8-VSB versus OFDM: more than a tempest in a TV?

Dan Strassberg - May 25, 2000

A tempest in a TV? Maybe. But last February, when it denied a petition from multistation owner Sinclair Broadcast Group (www.sbgi.net), the Federal Communications Commission (FCC, www.fcc.gov) just might have signed the death warrant for US over-the-air terrestrial TV broadcasting. The petition, filed after months of rancorous debate, asked the Commission to allow stations a choice of modulation techniques for digital-TV (DTV) broadcasts. Sinclair felt that, if allowed to do so, many stations would substitute orthogonal frequency-division multiplexing (OFDM), also called coded OFDM (COFDM) for the FCC-mandated eight-level vestigial-sideband (8-VSB) approach. The European digital-video broadcasting (DVB) DTV system uses OFDM. According to early reports, the system works well, albeit not flawlessly. The 8-VSB camp points out, however, that European and US TV differ significantly, so that the favorable reports imply little about OFDM's potential in US DTV.

Sinclair states that OFDM works well with indoor receiving antennas, such as bow ties, in many places where 8-VSB receivers don't produce a picture or require extreme measures to do so. Indeed, the company says it has found numerous locations where OFDM works better with indoor antennas than does NTSC (National Television Systems Committee) analog modulation—the more-than-0-year-old North American standard. Some proponents of 8-VSB say that outdoor antennas easily solve their system's reception problems. However, Sinclair reminds these people that, in apartment buildings, tenants who want to install outdoor antennas often cannot obtain the landlord's permission. Moreover, the company asserts that in most cities, satisfactory 8-VSB reception requires an antennarotator.

The company bases its claims of OFDM's superiority on comparisons with 8-VSB performance in multiple locations in several cities and in the surrounding suburbs. Proponents of 8-VSB insist that these tests were flawed. These critics say the tests failed to establish OFDM's superiority but did
demonstrate shortcomings in first-generation 8-VSB receivers and set-topboxes. When TV-set manufacturers conducted their own demos to show that 8-VSB works acceptably with indoor antennas, Sinclair said that these tests were flawed. Still, according to 8-VSB proponents, sets that incorporate newly announced 8-VSB-decoder ICs should perform quite acceptably with indoor receiving antennas similar to those of OFDM receivers.

Nevertheless, OFDM advocates offer a plausible explanation for their system's claimed advantages—at least in densely populated urban areas. A key consideration in designing OFDM, but not 8-VSB, was immunity to multipath interference—particularly dynamic multipath, such as that which occurs when signals bounce off airplanes and moving vehicles.

**Reflecting on multipath interference**

Multipath effects occur when signals reach the receiver via several paths, the shortest of which usually follows an indirect line of sight from the transmitting antenna to the receiving antenna. Other paths involve reflections from stationary or moving objects. With analog TV, reflections from stationary objects cause ghosts. Reflections from moving objects cause flutter as signals that follow different paths alternately reinforce and cancel one another.

Digitally modulated signals result in more complex effects, most of these signals pack multiple bits into individual symbols. Multipath effects cause inter-symbol interference (ISI), in which symbols that reach the receiver by short routes mix with previously transmitted symbols, which, because of reflections, travel farther and take longer to arrive.

Inter-symbol interface can be devastating. Unlike analog signals, digitally transmitted TV images don't usually suffer gradual degradation as the error rate increases. Rather, you either get a picture, or you don't. Moreover, once the screen goes blank, many seconds can elapse before the receiver starts displaying a picture again. Hence, conditions that might cause intermittent interference on an analog receiver can cause a complete picture loss on a digital receiver. Dynamic multipath commonly causes such interference.

**Heading off mass defections**

One of Sinclair's arguments asserts that the number of US households that receive TV broadcasts over the air from terrestrial transmitters has already declined sharply. More than two-thirds of US households now receive TV from cable or direct-broadcast satellites (DBS). If over-the-air viewers find DTV reception more challenging than the analog reception to which they are accustomed, they will follow the lead of almost 70% of their fellow citizens. Such a mass defection from over-the-air reception might make existing TV stations irrelevant.

Because over-the-air stations already use cable, and now DBS, to reach most viewers, you may ask why using these delivery systems to reach all viewers would affect the stations' relevance. The reason is that organizations that merely produce programs but do not deliver them are indistinguishable from independent program producers. The FCC requires cable systems to carry local stations' programming. Without some special regulation—for example, a grandfather clause for former over-the-air broadcaster—that requirement would cease to exist if the stations shutdown their transmitters.

Nevertheless, 8-VSB proponents labeled Sinclair's petition a stalling tactic perpetrated by a minority of TV broadcasters that see no economic advantage in DTV and that therefore want to delay system deployment. Sinclair counters that fully half of US TV-stationowners supported its petition. On the other hand, the broadcasting industry's most influential trade organization, the National Association
of Broadcasters (NAB, www.nab.org) backed the FCC's denial of the petition.

