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Before the
FEDERAL COMMUNICATIONS COMMISSIONS
Washington, D.C. 20554

In the Matter of

Advanced Television Systems and Their Impact on the Existing Television Broadcast Service	)	MM Docket No. 87-268
Review of Technical and Operational Requirements Part 73-E. Television Broadcast Station	)	
Reevaluation of the UHF Television Channel and Distance Separation Requirements of Part 73 of the Commission's Rules	)	

RESPONSE OF ZENITH ELECTRONICS CORPORATION TO FURTHER NOTICE OF INQUIRY

Zenith is the only major U.S. owned manufacturer of consumer electronics products, and also supplies head end and decoder equipment for cable TV operators. Since its presentation of opening comments and the Commission's release of the Further Notice of Inquiry, Zenith has presented its HDTV system proposal -- the only system which offers full HDTV performance and spectrum compatibility with present NTSC channel allocations without introducing interference or other artifacts for either NTSC or HDTV reception. Accordingly, Zenith has an extraordinarily strong interest in the outcome of these proceedings.

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The Further Notice of September 1, 1988 contains a thorough and useful survey of the status of many of the facets involved in achieving a terrestrial ATV broadcast service. In the Further Notice, the Commission presents a number of constructive and timely tentative decisions which begin to shape public policy and can guide industry effort.

Zenith's previous comments in this docket [1] and on the Advisory Committee Interim Report[2] stressed patience and time for system development and testing, lest unwise decisions and a service inferior in performance or interference result. In this Notice tentative resolution of several broad issues, generally not system-specific, is put forward. Zenith is pleased to support the following conclusions, for reasons along lines given in the Further Notice:

1) A terrestrial ATV service is in the public interest and the best way to initiate such a service is through the existing local broadcasting framework. (Paragraphs 4, 39)

2) Supplemental spectrum which may be needed in the implementation of ATV should be found in the present VHF and UHF broadcast television bands. (Paragraphs 4, 39, 75)

(1) Comments of Zenith Electronics Corporation in Docket 87-268 dated November 17, 1988 at pp. 3, 9.
(2) Comments of Zenith Electronics Corporation on FCC Advisory Committee Interim Report, dated June 16, 1988 at p. 3.

3) Supplemental spectrum should be limited to no more than 6 MHz. (Paragraphs 4, 82)

4) NTSC service should be continued to present receivers, at least during transition, whether by compatible ATV transmission or by simulcast. (Paragraphs 4, 39, 82, 125)

5) ATV systems should be planned and designed to operate within the spectrum limitations of present NTSC station assignments. (Paragraph 81)

I. ZENITH IS THE PROPONENT OF SUCH A SPECTRUM COMPATIBLE SYSTEM

Zenith engineers are developing a "Spectrum Compatible HDTV System" which is intended to fully meet the design objectives given in Paragraph 81 of the Further Notice. This system was disclosed to the Commission and to the Advisory Committee on September 1, 1988,(3) coincidentally the same day the Further Notice was released. It was discussed and some interference attributes demonstrated at the ATV Symposium September 7, 8, 9 in Washington, D.C.

(3) Zenith Spectrum Compatible HDTV System submission dated September 1, 1988.

In its Spectrum Compatible HDTV System, Zenith proposes the simulcast of a high performance HDTV signal in a 6 MHz VHF or UHF channel in a manner fully spectrum compatible with NTSC signals broadcast on present VHF/UHF assignments. This has been accomplished

1) by designing a totally new <u>transmission system</u> which can occupy channels presently foreclosed by the Taboos, yet coexist with NTSC signals and the present allocation plan, and
2) by designing a complementary <u>video encoding system</u> that facilitates transmission of HDTV images with double the horizontal and vertical resolution of NTSC and with CD quality stereo sound via the new transmission system.

A key attribute of the full HDTV transmission system is a reduction in transmitted peak and average power (and field strength) required for a given picture performance, with consequent reduction in interference potential.

Various encoding systems, prototype hardware and displays and HDTV simulations by others have shown impressive pictures and sound. But for terrestrial broadcast, the <u>transmission system</u> must deliver the promise of HDTV, and must provide a dependable way to transmit HDTV signals without degrading current NTSC reception.

