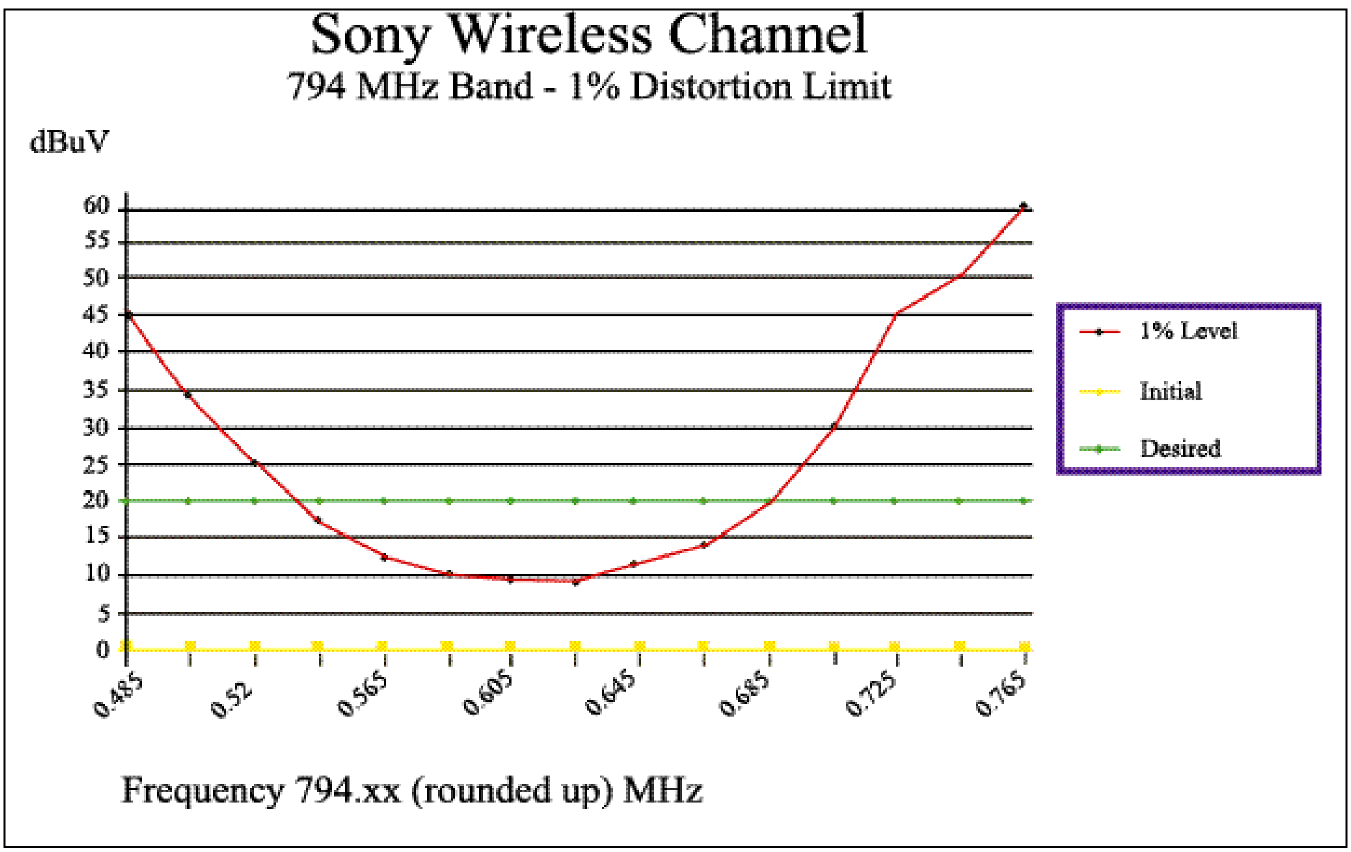


Figure 5: Labortory Similated DTV Interference Test



Figures 6 (above) & 7 (below):
Simiulated Public Safety Interference Tests with FM Carrier



What to Look For in a Wireless System

RF Stability

RF stability—the ability to lock onto and maintain a tight grip on the desired frequency—always has been critical to wireless performance, and the new DTV and Public Safety allocations will make this even more important in the years ahead. This stability is partially a function of the quantity and efficiency of the receiver's narrow-band IF (Intermediate Frequency) filters, as reflected in the device's *selectivity* rating—a measurement of how well the receiver can differentiate between adjacent frequencies. Sony wireless receivers offer exceptionally high selectivity, ranging from greater than 50 dB (in the WRR-820A and WRR-840Areceivers) to greater than 60 dB (in the WRR-801A, MB-806 and WRU-806A UHF tuners and other Sony broadcast systems).