Clearly, the Commission doesn't want to kill—or even harm—over-the-air TV, and the denial of Sinclair's petition included an olive branch for OFDM supporters. As part of its commitment to swift conversion of the country's over-the-air TV to a digital system, the FCC conducts periodic progress reviews. The Commission promised to look into OFDM again during its next regularly scheduled review.

**Long road, deliberate pace**

The road to the US ATSC (Advanced Television Systems Committee, www.atsc.org) DTV standard was long, and the trek was arduous. What's more, most of the effort proceeded at a deliberate pace and involved the industry's best engineering minds. All interested parties had a chance to express opinions and demonstrate results. Given that background, examining how the current situation came about should prove illuminating.

One allegation is that, by the time hardware became available for over-the-air testing, the ATSC was under considerable pressure to quickly complete the new standard. Because the members recognized existing indoor antennas' shortcomings for receiving 8-VSB signals, the committee used outdoor antennas on 30-ft masts to demonstrate satisfactory reception. The drafters knew that the antennas and receiver circuits would require further work, but they were confident that implementing such work would enable satisfactory reception with indoor antennas.

The committee considered OFDM, which, at the time, was new and completely unproved. All indications suggested that the DSP-based circuits' extreme complexity made OFDM economically impractical for use in mass-produced consumer products. As this article went to press, the ATSC decided to review its choice of modulation method, though not necessarily with a view toward replacing 8-VSB with OFDM.

**A good decision—at the time**

Meanwhile, good reasons existed for selecting 8-VSB. Compared with OFDM, 8-VSB was a known quantity. Moreover, 8-VSB seemed a good choice, given that, during the transition to DTV, NTSC and ATSC signals would have to share the same frequency bands. As with analog-modulated NTSC signals, one 8-VSB sideband is vestigial. This common property of the two signal types augured well for low interference between them.

Other reasons for adopting 8-VSB included the modulation system's low power requirements. High power not only leads to high electric bills for TV stations, but also necessitates more expensive transmitters, larger transmitting antennas, and larger transmission lines between the transmitter and the antenna. The larger these components are, the more they weigh. And, except for the transmitter, all of the listed components mount on a tower; thus the tower must be stronger, that is, wider, heavier, and more expensive. Although a tower's height is the most important factor in maintenance costs, heavier towers cost more to maintain.

OFDM proponents admit that obtaining equivalent coverage with their approach requires more power than with 8-VSB. But, despite 8-VSB proponents' claims of a 4-dB difference (about 2.5 to 1—this is power, not voltage), OFDM advocates say that the real difference is closer to 2 dB (about 1.6 to 1). Moreover, OFDM proponents assert that transmitted power need not necessarily increase, because a good receiving antenna can compensate for a weak signal. Weak-signal areas normally occur in sparsely populated areas. Although impractical in cities, 30-ft antenna masts present few problems in rural areas. In fact, rural residents who have no cable or DBS service expect to have to buy expensive
Oh, no! Not that again!

However, a cornerstone of 8-VSB proponents' argument against OFDM was that OFDM would require higher power, and that higher power would necessitate a complete overhaul of the table of TV-channel allocations. It was no small feat to design this table, which provides a second channel for each US TV station during the transition to DTV. The task required three years the first time around, and 8-VSB advocates insist that a redesign would take just as long. OFDM proponents counter by asserting that the experience gained during the initial table design should reduce the redesign time to three months, not three years.

Interference between NTSC service and new DTV service certainly enters into discussions about revising the allocation table, but so does Sinclair's proposal to let broadcasters choose between 8-VSB and OFDM. Part of the motivation for allowing but not requiring the use of OFDM was a desire to make the proposal less distasteful to broadcasters that have already invested heavily on conversion to 8-VSB.

Nevertheless, if every signal that might interfere with or receive interference from an OFDM signal was itself an OFDM signal, the allocation table could remain unchanged—even if power increases became necessary. Surely, in the long run, both consumers and broadcasters would benefit from the use of a single modulation standard. Although software-defined-radio technology offers the possibility of receivers that easily adapt to multiple standards, receivers that support a single standard would be simpler and cheaper. Unhappily, although the FCC's decision in favor of 8-VSB provides one standard for over-the-air terrestrial TV, cable and DBS have incompatible standards of their own.

Resisting the impulse

Yet another argument against OFDM is its susceptibility to impulse noise, particularly in the low-band VHF channels (channels 2 through 6). Allegedly, impulse noise has caused difficulties with DVB reception. OFDM advocates disagree about this problem's significance.

Other arguments against OFDM include the fact that the DVB system was designed for channels wider than the 6-MHz Western Hemisphere standard. When it conducted its tests of OFDM, Sinclair modified DVB modulators to confine the signal to a 6-MHz bandwidth. The result was that the OFDM bit rate was about 2% lower than the approximately 19 Mbps that 8-VSB transmits in the same bandwidth. OFDM and 8-VSB supporters disagreed on the significance of the small percentage decrease.