We believe that no other proposed ATV system can deliver true HDTV picture and sound services within the existing NTSC TV allocations structure (whether compatibly in 6 MHz, by spectrum augmentation, or by simulcast) without causing undue interference on and obsolescence of existing NTSC receivers.

The Zenith Spectrum Compatible HDTV System Proposal of September 1, 1988 is incorporated into these Comments and, for easy reference, is repeated here as Appendix A.

II. THE OPPORTUNITY FOR TABOO-FREE SPECTRUM EFFICIENCY

In the present proceedings the Commission will make decisions that will have a far reaching impact on the near and long term efficiency of the use of that limited resource, the radio frequency spectrum. The Commission has a unique opportunity to take action that could ultimately lead to much more efficient use of the spectrum now allocated to television.

Zenith agrees with the Commission's tentative finding that any spectrum capacity needed for ATV should be obtained from the spectrum now allocated to broadcast television. Zenith is convinced that with the Zenith transmission system enough spectrum exists in the VHF and UHF TV bands to provide every present TV broadcaster with the opportunity to transmit HDTV. Moreover, Zenith submits that the adoption

of a simulcast solution to compatibility and Zenith's proposed Spectrum Compatible HDTV System would provide the FCC the potential for the long term phase-out of the interference-prone NTSC system. Each broadcaster would then occupy only one 6 MHz channel, with an HDTV broadcast which can be displayed at various picture resolution levels ranging from HDTV to an improved NTSC level, dependent on consumer choice of receiver complexity, screen size, and cost. Most importantly, with the low power, interference-resistant structure of the Zenith HDTV System, we believe these long term HDTV allocations could be based solely on a significantly reduced cochannel separation and no other taboo requirements.

Of course simulcast of HDTV cannot assure that NTSC channels will be abandoned in the future. "Long term" in spectrum management is measured in decades, during which HDTV must prove to be the medium of broadcaster choice and during which the full range of consumer product needs must be met. Consumers will continue to require low cost, small screen, portable television receivers, not just the high cost, high end HDTV receivers which dominate today's ATV dialog. Moreover, NTSC receivers marketed today, in 1990, and later will continue to have an average life of at least fifteen years, many much longer.

III. BACKGROUND OF ZENITH SPECTRUM DEVELOPMENT

Zenith has a long record of technical innovation and of constantly striving to improve the performance and features of its electronic products. This has gone beyond leadership in consumer product areas (e.g., remote control, electronic tuning, innovative use of custom integrated circuits). Zenith has been a successful proponent of broadcast systems - FM Stereo and TV Stereo Sound - and more recently of cable TV delivery and security systems.

These technical achievements were supported by extensive Research and Development efforts into the basic and practical limitations of communications systems and electronic hardware and into opportunities for technology-based improvements.

Against this background Zenith's Research engineers came to the following observations impacting spectrum use and ATV system development:

1. The NTSC system, because of its multiple carrier and subcarriers and its high RF peak level during sync, is interference prone.
2. The combination of the character of the NTSC signal and receiver hardware limitations have led to the Taboo restrictions on television channel allocations.

3. Attempts at eliminating or reducing Taboos by means of receiver design alone have not been successful because of unacceptable performance and commercial trade-offs and, when receiver improvements are made, the long time required to change out the existing receiver population.
4. Because many of the Taboo interference mechanisms are non-linear, reductions in peak and average RF power levels can result in interference reductions which are a square or cube function of the power reductions.
5. Interference visibility can be vastly reduced by various video processing steps at both the transmitter and receiver of a new system.
6. Zenith has previously observed that "with time and improving technology, some way will be found to compress HDTV to fit within a 6 MHz channel with fully acceptable picture quality ....".(4) However, we do not believe this can be done with receiver compatibility, retaining the structure and limitations of NTSC. Further, even EDTV additions to the NTSC channel promise new undesirable artifacts in NTSC reception, and the NTSC artifacts to be removed are an unwarranted burden on an HDTV System.

(4) Comments of Zenith Electronics Corporation in Docket 87-268 dated November 17, 1987 at p. 5.

