Wireless Mics and Digital Television

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The advent of digital television (DTV) has made wireless mic operation much more complicated. The number of broadcast signals has doubled in most metropolitan areas over the past three years. Not only has this has increased the total interference level that a wireless mic must contend with, it has made it much more difficult to find open channels. And to make matters worse, many of these new digital stations are using channels where wireless mics have operated without interference for years.

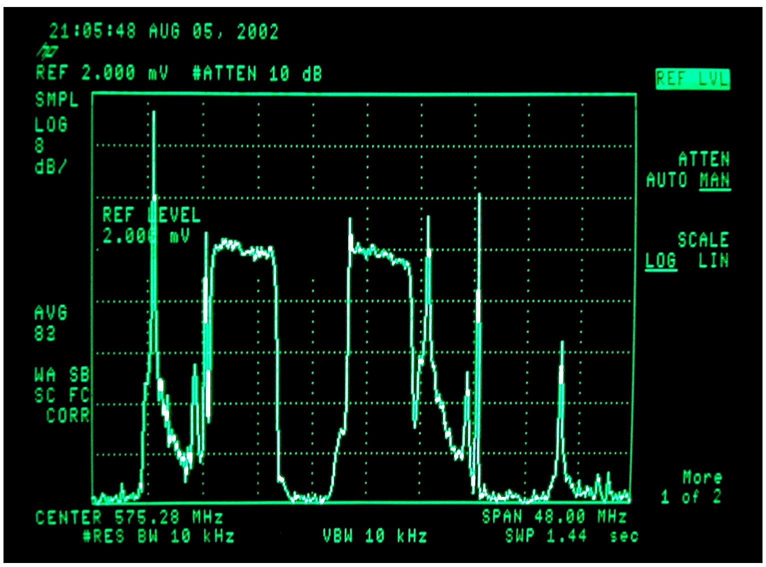

Fig 1. This spectrum analyzer's view of eight UHF TV channels clearly illustrates the nature of the interfering signals that a wireless mic system must compete with. Three analog TV stations and two DTV stations are transmitting in the eight TV channels shown in this scan. 18 months ago, those digital transmitters weren't on the air yet!

<u>Understanding The Analyzer Screens</u> The horizontal axis is frequency (the analyzer is set for 4.8 MHz/div), and the vertical axis is signal strength. The top of the screen is set to 2 mV. The analyzer is hooked to up an antenna on the roof of my home (about 7 miles from the

transmitters), and is tuned to look at TV channels 27-34. Here in Chicago, Ch 27 is unassigned, Ch 28 is analog, Ch 29 is digital, Ch 30 is unassigned, Ch 31 is digital, Ch 32 is analog, Ch 33 is unassigned, and Ch 34 is a low power analog station.

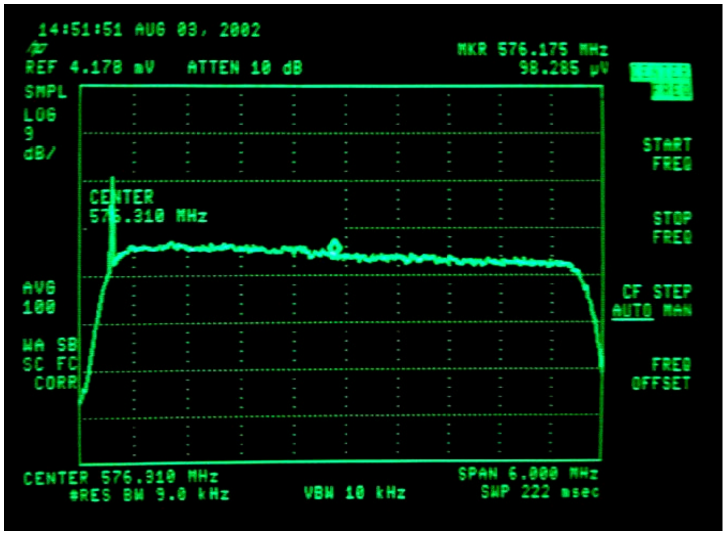

Fig 2. A 6 MHz wide view of one digital TV signal. The digital TV stations (Ch 29 and Ch 31 in Fig 1) show up as a flat trace that exactly fills their assigned channels. The high spike at the left of each DTV station is a pilot signal. Thus the digital station's power is spread equally throughout the channel.