Supporters of 8-VSB concede that OFDM may be superior in places where multiple geographically separated transmitters broadcast the same programs at the same time on the same channel. That situation exists in several European countries, which operate nationwide TV services in this manner. Except for a few TV stations that operate co-channel repeater transmitters in sparsely populated areas, no similar situation exists in the United States. That's one reason why, this group asserts, OFDM makes sense in Europe but not in the United States.

Everyone can agree, however, that in the years following the ATSC standard's completion, IC technology advanced at an unprecedented pace. As a result, the heretofore unthinkably complex OFDM circuits became amenable to low-cost mass production. Combined with explosive growth in wireless communication, this cost reduction sparked interest in, investigation of, and deployment of OFDM, though primarily in communications—not broadcasting. Even without its adoption for DVB, OFDM had become sufficiently well-understood that the ATSC might have adopted it—were it not for...
the earlier decision favoring 8-VSB.

Compared with 8-VSB and other digital-modulation systems, OFDM transmits symbols at lower rates, thus resisting intersymbol interference by lengthening the time available for echoes to die out. Packing more bits into each symbol compensates for the lower symbol rate. According to 8-VSB proponents, however, decoder ICs that incorporate newer filtering algorithms (Block diagram) make 8-VSB as resistant as OFDM to static-multipath interference. Compared with first-generation parts, these ICs also improve 8-VSB's immunity to dynamic multipath. If handheld 8-VSB DTV receivers existed, proponents say, you could happily watch one as you strolled around a shopping mall. Still, OFDM excels for reception in moving vehicles.

The 8-VSB camp insists that watching TV in moving vehicles is a red herring that OFDM supporters have tossed into the discussion to confuse the issue. Certainly, the ATSC never thought it was developing a system that would allow TV viewing in moving cars. But OFDM supporters say that the discussion is relevant.

TV-station operators are struggling to find ways obtain a reasonable return on their large, FCC-mandated investment in DTV conversion. At the moment, these operators hear no public outcry for the significantly higher picture quality that digital modulation and the associated high-definition picture formats allow. One proposal is to use the digital technology to enable the 6-MHz-wide channel to simultaneously transmit multiple standard-definition programs. The ATSC standard supports this mode of operation. Another proposal is to transmit one standard-definition (or even enhanced-definition) picture and use the bit stream's remaining payload for mobile-communication services. Because 8-VSB doesn't work satisfactorily in moving vehicles, this arrangement requires OFDM. (If you are tempted to suggest using 8-VSB for the signal's TV-program content and OFDM for the mobile-communication data, forget it. The signal is a stream of data packets. One modulation scheme must apply to all packets.)

**Did the FCC make the right decision?**

Meanwhile, back in the family room, the indoor-antenna brouhaha rages on. In most markets, the TV transmitters reside in different places. Moving all of the stations to one transmitting antenna is either prohibitively expensive or just plain impossible. With 8-VSB—even if the receiver uses the latest decoder ICs—you must usually reorient the receiving antenna to obtain an acceptable picture when you tune to a different station. According to Sinclair, OFDM often eliminates the need to move the receiving antenna to obtain satisfactory pictures from many stations, even where line-of-sight signals are unavailable.

When the dust settles, if 8-VSB provides satisfactory DTV reception, the FCC's action will certainly have saved money for those station operators who made early investments in converting to DTV. The decision will also have saved money for the small number of pioneering consumers who have so far purchased first-generation DTV receivers. (At $5000 or more apiece those receivers continue to represent major purchases.) Perhaps more important, the decision will have avoided an appreciable delay in the national conversion to DTV.

As one who has publicly criticized the FCC for bowing to political pressure and wreaking havoc by declining to make decisions (Reference 1), I will have to eat crow. Right or wrong, the Commission has acted decisively in this matter.

It appears that no amount of laboratory testing can indicate how well 8-VSB will perform where it matters— in viewers' homes. Not until the ATSC standard has undergone much more real-world use will broadcasters, consumers, and the FCC really know how well or how poorly the system works.
Most consumers who buy expensive DTV receivers over the next few years probably won't realize that they are paying a steep price for the dubious privilege of performing a beta test. If problems with the modulation scheme suggest a move to OFDM, the cost will be much greater than it would have been had the FCC decided differently last February. Indeed, with each passing day, the potential cost of reversing the Sinclair decision becomes greater and more politically unappealing.

On the other hand, if the public becomes sufficiently frustrated with over-the-air DTV and defect en masse to cable and DBS, the modulation technique for terrestrial broadcasts probably won't matter. Yet, even that situation would have a brightside—just not for over-the-air TV broadcasters. Over-the-air TV's demise would liberate hundreds of megahertz of highly prized VHF and UHF bandwidth that, thanks to FCC spectrum auctions, could yield billions for the USTreasury. And new wireless communication services would acquire frequencies that, right now, they can only dream about.

**Author info**

You can reach Senior Technical Editor Dan Strassberg at 1-617-558-4205, fax 1-617-558-4470, e-mailednstrassberg@cahners.com.

**REFERENCE**

1. **Strassberg, Dan**, "The marketplace shouldn't have to decide," *EDN*, Dec 23, 1999, pg38.