7. An ATV system consisting of a 6 MHz primary NTSC channel augmented by 3 MHz or 6 MHz additional spectrum will always be at least as interference-prone as the NTSC channel, will never be fully spectrum efficient and, especially if the additional spectrum is not contiguous, can be expected to be very critical with regard to propagation differences between the primary and augmentation channels.

The above observations led Zenith to forego its own initial partiality to direct NTSC compatibility and to develop the Zenith Spectrum Compatible HDTV System. The NTSC decisions and standard have been long-lived - nearly 50 years past and at least a decade ahead. We now face different spectrum pressures and new technology, and we have a different view of limitations imposed by the NTSC system. The present challenge is to provide a true HDTV system with the potential for new levels of spectrum efficiency, to serve the public for the next half century. Freedom in the longer term from NTSC limitations can only be gained by an interim simulcast of HDTV.

IV. DISCUSSION OF ZENITH SPECTRUM COMPATIBLE HDTV SYSTEM

The Zenith development program was defined by three commitments:

- NTSC service compatibility to be provided by simulcast,

with the long range potential for major spectrum economy when NTSC transmissions may no longer be required.

- A total redesign of the mechanism of television transmission to permit general allocation of the new signals to NTSC Taboo channels; the only holdover constraints from NTSC are a 6 MHz channel and the interference-free coexistence of the NTSC allocations.
- Application of state-of-the-art video encoding techniques to encode a full HDTV picture for transmission in the 6 MHz channel.

The technical basis and specific characteristics of the Zenith system are presented in considerable detail in the proposal document (Appendix A). Here we address a brief summary of the system and its relation to some specific issues raised in the Further Notice.

A. Transmission System

The new transmission system is based on reduction of the power (hence field strength) required to achieve a given service level and on design of carrier, modulation, signal parameters and video signal processing to further minimize the power of certain signal components and the level and visibility of interference to other signals including NTSC channels. (Appendix A, 2.2ff). The average power of HDTV transmission is less than 0.2% of the NTSC power required

for the same service area.

1. Basic power reduction is achieved by separating the very high power low frequency and DC picture content below 0.2 MHz and sync information from the remaining low power high frequency content, and utilizing different transmission formats. The broadband high frequency component is processed for transmission by analog means. The narrow band DC-0.2 MHz component is digitally processed and the resulting low-bit-rate signal is time-multiplexed into the vertical blanking interval but utilizing the full channel bandwidth. The result is a much flatter and lower spectral power distribution.

2. The HDTV signal is encoded to a transmission field and line rate the same as NTSC field and line rates (59.94 fields/second and 262.5 lines/field). HDTV spectral components can then be interleaved with existing NTSC cochannel components, enabling use of precision carrier offset and an optional vertical-rate lock to an NTSC channel for additional interference reduction.

3. Suppressed carrier modulation of two quadrature carrier components in the center of the band reduces visibility of cochannel interference components and also greatly decreases interference from adjacent channel transmissions. The transmitted power is

concentrated near the center of the band and there are no subcarriers to create interference or artifacts.

4. Temporal (field rate) pre-emphasis filtering reduces transmission of redundant picture content, hence reduces transmitted power and potential interference to NTSC. The complementary HDTV receiver process contributes to a robust HDTV service by reducing interference and noise.

5. The transmitted analog component is also subjected to companding, linear time dispersion, and pre-emphasis. These processes, in conjunction with their complements in the HDTV receiver, either reduce transmitted peak power or improve receiver S/N and interference robustness, or both.

B. HDTV Encoding

The encoding process is discussed in detail in Appendix A, 3.0 ff.

Encoder input is a 787.5 line 59.94 Hz progressively scanned HDTV signal of 28.9 MHz bandwidth and wide aspect ratio. This signal may be derived from a higher line-rate source, progressively scanned, as discussed below. The input signal is encoded to obtain the information compression, NTSC line rates, and carrier modulation signals

required to utilize the 6 MHz spectrum compatible transmission system. At the HDTV receiver, the signal is restored for HDTV display at 787.5 line, 59.94 Hz, progressive scan using approximately one megabyte of frame memory.