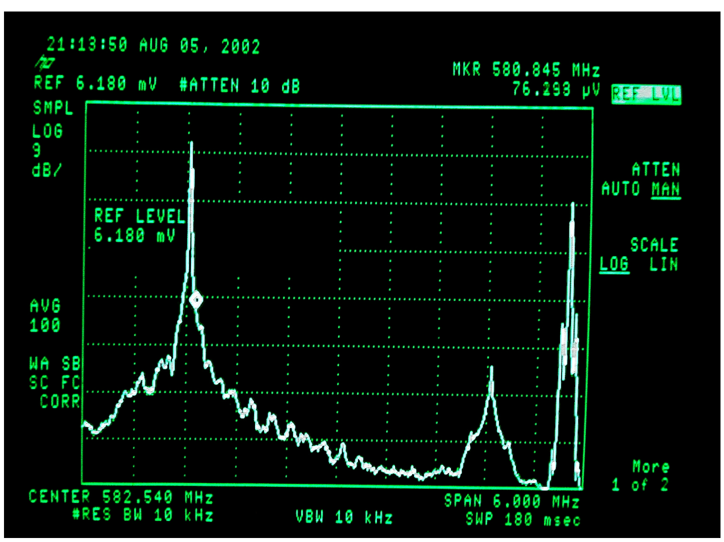

Fig 3. A 6 MHz wide view of one of the analog signals. There are two strong spikes (their picture

and sound carriers), with energy concentrated relatively close to those carriers. The tall spike at the left of the trace is the video carrier, with most of the power concentrated in sidebands relatively close to it. The tall spike at the right of the trace is the sound carrier. The bump to the left of the sound carrier is the color sub-carrier with its associated energy.

How much energy is in these signals? The transmitter for the analog picture carrier has an effective radiated power of 3 Megawatt (3 Million watts), while the sound transmitter is 750 Kilowatt (6 dB less). Opening up the spectrum analyzer bandwidth to 3 MHz reveals that the total power in the digital signal can be comparable to that in the analog signals! We say it can be because many broadcasters are running their DTV transmitters at less than full licensed power to avoid interference to adjacent analog channels.

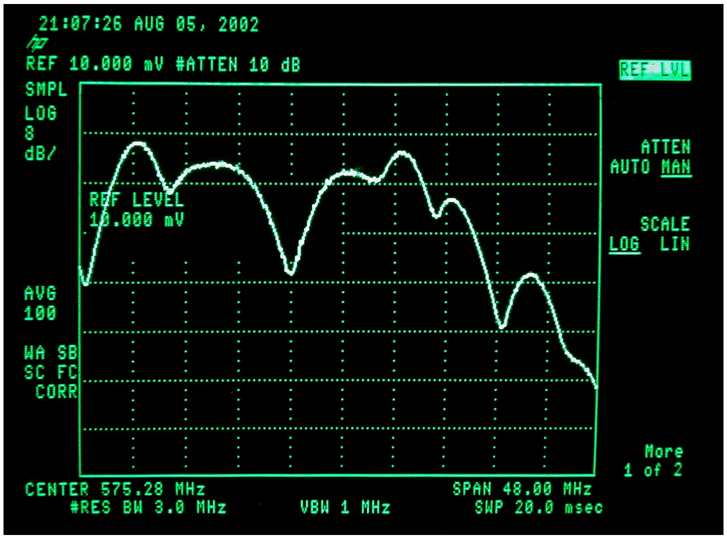

Fig 4 The same eight channels of Fig 1, but with the analyzer bandwidth set to 3 MHz.

[Effective radiated power is the transmitter's actual output power multiplied by the directional gain of the antenna and divided by the loss in the feedline. TV transmitting antennas are highly directional vertically -- they concentrate their power in the horizontal plane (that is, relatively little signal goes straight up or down), but are usually not directional horizontally (that is, they radiate equally to all azimuths). Typical antenna gains are on the order of 8-15 dB.]

Why Wireless Mics Don't Work Well in DTV Channels

The picture carrier of the analog station is producing about 30 mv at my antenna, while the digital station's signal is giving me 2 mv throughout its channel. Doing the arithmetic, a 1 MW transmitter is putting 8,300 watts **within every 50 khz piece of the channel**! What this means in practical terms is that my 10 mw wireless mic is trying to compete with a TV transmitter on a tall building that is 830,000 times more powerful, giving the TV transmitter an advantage of 59.2 dB!

Ah, you say, but our wireless mic is much closer to the receiver. So even though the TV transmitter is so much more powerful, inverse square law (the dispersion of transmitter power with distance) will weaken the signal from that big transmitter enough that my wireless mic can be heard over it. And if the wireless receiver is inside a building with a lot of metal in its shell, the TV transmitter may be reduced in strength by a factor between 10 and 100 (10-20 dB). Sometimes these factors can be enough to allow things to work. But remember -- that broadcast transmitter is working into a very good antenna that is high and in the clear, while the wireless mic, uses a tiny antenna, much of whose radiation is soaked up or blocked by the body of the person wearing it!

So, most of the time, guess who wins? The answer is that unless the wireless transmitter is very close to its receiving antenna, the TV transmitter will override it, and all we'll hear is digital noise. So in practical terms, the DTV transmitter severely limits the working distance of the wireless system, often to 25 feet or less.

More to the point, how can we help our wireless transmitter win? We can: 1) put the receiving antenna closer to our transmitter; 2) use a more powerful wireless transmitter (if the FCC allows it and if we can get enough battery life at the higher power level); 3) use a directional antenna that points toward our transmitter and away from the DTV transmitter; 4) move our wireless system to a channel where there is no interference. In most real world situations, #1 or #4 are the most practical solutions.