The use of PLL (Phase-Lock Loop) synthesizer circuitry in wireless microphone systems was pioneered by Sony and is included in all Sony wireless products. This provides direct onboard control over all transmitting and receiving frequencies, and enables an extraordinary degree of frequency-agility. Sony systems provide 282 different operating frequencies on 6 TV channels (64, 65, 66, 67, 68, and 69).

Sony wireless systems are unique in that they employ direct 800 MHz VCO oscillation in order to eliminate spurious harmonics generated by the multiplication circuits used in crystal-controlled systems (for example, in the case of the WL-800 series, the second harmonic is around 1.6 GHz—well outside the broadcast spectrum).This not only reduces off-band interference but also ensures minimal carrier drift, making for a much more stable signal.

Sony Channel Plan

(64)				(66)				(68)			
	64		65		66		67		68		69
	64-09		65-09		66-09		67-09		68-09		69-09
	64-11		65-11		66-11		67-11		68-11		69-11
	64-19		65-19		66-19		67-19		68-19		69-19
L1	64-25	H1	65-25	L1	66-25	H1	67-25	L1	68-25	H1	69-25
	64-30		65-30		66-30		67-30		68-30		69-30
	64-34		65-34		66-34		67-34		68-34		69-34
	64-37		65-37		66-37		67-37		68-37		69-37
	64-10		65-10		66-10		67-10		68-10		69-10
	64-13		65-13		66-13		67-13		68-13		69-13
	64-17		65-17		66-17		67-17		68-17		69-17
L2	64-22	H2	65-22	L2	66-22	H2	67-22	L2	68-22	H2	69-22
	64-28		65-28		66-28		67-28		68-28		69-28
	64-36		65-36		66-36		67-36		68-36		69-36
	64-38		65-38		66-38		67-38		68-38		69-38

Figure 8: Sony channel plan for multichannel operation on multiple TV Bands with use of Sony WD-880ABand Splitting Divider.

Versatility

Clearly, one of the keys to surviving the changing RF environment is to use a frequency-agile system. However, the use of such a system does not in and of itself guarantee that you will be able to use multiple systems in the same location. Indeed, the problems of intermodulation distortion increase logarithmically as each new system is added.

The larger the number of channels made available by the system, the less the potential for interference. All Sony wireless systems are frequency-agile, and they provide an unusually large and versatile intermodulation-free channel plan, with 282 different operating frequencies on 6 TV channels. (see figure 8)

Another unique feature of Sony wireless products is the storage of this channel plan in permanent memory, allowing immediate access to alternate frequencies at the push of a button. With the use of an optional band-splitting divider*, up to 42 Sony systems can be used in one location at the same time.

Sony wireless systems also offer a variety of high-quality components so as to optimize performance in even the most hostile RF environments. For example, it is often desirable to reduce transmitter output power (using active antennas at the receiver end to compensate and achieve the same operating range) when a large number of systems are required at one location. Accordingly, Sony systems offer a variety of antenna types (both passive 1/4 wave and active), with transmitters that can provide varying RF output power (from 2.5 - 50 mW).

* Sony WD-880Aor WD-820A

Summary

The new RF landscape will make it increasingly important to evaluate the environment in which you will be working. Information on licensed RF activity for any given location is available locally, or on the FCC website (www.fcc.gov). This will go a long way in enabling you to properly design the correct wireless system for your needs and to creating a well-coordinated channel plan. It is also strongly suggested that you make use of an RF spectrum analyzer, or a portable scanner, to confirm whether there is in fact RF activity on or near your assigned channels.

The bottom line is: Reliable wireless operation should no longer be taken for granted. Plan to do some homework. With this approach, together with a properly designed wireless system (one with frequency agility and stable RF performance), this new RF environment will be far easier to navigate than some might think.

Sony is committed to supporting the continued operation of its current wireless product lines and to exploring the new RF technologies of the future. For additional up-to-date information, visit our website at www.sony.com/proaudio or the FCC's DTV website at http://www.fcc.gov/dtv/.