The compression processing takes advantage of the capability of the human visual system to perceive detail: stationary video is transmitted at higher resolution than motion video. The basic principle is to divide the two-dimensional luminance and color difference frequency space of the source signal into components or segments and to send only those segments which are a good match to the human visual system. On a temporal basis, low frequency luminance components are transmitted at 59.94 frames/second, while higher frequency luminance and the color difference signals are updated 11.988 times/second.

Motion compensation is applied in two ways to those signals which are updated at one-fifth frame rate. The encoder computes the motion-related errors the receiver would make and minimizes them by modifying the transmission. Additional receiver motion compensation acts, in response to a transmitted data signal, to confine compensation action to areas of the picture displaying motion.

After very low frequencies and DC are removed for digital transmission and after suitable sampling and time

expansion of the several analog signal segments, there are 480 63.55 uS 2.675 MHz luminance and color difference components to be transmitted every HDTV frame. When modulated in pairs on the quadrature HDTV carriers, these components occupy 240 of the 262.5 NTSC-timed lines to be transmitted. The remaining 22 or 23 lines of each field comprise a "vertical blanking interval" used to transmit a data signal which carries compressed digital stereo audio, low frequency video, synchronization and conditional access signals, error protection and selected auxiliary services.

C. Spectrum Compatibility of Zenith Proposal

From a spectrum viewpoint, the proposed System is designed to coexist in today's NTSC allocation plan, with HDTV allocations made to channels now held vacant by the VHF and UHF Taboos. For interference to NTSC reception the new signal structure allows for cochannel operation at a Undesired-to-Desired (U/D) field strength ratio of 0 dB, and essentially eliminates the other Taboos as a consideration in allocations of the HDTV service. Pending specific studies, we believe this ability to coexist with NTSC service extends to the international border arena including similar HDTV allocations in Mexico and Canada, subject only to the 0 dB U/D cochannel limitation.

Interference testing has been done on a variety of NTSC

receivers having the expected large spread in NTSC into NTSC UHF Taboo performance. For interference tests of the Zenith Spectrum Compatible HDTV System into NTSC, these same receivers exhibit at most a very small spread, with the worst receivers showing the biggest improvements. This reflects the expected non-linear response to the signal power reductions inherent in the Zenith transmission system.

We have not completed interference analysis or testing of the Zenith System under NTSC into HDTV or HDTV into HDTV conditions. Many of the steps which have been taken in system design are bilateral, as described in Appendix A. Projections based on the expected effects of the various processing steps on interference indicate NTSC into HDTV and HDTV into HDTV cochannel performance should approximate that of HDTV into NTSC. The limiting factor is expected to be data channel errors rather than directly visible picture interference. The impact on the victim service area will depend on transmitter powers, offsets, spacings, as well as front-to-back ratios of receiving antennas. We are confident that, in addition to spectrum compatibility and efficiency, the Zenith proposal offers the promise of a superior HDTV service.

V. ZENITH HDTV SYSTEM AND ISSUES RAISED IN THE FURTHER NOTICE

A. Program Signal Format

Virtually all of the ATV systems proposed for terrestrial broadcast use a basic transmission rate of 59.94 fields or frames per second, because an NTSC-related transmission format facilitates providing service to NTSC receivers, whether by receiver compatibility or by means of a ATV to NTSC decoder.

As discussed above, Zenith has determined that an NTSC-related transmission format also has important advantages in reducing cochannel interference and achieving spectrum compatibility. The input or transmission source format of the Zenith system is 787.5 lines, 59.94 frames per second, progressively scanned. ATV source material produced with other formats must be scan converted. The preferred source format, which would produce no motion artifacts and result in the highest possible Kell factor, would be 1050 line, 59.94 frames per second, progressively scanned.

The Further Notice notes on Paragraph 21 that ATSC and SMPTE have approved a (emphasis added) voluntary production standard of 1125 lines, 60 fields per second, 2:1 interlaced. There was significant opposition to this standard in ATSC and it remains controversial because it is inappropriate in relation to the NTSC environment in which ATV must also provide service and share spectrum without interference.

The standard adopted[5] "defines the basic characteristic of the video signals associated with the origination equipment operating in the 1125/60 high definition television production system." It provides guidance to those using 1125/60. The 1125/60 system did not receive ATSC approval as the American production standard.