How Does DTV Affect Intermodulation and Receiver Desensitization?

The answer to this question relates to the bandwidth of the input stage. If the input stage is broadband and includes the interfering signal, the total signal strength of a DTV signal integrates (sums) to be almost exactly equal to the total strength of what an analog transmitter would produce. This is because the broadband input stage sees all of the input voltage within its bandwidth and adds it together.

To reduce the overload of the input stage, we must reduce the voltage it sees. One way to do that is to attenuate (weaken) all signals (with a broadband attenuator, called a "pad"), but that will also attenuate our signal in the process. If we still have enough of our own signal, that's a reasonable solution. But that isn't always the case, especially with very strong interfering signals.

The other way to eliminate or reduce overload is to use a sharply tuned filter that allows the wireless transmitter to come through but attenuates signals on other frequencies. In other words, the receiver must be tuned to receive only the desired channel and reject other channels. Since the earliest days of radio, these tuning circuits have been critical parts of receivers, and the technology to implement them is well developed.

Over the past decade, many radio and TV receiver manufacturers, in the quest for cheaper and more compact products, have been leaving out these important components. In other words, they are selling an incomplete product, one that is missing some critical parts. If you don't use their product to listen to small or more distant transmitters close to big transmitters, you may never notice that the parts are missing. But if you try to listen for those small transmitters (the public stations or those from out of town), you won't hear them -- instead, you'll hear only the big transmitter(s) or noise.

According to FCC data, a full power transmitter (100 KW) at 1,000 ft on channels 2-6 will generate 1.26 Vm at 1 mile for a receiving antenna at a height of 30 ft; for channels 7-13 (316 KW) the field strength is 2.24 V/m; and for channels 14-69 (1 MW) it is 3.98 V/m.

Multiple radio frequency signals combine according to the square root of the sum of the squares of the individual voltages (RSS). In a typical large US city (Chicago), the combined field strength at one mile from the two analog and one digital transmitters on "low-band VHF" channels 2-6 is 2.2 V/m; for the three analog transmitters on the "high-band VHF" channels 7-13 the total is 3.9 V/m; and for the eleven analog and nine digital UHF transmitters (channels 14-69) the total is 17 volts/meter. The combined field strength of those five broadcast signals in our spectrum analysis example is about 7 volts/meter.

It is the total voltage at the receiver input that causes desensitization by rectification at the input stage. The instantaneous voltage on any given frequency will determine the strength of the intermodulation product from combining signals. Digital signals will certainly contribute to intermodulation distortion, but their product will be broadband noise that is lower in strength for any given interfering signal on any given wireless mic frequency. That's the good news. The bad news is that the noise will be spread over a wide spectrum, and will be contributed to by multiple transmitters on either side of the wireless channels.

The result is that intermodulation caused by digital transmitters will likely be every bit as bad as that from analog signals, but because it is broadband noise, it may never be identified as having resulted from intermodulation! And the overall effect on wireless mics will be to reduce their transmitting range.

Intermodulation occurs outside our equipment -- in non-linear junctions in building structure, etc. -- and inside our equipment (due both to the non-linearity of semiconductor devices, and to overload). We have no control over the intermod that happens outside our equipment, but we <u>can</u> control what happens inside our equipment with careful front end filtering (i.e., between the antenna and the first electronic stage) to eliminate interfering signals before they can produce intermod in our equipment.

There are at least two good strategies for front end filtering. **<u>Broadband</u>** filtering can be tuned to accept only signals within a single 6 MHz TV channel that we know to be free of interference. **<u>Narrowband</u>** filtering, set to a bandwidth on the order of 100 KHz, can be used to squeeze a wireless system into a part of an analog channel that contains relatively little energy (for example, between the color sub-carrier and the sound carrier). Broadband filtering is relatively inexpensive, although no wireless mic manufacturers have yet figure that out and used it in their products. Narrowband filtering is quite expensive, especially if it has to track a frequency-agile transmitter. This author is aware of only two manufacturers, Lectrosonics and Sennheiser, who currently manufacture systems that have narrowband filters, and only relatively expensive Sennheiser products have these filters.

Keeping track of the new digital TV stations The National Association of Broadcasters maintains a list of active DTV stations on their website. The url is http://www.nab.org/newsroom/issues/digitaltv/dtvstations.asp. You can also buy a set top box and hook it up to a video monitor to watch these channels.

In the earliest stages of DTV, most digital transmitters were only on the air during prime time and on weekends. That time is nearly past, since we've past the date that every licenced broadcaster is required to be on the air with a digital signal or risk losing his digital license. Many educational broadcasters and a few commercial broadcasters who have applied for and received temporary waivers are not on the air yet.

And don't assume that because a DTV station is on the air and not interfering with you now that it won't interfere with you in the future. Some broadcasters, especially those with their DTV channel adjacent to their analog channel, are running their DTV transmitter well below their licensed power to avoid interference to their analog channel -- after all, 99.9% of their viewers are watching the analog signal. As the number of their DTV viewers increases the DTV transmitter is likely to begin transmitting at full power.