Zenith's position on this standard is stated in the letter attached as Appendix B. We note that, led by NBC, American companies with diverse interests in ATV have taken the positive step of proposing that SMPTE formalize a production standard based on 1050/59.94.[6] Zenith is pleased to support this effort.

B. Transcoding to NTSC

The Zenith HDTV signal is readily transcoded to NTSC formats in professional or consumer equipment because both the HDTV encoded signal and the HDTV transmission field and line rates are directly related to NTSC field and line rates. Simple interpolation filters convert 787.5 lines progressively scanned to 525 lines 2:1 interlaced. NTSC composite, wideband Y/C or RBG signals can be output depending on application. Y/C and RBG are free of NTSC sub-

(5) ATSC Document T3/142, "Signal Parameters of the 1125/60 High Definition Television Production System," September 4, 1987.
(6) NBC Submission to SMPTE, "Proposed American National Standards for Television Signal Parameters," dated October 14, 1988.

carrier artifacts and can support IDTV level resolution. For display at NTSC resolution levels, simplified HDTV decoding may be used.

C. CATV Issues

All ATV systems which require additional spectrum present a potential new burden to retransmission media. The impact on CATV will be, in large measure, system-specific, depending on CATV plant, number of channels, conditional access requirements and other factors.

The Zenith system can deliver HDTV into the home via CATV and has a number of advantages in addressing the issues of spectrum and carriage.

- The Zenith transmission system is not limited to HDTV video. Video signals at any performance level, including NTSC performance, can be processed for transmission with dramatically reduced power levels, or improved signal-to-noise ratio (S/N) much-needed by cable, or both. Substitution of Zenith's transmission signals for NTSC-encoded transmissions in cable systems will reduce intermodulation distortion, improve S/N and permit carriage of more

channels without cable plant rebuild.

- We believe that in most cases some Zenith HDTV transmission channels can be added or substituted in a given cable plant without contributing to intermodulation and other intraplant interferences. The Zenith signal itself is designed to be robust to the conventional 6 MHz comb of intermodulation components.
- Retransmission of terrestrial broadcast signals which have been simulcast may not require carriage of both NTSC and HDTV channels on the cable. An HDTV-to-NTSC converter can deliver signals to NTSC receivers without using additional cable spectrum.
- Conversion to HDTV of the many non-broadcast channels carried on cable does not require additional spectrum. In contrast to proposals requiring augmentation spectrum, the Zenith System delivers HDTV in the original single 6 MHz channel, again with the display decision made at the consumer terminal equipment.
- The Zenith transmission system is designed to incorporate secure hard encryption of both audio and video, offering a much-sought and cost effective improvement in delivery of premium programs.

D. Transmitter Average Power Reduction

While simulcast and some augmentation solutions will require second broadcast facilities, most significantly a second transmitting antenna with at least near-colocation, the low power demand of the Zenith transmission system is a mitigating factor.

We estimate that a typical NTSC UHF station delivering 5 megawatts ERP with 16 dB antenna gain requires 240 kW from the power line at a cost of about $189,000/year. The Zenith HDTV transmission can provide the same coverage using the same antenna with only 450 watts. Obviously the HDTV antenna need not be as efficient as the NTSC antenna: design of the second, HDTV, facility for lower antenna gain would reduce capital costs at a small increase in power requirements.

Long term, the reduction in operating costs of an HDTV channel can be a factor stimulating eventual phase out of NTSC channels.

E. Relays, Satellite and Tape Recording

The Zenith HDTV system is directly transcodable to a signal suitable for FM modulation required by various services. When the two 3 MHz signals used for quadrature modulation in AM terrestrial transmission are each time-

compressed 2:1 and time-multiplexed, a full 6 MHz HDTV baseband signal results.

This one-wire "composite" signal is suitable for higher levels of production and network switching and distribution and for FM modulation in relay service, satellite distribution and DBS, and professional and VCR recording. Because this signal includes all chroma, S-VHS technology without color-under signals is expected to permit design of a full HDTV consumer-affordable VCR.

The signal processing, which results in power reduction in AM modulation, translates in FM systems to significant reduction in average and peak deviation. The result will be improved S/N and threshold performance of systems using FM modulation.

IV. OTHER SPECTRUM INTERFERENCE ISSUES

A. Comments on Documents

Zenith emphasizes the need for due caution in the deliberations, conclusions and recommendations of the various Subcommittees and Working Parties, as well as the FCC Technical Staff. Some specific comments follow.

- In FCC/OET TM88-2, the Executive Summary concludes that "most of the Taboo channels look favorable for potential use as ATV augmentation channels." There

is no information in this report or in FCC/OET TM88-1 to support such a broad conclusion.

The following qualifier reflecting the conditions of the study should be added:

"....if the augmentation (or simulcast) transmitter is colocated with the primary channel to which it has a Taboo relationship and provided that there are no other non-colocated channels in the area to which the augmentation channel has a Taboo relationship."

- Additionally in FCC/OET TM88-2 at p. 12, we concur that, when the interference target is the primary audience, the receiver population to be protected by planning should be increased to 90%.

- As indicated in the Notice, the spectrum scenarios considered and reported on by PS/WP3 and FCC/OET TM88-1 have thus far only considered the dominant allocation restrictions caused by Co-channel and Adjacent channel interference. However, other Taboo restrictions are intended to be included in further studies by PS/WP3 as they could possibly have a further restrictive impact on the accommodation percentages in particular in the major markets.

These studies and FCC/OET TM88-1 are all based on ATV signals assumed to have an NTSC-like character except that they will somehow have to be more immune to interference. When the ATV transmission does not use NTSC carriers (e.g., Zenith), the characterization of NTSC receiver taboo immunity is no longer valid and new studies are required.

- The Jansky/O'Connor Report referenced in Paragraph 58 of the Further Notice <u>concludes</u> that "....ATV systems can be designed to use Taboo spectrum without causing unacceptable interference to NTSC receivers...."

  Although they may eventually be proven right by the Zenith Spectrum Compatible HDTV System, there is no new information in the report to support such a broad conclusion.

  The Jansky-O'Connor report has been helpful in focusing attention on the importance of the Taboos and other spectrum issues in the ATV proceedings. Although it was appended to the Advisory Committee Interim Report, Jansky-O'Connor was only one contribution to an evolutionary process in PS/WP3 to

deal with these complex questions. Zenith has also submitted several documents to the record of PS/WP3. PS/WP3 will hopefully arrive at a comprehensive document that will be useful to systems proponents, other working parties of the Advisory Committee and to the FCC in guiding the understanding and testing of systems and in reaching conclusions.

- It is important to realize (although definitions are seldom given) that when broadcasters and spectrum managers refer to U/D ratios they mean field strength ratios, while receivers are evaluated in terms of input signals. The difference between these parameters lies in the Planning Factors. Zenith would welcome a re-examination of the Planning Factors in light of new technology and the picture quality requirements of ATV.

B. Interference Testing and Data Analysis

Zenith recognizes, as must the Commission, that all the candidate ATV systems must be fully tested for interference characteristics - both to demonstrate proof of claims and to insure that no superficial but erroneous conclusions are reached by proponents, Advisory Committee or Commission.

The testing should include the following for a range of desired signal levels:

a) Interference of NTSC transmissions into NTSC reception as a reference.

b) Interference of ATV transmissions into NTSC reception.

c) Interference of NTSC transmission into ATV reception.

d) Interference of ATV transmission into ATV reception.

The resulting receiver data indicating the threshold of interference in terms of Undesired to Desired signal ratios as function of Desired signal level can then be combined with the F (50, 50) Desired and F (50, 10) Undesired signal propagation curves (see Paragraph 73.699 of the FCC Rules) to derive a direct graphic display of the areas within the victim station's service area where the thresholds of perceptible interference would be exceeded by that ATV system for the particular Taboo channel relationship and distance spacing.

Zenith has recently submitted a preliminary document (attached as Appendix C) to PS/WP3 of the ATV Advisory Committee. It describes the above method further and uses as an example the receiver data from FCC/OET TM-1 and minimum transmitter spacings for the various Taboos. (From this example it is clear that the present allocation scheme and receiver performance would be far from interference free